Natural England Commissioned Report NECR010

# River Wensum restoration strategy

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# Introduction

This report was commissioned by Natural England and overseen by a steering group convened by Natural England in partnership with the Environment Agency and the Water Management Alliance (internal drainage board). The report was produced by JBA Consulting, building on a fluvial audit by Geodata Services. The River Restoration Centre acted in an advisory role. The views are those of the authors and do not necessarily represent those of Natural England.

## Background

The River Wensum rises near South Raynham in Norfolk and flows east through Norwich, joining the Yare on the south-east side of the city. Upstream of Norwich, 71 km has been notified as a Site of Special Scientific Interest (SSSI), and it is one of 16 rivers in England designated as a European Special Area of Conservation (SAC).

A survey in 2002 showed that the ecological condition of the river had declined, and the principal reasons for unfavourable condition were water quality and siltation. The siltation problem is exacerbated by structures which impede the river's hydrological functioning.

The water quality is being addressed, but the physical character of the river channel also needs to be restored to secure good ecological and hydrological functioning.

In 2004, a geomorphological appraisal of the River Wensum was carried out by Geodata Services, University of Southampton. JBA Consulting used these results to prepare this technical report and restoration strategy.

This is the first 'whole river' restoration strategy to be prepared in the UK. After consultation with key stakeholders, it has been agreed by the partners and is starting to be implemented.

This report is being published to help Natural England:

- Develop a standard approach to river restoration that is accepted and understood by key partners, such as the Environment Agency, and stakeholders, including riparian landowners and fisheriy managers.
- Apply sound science and surveys to ensure rivers are successfully restored.

Natural England is using the findings in this report to:

- Identify and prioritise physical restoration measures on the River Wensum SAC that will help to achieve its conservation objectives in the most cost-effective way.
- Develop and test a methodology for producing a restoration strategy on a whole-river basis that can be applied more widely to other river SSSIs.

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**Keywords** - River Wensum, SSSI, SAC, river, restoration, geomorphology, fisheries, diffuse pollution, siltation, hydrology, physical modification

**Further information**
This report can be downloaded from the Natural England website: **www.naturalengland.org.uk**. For information on Natural England publications contact the Natural England Enquiry Service on 0845 600 3078 or e-mail **enquiries@naturalengland.org.uk**.



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# Project details

This report results from research commissioned by English Nature and later, Natural England to prepare a restoration strategy for the River Wensum in Norfolk. Natural England's, Project Officer overseeing this contract was David Withrington. The work was undertaken by the following team: Tony Green, Anna Curini, Howard Keeble, Philip Soar and Martin Coombes of JBA Consulting.

This report should be cited as:

COOMBES, M., CURINI, A., HOWARD KEEBLE, A., GREEN, T. and SOAR, P. 2007. River Wensum Restoration Strategy. Natural England Research Reports, Number 024.

# Acknowledgments

The authors of this report would like to thank the following for their advice and/or contributions to the development of the River Wensum Restoration Strategy:

- Steering Group Members (as listed in Section One of this report).
- GeoData Institute (Southampton University) for clarification on the Geomorphological Appraisal.
- Landowners who gave permission for access.
- Representatives of the Country Land and Business Association, Norfolk Rivers IDB, Anglian Water, Norfolk Anglers' Conservation Association and Wensum Valley Project who provided feedback at the initial stakeholder meeting.
- The River Restoration Centre for their advice and review.
- Norfolk County Council for the information that they provided in relation to local heritage.
- Norfolk Anglers' Conservation Association and Bintry Mill Trout Fishery for providing details of their river rehabilitation schemes.

# Summary

The River Wensum rises near South Raynham in Norfolk and flows east to Norwich, joining the Yare on the south-east side of the city. Upstream of Norwich, 71km has been notified as a Site of Special Scientific Interest (SSSI), and it is one of 16 rivers in England designated as a European Special Area of Conservation. The Wensum is a valued fishery and landscape feature in the Norfolk countryside.

Before its designation, the river was surveyed (Holmes, 1980), indicating that in its upper reaches the plant communities were characteristic of chalk rivers, with a transition to lowland rivers of mixed geology in the lower sections. A repeat survey (Grieve et al, 2002) indicated that the ecological condition of the river had declined at four out of the five survey sites.

The condition assessment carried out by English Nature (now Natural England) in 2002 concluded that the river was in unfavourable condition. The principal reasons were: water quality (high levels of phosphate), siltation, and physical modifications impeding the river's hydrological functioning.

The water quality problems are being addressed principally by phosphate removal at Anglian Water's sewage treatment works at Fakenham and Dereham and other smaller works in the catchment. Agricultural run-off is being tackled by a Catchment Sensitive Farming pilot project administered by Natural England. This leaves the physical modifications to the river that now require attention to return the river to good ecological status.

## Development of a restoration strategy

In 2004, a geomorphological appraisal of the River Wensum was commissioned by English Nature (now Natural England), in partnership with the Environment Agency and the King's Lynn Consortium of Internal Drainage Boards (now Water Management Alliance). This was undertaken by Geodata Services, University of Southampton, and produced detailed maps, dividing the river into 41 reaches, showing modifications to the river channel and the behaviour of sediments. It indicated the type of restoration work appropriate for each reach.

In 2005 English Nature convened a steering group of the partners to consider the results of the geomorphological appraisal and to decide on the next steps. They decided that a restoration strategy was needed, which would set out a vision for the River Wensum, evaluate options for physical restoration, and consider costs - as well as constraints and possible synergies with other plans and initiatives. JBA Consulting were appointed to prepare a report and a restoration strategy.

At an early stage of the work (May 2006) the partners (Natural England, Environment Agency and Water Management Alliance) held a meeting to discuss their plans with stakeholders, including Anglian Water, local authorities, fisheries and farming interests. There was general support for a river restoration project, but a number of possible constraints were identified.

## The objective of a restoration strategy for the Wensum

The aim of river restoration is not to achieve some former 'natural' condition of the river, but to restore a measure of hydrological functioning so that it can sustain wildlife and fisheries characteristic of the river type. Once the appropriate measures have been implemented, the SSSI can be assessed as 'recovering' towards 'favourable condition'. The rationale for this is set out in draft guidelines for restoration of river SSSIs, prepared jointly by Natural England and the Environment Agency.

The key to this approach is understanding how the river functions as a whole and within its catchment. Hitherto, most river restoration in the UK has been piecemeal and opportunistic in its

approach, has been limited to only few stretches or has only tackled one impact (for example, trampling of banks by livestock). However, the Wensum has been chosen as a pilot for a 'whole-river' restoration strategy. Restoration measures will be undertaken where they are likely to have the greatest effect on the hydrological functioning of the river.

The main drivers for physical restoration of the Wensum are to achieve favourable or recovering condition under the Government's PSA target for SSSIs (95% in target condition by 2010) and to contribute to 'favourable conservation status' of the European Natura 2000 series of 'plain to mountainous rivers with characteristic plant communities of water crowfoot and starwort'. The Wensum is also of European importance for two species of fish (brook lamprey and bullhead), as well as white-clawed crayfish and Desmoulin's whorl snail. All these species are expected to benefit from physical restoration of the river.

A further driver for the restoration of the Wensum is its status as a Protected Area under the Water Framework Directive. This means that measures have to be included in the Anglian River Basin Management Plan in 2009 to address hydromorphological pressures that prevent it from achieving its environmental objectives.

# Conclusions of the restoration strategy

Finalised in November 2007, the restoration plan identified the 14 redundant mill structures along the Wensum as the most significant factor affecting the morphology of the river channel as 67% of the river is backed up behind these structures. Out of a total fall in head along the Wensum of 34 metres (from above Sculthorpe Mill to downstream of Hellesdon Mill), 60% of the drop occurs at mill structures, rather than progressively along the channel.

Most of the changes to the natural channel morphology took place between 1200 AD and 1900 AD at mill sites. Historically, working mills stored water upstream and used the head to drive water wheels or turbines. As a result sediment was flushed downstream on a regular basis and was unable to accumulate behind the mill dams. However, the last of the mills ceased to operate by the end of the 1960s. Since then, mill owners have tended to operate sluices infrequently or to keep them closed. As water levels do not fluctuate on a regular basis and silt ingress has significantly increased over recent decades, upstream mill ponds are characterised by sluggish flows and deep accumulation of sediment.

Further key influences have been channel dredging (deepening and widening - 35% of the river length is assessed as more than 5 metres wider than it should be); straightening; and the presence of embankments. Only about 20% of the surveyed channel remains largely unmodified (for example, parts of the lower course of the Langor Drain and sections of the Wensum between Lenwade Mill and Attlebridge Hall, and downstream of Taverham Mill). Catchment influences include increasingly intensive agriculture in the upper catchment, generating run off of silt and nutrients, and an extensive network of drainage channels in the floodplain, affecting flows and water levels.

# Recommended measures

Works at mill-structures are an essential component of the River Wensum Restoration Strategy. If the restoration of the whole river is to be sustainable, these works need to be completed prior to any channel restoration up and downstream. A timeframe for restoration work is set out in Table 7. This proposes the following sequence of measures:

1) Lower water levels at mill structures through alteration of operational regimes (between 0.1m at Fakenham and 1.36m at Elsing). This would require limited structural work, and it would reduce the ponded length of river by 18km. The effects should be monitored to inform further work at (2) and (3) below.
2) Bed-raising and other channel enhancements linked to the lowering of redundant mill structures. Silt management could include creation of berms (redistribution of silt) along

channel margins where it is currently over wide. Woody debris could be introduced where appropriate.

3) Carry out physical modifications (lowering or removal of structures) at most of the 14 mills (see Table 9), each one to be carefully assessed and planned, taking account of by-passes and multiple channels. This would substantially remove ponding throughout.
4) In the upper Wensum, re-meandering in four reaches and reconnection of 8km of river to its original channel.
5) Targeted channel narrowing and bed raising, where the river channel is showing little sign of natural recovery.

# Costs

The costs per kilometre have been estimated: bed-raising £180,000; channel narrowing £200,000; and restoring meanders/former channel £150,000. Because of the high costs, it is recommended that these measures are carefully targeted. The costs for modifying or removing mill structures will vary from one to the other: the River Wensum Water Level Management Plan estimates that the main structural changes required could be achieved with a total budget of £4 million.

# Synergies

Synergies have been identified between the River Wensum Restoration Plan and a wide range projects and local initiatives including:

- The Broadland Rivers Catchment Flood Management Plan (Environment Agency).
- The Flood Risk Management Strategy, including lowering of mill structures as a cost-effective means of reducing flood risk at Fakenham and Lyng (Environment Agency).
- The Water Level Management Plan (2007) prepared by the Environment Agency for the River Wensum SSSI.
- The Fisheries Action Plan prepared by the Environment Agency.
- The Wensum Catchment Sensitive Farming initiative (Natural England).

# Recommendations

The report makes the following recommendations:

1) The River Wensum Restoration Strategy Steering Group should now take forward the project to an implementation stage. This is important to select the optimal delivery mechanism, identify funding sources and identify the organisation(s) which would best lead the project.
2) More detailed consultation with stakeholders is needed early in the next stage, both to promote the overall vision, and to discuss how local changes would be implemented.
3) Discussions with stakeholders that want to implement works on the river in the very near future, including Anglian Water, NACA (angling club) and the Environment Agency flood risk management team, should be continued at the earliest opportunity.
4) Further study is required on how to implement the proposed changes in water levels at mills. It would seem appropriate that this should be progressed as part of the implementation of the River Wensum Water Level Management Plan, but this aspect must remain an integral part of the River Wensum Restoration Strategy.
5) Plans should be made for a demonstration site where the operating level at a mill can be progressively lowered. The changes in the river should be monitored to establish how lowering of water level can be achieved without creating unsightly muddy banks, or causing silts to be deposited on high quality gravel bed downstream of the mill.
6) During the development of the restoration strategy there were uncertainties in the methods used for calculating reference river widths and depths. Monitoring of the initial

works under the plan should be undertaken to refine the prediction techniques and the most effective way of achieving river improvements.

7) The effects of potential restoration works on the flooding regime should be studied in more detail.
8) The River Wensum Restoration Strategy could be promoted as a pilot for improvement of river condition under the Water Framework Directive.
9) Personal accounts of observed changes in the river (such as in Appendix 4) have been useful to this study. Effort should be made to collate similar accounts for other rivers.

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# Abbreviations

| | |
|---|---|
| AMP3 | Asset Management Plan (2000-2005) |
| AMP4 | Asset Management Plan (2005-2010) |
| BAP | Biodiversity Action Plan |
| CAMS | Catchment Abstraction Management Strategy |
| CAPM | The Centre for Aquatic Plant Management |
| CFMP | Catchment Flood Management Plan |
| CRoW | Countryside and Rights of Way Act 2000 |
| CSS | Countryside Stewardship Schemes |
| ECSFDI | England Catchment Sensitive Farming Delivery Initiative |
| ELS | Entry Level Scheme (of Environmental Stewardship) |
| ECON | Ecological Consultancy |
| EN | English Nature |
| ESA | Environmentally Sensitive Area |
| ESS | Environmental Stewardship Scheme |
| FAP | Fisheries Action Plan |
| HLS | Higher Level Scheme (of Environmental Stewardship) |
| IDB | Internal Drainage Board |
| ISIS | 1-dimensional hydraulic model by Halcrow/HR Wallingford |
| JBA | Jeremy Benn Associates |
| JNCC | Joint Nature Conservation Committee |
| MCA | Multi-Criteria Analysis |
| NACA | Norfolk Anglers Conservation Association |
| NE | Natural England |
| NRIDB | Norfolk Rivers Internal Drainage Board |
| OELS | Organic Entry Level Scheme (of Environmental Stewardship) |
| ORSU | Off-River Supplementary Unit |
| PSYCHIC | Phosphorus and Sediment Yield Characterisation in Catchments |
| QMED | Median annual maximum flood |
| RBMP | River Basin Management Plan |
| RHS | River Habitat Survey |
| RoC | Review of Consents under Regulation 50 of the Conservation (Natural Habitats &c.) Regulations 1994 |
| RRC | River Restoration Centre |
| RSAP | Restoring Sustainable Abstraction Programme |
| RSS | Regional Spatial Strategy |
| RWRS | River Wensum Restoration Strategy |
| SSSI | Site of Special Scientific Interest |

| | |
|---|---|
| SAC | Special Area of Conservation |
| WFD | Water Framework Directive |
| WLMP | Water Level Management Plan |
| WMA | Water Management Alliance |

# 1 Introduction

## Background

### River type

1.1 The River Wensum is one of 31 rivers in England to be designated a 'whole river Site of Special Scientific Interest (SSSI)'. It was selected in recognition of being one of the best examples of an 'enriched calcareous lowland river'. Whilst England contains numerous examples of chalk river, particularly in the south, East Anglia and up to Lincolnshire and Yorkshire, they have a limited distribution throughout the rest of Europe (UK Biodiversity Steering Group, 1995). Owing to their international importance, UK chalk rivers, such as the River Wensum, have been identified as a priority habitat by the UK Biodiversity Steering Group. They are also recognised as being a unique and irreplaceable part of English heritage and landscape. Chalk rivers and their underground aquifers provide water resources for domestic, industrial and agricultural usage and they are often world famous for their fly-fishing. However, they face mounting pressure from water abstraction, urbanisation, flood defence, agriculture and industry. These pressures threaten to damage the characteristic habitats that are considered typical of chalk rivers (UK Biodiversity Action Plan Steering Group for Chalk Rivers, 1994).

