Restoring the Yorkshire River Derwent

Technical Report

Final report
June 2010

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1 INTRODUCTION

1.1 Background

This document forms one of the outputs from the River Derwent Geomorphological Assessment and Restoration Plan, commissioned by the Environment Agency (North East Region) and Natural England in June 2008.

The River Derwent rises on Fylingdales Moor in the North York Moors National Park, flowing south through the Forge Valley and lower ground to its confluence with the River Hertford. The river then flows westwards through the Vale of Pickering and turns south at the River Rye confluence (the upstream boundary of the SSSI). The river passes through Kirkham Gorge and the Vale of York before joining the River Ouse at Barmby-on-the-Marsh (**Figure 1.1**). The catchment drains an area of approximately 542 km^2.

The River Derwent is a Site of Special Scientific Interest (SSSI) and Special Area of Conservation (SAC). The Yorkshire Derwent is considered to represent one of the best British examples of the classic river profile and the River Derwent SSSI has been designated for its natural lowland character. The SSSI comprises the River Derwent downstream of the confluence with the River Rye and lies between the Howardian Hills and the Yorkshire Wolds (**Figure 1.1**).

The site is divided into 21 SSSI units which Natural England uses in order to manage and monitor the condition of the site. Four of these units relate to the river itself, whilst the remainder relate to land-based supporting habitats along the river corridor. The four river-based units are detailed in **Table 1.1** and their location illustrated in **Figure 1.1**.

Table 1.1: Rivers and Stream SSSI habitat units within the River Derwent SSSI

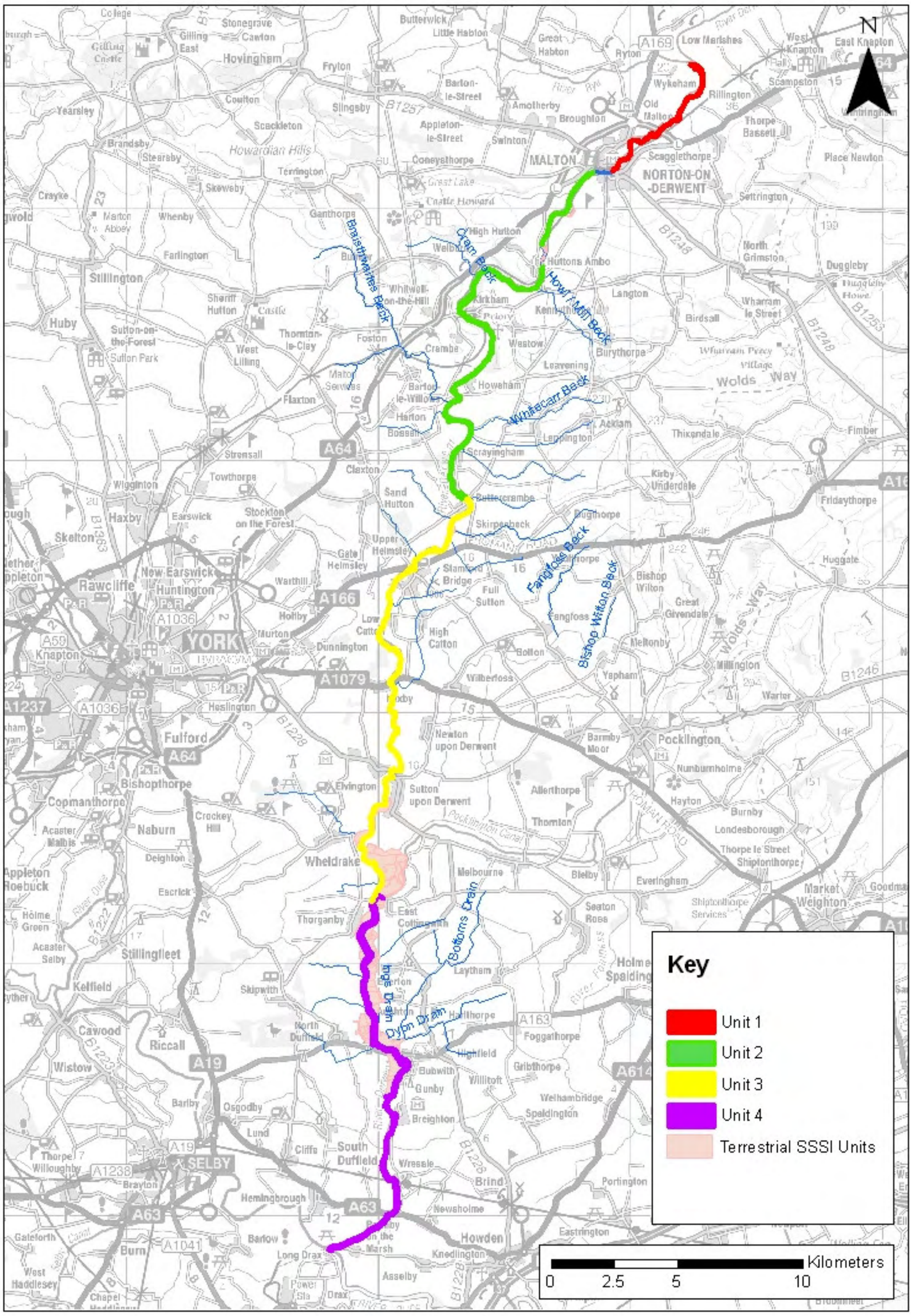
SSSI Unit	Location of SSSI Unit / Watercourse	Length (km)
1	Ryemouth to Malton	8
2	Malton to Buttercrambe.	21
3	Buttercrambe to The Beck	24
4	The Beck to Barmby Barrage.	17

Natural England is responsible for assessing the conservation status of all designated sites in England, including the River Derwent SSSI. Natural England's condition assessments in both 2003 and 2009 identified that all four river SSSI units in the River Derwent are still in an unfavourable condition.

The Environment Agency is responsible for a number of generic remedies agreed with Natural England to help meet the Public Service Agreement (PSA) target to restore 95% of SSSIs by area in England & Wales into favourable/favourable recovering condition by 2010. This target also forms one of the Environment Agency's own Biodiversity Outcome Measures. As such, the River Derwent has been selected for a catchment-scale geomorphological study concluding in developing a Catchment Restoration Action Plan, with a view to meeting Natural England's favourable condition targets.

This report presents the method and findings of the desk based and field assessment of geomorphological and ecological conditions in the River Derwent catchment, and forms part of the River Derwent Geomorphological Assessment and River Restoration Plan project.

Figure 1.1: The River Derwent SSSI



Whilst this project is primarily concerned with the riverine units of the River Derwent SSSI, the relationship and potential influence of management of the River Derwent SSSI on the Derwent Ings, Newton Mask and Breighton Meadows SSSIs needs to be taken into account. These are terrestrial SSSIs bordering the main River Derwent (**Figure 1.1**). They consist of a series of neutral alluvial flood meadows, fen and swamp communities and freshwater habitats lying adjacent to the River Derwent between Sutton-upon-Derwent and Breighton. They also form part of the internationally designated Lower Derwent Valley Special Protection Area (SAC),and Special Protection Area (SPA)/Ramsar site which contains habitat of outstanding importance for lowland hay meadows and a diverse range of breeding and overwintering waders and waterfowl respectively. All of the units within the Newton Mask and Breighton Meadows SSSIs are in favourable condition, while only three within the Lower Derwent Ings SSSI are unfavourable.

1.2 Aims and objectives

The overall aim of the project is to develop an understanding of the geomorphological processes and issues within the catchment, to identify possible actions to restore the river towards favourable condition. The actions will be focussed towards improvement for the specific SAC and SSSI target species outlined above. All actions will be documented in a strategic restoration plan.

The specific objectives of this project are:

i) To undertake a geomorphological assessment and ecological interpretation of physical impacts on the river;
ii) To provide a spatial and chronological account of the management changes that have occurred on the river, and assessment of the ecological implications for the characteristic biological communities;
iii) To produce a conceptual model of natural and existing river processes, including a spatial account of key geomorphological features and their influence on the sediment regime, including the impacts of past and present river and land management upon it;
iv) To assist the Environment Agency and Natural England in a consultation exercise with stakeholders; and
v) To produce a final restoration plan for the whole River Derwent SSSI site, including delivery mechanisms and approximate costings, incorporating the results of the consultation exercise.

1.3 Aims and objectives of the Technical Report

This Technical Report is for use by river managers and regulating bodies (Natural England, Environment Agency) as supporting information for the accompanying River Restoration Plan. The aim of the Technical Report is to report on the findings of the geomorphological assessment and ecological interpretation of the physical impacts of the river. This specifically involves drawing together the findings of the desk based assessment and field survey to build a conceptual model of geomorphological functioning. This model describes the inputs, functioning and outputs from the river system. The ecological assessment is then related to the geomorphological model and possible causes of unfavourable condition are identified to provide a basis for developing actions at a strategic scale.

1.4 Structure of the Technical Report

This report is divided into eight discrete chapters, which describe the purpose of this investigation, the methods employed, the morphological and ecological functioning of the system, and a consideration of potential solutions to the key issues identified. **Table 1.2** provides details of the content of each of the sections of this report.

Table 1.2: Outline of reporting content and how it should be used

Report section		Description
1	**Introduction (this section)**	Introduces the project, and outlines the main aims and objectives
2	**Catchment Fluvial Audit: overview & method**	Provides details of the field-based and desk-based methods used in this study
3	**The River Derwent SSSI**	Provides a summary of the interest features of the SSSI and the findings of the most recent condition assessments
4	**Catchment controls**	Provides a discussion of the principal factors that control the geomorphological behaviour of the catchment
5	**Geomorphological behaviour**	Provides details of the geomorphological responses of the catchment to the controls discussed in the previous section
6	**Key issues for ecology and habitat**	Provides a discussion of the main catchment-wide geomorphological and ecological trends, and identifies the key issues in the catchment
7	**Potential solutions**	Describes the solutions that could be applied to address the key issues
8	**References**	Literature used to inform the development of this report

2 CATCHMENT FLUVIAL AUDIT: OVERVIEW & METHOD

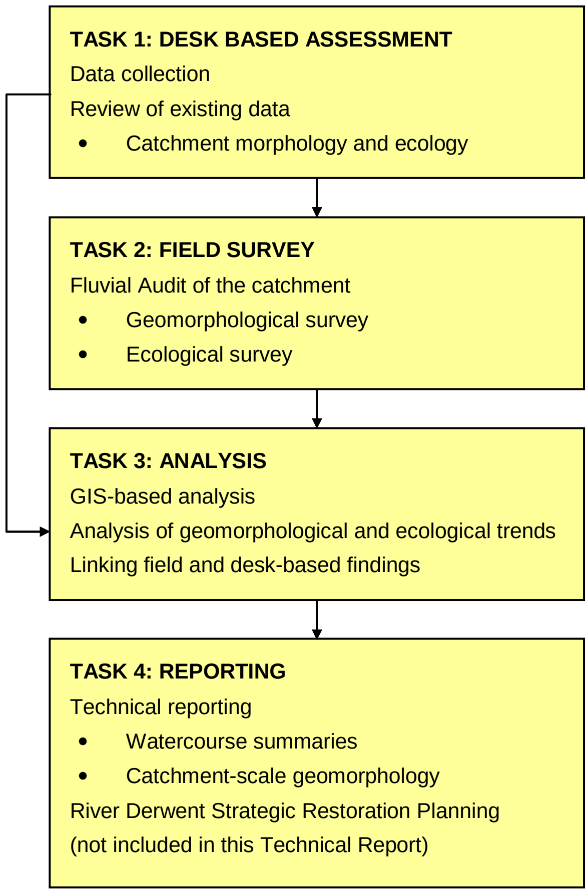
2.1 Purpose of this section

This section presents an overview of the methods used to undertake a detailed fluvial audit of the River Derwent SSSI, including a desk-based assessment, field assessment and spatial analysis of data to determine the main characteristics of the system and identify the key geomorphological and ecological characteristics which affect the SSSI. A description of the method for each stage is presented in the subsequent sections.

2.2 Overview of method

Catchment-scale Fluvial Audit is a method of gathering relevant desk and field-based data and using this information to characterise the geomorphological behaviour of watercourses within the catchment. This approach comprises four main tasks, which are outlined in **Figure 2.1**. Details of the approach used to complete each task are provided in the subsequent sections.

Figure 2.1: Overview of the Catchment Fluvial Geomorphological Audit process



2.3 Desk-based assessment

2.3.1 Data collection

All available data on the River Derwent catchment were provided by the Environment Agency and Natural England. These data can be grouped into three main categories (**Table 2.1**). All data were logged upon receipt to form a master data register. Where appropriate, all spatially-referenced data were incorporated into a Geographic Information System (GIS) so that spatial trends could be analysed.

An overview of the condition of the River Derwent SSSI was obtained using Natural England's website (www[4]), supplemented by detailed condition assessment reports provided directly by Natural England (Natural England, 2003).

Table 2.1: Data analysed during the desk-based assessment

Data	Description
Empirical data	Current and historical mapping, aerial photography, LiDAR, topographic channel survey, information relating to structures and channel modifications, and ecological survey data.
Hydraulic models	Models and accompanying reports, covering flood extents, the impacts of flood alleviation schemes, and simulations to identify the impacts of modifications to structures.
Existing reports	Condition assessment reports and other information providing details of existing initiatives within the catchment, including the Lower Derwent Project and Catchment Flood Management Plan.

2.3.2 Review of existing data

The available data were reviewed and analysed in order to determine:

- Key ecological interest features of the River Derwent system and their physical habitat requirements;
- Past geomorphological conditions and how these have changed through time;
- The current hydrological and flow regime, and the major factors that influence its function;
- The current sediment regime, and how it is influenced by geomorphological and ecological factors;
- Existing policy initiatives in the catchment and their implications for geomorphology and ecology.

The main methods used to undertake the desk-based assessment were:

- **Initial review** of existing reports to extract relevant information relating to the objectives listed above. The reports produced to accompany the hydraulic models of the catchment were of particular importance in this task.
- **GIS-based analysis** of aerial photography, map data and key structures to identify the key geomorphological characteristics of the river channel, tributaries and surrounding floodplain. These characteristics were annotated on a series of base maps to facilitate further desk-based assessment and prepare for the fieldwork stage of this project.

- **Historical trend analysis:** Ordnance Survey First Edition Maps (dated 1849-1854) and historical land use records were compared with current map sources and contemporary land use records to identify changes in channel planform, land use, and sediment supply.
- **Analysis of channel characteristics**, based on cross sectional data taken from the hydraulic models of the catchment.
- **Analysis of the channel long profile**, reconstructed from the bed levels contained in the cross sectional data.

The results of the desk-based assessment are presented in **Sections 4 – 6** of this report, which detail the baseline geomorphology, ecology, and catchment-wide policy initiatives, respectively.

2.4 Field survey

2.4.1 Field survey sheet development

The field survey sheet used for the River Derwent Fluvial Audit was developed in consultation with the Environment Agency and Natural England. The sheet was based on an established approach previously used for catchment-scale fluvial audit of the Esk, Tees and Wear catchments as part of the Salmon Rivers project (Babtie, Brown and Root, 2005). This survey sheet was previously cited in Natural England's "Proposed Guidance for the restoration of physical and geomorphological favourable condition on river SSSIs in England" and has also been successfully applied to the Axe and Yare catchments.

The existing survey sheet was modified to incorporate recording of additional geomorphological and ecological parameters relevant to favourable condition of the SSSI. This included habitat features of specific relevance to the interest features of the River Derwent SSSI. Other parameters were removed as they were less applicable to the lowland nature of the River Derwent. Additional sections were also added to facilitate initial assessment of the links between geomorphology and ecology on site, together with potential river restoration measures. A copy of the field survey sheet is provided in **Appendix A**.

2.4.2 Reach definition

The field survey of the catchment involved a walkover survey of the riverine units of the SSSI (70 km in length). During the survey, visual observations and physical measurements of key geomorphological and ecological parameters were recorded from the bank top. The survey did not involve intrusive investigations or in-channel survey.

Key geomorphological and ecological parameters were recorded on a reach-by-reach basis. Reach boundaries were based on changes to the predominant geomorphological, ecological and land use characteristics of the river, as observed in the field. Each reach was assigned a unique identification code formed of three letters (DER) and three numbers. A total of 84 reaches were identified along the River Derwent SSSI.

2.4.3 Recording of field data

The geomorphological characteristics of each reach were recorded in Parts II to VIII of the survey sheet. Sediment sources, sediment sinks and flow types were continuously tallied for each reach, and overall morphological parameters relating to the valley form, channel geometry, and boundary conditions of the reach were recorded. Grid references were recorded using a GPS for key features, including tributaries, field drains and weirs.

The ecological characteristics of each study reach were recorded in Parts IX to XII of the study form. The presence of riparian vegetation and invasive species was recorded, and key habitat requirements for SSSI interest species were assessed.

The field data collected were based on visual observation and therefore to some extent dependant on the conditions found on the day of survey. During the survey water levels and turbidity were particularly high as a result of the high rainfall in the preceding weeks. The resultant lack of visibility within the river made observation of bed characteristics and in-channel vegetation difficult and, in places, impossible.

2.4.4 Photographs

At least one typical photograph was taken for each reach together with additional photographs where particular geomorphological and ecology features are observed. The grid reference of each photograph was recorded using a GPS with a short description of the subject. Photographs were labelled according to the reach identification code (see **Section 2.5.4**) followed by a sequential alphabetical suffix assigned in the downstream direction (e.g. DER-001a, DER-001b, etc.). These photographs are provided as an electronic appendix (**Electronic Appendix A: River Derwent Photo Viewer**).

2.5 Data management and analysis

2.5.1 Database development

The data captured on the field survey sheets were entered into a Microsoft Access database. The structure of the Access database was developed to correspond to the structure of the field survey sheet. In addition to managing the collection of field data, the Access database provides a tool that can be used to store and access the field data. Search functions are built into the database in the form of drop down boxes that enable navigation to a particular reach according to catchment, watercourse and reach code.

2.5.2 GIS development

Data from the Access database were exported and used in ArcGIS to create GIS shapefiles containing the field data collected for the surveyed length of river, based on a shapefile of the river centreline. The river centreline shapefile was segmented into the reaches identified during the field survey and the survey data associated as appropriate. Where grid references of particular sources and sinks have been taken using a GPS, additional point shapefiles were created. The GIS is provided as an electronic appendix (**Electronic Appendix B: River Derwent GIS data**).

2.5.3 Classification of river management reaches

A total of 84 individual reaches were identified during the field survey. For the purposes of management, the field reaches were combined into 22 larger river reaches, based on their predominant geomorphological, ecological, land use and topographic characteristics. These reaches, which have been numbered sequentially from D01 to

D22, have been used in subsequent analysis and will form the basis of the River Restoration Plan. The limits of each watercourse are outlined in **Table 2.2**.

2.5.4 Watercourse summary sheets

The original field data were used to produce detailed summary sheets which characterise the primary geomorphological and ecological features of each of the 22 river management reaches outlined in **Table 2.2**. The key issues that influence the geomorphological and ecological characteristics of each watercourse were then identified. The watercourse summary sheets for each reach are presented in **Appendix B**. Each summary table is accompanied by an annotated aerial photograph, on which key geomorphological and ecological features and issues are identified.

Table 2.2: Watercourse boundaries for the River Derwent

Reach	Upstream limit	Downstream limit	Field reaches
D01	Rye – Derwent confluence	A64 road bridge	DER001 – 003
D02	A64 road bridge	Upstream limit of Malton	DER003 – 005
D03	Upstream limit of Malton	Downstream limit of Malton	DER006
D04	Downstream limit of Malton	Upstream limit of Low Hutton	DER007 – 010
D05	Upstream limit of Low Hutton	Howl and Mill Beck	DER011 – 013
D06	Howl and Mill Beck	End of Kirkham Park Wood	DER014 – 017
D07	End of Kirkham Park Wood	End of Howsham Wood	DER018 – 022
D08	End of Howsham Wood	Buttercrambe Weir	DER023 – 035
D09	Buttercrambe Weir	End of Buttercrambe Weir reach	DER036
D10	End of Buttercrambe Weir reach	Upstream limit of Stamford Bridge	DER037 – 044
D11	Upstream limit of Stamford Bridge	Downstream limit of Stamford Bridge	DER045
D12	Downstream limit of Stamford Bridge	Downstream border of Low Catton	DER046 – 047
D13	Downstream border of Low Catton	Upstream limit of Kexby	DER048 – 049
D14	Upstream limit of Kexby	Downstream limit of Kexby	DER050
D15	Downstream limit of Kexby	Upstream of Sutton Wood	DER051 – 052
D16	Upstream of Sutton Wood	Upstream limit of Elvington	DER053 – 055
D17	Upstream limit of Elvington	Downstream limit of Elvington	DER056 – 057
D18	Downstream limit of Elvington	Confluence with Pocklington Canal	DER058 – 063
D19	Confluence with Pocklington Canal	Bubwith	DER064 – 072
D20	Bubwith	Upstream limit of Menthorpe	DER073 – 076
D21	Upstream limit of Menthorpe	Downstream limit of Menthorpe	DER077
D22	Downstream limit of Menthorpe	Barmby Barrage	DER078 – 084

2.5.5 Analysis of spatial trends

Spatial patterns in the data were identified through detailed GIS analysis. Morphological and ecological data were considered together so that potential linkages and inter-relationships could be identified. The GIS-based data were also used to identify the primary geomorphological and ecological issues that affect the condition of the SSSI within each of the 22 study reaches. The results of the field survey and subsequent analysis are presented in **Sections 4 – 7**.

2.6 Reporting

The results of the previous three stages are presented in the subsequent sections of this report. Specific restoration actions are detailed in the accompanying **River Derwent Restoration Plan**.

3 THE RIVER DERWENT SSSI

3.1 Purpose of this section

This section presents a description of the River Derwent SSSI, including an outline of the main interest features and the condition of each SSSI unit. The purpose of this section is therefore to provide an understanding of why the catchment has been designated as a SSSI, and of the current baseline conditions within the area.

3.2 SSSI interest features

3.2.1 Designations

The River Derwent is valued for its natural lowland character and is protected by its designation as a SSSI under the Wildlife and Countryside Act 1981. In addition, the site is also internationally designated as a Special Area of Conservation (SAC) under the EC Habitats Directive. The additional SAC designation is recognition that the vegetation community, otter, bullhead and river and sea lamprey are particularly valued in a European context. The following sections outline the habitats and species for which the River Derwent is designated.

3.2.2 Classic lowland river profile with diverse flora and fauna

The key habitat interest within the River Derwent SSSI is the lowland river habitat, which supports diverse communities of aquatic flora and fauna, many elements of which are nationally significant.

3.2.3 Floral interest characteristic of lowland rivers

In contrast to the upland reaches of the River Derwent, the River Derwent SSSI is rich in nutrients and relatively unpolluted and supports aquatic flora uncommon in Northern Britain. Several species are typically found in lowland rivers in southern England, and several occur here near their north-eastern limit in Britain, including:

- Flowering rush (***Butomus umbellatus***);
- Shining pondweed (***Potamogeton lucens***);
- Arrowhead (***Sagittaria sagittifolia***);
- Opposite-leaved pondweed (***Groenlandia densa)***; and
- Narrow-leaved water-parsnip (***Berula erecta***).

The presence of the unbranched bur-reed (***Sparganium emersum***) and yellow water-lily (***Nuphar lutea***) add to the floral interest.

3.2.4 Invertebrates

The River Derwent possesses an exceptionally rich invertebrate assemblage which is similar to low lying rivers in the south of England. For example, the mayfly species ***Baetis buceratus***, ***Heptagenia fusogrisea*** and ***Brachycerus harisella*** are of particular conservation interest, as well as the stonefly ***Taenioperyx nebulosa***. Eleven species of dragonfly have been recorded including the banded agrion (***Agrion splendens***) at its most north-easterly site in the country.

3.2.5 Fish

The river is also noted for its diversity of fish species, which include or have included:

- Bleak (***Alburnus alburnus***);
- Ruffe (***Gymnocephalus cernuus***)***;*** and
- Burbot (***Lota lota***) (now nationally and locally extinct).

The presence of these European species reflected the River Derwent's geographical position at the end of the Ice Age when migration of fish from the Rhine and other European rivers was possible across the North Sea which, at that time, was a fresh-water lake.

3.2.6 Breeding birds

The riverine habitat within the River Derwent SSSI supports an excellent breeding bird community including

- Common sandpiper (***Actitis hypoleucos***);
- Dipper (***Cinclus cinclus***);
- Kingfisher (***Alcedo atthis***);
- Yellow wagtail (***Motacilla flava***);
- Grey wagtail (***Motacilla cinerea***); and
- Bewick's swan (***Cygnus columbianus***).

During the winter, the lower Derwent is important for wintering wildfowl for which the flood embankments provide important grazing areas.

3.2.7 Otters

The Derwent is one of the rivers in lowland Britain which supports a breeding population of otters (***Lutra lutra***).

3.3 SAC interest features

The international SAC designation of the River Derwent is based on the following interest features:

- Natural lowland river character;
- ***Ranunculion fluitantis*** and ***Callitricho-Batrachion*** vegetation community (an assemblage of floating and submerged species, including river water-crowfoot and water starworts);
- River lamprey (***Lampetra fluviatilis***);
- Sea lamprey (***Petromyzon marinus***);
- Bullhead (***Cottus gobio***); and
- Otter (***Lutra lutra***).

3.4 SSSI condition status

The majority of the River Derwent SSSI is in unfavourable status. 90.8% of the site's area is 'unfavourable no change' while 0.1% is 'unfavourable declining'. The remaining 9.1% of the site is favourable or favourable recovering (i.e. meets the requirements of the PSA target). All four riverine units are currently classified as 'unfavourable no change' (www[4]). The findings of the 2003 condition assessment of the River Derwent SSSI for riverine units 1-4 are summarised in **Table 3.1**. Reasons for the unfavourable condition of the riverine SSSI units in the current condition assessment tables (www[4]) include:

- Water pollution – agriculture/run off;
- Siltation;
- Inland flood defence works;
- Inappropriate weirs, dams and other structures; and
- Invasive species such as Himalayan balsam (***Impatiens glandulifera***) and giant hogweed (***Heracleum mantegazzianum***).

The 17 small floodplain units of the River Derwent SSSI are in favourable condition, apart from Units 8 and 15 where Himalayan balsam is present, and unit 14 which is overgrazed. Only one of the 78 SSSI units within the Derwent Ings is in unfavourable condition due to overgrazing (Unit 163).

Table 3.1: Riverine SSSI Unit Condition Assessment Summary (2003)

SSSI Unit No.	Stretch of River	River length (km)	Reason for status						
			Water Quality	Flow	Siltation	Channel Structure	Management	Biological Disturbance	Access
1	Ryemouth to Malton	8	All parameters exceeding target: **Favourable.**	No known abstraction problems: **Favourable.**	No known siltation problems. The adjacent land has become more intensive without buffering. **Unfavourable.**	Channel extensively embanked. **Unfavourable.**	Bankside vegetation allowed to flower. No weedcutting. No known problem regarding eroding banks due to overgrazing and poaching by livestock. Possibly other detrimental management practices (herbicide): **Favourable.**	Himalayan Balsam present, but unlikely to affect interest features. No fish stocking / culling within the SSSI unit. No known other types of disturbance (e.g. boats) affecting the wildlife. **Favourable.**	No artificial barriers to upstream migration by fish. **Favourable.**
2	Malton to Buttercrambe	21	Phosphorous (annual average) failing target: **Unfavourable**	No known abstraction problems: **Favourable**.	No known siltation problems. The adjacent land has become more intensive without buffering. **Unfavourable.**	Channel not extensively deepened or widened. **Favourable.**	Bankside vegetation allowed to flower. No weed cutting. No known problem regarding eroding banks due to overgrazing and poaching by livestock. Possibly other detrimental management practices (herbicide): **Favourable.**	Himalayan Balsam present, but unlikely to affect interest features. No fish stocking / culling within the SSSI unit. No known other types of disturbance (e.g. boats) affecting the wildlife. Both Crassula and Japanese Knotweed known in catchment but present no problem. **Favourable.**	Artificial barriers to upstream fish migration. Measures in hand to remove or by-pass them. Fish passes present at Kirkham and Howsham but may not be effective for Sea Lamprey. **Favourable.**
3	Buttercrambe to confluence with The Beck	24	Phosphorous (annual average) failing target: **Unfavourable**	No known abstractions within stretch: **Favourable.**	No known siltation problems. The adjacent land has become more intensive without buffering. **Unfavourable.**	Channel not extensively deepened or widened. **Favourable.**	Bankside vegetation allowed to flower. No weed cutting. Banks eroding due to overgrazing and poaching by livestock. Possibly other detrimental management practices (herbicide): **Favourable**	Himalayan Balsam present, but unlikely to affect interest features. No fish stocking / culling within the SSSI unit. No known other types of disturbance (e.g. boats) affecting the wildlife. Both Crassula and Japanese Knotweed known in catchment but present no problem. **Favourable.**	Artificial barriers to upstream fish migration. No measures in hand to remove or by-pass them. Buttercrambe weir has no fish pass. Research at Stamford Bridge fish pass has shown Sea Lamprey do get past it. **Unfavourable.**
4	Buttercrambe to the confluence with the River Ouse	17	Phosphorous (annual average) failing target: **Unfavourable**	No known abstraction problems: **Favourable.**	No known siltation problems. Adjacent land becomes more intensive without buffering. No to remedy soil erosion. **Unfavourable.**	Channel extensively deepened, widened or embanked. Feasible to restore the channel. **Unfavourable.**	Bankside vegetation allowed to flower. No weed cutting takes place in the stretch. Banks are eroding due to overgrazing and poaching by livestock. Possibly other detrimental management practices (herbicide): **Favourable**	Himalayan Balsam present, but unlikely to affect interest features. No fish stocking / culling within the SSSI unit. No known other types of disturbance (e.g. boats) affecting the wildlife. Both ***Crassula*** and Japanese Knotweed known in catchment but present no problem. **Favourable.**	Artificial barriers to upstream fish migration. Not feasible to remove or by-pass the barriers. **In-conclusive status.** Experts divided as to what extent Barmby Barrage prevents the passage of notified species.

Source: Natural England SSSI /cSAC Condition Assessment, 2003 (orange colour indicates unfavourable condition)

4 CATCHMENT CONTROLS

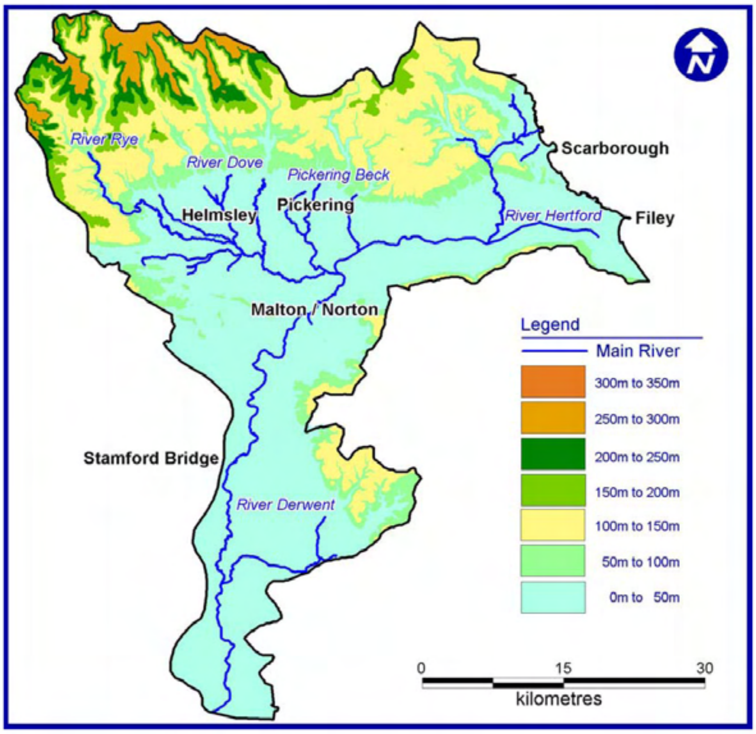
4.1 Purpose of this section

The purpose of this section is to provide an understanding of the main factors which control the development and condition of habitats within the River Derwent SSSI. This includes a description of the baseline physical factors (e.g. topography and geology), hydrology, land use and physical modifications (e.g. in-channel structures, channel modifications and embankments) which combine to control the way the river system and the habitats it supports function.

4.2 Topography and drainage network

The River Derwent catchment contains two topographically distinct areas that effectively divide the catchment into two; high gradient upland headwaters in the north, and a lower-gradient lowland channel in the south. The headwaters of the River Derwent and its tributaries, the River Rye and River Hertford, drain the Howardian Hills to the west and the Yorkshire Wolds to the east (**Figure 4.1**). The three rivers converge at the base of the upland areas and the River Derwent then flows in a southerly direction. The topography changes to gently undulating land, with a maximum elevation of 10 mAOD. The River Derwent flows through a wide valley floor, before joining the River Ouse and flowing into the North Sea through the Humber Estuary.

Figure 4.1: Topography of the River Derwent catchment

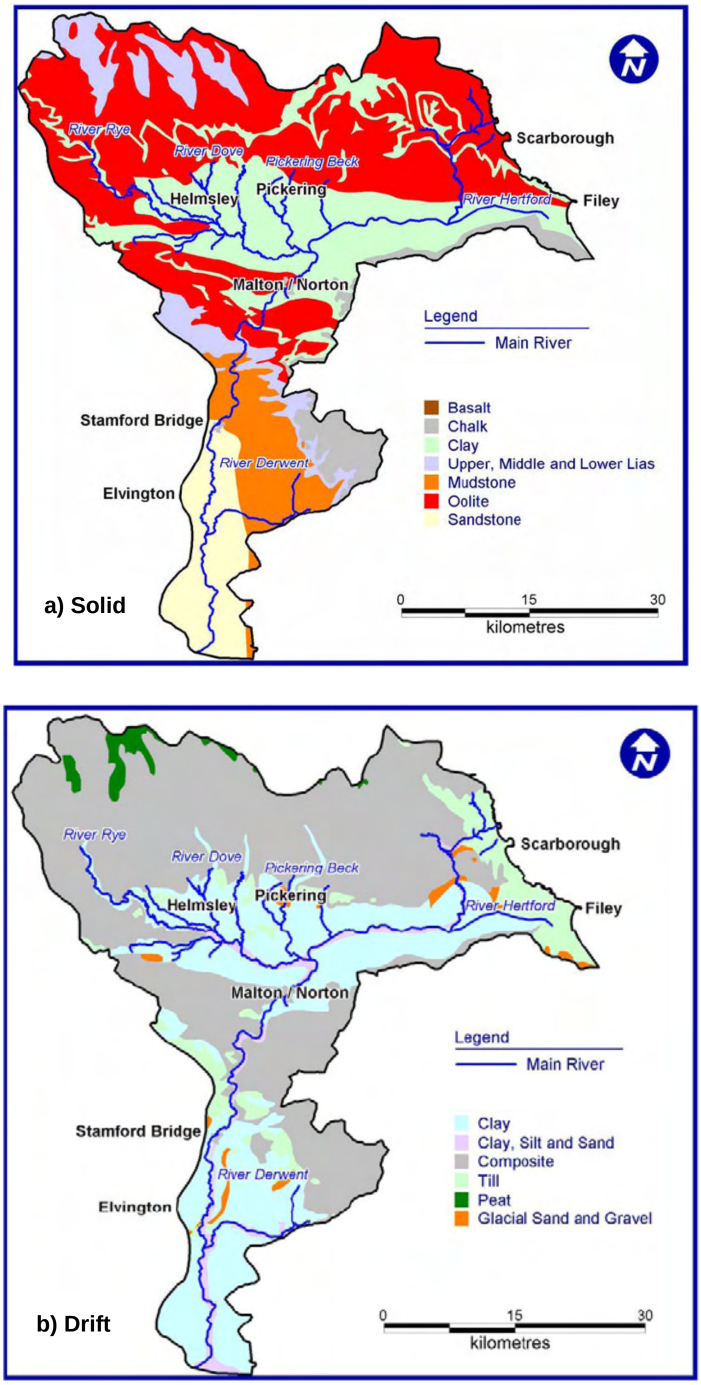


Source: Environment Agency (2007)

4.3 Solid and drift geology

The River Derwent catchment is underlain by a series of solid sedimentary strata that were formed between the late Permian and Cretaceous periods (Environment Agency, 2006; British Geological Survey, 2008) (**Figure 4.2a**). The sandstones and siltstones of the Sherwood Sandstone formation form the base of the sequence, and outcrop in the south of the catchment. These are overlain by the mudstones, siltstones and marls of the Triassic Mercia Mudstone Group. These rocks are in turn overlain by a series of Jurassic strata, with the marine mudstones, siltstones and sandstones of the Lias Group and fluvial sandstones and mudstones of the Ravenscar Group at the base.

Figure 4.2: Geology of the River Derwent catchment



Source: Environment Agency (2007)

The Ravenscar Group is overlain by the fine mudstones of the Oxford Clay, a thin band of which outcrops in the north of the catchment. This is overlain by the limestones, marls, sandstones and silts of the Corallian Group, and the mudstones and siltstones of the Kimmeridge Clay. Together, these two formations underlie a large proportion of the northern part of the catchment. The top of the sequence is comprised of the Cretaceous Chalk Group, which outcrops along the eastern boundary of the catchment.

Drift geology is absent from much of the upland areas in the north of the catchment, due to the impact of historical glacial processes (**Figure 4.2b**). There are, however, thick glacial and post-glacial drift deposits in the lower-lying areas in the south of the catchment. Alluvial deposits overlay much of the Sherwood Sandstone and Mercia Mudstone Groups in the south of the catchment. The Kimmeridge Clay towards the north of the catchment is overlain by lacustrine and alluvial deposits, which are replaced by sands and gravels and glacial till towards the eastern boundary of the catchment.

4.4 Soils

A number of major soil types are present within the Derwent catchment. Within the low-lying land of the former glacial outwash lake, Lake Pickering, the soils are dominated by alluvial gleys and stagnogleys, with peats towards the eastern end of the River Hertford. Podzols and brown rendzinas are associated with forest soils and chalk of the Yorkshire Wolds respectively.

The soils of the Derwent catchment are highly erodible, particularly those associated with post-glacial sands and gravels in the south east of the catchment (Sear, 1992). Sediment fingerprinting and cluster analysis (see Sear, 1992 for a full description of the techniques) has demonstrated that soil erosion from erodible agricultural soils upstream of Ryemouth is a dominant source of sediment supplied to the lower Derwent catchment. This analysis suggests that soils are eroded from the surface of agricultural fields, and supplied directly to the surface drainage network.

4.5 Hydrology

Average precipitation varies considerably across the River Derwent catchment, with an average of approximately 1000 mm a^{-1} in the uplands and an average of approximately 630 mm a^{-1} in the lowlands (Environment Agency, 2008). Rainfall patterns vary seasonally, with greatest precipitation historically occurring during the winter months (November – February). The smaller watercourses in the upland parts of the catchment respond rapidly to precipitation, with water levels increasing and decreasing rapidly in response to individual rainfall events. Further downstream, the lower reaches of the River Derwent respond more slowly to precipitation, and water levels can remain elevated for a several days after a period of rainfall (Environment Agency, 2006). This reflects the influence of groundwater on flows within the catchment. However, it is reported that the responsiveness of the middle and lower catchment has increased in recent years.

Figure 4.3: Mowthorpe sluice gate crossing the River Derwent

The River Derwent was formally tidal upstream to Elvington Sluice. However, the installation of Barmby Barrage at the Derwent-Ouse confluence in the 1970s has removed tidal influence from the river. Simulations by JBA Consulting (2004) suggest that a small amount of tidal influence is still exerted on water immediately upstream of the barrage during high flows. However, this influence is generally small, and non-existent during low flow conditions (JBA Consulting, 2004).

The hydrology of the Derwent catchment has also been modified by the construction of the Scalby Sea Cut, excavated between 1800 and 1804 in response to severe flooding in the lower Derwent catchment in 1799. The Sea Cut consists of a channel that links the River Derwent at Mowthorpe with Scalby Beck, which drains directly into the North Sea. There are sluice gates across the River Derwent at Mowthorpe which are partially closed during high flows (**Figure 4.3**), diverting the majority of the flow down the Sea Cut. When the sluices at Mowthorpe are closed, flow within the upper River Derwent is diverted fully along the Sea Cut and into the sea, bypassing the lower catchment.

4.6 Hydrogeology

The Derwent catchment contains two major aquifers: the Sherwood Sandstone formation and the rocks of the Corallian Group. The aquifers have direct connectivity with surface waters in upland parts of the Derwent catchment, (Environment Agency, 2006). The River Derwent is thus partially fed by groundwater, which is reflected in the response of the river to rainfall. Although the upper tributaries can show a rapid surface response, the influence of slower subsurface flows, coupled with the shallow gradient of the river, leads to slower rise and fall of flood flows in the middle and lower Derwent (although anecdotal evidence suggests that this response time may be becoming faster).

The influence of groundwater on flows within the River Derwent is most apparent during the prolonged periods of low precipitation, when groundwater levels drop considerably. During these conditions, flow in parts of the upper catchment can be considerably reduced, as water recharges the Corallian aquifer through a series of swallow holes (Environment Agency, 2006; Ove Arup and Partners, 1998). This is likely to impact water levels in the Derwent further downstream, which may impact the geomorphological functionality of the system.

4.7 Water abstraction

Abstraction within the Derwent catchment is strategically managed through the Catchment Abstraction Management Plan (CAMS). Within the Derwent CAMS area, the Environment Agency has issued 240 abstraction licenses. Public water supply is the most dominant use of licensed water comprising 59.2% of the total licensed volume for the catchment. Two major surface water abstraction points are located at Loftsome Bridge and immediately upstream of Sutton upon Derwent (Environment Agency, 2006). The second most dominant use is fish farming, comprising 37.6% of the total licensed volume. However fish farming is non-consumptive, whereby the water abstracted is returned to the river. The remaining proportions are abstracted for spray irrigation, industrial and commercial use, domestic and agriculture use, and 'other' uses (Environment Agency, 2006).

It is important to note that only 52.6% of the licensed quantity of water is actually abstracted in an average year in the Derwent CAMS area. Actual abstraction for public water supply, however, remains the largest use accounting for 29.7% of the licensed quantity of water.

In terms of future water resources management, the majority of areas are classified in the CAMS as having no water available. In addition, the Sutton on Derwent Water Resource Management Unit is classified as being over-licensed, and the West Ayton Water Resource Management Unit is classified as being both over-licensed and over-abstracted.

4.8 Land use

4.8.1 Current land use

Land use within the Derwent catchment is predominantly agricultural. Due to the recognised adverse influence of fine sediment and nutrients on the River Derwent and Derwent Ings SSSIs, the Yorkshire Derwent has been selected as a priority catchment under the Catchment Sensitive Farming initiative. Recent characterisation of landuse undertaken for the England Catchment Sensitive Farming Delivery Initiative indicates that 42% of the catchment area is arable land, 23% improved grass and 13% rough grazing. The upland in the north of the catchment is dominated by heather and grass moorland, which is used for rough grazing and grouse rearing, and by managed forestry plantations. In the lower-lying southern area catchment, where the River Derwent SSSI is located, arable farming is more important (ADAS, undated).

Based on 2004 agricultural census data, the major crops in the Derwent catchment are:

- Winter wheat (39% of arable land)
- Winter barley (14% of arable land)
- Spring barley (12% of arable land)
- Oilseed rape (10% of arable land)

4% of arable land is used for potatoes, a crop perceived as being “risky” in and agricultural sense due to their high fertiliser requirement and the potential for soil damage during harvest. A further 4% is under sugar beet, also perceived as a “risky” crop because of its late harvest, although this is likely to have reduced significantly recently as the result of the closure of the York sugar beet plant. 10% of arable land is set aside (ADAS, undated). Whilst there figures apply to arable land throughout the catchment, the majority of arable land, as previously noted, is in the lower catchment.

4.8.2 Land use change

Agricultural changes

The land adjacent to the River Derwent SSSI, was originally waterlogged and frequently inundated as a functional river floodplain. Drainage and construction of flood embankments from the 17th Century onwards reduced flooding of the land adjacent to the river and enabled cultivation for agricultural purposes.

Comparison of First Edition Ordnance Survey maps (dated 1849 to 1854) with current mapping of the River Derwent SSSI indicates that there has been limited change in the area of rural landuse along the River Derwent over the last 150 years. However, intensification of farming activities since the 1960s has increased crop yields. Furthermore, the amount of land used as pasture and to grow spring crops has reduced in favour of the more intensive cultivation of winter cereal crops. This is likely to have increased sediment yield from agricultural areas, since the ground is left bare during the winter months when rainfall is generally at its highest. However, anecdotal information states that broad-scale farming of land within the Derwent Ings SSSI has not changed between the early 1900s to the present day (McDonald and Howard, undated).

Afforestation

Afforestation of the catchment for commercial timber plantations began shortly after the First World War and there are now several major wooded areas in the uplands (Babtie, Brown and Root, 2002). Significant areas of the upland area has been afforested since the 1950s in response to commercial timber demand, with an increasing number of coniferous plantations evident from this time period onwards. However, Ove Arup (1999) considered this was unlikely to have a major impact on sediment yields within the catchment, due to management practices and an expansion in the planting of broadleaved species. However, field monitoring suggests that felling operations have historically increased sediment yields in the catchment.

Urbanisation and infrastructure

Over the past century, there has also been some increase in urbanisation along the River Derwent SSSI, although expansion is minimal compared to other neighbouring catchments. Urban areas that have expanded include Malton, Stamford Bridge, Elvington, Wheldrake and Bubwith. The majority of development has been located on or close to the floodplain, and could therefore impact on sediment supply and runoff characteristics. In terms of infrastructure, the key change between 1800 to the present day is the construction of the railway which follows the river closely from Malton to Howsham, and then along the south of the catchment crossing the Derwent near Wressle. The railway replaced navigation as the key transportation method in the 1840s and 1850s.

4.9 Channel modifications

Large parts of the River Derwent channel and riparian corridor have been heavily modified for agricultural, navigation and flood defence purposes. These modifications can be divided into six categories: floodplain drainage, construction of flood embankments, channelisation, water level control and recent flood defence and river maintenance.

4.9.1 Floodplain drainage

Large areas of the River Derwent catchment have been historically modified to enhance the agricultural productivity of the area, by improving drainage and alleviating flooding in the low-lying land, or ings, which fringe the river. The main dykes that drain the floodplain were excavated c.1620 (precise date unknown) to improve the drainage of adjacent farmland. Additional channelisation work and drainage of the Derwent Carrs was undertaken between c.1813 and 1830 (Sear, 1992). These works are likely to have increased the hydrological responsiveness of the catchment, and increased the supply of fine sediment from agricultural areas into the main channel system.

In the 1970s and 1980s, the dykes constructed in the 1620s were blocked and a new partial under-drainage scheme was established. Under this system, flood water that becomes trapped behind the flood embankments along the river is allowed to drain back to the channel through a network of drains which transport water under the embankments and allow it to discharge into the main channel through flapped drainage outfalls or cloughs (Lower Derwent Project, 2004). The influence on cloughs on the function of the River Derwent SSSI is discussed in **Section 5.3**.

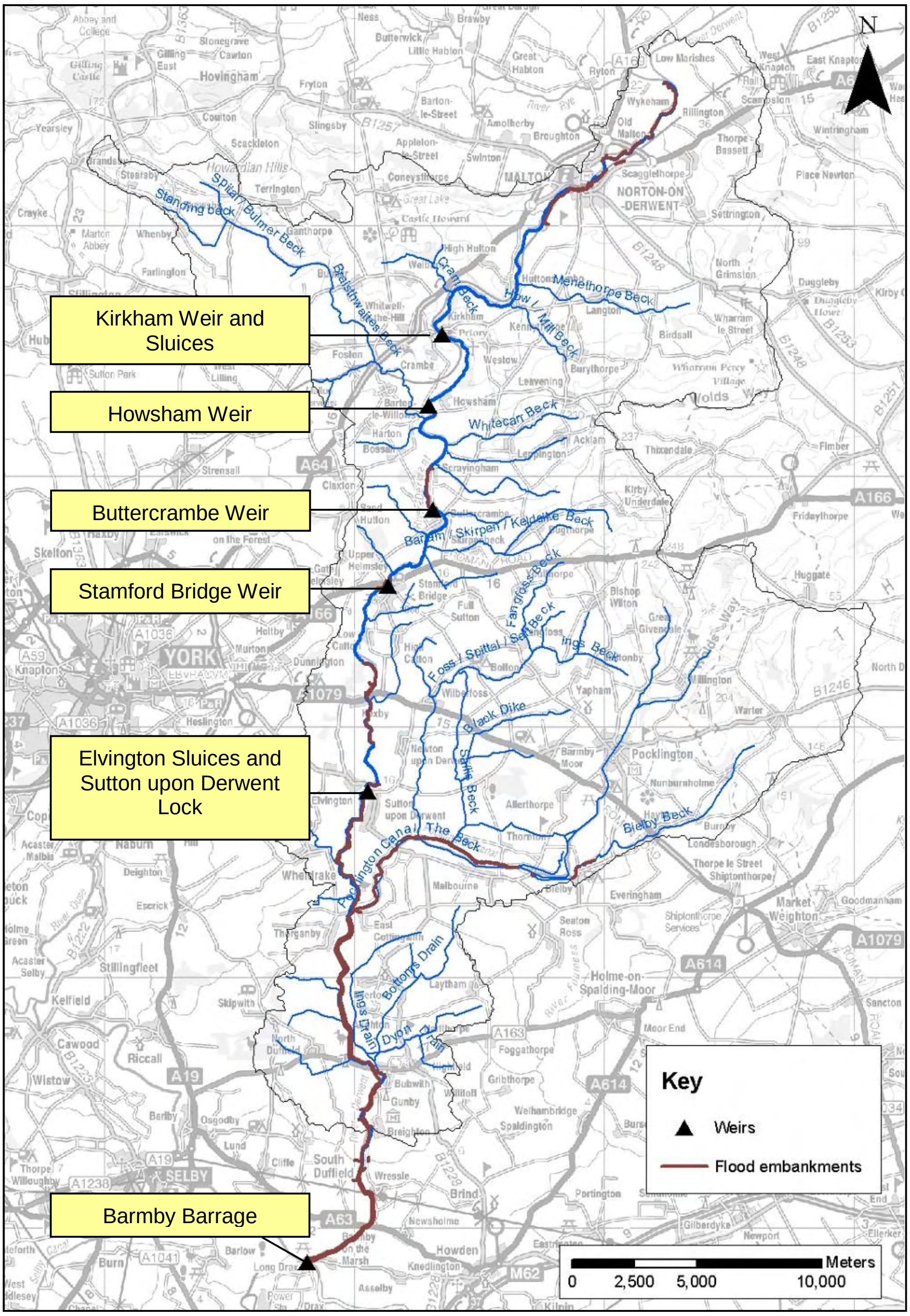
4.9.2 Construction of flood embankments

Flood defence embankments were constructed along much of the course of the River Derwent (**Figure 4.4**) prior to the production of the OS First Edition maps in the 1850s. In 1662, the Court of Sewers reportedly constructed a flood bank along the lower reaches of the River Derwent (roughly the formal tidal stretch extending upstream to Sutton Lock). The embankment prevented flooding in summer but not in the winter (Burnett et al, 1978).

In the 1950s, the River Ouse (Yorks) Catchment Board raised and strengthened the flood embankments of the River Derwent between Cottingwith and Barmby to prevent inundation of the adjoining floodplain. The aim was to reduce the frequency of flooding and make better use of floodplain storage capacity during periods of high flows. The works also included the reconstruction of a number of the gravity outfalls discharging the drainage ditches and minor tributaries to the River Derwent (Yorkshire Water Authority Rivers Division, 1978).

In the upper parts of the SSSI, the embankments are discontinuous and often restricted to a single side of the river channel (for example, around Malton, through Norton-on-Derwent, and the area adjacent to Wilberfoss and Newton upon Derwent). These embankments are intended to protect discrete areas (e.g. towns and villages) from inundation. Downstream of the confluence with the Pocklington Canal, however, the embankments become almost continuous on both sides of the river channel. These embankments, which are typically between 2 and 5 metres high, were designed to prevent the inundation of agricultural land during high frequency, low magnitude floods, whilst allowing overtopping during low frequency, high magnitude events. New flood embankments have also recently been constructed as part of flood defence schemes to protect urban development at Old Malton, Malton, Norton-on-Derwent, Stamford Bridge and Elvington.

Figure 4.4: Flood embankments and structures within the River Derwent SSSI



4.9.3 Channelisation

Navigation

The River Derwent was heavily channelised between c. 1720 and 1840 for navigational purposes. The first records of navigation on the lower stretches of the River Derwent date from the Middle Ages (Burnett et. al., 1978). In 1702, a Bill for a Navigation from Barmby on the Marsh to Malton received Royal Assent. During the first 20 years, few improvements were made apart from the provision of a lock at Sutton on Derwent and complaints were received regarding the lack of dredging undertaken. Subsequently, locks were constructed at Stamford Bridge, Buttercrambe, Howsham and Kirkham. The navigation became more profitable and was well used by commercial vessels (Burnett et. al., 1978). Dredging of the channel would have been undertaken throughout this period to maintain the navigation, resulting in widening and deepening of the channel along the majority of the River Derwent SSSI.

The 1840s and 1850s saw the expansion of the railways and the decline of navigation in the river. In 1855, the navigation was sold to an agent of the North Eastern Railway Company and maintenance of the navigation was reduced as transportation moved to the railways. In 1906, the Royal Commission on Inland Waterways commented ***"very little, if any, dredging appears to be done, and there are several dangerous shoals in the river and trees overhang in many places, and the water is overgrown with weeds."*** In 1935, the Derwent Navigation was transferred to the Yorkshire Ouse Catchment Board (Burnett et. al., 1978), and the River Derwent Navigation Act Revocation Order revoked the public right of navigation upstream of Sutton on Derwent.

In 1951, Elvington (Sutton) Lock was closed (IWA). In December 1991, a decision by the Law Lords ruled against the re-establishment of the right to navigate upstream of Sutton Lock and Yorkshire Wildlife Trust now owns the lower lock gate. The public right of navigation ends at Sutton Lock. Further information regarding the navigation can be found within Jones (2000) and Carstairs (2007).

Yorkshire Ouse River Board "Improvement works"

Comparison of current mapping with historical First Edition Ordnance Survey mapping of the area also indicates that the general planform of the River Derwent SSSI has not altered significantly for at least 150 years (since between 1849 and 1854). However, numerous improvement works, including. widening and deepening, were carried out by dragline excavator on the river in the 1930s and early 1940s. This included work at Wheldrake, Bubwith, Menthorpe, Breighton, Bowthorpe and Barmby. Further channelisation works were undertaken by the Yorkshire Ouse River Board between 1948 and 1958 (Yorkshire Ouse River Board, 1958). Channel works within the River Derwent SSSI included:

- Substantial widening between Ryemouth and Kirkham via dragline excavator, with the excavated material being spread on the adjoining land.
- Widening the channel at Espersykes Farm by approximately 6 m.
- Installation of approximately 65 m of steel sheeting piling with 6-9 m steel piles, through Malton and Norton.
- Excavation of limestone outcrop bedrock, approximately 180 m in length and at an average depth of 0.6 m, upstream of Old Malton. Loosened stone was subsequently removed using a dragline excavator.

Localised changes in planform within the River Derwent SSSI can be observed using First Edition and current mapping and are described below:

Downstream of Ryemouth

The meanders immediately downstream of Ryemouth (**Figure 4.5**) were straightened c. 1958 to improve drainage of the adjoining land. Previously water levels were considered to be too high, and a new channel was cut and the channel further downstream was widened and deepened. The old meanders were filled with the material excavated during the creation of the new channel (Yorkshire Ouse River Board, 1958).

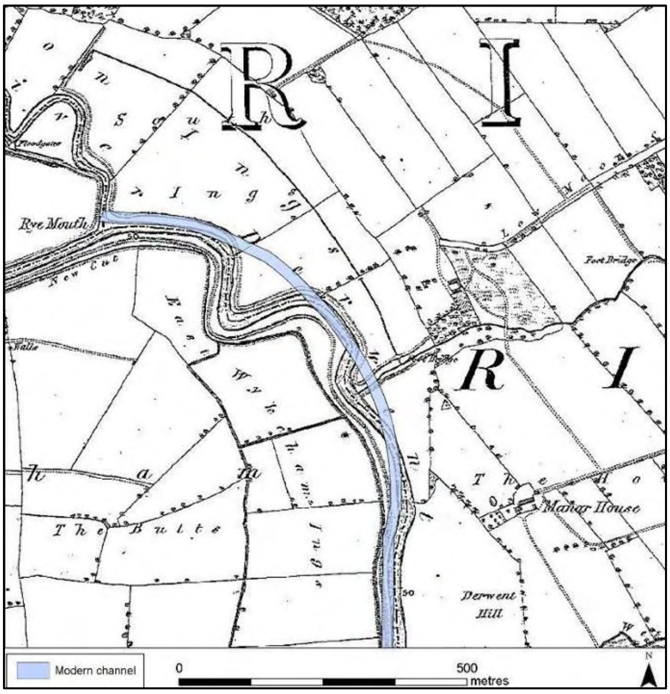


Figure 4.5: Channel straightening at Ryemouth (c.1958)

Downstream of Elvington

The relic meander at Elvington / Sutton-upon-Derwent (**Figure 4.6**), known as the Swallows, was straightened c.1946 as part of a land drainage ‘Channel Improvement Scheme’ (Environment Agency, 1998), and may have been part of the Yorkshire Ouse River Board “Improvement works”.

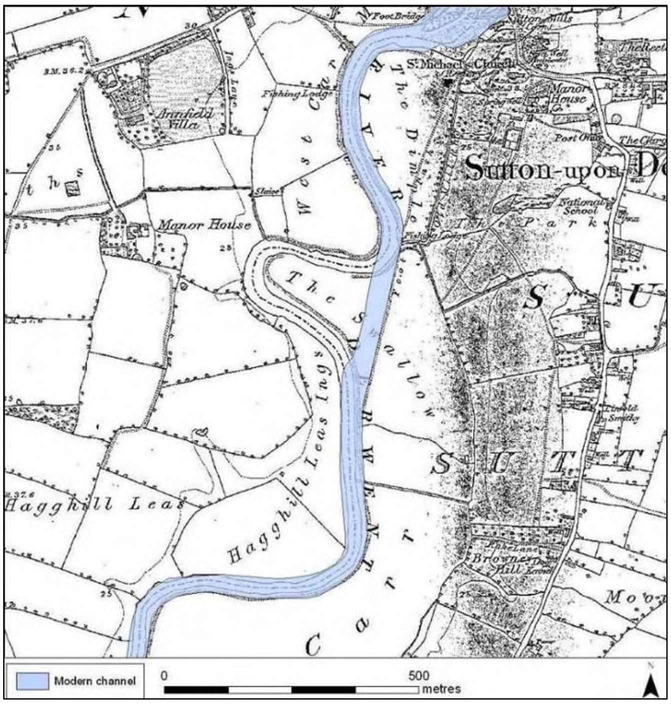


Figure 4.6: Meander cut-off at Sutton-on-Derwent (occurred c. 1946)

South Duffield

Analysis of First Edition historic mapping also illustrates the straightening of the river to cut off a meander at South Duffield (**Figure 4.7**) and several tight meanders at Barmby on the Marsh (although both of these sites are outside of the River Derwent SSSI).

The First Edition mapping also indicates that straightening works on a large meander downstream of Malton, associated with the construction of the railway line, had already occurred prior to 1849.

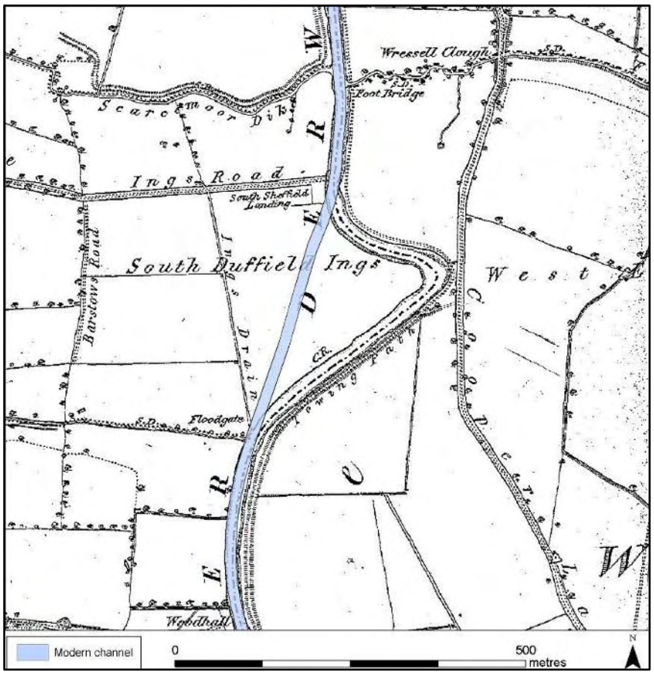


Figure 4.7: Meander cut-off at South Duffield ings (occurred in 1933/34)

4.9.4 In-channel structures

A number of weirs and sluice gates have been constructed along the River Derwent SSSI (**Figure 4.4**). The structures are used to control water levels or manage flood risk.. The primary structures within the River Derwent SSSI and details of their function are described in **Table 4.1**.

Many of the structures were originally constructed in association with historical milling activities (e.g. at Howsham, Buttercrambe and Stamford Bridge) and locations of the mills are evident on First Edition Ordnance Survey mapping (1849 – 1854). By 1958, automatic sluices were installed at Kirkham by the Yorkshire Ouse River Board as part of their programme of "improvement works (Yorkshire Ouse River Board, 1958). Many of the water level control structures were originally bypassed by locks in order to enable navigation. However, now only the locks at Sutton-upon-Derwent and Barmby Barrage are functional. Sutton-upon-Derwent lock is only operated with permission from the Yorkshire Wildlife Trust who own the lower lock gate. The old lock channel at Buttercrambe has been partially filled in.

Table 4.1: In-channel structures within the River Derwent SSSI (and Barmby Barrage)

Structure		Description	Function
Kirkham Weir and Sluices		The River Derwent bifurcates at Kirkham around a small island. Kirkham Weir spans the right channel, and there is a fish pass located towards the right bank. Across the left channel there is a set of automated sluices, which comprise two 6 m by 1.5 m steel doors set in a concrete and sheet pile structure.	The sluices are owned and operated as flood defence assets by the Environment Agency. Although their function is currently under review, they are designed to protect properties between Howe Bridge and Kirkham from inundation during major flood events and to retain water levels in the river between Old Malton and Kirkham during periods of low flow.
Howsham Weir		Howsham Weir is a relatively low structure that incorporates a turbine. Although the structure does not include a fish pass, it is reported that it is passable during normal flow conditions (Yorkshire Fishery Board, 1946).	The weir was originally used to raise water levels for Howsham watermill, which is currently being restored (www[1]). The structure is owned by the Environment Agency, and incorporates a functional Archimedes Screw for hydro-power generation.
Buttercrambe Weir		Buttercrambe Weir is a concrete structure that does not incorporate a fish pass and is too high to pass in most flow conditions.	A weir was originally constructed to raise water levels for Buttercrambe Mill. This was replaced in 1972/73 with the current structure which is associated with the Environment Agency gauging station.
Stamford Bridge Weir		Stamford Bridge Weir is a concrete, broad-crested weir, 31 m wide (www[8]), located in the town of Stamford Bridge.	The weir was originally constructed to raise water levels for milling at Stamford Bridge. The structure was used as a flow gauge between 1932 and 1977 (www[8]), It does not appear to have a current function, however. There is a sluice in the old navigation cut.
Elvington Sluice and Sutton upon Derwent Lock		Elvington Sluice consists of two counter-balanced concave steel gates set in a concrete superstructure. A fish pass was installed in 1939. Sutton Lock consists of a guillotine structure at the upstream end and a conventional lock gate at the downstream end.	The sluice, is owned and operated by the Environment Agency. The sluice maintains water levels in the river to facilitate water abstraction from the Elvington water treatment works. Sutton Lock is used to a limited extent by boat owners for navigation and requires permission from Yorkshire Wildlife Trust.
Barmby Barrage		Barmby Barrage consists of two vertical lifting gates set in a concrete structure, and a lock to allow boat passage upstream.	The structure is operated to enable abstraction for water supply to occur and includes a clause which requires sufficient depth for boats to pass upstream.

In-channel structures can have a considerable influence on the geomorphology and ecology of rivers, impounding water, increasing sedimentation upstream and acting as a barrier to sediment transport and migration of aquatic species. The Barmby Barrage, situated at the confluence between the River Derwent and the River Ouse, is of particular significance to the geomorphology and ecology of the River Derwent SSSI (see **Section 4.9.5**).

4.9.5 Barmby Barrage

Function

Barmby Barrage was commissioned as an operational structure in 1975 and consists of two vertical lifting gates (7 x 5 m) and a lock to provide boat passage around the structure (Chalk, 2004).

The barrage was originally constructed to meet three specific objectives:

- To prevent poorer quality water from the tidal River Ouse entering the lower Derwent (unless operated to relieve flooding in Selby);
- To retain adequate water levels for abstraction at Loftsome Bridge Water Treatment Works, a short distance upstream. This is defined in the Barmby Tidal Barrage Order (1972) as a minimum of +1.3 mAOD; and
- To maintain sufficient water levels for navigation between Barmby and Sutton Lock, particularly over a shallow shoal situated approximately 450 m upstream of the structure. This is defined in Clause 13 of the Barmby Tidal Barrage Order (1972) as "not less than 1.5 m whenever drainage of land adjacent to the river … will not be prejudicially affected", or 1.2 m at all other times."

In addition to this, the barrage is also used to mitigate against potential flooding in Selby. During high tides when flow is high in the River Ouse and there is a risk of flooding to people and property, the structure is operated to allow water into the Derwent. Barmby Barrage is therefore a major structure that has a considerable impact on the flow regime of the lower River Derwent changing it from a tidal regime to a regulated freshwater regime.

Operation

The barrage is operated within a strict set of parameters. Until 2003, the retention level was set on a daily basis to meet the requirements of the Barmby Tidal Barrage Order (1972), depending on the discharge recorded at Buttercrambe Weir (Chalk, 2004). As flow decreased, the retention level was increased in order to maintain the water levels required for navigation and water abstraction. Operation criteria varied according to water levels in the Derwent, and gate movements were controlled automatically by sensors on the upstream and downstream faces of the barrage. To avoid excessive gate movement, gates were operated within specified tolerances of the required retention level. The barrage was operated on four phases, depending on the tidal state.

The operating procedures at Barmby Barrage were revised during 2003, to allow more refined control of the water level and so avoid the oscillation of water levels that was experienced with the original procedures (JBA Consulting, 2004; Chalk, 2004). Revision of the operating procedure set a gate opening protocol based on flow in the River Derwent at the Loftsome Bridge water abstraction intake and at the shoal 450 m upstream of the barrage, and the water level in the River Ouse. When river flow at the barrage is above a preset value of 6 m^3s^{-1} the structure will attempt to maintain a level of 1.6 mAOD at the Loftsome Bridge intake (JBA Consulting, 2004). When the flow falls below the set value the system refers to a lookup table to determine the appropriate retention level (**Table 4.2**).

Table 4.2: Determination of retention levels at the Barmby Barrage

Discharge measured at barrage (m^3s^{-1})	Retention level (mAOD)
0	2.40
1	2.37
2	2.33
3	2.28
4	2.18
5	2.07
6	1.95
7	1.72

Source: JBA Consulting (2004)

The revised operation still operates in a four-phase tidal cycle (Chalk, 2004), as described in **Table 4.3**.

Table 4.3: Four-phase tidal cycle operation of the Barmby Barrage.

Operation Procedure	Water level (Ouse above Derwent)	Operation
Phase 1: Tide Lock	within 100 mm	Initiated by Ouse level rising to within 100 mm of Derwent. Gates automatically close. System remains in this phase while the Ouse level is greater than the Derwent.
Phase 2: Free Flow	-150 mm	Assumed that all upstream levels are above set points. Phase is initiated by Derwent being more than 150 mm above Ouse level. Gate calculates a gap where the bottom of the gate is 1.4 m immersed and adjusts every 4 minutes. This continues until the set point for the intake is less than 1.6 mAOD or the Derwent falls too low (triggering Phase 1 again).
Phase 3: Initial Retention	< 1.6 mAOD	System opens gate to allow discharge (based on lookup table) to pass through based on upstream & downstream water levels.
Phase 4: Controlled Retention	(see Table 3.1)	System continues to recalculate gate position (based on lookup table) every 15 minutes and adjusts by either +70 mm or -100 mm to maintain river levels.

4.9.6 Recent flood defences

Flood defences within the River Derwent SSSI consist largely of the raised flood embankments which have been maintained and in places raised since their original construction (see **Section 4.9.2**). In addition, key water level control structures also serve as flood defences (see **Table 4.1**). Localised walling has also been constructed, most notably in Malton/Norton, to provide flood defence and prevent bank erosion.

Since flooding within the Derwent catchment in 1999, additional flood defences have been constructed to reduce flood risk. New flood alleviation schemes have been implemented along the River Derwent SSSI at Old Malton, Malton, Norton (2003), and Stamford Bridge (2004). At each of these locations, additional lengths of flood embankment and walling have been constructed to protect properties.

In 2007, new flood defences were also constructed at Elvington where backing up of Elvington Beck when flows in the River Derwent are high resulted in flooding within the village. The works consist of an embankment, culvert, penstock and pumping station, to protect property against a 1 in 100 year flood event.

4.9.7 River maintenance

Maintenance regimes within the Derwent catchment include a yearly programme of grass cutting, vermin control on flood banks, weed control of watercourse channels to maintain water flow in the smaller watercourses, and visual inspection of all defences to ensure the flood alleviation schemes are in good condition. This work is planned on an annual basis. The Internal Drainage Boards within the Derwent catchment also undertake similar maintenance works on drainage channels to improve land drainage.

