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River Wensum Restoration Strategy

Implementation River Unit 50 Bintree Mill to North Elmham Mill

FEASIBILITY & ENVIRONMENTAL SCOPING ASSESSMENT

December 2009

Reference number/code

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Abbreviations

Acronym	Meaning
BAP	Biodiversity Action Plan
BDC	Breckland District Council
CWD	Coarse Woody Debris
CSF	Catchment Sensitive Farming
CWS	County Wildlife Site
EIA	Environmental Impact Assessment
ECSFDI	England Catchment Sensitive Farming Delivery Initiative
ESA	Environmentally Sensitive Area
ESA	Environmental Stewardship Agreements
IDB	Internal Drainage Board
LWD	Large Woody Debris
mbgl	Metres below ground level
MCA	Multi-Criteria Analysis
NCC	Norfolk County Council
NLBAP	Norfolk Local Biodiversity Action Plan
OM 4	Outcome Measure 4
PSA	Public Service Agreement
RWRS	River Wensum Restoration Strategy
SAC	Special Area of Conservation
SAM	Scheduled Ancient Monument
SGVs	Soil Guidance Values
SSSI	Site of Special Scientific Interest
TLHB	True Left Hand Bank
TRHB	True Right Hand Bank
TWS	Total Weighted Score
WFD	Water Framework Directive
WLMP	Water Level Management Plan

Note – All references to the place and to the mill are called ‘Bintree’, whilst references to the fishing club are called ‘Bintry Mill Trout Fishery’.

Non Technical Summary

This feasibility and environmental scoping report is one of a series of reports produced by Atkins for the Environment Agency. The purpose of the report is to identify river restoration measures and options to restore the River Wensum SSSI to 'unfavourable recovering' or 'favourable' ecological condition.

Although the River Wensum is of national and international importance for its wildlife, past physical modifications continue to significantly impact on the natural geomorphology and ecology of the river. These modifications include straightening and deepening of the channel, removing the gravel bed, and the presence of mill structures that back up water for long distances upstream. The River Wensum Restoration Strategy (RWRS) (JBA, 2007) was developed to provide guidance on the actions needed to address these issues and restore the ecology of the river.

The main driver for this project is the Government's Public Service Agreement (PSA) national target that 95% of all SSSIs be in 'favourable' or 'unfavourable recovering' condition by December 2010. Other key drivers include: moving the River Wensum towards 'favourable' conservation status for European designated features; the Water Framework Directive, which requires certain measures to be implemented to achieve Good Ecological Status; the Wensum Fisheries Action Plan, which seeks habitat improvements to promote sustainable fisheries, and the objectives of the Chalk Rivers Habitat Action Plan.

This feasibility and environmental scoping report relates specifically to Unit 50 of the River Wensum SSSI, between Bintree Mill and North Elmham Mill, which is broken down into three smaller reaches, namely:

- Reach 19 - Bintree Mill to Dell View Farm
- Reach 18 - Dell View Farm to Bintree Woods
- Reach 17 - Bintree Woods to North Elmham Mill.

Feasibility and environmental scoping reports have also been produced for:

- Unit 46 – River Tat
- Unit 48 – Fakenham Mill to Great Ryburgh Mill
- Unit 52 – Elsing Mill to Lenwade Mill
- Unit 53 – Lenwade Mill to Taverham Mill.

This report seeks to implement and build upon the River Wensum Restoration Strategy. It considers measures recommended in the RWRS report, as well as new options for river restoration and management.

Detailed baseline conditions have been established through site visits and a thorough review of data and reports produced on the River Wensum.

Following on from this, a full suite of possible restoration options and measures has been identified. This is through a review of key documents, including the RWRS and also through stakeholder consultation in the form of public drop-in sessions, meetings and subsequent correspondence. The public drop-in session in late 2008 was well attended and suggests strong support for implementing restoration measures and overall environmental enhancements.

Six main option groups have been identified:

- Do nothing – no maintenance or restoration
- Do minimum – minimal restoration

- Targeted maintenance
- Continue as present
- River restoration – made up of three sub-groups:
    - Mill structures
    - Gravel works
    - Other
- Alternative options.

Options and measures have been evaluated on a reach-by-reach basis using a Multi-Criteria Analysis (MCA) tool, which sets out and weighs criteria for success, including ecological benefit, project delivery and technical feasibility. The MCA has shown that the recommended options for Unit 50 are:

- River restoration – whereby works to mill structures should take place first, followed by measures including reintroduction of gravel river bed, installation of gravel glides and riffles, backchannel reconnection, new backchannels, deflectors (using large woody debris), channel re-sectioning and berm creation.
- Targeted maintenance – suggestions under this option will inform a targeted maintenance protocol, currently being developed, which will set out how, where, when and by whom maintenance will be undertaken.

The highest scoring options have been taken forward into a series of conceptual designs, which in future can be developed into detailed projects and implemented to help the river move towards 'favourable' or 'unfavourable recovering' status. Consideration has been given to terrestrial SSSI units on the functional flood plain where there is the prospect of improving hydrological linkage with the river.

Detailed cost estimates have been developed for conceptual designs, based on a cost per unit length for each measure. The estimated costs for the recommended options for this unit are £1,487,000. Cost savings have also been explored through the reuse of previously excavated spoil (containing gravel) to raise the river bed, reducing the extent of certain measures without compromising their function, using locally sourced materials and by phasing the work efficiently. This reduces costs by 11% to £1,327,000. These estimates lie between those made by the RWRS in 2007 and by Halcrow in 2008.

The conceptual restoration design has been subjected to an environmental scoping exercise. This has involved determining which environmental features identified in the baseline review may be significantly impacted by the scheme and so will require further review and assessment in the next stage of the Environmental Impact Assessment (EIA). The topics that have been scoped in include:

- Protected species
- Fisheries, invertebrates and flora
- Invasive and non-invasive species
- Trees
- Historic environment
- Land use
- Traffic and transport
- Utilities

- Recreation
- Landscape and visual amenity
- Geomorphology
- Drainage and flood risk
- Water quality
- Soils
- Ground contamination.

The next phase of the River Wensum Restoration Strategy on this unit will be to develop and implement detailed projects for specific reaches or sub-reaches of river between Bintree Mill and North Elmham Mill. Further consents and permissions may be required to progress such schemes. These relate to:

- Planning consents
- Listed building consents
- Flood defence consents (formerly known as 'land drainage consents')
- Countryside and Rights of Way Act
- Protected species surveys and mitigation licences
- Waste licences
- Landowner consents.

Ongoing stakeholder engagement is a key part of the project and this will include landowners and occupiers, local government, internal Environment Agency functions, Natural England, Norfolk Rivers Internal Drainage Board, recreational users and local interest groups.

A number of project risks have also been identified which may delay the delivery or success of the recommended restoration. These include funding, costs, the extent to which changes in mill operation and structure can be implemented, protected species survey and mitigation, inappropriate maintenance, landowner consents and changes in legislation.

Managing these risks, the implementation of the River Wensum Restoration Strategy will help improve the ecological status of the river and achieve wider environmental and social benefits.

1. Introduction

1.1 Context

1.1.1 River Wensum

The River Wensum is a low gradient chalk river located in Norfolk, England (see Figure 1.1). The river, and a number of adjacent floodplain land parcels, are designated as a Site of Special Scientific Interest (SSSI) and as a Special Area of Conservation (SAC). As a chalk river the Wensum is also recognised as a priority habitat within the UK Biodiversity Action Plan (BAP).

Past physical modifications to the River Wensum have been undertaken to drain adjacent lands to improve their agricultural value, and to provide water storage for milling. These modifications have included extensive dredging which has straightened and over-deepened the channel, significantly impacting on the natural geomorphology and ecology of the river. The 14 redundant mill structures along the course of the River Wensum have significant hydrological impounding effects, with 67% of the river backed up behind these structures. This results in sluggish flows and accumulation of sediment in the channel, which, over time, have also contributed to the River Wensum being in unfavourable condition.

The latest condition assessment of the SSSI (English Nature, 2002) found all of the riverine SSSI units to be in '*unfavourable declining*' condition. Reasons cited for this included poor water quality, excessive siltation and physical modifications. Physical modifications of the river, and to some extent siltation, will be addressed through a programme of river restoration measures designed to help return the river to '*unfavourable recovering*' or '*favourable*' ecological condition. This feasibility report considers various options and measures by which this restoration can be achieved. Issues of poor water quality are being addressed at a strategic level through other projects such as the England Catchment Sensitive Farming Delivery Initiative (ECSFDI) and a review of existing abstraction licences and discharge consents.

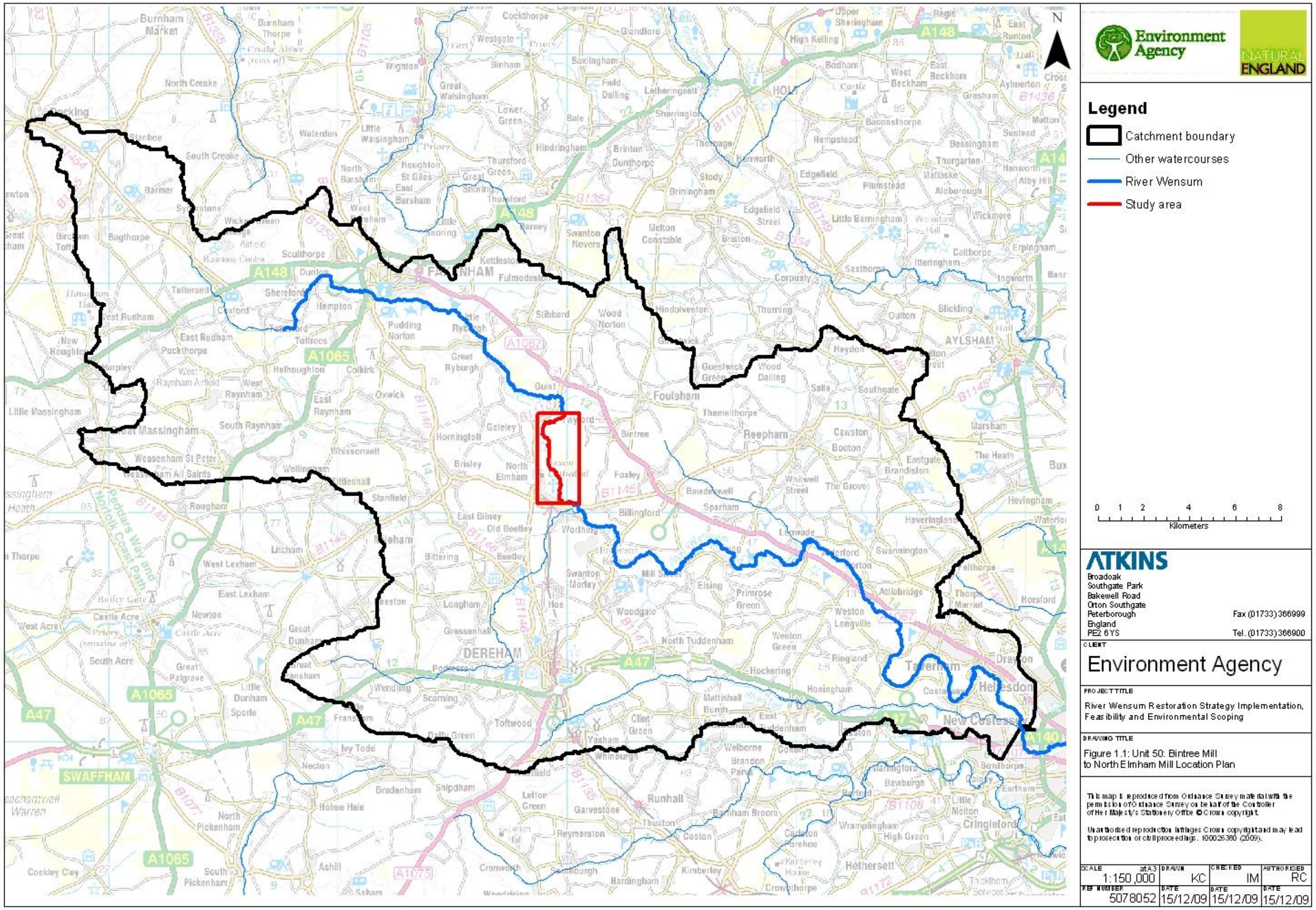

Figure 1.1 Location of the River Wensum showing the catchment boundary (outlined black), the River Wensum and the study area between Bintree Mill and North Elmham Mill Unit 50 (outlined red)

1.1.2 Feasibility Report

This report continues the work commenced through the River Wensum Restoration Strategy (RWRS) (JBA, 2007), and represents the next step in the implementation of restoration. It defines a preferred restoration approach for Unit 52. The outcomes of this Feasibility Report will inform the detailed design and implementation of river restoration for this section of channel.

The feasibility assessment continues the partnership between the Environment Agency and Natural England (formerly English Nature). It relates specifically to Unit 52 (Elsing Mill to Lenwade Mill) and the three 'Reaches', 11, 12 and 13 which fall within this unit (see Section 2.1 for definitions of the terms 'Reach' and 'Unit'). Figure 1.2 illustrates where this feasibility assessment fits within the planning of restoration on the River Wensum.

It should be noted that this unit abuts with Unit 51 upstream (North Elmham Mill to Elsing Mill) and with Unit 53 downstream (Lenwade Mill to Taverham Mill).

Feasibility reports are also available as separate documents for the following river SSSI units:

- Unit 46 River Tat
- Unit 48 Fakenham Mill to Great Ryburgh Mill
- Unit 50 Bintree Mill to North Elmham Mill
- Unit 53 Lenwade Mill to Taverham Mill.

1980	Ecological survey	An ecological survey (Holmes, 1980) of the river established that plant communities present in the upper reaches were typical of chalk rivers. This survey was repeated in 2002 (Grieve *et al*, 2002).
1988	Wensum Valley Countryside Management Project	The Wensum Valley Countryside Management Project was established in 1988 as a joint venture between the Countryside Commission and local authorities. The objectives of the project included the enhancement of wildlife habitats, landscape and recreational value of the valley.
1993	SSSI designation	The entire river was notified as a SSSI in February 1993, as an example of an enriched calcareous lowland river. The citation describes it as "probably the best whole river of its type in nature conservation terms".
1994	Wensum Valley Strategy	The Wensum Valley Strategy was published in 1994 by the Wensum Valley Project to provide a framework for taking the project objectives forward and defines policies for future management of the valley.
1999	River Rehab Feas Study; WLMP	The study by Econ represented the first specific review of restoration options for the River Wensum. In 1999, the first Water Level Management Plan for the Wensum was also produced.
2002	Wensum Forum	The Wensum Valley Project hosted a meeting between the EA, English Nature and local landowners/IDB members.
2002	SSSI Condition Assessment	A condition assessment of the SSSI unit was undertaken by English Nature (now Natural England) and concluded that the river was in '*unfavourable declining*' condition due mainly to water impoundment caused by physical structures (e.g. mills), siltation and water quality.
2004 - 2005	Geomorphological appraisal of the River Wensum SAC	Geodata Services assessed the form and function of the river, and provided reach-based guidance on the management required to restore the natural geomorphology.
2004	Wensum Fisheries Action Plan	The Wensum Fisheries Action Plan group identified the need to fund and implement further habitat restoration schemes on the river to aid the sustainable recovery of fish stocks
2005	English Nature Steering Group convened	This steering group was convened in order to consider the outcomes of the geomorphological appraisal and to determine a way forward for improving the condition of the SSSI through river restoration.
2005	SAC designation confirmed	Qualifying features for the SAC designation are white-clawed crayfish, Desmoulin's whorl snail, brook lamprey, bullhead and water crowfoot vegetation communities
2007	Water Level Management Plan, River Wensum SSSI	This revision of the previous Water Level Management Plan (1999) provides a framework for managing appropriate water levels, and was driven largely by the need to achieve nature conservation objectives. Recommendations related to promoting agri-environment schemes and modifying impounding mill structures.
2007	River Wensum Restoration Strategy	The River Wensum Restoration Strategy (RWRS) was completed by JBA in November 2007 for Natural England, and represents a culmination of much of the previous work. This strategy considered the entire River Wensum but identified a range of high level river restoration options on a reach-by-reach basis.
Present 2009	Feasibility Report: Unit 50-Bintry Mill to North Elmham Mill	This report considers a number of restoration options specifically for Unit 50 and recommends the preferred restoration measure, or suite of measures, for each reach within the unit. The report makes recommendations as to which of these measures should be progressed to achieve improvement for the unit as a whole.
Future	Outline and Detailed design of recommended options for the unit	The detailed design of the recommended measures will be undertaken and associated consent applications (e.g. Flood Risk Consent) will be made. An environmental assessment of the proposed scheme will be undertaken.
Future	Construction	River restoration measures will be constructed.
Future	Monitoring	Monitoring of the effectiveness of the constructed measures will be on-going.

Figure 1.2 - Timeline of environmental and restoration related investigations and events, showing how this assessment fits within the process of realising restoration on the River Wensum.

1.1.3 Structure of this report

This report has been structured to reflect the sequential process by which the recommended restoration options have been determined. Table 1.1 lists the report chapters and provides a brief description of their contents.

Table 1.1 -Chapters constituting this report

Chapter	Title	Description
1	Introduction	This chapter presents the context of the River Wensum, and introduces the RWRS. It also discusses the methodology used in this report.
2	Bintree Mill to North Elmham Overview	Chapter 2 introduces the specific section of river considered in this report, namely Unit 50, discussing location, previous restoration initiatives, and those restoration measures recommended by the RWRS.
3	Environmental Baseline	Chapter 3 provides an overview of the environmental baseline for the unit. It is provided on a reach by reach basis, focusing on reach-specific information.
4	Consultation	Chapter 4 provides details of the consultation process undertaken as part of this feasibility assessment, and the main issues raised.
5	Options Appraisal	Chapter 5 presents the Multi-Criteria Analysis explaining the methodology and those options which scored highest for each reach.
6	Developing Conceptual Design	Chapter 6 presents a conceptual design for the recommended restoration measures for each reach based on results from the Multi-Criteria Analysis.
7	Cost Estimates	Chapter 7 describes the outcome of the consideration of costs for each of the reaches and identifies potential cost saving efficiencies in materials and phasing of the proposed works.
8	Environmental Scoping	The specific restoration plan proposed for the unit is subjected to an environmental scoping process. This determines the key environmental issues to be considered in the subsequent environmental reporting for these works.
9	Consents	Chapter 9 discusses the consents that would be required prior to construction of the restoration works.
10	Project Risks	This chapter tables the key project risks associated with the planning and implementation of the project.
11	Conclusions and Recommendations	Chapter 11 concludes the report with recommendations for taking the project forward.

1.2 River Wensum Restoration

The project was initiated in response to a number of key drivers. The most significant of these are listed below.

- The Government's Public Service Agreement (PSA) target for SSSIs constitutes the main driver for physical restoration of the river, and hence the main driver behind the RWRS. River restoration on the Wensum will contribute to the national target of 95% (by area) of SSSIs being in *'favourable'* or *'unfavourable recovering'* condition by 31 December 2010. All riverine units within the Wensum SSSI are currently in 'unfavourable declining' condition.

- As a European Natura 2000 site, measures are required to ensure that the River Wensum moves towards 'favourable' conservation status. The European features of the site are; bullhead, brook lamprey, Desmoulin's whorl snail, white-clawed crayfish and water crowfoot plant communities.
- The Water Framework Directive (WFD) defines the River Wensum as a 'Protected Area' and as such, measures have to be implemented to address those factors limiting natural hydro-morphological functioning of the river.
- Chalk rivers are a priority BAP habitat, with England supporting 85% of the world resource. The Environment Agency is the lead authority for this habitat, and objectives are defined in the Chalk River Habitat Action Plan produced jointly by the Environment Agency and Natural England. The Action Plan recognises the quality and importance of chalk rivers ecologically, hydrologically, recreationally and culturally (Environment Agency / Natural England 2004).
- River restoration will also contribute to the objectives of the River Wensum Fisheries Action Plan, River Wensum Water Level Management Plan and Broadland Rivers Catchment Flood Management Plan.

1.2.1 Approach

The RWRS report provided comprehensive high level guidance for restoration of the River Wensum. The chief aim of the *Strategy* was to provide a whole river vision for implementation of restoration by developing restoration delivery plans on a reach-by-reach basis throughout the SSSI. The undertaking of the RWRS involved, amongst others, the following key activities:

- Reviewing of existing baseline information.
- Consulting with steering group members including the River Restoration Centre (RRC), as well as with key local stakeholders.
- Reviewing the river reaches and restoration measures proposed in the Geomorphological Appraisal.
- Mapping current conditions on the River Wensum and comparing them to expected semi-natural conditions in Norfolk.
- Determining a cost-band for each of the RWRS reaches.
- The above culminated in the production of a technical report (JBA, 2007).

1.2.2 Outputs

The RWRS identified and recommended a number of restoration and management measures including:

1. Implement structural modification to lower, remove or bypass water control structures at mills.
2. Raise bed levels and restore the gravel bed substrate where appropriate.
3. Narrow over-widened sections of river.
4. Introduction/retention of woody debris.
5. Reconnection of 8km of channel to its original channel.
6. Reconnection of the river to its floodplain through removal of embankments where appropriate.
7. Creation of berms to stabilise silt/control silt deposition in the channel.

The *Strategy* culminates in a suite of high level recommendations presented for each of the reaches in Unit 50. This provides a framework for delivering restoration and a starting point for the implementation of restoration on a reach by reach basis.

1.3 Feasibility assessment aims

The overall aim of this feasibility assessment, and hence this report, is to progress the implementation phase of restoration and deliver the PSA objectives for the River Wensum SSSI by 31st December 2010. The key objectives of this feasibility assessment are to:

- Determine the most suitable restoration measure, or suite of measures for Reaches 19, 18 and 17.
- To consult with local landowners and stakeholders on the opportunities and constraints for restoration on a reach by reach basis.
- To subsequently recommend an overarching restoration and river management conceptual design for Unit 50.
- To provide a detailed cost estimate of implementing the conceptual design.
- Undertake an environmental scoping assessment of the recommended restoration options.

In restoring the hydrological linkage between the river and its floodplain, there should also be consideration of the hydrological linkage between the river SSSI unit (Unit 50 in this instance), and adjacent terrestrial units of the River Wensum. There are two terrestrial SSSI units adjacent to Unit 50 of the River Wensum SSSI.

This feasibility assessment builds on the RWRS by considering the measures recommended in the Strategy, as well as new options for river restoration and river management. A process of Multi-Criteria Analysis (MCA) has been used to determine the most suitable restoration measures or suite of measures for each reach. Section 1.4 provides further detail regarding the adopted methodology.

1.4 Methodology

This feasibility assessment involved undertaking the following key activities listed in chronological order. These are described in detail in Sections 1.4.1 to 1.4.7, and Figure 1.3 illustrates the process.

1.4.1 The establishment of detailed baseline conditions for a specific reach.

A large amount of baseline data exists for the River Wensum. Numerous reports and raw data were reviewed as part of this feasibility assessment. The majority of this information relates to the River Wensum as a whole, and detailed reach-specific data is less readily available. Section 3.1 sets out more information. In addition, a number of site visits were undertaken throughout the unit by different members of the project team to confirm desk-top research. Specific baseline conditions for each reach were mapped on an environmental constraints plan.

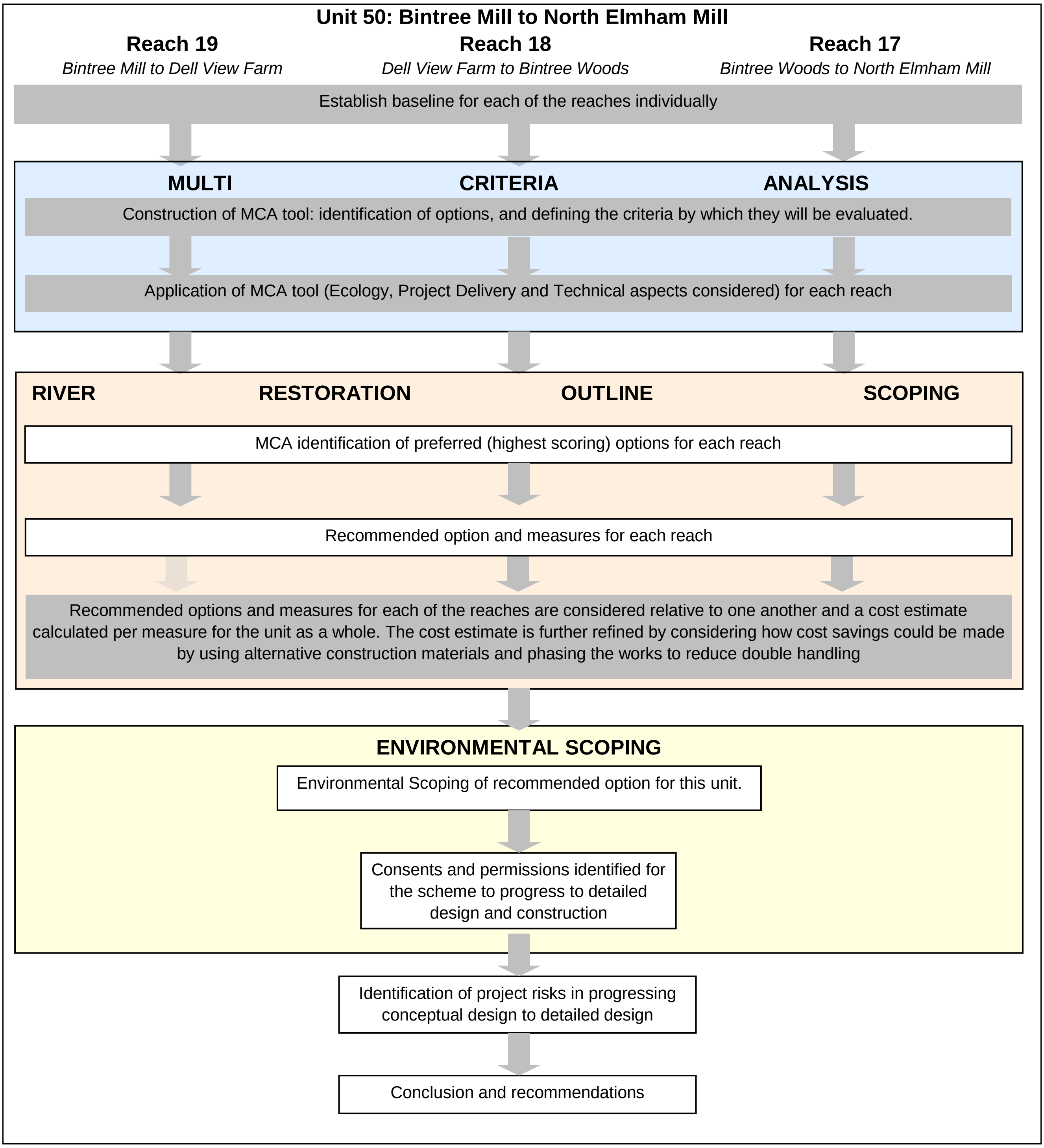

Figure 1.3 - The approach adopted during feasibility assessment for determining the recommended restoration option on individual reaches and the river unit

1.4.2 The identification of a full suite of possible restoration measures, including those recommended in the RWRS

A generic list of all management and restoration options possibly applicable to the River Wensum was generated through reviewing key documents such as the RWRS (JBA, 2007); public consultation and through a public drop-in session undertaken by the Environment Agency, Natural England and Atkins in December 2008. From the above activities, six main option groups were identified, and were taken forward for consideration using the Multi-Criteria Analysis (MCA) tool. These options are discussed further in Chapter 5, and supported in Appendix A:

1.4.3 The evaluation of restoration, maintenance and alternative options by means of Multi-Criteria Analysis

Once identified, the six main option groups were evaluated for each reach using a MCA tool. This was considered necessary to ensure that a transparent, defendable and replicable technique of selecting options could be consistently applied. The MCA technique scores the listed options in terms of the degree to which they meet certain criteria, which are broadly grouped under the headings of ‘Ecological’, ‘Project Delivery’ and ‘Technical’. The highest scoring options were considered to be the ‘preferred suite of options’ for that specific reach and were taken forward for consideration in terms of cost. The MCA technique was carried out on a reach-by-reach basis.

1.4.4 The development of a conceptual design based on the recommended options and suite of measures for each of the reaches considered

The recommended options for each reach were considered and professional judgement was applied in order to determine the appropriate combination of the reach-specific solutions in order to realise improved conditions for the SSSI unit as a whole. A conceptual design was developed for each reach and these are displayed on base maps in Chapter 6.

1.4.5 The consideration of costs associated with these options and specific river restoration measures

A detailed cost estimate was calculated and this was based on a cost per unit length for the different measures and applied to a conceptual design for each reach. Cost savings from phasing work appropriately and using local materials were explored. Chapter 7 describes this in further detail.

1.4.6 Environmental Scoping of the recommended option for the unit

The recommended option (conceptual design) was subjected to an environmental scoping exercise, so as to determine the environmental issues which would warrant a detailed assessment at the next stage of the process. This includes an Environmental Report to be drafted in parallel with the detailed design. The details of this scoping exercise are provided in Chapter 8.

1.4.7 Identification of potential project risks, permissions and consents

As part of the next phase of implementation, consents and permissions that will be required to progress the recommended conceptual design to detailed design and construction were identified along with potential risks to the project. These are described in Chapters 9 and 10 respectively.

2. Bintree Mill to North Elmham Mill overview

2.1 Terminology and site location

2.1.1 Terminology

In order to determine restoration options applicable to the River Wensum, the following terms are used:

The term **'unit'** is used only in reference to particular riverine SSSI units, which are officially demarcated sub-components of the River Wensum SSSI. These units, of which there are 10 within the study area (Units 45-54), are up to 20 kilometres in length. Each feasibility report looks at one SSSI unit, and this report addresses Unit 50 (Bintree Mill to North Elmham Mill).

The term river **'reach'** is used to describe smaller stretches of the river that have been defined according to their geomorphological environment. Whilst not related to the SSSI designation, a number of these reaches fall within each unit. This report recommends restoration options that may be appropriate to river Reaches 19, 18 and 17. Due to their shorter length, reaches are considered preferable to units for planning restoration. The advantage of taking this approach is that many of the restoration options that apply to the entire unit can be broken down and assessed at an individual reach scale.

The term **'section'** has been used as a generic term referring to any portion of the river. For example, 'the section of river between the bridge and the mill'.

The term **'option'** is used to describe a suite of measures that could be implemented to return Unit 50 to '*unfavourable recovering*' or '*favourable*' ecological condition. For example 'Do nothing', 'Do minimum', 'River restoration', 'Targeted maintenance' are all options.

The term **'measure'** is used to describe a specific technique or work element that falls within an option. For example, bed raising is a measure of the 'River restoration' option, silt removal at mill ponds is a measure of the 'Targeted maintenance' option.

2.1.2 Site location

This feasibility report addresses options for SSSI Unit 50, and Reaches 19, 18 and 17 which all fall within this Unit. These are listed below and shown in Figure 2.1.

- Reach 19 - Bintree Mill to Dell View Farm
- Reach 18 - Dell View Farm to Bintree Woods
- Reach 17 - Bintree Woods to North Elmham Mill.

This SSSI Unit falls within the boundaries of Breckland District Council (BDC).

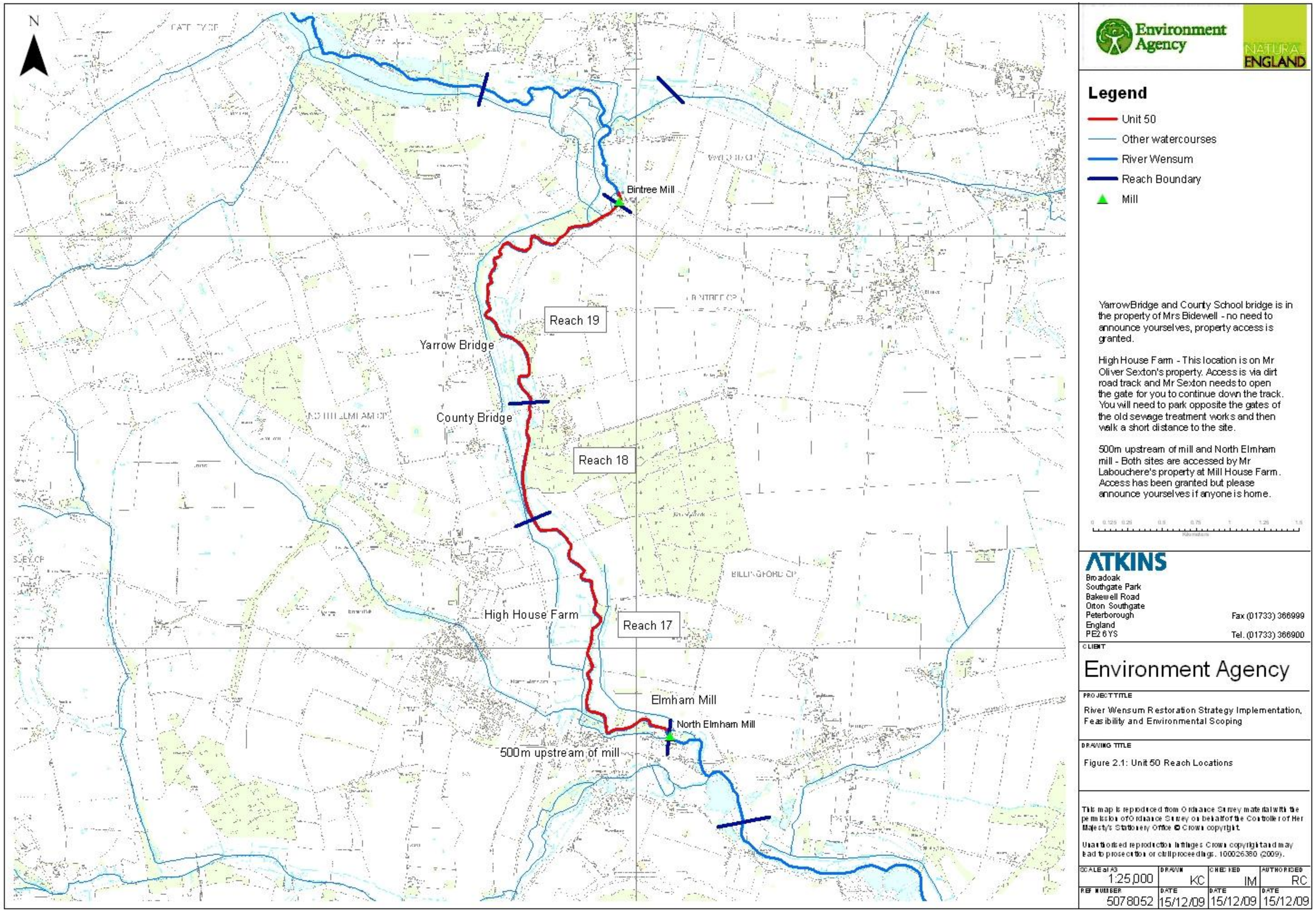

Figure 2.1 - Location of Reaches 19, 18 and 17 within SSSI Unit 50

2.2 Previous works within Unit 50

Since its designation as a SSSI in 1993, there have been a variety of engineering and environmental surveys and investigations carried out on the River Wensum. Recommendations from various survey reports have been realised in a range of consented river restoration works along sections of the River Wensum. Table 2.1 lists all previous restoration works within Unit 50.

Table 2.1 - Summary of previous river restoration works consented on Unit 50

Reach	Location	Previous Works Consented	Year
19	Bintree Mill to Dell View Farm	Between 2000 and 2006 the Environment Agency and Bintree Mill Trout Fishery implemented the following restoration measures: • Importing of gravel to replenish natural substrate aimed to promote pool-riffle features; • Creation of pool-riffle features; • Channel narrowing and bank reprofiling; • Installation of deflectors; • Fencing and planting of bankside trees; and • Construction of cattle drinks.	2000 to 2006
18	Dell View Farm to Bintree Woods	None	N/A
17	Bintree Woods to North Elmham Mill	Private land owner augmented right bank with gravel to improve fish habitat.	N/A

2.2.1 Restoration measures undertaken on Reach 19

Restoration measures were mainly carried out along the upstream section of this reach. They aimed to address the problems that had been created through historical land and river management practices and to improve fisheries habitat, particularly for brown trout.

According to the River Restoration Centre report (RRC, 2007), which reviewed past restoration projects on this reach, the restoration measures have improved conditions. In particular:

- Flow diversity has improved and there is a general increase in flow velocity.
- The River substrate now contains some gravel, although it is still dominated by silt.
- Bankside erosion has significantly reduced.
- The river bed is now more morphologically varied.
- There is now a greater diversity in riparian vegetation.
- Fencing this section of the River Wensum on the left bank has helped to prevent livestock from poaching and eroding the river banks. This has enabled the river to narrow to a more natural width (Plate 1.). In turn, this has helped to re-establish natural physical processes under the different flow conditions.

Plate 1 - Natural narrowing of the river in Reach 19. Protection from cattle poaching by fencing the left bank has resulted in natural narrowing in places (source: RRC, 2007)

The physical impacts of the works are few and are limited to the local area (RRC, 2007). Of all the works carried out between 2000 and 2006, the most successful elements included the installation of gravel, natural narrowing from vegetation growth, and artificial narrowing using compacted chalk. Together, these have resulted in more variation in channel morphology than was previously present.

2.2.2 Lessons learnt from previous restoration measures at Bintree

Some of the features implemented during the period 2000 to 2006 have had limited success due to natural physical processes impacting on the features. According to the RRC report (2007), some of the features would have benefited from an alternative design or location. For example, two 'V shape' deflectors that were installed, had limited success primarily due to the inadequate size of the structures and their positioning in the channel (see Plate 2) which led to scouring of sections of the opposite bank and locally increasing in-stream silt loads (RRC, 2007).

The RRC report (2007) concluded that overall in-stream invertebrate community populations had improved. The report suggested that the creation of additional backwater features, wider landscaping, including additional riparian tree planting, and a wider effort to re-connect the river to its floodplain would further improve the overall geomorphology of the river and, in turn, improve the terrestrial and aquatic habitats.

Plate 2 - A deflector installed in Reach 19. This deflector was not substantial enough to be effective (source: RRC, 2007)

2.3 RWRS restoration vision for Unit 50

A condition assessment of the SSSI was conducted by English Nature in 2002. All riverine SSSI units were recorded as being in '*unfavourable declining*' condition. The vision of the RWRS is to provide a framework that leads to the delivery of restoration that improves the condition of SSSI units from their current *'unfavourable declining'* condition towards a more naturally functioning and ecological sustainable system in '*unfavourable recovering*' or *'favourable'* ecological condition.

The RWRS recommended a variety of restoration options for each reach. These are listed in Table 2.2.

Table 2.2 - Recommended restoration measures for each reach as provided in the RWRS (JBA, 2007)

Reach	Length (km)	Restoration Recommendation from the RWRS
19	2.67	In the first 100 to 200 m downstream of Bintree Mill, no works are required. This area should be conserved and allowed to re-vegetate naturally. Reduce depth by an average of 0.7 m and raise bed using up to 47 gravel glides or riffles in the reach. Adopt and maintain a maintenance regime and riparian management to allow channel to narrow naturally.
18	0.86	Augment bed on average by 0.7 m using local gravels wherever possible and create up to 15 gravel glides or riffles in the reach. Physical narrowing may have to be considered to restore the full functioning of the channel in this reach. Adopt and maintain a maintenance regime and riparian management to allow channel to create natural variations in local channel width and habitat niches.
17	2.60	Initial work required is for bed and bank stabilisation associated with removal of North Elmham Mill structures at downstream end of reach. Appropriate measures required to manage silt deposits upstream of the mill. Augment bed on average by 1.5 m using local gravels wherever possible and create up to 45 gravel glides or riffles in the reach. Physical narrowing may have to be considered to restore the full functioning of the channel in this reach following works at the mill. Adopt and maintain a maintenance regime and riparian management to allow channel to create natural variations in local channel width and habitat niches. Post project monitoring is required, especially in association with works at the mill structures.

The measures are relatively broad-scale and will require more detailed appraisal to determine the suitability and extent of each restoration measure. In order to appraise and define these measures, a detailed understanding of reach-specific baseline conditions is required. Chapter 3 of this Report presents this baseline.

3. Environmental Baseline

3.1 Introduction

This chapter presents environmental baseline information for Reaches 19, 18 and 17. Environmental constraints for Unit 50 are shown on Figure 3.1.

A review of the existing environmental setting has been undertaken through a combination of desk study and preliminary site surveys. Data has been obtained from existing survey reports, and discussion with a number of individuals and organisations including Environment Agency internal functional specialists (e.g. Fisheries, Recreation and Biodiversity, National Environmental Assessment Service, Operations Delivery), Natural England, and Norfolk County Council (NCC). Information sources consulted include, but are not restricted to, the following:

- The Environment Agency, www.environment-agency.gov.uk
- Breckland District Council
- Norfolk County Council, www.norfolk.gov.uk
- Norfolk Rivers Internal Drainage Board (IDB)
- Defra Multi-Agency Geographic Information for the Countryside, www.magic.gov.uk
- Natural England, www.naturalengland.org.uk
- Norfolk Mills, www.norfolkmills.co.uk
- Norfolk County Council historic maps, www.historic-maps.norfolk.gov.uk
- River Wensum Restoration Strategy (RWRS) JBA (2007)
- Water Management Alliance
- River Restoration Centre (Mant, J. & Fellick, A. 2007)
- River Wensum Water Level Management Plan (2007)
- Environment Agency National Fisheries Monitoring Programme database.

3.1.1 Approach to presenting baseline information

Presenting specific baseline information for each reach allows a better understanding of the existing environmental constraints that need to be considered when developing river restoration options.

This information will be included in the options appraisal process and the Multi-Criteria Analysis (MCA). More information about the aims and objectives of the MCA is provided in Chapter 5.

Baseline information common to environmental features across all reaches is described in Section 3.2 and specific baseline information for each reach is described in Tables 3.3 to 3.5.

Figures 3.2 to 3.4 and supporting plates complement the baseline text.

3.1.2 Applicable environmental legislation and policy

Environmental legislation that drives this project and will need to be considered alongside associated restoration and management options include:

- The Conservation (Natural Habitats &c.) Regulations 1994 (as amended).
- The Wildlife and Countryside Act 1981 (as amended).

3.1.3 Limitations to collating baseline information

The baseline data has been derived from a review of existing information and preliminary walkover surveys. There are a number of gaps in the baseline data which will need to be addressed during the ongoing Environmental Impact Assessment (EIA) should restoration options identified in this report progress to the detailed design stage.