1.2 The River Wensum, whilst an attractive looking river to the casual visitor, has been adversely affected by physical modifications that limit its ecological potential to support chalk river habitat. The vision of the River Wensum Restoration Strategy is to reverse some of these changes and enhance the natural functioning of the river. This will produce multiple benefits in the form of a richer riverine environment, improved fisheries and a more naturally functioning hydrological regime that will assist with the management of water resources and flood control in Norwich. Unlike many river restoration projects undertaken in the UK that tend to be localised, one-off schemes, the River Wensum Restoration Strategy envisages large scale modifications to 71km of river channel. It may not be possible to carry out improvements at all locations simultaneously but there will undoubtedly be benefits in identifying the key issues in the catchment, producing a clear vision of what is desirable and an understanding of how this may be achieved when planning individual schemes at a local scale.

1.3 The River Wensum SSSI designation covers 393ha. It recognises the presence of a rich assemblage of aquatic and emergent plants (with over 100 species of vascular plant recorded), and a rich invertebrate fauna. It includes the river channel up to the first major change in bank angle, and 20 parcels of land which were included within the boundary as they are hydrologically linked to the river and support semi-natural vegetation (including fen, reed bed, floodplain grassland and carr woodland). Whilst the river is of rich ecological and cultural value in its present state, the features of special interest of the River Wensum SSSI are currently regarded as being in an 'unfavourable condition'. In order to reach favourable condition, a wide range of issues need to be addressed including those relating to water quality, water quantity and channel form and function.

1.4 In 2000, the River Wensum was transmitted to Europe as a candidate Special Area of Conservation (SAC) and the site was confirmed as a SAC in 2005. European features supported by the River Wensum SAC include Annex I habitat (watercourses of plain to montane levels with *Ranunculion fluitantis* and *Callitricho-batrachion* vegetation) and Annex II species (white-clawed crayfish, Desmoulin's whorl snail, bullhead and brook lamprey).

1.5 A wide range of government bodies have a statutory interest in the River Wensum and its floodplain, including:

- The Environment Agency.

- The Norfolk Rivers Internal Drainage Board (NRIDB) which includes the former River Wensum IDB and which is a member of the Water Management Alliance (WMA).
- Natural England (formerly the Rural Development Service, the Countryside Agency and English Nature).

1.6 Previously each agency had its own agenda in relation to the management of the river and its floodplain and, hence, it was difficult to develop a unified vision for the river. This was highlighted in a meeting of the River Wensum Forum in November 2002.

1.7 Natural England have identified a wide range of 'Adverse Condition Reasons' contributing to the unfavourable condition of the river and have liaised with other organisations in order to find solutions and mechanisms to remedy these issues. The Government has set a Public Service Agreement (PSA) target to attain 95% of SSSIs in favourable (or unfavourable recovering) condition by 2010. This has given the impetus for all public bodies and agencies to work together towards a shared vision for the river. Additional objectives, such as those of the Fisheries Action Plan and the Water Level Management Plan for the River Wensum, are compatible with Natural England's objective of restoring the river to favourable condition. In this context, the River Wensum Restoration Strategy will form a pilot scheme for the development of catchment scale restoration plans that address unfavourable condition.

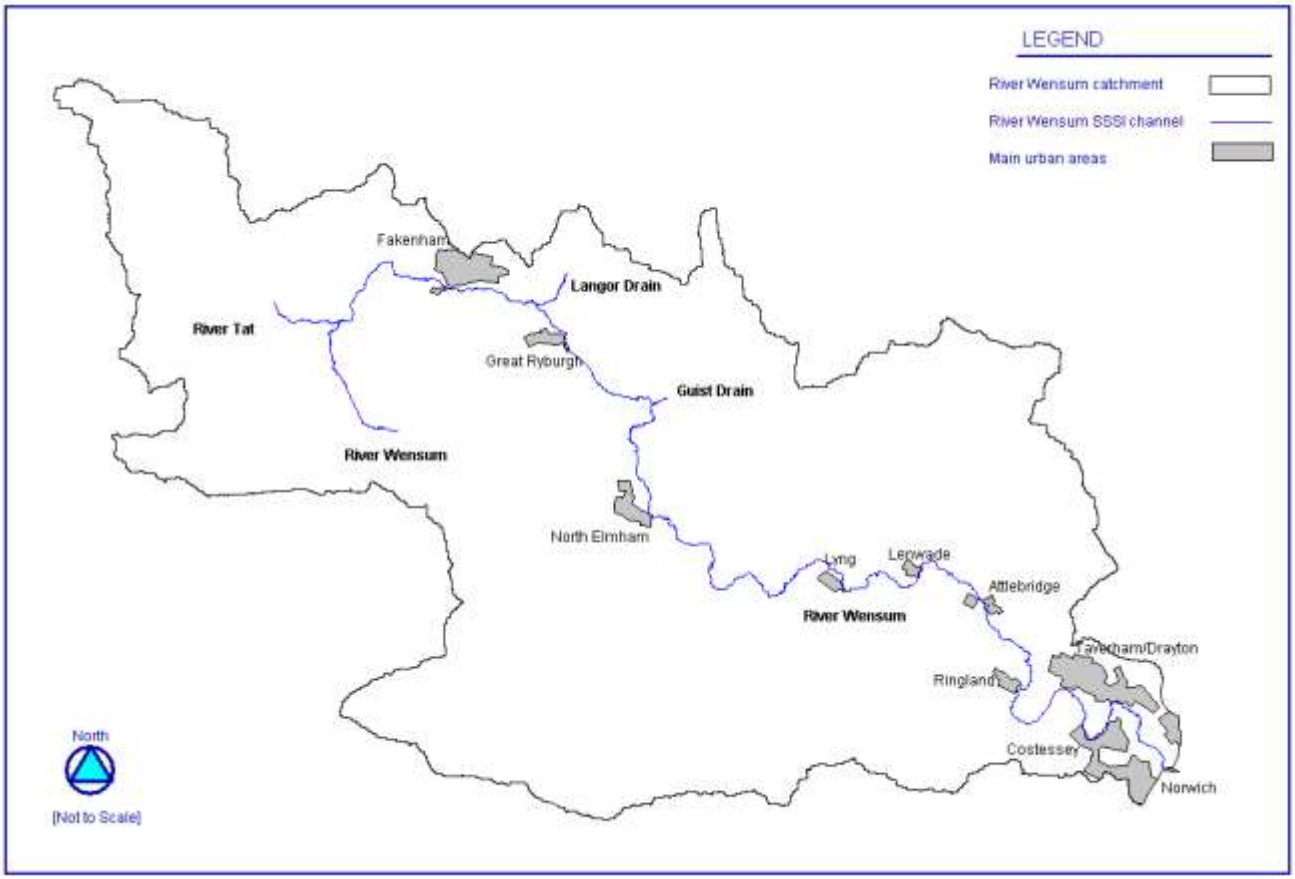
1.8 In 2005, English Nature and the Environment Agency drafted proposed guidelines for the restoration of physical and geomorphological favourable conditions on river SSSIs in England (Fraser et al., 2005). The guidelines highlight the need for a restoration plan for each river that is technically feasible, practical and capable of being costed. Experiences gained through the River Wensum Restoration Strategy pilot will help to inform the development of these guidelines.

1.9 Guiding principles for restoration proposals are that they should conserve the characteristic ecology (flora and fauna) of the river type. The working assumption is that, generally, increasing physical naturalness and reducing morphological modification will improve ecological conditions. Ecological studies have shown that whilst localised river restoration works may have benefits for target species, these are very much limited by the level of modification to the whole river system which may be poor elsewhere. The argument for a whole river approach is thus supported by the biological evidence. The aim in the River Wensum Restoration Strategy is to restore natural river form and process in order to improve the chalk river habitat throughout the catchment, whilst recognising that the River Wensum is part of a wider, historic landscape whose character it is important to retain.

## Study area

1.10 Figure 1 shows the location of the River Wensum catchment to the north west of Norwich. The River Wensum Restoration Strategy covers all sections of the channel within the River Wensum SSSI. The study catchment area is approximately 650km2 and the site extends approximately 71km, from just upstream of the City of Norwich at Hellesdon Mill (TG 198 105) to near its source at Pear Tree Corner (TF 898 237). It incorporates the lower part of the River Tat and the downstream reaches of the Langor Drain and the Guist Drain.

1.11 The River Wensum is a low gradient, groundwater dominated river. It flows at an average slope of 0.00082 over Senonian Chalk that has been overlain by a complex sequence of glacial drift, sands and gravels. These deposits tend to increase in thickness towards the lower end of the catchment. As the river is often separated from the chalk aquifer by considerable depths of superficial material, it does not exhibit some of the characteristics of the 'classic' chalk rivers of southern England. Intensive arable land-use dominates the landscape on the higher plateaus and valley sides, and grazing marsh, fen, reedbed, scrub and scattered woodland characterise the floodplain. Unusually for a lowland river, much of the floodplain of the River Wensum is still traditionally managed and relatively natural, although there are a series of flooded gravel pits, particularly in the vicinity of Costessey, Lenwade, Lyng, Fakenham and Great Ryburgh. Views of the River Wensum and its floodplain are shown in Plate 1.




NOTE: Only the SSSI channel is shown. Other watercourses/tributaries have been omitted.

**Figure 1** Location of study area

1.12 Whilst the hydrological regime of the Wensum is that of a groundwater fed river, water management and artificial drainage significantly affect the levels of water and flow in the catchment. The current river channel is the product of a long history of modification and management. Since clearance of the floodplain forests for settlement and agriculture approximately 4,500 years ago, sections of the post-glacial meandering and sometimes anastomosing channel were straightened and dredged, diverted, impounded and embanked. For many centuries, the waters of the Wensum have been harnessed to provide power for water mills and, whilst there are no working mills remaining, 14 mill structures are still present along the course of the river. Anthropogenic influences have had a dramatic effect on the ecology and hydrology of the River Wensum, in particular at sites up and downstream of mill structures, sites affected by excessive silt ingress, sites that are heavily maintained and sites that lack natural riparian vegetation.

## Project objectives

1.13 Jeremy Benn Associates Consulting (JBA) was commissioned by English Nature (now a part of Natural England), in October 2005, to produce an outline restoration strategy and vision for the River Wensum SSSI. The wider project objectives have been developed through a project steering group. These included:

- Development of the River Wensum Restoration Strategy for the whole of the SSSI (this report).
- Development and implementation of reach based delivery plans, including consultation and involvement of stakeholder interests (to be undertaken as a separate exercise after completion of the strategy).

**Plate 1** Views of the River Wensum. Left: *Ranunculus* vegetation; Right: Winter flooding of grazing marshes

## Approach to the study

1.14 The approach used in producing the River Wensum Restoration Strategy includes:

- A review of all available information, including the following supplied primarily by Natural England and the Environment Agency:
  - River Rehabilitation Feasibility Study for the Wensum (Ecological Consultancy, 1999).
  - Water Level Management Plan for the River Wensum SSSI (Environment Agency, 1999 - currently being rewritten).
  - Macrophyte Survey of the River Wensum SAC (Centre for Aquatic Plant Management, 2002).
  - Condition Assessment, including River Habitat Survey (RHS) data (English Nature, 2002).
  - Conservation Objectives for the River Wensum (2002) and revised objectives in draft (2007).
  - Hydrological Model of the River Wensum and the Upper River Wensum Strategy Study (Babtie, Brown and Root, 2003 - hydraulic modelling completed by JBA Consulting).
  - Fisheries Action Plan for the River Wensum (Environment Agency, 2003).
  - River Wensum SAC Geomorphological Audit by GeoData Institute (completed in 2005), published in 2006 as English Nature Research Report 685 - A Geomorphological Appraisal of the River Wensum Special Area of Conservation. This document is referred to as the 'Geomorphological Appraisal' in the remainder of this report and data collected during the appraisal is referenced to GeoData (2006).
  - Broadland Rivers Catchment Flood Management Plan (JBA, ongoing).
  - Previous river restoration or flood risk management works undertaken in the River Wensum catchment and, where relevant, management works undertaken on other chalk rivers.
  - In addition, consideration has been given to the UK Common Standards Monitoring guidance, the Strategic Environmental Assessment Directive and the principles of the Water Framework Directive (WFD).
- On-going consultation with the River Restoration Centre (RRC) and steering group members (Table 1).
- Development of an understanding of the characteristic geomorphology and habitat/ecological communities of chalk rivers.
- Mapping of current conditions in the Wensum and comparison to semi-natural conditions expected in Norfolk rivers (for example, relating to impounded reaches/silt accumulation, channel width and depth etc.).
- Site visits to relevant stretches of the River Wensum.
- An assessment of constraints that may curtail restoration plans.

- A review of reaches and restoration measures proposed in the Geomorphological Appraisal.
- Collation of all data related to each reach and at each mill structure site and recording of data, decision rules and recommendations for restoration in summary tables.
- The placing of each River Wensum Restoration Strategy reach into an approximate cost band and identification of potential sources of funding.
- Initial consultation with 'key' local individuals (stakeholder names supplied by the Steering Group).
- Technical report production.

1.15 The strategy has been developed without detailed scenario modelling (that is, without use of the Upper Wensum Strategy (2003) flood model). However, modelling will be necessary during the development of reach based restoration schemes.

**Table 1** Steering group members and advisors

| Organisation | Steering Group Member | Title |
|---|---|---|
| English Nature/ Natural England | David Withrington | Senior Freshwater Officer |
| | Richard Leishman | Conservation Officer, Norfolk |
| Environment Agency | Rob Dryden | Technical Specialist, Fisheries Recreation and Biodiversity Team |
| | Phil Usher | Technical Specialist, Asset Systems Management |
| | Johanne Steward | Team Member 1, Flood Risk Management |
| Water Management Alliance (WMA) | Lou Mayer | Conservation Officer |
| | Tony Goodwin | Engineer |
| Jeremy Benn Associates (JBA) | Tony Green | Project Manager |
| | Anna Curini | Geomorphologist |
| DEFRA Rural Development Services/Natural England | Dougal McNeill (Advisor to steering group) | Wensum Catchment Sensitive Farming Officer |
| River Restoration Centre (RRC) | Martin Janes | RRC Centre Manager |
| | Jenny Mant (Advisors to steering group) | RRC Projects Adviser |

## Project outcomes

1.16 The River Wensum Restoration Strategy is presented in this technical report using a series of maps that are suitable for consultation. All maps are presented in A4 format in Appendix 11 at the end of this report to aid clarity. A summary map is provided to illustrate the changed vision for the River Wensum SSSI post-restoration. This map is linked to tables giving more detailed, reach-scale or site-specific information where necessary (Appendices 1 and 2, respectively). A brief ecological analysis is also provided to describe the expected benefits of the restoration measures to characteristic biological communities. A Microsoft PowerPoint presentation of the proposals was also produced and used during the initial consultation exercise with key stakeholders.

## Report structure

1.17 Section 2 of this report summarises the main findings of the Geomorphological Appraisal (GeoData, 2006) and goes on to analyse in more detail some of the main issues and problems in the Wensum catchment. Section 3 considers the baseline condition for restoration of the Wensum and explains the method used to develop the River Wensum Restoration Strategy. Given numerous parallel initiatives, schemes and strategies in the Wensum catchment, Section 4 describes where integration with these and the River Wensum Restoration Strategy may be both possible and beneficial to the strategy. Constraints to restoration within the River Wensum SSSI are discussed in Section 5. The last section in this technical report is key. It describes the strategy, its recommended timeframes, scales and plan of implementation. It also provides details of initial costs and potential sources of funding.

# 2 Catchment characteristics and issues

## Catchment characteristics

2.1 A comprehensive Geomorphological Appraisal of the River Wensum was conducted by GeoData (2006). This document provided a starting point for development of the River Wensum Restoration Strategy (refer to Appendix 3 for a summary).