More recently, sympathetic tree management has also been undertaken within the SSSI, including tree and shrub maintenance (including pollarding) at Wheldrake (2008) and Buttercrambe (2009).

4.10 Chronology of anthropogenic change in the Derwent catchment

Sections 4.8 and **4.9** demonstrate that land use and the physical structure of the River Derwent have altered considerably in the last few centuries. An outline chronology of these changes is provided in **Table 4.4**. This demonstrates that major channelisation works and drainage improvements were implemented in the 1950s, and that modifications have continued until the late 1970s.

Table 4.4: Chronology summarising anthropogenic changes within the River Derwent SSSI

Change	Pre-1800s	1800s-1850s	1850-1930s	1940s-1960s	1970s-1980s	1990s - 2000s
Floodplain drainage and embankment construction	**c. 1620s** - Excavation of main dykes **1662** – construction of embankments by Court of Sewers	Works to alleviate flooding and increase areas of productive farmland **c.1813 to 1830** – Drainage of Derwent Carrs and Ings		**1950s to 1960s** - Raising and strengthening of flood embankments by River Ouse (Yorks) Catchment Board between Cottingwith and Barmby	Construction of under drainage system (flapped outfalls and associated pipework under the flood bank which allow the drain to flow depending on river levels)	**1990s** – Mining under North Duffield Carrs **2003 and 2004** - Construction of Flood Alleviation Scheme embankments at Old Malton, Malton and Norton (2003) and Stamford Bridge (2004)
Landuse change	Increased agricultural production within the floodplain		Intensification of farming and expansion of cereal production			Less intensive maintenance of grips and investigation of their impact on drainage
				Post-war afforestation of upland areas of the Derwent catchment for commercial timber		
Channelisation and in-channel structures	Construction of weirs for milling purposes at Howsham, Buttercrambe and Stamford Bridge **1677** - Construction of Kirkham weir (Foston, 2002)	**1800-1804** - Construction of Scalby Sea Cut as part of the Mowthorpe Sluice flood alleviation scheme Construction of railways and associated embankments	**1933-1944 -** Improvement work at Wheldrake, Ellerton, Aughton, Bubwith, Menthorpe, Gunby, Breighton, Bowthorpe and Barmby **1939** - Elvington fish pass completed	**1948-1958** - Yorkshire Ouse River Board Improvement works between Ryemouth and Kirkham. Localised planform realignment at Ryemouth and The Swallows **1951** – Elvington (Sutton) lock closed **1958**- Installation of automated sluices at Kirkham	**1972** – Restoration of Sutton Lock **1975** - Construction of Barmby Barrage	**2003** – Modification pf operation of Barmby Barrage
River Maintenance (and navigation)	**1702** - Navigational rights given by Act of Parliament **1702 to c.1720** – Little channel maintenance **c. 1720 onwards** – construction of locks and dredging maintenance for navigational purposes	**Until 1840** - Continued maintenance for commercial navigation **1840s-1850s** – Decline of navigation due to railway expansion	**1855** – navigation sold to North Eastern Railway Company **1906** – little maintenance observed by Royal Commission of Inland Waterways **1935**- Navigational rights above Sutton Lock revoked	Maintenance of navigation downstream of Sutton Lock		
					Grass cutting, vermin control, weed control, pollarding and visual inspection of defences	
					1977 - Dredging of shoals following temporary suspension of Clause 13	**2008/9** – sympathetic tree and shrub maintenance (including pollarding) at Wheldrake (2008) and Buttercrambe (2009)

5 GEOMORPHOLOGICAL BEHAVIOUR OF THE RIVER DERWENT

5.1 Purpose of this section

This section presents an analysis of the geomorphological behaviour of the River Derwent within the study area combining the results of the desk based assessment and field survey. The field survey data has been analysed using a GIS to display spatial trends of parameters which can be used to indicate the characteristics of the morphology and sediment regime catchment wide. More specific details on reach-scale characteristics can be found in the watercourse summary sheets, which are presented in **Appendix B** and which have also been analysed to identify catchment scale trends. Cross-reference will be made to **Section 4** which describes the factors influencing geomorphological response.

5.2 Channel geomorphology

5.2.1 Long profile

Detailed channel cross sections have been used to compile a high-resolution long profile of the bed of the River Derwent. Three surveys were used:

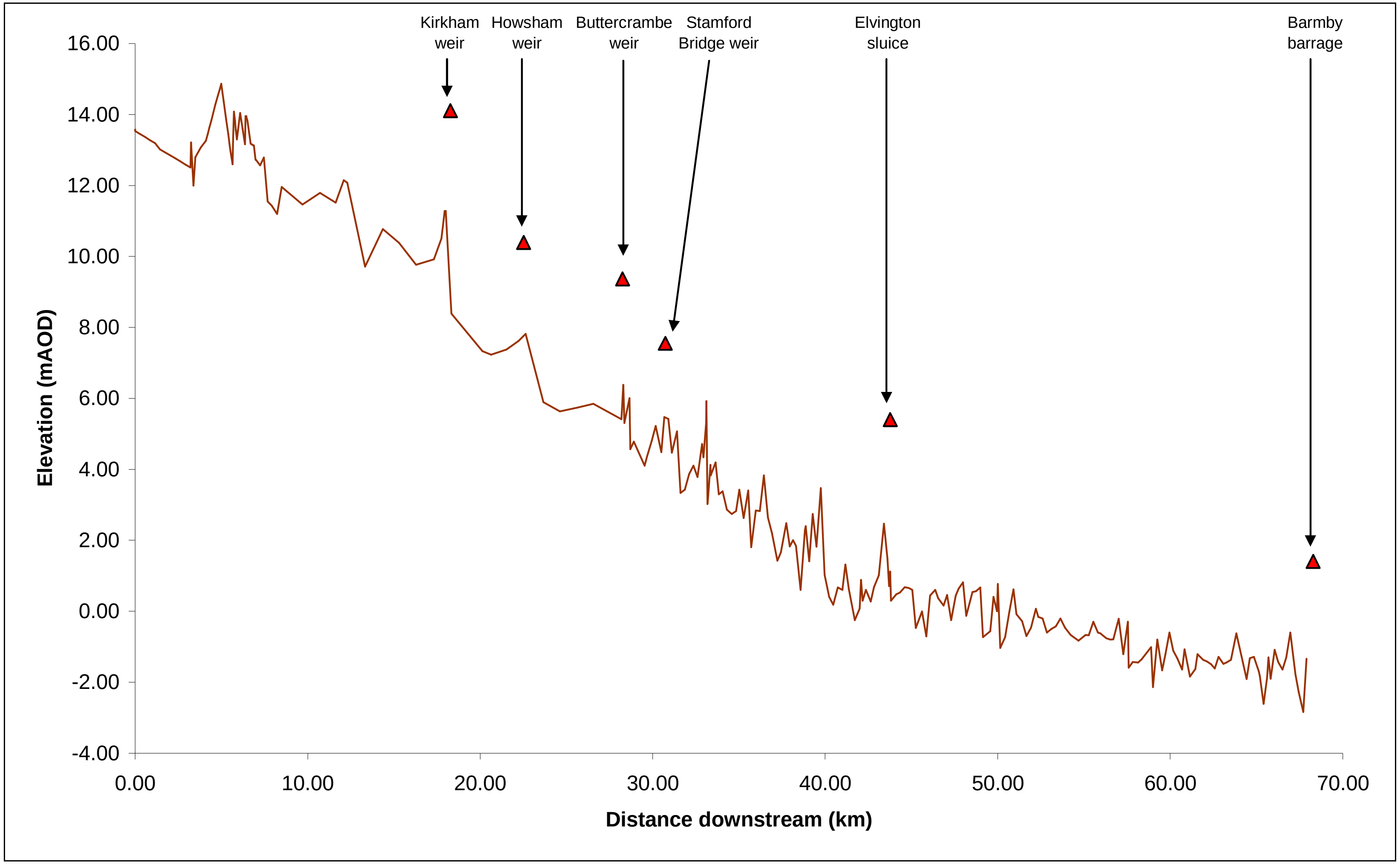
- Rye and Derwent Catchment Flood Forecasting Model: Rye-Derwent confluence downstream to Malton, surveyed in August 2007.
- Malton Data Improvements: Malton to Buttercrambe, surveyed in March 2008.
- Lower Derwent Project: Buttercrambe to the Derwent-Ouse confluence, surveyed in July 1998.

Once assembled, these data comprised 263 cross sections between the Rye-Derwent confluence and Barmby Barrage.

The estimated long profile for the River Derwent SSSI is reproduced in **Figure 5.1**. Although there are differences in resolution and time of collection, these data show a coherent long profile with gradient falling steadily with distance downstream before adopting a stable low gradient in the final 25 km of channel (downstream of the former tidal limit at Elvington).

The uppermost reach has a mean bed slope of 0.017, and bed elevation falls from approximately 14 mAOD at the upstream limit of the reach to approximately 0.5 mAOD at the downstream limit. Increases in bed elevation can be observed immediately upstream of the major weirs and sluices that cross the channel, and are likely to reflect sedimentation upstream of these structures. Channel gradient reduces considerably in the lower reach, downstream of Elvington Sluice, with mean bed slope falling to 0.003. In this 25 km-long section of the channel, bed elevation falls from 0.5 mAOD to 1.6 m below Ordnance Datum immediately upstream of Barmby Barrage.

Figure 5.1: Long profile of the River Derwent study reach



5.2.2 Channel characteristics

Direct field observations and analysis of cross-sectional data demonstrates that the shape of the Derwent is generally uniform U-shaped cross section, with steep or re-graded banks composed of fine grained sediments (**Table 5.1** and **Figures 5.2** to **5.4**). With the exception of several localised constrained reaches, the channel generally flows within a wide, flat valley. This consistency in channel shape reflects the extensive modification of the channel form for navigation and flood defence (see **Section 4.9**). New sections of channel constructed to straighten the river, such as those referred to in **Section 4.9.3**, have been built in this form.

Table 5.1: Channel characteristics

Feature	Distribution
Valley form (**Figure 5.2**)	In the upper parts of the study reach (D01 – D19), the River Derwent generally flows through a shallow u-shaped valley, although it also passes through several narrower, more constrained reaches (D05 and D07). Downstream of Wheldrake (D19 – D22), the floodplain becomes considerably wider, with little variation in relief.
Channel planform (**Figure 5.3a**)	On a large scale, the Derwent follows a slightly sinuous course. However, more detailed investigations demonstrate that a large proportion of the channel has been artificially straightened, even though these reaches follow a broadly meandering planform on a catchment-scale. Old channel courses are evident on aerial photographs.
Channel cross section (**Figure 5.3b**)	The cross section of the channel is generally U-shaped, with little variation apparent along the study reach.
Bank material (**Figure 5.3c**)	The banks of the Derwent are dominated by fine sediments (< 2 mm) along the entire study reach. Localised areas of the bank have been artificially reinforced (e.g. D02, D11, D13 and D21).
Vertical bank profile (**Figure 5.4a**)	Vertical banks are found along much of the Derwent, and dominate both banks upstream of Kirkham (D01 – D06), between Howsham and Low Catton (D09 – D13), and upstream of Thorganby (D19 – D20).
Stepped bank profile (**Figure 5.4b**)	Stepped banks occur throughout the reach, and occur on both sides of the channel upstream of Malton (D01 – D02), between Huttons Ambo and Howsham (D05 – D08), and between Stamford Bridge and Thorganby (D12 – D20). These banks occur in areas where vertical bank profile also occurs, and are likely to be formed as a result of bank failure.
Graded bank profile (**Figure 5.4c**)	Graded banks have been observed in the upper reaches between Malton and Howsham (D03 – D09), but are most commonly found downstream of Stamford Bridge (D12 – D22). This bank profile is likely to be indicative of historical regrading works.
Flow type	Flow in the Derwent is almost universally of a “glide” flow type, with the majority of reaches exhibiting deep, slow, flow patterns. Localised areas of turbulent flow can be observed downstream of Kirkham, Howsham, Buttercrambe and Stamford Bridge Weirs, due to the presence of the structures themselves.

Figure 5.2: Valley characteristics within the River Derwent SSSI

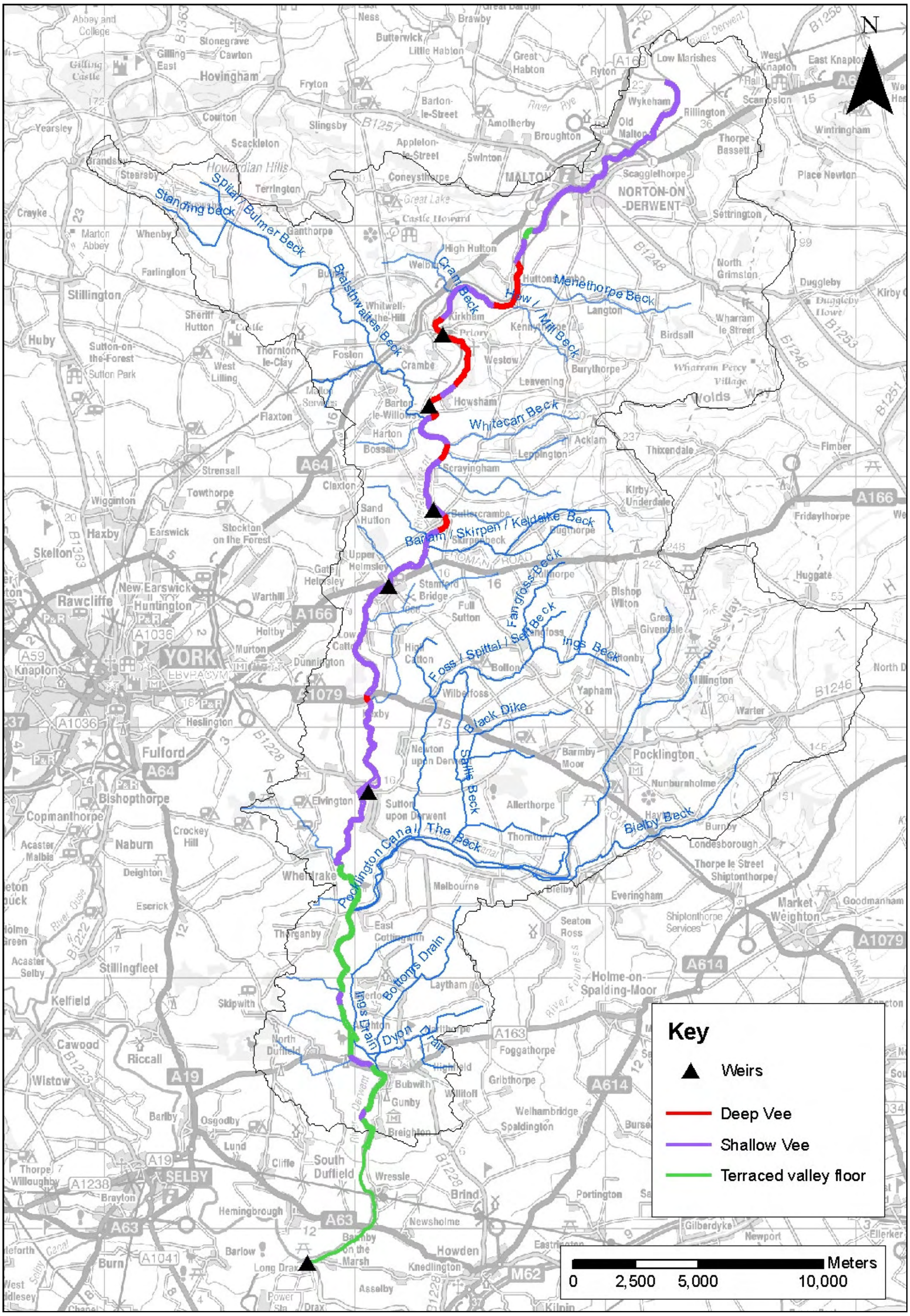
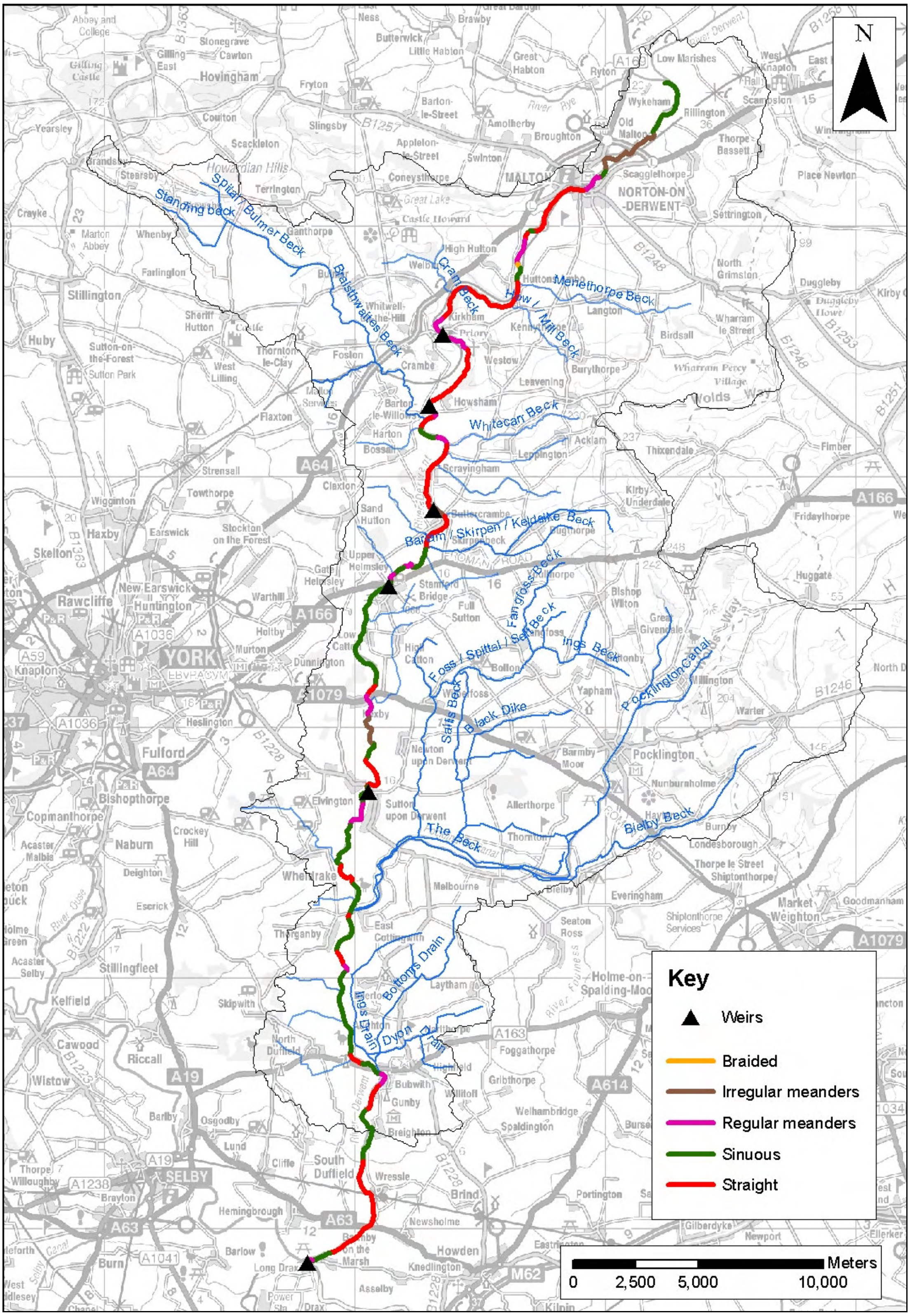
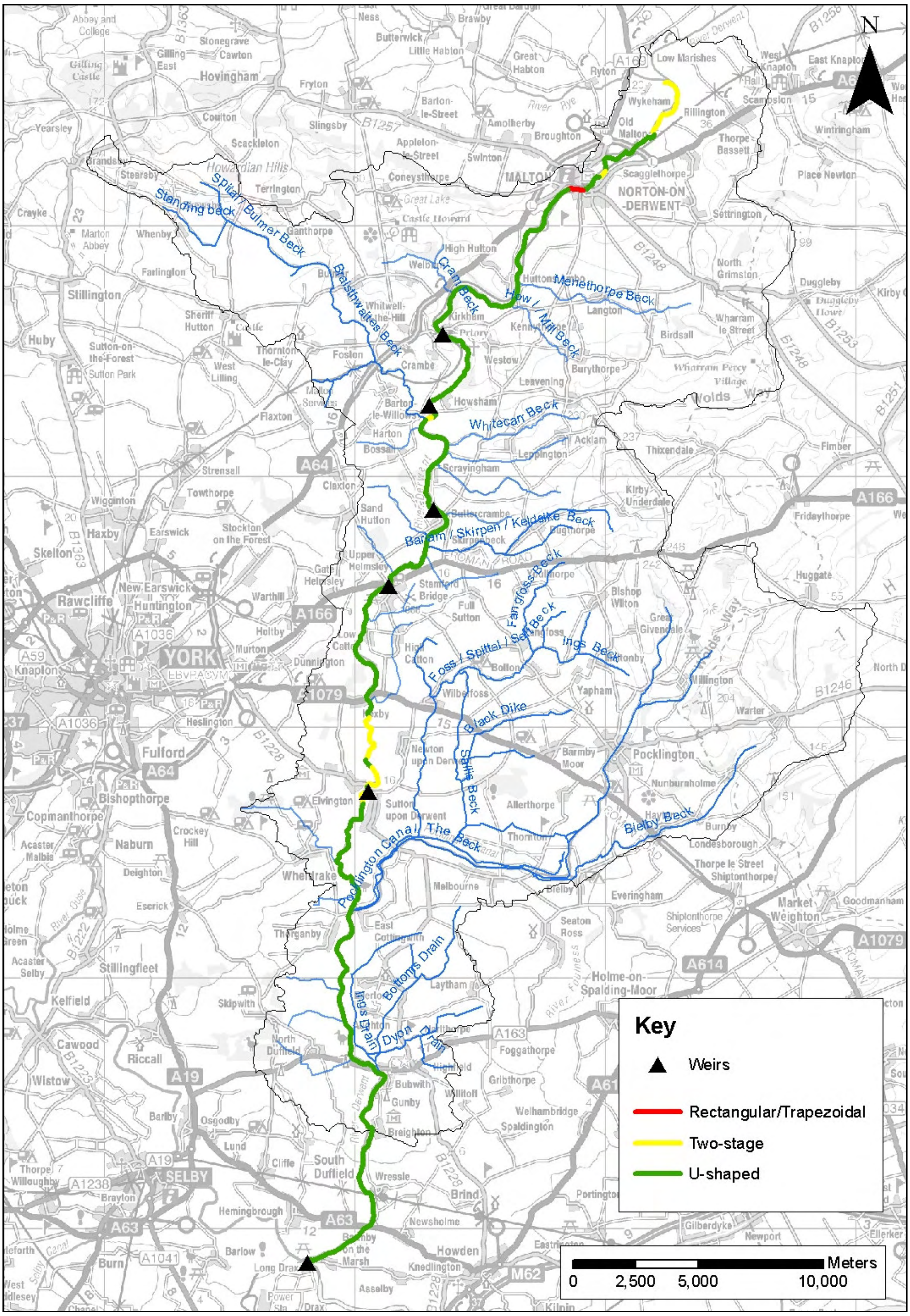


Figure 5.3: Channel characteristics within the River Derwent SSSI

(a) Channel planform



(b) Cross-sectional profile



(c) Bank material

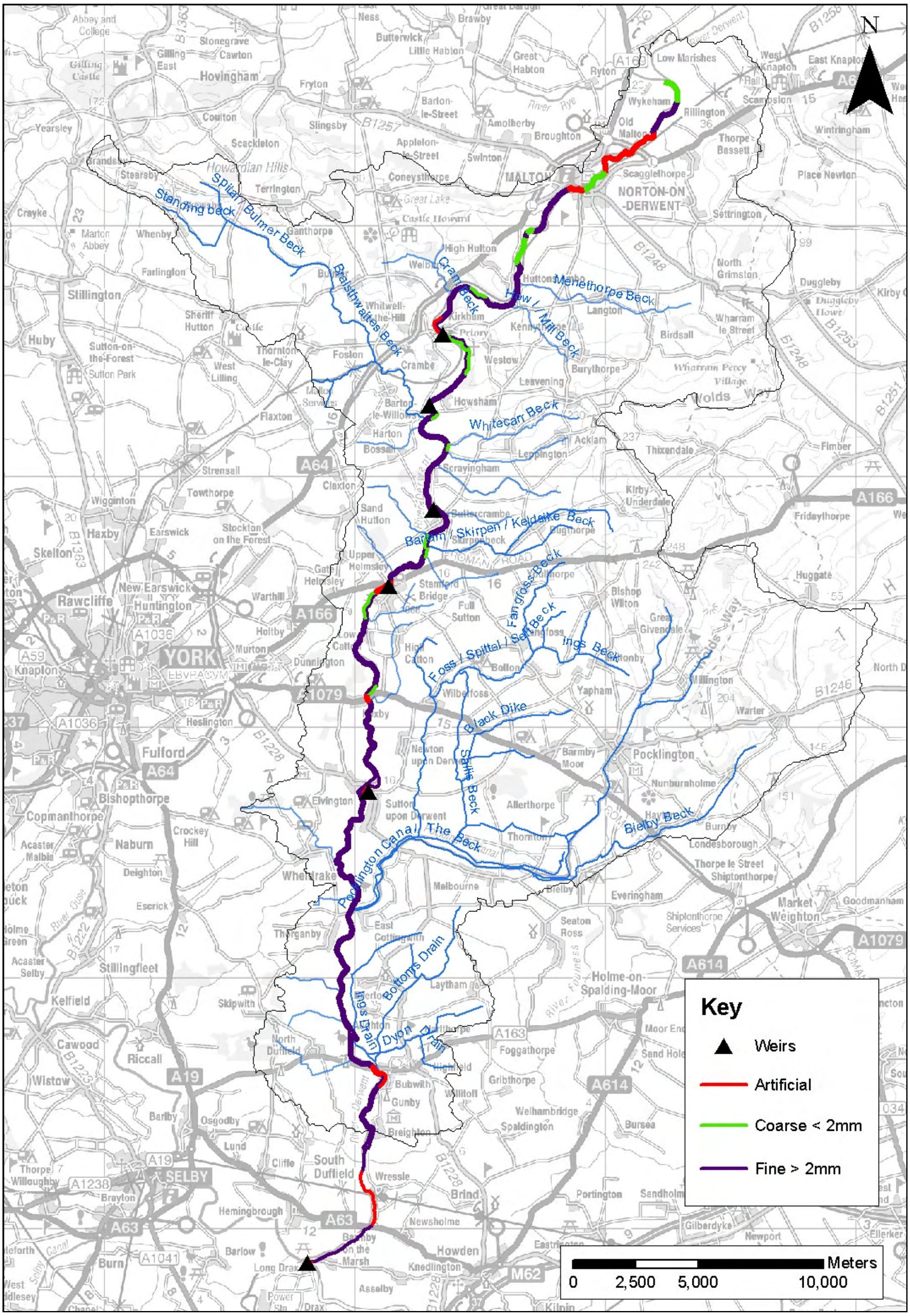
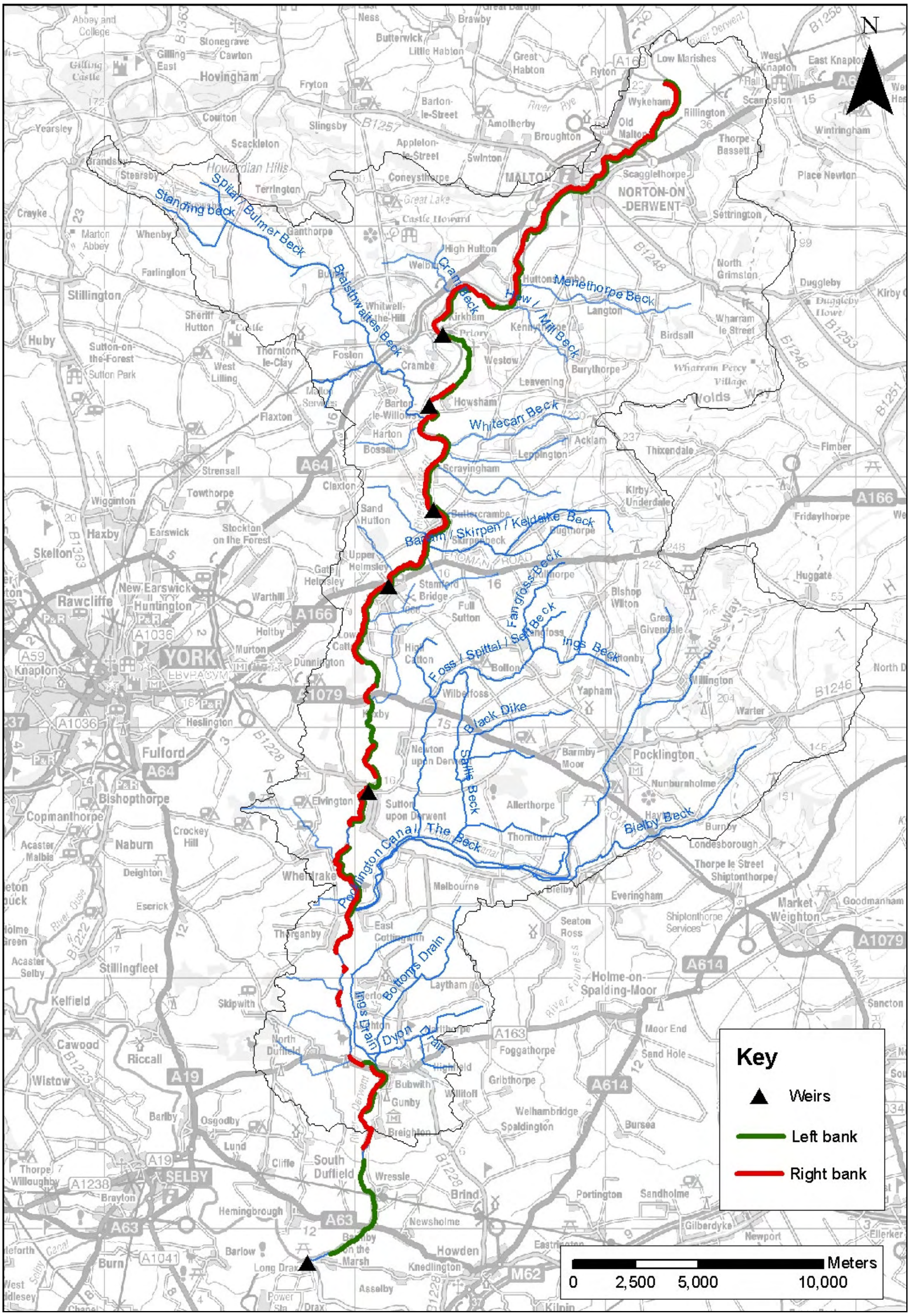
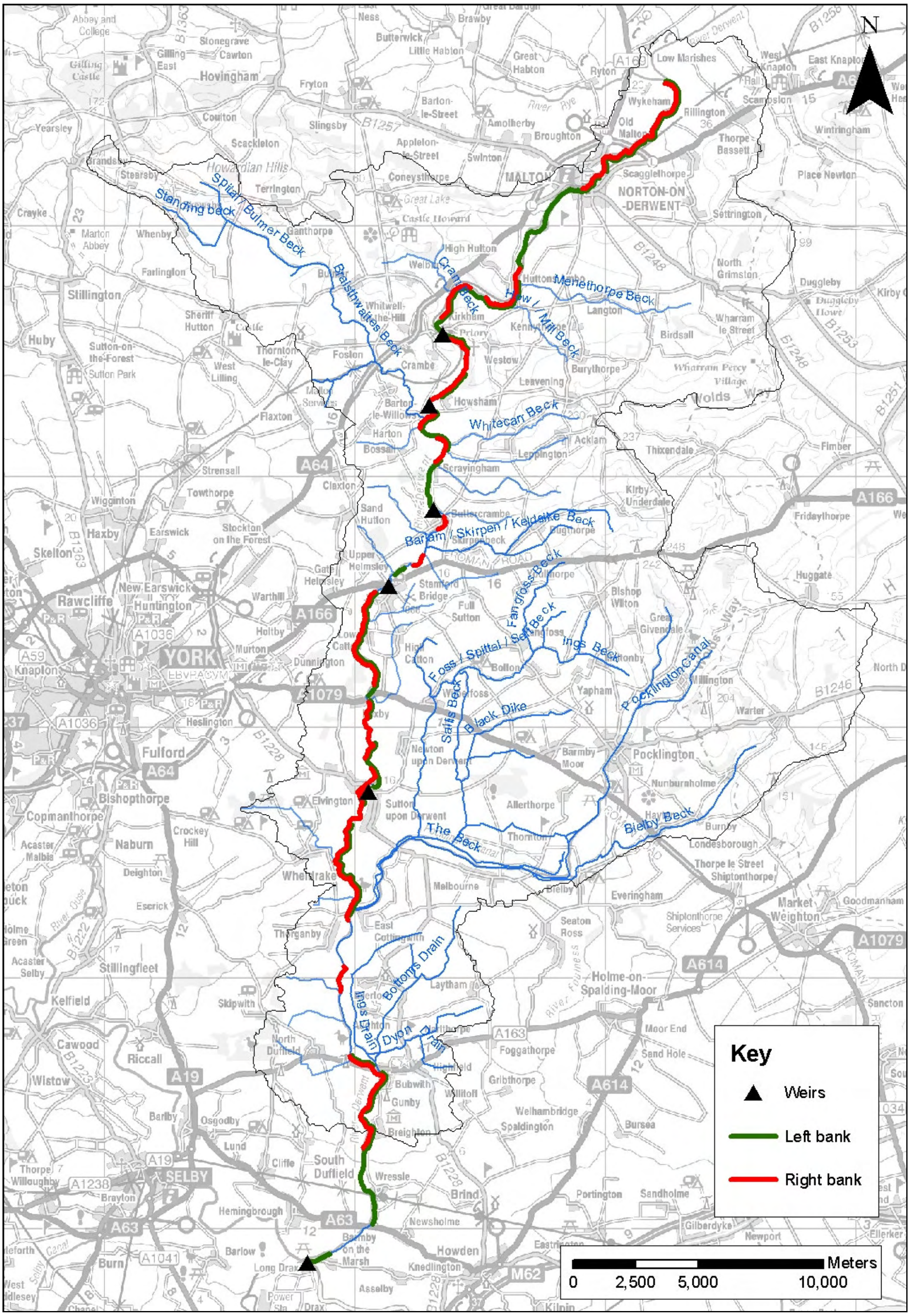


Figure 5.4: Bank profile characteristics within the River Derwent SSSI

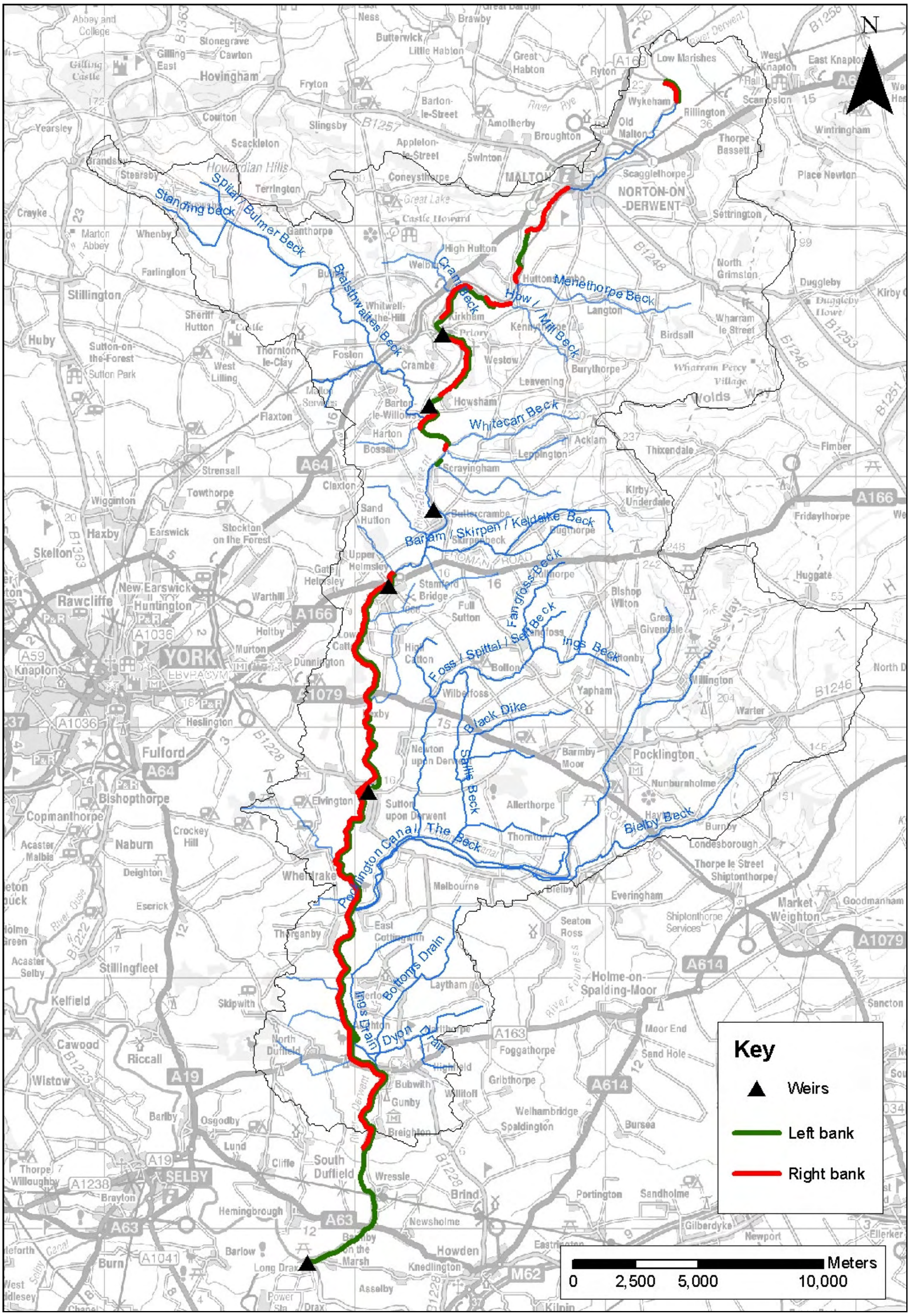
(a) Vertical bank profile



(b) Stepped bank profile



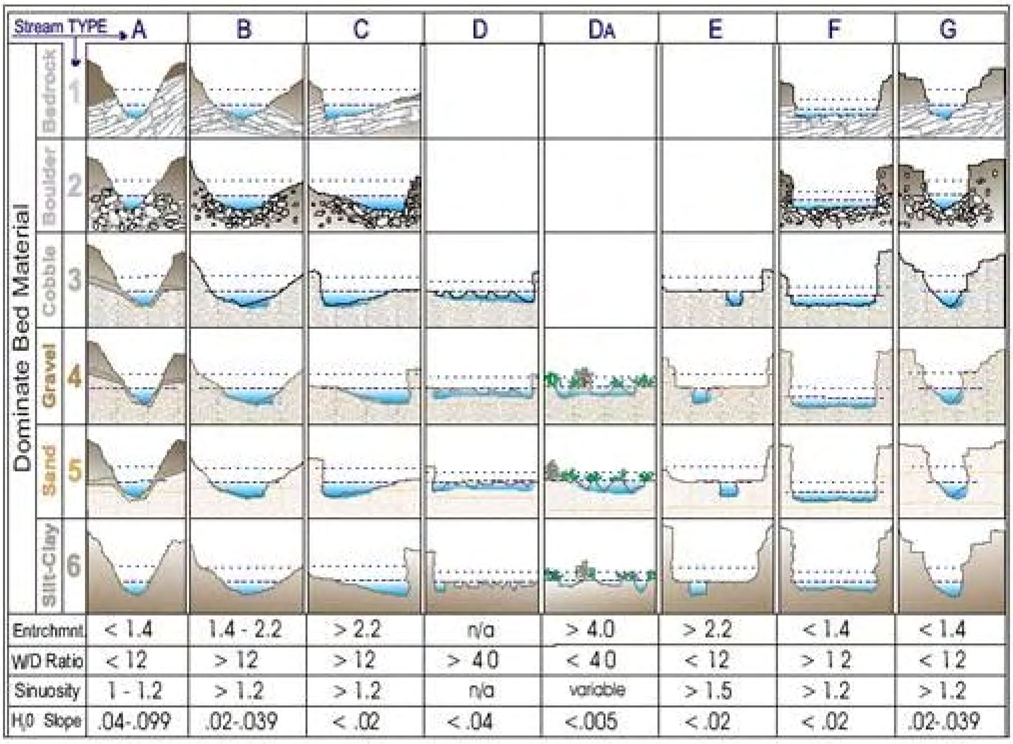
(c) Graded bank profile



The bankfull width and depth of the river channel were obtained from the channel cross sections, and width:depth ratios were calculated (**Figure 5.5a to c**). There is considerable local variation, with areas of higher width:depth ratio coinciding with Howsham Weir, Sutton Lock and Barmby Barrage. This may reflect shallower wide sections of channel upstream of the structures. Mean bankfull width is 28.6 m, and mean bankfull depth is 6.75 m. Width:depth ratios range from 1.5 to 20, with a mean value of 6.03 (**Figure 5.5a**). This value is relatively low in comparison with many river systems.

The Rosgen (1994) classification system (a widely-used method for classifying streams and rivers based on common patterns of channel morphology), considers any natural channel with a width:depth ratio of less than 12 to be low. This may in some part be characteristic of the "type" of river the River Derwent represents (based on initial analysis most likely type E which is characterised by a low width:depth ratio).

Figure 4.7: Rosgen classification system

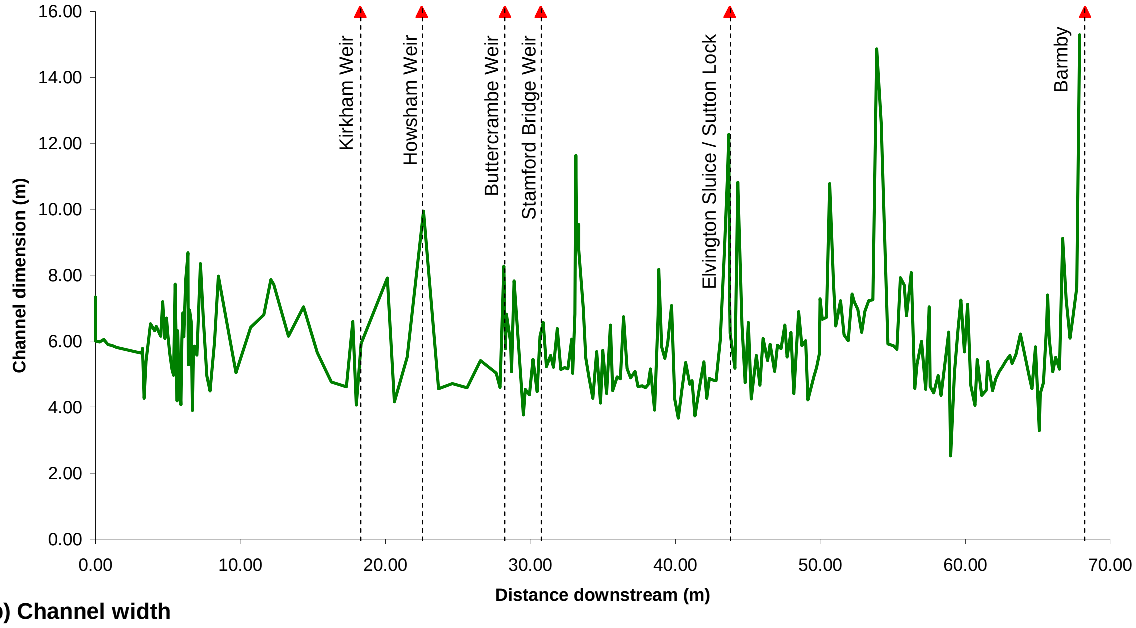


Source: Rosgen (1994)

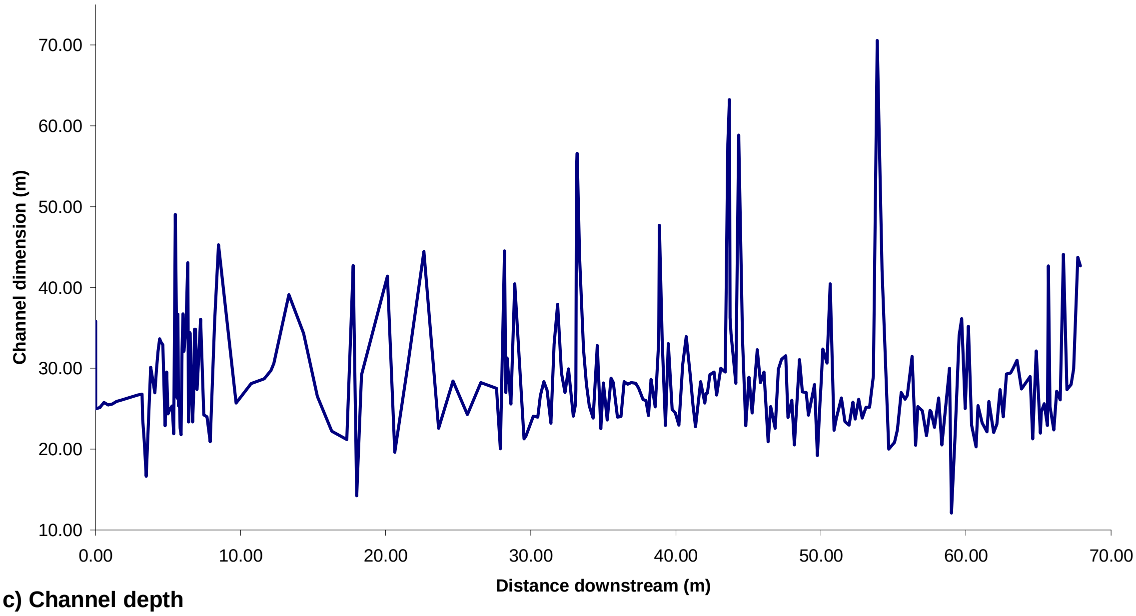
However, it is also likely that the majority of the River Derwent SSSI has been over-deepened, as a result of historical dredging activities for navigation and land drainage purposes (see **Section 4.9.3**). In particular, it appears that several of the areas of localised increases in width are located downstream of Stamford Bridge, reflecting the previous extent of public navigation rights. In interpreting the data, it should also be noted that there is greater resolution of cross-sectional data available downstream of Buttercrambe and within Malton/Norton than between Malton and Buttercrambe. This may also influence the identification of localised areas of higher width:depth ratios within the River Derwent.

Figure 5.5: Bankfull width and depth relationships

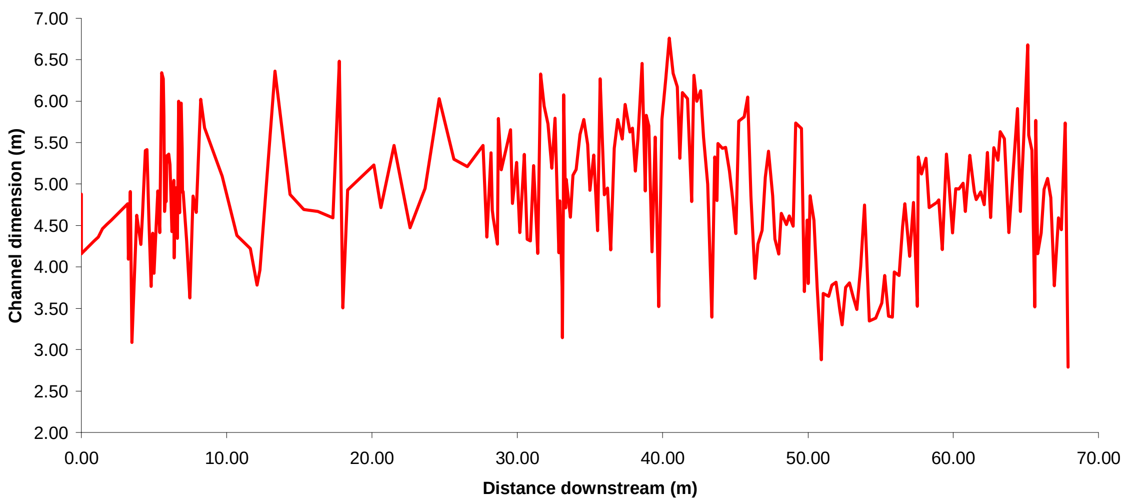
a) Width:depth ratio



b) Channel width



c) Channel depth



5.3 Hydrological regime

5.3.1 Flooding regime

Historical and gauged records demonstrate that there is a long history of winter flooding in the River Derwent catchment, with particularly large events recorded in 1947, 1977, 1991, 1999 and 2000. In addition, large flood events have often been recorded during the summer (Environment Agency, 2007). The recent summer floods of 2007 and 2008 caused prolonged inundation in the hay meadows which fringe the lower Derwent.

The flood embankments situated along the banks of the lower Derwent prevent overbank flooding during low magnitude events. However, simulations by JBA Consulting (2005) suggest that large areas of floodplain (known locally as ings) become inundated by events with a return period of 1 in 5 years (**Figure 5.6**). The maximum extent of inundation varies slightly according to the size of the event (particularly downstream of Wressle), but is generally most dependant on valley topography (cf. JBA Consulting, 2005). A brief summary of the main occurrences of flooding in the lower Derwent catchment is provided in **Table 5.2**.

Several other factors that cause flooding in the ings have also been identified (JBA Consulting, 2004; Environment Agency, 2005; JBA Consulting, 2006). These include:

- The size and level of the outfall drains or cloughs that run underneath the embankments. If water is not able to drain through the outfalls sufficiently quickly, floodplain drainage is impeded and flooding can occur as a result of the floodplain drainage system becoming overtopped.
- Water levels in the River Derwent. If water levels in the main river are higher that the outfall level, the flow of water out from the drains can be restricted. This process, called surcharging, causes water to back up in the ings.
- The condition of the outfall drains. If the drains are in poor condition, for example lacking an operable flap valve, water from the main river can back up through the drain and flood across the ings.
- The condition of the drainage network. The build up of sediment and vegetation within floodplain drains can reduce their ability to convey water into the main channel, leading to flooding in the ings.
- Heavy rainfall leading to high surface runoff. This means that large volumes of water enter the floodplain drainage network, and the outfalls become overwhelmed. This leads to flooding.

The main factors which affect water levels in each ing, as identified in the Lower Derwent Project, are summarised in **Table 5.3**. Water levels in the River Derwent, overtopping of existing flood embankments, and the outfall level of the cloughs are the most important factors that control flooding in the ings. Due to the form of the Derwent valley, flood embankments have limited influence on flood extents within the area of the Derwent Ings SSSI, because they overtop relatively frequently. Indeed, they may actually exacerbate flooding in the ings by holding water on the floodplain, and impeding drainage of overbank flows and flow from the floodplain drainage network.

However, simulations by JBA Consulting (2005) suggest that, if the flood embankments were to be removed, flood inundation extent would increase at selected areas of lower lying land, upstream at Stamford Bridge, and downstream at Wressle and Barmby. Conversely, floodplain inundation between East Cottingwith and Wressle would reduce as a result of increased flood storage downstream between Newsholme and Barmby (JBA Consulting, 2005).

Figure 5.6: Simulated extent of the 1 in 5 year and 1 in 1000 year floods (after JBA Consulting, 2005)

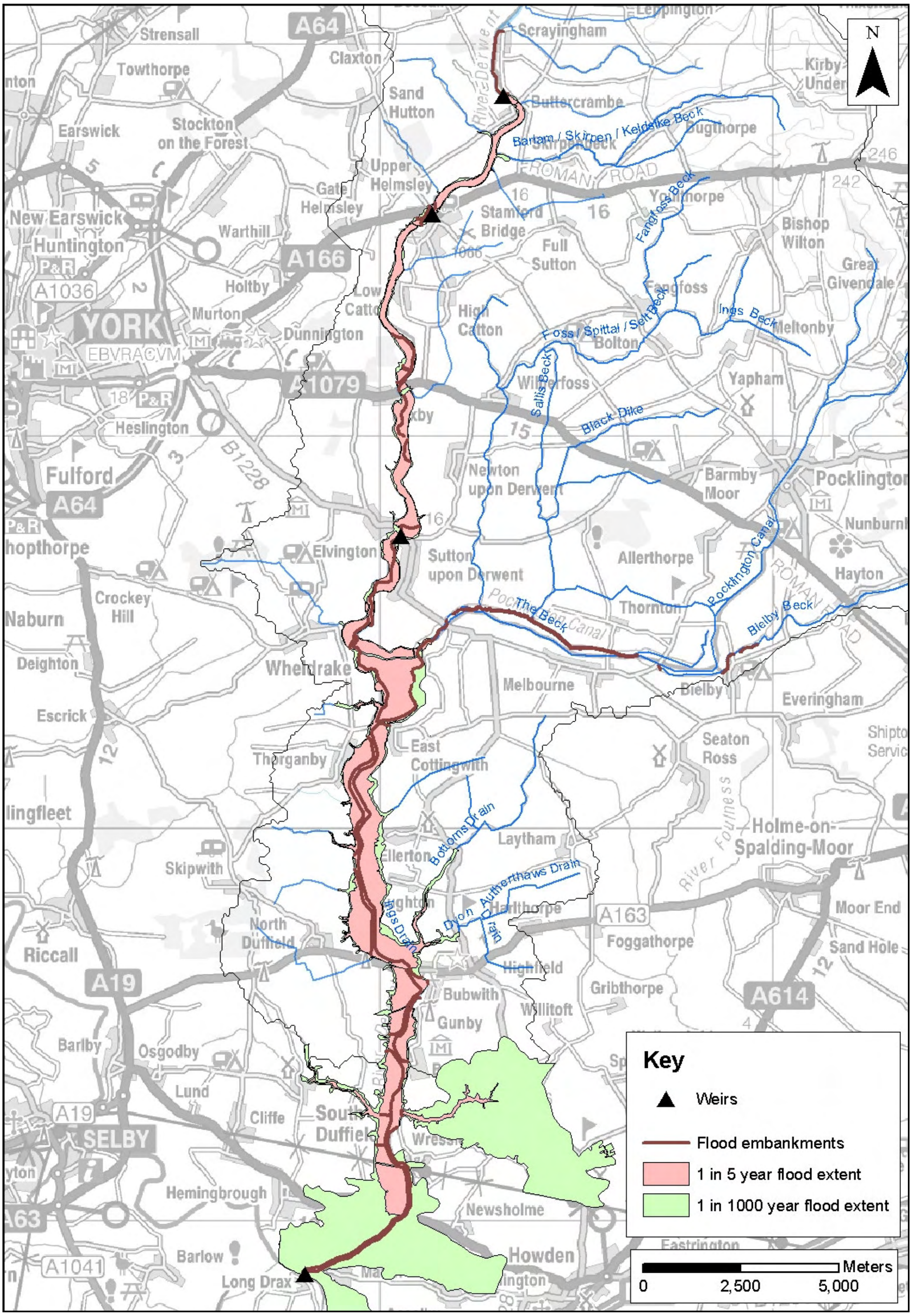


Table 5.2: Flooding and flooding mechanisms in the lower Derwent

Area	Major flooding mechanisms
Upstream of Buttercrambe	The relatively steep valley sides upstream of Buttercrambe restrict flooding to a narrow area of floodplain on the LHB. Flooding occurs due to a combination of insufficient channel capacity and the restriction caused by Buttercrambe Bridge.
Buttercrambe	Flooding is confined to a narrow floodplain corridor on the RHB. The low flood banks are overtopped during flows of 1 in 5 years or greater, allowing water to be conveyed along the floodplain.
Stamford Bridge	The Stamford Bridge Flood Alleviation Scheme generally restricts flooding in the settlement to undefended areas. Downstream of Stamford Bridge, flooding occurs in a narrow floodplain corridor on both banks of the channel. Flooding occurs as a result of insufficient channel capacity, and is likely to occur during events with a return period of 1 in 2 years or greater. This is likely to lead to the inundation of between 200 m (2 years) and 400 m (1000 years) wide are s of floodplain land.
Kexby	Considerable overbank flooding and temporary flood storage occurs upstream of Kexby road bridge, as a result of the road embankments and low flood embankments that prevent water returning to the channel Downstream of the bridge, the embankment on the LHB is overtopped by flows with a return period of 1 in 5 years or greater. The embankment then acts as a barrier, preventing flow returning to the channel and creating temporary flood storage in Low Catton and Northland Ings.
Elvington	Upstream of the road bridge, flow overtops the RHB and floods North Ings, as a result of the impounding effect of the bridge during high flows. Downstream of the bridge, the floodplain around the sluices and West Carr Masks becomes inundated. This occurs due to insufficient channel capacity and overtopping of the flood embankments, and is likely to occur during events with a return period of 1 in 5 years or greater. Further downstream, large areas of the floodplain ings (e.g. West Carr, Low Grounds and Wheldrake Ings) become inundated during floods of the same magnitude. The floodwater is likely to remain within the ings until water levels in the main channel fall sufficiently for the drainage channels which cross underneath the embankments to operate correctly. Drainage at Wheldrake Ings is controlled by penstocks on Wheldrake Ings Clough and North Hills Ings Clough. Maximum inundation ranges from between 130 m and 550 m away from the river channel, depending on the topography of the valley bottom.
Thorganby, Bubwith and Menthorpe	The flood embankments which are present on both sides of the river channel become overtopped during flows with a return period of 1 in 5 years or more. Water remains in the ings until water levels in the main channel falls sufficiently for the drains to discharge effectively.
Wressle	Downstream of Breighton, the floodplain ings flood along the course of Fleet Dike Drain, which drains the wide, flat floodplain to the east of the river channel. Floodwaters are contained within this area by Wood Lane, which is raised above the floodplain. This is likely to be overtopped by flows with a return period of greater than 1 in 1000 years.
Downstream of Wressle	Downstream of Loftsome Bridge, the flood embankments which fringe the channel contain flows with a return period of 1 in 5 years. However, overtopping occurs during larger events, with the area between Newsholme and the Old Derwent (a small tributary) on the LHB and on the RHB between Loftsome Bridge and Barmby becoming inundated during flows with a return period of 1 in 100 years.

Source: Adapted from JBA Consulting (2005)

Table 5.3: Main factors affecting water levels in the ings

Ing	Overtopping of embankments	Clough size	Clough level	Water level in Derwent	Condition of drains/ outfalls	Surface runoff
West Carr	✓		✓	✓		
Ing Marsh	✓	✓		✓	✓	
The Low Grounds		✓	✓	✓	✓	
Wheldrake Ings	✓			✓	✓	
Thorganby Ings			✓	✓		
East Cottingwith Ings				✓	✓	
Ellerton Ings	✓			✓	✓	
Aughton Ings	✓			✓		
Bubwith Ings				✓		✓
North Duffield Carrs				✓		
North Duffield Ings			✓	✓		
Menthorpe Ings	✓			✓		
Gunby Ings			✓	✓	✓	
Wressle Ings	✓		✓	✓		
South Duffield Ings	✓			✓		

Source: adapted from JBA Consulting (2006)

5.3.2 Water levels in the River Derwent

Although water levels in the catchment are monitored at several strategic sites, there is no complete record along the entire SSSI. The lowest modelled water level data available for a large proportion of the Derwent catchment is for the 1 in 5 year flood. Water levels during this event are considerably higher than bank full levels along the majority of the river, and are therefore not appropriate for use in determining the degree of impoundment caused by in-channel structures under baseline flow conditions.

In the absence of comprehensive modelled data, water levels have been estimated using the following sources:

- Simulated water levels for a 1 in 1.5 year event from the Rye-Derwent Flood Forecasting Model (JBA Consulting, 2008) have been used for the upper 8.5 km of the channel (from the Rye-Derwent confluence to Malton). The structures may be drowned out by flows of this magnitude, making assessment of impoundment problematic. However, the area covered by this data set is a considerable distance upstream of the most upstream structure, and therefore may not impact upon the assessment.
- Water levels measured during the channel survey of the lower Derwent were used for the lower Derwent between Buttercrambe and the Barmby Barrage. These measurements were taken during a period of "normal" flow and are thus the most accurate.
- No measured or modelled water levels were available for the middle section of the river, between Malton and Buttercrambe. As a proxy, these data have been estimated using the crest level of Howsham and Kirkham weir both of which were overtopping under normal flows. Water levels were estimated at each measured cross section for which photographic evidence was available.

Features from the cross sections were identified on each photograph (e.g. breaks of slope and, in some cases, structures). The relative distance between these features and the water level on the photograph was then estimated using the scaled cross sections. Although efforts were made to ensure that this process was as accurate as possible, it is acknowledged that these data will not be as robust as those that were physically measured in the field or simulated using a hydraulic model.

Figure 5.7 demonstrates that the simulated water levels at the upstream end of the reach appear to be higher than the measured and estimated water levels. This should be expected because these data are representative of a small flood event rather than baseline flow conditions. The measured and estimated levels further downstream clearly show impounded conditions behind each structure.

An independent check on the estimated water levels was made by comparing the reconstructed data to flow level data recorded by the Environment Agency at Buttercrambe (mean daily water level), Bubwith and the Barmby Barrage (where water levels were recorded every 15 minutes) between 1st June 2007 and 23rd August 2007. Although these data may not be fully representative of long term trends, they are at the time of writing the best available records of water level variations in the lower Derwent SSSI. Mean, minimum and maximum water levels at each site were calculated, and these are shown on **Figure 5.7** (mean water levels are represented by a point, while the range of recorded flows is shown by the upper and lower error bars). These data show that the reconstructed water levels are lower than mean levels during summer 2007, but considerably higher than the minimum flows recorded during this period. This may be explained by the fact that severe flooding occurred during this period, and it therefore may not be typical of normal summer low flows. This suggests that the reconstructed data are broadly representative of water levels in the lower Derwent SSSI.

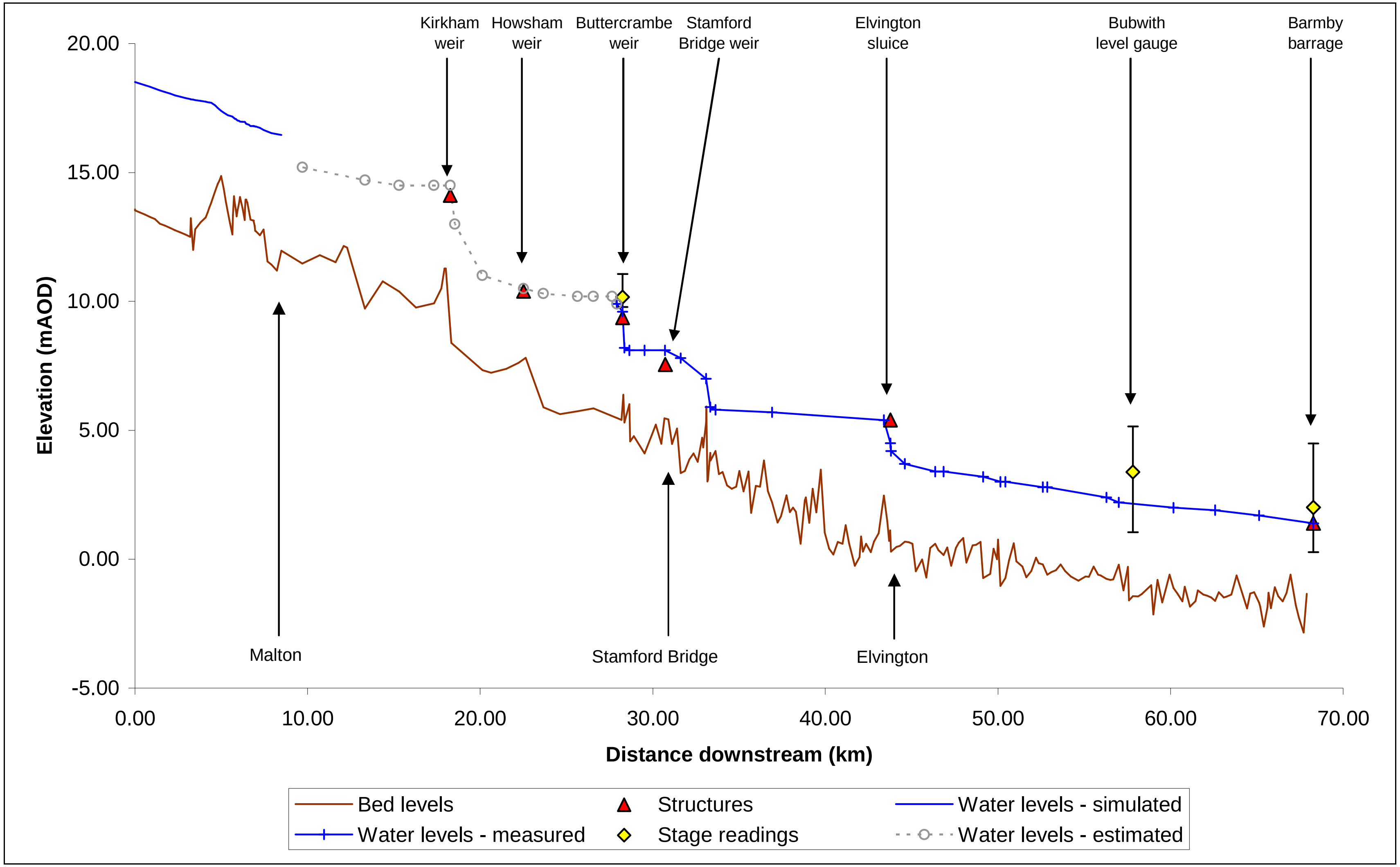
The fragmentary nature of the record means that there are considerable uncertainties associated with the water level data along much of the river channel. Where accurate measured water levels are available (downstream of Buttercrambe weir), these represent a single spot measurement taken during a channel survey at an unknown discharge, and as such they are not necessarily representative of normal low flow conditions in the channel. The estimated water levels (between Malton and Buttercrambe) have added uncertainty since they are inferences rather than actual measurements. Finally, it is clear that the existing modelled data is considerably higher than the measured (or inferred) water levels, which represent low flow conditions.

5.3.3 Influence of structures and channel modifications

Influence of weirs and sluices

On the basis of the estimated water levels associated to structures, an impoundment effect can be clearly seen upstream of Kirkham, Buttercrambe, Stamford Bridge and Elvington (**Figure 5.7**). Whilst the structure at Howsham is also likely to have some effect, the crest height is not as significant as other structures and estimated water levels do not show the effect to be extending as far back as Kirkham. This could simply be a function of estimated data, but can also be explained by the fact that the weir overtops at this location and is drowned out under normal flow conditions possibly reducing the impoundment effect.

Figure 5.7: Estimated water levels in the River Derwent



Kirkham weir has a significant impounding effect, maintaining artificial water levels which extend up to 14 km upstream of the weir. The impounding effect from Howsham weir is not clearly demonstrated by the data, although if Kirkham were removed this will alter water levels downstream and cause the weir to have a more pronounced impact. A key impounding effect is from Buttercrambe weir, where without the weir at Howsham which is fixing the bed levels upstream of this point, the impounding effect would extend as far back as Kirkham. At Stamford Bridge, the impounding effect extends as far back as Buttercrambe. Elvington sluice also causes a considerable impounding effect, which propagates approximately 10 km upstream to a raised section of the bed downstream of Stamford Bridge.

Influence of the Barmby Barrage

The hydrological regime of the lower Derwent catchment is tightly controlled by the operation of the Barmby Barrage during most flow conditions. MIKE-11 simulations produced by JBA Consulting (2004; 2006) suggest that the barrage has a considerable impact on the lower Derwent, the drainage channels that feed into it, and the adjacent floodplain land. By increasing water levels in the lower Derwent channel, Barmby Barrage increases water levels and inundation frequency in the ings that fringe the channel. This increase in water levels is attributed to increased surcharging in the drainage cloughs that fringe the river, although overtopping is also likely to occur during winter months. The increase in water levels is most marked between Wheldrake Ings and Bubwith, where high flows are likely to cause surcharging during most flow conditions throughout the year (JBA Consulting, 2004; 2006).

Influence of the Scalby Sea Cut

The construction of the Scalby Sea Cut has altered the hydrology of the Derwent catchment. The Sea Cut was constructed in 1804 to prevent flooding in the lower Derwent, and as such allows water to be diverted from the upper catchment and into the North Sea via Scalby Beck. This has caused a decrease in water levels in the main river downstream of the channel. Environment Agency gauged records show that flows in excess of 40 m^3s^{-1} have been observed in the Sea Cut. In comparison, the maximum flow recorded at West Ayton, downstream of the structure, is only 1.5 m^3s^{-1} (Ove Arup and Partners, 1998).

5.3.4 Impact of abstraction

Large volumes of surface water are extracted directly from the River Derwent, which could potentially have a significant impact on water levels. However, detailed hydrodynamic modelling undertaken as part of the Lower Derwent Project has demonstrated that abstraction does not have a pronounced impact on water levels (JBA Consulting, 2000). Upstream of Stamford Bridge, abstraction has no discernible impact on water levels, while between Stamford Bridge and Sutton Lock maximum permissible abstraction lowers water levels by less than 0.32 m (10% of the average water depth). Downstream of Sutton Lock, where water levels are strongly influenced by the operation of Barmby Barrage, maximum permissible abstraction lowers water levels by a maximum of 0.35 m during high flows (JBA Consulting, 2000).

5.3.5 Functionality of the hydrological regime

The evidence presented in the previous sections demonstrates that the hydrological regime of the River Derwent is strongly influenced by past and present management activities. Key features are summarised below:

- Flood embankments along the course of the lower reaches of the channel prevent overbank flooding in low magnitude events. However, they are generally overtopped by flows with a return period of 1 in 5 years or greater.

- The magnitude of flood flows is reduced in the lower catchment, as a result of diversion of floodwaters from the upland headwaters into the North Sea through the Scalby Sea Cut.