3.2 Common environment features across all reaches

3.2.1 Defining the character of chalk rivers

A prominent feature of the cretaceous deposits of England is successive strata of chalk which dip gently to the west and are exposed along a wide front running roughly diagonally from Hampshire to Norfolk and Lincolnshire. In Norfolk, chalk strata predominate as the underlying geology. However, as one travels from Hampshire to Norfolk, the influence of the chalk on the land surface becomes increasingly masked by glacial and fluvio-glacial silts, sands, gravels and boulder clays. This reflects the fact that, even during the most severe glaciations over the pleistocene period, the ice-sheets only extended as far south as the Thames.

All chalk rivers are characterised by a high base flow throughout the year, with buffering of high flows during the winter as water percolates into the underlying aquifer, and buffering of low flows during the summer as water is gradually released from the aquifer. However, the influence of superficial deposits has a profound impact on how the chalk river habitat is expressed on the land.

The southern chalk rivers such as the Hampshire Avon, the Frome, and the Test are regarded as ‘classic’ chalk rivers. In some of these, up to 90% of the flow enters the river through its bed, and as a consequence there is a low density of tributaries in the catchment. As these rivers lie very close to the chalk, there tends to be a relatively smooth pattern of flow accretion along the length of the river. Accretion tends to be greatest along those reaches with the highest gradient, and decreases as the river reaches the lower gradients typical of mature river and floodplain. The close association of the river bed to the chalk bedrock means that the headwaters are often winterbournes (watercourses which only flow in winter due to a seasonal increase in the water table).

The way in which the chalk river is expressed is affected where the chalk is obscured and overlain by a considerable depth of superficial clays, sands and gravels. In most cases, it means that the chalk aquifer is separated from the river by one or more intermediate aquifers within the superficial deposits. Where the properties of the overlying drift change across the catchment, this results in a situation where tributaries from some sub-catchments more closely resemble chalk rivers than others. In situations where the land surface is less permeable, then there will tend to be a higher density of tributaries. Deep deposits of superficial material between the chalk and the land surface prevent the occurrence of winterbournes

Since northern chalk rivers run over material of varying permeability, so the level of accretion is more variable along different reaches. In Norfolk, the hydrology of chalk rivers is further complicated by the fact that the glacially scoured valleys in the chalk run north to south, whereas the rivers tend to run west to east.

With northern chalk rivers the nature of the superficial deposits will also influence the proportion of water that reaches the river as overland flow, and also the material that is available to wash into the river and tributaries from rainfall. It will also affect the land use and hence the vulnerability to erosion of soils in the catchment. In Norfolk, intensive arable agriculture is more prevalent than in the south of England, and hence the river faces much greater vulnerability to diffuse water pollution from agricultural sources.

Because Norfolk chalk rivers differ from their 'classic' counterparts in the south of England, restoration designs that are developed in the south of England may not necessarily be appropriate in Norfolk. The template for a Norfolk chalk river is explored in detail in the Geomorphological Appraisal of the River Wensum by Sear et al. (2006) and also summarised in the JBA report (2007).

3.2.2 The current chalk status of the River Wensum

As a northern chalk river, the Wensum catchment is characterised by superficial deposits of sands, gravels and clays, resulting in a chalk river habitat which shows some affinities with other lowland river types. These deposits are variable in nature, and there tends to be greater permeability towards the north of the catchment, with other areas characterised by more impermeable clays. However, as with other chalk rivers, there is a very high base flow, and there is no ambiguity that this is a chalk river, with accretion from the aquifer throughout its length.

The variability in overlying substrates, and complex underlying geology and landforms, results in the River Wensum exhibiting a higher density of tributaries than is characteristic of 'classic' chalk rivers. It also influences the availability of material that can be washed into the system during rainfall events, and some of the subcatchments tend to accrete large volumes of sand. The system has been significantly impacted by the influence of intensive arable agriculture, which dominates much of the Norfolk landscape, and has lead to much higher vulnerability of soils than would have been the case post war, when Norfolk was characterised by a more mixed agricultural system.

Whilst the Wensum retains its baseflow connectivity throughout its length, even to Costessey, the increasing thickness of the overlying glacial drift, sands and gravels along the lower catchment (downstream of Fakenham) increasingly dominates the physical character and structure of the river. As a result, the lower Wensum does not exhibit the characteristics of the classic southern England chalk rivers, where the underlying chalk is consistently closer to the river bed and influences the character of the river to a much greater degree.

Another feature of the Wensum is that the river course reflects the periglacial conditions that prevailed immediately after the retreat of the last ice age. At this time the river was a high energy system with a wide meandering form that cut down into superficial deposits, creating a wide valley and floodplain within the landscape. The low energy system of later periods has modified this large-scale meandering system with secondary sinuosity within the floodplain. This pattern is well represented on the lower reaches of the river between Ringland and Hellesdon.

As previously described, the impact of intermediate aquifers in the overlying deposits means that winterbournes are not expressed within the landscape in the way that they are in the 'classic' chalk rivers.

Despite the majority of the Wensum floodplain remaining relatively natural and managed for grazing, the drainage of the catchment has been substantially altered over time by channel simplification, floodplain drainage and the presence of mills and their associated structures. The mill structures exert a disproportionate impact on the river, with over two thirds of its length impounded, so that in many cases the Wensum behaves more like a series of linear lakes than free-flowing river. A further complexity of impounded reaches is that it is no longer possible to drain the land directly into the river, and a secondary drainage system has been developed on the floodplain on either side of the river, draining back into the river immediately below the mill structures. This pattern is repeated at most of the 14 mill structures along the river, the arterial drains being managed by the Norfolk Rivers Internal Drainage Board.

On free-flowing reaches, dredging activities have also had profound impacts on the river, resulting in channel deepening and removal of the gravel bed. The Geomorphological Appraisal demonstrated that the Wensum was such a low gradient system that it was unable to replace these gravels through natural processes, and the only mechanism through which the river is able to reduce the cross-sectional area of the channel is through the development of silt berms which result in a further narrowing and deepening of the system.

Despite these changes, in 1980, Holmes classified sections of the upper river as JNCC River Type III (chalk rivers and other base rich rivers with stable flows), with downstream transitions to Type I (lowland rivers with minimal gradients on mixed geology in England). In 2002, Grieve et al. reclassified the upper reaches as Type IIIb to Iva (base rich/neutral impoverished rivers, normally close to source) and the lower reaches were similar to the middle reaches Type Ic to IIc, both of which demonstrated a degraded river type compared to previous surveys.

As indicated in the previous section, it is essential to have a clear understanding of the characteristics of a Norfolk chalk river before developing detailed restoration designs. The studies carried out as part of the Geomorphological Appraisal, River Wensum Restoration Strategy and these feasibility assessments have enabled us to refine our knowledge and understanding of the expected form and function of the Wensum.

3.2.3 Historic environment

Consultation with the Environment Agency National Environmental Assessment Service (NEAS) Archaeologist and Norfolk Landscape Archaeology confirms that there is nothing on the Norfolk Historic Environment Record to suggest there would be any archaeological implications of the proposed works. In view of this, Norfolk County Council has not requested any archaeological monitoring on the scheme (James Albone, Pers Comm., August 2008).

Items of historical and cultural significance have been mapped for each reach and are shown in Figures 3.2 to 3.4. Where appropriate these are described in detail within Tables 3.3 to 3.5.

Plate 3 illustrates Bintree Mill which is a Grade II listed building. Plate 4 shows North Elmham Mill, which is of historical and cultural significance.

Plate 3 - Bintree Mill Grade II listed building

Plate 4 - The River Wensum in Reach 17, with North Elmham Mill in the background

(See also Plate 10)

3.2.4 Landscape character and visual amenity

Field assessment of the local landscape character and key visual receptors in each reach was not undertaken for this Feasibility Assessment. However, preliminary site walkovers show there are strong landscape features within and surrounding Reaches 19, 18 and 17 that are dominated by the natural meandering river course, particularly in Unit 19 just downstream of the mill.

There are associated natural and human influenced features including wetland features, small-scale grazed pastures intersected by dykes and traditionally built structures such as bridges and weatherboard mills. These features combine to create an intimate and varied landscape. Plates 5 to 9, illustrate some of the landscape character features associated with the river and its surrounding environment.

Plate 5 - Typical section of chalk river and landscape in Reach 19

Plate 6 - Marginal wetland vegetation and mature trees and woodland within the floodplain

Plate 7 - Rush vegetation within wetter areas of the floodplain

3.2.5 Land use

The predominant land use across each reach is semi-improved pasture, parts of which are seasonally inundated (refer to Plate 8). The marshes are intersected by a network of drainage dykes (refer to Plate 9). In addition there are areas of wet woodland and fen.

Plate 8 - Grazing marsh and wet woodland: typical land use within this unit

Outside the floodplain of the River Wensum much of the surrounding land is intensively farmed. Much of this includes cereal cropping with potatoes and sugar beet in the rotation. It is the aim of England Catchment Sensitive Farming Delivery Initiative to reduce diffuse pollution from agriculture. Soil eroding from fields can enter watercourses through drains, ditches and via roads and ford crossings. Root crops are often grown on land that is at risk of soil erosion during periods of heavy rainfall when land is bare. Heavy machinery required to lift these crops may also lead to soil compaction.

Floodplain drainage is affected primarily by IDB main drains that run parallel to the river. These receive water from field drains (Plate 9) before discharging to the Wensum downstream of North Elmham Mill.

To allow IDB channels to discharge under high flow conditions, the main river immediately downstream of the confluence needs to be able to consistently take the combined flows of the main and IDB channels. This is achieved by creating sufficient channel capacity (through cross-section size), and by maintaining low bed and bank roughness (by cutting aquatic vegetation) to provide conveyance at higher water levels, and requires maintenance.

If the main channel downstream of the confluence is too restricted, an impoundment effect will be created causing water to back up in the IDB channel. This reduces water velocity which in turn increases siltation (and the need for more maintenance), as well as increasing flood risk by preventing outfall for surface water drains.

Terrestrial SSSI units are present along Unit 50 (see Appendix D). This feasibility report has sought to improve the hydrological connectivity between the riverine and terrestrial SSSIs units of the River Wensum through the proposed conceptual design measures outlined in Section 6 on conceptual design.

Plate 9 - Grazing marshes intersected by field drains support a diverse flora and fauna

3.2.6 River management

Weed cutting by boat is normally carried out once a year within this river Unit, by the Environment Agency. Up to 50% of the narrowed (wetted) channel is cut in sections of free-flowing water (e.g. downstream of Bintree Mill), and up to 75% of the narrowed (wetted) channel in impounded sections of channel (e.g. upstream of North Elmham Mill). Selective tree and shrub management is also carried out (e.g. tree trimming to allow the passage of boats for weed cutting, and removal of fallen trees that might cause unacceptable flood risk). Silt removal is carried out selectively by the Environment Agency where it will result in demonstrable conservation benefits, or result in a reduction in flood risk to people or property.

3.2.7 Water Mills

Water milling has historically taken place at 14 locations along the River Wensum. At six of these the mill buildings remain in use (residential), with most (but not all) of the mills being Grade II listed structures.

In times of flood, mill owners may independently open their structures (if operable) as they see fit, with no consistent river-wide approach (Environment Agency, 2007). By retaining high water levels upstream, the mill structures have a major influence on the river. They have the potential to constrain the scope and effectiveness of river restoration, especially in sections of channel upstream of the mills.

Unit 50 features the following mills:

- North Elmham Mill (TG 003 204) (see Plate 4 and 10)
- Bintree Mill (TF 998 243) (see Plate 3).

With regard to the In relation to the impact of mill structures on this river Unit, North Elmham Mill (Plate 10) is most important, as it is responsible for controlling water levels throughout much of the length of the Unit. The structure has no listed status. The sluice and water rights are in private ownership, and there is no Environment Agency gauging station at this site.

Plate 10 - View of North Elmham Mill

Technical details of the mill layout are given in the River Wensum Water Level Management Plan. Key aspects are as follows:

- Main channel (through mill) with 2 vertical lifting gates, restored recently.
- Two additional channels with no level control, the lowest (bed 36cm lower) sets the water level and their capacity restricts flow.
- Bypass sluice with 2 vertical lifting gates and a high-level overspill. Sluice gate repaired but wing-wall in poor condition.
- Levels are mainly controlled by adjusting the 2 vertical lifting gates at the mill and the lifting gate above the bypass channel.
- The WLMP reports that under mean flows, 80% of the flow is being diverted into the bypass channel.

The WLMP also presents the information shown in Table 3.1.

Table 3.1 Mill details in Unit 50 (Entec 2007)

Mill Name	Section length (km)*	Height drop at Structure (mean flow), (m)	Backwater Length (mean flow), (km)	Backwater Length (% of section length affected by backwater from mill)	Structure Elevation (m AOD)
North Elmham	6.34	1.90	5.25	83	22.5

Notes * Section length in the sense of the Entec reports is the length of river channel to the next water level control structure upstream (Bintree Mill)

The site was visited in February 2009, during a period of high flows, and it was confirmed that a significant proportion of flow was directed through the bypass sluice rather than through the main mill. Just upstream of the mill building, between the mill and bypass, a considerable volume of silt has been deposited forming a vegetated island (Plate 11).

Plate 11 - Accumulated silt in main channel (as depicted by the arrow) immediately upstream of North Elmham Mill, Feb 2009

The RWRS recommended lowering the existing mill lifting gates, and indicated that a significant reduction in operating water level could be possible without major modifications. It is envisaged that the lower operating water levels could be achieved by making gradual changes using the existing sluice. According to the RWRS, changing the sluice operation alone could result in a 0.72 m water level drop and a reduction in the backwater extent of more than 3.25 km (JBA, 2007).

A water level trial at North Elmham Mill was conducted in April 2009 by Atkins and the Environment Agency to provide important information for two aspects of the strategy:

- To verify hydraulic model findings by JBA about the extent of the backwater from North Elmham Mill.
- To provide additional information to inform the design of the Bintree restoration scheme.

The trial consisting of fully opening North Elmham Mill bypass channel sluice gates over a period of 5 hours whilst monitoring water levels using installed diver data loggers. The results of the trial are documented in Atkins (2009a) and indicated that during a flow of approximately 1.55m3/s, representing a flow exceedance of Q20 to Q30, the backwater extent was limited to 2.1km upstream of North Elmham Mill.

3.2.8 Soils and geology

The predominant soil type in Unit 50 is composed of medium loam over chalky boulder clay. These soils are characteristically poorly drained. Preliminary, baseline information relating to soils was collated by Atkins in October 2008 in Reach 19. Plate 12 shows a section of some of the local gravels (from past river dredging) that have been deposited on the floodplain.

The predominant solid geology in Unit 50 is composed of senonian chalk, a fine grained fissured limestone of the upper cretaceous period (Sear *et al*., 2006; JBA, 2007). These deposits are overlain with drift material (<10 m thickness). Drift deposits, together with later alluvial sediments laid down over the floodplain, have a strong influence on the soils within the Wensum valley (Wensum Valley Project, 1994).

In terms of ground contamination, chemical analysis of in-river silts was undertaken by JBA in 2007 (through the Environment Agency National Laboratory Service) at different points along the Wensum. Data was generally collected upstream of mills, which means that for this Unit, data is available for and applicable at North Elmham Mill (but not at Bintree Mill).

The sample at North Elmham Mill failed to meet the waste acceptance criteria required for landfill. This was mainly due to the organic content of the sample. Additionally, the location failed to meet the standards for hazardous, non-hazardous and inert waste for landfill due to contaminants that are not covered by the soil guidance values (SGVs). Further checks would need to be made on the contaminants not covered by the SGVs. If these are found to be within tolerable ranges, the appropriate Waste Exemption may be applied for.

Plate 12 - A section of gravels found on the right bank in Reach 19

3.2.9 Water Environment

Water Quality

At the time of submitting this report, no specific baseline water quality information was available for Reaches 19, 18 or 17. However, there is one water quality monitoring location upstream of Reach 19, at Great Ryburgh/Swanton Morley. The data from the Environment Agency's website indicate the chemical quality as '*good*' (Grade B) and biological quality as '*very good*'(Grade A).

Abstractions

The single largest abstractor in the Wensum catchment is Anglian Water Services Ltd., taking groundwater from a number of boreholes, and surface water at Costessey, for public water supply. Abstraction of surface water and ground water also occurs for agricultural needs, mainly summer spray irrigation (Environment Agency, 2007).

The Environment Agency is investigating the impacts of abstraction through the Review of Consents (Regulation 50 of the Conservation (Habitats &c.) Regulations 1994). Once this process has concluded, the Environment Agency will draw up an action plan to address the issues identified.

To feed into this process the Environment Agency and Anglian Water carried out an aquatic macrophyte survey of the river (@OneAlliance, 2007). This study confirmed that all reaches of the River Wensum were capable of supporting 'Ranunculus vegetation', but that a number of components of this biotope were, at present, poorly represented.

Surface water drainage

The Norfolk Rivers IDB drains areas of agricultural and residential surface water run-off by using tributaries along the River Wensum. Local surface water flooding tends to occur in flashy rainfall events. This can be exacerbated in the event that main river flows overtop and water from the river drains into IDB drains which outfall near built-up urban areas such as Reach 17.

Surface water drainage in Reaches 18 and 19 tends to comprise privately owned field drains or IDB drains. Drainage in these areas is predominately restricted to agricultural fields and does not generally pose any potential flood risk to local built-up areas.

A wider initiative called the England Catchment Sensitive Farming Delivery Initiative (ECSFDI) was launched in 2005 and is being promoted by Natural England with the aim of raising awareness of diffuse water pollution and encouraging voluntary action from farmers.

The 50 priority catchments were identified jointly by the Environment Agency and English Nature, and cover about 40% of the agricultural area of England (with about 50,000 farmers, of which some 30,000 manage holdings of over 20 hectares in size). Catchments were identified using data gathered for Water Framework Directive (WFD) purposes on nitrate, phosphate and sediment pollution, combined with data on sensitive freshwater fisheries, chalk streams, failing bathing waters, groundwaters and SAC-designated lakes.

The ECSFDI is also relevant to the achievement of the Government's PSA target for the end of 2010 for 95% of SSSIs to be in 'favourable' or 'unfavourable recovering' condition.

A specific sediment fingerprinting exercise is being undertaken on the River Wensum which is expected to be published in 2010. This may contain further baseline information which will input to the RWRS, in particular the strategy's ecological improvement objectives. In much of the River Wensum, it is considered that diffuse pollution from agriculture comes from tributaries whereas the immediate flood plain does not pose such a threat.

3.2.10 Utilities

At the time of submitting this report, information regarding utilities had not been obtained. This is a residual data gap, and more information will be collated should this Unit progress to detailed design.

3.2.11 Condition of attributes in Unit 50

For river units of river SSSIs to be regarded as in '*favourable*' condition, targets on various attributes need to be met. Currently, Unit 50 is classified as '*unfavourable'* for many environmental attributes (Table 3.2).

Table 3.2 - Condition summary of Unit 50 attributes (Natural England, 2002)

Location	European Features	Siltation	Water Quality	Access	Channel Structure	Biological Disturbance	Flow	Management
To Bintree Mill	U	U	-	U	U	F	F	F
To North Elmham Mill	U	U	-	U	U	F	F	F

Key: U=Unfavourable' F=Favourable

3.3 Environmental baseline for each reach within Unit 50

Specific baseline information for Reaches 19, 18 and 17 are described in Tables 3.3 to 3.5 with Figures 3.2 to 3.4 and supporting plates.

3.3.1 Reach 19

This reach incorporates the recently restored sections (by the Environment Agency and Bintry Mill Trout Fishery), as described in Table 2.1. Aquatic vegetation within the sections immediately downstream of the mill and within the restored sections has developed into a diverse range of typical chalk river macrophytes, occasionally forming chequerboard, clumped distributions across the river bed.

The shallower riffles/runs/glides provide ideal flow and sediment conditions to encourage the growth of *Callitriche* spp., *Ranunculus* spp., and *Zannichellia palustris,* and the aesthetic and ecological value of these areas is high. Although this cannot be recreated in most of the River Wensum, these areas could form the basis of an idealised template for macrophytes and habitat improvements in many other reaches of the river and a demonstration to partners, land owners and stakeholders as to what can be achieved.

Further downstream, towards Yarrow House, the river becomes increasingly deep and sedimentary in nature, with *Glyceria maxima, Phalaris arundinacea, Sparganium erectum* and occasional *Phragmites australis* along the margins together with clumps of *Rorippa nasturtium-officinalis* and *Apium nodiflorum*. The submerged vegetation included *Sparganium emersum and Callitriche* spp.

The Environment Agency regulates weed growth in some areas by cutting up to 50% of the weed in free-flowing sections and up to 75% in impounded sections, as well as maintaining access routes for the weed cutting boat by removing obstacles (e.g. large woody debris or overhanging branches) (Green *et al*., 2007).

3.3.2 Reach 18

Specific environmental baseline information for Reach 18 is given in Table 3.4 and Figure 3.3.

Most of this reach is affected by the backwater from North Elmham Mill and has been over-widened and over-deepened with silty bed substrates and few areas of gravel bed. The Environment Agency cuts weed in up to 75% of the narrowed (wetted) channel and maintains access for the weed cutting boat (Green *et al*., 2007).

Most of the floodplain consists of either woodland or grazing marsh. The floodplain in this reach has many field drains that are commonly separated from the main river by raised spoil banks as shown in Plates 13 and 14.

Plate 13 - A section of river in Reach 18 which has been straightened, widened and deepened

Plate 14 - River Wensum on the left, a raised spoil bank centre and an existing field drain to the right. A small wet woodland can also be seen in the distance

3.3.3 Reach 17

Specific environmental baseline information for Reach 17 is given in Table 3.5 and Figure 3.4.

The whole of this reach is affected by the backwater from North Elmham Mill. The Environment Agency cuts up to 75% of the weeds within the wetted channel during the summer and manages trees and other obstacles to allow passage of the weed boat (Green *et al*., 2007). Floodplain land-use is mainly grazing marsh (including a SSSI land parcel: North Elmham Mead).

Few shallow, fast-flowing areas are present to encourage the development of *Ranunculus* and C*allitriche* vegetation types (as shown in Plate 15).

Plate 15 - *Callitriche* growing within Reach within Reach 17

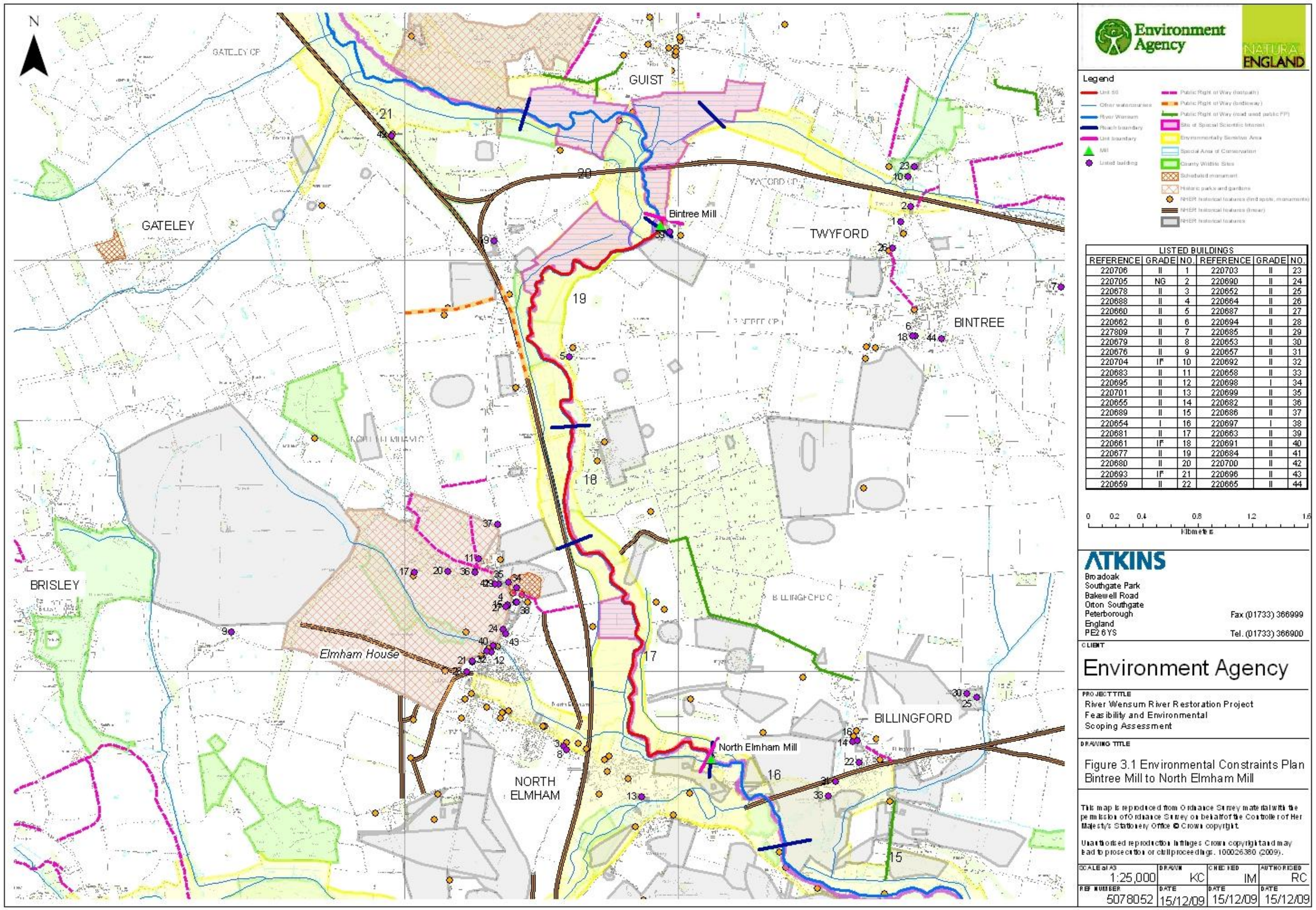

Figure 3.1 - Environmental constraints plan for Unit 50

Table 3.3 - Baseline information specific to Reach 19 (2.76km)

Environmental Feature	Baseline Information
Ecology (Protected Species)	• Data provided by Norfolk Biological Information Service (NBIS) shows records of great crested newts Triturus cristatus in Reach 19 between 2001 and 2005. • This reach supports optimal water vole and otter habitat (Halcrow, 2008). Refer to Figure 3.2 for more information. At the time of submitting this report, specific baseline surveys for bats and badgers had not been conducted. Previous surveys however (Abrehart, 2008), indicate that riparian vegetation is likely to support bat and badger habitat in Reach 19. • Abrehart (2008) indicated that water shrew *Neomys fodiens* are present in Reach 19. Water shrew is protected under Schedule 6 of the Wildlife and Countryside Act 1981 (as amended) and cannot be killed or taken by certain methods. In addition, the River Wensum is known to support breeding populations of kingfisher (*Alcedo atthis*) and little grebe (*Tachybaptus ruficollis*) and the adjacent wetlands have good populations of reed warbler (*Acrocephalus scirpaceus*), sedge warbler (*Acrocephalus schoenobaenus*) and barn owls (*Tyto alba*). • An otter was seen swimming along this reach in 2008 during an ecological survey of the adjacent grazing marsh (Abrehart, 2008).
Ecology (Statutory Designated Areas)	• There is one terrestrial SSSI unit on the floodplain for this river reach: • Unit 31: 20.26ha of neutral grassland – lowland. • Further details, possible hydrological linkages, and appropriate actions are detailed in Appendix D.
Ecology (Non-Statutory Designated Areas)	• There is a County Wildlife Site (ref 1054) called Broom Green, designated for marshy acidic grassland and alder carr on the TLHB. On the opposite bank is another CWS (ref 1049), designated for unimproved neutral grassland.
Ecology (Fisheries, Invertebrates & Flora)	• Bintry Mill Trout Fishery regularly stock trout in this reach. Whilst the restoration measures undertaken in this reach have improved the habitat for fish, there is a lack of refuges or backwaters for fry to aid in recruitment. • Environment Agency routine biological samples at Bintree Mill since 1990 have found species of interest that include white-clawed crayfish, mayflies (*Baetis scambus*), stoneflies (*Nemoura avicularis*, *Leuctra fusca, L. geniculata*) and caddis flies (*Athirpsodes bilineatus, Lepidostoma hirtum, Apatina muliebris*). • Additional samples collected during 2001 (Stansfield et al., 2001) at newly created riffle, deflector and cattle drink sites found mayflies (*Ecdyonurus dispar*), snails (*Bythinia leachii*), caddis larvae (*Athripsodes bilineatus, Lepidosoma hirtum*) and stoneflies (*Leuctra geniculata, L. fusca*) – indicating that newly created, more natural habitats would be rapidly colonised by chalk-character invertebrate communities. • River margins are dominated by reed sweet-grass (*Glyceria maxima*), reed canary-grass (*Phalaris arundinacea*), branched bur-reed (*Sparganium erectum*), some common reed patches (*Phragmites australis*), greater pond sedge (*Carex riparia*), water-cress (*Rorippa nasturtium-aquaticum*), fool's water-cress (*Apium nodiflorum*). These features have created solid or floating berms between 1-4 m wide (refer to Figure 3.2 for more information). • Aquatic, in-channel vegetation includes river water-dropwort (*Oenanthe fluviatilis*), flowering rush (*Butomus umbellatus*), perfoliate pondweed (*Potamogeton perfoliatus*), unbranched bur-reed (*Sparganium emersum*), water starwort (*Callitriche* spp.), horned pondweed (*Zannichellia palustris*),

Environmental Feature	Baseline Information
	water crow-foot (*Ranunculus* spp), fennel pondweed (*Potamogeton pectinatus*), blue water-speedwell (*Veronica anagallis-aquatica*) • Floodplain drain networks support plants of local conservation interest including frogbit (*Hydrocharis morsus-ranae*) and common bladderwort (*Utricularia vulgaris*) Abrehart (2008) and provide additional wetland habitats. Refer to Figure 3.2 for the locations of these species. • Detailed floral information obtained from a recent survey undertaken by Abrehart (2008) within the right bank floodplain area, at the lower end of Reach 19, found that of the 95 plant species identified across the 5 ha of grazing marsh, none were rare or of restricted distribution.
Ecology (Invasive / Non-Native species)	• Yaxley (2003) recorded mink in Reach 19 at Bintree Mill during the water vole survey in 2003. • Canadian pondweed (*Elodea canadensis*), monkeyflower (*Mimulus* spp).
Ecology (Trees)	• Currently there are no Tree Preservation Orders (TPOs) between North Elmham and Bintree. However, there are many trees located on the banks of Reach 19.
Geomorphology	• A geomorphological appraisal was undertaken in 2005 (Sear et al., 2006). This assessed Reach 19 as being in degraded condition. • The reach has maintained a reasonable level of sinuosity, particularly in the mid-reach section but has been over-widened and over-deepened with a loss of geomorphic function. During Atkins' site visits in 2008, the river was noted to be narrowing naturally in places, with silted berms becoming stabilised by vegetation. • Immediately below Bintree Mill, there is a short section of shallow, gravel-dominated, faster-flowing water with exposed chalk in the banks and bed in places. This formation is more typical of a chalk river habitat and it supports a diverse range of aquatic plants (Atkins' observation, October 2008).
Previous Restoration Works	• Downstream of Bintree Mill, and since 2001, various schemes have been carried out by the Environment Agency and Bintry Mill Trout Fishery along a 2 km section of river. These have involved the creation of vegetated berms, gravel runs/glides, channel narrowing (using spiling techniques) and fencing to prevent poaching, and have helped to increase flow diversity and improved fish spawning grounds. There were concerns regarding over-sizing of gravel with potentially reduced functionality for spawning (Mant & Fellick, 2007) but river flows have redistributed some of the gravel, creating scour pools and side bars. Deflectors have been less effective at altering flows or preventing siltation of nearby gravels. Restricting grazing pressure on the river margins by fencing has allowed the development of lush marginal vegetation and natural channel narrowing through formation of vegetated berms.
Flood Risk	• Reach 19 has a low level of flood risk and there are no properties in the 1% annual exceedence probability zone. The extent of the floodplain for Reach 19 is shown on Figure 3.2. Norfolk Rivers IDB drains indirectly assist in reducing flood risk by being able to hold up surface water and prevent flood risk in built-up urban areas downstream of this Reach. This same principle applies to Reaches 18 and 17.
Human Environment	• The main settlements and public recreation opportunities such as walking or horse riding for Reach 19 are shown on Figure 3.2. Angling tends to be the dominant recreational activity associated with Reach 19.
Historic Environment	• There are three Grade II listed buildings within Reach 19 and the locations are shown on Figure 3.1. Bintree Mill, College Farm (approximately 450 m from Reach 19) and Yarrow House (approximately 120 m from the left-hand bank). There are no Scheduled Ancient Monuments (SAMs) listed within Reach 19.

Environmental Feature	Baseline Information
Land Use	• Land use is predominantly seasonally grazed pasture. Much of the land is within Environmentally Sensitive Area/Environmental Stewardship agreements.
Traffic and transport	• There are two roads that feature within the boundary of Reach 19 (refer to Figure 3.2). The road that crosses in front of Bintree Mill supports local traffic. The second (private) road crosses Yarrow Bridge and supports local traffic only. There are no other roads that lead to the river in this Reach.
Utilities	• There is a high pressure gas main (Bacton to King's Lynn) just upstream of Yarrow Bridge and electricity cables that cross the road near Yarrow Bridge. Refer to Figure 3.2 for more information.

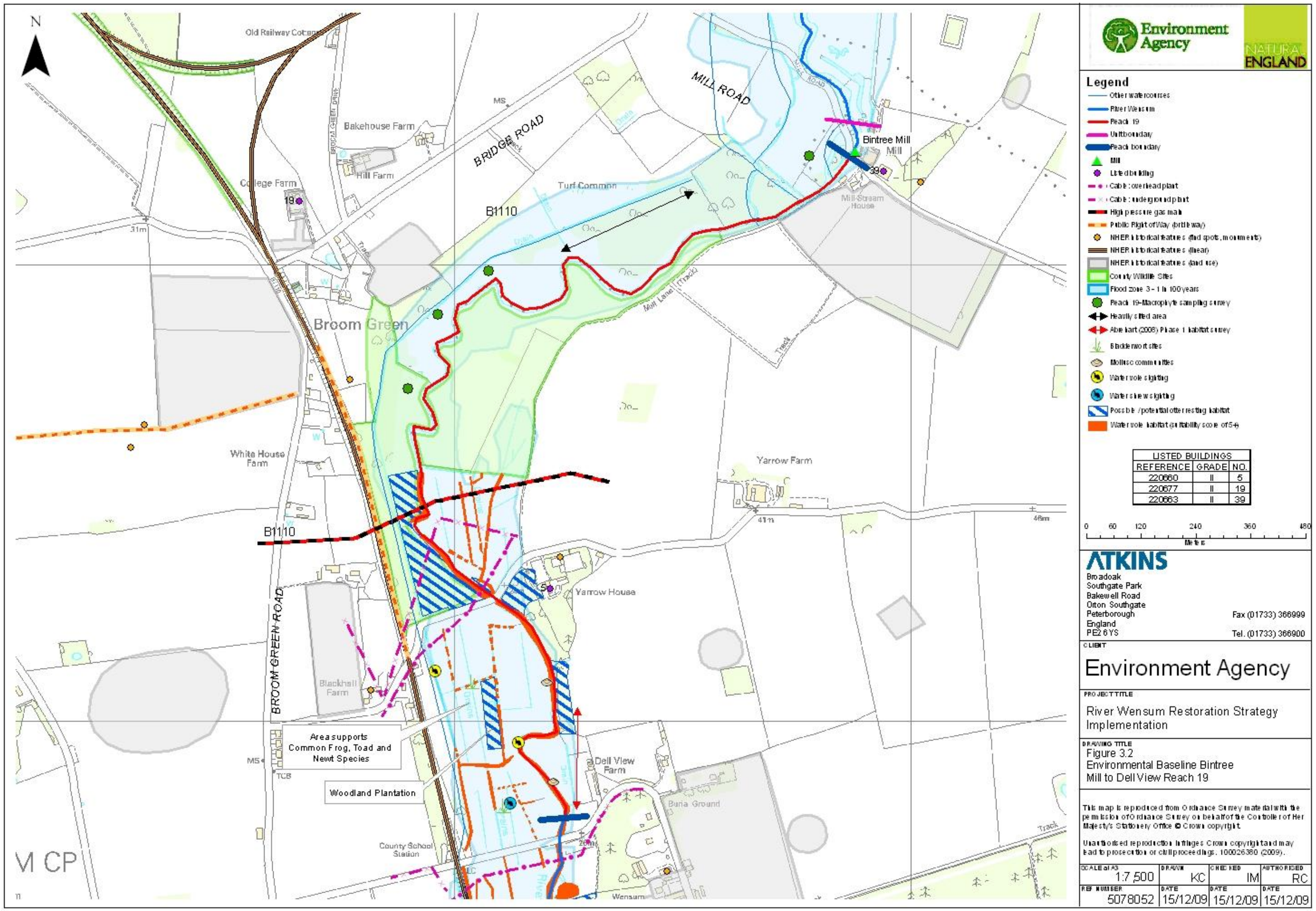

Figure 3.2 - Environmental baseline for Reach 19

Table 3.4 - Baseline information specific to Reach 18 (0.85km)

Environmental Feature	Baseline Information
Ecology (Protected species)	• Previous surveys (Halcrow, 2008) indicate the upstream section of this Reach supports optimal water vole habitat, and that feeding remains, feeding stations and latrines are also present. Refer to Figure 3.3 for more information. There is no data available for the downstream section of Reach 18. • Previous surveys (Halcrow, 2008) on this Reach indicate that otter are present, with feeding remains, spraints and possible holt sites within the upstream section only. Refer to Figure 3.3 for more information. There is no data available for the downstream section of Reach 18.
Ecology (Statutory Designated Areas)	• There are no terrestrial SSSI units on the floodplain for this river Reach.
Ecology (Non-Statutory Designated Areas)	• There is a County Wildlife Site (ref 2001) in a meadow on the TLHB, designated for semi-improved neutral grassland. This extends into Reach 17.
Ecology (Fisheries, Invertebrates & Flora)	• Recent routine Environment Agency surveys (conducted in 2006) showed that minnows were the most abundant species, followed by pike, in Reach 18. Historic data (1986 – 2006) highlights the presence of two species of European interest, namely bullhead (*Cottus gobio*) and brook lamprey (*Lampetra planeri*). 13 species have been recorded in total including brown trout. • There are no Environment Agency macro-invertebrate sampling sites within Reach 18. • Aquatic species are dominated by unbranched bur-reed (*Sparganium emersum*) and perfoliate pondweed (*Potamogeton perfoliatus*), with occasional lesser water parsnip (*Berula erecta*), flowering rush (*Butomus umbellatus*) (Grieve *et al*., 2002) • Most of the floodplain within Reach 18 consists of (occasionally wet) woodland or areas of permanent grassland (Natural England, 2007; Atkins' observations 3rd December 2008).
Ecology (Invasive / Non-Native Species)	• Canadian pondweed has been recorded (Grieve *et al*., 2002) from the Reach.
Ecology (Trees)	• There are currently no Tree Preservation Orders (TPOs) within Reach 18. There are, however, many trees located on the left bank of Reach 18, which are part of Bintree Woods as shown in Plate 6
Geomorphology	• A geomorphological appraisal was undertaken in 2005 (Sear et al., 2006). This assessed Reach 18 as being in *degraded* condition. This Reach has been subject to historical straightening, and is over-wide by an average 5.6m and over-deepened by approx. 0.7m, with silt accumulations along much of its length (Babtie *et al.* 2003). • Embankments, possibly consisting of dredged bed materials, line most of the banks along either one side or the other within Reach 18 and these are shown on Figure 3.3 Floodplain connectivity, particularly on the right bank, is limited as a result of historical dredging spoil raising land levels (refer to Plate 4). A

Environmental Feature	Baseline Information
	small backwater feature is present just upstream of Yarrow Bridge. • The flows along Reach 18 are impacted by the backwater effect from North Elmham Mill, which creates sluggish and deep water conditions, exacerbating the rate of silt deposition.
Previous Restoration Works	• None recorded.
Flood Risk	• Reach 18 has a low level of flood risk and there are no properties in the 1% annual exceedence probability zone. The extent of the floodplain in Reach 18 is shown on Figure 3.3
Human Environment	• The main attraction near Reach 18 is the County School Station, located approximately 200m from the right bank and is shown on Figure 3.3. • There is one Right of Way within Reach 18 (Bintree Woods) and the location of this is shown on Figure 3.3.
Historic Environment	• There are six Grade II listed buildings within the vicinity of Reach 18 and the locations are shown on Figure 3.3. There are no SAMs listed within Reach 18.
Traffic and transport	• One private road, serving residential properties, crosses the river at the upstream end of the Reach. A disused railway line runs parallel to the right hand bank of the river.
Utilities	• A baseline services search was not carried out for this particular Reach. This remains a knowledge gap in the environmental baseline.