2.2 The main characteristics of the catchment currently include:

- The River Wensum has a low energy, meandering channel as a consequence of its subdued relief and groundwater dominated hydrology (the base flow index at Fakenham and Costessey is 0.82 and 0.73, respectively). The flow regime is similar to that of a typical chalk stream, although the influence of overlying drift deposits is increasingly obvious downstream of Fakenham. Geomorphologically, the channel is classified as 'inactive'. Channel planform, long profile, cross sectional form, coarse bedforms and connectivity with the floodplain are relics of past processes from an earlier climatic regime, and, as a result, the river will not naturally recover to a pre-disturbance state.
- Typically, the soils of the upper catchment and valley sides are well drained and have been intensively farmed for arable crops, livestock and, more recently, outdoor pig units. On the floodplain, low intensity grazing has dominated as a consequence of the higher water table and the poor agricultural quality of this land. The floodplains are generally a mosaic of pasture, scrub, gravel pits (mainly disused but remaining as lakes), wetlands and scattered woodlands.
- Whilst important parts of the River Wensum floodplain are considered to be traditionally managed and relatively unmodified, the channel has been subject to a high degree of modification over the past 4,000 years. Water level management, the presence of water mills and an extensive drainage network have significantly affected levels and flows. Further modifications to the flow regime are related to abstractions (both surface water and borehole) and discharges.
- The influence of the mills is the most significant factor directly affecting the morphology of the channel. The mill sluices and their millponds generate stepped bed and water surface profiles that are steeper downstream of the mills and less steep in the ponded stretches upstream. Backwaters can be extensive at low flows.
- Activities such as channel dredging (deepening and widening), straightening and embankment building have also altered natural river channel form and process in the Wensum. Further, contemporary channel management (including weed-cutting) and land-use have modified the hydrology, sediment production and transport, and channel morphology. Only about 20% of the surveyed channel remains largely unmodified (for example, parts of the lower course of the Langor Stream, sections of the Wensum between Lenwade Mill and Attlebridge Hall, and downstream of Taverham Mill).
- A visual assessment of bed sediments in the Wensum suggests a dominance of fine silts and sand throughout the channel length and only short reaches of gravel substrate (mostly downstream of mills). Where semi-natural, the gravel bed and channel morphology are amongst the highest value conservation features on the River Wensum. The mill ponds are the main traps of fine sediment and their management will be an essential part of restoring the natural physical processes and related ecological communities in the catchment.
- Clay to coarse sand-sized sediments are the main materials entering the channel system and tend to be derived from the wider catchment, rather than from sources local to the channel,

such as the bed/banks of the river. Catchment sediment sources include runoff from eroding arable fields and pasture, roadside verges, heavily stocked floodplain meadows, pig farm units, and recently cleared drains. Points of ingress occur where runoff from the catchment surface intersects with the main channel, possibly via a drainage network or road system. These points include tributary confluences, field or road drains, footpath/tracks and runoff from hill-slopes. The main locations of sediment ingress to the river include the headwaters to Great Ryburgh, around Lenwade and around Taverham. However, there are many ingress points that have not been identified on the system of tributaries. The River Wensum is included in Defra's England Catchment Sensitive Farming Delivery Initiative. The objective of this initiative is to change farmer behaviour and control diffuse pollution, thereby improving riverine ecology.

- Natural processes of river channel narrowing and recovery of natural channel form in the Wensum are dominated by fine sediment deposition and the growth of aquatic vegetation. Lateral sediment accumulation and berm building is extensive along stretches of the River Wensum, and is often associated with dense stands of *Glyceria maxima*. Fine sediment deposition into the channel may actually provide a cost efficient resource for natural channel recovery, particularly in stretches that are over-wide but have not been over-deepened. However, an intensive maintenance regime would prevent or slow down this type of natural recovery.
- Conversely, the presence of emergent and submerged macrophytes in association with low flow discharges, degraded channel morphology and a high fine sediment load can result in excessive deposition in the channel and the infilling and blanketing of gravel substrate with fines. The maintenance regime must strike a fine balance.

# Summary of key issues

2.3 Information from the Geomorphological Appraisal, the Ecological Consultancy Habitat Survey (ECON, 1999) and the English Nature Condition Assessment (English Nature, 2002) were reviewed as part of this study. The main issues that are identified in these investigations and which must be addressed by the River Wensum Restoration Strategy include:

- Artificial long profile and barriers to fish passage at mill structures.
- Silt accumulation - especially upstream of mills.
- The over-wide nature of much of the channel, lack of diversity of velocity, flow structure and habitat.
- The over-deep nature of much of the channel, and loss of gravel bed material.
- The channel has been straightened and embanked along much of its length.
- The lack of aquatic, marginal, bankside and floodplain vegetation.
- Historical land drainage activities which have modified hydrology and silt ingress.
- Pollution.
- Depleted fisheries.
- The colonisation and spread of non-native species.

2.4 Some of these issues are discussed in more detail below.

# Mill structures and backwaters

2.5 There are currently 14 mill structures along the River Wensum (excluding Guist Mill which is currently flooded by the structure at Bintry) and the study area includes 13 of them. The final structure, New Mills, is downstream of Hellesdon and outside the boundary of the SSSI and so is not included in this study. However, it may still have an influence on the geomorphology of the reach above and can influence water levels at Hellesdon.

2.6 The Geomorphological Appraisal highlights that the main changes to the morphology of the river channel took place between 1200 and 1900 at mill sites, including channel straightening,

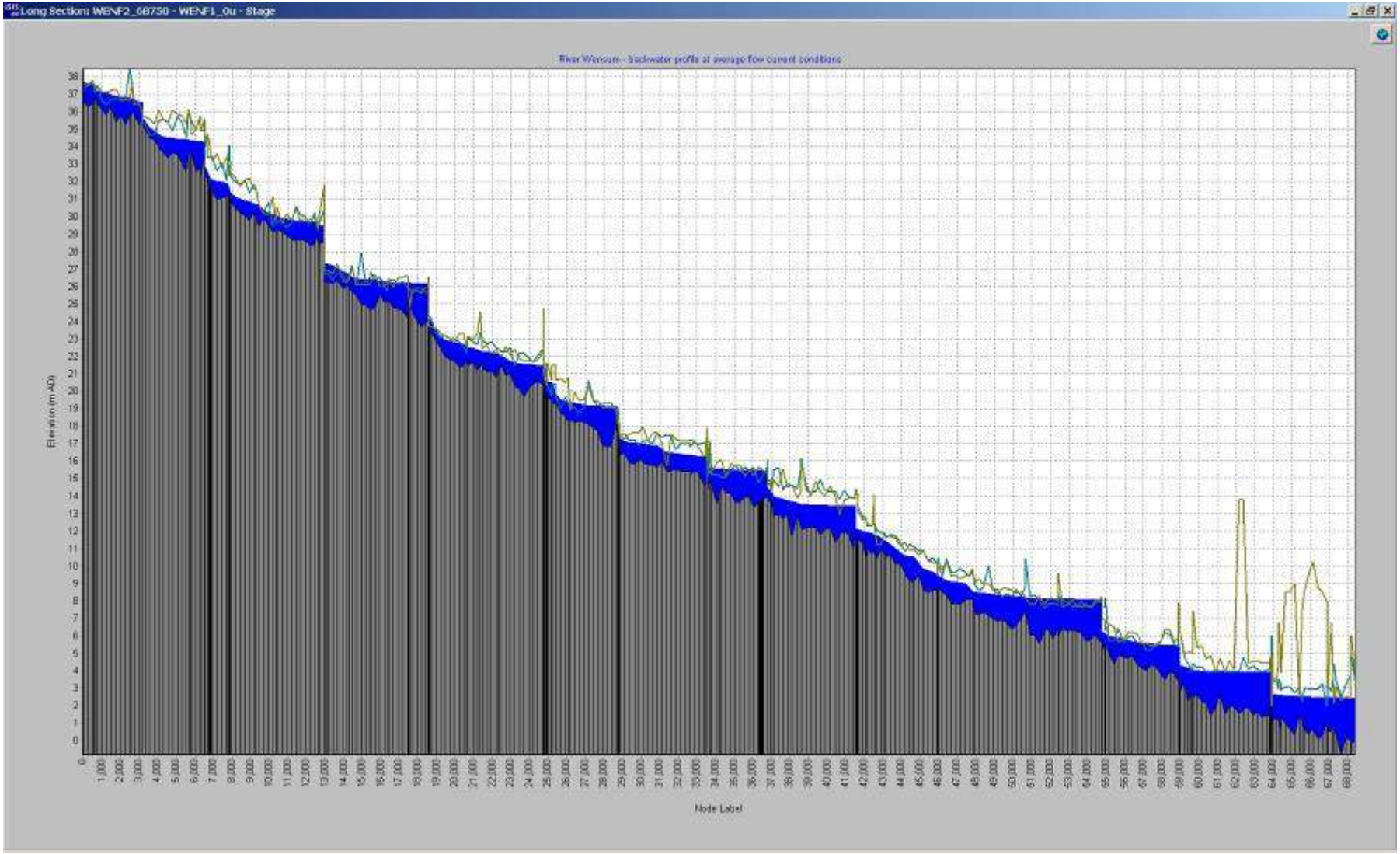
deviation, enlargement, impoundment and flood defence. The influence of mills on the River Wensum system is summarised in Appendix 3, including local changes to channel dimensions, flow velocity and sediment distribution.

2.7 Historically, working mills stored water upstream and used the head of water to drive water wheels or turbines. As a result, there were marked daily fluctuations in water levels upstream and downstream of the mills. Sediment was flushed downstream on a regular basis and was unable to accumulate in the mill dams. Further, structures at mills were opened during high flows to evacuate floodwaters. However, as the mills became outmoded, they fell into disrepair and were abandoned. Since then, mill owners have tended to operate sluices infrequently or keep them closed, thereby retaining constant high water levels upstream of the mill structures. The last of the mills ceased to operate by the end of the 1960s. As water levels do not fluctuate on a regular basis and silt ingress has significantly increased over recent decades, upstream mill ponds are characterised by sluggish flows and deep accumulations of sediment.

2.8 Fine sediment accumulation can have a negative impact on the ecological communities upstream of the River Wensum mills (for example, through the infilling of spawning gravels). There are additional detrimental impacts to channel aesthetics, recreation/angling interests and flood risk management.

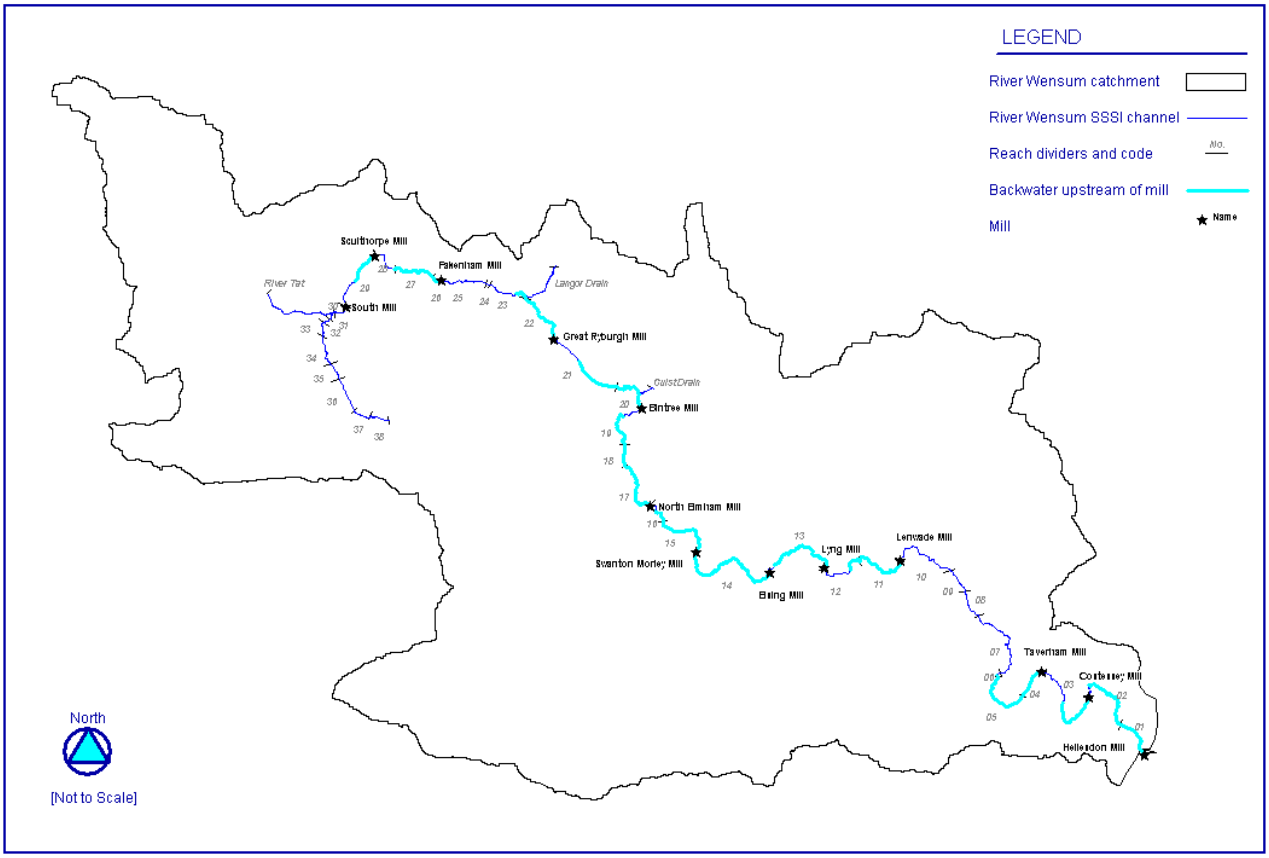
2.9 The extent of the influence of mill backwaters on the Wensum has been investigated further as a part of this study. The backwater from mills was assessed using the ISIS model developed originally for the Environment Agency for flood investigation in the Upper River Wensum Strategy Study (2003; Figure 2). This was used to determine backwater lengths upstream of the main mill structures given an average flow. No information was available to assess backwater at South Mill at the upper end of the catchment as this is beyond the Main River limit of the Environment Agency. The structure at this location is known to be a small sill across the bed and, as the river becomes steeper in the upper catchment, any associated backwater is assumed to be negligible.

2.10 Out of a total fall in water head along the Wensum of 34.2m (from above Sculthorpe Mill to downstream of Hellesdon Mill), 60% of the drop occurs at mill structures, rather than occurring progressively along the channel. The result is a stepped profile, with impounded reaches upstream of mills and short, steeper reaches downstream. Between Shereford and Hellesdon, 67% of the River Wensum (45.7km) is affected by backwater conditions (Figure 3 and Table 2). Due to the relatively small distance between many of the mills, there is an almost uninterrupted impoundment of river channel between Sennowe Hall (upstream of Bintry Mill) and Lenwade. The longest stretch of river with no backwater effect is between Lenwade and Ringland. This is because the distance between Lenwade and Taverham mills is relatively large (13.2km) and the channel is able to recover and maintain a more naturally functioning regime downstream of Lenwade before being influenced by the ponded water upstream of Taverham Mill.




Note: Grey area is bed level; blue area shows water level at average flow; green lines represent top of banks.