- Large areas of floodplain still become inundated with surface runoff from the surrounding agricultural land, which overwhelms the floodplain drainage network and builds up behind the embankments.

- Drainage into the Derwent is impeded by the nature of the drainage outfalls, and high water levels in the main channel that prevent these outfalls functioning correctly.

- Water levels in the main catchment are maintained at an artificially high level by the Barmby Barrage, which is operated to prevent the ingress of tidal water into the lower Derwent whilst retaining sufficient water for abstraction and navigation purposes. The other in-channel structures in the catchment have a considerable impounding effect further upstream.

In comparison with changes to the flow regime caused by structural modifications to the channel and riparian zone, controlled abstraction appears to have a relatively small influence on the hydrological regime of the river.

5.4 Sediment regime

5.4.1 Sediment sources

Detailed field assessment and analysis of high resolution aerial photographs of the catchment have demonstrated that there are a variety of potential sources of sediment into the river system. The principal sources of sediment identified during the walkover survey are summarised in **Table 5.4** and **Figures 5.8a** to **5.8c**.

Table 5.4: Sediment sources

Feature	Distribution
Point sources (**Figure 5.8a**)	The primary point sources of sediment in the catchment are field drains, cloughs with an outfall valve, and natural tributaries. The majority of the point sources enter the main channel in the reaches between Kirkham and Kexby (D07 – D15) and between Bubwith and Barmby (D20 – D22). Field drains are the most common point sources of sediment in the reach between Kirkham and Kexby, and valved cloughs are the most frequently occurring in the reach downstream of Bubwith. The sediment contributed by these drains is generally derived from agricultural runoff (e.g. Whitecarr Beck in D08 and the old course of the Derwent in D18).
Bank failure (**Figure 5.8b**)	Geotechnical bank failure is most prevalent in the upper part of the study reach, upstream of Malton (D01). A high occurrence of bank failure is also apparent downstream of the Pocklington Canal confluence (the upper part of D20) and downstream of Wressle (D22). Bank failure is most prevalent in areas with a vertical bank profile.
Cattle trampling (**Figure 5.8c**)	Cattle trampling is most prevalent in the upper part of the study reach (D01), in the reach downstream of Stamford Bridge (D13 – D16), and in the lower reaches upstream of Bubwith (D20 and D21). There is a potential relationship with bank failure; trampling makes the banks unstable, promoting further bank failure, and conversely, bank failure may encourage cattle trampling through provision of toe material. Trampling appears to occur most frequently in areas with a vertical profile.

There are therefore three main sources of sediment within the River Derwent SSSI:

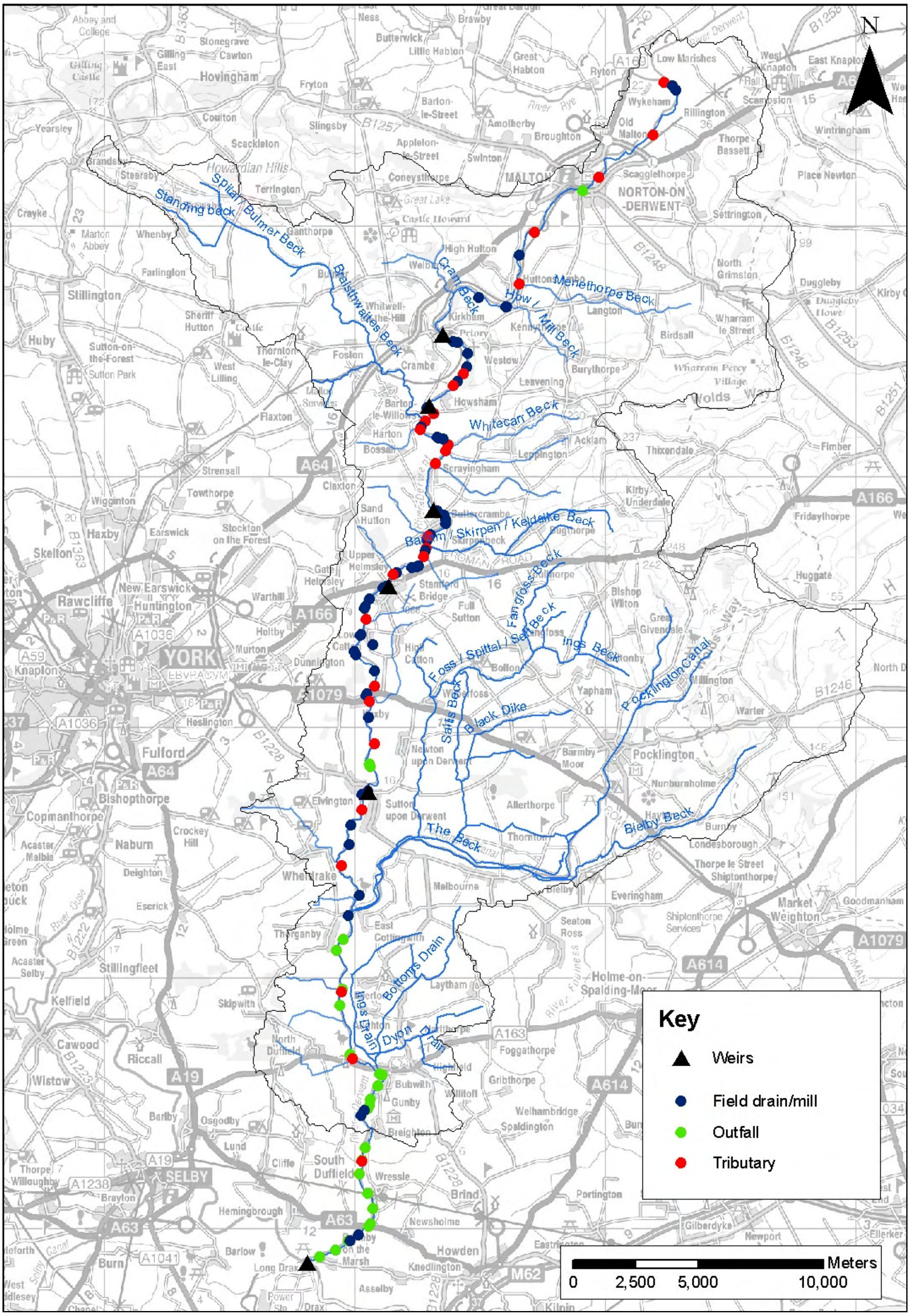
- In-wash of sediment from heavily tilled fields adjacent to the main channel and floodplain drainage channels which transport sediment direct to the channel;
- Erosion of the banks of the main river, particularly in the upper reaches; and
- Damage to the river banks caused by livestock trampling.

At the time of survey, flow within the River Derwent SSSI was observed to be extremely turbid due to supply of fine sediment.

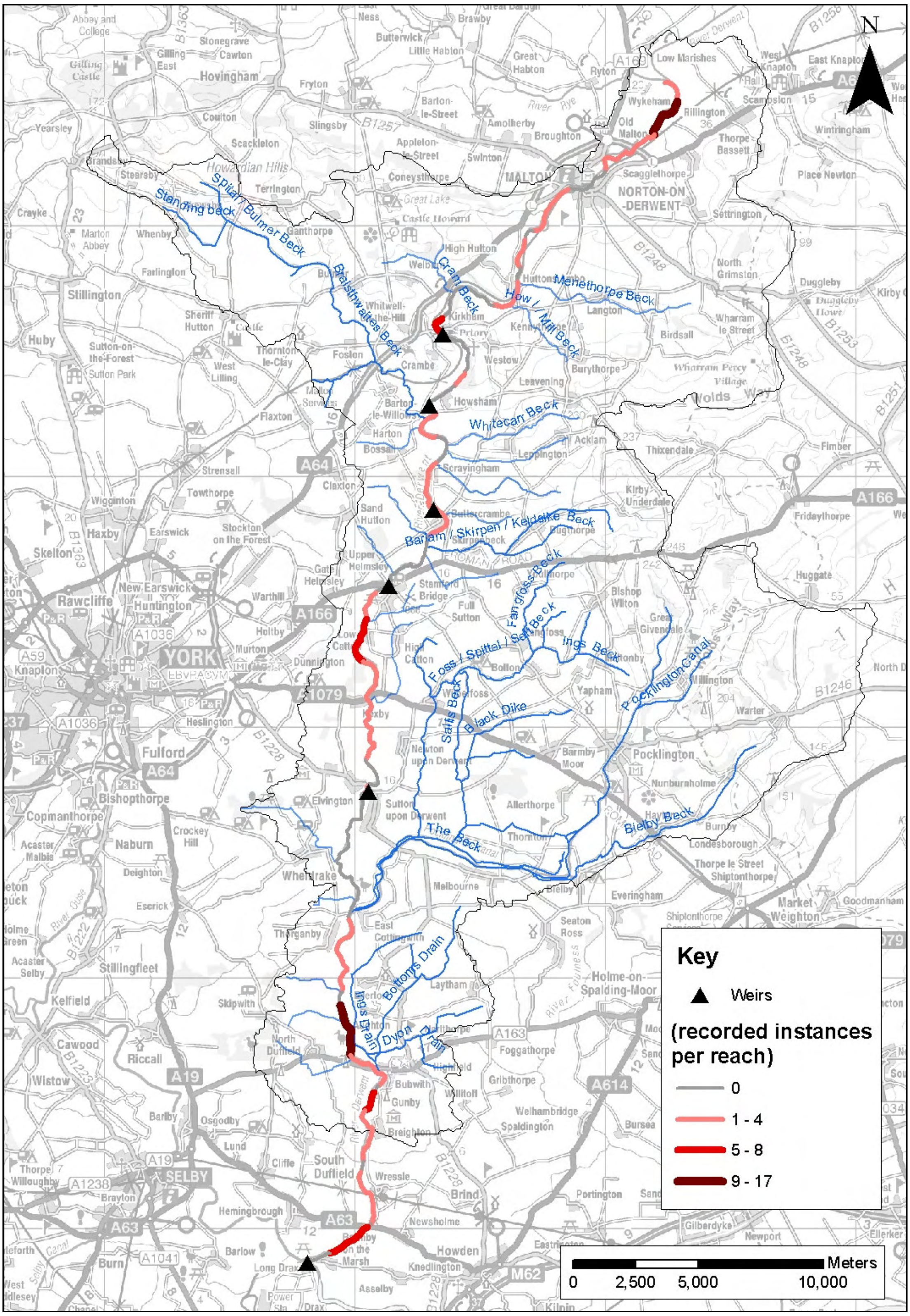
In addition to observed sources within the River Derwent SSSI, significant sediment is likely to be sourced from the upper catchment, upstream of the River Derwent SSSI. Sediment modelling within the River Derwent catchment has been undertaken using PSYCHIC, a process-based model of phosphorus (P) and suspended sediment (SS) mobilisation in land runoff and delivery to watercourses. Findings of the modelling show that sediment loss is predicted to be greatest in the uplands in the north of the catchment, and from the areas of clay and clay loam soil in central and southern parts of the catchment (ADAS, undated).

Figure 5.8: Sediment sources within the River Derwent SSSI

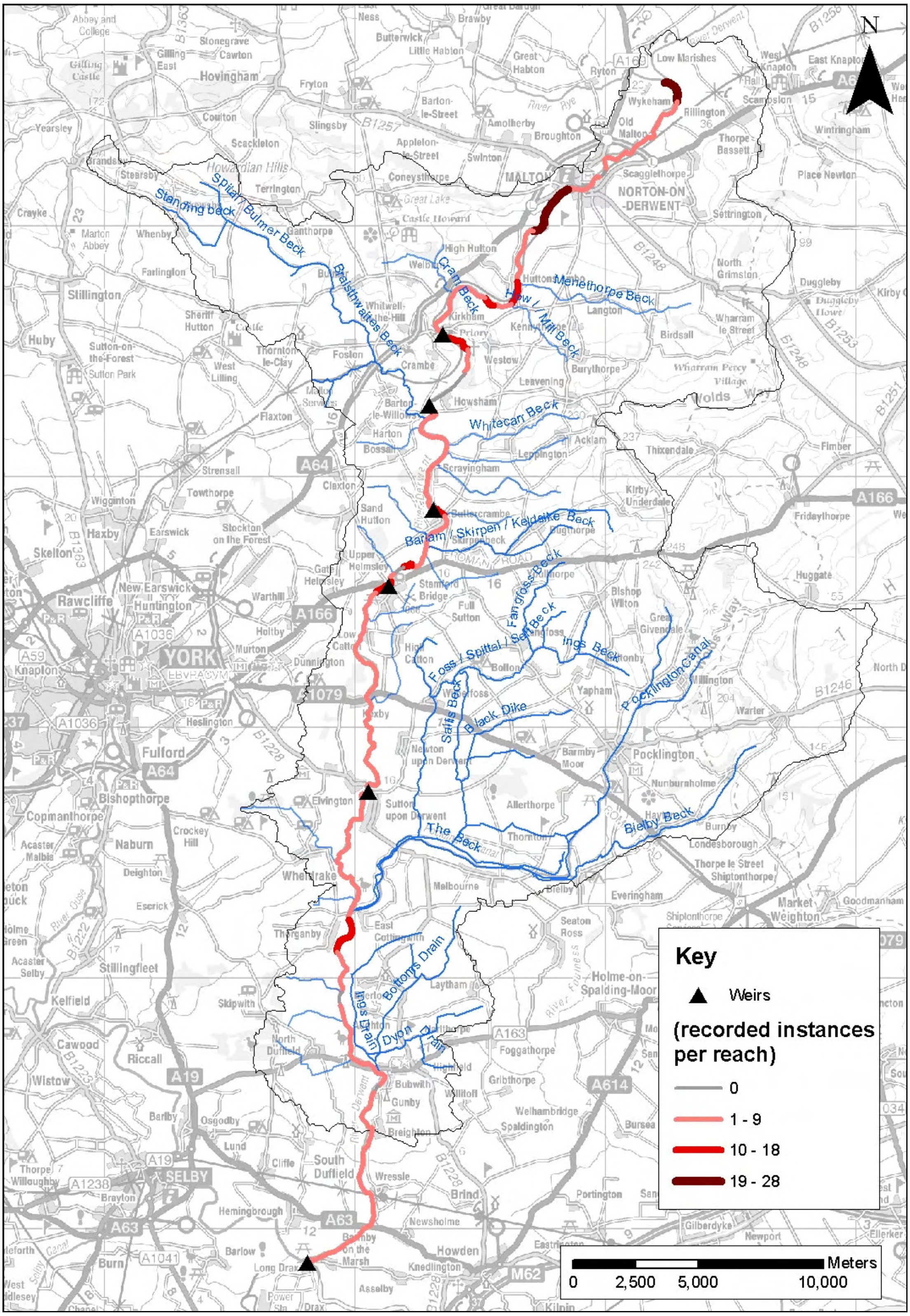
(a) Point sources



(b) Cattle trampling



(c) Bank failure



Aerial photographs clearly show large areas of heavily tilled and bare ground adjacent to the drainage channels throughout the study catchment, and, in some cases, directly adjacent to the main river channel (**Figure 5.9**).

Furthermore, the growth of winter cereal crops in the lowland catchment from the 1950s onwards leaves these soils without vegetation cover during the wettest months of the year, and thus makes them vulnerable to erosion through surface runoff. It is likely that, during high rainfall events, this material is easily eroded and transported into the river network via surface runoff.

Figure 5.9: Tilled land adjacent to Dyon Drain

Once within the lower River Derwent SSSI channel it is likely that a considerable proportion of material which enters the river remains in situ and is not transported a significant distance (see **Section 5.4.2** for further details). In contrast, however, the supply of sediment into the drainage system, and subsequently the channel, from the agricultural land on the floodplain is likely to be a major source of sediment. Qualitative field observations confirm that lowland drains such as Whitecarr Beck are particularly significant sources of sediment into the main river system.

These observations reflect the findings of earlier investigations into sediment sources in the upper catchment. Composite fingerprinting of sediment sources at Ryemouth suggested that a large proportion (65%) of in-channel sediment was derived from runoff from agricultural soils (Sear, 1992). The banks of small tributaries and field drains contributed 15%, with the banks of the main channel contributing a further 15%. The remaining 5% material was derived from the upland tributaries of the River Rye, which suggests that the headwater catchments of the river appear to be a more limited source of sediment when compared to agricultural sources (cf. Ove Arup and Partners, 1998). The absence of drift cover in much of the uplands means that the river is more likely to be bedrock-controlled, and the supply of sediment to the channel is more limited.

Sediment modelling using PSYCHIC also predicts that drains are the dominant pathway for sediment transfer to watercourses and clay loam soil, such as is present in the central and southern areas of the catchment, and is predicted to present the greatest risk of sediment transfer, with annual losses to watercourses of up to 0.7 t ha^{-1}. Losses in surface runoff may also be significant, however, with predicted losses reaching values close to 0.1 t ha^{-1} in much of the uplands, and 0.2 t ha^{-1} in a small area on the eastern side of the catchment, to the south east of Norton-on-Derwent. In the latter area, elevated losses of sediment are associated with steeper slopes and clay loam soils (ADAS, undated).

5.4.2 Sediment deposition

The main depositional features recorded during the walkover survey are summarised in **Table 5.5** and **Figures 5.10a** to **5.10c**.

Table 5.5: Depositional features

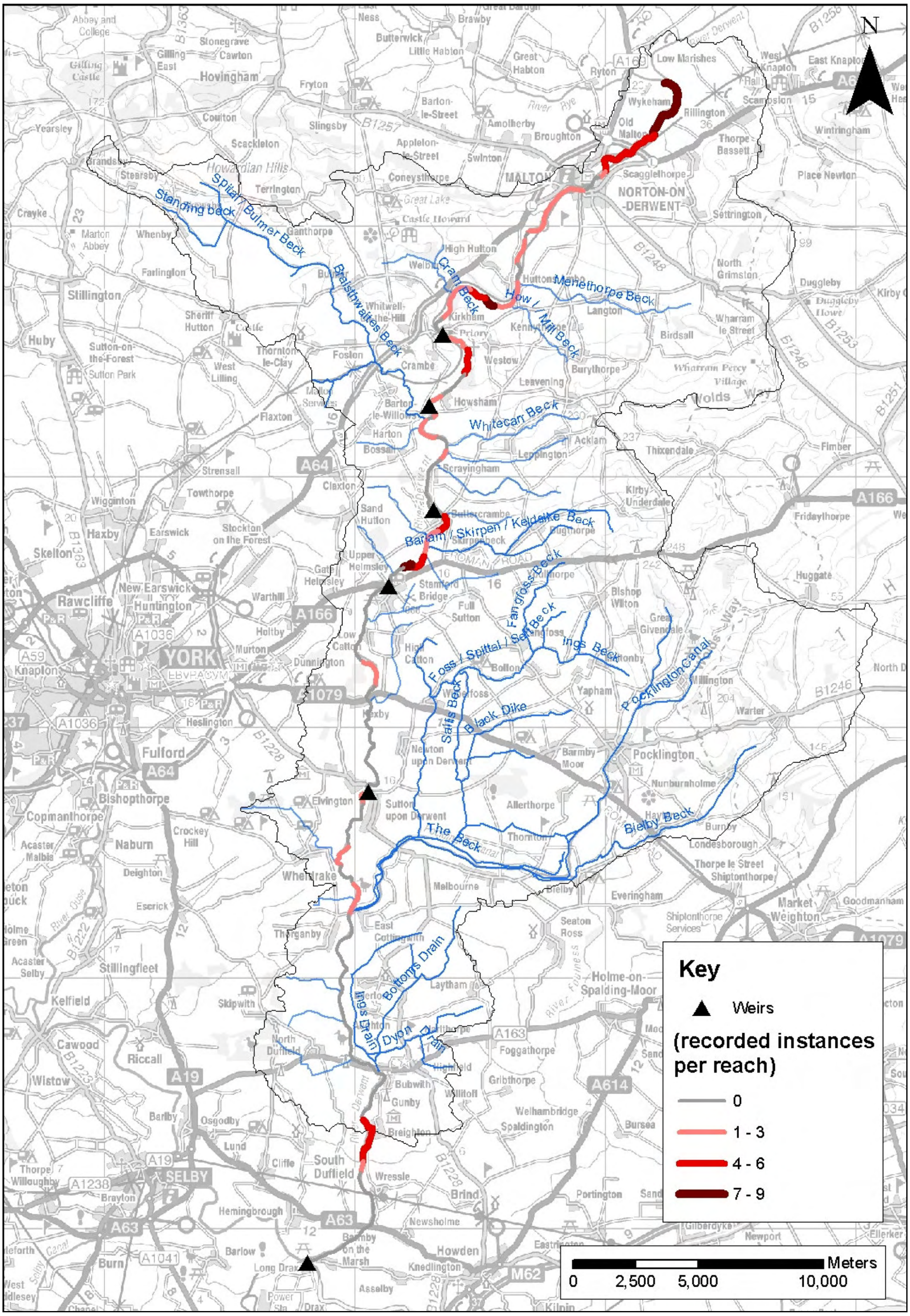
Feature	Distribution
Non-stabilised channel-edge deposits (**Figure 5.10a**)	These deposits are prevalent in the upper reach (D01) and in the reach downstream of Wressle (D20), in areas where bank failure has been observed. Similar deposits are apparent adjacent to the wetland area upstream of Kirkham (D06), in a wide alluvial reach situated immediately downstream of a more constrained valley. Temporary toe deposits are also recorded between Buttercrambe and Stamford Bridge (D10 – D12), coincident with a high concentration of field drains and tributaries.
Semi-stabilised channel-edge deposits (**Figure 5.10b**)	The semi-stabilised depositional features recorded are generally comprised of bank toe deposits that are starting to be colonised by marginal or riparian vegetation. These deposits generally occur in the reaches between Stamford Bridge and Elvington (D12 – D18), and are coincident with a high concentration of cattle trampling and at Elvington with previously overhanging tree branches (which have been sympathetically managed over the last two years).
Stabilised channel-edge deposits (**Figure 5.10c**)	The stable depositional features recorded during the field survey consist of bank toe deposits that have been stabilised by riparian and/or marginal vegetation. These deposits occur in the reach upstream of Kirkham (D07), where the land is managed to preserve the marginal zone. Stable toe deposits are also observed in the reach between Wressle and Barmby (D21 – D22), in an area where historic bank slumps and trampled areas have re-vegetated.
In-channel deposits	Due to the high turbidity of the river, it was not possible to identify the nature or distribution of in-channel depositional features during the walkover survey. However, survey data used by JBA has reported increases in sedimentation on channel bed.

Channel-edge deposits occur in some form along much of the study reach. Non-stabilised deposits are generally found in the upper reaches of the river, and are coincident with the occurrence of contemporary bank erosion. Semi-stabilised deposits occur most frequently downstream of Stamford Bridge, in the middle reaches of the study area. These are generally coincident with the occurrence of cattle trampling. Vegetated channel-edge deposits occur in discrete reaches downstream of Stamford Bridge and Elvington, but are most concentrated in the lower reaches in areas where historical zones of bank failure and cattle trampling have become re-vegetated. This suggests that a large proportion of bank failures (including geotechnical failure and cattle trampling) lead to the formation of bank-toe deposits, which gradually stabilise over time. It is therefore unlikely that the material which forms these deposits is transported for a significant distance by the river. Instead, it remains in situ.

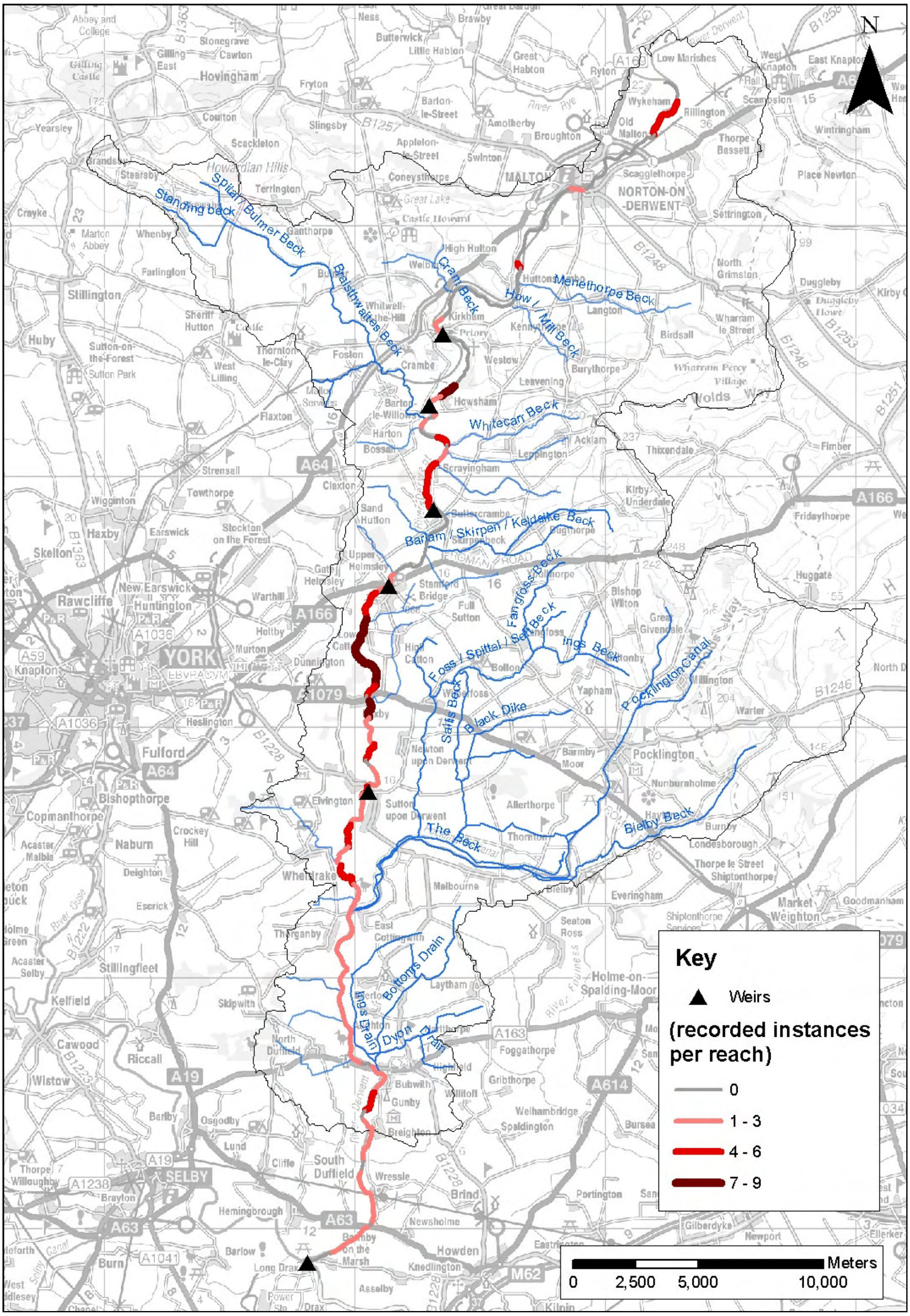
It is probable that a large proportion of material that enters the river from the field drain and tributary systems is transported and stored in the main channel, and does not form a significant part of the channel-edge deposits. Instead, it is likely that this material is deposited on the bed, and is likely to be responsible for the bed accretion observed in the lower Derwent (see below). This is, in part, demonstrated by the high turbidity of the water column, which prevented the observation of bed formations during the walkover survey. A large proportion of the suspended material is likely to be derived from the field drains and tributaries, rather than the bank failures which create more static bank toe deposits.

Figure 5.10: Channel deposits within the River Derwent SSSI

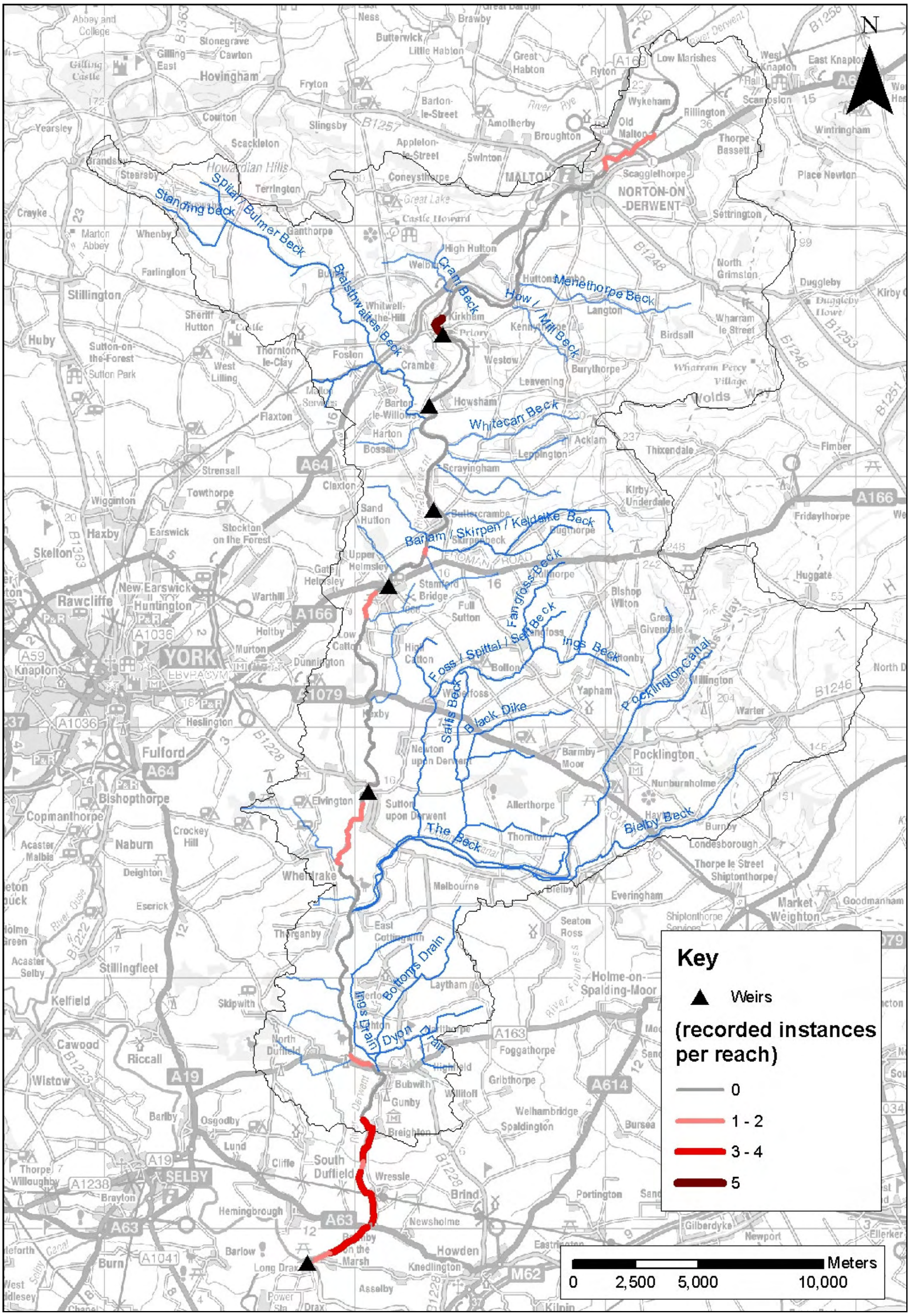
(a) Non-stabilised channel-edge deposits



(b) Semi-stabilised channel-edge deposits



(c) Stabilised channel-edge deposits



A detailed survey of channel cross sections in the lower Derwent between Elvington Sluice and Barmby Barrage was undertaken in 1998, and repeated in 2005 (JBA Consulting, 2006). This demonstrates that an average of 0.3 m (minimum 0.05 m, maximum 1.16 m) of sediment has accreted along this reach, with the majority of accumulation occurring in the 10 km of river channel downstream of Elvington Sluice. This is likely to be attributable to the low gradient, low energy nature of the channel and the impounding effects of Barmby Barrage. When the resurvey was undertaken, it was observed that a large amount of aquatic vegetation growth was apparent in the river channel (JBA Consulting, 2006). It is likely that this growth, the species composition of which was not recorded, is partially responsible for the accumulation of sediment, by increasing channel roughness, reducing flow velocity, and encouraging the deposition of fine sediment. This sedimentation, when combined with the impacts of Barmby Barrage on water levels in the main river, causes the drainage cloughs between Wheldrake Ings and Bubwith to surcharge under most flow conditions throughout the year.

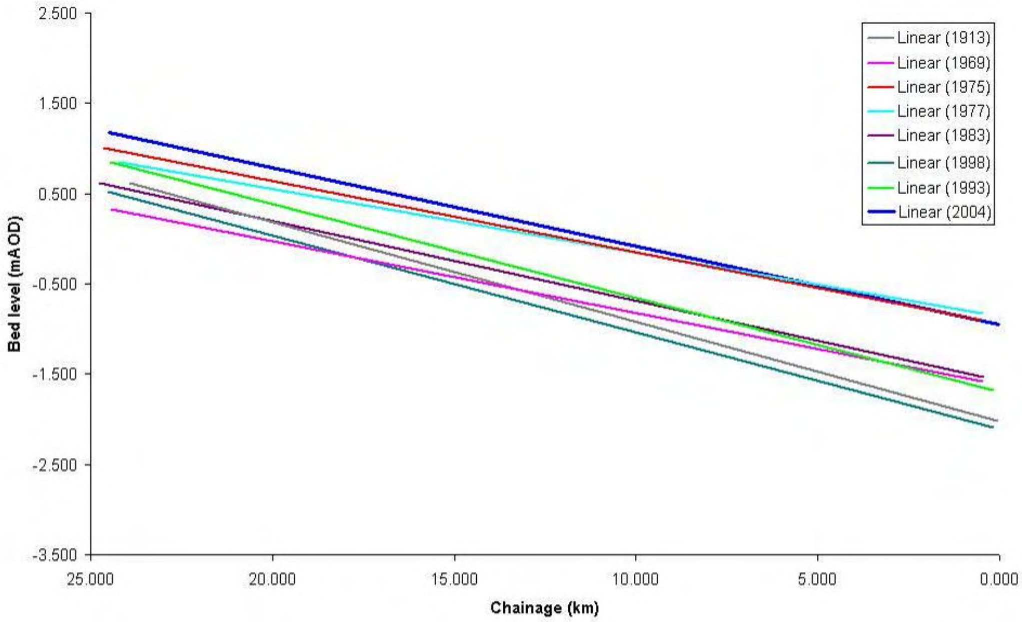
Comparison of long profile data collected along the lower River Derwent (Elvington Sluice – Barmby Barrage) between 1913 and 2005 also demonstrates that there have been several periods of bed incision and accretion (**Table 5.6** and **Figure 5.11**). These data were collated from previous surveys of the Derwent channel, and were previously reported in JBA Consulting (2006).

Table 5.6: Bed level changes in the lower Derwent

Period	Predominant bed level trend	Additional comments
1913 – 1969	Incision	Incision is dominant, although localised accretion was observed in 10km channel upstream of barrage
1969 – 1975	Accretion	Accretion throughout study reach
1975 – 1977	Static	Localised lowering in middle of study reach
1977 – 1983	Incision	Lowering throughout study reach
1983 – 1993	Static	Localised accretion in upper 15 km of study reach, and localised erosion further downstream
1993 – 1998	Incision	Average decrease of 0.35 m
1998 – 2005	Accretion	Accretion of at least 0.40 m along the study reach

Source: data reported in JBA Consulting (2006)

Figure 5.11: Bed level changes in the lower Derwent (Elvington/Sutton Lock – Barmby)



Source: data reported in JBA Consulting (2006)

This comparison demonstrates that there have been several alternating periods of erosion and accretion in the last 100 years. The general decrease in bed levels between 1913 and 1969 may indicate the impact of dredging of the channel for navigation and flood defence purposes. Subsequent accretion and bed level decreases are likely to reflect the gradual accumulation of sediment upstream of Barmby Barrage between intermittent dredging works. Now that dredging no longer takes place, the accumulation of sediment has raised bed levels along much of the channel between 1998 and 2005 (cf. JBA Consulting, 2005).

5.4.3 Influence of in-channel and marginal vegetation

Increased growth of aquatic vegetation in the river channel can increase the roughness of the channel bed during the growing season (typically May to September), reducing flow velocities and encouraging the deposition of fine sediments within the river channel. Anecdotal observations during previous survey work indicate that this may have had an influence on sedimentation in previous years (Sear, 1992; JBA Consulting, 2006). Increased growth of some species (e.g. algae) may be attributable to the in-wash of nutrients such as dissolved nitrogen and particulate phosphorus from agricultural sources in the catchment (as recorded by Neal ***et al.***, 1998) (see **Section 5**).

However, it was not possible to observe changes in the growth of in-channel vegetation during this survey and other recent surveys. It is therefore believed that the extent to which in-channel vegetation is acting to trap fine sediments is limited. In places however, overhanging trees and shrubs that are rooted in the channel do encourage localised in-channel sedimentation (see **Section 5**).

5.4.4 Influence of the altered hydrological regime

Sections 4.9 and **5.3** demonstrate that the hydrological regime of the Derwent catchment has altered considerably. The impounding effects of major structures, particularly Barmby Barrage, are likely to increase sedimentation as a result of decreased flow velocities (cf. JBA Consulting, 2006). The decrease in discharge and the frequency of flushing flows downstream of the Scalby Sea Cut is likely to exacerbate this effect. Furthermore, the flood embankments that fringe much of the lower Derwent prevent overtopping during small overbank events. This means that the increased sediment load of the river is generally retained within the channel, and is only 'lost' to floodplain storage during larger magnitude floods which overtop the flood embankments. Material that is deposited on the floodplain is likely to be transported back into the channel during lower flow events when the valves on the drainage cloughs remain open but there is sufficient surface wash off to mobilise sediments.

5.4.5 Functionality of the sediment regime

The evidence presented in the previous sections demonstrates that large amounts of sediment deposition are occurring in the River Derwent catchment. The key features of the sediment regime are summarised below:

- Fine in-channel sedimentation has been observed through the study reach.
- The primary source of this sediment is the direct transport of sediment from highly erodible agricultural soils currently used for cereal.
- Reduction of the connectivity of the channel with the floodplain prevents transfer of fine sediments onto the floodplain.
- Limited transfer of sediments into tidal system with unknown ingress of sediment where tidal waters are allowed up the channel.

- Increased vegetation growth where it occurs also encourages in-channel sedimentation.

5.5 Key geomorphological issues within the Derwent catchment

The desk based and field assessments have demonstrated that the River Derwent is a geomorphologically complex system, in which geomorphological behaviour is influenced by the interaction of a range of physical and hydrological parameters. Several key parameters that are likely to influence the behaviour of the catchment are apparent:

- **Fine sedimentation:** The floodplain soils in the Derwent catchment are easily erodible, and sediment from agricultural land is input into the floodplain drainage network and subsequently the main river. Fine sedimentation is recorded as being an issue throughout the catchment (cf. Sear, 1992; Ove Arup and Partners, 1998; JBA Consulting, 2006), and is particularly marked in the lower reaches, downstream of Pocklington Canal.

- **Channel modifications:** Large sections of the river channel have been historically altered, producing a uniform U-shaped channel with steep sides and little morphological diversity. Historical dredging and resectioning has caused extensive over-deepening, and increased the channel capacity. This overcapacity is likely to be a contributory factor to the fine sedimentation issues observed throughout the catchment as carrying capacity of the channel is increased by the increase in cross-sectional area.

- **Altered flow regime:** The flow regime of the Derwent has been extensively modified by human intervention, producing artificially uniform flow patterns. The Scalby Sea Cut has reduced flows in the main river downstream, reducing its sediment transport capacity and reducing the occurrence of high magnitude flushing flows. The lower Derwent was historically tidal, but the tidal barrage at Barmby has removed this influence and artificially impounded water levels in the downstream section. In addition, smaller impoundments occur upstream of the weirs and sluices that occur along the main channel. Furthermore, the presence of flood embankments along much of the lower reaches reduces the frequency of overbank flooding. It is likely that these changes to the natural flow regime are a significant contributory factor to the fine sedimentation issues observed throughout the catchment.

This section therefore demonstrates that the Derwent catchment has a highly modified geomorphological, hydrological and sedimentary regime. This is likely to have a considerable impact on the key ecological interest features of the Derwent SSSI, by altering the quality of their habitat. These features will be discussed in detail in the subsequent section.

6 KEY ISSUES FOR ECOLOGY AND HABITAT

6.1 Purpose of this section

This section presents an analysis of the ecological characteristics of the River Derwent SSSI and the morphological factors which influence the quality of the habitats they depend upon. The results from the desk-based assessment are combined with available field survey data to highlight the key issues prior to defining potential solutions in **Section 7**. More specific details on reach-scale patterns can be found in the watercourse summary sheets, which are presented in **Appendix B**.

6.2 Overview of ecological conditions

The Yorkshire River Derwent has been designated as a SSSI for the following main characteristics:

- A lowland river with diverse flora and fauna.
- Aquatic plant community characteristic of lowland rivers including un-branched bur-reed (***Sparganium emersum***), yellow water-lily (***Nuphar lutea***), flowering rush (***Butomus umbellatus***), shining pondweed (***Potamogeton lucens***), arrowhead (***Sagittaria sagittifolia***) and narrow-leaved water-parsnip (***Berula erecta***).
- Diverse fish communities including bleak (***Alburnus alburnus***) and ruffe (***Gymnocephalus cernuus***).
- Rich assemblage of invertebrates including mayflies (***Baetis buceratus***, ***Heptagenia fuscogrisea*** and ***Brachycerus harisella***) as well as the banded agrion dragonfly (***Agrion splendens***).
- The breeding bird community including common sandpiper (***Actitis hypoleucos***), dipper (***Cinclus cinclus***), kingfisher (***Alcedo atthis***), yellow wagtail (***Motacilla flava***) and grey wagtail (***Motacilla cinerea***).

In addition to being designated as a SSSI, the River Derwent is also internationally designated as a Special Area of Conservation (SAC). The SAC designation is based on the following interest features:

- Natural lowland river character.
- ***Ranunculion fluitantis*** and ***Callitricho-Batrachion*** vegetation communities.
- River lamprey (***Lampetra fluviatilis***) and sea lamprey (***Petromyzon marinus***).
- Bullhead (***Cottus gobio***).
- Otter (***Lutra lutra***).

Comprehensive surveys of the River Derwent have been carried out recently for macrophytes including the ***Ranunculion fluitantis*** and ***Callitricho-Batrachion*** communities (Scott Wilson, 2002) and for river lamprey and sea lamprey spawning habitat distribution (Jang ***et al***., 2004). Up-to-date and detailed information is therefore available for these features. The same information is not currently available for otter and bullhead, however. Additional observations were made regarding the overall ecological health of the lowland river habitat within the River Derwent SSSI, as well as the availability of habitat for specific SSSI and SAC designated species, during a combined ecological and geomorphological audit undertaken in September 2008 by Royal Haskoning (see **Section 2.4** for further details).

6.3 Habitat requirements of key species

The key species within the River Derwent SSSI are all dependent to some extent on the hydrological and geomorphological conditions within the river system. The precise relationships between ecology and the physical characteristics which support it still remain to be defined by the research community, but it is possible to determine the general requirements for the Derwent based on the characteristics of river reaches where habitat is in good condition and known evidence base. **Appendix C** provides background information on the physical habitat requirements of the different ecological interest features. The physical characteristics of the river system upon which the ecological factors are dependent upon are summarised in **Table 6.1**.

Table 6.1: Physical habitat requirements of SSSI and SAC designated species

Ecology	Interest Feature	SSSI designated	Physical characteristics supporting good habitat
Vegetation	Flora characteristic of lowland rivers	Yes	Moderate to high nutrient levels
			Still or slow flowing water
			Soft sediments
			Deep water
	Assemblage of floating and submerged plants	No	Swift to moderate, clear flows
			Channel dominated by clean, stable gravel
			Adequate in-channel light
Invertebrates	Rich assemblage of invertebrates	Yes	Terrestrial and aquatic habitats containing diverse vegetation communities for feeding, breeding and over wintering
Birds	Excellent breeding bird community	Yes	Healthy fish and invertebrate communities for feeding
			Shelter and nesting sites
Fish	Diverse fish communities	Yes	Vegetation or stony/gravely substrates for egg laying (depending on species)
			Shallow areas with low flow velocities for nursery habitat
			Availability of invertebrate prey and smaller fish for feeding
	River Lamprey & Sea Lamprey	No	Channel dominated by clean, stable gravel for spawning
			Appropriate shelter for spawning
			Stable silt or sand dominated substrate for nursery habitats
			Areas of shallow low velocity flow for nursery habitats
			Organic detritus for nursery habitats
			Tree roots / large woody debris for migration
	Bullhead	No	Swift to moderate, clear flows

Ecology	Interest Feature	SSSI designated	Physical characteristics supporting good habitat
			Channel dominated by clean, stable gravel
			Riffle habitat features
			Macrophyte cover <40%
			Shading
			No barriers >18cm
			Tree roots / large woody debris
Mammals	Otter	No	Bankside shelter for day cover
			Undisturbed areas for holts
			Adjacent wetland floodplain habitat
			Suitable habitat for fish for feeding pups
			Shelter and nesting sites

Conservation objectives have been set for the key features of the lowland river habitat within the River Derwent SSSI, taking into account these features. Specific objectives have been set for key interest species or communities and the functioning of aspects of the water habitat. These are summarised in **Table 6.2**.

Table 6.2: General objectives for the River Derwent SSSI (Natural England, 2008)

Attribute	Ecological targets
Otter	Population maintained or increasing
	Fish biomass stays within expected natural fluctuations
Bullhead	No reduction in densities from existing levels
	Bullheads should be present in all suitable reaches. As a minimum, no decline in distribution from current
	Young-of-year fish should occur at densities at least equal to adults
	Woody debris removal should be minimised and restricted to essential activities such as flood defence
	Weed cutting should be limited to no more than half of the channel width
	No significant impediment to essential fish movement between reaches. However, debris dams and woody debris should be retained where characteristic of the river reach
River and sea lamprey	For samples of 50 or less, at least two distinct size classes should normally be present. If more than 50 ammocoetes are collected, at least three size classes should be present
	Lampreys should be present at not less than 2/3 of sites surveyed. As a minimum, there should be no reduction in the distribution of ammocoetes within the catchment. Where barriers to migration or pollution issues are thought to be a problem, the population should be classed as being in unfavourable condition and targets for an appropriate increase should be set
	Ammocoetes should be present in at least four sampling sites, each not less than 5km

Attribute	Ecological targets
	apart
	Areas of spawning and nursery habitat identified by fluvial audit should not show signs of decline
	No artificial barriers significantly impairing adults from reaching existing and historical spawning grounds
	River habitat SSSI features should be in favourable condition, with sediment transport processes both within the catchment and river channel being appropriate for the maintenance and enhancement of lampreys for the foreseeable future
Breeding birds	Maintain assemblage diversity. If the number of breeding species falls by 25% or more, the feature is in unfavourable condition
Non-breeding birds	Maintain assemblage diversity. If the number of wintering species falls by 25% or more, the feature is in unfavourable condition (November – February). If the number of passage species falls by 25% or more then the feature is in unfavourable condition (August – October and March – April)
Invertebrates (Odonata species assemblage)	Monitor the assemblage once in every 6 year monitoring cycle. The following thresholds to be met are: W11 fast flowing water: SQI score 150 W111 shingle bank: WSS 9 W112 stony river margin: WSS 4
Invertebrates (surface topography of vegetation types)	Single surface present in no more than 5 out of 10 Structural Recording Surveys. >3 different surfaces present in at least 20% SRSs. Preferred surfaces are: Water Marginal bare muds Medium layer Taller graminoid layer
Plant community - reproduction	A sufficient proportion of aquatic macrophytes should be allowed to reproduce in suitable habitat unaffected by river management practices
Habitat structure - substrate	No excessive siltation. Channels should contain characteristic levels of fine sediment for the river type
Habitat structure - channel and banks	Bank and riparian zone vegetation structure should be near natural
	Channel form should be generally characteristic of river type, with predominantly unmodified planform and profile. No RHS site to have any of the eight categories of bank profile modification recorded as extensive
Habitat functioning - suspended solids	No unnaturally high suspended solid loads
Negative indicators - in-stream barriers	No artificial barriers significantly impairing characteristic migratory species from essential life cycle movement

The subsequent sections consider the extent to which the conservation objectives relevant to ecology are being met and where the geomorphological conditions may be preventing the river from reaching favourable condition. The outcomes of this analysis can then be used to identify the key geomorphological issues within the catchment before identifying potential solutions in **Section 7**.

6.4 Aquatic vegetation communities

6.4.1 Current ecological condition

Previous investigations

A survey of thirteen 1km stretches of the Lower River Derwent aquatic plant communities was carried out by boat in 2002 (Scott Wilson, 2002). The survey demonstrated that the macrophyte community was typical of a clay-dominated river community. This means that the flora is impoverished and is dominated by species tolerant of enrichment, such as fennel-leaved pondweed (***Potamogeton pectinatus***), un-branched bur-reed (***Sparganium emersum***) and yellow water lily (***Nuphar lutea***) (the latter two species are mentioned in the SSSI designation). River water-crowfoot (***R. fluitans***) was found at seven of the thirteen sites, and had a distribution similar to that found in previous surveys. Two species of water starworts (***Callitriche platycarpa*** and ***C. stagnalis***) were found in the river, but they were only recorded at two sites and so were considered to be rare.

A macrophyte survey undertaken in 2009 confirmed a similar situation to the 2002 survey. The distribution of macrophytes was generally patchy and failed to meet the required standards for the SSSI.

The nature of the aquatic vegetation appeared to be broadly similar to that recorded during previous surveys carried out in 1978, 1998, 1999 and 2001 (Hobbs ***et al***., 1978; Scott Wilson, 1998; Environment Agency, 1999; Scott Wilson, 2002). No definitive trends in the distribution and abundance of river water-crowfoot were demonstrated from the survey data.

Field observations

During the field survey undertaken as part of the current project, water levels in the channel were high, and the high sediment load resulted in poor visibility of plants and channel bed. Few signs of the interest macrophyte species were detected, and few areas of habitat that appeared suitable for them were observed. These species could either be largely absent from the site or be obscured by turbid water. Note that the comprehensive survey carried out in 2002 (Scott Wilson, 2002), was undertaken from a boat in order to give sufficient access to the channel to identify and sample any macrophytes found. For the current project, observations were made from the bank top and so in-channel vegetation was not readily identifiable. However, the formation of the observed macrophytes (e.g. long-tendrils forming clumps) could usually be discerned.

During the field survey, clumps of in-channel vegetation resembling river water-crowfoot were observed at three of the five weir sites (**Table 6.3**). The observation of ***R. fluitans*** at several of the weir sites during 2008 and 2009 complies with the findings of the 2002 comprehensive boat survey.

Water starwort (***Callitriche*** spp.) was observed sporadically for approximately 1 km along the right bank in reach 20 (beginning downstream of Bubwith Bridge and running for approximately 1 km in a downstream direction). The species resembled ***C. platycarpa*** in its morphology, with only the submerged leaf form present. Downstream of Malton, in reach 4, some fennel-leaved pondweed (***P. pectinatus***) was observed growing in the channel near to the left bank. Clumps of the weed continued for approximately 50 m. Its presence at this location indicates that there are shallower areas near the bank here that are absent from much of the rest of the river.

Table 6.3: Observations of in-channel vegetation resembling river water-crowfoot

Weir	Field observations
Kirkham Weir	Fronds of in-channel vegetation were observed immediately upstream of the weir and resembled ***R. fluitans***. Since Kirkham weir was found to be a stronghold for the species during the 2002 survey, it is entirely possible that the vegetation was indeed R. ***fluitans***. It was not possible to determine if similar clumps of vegetation were present on and downstream of the weir.
Howsham Weir	A large quantity of in-channel vegetation strongly resembling ***R. fluitans*** was present downstream of Howsham Weir, in the more sheltered areas above and below the island located there. While the same identification problems were encountered as at Kirkham Weir, the greater quantity of vegetation present enabled a more confident identification that the primary species was indeed ***R. fluitans***. The weir was identified as a stronghold for the species during the 2002 survey, lending weight to the assumption that the vegetation was indeed ***R. fluitans***. The influence of Howsham Weir appeared to extend downstream. Swifter flows and clumps of in-channel vegetation continued downstream for approximately 200 m.
Buttercrambe Weir	Clumps of vegetation were observed within the smooth flow on Buttercrambe Weir. A positive identification was difficult for the same reasons as the two weirs discussed above, but the vegetation clumps appeared, from a distance, to resemble ***R. fluitans***. No other in-channel vegetation could be observed in the vicinity of the weir.

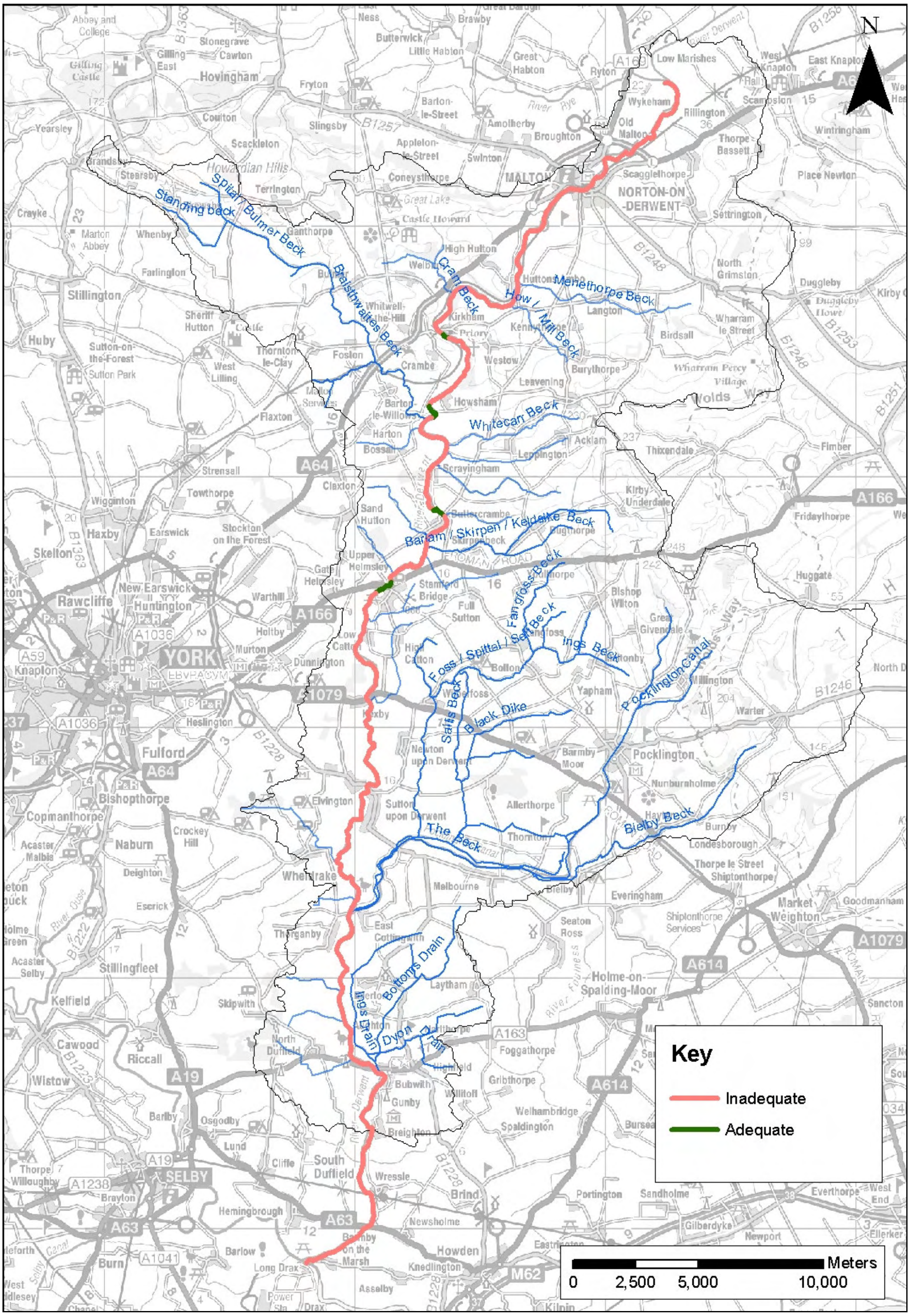
6.4.2 Physical character contributing to ecological condition

The in-channel macrophyte species identified within the River Derwent SSSI citation are typical of lowland rivers. They generally require still or slow flowing water with moderate to high nutrient status. They do not require a gravel or stony substrate, but can take root in soft sediments and can grow in relatively deep water (up to and in some cases over 1 m deep). In general, however, the channel is too uniformly deep for ***R. fluitans,*** and other in-channel vegetation to become widespread due to the lack of light availability. Species that grow in fine sediments, such as perfoliate and shining pondweed and spiked water-milfoil, may also be limited by the highly turbid conditions which restrict light to the channel bed. A reduction in the sediment load would improve the light conditions and make some additional areas of substrate available for colonisation.

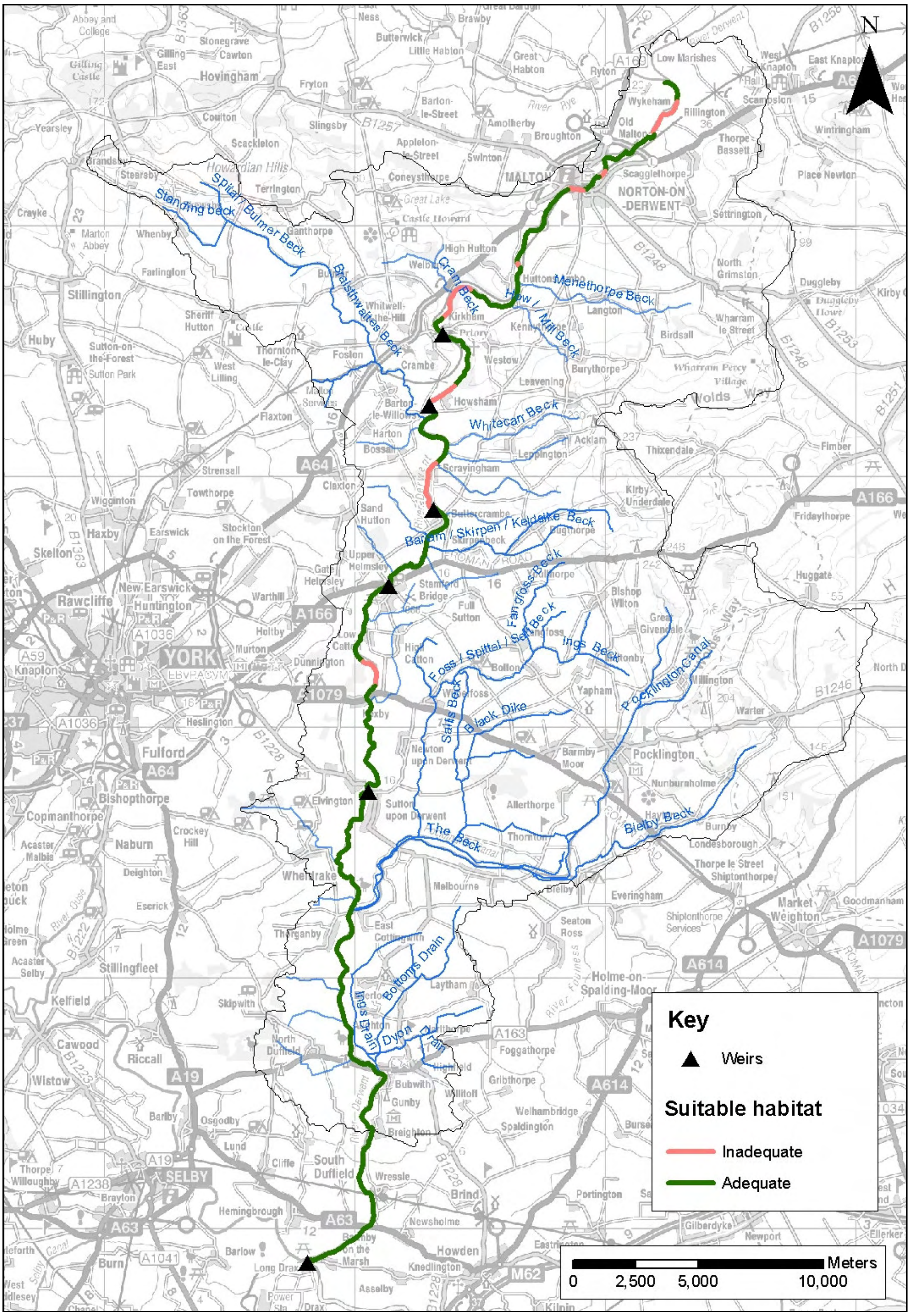
River water-crowfoot was found to be restricted to areas of faster flowing water such as weir pools and around meanders. However, due to the extensive canalisation of the channel, these variable habitats are rare and restricted in size. The weir pools are thought to reflect an element of the historical plant communities that would normally have been found in shallower sections with increased velocity. These naturally shallower sections are no longer present on the river, and so weir pools provide a vitally important habitat that is otherwise missing from the river. In addition to the lack of shallower sections, macrophytes may be restricted by the overshading of the channel in places by bankside trees. The location of areas with clean gravels and swift to moderate flows is illustrated in **Figure 6.1a**. The map demonstrates that this type of habitat is restricted to very localised reaches associated with in-channel structures, which is key in limiting the extent of SSSI/SAC plant and fish species.

Water starworts are shallow rooting species that grow in slow or negligible flow. They survive high flow events by being able to re-colonise quickly. It is therefore important that a good stock of the plants is present upstream from which downstream communities can regenerate. In the River Derwent, water starworts were associated with sheltered areas of shallow water in the channel margins (where light conditions were appropriate and not too overshaded by bank vegetation). The location of areas where there is adequate light for in-channel vegetation is illustrated in **Figure 6.1b**. Although the majority of the River Derwent SSSI has adequate in-channel light they are key areas where lack of light is limiting the growth of in-channel vegetation.

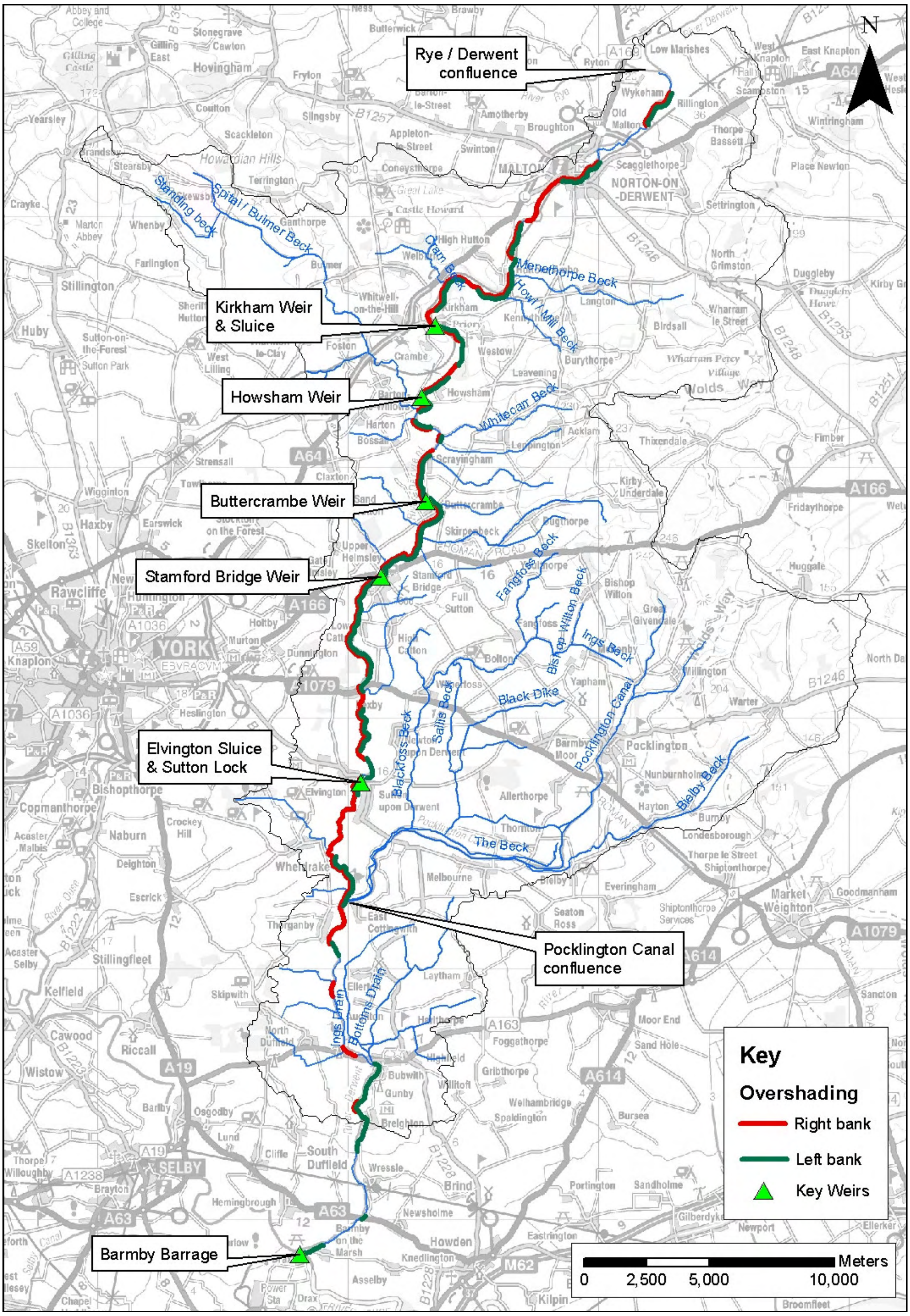
Figure 6.1: Channel characteristics affecting vegetation communities within the River Derwent SSSI
(a) Reaches of swift to moderate flows and gravels



(b) Reaches with adequate in-channel light



(c) Reaches where overshading is present



In addition to in-channel species, marginal vegetation is also an important aspect of the River Derwent SSSI designation. Marginal species that typically grow in shallow water, such as narrow-leaved water parsnip and river water dropwort, are likely to be adversely affected by the uniform and steep nature of channel banks along the River Derwent SSSI. However, flowering rush, which can tolerate deeper waters was observed to be widespread within the site.

Field observations indicated that, in some locations, landuse management practices mean that there is a lack of riparian zone vegetation due to grazing of livestock. In other reaches, overshading by bankside trees is reducing light availability for in-channel vegetation species (**Figure 6.1c**). However, bank failures due to trampling by grazing livestock were observed to provide suitable habitats for some marginal species, including ***C. platycarpa and P. pectinatus***. This had created shallow marginal areas with favourable light conditions for macrophyte growth, which remained undisturbed for long enough for vegetation to grow, and had since become colonised by marginal plants from upstream.

6.4.3 Key issues for aquatic vegetation communities

Assessment of the physical character attributes which affect the suitability of the River Derwent SSSI for aquatic vegetation communities has highlighted the following key issues:

- High turbidity: High suspended sediment loads may be having a detrimental impact on the habitat requirements of plant species, as the depth to which light can penetrate is greatly reduced. This restricts the area available to be colonised by in-channel vegetation as much of the channel is too deep for sufficient light to reach the bed.
- Fine sedimentation on the channel bed: Fine sedimentation has a detrimental effect on in-channel habitats for aquatic plant species such as river water-crowfoot and water starwort, which need gravely/stony substrate to take root.
- Lack of marginal habitat niches: Channelisation along the river has reduced the availability of physical habitats that are suitable for colonisation by marginal vegetation. The channel margins are frequently too deep to support marginal species.

Whilst these issues are occurring, the Derwent is a lowland alluvial system with a typically high sediment load during above normal flow conditions. It is therefore important to focus on where typical characteristics become problems; for example, excessive sedimentation over and above what would normally be expected. It is also important to better understand the tolerance of species to changes in flow that may result from any of the proposed actions, for example, some species may remain even if gravels are not as exposed as at present.