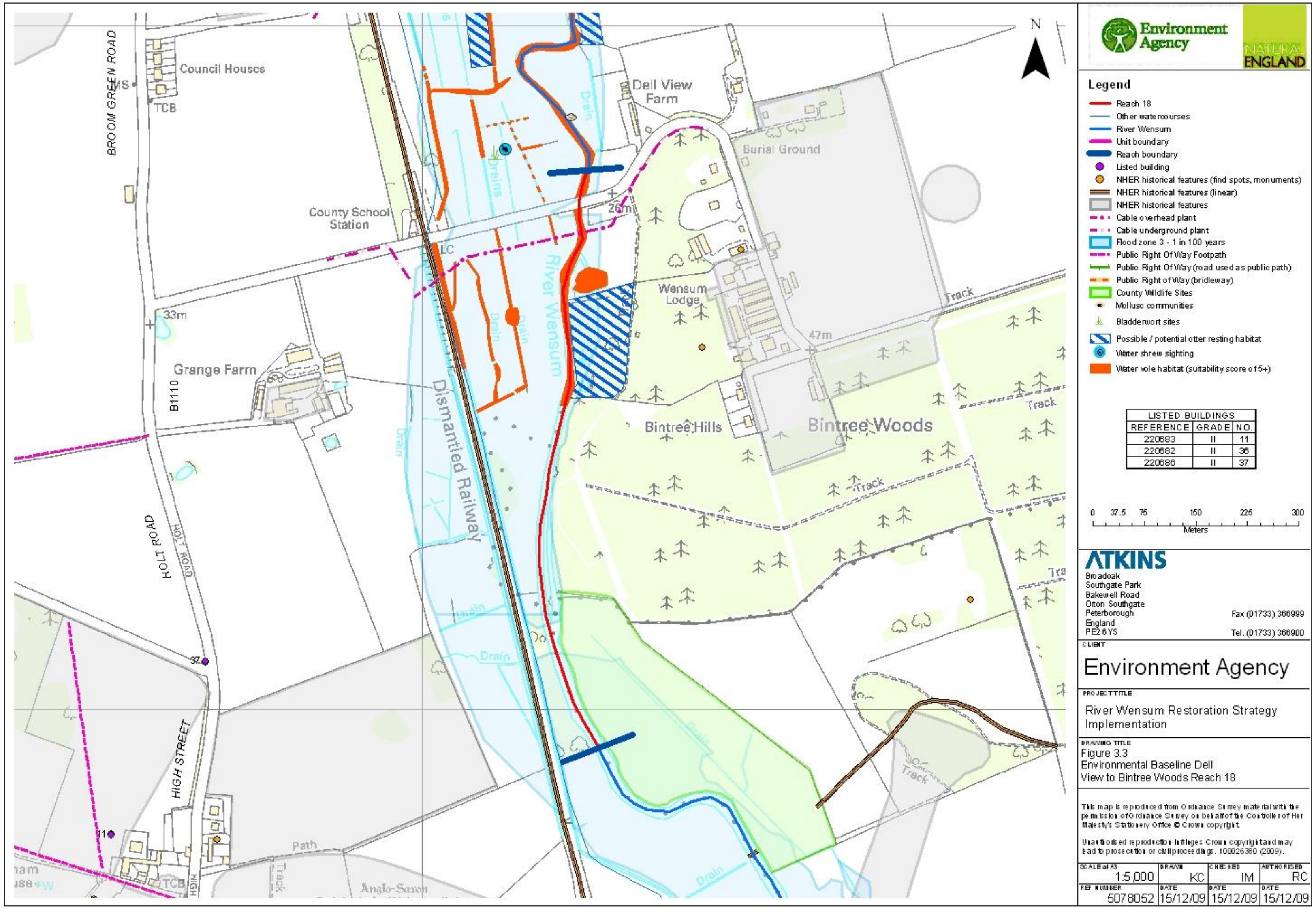

Figure 3.3 - Environmental baseline for Reach 18

Table 3.5 - Baseline information specific to Reach 17 (2.6km)

Environmental Feature	Baseline Information
Ecology (Protected species)	• At the time of submitting this report, specific baseline surveys for water vole, otter, bats, badgers and birds within Reach 17 had not been conducted. This remains a knowledge gap in the environmental baseline.
Ecology (Statutory Designated Areas)	• There is one terrestrial SSSI unit on the floodplain for this river Reach: • Unit 32: 2.79ha of neutral grassland – lowland • Further details, possible hydrological linkages, and appropriate actions are detailed in Appendix D.
Ecology (Non-Statutory Designated Areas)	• There is one County Wildlife Site (CWS) in Reach 17 (reference 2001). This is designated for its semi-improved neutral grassland. It extends into Reach 18.
Ecology (Fisheries, Invertebrates & Flora)	• Fisheries: Limited numbers of cyprinid fish fry were recorded in2003 and 2005 along 1.2km of river upstream of North Elmham Mill (Environment Agency, 2003 and 2005). Minnows were the dominant species recorded, although small numbers of roach fry, three-spined stickleback, bullhead and stone loach were present in this reach. Similar to Reach 18, this Reach has limited habitat for fish and in particular lacks suitable refuges or backwaters for juveniles. • Macro invertebrates: No routine samples are collected by the Environment Agency within this Reach. • Flora: Marginal vegetation is dominated by reed sweet-grass (Glyceria maxima) which creates floating berms in places, fool's water-cress (Apium nodiflorum), water-cress (Rorippa nasturtium-aquaticum) and water forget-me-not (Myosotis scorpioides) • Aquatic species include unbranched bur-reed (Sparganium erectum) and perfoliate pondweed (Potamogeton perfoliatus), filamentous algae (Cladophora spp.) water star-wort (Callitriche spp.), fennel pondweed (Potamogeton pectinatus).
Ecology (Invasive / Non-Native species)	• Canadian pondweed (Elodea canadensis) has been recorded from the Reach.
Ecology (Trees)	• There are no Tree Preservation Orders (TPOs) within Reach 17. There is an extensive Conservation Area in North Elmham either side of County School Station which contains many trees (Refer to Figure 3.3).
Geomorphology	• A geomorphological appraisal was undertaken in 2005 (Sear et al., 2006). This assessed Reach 17 as being in degraded condition. • North Elmham Mill is a severe constraint on habitat conditions and creates severely impounded conditions for at least 2km upstream and significant siltation across the channel bed. The channel has retained a good, natural level of sinuosity, with some straightened sections. The channel has been over-widened (by up to 13m) and is severely over-deepened (by up to 1.5m), with steep banks and reduced floodplain connectivity.

Environmental Feature	Baseline Information
Previous Restoration Works	• Small scale augmentation of right bank with gravel – landowner scheme to improve fish habitat.
Flood Risk	• Flood risk in Reach 17 is considered high with 17 properties in the 1 in 100 year flood risk zone. Refer to Figure 3.4.
Human Environment	• There are many properties that exist near North Elmham Mill and adjacent to Wensum Drive (refer to Figure 3.4). At the western end of Green Lane there is a sewage treatment works which lies close to the main river (refer to Figure 3.4).
Historic Environment	• There are 20 Grade II and 1 Grade I listed buildings within the vicinity of Reach 17. There are no SAMs within Reach 17.
Traffic and Transport	• North Elmham Mill is accessed via a private road from Billingford Road but access to the remainder of the main river is limited to two tracks (refer to Figure 3.4).
Utilities	• A baseline services search was not carried out for this Reach. This remains a knowledge gap in the environmental baseline section.

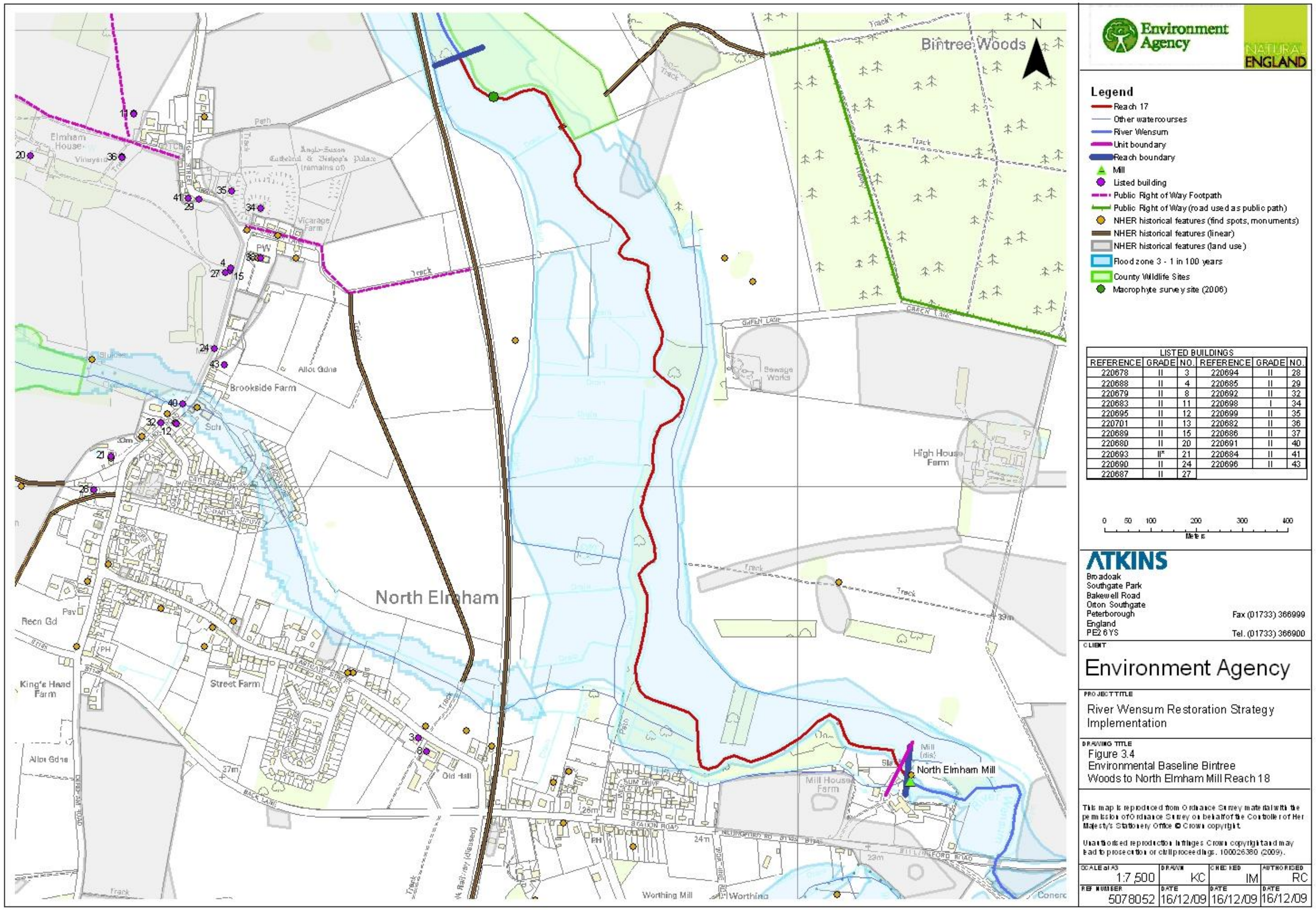

Figure 3.4 - Environmental baseline for Reach 17

4. Consultation

4.1 Introduction

This chapter summarises comments received from key statutory stakeholders and public feedback from the December 2008 drop-in session held at Swanton Morley. The drop-in session provided the project team with the opportunity to identify constraints and opportunities associated with river restoration that had not been recognised at this point of the EIA.

4.2 Consultation with key stakeholders

Since 2008, the project team has been actively communicating with various internal and external stakeholders during the feasibility assessment and the Environment Agency has contacted key staff within different organisations regarding various EIA and planning matters for the River Wensum as a whole. Table 4.1 summarises the responses of these organisations.

Table 4.1 - Consultation undertaken to date (May, 2009)

Organisation	Date Consulted	Nature of Consultation / Consultee Responses
	Statutory Consultees	
Breckland District Council - Planning Department	January 2009, June 2009	A pre-planning application meeting with the planners, discussed the River Wensum Restoration Strategy and its objectives and confirmed that no planning consent is required.
Norfolk Rivers IDB/Water Management Alliance	September 2008 and May 2009	The first meeting presented the objectives of the *Strategy*. The IDB did not disagree with the overall proposals but expressed concern over Environment Agency maintenance on the main river. The second meeting discussed a number of potential joined up approaches to targeted river maintenance. This collaborative approach would see a shift to river maintenance practices which are likely to benefit both river restoration in the long term and angling interests.
Internal Environment Agency Functions	November 2008	Development Control has confirmed that a Flood Risk Assessment (FRA) will be required. The FRA will have to show: 1) Any changes in the extent of the floodplain 2) Any changes in depth of flooding 3) Likely impact on any properties
Norfolk County Council – Landscape	March 2009	A reply was received in April 2009. The landscape team requested a further EIA assessment in order to make a detailed appraisal of potential impacts (positive and negative) to the landscape character and visual amenity of the River Wensum.
Norfolk County Council - Minerals	November 2008	Key staff were briefed, including issues of winning gravels from site or from an external source e.g. existing gravel pit site. Council provided their “in principle” support for restoration and indicated that if gravels had to be brought to site from elsewhere then planning permission may be required.
Breckland District Council - Planning Department	December 2008	A scoping and screening letter was sent to the Planning Department. BDC have confirmed that planning consent will not normally be required for river restoration. However, further consultation will be required for some elements of schemes, such as importing gravels to site.

Organisation	Date Consulted	Nature of Consultation / Consultee Responses
Natural England	2008	Recognises the need to implement a preferred option to deliver '*favourable'* condition to the SSSI.
England Catchment Sensitive Farming Delivery Initiative	April 2008	The Initiative is a partnership between Defra, Natural England and the Environment Agency. Ongoing consultations with local Catchment Sensitive Farming officer, to identify specific diffuse pollution from agriculture problems together with identifying and meeting with partner and stakeholder groups
Non-Statutory Consultees		
Broads Forum	October 2008	This was a joint presentation with a representative from the England Catchment Sensitive Farming Initiative highlighting the benefits of reducing sediment input into the Wensum. Another key message was the need to prevent silt ingress into river reaches downstream of restoration sites.
Wensum Valley Trust	July 2008	The meeting focused on understanding their objectives for the Wensum Valley, particularly in relation to river restoration.
Norfolk Anglers Conservation Association (NACA)	May 2008	The presentation focused on the synergy between river restoration and benefits for fisheries. Support was expressed for implementation of the *Strategy.*
National Farmers Union (NFU)	April 2008	The meeting was intended to bring the NFU up to speed with the development of the *Strategy* and to give them an understanding of what we are trying to achieve.
Waterbodies BAP Topic Group	October 2007	The Group expressed a general support for the implementation of the *Strategy*.
River Restoration Centre Annual Network Conference	April 2007	Presentation focused on how the *Strategy* was developed, the issues that it will address and how we intend to take it forward.
Norfolk Biodiversity Partnership	January 2007	Presentation was given to the Steering Group which focused on the benefits of re-establishing the hydrological relationship between river and floodplain and the potential benefits to BAP habitat. The Group was enthusiastic, but as a policy they do not express support for specific projects.

4.3 Drop-in session December 2008

A drop-in session about the implementation of the River Wensum Restoration Strategy for Unit 50 was held in December 2008 at Swanton Morley Village Hall. The objectives of the session were:

- To engage with people who live within the vicinity of this part of the river, and are likely to be affected by the proposed restoration works.
- To identify the key environmental concerns/constraints and opportunities with respect to strategic options available for implementing river restoration between Bintree Mill and North Elmham Mill.
- To gain an insight into local knowledge of the river.
- To help identify acceptable options, that are environmentally, technically and economically feasible, to deliver 'unfavourable recovering' or 'favourable' ecological condition.

The drop-in was designed to ensure that the local landowners, parish councillors and interested stakeholders had an opportunity to comment and present their views on river restoration specific to Unit 50. A total of 21 people attended the drop in session.

Attendees recognised the general decline in the river's condition, particularly its ecological character. Many noted the lack of native fish species apparent in the river and the high presence of invasive species. Many agreed that the river is in need of some restoration work. The majority of people left the drop-in session with a positive view of our proposed restoration *Strategy* and that the Environment Agency will be addressing current problems.

Sample comments related to:

- Insufficient river maintenance, including irregular weed cutting and dredging.
- The legacy problems associated with silt ingress.
- Access being a constraint to the proposed works.
- The need for the project team to explore the possibilities of generating hydropower (and its compatibility with river restoration) at the detailed design stage.

Tables 4.2 and 4.3 provide more detail on the specific opportunities and constraints with respect to the restoration options between Bintree Mill and North Elmham Mill.

Table 4.2 - Key opportunities associated with river restoration in Unit 50

Opportunity	Consultee Comment	Measures/actions for next stage of EIA
Renewable energy	A number of landowners expressed an interest in the possibility of generating hydro-electricity from the existing mill structures on the river.	Review national guidance and explore the possibilities for this in more detail at the detailed design stage.
Ecology	Many local residents, who are also keen fishermen, are interested in seeing what benefit restoration will have on increasing the population of native fish species.	The habitats required to support native fish species, at all stages of their lifecycle, should benefit as a result of restoring natural form and function to the river. This will be described in each of the detailed designs.
Developing effective communication and increasing awareness between the local community and statutory bodies	There is an opportunity to develop more effective communication and consultation with mill owners (particularly North Elmham) and riparian land-owners regarding their maintenance responsibilities.	Forward advisory leaflets regarding the responsibility that riparian owners have in maintaining the bed and banks of the watercourse including the removal of debris, keeping the bed and banks clear of material that could cause obstructions, and keeping weirs and mill gates clear of obstructions.
	Many people were unaware of the Flood Warning service that the Environment Agency provides. There is an opportunity to increase the local communities' awareness regarding flooding in the valley and the responsibilities of riparian landowners.	Forward advisory leaflets, such as "*Living On The Edge,*(Environment Agency,2007)" Advise the Flood Incident Management team that the people in the valley may need some flood awareness information.
Flow conveyance	River restoration can help trap some of the silt, and will restore energy to the river so that silt is transported freely downstream.	Detailed designs will consider appropriate silt management within each reach.
Land- use	Reconnecting the river with its floodplain could reduce the length of time that floodwaters stay on the floodplain by allowing it to drain freely back into the river	Identify the specific locations within the unit where re-connection is proposed.

Table 4.3 - Key constraints associated with river restoration in Unit 50

Constraint	Comment	Measures / actions for next stage of EIA
Accessibility	Some landowners raised the issue of poor access to the river. This could make bringing machinery and materials on site and operating large machinery difficult.	Consider the technical feasibility of undertaking the different restoration activities at each site at an early stage. May need to carry out other works to improve access.
Historic environment	Existing mill structures at Bintree Mill, which is a Grade II Listed Building, could constrain restoration of the river in its existing form.	There are many issues around the future management of the mill structures that will have to be carefully considered. This includes their amenity, landscape and heritage value as well as the engineering constraints of modifying their impact on the river.
	On a local level industrial heritage might be seen as important as natural heritage.	It is important that the design of our preferred option is sensitive to existing features and does not de-value the historic valley scene.
Integration to wider catchment schemes	Despite the efforts of the Catchment Sensitive Farming Team, silt does and will continue to enter the river.	There will always be an issue of silt entering the river in run-off water from surrounding land and highways. However, this can be reduced through careful land management and good relationships with local landowners.
Land-use	Currently, marshes are grazed between May and October, and there is a concern that, post-restoration, these marshes will not be sufficiently dry to enable grazing.	During detailed design these issues will be discussed with the landowners, so restoration does not have an adverse impact on Higher Level Stewardship (HLS) agreements or the grazing value of the land.
Finance	Many residents were interested in finding out about how much restoration would cost.	River restoration is an expensive activity. The cost of each restoration option will vary according to technical constraints such as access and scale of project. We will work efficiently to help minimise costs.
Water environment	Lowering the level of the mill structures could expose significant expanses of mud, silts, and bare river bed, which would have adverse impact on water quality in terms of silt and nutrient release.	If restoration works involve undertaking earthworks on mill structures, it is important to manage run-off and silty water. Measures to prevent this will be undertaken in accordance with the Environmental Good Practice Site Guide (Environment Agency, 2005) and Planning Policy Statement 23.
	By creating lower water levels in the channel upstream of a mill we might influence the amount of water passing through the mill.	This will be considered carefully during the detailed design of any works that might affect mill structures.
	High floodplain groundwater levels have many impacts. One such impact is the potential to interfere with the efficiency of existing septic tanks.	The wider catchment effects of the restoration works must be considered. We will gain a better understanding of local surface water drainage by talking to local people during the design phase.
	The impact of untreated storm run-off	As above

Constraint	Comment	Measures / actions for next stage of EIA
	at Dereham.	
	A few residents were aware of the possibility that restoration works could raise the risk of flooding to their properties.	River restoration works will not increase the flood risk to people or buildings.
Human Environment		It is important that local people and tourists have access to, and can use, the river. This will be considered carefully for each detailed design.

4.4 Future consultation

Further consultation will be carried out during the preparation of the detailed designs for river restoration on particular stretches of river. One of the purposes of this will be to explain how the identified constraints and opportunities have been considered and incorporated into the selection of the preferred restoration options.

An Environmental Report, outlining the key management actions that would be taken to reduce the potential impacts to the environment as a result of the recommended river restoration option(s), will be produced in parallel with the detail design. Further consultation with local landowners and internal and external stakeholders will be undertaken as part of this process.

4.5 Conclusion

The drop-in session proved a useful tool in communicating with the local community the objectives of the RWRS and the feasibility studies.

The event was very useful in identifying additional opportunities and constraints associated with river restoration between Bintree Mill and North Elmham Mill. This information has been incorporated into the MCA. Feedback was provided to the attendees in the form of a thank you letter that contained a summary of responses and an outline of the restoration implementation process.

5. Multi-Criteria Analysis Options Appraisal

5.1 Introduction

A MCA system, based on weighted numerical scoring system, has been used to help select appropriate restoration options/measures for each river reach. This was considered necessary to ensure that a transparent, defendable and replicable technique of selecting options/measures was applied. This chapter describes the process by which the MCA tool was designed and subsequently applied.

A number of options have been considered which could be implemented individually, or as a group, to restore '*unfavourable recovering*' or '*favourable*' condition to the River Wensum. The chapter concludes by presenting the most favourable scoring options/measures for the study reaches. Costs have been excluded from this MCA process and are considered subsequently in Chapter 7. Further details of the MCA process (MCA technical note and MCA table) can be found in Appendix A to this report.

Table 5.1 provides an overview of the steps involved in constructing and applying the MCA tool, and Section 5.2 provides more detail.

Table 5.1 - Overview of the process by which the MCA was constructed and applied

A	Constructing The MCA Tool
1	Identification of options/measures
2	Selection of success criteria
3	Ranking of success criteria
4	Setting up the MCA table
B	**Applying The MCA Tool (Spreadsheet) To Specific reaches**
1	Is the option/measure applicable to the reach? If no, discard.
2	Work through each criterion by option/measure.
3	Apply weighting and determine total weighted score (TWS)
4	Mill structure measures: Apply the best scoring measure.
5	Other measures: Undertake statistical analysis and discard measures scoring below lower limit.
6	Other measures: Apply remaining measures in order of highest to lowest scoring.
7	Gravel works: Apply best scoring measure.

5.2 Constructing the MCA tool

The MCA Table provides the framework for the options appraisal process, and scores the degree to which all the proposed restoration options/measures meet the defined criteria. The initial stage in the options appraisal was the construction of the Table, which involved defining the options/measures to be considered, and defining the criteria against which the options/measures are evaluated. Following the construction of the Table, it was applied as a tool to determine the highest scoring options/measures for each reach.

5.2.1 Identification of options/measures

A generic list of all restoration options/measures possibly applicable to the River Wensum was generated through the following activities:

Document review: All options and restoration measures recommended in the RWRS and the Geomorphological Appraisal were considered and all were included in the final list of options. Table 5.2 lists the measures recommended in these two reports.

Table 5.2 - Restoration measures recommended in previous studies

Reach	Geomorphological Appraisal	River Wensum Restoration Strategy
19	Reduce channel width. Augment bed with gravels or reduce water levels. Monitor. Improve flow and habitat diversity. Fix sediment ingress points.	All works to integrate with lowering of levels at North Elmham Mill and existing restoration schemes in this reach. Encourage natural reduction in channel width. Augment bed with gravels to create glides and riffles. Remove embankments to reconnect River to floodplain. Design maintenance regime so as to allow habitat niches.
18	Reduce channel width. Augment bed with gravels or reduce water levels. Fix sediment ingress points.	All works to integrate with lowering of levels at North Elmham Mill. Reduce channel width. Augment bed with gravels to create glides and riffles. Use coarse woody debris to increase sinuosity. Remove embankments to reconnect River to floodplain. Design maintenance regime so as to allow habitat niches.
17	Reduce weir levels. Reconnect river to floodplain. Reduce channel width. Augment bed with gravels or reduce water levels.	North Elmham Mill structure to be lowered. De-silting of channel immediately upstream of mill. Reduce channel width. Augment bed with gravels to create glides and riffles. Remove embankments to reconnect River to floodplain. Design maintenance regime so as to allow habitat niches.

Consultation: This took the form of a public drop-in session as described in Section 4.3. Consultation with authorities such as BDC and NCC was also undertaken as described in Section 4.2.

Workshop: An MCA workshop, attended by the Environment Agency, Natural England and Atkins, was held on 29th January 2009 with the purpose of working through the MCA approach.

From the above sources, six main option groups where identified namely 'Do nothing', 'Do minimum', 'Targeted maintenance', 'Continue as present', 'River restoration' and 'Alternative options'. These are explained in Table 5.3. Appendix A provides further information regarding the options.

Table 5.3 - Options identified for restoration on the River Wensum

No.	Option	Description
G1	**Do nothing.**	No maintenance to main river or IDB channels. No restoration to any channels or floodplain. No operational activities such as weed cutting.
G2	**Do minimum.**	No maintenance to main river or IDB channels. Opportunistic restoration in certain areas (e.g. trees may be felled where appropriate thereby reducing channel shading). No operational activities such as weed cutting.
G3	**Targeted maintenance**	Reduced maintenance to include only reactive activities e.g. removal of debris posing an immediate flood risk or removal of silt in specific locations. Mitigation for activity in the form of small scale restoration. Limited operational activity e.g. sluice management for high flows.
G4	**Continue as present**	Continuation of existing activities which includes maintenance (debris removal, bank repairs, selected desilting and selected weed cutting). Undertaking small scale, opportunistic restoration activities. Continuation of operational activities such as sluice management during high flows.
G5	**River restoration**	Active restoration measures of which 21 such measures have been identified and grouped into three sub-groups namely 'Mill structures', 'Gravel works' and 'Other'. See Appendix A for a full list of these measures.
G6	**Alternative options**	Three options have been considered within this group, namely 'Increasing main river maintenance', 'Increased main river and IDB maintenance', and 'Mills re-used for hydro-power'. These are explained further in Appendix A.

Three groups of 'measures' have been defined under the option G5 (see Table 5.4 for full details). These include:

- Various works around **mill structures** including changes to operating protocol, lowering mill sill levels and constructing/utilising existing bypass channels.
- Various **gravel works** including large scale bed raising.
- **Other measures**.

Table 5.4 - Description of river restoration measures as defined under option G5

Group	Restoration Measure	Description
Mill Structure Works These works need to be undertaken first to ensure the success of any subsequent measures	Improve operation protocols	Modify existing mill operating protocols to ensure water level management is in line with SSSI management
	Remove flow control mechanisms	Remove all sluice control mechanisms and allow the river to be free flowing
	Lower mill sill levels	Lower the level of the mill sill to reduce the extent of backwater in low flows
	Create bypass channel around mill	Construction of channel around mill to split flows to allow fish passage and continuity of stream processes
	Install fish pass	Construction of fish pass alongside mill structure to enable free passage of fish upstream
	Remove mill structure	Remove entire mill structure
Gravel Works Need to be considered (and constructed) after Mill Structure Works have been completed	Gravel glides	Creation of short lengths of full width raised bed, dressed in gravel, to create variation in flow and habitat for fish and invertebrates.
	Gravel glides and transverse hurdles	Creation of short lengths of raised gravel bed with hurdles made from post and faggots to trap suspended sediment thereby extending the length of the glide over time.
	Bed raising	Creation of extended lengths of full width raised bed – to reduce water depth and allow characteristic plant communities to develop.
Other Measures These need to be considered after Mill Structure Works and Gravel Works have been identified	Fencing	Fencing constructed landward of the river bank to prevent bank erosion from the impacts of cattle grazing.
	Tree planting	Tree planting to cast shade over the water to control macrophyte growth, provide cover for fish, and to develop erosion resistance from root reinforcement.
	Tree thinning	Selective felling or lopping to provide light onto the water to encourage macrophyte or emergent plant growth, and generate arisings for deflectors.
	Deflector (using Large Woody Debris- LWD, and filled in with brush mattress)	Downstream pointing LWD placed at the upstream side of deflector to create flow diversity; in-filled downstream with brush to promote silt deposition and plant growth.
	Lower spoil embankments	Removal of dredging based informal embankments to allow out of bank flow across the floodplain, and back into the river. Use of arisings for riffles/general bed raising if needed.
	Berm creation	Horizontal lowering of bank top up to ½ channel width to increase flood flow capacity and generate arisings for bed raising where no embankments.
	Backchannels – reconnections to IDB and existing field drains	Utilizing existing wet features by connecting them to the river to create essential habitat for fish and other fauna.
	Backchannels – create new features	Creating habitat where no other water bodies exist e.g. dog-leg with downstream end open and upstream end fed by percolation.

Group	Restoration Measure	Description
	Channel realignment to increase river sinuosity	Full depth excavation from bank top to increase lateral variation in plan form either one bank or both with arisings used to infill opposite bank.

5.2.2 Selection of success criteria

'Criteria' refer to the various standards against which the proposed options/measures are evaluated. A range of criteria (12 in total) were defined during a workshop between Atkins, Environment Agency and Natural England in January 2009. These criteria have been grouped under the following three broad headings:

1. Ecology: This includes criteria relating to legally protected ecology such as compliance with the SSSI designation as well as that which is not legally protected, but where the proponents of the works still have a responsibility to safeguard and improve ecological value of the site. Three of the criteria within this group relate to three levels of legal designations, and the final criterion covers all non-legal responsibilities.
2. Project delivery: This considers compliance with the objectives of the RWRS and takes into account stakeholder opinion. Hence compliance/agreement with requirements of statutory and non-statutory stakeholders is considered.
3. Technical: This group considers delivery of the technical aspects of the RWRS objectives including technical feasibility, geomorphic form, flood risk and climate change.

All criteria and accompanying descriptions are provided in Table 5.5.

5.2.3 Ranking success criteria

While all of the defined criteria groups are important, it is acknowledged that some are more so than others. For example, ecology is the main driver of the project and the primary objective is to improve the ecology of the River Wensum. Hence, compliance with these criteria can be considered as more important than, for example, technical considerations and hence a weighting system has been applied to these groups.

Similarly, different criteria within a single group such as '*Ecology*' are not necessarily of equal importance. For example, the criterion '*Compliance with National Designation*' (such as SSSI)', which falls within the '*Ecology*' group, is the main driver for this project, and hence compliance with this criterion is considered essential for achieving project objectives. The criterion '*Contribution to overall ecology*' would be considered less important. Hence, a similar weighting system has been applied to individual criteria within the three groups.

Professional judgement was applied in determining the numerical weighting for each criteria group and each criterion. A weighted score between zero and one was applied and agreed to in the MCA workshop. An '*effective weighting factor*' for each criterion was calculated by multiplying the group criteria weighting and the individual criteria weighting. Table 5.5 presents the criteria and applied weightings and Appendix A provides a detailed explanation for the weighting of criteria.

Table 5.5 – Scoring system defined for the MCA

Group (Group weighting)	Criteria	Description / Example	Weighting within group	Effective weighting factor
Ecology (1)	Compliance with national designation	SSSI requirements for the river e.g. improved flow regime, water quality and channel form.	1	1
	Compliance with international designation	SAC requirements including maintaining favourable habitat for EU designated species.	0.8	0.8
	Compliance with regional/local designations	BAP requirements such as, maintaining flora and fauna characteristic of chalk rivers.	0.6	0.6
	Contribution to overall ecology	Compliance with the Environment Agency's general duty to further conservation	0.5	0.5
Project delivery (0.9)	Compliance with *Strategy* (RWRS) objectives	Meeting objectives of the RWRS as well as the specific reach recommendations.	1	0.9
	Compliance with statutory stakeholders	Stakeholders include Environment Agency, Natural England, BDC, and NCC.	0.9	0.81
	Agreement with non-statutory stakeholders	Angling clubs, land owners and tenants.	0.9	0.81
	Human environment	Consideration of or improvements to archaeology, landscape, and recreation value.	0.4	0.36
Technical (0.8)	Technical feasibility & practicality	Consideration of design, construction process, commercial risk, and maintenance.	1	0.8
	Geomorphic form and function	Consideration of the shape and flow of the river.	1	0.8
	Flood risk	Consideration of the impact of restoration on flood risk.	1	0.8
	Climate change and sustainability	Considers the robustness of the measures in terms of future flood risk and carbon footprint.	0.8	0.64

5.2.4 Setting up the MCA table

Defining the scoring system

The MCA Table lists all of the options/measures against the 12 defined criteria and a score is allocated depending on the degree to which the individual options/measures comply with the criteria.

The term '*relevance*' is used to describe where a particular option/measure complies with the criteria or brings about betterment of the features pertaining to those criteria. The term '*detriment*' is used where a particular option/measure does not comply with the criteria or results in an adverse change to a particular feature pertaining to those criteria. A five point scoring system is utilised with +2 allocated if the option/measure is of high relevance and -2 allocated where the option/measure is of high detriment. These terms are presented in Table 5.6.

Table 5.6 – Scoring System defined defined for the Multi-Criteria Analysis

Score	Description
+2	High relevance
+1	Low relevance
0	Neutral
-1	Low detriment
-2	High detriment

These are applied as '*raw scores*'. From here, a '*weighted score'* is derived by multiplying the '*raw score*' by the '*effective weighting factor*'. A '*total weighted score*' for an individual option/measure is derived by summing all of the '*weighted scores*' for that option/measure.

The consideration of costs was deliberately excluded from the MCA analysis so as not to discriminate against any options or measures, and so determine the best technical solution irrespective of cost.

5.3 Using the MCA Tool

The MCA tool has been applied to each of the reaches separately on a reach-by-reach basis. The following main steps were undertaken:

- The applicability of the option/measure was considered. Where the option/measure is not applicable (e.g. 'Changing primary and secondary channels' may not be applicable if no secondary channel exists) then this option/measure has been discarded.
- The remaining criteria were then worked through for one option/measure at a time and raw scores allocated. Working through by option/measure allowed greatest consistency of scoring.
- Weightings were applied to the raw scores to generate weighted scores.
- Total weighted scores (TWS) were calculated for each option/measure by summing all of the weighted scores.
- Statistical analysis was applied to the scores within the 'River Restoration' (G5) options category. Those scoring below a defined statistically lower limit were discarded. Appendix A provides further information on the statistical methods.
- The measures with the highest TWS represent the preferred suite of options and associated measures for that specific reach. These were applied, in their scored order, for designing a preferred restoration plan for the reach.

The results of the MCA analysis for Reaches 19, 18, and 17 are displayed in Tables 5.7, 5.8 and 5.9 respectively.

Table 5.7 - Results of MCA for Reach 19

River Wensum Multi Criteria Analysis

	Criteria Group		**Ecology [A]**				**Project Delivery [B]**				**Technical [C]**				**Unit:**	50	Bintry Mill to N Elmham Mill
	Group weighting		1				0.9				0.8				**Reach:**	19	Bintry Mill to Dell View Farm
	Individual weighting within group		0.8	1	0.6	0.5	1	0.9	0.9	0.4	1	1	1	0.8	**Length:**	2670	metres
	Criteria	**Option /measure applicable to reach**	Compliance with International Designation (SAC) [A.a]	Compliance with National Designation (SSSI) [A.b]	Compliance with Regional/Local designation (BAP) [A.c]	Contribution to overall ecology [A.d]	Compliance with Strategy objectives (Wildlife & Fisheries & River Form & Process) [B.a]	Compliance with Statutory Stakeholders (EA; NE; BDC; NCC) [B.b]	Agreement with Non-statutory Stakeholders (Anglers; owners; occupiers) [B.c]	Human Environment: Archaeology; landscape; recreation [B.d]	Technical Feasibility & practicality [C.a]	Geomorphic form & function [C.b]	Flood Risk [C.c]	Climate Change & sustainability [C.d]	**Total Raw Score** (highest possible score 24)	**Total weighted score**	**Rank order**
	Individual weighting factor =		0.8	1	0.6	0.5	0.9	0.81	0.81	0.36	0.8	0.8	0.8	0.64			
Option No.	Option / measure																
G1:	**Do Nothing:** No maintenance or restoration: raw score	Y	0	0	0	1	-2	-1	-2	-1	2	1	-2	-1	-5		
	Weighted score		0	0	0	0.5	-1.8	-0.81	-1.62	-0.36	1.6	0.8	-1.6	-0.64		-3.93	
G2:	**Do Minimum:** minimal restoration: raw score	Y	0	0	0	0	0	-1	-1	0	1	1	-1	-2	-3		
	Weighted score		0	0	0	0	0	-0.81	-0.81	0	0.8	0.8	-0.8	-1.28		-2.1	
G3:	**Targeted Maintenance:** Raw score	Y	0	1	1	1	1	0	1	0	2	0	1	1	9		
	Weighted score		0	1	0.6	0.5	0.9	0	0.81	0	1.6	0	0.8	0.64		6.85	10
G4:	**Continue as present:** raw score	Y	-1	-2	-1	-1	-2	-1	-1	0	1	0	1	0	-7		
	Weighted score		-0.8	-2	-0.6	-0.5	-1.8	-0.81	-0.81	0	0.8	0	0.8	0		-5.72	
G5:	**River Restoration**																
G5a	***Mill Structures:***																
5.1m	Mill structures - improve operability + protocols: raw score	N													0		
	weighted score		0	0	0	0	0	0	0	0	0	0	0	0		0	
5.2m	Mill structures - remove flow control mechanisms: raw score	N													0		
	weighted score		0	0	0	0	0	0	0	0	0	0	0	0		0	
5.3m	Mill structures - lower mill sills levels	N													0		
	Weighted Score		0	0	0	0	0	0	0	0	0	0	0	0		0	
5.4m	Mill structures – bypass channels (flow into IDB drain)	N													0		
	Weighted Score		0	0	0	0	0	0	0	0	0	0	0	0		0	
5.5m	Fish passes	N													0		
	Weighted Score		0	0	0	0	0	0	0	0	0	0	0	0		0	
5.6m	Mill structures - remove all	N													0		
	Weighted Score		0	0	0	0	0	0	0	0	0	0	0	0		0	
G5b	***Gravel works:***																
5.7g	Gravel glides	Y	2	2	2	2	2	2	2	2	2	2	-1	0	19		
	weighted score		1.6	2	1.2	1	1.8	1.62	1.62	0.72	1.6	1.6	-0.8	0		13.96	3
5.8g	Gravel glides + transverse hurdles: raw score	Y	2	2	2	2	2	2	1	1	2	2	-1	0	17		
	weighted score		1.6	2	1.2	1	1.8	1.62	0.81	0.36	1.6	1.6	-0.8	0		12.79	
5.9g	Bed raising (large scale)	Y	2	2	2	1	2	1	1	2	1	1	-2	-1	12		
	Weighted Score		1.6	2	1.2	0.5	1.8	0.81	0.81	0.72	0.8	0.8	-1.6	-0.64		8.8	
G5c	***Other:***																
5.10	Fencing: Raw Score	Y	1	1	1	1	1	1	0	-1	2	0	-1	0	6		
	Weighted Score		0.8	1	0.6	0.5	0.9	0.81	0	-0.36	1.6	0	-0.8	0		5.05	12
5.11	Tree planting on top of bank: raw score	Y	0	1	1	1	2	1	1	2	2	1	0	1	13		
	Weighted score		0	1	0.6	0.5	1.8	0.81	0.81	0.72	1.6	0.8	0	0.64		9.28	8
5.12	Tree thinning: raw score	Y	1	1	1	1	1	1	0	0	2	1	0	1	10		
	weighted score		0.8	1	0.6	0.5	0.9	0.81	0	0	1.6	0.8	0	0.64		7.65	9
5.13	Deflector (using LWD and filled in with brush mattress)	Y	2	2	2	2	2	1	1	1	1	2	-1	0	15		
	weighted score		1.6	2	1.2	1	1.8	0.81	0.81	0.36	0.8	1.6	-0.8	0		11.18	7
5.14	Lower spoil embankments	Y	1	1	1	1	2	2	1	1	2	1	2	2	17		
	weighted score		0.8	1	0.6	0.5	1.8	1.62	0.81	0.36	1.6	0.8	1.6	1.28		12.77	5
5.15	Channel Re-sectioning	Y	1	1	1	1	1	2	1	2	2	1	2	2	17		
	weighted score		0.8	1	0.6	0.5	0.9	1.62	0.81	0.72	1.6	0.8	1.6	1.28		12.23	6
5.16	Berm creation where appropriate	Y	1	1	1	2	1	2	2	2	2	2	1	2	19		
	weighted score		0.8	1	0.6	1	0.9	1.62	1.62	0.72	1.6	1.6	0.8	1.28		13.54	4
5.17	Backwaters – reconnections to IDB, field drains	Y	2	2	2	2	2	2	1	2	1	2	2	2	22		
	weighted score		1.6	2	1.2	1	1.8	1.62	0.81	0.72	0.8	1.6	1.6	1.28		16.03	1
5.18	Backwaters - new	Y	2	2	2	2	2	2	0	2	1	2	2	2	21		
	weighted score		1.6	2	1.2	1	1.8	1.62	0	0.72	0.8	1.6	1.6	1.28		15.22	2
5.19	Channel realignment	Y	1	1	1	1	1	1	-1	1	2	2	-1	-1	8		
	weighted score		0.8	1	0.6	0.5	0.9	0.81	-0.81	0.36	1.6	1.6	-0.8	-0.64		5.92	11
5.20	Changing primary and secondary channels (e.g. Ryburgh)	N													0		
	weighted score		0	0	0	0	0	0	0	0	0	0	0	0		0	
5.21	Lower embankments	N													0		
	Weighted Score		0	0	0	0	0	0	0	0	0	0	0	0		0	
G6:	**Alternative Options**																
6.1	Increase Main river maintenance: raw score	Y	-2	-2	-2	-2	-2	-2	2	-1	2	-2	2	0	-9		
	Weighted score		-1.6	-2	-1.2	-1	-1.8	-1.62	1.62	-0.36	1.6	-1.6	1.6	0		-6.36	
6.2	Increase main river & IDB channel maintenance: raw score	Y	-2	-2	-2	-2	-2	-2	2	-1	1	-2	2	0	-10		
	Weighted score		-1.6	-2	-1.2	-1	-1.8	-1.62	1.62	-0.36	0.8	-1.6	1.6	0		-7.16	
6.3	Mill Structures - reinstatement & maintenance + hydropower	N													0		
	Weighted Score		0	0	0	0	0	0	0	0	0	0	0	0		0	
Total Score			23.4	28	24	23	28.6	24.53	21.91	20.04	53.8	29.6	11	14.12			

Key

Score	Description
2	High Relevance
1	Low Relevance
0	Neutral
-1	Low Detriment
-2	High Detriment