**Figure 2** Long profile of the River Wensum showing average flow




Note: For larger version of this figure (A4-size), refer to Appendix 11 at back of this report. Derivation of reaches is described in Sections 3.10 - 3.11 of this report

**Figure 3** Extent of backwater effect upstream of mills

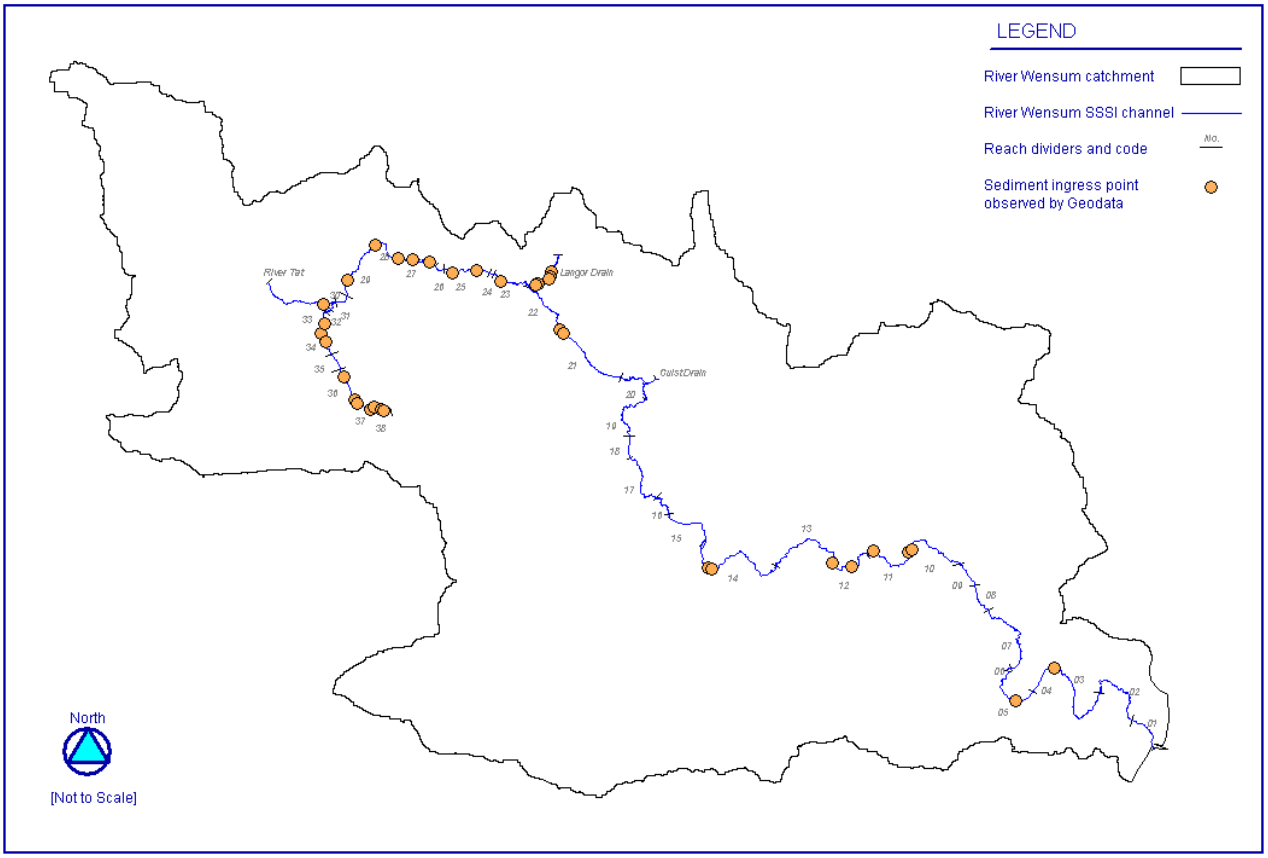
**Table 2** Drop in head of water and backwater length at mills

| Structure | Length of channel to mill upstream (km) | Drop at structure (summer flows) (m) | Backwater length (km) | Backwater length (as % of length of channel to mill upstream) |
|---|---|---|---|---|
| New Mills | 4.50 | 1.95 | 4.50 | 100% |
| Hellesdon Mill | 5.00 | 1.21 | 4.35 | 87% |
| Costessey Mill | 4.00 | 1.10 | 2.25 | 56% |
| Taverham Mill | 13.23 | 1.41 | 4.33 | 33% |
| Lenwade Mill | 5.02 | 1.50 | 3.16 | 63% |
| Lyng Mill | 3.25 | 1.50 | 3.25 | 100% |
| Elsing Mill | 5.00 | 1.85 | 4.71 | 94% |
| Swanton Morley Mill | 3.66 | 0.64 | 3.17 | 87% |
| Elmham Mill | 6.34 | 1.90 | 5.25 | 83% |
| Bintry Mill | 5.48 | 1.88 | 4.09 | 75% |
| Great Ryburgh Mill | 6.57 | 2.91 | 3.02 | 46% |
| Fakenham Mill | 3.52 | 1.22 | 2.20 | 62% |
| Sculthorpe Mill | 2.69 | 1.16 | 1.44 | 53% |
| **TOTAL** | **68.25** | **20.23** | **45.72** | **67%** |

# Catchment and bed sediments

2.11 A second major issue to be highlighted in the Geomorphological Appraisal report was the extent of sediment ingress into the channel and the accumulation of fine silt in the channel, especially upstream of mill structures.

2.12 Figure 4 shows locations throughout the catchment where the Geomorphological Appraisal identified points of sediment ingress into the river channel. The main sources of sediment are the headwater reaches of the river, where the floodplain is relatively narrow and unable to act as an adequate buffer between the arable fields and the river, and at the confluence with some of the tributaries. Silt from the tributaries is transported from their own headwaters and, in the case of smaller water bodies, can also be derived from direct runoff into the channel from the surrounding land. It is also apparent that during rainfall events, the road network becomes an extension of the drainage system that can act as a conduit for the transportation of sediments between wider catchment sources and the Wensum or its tributaries. Sources and points of entry are summarised in Appendix 3. Overall, fine sized sediments are the main source of materials from the catchment.




Note: For larger version of this figure (A4-size), refer to Appendix 11 at back of this report. Data from GeoData (2006).

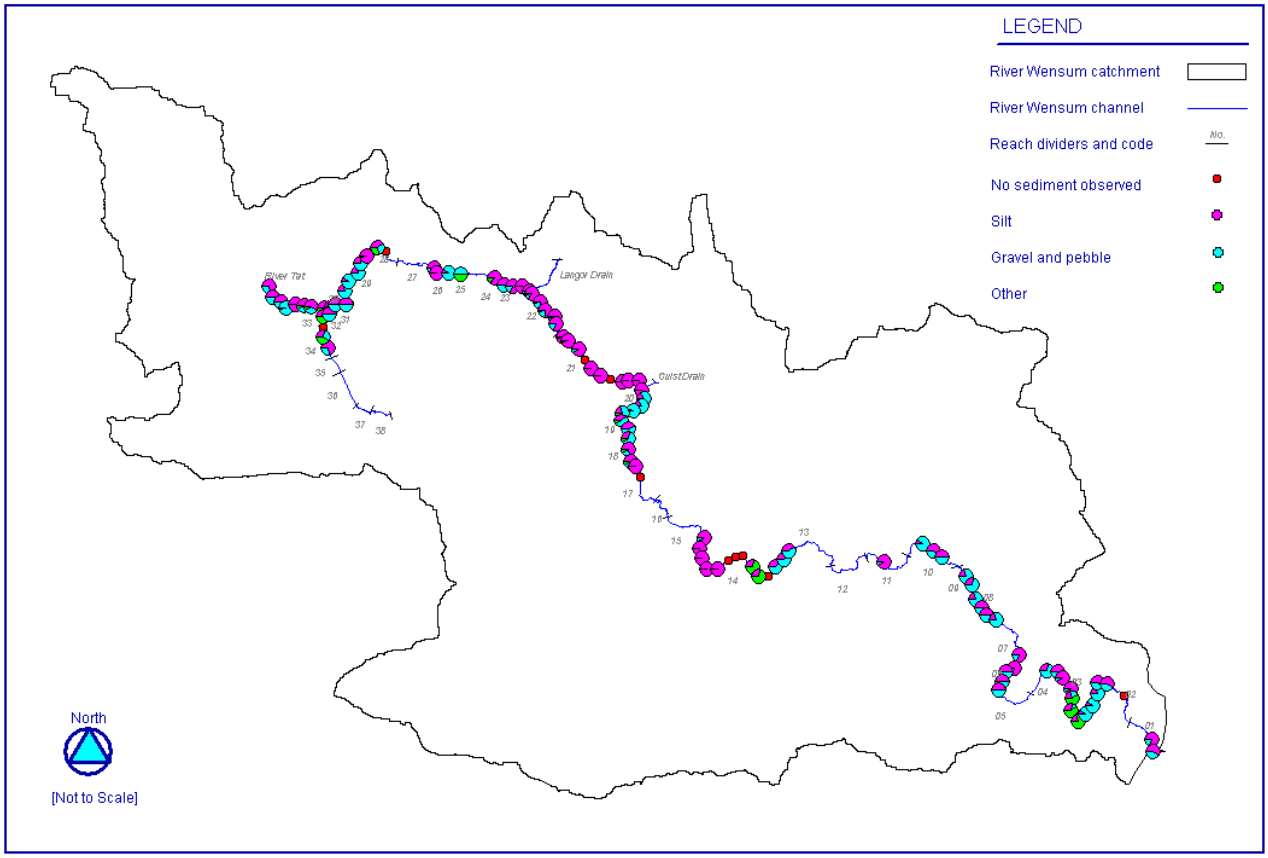
**Figure 4** Sediment ingress points

2.13 The Water Level Management Plan for the River Wensum SSSI (Environment Agency, 1999) stated that annual maximum concentrations of suspended material in the river have increased threefold since recording began in 1977. The reasons cited (after Boar, 1994) include:

- The cessation of milling in the 1960s, which would have 'flushed' silt through the system.
- The cultivation and drainage of floodplain grassland, which has increased inputs of fine silty sediments to the river.
- Surface drainage from roads, housing and other developed areas.
- Sand and gravel working on the floodplain.

2.14 More recent information from the Geomorphological Appraisal suggests that large volumes of silt enter the river from the upland catchment. This silt can be transported considerable distances before being deposited in the river channel.

2.15 In Figure 5 the types of bed sediment observed during the macrophyte survey (2002) are shown. Many locations appear to be predominantly silty, such as along the River Tat and between Fakenham and Elsing, although there are areas where the bed was composed largely of gravel (downstream of Sculthorpe, Fakenham, Bintry and Elsing mills and in the free-flowing stretch downstream of Lenwade Mill). It is to be expected that sediment (particularly fines) is mobilised by high in-bank flows in a natural river. However, where velocity is reduced by ponding (for example, upstream of mills) deposition will occur and will be a significant factor affecting the condition of the river.




Note: For larger version of this figure (A4-size), refer to Appendix 11 at back of this report. Data from Macrophyte Survey (2002).

**Figure 5** Bed sediment types

# Channel dimensions

2.16 A third major issue to be highlighted in the Geomorphological Appraisal was the generally over widened and over deepened cross-sectional area of the river channel throughout the catchment. A long history of channel dredging and annual maintenance, including weed-cutting, has increased the width and depth of the channel beyond natural dimensions. Related problems include uniformity of channel form, loss of riverside vegetation (for example, trees) and a loss of both flow and habitat diversity. Further, an increase in channel cross-sectional area also results in a reduction in flow velocity, encouraging an increase in fine sediment deposition. This, in combination with the removal of relic gravel bed materials during dredging, has reduced the extent of the ecologically valuable gravel substrate and glide/riffle features that are characteristic of chalk rivers and which are required as spawning and feeding grounds for a number of the fish species that are native to the Wensum. Appendix 4 includes an account written by a local resident to describe changing maintenance and channel regimes and their perceived impacts on the Wensum fisheries since the 1950s.

2.17 Widths and depths in a river obviously vary with the flow rate. In the analysis completed here, channel size refers to ‘bankfull conditions’. This is a standard reference point that is typically used in geomorphological analysis. Knighton (1998) states that it is reasonable to suppose that natural river channels are adjusted on average to a flow that just fills the available cross section. This flow is also known as the dominant discharge, or the discharge that performs the most work by transporting the most sediment, and it is often given morphological significance by equating it to the bankfull flow. Leopold et al. (1964) found that the frequency of bankfull flow is approximately once every 1.5 to 2 years.

## Width

2.18 Quantitative data on bankfull channel widths were collected at spot locations in each reach assessed during the Geomorphological Appraisal. Widths were found to be highly variable (between 5m and 50m). The Geomorphological Appraisal also provided a regression curve relating catchment area to bankfull width in semi-natural channels in Norfolk. However, this curve is only applicable for areas in the mid to upper catchment. As part of this study, options for a reliable predictor of natural channel width throughout the Wensum catchment were investigated further.

2.19 Equation 2.1 after Soar (2000) was chosen for use in this study for a number of reasons. It provides a relationship between median annual maximum flood (QMED) and bankfull width and it is suitable for use in UK gravel bed rivers. QMED is regarded as a better indicator of bankfull flows than catchment area. Further, the equation produces a range of width values (that is, within error bands based on channels with both erodible and resistant bank materials, where resistant materials include those with high clay content or banks that are resistant as a result of the root strength provided by bank-side vegetation). This allows for natural variability in the channel width at the reach-scale and highlights that any relationship between flow and channel dimensions should only be viewed as indicative. For instance, a variation of channel width of around 35% can be expected within a meander bend.

**Equation 2.1**

$$w = (2.48 + 1.27V)\, Q^{0.5}\, e^{\pm 0.051}$$

where:

w = bankfull width (m)

V = 1 (banks grass lined with less than 5% tree/shrub cover) or

0 (bank tree lined with at least 5% tree/shrub cover)

Q = median discharge ($m^3/s$)

e = exponential.

2.20 Figure 6 illustrates the regression curve provided by the Geomorphological Appraisal. This is compared with the relation of Soar (2000) for resistant and erodible banks. The Geomorphological Appraisal curve falls between the two Soar curves but tends to an unrealistic, constant value at higher flows. The semi-natural widths recorded in the ECON (1999) survey of the Wensum channel compare well with the Soar (2000) curve for resistant banks.

2.21 Figure 7 shows the extent of narrowing that is required along the River Wensum to return bankfull widths to a more natural condition. Given that chalk streams generally have a large width to depth ratio compared to other UK gravel bed rivers, these requirements are based on width calculations for banks with erodible materials. Initial calculations in the River Wensum and River Tat suggest that approximately 65% of the channel requires less than a 5m reduction in width, 21% requires between 5 and 10m reduction and 14% more than a 10m reduction to return it to an average semi-natural condition. Narrowing requirements are greatest upstream of mills, though some degree of narrowing is generally required throughout the length of the SSSI (Figure 7).