6.5 Fish

Previous investigations

The River Derwent SSSI is regarded as being a coarse fishery containing pike, roach, dace, barbel, chub, grayling, perch, ruffe and bleak. Fisheries are surveyed by the Environment Agency annually at sites on the Upper and Lower River Derwent as part of the National Monitoring Programme. Data from electrofishing surveys that took place between 2002 and 2004 are presented in the Howsham Weir Fisheries Assessment (Turnpenny, 2005). These data show that in the upper catchment, resident brown trout (***Salmo trutta***) and grayling (***Thymallus thymallus***) are the dominant species. However, in the lower catchment (the River Derwent SSSI), the assessment confirms that coarse fish dominate the fish community. The following species were recorded during 2002 and 2004 in the lower part of the river (in approximate order of abundance):

- Gudgeon (***Gobio gobio***)
- Pike (***Esox lucius***)
- Roach (***Rutilus rutilus***)
- Dace (***Leuciscus leuciscus***)
- Barbel (***Barbus barbus***)
- Grayling (***Thymallus thymallus***)
- Chub (***Leuciscus cephalus***)
- Brown trout (***Salmo trutta***)
- Perch (***Perca fluviatilis***)
- Ruffe ***(Gymnocephalus cernuus)*** ***(noted in SSSI citation)***
- Bleak ***(Alburnus alburnus)*** ***(noted in SSSI citation)***
- Bullhead (***Cottus gobio***) ***(SAC designated species)***
- Minnow (***Phoxinus phoxinus***)
- Stone loach (***Nemacheilus barbatus***)
- River lamprey (***Lampetra fluviatilis***) ***(SAC designated species)***
- Sea lamprey (***Petromyzon marinus***) (***SAC designated species)***
- Flounder (***Platichthys flesus***)
- Eel (***Anguilla anguilla***)

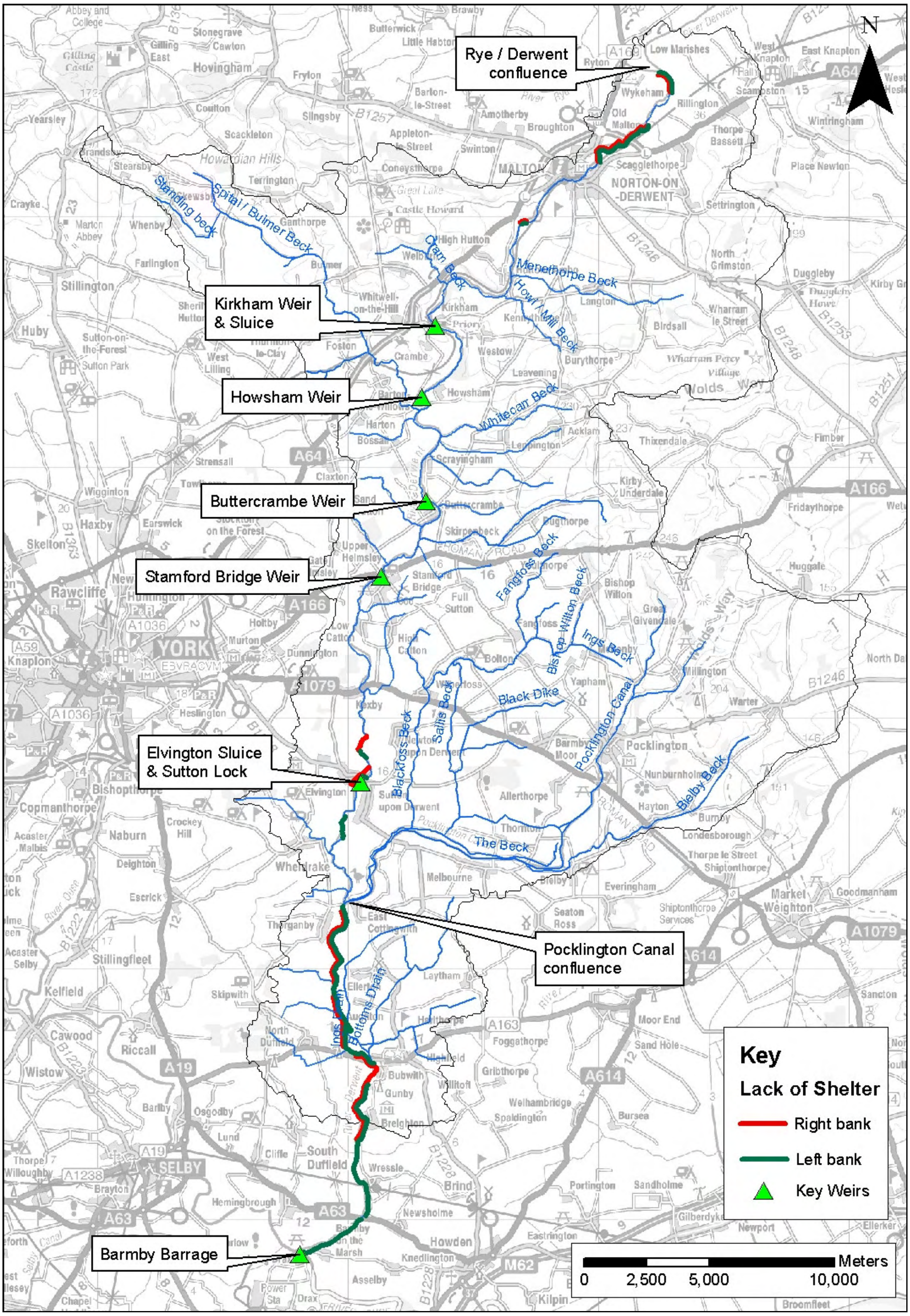
Bullhead (which are included in the SAC designation), were observed in low numbers at most of the sites monitored as part of the electrofishing surveys on the lower Derwent (Turnpenny, 2005). Populations were most abundant at the monitoring sites between Kirkham Abbey and Sutton upon Derwent, in the vicinity of the weirs.

In addition, more detailed surveys of lamprey species, which are included in the SAC designation, were undertaken between March and June 2003. These identified that the canalised river channel provided suitable habitats for larvae (Jang ***et al***, 2004). Abundant spawning habitat was recorded upstream of Ryemouth, upstream of the study area, although suitable habitat was extremely limited in the lower reaches. River lampreys were only observed in the lower reaches of the river.

Field observations

During the walkover survey, large stretches of the banks of the River Derwent were identified as being heavily tree-lined resulting in provision of woody debris and exposed tree roots, which are partially submerged along the margins of the channel. This provides shelter and feeding habitat for local fish populations and migrating lamprey. Areas lacking in bankside and in-channel cover for fish were also observed, particularly upstream of Malton, upstream of Elvington, and downstream of Wheldrake (**Figure 6.2**).

Figure 6.2: Reaches where lack of bankside cover was observed



Short reaches of the river, downstream of the five weirs, were identified as providing suitable habitat for spawning lamprey. The majority of the channel, however, was considered to be largely unsuitable. Conversely, suitable lamprey nursery habitat was identified at Kirkham weir, Howsham mill leat, Buttercrambe mill leat, Stamford Bridge lock channel and the Sutton Lock channel.

The majority of the river was identified as providing sub-optimal habitat for bullhead, with the exception of the pools downstream of each of the weirs.

6.5.1 Physical character contributing to ecological condition

Four key physical factors impact on fish populations in rivers: water depth; flow velocity, stream bed substrate and cover. The geomorphological characteristics of the channel are important in determining the first three of these factors directly. Indirectly, geomorphological character also impacts on vegetation growth, which in turn provides cover for fish species as well as exerting a physical influence in turn on water depth and flow velocities. In-channel structures may also act as barriers limiting the movement of fish within the river. In addition, the lack of bankside cover (overhanging or aquatic vegetation, river banks, surface turbulence, water depth and/or in-stream structures) can be important in influencing habitat use and providing shelter from predation. Lack of cover is an issue particularly within the lower reaches of the River Derwent SSSI.

The channel was generally too deep to provide good spawning habitat for lamprey and there was a lack of areas with clean gravels available. The gravels suitable for spawning tend to be found at the tails of pools, where there is some water flow through the gravels. Short stretches downstream of the five weirs, however, are more suitable for spawning as the water is shallower, the flow swifter and where visible, the substrate appears stony and free of silts (**Figure 6.1**). Habitat in these stretches is therefore suitable for spawning which was indeed found to take place in these areas during the 2003 survey (Jang ***et al***., 2004).

Although they provide spawning habitat, the barriers on the lower River Derwent also present a constraint to lamprey spawning by limiting access to suitable spawning sites upstream. Of the weirs with fish passes, only the pass at Sutton upon Derwent is well suited to allow lamprey to pass as it is of a staggered design with backwaters available for resting on the way up. At Kirkham and Stamford Bridge, the fish passes are straight with high velocity flows and no back water areas providing resting places. At some flow levels, they may be passable, but at other times, lamprey may struggle against the current. The 2003 survey found that Stamford Bridge was the primary area for river lamprey spawning, with few lamprey spawning upstream of this location. The area of suitable spawning habitat could therefore be increased by improving access to suitable sites upstream, or alternatively by increasing the area available downstream of Stamford Bridge. Although spawning habitat in the lower Derwent is restricted, excellent nursery habitat for lamprey ammocoetes is supported by the fine, stable silts found in the mill leats near each of the weirs. These habitats are also likely to be found elsewhere in the river, in sheltered areas away from the main flows where deposition is prevalent.

Bullhead population densities are likely to be limited by the lack of a clean gravel substrate (**Figure 6.1a**). However, the reaches downstream of the weirs at Kirkham, Howsham, Buttercrambe, Stamford Bridge and Sutton appear to provide habitat that is more suitable for bullhead. Flows over and downstream of the weirs are swifter than in the majority of the river. In some places near the weirs, small sections of the substrate were observed due to the reduction in depth of the water (**Figure 6.1a**). It appeared that cobbles and large stones, free of sediment, were present in some areas downstream of the weirs, presumably as a result of variation to the flow regime (i.e. higher flows).

Shelter and shading are important for bullhead, lamprey and other fish species to help avoid predation, and as suitable habitat for prey species. Since there are many heavily tree-lined stretches of the River Derwent, shelter and shading are plentiful and should not limit the survival and densities of most fish populations. However, the large exposed reaches in the lower parts of the system, where the presence of large embankments limits the development of marginal and riparian habitats (**Figure 6.2**) limit the quality of habitats in this part of the river.

6.5.2 Key issues for fish populations

Assessment of the physical character attributes which affect the suitability of the River Derwent SSSI for fish communities has highlighted the following key issues:

- Fine sediment supply and in-channel sedimentation: The over-supply of fine sediments can smother coarser bed habitats, leading to a lack of a clean, stony substrate for species that require this substrate for spawning.
- Channelisation: Extensive modifications to the river channel create a lack of habitat diversity to support a full range of fish species, particularly salmonids which require faster, shallower flow conditions.
- In-channel structures: These present a physical barrier to migration for coarse fish and salmonids, which may be unable to pass structures within the SSSI.

6.6 Breeding birds

6.6.1 Current ecological condition

The River Derwent supports an excellent breeding bird assemblage including the common sandpiper (***Actitis hypoleucos***), dipper (***Cinclus cinclus***), kingfisher (***Alcedo atthis***), yellow wagtail (***Motacilla flava***) and grey wagtail (***Motacilla cinerea***).

The Derwent Ings, Newton Mask and Breighton Meadows SSSIs which adjoin the River Derwent SSSI are internationally designated as part of the Lower Derwent Valley SPA for birds. The area is one of the largest and most important wetlands in the United Kingdom, which supports significant wetland plant communities and excellent habitats for breeding birds.

The 17 small floodplain units that form part of the River Derwent SSSI are already assessed to be in favourable condition, apart from Units 8 and 15 where Himalayan balsam, an invasive species, is present, and unit 14 which is overgrazed. It is therefore considered that only localised issues are adversely affecting breeding birds within the River Derwent and Derwent Ings, Newton Mask and Breighton Meadows SSSIs.

6.6.2 Physical character contributing to ecological condition

The condition of breeding bird communities is limited by the extent of floodplain habitats and the structure of riparian habitats. In the Derwent catchment, these are limited by the presence of the flood embankments which fringe a large proportion of the river channel, particularly in the lower reaches. There may therefore be opportunities for solutions that improve habitat conditions along the River Derwent SSSI to also contribute to further improvement of breeding bird habitat (i.e. through the extension of existing wetland habitat).

6.6.3 Key issues for breeding birds

The key issues which affect the breeding birds have been identified as:

- Channelisation, leading to restricted riparian habitats for feeding, nesting and shelter.

6.7 Otters

6.7.1 Current ecological condition

The walkover survey focussed on assessing the presence or absence of otters through the observation of obvious spraints and footprints. During the current project, otter spraints and footprints were observed at various points along the river banks. In some places these signs were fresh and numerous. At one location, footprints of two very distinct sizes were found, giving the strong suggestion that juveniles are present in the area and hence that breeding is taking place. While not enough information was gathered to provide a comprehensive assessment of the local otter population, it is concluded that there is suitable habitat along most of the length of the river with otter activity observed at numerous locations. Fisheries data and the presence of many angling stands suggest that the channel has a plentiful supply of fish which could attract and support an appreciable otter population. In addition, much of the river is lined with bankside trees indicating that holt and breeding sites are also likely be plentiful.

6.7.2 Physical character contributing to ecological condition

Habitat along the River Derwent is largely very suitable for otters. Despite the fact that lamprey and bullhead may be limited, and some fish species may have difficulty passing upstream, there are many other fish species (mainly coarse fish) that can thrive quite effectively resulting, in available food source.

There are many stretches of various lengths on the River Derwent where bankside shelter is abundant, often to the extent that there is excessive shading limiting aquatic macrophyte growth. The shelter most often takes the form of a line of trees overhanging the banks providing suitable habitats for otters and areas for foraging.

There is only one location where trees and vegetation are missing from the banks to the extent that it could impact upon otters using the area. Reach 19, which begins immediately downstream of the Pocklington Canal has set-back flood embankments present for its entire length (7.37 km). The upper sections of this reach in particular are almost entirely devoid of bankside shrubs and trees which leaves the area with no shelter or cover for otters. This could discourage otters from breeding in the area or moving upstream through the area during foraging and could make them more vulnerable to disturbance. However, as the remainder of the Lower River Derwent appears to be suitable for otters, they are known to occur in this area and the Lower Derwent Valley is an SAC for otter, the presence of one unvegetated reach is unlikely to adversely impact on the otter community overall.

While the SSSI interest features do not appear to be directly dependant on the geomorphological changes that have been observed in the River Derwent, they do depend indirectly upon them. For example, while a certain density of birds can be supported by current levels of invertebrate prey, this density could potentially be higher if there was more vegetated marginal habitat providing more invertebrate habitat and therefore more invertebrate prey for birds to feed on. However, this must be balanced against the importance of open areas for SPA birds in the Lower Derwent Valley. Similarly, more vegetated marginal habitat would equate to a larger area of sheltered nursery habitat for fish fry, perhaps leading to even larger fish communities.

The issues affecting the SAC features therefore also affect the SSSI features, albeit more indirectly. Any action taken to improve conditions for SAC features is also likely to have a secondary beneficial impact upon the SSSI features.

6.8 Key issues in the River Derwent SSSI

The previous sections have demonstrated that the geomorphology of the River Derwent SSSI is controlled by the interaction of a complex range of physical and hydrological parameters. Four main factors have been identified as key issues which affect the condition of the SSSI:

- Fine sediment supply and deposition.
- Channelisation and disconnection from the floodplain.
- Lack of bankside shelter and shading, and overshading.
- In-channel structures.

The main impacts of these factors on the SSSI are summarised in **Table 6.4**, and described in more detail in the subsequent sections.

Table 6.4: Key issues identified within the River Derwent SSSI

Key issue	Characteristics impacting on the ecology of the SSSI
Fine sediment supply and deposition	• High turbidity in the water column limiting light penetration for macrophytes • Fine sedimentation on the channel bed limiting habitats for macrophyte communities, invertebrates and fish
Channelisation and disconnection from the floodplain	• Lack of marginal habitats for colonisation by aquatic vegetation • Lack of morphological and flow diversity, limiting the range of habitats for fish and invertebrate communities • Floodplain disconnection, limiting the development of riparian and wetland habitats for bird populations
Lack of bankside shelter and shading, and overshading	• Limited in-channel shelter for fish populations and invertebrates • Limited riparian shelter for bird communities and mammals • Lack of light penetration in overshaded reaches, making in-channel conditions unsuitable for macrophytes • Dense tree cover that is unsuitable for bird populations in the lower Derwent
In-channel structures	• Physical barrier to free movement of fish populations

6.8.1 Fine sediment supply and deposition

The issues related to sediment supply and deposition can be divided into three categories:

a) Fine sedimentation in channel bed

Fine sedimentation is a persistent issue throughout the River Derwent SSSI, and is largely attributable to the input of fine sediment from erodible agricultural soils into the floodplain drainage ditches and subsequently the main river channel. An increase in channel capacity as a result of historical over-widening and over-deepening and a change in river flow regime due to the influence of the Scalby Sea Cut and Barmby Barrage combine with the increased sediment supply to promote in-channel sedimentation. Excessive fine sedimentation has a detrimental effect on river habitat by reducing the diversity of the channel bed and creating uniform, silted conditions. Where coarser sediments are present, sedimentation will also inhibit their use by flora and fauna that rely on these sediments. For example, lamprey must have access to clean gravels for spawning, to prevent smothering of eggs and ammocoetes, while bullhead need clean stones amongst which to find shelter and deposit eggs. River water-crowfoot and water starwort also need gravely/stony substrate to take root. These species are therefore adversely affected by fine sedimentation of gravels on the channel bed.

b) Turbidity

Turbidity was observed throughout each of the study reaches during the field survey. This is largely attributable to the high suspended sediment content of the floodplain drainage ditches, which receive large quantities of fine sediment in-wash from the agricultural fields that they drain. Turbidity has a detrimental impact on the habitat requirements of plant species as the depth to which light can penetrate is greatly reduced. This restricts the area available to be colonised by in-channel vegetation as much of the channel is too deep for light to reach the bed. The problem is exacerbated by channel modifications that have resulted in an increase in depth throughout much of the river's course and a general lack of shallow marginal areas. The resulting lack of plant cover has implications for many other aspects of the river ecosystem, for example, there is less cover and shelter available for fish fry and juveniles, and less habitat present for aquatic invertebrates to occupy.

c) Lack of a suitable gravel substrate for plant and fish species

The lower River Derwent is a typical lowland river underlain by predominantly fine-grained superficial geology. As a result, the substrate would not be expected to be gravel throughout the length but diversity in substrate conditions would be expected across a river of this length. There are a few exceptional areas where gravel and stony substrate is present. Several important areas are located immediately downstream of four of the weirs (Kirkham, Howsham, Buttercrambe and Stamford Bridge). In these areas, the hydraulic conditions result in shallow, faster flow with areas of gravel and cobble scoured clean. In addition, areas of gravel bed are reported to occur in the lower reaches in association with natural geological outcrops. Due to the scarcity of these coarser habitats, the impact of excessive fine sedimentation (resulting in considerable depth of fine sediment) is increased. For example, existing gravel habitats in the upper parts of the study reach have been smothered for example at Malton (D03). This has a detrimental effect on the habitats of plant and fish species that require some areas of clean gravels. The definitive presence and extent of gravels on the channel bed and supply of gravels to the channel is currently unknown. Access to gravels upstream for migratory species that require this habitat is therefore of high importance. Further downstream, opportunities to create spawning grounds around existing structures might be the best opportunity where gravels are not naturally found to be present.

6.8.2 Channelisation and disconnection from the floodplain

The flood embankments that fringe large reaches of the river prevent the floodplain functioning naturally, by limiting inundation during smaller floods and, when inundation does occur, preventing the natural drainage of the floodplain. In addition to limiting the morphological diversity of the channel margins, this alters flow and sediment dynamics and limits the potential for the development of natural floodplain habitats.

Large reaches of the River Derwent are fringed by flood embankments that were constructed prior to the production of the 1st Edition Ordnance Survey maps of the area in the 1850s. In some cases, these structures fulfil a flood defence function by protecting properties and infrastructure from inundation. However, extensive modelling of the lower Derwent catchment undertaken by JBA Consulting (2005) suggests that many of the flood embankments do not serve an important flood defence function.

The presence of the embankments reduces inundation frequency, particularly during small floods, and therefore limits the potential for floodplain storage of fine sediments. Removal or alteration of these structures in cases where they do not perform a flood defence function could therefore help to address the issue of fine sedimentation in the catchment by increasing channel-floodplain connectivity and allowing greater floodplain storage of fine sediments. In addition, many of the flood embankments that fringe the river currently prevent the development of riparian habitats, due to their close proximity to the channel edge. Removal or set back of these structures would allow the bank to be reprofiled if necessary and promote the development of higher-quality riparian habitats. However, this would need to be carefully evaluated against the potential for increased summer flooding that could impact on the Lower Derwent Valley SAC.

6.8.3 Lack of bankside shelter and shading, and overshading

Inappropriate bankside shelter has four main impacts on the ecology and condition of the River Derwent SSSI:

a) Lack of in-channel shelter
Lamprey, bullhead and otter prey species require tree roots and woody debris within the channel to provide them with shelter. The construction of the flood embankments along the lower reaches of the river has limited tree lining and thus reduced the frequency of tree roots and woody debris in the channel, constraining the quality of habitats that the channel supports. Lack of in-channel shelter has been identified as an issue in isolated reaches throughout the SSSI.

b) Lack of bankside shelter
Some stretches of the river channel are lacking in bankside trees and vegetation cover. Trees and shrubs provide shelter for foraging otters as they move along the channel hunting for fish prey, as well as undisturbed areas that are suitable for otter holts and breeding dens (e.g. holes within tree root systems). Exposed stretches may still be used by otters if there are fish present, but they are more vulnerable in these areas, and so they could represent a barrier to free movement of otter populations. However, anecdotal evidence suggests that otters are freely moving along the River Derwent SSSI. In addition, lamprey moving upstream to spawning areas require bankside cover in the form of submerged tree roots in which to shelter from predation from otters and birds. As lamprey must pass through such exposed areas to reach spawning grounds,

they are forced to accept a greater risk of predation. Lack of bankside shelter has been identified as an issue in isolated reaches in the middle and lower Derwent.

c) Shading

Some stretches of the River Derwent are lacking in bankside trees and vegetation, resulting in a lack of shade within the channel. To reduce vulnerability to predation, bullhead prefer to occupy habitats with an appreciable level of shading present. Areas lacking in riparian vegetation are therefore likely to be poor quality habitats for bullhead. Lack of shading has been identified as an issue in isolated reaches throughout the SSSI.

Conversely, some reaches of the Derwent have too much shading due to dense riparian vegetation cover. Overshading can be detrimental to in-channel habitats by limiting the amount of light which penetrates the water column. This reduces photosynthesis and plant growth, and can restrict habitats for fish and other aquatic organisms. Over-shading has been identified as an issue in isolated reaches throughout the SSSI.

d) Restricted extent of floodplain wetland habitat

Wetland areas adjacent to the river channel provide additional habitat for otters, so that they are not restricted solely to the river channel in their movements. Floodplain wetlands are currently restricted in the catchment as a result of current land use practices and the disconnection caused by the flood embankments. Increased areas of floodplain habitat would reduce the vulnerability of otters to predation and intraspecific competition. In addition, floodplain wetlands also provide valuable habitats for a variety of bird species. Restricted floodplain habitats have been identified as an issue in the upper and middle parts of the River Derwent SSSI, and in the lower reaches immediately upstream of Barmby Barrage.

6.8.4 In-channel structures

In-channel structures impact upon the condition of the River Derwent SSSI in two main ways:

a) Impoundment

In-channel structures such as weirs and sluices alter the natural functionality of the geomorphological and hydrological processes that operate within the river channel, creating slow flowing impounded conditions upstream.

b) Barriers to fish passage

In-channel structures also act as significant barriers to the free passage of migratory fish species such as lamprey, preventing access to suitable spawning habitats upstream of these features. The movement of weak-swimming coarse fish populations is also likely to be limited. There are six major sets of structures which are located along the length of the River Derwent SSSI; Kirkham Weir and Sluices, Howsham Weir, Buttercrambe Weir, Stamford Bridge Weir, Elvington Sluice, and the tidal barrage at Barmby. As such, a significant proportion of the SSSI is impacted upon by in-channel structures.

Potential solutions for each of the key issues described in the previous sections are discussed in **Section 7**.

7 POTENTIAL SOLUTIONS

7.1 Purpose of this chapter

The previous section has demonstrated that there are a number of key geomorphological issues within the River Derwent SSSI that are adversely affecting the lowland river habitat. These habitats are to some extent dependent on the physical habitat conditions which support them, which are themselves controlled by the interaction of geomorphological and hydrological parameters.

The aim of this section is to describe the types of solutions that could be implemented to improve the geomorphological and hydrological processes which operate in the Derwent catchment, and enhance the key ecological interest features in the SSSI. The issues that each group of solutions address will be discussed, along with the potential constraints and their contribution towards climate change adaptation in the catchment.

7.2 Types of solutions

A suite of potential solutions to address the issues identified in the River Derwent SSSI have been identified; these are outlined and related to the key issues in **Table 7.1**. Further details of potential solutions are provided in the accompanying River Restoration Plan for the River Derwent SSSI.

Several of the solutions identified can be used to help assess more than one of the key issues. This also reflects the fact that these issues are themselves interlinked. For example, the presence of in-channel structures limits the migration of fish and lamprey species as well as creating impounded conditions upstream that exacerbate siltation on the channel bed. Within the River Restoration Plan, reach-scale actions are identified based on these solutions, bearing in mind the key constraints.

Table 7.1: Potential solutions identified within the River Restoration Plan for the River Derwent SSSI

Category	Solution	Key Issues			
		Fine sedimentation	Channelisation and disconnection from the floodplain	Lack of shelter and shading	In-channel structures
A - Changing agricultural and land drainage management practices	Investigate and manage fine sediment input	✓			
	Selectively restrict livestock access to banks	✓		✓	
B - Alter flood embankments	Remove, breach, lower or set back embankments	✓	✓	✓	
C - Enhance riparian, wetland and marginal habitats	Tree,shrub and non-native invasive plant management)	✓		✓	
	Bank rehabilitation		✓	✓	
D - Modify in-channel structures	Remove structures	✓			✓
	Modify structures	✓			✓
	Alter operation of structures	✓			✓
	Provide a suitable fish pass				✓
E - Preserve existing habitats	Preserve existing quality habitats	n/a	n/a	n/a	n/a
	Preserve existing woody debris in the river channel	n/a	n/a	n/a	n/a

7.3 Changing agricultural and land drainage management practices

7.3.1 Issues tackled

The main issue addressed by changing land management practices is diffuse sediment supply, which occurs throughout the River Derwent SSSI. Three closely related issues related to diffuse sediment supply are evident in the catchment:

- Fine sedimentation on the channel bed.
- Turbidity.
- Lack of suitable gravel substrate for plant and fish species.

These are described in more detail in **Section 6.8.1**.

7.3.2 Potential solutions

a) Development of a strategic plan to address sediment supply

Issues related to diffuse sediment supply are ubiquitous in the River Derwent SSSI, with sediment sourced directly from erodible soils, from intensively cropped land via drainage ditches, and directly to the channel through small rills or as overland flow. There is no rapid solution to this problem, but the most successful solution will be to develop a strategic plan which sets out measures to reduce sediment supply from the SSSI and the River Derwent catchment further upstream. This will require close working with landowners and Internal Drainage Boards to change current land management practices or, if necessary, reversion of arable land, in order to achieve a reduction in sediment supply over time. The plan could include specific measures to address diffuse and point sources of sediment supply, including:

- Reviewing and improving the maintenance regime of tributaries and drains.
- Establishing buffer strips adjacent to tributaries and field drains.
- Selectively restricting livestock access to banks.

b) Changes to structures and flow regime

In addition to the main solution outlined above, measures to reduce impoundment and improve channel-floodplain connectivity could also be implemented to address fine sedimentation issues. This would improve the flow regime and help to address fine sedimentation issues by allowing natural overbank sedimentation to occur. These measures are described in more detail in **Sections 7.4** and **7.6**.

7.3.3 Potential constraints

The development of a strategic plan to address sediment supply will require partnership working with landowners and Internal Drainage Boards to ensure that sustainable long-term solutions are identified. The major barriers to implementation of the plan are the large size of the catchment, the high number of potential sources of sediment and the numerous stakeholders involved, some of whom may be unwilling to change current practices. Although some measures may be implemented voluntarily e.g. through Natural England Stewardship schemes), a degree of incentivisation may be required.

7.3.4 Contribution to climate change adaptation

Changes to agricultural and land drainage management practices in the River Derwent catchment can help the catchment to adapt to predicted future climate change. The latest climate projections (UKCP09) produced by the UK Climate Impacts Programme (UKCIP) suggest that, over the next 20-50 years, temperatures and precipitation levels could be considerably different to current conditions. A summary of how changing land management practices could contribute towards adapting to these changes is provided below:

- Temperature increase by up to 2°C: Improved conditions for vegetation growth in the channel and riparian zone could encourage sediment trapping if management practices are altered.
- Summer precipitation decrease by up to 40%: Reduced summer flows could increase livestock trampling pressures, so improved watercourse management could prevent further increases in sediment supply. (Note that this prediction, which is based upon recent climatic modelling, is not reflected by current experience of wet summers and increased severe rainfall events in the catchment in recent years which have led to summer flooding.)
- Winter precipitation increase by up to 10%: An altered land management regime could help to mitigate potential increases in sediment runoff from agricultural land.

7.3.5 Restoration actions

Main tributaries where sediment supply may be excessive were identified during the Fluvial Audit process, and identified in **Appendix B.** For each of these watercourses, the recommended action is to tackle sediment supply at source using measures to reduce erosion or transport of fine sediment within the drainage network. Co-ordination of practical actions may be of benefit in tackling the problem thus this action would be best approached strategically.

7.4 Alter flood embankments

7.4.1 Issues tackled

The main issue addressed by altering the flood embankments is disconnection from the floodplain. This issue is described in more detail in **Section 6.8.2**.

7.4.2 Potential solutions

The presence of the embankments reduces inundation frequency, particularly during small floods, and therefore limits the potential for floodplain storage of fine sediments. Removal or alteration of these structures in cases where they do not perform a flood defence function could therefore help to address the issue of fine sedimentation in the catchment by increasing channel-floodplain connectivity and allowing greater floodplain storage of fine sediments (although the scale of benefits achieved in relation to sediment storage is currently difficult to quantify). In addition, many of the flood embankments that fringe the river currently prevent the development of riparian habitats, due to their close proximity to the channel edge. Removal or modification of these structures would allow the bank to be reprofiled if necessary and promote the development of higher-quality riparian habitats.

There are four potential mechanisms for removal or modification of the embankments in the River Derwent catchment:

1. Removal of existing structures: complete removal to allow unimpeded floodplain inundation and, if appropriate, regrading of the river banks.
2. Breach of existing structures: removal of a portion of the embankment, particularly in areas adjacent to field drains and tributaries, to improve floodplain drainage and allow more natural floodplain inundation. This action will allow the drainage cloughs to be removed, and more natural open channels to be provided in their place.
3. Set back of existing structures: removal of existing structures and re-construction at a point behind the functioning floodplain. This will increase floodplain inundation whilst retaining flood protection where necessary.
4. Lowering of existing structures: lowering the crest height of existing embankments to increase the frequency of overtopping and floodplain inundation.

7.4.3 Potential constraints

The flood embankments that fringe parts of the River Derwent provide a number of functions. In some cases, these structures protect housing, infrastructure or other assets from inundation. Some of the embankments are now considered obsolete, and could potentially be removed without increasing flood risk for infrastructure and assets on the floodplain.

Potential impacts on flood risk management

Large reaches of the River Derwent SSSI are fringed by flood embankments that were constructed prior to the production of the First Edition Ordnance Survey maps of the area in the 1850s. In addition, much embankment and other river improvement work was carried out between the 1940s and 1960s. In some cases, these structures still fulfil a flood defence function by protecting properties and infrastructure from inundation. However, extensive modelling of the lower Derwent catchment undertaken by JBA Consulting (2005) suggests that many of the flood embankments do not serve an important flood defence function and it may be feasible to remove or modify portions of the embankments without significantly increasing the area of inundation in many areas of the floodplain. Furthermore, additional simulations by JBA Consulting (2004; 2006) have demonstrated that the flood embankments exacerbate flooding in the ings by impeding the natural drainage of the floodplain. However, this would need to be carefully evaluated against the potential for increased summer flooding that could impact on the condition of the Lower Derwent Valley SAC.

Modification of the embankments could potentially be justified under the policy objectives outlined in the draft Derwent Catchment Flood Management Plan (Environment Agency, 2010). Whilst it is proposed that defences in Malton and Norton and Stamford Bridge are maintained the CFMP also promotes the possibility of using natural processes and reconnecting the river and its floodplain. Modification of the existing embankments is likely to be a major mechanism for the delivery of these CFMP policies (**Table 7.2**).

Table 7.2: Potential CFMP policies with relevance to the embankments

CFMP Policy Unit	Potential policies related to embankments
Sub-area 5. Rye and Derwent	We will continue our current management actions such as maintaining the flood banks. We need to consider a more sustainable strategic approach to long term management. We will undertake a detailed study of the Rye and River Derwent expanding on current knowledge. Through a review of the flood banks within the sub area and by working with other organisations within the Vale of Pickering, benefits can be realised to both properties and the local environment. This study will build upon recent work to provide us with a clear picture of the benefits that can be gained from lowering, maintaining and strengthening banks in different areas. We will look to see how natural processes can be used to maximum benefit in managing local and catchment-wide flood risk ahead of maintaining defences.
Sub-area 6 Lower Derwent and the Wolds	We will continue with our current activities in the area. In the long term we will need to address the condition of the flood banks. Following the improved understanding of defences in the sub-area, reassess the long term strategic CFMP policy to ensure that the most sustainable approach to managing flood risk has been adopted.
Sub-area 9 Malton, Norton and Stamford Bridge	We will continue with the long term maintenance of the flood defences through the area in order to continue to provide a high standard of protection to people at risk. Although the standard of protection offered by the flood defences will reduce over time we will not undertake additional activities in the area. However, upstream improvements to the way that the system of floodbanks and washlands work will counter the effects of climate change here, as will actions to reduce runoff in the upstream sub-areas.

Flood risk management may therefore act as a driver as well as a constraint for the removal or modification of flood embankments.

Potential impacts on floodplain habitats

Modification of the embankments is likely to have significant impacts on floodplain habitats adjacent to the River Derwent including the Derwent Ings, Newton Mask and Breighton Meadows SSSIs / Lower Derwent Valley SAC, SPA and Ramsar site. The aim of the intervention would be that the impact would be favourable, for example extending or enhancing wetland interests and facilitating appropriate water level management. However, the SSSI is currently assessed to be predominantly in favourable condition and care is required to ensure there is no adverse impact on interest floodplain habitats and species, including MG4 grassland and wintering and breeding birds. The potential for removal or modification of the embankments will therefore depend on whether the works are likely to enhance or provide conditions for these key floodplain habitats.

Having noted this, modification of flood embankments could potentially be justified under the aims of the existing Lower Derwent Valley Management Plan (Lower Derwent Project, 2005). This document outlines specific management objectives for each of the Lower Derwent ings, with the aim of protecting and enhancing the ecological value of the Derwent Ings SSSI, SAC and SPA. A brief summary of the potential management issues related to the embankments identified in the management plan is provided in **Table 7.3**.

Table 7.3: Ing management issues related to the presence of embankments

Area	Potential issues related to the embankments
West Carr	The site is regularly flooded when the embankments overtop. Subsequent drainage is controlled by the invert level of the cloughs on Southwood Bottoms Drain and West Carr Drain, which discharge to the Derwent via flapped outfall valves. Improved management of the cloughs could help to improve the quality of the MG4 grassland habitat at the site.
Ing Marsh	The embankments are regularly overtopped, flooding the marshland behind them. Water drains back into the Derwent through a single clough, and drainage is impeded by the small size of this outfall. Drainage in the spring could be improved by the installation of a larger outfall.
The Low Grounds	Drainage of the Low Grounds, which slope towards the river channel, is impeded by the size and invert level of the drainage clough and unflapped pipes into the old course of the River Derwent and Bielby Beck. In addition, the flap valve at the end of the clough becomes jammed open with debris, leading to further inundation of the area. Improved management of the cloughs and outfalls is required to improve the condition of the MG4 grassland in the area, which is currently too wet.
Wheldrake Ings	The embankments overtop regularly, and subsequent drainage is controlled by penstocks on Wheldrake Ings Clough and North Hills Ings Clough.
Thorganby Ings	The embankment is relatively high, and is only likely ot overtop during wet years. However, a large dip in the southern end of the embankment makes the adjacent area considerably wetter. Fixing this embankment is likely to improve the condition of the area.
East Cottingwith Ings	Overtopping of the embankments is relatively uncommon, leading to a reduced nutrient supply and poorer quality grassland habitats. In addition, drainage through Pocklington Beck Clough and East Cottingwith Clough is impeded by high water levels in the River Derwent.
Ellerton Ings	The embankments regularly overtop, inundating the ings. Drainage through Ellerton Clough and Pickering Clough is impeded by high water levels in the Derwent, which are frequently above the invert level of the cloughs.
Aughton Ings	Drainage through Aughton Clough is impeded by high water levels in the Derwent, which are frequently above the invert level of the clough.
Bubwith Ings	The embankments rarely overtop, but when inundation does occur drainage is impeded by the invert level of Dyon Drain Clough, which is generally below the level of the River Derwent.
North Duffield Carrs	The embankments do not overtop every year, but when inundation occurs drainage is impeded by water levels in the River Derwent, which prevent water draining through North Duffield Carrs Clough.
North Duffield Ings	The embankments are relatively high, and generally do not overtop during wet years. The ings are amongst the driest in the lower Derwent valley. Water levels in the ings are controlled by the invert level of North Duffield Ings Clough, which is above low flow river levels but overtopped during higher flows. Improved drainage may benefit MG4 grassland in the south east of the site.
Menthorpe Ings	The embankments are regularly overtopped, inundating the ings during high flows. Drainage is controlled by water levels in the River Derwent, which rarely falls to below the invert levels of Menthorpe Ings Drain Clough and Menthorpe Marsh Clough.
Gunby Ings	The embankments rarely overtop. During drier periods, water levels in the ings are controlled by the invert levels of Thornton Hole Clough and Breighton Landing Clough. When water levels in the Derwent are higher, these invert levels are exceeded, and water levels are controlled by those in the main river. The cloughs are silting up, leading to an increase in wetness in the ings.
Wressle Ings	The large embankments at the northern end of the ings rarely overtop. However, the lower berms at the southern end of the site, downstream of Fleet Dike, overtop more regularly. Water levels in the ings are generally controlled by the level of the River Derwent.
South Duffield Ings	The embankments overtop regularly. Water levels in the ings are controlled by the level of the River Derwent, which can exceed the level of Scarecemoor Dyke Clough and Woodhall Lane Clough.

7.4.4 Contribution to climate change adaptation

Changes to flood embankments in the River Derwent catchment could potentially contribute towards climate change adaptation (as predicted in the UKCP09 projections) in the following ways:

- Summer precipitation decrease by up to 40%: Decreased summer precipitation will reduce flow levels, so removal or lowering of embankments will help to maximise inundation frequency and maintain wetland habitats. (Note that this is not reflected by current experience of wet summers and increased severe rainfall events in the catchment in recent years which have led to summer flooding.)

- Winter precipitation increase by up to 10%: Increased winter precipitation will increase flow levels. Removal or modification of selected embankments will allow more frequent floodplain attenuation of high flow events.

7.4.5 Restoration actions

The restoration plan identifies where removal or modification of embankments might be an option and recommends feasibility assessment as necessary action to take forward the solution prior to implementation. This is to take account in more detail of the particular constraints with each embankment.

7.5 Enhance riparian, wetland and marginal habitats

7.5.1 Issues tackled

Several issues relating to the quality of in-channel, riparian and floodplain habitats for interest species such as otters, bullhead and lampreys can be addressed through the creation and enhancement of the river corridor. These measures can address four related issues:

- Lack of in-channel shelter.
- Lack of bankside shelter.
- Shading.
- Restricted extent of floodplain wetland habitat.

These issues are described in more detail in **Section 6.8.3**.

7.5.2 Potential solutions

a) Establish and maintain suitable bank habitats

Measures to establish suitable bank habitats can improve in-channel and riparian habitats for SSSI interest features such as lamprey and bullhead. In areas where lack of in-channel and bankside shelter is an issue, habitats can be enhanced through planting of suitable native tree and shrub species. Where overshading is an issue, targeted removal of trees and/or branches (including techniques such as coppicing and pollarding) can be used to increase the amount of light that reaches the river channel.

b) Bank rehabilitation

Where the structure of the river bank and riparian zone is not able to support high quality bank habitats, it may be necessary to undertake more extensive bank works. Bank rehabilitation techniques combine physical modification of the bank structure, for example through reprofiling to make them less steep or the creation of a new stepped profile capable of supporting a range of habitat niches, with targeted planting to establish high quality bank habitats.

c) Preserve existing habitats
Parts of the river contain, or are adjacent to, areas of high quality habitat for the SSSI interest features. Suitable management may be required to maintain and/or enhance these habitats to maximise their potential to support a wide range of species. These measures are described in more detail in **Section 7.7**.

7.5.3 Potential constraints

These potential solutions could potentially be constrained by existing land usage and management practices along the edge of the river SSSI. Close consultation with key stakeholders such as landowners will be required to ensure that they are implemented successfully.

7.5.4 Contribution to climate change adaptation

Changes to riparian, wetland and marginal habitats in the River Derwent catchment could potentially contribute towards climate change adaptation (as predicted in the UKCP09 projections) in the following ways:

- Temperature increase by up to 2°C: Improved conditions for vegetation growth in the channel and riparian zone could help in-channel, marginal and riparian communities establish naturally.
- Summer precipitation decrease by up to 40%: Reduced summer precipitation could lead to stresses in important habitats, making the presence of high quality riverine habitats more important for SSSI interest features.
- Winter precipitation increase by up to 10%: Increased winter precipitation could increase the frequency of overbank flooding, providing suitable conditions for wetland habitat development in more locations.

7.5.5 Restoration actions

In some cases, bank rehabilitation, fencing and planting may be progressed without further feasibility work. In others where works to channel banks may be more extensive and for those reaches where embankments are present, re-profiling may not be possible without works to the embankment and will therefore need to be considered further as part of feasibility of embankment removal.

7.6 Modify in-channel structures

7.6.1 Issues tackled

In-channel structures have two major impacts on the functioning of the River Derwent SSSI:

- Impoundment.
- Barriers to fish passage.

These issues are described in more detail in **Section 6.9.4**.

7.6.2 Potential solutions

A variety of potential solutions could be implemented to address the impoundment and fish passage issues caused by in-channel structures, including:

a. Remove the structure: Complete removal of the structure to remove impoundment and restore natural flow patterns and sediment dynamics.
b. Modify the structure: Modify the structure to reduce the extent of impoundment and improve fish passage.
c. Alter operation of structure: Change the way the structure is operated to reduce the extent of impoundment and improve fish passage.
d. Install a fish pass: Improve fish passage through installation of a fish pass or bypass channel.
e. Do nothing: Retain the structure in place if constraints prevent its removal.

Potential for removal of each structure has been considered as a starting point, because this option is likely to deliver the greatest benefits to the SSSI in terms of flow and sediment regime and in-channel habitats for key interest features. If that is unlikely to be achievable due to overriding constraints, alternative options to modify each structure or change the way it is operated have been considered. If these options are not possible, interim measures to install a fish pass are considered. The "Do nothing" option is only considered if the structure cannot be removed or modified due to major constraints (such as its existing function), and it already incorporates provision for fish passage.

Description of solutions
The following sections provide a discussion of the potential solutions, and how they apply to the different in-channel structures.

a) Removal the structure
It may be possible to remove some or all of the structures in order to reduce impoundment, reinstate natural hydromorphological functionality, and allow free movement of fish populations. However, the removal of large structures is not a simple process, and can have a considerable effect on the river. Before a structure can be removed, it is first necessary to undertake a detailed assessment of the nature of the structure, its impact upon the river, and the likely consequences of removal (both positive and negative). This assessment can be summarised using the following key questions, taken from the Natural England ***Rationale for the physical restoration of the SSSI river series in England*** (2007):

- Why does the modification exist? An assessment of whether the structure serves a valid function, or is no clear purpose apparent.
- Is the modification still relevant? An assessment of whether the purpose is still on-going. For example, structures built as part of mill complexes may no be obsolete.
- If still relevant, are the reasons for retaining the modification valid in the face of restoration objectives for the SSSI? An assessment of whether the reasons for retaining a structure outweigh the benefits to the SSSI gained from its removal. For example, structures built for public water supply purposes may need to be retained, even if the SSSI would benefit from their removal.
- If valid, what are the benefits to stakeholders of restoring the river and do these outweigh the disbenefits to stakeholders (considered both individually and collectively)?

- Can appropriate mitigation measures be applied to resolve disbenefits that are acceptable to those affected?
- If the vision cannot be achieved on a particular stretch, is there a compromise restoration measure that could be deemed to be consistent with Favourable Condition that will maintain river/land use or transform it in innovative ways that are acceptable to those affected?

Once these questions have been addressed, recommendations can be made as to the preferred option (or options) for each structure.

b) Modification of the structure

In cases where complete removal of a structure is unfeasible, some benefits to the SSSI could potentially be achieved through the modification of the structure to reduce impoundment. This option is not generally preferred, but could be considered in more detail if further investigations demonstrate that it is not feasible to remove any of the structures for which this option is preferred.

c) Alter the operation of the structure

Some benefits to the SSSI could potentially be achieved through modification of the operating protocol of structures in order to reduce impoundment and improve fish passage. However, this measure is limited to four operational structures in the catchment: Kirkham sluice, Elvington sluice, Stamford Bridge sluice and Barmby Barrage.

d) Installation of a fish pass

An alternative to removal or modification of a structure is to provide a fish pass if there is not one already in place, or modify existing fish passes to improve their suitability for weak swimming lamprey and coarse fish species.

e) Do nothing

This option rules out further action at an in-channel structure. Although it will not address any of the key issues or improve the condition of the SSSI, this option has been included as a last resort if it is not feasible to remove or modify a structure, or if the benefits of doing so would be outweighed by the disadvantages.

Assessment of potential solutions for each structure

An assessment of the impact of each structure on the SSSI has been undertaken using available bed level and water level data (**Sections 5.2.1** and **5.3.2**). This assessment indicates that Kirkham weir, Buttercrambe weir, Stamford Bridge weir and Elvington sluice all have a considerable impounding effect on upstream water levels, and therefore the SSSI would benefit from their removal. In addition, the impounding effect of Howsham weir is likely to increase if other structures were to be removed. Conditions in the SSSI are therefore likely to improve if this structure was also removed.

An engineering assessment and an assessment of the risk associated with removing Kirkham, Howsham, Buttercrambe and Stamford Bridge weirs were undertaken in order to inform the development and selection of potential options to address the issues caused by each structure. The results of these assessments are presented in **Appendix D** and **Appendix E**, respectively. Elvington sluice and Barmby Barrage were not assessed further at this stage due to their key strategic function in maintaining water levels for public drinking water abstraction.

Recommended options for addressing the issues created by each structure are summarised in **Table 7.4**. In order to deliver the maximum benefit for the SSSI, the removal of Kirkham weir, Howsham weir, and Stamford Bridge weir should be considered in more detail by undertaking dedicated feasibility studies.

Buttercrambe weir has a considerable impounding impact but is currently required to gauge flows in the river. A fish pass is currently being designed and will be installed as a short term measure. However, a feasibility study to develop options to replace the structure with an alternative which has a less significant impact upon the river (such as a hydro-acoustic flow gauge) should be undertaken over longer timescales. This is unlikely to be considered until the current structure is nearing the end of its operational life.

Elvington sluice and the Barmby Barrage both fulfil a key strategic water supply function, supplying public drinking water to the Yorkshire Grid. The structures are operated within tight parameters, but it may be possible to alter their operating protocols to reduce the impact they have upon the river and floodplain SSSIs (although the operation of the barrage has been recently updated). However, it may be beneficial to undertake more detailed feasibility studies to explore this option more thoroughly.

Measures to improve fish passage could also be considered to improve the existing fish pass at Elvington sluice and install a new fish pass at the Barmby Barrage (trials are currently being undertaken by the Environment Agency), although it is recognised that this option has limited benefits for the overall condition of the SSSI.

Table 7.4: Appraisal of options to address in-channel structures

Structure	Remove	Modify	Alter operation	Install fish pass	Do nothing	Recommended action
Kirkham weir	✓	✓	✓	✓(modify)	✗	Investigate feasibility of weir removal as the preferred option. Consider weir modification if removal is not possible. Also changing the operation of the sluice and modifying the fish pass.
Howsham weir	✓	✓	n/a	✗	✗	Investigate feasibility of weir removal as the preferred option. Consider weir modification if removal is not possible.
Buttercrambe weir	✓	✗	n/a	✓	✗	Install fish pass as a short term measure, and investigate feasibility of weir removal in the long term.
Stamford Bridge weir	✓	✓	✓	✓(modify)	✗	Investigate feasibility of weir removal as the preferred option. Consider weir modification if removal is not possible. Also consider alteration of sluice operation and modification of the fish pass.
Elvington sluice	✗	✗	✓	✓	✗	Investigate feasibility of changing operation, and investigate options to improve the existing fish pass.
Barmby Barrage	✗	✗	✓	✓	✗	Investigate measures to improve fish passage (trials currently underway), and investigate potential to alter structure operation.

7.6.3 Potential constraints

In order to improve fish and lamprey passage and improve flow conditions to reduce sedimentation, removal or modification of in-channel structures may be considered as an option. However, there are several constraints that influence the feasibility of modifying or changing the operation of in-channel structures, including their function of:

- Flood risk management.
- Water level control.
- Supporting existing habitats for key species.

Potential impacts on flood risk management
Although most of the land within the River Derwent catchment is agricultural, there are localised areas within the lower Derwent catchment where people and properties are at risk of flooding. These include Old Malton, Malton, Norton, Stamford Bridge, Kexby Bridge, Elvington, Thorganby, Bubwith, Menthorpe and Breighton.

Future management of flood risk within the River Derwent catchment over the next 50-100 years is being considered within the Catchment Flood Management Plan (CFMP). Management of the River Derwent SSSI should not increase flood risk to people and properties and will need to take account of the role of flood defence assets. Potential impacts of modification or changes in operation on flood risk management would therefore require careful consideration.

Potential impacts on flow gauging
Buttercrambe Weir is associated with the Environment Agency's main flow gauging station within the River Derwent, which has records since 1973. Data from this gauging station is important in managing the River Derwent SSSI and the catchment. This is a key constraint to be considered in relation to modification of the weir at Buttercrambe.

Potential impacts on existing habitats
The removal of existing weirs may have a negative impact on key habitats and interest features within the River Derwent SSSI/SAC. The weirs currently provide the only areas on the lower river with the hydraulic conditions required to provide clean, silt-free substrates. These areas are currently vital for lamprey spawning as well as providing areas where ***R. fluitans*** can take root.

Removal of the Stamford Bridge Weir, for example, could have the result of destroying the vital spawning area located just downstream of it, where the vast majority of lamprey breeding takes place. During the works that would be required to remove the weir, it may be expected that large amounts of sediments would be released from behind the weir posing an intense threat of sedimentation to the lamprey spawning area. In the longer term, the swift flows produced by the weir would be lost to a greater or lesser extent depending on the design of the replacement channel. In this case, there is the risk that the gravel substrate would not be scoured clean or maintained. This could reduce reproductive success unless it was first confirmed that lamprey could make full use of the improved access to spawn at alternative sites.

In addition, it is possible that suitable habitat for ***R. fluitans*** would be lost if the weirs were removed. The swifter flows and cleaner, larger substrate type associated with the weirs provides some of the few areas of suitable habitat for this species. However, several factors should be considered at this point. Firstly, it is not clear how widespread this species would be in the Lower River Derwent if it were in its natural channel state. It is possible that even without the modifications that have been made to the channel (e.g. deepening and straightening), the low gradient and prevalent soft, silty substrate would prevent this species from taking hold widely. Secondly, the species has historically been prevalent in Malton (Scott Wilson, 2002). There is no weir here, although the species is associated with Malton Road Bridge which is likely to artificially increase and focus flows. The presence of the species upstream of the weirs and at the uppermost stretch of the Lower River Derwent (Malton) means that innocula is present to potentially reseed downstream sites. However, it may be that the upstream sections and the upper catchment are naturally more suited to the species, and its distribution would be limited in the lower river even under natural channel conditions.

The distribution and dynamics of bullhead in the River Derwent SSSI is not known in great detail, other than that it is present in low numbers at most of the eight regularly spaced sites surveyed throughout the lower river (Turnpenny, 2005). Five of the eight sites are in the vicinity of the weirs. Given that the ideal habitat requirements are swifter flows and a clean substrate, bullhead distribution may be related to the presence of the weirs and so their removal could reduce the suitability of habitat for bullhead in addition to lamprey and ***R. fluitans***. The lack of suitable habitat could account for the low numbers of bullhead found during general surveying, so removal of the weirs, leading to even less suitable habitat, is likely to be detrimental to the species.

Given the potential hazards of weir removal, the preferred options for improving access to upstream areas include improving the functioning of Stamford Bridge and Kirkham fish passes, and installing an appropriate fish pass at Buttercrambe weir.

Modification of Barmby Barrage

Removal of Barmby Barrage would be likely to have a major impact on the River Derwent (JBA Consulting, 2004). The tidal influence would be restored to the lower 25 km of the river, between Elvington and the Ouse confluence. During high tides, water from the Ouse would enter the lower Derwent, increasing water levels by 1 m at the tidal limit and 3 m at the river mouth (JBA Consulting, 2004). Conversely, the loss of the impounding influence of the barrage would decrease low flow water levels in the lower Derwent by up to 2 m.

Although water levels would be sufficiently high to allow abstraction at Loftsome Bridge the water quality requirements for abstraction at the Loftsome Bridge Water Treatment Works would not be met due to poorer quality water entering from the River Ouse.

The minimum water levels required for the public navigation would not be met under the majority of flow conditions if the Barmby Barrage was removed.

Removal of the barrage is also likely to have a considerable impact on the Derwent Ings SSSI, by increasing wetness during winter and spring high flows and decreasing water levels during summer low flows (JBA Consulting, 2004). If the embankments were also removed and floodplain drainage was improved, inundation frequency is likely to increase, but duration of inundation is likely to decrease. The Derwent Ings SSSI is part of the Lower Derwent Valley SPA and is currently predominantly in favourable condition. The change in inundation timings and water levels may have an adverse impact on the condition of the site, which is important for its lowland hay meadows as well as for its bird interest.

The restoration of the lower section of the River Derwent to tidal waters would impact heavily upon the macrophyte community currently present. Rapid and repeated fluctuations in water level would stress marginal aquatic species while increases in salinity would quickly wipe out the aquatic plant species that are not tolerant to saline conditions i.e. the majority of those present. No saline tolerant species are likely to be present upstream of the barrage as the habitat upstream is entirely freshwater. Therefore, there would be no opportunity for pioneer brackish species to colonise the newly brackish habitat from upstream innocula.

While the conversion to a purely freshwater habitat was characterised by colonisation and succession of a diversity of freshwater macrophyte, the reversal to tidal waters is more likely to be characterised by a rapid loss of species without replacement by new ones. It is likely that this process would eventually result in the dominance of only one species – reed sweet-grass (***Glyceria maxima***), which was the only species present along the margins of the tidal section before the installation of the barrage.

The change would therefore be back to a more estuarine environment in which other species would begin to flourish. Their establishment would however also be dependent upon the sediment regime which would need further assessment in terms of the extent to which the system would be ebb or flood dominated and how much sediment would be retained within the system. The extent to which the upstream shoal (450 m upstream) would be retained is likely to be dependent upon the new tidal exchange, which would be increased given the enlarged capacity of the Derwent upstream to Elvington.

In terms of impact on the use of the current system, removing the barrage would not impact upon the current water level required for abstraction (JBA Consulting 2004) but would impact on the depth of water at the shoal required to maintain navigation. Operational changes which reduce water levels and improve ecological value without impacting upon abstraction may therefore be possible, although boat traffic would be affected.

7.6.4 Contribution to climate change adaptation

Changes to in-channel structures in the River Derwent catchment could potentially contribute towards climate change adaptation (as predicted in the UKCP09 projections) in the following ways:

- Summer precipitation decrease by up to 40%: Decreased summer precipitation will reduce flows over in-channel structures, potentially making them more of a barrier to fish passage. The modification or removal of these structures will therefore help to ensure that they remain passable to fish populations during predicted lower flows.

7.6.5 Restoration actions

Feasibility studies will be required prior to implantation of weir removal and the timing of these has been identified in the restoration plan.

7.7 Preserve existing habitats

7.7.1 Issues tackled

Although key issues such as lack of appropriate in-channel and riparian shelter adversely affect the quality of habitats for various species (**Section 7.5**), the River Derwent SSSI does include valuable areas of habitat for key interest features. These habitats include floodplain wetlands and cut-off meanders for birds and mammals, coarse gravels for spawning fish, fine sediments in mill leats for lamprey and woody debris as in-channel shelter.

These high quality habitats are distributed throughout the SSSI, although their spatial extent can be limited. It is therefore important that they are preserved to avoid degradation to the status of the SSSI.

7.7.2 Potential solutions

The preservation of existing quality habitats within the SSSI does not require extensive direct action. Instead, it is necessary to consider the type and distribution of these habitats while undertaking works in or adjacent to the river, to ensure that they are not adversely affected. In particular, river maintenance activities (e.g. vegetation clearance and desiltation) should be undertaken in a sensitive manner to ensure that habitat degradation does not occur.

7.7.3 Contribution to climate change adaptation

These measures are unlikely to contribute directly towards climate change adaptation in the River Derwent. However, measures to preserve existing high quality habitats in the catchment should help to ensure that these are not lost as a result of changing temperatures and precipitation patterns.

7.8 Next steps

This section has demonstrated that there are a range of potential solutions which can be implemented to address the key issues which affect the condition of the River Derwent SSSI. These solutions are described in more detail in the accompanying Restoration Plan, which recommends specific solutions to improve the condition of the SSSI on a reach by reach basis.

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ROYAL HASKONING

APPENDIX A

FIELD SURVEY SHEET

ROYAL HASKONING

Part I: SURVEY CONDITIONS

See relevant 1:25000 mapping and watercourse summary sheet for watercourse name and Reach ID code				
Catchment	Watercourse	Reach ID	NGR Start / NGR End	Surveyor
Date	Time	Flow (tick): ☐ Low/base ☐ Above low ☐ High		
Conditions influencing survey quality:	LHB ☐ RHB ☐	Reason for upstream reach boundary:	Record photo NGR (GPS) and mark on map	No. of Photos

Part II: SEDIMENT SOURCES

Tally fine and coarse sediment sources, place totals in final box (e.g. F2, C4). * = Take GPS reading and mark on map
Diffuse sources: tally with F for fine and C for coarse under Micro, Meso or Macro and direct from slope or indirect e.g.through creep

Point Sources

	Fine	Coarse	Totals		Fine	Coarse	Totals
Tributaries*				Scour at structure			
Field drain/mill leat*				Tree fall			
Tipped Material*				Footpath			
Collapsed building/wall*				Burrowing			
Vehicle access				Poaching			
Outfalls				Fishing access			

Diffuse Sources (mark above tally with a * where process accelerated, take GPS and mark on map)

Fluvial erosion	Micro	Meso	Macro	***Geotechnical failure***	Micro	Meso	Macro
Toe scour				Toe undermining			
Eroding cliff				Translational			
				Rotational slip			
Hillslope supply	Micro	Meso	Macro	Complex failure			
direct				Channel weathering			
indirect							

Part III: SEDIMENT TRANSPORT

Tally each morphological form observed along the reach, most likely to be in sequences according to associated gradient (e.g. pool-riffle)

Morphological Forms

	Tally	Total		Tally	Total
Waterfall			Boil		
Chute			Glide		
Rapid			Pool		
Riffle			Ponded reach		
Run			Marginal deadwater		

Gradient (tick one) (use look back test)
☐ High
☐ Medium
☐ Low

Velocity (tick one)
☐ Uniform
☐ Varied
☐ Highly varied

Part IV: SEDIMENT SINKS

Tally fine and coarse sediment sources, place totals in final box (e.g. F2, C4)

Point Sinks

	Fine	Coarse	Totals		Fine	Coarse	Totals
Weirs*				Bridge			
Dams				Large woody debris			
Fords				Other…………………..			

Diffuse Sinks

	Permanent			Semi-permanent			Temporary		
	Micro	Meso	Macro	Micro	Meso	Macro	Micro	Meso	Macro
Floodplain deposits									
Splays									

Channel Deposits (mark with a * where process accelerated by human intervention)

Tally and total permanent, semi-permanent and temporary sediment deposits Micro = <10m^2 , Meso = 10-150m^2 , Macro = < 150m^2
Tick types of storage present, place an E on right of box if extensive (>33%) - do not tally isolated boulders

	Permanent			Semi-permanent			Temporary		
	Micro	Meso	Macro	Micro	Meso	Macro	Micro	Meso	Macro
Boulder/cobble									
Pebble/gravel									
Fine material									

Type of Storage

☐ Mid channel bar	☐ Berms	☐ Isolated boulders
☐ Side bars	☐ Mature Islands	☐ Trapping by marginal vegetation
☐ Point bars	☐ Toe accummulation	

Part V: VALLEY OVERVIEW

Landuse codes:Coniferous Woodland (CW), Broadleaf Woodland (BL), Scrub (SH), Wetland (WL), Moorland Heath (MH), Grazing (G), Tall Herb (TH), Tilled land (TL), Standing water (SW), Recreational (RE), Road/Track (RT), Suburban/urban (SU)

Valley Form (tick one)

☐	Shallow Vee
☐	Deep Vee
☐	Gorge
☐	Concave/Bowl
☐	Terraced valley floor
☐	Not visible

Landuse (dominant type)

	5m	50m
LH		
RH		

Floodplain (tick one) / Width (tick one)

		LH	RH	
☐	None	☐	☐	< 1 river width
☐	One bank	☐	☐	1-5 river widths
☐	Alternate	☐	☐	5-10 river widths
☐	Both banks	☐	☐	> 10 river widths

Riparian Buffer Strip (tick one)

LH	RH	
☐	☐	None
☐	☐	Discrete
☐	☐	Fragmentary
☐	☐	Continuous

Width of buffer strip (tick one)

LH	RH	
☐	☐	None
☐	☐	< 1 river width
☐	☐	1-5 river widths
☐	☐	> 5 river widths

Levees (tick if present)

LH	RH		Continuous	Fragmented
☐	☐	None		
☐	☐	Natural	☐	☐
☐	☐	Man Made	☐	☐

Part VI: CHANNEL GEOMETRY

Planform (tick one)

☐	Straight
☐	Sinuous
☐	Irregular meanders
☐	Regular meanders
☐	Braided

Cross-section (tick one)

☐	Rectangular/Trapezoidal
☐	U-shaped
☐	Two stage
☐	Multi-stage

Channel Dimensions

Width	Depth	Symmetry	(tick one)
☐	☐	☐	Uniform
☐	☐	☐	Variable with planform
☐	☐	☐	Variable without planform

			Estimate (m)
		Qbf Min	
		Qbf Max	
		Qbf Mean	

Channel/Flow Modification	Yes	No	Length
Impounded?	☐	☐	
Overwidened / overdeepened?	☐	☐	
Realigned?	☐	☐	
Culverted?	☐	☐	
Disconnected floodplain?	☐	☐	

Part VII: BOUNDARY CONDITIONS

Material
(tick all present, E if > 33%, ring dominant)

Bank LH	Bank RH		Bed
☐	☐	Obscured	☐
☐	☐	Clay	☐
☐	☐	Silt	☐
☐	☐	Sand	☐
☐	☐	Fine gravel	☐
☐	☐	Coarse gravel	☐
☐	☐	Cobble	☐
☐	☐	Boulder	☐
☐	☐	Bedrock	☐
☐	☐	Artificial hard	☐
☐	☐	Artificial soft	☐
Y/N	Y/N	Cohesive?	Y/N
Y/N	Y/N	Stable?	Y/N

Bank Profile (tick if present, E if > 33%)

LH	RH	
☐	☐	Cliff/Vertical
☐	☐	Stepped
☐	☐	Graded

Bank Protection
(tick if present, E if > 33%)

LH	RH	
☐	☐	None
☐	☐	Toe
☐	☐	Full
☐	☐	Discrete
		Length
☐	☐	Continuous
☐	☐	Fragmentary
☐	☐	Obsolete

Tree lining (tick one for each bank)

LH	RH	
☐	☐	None
☐	☐	Isolated/scattered
☐	☐	Reg. spaced/singular
☐	☐	Occasional clumps
☐	☐	Semi-continuous
☐	☐	Continuous
Y/N	Y/N	Recent tree planting

Bank face vegetation (tick one for each bank)

LH	RH	
☐	☐	None
☐	☐	Uniform
☐	☐	Simple
☐	☐	Complex

Part VIII: GEOMORPHOLOGICAL OVERVIEW

Channel Modification Summary:

Bed and Banks Modified through hard bank protection >33%	☐
Resectioned and/or realigned for >33%	☐
Banks Modified through hard bank protection >33% (bed unmodified)	☐
Discrete sections of bank engineering	☐
In-channel structures resulting in impoundment affecting >33%	☐
Environmental engineering of bed and banks (recent)	☐

Reach Actions

Management	☐
Restoration	☐
Enhancement	☐
Analogue	☐

Key notes

Geomorphological form

Geomorphological behaviour

Issues & constraints

Part IX: VEGETATION MANAGEMENT

Bank top vegetation (tick one)			**Invasive Species**			**Riparian management features**		
LH	RH		LH	RH		LH	RH	
☐	☐	Uniform	☐	☐	Giant Hogweed	☐	☐	Diseased alders
☐	☐	Simple	☐	☐	Japanese Knotweed	☐	☐	Overshading %
☐	☐	Complex	☐	☐	Himalayan Balsam	☐	☐	Lack of shelter
			☐	☐	Other	☐	☐	Exposed tree roots
						☐	☐	Grazing
						☐	☐	Other (specify in notes)

Channel vegetation:		Submerged in-channel vegetation		Filamentous algae
Record % cover		Surface floating vegetation		Moss/lichen/liverworts
		Emergent reeds/sedges/rushes		Overall

Part X: TARGET ECOLOGICAL HABITAT AND SPECIES

Floodplain habitats present (tick all that apply)		**Interest species**	Suitable Habitat	Un-suitable Habitat	Potential to improve habitat through restoration
Broadleaved mixed & yew woodland	☐	***Ranunculion fluitantis and Callitricho-Batrachion Vegetation***	☐	☐	☐
Neutral grassland - lowland	☐	***River Lamprey***	☐	☐	☐
Fen, marsh & swamp	☐	***Sea Lamprey***	☐	☐	☐
Standing water & canals	☐	***Bullhead***	☐	☐	☐
		Otter	☐	☐	☐

Part XI: PHYSICAL HABITAT FEATURES

Assess presence or absence of physical attributes for each interest feature. Record NV if Not Visible.

Interest Feature		Physical Habitat Attribute	Present	Absent	Potential to reintroduce through restoration
Ranunculion fluitantis and Callitricho-Batrachion Vegetation		A1) Swift to moderate, clear flows	☐	☐	☐
		A2) Channel dominated by clean, stable gravel	☐	☐	☐
		A3) Adequate in-channel light	☐	☐	☐
Relevant comments (sediment accumulation, water levels, turbidity)					
River & Sea Lamprey	Spawning:	See (A2)			
		B1) Appropriate shelter	☐	☐	☐
	Nursery:	B2) Stable silt or sand dominated substrate	☐	☐	☐
		B3)Areas of shallow, low velocity flow	☐	☐	☐
		B4) Organic detritus	☐	☐	☐
		B5) Tree roots/large woody debris	☐	☐	☐
Relevant comments:					
Bullhead		See (A1)			
		See (A2)			
		C1) Riffle habitat features	☐	☐	☐
		C2) Macrophyte cover <40%	☐	☐	☐
		C3) Shading	☐	☐	☐
		C4) Barriers > 18cm	☐	☐	☐
		C5) See B5	☐	☐	☐
Relevant comments:					
Otter		D1) Bankside shelter for day cover	☐	☐	☐
		D2) Undisturbed areas for holts	☐	☐	☐
		D3) Adjacent wetland floodplain habitats	☐	☐	☐
		D4) Suitable fish habitat for feeding purposes	☐	☐	☐
Relevant comments:					

Part XII: ECOLOGICAL OVERVIEW

Existing channel & floodplain ecology:	Sketch pad
Influence of functionality of channel and floodplain ecology:	
Significant opportunities / constraints:	

APPENDIX B

WATERCOURSE SUMMARY SHEETS

Summary Details	D01		
Upstream survey limit:	SE82369 75738 - Confluence with River Rye		
Downstream survey limit:	SE82847 74974 - Change in riparian characteristics		
Length of river surveyed:	3.97km	Survey reaches:	DER001 – DER003

Geomorphological Character:

Form

- Slightly sinuous course, but sub-reaches are relatively straight.
- The watercourse has a shallow gradient and a sandy/silty bed.
- Bank material is predominantly fine grained. Dominated by sandy clay with a large proportion of silt in places. Both banks of DER001 have a graded profile with no vegetation cover. DER002 has stable tree-lined cliff banks, and DER003 has both profiles depending on channel vegetation.
- Uniform laminar flow along all 3 reaches. Pools and marginal deadwaters present in all but DER001.

Processes

- The majority of channel-edge deposits formed by toe accumulation, interspersed between trapping by marginal vegetation. Overall, there are a large number of temporary fine channel deposits, but no coarse deposits.
- Extensive geotechnical bank failure (rotational, translational, toe undermining and weathering), and cattle trampling that has contributed to the failure, on both banks. Geotechnical failure is focussed in the upper reach (DER001) and trampling in the lower reaches.

Channel Modification

- There are no in-channel structures in the reach. The A64 road bridge crosses the river at the DS end of the reach.
- There is no bank protection but both banks appear to have been re-graded in reach DER001. There are embankments set back approximately 10-50m on the right hand bank along the entire reach.
- There has been no significant channel planform change since 1850, although palaeochannels are visible on the floodplain.
- Land use is predominantly grazing on the right-hand bank and tilled land (separated from the channel by a riparian corridor) on the left-hand bank.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**

- The channel is too deep, turbid and slow-flowing to support the interest macrophyte species.
- Narrow marginal habitat, so few aquatic macrophytes are present aside from patches of reeds, ***Potamogeton*** (broadleaved pondweed) or ***Myosotis*** (forget-me-not).

River and Sea Lamprey

- Unlikely there is breeding lamprey habitat due to the slow flowing, deep and turbid channel. They could pass through the reach to find more suitable habitat upstream.
- The upper, treeless part of the reach would not provide good shelter for lamprey, but there is plenty of shelter in the downstream part of the reach.

Bullhead

- The reach is unlikely to be particularly suitable for bullhead as riffle habitat with swifter flows and clean gravel is absent.

Otter

- In DER001 only isolated trees are present on the banks, thus the area is lacking in cover for otters. They may pass through the reach as there are fish present for feeding, but there is likely to be little opportunity for holts or breeding dens.
- From DER002 downstream, the reach has dense riparian vegetation and trees on both banks with occasional open areas. This provides good shelter for otters, and signs were recorded here including spraints and adult and juvenile footprints indicating breeding.
- The Derwent supports plenty of fish species for angling in this reach and hence is able to provide prey to sustain otters.

Key Issues:

Channel Planform Constraints – RHB Embankment

The channel meanders across the floor of a shallow v-shaped valley, constrained on its right-hand bank by the presence of flood embankments, which defines the maximum extent of the floodplain. Grazing is the predominant land use adjacent to the channel, although tilled land is set back along the left-hand side.