Mean:	10.887
sd:	3.599
High imp:	>14.486
Low imp:	<7.288

Table 5.8 - Results of MCA for Reach 18

River Wensum Multi Criteria Analysis

Option No.	Criteria Group	Option /measure applicable to reach	Ecology [A]				Project Delivery [B]				Technical [C]				Unit:	50	Bintry Mill to N Elmham Mill Dell View Farm to Bintry Woods
	Group weighting		1				0.9				0.8				Reach:	18	
	Individual weighting within group		0.8	1	0.6	0.5	1	0.9	0.9	0.4	1	1	1	0.8	Length:	855m	
	Criteria		Compliance with International Designation (SAC) [A.a]	Compliance with National Designation (SSSI) [A.b]	Compliance with Regional/Local designation (BAP) [A.c]	Contribution to overall ecology [A.d]	Compliance with Strategy objectives (Wildlife & Fisheries & River Form & Process) [B.a]	Compliance with Statutory Stakeholders (EA; NE; BDC; NCC) [B.b]	Agreement with Non-statutory Stakeholders (Anglers; owners; occupiers) [B.c]	Human Environment: Archaeology; landscape; recreation [B.d]	Technical Feasibility & practicality [C.a]	Geomorphic form & function [C.b]	Flood Risk [C.c]	Climate Change & sustainability [C.d]	Total Raw Score (highest possible score 24)	Total weighted score	Rank order
	Individual weighting factor =		0.8	1	0.6	0.5	0.9	0.81	0.81	0.36	0.8	0.8	0.8	0.64			
Option No.	Option / measure																
G1:	**Do Nothing:** No maintenance or restoration: raw score	Y	0	0	0	1	-2	-1	-2	-1	2	1	-2	-1	-5		
	Weighted score		0	0	0	0.5	-1.8	-0.81	-1.62	-0.36	1.6	0.8	-1.6	-0.64		-3.93	
G2:	**Do Minimum:** minimal restoration: raw score	Y	0	0	0	0	0	-1	-1	0	2	0	-1	-2	-3		
	Weighted score		0	0	0	0	0	-0.81	-0.81	0	1.6	0	-0.8	-1.28		-2.1	
G3:	**Targeted Maintenance:** Raw score	Y	0	1	1	1	1	0	1	0	2	0	1	1	9		
	Weighted score		0	1	0.6	0.5	0.9	0	0.81	0	1.6	0	0.8	0.64		6.85	10
G4:	**Continue as present:** raw score	Y	-1	-2	-1	-2	-2	-1	-1	0	1	0	1	0	-8		
	Weighted score		-0.8	-2	-0.6	-1	-1.8	-0.81	-0.81	0	0.8	0	0.8	0		-6.22	
G5:	**River Restoration**																
G5a	***Mill Structures:***																
5.1m	Mill structures - improve operability + protocols: raw score	N													0		
	weighted score		0	0	0	0	0	0	0	0	0	0	0	0		0	
5.2m	Mill structures - remove flow control mechanisms: raw score	N													0		
	weighted score		0	0	0	0	0	0	0	0	0	0	0	0		0	
5.3m	Mill structures - lower mill sills levels	N													0		
	Weighted Score		0	0	0	0	0	0	0	0	0	0	0	0		0	
5.4m	Mill structures – bypass channels (flow into IDB drain)	N													0		
	Weighted Score		0	0	0	0	0	0	0	0	0	0	0	0		0	
5.5m	Fish passes	N													0		
	Weighted Score		0	0	0	0	0	0	0	0	0	0	0	0		0	
5.6m	Mill structures - remove all	N													0		
	Weighted Score		0	0	0	0	0	0	0	0	0	0	0	0		0	
G5b	***Gravel works:***																
5.7g	Gravel glides	Y	2	2	1	2	2	2	2	2	2	2	-1	0	18		
	weighted score		1.6	2	0.6	1	1.8	1.62	1.62	0.72	1.6	1.6	-0.8	0		13.36	5
5.8g	Gravel glides + transverse hurdles: raw score	Y	2	2	2	2	1	1	1	1	2	2	-1	0	15		
	weighted score		1.6	2	1.2	1	0.9	0.81	0.81	0.36	1.6	1.6	-0.8	0		11.08	
5.9g	Bed raising (large scale)	Y	1	2	1	1	1	1	1	2	1	1	-2	-1	9		
	Weighted Score		0.8	2	0.6	0.5	0.9	0.81	0.81	0.72	0.8	0.8	-1.6	-0.64		6.5	
G5c	***Other:***																
5.10	Fencing: Raw Score	Y	1	1	1	1	2	2	0	-1	2	0	-1	0	8		
	Weighted Score		0.8	1	0.6	0.5	1.8	1.62	0	-0.36	1.6	0	-0.8	0		6.76	11
5.11	Tree planting on top of bank: raw score	Y	0	-1	-1	0	0	1	1	1	2	1	0	1	5		
	Weighted score		0	-1	-0.6	0	0	0.81	0.81	0.36	1.6	0.8	0	0.64		3.42	12
5.12	Tree thinning: raw score	Y	2	2	2	2	2	2	1	2	2	2	0	1	20		
	weighted score		1.6	2	1.2	1	1.8	1.62	0.81	0.72	1.6	1.6	0	0.64		14.59	2
5.13	Deflector (using LWD and filled in with brush mattress)	Y	2	2	2	2	2	1	1	1	2	2	-1	0	16		
	weighted score		1.6	2	1.2	1	1.8	0.81	0.81	0.36	1.6	1.6	-0.8	0		11.98	7
5.14	Lower spoil embankments	Y	1	1	1	1	2	2	1	1	1	1	2	2	16		
	weighted score		0.8	1	0.6	0.5	1.8	1.62	0.81	0.36	0.8	0.8	1.6	1.28		11.97	8
5.15	Channel Re-sectioning	Y	1	1	1	1	1	2	1	2	2	1	2	2	17		
	weighted score		0.8	1	0.6	0.5	0.9	1.62	0.81	0.72	1.6	0.8	1.6	1.28		12.23	6
5.16	Berm creation where appropriate	Y	1	1	1	2	2	2	2	2	2	2	1	2	20		
	weighted score		0.8	1	0.6	1	1.8	1.62	1.62	0.72	1.6	1.6	0.8	1.28		14.44	3
5.17	Backwaters – reconnections to IDB, field drains	Y	2	2	1	1	2	2	1	1	2	2	2	2	20		
	weighted score		1.6	2	0.6	0.5	1.8	1.62	0.81	0.36	1.6	1.6	1.6	1.28		15.37	1
5.18	Backwaters - new	Y	2	1	2	2	2	1	0	2	1	2	2	2	19		
	weighted score		1.6	1	1.2	1	1.8	0.81	0	0.72	0.8	1.6	1.6	1.28		13.41	4
5.19	Channel realignment	Y	1	2	2	2	2	2	-1	2	1	2	-1	-1	13		
	weighted score		0.8	2	1.2	1	1.8	1.62	-0.81	0.72	0.8	1.6	-0.8	-0.64		9.29	9
5.20	Changing primary and secondary channels (e.g. Ryburgh)	N													0		
	weighted score		0	0	0	0	0	0	0	0	0	0	0	0		0	
5.21	Lower embankments	N													0		
	Weighted Score		0	0	0	0	0	0	0	0	0	0	0	0		0	
G6:	**Alternative Options**																
6.1	Increase Main river maintenance: raw score	Y	-2	-2	-2	-2	-2	-2	2	-1	2	-2	2	0	-9		
	Weighted score		-1.6	-2	-1.2	-1	-1.8	-1.62	1.62	-0.36	1.6	-1.6	1.6	0		-6.36	
6.2	Increase main river & IDB channel maintenance: raw score	Y	-2	-2	-2	-2	-2	-2	2	-1	1	-2	2	0	-10		
	Weighted score		-1.6	-2	-1.2	-1	-1.8	-1.62	1.62	-0.36	0.8	-1.6	1.6	0		-7.16	
6.3	Mill Structures - reinstatement & maintenance + hydropower	N													0		
	Weighted Score		0	0	0	0	0	0	0	0	0	0	0	0		0	
Total Score																	

Key

Score	Description
2	High Relevance
1	Low Relevance
0	Neutral
-1	Low Detriment
-2	High Detriment

Mean:	11.346
sd:	3.61
High imp:	>14.956
Low imp:	<7.74

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Table 5.9 - Results of MCA for Reach 17

River Wensum Multi Criteria Analysis																	
Criteria Group			Ecology [A]				Project Delivery [B]				Technical [C]				Unit:	50	Bintry Mill to N Elmham Mill
Group weighting			1				0.9				0.8				Reach:	17	Bintry Woods to N Elmham Mill
Individual weighting within group			0.8	1	0.6	0.5	1	0.9	0.9	0.4	1	1	1	0.8	Length:	2600m	
Criteria		Option /measure applicable to reach	Compliance with International Designation (SAC) [A.a]	Compliance with National Designation (SSSI) [A.b]	Compliance with Regional/Local designation (BAP) [A.c]	Contribution to overall ecology [A.d]	Compliance with Strategy objectives (Wildlife & Fisheries & River Form & Process) [B.a]	Compliance with Statutory Stakeholders (EA; NE; BDC; NCC) [B.b]	Agreement with Non-statutory Stakeholders (Anglers; owners; occupiers) [B.c]	Human Environment: Archaeology; landscape; recreation [B.d]	Technical Feasibility & practicality [C.a]	Geomorphic form & function [C.b]	Flood Risk [C.c]	Climate Change & sustainability [C.d]	Total Raw Score (highest possible score 24)	Total weighted score	Rank order
Individual weighting factor =			0.8	1	0.6	0.5	0.9	0.81	0.81	0.36	0.8	0.8	0.8	0.64			
Option No.	Option / measure																
G1:	**Do Nothing:** No maintenance or restoration: raw score	Y	0	0	0	1	-2	-1	-2	-1	2	1	-2	-1	-5		
	Weighted score		0	0	0	0.5	-1.8	-0.81	-1.62	-0.36	1.6	0.8	-1.6	-0.64		-3.93	
G2:	**Do Minimum:** minimal restoration: raw score	Y	0	0	0	0	0	-1	-1	0	2	1	-1	-2	-2		
	Weighted score		0	0	0	0	0	-0.81	-0.81	0	1.6	0.8	-0.8	-1.28		-1.3	
G3:	**Targeted Maintenance:** Raw score	Y	0	1	1	1	0	-1	1	0	1	0	1	0	5		
	Weighted score		0	1	0.6	0.5	0	-0.81	0.81	0	0.8	0	0.8	0		3.7	13
G4:	**Continue as present:** raw score	Y	-1	-2	-1	-1	-2	-1	-1	0	0	-1	1	0	-9		
	Weighted score		-0.8	-2	-0.6	-0.5	-1.8	-0.81	-0.81	0	0	-0.8	0.8	0		-7.32	
G5:	**River Restoration**																
G5a	***Mill Structures:***																
5.1m	Mill structures - improve operability + protocols: raw score	Y	1	1	1	1	1	1	2	1	2	0	1	1	13		
	weighted score		0.8	1	0.6	0.5	0.9	0.81	1.62	0.36	1.6	0	0.8	0.64		9.63	
5.2m	Mill structures - remove flow control mechanisms: raw score	Y	1	1	1	1	2	2	1	1	1	1	1	1	14		
	weighted score		0.8	1	0.6	0.5	1.8	1.62	0.81	0.36	0.8	0.8	0.8	0.64		10.53	
5.3m	Mill structures - lower mill sills levels	Y	2	2	2	2	2	2	0	-1	1	1	2	2	17		
	Weighted Score		1.6	2	1.2	1	1.8	1.62	0	-0.36	0.8	0.8	1.6	1.28		13.34	
5.4m	Mill structures – bypass channels (flow into IDB drain)	Y	2	2	2	2	1	2	-1	0	0	2	2	2	16		
	Weighted Score		1.6	2	1.2	1	0.9	1.62	-0.81	0	0	1.6	1.6	1.28		11.99	
5.5m	Fish passes	Y	2	1	2	2	1	1	2	2	1	0	-1	-1	12		
	Weighted Score		1.6	1	1.2	1	0.9	0.81	1.62	0.72	0.8	0	-0.8	-0.64		8.21	
5.6m	Mill structures - remove all	Y	2	2	2	2	2	2	-2	-2	1	2	2	2	15		
	Weighted Score		1.6	2	1.2	1	1.8	1.62	-1.62	-0.72	0.8	1.6	1.6	1.28		12.16	
G5b	***Gravel works:***																
5.7g	Gravel glides	Y	2	2	2	2	2	2	2	2	2	2	-1	0	19		
	weighted score		1.6	2	1.2	1	1.8	1.62	1.62	0.72	1.6	1.6	-0.8	0		13.96	3
5.8g	Gravel glides + transverse hurdles: raw score	Y	2	2	2	2	2	2	1	1	1	2	-1	0	16		
	weighted score		1.6	2	1.2	1	1.8	1.62	0.81	0.36	0.8	1.6	-0.8	0		11.99	
5.9g	Bed raising (large scale)	Y	2	1	2	1	2	1	1	1	1	1	-2	-1	10		
	Weighted Score		1.6	1	1.2	0.5	1.8	0.81	0.81	0.36	0.8	0.8	-1.6	-0.64		7.44	
G5c	***Other:***																
5.10	Fencing: Raw Score	Y	1	1	1	1	1	1	0	-1	2	0	-1	0	6		
	Weighted Score		0.8	1	0.6	0.5	0.9	0.81	0	-0.36	1.6	0	-0.8	0		5.05	12
5.11	Tree planting on top of bank: raw score	Y	0	1	1	1	2	1	1	2	2	1	0	1	13		
	Weighted score		0	1	0.6	0.5	1.8	0.81	0.81	0.72	1.6	0.8	0	0.64		9.28	9
5.12	Tree thinning: raw score	Y	1	1	1	1	1	1	0	1	2	1	0	1	11		
	weighted score		0.8	1	0.6	0.5	0.9	0.81	0	0.36	1.6	0.8	0	0.64		8.01	10
5.13	Deflector (using LWD and filled in with brush mattress)	Y	2	2	2	2	2	1	1	1	1	2	-1	1	16		
	weighted score		1.6	2	1.2	1	1.8	0.81	0.81	0.36	0.8	1.6	-0.8	0.64		11.82	6
5.14	Lower spoil embankments	Y	1	1	1	1	2	2	1	1	2	1	2	2	17		
	weighted score		0.8	1	0.6	0.5	1.8	1.62	0.81	0.36	1.6	0.8	1.6	1.28		12.77	4
5.15	Channel Re-sectioning	Y	1	1	1	1	1	2	-1	1	2	1	2	2	14		
	weighted score		0.8	1	0.6	0.5	0.9	1.62	-0.81	0.36	1.6	0.8	1.6	1.28		10.25	7
5.16	Berm creation where appropriate	Y	1	1	1	2	2	1	1	1	1	2	0	1	14		
	weighted score		0.8	1	0.6	1	1.8	0.81	0.81	0.36	0.8	1.6	0	0.64		10.22	8
5.17	Backwaters – reconnections to IDB, field drains	Y	2	2	2	2	2	2	1	2	1	2	2	2	22		
	weighted score		1.6	2	1.2	1	1.8	1.62	0.81	0.72	0.8	1.6	1.6	1.28		16.03	1
5.18	Backwaters - new	Y	2	2	2	2	2	2	0	2	2	2	1	1	20		
	weighted score		1.6	2	1.2	1	1.8	1.62	0	0.72	1.6	1.6	0.8	0.64		14.58	2
5.19	Channel realignment	Y	1	1	1	2	1	1	-1	2	1	2	-1	-1	9		
	weighted score		0.8	1	0.6	1	0.9	0.81	-0.81	0.72	0.8	1.6	-0.8	-0.64		5.98	11
5.20	Changing primary and secondary channels (e.g. Ryburgh)	N													0		
	weighted score		0	0	0	0	0	0	0	0	0	0	0	0		0	
5.21	Lower embankments	Y	1	1	1	1	2	1	1	1	2	1	2	2	16		
	Weighted Score		0.8	1	0.6	0.5	1.8	0.81	0.81	0.36	1.6	0.8	1.6	1.28		11.96	5
G6:	**Alternative Options**																
6.1	Increase Main river maintenance: raw score	Y	-2	-2	-2	-2	-2	-2	2	-1	2	-2	2	0	-9		
	Weighted score		-1.6	-2	-1.2	-1	-1.8	-1.62	1.62	-0.36	1.6	-1.6	1.6	0		-6.36	
6.2	Increase main river & IDB channel maintenance: raw score	Y	-2	-2	-2	-2	-2	-1	2	-1	1	-2	2	0	-9		
	Weighted score		-1.6	-2	-1.2	-1	-1.8	-0.81	1.62	-0.36	0.8	-1.6	1.6	0		-6.35	
6.3	Mill Structures - reinstatement & maintenance + hydropower	Y	-2	-2	-2	-1	-1	0	1	2	1	-1	1	0	-4		
	Weighted Score		-1.6	-2	-1.2	-0.5	-0.9	0	0.81	0.72	0.8	-0.8	0.8	0		-3.87	
Total Score			39.6	42	38.4	39.5	47.6	42.63	23.72	24.12	64.6	38.6	25.4	25.6			

Key

Score	Description
2	High Relevance
1	Low Relevance
0	Neutral
-1	Low Detriment
-2	High Detriment

Mean:	10.568
sd:	3.692
High imp:	>14.261
Low imp:	<6.876

5.3.1 Results of the MCA options appraisal

The MCA is not just about which options improve ecology. As discussed, implicit in the MCA is the assessment of options and measures against other issues such as flood risk, the human environment, construction feasibility and agreement with landowners and stakeholders. Assessing these issues alongside ecological factors allows the options and measures to be assessed realistically, and to identify where other issues may conflict with the objective of achieving '*unfavourable recovering*' or '*favourable*' ecological condition.

It should be noted that information from the environmental baseline and stakeholder consultation specific to each reach was applied to the MCA for that reach. This is why the measures associated with North Elmham Mill only apply to Reach 17. Also, the results assume that changes to any mills need to be conducted first in order for the maximum benefits of the other options to be fully realised.

The results from the MCA for Reaches 19, 18 and 17 do differ but have a number of similarities including:

- The options of 'Do nothing', 'Do minimum', 'Continue as present' and 'Alternative options' all produced negative scores.
- The options of 'Targeted maintenance' and' River restoration' all produced positive scores.

A negative score indicates that the option is detrimental to the project's objectives of achieving '*unfavourable recovering*' or '*favourabl*e' condition status for the River Wensum. This suggests that '*Do nothing*' (i.e. abandoning the scheme) is not an option and work is required to achieve the objective. This is surprising as a popular notion within the river restoration community is that sometimes allowing the river '*to sort itself out*' can be viewed as the best option, particularly if maintenance is considered to be harming the river condition rather than improving it.

In the case of Unit 50, the overall impact of North Elmham Mill on the form, function and ecology of the channel is so significant that the '*Do nothing*' option will not change this impact and action is required. Furthermore, the options of '*Do minimum*' and '*Continue as present*' are considered detrimental to the objectives indicating that large scale changes are required, rather than continuing with the current maintenance regimes or opportunistic restoration schemes.

The '*Alternative options'* and measures also received negative scores: this is largely a consequence of the scores attributed to the '*Ecology*' criteria.

This applies to hydropower options, which involve the generation of energy through harnessing the kinetic energy of water. Hydropower is seemingly attractive, as it is a form of renewable and 'clean' energy with added benefits such as reusing historic structures along watercourses. Hydropower is being implemented elsewhere and the Environment Agency has produced a position statement (2009a) and guidance (2009b) on how such projects should be developed, assessed and implemented. Similarly, Natural England has also developed a guidance document, though this is currently in draft form.

When assessed against both the Multi-Criteria Analysis and EA and NE guidance, the implementation of hydropower schemes for the River Wensum have been found to score negatively. Impacts on geomorphology, hydraulics, flow regimes and biological connectivity may have an adverse effect on flora and fauna (e.g. fish). Thus, whilst providing some benefits, hydropower ultimately runs counter to the high-level project objectives for geomorphological and ecological enhancement. Any likely wider benefits of renewable energy are negated by the potential for adverse local effects on other natural resources and receptors.

Options with negative scores will not be progressed as part of the River Wensum Restoration Project as they will not improve the ecological or geomorphological condition of the river.

The MCA has demonstrated that the options of '*River restoration'* and '*Targeted maintenance'* will help Unit 50 to achieve favourable condition. The 'River restoration' option has a number of associated measures with different scores. All of these scores are positive, indicating they should be included as part of the preferred restoration design. Additionally, each reach has different scores for each measure due to the results of the MCA reflecting the baseline condition of the reach (Table 5.10).

Table 5.10 - Summary of favourable options and measures for Unit 50

	Reach 19	Reach 18	Reach 17
Favourable options	River Restoration Targeted Maintenance	River Restoration Targeted Maintenance	River Restoration Targeted Maintenance
Mill Structures	N/A	N/A	Lower mill sill levels
Top 5 River Restoration Measures	1. Reconnect backwaters 2. Create new backwaters 3. Gravel glides 4. Berm creation 5. Lower spoil embankments	1. Reconnect backwaters 2. Tree thinning 3. Berm creation 4. Create new backwaters 5. Gravel glides	1. Reconnect backwaters 2. Create new backwaters 3. Gravel glides 4. Lower spoil embankments 5. Lower embankments

It should be noted that the above river restoration measures would need to be undertaken after works to the mill structure (at least in those sections of channel affected by the mill backwater) in order to ensure that the major influence upon the river is addressed first, as this will affect their success. The mill options all come up strongly positive.

The value of the weighted scores provides an indication of the relative importance of the measures in achieving 'unfavourable recovering' or 'favourable' ecological condition for the reach and suggests the order (within the context of the sequence of works in 1) mill structures, 2) gravel works and 3) other) in which measures could be applied. This provides a useful indicator for identifying which opportunities to look for first in a reach.

For example, in Reach 19, the highest scoring measure is reconnection of field drains, so this is the first opportunity looked for in the reach, followed by the second highest measure, identifying opportunities to create new backwaters and so on. All of the measures are valid so it is not recommended that a cut-off be imposed at a certain value. However, the positively scoring measures have been grouped into bands of importance to give an indication of their relative importance in restoring the reach to favourable condition (see Section 6 for further details). The frequency, location and manner in which measures are applied requires professional judgement, informed by in-depth understanding of the baseline conditions of the reach.

It is important to highlight that cost has not been included in the MCA as it is imperative that options and measures that move the reach towards achieving '*unfavourable recovering*' or '*favourabl*e' ecological condition are identified regardless of cost. Whilst cost is an important factor, it should not preclude an option or measure being identified and implemented. Instead, costs should be considered in terms of how options are implemented, and used to identify savings by using local material, phasing work appropriately or using different techniques (i.e. a LWD deflector compared with a concrete deflector) to achieve the same result at a lower cost.

The MCA provides a powerful tool for appraising all options and associated measures in a consistent, replicable and transparent way. It should be noted that the MCA should be viewed as a filtering tool to allow favourable options to be identified and unfavourable options to be dropped.

How those favourable options and measures are applied to a reach is a case of professional judgement, and this is discussed in Chapter 6.

6. Developing Conceptual Design

6.1 Introduction and approach

This chapter explains how the recommended options of 'River restoration' and 'Targeted maintenance' can be applied to each reach. To set this in context, the chapter initially details:

- The project in the context of river restoration (Section 6.2.1).
- How ecology has been integrated into the conceptual design process (6.2.2).
- How *'Targeted maintenance'* is included within the recommended option (Section 6.2.3).

Reach objectives, their review, and preferred restoration measures for each for Reaches 19, 18 and 17 are outlined in Sections 6.4 - 6.10 respectively.

6.2 Description of River Restoration and Targeted Maintenance Options

6.2.1 River restoration

The term river restoration can be used to describe a number of different activities that require different levels or magnitudes of change. River alteration projects form a continuum from '*full restoration*' through to '*erosion control*' (Figure 6.1).The range reflects the varying level of human intervention in natural systems to manage risk (Gillian, *et al*, 2005).

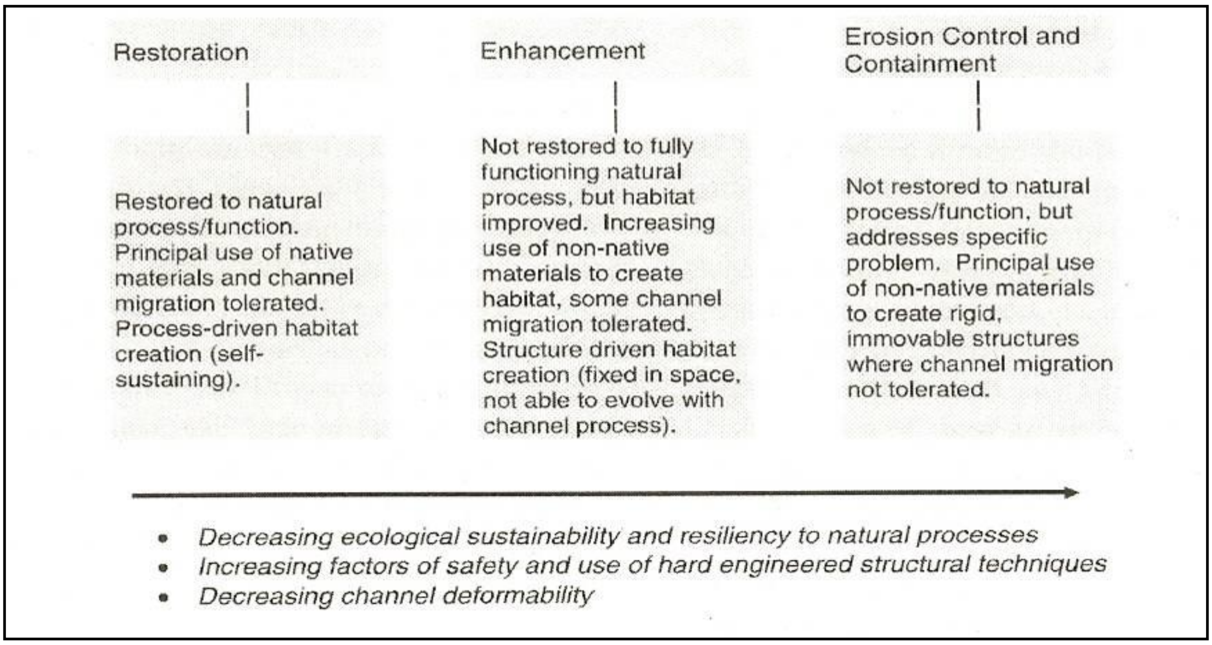

Figure 6.1 - River channel projects differ from full restoration to erosion control measures

This distinction between levels of work and sustainability was developed further in the geomorphological appraisal of the River Wensum, where Sear *et* al (2006) categorised the geomorphology of reaches on the River Wensum into six management classes of river restoration (Table 6.1). This provides a method of quantifying the magnitude of restoration needed on a reach by reach basis depending on the baseline conditions and opportunity for change.

Table 6.1 - Different management classes of restoration activity

Term	Definition
Restoration	Restoration of channel processes and forms to pre-disturbance conditions.
Rehabilitation	Physical modification to the river form to re-create physical habitats (e.g. re-meandering, riffle installation, bed level raising).
Enhancement	Addition of structural features to improve physical habitat diversity (e.g. narrowing, woody debris).
Protect & monitor	Afford legal protection to the site and monitor for change in status. Given that the site has legal protection (SSSI/SAC), monitor to ensure that the status is maintained and take action if required.
Assisted natural recovery	Amplification of existing processes to encourage recreation of physical habitats (e.g. encouraging berm formation to narrow channel, removal of bank revetment to create sediment supply).
Conserve	Protect site against further degradation not necessarily with legal statute.

Sear *et al* (2006) developed this further by categorising river restoration techniques into active and passive restoration based on the restoration approach of form mimicry or process based restoration (Table 6.2). This presents a range of typical river restoration measures that can be followed and all of these were included in the MCA analysis as all are applicable to the Wensum to varying degrees.

Table 6.2 - Active and passive river restoration measures

	Active restoration – physical creation of forms or removal of structures to improve degraded ecosystems.	Passive restoration – physical manipulation of flow and sediment transport regime to create physical habitat and to improve degraded ecosystems.
Form-mimicry – The re-creation of physical habitat features without reference to the processes required to create them.	Riffle recreation. Re-meandering.	Gravel augmentation which then is moulded by river flows into bed features (riffles).
Process-based restoration – The use of physical processes to restore degraded physical habitats to a more natural form.	Mill weir removal – restores sediment connectivity and hydraulic gradient. Re-occupation of an old channel course.	Reduction in catchment sediment supply. Management of flow regime (flow re-naturalisation).

All three reaches in Unit 50 have been categorised into the ‘Rehabilitation’ Management class (see Table 6.1) (Sear *et al* 2006; JBA, 2007). This is defined as:

> ‘’*Physical modification of the channel to re-create self sustaining physical habitats (e.g. riffles, side berms), generally where the channel is currently substantially over deep and/or over wide*’’.

Therefore ‘Rehabilitation’ <u>does not</u> mean that the aim of the ‘River restoration’ option is to:

- Return the river and floodplain to pre disturbance conditions; or
- Return the river to its high maintenance regime of wholesale dredging of the river channel; or
- Return the functionality of the mill systems.

The emphasis for Unit 50 is on changing present river form and flow processes to help the river develop conditions more typical of its chalk river type. This does not mean that this is undertaken in isolation to the wider issues and constraints of the catchment (e.g. flood risk).

Rather, improving the river condition should aim to provide multiple benefits in terms of reducing flood risk, reducing the need for regular extensive maintenance by creating a self-sustaining system, creating managed '*hotspots*' for 'Targeted maintenance', improving amenity value and improving habitat condition and diversity for a variety of flora and fauna.

In order to do this, different restoration measures can be used to varying degrees. The density and type of river restoration measures can be applied in three ways to provide the following design philosophies:

- *Total Restoration Design Philosophy* (High-density application of fully formed restoration features) – This approach provides 'complete' river restoration and is applicable when the river does not have the capacity to form features itself.
- *'Kick Start' Restoration Design Philosophy* (Medium-density application of partially formed features) – This approach uses the existing form and function of the river and provides in channel and out of channel features to allow the river to kick start natural geomorphological process by building upon the features provided.
- *Opportunistic Restoration Design Philosophy* (Low-density application of fully formed features) – This approach is indicative of opportunistic river restoration design where restoration measures are applied to a short length of river due to favourable circumstances. This often provides improvement to the river condition locally but can have limited benefit for the river condition on a SSSI unit basis.

River restoration that has been undertaken on the River Wensum in the past has been undertaken within the *Opportunistic Restoration Design Philosophy*. The RWRS has provided the opportunity to change this philosophy by providing a whole river vision and mechanism to achieve river restoration on a catchment-scale.

To achieve the vision of the RWRS, it is recommended that the '*Kick Start' Restoration Design Philosophy* is applied for the following reasons:

- The river is slowly recovering naturally from legacy maintenance practices, demonstrating the capacity to develop morphology features and 'self heal'.
- Whilst not ideal or recommended, modifications to mill operating regimes are likely to be undertaken at different timescales to river restoration. Consequently, implementing total restoration while mill structures are unchanged represents a future risk to the design if water levels change significantly.
- It provides value for money by not installing features that the river can form naturally over time.
- It allows a phased approach to be adopted by allowing the river time to adapt to river restoration measures before determining if additional measures are required.

Therefore, the approach of '*Kick Start' Restoration Design Philosophy*, within the context of the 'Rehabilitation' management class for the River Wensum, is to deliver the minimal amount of physical works in the river that will achieve sufficient change in hydromorphological form and fluvial processes to accelerate the river's natural ability to '*self-heal'*.

More specifically the design philosophy is to:

1. Restore the river to a form and function characteristic of a Norfolk chalk river.

2. Put forward recommendations that will see restoration measures implemented by 2010 to help restore '*unfavourable recovering*' or '*favourable*' ecological condition to the SSSI habitat features.

3. Provide a *'kick-start'* by only undertaking works to create features that the river would not be able to do itself.

4. Provide an increase in the patchiness and diversity of features that are sufficient to allow an improvement in natural processes and which will increase both the rate, and amount of self-restoration at any point along the unit.

5. Provide sufficient strength of processes that will allow significant self-restoration by 2015 to meet WFD timeframes.

6. Place measures at an appropriate frequency of 20m to match present day flow rates and erosion / deposition patterns. However, they must also respect the larger channel form features such as the relic bend length of 35 m derived from ancient river flow rates. This will ensure there is sustainability over any likely range of flow rates, and their associated erosion/ deposition patterns.

7. Ensure that the channel forms provide durable results against the varying flows and water levels generated by long-term climate change impacts, and in-channel vegetation growth in the short-term.

In respect to point 1 above, it is recognised that the River Wensum, and other Norfolk chalk rivers, are slightly different from 'classic' chalk rivers. This is explored in detail in Section 3.2 and the Geomorphological Appraisal of the River Wensum by Sear et al. (2006) and also summarised in the JBA report (2007).

6.2.2 Designing for ecology

The restoration strategy applied to each reach must provide a measurable ecological benefit at both a species and community scale in order for the River Wensum to achieve 'favourable' ecological condition. Ecological monitoring of river restoration sites will be one of the key ways of assessing the success of implementing the strategy.

Equally, prior to the implementation of specific river restoration measures, consideration must be given to the potential for harm to be caused to existing ecological features through direct damage, loss of habitat, or alteration to existing river form and function. The permanency of any effect, adverse or beneficial, will need to be assessed as well as the potential for natural recovery within the system.

This process has required an extensive ecological baseline review of the distribution and status of ecological features in the River Wensum, as discussed in Section 3. This has been coupled with the identification of physical habitat constraints and catchment scale pressures that are influencing condition status. Furthermore, a detailed review of the SSSI/SAC interest features has been undertaken in order to promote appropriate restoration measures for these key species and community assemblages.

It is important to note that at this stage the review has concentrated on designated ecological features only, although the intention is to add additional ecological features, following consultation with statutory stakeholders.

The following information has been collated for each of the key ecological features through extensive literature and data review:

- Protected status and UK distribution.
- General ecology e.g. life cycle, feeding requirements.
- Specific habitat requirements for all life stages, including;

- Substrate;
- Water quality;
- Water quantity; and
- Factors known to currently affect species/community distribution and populations.

For each of the *Strategy* wide restoration measures (e.g. tree thinning, gravel glide placement), both the positive and negative effects of implementation has been determined through an initial identification of the habitat requirements for each species and community. Following this, an assessment was made of how the habitat may alter following implementation of a river restoration measure and the resultant impact, adverse or beneficial, that this could have on species distribution and community persistence.

The recommended restoration measures that were identified using the MCA are displayed in Table 6.3 along with the associated potential ecological benefits to different species and communities. These benefits will arise by ensuring that the adopted restoration measures are integrated (e.g. berms are installed to promote favourable flow over the top of installed gravel glides). Integrated measures to maintain appropriate geomorphic form and function and maximum ecological benefit will ensure resilience and persistence of the ecological communities that develop. The designated species that are likely to benefit from specific restoration measures are also listed in Table 6.3. Further details of how the measures benefit the designated species and communities can be found in Appendix C.

Table 6.3 - River restoration measures and their potential ecological benefits

Restoration Measure	Description & Potential Ecological Benefits
Fencing	Fencing constructed landward of the river bank to prevent bank erosion from the impacts of cattle grazing, with a reduction in sediment ingress. Protects marginal habitat and promotes growth of emergent and aquatic plants, with associated improvement for aquatic macroinvertebrate fauna (e.g. Desmoulin's whorl snail *Vertigo moulinsiana)*.
Tree planting	Tree planting to cast shade over the water to control excessive macrophyte growth, provide cover for fish and to develop erosion resistance from root reinforcement. Also provides input of leaf litter and LWD of value to macroinvertebrate fauna including white-clawed crayfish
Tree thinning	Selective felling or lopping to provide light onto the water to encourage marginal and submerged macrophyte development and associated macroinvertebrates. In addition, this will generate appropriate materials for use in restoration measures, e.g. brush-fill and deflectors.
Deflector (using LWD and filled in with brush mattress)	Downstream pointing LWD placed and secured at the upstream side of the deflector to create flow diversity; in-filled downstream with brush to promote silt deposition and marginal plant growth. Provides refuge for fish fry behind structure and good flow diversity for macroinvertebrates and submerged macrophytes (e.g. *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation).
Lower spoil embankments	Removal of dredging-based informal embankments to allow out-of-bank flow across the floodplain, and back into the river. Ensures fish that are washed out of the channel during flood can return to the river as the floodwaters recede. May also improve adjacent wetland systems through water level regime.
Berm creation	Horizontal lowering of bank top up to half the channel width to increase flood flow capacity and generate arisings for bed raising where no embankments exist. Creates marginal shelf habitat for macrophytes and associated fauna plus refuges from high flows for fish fry. Improvement to instream flow conditions.
Backchannels – reconnections	Utilizing existing wet features by connecting them to the river to create

Restoration Measure	Description & Potential Ecological Benefits
to IDB and existing field drains	essential refuge habitat for fish and other fauna. This measure is implemented to aid the natural recruitment of fish stocks. Achieved through provision of nursery habitat and refuge from high-flow events. Additional utilisation by a variety of aquatic biota, e.g. brook lamprey ammocoetes
Backchannels – create new features	Creating habitat where no other water bodies exist e.g. dog-leg with downstream end open and upstream end fed by percolation. This measure provides refuge for fish and a place for fry to rest during floods, so limiting the loss of fry to reaches downstream of mill structures. Benefits all fish species through increasing recruitment potential.
Gravel riffles	Creation of short lengths of full raised bed, dressed in gravel, to create variation in flow and habitat for various macroinvertebrates and macrophytes in addition to provision of spawning substrate for fish species, e.g. trout, barbel and brook lamprey
Bed raising	Creation of long lengths of full width raised bed, dressed in gravel, to reconnect channel with floodplain and create variation in flow and habitat for various fish species, macroinvertebrates and macrophytes.
Channel realignment to increase river sinuosity	Full depth excavation from bank top to increase lateral variation in plan form, either one bank or both, using arisings to infill opposite bank. Improved geomorphological form and function beneficial to a range of associated biota.

Each of these measures has a different effect dependant on the flows in the river. Table 6.4 summarises the relationship between flow height and impact.

Table 6.4 - The effect of river restoration measures according to flow condition

River flow/level	Mill structures	Gravel glides	Deflectors	New back channels	Back-channel connection	Berm creation	Channel re-alignment	Channel re-sectioning	Removal of embankment	Removal of spoil	Tree thinning	Tree planting	Fencing
Over bank	I				I				D	D	D	D	D
Bank full	D	I	I	I	D	I	D	D	D	I			
High flow	D	I	I	D	D	D	D	D	I				
Low flow	D	D	D	D	I	D	D	I					

Key: I=Indirect; D=Direct

The effects can be direct (D), such as deflectors which will physically push flow across the river at low flows. Higher flows will go over the top of the deflector and therefore there will be no direct effects. However, the impact at low flow will have changed local silt deposition and hence vegetation patterns. The combined effect of the deflector and the vegetation will have an impact on the higher flows, but this depends on several factors such as plant growth; this effect is described as indirect (I).

The combination of each of the different measures ensures that process and form of the river is impacted under all flows and so will increase the rate of change towards self-healing. From an ecological view it means that conditions within the channel vary so that biota can move to similar conditions, but in a different location, as flow increases.

6.2.3 Targeted maintenance

The '*Targeted maintenance*' option recognises that there is a need for some maintenance to be undertaken on the River Wensum due to the various pressures that limit the potential for the channel to be a totally self-cleansing and regulating system. It also is an option that can be undertaken while river restoration measures are being designed and implemented,

A separate targeted maintenance protocol is being developed which sets out in more detail where, how, when and by whom maintenance will be undertaken. The protocol will allude where possible to policies such as those contained in the Broadland Rivers Catchment Flood Management Plan, specifically the reduction in maintenance of fluvial systems. In addition, the protocol will draw upon consultation with internal Environment Agency functions and other stakeholders and will have regard to current maintenance practices.

The measures that are included within the '*Targeted maintenance*' option are outlined below.

Silt removal at identified '*hotspots*'

These are sections of the river where silt accumulation will have an operational impact in terms of flood risk management. Typically these are sections of channel upstream of mill structures where silt deposits interfere with the flow of water approaching the structure, and limit the structure's capacity, so increasing local flood risk. Generally it is recommended that a 200 m length of channel upstream of each mill is targeted for de-silting. This will also allow the character of the mill leat to remain. Without the implementation of river restoration and lowering of levels at mills, desilted sections of river will tend to accumulate fresh deposits of silt. The desilting operation is therefore non-sustainable in the long term.

It is worth noting too that Norfolk chalk rivers have a higher sand content in the river substrate than a typical chalk river, in downstream sections, as a result of ingress of material from the drift. Restoration and targeted maintenance will not seek to remove these features and will work with them.

Clearance of main channel immediately downstream of identified IDB drain outfalls

This is to allow the IDB drains to discharge freely, otherwise their ability to flow freely is compromised, which in turn increases siltation, and so increases the need for maintenance in areas which are often valuable as nursery habitat for fish. The inability to discharge also increases flood risk from the drain, which in some instances will significantly impact on property flooding. It is recommended that 100 m downstream of confluences are regularly inspected and cleared of silt and excessive marginal vegetation if necessary.

Clearance or realignment of fallen trees blocking the channel

Clearance of fallen trees only needs to occur if they are within the impounded section immediately upstream of the mills, or the 100 m stretch downstream of IDB drain confluences, or are impacting directly on flood risk to houses, such as river blockages at bridges. Otherwise, the trees should be re-aligned to provide flow diversity, and LWD. Trees may present a problem on impounded river reaches, as they may assist a breach in a river bank where the river is a high level carrier. This is undesirable, in that the objective of the strategy is to manage change, rather than to allow unchecked natural change to manage the river

Strategic weed cutting

This should only be carried out where there is a direct flood threat to houses caused by elevated water levels, or where freeboard is unlikely to be sufficient to receive likely rainfall. It is likely to be required in the 200 m mill leat and 100m IDB drain confluence sections. As these are discrete sections, where access is reasonable, the use of weed cutting bucket equipped excavators can be used, without the need for weed boats to travel substantial lengths of the river, and thereby removes the need for boat clearance works.

6.3 Reach 19: Bintree Mill to Dell View

This section sets the scene for defining the preferred measures for Reach 19, by describing key existing features; reviewing the recommended measures as stated in the RWRS; presenting the results of the MCA scoring and details of the rehabilitation measures applied to the Reach.

6.3.1 Key existing features influencing proposed restoration measures

Table 6.5 presents a brief description of the existing conditions of the reach has observed during the site visit conducted on 3rd December, 2008. The purpose of the visit was to consider the reach objectives on the ground.

Table 6.5 - Significant features and possible measures observed for Reach 19 during site visit

Noted feature	Possible restoration measures
Good plan-form, particularly in the middle section.	N/A
The Reach is partially affected by backwater from North Elmham Mill. Possible that Yarrow Bridge provides upstream limit as local conditions would be more predominant.	Island immediately upstream of Yarrow Bridge needs channel to True Left Hand Bank (TLHB) side re-opening and managing as a backwater. This will help relieve pressure on True Right Hand Bank (TRHB) bridge abutment which is progressively being outflanked.
An embankment between Yarrow Bridge and County School Bridge on TRHB.	Remove embankments and use gravel arisings to raise the bed.
Only one glide noted downstream of Yarrow Bridge.	Berm the bank to increase flood capacity and generate arisings for foundation to glides.
River narrowing naturally.	Access is good, so could win timber and brush from local woodland: use Large Woody Debris (LWD) deflector with brush infill downstream to create silting area and encouragement of natural narrowing.
Little riparian vegetation on the banks.	Could add specimen trees to supplement existing trees on the river bank top to provide shade (and cover), bank stability to the outside of sharper bends, and visual amenity.
No fish refuge habitat identified.	Use dog leg backchannel to create further backchannels upstream. Locate between existing riffle works to help provide linking habitat.