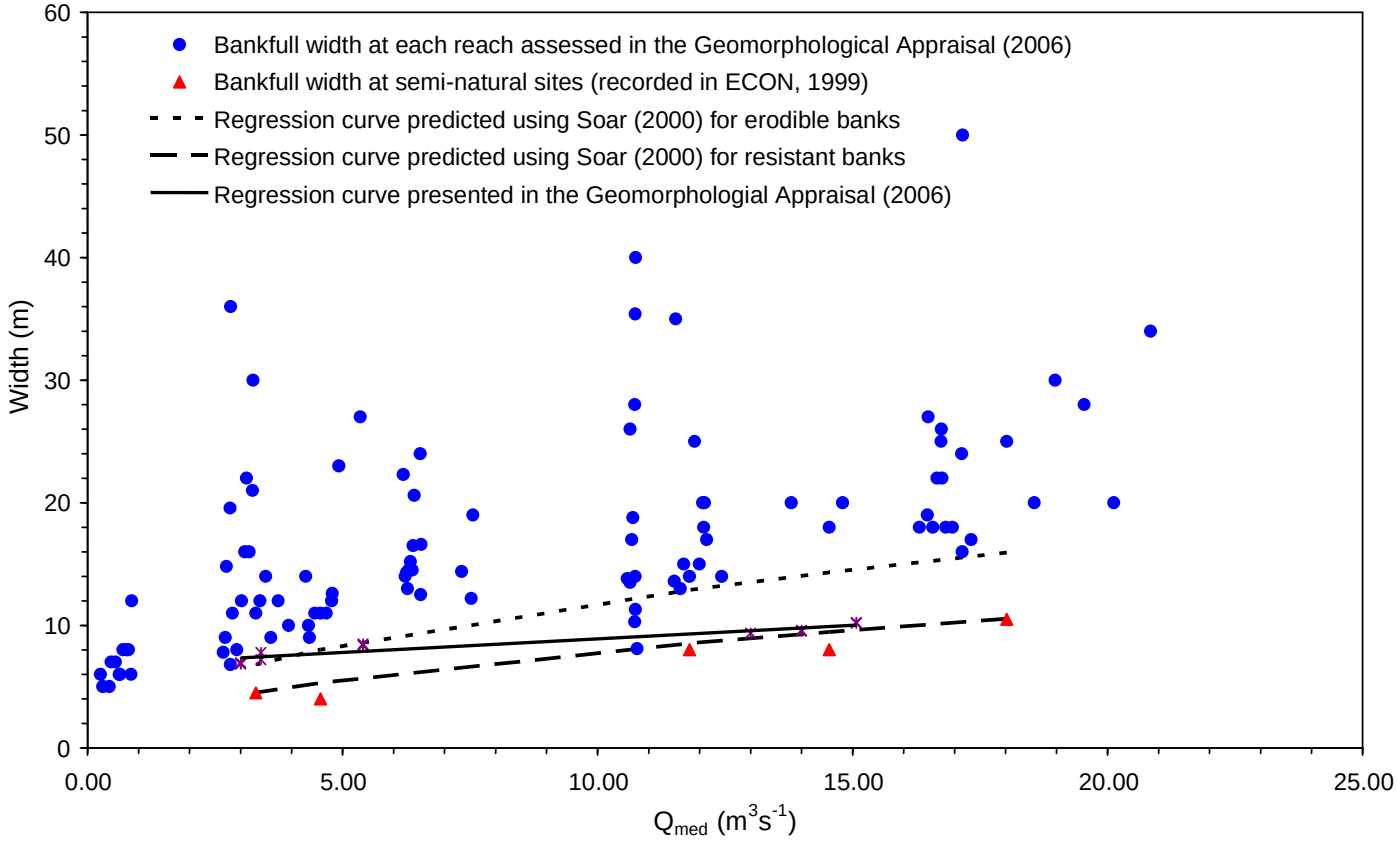
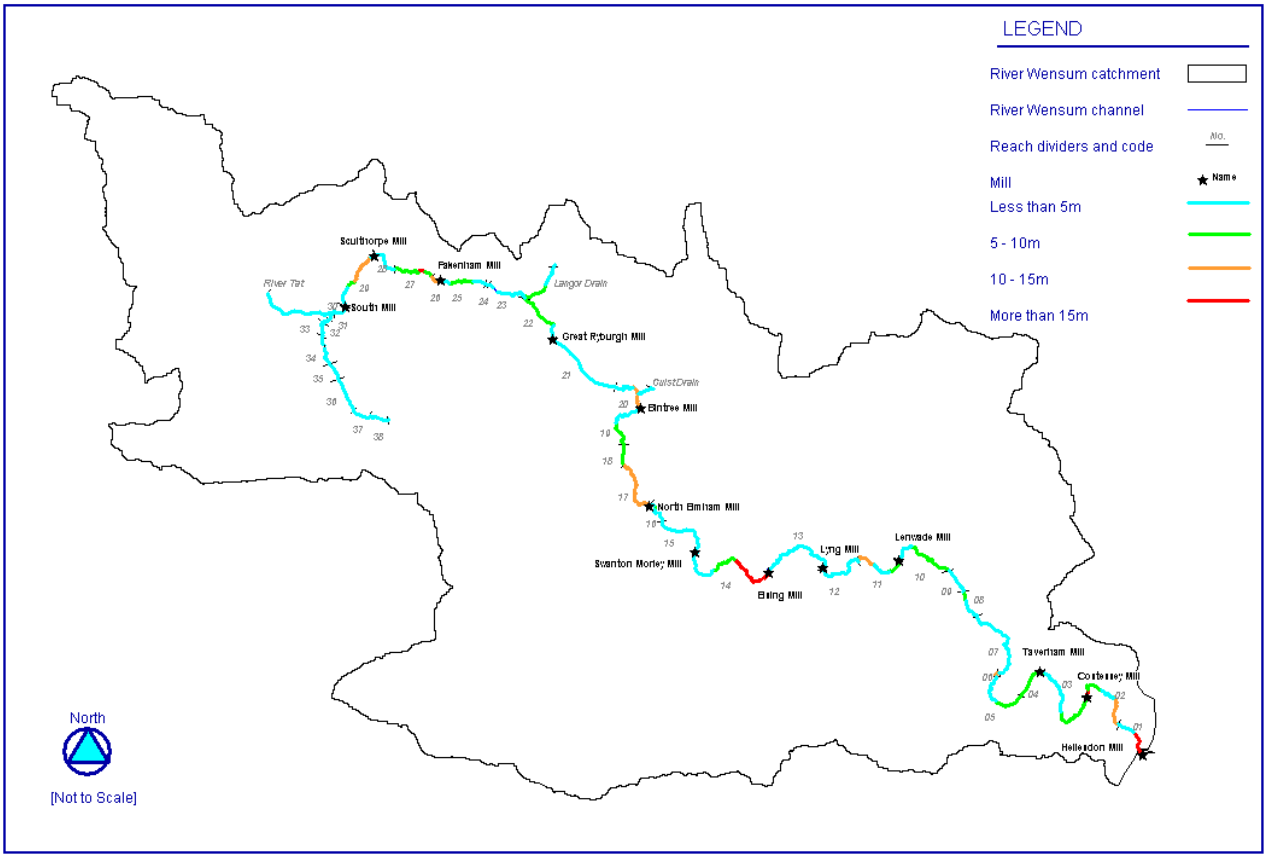



**Figure 6** Width of semi-natural lowland rivers in Norfolk

2.22 Provided that they are not removed during maintenance activities, fine sediment deposition occurs along the margins of over-widened sections of the River Wensum. The growth of marginal plants on these silt berms can help to further consolidate them due to fine sediment accumulation around the base of the plants. In turn, this has, in certain locations, narrowed the channel through natural processes. The best developed berms have previously been recorded between Great Ryburgh and North Elmham, and between Taverham and Hellesdon. The timescale of narrowing is not known in great detail on a catchment basis but anecdotal evidence suggests that a 5m wide berm may take between 10 to 15 years to develop and that they are often vegetated with *Glyceria maxima*. A record of vegetated sediment berm locations observed during the Geomorphological Appraisal is shown in Figure 8. It should be noted that, if the channel is overly deep as well as overly wide, the berm will sit within a two-stage channel. The top of the berm will stabilise at the approximate level of a two year return period or bankfull flow level but will sit below the current bank top as the channel is artificially incised due to past river engineering.

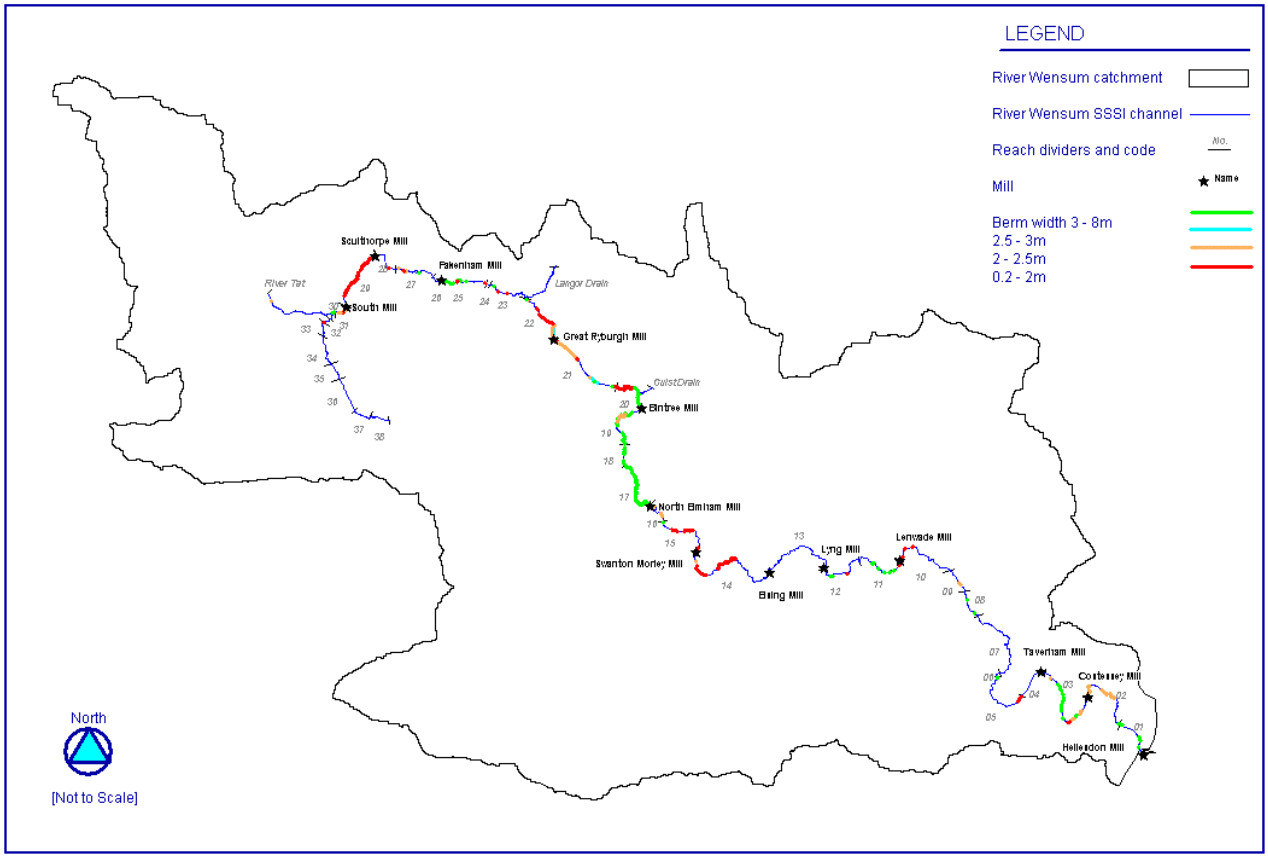



Note: For larger version of this figure (A4-size), refer to Appendix 11 at back of this report.

**Figure 7** Approximate bankfull channel narrowing requirements for the River Wensum SSSI

## Depth

2.23 Quantitative data on channel depth recorded in the Geomorphological Appraisal was related to depth of flow on the day of survey rather than bankfull depth, as the values provided were relatively small and did not vary significantly throughout the catchment. The ISIS flow model generated by JBA during the development of the Upper River Wensum Strategy Study (2003) was used to estimate current maximum bankfull depths at key locations (using bankfull elevation minus the lowest elevation on the bed in each cross section). Comparison of this data with a regression equation for bankfull depth in UK rivers was not possible without more detailed information regarding bed material gradation, including sediment size distribution and an average sediment size (Hey and Thorne, 1986). Instead, the Manning equation was used to provide predicted bankfull depth values (Equation 2.2). Given that chalk streams generally have a large width to depth ratio compared to other UK gravel bed rivers and, therefore, tend to be relatively shallow, these depths are based on width calculations for banks with resistant materials. It is believed that this approach is appropriate and likely to have a greater certainty than typical regression relationships that have been established elsewhere.




Note: For larger version of this figure (A4-size), refer to Appendix 11 at back of this report. Data from GeoData (2006).

**Figure 8** Location of vegetated sediment berms

**Equation 2.2**

$$d = (Qn/ws^{0.5})^{3/5}$$

where:

d = bankfull depth (m)

w = bankfull width (m), as predicted from Soar (2000)

n = Manning resistance coefficient (m) from ISIS model

Q = median discharge ($m^3/s$)

s = bed slope from ISIS model.

2.24 Estimated depths derived from the ISIS model show that existing maximum bankfull depth ranges between 1 and 2.5m. While lesser bankfull depths tend to occur upstream, there is a high degree of variability in the data. In comparison with expected values, bankfull depth is generally much greater than would be expected in a natural regime channel (0.5 to 1.5m). At the upper end of the catchment, predictions suggest that bankfull depth should be about 0.7m. At the lower end of the catchment, bankfull depth should be about 1.7m (Figure 9).