Bank Erosion and Geotechnical Failure

The reach has a high proportion of diffuse and point sources of fine sediment, from bank failure and trampling respectively. Geotechnical bank failure, probably as a result of undermining by large flows downstream of the Rye-Derwent confluence, provides the primary source of sediment in the upper part of the reach. Downstream, there is greater bank stability, partly due to the riparian tree-lining and partly due to the shallower bank edge gradient. This is interspersed with further geotechnical bank failure in the same form as upstream.

Trampling

Failure has been exacerbated by the presence of livestock trampling and the lack of riparian vegetation to stabilise the bank.

Limited Zones of Deposition

There are very few zones of channel-edge deposition along the entire reach. These are focussed exclusively around bank slumping that has led to berm establishment and a mix of terrestrial and marginal vegetation. These are easily and actively eroded.

Tributaries and Field Drains

The reach is supplied with fine sediment via field drain tributaries – particularly the beck at the upstream boundary between reaches DER002 and DER003.

Floodplain

Floodplain disconnection is apparent. The exception is DER001 where flood storage has been encouraged and the right-hand side embankment is set back at the inside of the meander. This is likely to counteract the flume created by the Rye-Derwent confluence, 200m upstream.

Reach Summary:

The main issues are the major geotechnical bank failure and a lack of riparian vegetation in the upper reaches.

Sympathetic management (e.g. bank stabilisation and prevention of trampling) is likely to help resolve these issues and improve the entire reach.

Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**

Measures to produce variability within the channel would be required to create the shallower areas and gravel substrate favoured by ***R. fluitantis.*** Re-profiling of the banks to reduce the gradient and produce shallow margins, coupled with fencing to protect from livestock trampling would encourage the spread of ***Callitriche*** spp and associated species by increasing the available area of suitable marginal habitat.

River and Sea Lamprey

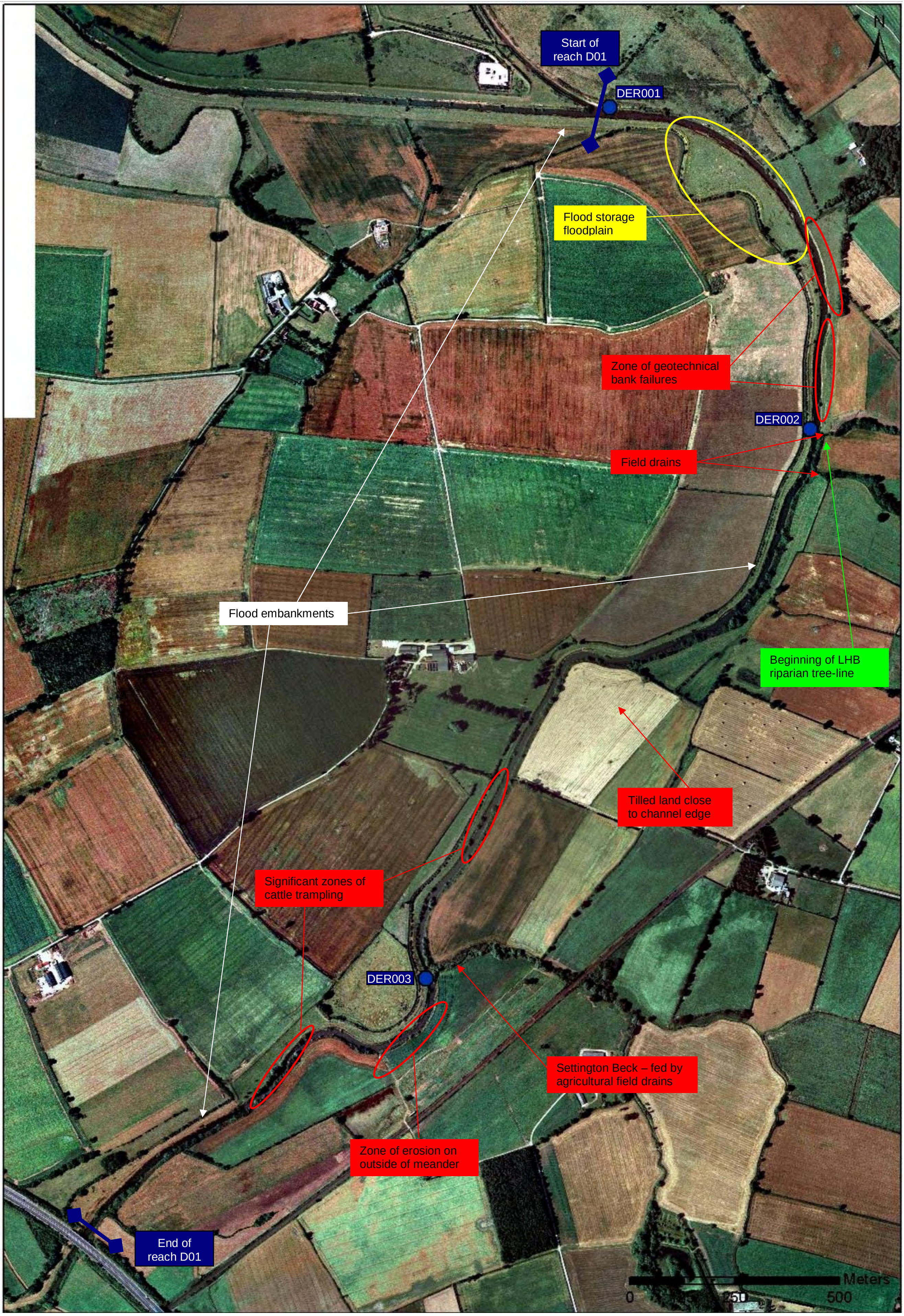
Measures to create shallower areas with gravel substrate would also benefit river and sea lamprey by producing habitat suitable for spawning. Greater variability of habitat within the channel would also promote shallow areas with stable silt or sand dominated substrate suitable for lamprey nursery habitat. Tree planting on the banks would provide shelter for migrating lamprey.

Bullhead

Bullhead favour habitat similar to ***R. fluitantis*** i.e. faster flows and clean gravel substrate hence would benefit from the same measures given for ***R. fluitantis*** above.

Otter

Food and some areas of shelter are already present for otter, but the population would benefit from an increase in wetland habitat on the floodplain. In addition, any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species.


Start of reach D01
DER001
Flood storage floodplain
Zone of geotechnical bank failures
DER002
Field drains
Flood embankments
Beginning of LHB riparian tree-line
Tilled land close to channel edge
Significant zones of cattle trampling
DER003
Settington Beck – fed by agricultural field drains
Zone of erosion on outside of meander
End of reach D01
N
Meters
0
250
500

Summary Details D02

Upstream survey limit: SE82847 74974 – Change in riparian characteristics
Downstream survey limit: SE79093 71483 – Start of urbanised/channelised reach
Length of river surveyed: 3.17km Survey reaches: D02 (DER003 – DER005)

Geomorphological Character:

Form

- Irregular meandering course. Channel width increases at meanders.
- The watercourse has a shallow gradient and a sandy/silty bed.
- Bank material is predominantly fine grained. Dominated by sandy clay, with a large proportion of silt in places. Both banks display lengths of stable tree-lined cliff banks. Character changes as reach progresses DS, the LHB is constricted by the railway and the RHB develops a steep terraced profile. In the final reach (DER005) the banks have been artificially re-graded; vegetation remains a stabiliser for the bank.
- Uniform laminar flow. Marginal deadwaters are present between exposed tree roots within DER003 and DER004.

Processes

- Wetland habitat created at inside of the meander in DER005. New embankments constructed at a former flood storage area. Likely to be a flood protection measure and mitigation measure for loss of flood storage land.
- Toe scour focussed along wetland habitat. Fine grained toe accumulation apparent between marginal vegetation.

Channel Modification

- No in-channel structures in the reach. Disused railway formerly crossed the river in DER005. Struts are set back from the bank edge. Fishing platforms are commonplace in the upper extent of the reach.
- There is no bank protection but embankments continue along the RHB until the village of Old Malton. In reach DER004, the proximity of the railway requires a flood wall that constricts the LHB of the channel.
- There has been no significant channel planform change along the entire reach since 1850.
- Land use is mixed. In the US of the reach it is predominantly agricultural (arable and pasture) which progresses into flood storage adjacent to urban areas further DS. At DS end, RHB is boggy marsh and drain.
- DS at railway wall, RHB floodplain is set back behind steep gradient terraced bank.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**

- Marginal habitat in this reach is constrained to a great extent by riparian vegetation and tree-lining that was continuous for long stretches.
- Marginal habitats are narrow, restricted in distribution and unsuitable for submerged or emergent macrophytes.
- The channel was turbid, deep and slow-flowing and hence was not suitable for ***R. fluitantis***.

River and Sea Lamprey

- Extensive tree-lining of the banks and the presence of in-channel debris provides abundant shelter for lamprey moving up-river to spawning areas.
- No habitat or flow suitable for spawning in this reach, or shallow areas to provide nursery habitat.
- The straightness and uniformity of the channel makes it unlikely there will be stable silts present.

Bullhead

- Reach is unlikely to be particularly suitable for bullhead as riffle habitat with swifter flow and clean gravel was absent.

Otter

- The reach is suitable for otters to feed and reproduce as there is plenty of bankside vegetation and trees for shelter.
- Spraints and otter prints were found in this reach, particularly in the upper section.
- The Derwent supports plenty of fish species for angling and hence is able to provide prey to sustain otters.
- “The Cut” was of low conservation value as it was very over-shaded, did not support aquatic vegetation or provide cover or feeding for the interest species.

Key Issues:

Channel Planform Constraints

The channel meanders irregularly across the floor of a shallow v-shaped valley, constrained on its right-hand bank by the presence of flood embankments that protect Old Malton. The embankment on the right hand bank limits the floodplain to the lower-lying tilled land on the left hand bank. . The right-hand bank is used recreationally, with the embankment acting as a walkway (encouraged via occasional benches).

Fishing Access

Numerous fishing platforms. Whilst reinforced with wooden piling, these platforms are exposed earth and a likely sediment contribution when flow overtops them.

Bank and Channel Profile

The increased width and depth of the channel decreases flow velocity and therefore may promote in-channel deposition. Zones of erosion and channel-edge deposition are focussed exclusively around deadwaters and pockets of toe scour created by exposed tree roots. Further downstream, the right-hand bank profile changes significantly as the set back embankments are no longer present. The inside of the meander, opposite to the left-hand bank railway flood wall, appears to be flood storage land, drained by ‘The Cut’ running parallel to the main river. The banks may have been re-graded to accommodate this and focus flow away from the railway wall; however historical bank failure has given the bank a terraced profile and the height of the bank implies disconnection.

New Wetland Habitat

Floodplain wetland habitat is newly created (not present on aerial photography – 2000), as are the left-hand bank embankments. Likely response to the housing development constructed on the north-east edge of Norton. The wetland is fed from the main river via a new tributary/lake feed. This is a likely sediment input. The banks have been artificially re-graded at this location as part of the wetland creation scheme and as such there is extensive toe scour erosion. The banks themselves are stable due to the presence of riparian vegetation. The loss of the left-hand bank as historical flood storage may have increased flood inundation onto the right-hand bank. Evidence of this includes the extreme boggy nature underfoot and damage to wooden viewing platforms during recent flood flows.

Reach Summary:

The channel is too wide and flow is too uniform, promoting in-channel deposition. Both banks are high and steep in gradient, and there is no natural erosion or deposition despite the fact that this is a meandering reach. The channel is highly constricted by embankments and infrastructure.

Creation of the wetland habitat and embankments as a result of the housing development, proximity of the railway flood wall and the height of the banks at flood storage points indicates that functional floodplain is limited, or at least disconnected.

Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**

Measures to create shallower areas and gravel substrate would be favoured by ***R. fluitantis.*** Re-profiling of the banks to reduce the gradient and produce shallow margins, coupled with fencing to protect from livestock trampling encourage the spread of ***Callitriche*** spp and associated species by increasing the available area of suitable marginal habitat.

River and Sea Lamprey

Measures to create shallower areas would also benefit river and sea lamprey by producing habitat suitable for spawning. Greater variability of habitat within the channel would promote shallow areas with stable silt or sand substrate suitable for lamprey nursery habitat.

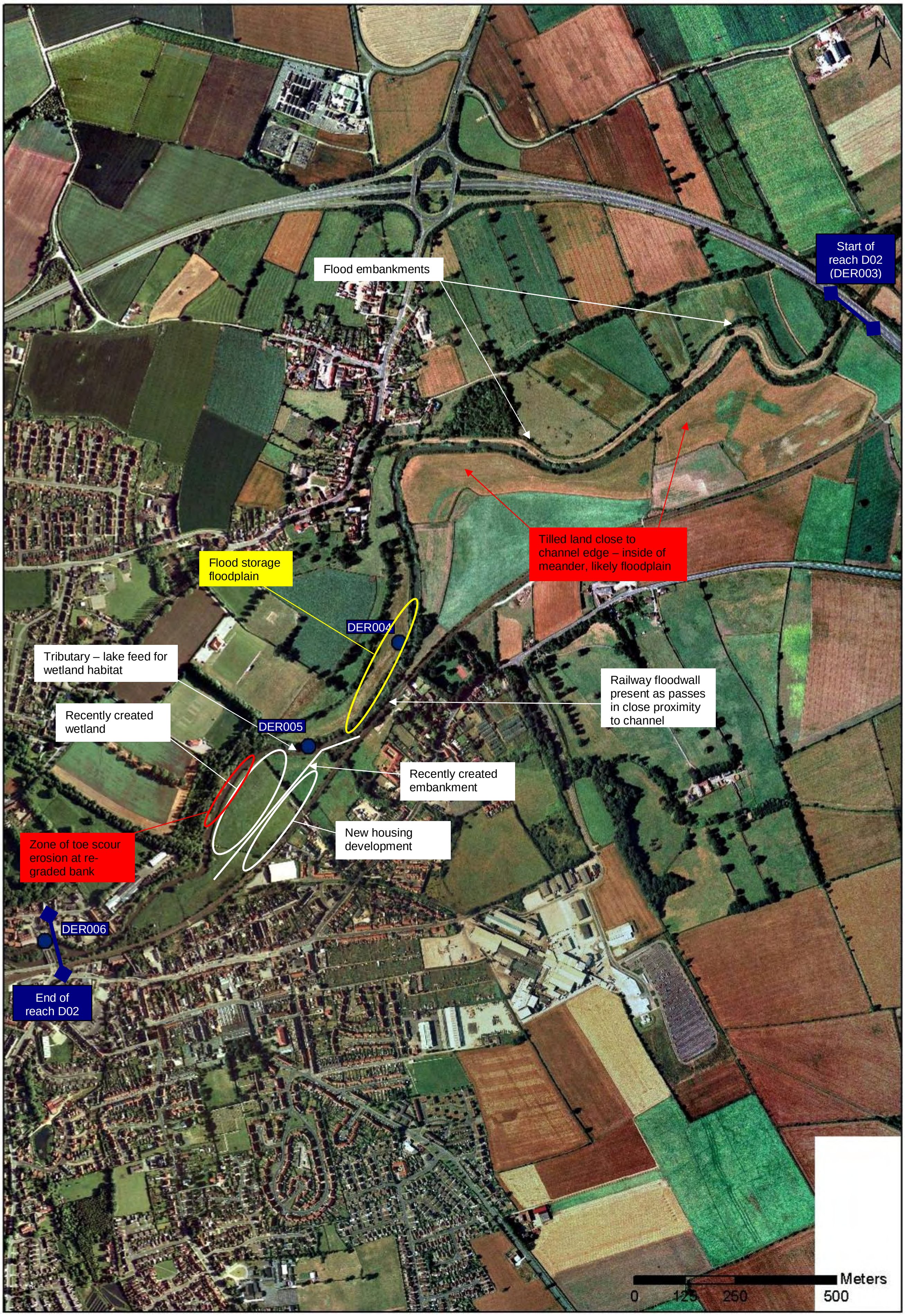
Bullhead

Bullhead favour habitat similar to ***R. fluitantis*** i.e. faster flows and clean gravel substrate hence would benefit from the same measures given for ***R. fluitantis*** above.

Otter

Food and shelter are already present for otter, but the population would benefit from an increase in wetland habitat on the floodplain. In addition, any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species.

ROYAL HASKONING



Summary Details D03

Upstream survey limit:	SE79103 71463 – Start of Malton		
Downstream survey limit:	SE78525 71457 – End of Malton		
Length of river surveyed:	0.62km	Survey reaches:	DER006

Geomorphological Character:

Form
- Straight course. Planform is constricted by urban development on both banks.
- Watercourse has shallow gradient and a sandy/silty bed. Due to the turbid nature of the flow, it is impossible to determine whether the bed is reinforced.
- Natural banks are fine grained (sandy clay) and graded at a steep angle to protect this urbanised stretch of the river. Bank profiles are either vertical or steep gradient stabilised by planted vegetation.
- Uniform laminar flow with no variation along the entire reach.

Processes
- In-channel deposits are focussed around the mature island at Malton Bridge. Some deposits of coarser material at this location. Number of temporary fine side-channel deposits at the base of engineered concrete walls.

Channel Modification
- The river has been channelised and engineered for bank protection through the reach. Stretches of the reach are vertical concrete walls that are approximately 10m in height. Where not concreted, the banks have been artificially graded to a similar height.
- Malton Bridge and the Malton Station Roadbridge both cross the river. Both have two in-channel supports.
- There has been no significant channel planform change along the entire reach since 1850.
- Land use is exclusively urban. Park land provides some soil cover but the majority of land is impermeable with drains for overland runoff. These feed directly into the channel.
- No discernible floodplain. Bank height and concrete walls separate the channel from the bank top.
- Reach is heavily modified. Bed may be engineered in some manner.

Ecological Character:

Vegetation Community
- Little or no in-channel vegetation evident. Bankside vegetation is managed for amenity purposes.
- Some channel-edge vegetation has established on the fine deposits at the base of the concrete walls.
- Both banks are heavily lined by trees so no suitable conditions to support emergent macrophytes as margins are severely light-limited. Where light does reach the channel (e.g. centre channel), the water is too deep to support macrophytes.
- High turbidity decreases light penetration. The entire reach is unsuitable for the interest macrophytes.

River and Sea Lamprey
- Tree-lined banks provide plenty of shelter for migrating lamprey.
- No shallow areas to act as nursery habitat.
- No swift flow or clean gravel to allow spawning to take place.

Bullhead
- The reach is deep, turbid and slow flowing and there is therefore no suitable habitat for bullhead.

Otter
- Heavy tree-lining means that the reach is suitable for otters to move through; feed and find shelter.
- Urban nature of the reach may mean that disturbance is great enough to discourage breeding.

Key Issues:

Urban Land Use
The channel character is altered by the FAS through the town of Malton. Both banks are constrained by the presence of concrete engineering. The intensive urban land use adjacent to the channel defines the character of the reach. Tarmac car parks drain overland runoff directly into the channel via piping.

Channelisation
The straight and concrete channelisation of the reach leads to a lack of zones of erosion or significant zones of deposition. There are toe deposits at the bank edge as sediment within the system has nowhere else to go. There is some fine and coarse deposition at Malton Bridge, and fine sediment gathers behind the in-channel debris caught amongst the struts of the downstream bridge (Malton Station Roadbridge) and behind the struts themselves. The mature island gathers fine sediment at its downstream end and coarser sediment is trapped within the bridge struts between the channel and the island.

Lack of Floodplain
The lack of channel floodplain throughout the reach, coupled with the straight engineered concrete walls mean the reach is acting as a flume, particularly during flood flows. The lack of flood storage means that any out-of-bank flow will encroach either into housing or commercial properties and is likely to focus flows around the bridge struts – a potential for damage.

Outfalls & Drains
The large numbers of surface drainage outfalls are likely to contribute additional sediment to the system, but a lack of deposition zones (related to the bank protection) will mean sediment remains in the system, certainly within reach D03.

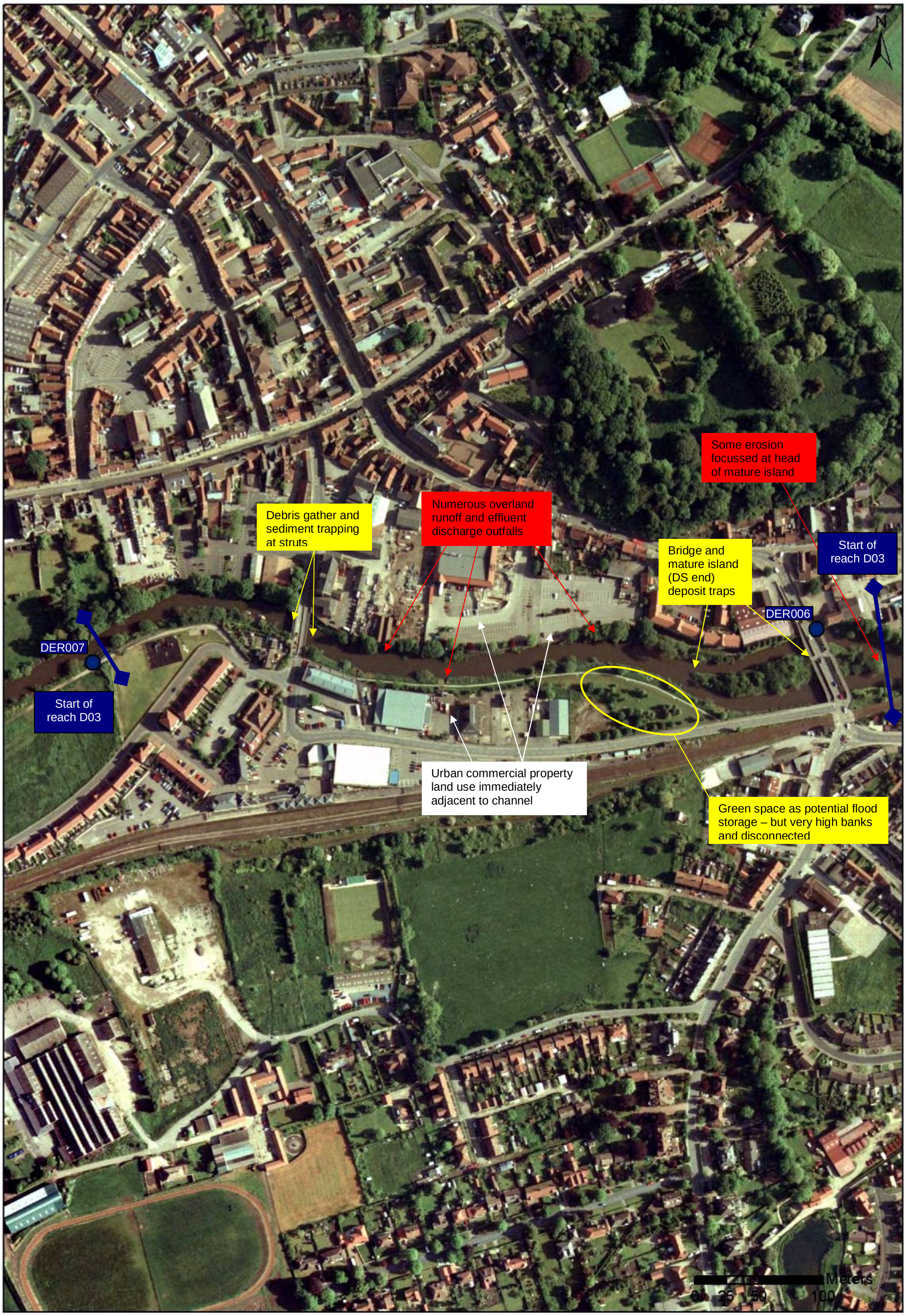
Invasive Species
Himalayan balsam and Japanese knotweed were present on the left bank of this reach.

Reach Summary:

This is a heavily urbanised and engineered reach. The concreted nature of the channel and surrounding land use means the river is severely constricted. There are very few opportunities for physical modification within this reach due to the heavy engineering and lack of available floodplain. In-channel structures and outfalls limit the benefits that any works could provide and any potential works would need to carefully monitor any impact on flood risk.

Reach Potential Based on Existing Ecology:

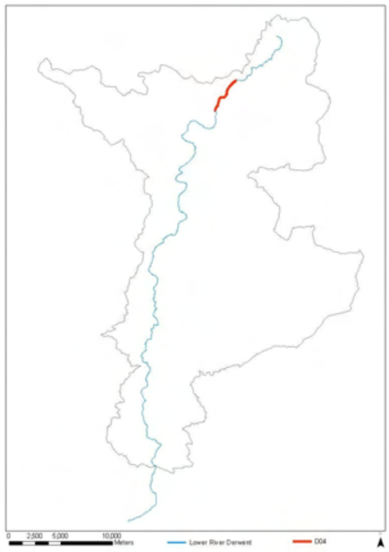
There is little potential to improve the reach for the macrophyte species, lamprey or bullhead as other issues such as amenity and flood prevention over-ride the benefit of improvements such as bed or bank re-grading.



Some erosion focussed at head of mature island
Numerous overland runoff and effluent discharge outfalls
Debris gather and sediment trapping at struts
Bridge and mature island (DS end) deposit traps
Start of reach D03
DER006
DER007
Start of reach D03
Urban commercial property land use immediately adjacent to channel
Green space as potential flood storage – but very high banks and disconnected
N
Meters
0 25 50 100

Summary Details D04

Upstream survey limit: SE78515 71478 – End of urbanised/channelised reach
Downstream survey limit: SE76486 68516 – Beginning of constricted valley
Length of river surveyed: 3.91km Survey reaches: DER007 – DER010



Geomorphological Character:

Form

- Straightened course with several low sinuosity meanders.
- The watercourse has a shallow gradient and a sandy/silty bed.
- Bank material is fine grained. Dominated by sandy clay, with a proportion of silt.
- Varied bank profiles fall into 3 categories: stable tree-lined cliffs, low height terracing with cliff edge (possible historical bank slump) and shallow graded – dependent on land use. At the industrial estate, a section of the RHB has been re-graded to increase overland flow conveyance back into the channel.
- Uniform flow type (glide) with across the entire reach. Some marginal deadwaters present in reach DER007.

Processes

- There is only minor channel-edge deposition in the form of toe accumulation, predominantly amongst exposed tree roots and marginal vegetation. There is no coarse deposition.
- Trampling is widespread at the very DS extent of the reach.
- The meander cut off is a major interest feature. Not specifically allocated SSSI, the meander still displays signs of flow and as such is a discrete functioning system. Its morphology is similar to that of the main river.

Channel Modification

- There are no in-channel or channel edge structures within the reach.
- There is no bank protection, but embankments set back on the LHB to protect the railway line extend from Malton DS to the southerly tip of the golf course (approx. 350m). Set back ranges from 10-150m.
- There has been no significant channel planform change along the reach since 1850. The meander was cut-off prior to this date.
- Land use is predominantly pastoral on both banks. At the very US extent the land use is unmanaged recreational land and there is some tilled land at the DS end of the reach.

Ecological Character:

Vegetation Community

- In the upper part of this reach, narrow leaved pondweed was observed growing along a 50m stretch of channel edge at the left bank. Water levels were too high and clarity too poor to determine what aspect of the river made it suitable to support in-channel vegetation at this point while it was not present anywhere else, but if there was suitable habitat for narrow-leaved pondweed, then it is also possible that ***R. fluitantis*** could exist here (although none was visible).
- For much of the reach, emergent vegetation was absent, but there were some stretches with emergent reeds, water dropwort and forget-me-not emerging from the water and growing well up the banks.
- A point in DER010, a field drain had accumulated sediments at its mouth that were stable enough to support water lilies and ***Potamogeton*** spp.

River and Sea Lamprey

- Continuous or sporadic lining of the banks by riparian trees, and the presence of in-channel debris provides abundant shelter for lamprey moving up-river to spawning areas.
- A short stretch towards the downstream end of the reach has no trees and is therefore lacking in shelter.
- There is no habitat or flow suitable for spawning in this reach, or shallow areas to provide nursery habitat.
- It was not possible to determine the nature and structure of the substrate as the water was so deep and turbid.

Bullhead

- It was not possible to determine the nature of the substrate due to the turbidity; the reach is unlikely to be suitable for bullhead as riffle habitat was absent.

Otter

- The presence of trees and fish prey means that the reach is suitable for otters to pass through, feed, live and reproduce undisturbed.
- At the downstream end of the reach, otter prints and spraints were observed on a sandy bank under a mature willow tree.

Key Issues:

Channel Planform Constraints

The straight channel crosses the floor of a shallow v-shaped valley, and has a historical cut off of the meander (possibly as part of the railway works). The channel is constrained on its left-hand bank by the railway and its embankment protection. The industrial estate midway through DER007 also constrains the planform. Grazing is dominant land use; presence of tilled land in the downstream end is a likely sediment contributor. In DER010 the channel is slightly more constrained as the valley closes in. Hillslope is set back approximately 20m at the very end of the reach. Straightness restricts traditional zones of erosion and deposition, which are focussed predominantly around tree roots and channel margin vegetation. Sediment is also input from the localised trampling in the downstream section of the reach.

Terraced Bank Profile

Upstream historical bank slumping has formed a stepped profile; as a likely response to the increased discharges funnelled through Malton during flood flows. Immediate end of channelisation would spill floodwaters up to the set back embankments (to protect railway and recent housing development). It is likely that these banks were also re-graded upon the creation of the embankments.

Industrial Estate Bank Re-grade

The short distance through the industrial estate has an exposed graded bank profile to convey surface runoff in the truck park into the river. This may contribute significant amounts of sediment into the system.

Floodplain

Floodplain connectivity is good. Despite the proximity of the railway embankment, the bank heights are not over-deep considering the width of the channel, and the opposite (RH) bank has storage capacity. The downstream end is more regular meandering and floodplain is present on both banks. Zones of erosion and deposition were observed here – marginal vegetation at the inside of meanders trapping sediment and toe scour erosion at the outside.

Reach Summary:

The reach is too straight. There is no geomorphological interaction between zones of erosion and deposition and the channel cannot adjust. There is a fair degree of channel constriction in the upper section of the reach due to the embankment and railway, and to some degree the industrial estate.

The cattle trampling in the lower downstream section of the reach is also an issue.

Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis & Callitricho-Batrachion* Vegetation**

Re-grading of the bed or deflectors to produce variability within flow would be required to create the shallower areas and gravel substrate favoured by ***R. fluitantis.*** Tree thinning to increase light penetration and re-profiling of the banks to reduce the gradient and produce shallow margins could encourage interest macrophyte species by increasing marginal habitat.

River and Sea Lamprey

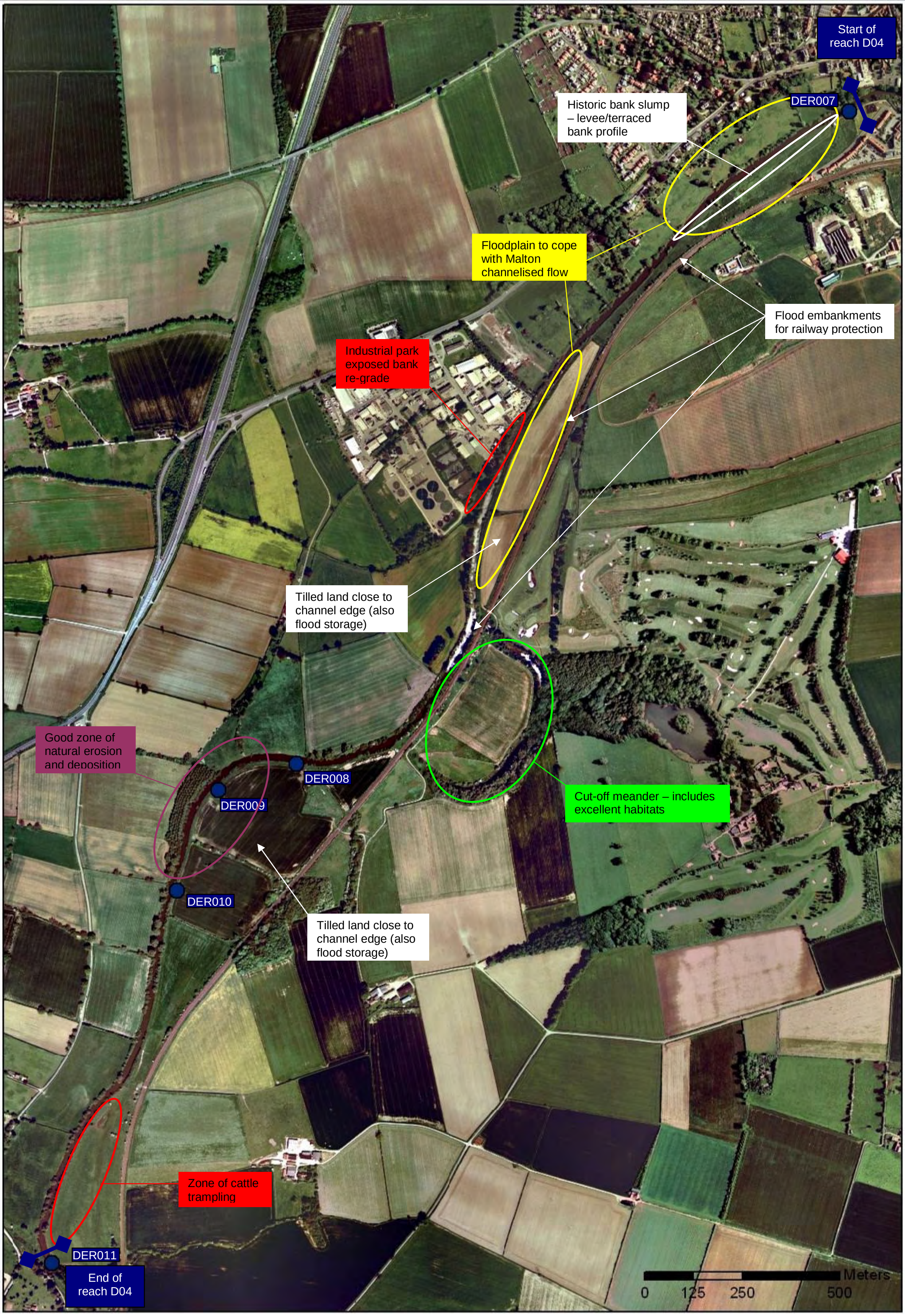
The above measures to create shallower areas would also benefit river and sea lamprey by producing habitat suitable for spawning. Greater variability of habitat within the channel would also promote shallow areas with stable silt or sand dominated substrate suitable for lamprey nursery habitat.

Bullhead

Bullhead favour habitat similar to ***R. fluitantis*** i.e. faster flows and clean gravel substrate hence would benefit from the same measures given for ***R. fluitantis*** above.

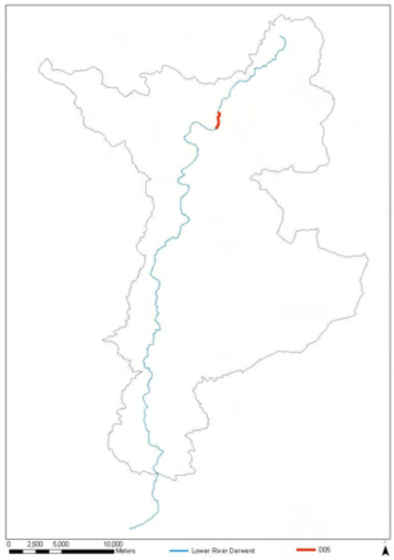
Otter

Food and shelter are already present for otter, but the population would benefit from an increase in wetland habitat on the floodplain. In addition, any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species.


Start of reach D04
DER007
Historic bank slump – levee/terraced bank profile
Floodplain to cope with Malton channelised flow
Flood embankments for railway protection
Industrial park exposed bank re-grade
Tilled land close to channel edge (also flood storage)
Good zone of natural erosion and deposition
DER008
DER009
Cut-off meander – includes excellent habitats
DER010
Tilled land close to channel edge (also flood storage)
Zone of cattle trampling
DER011
End of reach D04
Meters
0 125 250 500

Summary Details D05

Upstream survey limit:	SE76475 68527 – Beginning of constricted valley
Downstream survey limit:	SE76261 66886 – Beginning of LHB wetland
Length of river surveyed:	1.78km Survey reaches: DER011 – DER013



Geomorphological Character:

Form

- Straightened course.
- The watercourse has a shallow gradient and a sandy/silty bed.
- Bank material is predominantly fine grained. Dominated by sandy clay with a proportion of silt. The reach is predominantly characterised by stable tree-lined cliff banks. This is the case along the entire LHB until the very DS end of the reach. The RHB is a stabilised cliff that alters to an exposed stepped/graded profile.
- Uniform laminar flow with little or no variation across the entire reach.

Processes

- In-channel deposition is focussed at the braided island system at the US end and the railway bridge in the middle of the reach. Tail-end deposition occurs at both, and there is a small degree of sediment trapping amongst the debris at the bridge. The RHB displays significant toe accumulation DS of the railway bridge, along the exposed section of bank.
- Trampling and rotational bank failure is extensive along the RHB for the entirety of the reach, excluding the area immediately alongside the bridge.
- Menethorpe Beck is fed by upland hillslope drains.

Channel Modification

- There are two bridges that cross the river along reach D05; a footbridge with no supports and the railway bridge at Low Hutton that has two main supports with 10 struts per support.
- There is no bank protection, even at the bridge, but the railway embankments are continued along the LHB and then the RHB as per the previous reach (D06), set back between 10m and 70m.
- There has been no significant channel planform change along the entire reach since 1850.
- Land use is pastoral on the RHB and US on the LHB, with woodland for the remainder of the reach.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**

- The channel is very deep and turbid and therefore unsuitable for in-channel vegetation.
- There are a few open stretches of bank with emergent macrophytes such as reeds and water forget-me-not.
- Much of the banks are over-shaded by thick vegetation and trees and therefore unavailable to marginal macrophytes.

River and Sea Lamprey

- Extensive lining of the banks by riparian trees, and the presence of in-channel debris provides abundant shelter for lamprey moving up-river to spawning areas.
- There is no habitat or flow suitable for spawning in this reach, or shallow areas to provide nursery habitat.

Bullhead

- The reach lacks faster flow and is unlikely to have clean stable gravel on its substrate.
- The presence of cover and shading is suitable for bullhead, and the absence of barriers over 18cm in height means that they could potentially move around freely.

Otter

- The reach is suitable for otter to feed, live and breed as there is plenty of bankside vegetation and trees to provide cover, as well as fish prey species available.
- Wetland habitat is present in the floodplain at the upstream and downstream sections of the reach.
- Otter footprints were observed on a sediment bank on the inside of a meander in the upper part of the reach.

Key Issues:

Channel Planform Constraints – Valley & Railway

The channel traverses the floor of a deep v-shaped valley in a very straight course, constrained by the valley topography and by the railway line and its associated embankment flood protection, as per the previous reach (D04). Grazing and woodland dominate the land uses.

Cattle Trampling, Toe Scour & Geo-technical Bank Failure

The grazing land downstream of the railway bridge is likely to be a contributor of sediment as bank failure and trampling combine to create the stepped bank profile. This is a likely response to the constrained funnelling of the flow underneath the railway bridge. The LHB embankment is almost at the channel edge and the RHB hillslope is similar, providing almost no floodplain for out-of-bank flow. Flow at the bridge is likely to have a high velocity. Toe scour is significant at this location as well as immediately upstream and downstream of it, reflected in the widening of the channel at the bridge. The banks downstream of the bridge have been eroded and subsequently collapsed due to exposure to livestock drinking, where bank stability appears to be an issue.

Hillslope Sediment Supply

The accentuated hillslope is a secondary contributor, bringing surface runoff into the channel in a far more direct manner than upstream; as well as contributing additional sediment through the main drain of Menethorpe Beck.

Island System

The channel widens significant at the upstream end of the reach and point bar deposition can be observed at the inside of the meander leading into the island system. Deposition is also common behind each island (eroding cliffs are to be found at the outer extremes banks of the system) and ends abruptly as it began. There are some small buildings on some of the islands as the location appears a good fishing platform.

Floodplain

Floodplain connectivity is good. Both banks are low in height and although the floodplain is constrained by the railway embankment on the left-hand bank, the right-hand bank floodplain is extensive, despite the embankment continuing along the right-hand bank after the railway crossing. The embankments are set back approx. 50-70m.

Reach Summary:

The reach is straight and constrained. The constrained nature of the valley, the railway embankments and the urban residential area of Low Hutton means the channel is increasing velocities impacting on the right-hand bank.

The cattle trampling along almost the entirety of the right-hand bank is also an issue. As is the spread of Himalayan Balsam on the left-hand bank adjacent to the island system.

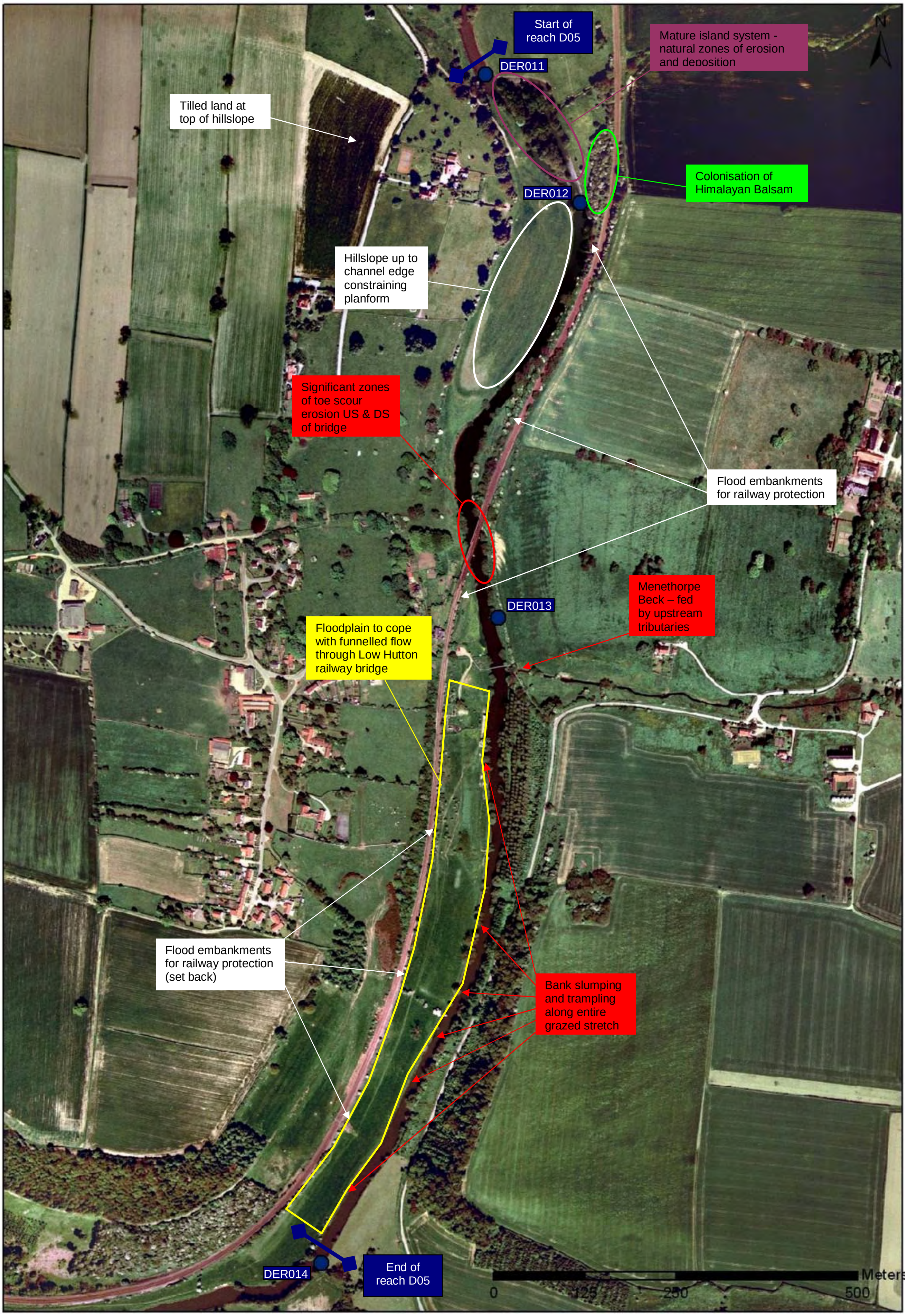
Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis* & *Callitricho-Batrachion*, Macrophytes, Bullhead & River and Sea Lamprey**

Measures to produce variability within the channel would be required to create the shallower areas and gravel substrate favoured by ***R. fluitantis.*** Tree thinning to increase light penetration and re-profiling of the banks to reduce the gradient and produce shallow margins, would also encourage the interest macrophyte species by increasing marginal habitat. Greater variability of habitat within the channel would also promote shallow areas with stable silt or sand dominated substrate suitable for lamprey nursery habitat.

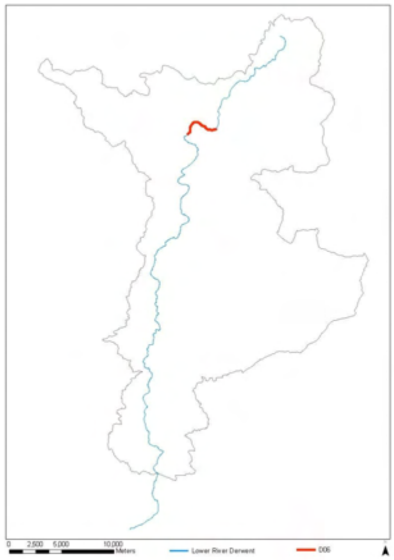
Otter

Shelter and wetland are already present for otter, but any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species. An improvement in prey availability and habitat quality would enable larger populations to be supported.


Start of
reach D05
DER011
Mature island system -
natural zones of erosion
and deposition
Tilled land at
top of hillslope
Colonisation of
Himalayan Balsam
DER012
Hillslope up to
channel edge
constraining
planform
Significant zones
of toe scour
erosion US & DS
of bridge
Flood embankments
for railway protection
Menethorpe
Beck – fed
by upstream
tributaries
DER013
Floodplain to cope
with funnelled flow
through Low Hutton
railway bridge
Flood embankments
for railway protection
(set back)
Bank slumping
and trampling
along entire
grazed stretch
DER014
End of
reach D05
Meters
0
125
250
500

Summary Details D06

Upstream survey limit:	SE76255 66880 – Beginning of LHB wetland
Downstream survey limit:	SE73487 66302 – End of LHB wetland
Length of river surveyed:	3.89km Survey reaches: DER014 – DER017



Geomorphological Character:

Form
- A sinuous course, with a constrained valley and a large meander at the DS end.
- The watercourse has a shallow gradient and a sandy/silty bed.
- Bank material is predominantly fine grained. Dominated by sandy clay with large proportion of silt in places. The LHB profile is stepped / graded, with a stable cliff at tree-lined sections. The RHB continues the same profile as the previous reach (D05) until the railway becomes closer, at which point the profile follows the same pattern as the LHB.
- Uniform laminar flow. Marginal deadwaters present in reach DER017.
- Howl Beck and Mill Beck are fed by upland hillslope drains.

Processes
- RHB (DER014 & DER015) experiences toe accumulation interspersed with trapping by marginal vegetation along the exposed grazed stretch. LHB of DER016 contains stretches of marginal vegetation trapping sediment.
- Extensive rotational geotechnical failure and trampling through the grazed pasture section along RHB.
- Wetted woodland (LHB & RHB) has numerous drains containing large quantities of sediment at the time of survey.

Channel Modification
- Land use is agricultural grazing on the RHB and also on the LHB at the US end. The LHB then alternates between wetted woodland and wetted scrubland/marshland. The RHB alters to wetted woodland at the point where the railway embankment runs directly adjacent to the channel, at the end of pasture land.
- There are no in-channel structures in the reach.
- There is no bank protection but the RHB railway embankment is in close proximity to the channel, set back as close as 10m. The deep v-shaped valley is also very constricting, particularly through the woodland sections.
- There has been no significant channel planform change along the entire reach since 1850.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**
- The channel is deep and turbid in this reach and no in-channel vegetation was evident and so this reach is not very suitable for ***R. fluitantis***.
- Some good marginal habitat present as bankside trees were present and quite dense in some areas.
- Open areas (i.e. those not over-shaded by trees) support good margins of emergent reeds, but no ***Callitriche*** spp. was visible.

River and Sea Lamprey
- The channel is deep and turbid in this reach and no in-channel vegetation was evident and so this reach is not very suitable for ***R. fluitantis***.
- Extensive lining of the banks by riparian trees, and the presence of in-channel debris provides abundant shelter for lamprey moving up-river to spawning areas.
- There is no habitat or flow suitable for spawning in this reach, or shallow areas to provide nursery habitat.

Bullhead
- The reach lacks faster flow and is unlikely to have clean stable gravel on its substrate.
- The presence of cover and shading is suitable for bullhead, and the absence of barriers over 18cm in height means that they could potentially move around freely.

Otter
- Good shelter is available for otters as there are so many trees lining parts of the banks and the floodplain contains appreciable areas of wetland and wet woodland.
- This reach is very suitable for otters.

Key Issues:

Wetted Bankside Corridor
The channel winds sinuously across the floor of a deep v-shaped valley, constrained on its right-hand bank by the presence of railway embankments. The set back of the embankments defines the floodplain. Grazing and wetted marsh/scrub/woodland is the predominant land use adjacent to the channel, particularly along the left-hand side at the inside of the large meander. These wetted sections contain large quantities of sediment in marshy conditions that gather runoff from the tilled land located on the steep gradient valley sides. Whilst this tilled land is set back behind this fairly extensive wetted margin, creating a natural barrier to the conveyance of sediment directly into the river, the drains exiting these wetland patches are likely to supply fine sediment into the main channel system.

Tributaries
Howl Beck and Mill Beck are inputs of sediment, draining off the upland hillslopes.

Cattle Trampling & Geotechnical Bank Failure
The grazing along the RHB in the upper section of the reach is similar to that of the previous reach (D05) in that there is extensive rotational geotechnical bank failure coupled with significant cattle trampling. This RHB lacks any riparian vegetation and is exposed, in stark contrast to the left-hand bank which contains woodland and overgrown wetland vegetation and offers significant riparian cover.

Riparian Vegetation
The straightened nature of the channel has led to eddying scour around the tree roots of the left-hand bank and toe accumulation amongst the slumped bank and marginal/terrestrial vegetation along the right-hand bank. Occasional clumps of marginal vegetation create zones of deposition, but this is not a dominant geomorphological feature. As the character of the right-hand bank changes with the increased proximity of the railway embankment, the tree-lining encourages scour around the roots. The overhanging bows associated with the tree-line have created some marginal deadwaters in the very downstream of the reach, as well has fallen wooden debris gathering fine sediment. The channel widens at the end of the meander, at the end of the wetted margin section.

Floodplain
Floodplain connectivity is good. Both banks are low in height and although the floodplain is constrained by the railway and its embankment on the right-hand bank, the left-hand bank floodplain is not so constricted, as the wetted woodland provides significant opportunity for inundation.

Reach Summary:

The reach is too constrained, as a result of valley topography, railway embankments and the village of Crambeck.

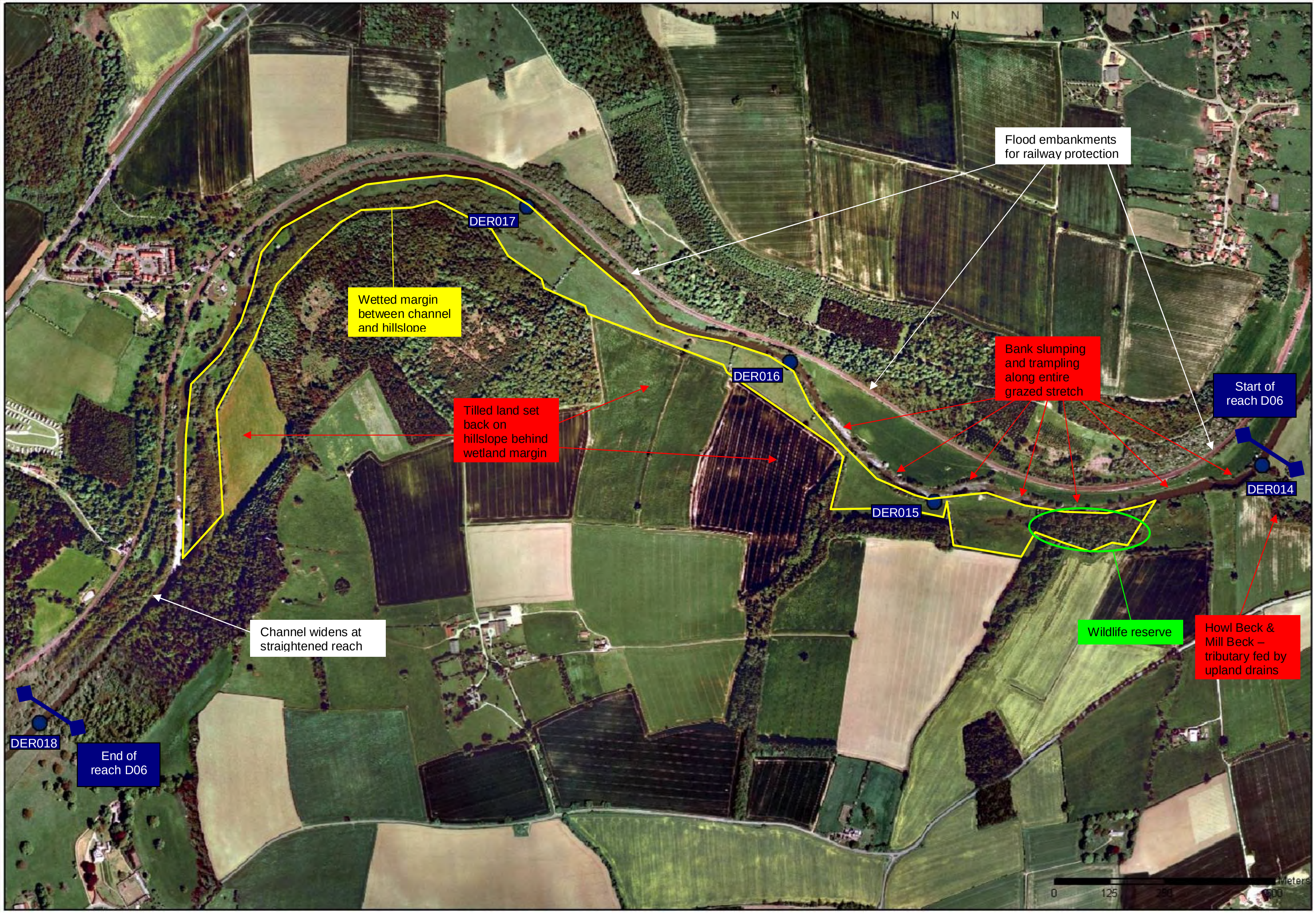
The cattle are trampling along a large section of the right-hand bank (as per the previous reach - D05) is also an issue.

Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation, River and Sea Lamprey & Bullhead**
Re-grading of the river bed or the use of deflectors to produce variability within the channel would be required to create the shallower areas and gravel substrate favoured by ***R. fluitantis.*** Tree thinning to increase light penetration and re-profiling of the banks to reduce the gradient and produce shallow margins, would also encourage the interest macrophyte species by increasing marginal habitat. Greater variability of habitat within the channel would also promote shallow areas with stable silt or sand dominated substrate suitable for lamprey nursery habitat.

Otter
Food, shelter and wetland are already present for otter, but any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species. An improvement in prey availability and habitat quality would enable larger, more resilient otter populations to be supported.

ROYAL HASKONING



Summary Details D07

Upstream survey limit: SE73497 66293 – End of LHB wetland
Downstream survey limit: SE73959 63637 – End of constricted valley
Length of river surveyed: 3.81km Survey reaches: DER018 – DER022

Geomorphological Character:

Form
- Channel follows a sinuous, irregularly meandering course. Planform is still constricted by deep valley.
- Watercourse has shallow gradient and sandy/silty bed. Bed is boulder reinforced DS of Kirkham Weir.
- Bank material is fine grained. Dominated by sandy clay with a proportion of silt.
- Bank profile is predominantly graded / stepped with a single length of stable tree-lined cliffs through Howsham Wood.
- Uniform laminar flow, aside from immediately downstream of Kirkham Weir, where drop in bed level results in increased velocities and turbulent flow. Marginal deadwaters are present between exposed tree roots within reaches DER018 and DER021.

Processes
- The channel widens significantly immediately downstream of Kirkham Bridge.
- LHB DS of weir suffers extensive geotechnical bank failure and erosion – bank slump aided by trampling.
- In-channel deposition is focussed around the 2 major structures. Deposition gathers DS of Kirkham Bridge supports and the mature island DS of Kirkham Weir. In-channel islands DS of the weir gather coarse deposits.

Channel Modification
- Agricultural land use varies between pasture and tilled land. Howsham Wood dominates LHB from DER021.
- The Kirkham Bridge has two in-channel support legs and Kirkham Weir is approximately 30-40m wide.
- RHB (outside of meander) at Kirkham Bridge has concrete toe protection for approximately 5m. At Kirkham Weir the LHB entering the lock channel is lined by sheet piling, and RHB of weir is concrete wall. Central island not protected.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**
- Area US of weir, and around 50-100m DS of weir is suitable for ***R. fluitantis*** as the water depth is shallower, with swifter flow and some clean rocky substrate visible.
- Some in-channel vegetation was visible above the weir that appeared to be ***R. fluitantis*** (identification was hindered by turbidity and distance from the bank).
- Around the weir, marginal habitat is limited by over-shading; other sections contain excellent margins, particularly the upper part, above Kirkham Bridge.
- At Kirkham Bridge the left bank is low and gently sloping, creating wide and well vegetated margins, however, no ***Callitriche*** spp. was observed in this reach.
- No vegetation was visible behind Kirkham Bridge.

River and Sea Lamprey
- Plenty of bankside trees and debris provide cover for lamprey.
- Habitat suitable for lamprey spawning is present downstream of weir, where swifter flows gives rise to cleaner substrate as well as greater flow variability.
- Shallow areas with slower flow were also present, suitable for nursery habitat.

Bullhead
- The weir provides habitat that appears more suitable for bullhead i.e. swifter flows, shallower depth and potentially clearer substrate.
- The weir itself provides a barrier impassable to bullhead. The fish pass along the right bank was flowing at a rate that may be too powerful for bullhead.

Otter
- The reach is suitable for otter to feed, live and even breed as there is plenty of bankside vegetation and trees to provide cover, as well as fish prey species available.

Key Issues:

Channel Planform Constraints
The channel winds sinuously across the floor of a deep v-shaped valley, constrained by the contours of the valley, the in-channel structures and initially the proximity of the railway and its associated embankments.

Land Use Runoff
Agricultural practices dominate the reach, with grazing pasture along the left-hand and right-hand banks until Kirkham Weir and Howsham Wood respectively, and tilled land along the left-hand bank downstream of the weir. This comes into close proximity of the channel, despite being located on the hillslope, and is only separated from the channel by a thick riparian corridor. Nevertheless, sediment runoff is likely to be a major contributor into the system at this reach.

River Channel Management
At the very upstream end of the reach the land appear to be managed. The outside of the meander is subject to toe scour amongst tree roots and the inside of the meander gathers deposition around marginal vegetation. Despite the presence of cattle on the floodplain, and trampling point sources, the margin is relatively healthy and reach DER018 displays good geomorphological functionality. Overhanging boughs create marginal deadwaters. This floodplain appears to be flood storage to minimise flows passing through Kirkham Bridge during flood conditions.

In-Channel Structures – Kirkham Weir & Bridge
Immediately downstream of Kirkham Bridge the channel widens significantly. This is likely to be a result of historic erosion as the bridge funnels flood water through a constrained channel. Bridge appears to have been repaired / replaced recently and flood flow through the upper section of the reach is extreme, despite the presence of the large floodplain at the inside of the upstream meander. Flow velocity is increased immediately downstream of Kirkham Weir and bank erosion is concentrated on the right-hand bank. Toe accumulation occurs along the left-hand bank at the weir island as flow is directed away by the weir and at the downstream end of the island. At the exit if the island, and the rejoining of the lock and main channel, the left-hand bank is heavily eroded and geotechnical bank failure is extensive. Flood flow passing through the weir system is funnelled. Tree destruction along the left-hand bank shows flood damage to be at a height far greater than the bank.

Howsham Wood and Riparian Vegetation
Downstream of the weir system the river reverts to form seen previously in upstream reaches. Eddying scour is present at the base of tree roots and in-between clumps of tree-lining toe accumulation appears to dominate the left-hand bank. Howsham Wood is contributing woody debris into the channel and fine sediment is depositing amongst it. Right-hand bank is lined with riparian vegetation and vegetated berms, historically developed due to the steep gradient of the bank, influenced by the hillslope. Sediment accumulation is the dominant feature, influenced heavily by the adjacent tilled land. No active zones of erosion.

Reach Summary:

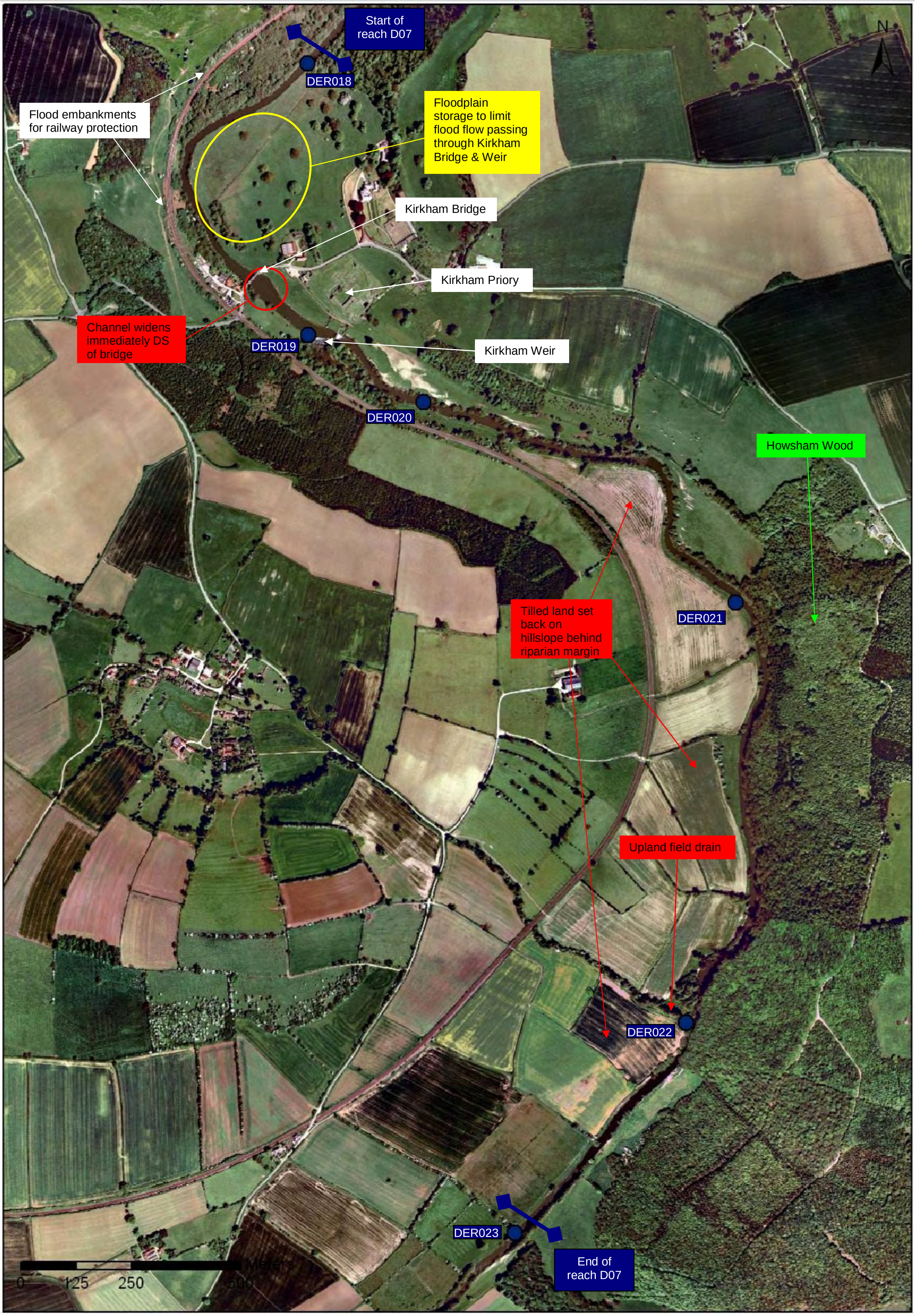
The constrained nature of the valley, the upstream railway embankments, the settlement and priory at Kirkham and the Kirkham Bridge and Weir means the channel has very little opportunity to alter its planform. Flow is forced through two main structures and eroding the banks.
The cattle trampling along a large section of the left-hand bank (as per the previous reaches - D05 & D06) and the proximity of tilled land on the left-hand bank without a decent margin are also issues.

Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation, River and Sea Lamprey & Bullhead:**
The area downstream of the weir is suitable for the macrophyte species, bullhead and lamprey spawning, with the influence of the weir (flow turbulence) extending up to 100 m downstream. In-channel works in the lower parts of the reach could potentially capitalise on the presence of some good quality habitat below the weir by extending it downstream. Improved conditions for marginal vegetation in the downstream section would benefit from bank re-profiling and thinning of bankside vegetation to enhance light penetration.

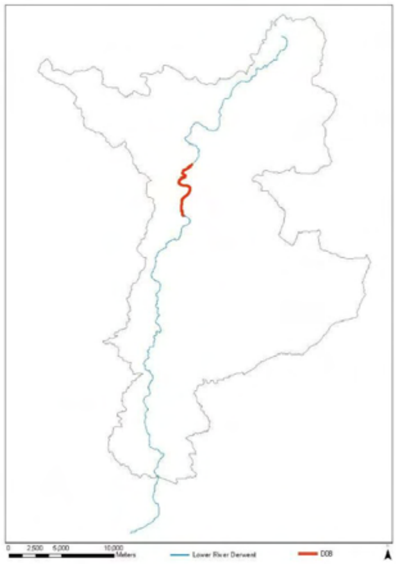
Otter
The potential of the reach to support otter is high, but any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species. An improvement in prey availability and habitat quality would enable larger, more resilient otter populations to be supported.

ROYAL HASKONING



Summary Details D08

Upstream survey limit:	SE73959 63637 – End of constricted valley
Downstream survey limit:	SE73126 58688 – Buttercrambe Weir
Length of river surveyed:	7.02km Survey reaches: DER023 – DER035



Geomorphological Character:

Form
- Irregularly meandering course with individually straight reaches.
- The watercourse has a shallow gradient and a predominantly sandy/silty bed, aside from at Howsham Weir where the bed is engineered with boulder reinforcement immediately DS.
- Bank material is fine grained. Dominated by sandy clay with a proportion of silt. Bank profile is graded / stepped with occasional lengths of stable tree-lined cliffs through wooded reaches.
- Uniform laminar flow aside from immediately downstream of Howsham Weir, where drop in bed level results in increased velocities and turbulent flow. Marginal deadwaters are present between exposed tree roots within reaches DER025, DER032, DER033 and DER035.

Processes
- Deposition occurs at DS end of the mature island DS of Howsham Weir and at Howsham Bridge supports. There are in-channel islands immediately DS of the weir and US of the bridge (artificial) that accumulate coarser deposits.
- LHB has been re-profiled in upstream section to protect new building development from flooding.
- Channel widens immediately DS of Howsham Weir and Howsham Bridge.
- Adjacent grazing land leading to trampling of bank accompanying historical bank slump and erosion.

Channel Modification
- Agricultural land use varies between pasture and tilled land. Small stretches of woodland.
- Howsham Weir and Howsham Bridge are two significant in-channel structures. The bridge has two support legs that are in-channel and the weir is approximately 40-50m wide.
- Howsham Weir has sheet piling lining the LHB entering the lock channel; RHB at weir is concrete wall. Central island LHB is concrete reinforced for ~20m. Both banks at Howsham Bridge have full concrete bank protection for ~15m.
- There has been no significant channel planform change along the entire reach since 1850.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**
- Habitat US of Howsham Weir and the stretch below are suitable for interest macrophyte species due to swift flow, shallower water and cleaner substrate.
- Below the weir, many clumps of submerged vegetation were observed in areas sheltered from the full force of the flow. These resembled ***R. fluitantis*** in their form,
- The influence of the weir continues downstream beyond Howsham Bridge (> 200 m), and further clumps of ***R. fluitantis*** were observed.
- No ***Callitriche*** spp. macrophytes were observed in this reach, and very little in-channel vegetation was seen anywhere else within the reach.

River and Sea Lamprey
- The entire reach was suitable for lamprey to pass through as there was plenty of bankside vegetation and trees that could provide shelter.
- Suitable spawning and nursery habitat was limited to 200m DS of Howsham weir. Swift flow and variable depth means cleaner substrate and in-channel variation.

Bullhead
- Downstream of the weir – riffle habitat, cleaner substrate and swifter flows were all present here.
- The weir would not be passable to bullhead as there is no fish pass, and it is around 1.8 m high.
- The remainder of the reach was unsuitable for bullhead as the channel was too turbid and slow.

Otter
- Reach is suitable for otter as there is plenty of riparian vegetation present.
- Bankside vegetation is variable in nature as the tree lining is continuous in places and broken in other areas, with variable levels of rank vegetation.
- Otter prints and spraints were observed in this reach, confirming their presence in the area

Key Issues:

Channel Planform Constraints
The channel winds across the floor of a v-shaped valley that alternates between a shallow and a steeper gradient. The reach is not as constrained as previous reaches, but is limited in its planform movement by the structures of Howsham Weir and Howsham Bridge, and the occasional steeper gradient along the left-hand bank.