6.3.2 Review of Reach 19 Restoration Strategy Objectives

Appendix A to the RWRS details a ‘Reach Restoration Strategy’ for each reach. These objectives have been the starting point for the consideration of rehabilitation activities within each reach. A review of these objectives is presented below in Table 6.6.

Table 6.6 - Review of requirements as defined for Reach 19 in Appendix A of the RWRS

	Objectives	Comments
1.1	All works must integrate with plans to lower structure at North Elmham Mill, lower structure at Bintree Mill and associated river works.	**Agree**: Two-thirds of the Reach is impacted by North Elmham Mill backwater, so restoration must integrate with work in this location.
1.2	They must also link in with the schemes already completed at this site.	**Agree:** Existing works are providing benefits so new works must be complementary.
1.3	Some sections of this Reach have emergent vegetation that is naturally narrowing the channel and this should be encouraged to continue.	**Agree:** The aim of restoration is to accelerate natural recovery not replace it. New works must be appropriate to this principle.
1.4	Augment bed with gravel towards the lower section of the Reach and remove embankments to reconnect the river to its floodplain.	**Agree**: Old bed has been dredged out to form embankments; reversing the operation will benefit natural processes and so aid recovery.
2.1	In the 100 to 200 m downstream of Bintree Mill and in immediate scour pool area of good habitat value, no works are required and this area should be conserved and allowed to re-vegetate naturally.	**Agree:**
2.2	Reduce depth by an average of 0.7 m and raise bed using up to 47 gravel glides or riffles in the Reach.	**Partially Agree**: Bed needs raising in places to create variation in flow and provide more typical substrate. The number of glides required needs to match plan form and scale.
2.3	Assume Reach will narrow naturally in time.	**Agree**: This process has already started to happen.
2.4	Adopt/maintain maintenance regime and riparian management to allow channel to narrow naturally.	**Agree:** Fallen timber would be particularly useful for encourage the river to narrow naturally. The combination of removing the mill backwater effect from this Reach and narrowing works should mean that de-silting will not be required here. Lower general water levels due to mill works will give extra freeboard for macrophyte growth so weed cutting may also not be required.
Summary Reach 19: Atkins agrees or partially agrees with all the principles established by JBA for this Reach. The only disagreements are over the details, such as number of glides. This variation is not surprising given the different level of analysis undertaken at the two different stages of the project.		

6.3.3 Reach 19: Recommended restoration

This section provides the details of the options and measures proposed for this Reach, which have been derived from the Multi-Criteria Analysis (refer to Section 5.3). A summary of the MCA results in their ranked order is provided in Table 6.7 and these are further divided into significance according to how far the measure will move the Reach towards '*unfavourable recovering*' or *'favourable'* ecological condition.

Table 6.7 - Summary of restoration measures for Reach 19 derived from the MCA

Option:	Description	Weighted score
Highly Important Measures		
5.17	Backwaters – re-connection to existing channels	16.03
5.18	New Backwaters	15.22
Important Measures		
5.7g	Gravel Glides	13.96
5.16	Berm Creation	13.54
5.14	Lower spoil embankments	12.77
5.15	Channel Re-sectioning	12.23
5.13	Deflectors	11.18
5.11	Tree Planting	9.28
5.12	Tree Thinning	7.65
Less Important Measures		
G3	'Targeted maintenance'	6.85
5.19	Channel Re-alignment	5.92
5.10	Fencing	5.05

6.3.4 Targeted maintenance

Following the principles established in Section 6.2.2 the following measures are suggested and may form part of the targeted maintenance protocol being developed for this unit. These include:

1. *Silt remova*l. This is recommended immediately upstream of control structures. There are none on this Reach and the Elmham Mill backwater terminates kilometres downstream. However, there will be the need to maintain clear approaches and departures from Yarrow Bridge, so monitoring and clearance of encroaching silt will be needed within 10 m upstream of the bridge (equal to 1 channel width) and 20 m downstream (equal to 2 channel widths).
2. *Clearance of main channel downstream of confluence with IDB drains*. There are none on this Reach, so there is no requirement for this type of work.
3. *Clearance or realignment of fallen trees blocking channel*. Clearance is only required where they are impacting directly on flood risk to property or the structural integrity of third party assets. The only significant structure is Yarrow Bridge, and therefore, the same clearance distances as identified for de-silting applies here. Any fallen trees downstream of this need to be considered on their individual merit due to the close proximity of properties on this Reach.
4. *Strategic weed cutting*. This is only needed where there is direct threat to houses caused by elevated water levels, or where freeboard is unlikely to be sufficient to receive likely rainfall. As this will be a discrete section (probably downstream of Yarrow Bridge), with reasonable access, the use of weed cutting bucket equipped excavators can be used.

6.3.5 Restoration measures

All the restoration measures identified by the MCA have been incorporated in the preferred outline restoration design for Reach 19. The proposed conceptual design for the recommended restoration for Reach 19 is shown in Figure 6.2.

The highly important measures for Reach 19 are:

Backchannel creation by connection to existing channels

There are 3 existing drains that fall into this category. These include:

- The ditch between Dell View Farm and the river (180 m).This will require little work.
- The back-channel round the island immediately upstream of Yarrow Bridge (80 m). This requires clearing of the side channel of silt and vegetation growth to allow flow. Also, flow to the main channel side of the island will need to be altered, but this can be achieved with: upstream berm creation; downstream deflector works; downstream gravel works; all of which will preferentially push flow towards the off take round the back of the island. This will need to be carefully considered with regard to conveyance through Yarrow Bridge and the stability of its weakened wing walls.
- The field ditch on the TLHB starting inline with Yarrow Farm, and ending in the island back-channel (320 m). This will need a connection to the river at the upstream end, and maintenance of access across the drain but this can be combined with a flow throttle at the upstream end to prevent uncontrolled flow into the backwater by using an under-sized culvert. The ditch will need to be re-profiled to allow better and varied flow. This needs to be carried out in combination with modifications to the main channel to preferentially push flow towards the off-take, but this can be achieved with a combination of upstream berm creation, downstream deflector works and downstream gravel works.

Backchannel creation by new back channels

There are 3 significant straights within this Reach where short backwaters could be located. These could be provided in the form of fully formed bends reconnected to the river but this would not give true backwater conditions, particularly under high flow conditions. The amount of sediment within the system also needs to be considered. The suggested design is therefore using the expected bend geometry of the Reach, to provide stability against long-term erosion, but only fully open at the downstream end. The upstream end is plugged with gravel rejects to provide a sweetening flow under all flow states, and also to prevent the downstream end silting up. Figure 6.2 sets out the outline plan for the preferred restoration design for Reach 19.

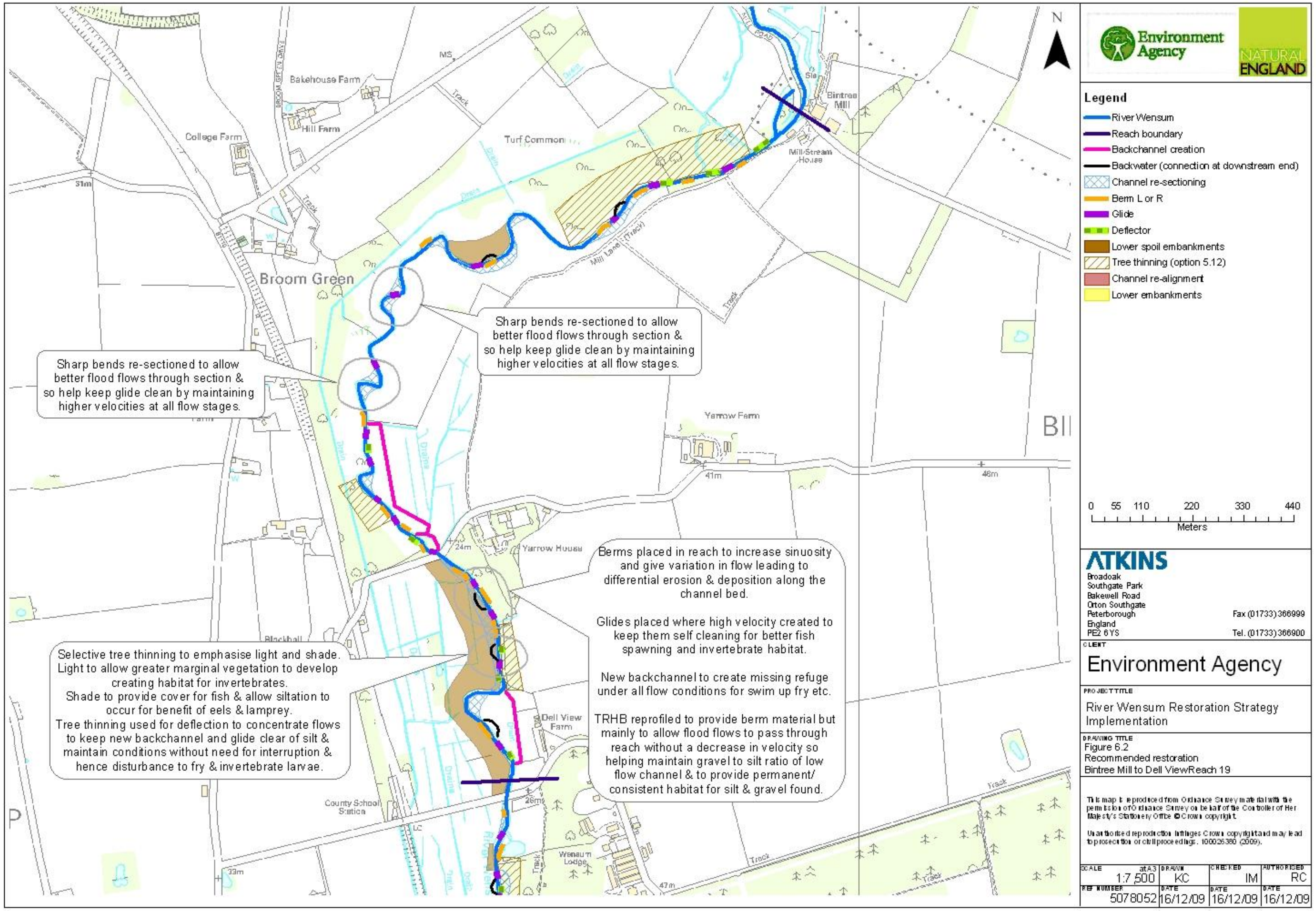

Figure 6.2 - Outline plan for the preferred restoration design for Reach 19

6.4 Reach 18: Dell View to Bintree Woods

This section sets the scene for defining the preferred restoration of Reach 18, from just upstream of County School Bridge to the southern boundary of Bintree Woods by describing key existing features; reviewing the recommended measures as stated in the RWRS; presenting the results of the MCA scoring and details of the rehabilitation measures applied to the Reach.

6.4.1 Key existing features influencing proposed restoration measures

Table 6.8 presents a brief description of the existing conditions of the Reach as observed during the Atkins site visit conducted on Wednesday 3rd December. The purpose of the visit was to consider the Reach objectives on the ground.

Table 6.8 - Significant features and possible measures observed in Reach 18 during site visit

Noted feature	Possible restoration measures
The entire Reach is impacted by North Elmham Mill.	Water levels at North Elmham Mill to be lowered.
Floodplain to TRHB is terminated by railway embankment. The land use here is closest example of 'flood meadows' in Wensum Valley.	No measures
Island shown as being reclaimed by the wet woodland from the True Left Hand Bank (TLHB).	The silting TLHB channel could be managed as a backwater.
Significant amount of timber available for in-channel deflectors: brush infill to downstream side. However unless riverside trees are used access is difficult due to poor ground conditions.	Deflectors to be spaced at nominally 40 m intervals to create meander patterns.
No fish refuge habitat identified.	Could add dogleg backwater on old line of river to TRHB. Arisings could be used for riffle foundations if suitable
No significant embankments, therefore no material will be generated by their removal.	Construction of riffles will, therefore, need significant supplementation with imported gravel.

6.4.2 Review of Reach 18 Restoration Strategy Objectives

Appendix A to the RWRS details a 'Reach Restoration Strategy' for each reach. These objectives have been the starting point for the consideration of rehabilitation activities within each reach. A review of these objectives is presented below on Table 6.9.

Table 6.9 - Review of requirements as defined for Reach 18 in Appendix A of the RWRS

	Objectives	Comments
1.1	All works must integrate with lowering of structure at North Elmham Mill and associated river works.	**Agree**: Impact of mill backwater is so significant it must be taken into account.
1.2	Physically narrow channel and augment bed with gravel.	**Partially Agree**: Channel is over-wide and over-deep. However there is a need to allow for discharge through bridge to avoid flooding Dell View Farm.
1.3	Remove embankments to reconnect the river to its floodplain.	**Agree**: The TRHB would particularly benefit from this. This is more difficult to achieve on the TLHB due to the presence of woodland.
1.4	Develop marginal/bankside vegetation and use coarse woody debris structures to exacerbate sinuosity.	**Agree**: The Reach has been significantly straightened. Timber for coarse woody debris is in close proximity.

	Objectives	Comments
2.1	Augment the bed on average by 0.7m using local gravels wherever possible and create up to 15 gravel glides or riffles in the Reach.	**Partially agree**: The bed requires raising in places to create variation in flow and provide more typical substrate. The number should match plan form and scale.
2.2	The channel is on average 5.6 m over wide and physical narrowing (with associated landscaping and fencing) may have to be considered to restore the full functioning of the channel in this Reach.	**Agree**: See comments under 1.2.
2.3	Adopt/maintain maintenance regime and riparian management to allow channel to create natural variations in local channel width and habitat niches.	**Agree**: Fallen timber would be particularly useful for this. With removal of the mill backwater from this Reach and narrowing works, de-silting will not be required. Lower general water levels due to mill works will give extra freeboard for macrophyte growth so weed cutting would also not be required.
Summary: All the principles presented in the RWRS for this Reach are generally supported, however certain details, such as number of glides, need to be reconsidered.		

6.4.3 Reach 18: Recommended restoration

This section provides the details of the options and measures proposed for this Reach which have been derived from the Multi-Criteria Analysis (refer to Section 5.3) A summary of the MCA results in their rank order, is provided in Table 6.10 and these are further divided into importance according the how far the measure will move the Reach towards achieving '*unfavourable recovering*' or *'favourable'* ecological condition.

Table 6.10 - Summary of restoration measures for Reach 18 derived from the MCA

Option	Description	Weighted score
Highly Important Measures		
5.17	Backwaters – re-connection to existing channels	15.37
Important Measures		
5.12	Tree Thinning	14.59
5.16	Berm Creation	14.44
5.18	New Backwaters	13.41
5.7g	Gravel Glides	13.36
5.15	Channel Re-sectioning	12.23
5.13	Deflectors	11.98
5.14	Lower spoil embankments	11.97
5.19	Channel Re-alignment	9.29
Less Important Measures		
G3	'Targeted maintenance'	6.85
5.10	Fencing	6.76
5.11	Tree Planting	3.42

6.4.4 Targeted maintenance

Following the principles established in Section 6.2.2 the following measures are suggested and may form part of the targeted maintenance protocol being developed for this Unit. These include:

- Silt removal. This is recommended immediately upstream of control structures. There are none on this Reach and the Elmham Mill backwater terminates in Reach 17. However, there still remains a need to maintain clear approaches and departures from County School Bridge, so monitoring and clearance of encroaching silt will be needed within 10 m upstream of the bridge (equal to 1 channel width) and 20 m downstream (equal to 2 channel widths).
- Clearance of main channel downstream of confluence with IDB drains. There are none on this Reach, so there is no requirement for this type of work.
- Clearance or realignment of fallen trees blocking channel. Clearance is only required where they are impacting directly on flood risk to property or the structural integrity of 3rd party assets. The only significant structure is County School Bridge, and therefore, the same clearance distances as identified, for de-silting apply. Any fallen trees downstream of this can be simply trimmed and re-aligned as there are no properties on this Reach.
- Strategic weed cutting. This is only needed where there is direct threat to houses caused by in-stream vegetation causing elevated water levels, or where channel capacity is unlikely to be sufficient to contain likely rainfall inputs. As this will be a discrete section (probably downstream of County School Bridge), with reasonable access, the use of weed cutting bucket equipped excavators can be used.

6.4.5 Restoration Measures

All of the restoration measures identified in the MCA have been incorporated in the proposed conceptual restoration design for Reach 18 (Figure 6.2). The proposed river restoration measures have been developed on the assumption that works at North Elmham Mill (Reach 17) can and will be achieved before other restoration activities take place.

The only highly important measure for Reach 18 is:

Backchannel creation by connecting to existing channels

Whilst there are some channels on the TRHB floodplain in this Reach, none of them present practical propositions as backwaters as they are either set back from the river, or act as outfalls for ditches culverted under the road. However, on the TLHB there is the channel separating the ‘island’ from the TLHB itself. Although this is heavily silted and partially blocked by fallen woody debris, it can be re-configured to provide a backwater. This is important because otherwise there is no backchannel habitat on the Reach, which may mean that the Reach’s ability to retain fish and other biota during flood events is negligible.

Figure 6.3 sets out the outline plan for the preferred restoration design for Reach 18.

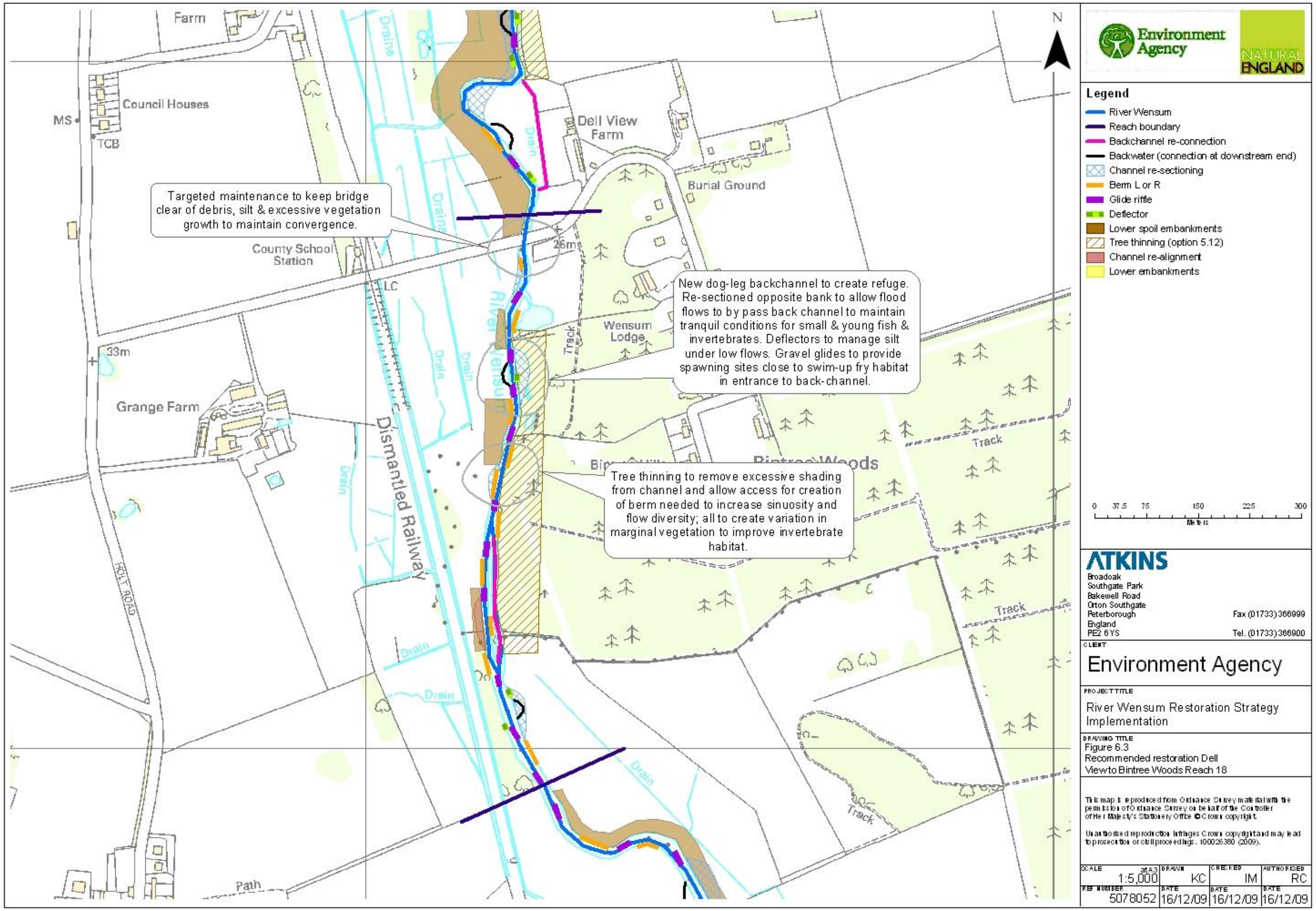

Figure 6.3 - Outline plan for the preferred restoration design for Reach 18

6.5 Reach 17: Bintree Woods to North Elmham Mill

This section sets the scene for defining the preferred restoration of Reach 17 by describing key existing features; reviewing the recommended measures as stated in the RWRS; presenting the results of the MCA scoring and details of the rehabilitation measures applied to the Reach.

6.5.1 Key existing features influencing proposed restoration measures

Table 6.11 presents a brief description of the existing conditions of the Reach as observed during the site visit conducted on 3rd December, 2008. The purpose of the visit was to consider the Reach objectives on the ground.

Table 6.11 - Significant features and possible measures observed in Reach 17 during site visit

Noted feature	Possible restoration measures
The entire Reach is impacted by water backing up behind North Elmham Mill.	Levels at North Elmham Mill need to be lowered.
The channel is significantly wide and deep in places.	These sections should be narrowed.
Self narrowing on both banks is occurring in places, but this process is not necessarily influenced by river bends.	Investigate possible sources of channel narrowing including diffuse silt pathways into the main river.
No significant riparian vegetation including mature trees over majority of Reach. This reduces the opportunity for shade, fish cover or shading for macrophyte control.	Suggest planting specimen trees on outside of bends to provide shade onto water and ultimately to reinforce the riverbank.
Embankments to TLHB of variable height and width. Not enough for riffle creation alone.	Lower bank to intermediate height to create three stage channel, and dig a soak dyke parallel to river 4m back to intercept ground water, with outfall into IDB drain. This would make soil water conditions more manageable and perhaps allow seasonal wetting to be retained. All spoil to be used for riffle foundations.
No backwaters seen.	Create dogleg backchannel to either bank.
IDB drain to TLHB at least 2 m deep so good outfall for surface water or floodplain drainage.	Investigate opportunities to re-connect the main river to these surface water drainage features.

6.5.2 Review of Reach 17 Restoration Strategy Objectives

Appendix A to the RWRS details a ‘Reach Restoration Strategy’ for each reach. These objectives have been the starting point for the consideration of rehabilitation activities within each reach. A review of these objectives is presented below in Table 6.12.

Table 6.12 - Review of requirements as defined for Reach 17 in Appendix A of the RWRS

	Objectives	Comments
1.1	All works must integrate with lowering of structure at North Elmham Mill and associated river works.	**Agree**: The impact of mill backwater effect is very significant (100% of this Reach) and it must be addressed.
1.2	De-silt channel just upstream of North Elmham Mill, physically narrow and augment bed with gravel.	**Partially Agree**: Channel should be desilted to remove silt from the system. However the channel is considered too mal-formed to modify successfully, and so best kept as a focus for maintenance works.
1.3	Remove embankments to reconnect the River to its floodplain and encourage development of marginal/bankside vegetation.	**Partially Agree**: The embankments should be removed as this will help attenuate flood flows and probably improve flood plain drainage. This will however not assist with the development of marginal vegetation. This would require berms or re-sectioning.
2.1	Initial work required is for bed and bank stabilisation associated with removal of North Elmham Mill structures at downstream end of Reach.	**Partially Agree**: Agree in principle to monitoring the impact on bed and bank stability during a draw down trial at the mill. Existing berm development seems to have stabilised banks. De-silting by the mill will trap any mobilised bed material.
2.2	Appropriate measures required to manage silt deposits upstream of the mill.	**Agree**: The design and implementation of any new structures or features need to consider positive or negative silt movements within the water column.
2.3	Augment bed on average by 1.5 m using local gravels wherever possible and create up to 45 gravel glides or riffles in the Reach.	**Partially agree**: The bed should be raised in places to create variation in flow. The number of glides or riffles proposed should match the plan form and flow pattern. However a total of 45 glides does not easily match.
2.4	The channel is on average 12.9 m over wide and physical narrowing (with associated landscaping and fencing) may have to be considered to restore the full functioning of the channel in this Reach following works at the mill.	**Agree**: The natural channel width is about 6 m, so existing self narrowing due to excessive silt loads needs to be encouraged in order to create greater variation in flow.
2.5	Adopt/maintain maintenance regime and riparian management to allow channel to create natural variations in local channel width and habitat niches.	**Agree**: Reach restoration should be self-sustaining, and so not require maintenance where form and process can work. Section 200m upstream of mill needs to be retained as classic mill leat to provide variety and act as a silt trap to focus maintenance needs on.
2.6	Post-project monitoring is required, especially in association with works at the mill structures.	**Agree**: Mill works need to be implemented first so that effects can be fed into upstream in-channel works.
Summary: All the principles presented in the RWRS for this Reach are generally supported, however certain details, such as number of glides, need to be reconsidered.		

6.5.3 Reach 17: Recommended Restoration

This section provides the details of the options and measures proposed for this Reach which have been derived from the MCA (refer to Section 5.3). A summary of the MCA results in their rank order is provided in Table 6.13 and these are further divided into significance according to how far the measure will move the Reach towards '*unfavourable recovering*' or *'favourable'* ecological condition.

Table 6.13 - Summary of restoration measures for Reach 17 derived from the MCA

Option No.:	Description	Weighted score
Highly Important Measures		
5.17	Backwaters – re-connection to existing channels	16.03
5.18	Backwaters - new	14.58
Important Measures		
5.7g	Gravel glides	13.96
5.3m	Mill structures – lower mill sill levels	13.34
5.14	Lower spoil embankments	12.77
5.21	Lower embankments	11.96
5.13	Deflector	11.82
5.15	Channel re-sectioning	10.25
5.16	Berm creation	10.22
5.11	Tree planting	9.28
5.12	Tree thinning	8.01
Less Important Measures		
5.19	Channel re-alignment	5.98
5.10	Fencing	5.05
G3	'Targeted maintenance'	3.7

6.5.4 North Elmham Mill

Modifying North Elmham Mill was one of the more important measures identified and it is important that structure works are undertaken before other restoration activities are undertaken. However further investigation is required to determine the feasibility of possible modifications of lowering the sill levels. The River Wensum Restoration *Strategy* recommended lowering water levels at the mill (without lowering the sill levels), and indicated that a significant reduction in operating level could be possible without major modifications. It was envisaged that the lower water levels could be achieved by making gradual changes using the existing sluices. According to the RWRS, changing the sluice operation alone could result in a 0.72 m level drop and a reduction in backwater over 3.25 km.

A site visit to North Elmham Mill was conducted by Atkins in February 2009, to investigate the engineering feasibility of the following options:

- Modification of existing sluice operation.
- Removal of sluice gates.
- Lowering of sill levels.
- Creation of fish-pass channel.

The site visit found that the accumulated silt immediately upstream of the mill is affecting flows. It was recommended that this silt needs to be removed and another assessment of the structure be performed. Removal of the silt is scheduled for Autumn 2009.

A short-term trial was undertaken in April 2009 to assess the effect of sluice operation on upstream levels. During the trial, gaugeboards equipped with dataloggers were installed upstream in order to monitor water levels. The results from the trial demonstrated that the mill has a significant impact on the water level in the lower 2km of the Reach during most flows and adjustment of the sluice has about a 15 – 30 minute time lag before the backwater effect at High House (x km upstream of the mill) is reduced. The results from this investigation could be used to help prepare a preferred operating regime for the structure in consultation with the mill owner.

Alterations to the bypass channel and, in particular, the high-level overspill could also be considered. Although the mill is not a listed building, such an approach would need to take any construction works would need to occur away from the immediate proximity of private homes.

Full removal of the sluice gates is thought to be technically possible although such an option would need to be assessed in detail. Similarly, lowering of the sill level may be possible but a full structural survey would be necessary to inform any such modifications. However, more extensive construction work, for instance complete removal of the structure, would be technically challenging and costly.

If the need for a fish-pass is identified, then the area around the bypass sluice would appear to be an appropriate location. However, the feasibility of this has not been considered in detail.

The RWRS reports that some structural work was undertaken previously to enable turbines to run. Details have not been obtained, but it is assumed that the turbines are no longer in use.

In summary, based on the findings from the site visit the most likely solution for improving water levels will involve changing the operation of the sluice gates. The river restoration measures proposed for Reaches 19, 18 and 17 have been developed based on the assumption that this can be achieved.

6.5.5 Targeted maintenance

Following the principles established in Section 6.2.2 the following measures are suggested and may form part of the targeted maintenance protocol being developed for this Unit. These include:

Targeted maintenance should be undertaken immediately upstream of the mill to remove the sediment deposited in the form of a vegetated island. This will ensure the full flow capacity of the mill sluices is maintained.

Localised removal of weeds and silt should be undertaken downstream of large IDB drain outfalls where these factors cause significant impediment to the discharge of surface water.

6.5.6 Restoration measures

All of the river restoration measures identified in the MCA have been incorporated into the preferred outline restoration design for Reach 17. The proposed conceptual design for the recommended restoration for Reach 17 is provided in Figure 6.3. As stated in Section 6.5.4, the proposed river restoration measures have been developed based on the assumption that work at North Elmham Mill can and will be achieved before other restoration activities take place.

The proposed design has identified a number of opportunities to create backwater habitat by linking with existing drains, and has also identified locations for the creation of new backwaters to provide refuges for fish and to aid in the recruitment of juvenile fish in this Reach. At the moment backwater habitats are severely limited in this Reach. The location and density of different restoration measures has been determined based on professional judgement and detailed understanding of the baseline conditions of the Reach. The design has deliberately stopped 100 m upstream of the mill as this area will be the focus for ‘Targeted maintenance’. Figure 6.4 sets out the outline plan for the preferred restoration design for Reach 17.

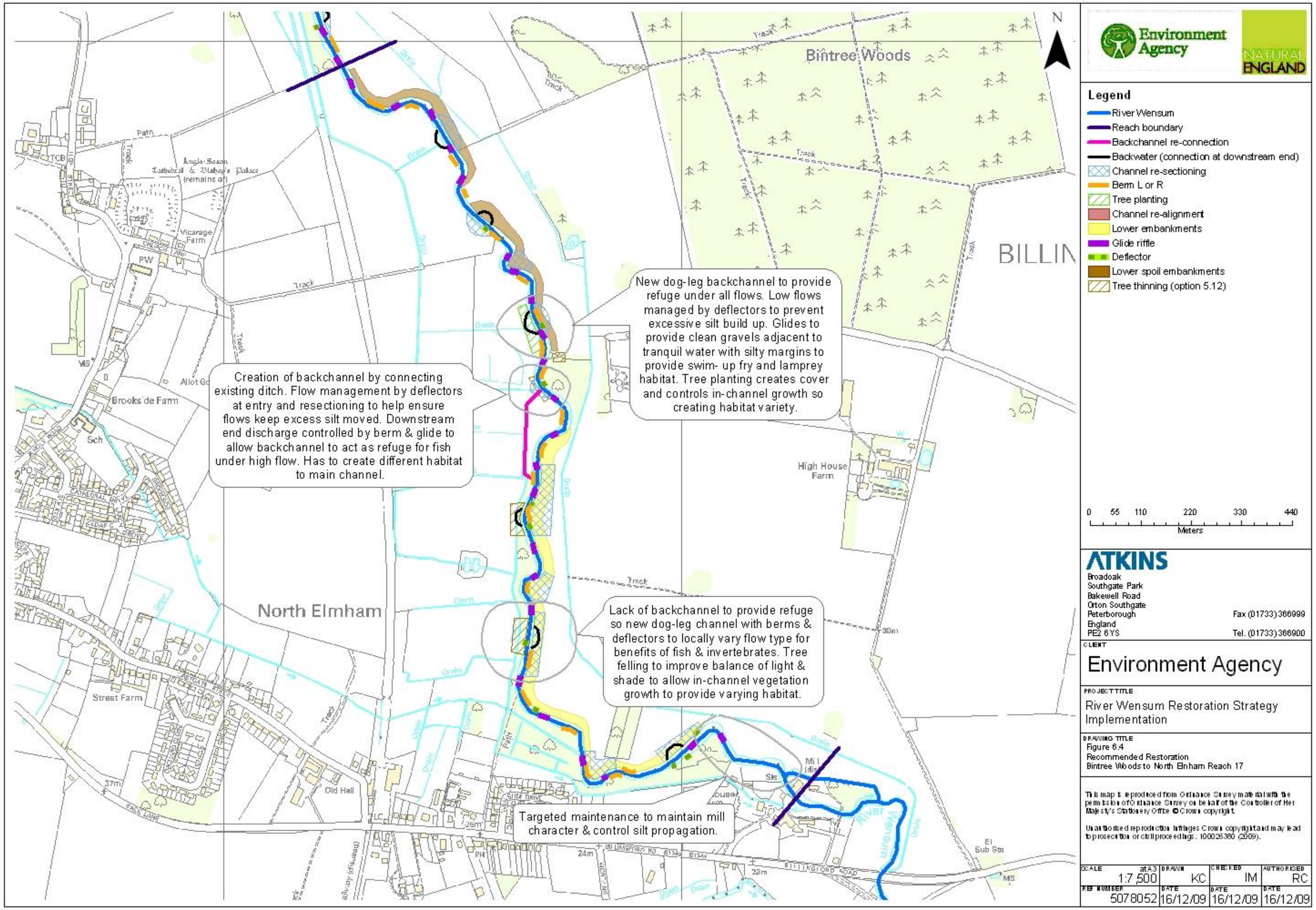

Figure 6.4 - Outline plan for the preferred restoration design for Reach 17

7. Cost Estimate

This chapter covers the cost estimate for delivering the preferred restoration options for each reach as outlined in Chapter 6. To set this in context, a brief background history of previous published reports and their cost estimates is first summarised in Section 7.1, before the present or current cost estimates are presented in Section 7.2 together with the main assumptions for the estimates. Potential cost savings are presented in Section 7.3, and delivery or phasing aspects are detailed in Section 7.4.

7.1 Previous Cost Estimates

7.1.1 Background

Two previous reports, The River Wensum Restoration Strategy (RWRS) (JBA, 2007), and Estimating Costs of Delivering the River Restoration Element of the SSSI Target (Halcrow, 2008), have provided some costings for restoration options on the river.

The RWRS estimated costs per kilometre of in-channel river works including bed raising, channel narrowing and restoring meanders. Based on these rates and the recommendation in the report for Unit 50, this equates to the costs outlined in Table 7.1.

Table 7.1 - RWRS Unit 50 cost estimate (JBA, 2007)

Reach:	17	18	19
Reach length: km	2.6	0.86	2.67
Length of recommended works: km	2.6	0.86	2.47
Narrowing <10m	0	£172,000 total	0
Narrowing >10m	£1,040,000	0	0
Bed raising	£468,000	£154,800	£444,600
Modification of mill structures	£285,700	0	0
Total for reach:	£1,793,700	£326,800	£444,600
Total for Unit 50:	**£2,565,100**		

The River Restoration SSSI Cost Estimate Report (Halcrow, 2008) covers all river SSSIs in England and includes the prevailing views of Natural England and the Environment Agency regarding appropriate measures for each unit on each river. For Unit 50 the cost estimate details are listed in Table 7.2.

Table 7.2 - Halcrow PSA Unit 50 cost estimate

Unit 50: Length 5.6km	Fencing	Large Woody Debris	In-stream Structures	Cross Section Modification	Bed Raising	Structure modification	Meandering
% length requiring work	0	20	20	30	30	30	0
Length in km requiring work	0	1.12	1.12	1.68	1.68	1.68	0
Cost per km of activity	£18k	£26k	£105k	£77k	£197k	£210k	£1603k
Cost of activity	0	£29.12k	£117.6k	£129.36k	£330.96k	£352.8k	0
Total for Unit:	**£959,840k**						

These two cost estimates are summarised in Table 7.3 which shows that the previous cost estimates to restore Unit 50 of the River Wensum range between £960K to £2.5 million and are based on broad assumptions as both studies represent a high level assessment of possible restoration measures required. This feasibility report has looked at all options for restoration in more detail and hence it is appropriate that the associated costs for the recommended options are refined further.

Table 7.3 - Comparison of cost estimates between JBA and Halcrow reports for Unit 50

	Large Woody Debris	In-channel structures	Cross section modification	Bed Raising	Structure modifications	Total
RWRS	£172k	£1,040k	0	£1,067.4k	£285.7k	£2,565.1k
SSSI Cost Estimates	£29.12k	£117.6k	£129.36k	£330.96k	£352.8k	£959.84k

Notes: It has been assumed that the RWRS narrowing <10m equates to LWD, and >10m to in-channel structures). Meandering is included in the category 'cross section modification' as it is zero cost.

7.2 Present Cost Estimates

7.2.1 Unit 50 Cost Estimate

Costs for implementing the recommended options and measures for the whole of SSSI Unit 50 have been estimated based on information from the RWRS (JBA, 2007), SSSI Estimated Costs Report (Halcrow, 2008) and other sources. These sources have been used to ensure consistency in the cost estimates so that the feasibility report provides a refined cost estimate rather than an independent one.

Table 7.4 shows that the total cost estimate for the different river restoration measures recommended for Unit 50 is £1,487,000 (to the nearest thousand pounds). This estimate is based on a number of assumptions relating to sizes, quantities, materials and conditions. It also reflects current prices and costs which are subject to change (i.e. inflation). The targeted maintenance option has not been costed due to uncertainty in rates. This exclusion, along with the assumptions, will affect the accuracy of the final cost estimate. The full details are given in Appendix B.

Table 7.4 - Unit 50 cost estimates for various river restoration measures

Measure:	Description	Length	Rate	Cost
5.10	Fencing	6125m (100%)*	£4/m	£24,500
5.3m	Mill structures – lower mill sill levels	{5050m (82%)	Na	£175,000
5.16	Berm creation	2766m (58%)	£90/m	£248,940
5.15	Channel re-sectioning	2110m (34%)	£62.52/m	£131,919
5.14	Lower spoil embankments	1845m (30%)	£38.04/m	£70,175
5.21	Lower mill embankments	1280m (21%)	£31.33/m	£40,107
5.12	Tree thinning	1070m (17%)	£10/m	£10,700
5.17	Backchannel – re-connection	1030m (17%)	£58.49/m	£60,246
5.7g	Gravel glides	940m (15%)	£510.16/m	£479,650
5.19	Channel re-alignment	747m (12%)	£148.60/m	£111,006
5.13	Deflector	457m (7%)	£44/m	£20,108
5.11	Tree planting	576m (9%)	£9/m	£5,184
5.18	Backchannels - new	480m (5%)	£227.70/m	£109,296
G3	Targeted Maintenance	280m (5%)	Unknown	Unknown
Total:				**£1,486,831**

* Notes: It has been assumed that one whole length of river bank will be fenced, to allow for variation between both banks.

7.3 Potential Cost Savings

The total cost estimate of £1,487,000 (to the nearest thousand pounds) for Unit 50 is based on a number of assumptions, in particular the materials and installation methods for the different river restoration measures (see Appendix B for details). Similar results for restoration could possibly be achieved by different methods at a lower cost.

There are 3 particular river restoration measures that could be altered to reduce costs but still provide similar results:

- Measures that generate surplus spoil, and hence disposal costs.
- Bed raising.
- Gravel glides.

These measures are discussed in the following sections.

7.3.1 Spoil reduction

A number of the river restoration measures for Unit 50 generate spoil as outlined in Table 7.5.

Table 7.5 - Options that typically generate spoil

Reach:	17	18	19	Totals
Spoil Embankments (m^3)	4608	1475	2380	8463
Formal embankments (m^3)	4838	0	0	4838
Berms (m^3)	-3528	-1140	-3944	-8612
Re-sectioning (m^3)	8964	1685	5264	15,913
Connect backchannels (m^3)	1153	0	118	1271
New Backchannels (m^3)	4320	2160	2160	8640
Channel re-alignment (no net fill) (m^3)	0 (6910)	0 (438)	0 (2879)	0 (10,217)
Total surplus spoil (m^3):	20,355	4180	5978	30,513

Note: A negative number (-) indicates a measure requires spoil

Table 7.5 shows there is a surplus spoil volume of 30,513m^3 which, at £4.35/m^3 for spreading the material outside of the floodplain, represents £133,000 (to the nearest thousand) or 9% of the total cost. Any reduction in this quantity will reduce the amount of trafficking on site, and this will have beneficial consequences in terms of:

- Reduced land take.
- Reduced carbon footprint.
- Reduced grounds for landowner dissatisfaction.
- Reduced need for environmental mitigation.

Re-sectioning generates the largest amount of spoil (15,913 m^3). The 25 locations chosen are all variable in length, but by careful consideration, it is possible that 10% of the length, and hence volume and costs, could be reduced as shown in Table 7.6.

Of the remainder, it becomes very difficult to reduce the amount of works without impacting on their functionality. For example, new backchannels need to be the size recommended to provide long term stability, and so excavation lengths cannot be meaningfully reduced.

Based on the drift geology and preliminary auguring results in Unit 19, there is a good chance that some of the surplus spoil will contain gravel and could be used to help raise the river bed in certain locations. The exact amount is difficult to estimate, but further auger sampling in the features to be excavated is highly recommended to establish more reliable figures.

Table 7.6 assumes that all material is re-useable, and so gives the maximum potential benefit that might be achievable. Table 7.6 suggests that based on the excavation estimates and assuming the spoil material contains suitable gravels, the total lengths of river bed in Reaches 17, 18 and 19 can be raised by a depth of 0.72 m, 0.66 m and 0.39 m respectively. The depth available can be calculated from the useable material available. For example, if there is 50% gravel, then that will deliver 50% of the depth shown.