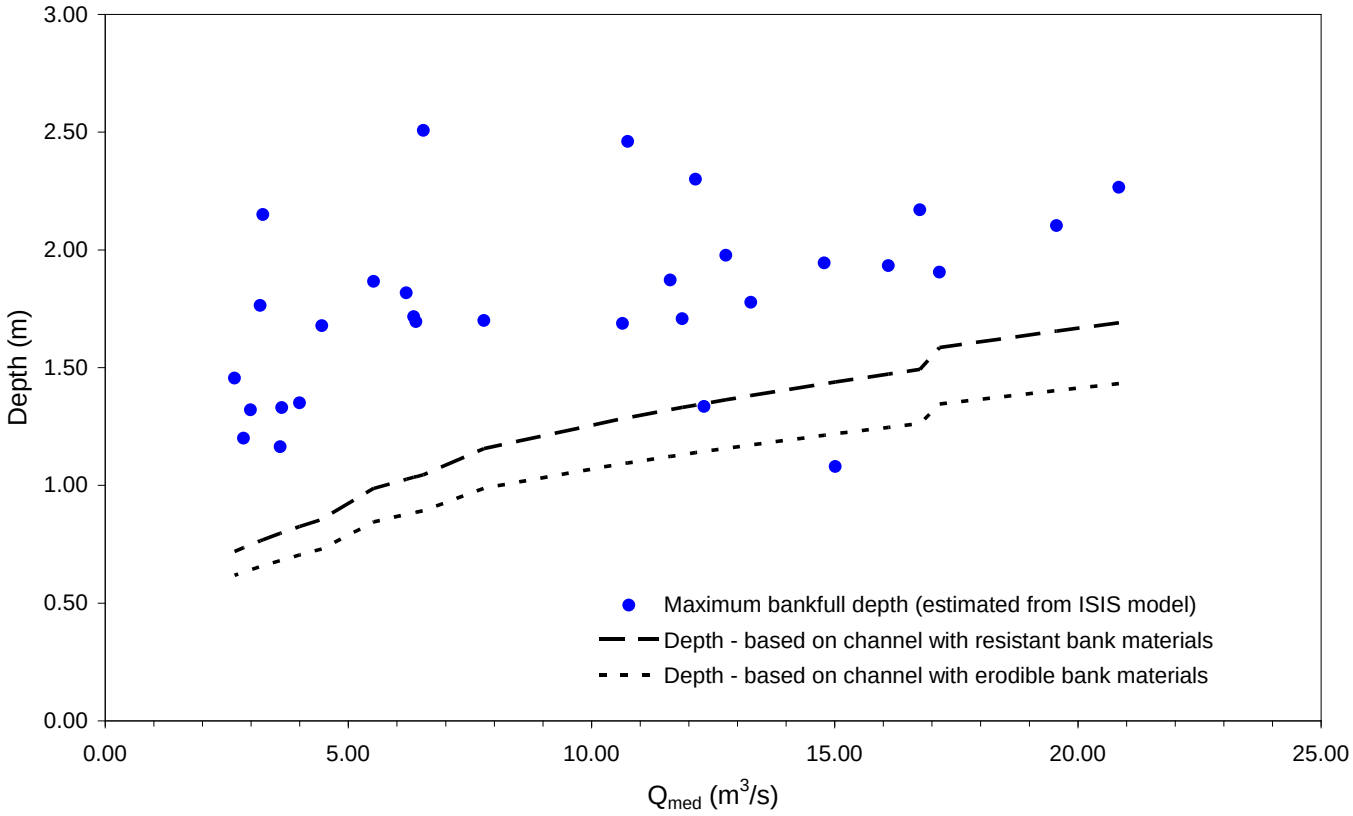


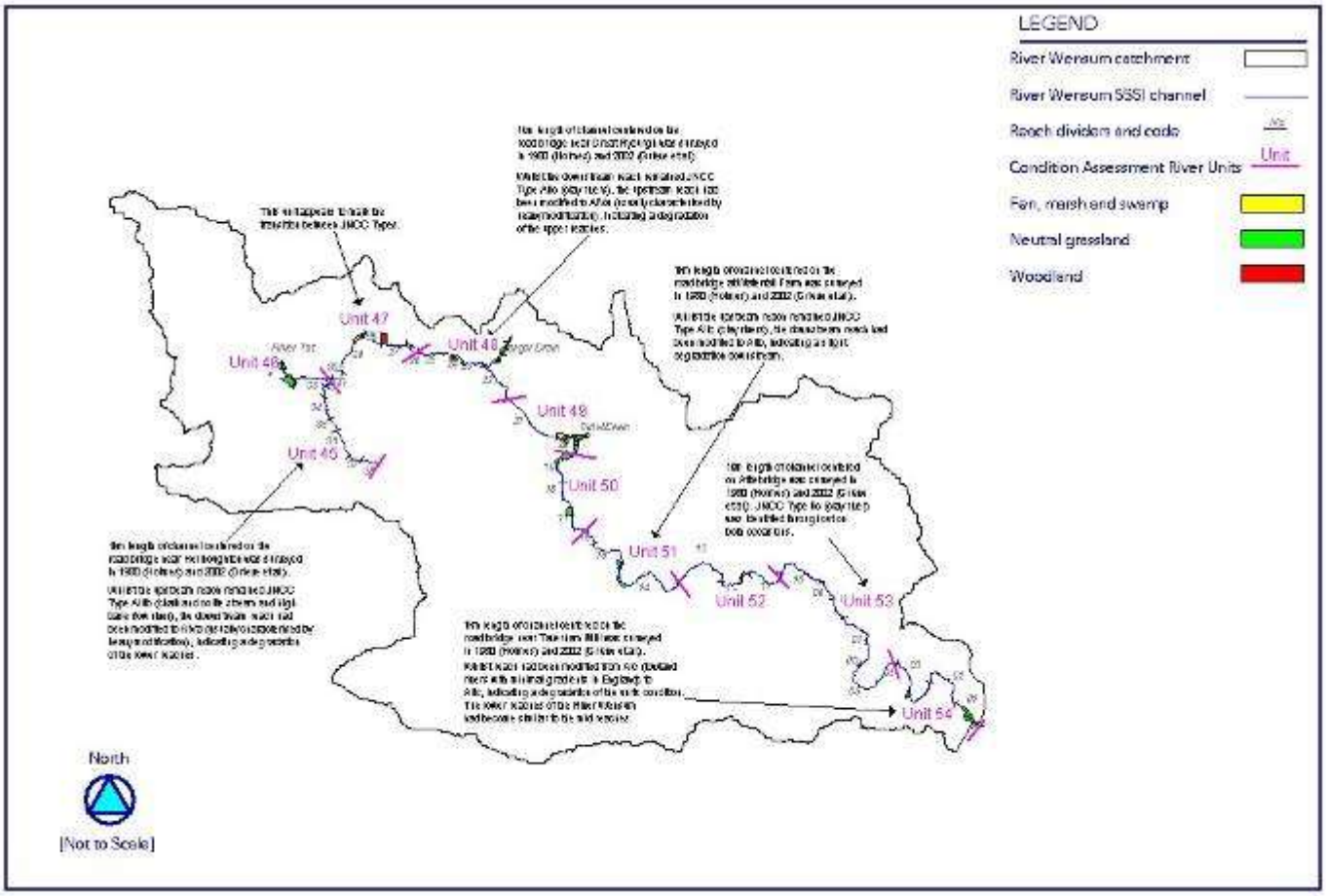

**Figure 9** Bankfull depth calculations for the River Wensum based on Manning equation

2.25 Comparison of the actual with the predicted bankfull depths suggests that relatively constant bed raising of about 0.5m is desirable throughout much of the River Wensum catchment. Any bed raising will need to be carried out using material of a size that could be transported in extreme events. Bed raising should include consideration of glide and riffle/pool features to ensure a suitable degree of channel heterogeneity. Further information on restoration techniques is provided in Appendix 5 of this report. Specific details regarding the location and design of gravel bed features will need to be considered during the implementation phase of the restoration strategy.

# Conservation value

2.26 In 1993, 393 ha of the River Wensum catchment (71km length of channel) were notified as a 'whole river SSSI'. The river was notified as 'an example of an enriched, calcareous lowland river … probably the best whole river of its type in nature conservation terms'. A detailed citation was drawn up by English Nature and is reproduced in Appendix 6. In terms of area, the majority of the River Wensum SSSI consists of floodplain land parcels (woodland, grassland and fen/marsh), with only 29% of the SSSI being river channel (Figure 10). Whilst, such floodplain land parcels would not individually merit notification, together they form an integral and dependent part of the river system.

2.27 In 2000, 382 ha of the River Wensum were submitted to Europe as a candidate Special Area of Conservation, the status of the site being confirmed as a Special Area of Conservation in 2005. For details of the designation see Appendix 7. The site supports five European features: Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation, white-clawed crayfish, Desmoulin's whorl snail, brook lamprey and bullhead. Whilst particular species may form part of the designation for a site, their requirements would normally only be catered for to an extent characteristic of the habitat type (Mainstone, 2006, Section 3). The ecological and environmental preferences of the European features of the Wensum SAC are described in Appendix 8.




Note: For larger version of this figure (A4-size), refer to Appendix 11 at back of this report. Data from English Nature (2002).

**Figure 10** Habitats and JNCC River Community Types

2.28 A condition assessment of the River Wensum SSSI was undertaken by English Nature in 2002 and a summary of the results is given in Table 3. Of the total SSSI area, only 41% was found to be in favourable condition. However, it should be noted that whilst much of the terrestrial habitat is in favourable condition, all river units are in unfavourable condition. The main reasons listed for adverse condition in non-river units include inappropriate scrub control, under or overgrazing and inappropriate cutting or mowing. These are issues that are being addressed through agri-environment schemes.

**Table 3** Percentage area of the River Wensum SSSI in favourable condition

| Habitat Type | Percentage area of each habitat type in a favourable condition | Percentage area of River Wensum SSSI in a favourable condition |
|---|---|---|
| Broadleaved, mixed and yew woodland - lowland | 32% | 2% |
| Fen, marsh and swamp | 50% | 8% |
| Neutral grassland - lowland | 63% | 31% |
| Rivers and streams | 0% | 0% |
| **Total** | | **41%** |

**Table 4** Condition of river SSSI units

| River Unit | Grid Reference | Location | European features | Siltation | JNCC Type | Water Quality | Access | Channel Structure | Biological Disturbance | Flow | Management |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 45 | 897238-875280 | Upstream Wensum to Tat confluence | U | U | U | U | F | F | F | F | F |
| 46 | 850288-875280 | River Tat from Broomsthorpe to Wensum confluence | U | U | - | - | F | F | F | F | F |
| 47 | 875280-918293 | Tat Confluence to Bridge Farm, Fakenham | - | - | - | U | - | - | - | - | - |
| 48 | To 963269 | To Great Ryburgh Mill | U | U | U | U | U | F | F | F | F |
| 49 | To 999242 | To Bintry Mill | U | U | - | - | U | U | F | F | F |
| 50 | To 003204 | To North Elmham Mill | U | U | - | - | U | U | F | F | F |
| 51 | To 050177 | To Elsing Mill | U | U | U | U | U | U | U | F | F |
| 52 | To 100181 | To Lenwade Mill | U | U | - | - | U | U | U | F | F |
| 53 | To 158138 | To Taverham Mill | U | U | F | U | U | U | U | F | F |
| 54 | To 199105 | To Hellesdon Mill | U | U | U | U | U | U | U | U | F |

NOTE: Condition F = favourable; U = unfavourable.

2.29 For the river units of river SSSIs to be regarded as being in favourable condition, targets on a number of basic attributes must all be met. A summary of the findings of the River Wensum SSSI river unit condition assessment (carried out in 2002) is given in Table 4. No river units of the River Wensum are currently in a favourable condition. Since the 2002 condition assessment, the Langor Drain has been recognised as a separate river unit (Unit 55).

2.30 In general:

- All units were in an unfavourable condition with respect to water quality (indications of eutrophication and, in many cases, high phosphate levels).

- All units were in an unfavourable condition with respect to siltation (with over 50% of the river channel comprising silt, reductions in coarse gravel substrate and no mechanisms in place to reduce soil erosion or silt ingress at that time). Particular loci for siltation were found to be Sennowe Hall to Bintry Mill (3.5km stretch of 100% silt cover), and Swanton Morley road bridge to Elsing Mill (4.5km stretch).
- In 1980, the River Wensum was surveyed by Holmes at 10 locations (along 1km reaches) to confirm the JNCC River Community Type (refer to Grieve et al. (2002) for information). The 1980 survey indicated that in its upper reaches it was dominated by JNCC Type III (lowland chalk and oolite rivers with generally stable flow regimes), with a transition downstream to JNCC Type I (lowland rivers with minimal gradients on mixed geology in England). During a repeat macrophyte survey (Grieve et al., 2002), a number of the reaches where these JNCC surveys were carried out were reassessed, which indicated that their condition had degraded at four out of the five survey sites. The lower reaches had become similar in type to the middle reaches (degraded from JNCC Type Ic to IIc) and the upper reaches had degraded from JNCC Type IIIb to IVa (base rich/neutral impoverished rivers, normally close to source).
- Access (artificial barriers to upstream migration) was poor at all but the most upstream units on account of the presence of mill structures.
- Channel structure was a mixture of modified and natural in all units. In downstream units the extent of natural channel features was poor, and impoundment, embankments and an over widened/deepened channel were increasingly evident.
- A lack of self sustaining fish populations and the invasion of non-native plant or animal species was increasingly problematic downstream.
- Flow requirements tended to be met 100% of the time in upstream reaches and 90% of the time in the middle reaches. However, there were major impacts on flow in the lower reaches as a result of the public water supply abstraction at Costessey.
- Overgrazing and poaching was not believed to be an issue in the SSSI, and in fact there is a tendency towards abandonment of floodplain pastures. The weed-cutting regime follows Environment Agency guidelines (agreed with Natural England) and all units were in a favourable condition with respect to management.
- The condition of the European SAC features was also considered unfavourable as a result of:
  - The dominance of JNCC Types IIb and IIc - upstream, many characteristic species of Ranunculus were absent or rare and there was a high frequency of algae and other negative indicators.
  - A predominantly modified river channel, although recovery is evident in some places from silt berms.
  - A high particulate load that, in combination with modified channel form and sluggish flows, has resulted in a predominantly silt dominated channel.

# Fisheries

2.31 Between 1940 and the 1970s, the River Wensum had a national reputation as a roach fishery. Phase I of the ECON study (Perrow and Punchard, 1998) concluded that there has been a major modern decline in the abundance of a number of native fish species in the river (for example, roach, dace, perch and trout). Failure to recruit was identified as the prime cause of decline, and this was attributed to:

- Sedimentation of spawning gravels - this particularly affects dace, brown trout, brook lamprey and bullhead, all of which are lithophilous (gravel spawning).
- Increased concentrations of ammonia and nutrients.
- A reduction in the complexity/diversity of habitat - the co-existence of a number of fish species, whose habitat requirements alter with life stage and season, depends on habitat complexity.
- A reduction in the number and quality of nurseries for larvae and fry (backwaters, structurally diverse dykes and side streams, as well as marginal and submerged macrophytes).

2.32 Where habitat quality is a limiting factor, large species such as chub dominate (they have expanded their population and range and now dominate the middle/lower reaches of the river). There has been widespread concern, amongst anglers, fisheries specialists and members of the Norfolk Anglers Conservation Association (NACA) that the value of the Wensum fishery continues to decline.

2.33 For this reason, the River Wensum Fisheries Action Plan group was established by the Environment Agency as a mechanism to address fisheries related issues, and to involve stakeholders in this process. Increasing physical habitat diversity is seen as one of the best ways of improving the quality of the fishery. Methods to achieve this and associated benefits include:

- The creation of gravel glides/riffles - used as foraging and spawning habitat. These provide flow diversity (including slack flow of use to fry as resting sites when moving upstream) and, hence, habitat diversity. An added advantage is that the bed becomes self-flushing due to local shallowing (and, therefore, greater stream power), so is kept free of silt and aerated, thereby enabling species with a higher water quality preference to colonise.
- The rehabilitation/creation of marginal features to provide shelter (nursery and refuge habitat, particularly for juvenile fish), temperature gradients and flow diversity. Improvements to river margins, such as development of wetland plant communities, more extensive plant cover and interaction with the river channel, also help to improve channel habitat as a more diverse range of ecological niches are created.
- The creation of off-river supplementary units - provide fish fry with cover, food, warmth and refuge from high velocity flows and predators.

2.34 The creation of gravel glides/riffles, the rehabilitation/creation of marginal features and the creation of off-river supplementary units are all compatible with Natural England's objective of restoring the river to favourable condition.

2.35 River restoration is a key objective in attempts to establish a self-sustaining population of barbel but it should be carried out so as to recreate river channels with a form and function that are characteristic of a chalk river in Norfolk.

# 3 Baseline for restoration

## Defining restoration

3.1 Restoration is defined as, “restoration of channel processes and forms to pre-disturbance conditions” (GeoData, 2006, Table 6.1). However, the objective of the River Wensum Restoration Strategy is not to restore the river to a form that was characteristic of a particular point in time. This would be unrealistic given the complex and lengthy history of anthropogenic changes in the River Wensum catchment and the cultural, heritage and social values that continue to be associated with many of these changes. Rather, the objective is to restore as much geomorphological function to the river as possible, within current constraints, in order to provide the conditions necessary for chalk river habitats and characteristic species to flourish. The term ‘restoration’ is used in the River Wensum Restoration Strategy in the following ways:

- In the general sense, as an all-embracing term that defines the practice of returning the river channel to a more natural state. This includes activities such as re-meandering, rehabilitation, enhancement and assisting natural recovery in specific sections or reaches of channel.
- In the more specific sense, restoration means re-creating form and function along a previous/original course of the river (for example, such as by moving the river from its existing course to a previous, more natural course).

3.2 To date there has been a relatively ad hoc approach to habitat restoration on the River Wensum. Several relatively small scale schemes with varying objectives and methods have been implemented by a number of interested parties, including the Environment Agency and NACA, as and when opportunities arose. The existence of the River Wensum Restoration Strategy will provide a more integrated approach to management of the river as a whole and will ensure that future restoration schemes developed at the local scale bear the catchment-scale objectives in mind. It will allow agencies, land owners or fisheries managers to initiate restoration schemes that are in keeping with the overall strategy.

## Reference condition

3.3 The aim of the River Wensum Restoration Strategy is to deliver a vision for restoration that can move the River Wensum from its current modified state towards a more naturally functioning and ecologically sustainable system. The channel must be restored to an appropriate river type or reference condition. This will encourage natural processes, including the creation of a self-regulating and dynamic river channel that minimises management interventions but maximises habitat diversity.