Intensive Agricultural Land Use
Agricultural land uses border the channel, interspersed with tree-lined or woodland sections (resulting in a stable cliff bank profile. Pasture is only found at the inside of meanders, reducing sediment supply from surface runoff under flood conditions. Tilled land is located at the outside of meanders, set back behind a tree-line. Deposition is focussed predominantly around marginal vegetation and toe accumulation alongside sections of bank slump or trampling. Bank profile is stepped / graded along these sections. Tilled land comes within close proximity of the channel and at times is set back on the hillslope and is a likely contributor of sediment to the channel.

Tributaries
The reach is fed by three relatively major watercourses – Whitecarr Beck, Leppington Beck and Swallowpits Beck. All are fed by upland agricultural land, and carry significant quantities of sediment that is transferred into the main channel.

Re-graded Bank
At the very upstream end (DER024) the channel has been modified to offer flood protection to a new development (a building extension) at the bank edge along the left-hand bank. The bank has been re-graded at a uniform gradient and an increased height to focus flood flow onto the opposite pasture land. The bank has been stabilised with newly planted trees. Stability is unlikely to last, considering the gradient of the re-grade and it is likely the bank will become heavily eroded at the next flood event.

In-Channel Structures – Howsham Weir & Bridge
Howsham Weir and Howsham Bridge are discreet sections of geomorphological activity. Flow is focussed toward the right-hand bank and the channel widens significantly but the bank is not reinforced. The left-hand bank is concrete reinforced but this is not in response to erosional processes, as deposition is the dominant process along the left-hand bank, but rather to channel flow through the Howsham turbine. Downstream of the weir system the banks are stable, indicating flood flow over the weir is not extreme as at Kirkham Weir. Howsham Bridge is concrete reinforced along both banks allowing flow to pass through the struts efficiently and creating a significant widening of the channel immediately downstream. Downstream of this the inside of the meander has been eroded, suffered historical bank slumping and is trampled.

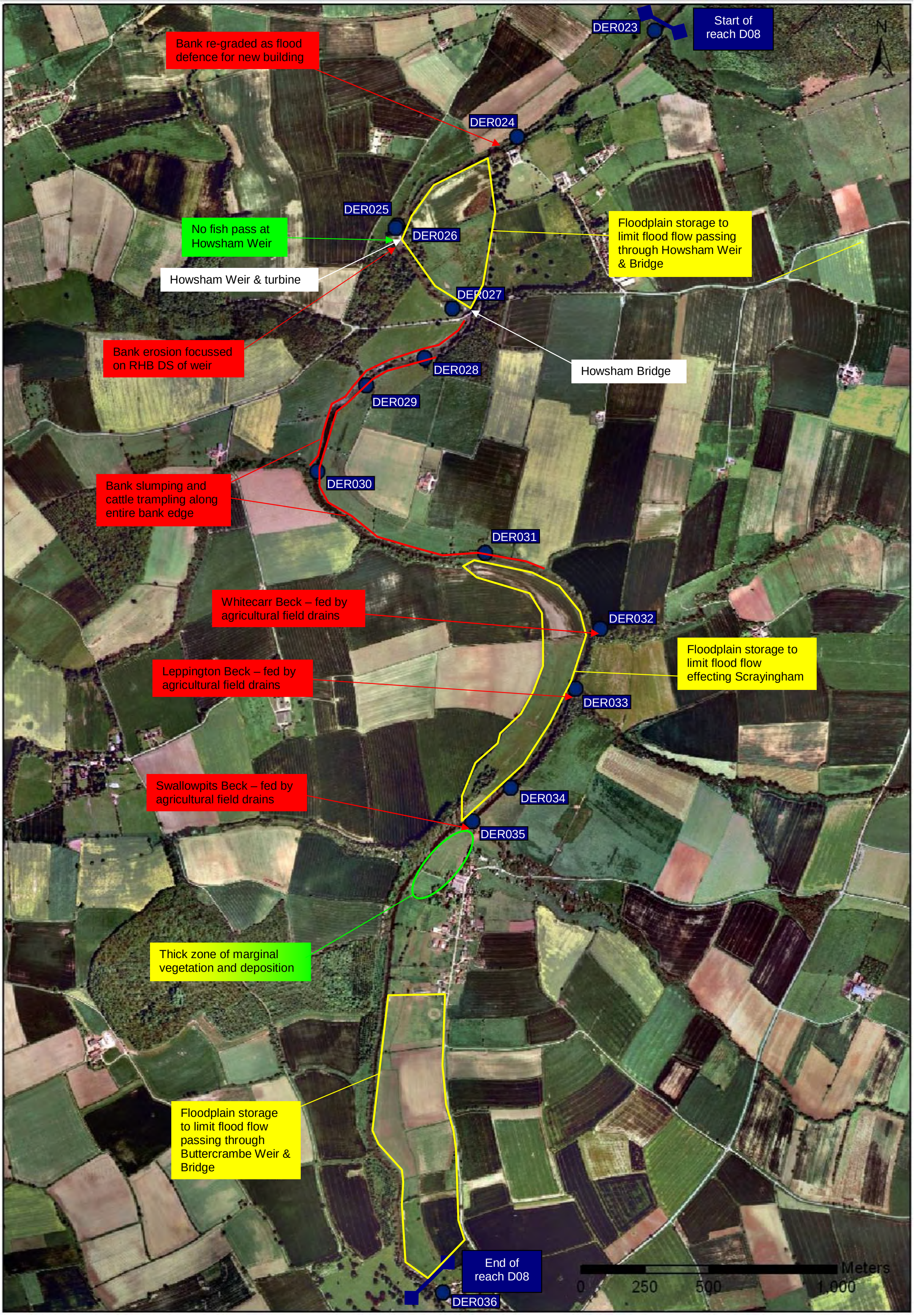
Reach Summary:

The reach has been straightened and there is little evidence of dynamic change. The channel is constricted in the upper section of the reach due to the weir and bridge.

Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation, River and Sea Lamprey & Bullhead**
The area downstream of the weir is suitable for the interest macrophyte species, bullhead and lamprey spawning, with the influence of the weir (i.e. increased flow velocity) extending up to 200 m downstream. In-channel works in the lower parts of the reach could potentially capitalise on the presence of some good quality habitat below the weir by extending it downstream.

Otter
The potential of the reach to support otter is high, but any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species.


DER023
Start of reach D08
Bank re-graded as flood defence for new building
DER024
DER025
No fish pass at Howsham Weir
DER026
Floodplain storage to limit flood flow passing through Howsham Weir & Bridge
Howsham Weir & turbine
DER027
Bank erosion focussed on RHB DS of weir
DER028
Howsham Bridge
DER029
DER030
Bank slumping and cattle trampling along entire bank edge
DER031
Whitecarr Beck – fed by agricultural field drains
DER032
Floodplain storage to limit flood flow effecting Scrayingham
Leppington Beck – fed by agricultural field drains
DER033
Swallowpits Beck – fed by agricultural field drains
DER034
DER035
Thick zone of marginal vegetation and deposition
Floodplain storage to limit flood flow passing through Buttercrambe Weir & Bridge
End of reach D08
DER036
Meters
0 250 500 1,000
N

ROYAL HASKONING

Summary Details D09

Upstream survey limit: SE73123 58690 – Buttercrambe Weir
Downstream survey limit: SE73577 58454 – End of Buttercrambe Weir reach
Length of river surveyed: 0.65km Survey reaches: DER036

Geomorphological Character:

Form
- Channel initially meanders but progressively straightens. Planform constricted by structures & road.
- Watercourse has a shallow gradient and a sandy/silty bed, aside from the drop in bed levels at Buttercrambe Weir.
- Bank material is predominantly fine grained, aside from immediately downstream of Buttercrambe Weir where bank is reinforced with boulder rip-rap. Dominated by sandy clay. Bank profile is predominantly tree-lined stable cliff, and graded/steeped on inside of meander.
- Agricultural pasture is dominant land use. Some urban settlements at DS end of reach.
- Uniform laminar flow aside from immediately DS of the weir where drop in bed level results in increased velocities and turbulent flow. Marginal deadwaters in DS of Buttercrambe Bridge amongst exposed tree roots.

Processes
- There is no evidence of in-channel deposition. Dominant process is erosion immediately downstream of Buttercrambe Weir, focussed by increased velocities passing over weir.
- The channel narrows significantly at Buttercrambe Weir but re-widens dramatically immediately DS.
- Adjacent mill leat runs entire length of reach. Feed for leat appears to be blocked off allowing only minimal input into system. Mill leat weir is similar size and width to Buttercrambe Weir.
- Functional floodplain on RHB. Floodplain on LHB constricted by presence of road and urban settlement.
- Mature tree fallen into channel on RHB US Buttercrambe Bridge.

Channel Modification
- Buttercrambe Weir ~25-30m wide. Buttercrambe Bridge is a clear span structure; constricts both banks.
- Little or no in-channel vegetation evident across the entire reach. Bankside vegetation is present in the form of a stabilising riparian tree-line throughout the majority of the reach.
- Bank protection is concentrated at the 2 structures. Both banks at Buttercrambe Weir are concrete reinforced and both banks are rip-rap supported for approximately 60m immediately downstream to limit the erosion of the banks. Both banks toes are concrete reinforced at Buttercrambe Bridge.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**
- This reach is suitable for the macrophyte species as the weir gives rise to an area of shallow, swiftly flowing water both above and below the structure. The faster flow is also likely to ensure that the substrate is free of silt (although this was not visible during the survey).
- Only in-channel vegetation observed at weir was located on the apron of the weir, where clumps of in-channel vegetation could be seen under the smooth water.
- Shading by trees in this section was at a relatively low level meaning that light was not limiting to macrophyte growth.
- The faster flow generated by the weir continued several hundred meters downstream, and was observed as far downstream as Buttercrambe Bridge (~400m).
- No in-channel macrophytes were recorded on the downstream side of the bridge, in the lee of the supports. Marginal habitat was absent from this reach as the banks were either too steep or too over-shaded.

River and Sea Lamprey
- The shallow, fast flowing water downstream of the weir is suitable for lamprey spawning.
- Likely that the faster flows minimise sediment accumulation, increasing the chances that the substrate is clean and suitable for spawning.
- The mill race and pond are undisturbed habitats, therefore providing stable sediments suitable as nursery habitat.
- There is no fish pass at the weir, and so it is difficult (but not impossible) for lamprey to access upstream areas, depending on flow conditions.

Bullhead
- Increased flows DS of weir indicate more suitable habitat due to riffle habitat, swift flows, potentially cleaner substrate, low level macrophyte cover and tree shading presence.
- The weir does not have a fish pass and is unlikely to be passable to bullhead, representing a barrier to movement and ecological and genetic interactions.

Otter
- The reach is very suitable for otters to feed, live and breed as there is abundant shelter from bankside trees and the area is relatively undisturbed.
- The bankside vegetation is variable in nature and the tree lining is continuous in places and broken in other areas, with variable levels of rank vegetation.
- Otter prints were observed in this reach, confirming their presence in the area.

Key Issues:

Channel Planform Constrains
The channel initially meanders and then straightens across the floor of a shallow v-shaped valley, constrained by the in-channel weir structure and bridge and urban settlements on both banks. Land use is predominantly grazed agricultural pasture, with the settlement of Buttercrambe influencing the left-hand bank at the downstream end of the reach. Grazing comes into close proximity of the channel despite the entirety of the reach being tree-lined.

Floodplain
The centre-island floodplain is likely to act as a sediment store in response to flood flow passing down from the weir.

In-Channel Structures – Buttercrambe Weir & Bridge
At the upstream end the channel morphology is dominated by Buttercrambe Weir. The channel narrows in order to force flow over the weir but then re-widens as the increased erosional strength of flow has historically influenced the width of the channel. The outside of the meander would be subject to toe scour were it not for the rip-rap protection at its base – flood flow evidently still impacts upon the bank profile as demonstrated by the eroding cliffs. Zones of erosion are heavily influenced by the meandering/sinuous nature of the channel. Points of erosion focussed around the bankside supports of Buttercrambe Bridge. There are no zones of in-channel deposition along the entire reach.

Bank Erosion
The reach is a focus of erosion. The steep, cliff-like nature of the bank profile is supported by the tree-line only. This section is likely to be subject to strong flow velocities under flood conditions, causing erosion on both banks and, in the past, bank slumping. This erosion is caused by changes to flow patterns caused by Buttercrambe Weir.

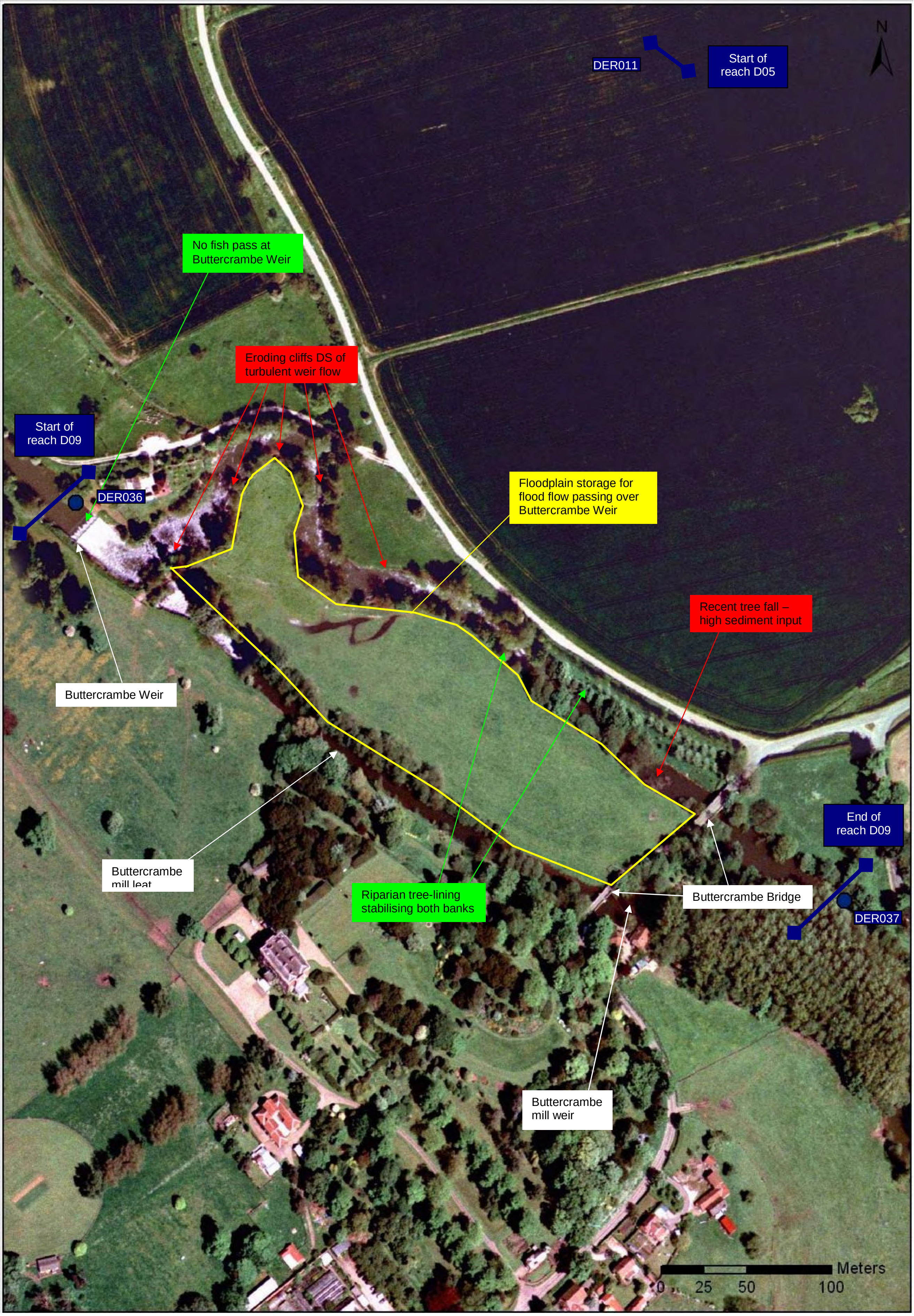
Reach Summary:

The reach is influenced by Buttercrambe Weir. The roads, Buttercrambe Bridge and settlement of Buttercrambe and the historic influence of the mill leat are leaving the planform little room for adjustment. The increased flow velocities passing over the weir and downstream turbulence leading to greater flow diversity than in other reaches.

Reach Potential Based on Existing Ecology:

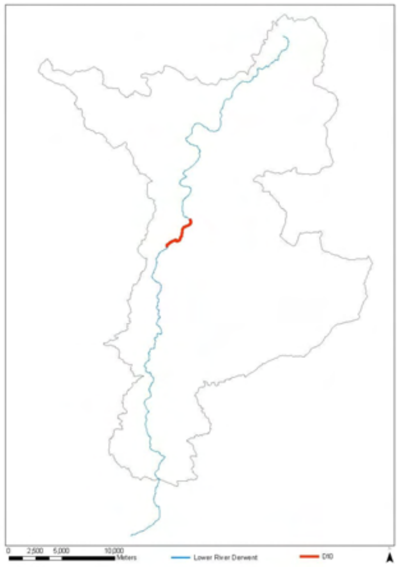
***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation, River and Sea Lamprey & Bullhead**
The area downstream of the weir is suitable for the interest macrophyte species, bullhead and lamprey spawning, with the influence of the weir (i.e. increased flow velocity) extending up to 400 m downstream. In-channel works in the lower parts of the reach could potentially capitalise on the presence of the good quality, variable habitat below the weir by extending it downstream. The reach lacks marginal habitat.

Otter
The potential of the reach to support otter is high, but any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species. An improvement in prey availability and habitat quality would enable larger, more resilient otter populations to be supported.


N
DER011
Start of reach D05
No fish pass at Buttercrambe Weir
Eroding cliffs DS of turbulent weir flow
Start of reach D09
DER036
Floodplain storage for flood flow passing over Buttercrambe Weir
Recent tree fall – high sediment input
Buttercrambe Weir
Buttercrambe mill leat
Riparian tree-lining stabilising both banks
Buttercrambe Bridge
End of reach D09
DER037
Buttercrambe mill weir
Meters
0 25 50 100

Summary Details D10

Upstream survey limit:	SE73578 58454 – End of Buttercrambe Weir reach
Downstream survey limit:	SE71459 55808 – Stamford Bridge
Length of river surveyed:	4.16km Survey reaches: DER037 – DER044



Geomorphological Character:

Form

- Channel follows a straightened course, which is slightly more sinuous in the DS end of the reach.
- The watercourse has a shallow gradient and a sandy/silty bed.
- Bank material is predominantly fine grained. Dominated by sandy clay with a large proportion of silt. Bank profile is predominantly characterised by a stable tree-lined cliff. This is the case along the entire reach until the very DS end, at which point the LHB becomes graded.
- Uniform laminar flow with little or no variation along the entire reach. Marginal deadwaters are present between exposed tree roots within reaches DER041, DER042 and DER043.

Processes

- Deposition is focussed around the bank edges. Toe accumulation and deposition on vegetated berms occurs between intermittent sections of toe scour focussed on eddies caused by tree roots. Little or no in-channel deposition.
- Major watercourses feed into the main river along the reach – Barlam Beck and Flawith Beck. Both drain runoff from agricultural tilled land.
- Channel widens significantly at DS end of reach at meander (DER042).
- Trampling and runoff from exposed hillslope at DS end of reach create a more graded bank profile.

Channel Modification

- Dominant land use varies between pasture and arable land. Stretch of hillslope woodland at very US end and small stretches of woodland along reach.
- There are no in-channel structures in the reach.
- There is no bank protection across the entire reach.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**

- The reach, the river is deep, uniform, slow-flowing, turbid and over shaded heavily by riparian trees and vegetation and currently unsuitable for in-channel vegetation.
- There is little marginal habitat present as the banks are steep and tree lined.
- In the short stretches where there are breaks in the trees and vegetation, narrow (1-2 m) margins are sometimes present when the bank is not quite vertical. These are dominated by emergent reeds and grasses.

River and Sea Lamprey

- The submerged roots of the riparian trees provide plenty of shelter for lamprey moving upstream to spawn.
- There is no suitable spawning habitat available in this reach, nor are there likely to be appreciable areas of stable silt sediment as the channel is so uniformly deep and straight.

Bullhead

- The reach is not suitable for bullhead as it lacks swift flowing riffle habitat and is unlikely to have a clean stony substrate (although the substrate was not visible due to the depth and turbidity of the water).
- There is sufficient shading for bullhead, and a lack of vegetation which suits the species.
- There is no barrier to movement of bullhead in this reach.

Otter

- The reach is suitable for otter to feed, live and even breed as there is sufficient bankside vegetation and tree cover as well as fish prey species available.
- There are also some areas of wetland in the floodplain, although these are restricted.

Key Issues:

Intensive Agricultural Land Use

The channel travels across the floor of a shallow v-shaped valley in a much straightened course. Grazing land dominates the left-hand bank, but not exclusively, with the right-hand bank dominated by tilled land.

Thin Riparian Corridor

When tilled land is adjacent to the river the riparian corridor is not particularly wide (c, 5-10m). This is likely to contribute overland sediment runoff into the main river system. Similarly, at the upstream end of the reach the left-hand bank is characterised by steep hillslope woodland. The number of overland drains, full of woody debris, indicates that the channel receives a large sediment input from the adjacent land.

Bank Stability

Despite the presence of grazing pasture along large sections of both banks, trampling is not an issue until the DS end. The banks are stabilised with a lining of trees that prevents ready access to livestock for drinking purposes.

Discreet Meander

At the downstream end of the reach the channel widens as the planform enters a meander. Bank scour at this section is increased dramatically as is the height of the bank. It is likely that the straightened nature of the channel upstream creates a chute and increases flow velocity during flood flow conditions. Erosion is focussed on the outside of the meander. Downstream of this section there is a large marginal vegetation trap on the right-hand bank (inside of meander). Downstream of this point the channel returns to its previous upstream state, maintaining a right-hand bank tree-line and the left-hand bank establishing a thick riparian corridor.

Reach Summary:

The channel is over-widened and straightened and flows and bank profile are consequently uniform. There is a general lack of geomorphological activity or diversity.

The adjacent tilled land is also a likely major input of sediment into the river system.

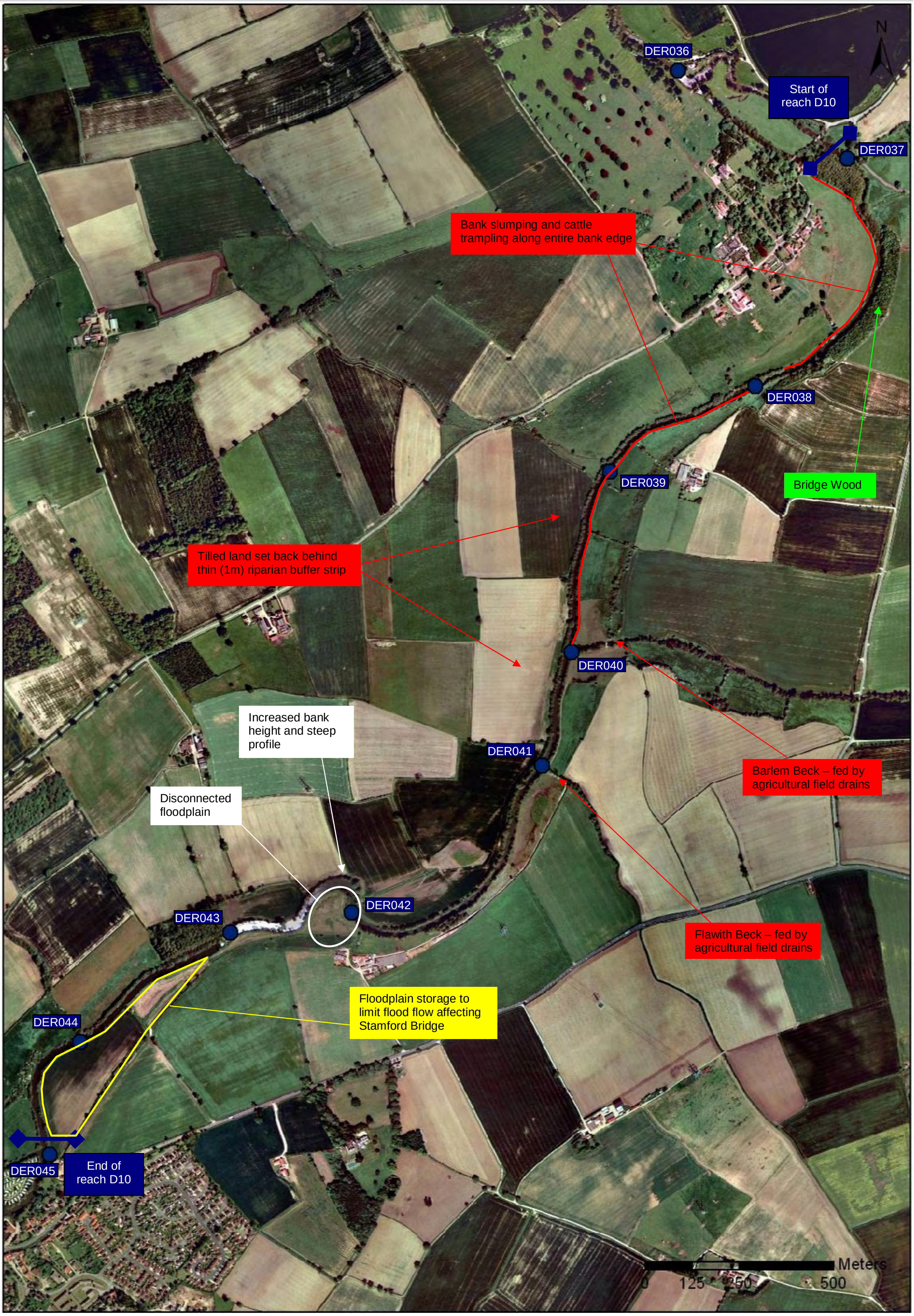
Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation, River and Sea Lamprey & Bullhead**

Measures to produce variability within the channel would be required to create the shallower areas and gravel substrate favoured by ***R. fluitantis.*** Tree thinning to increase light penetration and re-profiling of the banks to reduce the gradient and produce shallow margins, would also encourage the interest macrophyte species by increasing marginal habitat. Measures to create shallower areas would also benefit river and sea lamprey by producing habitat suitable for spawning. Greater variability of habitat within the channel would also promote shallow areas with stable silt or sand dominated substrate suitable for lamprey nursery habitat.

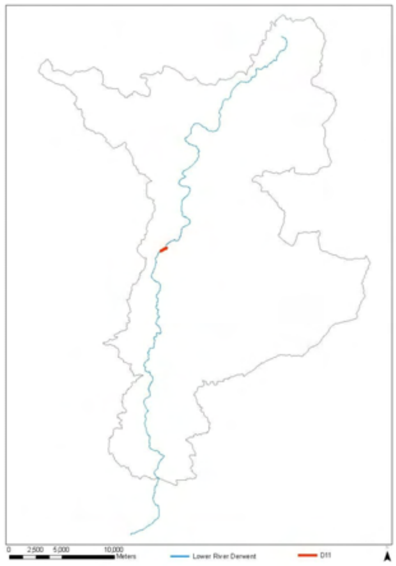
Otter

Shelter and wetland are already present for otter, but any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species. An improvement in prey availability and habitat quality would enable larger, more resilient otter populations to be supported.


N
DER036
Start of reach D10
DER037
Bank slumping and cattle trampling along entire bank edge
DER038
DER039
Bridge Wood
Tilled land set back behind thin (1m) riparian buffer strip
DER040
Increased bank height and steep profile
DER041
Barlem Beck – fed by agricultural field drains
Disconnected floodplain
DER042
DER043
Flawith Beck – fed by agricultural field drains
Floodplain storage to limit flood flow affecting Stamford Bridge
DER044
DER045
End of reach D10
Meters
0 125 250 500

Summary Details	D11		
Upstream survey limit:	SE71465 55802 – Stamford Bridge		
Downstream survey limit:	SE70839 55389 – End of Stamford Bridge		
Length of river surveyed:	0.78km	Survey reaches:	DER045

Geomorphological Character:



Form
- A straightened course. The channel is constrained by urban settlements on both banks.
- The watercourse has a shallow gradient, aside from a larger bed level drop at Stamford Bridge Weir. Bed material is sandy / silty.
- Bank material is predominantly fine grained (sandy clay). Bank profile is predominantly stable cliff with occasional sections of graded profile.
- Uniform laminar flow, aside from immediately downstream of Stamford Bridge Weir, where high velocity turbulent flow occurs.

Processes
- In-channel deposition is focussed around the Stamford Bridge. Deposition occurs at the DS end of the concrete-lined island DS of the bridge that serves as the exit point for the mill leat. Bankside deposition is concentrated immediately DS of the weir, due to toe accumulation.
- The caravan park along the RHB has a number of fishing platforms and boat moorings and launches.
- Channel widens significantly immediately downstream of Stamford Bridge Weir.

Channel Modification
- Land use is dominated by urban settlement. The RHB is caravan park up until the Stamford Bridge. The LHB is dominated by housing and commercial properties. DS of the old railway bridge, the reach is characterised by pasture on both banks.
- Stamford Bridge Weir is approximately 25-30m wide. Stamford Bridge is a major bridge but has no in-channel supports.
- Bank protection is extensive through the reach. Focussed heavily at the entrance to the mill leat (RHB), and the weir and bridge (both banks). Consists of concrete toe reinforcement (10m) at the mill leat entrance and the full bank at weir (20m) and bridge (15m).
- There has been no significant channel planform change along the entire reach since 1850.

Ecological Character:

***Ranunculion fluitantis & Callitricho-Batrachion* Vegetation**
- The weir at Stamford Bridge creates a stretch of shallow, fast-flowing channel that is suitable for the macrophyte species. The faster flow is also likely to ensure that the substrate is free of silt (although this was not visible during the survey).
- No in-channel vegetation was observed from the bank in this stretch, although any vegetation could be obscured by poor visibility and distance from the bank.
- Shading was minimal in this reach, meaning that light would not limit macrophyte distribution.
- Very small areas of marginal habitat were present where there were breaks in the bankside tree line.

River and Sea Lamprey
- The shallow, fast flowing water downstream of the weir is suitable for lamprey spawning. The faster flows minimise sediment accumulation, increasing the chances that the substrate is clean and suitable for spawning.
- The mill races are partially undisturbed habitats that could provide stable sediments suitable as nursery habitat for ammocoetes.
- There is a fish pass at the weir, enabling lamprey to access upstream areas, however, discharge from the pass appeared to be extremely strong, so it may not be fully passable in all flow conditions.

Bullhead
- The increased flows around the weir indicate that the habitat is more suitable for bullhead than other stretches as riffle habitat; swift flows, cleaner substrate, low level macrophyte cover and some tree shading were all present.
- The weir has a fish pass, but discharge from the pass is strong (relative to the channel) and is unlikely to be passable to bullhead, therefore representing a barrier to the population movements and ecological and genetic interactions that help propagate healthy populations.

Otter
- The reach contains plenty of riparian shelter and fish prey for otters.
- The setting is mainly urban and so there may be higher levels of disturbance reducing the suitability of the reach for breeding.

Key Issues:

Channel Planform Constraints
The channel is constrained by the settlement of Stamford Bridge on both banks. The in-channel structures and proximity of urban development and bank protection works constrains the channel planform significantly. Floodplain is generally restricted to the back gardens of residential properties. The channel is well tree-lined with a thick riparian corridor.

Urban Bank
At the very upstream end of the reach the toe is scoured where not protected. Deposition occurs -between each fishing platform on the right-hand bank.

In-Channel Structures – Stamford Weir & Bridge
The channel widens immediately downstream of the weir. Steep cliffs show signs of erosion during flood flows, although this is generally stabilised by riparian trees. Currently the dominant process is deposition, likely resulting from the over-wide and over-deep channel that has been eroded by the turbulent flow. Marginal vegetation has established amongst the toe deposits, continuing to trap further sediment. Further downstream, deposition is located downstream of the mill leat island. The channel widens further downstream of the bridge. This would indicate that flow velocity is increased downstream of Stamford Bridge, with the urbanised reach acting as a constricted chute.

Lack of Floodplain
The reach has no discernible floodplain until downstream of the bridge. The reach upstream of Stamford Bridge is likely used as flood storage and flood flow would dissipate on the floodplain downstream of the urbanised section. Bank height is high throughout the reach but large flood flows may overtop this.

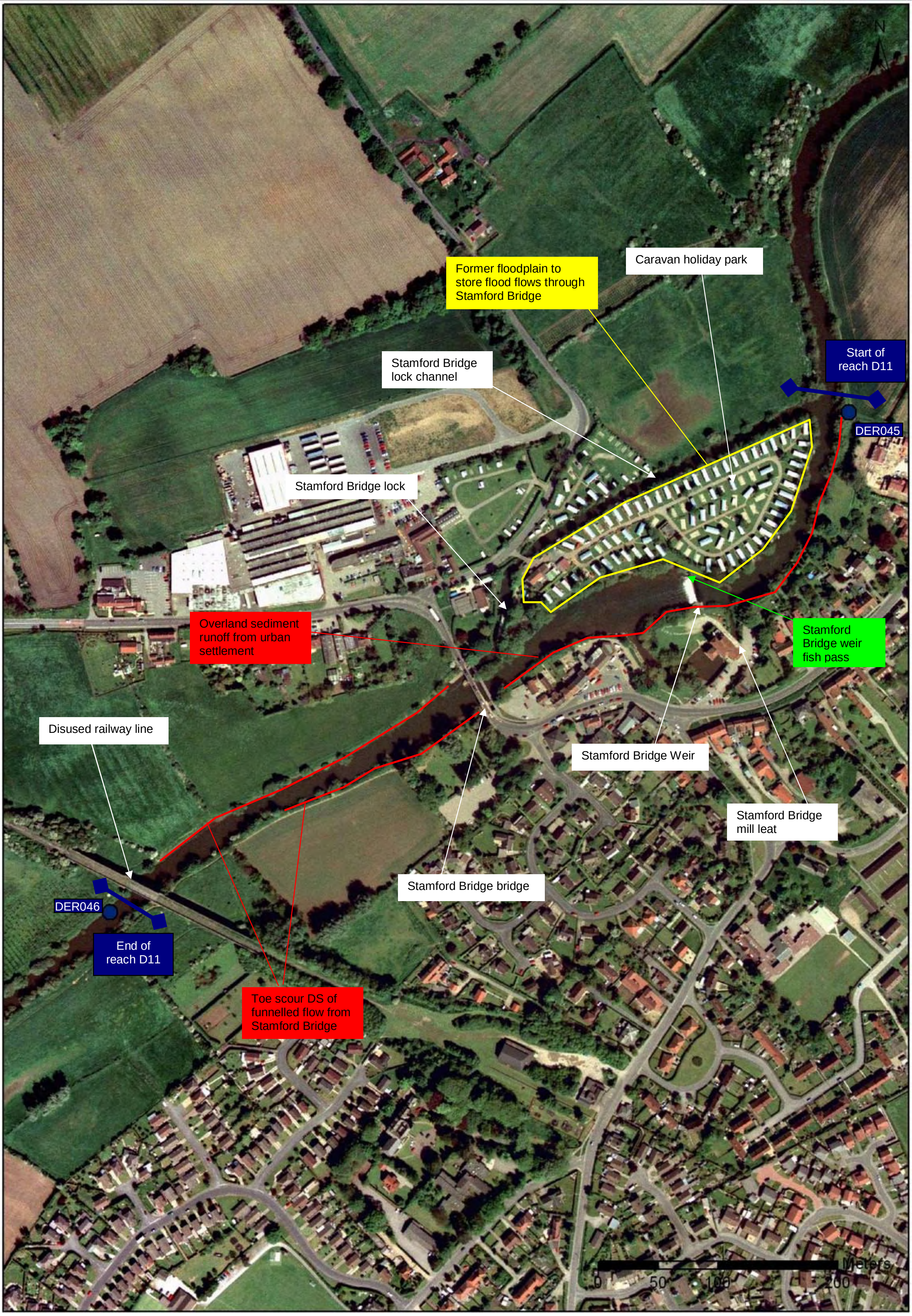
Reach Summary:

This is a heavily urbanised and engineered reach. The concrete nature of large sections of the bank, in-channel structures and the surrounding land use means the river is severely constricted. There are very little opportunities within this reach due to the heavy engineering and lack of available floodplain. In-channel structures and practical functionality of the reach limit the benefits that any works could provide and any potential works would need to carefully monitor any impact on flood risk.

Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis & Callitricho-Batrachion* Vegetation, River and Sea Lamprey & Bullhead**
The area downstream of the weir is suitable for the interest macrophyte species, bullhead and lamprey spawning, with the influence of the weir (i.e. increased flow velocity) extending several hundred metres downstream. In-channel works in the lower parts of the reach could potentially capitalise on the presence of the good quality, variable habitat below the weir by extending it downstream. The reach lacks marginal habitat, but alterations to the gradient of the banks would be restricted by the urban setting.

Otter
The potential of the reach for otter feeding and passage is fair, but the urban surroundings may reduce breeding opportunities. Any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species.


Former floodplain to store flood flows through Stamford Bridge
Caravan holiday park
Stamford Bridge lock channel
Start of reach D11
DER045
Stamford Bridge lock
Overland sediment runoff from urban settlement
Stamford Bridge weir fish pass
Disused railway line
Stamford Bridge Weir
Stamford Bridge mill leat
Stamford Bridge bridge
DER046
End of reach D11
Toe scour DS of funnelled flow from Stamford Bridge
0
50
100
200
Meters
N

Summary Details D12

Upstream survey limit: SE70838 55387 – End of Stamford Bridge
Downstream survey limit: SE70317 52615 – Re-start of embankments
Length of river surveyed: 3.16km Survey reaches: DER046 – DER047

Geomorphological Character:

Form
- Straightened course.
- The watercourse has a shallow gradient and a sandy/silty bed. Marginal deadwaters are present between some tree roots.
- Bank material is predominantly fine grained. Dominated by sandy clay, with a large proportion of silt. Bank profile is mixed, varying between stable vegetation-supported cliffs (riparian, tree root), stepped (trampled) or graded banks.
- Uniform laminar flow with little or no variation along the entire reach.

Processes
- Hillslope set back approximately 100m from channel.
- Both banks experience significant trapping of sediment by marginal vegetation, and toe accumulation along the entire exposed grazed stretch. Geotechnical bank failure and trampling is widespread.
- Smackdam Beck feeds into main channel upstream of Low Catton. Drains agricultural tilled land.

Channel Modification
- Land use is dominated by grazing pasture on both banks right up to the channel edge. There is a small section of common scrubland running parallel to the settlement of Low Catton and interspersed sections of tilled agricultural land, set back from the channel.
- There are no in-channel structures in the reach.
- There is no bank protection along any part of the reach.

Ecological Character:

***Ranunculion fluitantis & Callitricho-Batrachion* Vegetation**
- In this reach, the river is deep, uniform, slow-flowing, turbid and over-shaded heavily by riparian trees and vegetation.
- There is very little marginal habitat present as the banks are steep and tree lined.
- Some stretches of the bank are heavily trampled and completely bare of vegetation consisting only of exposed mud.
- The reach is not suitable for the macrophyte species.

River and Sea Lamprey
- The submerged roots of the riparian trees provide plenty of shelter for lamprey moving upstream to spawn.
- The slow flow means that there is no suitable spawning habitat available in this reach.
- Unlikely to be appreciable areas of stable silt sediment as the channel is so uniformly deep and straight.

Bullhead
- The reach is not suitable for bullhead as it lacks swift flowing riffle habitat and is unlikely to have a clean stony substrate (although the substrate was not visible due to the depth and turbidity of the water).
- There is sufficient shading for bullhead, and a lack of vegetation which suits the species.
- There is no barrier to movement of bullhead in this reach.

Otter
- The reach is suitable for otter to feed, live and even breed as there is plenty of bankside vegetation and tree cover as well as fish prey species available.
- There are few areas of wetland in the floodplain.

Key Issues:

Channel Response to Upstream Urbanisation
The reach is located at the base of a shallow v-shaped valley in a very straight course. There is some sinuosity but considering the lack of constraints on the channel planform, the straightness is a likely result of the increased flows caused by the upstream urban reach (D11).

Cattle Trampling & Geotechnical Bank Failure
Grazing dominates the reach and influences the bank profile and deposition characteristics of the channel. Trampling and historical bank slumping (possibly aided by trampling) are present throughout the reach. Tree fall is common in the upstream section of the reach, encouraged by cattle access to the channel.

Hillslope Sediment Supply
The hillslope is set back from the channel, but i***s*** likely to contribute sediment into the river due to a lack of riparian corridor, particularly on the right-hand bank. Limited sections of tilled land set back from the channel but on the hillslope are likely to contribute overland sediment runoff directly into the main channel system.

Tributary
Smackdam Beck drains overland flow from agricultural land from the set back hillslope of the valley. This is a likely sediment contributor into the system.

Lack of Geomorphological Functionality
Some erosion interspersed between zones of deposition, focussed around tree roots and where marginal vegetation cover recedes. No zones of fluvial erosion and deposition due to straightened nature of channel.

Reach Summary:

The channel is over-wide, straightened with a general lack of geomorphological activity or diversity.

The adjacent grazed land and subsequent trampling, and set back tilled land to a degree, is also a likely major input of sediment into the river system.

The channel is also slightly constrained by the presence of Low Catton on the left-hand bank.

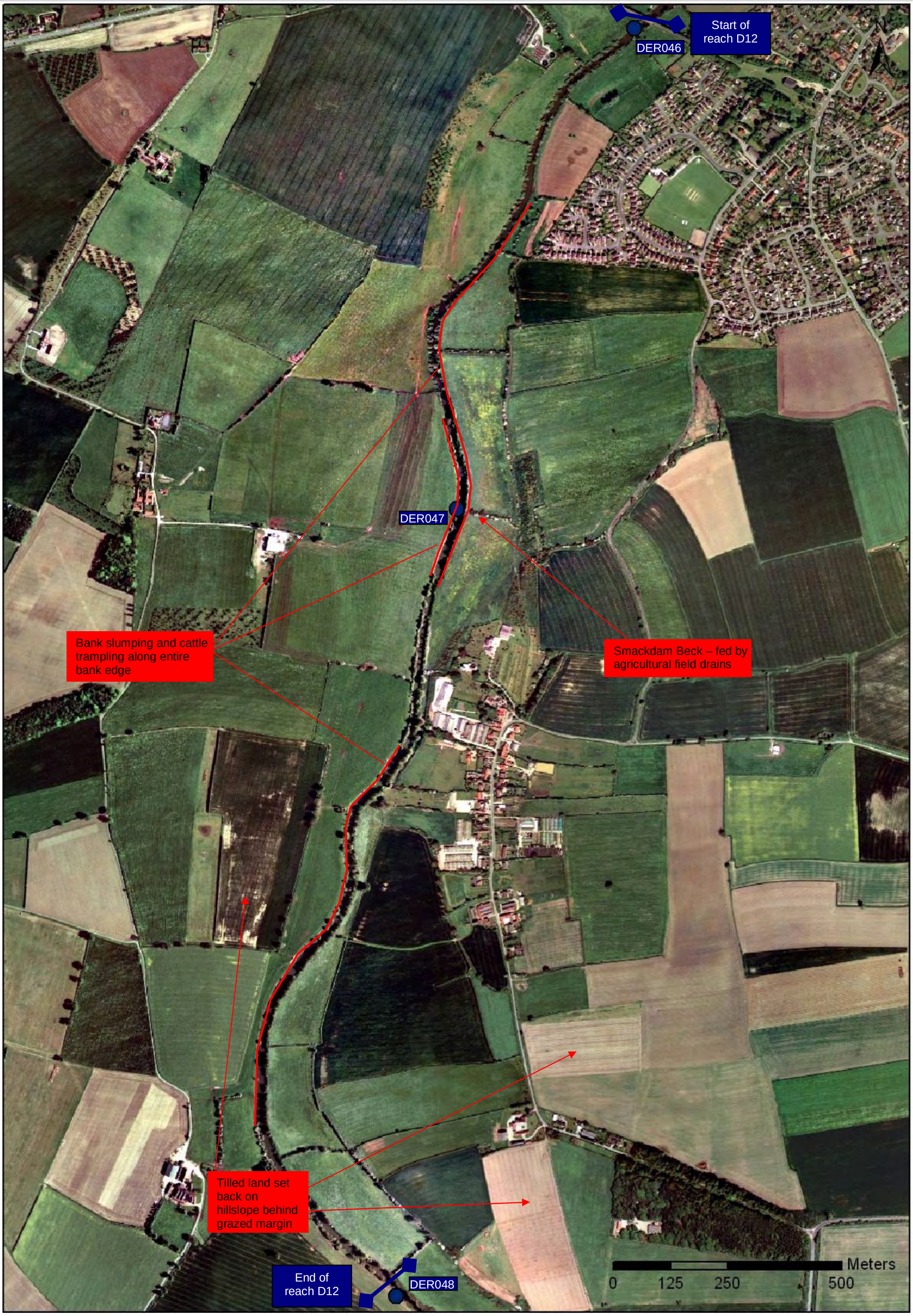
Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis & Callitricho-Batrachion* Vegetation & Bullhead**
Measures to produce variability within the channel would be required to improve and increase the shallower areas and gravel substrate favoured by ***R. fluitantis.*** Tree thinning to increase light penetration on the left bank and re-profiling of the banks to reduce the gradient and produce shallow margins, would also encourage the interest macrophyte species by increasing marginal habitat.

River and Sea Lamprey
The above measures to create shallower areas with gravel substrate would also benefit river and sea lamprey by producing habitat suitable for spawning. Greater variability of habitat within the channel would also promote shallow areas with stable silt or sand dominated substrate suitable for lamprey nursery habitat.

Otter
Food and shelter are present for otter, but any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species. Generally, a sediment management plan for the catchment would benefit all of the interest species as it would result in greater water clarity and cleaner substrate.

ROYAL HASKONING



Summary Details D13

Upstream survey limit:	SE70316 52616 – Re-start of embankments
Downstream survey limit:	SE70456 51277 – Start of Kexby
Length of river surveyed:	1.80km Survey reaches: DER048 – DER049

Geomorphological Character:

Form

- Reach located on outside of meander. Slight bend to planform.
- The watercourse has a shallow gradient and has a sandy/silty bed.
- Bank material is fine grained. Dominated by sandy clay with some silt. The reach is characterised by either a stable cliff in tree-lined sections (majority of LHB) or a stepped/graded bank profile, influenced by trampling (RHB).
- Uniform laminar flow with little or no variation along the entire reach. Some marginal deadwaters beneath tree-lined sections and amongst exposed roots.

Processes

- The RHB displays significant sediment trapping by marginal vegetation and toe accumulation along the entire exposed grazed stretch.
- Historical geotechnical bank failure and trampling is widespread along the RHB. Some eddying scour along LHB between exposed roots but minimal impact.
- Number of drains along the RHB feeding directly into the channel. Minimal flow from agricultural floodplain land.

Channel Modification

- Land use is predominantly agricultural. Grazing pasture at bank edge, tilled land set back. LHB is predominantly scrubland and woodland separating a margin between tilled land and the channel.
- There are no in-channel structures along the reach.
- There is no bank protection, but embankments line the RHB for the entirety of the reach. Embankments are set back approximately 1m from bank top and are only 1m in height. Embankments begin on the LHB at the very DS end of the reach. RHB embankments increase in height at this point.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**

- Reach is over-shaded along much of the left bank by riparian trees and vegetation.
- The right bank is more exposed and trampled. There is little marginal habitat present as the banks are steep and often tree lined.
- Some stretches of bank have been heavily trampled in the past, resulting in the production of some shallow marginal habitat. In some areas, the trampled banks have become stable enough to support terrestrial and aquatic vegetation, and some patches of fine-leaved pondweed were observed.

River and Sea Lamprey

- The submerged roots of the riparian trees provide plenty of shelter for lamprey moving upstream to spawn.
- There is no suitable spawning habitat available in this reach, nor are there likely to be appreciable areas of stable silt sediment to act as nursery habitat as the channel is so uniformly deep and straight.

Bullhead

- The reach is not suitable for bullhead as it lacks swift flowing riffle habitat.
- There is sufficient shading for bullhead, and a lack of vegetation which suits the species.
- There is no barrier to movement of bullhead in this reach.

Otter

- The reach is suitable for otter to feed, live and even breed as there is plenty of bankside vegetation and tree cover (RHB).
- There are also some areas of wet grassland in the floodplain.

Key Issues:

Channel Planform Constraints

The channel reach is part of a larger meander around the outside of a grazed floodplain. The valley has a shallow v-shape and is constrained on the right-hand bank by the presence of flood embankments, leading into the village of Kexby. The embankment is set back approximately 1m, limiting the floodplain to the scrubland and woodland on the left-hand bank. The grazing land on the right-hand bank, located on the inside of the meander, would be the natural floodplain but this land is embanked to protect the agricultural land. The right-hand bank is used recreationally, with the embankment acting as a public footpath with bridges and stiles crossing the drains.

Historic Trampling & Geotechnical Bank Failure

Deposition occurs along the right-hand bank as marginal deposits and toe accumulation at the base of the grazed bank. Historical bank slumping is likely to have influenced the profile of the bank and toe accumulation and marginal vegetation establishment are likely to have relied on livestock trampling. Erosion is focussed predominantly around exposed tree roots and between pockets of marginal vegetation. These instances are minimal. The reach is dominated by deposition.

Right-hand Bank Embankment & Floodplain

Floodplain connectivity is good despite the presence of embankments on the right-hand bank. The relatively low embankment height would imply they can be easily overtopped, and the natural inside of meander floodplain would mean discouraging this would require higher embankments. The embankment may even be for trapping water or sediment on the inside of the meander. Nevertheless, the left-hand bank is common-land and has limited agricultural value, offering good potential flood storage.

Left-hand Bank Tree-Line

The left bank is tree-lined and over-shaded while the right is exposed and trampled by cattle. There is little marginal habitat due to steep or over-shaded banks. What marginal and shallow habitat there is seems to have arisen from intensive trampling leading to bank collapse.

Reach Summary:

Reach is a zone of heavy deposition, constricted by flood embankments along the right-hand bank.

Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation & Bullhead**

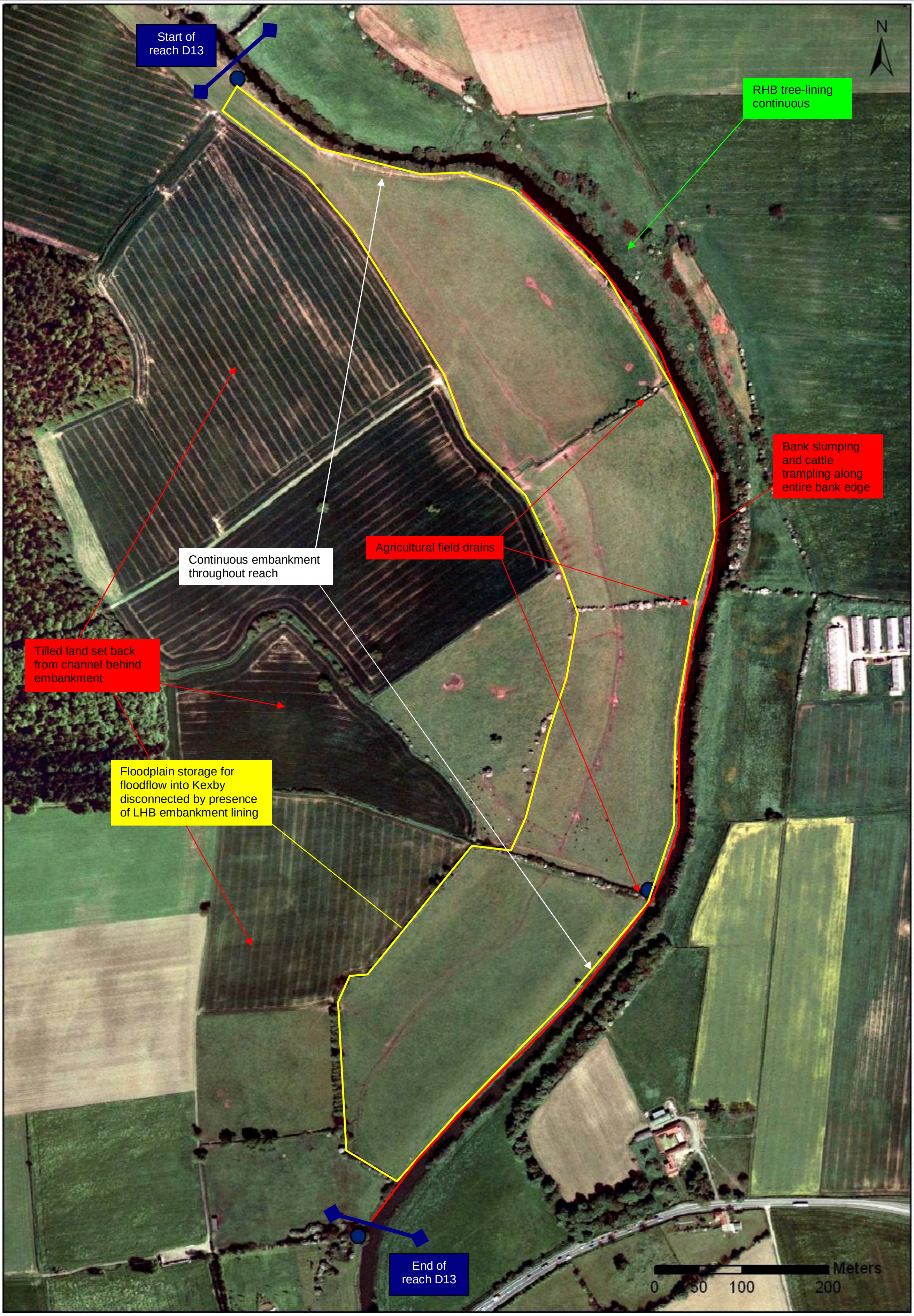
Measures to produce variability within the channel would be required to improve and increase the shallower areas and gravel substrate favoured by ***R. fluitantis.*** Tree thinning to increase light penetration on the left bank and re-profiling of the banks to reduce the gradient and produce shallow margins, would also encourage the interest macrophyte species by increasing marginal habitat.

River and Sea Lamprey

The above measures to create shallower areas would also benefit river and sea lamprey by producing habitat suitable for spawning. Greater variability of habitat within the channel would also promote shallow areas with stable silt or sand dominated substrate suitable for lamprey nursery habitat.

Otter

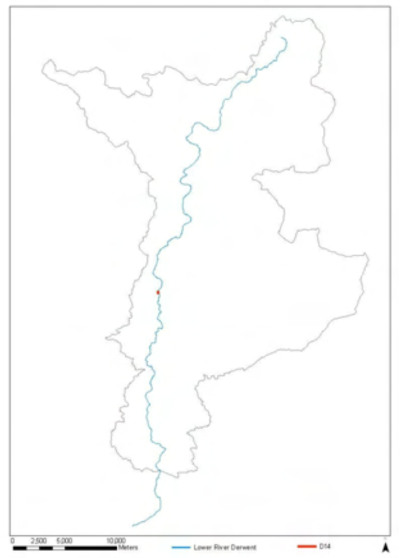
Shelter is available for otter, but any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species. In addition, tree planting along the right bank would decrease exposure for otter movements. An improvement in prey availability and habitat quality would enable larger, more resilient otter populations to be supported.



Start of reach D13
RHB tree-lining continuous
Bank slumping and cattle trampling along entire bank edge
Agricultural field drains
Continuous embankment throughout reach
Tilled land set back from channel behind embankment
Floodplain storage for floodflow into Kexby disconnected by presence of LHB embankment lining
End of reach D13
N
0 50 100 200
Meters

Summary Details D14

Upstream survey limit: SE70442 51283 – Start of Kexby
Downstream survey limit: SE70581 51045 – End of Kexby / re-start of embankments
Length of river surveyed: 0.28km Survey reaches: DER050



Geomorphological Character:

Form

- Reach located on outside of meander.
- The watercourse has a shallow gradient and a sandy/silty bed.
- Hillslope is connected to the channel in places.
- Bank material is predominantly fine grained (sandy clay). Bank profile is predominantly a stable tree-lined cliff, interspersed with a stepped/graded bank profile to protect the two Kexby bridges.
- Uniform laminar flow with little or no variation along the entire reach. Some marginal deadwaters between overhanging bows of riparian vegetation.

Processes

- In-channel deposition is focussed at the DS of Kexby Bridge. Debris was caught at the US end of the bridge support.
- Flow velocity is increased through the reach through Kexby, and is directed through the main archway of Kexby Bridge, away from the banks.

Channel Modification

- Land use is mixed. At the bank edge the channel has a thick riparian corridor and this leads into a common-land scrub on the RHB. The LHB is initially pasture but conforms to scrubland between the two bridges. Both banks also house suburban settlements DS of the bridges.
- Kexby Bridge has a single in-channel support strut. The A1079 road bridge crosses the river at the mid-point of the reach but has no in-channel supports.
- The Kexby Bridge RHB has a support that rests at the very edge of the channel, offering concrete protection for the bank. The embankments seen US in the previous reach (D13) merge into the hillslopes around Kexby.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**

- The channel is too deep and turbid to allow growth of in-channel vegetation.
- The reach lacks swift flow and any evident gravel substrate but there is good marginal habitat several meters wide in this stretch supporting emergent reeds as well as floating and submerged macrophytes.
- The reach has some potential to support the interest macrophytes near the banks, but overall, it is unsuitable.

River and Sea Lamprey

- The submerged roots of the riparian trees provide sufficient shelter for lamprey moving upstream to spawn.
- No suitable spawning habitat available in this reach, or are there likely to be appreciable areas of stable silt sediment as the channel is uniformly deep and straight.

Bullhead

- The reach is not suitable for bullhead as it lacks swift flowing riffle habitat and is unlikely to have a clean stony substrate (although the substrate was not visible due to the depth and turbidity of the water).
- There is sufficient shading for bullhead, and no areas of excessive vegetation, which suits the species.
- There is no barrier to movement of bullhead in this reach.

Otter

- The reach is suitable for otter to feed, live and even breed as there is sufficient bankside vegetation, tree cover and fish prey available.
- Since the reach is near a busy main road, levels of disturbance may be high enough to discourage use of the reach for breeding.

Key Issues:

Flood Protection Valley

The channel, in contrast to the previous reaches, is located in a discreet deep v-shaped valley. The valley is a result of construction works for the A1079 road bridge, acting as flood protection for the village of Kexby. The reach is located on the outside of a meander but is relatively straight in nature.

Channel Planform Constraints

The planform is constrained by the suburban settlement of Kexby, the hillslopes and the bridges crossing the channel. Upstream of the road bridge, land use is predominantly grazing, although evidence of access to the channel is limited. The reach is likely to act as a funnel for flood flows, pushing discharges through the two bridges to minimise impact on the settlement.

Riparian Corridor

Past the grazed upstream section, the riparian corridor thickens considerably. Again, this is likely to be encouraged as a measure to offer bank protection against the erosive effects of flood flows. Toe scour underneath the riparian line is widespread, as is scour immediately upstream and downstream of the bridge structures. There are no significant zones of deposition aside from at the support struts where flood debris has caught at the bank and at the tail-end of the single in-channel strut where fine sediment has accumulated.

Flood Flow Management

The channel widens to a minor degree coming into Kexby and again downstream of Kexby Bridge. This would indicate the erosive processes acting on the reach. The thick riparian corridor and tree-lining through the focus of the zone of geomorphological activity would indicate that the reach is managed to achieve flood conveyance and protect the settlement of Kexby.

Lack of Floodplain

The reach has no discernible floodplain through Kexby. Floodplain is present in the upstream section of the reach, and may be used as flood storage – the right-hand bank floodplain was waterlogged. Bank height is high throughout the reach, possibly to increase the capacity of the channel to contain large flood flows or as an unintended result of over-deepening.

Reach Summary:

This is a heavily modified. The accentuated hillslope, tree and riparian supported bank and bridge structures concentrate flow within the channel through the reach. The river is severely constricted. There are very few opportunities within the reach due to the modifications and lack of available floodplain. In-channel structures limit the benefits that any works could provide and any potential works would need to carefully monitor any impact on flood risk.

Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation & Bullhead**

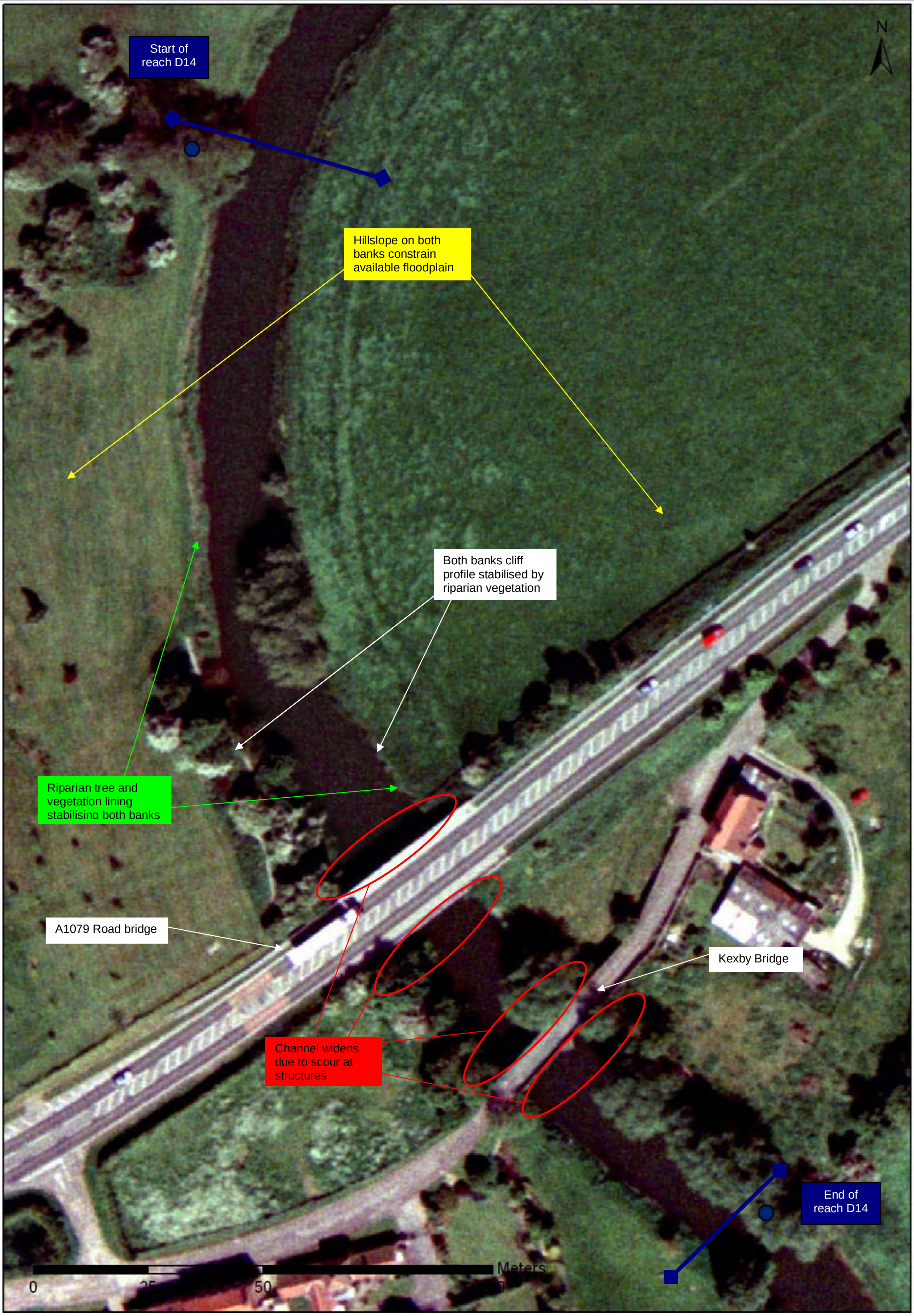
Measures to produce variability within the channel would be required to encourage the swifter flows and gravel substrate favoured by ***R. fluitantis.*** Re-profiling of the banks to reduce the gradient and produce shallow margins would also encourage the interest macrophyte species by increasing marginal habitat.

River and Sea Lamprey

The above measures to create shallower areas with gravel substrate would also benefit river and sea lamprey by producing habitat suitable for spawning. Greater variability of habitat within the channel would also promote shallow areas with stable silt or sand dominated substrate suitable for lamprey nursery habitat.

Otter

Shelter and wetland areas are already available for otter, but the reach may be too disturbed by traffic to provide suitable breeding habitat.



Start of reach D14
N
Hillslope on both banks constrain available floodplain
Both banks cliff profile stabilised by riparian vegetation
Riparian tree and vegetation lining stabilising both banks
A1079 Road bridge
Kexby Bridge
Channel widens due to scour at structures
End of reach D14
0
50
Meters

Summary Details D15

Upstream survey limit: SE70582 51046 – End of Kexby / re-start of embankments
Downstream survey limit: SE70781 49356 – End of embankments
Length of river surveyed: 2.05km Survey reaches: DER051 – DER052

Geomorphological Character:

Form

- Irregular meandering planform, although short reaches appear to have been straightened.
- The watercourse has a shallow gradient and a sandy/silty bed.
- Bank material is predominantly fine grained. Dominated by sandy clay, with large proportion of silt. Reach displays an alternating bank profile depending on the position at the inside or outside of a meander. Stable tree-lined cliffs at outside of meander, graded/stepped profile at inside of meander.
- Uniform laminar flow with little or no variation along the entire reach.

Processes

- Heavy channel-edge deposition due to trapping by marginal vegetation, focussed exclusively on the inside of the meander. Some minor toe accumulation at base of tree-lined sections, but not dominant process.
- Reach is located within ings. Bankside vegetation and livestock access is managed.
- Historic geotechnical bank failure and evidence of trampling evident in sections along reach.
- Arnull Golt feeds into river at upstream extent of reach.

Channel Modification

- Land use is dominated by agricultural grazing pasture – ings and waterlogged land. Some sections are unimproved, rotational pasture schedule. Recreational use along LHB as stiles and kissing gates offer access along entire length of reach.
- There are no in-channel or channel edge structures throughout the reach.
- There is no bank protection but embankments set back by approximately 10-25m on LHB along entire reach. Embankments define extent of LHB ings.

Ecological Character:

***Ranunculion fluitantis & Callitricho-Batrachion* Vegetation**

- In this reach, the river is deep, uniform, slow-flowing, turbid and over-shaded by riparian trees and vegetation along much of its length. It is therefore unsuitable for in-channel vegetation.
- There is limited marginal habitat present as the banks are quite steep and often over-shaded.
- The reach is unsuitable for the interest macrophyte species.

River and Sea Lamprey

- The submerged roots of the riparian trees provide shelter for lamprey moving upstream to spawn.
- There is no suitable spawning habitat available in this reach, nor are there likely to be appreciable areas of stable silt sediment as the channel is so uniformly deep and straight.

Bullhead

- The reach is not suitable for bullhead as it lacks swift flowing riffle habitat and is unlikely to have a clean stony substrate (although the substrate was not visible due to the depth and turbidity of the water).
- There is sufficient shading for bullhead, and no areas of excessive vegetation, which suits the species.
- There is no potential barrier to movement of bullhead in this reach.

Otter

- The reach is suitable for otter to feed and pass through as there is bankside vegetation present in some areas.
- Some parts of the reach lack shelter.

Key Issues:

Channel Planform Constraints & Land Use – LHB Embankment

The channel crosses the floor of a shallow v-shaped valley in a sinuous, almost irregularly meandering, course. Despite this planform, the channel appears straightened at field observation level. The channel is constrained along its entire left-hand bank by the presence of the ing embankments. Grazing is the dominant land use, particularly along the right-hand bank where it covers the entire reach. The left-hand bank embankments define the ings – kept wet and warm to encourage earlier pasture growth – and define land use as grazing, although there was limited livestock presence at the time of survey. Any hillslope runoff sediment supply along the left-hand bank will remain on the ing floodplain.

Geomorphological Functionality

Sinuous nature of reach is creating zones of natural erosion and deposition. Outside of meander is eroding cliff stabilised by tree-lining to prevent bank collapse, some toe scour and eddy scour amongst exposed tree roots. Inside of meander has graded bank profile with thick channel edge vegetation margin, trapping sediment. Livestock access to the channel is limited at the tree-lined cliff and encouraged at an access point on the inside of meander to enable further bank collapse and creation of a deposition margin.

Ings Management Plan

This reach forms part of the ings management regime. The tree-lining limits planform adjustment. The channel is heavily restricted from its natural course by the requirements of the adjacent farmland. The channel is fenced off in sections, particularly the tree-lined cliff, to prevent livestock access and trampling. Riparian corridor at these sections is thicker.

Tributary

The Arnull Golt drains an agricultural area and contains high quantities of sediment. This inputs directly in the main river system.

Floodplain

Good floodplain connectivity due to management of ings. Right-hand bank is exclusively dedicated to floodplain storage and inundation due to the left-hand bank embankments. The waterlogged nature of the ings indicates that overtopping is possible.

Reach Summary:

The channel is constricted along its left-hand bank by the presence of the ing embankment.

The reach is managed, under the ing management regime – protecting the outside of the meander with tree-lining and allowing the inside to offer potential flood storage. This is constricting the natural planform of the channel.

Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis & Callitricho-Batrachion* Vegetation & Bullhead**

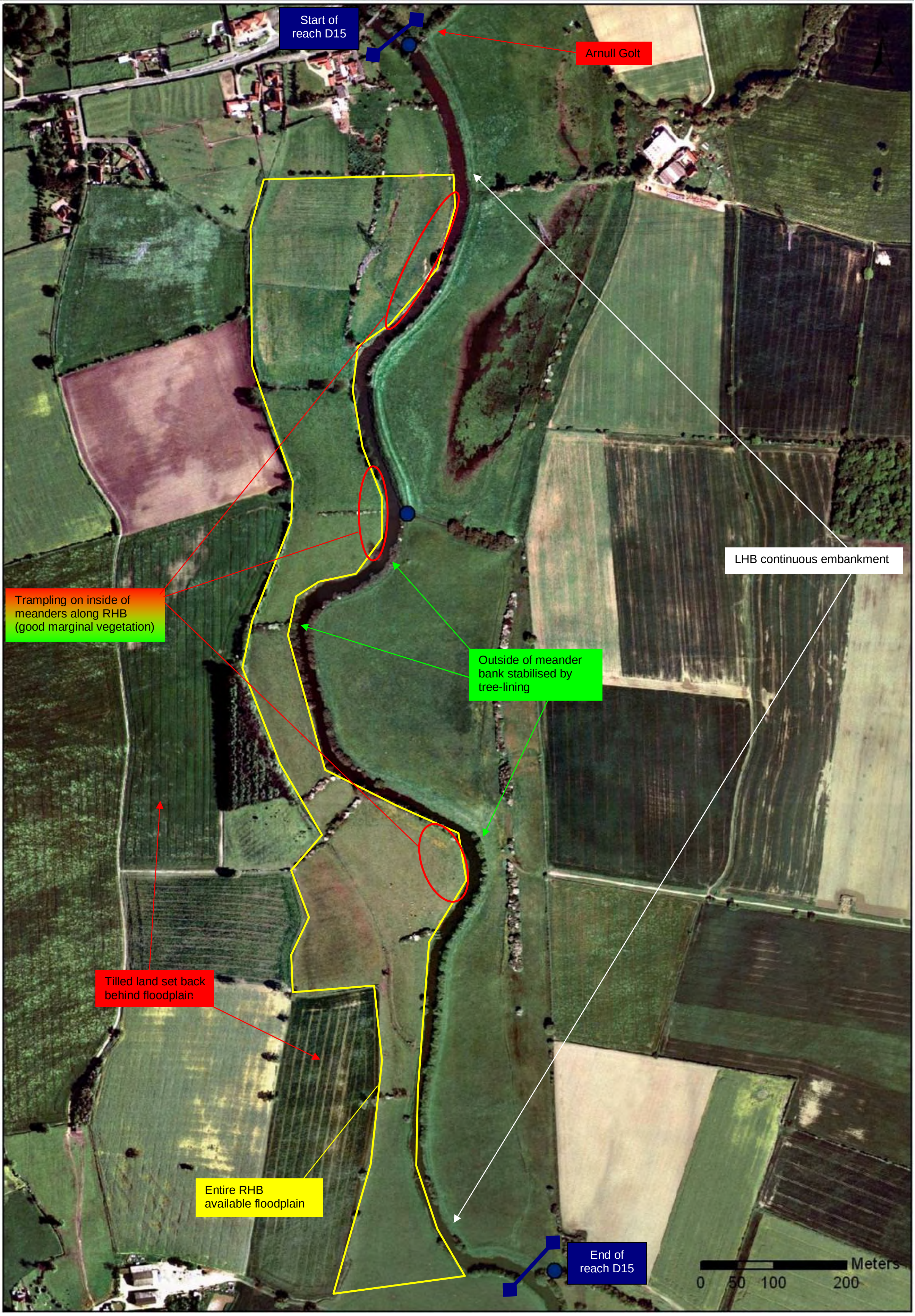
Measures to produce variability within the channel would be required to encourage the swifter flows and gravel substrate favoured by ***R. fluitantis.*** Re-profiling of the banks to reduce the gradient and produce shallow margins would also encourage the interest macrophyte species by increasing marginal habitat.

River and Sea Lamprey

The above measures to create shallower areas with gravel substrate would also benefit river and sea lamprey by producing habitat suitable for spawning. Greater variability of habitat within the channel would also promote shallow areas with stable silt or sand dominated substrate suitable for lamprey nursery habitat.

Otter

Shelter are present for otter, but any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species.


Start of reach D15
Arnull Golt
LHB continuous embankment
Trampling on inside of meanders along RHB (good marginal vegetation)
Outside of meander bank stabilised by tree-lining
Tilled land set back behind floodplain
Entire RHB available floodplain
End of reach D15
Meters
0
50
100
200

Summary Details D16

Upstream survey limit:	SE70781 49346 – End of embankments		
Downstream survey limit:	SE70746 47672 – Start of Elvington / Sutton-upon-Derwent		
Length of river surveyed:	2.08km	Survey reaches:	DER053 – DER055

Geomorphological Character:

Form
- Course of river is sinuous. DS end marks start of large meander.
- The watercourse has a shallow gradient and a predominantly sandy/silty bed.
- Bank material is predominantly fine grained. Dominated by sandy clay, with large proportion of silt. Reach displays an alternating bank profile depending on the position at the inside or outside of a meander. Stable tree-lined cliffs at outside of meander, graded/stepped profile at inside of meander.
- Uniform laminar flow with little or no variation along the entire reach.

Processes
- No in-channel deposition but heavy channel-edge deposition due to trapping by marginal vegetation, focussed exclusively at the inside of meanders. Some minor toe accumulation at base of tree-lined reaches, but not dominant process.
- Historical geotechnical bank failure and evidence of trampling are evident in sections along reach.
- LHB embankment ends at start of reach, natural levees on RHB at US and LHB at mid-section of reach.
- RHB marginal vegetation fenced off in DS section of reach to manage livestock access and trampling.
- RHB inside of meander provides floodplain storage US of Elvington / Sutton-upon-Derwent.
- US end of reach is managed as part of ing management regime – same as previous reach (D15).

Channel Modification
- Land use is dominated by grazing land. Some sections are unimproved. Recreational use along LHB indicated stiles and kissing gates offer access along sections of reach.
- There are no in-channel structures throughout the reach. The RHB has 2 concrete outfalls adjacent to the Elvington Water Treatment Works that are each approximately 10m in length.
- Bank protection is focussed exclusively around the two major intake points at Elvington Water Treatment Works. The entire bank is reinforced with concrete.

Ecological Character:

***Ranunculion fluitantis & Callitricho-Batrachion* Vegetation**
- The channel is too deep and turbid to allow growth of in-channel vegetation.
- The reach lacks swift flow but there are developed marginal zones in this stretch, supporting mainly emergent reeds and grasses.
- The reach has some potential to support the interest macrophytes near the banks.

River and Sea Lamprey
- The submerged roots of the riparian trees provide sufficient shelter for lamprey moving upstream to spawn.
- There is no suitable spawning habitat available in this reach, nor are there likely to be appreciable areas of stable silt as the channel is so uniformly deep and straight.

Bullhead
- The reach is not suitable for bullhead as it lacks swift flowing riffle habitat and is unlikely to have a clean stony substrate (although the substrate was not visible due to the depth and turbidity of the water).
- There is sufficient shading for bullhead, and no areas of excessive vegetation, which suits the species.
- There is no barrier to movement of bullhead in this reach.

Otter
- The reach is suitable for otter to feed, live and even breed as there is sufficient bankside vegetation, tree cover and fish prey available.
- In the upper part of the reach, there is wetland habitat on the floodplain of the left bank.

Key Issues:

Channel Planform Constraints – Water Treatment Works, Embankment & Land Use
The channel crosses the floor of a shallow v-shaped valley. The reach is not as constrained as previous reaches, but is limited in its planform movement by the upstream ing management regime and Elvington Water Treatment Works along a large stretch of the right-hand bank. The works are also protected by a flood embankment, set back from the channel by between 50 and 250m. Land use is mixture of grazing land, the water treatment works on the right-hand bank, and Sutton Wood on the left-hand bank (although the woodland does not reach the channel edge at any point). The majority of the left-hand bank has developed a natural levee.

Geomorphological Functionality
At the upstream end, the sinuous nature of the reach has created zones of natural erosion and deposition. The outside of the meanders consist of eroding cliffs stabilised by tree-lining to prevent bank collapse, some toe scour and eddy scour amongst exposed tree roots, and some minor toe sediment accumulation. The inside of the meanders are have a graded bank profile with thick channel edge vegetation, which encourages sediment deposition.

Ings Management Plan
Livestock access to the channel is limited at the tree-lined cliff and encouraged at an access point at the inside of the meander to enable further bank collapse and the creation of a stepped profile. This is part of the ing management regime. The tree-lining limits planform adjustment, and the channel is heavily restricted from its natural course by the requirements of the adjacent farmland. However, the straightness of the reach is counter-acted by the forced geomorphological response to the ing management regime.

Elvington Water Treatment Works Intakes
The intakes from the treatment works promote sediment deposition at the downstream end of the reach.

Floodplain
There is good floodplain connectivity due to the management of the ings. The inside of the meanders are available as floodplain storage. At the downstream end of the reach, the floodplain on both banks provides flood storage to protect Elvington and Sutton-upon-Derwent.

Reach Summary:

The constraints on the reach are more minimal than in previous reaches. The over-wide and over-deep nature of the channel, constant across the whole river, is the main issue.

The presence of Elvington Water Treatment Works and the downstream proximity of Elvington / Sutton-upon-Derwent are the main constraints on works.

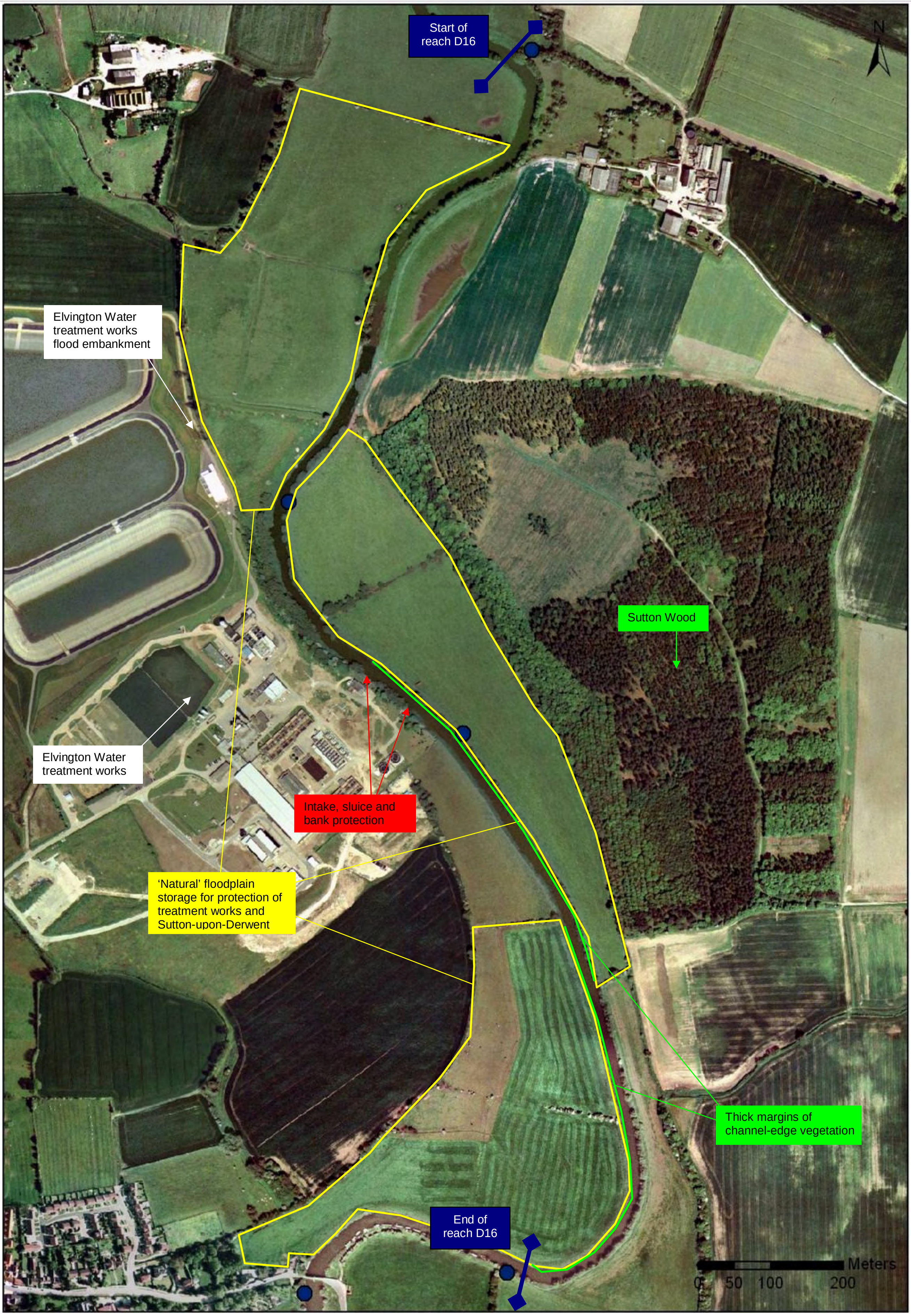
Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis & Callitricho-Batrachion* Vegetation & Bullhead**
Re-grading of the river bed or the use of deflectors to produce variability within the channel would be required to encourage the swifter flows and gravel substrate favoured by ***R. fluitantis.*** Re-profiling of the banks to reduce the gradient and produce shallow margins would also encourage the interest macrophyte species by increasing marginal habitat.

River and Sea Lamprey
The above measures to create shallower areas with gravel substrate would also benefit river and sea lamprey by producing habitat suitable for spawning. Greater variability of habitat within the channel would also promote shallow areas with stable silt or sand dominated substrate suitable for lamprey nursery habitat.

Otter
Shelter is available for otter, but any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species. An improvement in prey availability and habitat quality would enable larger, more resilient otter populations to be supported.

ROYAL HASKONING



Summary Details D17

Upstream survey limit: SE70739 47674 – Start of Elvington / Sutton-upon-Derwent
Downstream survey limit: SE70331 47368 – End of Elvington / Sutton-upon-Derwent
Length of river surveyed: 0.77km Survey reaches: DER056 – DER057

Geomorphological Character:

Form

- Reach composed of two large meanders.
- The watercourse has a shallow gradient, aside from the drop in bed levels at Elvington Sluice. The bed is not engineered at the sluice, and is predominantly composed of sand and silt.
- Bank material is predominantly fine grained (sand clay). The upstream section is characterised by LHB boat moorings stable cliff and RHB graded profile. Bank profile is mixed through Elvington– cliff, stepped, or graded.
- Uniform laminar flow, aside from immediately DS of the weir where high velocity turbulent flow occurs. Marginal deadwaters occur DS of sluice.

Processes

- In-channel deposition is focussed around Sutton Bridge, at the DS end of the in-channel support strut. Bank side deposition occurs due to trapping by bankside vegetation, and there is some toe accumulation DS of sluice.
- Permanent boat moorings in US section reinforced with steel sheet piling along LHB.
- Floodplain storage on RHB US of Sutton Bridge and LHB DS of Elvington Sluice.

Channel Modification

- Dominant land use is unimproved pasture, almost scrubland. Urban land uses at Elvington (NW) and Sutton-upon-Derwent (SE).
- Sutton Bridge and Elvington Sluice are both significant in-channel structures. The bridge has a single support strut in the channel and the sluice is approximately 30-40m wide. The sluice consists of a weir, approximately 1.5m in height, and automatic radial gates.
- Bank protection is concentrated at the 2 structures. Minimal concrete toe protection at Sutton Bridge. Banks are protected with steel sheet piling immediately US and DS of Elvington Sluice.
- There has been no significant channel planform change along the entire reach since 1850.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**

- In the upper part of the reach, the channel is too deep, slow flowing and turbid to support in-channel vegetation.
- There is good marginal habitat present, supporting emergent aquatic vegetation as the banks are not very over-shaded.
- Immediately downstream of the weir, there is swifter flow present that may provide some areas more suitable for ***R. fluitantis***, although none was visible from the bank.

River and Sea Lamprey

- Some bank shelter is provided by riparian trees, so that the reach is suitable for lamprey to pass through.
- The faster flows below the weir may also provide suitable spawning habitat, while the lock (that is rarely used) is likely to provide relatively undisturbed silts for nursery habitat.
- A good fish pass is present, allowing lamprey to migrate upstream.

Bullhead

- The weir may create habitat that is more suitable for bullhead i.e. swifter flows, shallower depth and cleaner substrate.
- The weir is a barrier that bullhead would be unable to pass, there is a good fish pass present that they may be able to navigate as it contains backwaters and areas of slower flow.

Otter

- The reach is suitable for otter to feed and shelter as there is bankside vegetation and tree cover as well as fish prey species available.
- Due to the proximity of Sutton village, boat traffic on the river, and a busy road bridge, there may be too much disturbance for breeding to take place in this area.

Key Issues:

Channel Planform Constraints – Urban Settlements & In-Channel Structures

The channel meanders within a shallow v-shaped valley, constrained on both banks by the settlements of Elvington and Sutton-upon-Derwent and the in-channel structures of Sutton Bridge and Elvington Sluice. Land use is predominantly unimproved pasture, with the two settlements set back from the immediate proximity of the channel. Agricultural land upstream and downstream is likely allocated as floodplain storage to manage flood flow through Elvington and downstream of the sluice.

Residential Lock Island

The lock island is currently being developed as a residential property and despite the likelihood of flood inundation; the island is not dedicated floodplain.

Permanent Boat Moorings

At the upstream end the channel morphology is constrained by the boat moorings along the left-hand bank. Erosion occurs upstream of the permanently-moored boats, and deposition occurs downstream. Sutton Bridge constricts the channel planform.

Marginal & Riparian Vegetation

There is minimal scour upstream of the structure, and the channel widens immediately downstream. Through the section between Sutton Bridge and Elvington Sluice the tree lining and bankside vegetation significantly thickens. Toe undercutting occurs on both banks. Deposition resulting from marginal vegetation occurs immediately upstream of Elvington Sluice and through lock.

In-Channel Structures – Elvington Sluice & Sutton Bridge

Downstream of Elvington Sluice the increased flow turbulence is heavily eroding the left-hand bank. Material accumulates at the bank toe during low flows. The steel piling reinforcement along the right-hand bank which protects the lock building adjacent to the sluice is influencing the natural erosive nature of the channel. The channel is significantly wider at the sluice than in the upstream reach, having eroded back the left-hand bank due to its inability to erode the reinforced right-hand bank.

Reach Summary:

The reach is constrained and influenced heavily by the bank and in-channel structures. The roads, Sutton Bridge, Elvington Sluice and settlements Sutton-upon-Derwent and Elvington and the historic influence of the lock channel leave little room for planform adjustment. The increased flow velocities passing over the weir and the reinforced right-hand bank (to protect the lock island) are leading to widening of the channel, focussed along the left-hand bank. This is likely to be accentuated during flood flow conditions.

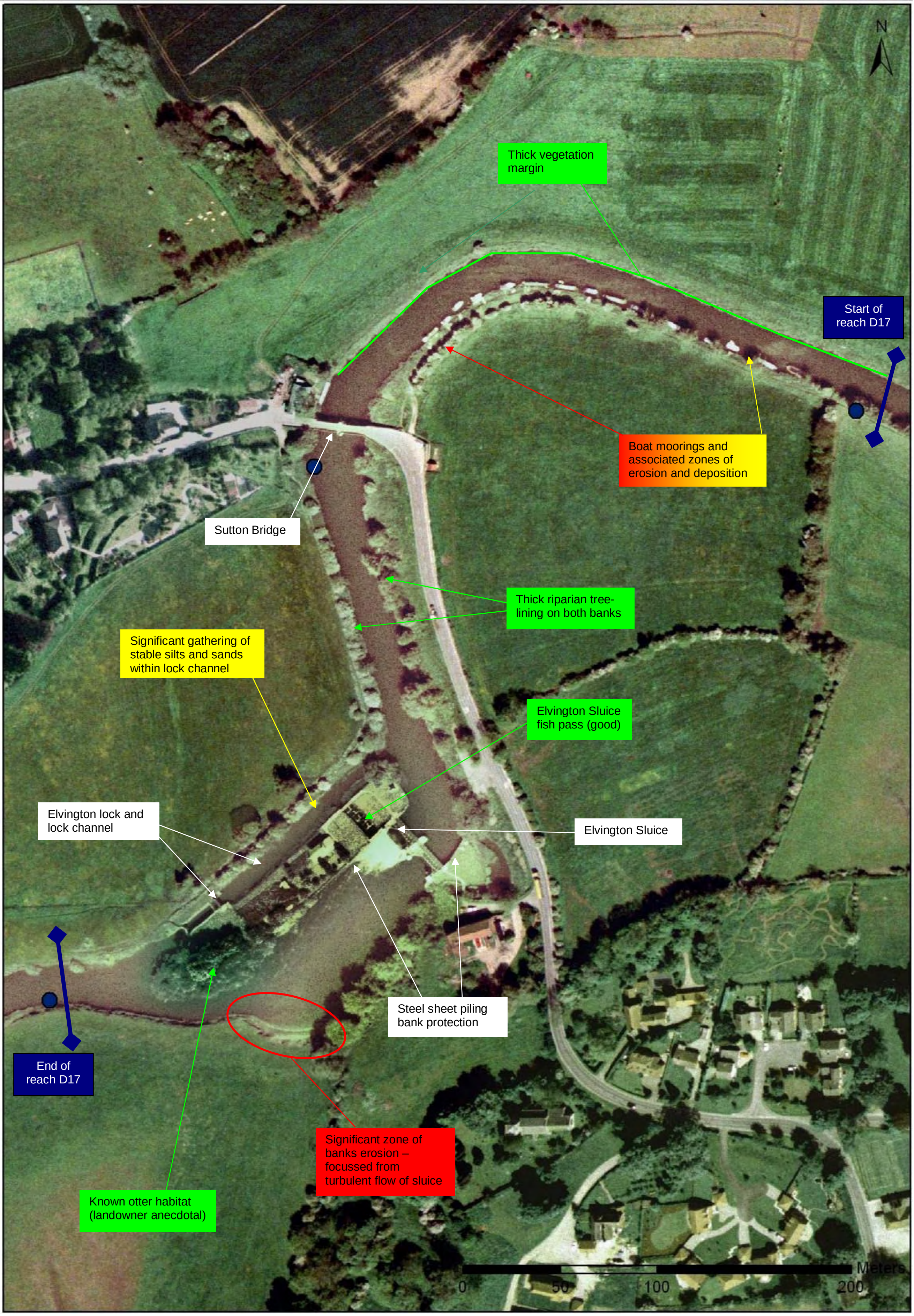
Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation, River and Sea Lamprey & Bullhead**

The area downstream of the weir is suitable for the macrophyte species, bullhead and lamprey spawning, with the influence of the weir (i.e. increased flow velocity) extending an appreciable distance downstream. In-channel works in the lower parts of the reach could potentially capitalise on the presence of some good quality habitat below the weir by extending it downstream.

Otter

The reach can support otters although there may be some disturbance due to the urban setting. Any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species. An improvement in prey availability and habitat quality would enable larger, more resilient otter populations to be supported.


N
Thick vegetation margin
Start of reach D17
Boat moorings and associated zones of erosion and deposition
Sutton Bridge
Thick riparian tree-lining on both banks
Significant gathering of stable silts and sands within lock channel
Elvington Sluice fish pass (good)
Elvington lock and lock channel
Elvington Sluice
Steel sheet piling bank protection
End of reach D17
Significant zone of banks erosion – focussed from turbulent flow of sluice
Known otter habitat (landowner anecdotal)
0
50
100
200
Meters

ROYAL HASKONING

Summary Details D18

Upstream survey limit:	SE70331 47368 – End of Elvington / Sutton-upon-Derwent		
Downstream survey limit:	SE69746 42533 – Pocklington Canal		
Length of river surveyed:	6.26km	Survey reaches:	DER058 – DER063

Geomorphological Character:

Form

- Irregular meandering reach, with locally straight sections.
- The watercourse has a shallow gradient and a sandy/silty bed. Marginal deadwaters are present at the DS end of the reach.
- Channel located within a shallow v-shape valley that flattens to a terraced valley floor at the DS end.
- Bank material is predominantly fine grained. Dominated by sandy clay, with large proportion of silt. Mixed bank profile, varying from stable vegetation-supported cliffs, stepped (historical trampling and bank slump) or graded depending on adjacent land use.
- Uniform laminar flow with little or no variation along the entire reach.

Processes

- Toe accumulation occurs along the grazed stretches along both banks as a result of trapping by marginal vegetation. Toe scour is widespread.
- There are 3 instances of an altered planform course along the reach: DS of Sutton-upon-Derwent (RHB); adjacent to Low Grounds (RHB); and the Old Course of the Derwent (LHB) around Wheldrake Ings. These changes all occurred prior to 1850. The cut off meanders are still visible.
- The reach is fed into by the Old Course of the Derwent and Common Drain. Both carry large quantities of sediment providing drainage for tilled agricultural land.
- US of the Old Course of the Derwent, the LHB has a levee set back approximately 5m.

Channel Modification

- Land use is dominated by pasture. Small sections of common scrubland have been allowed to overgrow into a riparian corridor separating footpaths from the immediate channel edge. Tilled land occasionally comes into close proximity of the channel, bounded by a thin riparian corridor.
- There are no in-channel structures in the reach. A bridge crosses the channel at the US end of Wheldrake Ings but it has no in-channel support struts or bankside protection.
- There is no bank protection along any part of the reach.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**

- The channel is deep and turbid in this reach and no in-channel vegetation was evident and so this reach is not very suitable for ***R. fluitantis***.
- Some good marginal habitat is available where tree lining is less dense.
- Open areas (i.e. those not over-shaded by trees) support good margins of emergent reeds, but no ***Callitriche*** spp. was visible.

River and Sea Lamprey

- Extensive lining of the banks by riparian trees, and the presence of in-channel debris provides abundant shelter for lamprey moving up-river to spawning areas.
- There is no habitat or flow suitable for spawning in this reach, or shallow areas to provide nursery habitat.

Bullhead

- The reach is unlikely to be suitable for bullhead as it lacks faster flow and is unlikely to have clean stable gravel on its substrate (although the substrate was not visible).
- The presence of cover and shading means that the reach is suitable for bullhead, and the absence of barriers means that, if present, they could potentially move around freely.

Otter

- Good shelter is available for otters as there are many trees lining parts of the banks and the floodplain contains appreciable areas of wetland.
- This reach is very suitable for otters to live and breed undisturbed.

Key Issues:

The reach is located at the base of a shallow v-shaped / terraced valley floor. The reach has irregular meanders, although localised reaches have been straightened.

Historical Trampling & Geotechnical Bank Failure

Grazing dominates the reach and influences the bank profile and depositional characteristics of the channel. Historical trampling and bank slumping (possibly aided by trampling) are present throughout the reach, defining the bank profile. The banks are very high, as result of the faster flows from the upstream weir scouring out the channel and re-grading in straightened sections.

Limited Geomorphological Functionality

Erosion is interspersed between zones of deposition, focussed around tree roots and areas where marginal vegetation cover recedes. Deposition is the more dominant feature; sediment deposition due to marginal vegetation is widespread.

Cut-Off Meanders

The cut-off meanders show no significant geomorphological difference from the main channel. These features have ecological value. The banks opposite the cut offs are more severely eroded. Deposition occurs immediately downstream. The Old Course of the Derwent has altered its geomorphology to an agricultural drain; dredged, straightened and with uniform bank profiles, inundated with sediment.

Tributaries

Common Drain and the Old Course of the Derwent receive drainage from agricultural land from the set back tilled land in the valley. This is likely to contribute sediment to the system.

Reach Summary:

There are no natural zones of erosion or deposition, and a general lack of geomorphological activity or diversity.

Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation & Bullhead**

Measures to produce variability within the channel would be required to encourage the swifter flows and gravel substrate favoured by ***R. fluitantis*** and Bullhead.

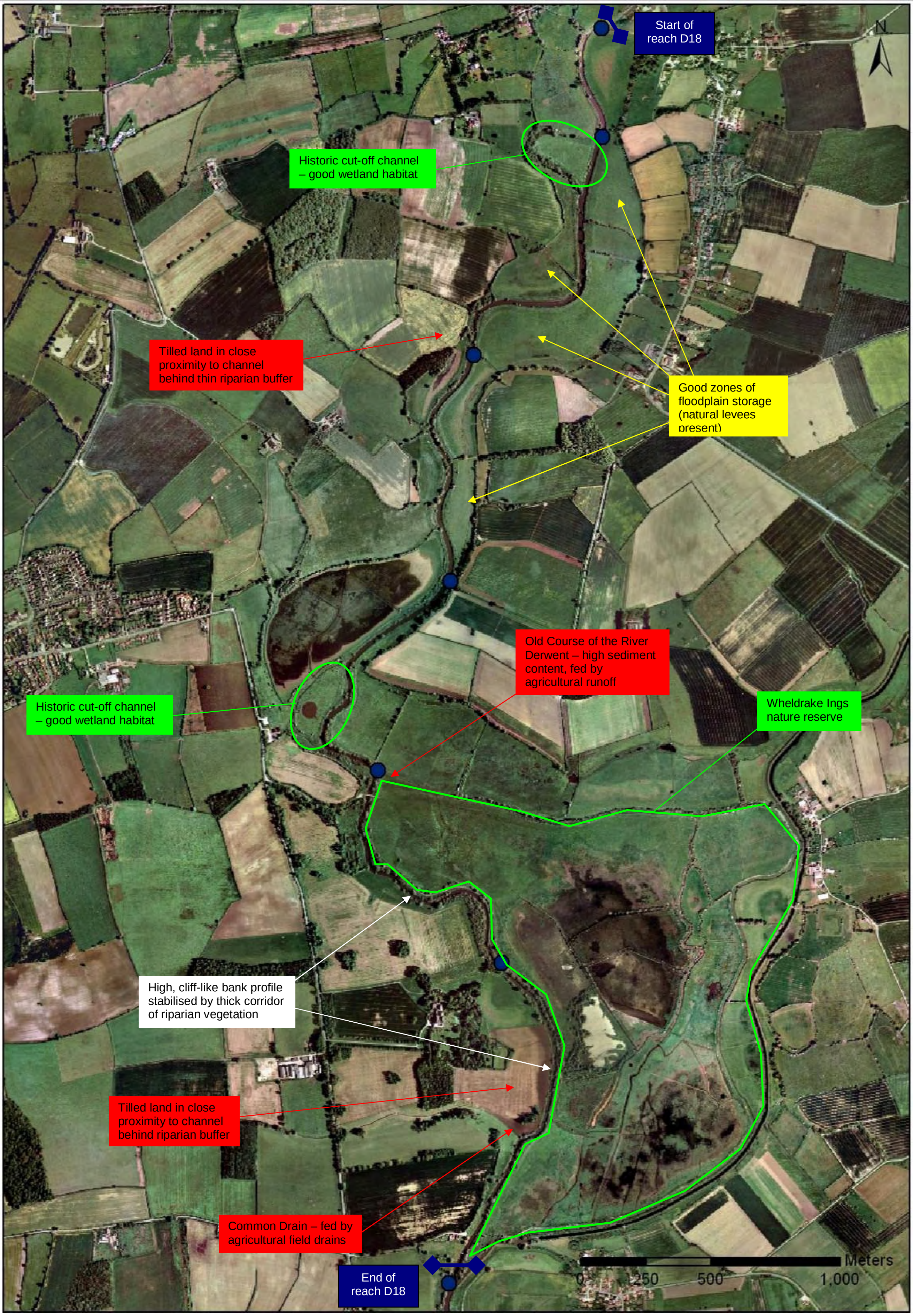
River and Sea Lamprey

The above measures to create shallower areas with gravel substrate would also benefit river and sea lamprey by producing habitat suitable for spawning. Greater variability of habitat within the channel would also promote shallow areas with stable silt or sand dominated substrate suitable for lamprey nursery habitat.

Otter

Any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species. An improvement in prey availability and habitat quality would enable larger, more resilient otter populations to be supported.

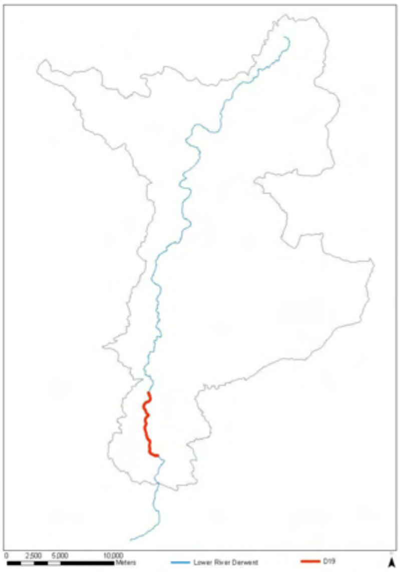
ROYAL HASKONING



ROYAL HASKONING

Summary Details D19

Upstream survey limit:	SE69764 42531 – Pocklington Canal		
Downstream survey limit:	SE70721 36496 – Bubwith		
Length of river surveyed:	7.37km	Survey reaches:	DER064 – DER072



Geomorphological Character:

Form

- Slightly sinuous planform comprised of straight reaches between small meanders.
- Watercourse has shallow gradient and sandy/silty bed.
- Fine grained bank material (sandy/silty clay). Reach displays an almost entirely uniform profile, with a graded slope from embankment to channel edge. Occasional stepping of profile caused by trampling. Small section of stable tree-lined cliff.
- Uniform laminar flow with little or no variation across the entire reach. Some marginal deadwaters at US end and within woodland section.

Processes

- Considerable channel-edge deposition due to trapping by marginal vegetation, focussed along large sections of the LHB and RHB. Some minor toe accumulation deposition at base of stepped bank profiles, contributed by trampling.
- Reach is located within the ings. Floodplain vegetation and livestock access is managed.
- Historical geotechnical bank failure and evidence of trampling evident in sections along reach.
- Freer Dike, Old Derwent, Ings Drain, Pickering Drain, Bottoms Drain and Main Drain all feed into reach. All sediment-rich.
- Floodplain levees present within embankments (LHB natural, RHB man-made). RHB levee built up to protect wetland habitat; significant geotechnical failure and bank erosion at location.

Channel Modification

- Land use is dominated by ings, which are waterlogged or wet underfoot. Some sections unimproved pasture. Small section of woodland along RHB where bank profile alters.
- There are no in-channel structures throughout the reach. Sluice outfalls are located on LHB and RHB adjacent to major ing drains. Outfalls are concrete reinforced for approximately 2m.
- Embankments are set back by between 10 and 35m on both banks, and line the channel for the entire reach.
- There has been no significant channel planform change along the reach since 1850.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**

- The channel is too deep, turbid and slow-flowing to support the interest macrophyte species.
- There is also very little marginal habitat and hence marginal vegetation present.
- The reach is eminently unsuitable for the interest species.

River and Sea Lamprey

- There is little shelter for migrating lamprey, spawning or nursery habitat present.
- The reach is not at all suitable for lamprey, although they clearly do pass through this reach as they are known to spawn upstream.

Bullhead

- There is no swift flow, and it is unlikely there are clean gravels present for bullhead.

Otter

- Otter may feed in this reach, but there is very little cover available, so they are not likely to breed here.
- The extended lack of shelter in this reach may even act as a barrier to otter movements, contributing to fragmentation of the population.

Key Issues:

Channel Planform Constraints – Embankments

The channel crosses the base of a terraced valley floor. The reach is highly constrained on both banks by the presence of embankments for flood protection and water-logging of the adjacent ings farmland. The set back of the embankment defines the immediate floodplain. Grazing is the predominant land use adjacent to the channel; tilled land is set back behind the embankments on both banks.

Trampling & Ings Cloughs

Considerable input of fine sediment from bank erosion (trampling) and sluiced ing outfalls into the main channel system, sourcing from the surrounding drains.

High Uniformity

Deposition is dominant, and is focussed around historical bank slumps and trampling, tree-lining, and intermittent thick marginal vegetation. The heavily modified nature of the reach is reflected in the straightness and uniformity of the entire length of the river. Floodplain connectivity is good.

Increased Channel Turbidity

Turbidity is much greater than in previous reaches. The channel appears to be conveying an increased sediment load and increased flow downstream of the confluence with the Pocklington Canal at the upstream end.

Attempted (Failed) Wetland Floodplain Protection

The discrete section of man-made levee on the right-hand bank inside the meander, immediately opposite Ings Lane, appears to have been constructed to protect the wetland habitat currently located on the right-hand bank floodplain. Re-grading and protection appears to have failed as geotechnical bank slumping and eroding cliffs are widespread; heavy deposition occurs immediately downstream. The ecological value of the area is questionable but could be enhanced.

A163 Road

At the downstream end of the reach the right-hand embankment merges with the A163 road. The road is built on the top of the slope and as such the embankment is not present. The steep gradient of this slope means that water and sediment runoff from the road rapidly enter the channel, with no floodplain attenuation.

Reach Summary:

The channel is severely constricted along both banks by the presence of the flood embankments.

The reach is managed for the benefit of the adjacent ings. There is very limited geomorphological or ecological functionality and diversity, and no natural zones of erosion or deposition. The embankments and straightened channel create a flume-like channel in flood conditions.

Cattle trampling is also a minor issue.

Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**

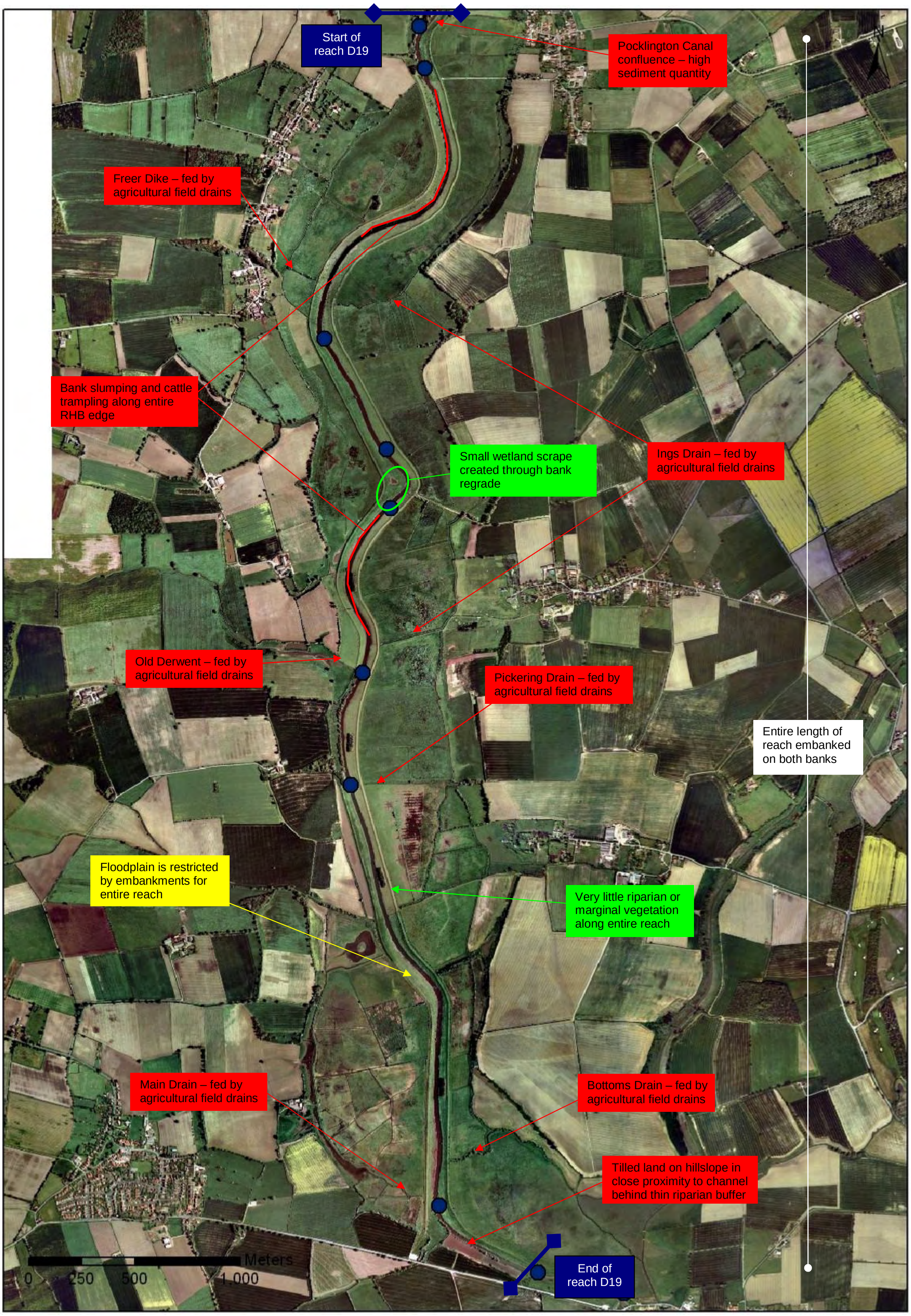
Re-grading of the river bed or the use of deflectors to produce variability within the channel would be required to encourage the swifter flows and gravel substrate favoured by ***R. fluitantis*** and Bullhead.

River and Sea Lamprey

The above measures to create shallower areas with gravel substrate would also benefit river and sea lamprey by producing habitat suitable for spawning. Greater variability of habitat within the channel would also promote shallow areas with stable silt or sand dominated substrate suitable for lamprey nursery habitat. Planting of the banks would provide much needed shelter for migrating lamprey.

Otter

Planting of the banks would provide much needed shelter to make this reach more hospitable for otter. Management of the floodplain to create wetland would also benefit the species.


Start of
reach D19
Pocklington Canal
confluence – high
sediment quantity
Freer Dike – fed by
agricultural field drains
Bank slumping and cattle
trampling along entire
RHB edge
Small wetland scrape
created through bank
regrade
Ings Drain – fed by
agricultural field drains
Old Derwent – fed by
agricultural field drains
Pickering Drain – fed by
agricultural field drains
Entire length of
reach embanked
on both banks
Floodplain is restricted
by embankments for
entire reach
Very little riparian or
marginal vegetation
along entire reach
Main Drain – fed by
agricultural field drains
Bottoms Drain – fed by
agricultural field drains
Tilled land on hillslope in
close proximity to channel
behind thin riparian buffer
Meters
0 250 500 1,000
End of
reach D19

Summary Details D20

Upstream survey limit:	SE70781 49346 – Bubwith
Downstream survey limit:	SE70746 47672 – Start of Menthorpe
Length of river surveyed:	2.34km
Geomorphological reaches:	D20 (DER073 – DER076)

Geomorphological Character:

Form
- Generally straight course, with a single large meander immediately DS of Bubwith Bridge.
- The watercourse has a shallow gradient and a predominantly sandy/silty bed.
- Bank material is dominated by sandy clay, with a large proportion of silt. Reach displays mixed bank profiles depending on the position of meander and bankside vegetation. Dominant profiles are stable tree-lined cliffs and historically trampled/slumped profile.
- Uniform laminar flow with little or no variation along the reach. Some ponding and marginal deadwaters amongst exposed tree roots.

Processes
- Majority of channel-edge deposits consist of toe accumulation interspersed between marginal vegetation. Historical bank slumping/trampling has added channel edge toe accumulation.
- Little or no in-channel vegetation evident along the entire reach. Entire RHB exposed, with no bankside vegetation cover. Marginal vegetation along entire RHB and on LHB downstream of former railway bridge. LHB is tree-lined. Thin riparian corridor observed on both banks DS of railway bridge.
- DS of railway bridge, both banks have high gradients. Floodplain constrained by embankments on both banks.
- The reach is fed into by Dyon Drain, which carries large quantities of sediment.

Channel Modification
- Land use is dominated by grazing land. Entire RHB is grazed by cattle. LHB has settlement of Bubwith at US end.
- There are no in-channel structures in the reach. Bubwith Bridge crosses the river at the US end of the reach, and the former railway viaduct crossed at the mid-point. Neither have in-channel support struts.
- Channel planform has not changed since 1850.
- Bank protection focussed exclusively around 2 bridges crossing the channel. Concrete reinforcement lines LHB and RHB for approximately 10m on both banks. Embankments line RHB for entire reach, set back between 10-300m from channel. LHB embankments start US of disused railway bridge, set back 10-25m.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**
- The channel is deep and turbid with no in-channel vegetation evident,
- Some good marginal habitat has been created by trampling leading to bank collapse followed by subsequent stabilisation. Some shallow marginal habitat has been created by this process that supports small areas colonised by ***Callitriche*** spp.

River and Sea Lamprey
- The presence in many areas of riparian trees and in-channel debris means that there is sufficient shelter for lamprey moving up-river to spawning areas.
- There is no habitat or flow suitable for spawning in this reach, or shallow areas to provide nursery habitat.

Bullhead
- The reach is unlikely to be suitable for bullhead as it lacks faster flow and is unlikely to have clean stable gravel on its substrate (although the substrate was not visible).
- The presence of cover and shading is suitable for bullhead, and the absence of barriers means that, if present, they could potentially move around freely.

Otter
- The reach is suitable for otter to feed and shelter as there is bankside vegetation and tree cover as well as fish prey species available.

Key Issues:

Channel Planform Constraints – Embankments & Urban Settlement
The channel is comprised of a low-sinuosity meander that skirts the village of Bubwith, over a terraced valley floor. The channel is constrained on both banks for the majority of the reach. At the upstream end, the channel is constrained on the left-hand bank by the settlement of Bubwith. The right-hand bank is embanked. At the apex of the meander the embankments are set back approximately 300m. The set back is to enable floodplain storage and prevent flood waters, funnelled through Bubwith Bridge, from overtopping into Bubwith by encouraging inundation on the opposite bank. Downstream of the railway bridge the flood embankments constrict the floodplain to a width of approximately 5-20m, creating a flume-like channel during flood conditions. Marginal vegetation is denser in the downstream reach, where the dominant geomorphological function is deposition.

Intensive Agricultural Land Use – RHB
The right-hand bank floodplain is grazed pasture, continuing on the right-hand bank for the entirety of the reach.

Trampling & Geotechnical Bank Failure
Zones of erosion and deposition are focussed around marginal vegetation and overhanging riparian bows. Toe scour is widespread underneath the riparian vegetation line. In the upstream section of the reach, adjacent to the floodplain, trampling and bank slumping is widespread.

Tributary
Dyon Drain supplies overland flow from agricultural land into the main channel. This is likely to be a significant source of sediment to the system.

Reach Summary:

The flood embankments and the urban residential area of Bubwith mean there is limited potential for planform adjustment.

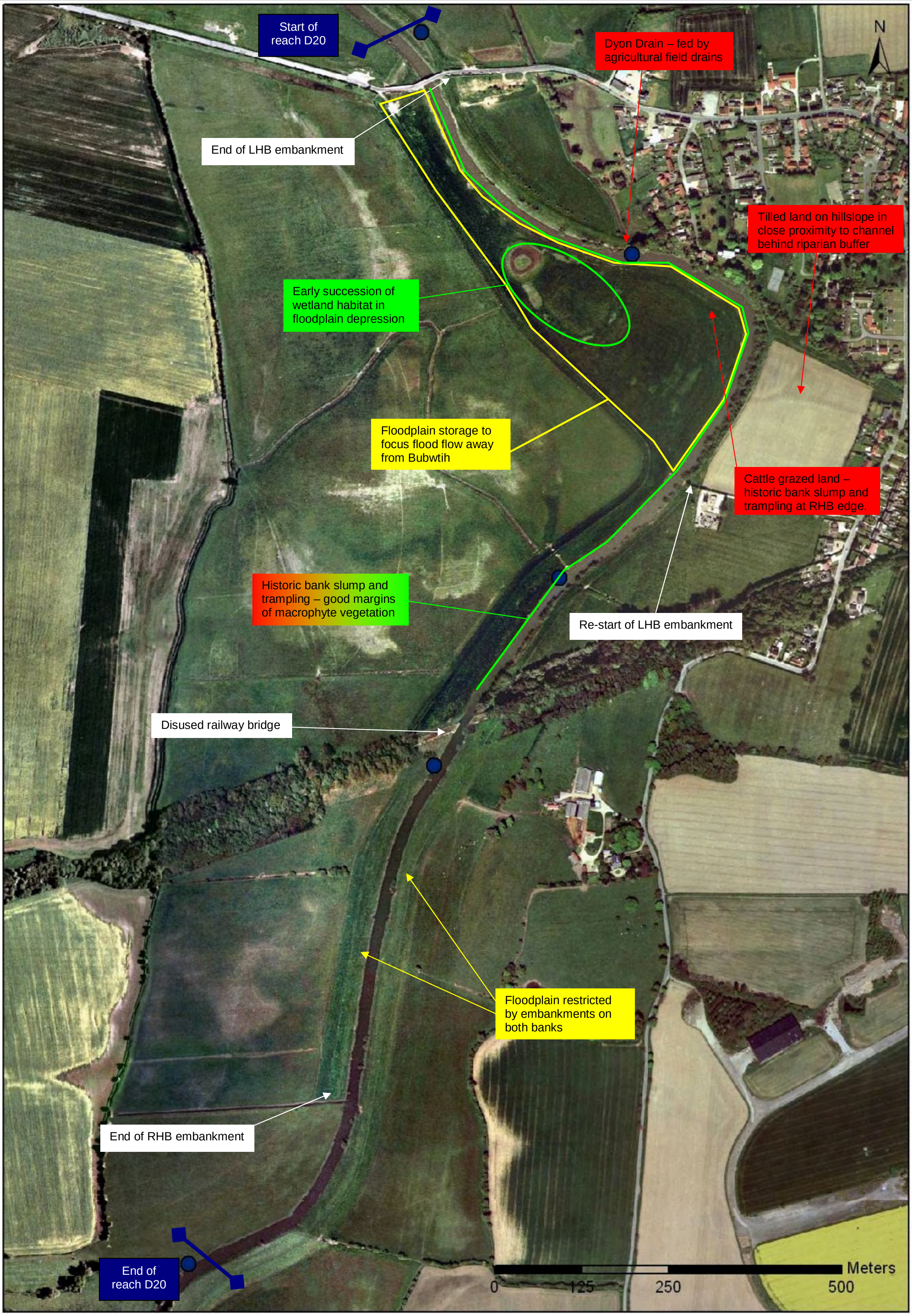
The cattle trampling along almost the entirety of the right-hand bank is an issue.

Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**
Fencing of trampled areas to allow them to stabilise could lead to the establishment of better marginal habitat supporting ***Callitriche*** spp. Re-grading of the river bed, or the use of deflectors to produce variability within the channel would be required to encourage the swifter flows and gravel substrate favoured by ***R. fluitantis*** and Bullhead.

River and Sea Lamprey
The above measures to create shallower areas with gravel substrate would also benefit river and sea lamprey by producing habitat suitable for spawning. Greater variability of habitat within the channel would also promote shallow areas with stable silt or sand dominated substrate suitable for lamprey nursery habitat.

Otter
Any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species. An improvement in prey availability and habitat quality would enable larger, more resilient otter populations to be supported.


Start of reach D20
Dyon Drain – fed by agricultural field drains
N
End of LHB embankment
Tilled land on hillslope in close proximity to channel behind riparian buffer
Early succession of wetland habitat in floodplain depression
Floodplain storage to focus flood flow away from Bubwtih
Cattle grazed land – historic bank slump and trampling at RHB edge.
Historic bank slump and trampling – good margins of macrophyte vegetation
Re-start of LHB embankment
Disused railway bridge
Floodplain restricted by embankments on both banks
End of RHB embankment
End of reach D20
0
125
250
500
Meters

Summary Details	D21		
Upstream survey limit:	SE70380 34719 – Start of Menthorpe		
Downstream survey limit:	SE70318 34349 – End of Menthorpe		
Length of river surveyed:	0.40km	Survey reaches:	DER077

Geomorphological Character:

Form

- Relatively straight course located on outside of a low-sinuosity meander.
- The watercourse has a shallow gradient and sandy/silty bed.
- Hillslopes come into closer proximity of the channel on RHB. Set back approximately 80m. Embankments are not present along the reach (ended upstream of the meander).
- Bank material is predominantly fine grained (sandy clay). The RHB bank profile is predominantly a steep stable cliff with bankside and marginal vegetation. LHB is graded to accommodate recreational land uses.
- Uniform laminar flow with little or no variation across the entire reach.

Processes

- Channel-edge deposits significant where trapped by marginal vegetation, focussed along large sections of RHB. Sediment accumulates in the gaps between moored boats. Some minor toe accumulation occurs at base of collapsed banks.
- Little or no in-channel vegetation. At bankside, exposed grassland on both banks leads down to thick marginal vegetation.
- Two minor becks feed into main channel at RHB at the upstream and downstream extents of reach.
- Bank heights are raised immediately DS of agricultural drain at apex of meander. Eroding cliffs and toe scour erosion focussed predominantly on RHB.
- Evidence of historical bank slumping and historic and recent trampling on RHB.
- Moored boats line entire LHB. Erosion and deposition zones focussed at either end of each individual boat.

Channel Modification

- Land use differs between banks. RHB comprised of grazed pasture. LHB used for recreational purposes (boat hire business), and surrounding land is mowed.
- There are no in-channel structures in the reach.
- Boat moorings are secured with steel sheet piling that intermittently lines the LHB. Some sections of banks are stabilised with scaffolding.
- There has been no significant channel planform change along the entire reach since 1850.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**

- The channel is too deep, turbid and slow-flowing to support the interest macrophyte species.
- There are some areas of marginal vegetation present, consisting of emergent reeds, but the reach is not suitable for the interest species.

River and Sea Lamprey

- Some bank shelter is provided by riparian trees, so that the reach is suitable for lamprey to pass through.
- There is no habitat suitable for spawning, however, and due to the straightness and uniformity of the channel.
- Unlikely there are stable silts suitable for nursery habitat.

Bullhead

- The reach is unlikely to be suitable for bullhead as it lacks faster flows and is unlikely to have clean stable gravel on its substrate (although the substrate was not visible).
- The presence of some cover and shading provides some shelter for bullhead.
- The absence of barriers means that, if present, they could potentially move around freely.

Otter

- The presence of some riparian trees and rank vegetation means that there is shelter available for otter.
- The presence of moored boats and a holiday park on the left bank means that the area may be too disturbed to allow breeding to take place.

Key Issues:

Change in Character – Lack of Embankments

The channel is located in a shallow v-shaped valley from which the flood embankments have are no longer present on both banks. The purpose behind the lack of flood embankments at this location is likely to be related to Hall Farm – situated slightly up the valley side. Livestock access to the river is not limited at any point in previous reaches but may have initially been focussed immediately adjacent to the farm. However, the reach is also located on the outside of a meander so may have historically been more disconnected than the left-hand bank.

Intensive Adjacent Land Use

Land use is separated by the activities on each bank. Grazing on the right-hand bank is replaced by recreational activities on the left-hand bank. The left-hand bank is heavily managed (mown) and appears to have been re-graded to allow access to boat moorings. Both banks are exposed, lacking in riparian vegetation. Again, this is a result of the land uses on the respective banks. Natural eroding cliffs are located on the right-hand bank at the meander apex.

Boat Moorings, Historical Bank Slumping & Geotechnical Bank Failure

Zones of erosion have developed along the left-hand bank between moored boats. Thick vegetation margins are present in isolated places on both banks – adjacent to historic bank slumping and trampling on the right bank and in the deadwaters created by the moorings on the left bank.

Overland Hillslope Sediment Supply

Both banks are likely to contribute sediment from overland runoff. However, the marginal corridor is likely to impede this input to some extent.

Limited Floodplain

The reach has a limited floodplain. Floodplain would naturally be present on the inside of the meander (left-hand bank) but the location of the settlement and boat moorings has limited this. They are at risk of flooding. Bank height is higher on the right-hand bank.

Reach Summary:

The lack of embankments changes the geomorphological functionality of the reach. Bank height has increased.

Boat mooring and boats lining the left-hand bank significantly impacts on the zones of erosion and deposition.

Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation & Bullhead**

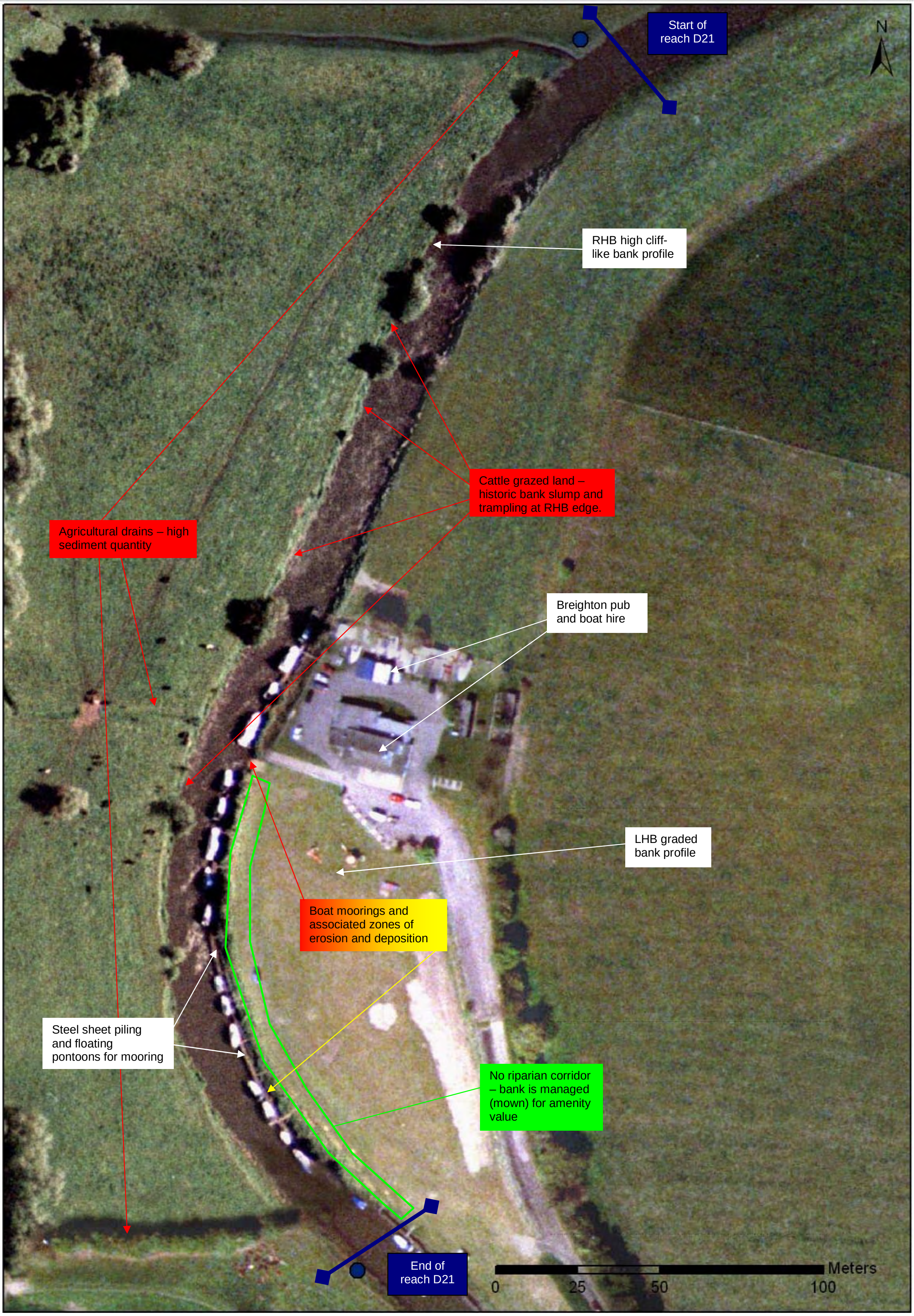
Measures to produce variability within the channel would be required to create the shallower areas and gravel substrate favoured by ***R. fluitantis*** and Bullhead**.** Re-profiling of the banks to reduce the gradient and produce shallow margins would also encourage the interest macrophyte species by increasing marginal habitat.

River and Sea Lamprey

The above measures to create shallower areas would also benefit river and sea lamprey by producing habitat suitable for spawning. Greater variability of habitat within the channel would also promote shallow areas with stable silt or sand dominated substrate suitable for lamprey nursery habitat.

Otter

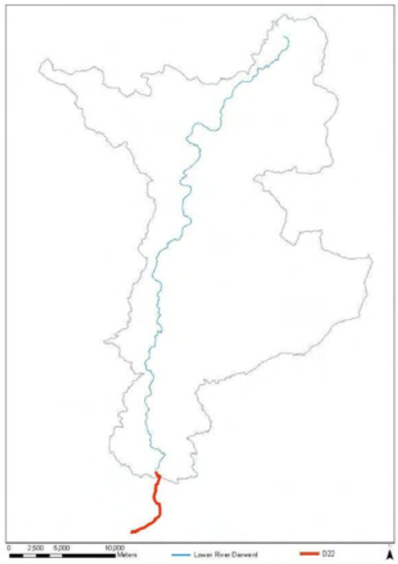
Some shelter is already present for otter, but any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species. An improvement in prey availability and habitat quality would enable larger, more resilient otter populations to be supported.



Start of reach D21
N
RHB high cliff-like bank profile
Cattle grazed land – historic bank slump and trampling at RHB edge.
Agricultural drains – high sediment quantity
Breighton pub and boat hire
LHB graded bank profile
Boat moorings and associated zones of erosion and deposition
Steel sheet piling and floating pontoons for mooring
No riparian corridor – bank is managed (mown) for amenity value
End of reach D21
Meters
0
25
50
100

Summary Details D22

Upstream survey limit: SE70321 34351 – End of Menthorpe
Downstream survey limit: SE68054 28606 – Barmby Barrage
Length of river surveyed: 7.96km Survey reaches: DER078 – DER084



Geomorphological Character:

Form
- Straightened reaches within large meander bend.
- The watercourse has a shallow gradient and a sandy/silty bed with a large proportion of silt in places. Both banks display a stepped/graded profile from top of embankment down to channel edge.
- Uniform laminar flow with little or no variation. Some marginal deadwaters beneath overhanging riparian tree-line.

Processes
- Channel-edge deposits trapped amongst marginal vegetation along sections of RHB. Sediment accumulation beneath overhanging bows of riparian tree-line on LHB. Minor toe accumulation at base of collapsed banks.
- Little or no in-channel vegetation. Bankside, exposed grassland on both banks lead down to thick vegetation margin.
- Scarcemoor Dike feeds into the main channel DS of Bowthorpe Hall. This conveys high quantities of sediment.
- Evidence of historical bank slumping and historic and recent trampling along large sections of RHB.
- Moored boats line sections of LHB. Zones of erosion and deposition focussed around individual boats.

Channel Modification
- Land use is predominantly agricultural (grazing) on both banks. Loftsome Water Treatment Works is located on the LHB DS of Loftsome Bridge. Both banks along entire reach are embanked.
- Barmby Barrage is a major in-channel structure at the very DS end of the reach. Wressle railway bridge and Loftsome road bridge both cross the reach but have no in-channel supports.
- Discrete sections of bank protection. Wressle railway bridge and Loftsome road bridge have concrete reinforced banks to prevent erosion. Loftsome Water Treatment Works has 2 large LHB concrete-reinforced intake structures. US of Barmby Barrage 3 intake gates are separated at intervals along the RHB and concrete reinforce the bank.
- No significant channel planform change along the entire reach since 1850. The cut-off meander DS of Loftsome has now been straightened and the Loftsome Water Treatment Works uses the original confluences as in-takes.

Ecological Character:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation**
- The channel is too deep, turbid and slow-flowing to support the interest macrophyte species.
- Some areas of marginal vegetation present, consisting of emergent reeds, and a few places where the bank has a shallow gradient (due to historical trampling).
- The reach is not very suitable for the interest macrophyte species.

River and Sea Lamprey
- Some bank shelter is provided by riparian trees, so that the reach is suitable for lamprey to pass through.
- There is no habitat suitable for spawning, and due to the straightness and uniformity of the channel.
- It is unlikely there are stable silts suitable for nursery habitat.

Bullhead
- The reach is unlikely to be suitable for bullhead as it lacks faster flows and is unlikely to have clean stable gravel on its substrate.
- The presence of some cover and shading provides some shelter for bullhead,
- The absence of barriers means that, if present, they could potentially move around freely.

Otter
- The presence of some riparian trees and vegetation provides shelter for otter.
- The reach is suitable for otter to feed and pass through.
- Otter may even breed in this reach, although the shelter is patchy.

Key Issues:

Channel Planform Constraints – Embankments
The channel crosses the base of a terraced valley floor. The reach is highly constrained on both banks by the presence of embankments for flood protection and water-logging of the adjacent farmland. The set back of the embankment defines the immediate floodplain. As per reach D20, the channel is constricted and acts as a flume under flood conditions. The embankments are located close to the channel and the floodplain is minimal, encouraging flood conveyance.

Sediment Input From Intensive Agricultural Land Use
Grazing is the predominant land use adjacent to the channel; tilled land is set back behind the embankments on both banks. High input of fine sediment from bank erosion (trampling) and sluiced ing outfalls that drain the adjacent tilled land.

Historical Trampling & Geotechnical Bank Failure
There are few zones of erosion or deposition along the entire reach. These are focussed exclusively around historical bank slumping and trampling, the tree-lining along a large section of the LHB, and intermittent thick marginal vegetation. The heavily modified nature of the reach is reflected in the straightness and uniformity of the entire length of the river. Connectivity is good within the constrained floodplain offered by the embankment lining.

Water Abstraction – Loftsome Water Treatment Works
The intake structures for Loftsome Water Treatment Works use the old course of the meander. This is reflected in the straightened nature of the channel. The straightening was completed prior to 1850 but may have been opened up again for use in the treatment works.

Barmby Barrage Impoundment
Barmby Barrage dominates the downstream end of the reach. The channel is heavily impounded by the dam-like function of the barrage. The channel is significantly wider at the downstream end, historically dredged and widened for navigational purposes. The geomorphological functionality is limited party due to this – there are restricted natural zones of erosion and deposition, despite the slightly sinuous planform.

Bridges – Wressle Railway Bridge & Loftsome Bridge
Some upstream scour at both bridge structures.

Reach Summary:

The constrained nature of the embankments, the railway bridges, the urban residential area of Loftsome and its associated water works, and the downstream Barmby Barrage means the channel is heavily modified. This is impacting on the lack of geomorphological functionality of the reach.

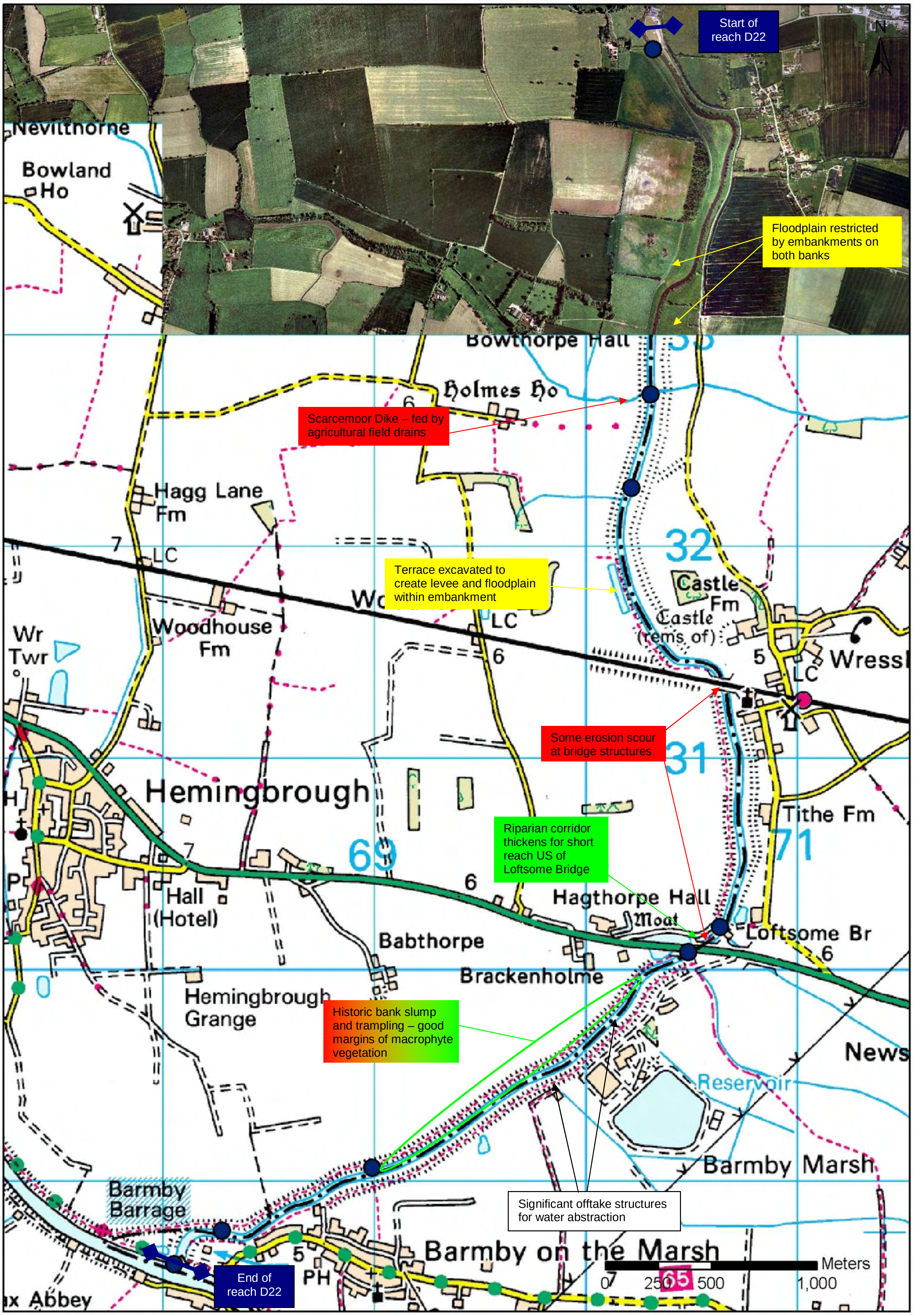
The cattle trampling along almost the entirety of the right-hand bank is also an issue.

Reach Potential Based on Existing Ecology:

***Ranunculion fluitantis* & *Callitricho-Batrachion* Vegetation & Bullhead**
Measures to produce variability within the channel would be required to create the shallower areas and gravel substrate favoured by ***R. fluitantis*** and Bullhead**.** Re-profiling of the banks to reduce the gradient and produce shallow margins would also encourage the interest macrophyte species by increasing marginal habitat.

River and Sea Lamprey
The above measures to create shallower areas with gravel substrate would also benefit river and sea lamprey by producing habitat suitable for spawning. Greater variability of habitat within the channel would also promote shallow areas with stable silt or sand dominated substrate suitable for lamprey nursery habitat.