Table 7.6 - Excavation arisings converted to bed fill depths for each reach

Reach	Reach bed area (m^2)	Spoil Embankment		Re-sectioning		New backchannels		Total Depth for entire reach (m)	Total depth for identified bed raising locations (m)
		Volume (m^3)	Bed depth (m)	Volume (m^3)	Bed depth (m)	Volume (m^3)	Bed depth (m)		
17	9.5 x 2600 = 24,700	4608	0.19	8964	0.36	4320	0.17	0.72	5.38
18	9.5 x 855 = 8122.5	1475	0.18	1685	0.21	2160	0.27	0.66	N/A
19	9.4 x 2670 = 25,098	2380	0.09	5264	0.21	2160	0.09	0.39	3.48

If all of the excavation material is suitable it is possible that it could be used to provide gravel for two-thirds of the depth of the bed raising and the gravel glides, which would result in significant savings. This possibility has been considered in the detailed design of restoration options for Reach 19 between Yarrow Bridge and County School Bridge (Atkins, 2009 in prep), by undertaking augering of the bank within the 9 m Environment Agency permitted development zone. It is recommended that this is repeated for other sections of river as part of the detailed design process.

Therefore, based on the cost savings from changing the construction methods for gravel glides, bed raising and reducing spoil, the revised total cost estimate for Unit 50 is £1,327,000 (to the nearest thousand) (refer to Appendix B for more detail). This gives a total cost of 11% less than the initial cost estimate, whilst retaining similar amounts of functionality.

7.3.2 Bed raising

The MCA identified that the most beneficial option of reintroducing gravel to the system was in the form of gravel glides. However, in some instances, bed level raising on a larger scale is more applicable particularly for linking two good habitat areas together to provide added benefit. This is an assessment made on best professional judgement and locations where this measure is best suited have been identified. Table 7.7 shows the details of the costs for bed raising based on a rate of £53/m^3 for importing and installing the gravel.

Table 7.7 - Details of costs and savings in raising the river bed with gravel in specific locations

Reach	Length of bed raising (m)	Depth of bed raising (m)	Width of channel (m)	Total volume (m^3)
17	350	1.5	9.5	4,987
18	0	0	0	0m
19	300	0.7	9.4	1974
Volume per unit:				6961
Rate per in £:				£53/m^3
Total cost				£368,933
Reduction in volume by 1/3rd				4641
Final cost				**£245,955**
Total saving				**£122,978**

The total cost of raising the river bed using gravel (£369,000) is greater than the savings from reducing the length of the gravel glides (refer to Table 7.8 - £279,000). As a number of the other river restoration measures provide surplus spoil (see Section 7.3.1 above) it could be assumed that some of this surplus spoil contains gravel material that could be used to raise the lower half of the bed.

A conservative estimate is that one third of the gravel required to raise the bed could be obtained from surplus excavation. This estimate reduces the cost to £246,000 for Unit 50. This cost could be further reduced if more of the arisings from excavation could be reused (although this may need to be washed to remove silt) to increase the bed level. This could be investigated further as part of detailed design. However, it is likely that the top one third of the raised bed would need to have imported gravel to ensure the top layer has clean gravel suitable for macroinvertebrate and fish spawning habitat.

7.3.3 Gravel Glides

Gravel glides comprise 32% of the total recommended option costs. i.e. to introduce gravel glides over the unit would cost £480,000 of the £1,487,000 total costs. As designed, the gravel glides are nominally three times the natural channel width of 6.3 m giving a glide length of about 19 m. This gives a glide length of one third of the bend length based on erodible river width. This is a reasonable compromise in terms of glide length when compared to existing gross channel shape and the smaller self-narrowing variations.

Cost savings could be made by replacing some of the gravel with other materials. For example, the first one third of the glide could be made of gravel, with the remainder comprising two cross-river hurdles spaced at a natural channel width in order to trap silt and infill downstream of the gravel. Changing the material and arrangement in this way could represent cost savings, as shown in Table 7.8, of £279,000 or 19%.

Table 7.8 - Potential savings to construction of gravel glides

Reach	No. glides	1/3 vol per glide (m$^{3)}$	Total volume (m$^{3)}$	Hurdles width per glide (m)	Total width per glide (m)	Grand Total
17	24	16	384	9.5	228	
18	10	40	400	9.5	95	
19	16	39	624	9.4	150	
Total measure:			1408		473m	
Rate in £:			£53/m^3		£267.25	
Total cost			**£74,624**		**£126,409**	**£201,033**
Total saving						**£278,617**

7.4 Delivery

Section 7.3 provides details of the costs for physical works, but this can be influenced by how the works are carried out. The following sections explore this further.

7.4.1 Phasing

The phasing of the excavation measures can reduce the amount of double handling needed. This has benefits in reducing the amount of physical work required, and therefore:

- Unnecessary disturbance and damage to the environment;
- Less disruption risk due to bad weather or poor ground conditions; and

- Scheme costs.

It is recommended the works be phased in the order listed in Table 7.9.

Table 7.9 - Recommended phasing of work

Ranking	Measure	Reason for phased order
1	Targeted maintenance	Provides flood risk management, silt control, and confirms Environment Agency presence on the river.
2	Modification to mill structures	An imperative first action to reduce channel water depth, improve in-stream velocities, and will also reduce silt deposition.
3	Spoil removal	Necessary, in order to allow access for machinery to the river from the floodplain.
4	Back channel re-connection	Highly important for project delivery, immediately helps with fish recruitment and flood risk, and generates large volumes of spoil.
5	Berm creation	Must follow spoil removal in order to access the river banks, the two previous operations will generate the arisings with which to complete berm creation.
6	Re-sectioning	The impact of berms on flow and level can be assessed, and so inform the required re-section depth.
7	Tree thinning	Previous measures have improved in-channel conditions to allow macrophyte growth, and so tree thinning is now required to remove shade.
8	Deflectors	Tree thinning and felling provides raw material for the deflectors, and re-sectioning has improved channel capacity.
9	Re-alignment	The impact of berms and deflectors on flow patterns can be assessed to inform the extent to which re-alignment is needed.
10	New backchannels	With new flow patterns established, new backchannels can be located to minimise silt transport into them.
11	Bed raising	With all previous in-channel works completed, bed raising can commence. Some silt may be released from under-fill to gravel blinding, so pure gravel works proceed afterwards.
12	Gravel glides	With all previous in-channel works, and any silt release completed, smaller gravel works can be placed in the channel at the best locations and shaped for maximum impact.
13	Lower embankments	Spoil embankments can be lowered in reaches with no increase in flood risk
14	Tree planting	With all the in-river features in place the location for the trees can be easily seen, and without further works the trees are unlikely to be damaged.
15	Fencing	If this is not done last, any further works will require its removal and re-construction.

7.4.2 Monitoring

The details for river monitoring need to be agreed between Natural England and the Environment Agency before any restoration measures commence on site. Monitoring will have to commence before restoration works start in order to collect baseline data. Monitoring will also allow a comparison of changes to be recorded as each phase is implemented.

7.4.3 Maintenance

If there are time gaps between implementing different restoration measures, then ‘Targeted maintenance’ will help manage the river appropriately until works can re-commence.

7.4.4 Local resources

If the implementation of the works is to be phased geographically, then there is merit in including the landowners in the tendering list, as they may have the necessary resources to complete the excavation and spoil movement and spreading. This would bring unrivalled local knowledge to bear on each river reach subsection, and would open-up opportunities that other contractors would not be able to realise.

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7.5 Summary

Table 7.10 summarises the recommended restoration measures, in order of phasing, for Unit 50.

This demonstrates why analysis should be carried out at the reach level and the results aggregated or upscaled to unit level, rather than studied at the unit level and downscaled to the reach level.

Table 7.10 - Recommended phasing of restoration measures for Unit 50

Options & Measures		Phasing	MCA Score			
			Reach 17	**Reach 18**	**Reach 19**	**Mean**
G3	'Targeted maintenance'	1	2.89	6.85	6.85	5.53
5.3m	Mill structures	2	13.34	na	na	13.34
5.14	Spoil Removal	3	12.77	11.97	12.77	12.50
5.17	Back channel re-connection	4	16.03	15.37	16.03	15.81
5.16	Berm creation	5	10.22	14.44	13.54	12.73
5.15	Re-sectioning	6	10.25	12.23	12.23	11.57
5.12	Tree thinning	7	8.01	14.59	7.65	10.08
5.13	Deflectors	8	11.82	11.98	11.18	11.66
5.19	Re-alignment	9	5.98	9.28	5.92	7.06
5.18	New backchannels	10	14.58	13.41	15.22	14.40
5.9g	Bed Raising (large scale)	11	8.72	6.5	8.8	8.01
5.7g	Gravel Glides	12	13.96	13.36	13.96	13.76
5.21	Lower Embankments	13	11.96	na	na	11.96
5.11	Tree Planting	14	9.28	3.42	9.28	7.33
5.10	Fencing	15	5.05	6.76	5.05	5.62
Mean score:			**13.76**	**11.35**	**10.89**	**10.76**
Highly Important:			**>10.54**	**>14.96**	**>14.49**	**>13.94**
Less Important:			**<7.32**	**<7.74**	**<7.29**	**<7.58**

The key points to note are:

- The phasing relates to the order of installation, not to the order of importance in delivering the changes in form and process to the main river channel.
- The scores derived from the MCA provide the method for placing each measure in relation to each other measure to give the combined final design that provides the best delivery in the long-term.

- The design for each reach is related to the conditions within the unit and takes account of the changes in other reaches that have inter-reach impacts, such as mill structure backwater effects.
- The phasing is independent of the length of river being tackled. However, the amount of material that may need to be stockpiled for later use may differ between reaches.
- The phasing of installation does not appear to conflict significantly with the MCA scoring, as there is a tendency for higher scoring measures to be installed earlier. This difference will have little practical impact providing there is no long-term delay between installations.
- The MCA analysis shows that the selection of the improvement measures gives the best solution for delivering the RWRS.

However, the analysis has shown something else that needs to be addressed. When looking at the other options, G3 '*Targeted maintenance'* is the best alternative option compared to all others, including *'Continue as present'*. The profound difference between these two options is that *'Targeted maintenance'* scores positively, and therefore, contributes towards the RWRS delivery; whereas *'Continue as present'* has the largest negative score and so is making RWRS delivery more difficult.

This is also true when compared to the *'Do nothing'* scenario which has a smaller negative score. This need for change is further reinforced by the consultation process where significant numbers of stakeholders expressed their desire to see a change in the current management of the river, and also broadly supported the RWRS objectives.

Therefore, to provide early benefit for both river and stakeholders, the existing management regime should be changed to 'Targeted maintenance' until improvement measures can be implemented to replace it, whether at section, reach, unit, or river level.

The initial cost estimate by Atkins for the recommended restoration design of Unit 50 is £1,486,831 (to the nearest thousand). This estimate has been revised based on a consideration of alterative materials and techniques and the phasing of the works.

The revised cost estimate for Unit 50 is £1,327,000 (to the nearest thousand), a potential saving of 11%. This revised estimate is less than previous cost estimates (JBA, 2007; Halcrow, 2008) although it is difficult to compare the three estimates due to the assemblage of different components. There also needs to be allowance made for different dates of each estimate. Table 7.11 summarises the differences between the three different cost estimates.

Table 7.11 - Comparison of costs between 2007 and 2009 studies

	Halcrow (Dec '2008		JBA (2007)		Atkins (2009)	
	Length (km)	Cost (£k)	Length (km)	Cost (£k)	Length (km)	Cost (£k)
Fencing	0	0	0	0	6.13	£24.5
LWD	1.12	£29.1	0.86	£172	0.46	£20.1
In-stream structures	1.12	£117.6	2.6	£1,040	2.77	£248.9
Cross section modification	1.68	£129.4	0	0	5.98	£340.0
Bed raising	1.68	£331.0	6.13	£1,067.4	0.94	£333.5
Structure modification	1.68	£352.8	0	£285.7	0.2	£175.0
Landscape	0	0	0	0	1.65	£15.9
Back-channel	0	0	0	0	1.51	£169.54
Totals:	7.28	£959.8	9.59	£2,565.1	19.64	£1,327.4
Overall rate:	**£156,570/km**		**£418,450/km**		**£216,540/km**	
Density of features	**1.19**		**1.56**		**3.20**	
Density adjusted rate	**£132,250/km**		**£268,240/km**		**£67,670/km**	

There are notable differences between the three estimates:

- The Atkins estimate includes costs for fencing, landscape and backchannel works for Unit 50.
- The JBA costs are considerably higher than Halcrow and Atkins.
- There is considerable difference in the cost estimate for altering the sill level at North Elmham Mill.
- There is a significant difference in the length of bed raising required.

An interesting comparison between the three cost estimates is that of the comparative 'density' of restoration: this indicates that the Atkins cost estimate is based on a higher density of features (3.20 features per kilometre as opposed to 1.19 for Halcrow). If the total length of all the features is divided into the total cost this gives the typical cost per km of river restored e.g. Halcrow £156,570/km, JBA £418,450/km, Atkins £216,540/km.

The Atkins' cost estimate rate provided for Unit 50 for the recommended options and measures in this report, falls between the two previous estimates and this is partly a reflection of the restoration design philosophy used which is to provide features that the river cannot restore itself (i.e. back-channels, gravel glides) and to provide features that will '*kick start*' the recovery process (i.e. deflectors, berms in key locations, channel re-sectioning). The difference in costs may also be due to the higher level of detail that could be afforded for the Atkins cost estimate based on a refined understanding of the baseline condition at a smaller scale. Previous estimates have presented a high level estimate for the entire river.

8. Environmental Scoping

8.1 Introduction

8.1.1 The need for Environmental Impact Assessment

The types of river restoration measures identified by this feasibility study are likely to fall within the Environment Agency's permitted development rights under Schedule 2, Part 15(b), of the Town and Country Planning (General Permitted Development) Order 1995 SI 95/418 (referred to as the GPDO), and it is anticipated that planning permission will not be required. As the details of any future schemes are developed, consultation with the relevant local planning authorities regarding the proposals will be required in order to confirm this view.

Any works that are undertaken under Schedule 2, Part 15(b) of the GPDO fall within the remit of the Environmental Impact Assessment (Land Drainage Improvement Works) Regulations SI 99/1783 (as amended by SI 2005/1399 and SI 2006/618). SI99/1783 (as amended) requires that the potential for the works to give rise to significant environmental effects is considered, and whether there is consequently a need to undertake an EIA of any such works. The Environment Agency has undertaken an internal screening exercise, and has determined that the works are unlikely to give rise to significant environmental effects, and will therefore not require a statutory EIA.

In accordance with the requirements of SI 99/1783 (as amended), the intention not to produce an Environmental Statement will need to be advertised. The advertising process will be undertaken once the details of any schemes have been developed, and the relevant local planning authorities have been consulted regarding the proposals.

Although a statutory EIA (with the production of an Environmental Statement) will not be required, it is Environment Agency policy to undertake EIA for its own works. Therefore, a non-statutory EIA for any subsequent restoration schemes will be undertaken, and this process will be documented via an Environmental Report.

8.1.2 Environmental scoping exercise

As part of this feasibility report, an environmental scoping exercise on the preferred restoration option for each reach was undertaken. The purpose of this exercise was to determine what issues will need to be considered during the Environment Agency's non-statutory EIA for any forthcoming restoration scheme. The scoping exercise will also form part of the required documentation to gain internal approval for the scheme. The purpose of the environmental scoping exercise is to:

- Provide a record of the scoping process.
- Identify the methodology for undertaking and evaluating the EIA.
- Identify what environmental issues will be scoped into the EIA.
- Identify what environmental issues will be scoped out of the EIA.
- Identify environmental constraints and opportunities that will need to be addressed at the detailed design stage.
- Consult with statutory bodies and interested parties on the proposed scope.

Whilst there is no formal requirement for scoping to be undertaken in the United Kingdom (IEMA, 2004), environmental scoping is a fundamental component of the EIA process because it identifies the key environmental issues and avoids progressing issues that are considered to be less key through to the next stage of EIA (IEMA, 2004).

Figure 8.1 illustrates where environmental scoping occurs within the EIA process, and how this has been applied to Unit 50.

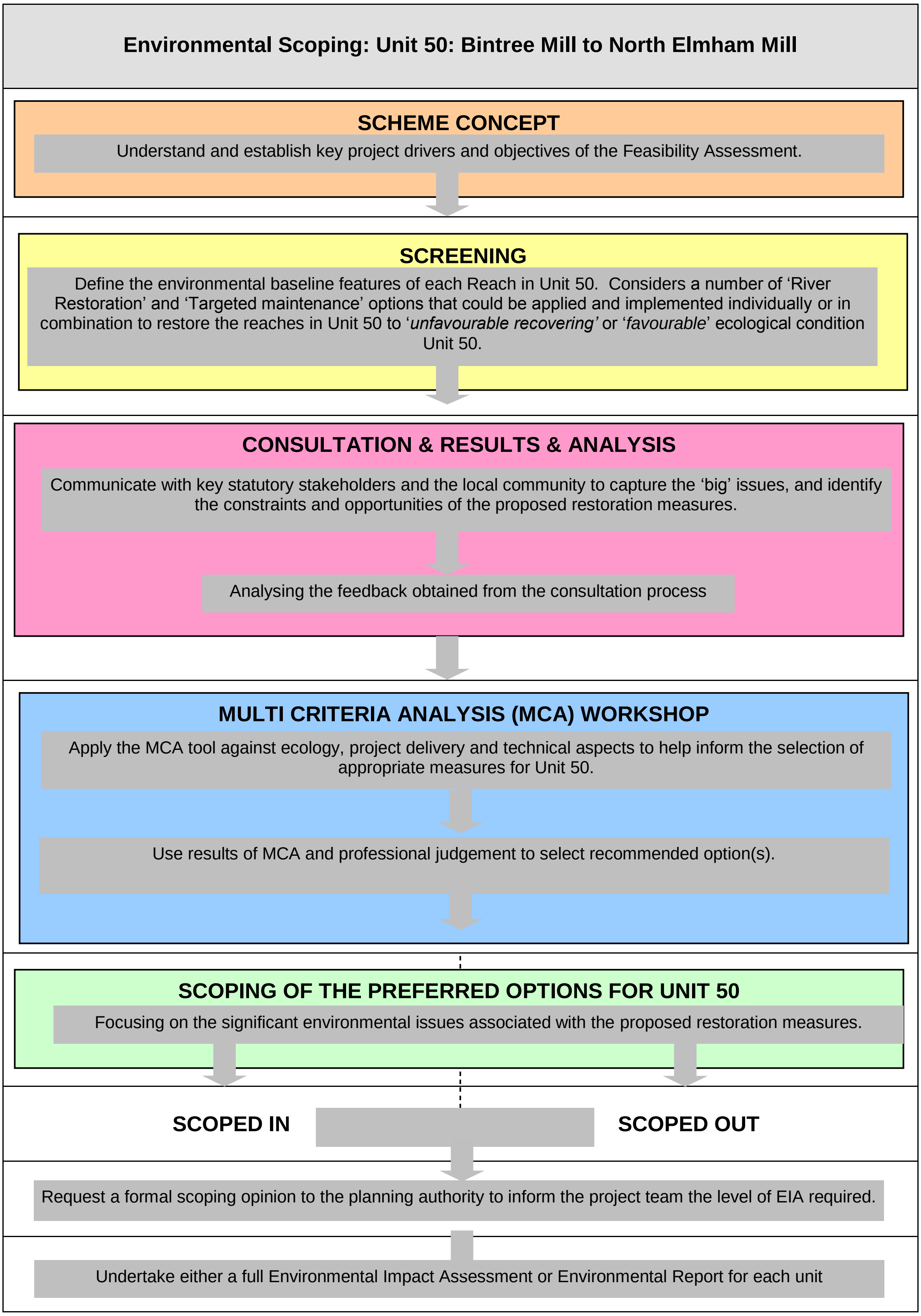

Figure 8.1 - Environmental Scoping within the EIA process

8.2 Method of assessment

The scheme is still at a strategic level so detailed monitoring of baseline environmental conditions has not been carried out. This means that professional judgement, in combination with the methodology explained below, was used to determine what environmental issues will be assessed in more detail at the next stage of the EIA process.

The options and measures that have been detailed in Table 8.2 require scoping for potential constraints and opportunities. To carry out this level of assessment, the European Commission guidance on Screening and Scoping (2001) has been adapted to determine what type of constraints and opportunities are likely to give rise to significant effects. Table 8.1 presents the framework for classifying and evaluating the significance of potential environmental effects of the preferred river restoration option.

Table 8.1 - Classifying and evaluating the significance of potential environmental effects in the scoping process (adopted from EC, 2001)

Key Questions Used In Environmental Scoping	Measure
Are the final proposed works out-of-character with the local environment?	Yes/No
What is the scale of the effect?	Limited/Widespread
Is there potential for effects on the environment outside of study area?	Yes/No
Are there many people affected?	Yes/No
Are there protected, rare or endangered features affected?	Yes/No
Is there a risk of breaching industry standards?	Yes/No
Probability of occurrence	Yes/No
What is the length of the effect?	Short/Medium/Long
Is the effect reversible?	Yes/No
Significant effect (without mitigation)	Major/Moderate/Minor

8.2.1 Restoration Options and Measures

Restoration options and measures outlined in Table 8.2 have been grouped to simplify the scoping process and to avoid repetition in assessing effects. The groups are:

- In-channel works; berm creation; gravel glides; channel re-sectioning; deflectors; channel re-alignment and lowering mill sill levels.
- Floodplain works; lowering spoil embankments; re-connecting to existing floodplain surface water drainage; new backwaters and tree thinning.
- Other works: *'Targeted maintenance'*, tree planting and fencing.

Using the information within Table 8.1 and professional judgement, the recommended restoration options and measures are assessed in terms of their significance of effect. This report has adopted the following categories to determine significance of effect:

- Potential adverse effect.
- Neutral effect (or one that could be designed out).
- Potential positive effect.

Using the results of Table 8.2, environmental issues are either scoped in or out. Issues that are scoped in will be carried through to the next stage of the EIA process. Issues scoped out are dropped from the EIA process but periodically reviewed should matters like scheme design elements change.

Section 8.3 presents the results of the scoping assessment.

8.3 Results of scoping

The scoping assessment was undertaken by using professional judgement and best practice literature (IEMA, 2004; and EU, 2001). It is considered to be in accordance with the legislation, procedure and guidance in force and with reference to international standards of EIA best practice. This section summarises the results of the scoping assessment.

The scoping assessment included the opinions of public and private stakeholders captured during the initial public 'drop-in days' and various consultations with statutory stakeholders (refer to Chapter 4 for more information). The early consultation within the EIA process provided timely and appropriate opportunities for public and stakeholder involvement. One of the key outcomes of early engagement has been the identification for the need to implement targeted maintenance ahead of main river restoration works.

The environmental scoping assessment has identified issues to be scoped in and out of the EIA process. Those issues scoped in to the assessment will require further assessment for their potential adverse or beneficial cumulative effect at the next stage of the EIA (detailed design).

Table 8.2 summarises the potentially key adverse and beneficial impacts associated with the preferred restoration options for Unit 50. It provides more accurate information on exactly what information and actions are required for the next stage of the EIA assessment (e.g. Environmental Report or Statement).

Table 8.3 lists those environmental issues that were scoped into the next stage of the EIA, and Table 8.4 lists those issues that were scoped out.

Information contained within Tables 8.2 to 8.4 ensure that the scope of the EIA will be focused only on key issues.

Table 8.2 - Environmental scoping assessment for recommended restoration options and measures

Environmental Group	Individual Environmental Features	In-channel works: Berm	In-channel works: Gravel glide	In-channel works: Channel re-sectioning	In-channel works: Deflectors	In-channel works: Connect to channels	In-channel works: Channel re-alignment	Floodplain works: Lower mill sill levels	Floodplain works: Lower spoil embankments	Floodplain works: Re-connect to floodplain drains	Floodplain works: New backwaters	Other works: Tree thinning	Other works: Targeted maintenance	Other works: Fencing	Other works: Tree planting	Aspect of proposed works giving rise to potential impact	Construction Phase	Operational Phase	Scoping Assessment: Scoped In	Scoping Assessment: Scoped Out
Air and climate	Air quality															Construction activities include additional vehicle movements. The number of Heavy Goods Vehicles (HGVs) needed to transport the required gravel is low and transport will be undertaken over a short-period of time. Therefore, adverse impacts to local ambient air quality are unlikely to be significant.	✓	x	x	✓
	Climate change															The restoration measures proposed are varied and designed to adapt to future uncertainty. Tree planting has the potential to become a natural carbon sink, therefore offsetting the impacts of tree felling. However, the restoration is unlikely to have a significant impact on climate change and is therefore scoped out.	x x	✓ ✓	x	✓
Landscape and visual amenity	Landscape character & visual amenity															Restoration of the river through introducing greater sinuosity or improvements to the riparian habitats should return the target reaches to a more natural state. Once established, these works would be expected to improve the visual amenity value of the reaches through softening the "man-made" feel of certain sections of the river, especially those where the channel has been canalised and all sinuosity has been lost.	x	✓	✓	x
																Tree felling and pollarding to improve river biodiversity and to provide woody debris for in-channel works are likely to impact locally on landscape and visual amenity. However, the magnitude of these works is low, and tree planting within the floodplain will offset tree removal.	✓	x		
Flora & fauna	Protected species															Physical works to the banks (e.g. re-profiling, construction of berms, reduction in spoil banks to source gravels and reconnect to floodplain) as well as access and plant movements have the potential to result in disturbance to water vole habitat, loss of feeding habitat and loss of some burrows.	✓	x	✓	x
																Nearby habitats will be enhanced to increase their value as water vole habitat.	✓	✓		
	Fisheries, invertebrates and flora															Ecological improvement of the river is the key objective of the proposal. The works are likely to result in long term improved habitat for key aquatic fauna. This may include Desmoulin's whorl-snail (*Vertigo moulinsiana*), bullhead (*Cottus gobio*), white-clawed crayfish (*Austropotamobius pallipes*) and brook lamprey (*Lampetra planeri*).	x	✓	✓	x
																Increasing the number and range of riffles, runs, pools and flow types will have adverse impacts to fish and aquatic populations during construction but will provide significant long term improvements to the habitats available for a wide range of macro-invertebrates.	✓	✓		
																One of the key PSA targets is the improvement of the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation community which is characteristic of the river type. .	x	✓		
																Works including bank re-profiling and bed-level raising have the potential to disturb in-situ sensitive aquatic species.	✓	x		
	Invasive and non-native species															Construction of some restoration options may leave open areas of bare ground which may give rise to opportunistic invasive plants. Reconnection to floodplain features (e.g. gravel pits, existing field drains and wetland pools) has the potential to spread invasive species such as *Crassula* and *Azolla*. Any reconnections considered as part of the restoration will require a site specific assessment of existing constraints and control options. Good construction and site management, including plant maintenance (e.g. vehicle cleaning) will be	✓	✓	✓	x

		In-channel works						Floodplain works				Other works				Aspect of proposed works giving rise to potential impact	Construction Phase	Operational Phase	Scoping Assessment	
Environmental Group	**Individual Environmental Features**	**Berm**	**Gravel glide**	**Channel re-sectioning**	**Deflectors**	**Connect to channels**	**Channel re-alignment**	**Lower mill sill levels**	**Lower spoil embankments**	**Re-connect to floodplain drains**	**New backwaters**	**Tree thinning**	**Targeted maintenance**	**Fencing**	**Tree planting**				**Scoped In**	**Scoped Out**
																necessary to prevent the spread of such invasive species.				
	Trees															Additional trees will, in time, provide submerged roots for colonisation by numerous macro-invertebrate species, from caddis flies to crayfish. The surrounding landscape will also benefit from additional tree planting. However, there may be tree thinning and felling.	x ✓	✓ ✓	✓	x
Water	Geomorphology															Physical changes through excavations, bank re-profiling, bed-raising and infilling, works to improve sinuosity and channel narrowing. Improvements in field surface water drains through re-connecting the main river to these drains will improve surface water drainage	x x	✓ ✓	✓	x
	Drainage and flood risk															River restoration measures such as lowering mill sill levels, lowering spoil embankments, channel re-sectioning and installing gravel glides all have the potential to change flood risk, both locally and further afield. This will need assessment at the detailed design stage.	x ✓	✓ x	✓	x
	Water quality															Bed raising with gravels and the creation of new pool, riffle and glide sequences all have the potential to improve existing water quality within the unit. This requires further investigation at the next stage of the EIA. In-channel construction will disturb bank and bed sediments and result in the release of sediment to the river and temporarily reduce water quality.	x ✓	✓ x	✓	x
Human environment	Humans															Angling: The rehabilitation works would provide significant opportunities to improve river angling. Canoeing: Whilst there are no statutory navigation rights on the River Wensum, where there is agreed access for canoeists, impacts and opportunities will be assessed. Where there is no agreed access for canoeists, this will be treated like a normal constraint.	x	✓	✓	x
	Land use															Rehabilitation works may involve minor realignments of the river channel which may result in the permanent loss of a small amount of grazing or arable land immediately adjacent to the river. The lowering of river banks and/or reconnection of the river to adjacent field drains may result in more frequent small scale flooding of the functional floodplain. However, the floodplain of the River Wensum is within the Broads ESA scheme so as to support extensive and traditional management regimes. Although the ESA scheme is closed to further entrants, the River Wensum is a target area with regard to Higher Level Stewardship. If changes in hydrological regime were to impact the feasibility of management prescriptions under existing schemes, then schemes would need to be modified.	x x	✓ ✓	✓	x
	Historic environment															Earthworks and construction may give rise to adverse effects on the historic environment. Excavation of banks for channel re-alignment and the lowering of raised spoil embankments may have adverse effects on unknown items of historic significance. Engineering works may have long-term adverse effects on mill buildings which are of historical and cultural importance.	✓ ✓	x ✓	✓	x
	Noise & vibration															Noise is expected to be created by construction works but this will be minimised through mitigation and best practice construction techniques. There will be no operational noise associated with the development.	✓	x	x	✓

		In-channel works						Floodplain works				Other works							Scoping Assessment	
Environmental Group	**Individual Environmental Features**	**Berm**	**Gravel glide**	**Channel re-sectioning**	**Deflectors**	**Connect to channels**	**Channel re-alignment**	**Lower mill sill levels**	**Lower spoil embankments**	**Re-connect to floodplain drains**	**New backwaters**	**Tree thinning**	**Targeted maintenance**	**Fencing**	**Tree planting**	**Aspect of proposed works giving rise to potential impact**	**Construction Phase**	**Operational Phase**	**Scoped In**	**Scoped Out**
	Traffic & transport															Construction: It is expected there will be a short term increase in traffic through local villages during construction as a result of importing materials to site.	✓	x	✓	x
	Utilities															Whilst the recommended works are not considered to give rise to effects on utilities, there remains too much uncertainty with respect to what route lorries will use bringing gravels to site. Effects to utilities such as overhead power lines or underground services require further consideration before this can be scoped out.	✓	x	✓	x
Soils & geology	Soils															The recommended restoration works are not likely to give rise to either adverse or positive effects on existing soils. An attempt will be made to balance cut and fill wherever possible to reduce soil demand and wastage. Demand for soil will be met by using local sources where practicable. Surplus soil (e.g. through the creation of berms and channel re-sectioning) will be disposed off on the landholding where practicable and if not, off-site as a form of waste.	✓	x	✓	x
	Geology															The recommended restoration works are not likely to give rise to either adverse or positive effects on existing drift geology or deep geology.	x	x	x	✓
	Ground contamination															Historical contamination: Desktop investigations have not revealed any significant historical industrial land use along the river margins other than that associated with mills. Additionally, the clay geology of the region would tend to prevent movement of contaminants, if present, both to the site and from the site. However, various samples taken at mills along the Wensum have failed to meet the waste acceptance criteria required for landfill as well as standards for hazardous, non-hazardous and inert waste for landfill due to contaminants that are not covered by the Soil Guidance Values (SGVs). Further checks prior to construction would need to be made on the contaminants not covered by the Soil Guidance Values.	✓	✓	✓	x
Waste	Waste															It is unlikely that the proposed works will generate excess waste that will have to be managed through a waste exemption licence or be taken off-site. A Site Waste Management Plan will be implemented as part of the Environment Agency's best practice approach to waste management.	✓	x	x	✓

Legend	
Potential adverse effect	
Neutral effect	
Potential positive effect	

Table 8.3 - Issues scoped into the EIA process

Environmental Group	Individual Environmental Features	Justification
Flora and fauna	Protected species	In-channel construction works have the potential to adversely affect protected species such as water vole and otter.
	Fisheries, invertebrates and flora	The key impacts of restoration works on these features during construction and operation will need to be identified.
	Invasive and non-native species	Some invasive species can represent a threat to the structural integrity of works, a risk to human health for both construction workers and the wider public, and also to the natural environment by taking over habitats, to the detriment of other native plant and animal species. It can be very expensive to remove invasive species (e.g. through physical removal and disposal of surrounding soil to landfill).
	Trees	Damage to trees may be caused by direct removal or by changes in the soil character upon spoil removal.
Human environment	Historic	The key construction and operational effects related to cultural heritage, archaeology and listed mill structures need to be identified.
	Land use	There are concerns expressed over long-term land use issues, and how the works could impact ESA agreements.
	Traffic & transport	It is expected there will be a short-term increase in traffic through local villages during construction as a result of importing materials to site.
	Utilities	There is insufficient data on the location of utilities and the possible impacts on these of river restoration.
	Recreation	The rehabilitation works would provide opportunities to improve river angling. Whilst there are no statutory navigation rights on the River Wensum, where there is agreed access for canoeists, impacts and opportunities will be assessed. Where there is no agreed access for canoeists, this will be treated like a normal constraint.
Land use	Landscape character and visual amenity	There are likely to be short-term localised impacts on land use through construction disturbance. The key construction and operational effects of the restoration works related to the landscape character and visual amenity of the River Wensum need to be identified.
Water environment	Geomorphology	The effects of physical changes (through excavations or deposition of materials) on geomorphology need to be investigated in more detail at the next stage of the EIA.
	Drainage and flood risk	Lowering mill sill levels and other river restoration measures have the potential to alter flood risk.
	Water quality	Water quality could be impacted/ contaminated during construction.
Soils & geology	Soils	The recommended restoration works are not likely to give rise to either adverse or positive effects on existing soils. However, there may be issues relating to balancing quantities of supply (cut) and demand (fill) which have environmental implications.

	Ground contamination	Data shows that sample points fail to meet the waste acceptance criteria required for landfill as well as standards for hazardous, non-hazardous and inert waste for landfill. Further investigation and consideration is required.

Table 8.4 - Issues scoped out of the EIA process

Environmental Group	Individual Environmental Features	Justification
Air and climate	Air quality	There will be short-term, localised impacts on air quality during construction. These impacts are considered to be temporary and not significant enough to warrant further investigation. Standard best practice in construction should be adequate to manage these impacts and therefore air quality is scoped out of the EIA.
Human environment	Noise & vibration	Noise is expected to be created by construction works, but this will be minimised through mitigation and best practice construction techniques. There will be no operational noise associated with the completed works.
Soils & geology	Geology	The restoration works are not likely to give rise to either adverse or positive effects on existing drift geology or deep geology.
Waste	N/A	It is unlikely that the proposed works will generate waste that will have to be managed through a waste exemption licence or be taken off-site.

9. Consents

A number of consents and permissions are likely to be required in order to implement the recommended River restoration options and measures for Unit 50. These are listed in Table 9-1, together with the organisations that are responsible for granting them and a summary of the action needed as the EIA progresses.

Table 9.1 - Likely planning consents and permissions

Likely Consent	Organisation	Comment
Permitted development rights	Environment Agency	The Environment Agency has permissive rights under the Land Drainage Act 1991 and Water Resources Act 1991 to carry out necessary restoration works within main rivers. The River Wensum is a main river so works within the channel do not require planning consent. The permissive rights extend to 9m either side of the main channel. Local planning authorities will be consulted to determine if any aspects of proposed river restoration schemes require planning permission.
Environmental Impact Assessment (statutory / non statutory)	In accordance with Environment Agency EIA policy.	The Environment Agency has screened the preferred restoration option as having a medium-level of environmental risk. This means that the works are not likely to require a full EIA (Environmental Statement) but as best practice the Environment Agency will submit an Environment Report.
Listed building consent	Local planning authority	If any of the works (particularly the mill works) involve alterations to listed buildings or structures, consultation with the relevant Conservation Officers from the local authorities will be required. A separate Listed Building Consent may be required from the local authority for works affecting listed buildings or structures. This should not affect permitted development rights.
Flood Defence Consent	Environment Agency	Development and Flood Risk has been consulted and a Flood Defence Consent will be required. This may include the need for a formal Flood Risk Assessment.
Assent under Section 28 of the Countryside and Rights of Way Act	Natural England	Natural England will need to give their written assent for any works to be carried out within the River Wensum Site of Special Scientific Interest. The proposals will be developed in partnership with Natural England, and assent will be obtained prior to any works starting on the SSSI.
Consideration of need for Habitats Regulations Assessment	Natural England	Confirmation of the need for an assessment under Regulation 48 of the Habitats Regulations 1994 (Appropriate Assessment) will be required from Natural England, due to the designation of the River Wensum as a Special Area of Conservation (SAC). It is anticipated at this stage that the works will be "directly connected with or necessary to the management of the site" and therefore Assessment under the Habitats Regulations will not be required. This will be confirmed in writing with Natural England.
Protected species and	Natural England	Natural England is actively working with the project team to assent the proposed works and ensure that

associated licences		the mitigation measures outlined below will not adversely affect protected species or their habitats. A consent letter from Natural England is needed before any works can begin. Although there is limited primary recorded evidence of water voles, otters and Desmoulin whorl snail in all parts of this unit, they are generally present on the Wensum. Since these are protected species, there will be a requirement to implement some mitigation measures as part of the proposed river restoration scheme. Consent from Natural England will be required to carry out mitigation activities if these require trapping or destructive search for water voles, for example.
Waste Management Licence	Environment Agency	The requirement for a Waste Management Licence will be reviewed once detailed designs are available.
Landowner consents	Various landowners	We need to continue liaison with key landowners.

10. Project Risks

A number of key project risks may delay the delivery of the recommended option for Unit 50 and these include:

1. Uncertainty of availability of funding to implement recommended option.
2. Uncertainty of the extent of changes to mill operation and structure that will be agreed to by mill owners.
3. Protected species survey and mitigation.
4. Inappropriate maintenance both prior to and post restoration.
5. Obtaining landowner consents to undertake enhancement works on private land.
6. Cost associated with the implementation of detailed designs.
7. Changes in UK or European environmental legislation.

To manage these risks it is recommended that there is ongoing communication with key stakeholders including landowners, BDC, NCC, internal Environment Agency functions, the Norfolk Rivers IDB, Natural England and the local communities within Unit 50 (Table 10.1).

Table 10.1 - Key project risks that may delay the delivery of the recommended options for Unit 50

Risk	Proposed Mitigation	Level of risk
Uncertainty over the extent of changes to mill operations that can be agreed with owners	Ongoing discussion with mill owners is recommended to inform them of the impact of their structures upon the river, and the potential for ecological improvements through a change in structure operation. Creation and sign-up to a sluice operation protocol with the mill owners to ensure that all owners work in tandem for the benefit of the river.	High
Landowners not giving permission for enhancement works	Ongoing and open discussion with landowners and other stakeholders to inform them of the potential for ecological improvements through enhancement works. Listen to landowners' concerns and work collaboratively to identify alternative methods or materials for proposed works.	High
Availability of funding for scheme	Raise profile of project nationally and seek early identification of external sources of funds.	High
The need to mitigate and plan around protected species	Measures to prevent this will be undertaken in accordance with the Environmental Good Practice Site Guide (Environment Agency, 2005) and Planning Policy Statement 23.	Medium
Inappropriate maintenance prior and post restoration	Work collaboratively with the EA Operations Delivery Team and the IDB to identify and agree an appropriate maintenance protocol with the context of the Targeted Maintenance option.	Medium
Uncertainty regarding costs	The cost of each restoration option will vary according to technical constraints such as access and scale of project. Cost will need to be revised during the detailed design stage.	Low
Lack of forward momentum to keep the scheme progressing to achieve benefits in the river	Ongoing consultations and discussions with the local residents and key stakeholders. Provide regular updates in the form of a newsletter.	Low
Change in UK or European environmental legislation (i.e. fisheries legislation)	Keep abreast of proposed changes in legislation so any changes in detailed design can be informed at an early stage.	Low

11. Conclusions and Recommendations

11.1 Conclusions

This report has identified river restoration measures and options to restore Unit 50 (Bintree Mill and North Elmham Mill) of the River Wensum SSSI to 'unfavourable recovering' or 'favourable' ecological condition. Implementation of these measures and options will help meet the Government's Public Service Agreement (PSA) target on SSSI condition.

River restoration measures and options have been identified through:

- Establishment of detailed baseline conditions.
- Review of previous reports and strategies, including the RWRS.
- Consultation with stakeholder groups, including landowners and the public.
- The development and application of the MCA tool.

The MCA has shown that the recommended options for Unit 50 are:

- River restoration – whereby works to mill structures should take place first, followed by measures including installation of gravel glides, backchannel reconnection, new backchannels, deflectors (using large woody debris), channel re-sectioning and berm creation.
- Targeted maintenance – suggestions under this option will inform a targeted maintenance protocol currently being developed which will set out how, where, when and by whom maintenance will be undertaken.

The highest scoring options have been taken forward into a series of conceptual designs which can be developed into detailed projects and implemented to help the river move towards 'favourable' or 'unfavourable recovering' status. Consideration has been given to terrestrial SSSI units on the functional flood plain where there is the prospect of improving hydrological linkage with the river.

Detailed cost estimates have been developed for conceptual designs, based on a cost per unit length for each measure. The estimated costs for the recommended options for this Unit are £1,487,000. Cost savings have also been explored through the reuse of previously excavated spoil (containing gravel) to raise the river bed, reducing the extent of certain measures without compromising their function, using locally sourced materials and by phasing the work efficiently. This reduces costs by 11% to £1,327,000. These estimates lie between those made by the RWRS in 2007 and by Halcrow in 2008.

The conceptual restoration design has been subjected to an environmental scoping exercise. This has involved determining which environmental features identified in the baseline review may be significantly impacted by the scheme and so will require further review and assessment in the next stage of the Environmental Impact Assessment (EIA). The topics that have been scoped in include:

- Protected species
- Fisheries, invertebrates and flora
- Invasive and non-invasive species
- Trees
- Historic environment

- Land use
- Traffic and transport
- Utilities
- Recreation
- Landscape and visual amenity
- Geomorphology
- Drainage and flood risk
- Water quality
- Soils
- Ground contamination.

11.2 Recommendations

The next phase of implementation of the River Wensum Restoration Strategy on this Unit will be to use the conceptual design as the basis for developing and implementing specific projects on reaches or sub-reaches of river between Bintree Mill and North Elmham Mill.

Certain consents and permissions may be required before schemes can be implemented. These relate to:

- Planning consents
- Listed building consents
- Flood defence consents (formerly known as 'land drainage consents')
- Countryside and Rights of Way Act
- Protected species surveys and mitigation licences
- Waste licences
- Landowner consents.

Ongoing stakeholder engagement as a key part of the project. Key groups include:

- Landowners and occupiers
- Local government
- Internal Environment Agency functions
- Natural England
- Norfolk Rivers Internal Drainage Board
- Water companies
- Recreational users, including anglers
- Local interest groups.