3.4 The English Nature/Environment Agency proposed guidelines for the restoration of physical and geomorphological favourable condition on river SSSIs in England (2005) assumes that, generally, an increase in physical naturalness and a reduction of morphological modification will improve ecological conditions. To this end, the Geomorphological Appraisal attempted to define naturalness for the River Wensum catchment using the broad river type, ‘groundwater dominated river flowing from chalk geology with overlying glacial deposits’. A summary of the reference reach conditions and management implications suggested in the Geomorphological Appraisal is provided in Appendix 3. Reference conditions for chalk streams are also discussed in the Chalk Rivers Handbook (Mainstone, 1999). Further, Mainstone (2006) summarises characteristics, physical impacts and benefits of restoration in lowland, low gradient rivers (JNCC Type I) and chalk rivers (JNCC Type III).

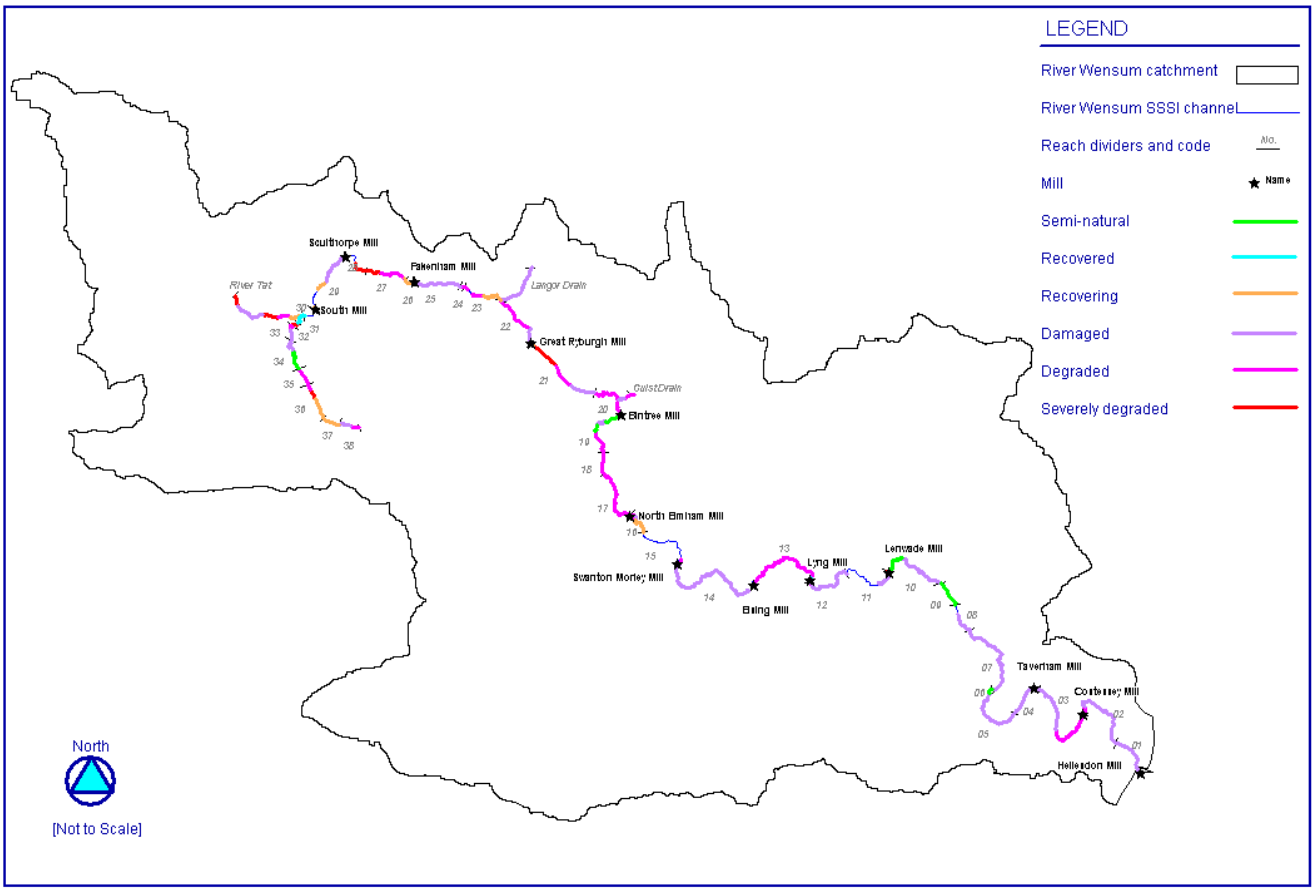
3.5 The main points to note with regard to chalk rivers are as follows:

1) Under natural circumstances, UK chalk rivers would have an anastomosed planform (multiple channels) running through a floodplain dominated by carr and fen habitat. Due to a lack of coarse sediment supply and stream power, they would have a relatively impoverished geomorphology compared to other UK gravel bed rivers, although relic gravel bed forms would have been inherited from glacial and peri-glacial geomorphology, providing suitable habitat for salmonid spawning.
2) A pragmatic reference condition (low anthropogenic impact) for chalk river catchments that inherently have low hydraulic energy is that of a meandering channel with a relatively high width to depth ratio (fairly shallow), a high occurrence of gravel substrate (that is, low silt content) and glide habitat. In addition, the land-use on the floodplain should be low-intensity pasture (with a high water table and frequent winter inundation of the floodplain) and riparian fen.
3) Any lengths of channel that remain in fen and carr habitat should be conserved as natural expressions of the river type. Gravel shoals and riffles/pools are of high value (for example, for invertebrates and fish) and should be retained.
4) Finer substrates have their place in natural chalk river systems and they provide important habitat conditions for a range of species, including nursery habitat for the ammocoete larvae of the brook lamprey. Silt is expected to accumulate locally behind natural structures, such as logs and woody debris, as side berms and increasingly on the bed towards the lower end of the catchment. A reduced silt ingress from catchment sources and a relaxation of channel maintenance operations will ensure that silt is accommodated in the system naturally.
5) Key restoration measures in the River Wensum will be to remove or lower in-channel control structures (that is, weirs and sluices) to manage silt and to augment impoverished beds with gravel. These actions will assist in restoring characteristic bankfull water depths and current velocities and will reduce the silt content and continued accumulation of silt in upstream gravel bed substrates.
6) The shallow cross sectional profile and low scouring energy of the restored channel will encourage a specialist range of in-channel and marginal plants that are typical of the chalk river type and provide habitat conditions required by invertebrates and fish. These include water crowfoots (*Ranunculus* spp.), starworts (*Callitriche* spp.), water-cress *(Rorippa nasturtium-aquaticum*), brooklime (*Veronica beccabunga*) and water forget-me-nots (*Myosotis* spp). The mosaic of submerged plants and gravels will enhance scouring between the plant beds and will help ensure that the restored gravel substrate is flushed free of silt.
7) Marginal vegetation characteristically encroaches into the channel as flows recede from spring through summer, thereby reducing effective channel width and maintaining current velocities in the main channel. Over the winter this vegetation is scoured out and the process begins again in the spring.
8) Woody debris is considered an important characteristic of chalk rivers, as is the co-occurrence of a mosaic of wooded and open river margins. As chalk rivers have strong lateral connectivity into riparian areas, herbaceous plants should dominate due to high floodplain water tables and marsh habitat will also exist in open groundwater pools on the floodplain. Development of such a range of habitat types (exposed tree roots, woody debris/leaf litter, varying light and temperature regimes, riparian scrub, grazed/ungrazed margins etc.) should ensure a characteristic and highly varied species assemblage following restoration.

3.6 It must be noted that the River Wensum is not a typical chalk river catchment. It is overlain by deposits of boulder clay on higher plateau ground and glacial sands and gravels on the valley flanks. As a result, the reference condition of the River Wensum is not that of a classic chalk river type but of a ‘chalk river type in Norfolk’. Regression equations for bankfull channel dimensions (see Section 2) were based on observations of semi-natural reaches in the River Wensum catchment in order to deal with this issue.

# Geomorphological Appraisal - restoration proposals

3.7 The restoration plans proposed in this study build on those presented in the Geomorphological Appraisal, which divided the study length of river into just under 120 geomorphological reaches of varying length. Multi-Criteria Analysis was conducted at each to define indices of modification and naturalness (refer to Appendix 3 for details). The reaches were then classified by 'reach status' (natural, semi-natural, recovering, recovered, damaged, degraded, severely degraded, artificial), which were mapped in a GIS format. 80% of the channel was identified as being either damaged or degraded and no reaches were identified as being completely natural (Figure 11).




Note: For larger version of this figure (A4-size), refer to Appendix 11 at back of this report. Data from GeoData (2006).

**Figure 11** Geomorphological Appraisal reach status

3.8 The status of each reach was then associated with a 'reach management class' (protect and monitor, conserve and monitor, assist natural recovery, rehabilitation, enhancement, restoration - definitions provided in Appendix 3) and a short statement describing 'indicative restoration options'. The final output of the Geomorphological Appraisal was a summary table (Table 5) supported by a series of GIS map layers.

3.9 The Geomorphological Appraisal reaches included river sections at mills. Suggested management options at mills were generally to lower the level of the mill structures and integrate bed levels or management options up and downstream. The option to remove mill structures completely was only considered at Hellesdon, Taverham and North Elmham.

**Table 5** Example of River Wensum Geomorphological Appraisal output table

| | | | | | |
|---|---|---|---|---|---|
| W201 | Degraded | Rehabilitation | Fix sediment ingress points. Remove Taverham Mill Sluice. Augment gravel bed. | 32.5 | 22.5 |
| W202 | Damaged | Assist natural recovery | Fix sediment ingress points. Desilt reach. Remove embankments, narrow channel and establish wet woodland on floodplain/riparian margins. Raise bed levels once Mill level removed. (see ECON 1999) | 9 | 9 |
| W203 | Damaged | Assist natural recovery | Desilt reach. Narrow reach and augmentation of gravel bed. Establish wet woodland/riparian margins. (See ECON 1999) | 31.5 | 22.5 |
| W204 | Damaged | Assist natural recovery | Fix sediment ingress points. Remove embankment and narrow where possible. | 32.5 | 22.5 |
| W205 | Semi-natural | Protect and monitor | Initiate monitoring. | 27.5 | 22.5 |
| W206 | Damaged | Assist natural recovery | Narrow existing channel and raise bed levels using dredged materials where possible. Establish patchy wooded riparian margins. Option exists to create an asastomosed (multi-channel) river system along the possible former course of old river Wensum channels in the floodplain. Remove embankments. | 22.5 | 22.5 |
| W207 | Damaged | Assist natural recovery | Restore old course of Wensum along north bank downstream of Attlebridge following a boundary. Use dimensions from old channel to narrow existing channel and retain as anastomosed (multi-channel) with wet woodland and floodplain. Establish patchy wooded riparian margins. Remove embankments. | 22.5 | 22.5 |
| W208 | Damaged | Assist natural recovery | Reduce maintenance regime to allow narrowing. Use downstream old course as a guide to channel dimensions. Remove embankments. | 22.5 | 22.5 |
| W209 | Semi-natural | Protect and monitor | Establish riparian patchy wooded margin and reduce maintenance to allow woody debris to influence channel processes. | 27.5 | 22.5 |
| W210 | Damaged | Assist natural recovery | Fix sediment ingress points. Establish riparian patchy wooded margin and reduce maintenance to allow woody debris to influence channel processes. | 32.5 | 22.5 |
| W300 | Semi-natural | Protect and monitor | Initiate monitoring - replace fishery enhancement weirs with debris structures. | 19 | 9 |
| W301 | Semi-natural | Protect and monitor | Fix sediment ingress points. Initiate monitoring. Replace fishery enhancement weirs with CWD structures. | 31.5 | 22.5 |

Note: From GeoData (2006).

# Preparing the Restoration Strategy

3.10 Whilst the Geomorphological Appraisal provides a useful reference, there are some inconsistencies in its output. For instance, in Table 5, reaches classified as 'assist natural recovery' have indicative restoration options that range from 'reduce maintenance regime to allow narrowing' (w208) to 'restore old course' (w207). With the aim of making recommendations consistent on a catchment scale, the River Wensum Restoration Strategy has integrated the information provided by previous studies on the River Wensum catchment with information from the Geomorphological Appraisal, analysis of river section data, site visits and discussion with key stakeholders. The starting point was to collate all geomorphological, rehabilitation and restoration information provided in previous studies (mainly the Geomorphological Appraisal but also the ECON (1999) report). This information was used to reduce the number of reaches to 41 (38 on the River Wensum and one reach on each of the River Tat, the Langor Drain and the Guist Drain). To distinguish between Geomorphological Appraisal reach codes, the revised reach code numbers were prefixed by RWRS (standing for River Wensum Restoration Strategy). All information available for each reach was then summarised on 'reach summary sheets' (Appendix 1), including:

- Reach code and Geomorphological Appraisal codes.
- Location details (including map of reach).
- Current condition, including English Nature condition assessment (2002).
- Constraints.
- Previous works or recommended works.

3.11 Works at mill structures are a priority consideration since these will dictate the restoration requirements upstream and downstream. As a result, the reaches at mill structures are treated as separate entities in this study. Information relating to the mills is summarised and recorded on 'mill summary sheets' (Appendix 2), including:

- Ownership and heritage details.
- Type of water control structure, by-pass channels and operational details.
- Previous works or recommendations.

3.12 The assumption in the Geomorphological Appraisal that restoration of the River Wensum catchment does not necessarily include removal of all mill structures is upheld in this study. The mills represent an important part of the heritage of the Wensum valley and some of them have been in place for centuries. Restoration requires that the site-specific issues at each mill be identified and dealt with. All options for restoration have been considered, from re-instating disused structures to removal, lowering and by-passing.

# 4 Relationship between the River Wensum Restoration Strategy and other catchment initiatives, studies, schemes and strategies

## Introduction

4.1 The rich environment of the Wensum valley is highly valued and there are already a number of initiatives and projects that link with the restoration objectives. Through development of the River Wensum Restoration Strategy by a Steering Group that contains representative from key organisations, the principles and rationale adopted in the strategy have also been adopted in the development of other initiatives in the catchment. Many strategies are now moving forward together to deliver river restoration in the widest sense and multiple benefits can potentially be realised.

4.2 All river units on the River Wensum SSSI are currently regarded as being in unfavourable condition, and there are a wide range of adverse condition reasons relating to channel form, water quality and water quantity on which these river units currently fail. It is necessary for a range of Section 28G Authorities (defined in the Wildlife and Countryside Act 1981 as publicly funded bodies) to address these issues in the normal execution of their duties. The mechanisms that need to be put in place have been captured in English Nature's 'Remedies' Programme. The River Wensum Restoration Strategy is, therefore, linked with all the other mechanisms and must be integrated so as to dovetail with each of these other initiatives, including:

- Water Resource Management, including Broadland Rivers Catchment Abstraction Management Strategy (CAMS).
- The Environment Agency Review of Consents under Regulation 50 of The Conservation (Natural Habitats & c.) Regulations 1994.
- The Water Level Management Plan (WLMP).
- The Wensum Catchment Sensitive Farming Project.
- The Broadland Rivers Catchment Flood Management Plan (CFMP).
- River Basin Management Plans (RBMP).
- Agri-environment Schemes.
- The Wensum Fisheries Action Plan (FAP).
- Habitat Restoration Schemes, both privately funded and those funded by the Environment Agency.
- Maintenance Programmes by the Environment Agency and Norfolk Rivers Internal Drainage Board.
- The Norfolk Biodiversity Action Plan (BAP).
- Regional Spatial Strategy and Ecological Network Mapping.
- Broads Authority Sediment Management Strategy.