Otter
Shelter are already present for otter, but any improvements made to the channel or sediments dynamics would benefit otters indirectly by benefiting their prey species.



Start of reach D22
Floodplain restricted by embankments on both banks
Scarcemoor Dike – fed by agricultural field drains
Terrace excavated to create levee and floodplain within embankment
Some erosion scour at bridge structures
Riparian corridor thickens for short reach US of Loftsome Bridge
Historic bank slump and trampling – good margins of macrophyte vegetation
Significant offtake structures for water abstraction
End of reach D22
Nevilthorne
Bowland Ho
Bowthorpe Hall
Holmes Ho
Hagg Lane Fm
Woodhouse Fm
Wr Twr
Castle Fm
Castle (rems of)
Wressl
Hemingbrough
Tithe Fm
Hall (Hotel)
Babthorpe
Hagthorpe Hall
Moat
Loftsome Br
Brackenholme
Hemingbrough Grange
News
Reservoir
Barmby Marsh
Barmby Barrage
Barmby on the Marsh
PH
Abbey
Meters
0
250
500
1,000

ROYAL HASKONING

APPENDIX C

HABITAT REQUIREMENTS OF KEY SPECIES

Macrophytes

The basic requirements of all plants are space, light, substrate, nutrients and water. The key factors that affect the occurrence and distribution of aquatic macrophyte communities are geology, water chemistry, flow regime, geomorphology, disturbance and management. Geomorphology, in particular, acts as a key influence on substrate, flow velocities and water depth (and therefore light availability). Diversity of habitat is important in providing suitable conditions for a range of in-channel, marginal and riparian vegetation species.

The in-channel macrophyte species identified within the River Derwent SSSI citation are typical of lowland rivers. They generally require still or slow flowing water with moderate to high nutrient status. They do not require a gravel or stony substrate, but can take root in soft sediments and can grow in relatively deep water (up to and in some cases over 1 m deep). In general, the River Derwent SSSI is likely to provide suitable habitat for these species. However, in-channel vegetation may be adversely affected by a lack of light due to high turbidity and unsuitably deep water.

Ranunculion fluitantis and ***Callitricho-Battrichion*** communities are specifically mentioned in the SAC designation for the Reiver Derwent. River water-crowfoot (***Ranunculion fluitantis***) grows successfully in swifter flows and responds less well to low flows. The species is relatively tolerant of eutrophication, but only if good flows are maintained and water clarity is good. If eutrophication is combined with low flows and high turbidity, the species does not survive as well. It can grow in depths up to and exceeding 1 m, and so is tolerant of greater depths than some of the other ***Ranunculus*** species. A clean substrate that is predominantly free of silt is preferred, and the species is unlikely to remain rooted in unstable sediments. A stony or rocky sediment is therefore more suitable for ***R. fluitans*** to take root, although where softer sediments are sheltered from the full force of the flow, the species can still do well. As with any submerged plant species, the light climate is very important. Shading from bankside trees or a turbid water column restricts growth. The plants are therefore sensitive to overshading. Water-starworts (***Callitricho-Batrachion*** communities) are generally found in slow-flowing waters where muddy or silty sediments predominate, although they can grow in conditions ranging from slow to swift-flowing water up to 1m deep.

Breeding birds

The river Derwent supports a diverse breeding bird assemblage, including the common sandpiper (***Actitis hypoleucos***), dipper (***Cinclus cinclus***), kingfisher (***Alcedo atthis***), yellow wagtail (***Motacilla flava***) and grey wagtail (***Motacilla cinerea***). The floodplain in the lower Derwent also provides important habitats for an internationally important population of Bewick's swan (***Cygnus columbianus***) during the winter.

The common sandpiper is a summer visitor to the UK that breeds along upland streams and lakesides. They frequent shingle or rocky shores, feeding on insects and molluscs at the waters edge.

Dippers are resident in the UK, inhabiting upland streams, and are generally regarded as being indicators of good water quality. They nest in cracks and crevasses in rocks or under bridges, and feed on aquatic insects and small fish by walking along the stream bed under water. During harsh weather, they move downstream to lowland habitats.

Kingfishers are relatively ubiquitous, and can be present on any watercourse that contains fish or frog prey of the correct size. They are resident in the UK all year, and may move towards the coast in winter if upland temperatures are below freezing. Nesting takes pace within holes in earth banks.

The yellow wagtail is a summer visitor to the UK which prefers lowland wet meadows and farmland where livestock are present. The grey wagtail is a UK resident which prefers upland streams.

Bewick's swan prefer wetland habitats, particularly shallow lakes and slow rivers near grassy meadows. They do not generally prefer areas with dense vegetation cover, instead favouring more open areas.

Fish

Fish populations in rivers are affected by a variety of factors, including water depth, flow velocity, bed substrate, marginal and riparian cover, barriers to free passage, water quality and temperature.

The River Derwent SSSI is regarded as being a coarse fishery containing pike (***Esox lucius***), roach (***Rutilus rutilus***), dace (***Leuciscus leuciscus***), barbel (***Barbus barbus***), chub (***Leuciscus cephalus***), grayling (***Thymallus thymallus***), ruffe (***Gymnocephalus cemuus***) and bleak (***Alburnus alburnus***). Populations of bullhead (***Cottus gobio***), river lamprey (***Lampetra fluviatilis***) and sea lamprey (***Petromyzon marinus***) are also important, and are included in the SAC designation.

Coarse fish and salmonids

Many coarse fish species can exist in, and even prefer, turbid, nutrient rich waters, such as present within the River Derwent SSSI. They do not generally require shallow or fast flowing, clear water. For many species, breeding takes place over vegetation or in the case of grayling, dace and barbell, over more gravelly or sandy substrates. These species are therefore likely to be less adversely affected by the geomorphological characteristics identified in much of the Derwent channel.

Both coarse and salmonid fish species may be limited in their passage throughout the River Derwent SSSI as a result of the presence of in-channel structures. Migratory fish, including brown trout and grayling utilising suitable habitat in the upper reaches, may be hindered in their movement by certain of these structures. However, salmonid species are typically stronger swimmers than coarse fish and Atlantic salmon (***Salmo salar***) and sea trout (***Salmo trutta***) reportedly do manage to pass upstream.

Lamprey

River and sea lamprey are anadromous, i.e. they live and grow in the sea but migrate into freshwaters to spawn. While in the sea, they live parasitically on other fish, but when they are migrating in freshwater, they do not feed. The brook lamprey does not migrate, and completes its life cycle within the river system, particularly in the upper reaches. In order to spawn and breed, adult lamprey migrate from coastal and estuarine areas into freshwater to reach suitable spawning areas. Spawning takes place in shallow, swift-flowing water over stony or gravelly substrate that must be clean and free of silt so that the eggs and larvae do not become smothered. Crude nests are constructed in the form of depressions in the substrate, by lifting away small stones using the sucking mouthpiece. Frequently, the nests are located in open shallow water and spawning adults are therefore vulnerable to predation. During migration and spawning the presence of shelter in the form of tree roots, woody debris or vegetation is therefore very important in order to reduce predation risk.

After hatching, the young ammocoete larvae move downstream to areas of sandy silt where they burrow and grow for several years. The silts must be stable to prevent the ammocoetes from being washed away and so slow flowing back waters are most suitable. The silt must also contain organic particles upon which the ammocoetes feed. A current is created by the ammocoete, drawing organic particles (e.g. bacteria and algae) into the pharynx where they are swallowed (a form of filter feeding). After several years spent in this way, the ammocoetes metamorphose into the adult form, and migrate downstream away from the nursery areas.

The main habitat requirements of lamprey while they are in freshwater are therefore a clear migration route to spawning areas, clean spawning gravels and slower flowing nursery areas with sandy silt for ammocoetes.

Bullhead

Bullhead are the only freshwater cottid fish species found in the UK (most cottids are marine species). They are small fish, rarely exceeding 15 cm in length, with distinctively large heads. The species is adapted to living on the bottom of flowing waters. The eyes are positioned on the top of the head, and the body is dorso-ventrally flattened and tapered to present minimal resistance to water flow.

Bullhead are widely distributed throughout Europe and across England and Wales. It is thought that they colonised the UK during the last ice age when the UK was connected to mainland Europe. They are found in stony streams and rivers with moderate flow, ranging from highland to lowland areas, and are also occasionally known to inhabit the stony margins and profundal zones of lakes. They are found in their highest densities in lowland streams, and it is thought that chalk streams may represent their most suitable habitat.

Bullhead spend much of their time sheltering from fish and bird predators amongst coarse substrates consisting of clean stones and gravels and feeding on the benthic invertebrates found there. Woody debris and tree roots may also provide some less effective shelter and feeding if stones are not present. The presence of stones and cobbles providing protection from predation and flow seems to be a critical factor in determining the suitability of habitat for bullhead to reach their maximum potential densities (Mills & Mann, 1983). In addition to cobbles and stones, shade is also desirable as it facilitates predator evasion.

Large stones are also required for breeding purposes. The male excavates a nest underneath a large stone, and the eggs laid by the female stick to its underside. In the absence of stones, some other media such as woody debris or tree roots may be used. The male then guards the eggs from predators and fans fresh oxygenated water over the nest with his pectoral fins. The young of the year favour shallow, stony riffles with their associated higher flows and oxygen levels.

Moderate flow velocities are required by adults, and heavily vegetated areas are avoided. The greatest densities of bullhead are found in natural channel forms with the associated variable riffle and pool structure. Depth is not thought to be a critical factor determining habitat suitability (Utzinger ***et al***., 1998).

Bullhead have the ability to home to a particular rock that they may use as a shelter for several years (Pecl, 1990). It is thought that bullhead are a sedentary species and do not regularly travel great distances. Reproductively isolated populations may therefore be present in different stretches of the same river.

Otters

Otters are classed as a European protected species under the Habitats Directive and therefore enjoy a high level of protection, for example not only is it an offence to capture or disturb an otter, it is also illegal to damage an otter's breeding site or resting place.

Otters occupy river corridors, small streams, canals, lakes and marshes. They also use dry ditches and can travel overland for surprisingly long distances to access suitable habitat. Home ranges can extend over tens of kilometres, and activity typically involves movement along a river channel or shoreline hunting for fish or resting in and around the banks. Otters can shelter above or below ground, in dense vegetation or tree root systems, but they must have access to undisturbed and secure sites were breeding can take place.

Otters are one of the largest predators found in Britain, and as they are at the top of the food chain they must consume around 15% of their body weight every day. Their diet consists mainly of fish, and so they require access to plentiful supplies to survive. Fish supply is therefore a primary factor in determining the suitability of an area for supporting otters.

Otters are more resilient than was previously supposed. As top predators, they are not adversely impacted by the same small scale environmental factors that can have a marked impact on riparian plants and invertebrates e.g. flow, water quality, sedimentation. Threats to otters are thought to include habitat destruction, for example management practices involving considerable change to riparian areas. Direct disturbance by humans and presence of bankside cover may also have an impact on otters. Bankside trees provide locations for shelter and breeding as well as locations for depositing spraints (droppings).

Sprains are important to otters as they are used as a form of communication. It is thought that sprainting may discourage potential competitors from entering a home range by advertising that the area is already in use or has recently been depleted of fish prey. They are therefore not deposited randomly along the river banks, but on prominent features such as tree bases, boulders, bridges, confluences and points of entrance and exit from the water.

APPENDIX D

WEIR ASSESSMENT TABLES

NOTES FROM ENGINEERING FIELD VISIT, 5TH MARCH 2010

Name:	Kirkham weir	**Thumbnail location plan**	
National Grid Reference:	471330, 455660 (SE 713 556)		
Watercourse:	River Derwent		

General description of structure and condition:

- A historical drawing of Kirkham weir (River Ouse Yorkshire Catchment Board drawing 15-146, dated November 1948) indicates that it is 195 feet (60m long), running from an open field on the right bank, across the river to an island on the left bank of the main river channel.
- This island is formed by the main channel to one side (south) and the old navigation cut to the north. The navigation closed in 1937, and reference to historical drawings suggests that the lock was removed in the 1950s and replaced by the current sluice gates.
- The weir construction is unknown, and historical drawings provided to Haskoning do not give any significant clues although they do indicate that the downstream apron of the weir is constructed from stone (River Ouse Yorkshire Catchment Board drawing 15-146, dated November 1948). The majority of the historical drawings provided focus on the locks and sluice gates.
- The weir structure was fully submerged on the day of survey, and is likely to remain so under most flow conditions, although it is equipped with a low flow channel approximately ¼ of the distance from right bank to left bank. This low flow channel does not appear on the historical drawings provided and so may well be a more recent addition (i.e. since, c. 1960).
- The weir has a fish pass on its right bank. This is shown on historical drawings, and so there has clearly been a fish pass at the weir for some time, although a new fish pass was installed in the 1990s.
- Significant flows pass through the sluices Kirkham. It should be noted that the section of watercourse downstream of the sluices, which rejoins the main channel some 130m downstream, is significantly wider than the old navigation cut.
- Access to the sluices was not possible on the day of the survey, and so their position is not known.

Photographs of Kirkham weir and environs

View of weir from right bank. Fish pass out of shot in foreground. Note low flow weir in middle of shot and sluice structure at rear left.

Sluices from upstream (closest accessible point on day of survey)

Kirkham Bridge

Panoramic view of weir from downstream, with fish pass visible on left of shot and low flow section visible in centre.

Kirkham weir – Engineering issues

Issue	Description of issue and possible mitigation	Confidence, and actions required to increase confidence
Access	• Pedestrian access to the site is straightforward. On the right bank, a public footpath follows the river and passes by the right bank end of the weir (at the fish pass). On the left bank, pedestrian access requires attendance from Environment Agency staff to open a gate from the Abbey car park, which provides access through a private field to the sluices. It is possible to cross the northern channel at the sluices to gain pedestrian access to the left bank end of the weir. • Vehicular access to the right bank generally is also straightforward, although it does require entry through private land. A gate adjacent to the level crossing at Kirkham provides vehicle access through a field to the right end of the weir and fish pass. • Vehicle access to the sluices is also easy, via the same route as pedestrians, described above. However, it is not possible to gain vehicle access to the island or the left bank end of the weir. • The width of the weir is a potential challenge in terms of access, as it would not be possible to work to the central part of the weir from one bank or the other, and so any works in the centre would mean working from the river, probably from a barge moored upstream or downstream of the weir.	• High confidence that pedestrian access and small vehicles can access the site. • Moderate confidence that larger construction vehicles would be able to get to the right bank if landowner permission was granted. • High confidence that left bank vehicle access to the weir is not possible.
Structural integrity	• The main weir structure was completely underwater on the day of survey, and a review of other photographs suggests that this is frequently the case. It has therefore not been possible to determine the structural condition of the weir. • No reference is made within this report to the sluice condition, as these have been surveyed separately for the Environment Agency in recent years.	• Low confidence. A full condition survey would need to be undertaken to confirm condition of weir, and this would have to be carried out during a period of prolonged dry weather to ensure that levels were low. It may be possible to artificially lower levels by fully opening the sluices, but again to expose a significant part of the weir this would still have to be done during a period of low flows.
Impact of changes to flow regime	• The biggest engineering impact of lowered water levels is likely to be to the historical Kirkham Bridge, upstream of the weir. Any significant lowering of water levels could result in a lowering of the bed level, which in turn could result in undermining of the bridge foundations. • Bank stability may also be a problem if water levels are lowered, although there are no properties close enough to the river bank to be significantly impacted by this risk. The banks upstream near Huttons Ambo are currently eroding, and this may be exacerbated if water levels were to fall.	• High confidence that lower water levels would adversely impact on bridge piers if they resulted in a lowering of the bed level. • High confidence that lowered river levels would have the potential to cause bank stability problems, but also that this would be unlikely to cause major problems with property.

	• Kirkham Priory is likely to be sufficiently high to be unaffected by water level changes, although further investigations into the floodplain groundwater regime will be required before a definitive assessment can be made. • The railway embankment in the immediate vicinity of the structure is unlikely to be affected by a drop in water levels associated with removal of the weir. However, there may be some potential impacts upon the railway further upstream, where the track runs very close to the river. However, more detailed assessments into ground conditions and the groundwater regime are required before a definitive assessment can be made,	• High confidence that lowered river levels would have the potential to cause bank stability problems, lower confidence on the likely implications for Kirkham Priory (although considered to be minimal). • High confidence that lowered river levels would have the potential to cause bank stability problems, lower confidence on the likely implications for the railway embankment (although considered to be minimal).

Kirkham weir – Commentary on options

Options	Brief commentary
Modify structure or complete removal	• Modification or complete removal of the weir structure would be relatively simple in engineering terms, provided that access issues to the left bank could be resolved. However, complete removal is likely to result in a significant lowering of upstream water levels, and consequent possible changes to the bed level, which could have the potential to significantly impact on the historical stone arched bridge at Kirkham. Significant engineering works may be required to protect this structure against such impacts, if, indeed, such works are feasible. Further works may also be required to protect Kirkham Priory and the railway line, although this may not be a significant issue. • Reference to historical drawings of the weir suggests that the weir typically retains upstream water levels by perhaps as much as 8.5 feet (see Yorkshire Ouse River Board drawing 4-97-15 dated January 1956, which shows 'normal' upstream water level as 47.47 feet Above (Liverpool) Ordnance Datum and 'normal' downstream water level as 39 feet AOD). A lowering of the weir could therefore potentially lower upstream levels by up to approximately 2600mm. • However, modification to the structure to reduce upstream water levels would not necessarily require the lowering of the whole weir. The weir is equipped with a low flow section, and this section could be widened and lowered further to give a partial reduction in upstream levels (particularly during drier periods).
Alter operation of structure	• The weir itself has no operating mechanisms. Upstream levels will be controlled by a combination of the fixed main weir, and flows that are permitted to go through the sluice gates. • A more detailed study is required to fully understand how the fixed weir and navigation sluice together influence upstream water levels. Reference to old drawings suggests that the navigation sluice sill level is lower than the main fixed weir (sill level 42.0 feet AOD vs. weir of 46.27 (ref. drawing 15-159, undated)). This suggests that if the sluice was fully opened during periods of low flow, the fixed weir itself would be dry, and all flows would run down the sluice cut. It should be noted, however, that this supposition is based on historical drawings and the relative sill levels and other dimensions should be fully verified as part of any future work.
Provide fish pass	• Kirkham weir is already equipped with a fish pass, but modifications are required to achieve fish pass approval. These need to be considered together with other options for the weir and sluices.
Other	• N/A.

<table>
<tr><td>Name:</td><td>Howsham weir</td><td rowspan="3">Thumbnail location plan</td><td rowspan="3">
</td></tr>
<tr><td>National Grid Reference:</td><td>472965, 462830
(SE 729 628)</td></tr>
<tr><td>Watercourse:</td><td>River Derwent</td></tr>
<tr><td>General description of structure and condition:</td><td colspan="3">

- Howsham weir is approximately 75m long, running from a steep cliff on its right bank, across the river to Howsham Mill on the left bank of the main river channel.
- There are two supplementary flow routes, around the main weir, which comprise the mill race under the old mill building, and the navigation cut.
- The weir construction is unknown; the weir structure was fully submerged on the day of survey, and is likely to remain so under most flow conditions.
- It is equipped with a central low flow channel
- On its left bank, an Archimedes screw hydropower unit has recently been installed, as part of the works to restore the old Howsham Mill to an education centre.
- The mill race culvert also still runs, although on the day of the survey it was closed by a sluice for works to the waterwheel. It is understood that the waterwheel will also shortly be operational once again, and will also be used to generate electricity.
- The canal cut leaves the left bank of the river further upstream, and rejoins the main channel downstream of the mill at a disused lock. On the day of the survey, some trench sheeting piles were in place at the upstream end of the canal cut. It was reported by the team restoring the old mill building that this had been done to allow the power cable from the hydroelectric plant to be laid across the old canal cut. Some of the piles had been removed, and there was flow down the canal cut. At its downstream end, only the upper pair of lock mitre gates is still in place, and these are in very poor condition.

</td></tr>
</table>

Photographs of Howsham weir and environs

General view of weir from right bank

View of left bank end of weir showing also Archimedes screw hydropower unit and old mill building

Low flow channel and / or fish pass

Old mitre gates at upstream end of disused lock

General view of weir from left bank, hydropower unit out of shot in foreground

View of right hand portion of weir

Howsham weir – Engineering issues

Issue	Description of issue and possible mitigation	Confidence, and actions required to increase confidence
Access	• Pedestrian access to the site is straightforward from Howsham bridge, which is located 400m downstream of the weir. On the right bank, a public footpath follows the river and passes by the right bank end of the weir albeit at elevated level. On the left bank, a public footpath runs from the bridge as far as the old mill (to get to this, turn south / downstream off the left bank bridge abutment, and follow the footpath that doubles back under the bridge). • However, vehicular access to the weir is not current possible. The right bank access is purely a footpath, and there is insufficient room at the weir end to widen this to a track if that was required, due to the steep wooded cliff on the right bank. • The left bank pedestrian access crosses several minor channels on footbridges; there is no track access and vehicle access would require the supplementing of the pedestrian bridges with new (perhaps temporary) vehicle bridges. • It is understood that all of the materials required for the mill restoration and hydropower installation were imported to site by hand or upstream on barge. • Historically, a swing bridge over the navigation cut would have provided some access to the mill from The Holms part of Howsham Hall park. However, this bridge is no longer in existence, although its abutments are still visible.	• High confidence that pedestrians can access the site. • High confidence that vehicle access is not currently possible and that engineering works including construction of new bridges would be required to enable vehicle access in the future if it was required.
Structural integrity	• The main weir structure was completely underwater on the day of survey, and a review of other photographs suggests that this is frequently the case. It has therefore not been possible to determine the structural condition of the weir. However, it is understood from conversations with the team restoring the mill who have seen the weir at low flows, that it is in a fair condition. • The old navigation lock mitre gates are in very poor condition, and if these gates failed it is likely that some drop in upstream water levels would be noticed, during low flows at least, due to the consequential increase in flows through the old lock structure.	• Low confidence. A full condition survey would need to be undertaken to confirm condition of weir, and this would have to be carried out during a period of prolonged dry weather to ensure that levels were low.
Impact of changes to	• The biggest impact of changes in water levels is likely to be to the mill restoration and its hydropower unit. There are no properties adjacent to the	• High confidence that lower upstream water levels would reduce the efficiency of the hydropower and waterwheel operation.

flow regime	weir that would be adversely impacted by lower water levels, unless lowered groundwater levels affected the mill building. Any lowering of upstream water levels will reduce the head available to drive the hydropower unit and waterwheel and clearly complete removal of the weir would make the hydropower and waterwheel inoperable. • Howsham Hall is fairly close to the river further upstream, and if lowering upstream water levels was to be proposed it would be recommended that a detailed survey of the potential impact on the hall should be undertaken. • Bank stability may also be a problem if water levels are lowered, the only property close enough to the river bank to be significantly impacted by this risk is likely to be Howsham Hall.	• Moderate confidence that lower water levels are unlikely to have a significant effect on existing properties. • High confidence that lowered river levels would have the potential to cause bank stability problems, but also that this would be unlikely to cause major problems with property.

Howsham weir – Commentary on options

Options	Brief commentary
Modify structure or complete removal	• Access will be the major challenge for any works at Howsham weir. There is no road access to the weir, and it is understood that all of the materials for the mill restoration have been imported either by hand or by drawing a barge up the river. If vehicle access was required for any works, the most viable route for vehicle access is likely to be to the mill site (main channel left bank) from the main driveway to Howsham Hall. Reference to aerial photographs suggests that vehicle access is possible to the left bank of the navigation cut. A new bridge over the canal cut would be required, potentially using the old swing bridge abutments. • The most significant impact of weir removal or lowering would be the consequent reduction in upstream water levels and thus loss of generation at the hydropower unit and waterwheel. • Bank stability would also be an issue, but it is considered unlikely that this would have a significant impact on properties. However, checks should be made particularly with reference to the mill and to Howsham Hall to confirm any possible impacts.
Alter operation of structure	• The weir structure itself is fixed, and altering its operation is not an option. • The only operable structure at the site is the sluice that feeds the mill race and waterwheel. However, as the mill race is relatively small section, even if this sluice was left fully open permanently it is considered unlikely that the weir would run completely dry. The relative levels of the sluice cill and weir are not known.
Provide fish pass	• There is ample space at the weir to provide a fish pass of a similar design to those at Kirkham and Stamford Bridge. The most difficult aspect of such works would be gaining access to the site, and importing the required materials and equipment. However, it is reported that it is passable during normal flow conditions by most fish species that are found in the river (Yorkshire Fishery Board, 1946).
Other	• The old navigation cut is an alternative route for some flows, and removal of the sheet piling and lock gate could result in lowered upstream water levels. This would be straightforward to achieve by simply removing the remaining trench piling at the upstream end of the cut, and removing the lock mitre gates, which are already in very poor condition. However, the effect of this would be to divert flows away from the main channel, and this would also impact on the operation of the hydropower and waterwheel units, so it is unlikely to be acceptable.

Name:	Stamford Bridge weir	**Thumbnail location plan**	
National Grid Reference:	471330, 455660 (SE 713 556)		
Watercourse:	River Derwent		

General description of structure and condition:

- Stamford Bridge weir is approximately 30m long, running from a caravan park on the right bank, across the river to the former Corn Mill on the left bank of the main river channel.
- The weir construction is unknown, although a drawing of the weir dating from 1969 suggests that the basic construction may be of block or stone work, which is exposed to flows on the upstream face, and covered with a mass concrete and wooden composite structure on the downstream side. The downstream face of the weir appears to be formed from 'stones and clay', overlain with a weak layer of concrete (refer to Yorkshire Ouse and Hull River Authority drawing number 4-136, dated 24 October 1969, showing details of proposed lowering of weir crest).
- Reference to an old photograph on the Environment Agency's HiFlows-UK website (http://www.environment-agency.gov.uk/hiflows/91727.aspx) indicates that the description generally matches the weir at the time of the photograph. However, the photo is undated and it is not known whether further, more recent, modifications have been undertaken.
- The weir structure was fully submerged on the day of survey, and is likely to remain so under most flow conditions. It does not appear to be equipped with a low flow channel.
- The weir has a fish pass on its right bank.
- The mill race culvert under the former Corn Mill appears to still run, with evidence of some flow through it on the day of survey.
- Significant flows also pass down the navigation cut at Stamford Bridge. This cut leaves the main river channel at the upstream end of the caravan park site, and runs parallel to the main channel, under the caravan park access bridge and through a sluice, before rejoining the main channel downstream of the Stamford Bridge (A166). The sluice is located at the upstream end of the old lock.
- On the day of the survey, the sluice was completely open, and was not controlling flows. There was a significant head loss through the sluice, and a hydraulic jump at the sluice. It was also noted that there was a significant head loss at the caravan park access bridge, with a second hydraulic jump under the bridge. This means that under certain flow conditions the channel at the bridge will have some control over upstream levels (along with the weir), rather than the position of the sluice or capacity of the old lock.
- Downstream of the sluice, the river runs immediately through the A166 Stamford Bridge. The main channel of the river runs through two arches (left and central) and the navigation runs through the third. Under flood conditions, however, the island separating the two is likely to become inundated (wrack marks observed on the day of the survey indicate that this is likely to have occurred in the recent past, perhaps during high river flows in late February 2010).

Photographs of Stamford Bridge weir and environs

Stamford Bridge weir, viewed from right bank caravan park

Fish pass at weir located under this grating

Sluice at upstream end of old lock

View upstream on navigation cut, from caravan park access bridge

View across river upstream of weir, from caravan park showing old Corn Mill

View of hydraulic jump under caravan park access bridge

Stamford Bridge weir – Engineering issues

Issue	Description of issue and possible mitigation	Confidence, and actions required to increase confidence
Access	• Pedestrian access to the site is straightforward, with the best views of the weir from the caravan park on the right bank (north side) of the river. This is not public access, however, and requires a courtesy call at the caravan park reception (although the Environment Agency may have right of access through the site to maintain the fish pass, should it be required). • Vehicular access is not as straightforward. The caravan park is accessed off Buttercrambe Road and across a bridge over the navigation cut. This bridge is likely to be a constraint to heavy construction traffic in terms of width and weight capacity. • However, it should also be noted that smaller constructed vehicles could cross this bridge with ease. It is also assumed that this bridge has historically been used to transport permanent caravans into the site, and therefore any weight restriction may not be an undue constraint to access. Liaison with the caravan park owners, which will be required in any case should access to the site be needed, may confirm the safe capacity of the bridge. • Once within the caravan park, access to the weir itself may require some of the permanent caravans to be moved, depending on the type of construction access required. This may in turn present constraints to works in terms of timing (outside holiday season, etc.). Further, any proposals to access through the site will need owner permission and have to carefully consider the safety of caravan park residents and staff. • Access from the left bank (south) may be more straightforward, but will be through private land associated with the old Corn Mill building. Due to the private access, it was not possible to survey this route, but reference to aerial photographs indicates that it may be possible. However, there are likely to be some constraints, including possible weight restrictions to the area over the old mill race culvert. • The width of the weir is also a potential challenge in terms of access, as it would not be possible to work to the central part of the weir from one bank or the other, and so any works in the centre would mean working from the river.	• High confidence that pedestrian access and small vehicles can access the site. • Moderate confidence that larger construction vehicles would be able to get to the site depending on more detailed appraisal of access constraints on right bank (caravan park bridge and route through park) and left bank (possible restrictions on access route through Cornmill).
Structural	• The main weir structure was completely underwater on the day of survey, and a review of other photographs suggests that this is frequently the case. It	• Low confidence. A full condition survey would need to be undertaken to confirm condition of weir, and this would have to be carried out during a period of prolonged dry weather to

integrity	has therefore not been possible to determine the structural condition of the weir. • No reference is made within this report to the sluice condition, as these have been surveyed separately for the Environment Agency in recent years.	ensure that levels were low. It may be possible to artificially lower levels by fully opening the navigation sluice, but again to expose a significant part of the weir this would still have to be done during a period of low flows.
Impact of changes to flow regime	• The biggest engineering impact of lowered water levels is likely to be the effect that this would have on groundwater levels. A drop in groundwater levels could cause subsidence to land and property adjacent to the river upstream of the weir. The old Cornmill may also be affected by lowered groundwater levels. • Bank stability may also be a problem if water levels are lowered. In terms of property, this is likely to be most significant to the caravan park. No other properties have been identified close enough to the river that lowered groundwater levels would adversely affect. • There are also two areas of wetland that may be affected by lowered water levels. The first is to the north of the navigation cut, and appears to be part of a recreation area for the caravan park. The second wetland is to the east of the river (left bank) just before it enters Stamford Bridge. Lower river levels that resulted in lowered ground water levels could cause these areas to dry, depending on a more detailed understanding of their hydrological regime.	• High confidence that lowered groundwater levels would have the potential to cause bank stability problems, and possibly also structural problems to the old Cornmill. • High confidence that lowered river levels would have the potential to cause bank stability problems, which may impact on some parts of the caravan park. • High confidence that lower river levels, and hence lowered ground water levels, could adversely affect these wetland areas.

Stamford Bridge weir – Commentary on options

Options	Brief commentary
Modify structure or complete removal	• Modification or complete removal of the weir structure is simple in engineering terms and could be easily be achieved if further examination of access options showed that access for construction traffic is straightforward. However, engineering works would be required to ensure that other structures, in particular the old Cornmill, are not impacted by reduced water levels and consequent reduction in groundwater levels. • Reference to historical drawings of the weir suggests that the weir typically retains upstream water levels by perhaps as much as 7 feet (compare Yorkshire Ouse and Hull River Authority drawing 4-136 dated 24 October 1969, which shows 'normal' upstream water level as 28.63 feet Above (Liverpool) Ordnance Datum, with River Ouse Yorkshire Catchment Board drawing 4/70 dated November 1936, which shows a normal downstream water level of 21 feet AOD). A lowering of the weir could therefore potentially lower upstream levels by up to approximately 2100mm. The weir crest is shown as being at approximately 26.63 feet AOD; it is not clear whether this is before or after the proposed lowering. • Modification to the structure to reduce upstream water levels would not necessarily require the lowering of the whole weir. The weir does not appear to be equipped with a low flow section; a section of the weir could be lowered to give a partial reduction in upstream levels (particularly during drier periods).
Alter operation of structure	• The weir itself has no operating mechanisms. Upstream levels will be controlled by a combination of the fixed main weir, and flows that are permitted to go through the navigation sluice and the Cornmill mill race (this latter is likely to be insignificant in terms of flow volume, but evidence on the day of survey indicated that there is still some small flow through here). • A more detailed study is required to fully understand how the fixed weir and navigation sluice together influence upstream water levels. Reference to old drawings suggests that the navigation sluice sill level is lower than the main fixed weir (sill level 21 feet AOD vs. weir of 26.63, and historically even higher than that). This suggests that if the navigation sluice was opened during periods of low flow, the fixed weir itself would be dry, and all flows would run down the navigation cut. It should be noted, however, that this supposition is based on historical drawings and the relative sill levels and other dimensions should be fully verified as part of any future work.
Provide fish pass	• Stamford Bridge is already equipped with a fish pass, although it was reported to Haskoning on the day of the survey (by staff at the caravan park) that the upstream sluice on the fish pass is currently inoperable.
Other	• N/A.

APPENDIX E

WEIR RISK ASSESSMENT TABLES

Kirkham Weir					
Constraint ***Constraints refer to disbenefits of undertaking a restoration action. E.g. loss of habitat, reasons that action is technically unfeasible. Constraints should be specific***	**Likelihood** ***How likely is it that the constraint will be realised (high- based on other examples or direct cause effect; medium- based on theoretical or indirect effect; Low – not known or not seen elsewhere but included as precautionary)***	**Consequence** ***For delivery of the action***	**Risk** ***(likelihood X consequence)***	**Confidence** ***Do we need to know more to be confident in constraint occurring and help support mitigation? Describe how certain the assessment is and what further work would achieve in reducing uncertainty. High – Has supporting scientific evidence Medium – Some evidence Low – Needs further research***	**Description of possible mitigation**
ENGINEERING					
Technically difficult to remove the structure	The construction of the weir is unknown. Access to the left bank is likely to be limited. The width of the structure suggests that some in-channel works would be required. The structure has been modified in the past by the addition of a low flow channel (since c. 1960), suggesting that works are likely to be feasible. **Medium**	The weir cannot be removed or it would be excessively costly to remove. **High**	**High**	A full condition assessment will be needed as part of a feasibility study to confirm the condition of the weir prior to removal. However, given that the structure is submerged under the majority of flow conditions this may be difficult to undertake. **Low**	A full condition assessment undertaken in dry conditions (e.g. with a coffer dam in place) or as a diver survey.
Potential undermining of Kirkham Bridge due to changes in water levels	A reduction in water levels and changes in flow dynamics could reduce bed levels upstream of the structure (see above), potentially undermining the foundations of the historic Kirkham Bridge. **Medium**	Lowering of the bed level is likely to affect the bridge piers. This could prevent the delivery of the action if the effect was too expensive to mitigate. **High**	**High**	Additional investigations into the likely scale of the reduction in bed levels will be required to determine whether the bridge foundations are at risk of being undermined. **Low**	Potential impacts upon the bridge piers could be mitigated by regrading the bed and incorporating sufficient reinforcement into sensitive areas of the channel.

Kirkham Weir					
Constraint ***Constraints refer to disbenefits of undertaking a restoration action. E.g. loss of habitat, reasons that action is technically unfeasible. Constraints should be specific***	**Likelihood** ***How likely is it that the constraint will be realised (high- based on other examples or direct cause effect; medium- based on theoretical or indirect effect; Low – not known or not seen elsewhere but included as precautionary)***	**Consequence** ***For delivery of the action***	**Risk** ***(likelihood X consequence)***	**Confidence** ***Do we need to know more to be confident in constraint occurring and help support mitigation? Describe how certain the assessment is and what further work would achieve in reducing uncertainty. High – Has supporting scientific evidence Medium – Some evidence Low – Needs further research***	**Description of possible mitigation**
Potential undermining of Kirkham Priory and the railway embankment due to bank collapse in response to reduced water levels.	A reduction in water levels and changes in flow dynamics could reduce bed levels upstream of the structure (see above), potentially undermining any structures in the floodplain. **Medium**	Lowering of water levels could lead to bank collapse, placing the historic priory buildings and the railway embankment at potential risk. This could prevent the delivery of the action if the effect was too expensive to mitigate. **High**	**High**	Additional investigations into the likely scale of the reduction in water levels and the corresponding response in the banks and floodplain will be required to determine whether the structures are at risk of being undermined. **Low**	Potential impacts on floodplain structures could be mitigated by increased bank protection and reinforced footings. The footings of the railway embankment were successfully repaired after collapsing during a large flood in 2002. However, this is unlikely to be unfeasible for widespread application on the historic priory buildings.
ECOLOGY AND SSSI					
Loss of gravel habitats downstream of structure	The weir supports high quality gravel habitats downstream. Removal of the weir may disrupt these habitats by reducing turbulence and allowing fine sedimentation to occur. **Medium**	Complete removal of the weir could potentially result in a reduction in habitat quality for key SSSI macrophyte communities and spawning fish included in the SAC designation. If the ecological impact of losing gravel habitats is deemed to be greater than the benefits of removing the structure, the removal of the weir could be prevented. **High**	**High**	Additional assessments are required to determine the scale of the bed habitats and identify potential impacts as a result of changes to flow dynamics and sedimentary conditions. **Medium**	A more detailed assessment of the changes to flow dynamics and sedimentation rates (including hydraulic modelling) will be required to assess the scale of the issue and the nature of any mitigation measures required.
Remobilisation of stored silt upstream of structure and	Any sediment accumulated upstream of the structure will	Complete removal of the weir could potentially result in a		Additional assessments into the scale of sediment accumulation	If the results of further monitoring and modelling

Kirkham Weir					
Constraint ***Constraints refer to disbenefits of undertaking a restoration action. E.g. loss of habitat, reasons that action is technically unfeasible. Constraints should be specific***	**Likelihood** ***How likely is it that the constraint will be realised (high- based on other examples or direct cause effect; medium- based on theoretical or indirect effect; Low – not known or not seen elsewhere but included as precautionary)***	**Consequence** ***For delivery of the action***	**Risk** ***(likelihood X consequence)***	**Confidence** ***Do we need to know more to be confident in constraint occurring and help support mitigation? Describe how certain the assessment is and what further work would achieve in reducing uncertainty. High – Has supporting scientific evidence Medium – Some evidence Low – Needs further research***	**Description of possible mitigation**
transfer to reaches downstream impacting on silt intolerant macro-invertebrates and macrophyte communities	be remobilised if it is removed, potentially leading to adverse effects on in-channel communities further downstream. Although detailed measurements of bed sedimentation are not available, given the prevalence of sedimentation in the channel and patterns demonstrated further downstream it is likely to occur. **High**	reduction in habitat quality for key SSSI invertebrate and macrophyte communities. However, since in-channel sedimentation is prevalent in the entire channel this may not be a major issue. If the ecological impact of sediment remobilisation is deemed to be greater than the benefits of removing the structure, the removal of the weir could be prevented. **High**	**High**	upstream of the structure are required to accurately assess the potential for silt remobilisation. Hydraulic modelling to determine changes in flow velocities and sediment transport potential is also likely to be required. **Medium**	suggest that there is a large amount of sediment upstream of the weir, and that it is likely to become mobilised once the structure has been removed, it should be possible to physically remove the material while works on the structure take place. This should be undertaken in a sympathetic manner to ensure that any existing habitats are not damaged.
GEOMORPHOLOGY					
Mobilisation and downstream transport of fine bed sediments	Considerable quantities of sediment are likely to have accumulated as far as 0.95km upstream of the structure. These are likely to be remobilised if the weir is removed. **High**	The remobilisation of bed sediments is likely to cause a temporary increase in turbidity, and lead to increased sediment deposition downstream. Although this may impact upon ecological communities further downstream (see above), the increase in sediment entrainment is unlikely to have a considerable impact on the geomorphology of the river. **Low**	**Medium**	Sediment remobilisation is highly likely to occur, although additional assessments are required to quantify the amount of sediment likely to be affected and determine likely increases in sediment entrainment (see above). **Medium**	Physical mitigation measures could be undertaken during construction to remove excessive sediment and prevent its entrainment (see above).

Kirkham Weir					
Constraint ***Constraints refer to disbenefits of undertaking a restoration action. E.g. loss of habitat, reasons that action is technically unfeasible. Constraints should be specific***	**Likelihood** ***How likely is it that the constraint will be realised (high- based on other examples or direct cause effect; medium- based on theoretical or indirect effect; Low – not known or not seen elsewhere but included as precautionary)***	**Consequence** ***For delivery of the action***	**Risk** ***(likelihood X consequence)***	**Confidence** ***Do we need to know more to be confident in constraint occurring and help support mitigation? Describe how certain the assessment is and what further work would achieve in reducing uncertainty. High – Has supporting scientific evidence Medium – Some evidence Low – Needs further research***	**Description of possible mitigation**
Adjustment of bed forms and potential loss of the weir pool	Removal of the weir is likely to cause considerable changes in the flow dynamics of the river channel. This is likely to lead to an adjustment of the existing bed forms, as sediment is remobilised and redeposited. This could potentially lead to the loss of the existing weir pool as a result of gradual infilling and loss of turbulent flows. **High**	Major bed readjustments could potentially cause the loss of the existing weir pool, as the flow conditions which maintain them are no longer prevalent. If the ecological impact of the loss of the weir pool is deemed to be greater than the benefits of removing the structure, the removal of the weir could be prevented. **High**	**High**	Adjustment of the existing bed forms is likely to occur as a result of the removal of the structure. However, additional measurements of the existing bed conditions and assessment of the likely adjustments as a result of changing flow conditions (e.g. physical survey and hydraulic modelling) are required before the likely impact can be determined accurately. **Medium**	The existing river bed could be regraded to produce a more varied suite of channel bed forms, including habitat niches that are deemed to be of importance for the condition of the SSSI.
Potential bank collapse as a result of decreased water levels	Removal of the weir is likely to decrease water levels, resulting in the potential for the banks to collapse due to geotechnical failure. Kirkham weir creates impounded conditions that extend at least 2.96 km upstream of the structure. The river bank is vulnerable to slumping , as observed further upstream at Huttons Ambo. **High**	Natural restructuring of the banks as a result of lowered water levels is likely to increase localised morphological diversity and allow more varied habitats to develop. However, it could cause river bank erosion, and may have the potential to effect the bridge and adjacent land (which includes the railway line from York to the coast). **High**	**High**	Given the steepness and height of the banks and the material that they are comprised of, it is likely that a degree bank collapse will occur in response to a decrease in water levels. However, there are currently no detailed data on the geotechnical condition of the banks. **Medium**	The banks are likely to collapse as a natural response to decreasing water levels upstream. This could require considerable mitigation depending on the effect on adjacent land and the bridge.

Kirkham Weir					
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HYDROLOGY					
Loss of existing water level control function	The sluices currently serve a water level control function. However, their role in managing flood risk is currently being reviewed.. ,The purpose of the weir is unclear, but it may contribute to the water level control function of the sluices. **High**	The need to retain the existing water level control function of the structure may prevent removal of the weir. **High**	**High**	A more detailed understanding of the interactions between the weir and sluice, and of upstream water levels, are required before a more accurate assessment can be made. **Low**	
Reduction in localised groundwater levels and floodplain connectivity	Removal of the structure will result in a reduction of upstream water levels by approximately 2600 mm. This may lead to localised decreases in groundwater levels in the floodplain, and reduce floodplain connectivity by effectively increasing the flow required to get out of bank. **Medium**	This response is unlikely to prevent delivery of the action, since any changes to floodplain conditions are likely to be localised. Any detrimental impacts on local ecology are likely to be outweighed by benefits to the river SSSI achieved by removing the impoundment. **Medium**	**Medium**	Additional assessment is required to determine the impact of reducing in-channel water levels on floodplain connectivity and groundwater levels (including hydraulic modelling to determine the precise drop in water levels and the impacts this would have on flood frequency). **Low**	Bed regrading works could potentially be undertaken to maintain water levels and prevent a reduction in floodplain connectivity. This is likely to be required to produce a functional bed profile (see above).
RECREATIONAL AND SOCIO-ECONOMIC					
Loss of weir pool and reduction in water levels upstream of the weir, leading	Removal of the weir may lead to the loss or alteration of the existing weir pool (see	The consequence of this action is a reduction in the amenity value of the site.		The precise impacts of removing the weir on the downstream weir pool are	The potential for adverse impacts on the quality of the reach as a recreational

Kirkham Weir					
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to a reduction in quality for recreational fishing	above), and reduce water levels upstream, which may adversely impact upon the quality of the site for recreational fishing. The stretch of river between the bridge and weir is an important area for coarse fish and for fishing and is also popular with tourists. **Low**	This is unlikely to be outweighed by the benefits to the SSSI that would be achieved by removing the structure. **Low**	**Low**	uncertain, and are dependant on factors such as changing flow velocities and patterns, and alterations in sediment transport and supply. Additional assessments (including hydraulic modelling) are likely to be required before this impact can be assessed fully. See above for water level recommendations. **Low**	fishery are likely to be mitigated by the improvements to fish habitat that would be delivered by removal of the weir.
CULTURAL HERITAGE					
Potential visual impacts on the setting of Kirkham Priory. The river is currently fringed with reeds and forms the foreground for the ruins of the 13th Century Kirkham Priory heritage site, which is a popular tourist attraction.	The visual amenity of the area is likely to be temporarily disturbed during construction. A reduction in water levels may permanently change the outlook of the structure. **Medium**	The consequence of this action is a reduction in the amenity value of the site. This is unlikely to be outweighed by the benefits to the SSSI that would be achieved by removing the structure. **Low**	**Medium**	Removal of the weir will require the use of large construction machinery and an associated site compound, which are likely to have a temporary visual impact on the structure. Longer term impacts are less clear. **Medium**	Construction works could be scheduled to avoid the tourist season. However, this may not be compatible with the technical considerations of undertaking works in the river channel, which will ideally take place during periods of low flow (e.g.during the summer tourist season).
Potential undermining of Kirkham Priory due to bank collapse in response to reduced water levels.	See discussion under “Engineering” above. **Medium**	See discussion under “Engineering” above. **High**	**High**	See discussion under “Engineering” above. **Low**	See discussion under “Engineering” above.

Kirkham Weir					
Constraint ***Constraints refer to disbenefits of undertaking a restoration action. E.g. loss of habitat, reasons that action is technically unfeasible. Constraints should be specific***	**Likelihood** ***How likely is it that the constraint will be realised (high- based on other examples or direct cause effect; medium- based on theoretical or indirect effect; Low – not known or not seen elsewhere but included as precautionary)***	**Consequence** ***For delivery of the action***	**Risk** ***(likelihood X consequence)***	**Confidence** ***Do we need to know more to be confident in constraint occurring and help support mitigation? Describe how certain the assessment is and what further work would achieve in reducing uncertainty. High – Has supporting scientific evidence Medium – Some evidence Low – Needs further research***	**Description of possible mitigation**

Overall risk to SSSI Condition	**Medium**	**Should option to be progressed for feasibility assessment?**	**Yes**

Howsham Weir					
Constraint ***Constraints refer to disbenefits of undertaking a restoration action. E.g. loss of habitat, reasons that action is technically unfeasible. Constraints should be specific***	**Likelihood** ***How likely is it that the constraint will be realised (high- based on other examples or direct cause effect; medium- based on theoretical or indirect effect; Low – not known or not seen elsewhere but included as precautionary)***	**Consequence** ***For delivery of the action***	**Risk** ***(likelihood X consequence)***	**Confidence** ***Do we need to know more to be confident in constraint occurring and help support mitigation? Describe how certain the assessment is and what further work would achieve in reducing uncertainty. High – Has supporting scientific evidence Medium – Some evidence Low – Needs further research***	**Description of possible mitigation**
ENGINEERING					
Technically difficult to remove the structure	The construction of the weir is unknown. Vehicular access to the structure is not possible. **High**	The weir cannot be removed or it would be excessively costly to remove. **High**	**High**	A full condition assessment will be needed as part of a feasibility study to confirm the condition of the weir prior to removal. However, given that the structure is submerged under the majority of flow conditions this may be difficult to undertake. **Low**	A full condition assessment undertaken in dry conditions (e.g. with a coffer dam in place) or as a diver survey.
Potential impacts on Howsham Hall due to reduction in water levels	Removal of the structure will decrease water levels in the channel, which may decrease floodplain groundwater levels. This could cause subsidence of the surrounding floodplain land. **Medium**	Decreased groundwater levels could potentially result in subsidence. This could potentially affect property close to the watercourse, particularly Howsham Hall. **High**	**High**	Additional assessment is required to determine the impact of reducing in-channel water levels on floodplain groundwater levels (including hydraulic modelling to determine the precise drop in water levels and the impacts this would have on floodplain wetness). **Low**	Bed regrading works could potentially be undertaken to maintain in-channel and groundwater levels. Additional works to prevent subsidence may also be required, if this is determined to impact upon the structure.

Howsham Weir					
Constraint ***Constraints refer to disbenefits of undertaking a restoration action. E.g. loss of habitat, reasons that action is technically unfeasible. Constraints should be specific***	**Likelihood** ***How likely is it that the constraint will be realised (high- based on other examples or direct cause effect; medium- based on theoretical or indirect effect; Low – not known or not seen elsewhere but included as precautionary)***	**Consequence** ***For delivery of the action***	**Risk** ***(likelihood X consequence)***	**Confidence** ***Do we need to know more to be confident in constraint occurring and help support mitigation? Describe how certain the assessment is and what further work would achieve in reducing uncertainty.*** ***High – Has supporting scientific evidence*** ***Medium – Some evidence*** ***Low – Needs further research***	**Description of possible mitigation**
Loss of hydropower from the Howsham Mill scheme	Removal of the structure will reduce water levels sufficiently to render the hydropower unit and water wheel inoperable. **High**	Loss of hydropower generating capacity may be perceived as more than a local issue if helping to meet regional development targets. **Medium**	**High**	A significant reduction in water levels associated with complete removal of the weir will prevent sufficient water reaching the generating unit. **High**	Changes to channel configuration could potentially maintain water levels to allow some hydropower generation to occur.
ECOLOGY AND SSSI					
Loss of gravel habitats downstream of structure	The weir supports high quality gravel habitats downstream. Removal of the weir may disrupt these habitats by reducing turbulence and allowing fine sedimentation to occur. **Medium**	Complete removal of the weir could potentially result in a reduction in habitat quality for key SSSI macrophyte communities and spawning fish included in the SAC designation. If the ecological impact of losing gravel habitats is deemed to be greater than the benefits of removing the structure, the removal of the weir could be prevented. **High**	**High**	Additional assessments are required to determine the scale of the bed habitats and identify potential impacts as a result of changes to flow dynamics and sedimentary conditions. **Medium**	A more detailed assessment of the changes to flow dynamics and sedimentation rates (including hydraulic modelling) will be required to assess the scale of the issue and the nature of any mitigation measures required.
Remobilisation of stored silt upstream of structure and transfer to reaches downstream impacting on silt intolerant macro-invertebrates and	Any sediment accumulated upstream of the structure will be remobilised if it is removed, potentially leading to adverse effects on in-channel communities further	Complete removal of the weir could potentially result in a reduction in habitat quality for key SSSI invertebrate and macrophyte communities. However,		Additional assessments into the scale of sediment accumulation upstream of the structure are required to accurately assess the potential for silt remobilisation. Hydraulic	If the results of further monitoring and modelling suggest that there is a large amount of sediment upstream of the weir, and that it is likely to become

Howsham Weir					
Constraint ***Constraints refer to disbenefits of undertaking a restoration action. E.g. loss of habitat, reasons that action is technically unfeasible. Constraints should be specific***	**Likelihood** ***How likely is it that the constraint will be realised (high- based on other examples or direct cause effect; medium- based on theoretical or indirect effect; Low – not known or not seen elsewhere but included as precautionary)***	**Consequence** ***For delivery of the action***	**Risk** ***(likelihood X consequence)***	**Confidence** ***Do we need to know more to be confident in constraint occurring and help support mitigation? Describe how certain the assessment is and what further work would achieve in reducing uncertainty. High – Has supporting scientific evidence Medium – Some evidence Low – Needs further research***	**Description of possible mitigation**
macrophyte communities	downstream. Although detailed measurements of bed sedimentation are not available, given the prevalence of sedimentation in the channel and patterns demonstrated further downstream it is likely to occur. **High**	since in-channel sedimentation is prevalent in the entire channel this may not be a major issue. If the ecological impact of sediment remobilisation is deemed to be greater than the benefits of removing the structure, the removal of the weir could be prevented. **High**	**High**	modelling to determine changes in flow velocities and sediment transport potential is also likely to be required. **Medium**	mobilised once the structure has been removed, it should be possible to physically remove the material while works on the structure take place. This should be undertaken in a sympathetic manner to ensure that any existing habitats are not damaged.
GEOMORPHOLOGY					
Mobilisation and downstream transport of fine bed sediments	Considerable quantities of sediment are likely to have accumulated upstream of the structure (up to about 1 km upstream). These are likely to be remobilised if the weir is removed. **High**	The remobilisation of bed sediments is likely to cause a temporary increase in turbidity, and lead to increased sediment deposition downstream. Although this may impact upon ecological communities further downstream (see above), the increase in sediment entrainment is unlikely to have a considerable impact on the geomorphology of the river. **Low**	**Medium**	Sediment remobilisation is highly likely to occur, although additional assessments are required to quantify the amount of sediment likely to be affected and determine likely increases in sediment entrainment (see above). **Medium**	Physical mitigation measures could be undertaken during construction to remove excessive sediment and prevent its entrainment (see above).
Adjustment of bed forms and potential loss of the weir pool	Removal of the weir is likely to cause considerable	Major bed readjustments could potentially cause the		Adjustment of the existing bed forms is likely to occur as a	The existing river bed could be regraded to produce a

Howsham Weir					
Constraint ***Constraints refer to disbenefits of undertaking a restoration action. E.g. loss of habitat, reasons that action is technically unfeasible. Constraints should be specific***	**Likelihood** ***How likely is it that the constraint will be realised (high- based on other examples or direct cause effect; medium- based on theoretical or indirect effect; Low – not known or not seen elsewhere but included as precautionary)***	**Consequence** ***For delivery of the action***	**Risk** ***(likelihood X consequence)***	**Confidence** ***Do we need to know more to be confident in constraint occurring and help support mitigation? Describe how certain the assessment is and what further work would achieve in reducing uncertainty.*** ***High – Has supporting scientific evidence*** ***Medium – Some evidence*** ***Low – Needs further research***	**Description of possible mitigation**
	changes in the flow dynamics of the river channel. This is likely to lead to an adjustment of the existing bed forms, as sediment is remobilised and redeposited. This could potentially lead to the loss of the existing weir pool as a result of gradual infilling and loss of turbulent flows. **High**	loss of the existing weir pool, as the flow conditions which maintain them are no longer prevalent. If the ecological impact of the loss of the weir pool is deemed to be greater than the benefits of removing the structure, the removal of the weir could be prevented. **High**	**High**	result of the removal of the structure. However, additional measurements of the existing bed conditions and assessment of the likely adjustments as a result of changing flow conditions (e.g. physical survey and hydraulic modelling) are required before the likely impact can be determined accurately. **Medium**	more varied suite of channel bed forms, including habitat niches that are deemed to be of importance for the condition of the SSSI.
Potential bank collapse as a result of decreased water levels	Removal of the weir is likely to decrease water levels, resulting in the potential for the banks to collapse due to geotechnical failure. Howsham weir creates an impoundment that extends upstream as far as Kirkham weir, a distance of 4.24 km. **Medium**	Natural restructuring of the banks as a result of lowered water levels is likely to increase localised morphological diversity and allow more varied habitats to develop. There are no riparian assets at the site that could be affected by this process. **Low**	**Medium**	Given the steepness and height of the banks and the material that they are comprised of, it is likely that a degree bank collapse will occur in response to a decrease in water levels. However, there are currently no detailed data on the geotechnical condition of the banks. **Medium**	The banks are likely to collapse as a natural response to decreasing water levels upstream. Since there are no assets in close proximity to the existing bankline, this is unlikely to require considerable mitigation.
HYDROLOGY					
Reduction in localised groundwater levels and floodplain connectivity	Removal of the structure will result in a reduction of upstream water levels upstream. This may lead to localised decreases in groundwater levels in the	This response is unlikely to prevent delivery of the action, since any changes to floodplain conditions are likely to be localised. Any detrimental impacts on local		Additional assessment is required to determine the impact of reducing in-channel water levels on floodplain connectivity and groundwater levels (including hydraulic	Bed regrading works could potentially be undertaken to maintain water levels and prevent a reduction in floodplain connectivity. This is likely to be required to

Howsham Weir					
Constraint ***Constraints refer to disbenefits of undertaking a restoration action. E.g. loss of habitat, reasons that action is technically unfeasible. Constraints should be specific***	**Likelihood** ***How likely is it that the constraint will be realised (high- based on other examples or direct cause effect; medium- based on theoretical or indirect effect; Low – not known or not seen elsewhere but included as precautionary)***	**Consequence** ***For delivery of the action***	**Risk** ***(likelihood X consequence)***	**Confidence** ***Do we need to know more to be confident in constraint occurring and help support mitigation? Describe how certain the assessment is and what further work would achieve in reducing uncertainty.*** ***High – Has supporting scientific evidence*** ***Medium – Some evidence*** ***Low – Needs further research***	**Description of possible mitigation**
	floodplain, and reduce floodplain connectivity by effectively increasing the flow required to get out of bank. **Medium**	ecology are likely to be outweighed by benefits to the river SSSI achieved by removing the impoundment. **Medium**	**Medium**	modelling to determine the precise drop in water levels and the impacts this would have on flood frequency). **Low**	produce a functional bed profile (see above).
RECREATIONAL AND SOCIO-ECONOMIC					
Loss of weir pool, leading to a reduction in quality for recreational fishing	Removal of the weir may lead to the loss or alteration of the existing weir pool (see above), which may adversely impact upon the quality of the site for recreational fishing. **Low**	The consequence of this action is a reduction in the amenity value of the site. This is unlikely to be outweighed by the benefits to the SSSI that would be achieved by removing the structure. **Low**	**Low**	The precise impacts of removing the weir on the downstream weir pool are uncertain, and are dependant on factors such as changing flow velocities and patterns, and alterations in sediment transport and supply. Additional assessments (including hydraulic modelling) are likely to be required before this impact can be assessed fully. **Low**	The potential for adverse impacts on the quality of the reach as a recreational fishery are likely to be mitigated by the improvements to fish habitat that would be delivered by removal of the weir.
CULTURAL HERITAGE					
No cultural heritage constraints have been identified for the weir. The structure has not been identified as a Listed Building. However, the old mill building is currently being restored.					

Overall risk to SSSI Condition	**Medium**	**Should option to be progressed for feasibility assessment?**	**Yes**

Stamford Bridge Weir					
Constraint ***Constraints refer to disbenefits of undertaking a restoration action. E.g. loss of habitat, reasons that action is technically unfeasible. Constraints should be specific***	**Likelihood** ***How likely is it that the constraint will be realised (high- based on other examples or direct cause effect; medium- based on theoretical or indirect effect; Low – not known or not seen elsewhere but included as precautionary)***	**Consequence** ***For delivery of the action***	**Risk** ***(likelihood X consequence)***	**Confidence** ***Do we need to know more to be confident in constraint occurring and help support mitigation? Describe how certain the assessment is and what further work would achieve in reducing uncertainty. High – Has supporting scientific evidence Medium – Some evidence Low – Needs further research***	**Description of possible mitigation**
ENGINEERING					
Technically difficult to remove the structure	The construction of the weir is unknown. Access to large construction vehicles is likely to be limited, although smaller vehicles can gain access. The width of the structure suggests that some in-channel works would be required. **Medium**	The weir cannot be removed or it would be excessively costly to remove. **High**	**High**	A full condition assessment will be needed as part of a feasibility study to confirm the condition of the weir prior to removal. However, given that the structure is submerged under the majority of flow conditions this may be difficult to undertake. **Low**	A full condition assessment undertaken in dry conditions (e.g. with a coffer dam in place) or as a diver survey.
Potential impacts on the old Corn Mill, Stamford Bridge and flood defences due to reduction in water levels	Removal of the structure will decrease water levels in the channel, which may decrease floodplain groundwater levels. This could cause floodplain subsidence. The effect on the stability of the flood defences and other structures such as the bridge and cut walls would need to be determined. Significant stretches of the defences are reinforced concrete walls with piled foundations so any reduction in bed level would have an impact on their stability. **Medium**	Decreased groundwater levels could potentially result in subsidence. This could potentially affect property close to the watercourse, particularly the old Corn Mill. **High**	**High**	Additional assessment is required to determine the impact of reducing in-channel water levels on floodplain groundwater levels (including hydraulic modelling to determine the precise drop in water levels and the impacts this would have on floodplain wetness). **Low**	Bed regrading works could potentially be undertaken to maintain in-channel and groundwater levels. Additional works to prevent subsidence may also be required, if this is determined to impact upon the structure.

Stamford Bridge Weir					
Constraint ***Constraints refer to disbenefits of undertaking a restoration action. E.g. loss of habitat, reasons that action is technically unfeasible. Constraints should be specific***	**Likelihood** ***How likely is it that the constraint will be realised (high- based on other examples or direct cause effect; medium- based on theoretical or indirect effect; Low – not known or not seen elsewhere but included as precautionary)***	**Consequence** ***For delivery of the action***	**Risk** ***(likelihood X consequence)***	**Confidence** ***Do we need to know more to be confident in constraint occurring and help support mitigation? Describe how certain the assessment is and what further work would achieve in reducing uncertainty. High – Has supporting scientific evidence Medium – Some evidence Low – Needs further research***	**Description of possible mitigation**
ECOLOGY AND SSSI					
Loss of gravel habitats downstream of structure	The weir supports high quality gravel habitats downstream. Removal of the weir may disrupt these habitats by reducing turbulence and allowing fine sedimentation to occur. **Medium**	Complete removal of the weir could potentially result in a reduction in habitat quality for key SSSI macrophyte communities and spawning fish included in the SAC designation. These gravels are particularly important for spawning river lamprey. If the ecological impact of losing gravel habitats is deemed to be greater than the benefits of removing the structure, the removal of the weir could be prevented. Any solution will need to ensure that the gravel habitats downstream of the structure are not compromised, **High**	**High**	Additional assessments are required to determine the scale of the bed habitats and identify potential impacts as a result of changes to flow dynamics and sedimentary conditions. **Medium**	A more detailed assessment of the changes to flow dynamics and sedimentation rates (including hydraulic modelling) will be required to assess the scale of the issue and the nature of any mitigation measures required.
Remobilisation of stored silt upstream of structure and transfer to reaches downstream impacting on silt intolerant macro-invertebrates and macrophyte communities	Any sediment accumulated upstream of the structure will be remobilised if it is removed, potentially leading to adverse effects on in-channel communities further downstream. Although detailed measurements of	Complete removal of the weir could potentially result in a reduction in habitat quality for key SSSI invertebrate and macrophyte communities. However, since in-channel sedimentation is prevalent in		Additional assessments into the scale of sediment accumulation upstream of the structure are required to accurately assess the potential for silt remobilisation. Hydraulic modelling to determine changes in flow velocities and	If the results of further monitoring and modelling suggest that there is a large amount of sediment upstream of the weir, and that it is likely to become mobilised once the structure has been removed, it should

Stamford Bridge Weir					
Constraint ***Constraints refer to disbenefits of undertaking a restoration action. E.g. loss of habitat, reasons that action is technically unfeasible. Constraints should be specific***	**Likelihood** ***How likely is it that the constraint will be realised (high- based on other examples or direct cause effect; medium- based on theoretical or indirect effect; Low – not known or not seen elsewhere but included as precautionary)***	**Consequence** ***For delivery of the action***	**Risk** ***(likelihood X consequence)***	**Confidence** ***Do we need to know more to be confident in constraint occurring and help support mitigation? Describe how certain the assessment is and what further work would achieve in reducing uncertainty. High – Has supporting scientific evidence Medium – Some evidence Low – Needs further research***	**Description of possible mitigation**
	bed sedimentation are not available, given the prevalence of sedimentation in the channel and patterns demonstrated further downstream it is likely to occur. **High**	the entire channel this may not be a major issue. If the ecological impact of sediment remobilisation is deemed to be greater than the benefits of removing the structure, the removal of the weir could be prevented. **High**	**High**	sediment transport potential is also likely to be required. **Medium**	be possible to physically remove the material while works on the structure take place. This should be undertaken in a sympathetic manner to ensure that any existing habitats are not damaged.
GEOMORPHOLOGY					
Mobilisation and downstream transport of fine bed sediments	Considerable quantities of sediment are likely to have accumulated upstream of the structure. These are likely to be remobilised if the weir is removed. Sediment is likely to have accumulated behind the structure for a distance of 1.24 km upstream. **High**	The remobilisation of bed sediments is likely to cause a temporary increase in turbidity, and lead to increased sediment deposition downstream. Although this may impact upon ecological communities further downstream (see above), the increase in sediment entrainment is unlikely to have a considerable impact on the geomorphology of the river. **Low**	**Medium**	Sediment remobilisation is highly likely to occur, although additional assessments are required to quantify the amount of sediment likely to be affected and determine likely increases in sediment entrainment (see above). **Medium**	Physical mitigation measures could be undertaken during construction to remove excessive sediment and prevent its entrainment (see above).
Adjustment of bed forms and potential loss of the weir pool	Removal of the weir is likely to cause considerable	Major bed readjustments could potentially cause the		Adjustment of the existing bed forms is likely to occur as a	The existing river bed could be regraded to produce a

Stamford Bridge Weir					
Constraint ***Constraints refer to disbenefits of undertaking a restoration action. E.g. loss of habitat, reasons that action is technically unfeasible. Constraints should be specific***	**Likelihood** ***How likely is it that the constraint will be realised (high- based on other examples or direct cause effect; medium- based on theoretical or indirect effect; Low – not known or not seen elsewhere but included as precautionary)***	**Consequence** ***For delivery of the action***	**Risk** ***(likelihood X consequence)***	**Confidence** ***Do we need to know more to be confident in constraint occurring and help support mitigation? Describe how certain the assessment is and what further work would achieve in reducing uncertainty.*** ***High – Has supporting scientific evidence*** ***Medium – Some evidence*** ***Low – Needs further research***	**Description of possible mitigation**
	changes in the flow dynamics of the river channel. This is likely to lead to an adjustment of the existing bed forms, as sediment is remobilised and redeposited. This could potentially lead to the loss of the existing weir pool as a result of gradual infilling and loss of turbulent flows. **High**	loss of the existing weir pool, as the flow conditions which maintain them are no longer prevalent. If the ecological impact of the loss of the weir pool is deemed to be greater than the benefits of removing the structure, the removal of the weir could be prevented. **High**	**High**	result of the removal of the structure. However, additional measurements of the existing bed conditions and assessment of the likely adjustments as a result of changing flow conditions (e.g. physical survey and hydraulic modelling) are required before the likely impact can be determined accurately. **Medium**	more varied suite of channel bed forms, including habitat niches that are deemed to be of importance for the condition of the SSSI.
Potential bank collapse as a result of decreased water levels	Removal of the weir is likely to decrease water levels, resulting in the potential for the banks to collapse due to geotechnical failure. Stamford Bridge weir creates impounded conditions 2.47 km upstream, to Buttercrambe weir. **Medium**	Natural restructuring of the banks as a result of lowered water levels is likely to increase localised morphological diversity and allow more varied habitats to develop. This may affect the land operated by the nearby caravan park. **Medium**	**Medium**	Given the steepness and height of the banks and the material that they are comprised of, it is likely that a degree bank collapse will occur in response to a decrease in water levels. However, there are currently no detailed data on the geotechnical condition of the banks. **Medium**	The banks are likely to collapse as a natural response to decreasing water levels upstream. mitigation to prevent economically productive land or assets (e.g. the caravan park) may be required, including potential bank reinforcement using suitable soft bank protection techniques.
HYDROLOGY					
Reduction in localised groundwater levels and floodplain connectivity	Removal of the structure will result in a reduction of upstream water levels by approximately 2100 mm. This may lead to localised decreases in groundwater	Decreased floodplain wetness and groundwater levels could potentially result in subsidence. This could potentially affect property close to the watercourse,		Additional assessment is required to determine the impact of reducing in-channel water levels on floodplain groundwater levels (including hydraulic modelling to	Bed regrading works could potentially be undertaken to maintain in-channel and groundwater levels. Additional works to prevent subsidence may also be

Stamford Bridge Weir					
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	levels in the floodplain, and reduce floodplain connectivity by effectively increasing the flow required to get out of bank. **Medium**	particularly the old Corn Mill. **High**	**High**	determine the precise drop in water levels and the impacts this would have on floodplain wetness). **Low**	required.
RECREATIONAL AND SOCIO-ECONOMIC					
Loss of weir pool, leading to a reduction in quality for recreational fishing	Removal of the weir may lead to the loss or alteration of the existing weir pool (see above), which may adversely impact upon the quality of the site for recreational fishing. The river is also enjoyed by tourists. **Low**	The consequence of this action is a reduction in the amenity value of the site. This is unlikely to be outweighed by the benefits to the SSSI that would be achieved by removing the structure. **Low**	**Low**	The precise impacts of removing the weir on the downstream weir pool are uncertain, and are dependant on factors such as changing flow velocities and patterns, and alterations in sediment transport and supply. Additional assessments (including hydraulic modelling) are likely to be required before this impact can be assessed fully. **Low**	The potential for adverse impacts on the quality of the reach as a recreational fishery are likely to be mitigated by the improvements to fish habitat that would be delivered by removal of the weir.
CULTURAL HERITAGE					
No cultural heritage constraints have been identified for the weir. The structure has not been identified as a Listed Building. However, Stamford Bridge bridge is located close by and has considerable historical significance.					

Overall risk to SSSI Condition	**Medium**	**Should option to be progressed for feasibility assessment?**	**Yes**