A number of project risks have also been identified which may delay the delivery or success of the recommended restoration. These include funding, costs, the extent to which changes in mill operation and structure can be implemented, protected species survey and mitigation, inappropriate maintenance, landowner consents and changes in legislation.

Managing these risks, the implementation of the River Wensum Restoration Strategy will help improve the ecological status of the river and achieve wider environmental and social benefits.

12. References

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Appendices

Appendix A : Multi-Criteria Analysis Technical Note

A.1 Introduction

Feedback from the MCA workshop with the Environment Agency and Natural England confirms the need for greater clarification of the MCA process and in particular how the criteria and options/measures are defined. This technical note is to address those queries.

This note is split into two sections:

- The first sets out the MCA criteria, scorings and weightings.
- The seconds sets out the options/measures and how they are defined.

A.2 MCA Criteria

Within the criteria definitions, explanation is given of the 5 point scoring to which the weightings are applied. Typical scoring considerations for each criterion have been given to provide greater consistency of scoring.

A.2.1 Criteria and criteria group definitions

The criteria are divided into 3 major groups:

- Ecology
- Project Delivery
- Technical.

The ecology is the main driver for the project and so has to have the highest weighting, which is 1.

The project objectives do not stand alone. Not only does the project have to succeed, but it must also be seen and felt to succeed. Therefore the aspirations of the stakeholders in the project also have to be recognized. This is nearly as important so the weighting for this is 0.9.

To make a difference to the ecology the RWRS has to be implemented. An assessment of the choices implementation generates needs to be made. We have called this group 'technical criteria'. There has to be a consideration of the practical delivery of the project in the real world as it is generally true that technical complexity generates cost, and impacts on quality and time. The weighting needs to be reasonably high, but not as high as the previous items, so 0.8 is used.

Each of the three criteria groups is made up of a number of related criteria, which in turn have relative importance and hence need different weightings. An 'effective weighting factor' for each criterion is calculated by multiplying the group criteria weighting and the individual criteria weighting.

A.2.2 Ecology

The primary objective of the project is to improve the ecology of the River Wensum. This falls into 2 parts: legally protected ecology and the rest. So, as a crude split the ecology needs to be divided into at least 2 sub groups. However, the legal protection is variable and progressive, with some species and habitats afforded greater protection than others. To demonstrate compliance with the law the criteria analysis needs to reflect the progressive nature of the legal protection. We have therefore divided the legally protected ecology into 3 sections to reflect the levels of importance:

- International: SAC
- National: SSSI
- Regional: BAP.

To this we add the non-protected ecology. This has to be included so as to satisfy the EA's broader legal duty to consider and further conservation. This gives a fourth sub-group as follows:

- Local: Contribution to overall ecology.

In terms of RWRS these 4 items are not equal. The definitions and weightings are explored below.

A.2.3 Compliance with National Designation: SSSI

The primary driver for the RWRS is the Defra PSA target based on SSSI condition (95% of SSSIs by area to be in favourable or unfavourable recovering condition by December 2010). The SSSI covers the following:

Table A.1 - SSSI Designation targets

Statutory / non statutory drivers	Conservation targets
SSSI Designation	• Flow: Flow regime should be characteristic of the river. Levels of abstraction should not exceed the generic thresholds laid down for moderately sensitive SSSI rivers by national guidance. • Water quality: Biological GQA Class B; Chemical GQA Class B; No unnaturally high loads of suspended solids. • Phosphate: An annual average phosphate concentration of 0.05mg/l from the upstream limits of the SSSI to the confluence of the River Wensum with the White Water (the tributary that drains from East Dereham), and 0.1mg/l from that confluence to the downstream limit of the SSSI. • Siltation: No excessive siltation. Channels should contain characteristic levels of fine sediment for the river type. • Channel form: should be generally characteristic of river type, with predominantly unmodified plan-form and profile. Bank and riparian zone vegetation structure should be near-natural.

So from a project perspective the national protection has to have the highest weighting. Thus, it is allocated the highest weighting which is 1.

With regard to scoring the following applies (Table A.2):

Table A.2 – SSSI Scoring

Compliance with National Designation: SSSI		
Score	**Description**	**Typical effect**
+2	High relevance	Direct immediate improvement in designated item
+1	Low relevance	Moving towards favourable condition
0	Neutral	No change
-1	Low Detriment	Moving away from favourable condition
-2	High Detriment	Permanent adverse changes

A.2.4 Compliance with International Designation (SAC):

The SAC covers the following:

Table A.3 – SAC designation targets.

Statutory/non statutory drivers	Conservation target
SAC Designation	The conservation objectives for the European interest features on the SSSI are: to maintain*, in favourable condition, the: • Water courses of plain to montane levels with the *Ranunculion* *fluitantis* and *Callitricho-Batrachion* vegetation to maintain*, in favourable condition, the habitats for the population of: • Bullhead (*Cottus gobio*) • Brook lamprey (*Lampetra planeri*) • White-clawed crayfish (*Austropotamobius pallipes*) • Desmoulin's whorl snail (*Vertigo moulinsiana*) *maintenance implies restoration, if the feature is not in favourable condition. PDFs of English Nature publications on the ecology and monitoring of the five European features can be downloaded from the publications catalogue on the Natural England website (www.naturalengland.org.uk).

The international protection must also rank highly, but from a project perspective, not as highly as the national importance; a weighting of 0.8 was used. With regard to scoring, Table A.4 outlines how SAC targets have been scored.

Table A.4 –SAC scoring.

Compliance with International Designation (SAC)		
Score	**Description**	**Typical effect**
+2	High relevance	Direct immediate improvement in designated item
+1	Low relevance	Moving towards favourable condition
0	Neutral	No change
-1	Low Detriment	Moving away from favourable condition
-2	High Detriment	Permanent adverse changes

A.2.5 Compliance with Regional Designation (BAP):

The biodiversity action plan most relevant to the River Wensum is the chalk rivers action plan. There are a number of additional species and habitat action plans that may be affected by river restoration on the Wensum. These are summarised in Table A.5. This criterion is also intended to cover protected species issues (e.g. those covered by the Wildlife and Countryside Act).

Table A.5 – Biodiversity Action Plan targets.

Statutory/non statutory drivers	Conservation target
UK Biodiversity Action Plan	The objectives of the UK National Chalk Rivers Habitat Action Plan are: • Maintain the characteristic plants and animals of chalk rivers, including their winterbourne stretches. • Restore all rivers notified as SSSI to favourable condition. • Restore important non-SSSI rivers to favourable condition. There are a large number of other national/Norfolk Habitat and Species Action Plans relevant to the Wensum, including floodplain and coastal grazing marsh, reed-bed, fen, otter, water vole, Desmoulin's whorl snail, white-clawed crayfish and bat species. All these SAP/HAPs have targets and objectives (www.norfolkbiodiversity.org)

Bearing in mind that both the national and international importance will provide a good level of protection for BAP species and habitats, from a project perspective, this was not felt to be as important to the project, but still needed to be included, so the weight is correspondingly lower. The value of 0.6 was used. Table A.6 lists how UK BAP targets were scored.

Table A.6 – UK BAP scoring.

Compliance with Regional Designation (BAP)		
Score	**Description**	**Typical effect**
+2	High relevance	Direct immediate improvement
+1	Low relevance	Indirect or minor improvement
0	Neutral	No change
-1	Low Detriment	Indirect or minor adverse change
-2	High Detriment	Permanent adverse changes

A.2.6 Contribution to overall ecology:

The non-protected ecology needs to be included to address the Agency's duty to further conservation. Table A.7 lists those issues/drivers that have been identified as being important to improving overall ecology in the Wensum.

Table A.7 – Issues identified in this study as being important drivers for restoration.

Statutory/non statutory drivers	Conservation target
North Norfolk Natural Area Profile	• Identify and promote flows necessary to sustain geomorphological and ecological interest of the system. • Identify, maintain, enhance, and restore both natural and man-made riverine features which provide ecological and conservation interest. • Ensure protection, enhancement and restoration of habitat features during the design and implementation of flood defence schemes. • Restore arable land adjacent to rivers back to pasture to reduce silt loading and improve habitats. • Manage associated dyke systems on a regular but not intensive regime.
Environment Agency	• To sustain and where appropriate enhance or restore the habitat diversity within the water environment. • To provide an environmental assessment and recommendations to ensure the maintenance and enhancement of conservation interest to flood defence. • Develop Water Level Management Plans to protect the ecology of sensitive wetlands. • Fisheries Action Plan for the Wensum.
European Water Framework Directive	• Take appropriate measures to ensure water bodies attain Good Ecological Status by 2015. • Establish a Programme of Measures to ensure water bodies attain Good Ecological Status.
European Habitats Directive	• Monitor, assess and enhance favourable condition of SAC rivers. • Review of consents under Regulation 50 of the Habitats Regulations is another major driver for the Environment Agency and other competent authorities.
UK Gov Public Service Agreement (PSA) Targets	• 95% of SSSIs by area in favourable or unfavourable recovering condition by December 2010.
Planning Policy Statement 9: Biodiversity and Geological Conservation	• PPS9 sets out the Government's national policies on protection of biodiversity and geological conservation through the planning system. • Plan policies on the form and location of development should take a strategic approach to the conservation, enhancement and restoration of biodiversity and geology.
Environmental Stewardship Targeting -	Higher Level Stewardship applications for environmentally sensitive farming practice:

Statutory/non statutory drivers	Conservation target
Mid Norfolk	• Maintain or enhance Sites of Special Scientific Interest (SSSIs). • Improvement of water quality through reduction of soil erosion (priority: R. Wensum catchment) and leaching of nutrients. • Conservation of landscape and wildlife associated with arable farming; in particular maintaining locally distinctive landscapes and reversing the decline in farmland birds. • Protection of historic and archaeological sites. • Access – provide further recreational facilities, to promote greater appreciation of the countryside. • Maintenance and restoration of BAP priority habitats. Conservation of BAP priority and locally important species. (Defra 2005).

However, again from a project perspective this is not as important so is weighted lower at 0.5. Scoring of this criterion is shown in Table A.8.

Table A.8 – Contribution to overall ecology - scoring.

Contribution to overall ecology		
Score	**Description**	**Typical effect**
+2	High relevance	Direct immediate improvement
+1	Low relevance	Indirect or minor improvement
0	Neutral	No change
-1	Low Detriment	Indirect or minor adverse change
-2	High Detriment	Permanent adverse changes

A.2.7 Project Delivery

To deliver the project the RWRS objectives need to be met, and the stakeholders they impact on need to support and promote those objectives. Thus, the criteria within this group can be subdivided into:

- RWRS objectives
- Stakeholders.

The stakeholders for this project naturally fall into 2 groups:

- Statutory stakeholders
- Non-statutory stakeholders.

The definition of statutory stakeholders is straight forward: it is those statutory bodies that are either funding the works or have a legal right to control the outcomes (for example: EA). Non-statutory stakeholders are those outside of the government bodies who have a legal right to comment and so influence the outcomes (for example: land owners).

The outcomes of the RWRS do not stand in isolation because besides impacting on the people in the valley they impact on the wider environment and its use. This is the non ecological environment of the valley which is predominantly of interest to people, so we have termed it:

- Human Environment.

This gives 4 sub-criteria, and again, in terms of the RWRS these are not equal. The definitions and weightings are explored below.

A.2.8 Compliance with Strategy Objectives

This whole project is about delivering the objectives of the RWRS. This comprises of 2 parts:

- The general objectives of the project, as covered in the RWRS Recommendations.
- The specific restoration measures for individual reaches as covered in RWRS Appendix A.

Clearly this is the most important criterion and so has to have the maximum weighting of 1. Scoring of this criterion is shown in Table A.9.

Table A.9 – Compliance with strategy objective scoring.

Compliance with Strategy Objectives		
Score	**Description**	**Typical effect**
+2	High relevance	Immediate and/or full delivery of easily identified RWRS objective
+1	Low relevance	Enabling or partial delivery of identifiable RWRS objective
0	Neutral	No change
-1	Low Detriment	Temporary or low level interference with RWRS objective
-2	High Detriment	Immediate and/or full interference of easily identified RWRS objective

A.2.9 Compliance with Statutory Stakeholders

This covers the views of those statutory bodies that have a legal and/or financial stake in the success of the project. In probable order of priority, this includes:

- Environment Agency
- Natural England
- Norfolk Rivers IDB
- Local authority
- Norfolk CC
- English Heritage.

For the project to be supported to fruition, with the objectives carried forward into the future, the statutory stakeholders will have to feel that the project is a success. This will have to consider views from the wider organisation where there is consultation.

Without the support of the statutory bodies the full delivery of RWRS reach objectives will be difficult. This is nearly as important as compliance with the RWRS itself, and so has a weighting of 0.9. Scoring of this criterion is shown in Table A.10.

Table A.10 – Stakeholder scoring.

Compliance with Statutory Stakeholders		
Score	**Description**	**Typical effect**
+2	High relevance	Large majority with favourable view
+1	Low relevance	Small majority with favourable view
0	Neutral	No issues
-1	Low Detriment	Small majority with concerns
-2	High Detriment	Large majority with concerns

A.2.10 Agreement with Non-statutory stakeholders

Non-statutory stakeholders are those outside of the government bodies who have a legal right to comment and so influence the outcomes. This covers, in probable order of importance:

- Land owners
- Agricultural tenants
- Fishery tenants
- Householders
- Commercial interests.

Although the statutory bodies have the ability to impose some aspects of the strategy on the valley, without support of those who own or occupy the land and river the process of implementation would be:

- Slow and expensive, due to legal process.
- Lacking in richness due to lack of local knowledge informing designs.
- Viewed as a failure and so lack long term viability.
- Impact on long term relationships with the statutory bodies in everything they do.

This is of importance to the project delivery and so is weighted at 0.9. Scoring of this criterion is shown in Table A.11.

Table A.11 – Non-statutory stakeholder scoring.

Agreement with Non-statutory stakeholders		
Score	**Description**	**Typical effect**
+2	High relevance	Large majority with favourable view
+1	Low relevance	Small majority with favourable view
0	Neutral	No issues
-1	Low Detriment	Small majority with concerns
-2	High Detriment	Large majority with concerns

A.2.11 Contribution to Human Environment

This covers both non-river statutory designations such as:

- Archaeology
- Town & Country Planning.

As well as human usage of the river and valley such as:

- Angling
- Canoeing
- Walking & footpaths
- Landscape and wider amenity.

Although this is the non ecological environment of the valley, it is predominantly of interest to people, so it must be included in the criteria. It is important, but not central to the delivery of the project and so has been given a weighting of 0.4. Scoring of this criterion is shown in Table A.12.

Table A.12 – Human environment scoring.

Score	Description	Typical effect
+2	High relevance	Widespread support
+1	Low relevance	Some support
0	Neutral	Indifferent
-1	Low Detriment	Some general concern or local concern about small issue
-2	High Detriment	Wide scale concern or strong concern over specific local issue

A.2.12 Technical

This criteria group concentrates on the delivery of the RWRS objectives. It is broken down into 4 sub-criteria areas:

- Technical feasibility & practicality
- Geomorphic form & function
- Flood risk
- Climate change & sustainability.

Each of these deals with particular risks that will vary by reach and by the selected restoration solutions applied at particular locations.

A.2.13 Technical Feasibility & Practicality

This item covers:

- Feasibility assessment
- Engineering design
- Construction process
- Commercial risk

- Maintenance liabilities.

This is the most important aspect regarding the management of risk in the project, and so is an important technical factor within the technical criteria group. A weighting of 1 has been used. Scoring of this criterion applies and is shown in Table A.14.

Table A.13 – Technical scoring.

Technical Feasibility & Practicality		
Score	**Description**	**Typical effect**
+2	High relevance	Large benefit with little risk
+1	Low relevance	Small overall benefit or lack of difficulty
0	Neutral	Average
-1	Low Detriment	Some difficulty
-2	High Detriment	Little benefit with large risk

A.2.14 Geomorphic form & function

The shape of the river and the flow processes are important for 2 reasons:

- The environmental designations specifically mention them.
- It is necessary to understand the processes and the resulting river shape to be able to design any of the restoration options/measures to produce predictable results that sustain into the future.

This is therefore important regarding the management of risk in the project, and so has to be an important technical factor within the technical criteria group. A weighting of 1 has been used. Scoring of this criterion is shown in Table A.15.

Table A.14 – Geomorphic scoring.

Geomorphic form & function		
Score	**Description**	**Typical effect**
+2	High relevance	Immediately delivers full form and/or mature processes
+1	Low relevance	Kick starts process or provides some form
0	Neutral	No change
-1	Low Detriment	Reinforces existing lack of processing at a local scale
-2	High Detriment	Reinforces existing lack of processing or creates inappropriate processing anywhere

A.2.15 Flood risk

Flood risk management is one of the EA's primary responsibilities, therefore project outcomes cannot increase flood risk to people or properties. This is particularly important on the Wensum as there are 44 properties at risk of flooding, and there are routine maintenance activities to control existing flood risk.

Any proposals that impact on water level or flow on statutory Main River require Flood Defence Consent from the EA, the primary objective of which is to demonstrate no detrimental effects on flood risk.

This is a significant factor within the technical criteria group and so has a weighting of 1. Scoring of this criterion is shown in Table A.16.

Table A.15 - Flood risk scoring.

Flood risk		
Score	**Description**	**Typical effect**
+2	High relevance	Good risk reduction locally and/or elsewhere
+1	Low relevance	Some reduction in flood risk anywhere
0	Neutral	No change
-1	Low Detriment	Some increase in flood risk anywhere
-2	High Detriment	Significant increase in local flood risk

A.2.16 Climate Change & Sustainability

This has been included to ensure that project proposals remain fit for purpose into the future.

Current UK guidance on the impacts of climate change on fluvial flooding from the government's Foresight Report, which has fed into PPS 25, recommends that an allowance of an extra peak flow of 20% is made, which covers the impact on flood risk change to 2050. Project proposals are viewed against their ability to withstand increased flows without detriment to themselves, the habitat created by them, or flood risk.

Clearly a lack of robustness is not very sustainable in its own right. However, given wider concerns, a view on the carbon footprint of proposals is also appropriate.

Whilst it is a useful criterion it is not the most important, so a weighting of 0.8 is used. Scoring of this criterion is shown in Table A.17.

Table A.16 – Climate change scoring.

Climate Change & Sustainability		
Score	**Description**	**Typical effect**
+2	High relevance	Is stable in the short and long term
+1	Low relevance	Is stable in the short term or provides a pre-cursor to later works
0	Neutral	No change
-1	Low Detriment	Is unstable in the short term or prevents later works
-2	High Detriment	Is unstable in the short and long term

A.2.17 Overall table of criteria defined for the MCA

The following table summarises the criteria and applied weightings:

Table A.17 - Criteria defined for the MCA.

Group (Group weighting)	Criteria	Description / Example	Weighting within group	Effective weighting factor
Ecology (1)	Compliance with national designation	SSSI requirements for the river e.g. improved flow regime, water quality and channel form.	1	1
	Compliance with international designation	SAC requirements including maintaining favourable habitat for EU designated species.	0.8	0.8
	Compliance with regional/local designations	BAP requirements such as maintaining flora and fauna characteristic of chalk rivers.	0.6	0.6
	Contribution to overall ecology	Compliance with the Environment Agency's general duty to further conservation	0.5	0.5
Project delivery (0.9)	Compliance with strategy (RWRS) objectives	Meeting objectives of the RWRS as well as the specific reach recommendations.	1	0.9
	Compliance with statutory stakeholders	Stakeholders include Environment Agency, Natural England, Breckland District Council, and Norfolk County Council.	0.9	0.81
	Agreement with non-statutory stakeholders	Angling clubs, land owners and tenants.	0.9	0.81
	Human environment	Consideration of or improvements to archaeology, landscape, and recreation value.	0.4	0.36
Technical (0.8)	Technical feasibility & practicality	Consideration of design, construction process, commercial risk, and maintenance.	1	0.8
	Geomorphic form and function	Consideration of the shape and flow of the river.	1	0.8
	Flood risk	Consideration of the impact of restoration on flood risk.	1	0.8
	Climate change and sustainability	Considers the robustness of the measures in terms of future flood risk and carbon footprint.	0.8	0.64

A.3 MCA Options and Measures

A.3.1 Introduction

6 major option groups have been identified:

- Do nothing
- Do minimum

- Targeted maintenance
- Continue as present
- River restoration
- Alternative options.

These are in rough order of increasing intervention with the natural processes. They are briefly described below:

A.3.2 Do nothing

As the objective of the strategy is to improve the ecology of the river, which is predicated on the return of natural form and process, this option means:

- No maintenance to main river or IDB channels.
- No restoration to any channels or flood plain.
- No operational activity.

A.3.3 Do minimum

This is from the view of the RWRS and so means:

- Opportunistic restoration, eg.
  - Securing fallen trees as LWD
  - Re-shaping shoals where growth occurs after floods.
  - Re-shaping bank profiles to create berms when bank collapse occurs.
- No maintenance.
- No operational activity.

A.3.4 Targeted maintenance

This covers:

- Reduced maintenance: reactive in selected critical areas.
- Mitigation for activity in form of small scale restoration.
- Operational activity; sluice management for high flows.

A.3.5 Continue as present

This covers existing arrangements:

- Planned maintenance: assessed LWD & CWD removal; selected weed cutting and silt removal.
- Opportunistic small scale restoration.
- Operational activity: sluice management for high flows.

A.3.6 River restoration

This covers 20 different restoration measures that have been identified for the river.

Each of these is assessed for its use on the particular reach being scored.

A.3.7 Alternative options

There are 3 options that have been considered:

- Increased main river maintenance. This includes:
  - Increased in-channel clearance of silt.
  - Increased frequency of weed cutting.
  - Return of channel to “design” dimensions.
  - Maintained timber clearance.
  - Bank repairs.
- Increased main river and IDB channels maintenance. This includes:
  - As above, plus.
  - Integrated programme for main river and IDB channels.
  - Inclusion of IDB channel main river confluences for regular maintenance.
- Mills re-use for hydro-power. This includes:
  - Overall generation of energy through harnessing the kinetic energy of water.
  - Operational reinstatement of all water level control structures.
  - Operating protocols for all structures.
  - Regular channel maintenance around control structures.

These options were derived from comments picked up at the ‘drop in’ sessions and represent broad aspirations.

A.4 Use of MCA scorings

A.4.1 Overall Process

The use of MCA and the resultant reach scores represents a key part of the design process. The overall process is shown in table A.18 as follows:

Table A.18 - SSSI Designation targets

A	Constructing The MCA Tool
1	Identification of options/measures
2	Selection of success criteria
3	Ranking of success criteria using weightings
4	Setting up the MCA table
B	**Applying The MCA Tool (Spreadsheet) To Specific Reaches**
1	Is the option/measure applicable to the reach? If no, discard.
2	Work through each criterion by option/measure.
3	Apply weighting and determine total weighted score (TWS)
4	Discard all options/measures with zero or negative scores.
5	Mill structure measures: Apply the best scoring measure.
6	Other measures: Undertake statistical analysis and discard measures scoring below lower limit.

7	Other measures: Apply remaining measures in order of highest to lowest scoring.
8	Gravel works: Apply best scoring measure.

A.4.2 Note on statistical approach

The options need to be checked for importance to see which ones are truly important and which ones are not. This has been determined by calculating which options have a TWS outside of one standard deviation either side of the mean. This was chosen as it is a standard measure of dispersion. Those with a value greater than the sum of the mean plus the standard deviation are of high importance: those with a value less than the sum of the mean minus the standard deviation are of low importance. Those of low importance represent those options that could easily turn negative were only a few criteria to get more harshly re-appraised: those of high importance are those that are very robust, and so represent the minimum options that should be carried out on any reach.

Appendix B – Costings

B.1 COST ASSUMPTIONS

The assumptions used to generate the cost estimate for Unit 50 fall into two categories:

- General assumptions that apply to all measures.
- Specific assumptions that apply to particular measures.

B.1.1 General assumptions

The following general assumptions apply

1. Site access is reasonable at all locations (the MCA considered this in the scoring).
2. There are no allowances for landowner compensation or accommodation works.
3. Each measure is executed independently of each other, such that arisings are disposed of just outside of the floodplain.

B.1.2 Specific Assumptions

Fencing

1. The equivalent of 1 bank length (6,125 m) will require fencing.
2. The fencing used is assumed to be simple livestock fencing:
   - 100mm diameter tantalized timber posts driven at 3 m centres.
   - 3 barbed wires (top wires at 1.2m and 1.1m).
   - Where land is sheep grazed then pig netting below it.
3. There are significant lengths of fencing to all reaches as listed in Table B.1, so the assumption is that the equivalent of one bank will be newly fenced to satisfy landowner requirements and bank protection needs.

Table B.1 Assumed fencing lengths.

Reach	Reach Length (m)	Assumed fencing length (m)
17	2600	2600
18	855	855
19	2670	2670
Total Length:		6125
Rate for supply & install:		£4/m
Cost for Unit:		£24,500

Mill structures

1. Works will be required to the upstream structure at North Elmham Mill to deliver a meaningful reduction in backwater length.
2. The minimum works to North Elmham Mill are the establishment of a hatch operating protocol, which is predicted to drop levels by 0.72 m and reduce the backwater length to 2km.
3. To achieve a backwater effect of 0.2km (to first meander bend upstream of the mill) a drop in sill level of 0.42m is required.

4. In principle, the works to achieve this should be technically possible although further surveys are recommended to help develop a method statement. It is envisaged that the existing weir and sluice structure would be broken out and a new structure constructed at the required (lower) level. The works should be relatively well contained within a small area.
5. It is envisaged that the proposed lowering and bypassing of the structure would involve the following works:
   - **Site set-up:** Set up small site compound as close as possible to the working area. This will be used to store materials and equipment. Ideally welfare facilities will also be set up close to the working area.
   - **Bypass and dewater**: Set up over-pumping equipment to divert flows around the structure. Place sandbags around structure and pump out to create a dry working area.
   - **Break out existing structure**: Saw cut to define extent to be removed (to avoid damaging sections which can remain). Break out hard material (masonry, stone, rock, concrete) using handheld breaker. Excavate in order to lower channel level as required. Remove excavated material from site. Prop existing structure as necessary. A key risk will be undermining the existing structure and causing unwanted damage.
   - **Inspection:** Having the structure dewatered would provide a good opportunity to inspect the structure. The suitability of the proposed design should be confirmed.
   - **Construct new structure:** The form of the new structure will be confirmed at detailed design stage. It is recommended that the appearance of new elements are as sympathetic as possible to the existing structure. The final design may include some of the following components: reinforced concrete slab, masonry walls (or cladding); concrete box culvert; sluice gates; fish pass.
   - **Demobilise:** Remove temporary works, make good any local damage, clear site.
6. Based on the works described above, an estimated cost for budgeting purposes would be in the region of **£150-200k**, to include surveys, detailed design, construction and supervision. £175k has been used as the mid point of the estimate.
7. At this stage of the project, a substantial risk contingency is normally allowed for – 60% is standard for feasibility stage. However, there is a similar ‘risk’ that the works will not be required to relieve backwater impacts so inclusion is not so straightforward. In addition there may be requirements for engineering solutions in order to maintain a sweetening flow through mill following changes to sill level.

Table B.2 Estimated costs for Reach 17.

Reach	Costs
17	£175k
18	0
19	0
Costs for Unit:	£175k

Berm Creation

1. This is assumed to be the creation of low level berms, below ½ bank height, on the inside of existing bends, to increase sinuosity of the channel.

2. The amount of self-narrowing prevalent on long lengths this measure is assumed to add to existing material.
3. Used on the inside of 68 bends for an average of 41m each.
4. Not all bends are to have berms added.
5. Construction consists of: removing vegetation for re-use; staking the new alignment with hardwood posts at 0.75 m centres; placing double height coir rolls against the stakes; backfilling with local material to blend height to local berm heights; replace vegetation.
6. The starting and finishing 3 m of the bio-engineering revetment to be cut back into existing bank material to stop outflanking, with overall length equivalent to ½ existing bend lengths for the Reach.

Table B.3 Total estimated costs for berm creation for Unit 50.

Reach	No. Bends bermed	Bend length (m)	Berm length (m)	Total length (m)
17	24	96	48	1152
18	10	78	39	390
19	34	72	36	1224
Unit total:				2766
Rate:				£90/m
Cost for Unit:				£248,940

Channel Re-sectioning

1. Resectioning proposed at 27 locations totalling 2,110 m in length.
2. This is assumed to be simple excavation work to the upper bank.
3. Depth of excavation will depend on local conditions, but should not be lower than existing self-formed berms, otherwise it will cause instability under flood flows as it will expose the softer material at the landward end of the berm. Nominally take ½ channel height.
4. The river edge vegetation is to be retained for re-use on the berm, and bank top vegetation and topsoil re-used on the rear slope of the berm to provide protection.
5. Rear slope to the berm to be at a self-stable angle of recline, and certainly no steeper than 1:2.
6. Width of the berm will depend on local conditions, but does not need to be wider than ½ existing channel top width from hard bank edge to middle of rear slope.
7. Length of berm along the river will depend on local conditions; primarily the proximity of other features.
8. It is assumed that arisings will be transported and spread within 100 m of the works, and outside of the floodplain.
9. The arisings have the potential to be used in the construction of other features.

Table B.4 Total estimated costs for excavation associated with re-sectioning for Unit 50.

Reach	Length (m)	Channel top width (m)	Nom. Width (m)	Channel depth (m)	Nom. Depth (m)	Nom. Volume (m^3)
17	900	16.55	8.3	2.51	1.2	8964
18	270	15.5	7.8	1.70	0.8	1685
19	940	14.1	7.0	1.72	0.8	264
Unit Volume:						15,913m^3
Excavation: reduce level not >1m: Rate:						£3.94/m^3
Spread material 100m from excavation: Rate:						£4.35/m^3
Cost for Unit:						£131,919

Lower Spoil Embankments

1. This is assumed to be simple excavation work to lower levels to natural ground level.
2. Typical maximum height 0.43 m, width 13 m, yield of 4.3m^3/m.
3. Embankments removed from a length of 1,845 m.
4. Depth of excavation will depend on local conditions, but should not be lower than existing natural ground level, and certainly no lower than self-formed berms, otherwise it will cause instability under flood flows as it will expose softer material.
5. The extent of the excavation will need to be marked prior to work as some of the embankments are not well defined.
6. Any river edge vegetation is to be retained for re-use. Similarly bank top vegetation should be retained for re-use on the new lowered ground surface.
7. It is assumed that arisings will be transported and spread within 100m of the works, and outside of the floodplain.
8. The arisings have the potential to be used in the construction of other features.

Table B.5 Total estimated costs associated with lowering spoil embankments for Unit 50.

Reach	Length (m)	Width (m)	Max height (m)	Typical volume (m^3/m)	Reach volume (m^3)
17	895	12.4	0.4	3.6	4608
18	250	12.9	0.5	5.9	1475
19	700	13.6	0.5	3.4	2380
Unit volume:				8465m^3	
Excavation: reduce level not >1m: Rate:				£3.94/m^3	
Spread material 100m from excavation: Rate:				£4.35/m^3	
Cost for Unit:				£70,175	

Lower Formal Embankments

1. This is assumed to be simple excavation work to lower levels to natural ground level.

2. Typical maximum height 0.4, width 12.4 m, yield of 3.8m3/m.
3. Formal embankments only removed on the TLHB of Reach 17 for a length of 1280 m.
4. Depth of excavation will depend on local conditions, but should not be lower than existing natural ground level, and certainly no lower than self-formed berms, otherwise it will cause instability under flood flows as it will expose softer material.
5. The extent of the excavation will need to be marked prior to work as some of the embankments are not well defined.
6. Any river edge vegetation is to be retained for re-use. Similarly bank top vegetation should be retained for re-use on the new lowered ground surface.
7. It is assumed that arisings will be transported and spread within 100m of the works, and outside of the floodplain.
8. The arisings have the potential to be used in the construction of other features.

Table B.6 Total estimated costs associated with lowering embankments for Unit 50.

Reach	Length (m)	Width (m)	Max height (m)	Typical volume (m^3/m)	Reach volume (m^3)
17	1280	12.4	0.4	3.78	4838
18	0	0	0	0	0
19	0	0	0	0	0
Unit volume:				4838m^3	
Excavation: reduce level not >1m: Rate:				£3.94/m^3	
Spread material 100m from excavation: Rate:				£4.35/m^3	
Cost for Unit:				£40,107	

Tree Thinning

1. Qualified arborists can typically trim, and control fell, 4 riverside trees (approximately 50 years old) over 50m of river, in a day.
2. Felling single trees to reduce shading, 1,070m total length of river in Unit 50 affected
3. Cost per day is typically £500 per team of 2.
4. Costs include cording the wood for log piles, or trimming and cutting trunks for re-use.
5. Costs do not include any transport or movement of timber once felled.
6. This gives an equivalent rate of £10/m of river.

Table B.7 Total estimated costs associated with tree thinning for Unit 50.

Reach	Length (m)
17	60
18	180
19	630
Length in Unit:	1070
Rate:	10/m
Cost for Unit:	£10,700

Backchannel re-connection

1. This is assumed to be simple excavation to connect existing channels with the river excavating a total of 80 m with no bank or bed protection.
2. To provide an appropriate size of channel, and stable bank profile, it has been assumed that the bed width of the excavation will be equivalent to the bank height height, and the top width will be 3x bed width, thus providing 1:1 side slopes, which matches natural bank angles.
3. Also included are appropriate works to re-form the backchannel to enhance its stability and habitat delivery. Typically this would be re-sectioning and removing encroaching silt and vegetation that would be removed by the new flows through the channel.
4. Re-connection at the downstream end will be excavation down to river bed level; re-connection at the upstream end will be by excavation down to the backchannel bed level, post any clearance/re-forming works.
5. It is assumed that bank protection works beyond re-placing vegetation turfs will not be required. Any further works will be dependent on local conditions found pre-works.

Table B.8 Total estimated costs associated with backchannel re-connection for Unit 50.

Reach	Exc. Length (m)	River depth (m)	Nom. Section (m^2)	Nom. Volume (m^3)	Exc. Rate (m^3)	Exc cost
17	60	2.51	19.22	1153	£11.36/	£13,098
18	0	1.70	5.78	0	£9.83/	0
19	20	1.72	5.92	118	£9.83/	£1160
Unit total:				1271		£14,258
Spread material 100m away: Rate:				£4.35/m^3		v
Cost for Unit:				£40,107	>	£54,365

Table B.9 Total estimated costs associated with lowering embankments per Reach.

Reach:	Backchannel work length (m)
17	250
18	200
19	580
Unit total:	1030
Clear & remove:	£5.71/m
Cost for Unit:	£5881

Gravel Glides

1. Cost is directly dependant on volume placed.
2. Use 20-50 mm gravel rejects, in 19 m long glides.
3. Gravel depth of 1.5 m in 24 glides, and 0.7 m in 26 glides.
4. Width of channel used is 'erodible bank width' from JBA, 2007 as that represents the realistic width of erosion, and therefore need for protection.

5. The depth of gravel used is the amount identified as needed to raise the bed.
6. The length of the glide is taken as 3 times the resistant bank width to ensure that 'edge effects' are controlled, so that these artificial glides more closely match those observed, and will realistically fit between the existing bends.
7. The long section through the glide assumes a 1:1 slope at the upstream and downstream ends to give some stability. This has been allowed for in the volume per glide.
8. The rate for supply and placement of gravel is based on a material supply cost of £27/t for 20-50mm gravel rejects and a placement cost of £4.85/m^3. At 1.78t/m^3 the gravel supply rate equates to £48.06/m^3, which combined with the placement rate gives an overall rate of £52.91/m^3, or a more useable £53/m^3.

Table B.10 Total estimated costs associated with installing gravel glides for Unit 50.

Reach	Bed Raising Required (m)	Erodible width (m)	Resistant Width (R) (m)	Length 3 x R (m)	Volume per glide*	Number of glides	Volume per Reach (m^3)
17	1.5	9.5	6.3	18.9	248	24	5952
18	0.7	9.5	6.3	18.9	121	10	1210
19	0.7	9.4	6.2	18.6	118	16	1888
Volume for Unit:							9050
Rate for supply and place:							£53/m^3
Cost for Unit:							£479,650

* Volume also includes the 1:1 slope upstream and downstream of the glide

Channel Re-alignment

1. This is assumed to be the excavation of the full height of the riverbank from bank top to river bed; unlike re-sectioning which is ½ height excavation.
2. Unlike other excavation based measures, the arisings from this operation are assumed to be re-used locally to in-fill the channel from the far bank.
3. Assume that the bank is re-aligned by the equivalent of a natural channel width. It is also assumed that the bank is cut at a stable angle of recline, and that no protection works are carried out to allow natural processes to prevail.
4. Occurs at one location of 40 m long, and 38 locations of 19 m long.

Table B.11 Total estimated costs associated with channel re-alignment for Unit 50.

Reach	No. locations	Length per location (m)	Reach lengths (m)	Channel width (m)	Channel height (m)	Volume (m^3)	Rate	Cost
17	23	19	437	6.3	2.51	6910	£11.36/m^3	£78,498
18	1	40	40	6.3	1.70	428	£9.83/m^3	£4,207
19	15	18	270	6.2	1.72	2879	£9.83/m^3	£28,301
Unit totals:			747			10,217m^3		£111,006

Deflector

1. It is assumed that these are created from LWD won locally under 'Tree thinning'.

2. The arrangements and locations are as described in Chapter 6: a deflector group consists of 3 deflectors pointing upstream; spaced at natural channel width along the bank; length determined locally so as to mobilize silts beyond them.
3. The deflector consists of clean timber tree trunks alternately staked and wired to hardwood stakes at 1 m centres; butt end embedded into the bank by 2 m or 1/3 length whichever is shorter; trunks to be laid on a faggot bedding.
4. Deflector height to be no higher than high summer water level so that it can drown out under higher flows.
5. Used in 26 locations in this unit.

Table B.12 Total estimated costs associated with implementing deflectors for Unit 50.

Reach	No. of groups	Length per Reach (m)
17	15	250
18	4	74
19	7	133
Total for Unit:		457
Rate per length of river:		£44/m
Cost for Unit:		£20,108

Tree Planting

1. Tree species are assumed to be appropriate native riverside species such as: alder, black poplar, and willow. The black poplar needs to be from a certified source (and of Norfolk provenance) as they hybridize readily.
2. Each tree planted individually to create shade and bank reinforcement in 144 locations
3. Planting costs include: supply of 2-3 m standard; planting; tube, stake & tie; deer proof enclosure.

   Where trees are planted in groups, 4 m needs to be left between the enclosures to allow access for machinery and control density of shading.

Table B.13 Estimated tree costs per Reach.

Item	Cost
Supply 2-3m standard tree	£10
Plant tree	£1
Supply & install: tube, stake, ties	£1
Deer proof enclosure	£24
Total per tree:	£36

Table B.14 Estimated costs for new tree planting per Reach and for Unit 50.

Reach	Trees
17	40
18	40
19	64
Total:	144
Rate:	£36
Unit total:	£5184

Backchannel creation

1. These are to be created by simple excavation, placement of gravel rejects and site won vegetation transplanting.
2. The geometry is to provide long term stability against flood flows and so is based on natural bend shape.
3. The channel is a 40 m long dogleg, with 26 m between entry and exit from the main channel. Bottom width is 6.2 m to conform to the natural channel width and a top width of 12 m. The cross section shape is an asymmetric trapezoid, with the outside of the channel at its natural angle of recline (not steeper than 1:1), with the inside sloped to achieve top width. Excavation volume is 720 m^3.
4. Backchannels created at 12 locations by simple excavation to full bank depth, and equivalent to river width for an open ended dogleg of 40 m
5. The channel is dug from the downstream end. Bank-side vegetation is carefully dug off for retention and re-use.
6. Once the channel is fully dug, and water flowing through it, the upstream end is blocked with washed gravel rejects. Volume required is 108 m^3 to provide a top width of 4 m (for safe access over) and stable side slopes.
7. Once flow has stabilised, the bank-side vegetation is placed at the relevant level compared to water level in the backchannel.
8. 4m from the edge of the outside bank of the backchannel for the first 20 m of the backchannel a small 0.3 m high bund with 1:2 slopes needs to be constructed from some of the surplus spoil to deflect flood flows round the feature, whilst still allowing floodplain run off to enter the feature as river levels recess.

Surplus spoil is to be disposed of within 100 m of the location. This is far enough for it to be outside of the flood plain. This material has the potential to be re-used to construct other features, in which case disposal costs can be reduced/deleted.

Table B.15 Estimated costs for backchannel works.

Task	Volume	Rate	Cost
Excavate	720	£3.80/m^3	£2736
Supply & place gravel rejects	108	£30/m^3	£3240
Bund creation & Spoil spreading within 100m	720	£4.35/m^3	£3132
Total per backwater:			£9108

Table B.16 Estimated costs for backchannel works per Reach and for Unit 50.

Reach	Backchannels
17	6
18	3
19	3
Total:	12
Rate:	£9108
Unit total:	£109,296

B.1.3 Cost Savings

The initial cost estimate for Unit 50 was £1,486,831.

Table B.17 Revised cost estimate for recommended options for Unit 50.

Measure:	Description	Length Applied	Rate	Cost
5.10	Fencing	6125m (100%)	£4/m	£24,500
5.3m	Mill structures – lower mill sill levels	{5050m (82%)}	Na	£175,000
5.16	Berm creation	2766m (58%)	£90/m	£248,940
5.15	Channel re-sectioning	2110m (34%)	£62.52/m	£131,919
5.14	Lower spoil embankments	1845m (30%)	£38.04/m	£70,175
5.21	Lower mill embankments	1280m (21%)	£31.33/m	£40,107
5.12	Tree thinning	1070m (17%)	£10/m	£10,700
5.17	Backchannel – re-connection	1030m (17%)	£58.49/m	£60,246
5.7g	Gravel glides	940m (15%)	£510.16/m	£479,650
5.19	Channel re-alignment	747m (12%)	£148.60/m	£111,006
5.13	Deflector	457m (7%)	£44/m	£20,108
5.11	Tree planting	576m (9%)	£9/m	£5,184
5.18	Backchannels - new	480m (5%)	£227.70/m	£109,296
Option G3	Targeted Maintenance	280m (5%)	Unknown	Unknown
Total:				**£1,486,831**

* This excludes the cost of bed raising in Reach 19 as it was assumed that the utilisation of site won gravel from the 9m zone from top of bank (Atkins, 2009 in prep). In practise, site excavations did not yielded the expected gravel volume s from this zone. However, conservative estimates for gravel requirements elsewhere on site precluded the requirement for additional imports and costs above those reported above.

By altering the construction methods for the gravel glides, bed raising and reducing the extent of spoil disposal, the revised cost estimate is £1,327,458. This is also based on a number of assumptions and this cost could be further reduced by how the works are phased.

The revised cost estimate of £1,327,458 falls within the estimates from previous studies as demonstrated in the table below.

Table B.18 Comparison of costs from 2007 and 2009 studies.

	Halcrow (2008)		JBA (2007)		Atkins (Mar2009)	
	Length (km)	Cost (£k)	Length (km)	Cost (£k)	Length (km)	Cost (£k)
Fencing	0	0	0	0	6.13	£24.5k
Large woody debris	1.12k	£29.1k	0.86	£172k	0.46	£20.1k
In-stream structures	1.12	£117.6k	2.6	£1,040k	2.77	£248.9k
Cross section modifications	1.68	£129.4k	0	0	5.98	£340.0k
Bed raising	1.68	£331.0k	6.13	£1,067.4k	0.94	£333.5k
Structure modifications	1.68	£352.8k	0	£285.7k	0.2	£175.0k
Landscape	0	0	0	0	1.65	£15.9k
Back-channel	0	0	0	0	1.51	£169.54k
Totals:	7.28	£959.8k	9.59	£2,565.1k	19.64	£1,327.4k
Overall rate:	£156.57k/km		£418.45k/km		£216.54k/km	
Density of features	1.19		1.56		3.20	
Density adjusted rate	£132.25k/km		£268.24k/km		£67.67k/km	

Appendix C - Ecology Tables

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C.1 River Wensum SSSI/SAC: Status, ecology and habitat requirements of European interest features.

Species / community	Designations and status	General ecology	Habitat requirements	Habitat requirements (continued)
Brook lamprey (*Lampetra planeri*)	Listed in annexes IIa and Va of the Habitats Directive, Appendix III of the Bern Convention, and as a Long List Species in the UK Biodiversity Action Plan. The most common of the 3 British lampreys occurring over much of the British Isles. Absent from much of Scotland north of the Great Glen.	Brook lamprey have both a sedentary larval (ammocoete) stage and an adult dispersal phase, during which spawning takes place. They do not feed as adults and hence spawning is generally considered to be preceded by a relatively short migration to the spawning areas. Brook lamprey tend to undertake small upstream migrations prior to spawning during which time they continue to burrow like ammocoetes or hide under stones during the day. The extent of the migration depends on stream gradient which may also impact upon the distance ammocoetes drift downstream during development, as well as spawning habitat availability. After spawning has occurred, newly hatched larvae leave the nest and distribute themselves by drifting downstream and burrowing in suitable areas of silty sand. *Life-cycle* Metamorphosis July to September Spawning migration November to February Spawning March to April (10-11oC)	<u>Ammocoete larvae</u> *Substrate* Ammocoetes occur in suitable silt beds, mainly in running water but sometimes in large numbers in silt banks in lakes. Preferred substrate varies in depth from a few cm to 30 cm and is generally composed of mud, silt, or silt and sand with a high organic content (optimum particle size 80–380 µm). Larval nursery beds are often located at the edges of streams and rivers, well away from the main current in flowing backwater sections. *Water quantity and quality* Flow rates of 0.5 m s-1 at the water surface, and 0.4 m s-1 at a depth of 25 cm have been observed above nursery beds and flows of 8–10 cm s-1 have been recorded over *Lampetra* burrows.	<u>Adult lamprey</u> *Adult spawning grounds* Spawning grounds are located in areas of small stones and gravel in flowing water, with spawning often occurring at lower ends of pools. The spawning gravels are composed of stones up to 3 in. with good permeability, although smaller consolidating particles are required. Stones embedded in fine sands or silts which form a hard bed are often avoided. The nest, which may be constructed by up to a dozen or more adults, is normally an oval depression about 20–40 cm across and 2–10 cm deep. *Water quantity and quality* The brook lamprey is regarded as being sensitive to pollution requiring at least UK Water Quality Class B (EA classification) in all parts of any river where brook lamprey life stages occur. At spawning sites flow velocities of 30–50 cm s-1 have been noted.
Bullhead (*Cottus gobio*)	In the UK the native range of *Cottus gobio* is restricted to England and Wales, although some introduced populations are established in Scotland. Listed in annexes IIa and Va of the Habitats Directive, Appendix III of the Bern Convention.	Common species of the headwaters of many types of upland and lowland river where it is associated with stony benthic habitats with moderate flow. Also occasionally found in lakes. Benthic macroinvertebrates such as *Gammarus* and *Asellus*, together with aquatic fly larvae are the dominant prey items. Habitat H3260 'Rivers with *Ranunculion fluitantis* and *Callitricho-batrachion* vegetation' is a key habitat for this species in the UK. Spawning occurs from February to July with the male excavating a nest under a suitable large stone to attract a female. Bullheads may use other media such as woody debris or tree roots. The female lays a batch of up to 400 eggs (2–2.5 mm in diameter), which adhere to the underside of the stone. The male defends the brood against predators and maintains water circulation by fanning the eggs. Eggs hatch after 20 to 30 days and after 10 days the fry (9 mm in length) disperse, colonising newly available habitat downstream including temporary channels, and floodplain lakes.	Bullhead habitat requirements are dependent on life stages. Coarse benthic substrates with large stones are required for breeding and shallow riffles and glides are utilised by YOY (young of year) fish. Adults appear to prefer sheltered sections created by woody debris, tree roots, leaf litter, macrophyte cover or large stones and all life stages require slack-water refuges during spate flows. Water quantity Water depth is not critical providing it is >5 cm and flow is adequate. High temperatures or low dissolved oxygen may be fatal in shallow water, because temperature fluctuations are greater. Typically, bullhead are found in depths of 20 to 40cm. Water quality Some tolerance to organic pollution (ammonia) and heavy metals is exhibited where oxygen saturation remains high. The bullhead's sympatric occurrence with brown trout indicates a requirement for oxygen concentration of 40% saturation and critical thermal limits of – 4.2 and 27.7°C have been described. Filamentous algal growth resulting from eutrophication is detrimental where algae covers the favoured coarse, hard substrate (see below) and influence food-web dynamics.	*Substrate* Benthic gravel and stones substrates are a vital habitat requirement for bullheads as they provide both spawning habitats and refuges against flow and predators. Bullheads will also utilise macrophytes as refuges from predators and flows if large stones are a limiting factor. If gravel and stone substrates are not limiting within the stream, bullheads will also associate with depositional habitats such as pools containing woody debris. *Channel structure* Natural channel forms exhibiting riffle/pool sequences provide appropriate substrate and flow character for bullhead, as a result supporting higher densities than heavily modified channels. Riparian trees are known to provide shade and shelter as well as valuable input of woody debris and leaf litter.

Species / community	Designations and status	General ecology	Habitat requirements	Habitat requirements (continued)
Desmoulin's whorl snail (*Vertigo moulinsiana*)	Desmoulin's whorl snail is listed under Annex II of the European Union Habitats and Species Directive. It is a priority species in the UK Biodiversity Action Plan (HMSO 1996) and is listed in the British Red Data Book (Bratton 1991) as an RDB3 (Rare) species. Scattered sites across southern England from Norfolk to Dorset, with isolated populations elsewhere. Southern chalk streams have been shown to be as important as the East Anglian fens as strongholds for this species.	Desmoulin's whorl snail lives in permanently wet, usually calcareous, swamps, fens and marshes, bordering rivers, lakes and ponds, or in river floodplains. It is most often found in open situations associated with the following vegetation: • Reed sweet grass (*Glyceria maxima*) • Sedges (*Carex riparia, C. acutiformis, C. paniculata, C. elata*) • Saw sedge (*Cladium mariscus*) • Reed (*Phragmites australis*) • Reedmace (*Typha latifolia* and *T. angustifolia*) • Branched bur reed (*Sparganium erectum*) • Iris (*Iris pseudacorus*) • Reed canary grass (*Phalaris arundinacea*) Adjacent to rivers, its presence/absence and population density are largely determined by the structure and topography of the banks and the nature of the riparian management. The most suitable riparian habitats comprise a relatively broad strip where *Glyceria* or *Sparganium spp*. form dense floating rafts on gently sloping banks. Steeper banks as a result of canalisation, impounding, channel dredging, and weed cutting reduces habitat development often resulting in the absence of the snail.	*Water level requirements* Hydrology is a factor determining the distribution of the Desmoulin's whorl snail with high groundwater levels throughout the year being one of the most important factors. Maximum snail densities are often located where water levels are continuously above the ground surface throughout the year, and where mean annual water levels are more than 0.25 m above the surface. Annual fluctuations of between about 0 m and 0.6 m above ground level provide optimum conditions with summer water level critical thresholds estimated to be at 0.5 m below surface ground level. *Humidity* Humidity is important since the snail spends much of the year climbing in the canopy of the vegetation well away from the ground. Humidity regimes are likely to be influenced by vegetation structure, which is clearly affected by management.	
3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation	Sub-type 1 rivers on chalk substrates. The community is characterised by pond water-crowfoot *Ranunculus peltatus* in spring-fed headwater streams (winterbournes), stream water-crowfoot *R. penicillatus ssp. pseudofluitans* in the middle reaches, and river water-crowfoot *R. fluitans* in the downstream sections. *Ranunculus* is typically associated in the upper and middle reaches with *Callitriche obtusangula* and *C. platycarpa.* Sub-type 2: This variant is found on other substrates, ranging from lime-rich substrates such as oolite, through soft sandstone and clay to more mesotrophic and oligotrophic rocks. Sub-type 3: This variant is a mesotrophic to oligotrophic community found on hard rocks in the north and west.	Characterised by the abundance of water-crowfoots *Ranunculus* spp., subgenus *Batrachium* (*Ranunculus fluitans*, *R. penicillatus ssp. penicillatus, R. penicillatus ssp. pseudofluitans*, and *R. peltatus* and its hybrids). They may modify water flow, promote fine sediment deposition, and provide shelter and food for fish and invertebrate animals. *Ranunculus* communities are associated with assemblages of other aquatic plants e.g. *Rorippa nasturtium-aquaticum, Callitriche spp., Sium latifolium* and *Berula erecta, Myriophyllum* spp. and *Myosotis scorpioides*. The cover of these species may exceed that of *Ranunculus* species. Three main sub-types are defined by substrate and the dominant species within the *Ranunculus* community.	*Ranunculus* follows a four phase cycle of biomass development: • Regrowth phase in autumn triggered by the seasonal increase in flow. • Extension phase over winter to April. Rapid increase in biomass with the development of long streamers in spring. • Consolidation and flowering phase over late spring to summer. • Biomass production increases then slows as energy is invested in flowers and seeds. • Decline phase over late summer to autumn. *Flow* Velocity and discharge are prime factors due to the high photosynthetic rate of *Ranunculus*: fast flows are required to deliver oxygen and carbon to the plant. Velocity also acts indirectly to remove potentially competitive or shading algae, and clearing silt from gravels. 0.3 – 0.5 ms-1 optimal summer velocity band. It is recognised that *Ranunculus* growth can occur above the threshold of 0.5 ms-1 but is subject to mechanical stresses. *Substrate* Clean gravel river beds encourage *Ranunculus* root development and prevent the development of other algal growth which is given an advantage on soft, silty substrates.	

Species / community	Designations and status	General ecology	Habitat requirements	Habitat requirements (continued)
White-clawed crayfish (*Austropotamobius pallipes*)	Listed under annexes II and V of the EU Habitats Directive and Appendix II of the Bern Convention. Protected under Schedule 5 of the Wildlife and Countryside Act (1981). Priority species under the UK Biodiversity Action Plan with its own Species Action Plan. *Austropotamobius pallipes* is widespread in most parts of England and is common in parts of eastern Wales. It is present in south-west Northern Ireland. A significant part of the EU resource is found in the UK, but the species is now seriously threatened over most of its range in Britain.	Crayfish distribution is influenced by geology, requiring relatively hard, mineral-rich waters of calcareous catchments. The species occurs in a variety of habitats including canals, streams, rivers, lakes, reservoirs and water-filled quarries. It is typically found in watercourses of 0.75 m to 1.25 m deep, but is also found in small streams (about 5 cm of water) and in deeper, slow-flowing rivers (2.5 m). In flowing water the white-clawed crayfish may be found associated with: • Undermined, overhanging banks. • Sections exhibiting heterogeneous flow patterns with refuges. • Under cobbles (juveniles) and rocks in riffles, and under larger rocks in pools. • Among roots of woody vegetation, accumulations of fallen leaves and boulder weirs. • Under water-saturated logs. The white-clawed crayfish is primarily carnivorous, feeding on aquatic macroinvertebrates and carrion. In addition, allochthonous material in the form of dead leaves may provide an important source of food.	*Water quality* The majority of records for the white-clawed crayfish occur in UK Environment Agency General Quality Assessment Class A and B waters, an indication of their association with unpolluted fluvial systems. The white-clawed crayfish is principally found in alkaline waters for which calcium and pH requirements are: • calcium (5 mg l-1 minimum) • pH (6.5–9.0) *BOD* The white-clawed crayfish is particularly susceptible to acute pollution incidents caused by spills of organic material with a high biochemical oxygen demand (BOD), such as cattle slurry or silage. *Turbidity and siltation* Gills are easily clogged by sediment and this may cause physico-pathological changes in the long term. White-clawed crayfish tend to avoid substrates covered in mud or silt unless they are actively foraging for food. *Vegetation* White-clawed crayfish utilise aquatic macrophyte vegetation for cover and food. They may be found amongst *Cladophora* spp; *Fontinalis* spp.; or vascular plants such as water crowfoot and watercress. Their association with such vegetation may be due to their foraging and is particularly important in shallow water habitats as they provide protection from predation and high flows.	

C.2 Potential impacts of mill modification on European interest features of the River Wensum SSSI/SAC.

	Mill structures					
Species / community	**Improve operability + protocols**	**Remove flow control mechanisms**	**Lower mill sill levels**	**Bypass channels**	**Fish passes**	**Remove all**
Brook lamprey (*Lampetra planeri*)	Due to the range of options available under this measure assessment of the potential positive/negative effects on the ecological feature cannot be commented on at this point. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	Due to the range of options available under this measure assessment of the potential positive/negative effects on the ecological feature cannot be commented on at this point. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	Due to the range of options available under this measure assessment of the potential positive/negative effects on the ecological feature cannot be commented on at this point. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	*Positive* Reduction of habitat severance and increase in available habitat for existing lamprey populations. Reduction in vulnerability of populations to anthropogenic disturbance through increase in extent of available habitat. Improved ammocoete dispersal and adult migration through removal of potential barriers. Increase in available habitat for all life stages. *Negative* Increased connectivity allowing colonisation of reaches by competitive/damaging species. *Design recommendations* Provision of appropriate flow velocities to ensure passage is not limited to more active swimming species.	*Positive* Reduction of habitat severance and increase in available habitat for existing lamprey populations. Reduction in vulnerability of populations to anthropogenic disturbance through increase in extent of available habitat. Improved ammocoete dispersal and adult migration through removal of potential barriers. Increase in available habitat for all life stages. *Negative* Increased connectivity allowing colonisation of reaches by competitive/damaging species. *Design recommendations* Provision of appropriate flow velocities to ensure passage is not limited to more active swimming species.	*Positive* Reduction of habitat severance and increase in available habitat for existing lamprey populations. Reduction in vulnerability of populations to anthropogenic disturbance through increase in extent of available habitat. Improved ammocoete dispersal and adult migration through removal of potential barriers. Increase in available habitat for all life stages. *Negative* Removal of barrier previously preventing colonisation by competitive/damaging species. *Design recommendations* Provision of appropriate flow velocities to ensure passage is not limited to more active swimming species.

Species / community	Improve operability + protocols	Remove flow control mechanisms	Lower mill sill levels	Bypass channels	Fish passes	Remove all
Bullhead (*Cottus gobio*)	Due to the range of options available under this measure assessment of the potential positive/negative effects on the ecological feature cannot be commented on at this point. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	Due to the range of options available under this measure assessment of the potential positive/negative effects on the ecological feature cannot be commented on at this point. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	Due to the range of options available under this measure assessment of the potential positive/negative effects on the ecological feature cannot be commented on at this point. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	*Positive* Reduction of habitat severance and increase in available habitat for existing bullhead populations. Reduction in vulnerability of populations to anthropogenic disturbance through increase in extent of available habitat. Improved dispersal and adult migration through removal of potential barriers. Increase in available habitat for all life stages. *Negative* Increased connectivity allowing colonisation of reaches by competitive/damaging species. *Design recommendations* Provision of appropriate flow velocities to ensure passage is not limited to more active swimming species.	*Positive* Reduction of habitat severance and increase in available habitat for existing bullhead populations. Reduction in vulnerability of populations to anthropogenic disturbance through increase in extent of available habitat. Improved dispersal and adult migration through removal of potential barriers. Increase in available habitat for all life stages. *Negative* Increased connectivity allowing colonisation of reaches by competitive/damaging species. *Design recommendations* Provision of appropriate flow velocities to ensure passage is not limited to more active swimming species.	*Positive* Reduction of habitat severance and increase in available habitat for existing bullhead populations. Reduction in vulnerability of populations to anthropogenic disturbance through increase in extent of available habitat. Improved dispersal and adult migration through removal of potential barriers. Increase in available habitat for all life stages. *Negative* Removal of barrier previously preventing colonisation by competitive / damaging species. *Design recommendations* Provision of appropriate flow velocities to ensure passage is not limited to more active swimming species.
Desmoulin's whorl snail (*Vertigo moulinsiana*)	Due to the range of options available under this measure assessment of the potential positive/negative effects on the ecological feature cannot be commented on at this point. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	Due to the range of options available under this measure assessment of the potential positive/negative effects on the ecological feature can be commented on at this point. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	Due to the range of options available under this measure assessment of the potential positive/negative effects on the ecological feature can be commented on at this point. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	n/a	n/a	Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.

Species / community	Improve operability + protocols	Remove flow control mechanisms	Lower mill sill levels	Bypass channels	Fish passes	Remove all
3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* **and** ***Callitricho-Batrachion*** **vegetation**	Reduction in impoundment will result in improved flow regime for *Ranunculus* communities. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	Reduction in impoundment will result in improved flow regime for *Ranunculus* communities. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	Reduction in impoundment will result in improved flow regime for *Ranunculus* communities. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	Reduction in impoundment will result in improved flow regime for *Ranunculus* communities. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	n/a	Reduction in impoundment will result in improved flow regime for *Ranunculus* communities. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.
White-clawed crayfish (*Austropotamobius pallipes*)	Due to the range of options available under this measure assessment of the potential positive/negative effects on the ecological feature cannot be commented on at this point. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	Due to the range of options available under this measure assessment of the potential positive/negative effects on the ecological feature cannot be commented on at this point. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	Due to the range of options available under this measure assessment of the potential positive/negative effects on the ecological feature cannot be commented on at this point. Review of effects to be determined on a site-by-site basis following establishment of options and resultant changes to physical habitat e.g. flow, sediment dynamics.	*Positive* Reduction of habitat severance and increase in available habitat for existing white-clawed crayfish populations. Reduction in vulnerability of populations to anthropogenic disturbance. Improved dispersal through removal of potential barriers. Increase in available habitat for all life stages. *Negative* Removal of barrier previously preventing colonisation of reaches by competitive and damaging species e.g. signal crayfish.	*Positive* Reduction of habitat severance and increase in available habitat for existing white-clawed crayfish populations. Reduction in vulnerability of populations to anthropogenic disturbance. Improved dispersal through removal of potential barriers. Increase in available habitat for all life stages. *Negative* Removal of barrier previously preventing colonisation of reaches by competitive and damaging species e.g. signal crayfish.	*Positive* Reduction of habitat severance and increase in available habitat for existing white-clawed crayfish populations. Reduction in vulnerability of populations to anthropogenic disturbance. Improved dispersal through removal of potential barriers. Increase in available habitat for all life stages. *Negative* Removal of barrier previously preventing colonisation of reaches by competitive and damaging species e.g. signal crayfish.

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C.3 Potential impacts of gravel works on European features of the River Wensum SSSI/SAC.

	Gravel works		
Species / community	**Gravel glides**	**Gravel glides + transverse hurdles**	**Bed raising (large scale)**
Brook lamprey (*Lampetra planeri*)	*Positive* Provision of suitable spawning habitat for adult brook lamprey. Improvement to local water quality through turbulent flow and resultant increase in DO concentration. *Negative* Small scale loss of silt bed areas suitable for ammocoete development. Potential to cause damage to existing populations during gravel placement. *Design recommendations* Provision of suitably sized spawning substrate. Glide depth and morphology to provide appropriate flow velocities that reduce fine sediment deposition. Maximise flow heterogeneity through the creation of diverse bed topography.	*Positive* Provision of suitable spawning habitat for adult brook lamprey as a result of gravel installation. Hurdle construction will promote deposition of fine sediment favouring ammocoete life stages. Improvement to local water quality through turbulent flow and resultant DO concentration. *Negative* Small scale loss of silt bed areas suitable for ammocoete development at site of gravel placement. Potential to cause damage to existing populations during gravel placement. *Design recommendations* Provision of suitably sized spawning substrate. Glide depth and morphology to provide appropriate flow velocities that reduce fine sediment deposition. Maximise flow heterogeneity through the creation of diverse bed topography.	*Positive* Significant increase in the extent of suitable spawning habitat for adult brook lamprey. Improvement to local water quality through turbulent flow and resultant DO concentration. *Negative* Potential for large scale loss of silt bed areas suitable for ammocoete development. Potential to cause damage to existing populations during installation of bed raising measures. *Design recommendations* Provision of suitably sized spawning substrate. Glide depth and morphology to provide appropriate flow velocities that reduce fine sediment deposition. Maximise flow heterogeneity through the creation of diverse bed topography.
Bullhead (*Cottus gobio*)	*Positive* Provision of vital habitat for bullhead spawning and adult and YOY (young of year) fish life stages. Improvement to local water quality through turbulent flow and resultant increase in DO concentration. Diversification of instream flow character. Provision of suitable habitat for macroinvertebrate prey items and macrophyte cover e.g. *Ranunculus*. *Negative* Potential to cause damage to existing populations during gravel placement. *Design recommendations* Habitat value can be further increased through addition of larger stone/boulder substrates within gravel glide. Maximise flow heterogeneity through the creation of diverse bed topography.	*Positive* Provision of vital habitat for bullhead spawning and adult and YOY (young of year) fish life stages. Diversification of instream flow character. Improvement to local water quality through turbulent flow and resultant DO concentration. Provision of suitable habitat for macroinvertebrate prey items and macrophyte cover e.g. *Ranunculus*. Improved depth through bed raising. *Negative* Potential to cause damage to existing populations during gravel placement. *Design recommendations* Habitat value can be further increased through addition of larger stone/boulder substrates within gravel glide. Maximise flow heterogeneity through the creation of diverse bed topography.	*Positive* Provision of vital habitat for bullhead spawning and adult and YOY (young of year) fish life stages. Diversification of instream flow character. Provision of suitable habitat for macroinvertebrate prey items and macrophyte cover e.g. *Ranunculus*. Improved depth through bed raising. *Negative* Potential to cause damage to existing populations during installation of bed raising measures. *Design recommendations* Habitat value can be further increased through addition of larger stone/boulder substrates within gravel glide. Maximise flow heterogeneity through the creation of diverse bed topography.

Species / community	Gravel glides	Gravel glides + transverse hurdles	Bed raising (large scale)
Desmoulin's whorl snail (*Vertigo moulinsiana*)	n/a	n/a	*Positive* Potential to improve local water level regime through more frequent inundation of marginal habitats. *Design recommendations* Incorporate measures such as lowering embankments and berm creation.
3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation	*Positive* Provision of suitable rooting habitat for *Ranunculus* community vegetation. Provision of favourable flow and depth conditions for development of *Ranunculus* vegetation. *Negative* *Design recommendations* Provide varied glide depth and morphology to maximised flow diversity. Consideration given to translocation of existing plants to encourage establishment.	*Positive* Provision of suitable rooting habitat for *Ranunculus* community vegetation. Provision of favourable flow and depth conditions for development of *Ranunculus* vegetation. *Negative* *Design recommendations* Provide varied glide depth and morphology to maximised flow diversity. Consideration given to translocation of existing plants to encourage establishment.	*Positive* Provision of suitable rooting habitat for *Ranunculus* community vegetation. Provision of favourable flow and depth conditions for development of *Ranunculus* vegetation. *Negative* *Design recommendations* Provide varied glide depth and morphology to maximised flow diversity. Consideration given to translocation of existing plants to encourage establishment.
White-clawed crayfish (*Austropotamobius pallipes*)	*Positive* Provision of suitable habitat and foraging area for white-clawed crayfish. Improvement to local water quality through turbulent flow and resultant increase in DO concentration. *Negative* Potential to cause damage to existing populations during gravel placement. *Design recommendations* Glide depth and morphology to provide appropriate flow velocities that reduce fine sediment deposition. Maximise flow heterogeneity through the creation of diverse bed topography. Habitat value can be further increased through addition of larger stone/boulder substrates within gravel glide.	*Positive* Provision of suitable habitat and foraging area for white-clawed crayfish. Improvement to local water quality through turbulent flow and resultant increase in DO concentration. *Negative* Potential to cause damage to existing populations during gravel placement. *Design recommendations* Glide depth and morphology to provide appropriate flow velocities that reduce fine sediment deposition. Maximise flow heterogeneity through the creation of diverse bed topography. Habitat value can be further increased through addition of larger stone/boulder substrates within gravel glide.	*Positive* Provision of suitable habitat and foraging area for white-clawed crayfish. Improvement to local water quality through turbulent flow and resultant increase in DO concentration. *Negative* Potential to cause damage to existing populations during gravel placement. *Design recommendations* Glide depth and morphology to provide appropriate flow velocities that reduce fine sediment deposition. Maximise flow heterogeneity through the creation of diverse bed topography. Habitat value can be further increased through addition of larger stone/boulder substrates within gravel glide.

C.4 Potential impacts of other river restoration measures on the European features of the River Wensum SSSI/SAC.

	Other											
Species / community	**Fencing**	**Tree planting on embankment**	**Tree felling**	**Deflector (using LWD and filled in with brush mattress)**	**Lower spoil embankments**	**Channel re-sectioning**	**Berm creation where appropriate**	**Backwaters – reconnections to IDB, field drains**	**Backwaters – new**	**Channel realignment**	**Changing primary and secondary channels**	**Lower embankments**
Brook lamprey (*Lampetra planeri*)	n/a	*Positive* Localised shading may inhibit development of algae, improving spawning habitat quality. *Design recommendations* Incorporate additional measures such as fencing to remove grazing/trampling pressure.	*Positive* General improvement to instream habitat through encouragement of natural narrowing process. *Negative* Reduced shade may encourage development of algae reducing spawning habitat quality at a local scale. *Design recommendations* Adopt selective felling to ensure some tree cover remains of varied age structure.	*Positive* Improvement of flow conditions adjacent to deflector which will act to improve spawning gravels through silt removal. Associated fine sediment deposition will provide ammocoete habitat. *Negative* Potential to cause damage to existing populations during gravel placement. *Design recommendations* Incorporate with additional measures such as gravel placement.	*Positive* General improvement to channel form and process through increase in duration of channel forming flows. Increased connectivity with floodplain features that provide shelter and refuge for lamprey. *Design recommendations* Incorporate with additional measures such as gravel placement.	*Positive* General improvement to channel form and process through increase in duration of channel forming flows. *Negative* Potential to cause damage to existing populations during implementation of measure.	*Positive* Berm creation will increase flow velocities (most effective during low flow periods) and reduce local fine sediment deposition improving spawning habitat if gravels are present. *Negative* Potential to cause damage to existing populations during implementation of measure. *Design recommendations* Incorporate additional measures such as gravel placement and deflectors.	*Positive* Increase in the extent of habitat available for utilisation by spawning adult or larval ammocoete life stages.	*Positive* Increase in the extent of available marginal ammocoete habitat. Provision of refuge areas during high flow events. *Design recommendations* Ensure sweetening flow is maintained to reduce risk of silting up of backwater features.	*Positive* Promotion of more natural flow character and sediment regime favouring habitat development for both adult and larval life stages. *Negative* Potential to cause damage to existing populations during implementation of measure.	*Positive* Potential to improve the extent of suitable spawning and/or larval habitat. *Negative* Potential to reduce habitat quality for ammocoete life stages where primary channel provides extensive silt beds for larval development. Potential to affect existing population through changes in water availability.	*Positive* General improvement to channel form and process through increase in duration of channel forming flows. Increased connectivity with floodplain features that provide shelter and refuge for lamprey. *Design recommendations* Incorporate with additional measures such as gravel placement.
Bullhead (*Cottus gobio*)	*Positive* Encourage riparian tree establishment to supply shade and shelter as well as valuable input of woody debris and leaf litter. Improved bank stability and reduced sediment input. *Design recommendations* Incorporate planting of native deciduous species that will provide seasonal input of leaf litter.	*Positive* Riparian tree development will provide shade and shelter as well as valuable input of woody debris and leaf litter. Reduction in localised sediment input through improved bank stability. *Design recommendations* Incorporate additional measures such as fencing to remove grazing/trampling pressure. Planting of native deciduous species that will provide seasonal input of leaf litter.	*Positive* General improvement to instream habitat through encouragement of natural narrowing process. *Negative* Localised removal of shade and shelter plus reduction in valuable supply of woody debris and leaf litter. Reduced shade may encourage development of algae reducing spawning habitat quality at a local scale. *Design recommendations* Adopt selective felling to ensure some tree cover remains of varied age structure.	*Positive* Improvement of flow conditions through deflector installation combined with marginal facilitation of fine sediment deposition. *Negative* Potential to cause damage to existing populations during gravel placement.	*Positive* Increased connectivity with floodplain features that provide shelter and refuge for bullhead. General improvement to channel form and process through increase in duration of channel forming flows.	*Positive* Return of natural channel form and function will promote conditions that will favour species and potentially improve densities and standing crop. *Negative* Potential to cause damage to existing populations during implementation of measure. *Design recommendations* Incorporate additional measures such as gravel placement.	*Positive* Localised channel narrowing may promote increased flow velocities, improving physical habitat conditions for bullhead. *Negative* Potential to cause damage to existing populations during implementation of measure. *Design recommendations* Incorporate additional design measures such as gravel placement and deflectors.	*Positive* Improved connectivity to additional habitats suitable for colonisation by bullhead. Increase in the extent of habitat available for utilisation by bullhead for shelter from high flow events and/or additional spawning habitat and nursery grounds.	*Positive* Increase in the extent of available marginal ammocoete habitat especially where fine sediment deposition is favoured. Provision of refuge areas during high flow events. *Design recommendations* Ensure sweetening flow is maintained to reduce risk of silting up of backwater features.	*Positive* Promotion of more natural flow character and sediment regime favouring habitat development for both adult and larval life stages. *Negative* Potential to cause damage to existing populations during implementation of measure.	*Positive* Potential to improve the extent of available habitat. *Negative* Potential to affect existing population through changes in water availability.	*Positive* General improvement to channel form and process through increase in duration of channel forming flows. Increased connectivity with floodplain features that provide shelter and refuge for bullhead. *Design recommendations* Incorporate with additional measures such as gravel placement.

Species / community	Fencing	Tree planting on embankment	Tree felling	Deflector (using LWD and filled in with brush mattress)	Lower spoil embankments	Channel re-sectioning	Berm creation where appropriate	Backwaters – reconnections to IDB, field drains	Backwaters – new	Channel realignment	Changing primary and secondary channels	Lower embankments
Desmoulin's whorl snail (*Vertigo moulinsiana*)	*Positive* Exclusion of grazing pressure from marginal areas and encouragement of marginal plant development. Reduction in poaching of marginal habitats. *Negative* May eventually result in development of marginal tree cover and hence loss of suitable habitat.	*Positive* *Negative* Increased shading of wetland plant communities associated with snail populations. Local effects on water availability through tree uptake. *Design recommendations* Ensure planting does not create a significant shading impact on existing suitable snail habitat.	*Positive* Reduced shading of wetland plant communities and reduction in local water demand. *Design recommendations* Encourage vegetation establishment on silt berms through transplantation of appropriate wetland plants.	*Positive* Potential for establishment of marginal wetland vegetation on lateral silt berms.	*Positive* Improve connectivity between river and marginal habitats. If suitable water level regimes are maintained snail populations may benefit. Improve dispersal of species through improved connectivity in river corridor. *Negative* Potential to cause damage to existing populations during implementation of measure. *Design recommendations* Encourage marginal vegetation establishment through transplantation of appropriate wetland plants in treated areas.	*Positive* Re-sectioning may favour growth of marginal plants and provided suitable water level regimes are maintained snail populations may benefit. *Negative* Potential to cause damage to existing populations during implementation of measure. *Design recommendations* Encourage marginal vegetation establishment through transplantation of appropriate wetland plants in treated areas.	*Positive* Berm creation may favour growth of marginal plants and provided suitable water level regimes are maintained snail populations may benefit. *Negative* Potential to cause damage to existing populations during implementation of measure. *Design recommendations* Encourage marginal vegetation establishment through transplantation of appropriate wetland plants in treated areas.	*Positive* Increase in the extent of habitat available for colonisation by wetland plants. Potential to improve water levels adjacent to main river.	*Positive* Backwater areas may improve the extent of area available for colonisation by marginal plants and, provided suitable water levels are maintained, snail populations may benefit. *Negative* Potential to cause damage to existing populations during implementation of measure. *Design recommendations* Encourage marginal vegetation establishment through transplantation of appropriate wetland plants in treated areas.	*Positive* Potential to improve marginal habitat quality. *Negative* Potential to cause damage to existing populations during implementation of measure. *Design recommendations* Promote suitable water level regimes in marginal areas through appropriate channel design.	*Positive* Improvement of water level regimes in adjacent floodplain area through increase in ground water levels. *Negative* Potential to affect existing population through changes in water availability.	*Positive* Lowering of embankments may improve the extent of area available for colonisation by marginal plants and, provided suitable water levels are maintained, snail populations may benefit. *Negative* *Design recommendations* Incorporate with additional measures such as gravel placement.
3260 Water courses of plain to montane levels with the *Ranuncuion fluitantis* and *Callitricho-Batrachion* vegetation	*Positive* Improved bank stability may reduce localised sediment input. *Negative* Development of riparian vegetation will increase shading increasing competition from more shade tolerant species.	*Negative* *Gradual increase in shading will, over time, favour more shade tolerant species.* *Design recommendations* Provide varied shade pattern through selective planting locations.	*Positive* Reduction of local shading will promote *Ranunculus* growth. Selective tree felling encouraged over widespread removal to provide a mosaic of shade and light habitats. *Negative* Potential to increase the development of competitive algal species e.g. epiphytes.	*Positive* Improvement of flow conditions favouring *Ranunculus* growth downstream of flow deflector. *Negative* Potential to cause damage to existing vegetation stands during implementation of measure. *Design recommendations* Incorporate with additional measures such as gravel placement.	*Positive* General improvement to channel form and process through increase in duration of channel forming flows. *Negative* *Design recommendations* Incorporate with additional measures such as gravel placement.	*Positive* General improvement to channel form and process. *Negative* Potential to cause damage to existing vegetation stands during implementation of measure. *Design recommendations* Incorporate with additional measures such as gravel placement.	*Positive* General improvement to channel form and process. *Negative* Potential to cause damage to existing vegetation stands during implementation of measure. *Design recommendations* Incorporate with additional measures such as gravel placement.	n/a	n/a	*Positive* Promotion of natural flow and sediment regime conducive to *Ranunculus* communities. *Negative* Potential to cause damage to existing communities during implementation of measure.	*Positive* Potential to provide more appropriate flow conditions for *Ranunculus* development. This potential is improved if secondary channel contains more appropriate substrate e.g. areas of gravel. *Negative* Potential to affect existing stands of vgetation through changes in water availability. *Design recommendations* Incorporate with additional measures such as gravel placement.	*Positive* General improvement to channel form and process through increase in duration of channel forming flows. *Negative* *Design recommendations* Incorporate with additional measures such as gravel placement.

Species / community	Fencing	Tree planting on embankment	Tree felling	Deflector (using LWD and filled in with brush mattress)	Lower spoil embankments	Channel re-sectioning	Berm creation where appropriate	Backwaters – reconnections to IDB, field drains	Backwaters – new	Channel realignment	Changing primary and secondary channels	Lower embankments
White-clawed crayfish (*A. pallipes*)	*Positive* Encourage riparian tree establishment to supply shade and shelter as well as valuable input of woody debris and leaf litter. Improved bank stability and reduced sediment input. *Design recommendations* Incorporate planting of native deciduous species that will provide seasonal input of leaf litter.	*Positive* Riparian tree development will provide shade and shelter as well as valuable input of woody debris and leaf litter. Reduction in localised sediment input through improved bank stability. *Design recommendations* Planting of native deciduous species that will provide seasonal input of leaf litter.	*Positive* Reduction of local shading will promote increased instream productivity potentially increasing availability of food items.	*Positive* Improvement of flow conditions adjacent to deflector which will act to improve habitat quality for white-clawed crayfish. *Negative* Potential to cause damage to existing populations during gravel placement. *Design recommendations* Incorporate with additional measures such as gravel placement.	*Positive* General improvement to channel form and process through increase in duration of channel forming flows. *Design recommendations* Incorporate with additional measures such as gravel placement.	*Positive* Return of natural channel form and function will promote conditions that will favour this species. *Negative* Potential to cause damage to existing populations during implementation of measure. *Design recommendations* Incorporate additional measures such as gravel placement.	*Positive* Localised channel narrowing may promote increased flow velocities improving physical habitat conditions for white-clawed crayfish. *Negative* Potential to cause damage to existing populations during implementation of measure. *Design recommendations* Incorporate additional design measures such as gravel placement and deflectors.	*Positive* Increase in available habitat and dispersal for existing white-clawed crayfish populations. Reduced vulnerability to anthropogenic disturbance. *Negative* Removal of barrier previously preventing colonisation of reaches by competitive and damaging species e.g. signal crayfish.	*Positive* Increase in available habitat and dispersal for existing white-clawed crayfish populations. Reduced vulnerability to anthropogenic disturbance.	*Positive* Promotion of more natural flow character and sediment regime favouring habitat development for white-clawed crayfish. *Negative* Potential to cause damage to existing populations during implementation of measure.	*Positive* Potential to improve the extent of available habitat. *Negative* Potential to affect existing population through changes in water availability.	*Positive* General improvement to channel form and process through increase in duration of channel forming flows. *Design recommendations* Incorporate with additional measures such as gravel placement.

Appendix D – Links between terrestrial and riverine units of the River Wensum SSSI

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Appendix D – Links between terrestrial and riverine units of the River Wensum SSSI units

Terrestrial SSSI units	Riverine SSSI units	RWRS reach/reaches	Details of Terrestrial SSSI unit	Natural England comments on linkage between terrestrial and riverine SSSI units	Action
31 (Full SSSI ID 1023136)	50	19	Name: Broom Green Turf Common Location: TF992241 Area: 20.26 hectares Type: Neutral grassland - lowland Condition: Favourable More details: This is a complex site, with a mosaic of grassland, fen and secondary scrub habitats. Some of the dryer grassland areas have been semi-improved and have been well grassed. However, many of the fen and wet grassland communities have been invaded by scrub and some of this has been established for a long period of time, overshadowing the fen species and drying out the ground conditions. W5 woodland with dead or moribund tussocks of Carex paniculata is indicative of this process. At the time of our visit, the site was grazed by sheep and the more heavily grazed dry grassland communities and rank marsh and fen with encroaching scrub were consistent with this grazing regime. With rank marshy grassland and fen, the site would benefit from cattle grazing rather than sheep. Although the fen scrub transitions form part of the special interest of the site, further scrub encroachment on the site would be detrimental to the open grassland and fen habitats. Scrub clearance would be desirable on the site, although this should be targeted to the clearance of scrub from recently colonised areas rather than the felling of well established alder carr.	• This Unit lies adjacent to the River Wensum downstream of Bintree Mill, on free flowing river. • There are significant accumulations of spoil along some of the river banks. This has some impact on the hydrological linkage between river and floodplain, and an IDB drain rises within this compartment, only joining the river downstream of North Elmham Mill. • Hydrological connectivity could be improved by removal of the spoil banks, but this is not regarded as below target in this instance. • Channel form and function highly modified, but this is discussed more fully in the Condition Assessment for Unit 49.	Conceptual design proposes: • Deflectors • Tree thinning • Gravel glides • Berm creation • Lower spoil embankment • Backwater s– new • Channel resectioning
32 (Full SSSI ID	50	17	Name: North Elmham County Farms Location: TF995213	• There are significant spoil banks between the river and Unit 32, and the river is impounded	Conceptual design proposes:

Terrestrial SSSI units	Riverine SSSI units	RWRS reach/reaches	Details of Terrestrial SSSI unit	Natural England comments on linkage between terrestrial and riverine SSSI units	Action
1023137)			Area: 7.02 hectares Type: Neutral grassland - lowland Condition: Unfavourable recovering More details: This Unit supports semi-natural vegetation and is hydrologically linked to the river. Since the last condition assessment, the management regime of this Unit has been changed and a seasonal grazing regime introduced. This regime is compatible with the river interests. However, water levels are very high and virtually the whole compartment was covered by standing water at the time of the site visit. For this reason it has not been practical to graze this compartment so far this summer	behind North Elmham Mill. • The Unit is hydrologically disconnected from the river, and is drained through an IDB Main Drain. • Channel form highly modified, but this is discussed more fully in the Condition Assessment for Unit 49 • Feasibility study for river restoration needs to consider the opportunities for reconnection of the appropriate hydrological relationship between the river and this Unit of the SSSI.	• Berm creation • Gravel glide • Deflector • Backwaters – new • Lower spoil embankments

Notes –

1. Terrestrial SSSI units' refers to non-riverine units of the River Wensum SSSI (e.g. SSSI ID 1023117)).
2. 'Riverine SSSI units' refers to those units of the River Wensum SSSI that comprise sections of river channel (e.g. Unit 48).
3. 'RWRS reaches' refers to reaches of river channel as defined in the River Wensum Restoration Strategy (e.g. Reach 10, Lenwade Mill to Marriots Way).
4. 'Details of terrestrial SSSI unit' are taken from Nature on the Map: http://www.natureonthemap.org.uk/
5. 'Natural England comments on linkage between terrestrial and riverine SSSI units' are those from an emerging condition assessment of terrestrial SSSI units undertaken by Natural England. The condition assessment is thus far incomplete and in draft form.
6. 'Action' refers to those proposed options/measures in the conceptual design undertaken by Atkins
7. Changes to river / floodplain hydrology will be considered at detailed design stage as modelling will be required to determine the extent of the relationship. It is inappropriate at this stage due to the potential complexity of this relationship. Reasons stated for "unfavourable condition" of individual SSSI units will be include in the drivers for the design.

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