4.3 Initiatives by local people including angling clubs and riparian owners are also important and have already been instrumental in measures taken to date.

# Water resource management

4.4 Water resource management within the Wensum SAC is guided by the Broadland Rivers Catchment Abstraction Management Strategy (CAMS). The Broadland Rivers CAMS was produced by the Environment Agency in 2006. The Wensum is currently classified as over-licensed in terms of water resources at low flows, and there is a target for the period to 2011 to reduce the overall amount of licensed abstraction but to remain within the over-licensed resource availability status. In general, new groundwater applications will not be considered. In terms of surface water, there is no water resource available at low flows for consumptive use, though applications for non-consumptive use may be considered. Limited quantities for consumptive purposes may be available at high flows. Currently, all new licenses and variations to licenses are issued with a time limit (2008) to coincide with the Habitats Directive review of consents. After this, any new licenses will be time limited to the CAMS common end date.

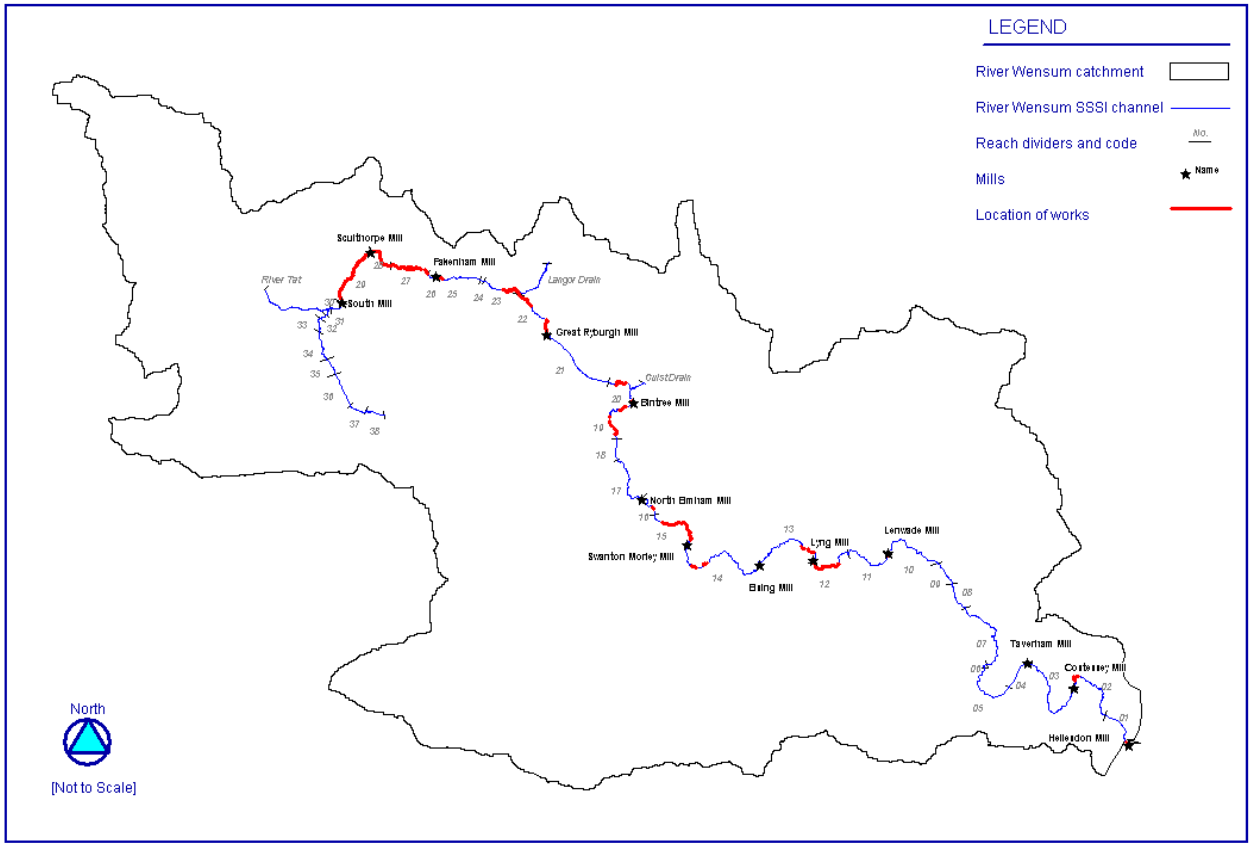
4.5 The single largest abstractor in the River Wensum catchment is Anglian Water Services Ltd., who operate boreholes for public water supply at a number of sites. In addition Anglian Water abstract surface water for public supply direct from the river at Costessey. Particular concerns have been expressed in relation to the Costessey surface water abstraction, which can take up to 50% of the flow during drought conditions. This concern has prompted an investigation into the impacts of public water supply abstractions (both groundwater and surface water) on the ecology of the River Wensum SAC. This investigation is being carried out under the 2005-2010 Asset Management Plan (AMP4) for Anglian Water Services Ltd.

4.6 Asset Management Plans (AMP) are five year investment programmes implemented by public water supply/sewage companies to effect environmental improvements. The current AMP programme (AMP4) runs from 2005 to 2010, and includes improvements to both water quality and water resources.

4.7 Water quality issues are of particular concern in the Wensum catchment in relation to phosphorus. Phosphate levels increased significantly in 1975 and were associated with effluent from sewage treatment works. Silt accumulation in the channel, particularly in the impounded reaches upstream of mill structures, provides a sink for phosphates. The remobilisation of phosphates is of potential concern if silts are flushed through the system. Phosphate stripping has been put in place at Fakenham and Dereham sewage treatment works under Asset Management Programme 3 (AMP3), and at the Bernard Matthews factory in Great Witchingham. Under AMP4, phosphate stripping may be installed at a further 7 sewage treatment works in the Wensum catchment.

# Consented works

4.8 The Environment Agency has the responsibility for a general supervision of all matters relating to Flood Risk Management along Main River (that is, all the River Wensum SSSI channel, except upstream of the confluence with the River Tat, the Guist Drain and the Langor Drain which are managed by the Norfolk Rivers Internal Drainage Board). As part of this process, any work in, over, under or adjacent to (within 9m of) Main River requires the consent of the Environment Agency under the Water Resources Act 1991. With regard to works carried out by the Environment Agency itself, it has duties under the Wildlife and Countryside Act 1981 (as amended) and under the Environment Act (1995) to ensure that these are carried out to an appropriate environmental standard. Figure 12 shows the location of the most significant works affecting the channel of the River Wensum which have been consented by/carried out by the Environment Agency since the 1990s (pers. comm. Rob Dryden of the Environment Agency and from information provided in the River Wensum Rehabilitation Project newsletter (No.3)). These include a number of habitat restoration schemes, mill structure refurbishments and flood risk management maintenance works.




Note: For larger version of this figure that is annotated with descriptions of the various restorations and other works on the river (A4-size), refer to Appendix 11 at back of this report. Information provided by the Environment Agency.

**Figure 12** Works consented/undertaken by the Environment Agency since the 1990s

**Plate 2** Previous rehabilitation sites - Lyng. Left: Downstream Lyng Mill - riffle, Right: Downstream Lyng Mill - pool

4.9 Some of the key river rehabilitation schemes that have already been completed along the River Wensum include:

- The Sayers Meadow Habitat Restoration Project[1] - Downstream of Lyng Mill at Sayer's Meadow is a Norfolk Anglers Conservation Association rehabilitation site aimed at improving instream and bankside habitats (Plate 2). Beginning in the 1990's, a series of restoration measures have been implemented. These include the construction of riffles and pools, channel narrowing, backwater creation and tree planting.

[1] URL: **www.norfolkanglers.com/projects/sayers_meadow.html**

- The Costessey Point Project[2] - Costessey Point/Drayton - Norfolk Anglers Conservation Association habitat restoration (Plate 3). Measures implemented here include the restoration of an important fish spawning and recruitment riffle at 'The Point' (confluence of the Old Costessey Mill stream with the River Wensum). Additional riffles, fry refuges and compensation floodplain storage were constructed.
- Hempton (upstream Fakenham Mill) - restoration of a by-passed meander bend (approximately 280m - vegetation clearance and restoring original channel dimensions) and installation of three riffles in the existing river course to divert flow into the meander loop (Plate 4).


**Plate 3** Previous rehabilitation sites - Costessey. Left: Costessey Point - fenced cattle drink, Right: Costessey Point - riffle


**Plate 4** Consented works - Hempton. Left: Upstream Hempton site - entrance to meander, Right: Upstream Hempton site - entrance to meander

- Upstream Fakenham Mill[3] - Coir mattresses, pinned using timber stakes at the waterline, used as bank revetment to alleviate bank erosion. Sediment dredged from the river was used to fill the gap between the mattresses and the top was pre-planted with wetland plants to provide habitat for fish, invertebrates and water vole. A number of fishing platforms were also installed. More details of the scheme can be found on the River Restoration Centre website[4]. This Environment Agency scheme was supported by North Norfolk District Council, the Wensum Valley Project, Fakenham Town Council and Fakenham and District Angling Club.
- Downstream Fakenham Mill - National Rivers Authority project to improve fisheries habitat, including the de-silting of pools using submerged vanes. The local angling club state that the

[2] URL: **www.norfolkanglers.com/wensum/**
[3] URL: **www.therrc.co.uk/case_studies/wensum_fakenham.pdf**
[4] URL: **www.therrc.co.uk/rrc_case_studies_list.php**

fisheries and biotic carrying capacity of the reach improved considerably. A summary of the works completed at this site is available in Thorne et al. (1997, p. 353).

- Great Ryburgh - Reconnection of previous river channel (1995). Downstream of Great Ryburgh Mill the Wensum occupies a straight, artificial channel. However, a section of the original channel, approximately 1200m in length, remains to the north of the existing river. This was reconnected to the main river in 1995. The original channel was de-silted, to give a wet width of approximately 2m and a depth of up to 1m, and tree management was carried out to allow access for machinery. A riffle/boulder weir was installed in the bed of the mill bypass channel to raise water levels and divert a proportion of the flow through the restored section of channel. Flint filled gabion mattresses were used to stabilize the river bank at the junction of the two channels. In addition, gravel point bars were placed in the straightest section of the restored channel to promote sinuosity and flow diversity. Whilst initially successful, the scheme has not proved sustainable in the longer term. The main reason for this is likely to be due to insufficient flow being passed through the reconnected channel.
- Bintry Mill (Plate 5) - Installation of a gravel glide and riffle in 2004 by Bintry Mill Trout Fishery to provide further habitat for brown trout and to extend previous Environment Agency restoration works (7 riffles, flow deflectors to create pool habitat, narrowing using faggot and chalk/gravel back-fill and 2-stage channels in 2001) at Bintree. The work in 2004 was commissioned by the Bintry Mill Trout Fishery and was part grant aided by the Environment Agency.

**Plate 5** Consented works - Bintry Mill site. Left: Bintry Mill restoration - cattle drink, Right: Bintry Mill restoration - restored pipeline riffle

- Billingford[5] - defunct meander loop reconnected back to the main channel to provide backwater nursery area for fish and a winter flow refuge for fry and adult fish (roach/chub). Fencing was also installed to aid establishment of overhanging vegetation/cover.
- Worthing to Swanton Morley - Phased habitat improvement works in areas identified as lacking physical habitat and flow diversity and as having poor fish recruitment success:
  - Phase I - Burgh Common (March 2005) - riffles and fry refuges created in previously uniform flow channel.
  - Phase II - Holkham Lake (October 2005) - 2 shallow gravel riffles, a gravel bar and 2 point bars and the creation of wetland margin along the bank.
  - Phase III - impounded reach above Swanton Morley weirs (March 2006) - creation of 4 off-channel fish refuges and extensive bank re-profiling/vegetation planting to improve physical habitat diversity in the impounded reach.

  Detailed proposals were prepared by the Environment Agency for the rehabilitation and enhancement projects at each of these sites (Environment Agency, 2005a, 2005b and 2006). Observations of the first two stages of the scheme suggest that flow diversity in the channel

[5] URL: **www.therrc.co.uk/case_studies/wensum_billingford.pdf**

has significantly improved. Fast flows, slack water areas, eddies etc. have replaced the former uniform flow and have improved the recruitment success of fry. Chub and minnows have been observed spawning on the riffles and brown trout have also been observed using the riffles at Swanton Morley (Plate 5).

- Lenwade Mill - An appraisal of flood defence options was undertaken at this mill where the existing manual sluice gates were in a poor condition and likely to fail. Options to improve river ecology were also assessed. One of the options considered in this appraisal was the removal of the sluices and installing of 3 gravel weirs upstream. However, the result of this would be to restore the channel to create a steep section of watercourse that is quite out of character with the river, and the impoundment upstream of the existing mill structures would be retained. As a consequence, this option was not favoured and, although the sluices were automated in 2004, it was engineered so that water levels could be managed in line with future recommendations on water level management. An report on environmental options for this site was prepared on behalf of the River Restoration Centre by Holmes (2002).

**Plate 6** Consented works - Swanton Morley. Left: Swanton Morley restoration - lower riffle, Right: Swanton Morley restoration - water crowfoot

4.10 In addition to existing schemes along the River Wensum, rehabilitation and restoration schemes on other UK chalk rivers may be used to guide principles and techniques for future restoration in the Wensum catchment. Projects include:

- The Upper Kennet Rehabilitation Project (1993 to 2004) - 10km stretch of channel with similar pre-scheme characteristics to the Wensum (SSSI chalk stream that is ponded upstream of mills, generally overly wide and silty, but which is a focal point in the landscape and a valued fishery). Rehabilitation focussed on restoring reaches that were particularly degraded, where landowners supported restoration, where value for money could be demonstrated, where work was practical and where restoration would not increase flood risk to people and property. Seven schemes have been implemented with early indications of success (Plate 7). Case studies for each of these schemes are available from Thames Water, including river narrowing (creation of an island, ledges and the use of deflectors and coir rolls), Ranunculus planting, bed raising, overbank spillways and modified water level management. Case studies give detailed design methods and post-project appraisal remarks. Further, a post-project monitoring report concludes much of the rehabilitation works have been successful (Hankinson Duckett Associates, 2004).
- River Shreen[6] (tributary of Dorset River Stour) - in partnership, the Environment Agency, Wild Trout Trust and the Duchy of Cornwall opened up the tree canopy and fenced out livestock to protect the natural habitat in this rare, unmanaged wild trout section of the River Shreen that was heavily shaded. They also provided places for livestock to drink together with other enhancements.

[6] URL: **www.environment-agency.gov.uk**

- River Avon SAC in Wiltshire and Hampshire[7] - one of the English Nature LIFE in UK Rivers sites where a conservation strategy was produced in 2003. The £1 million programme of river restoration was funded by the European Commission's LIFE-Nature programme and its aim was to demonstrate ecological restoration at six sites throughout the river system, covering a total of 10km of river channel. Following the strategy, a project was set up in September 2005 called STREAM. Work has recently started on two of the six sites identified in the strategy study. The STREAM project was designed to incorporate post-project monitoring of its restoration works.

Photographs provided by N. Holmes

**Plate 7** Other chalk river projects - Upper Kennet example. Left: Upper Kennet- narrowing upstream of Kennet Mill Right: Upper Kennet - In 2003, following establishment of marginal vegetation

# Water Level Management Plan (WLMP)

4.11 The initial WLMP for the River Wensum SSSI was agreed between the Environment Agency and English Nature in 1999. Its aim was to balance the water level requirements of different interests (nature conservation, flood defence, agriculture and recreation). The plan included a number of actions/recommendations, for example the installation of gauge boards on mills/bridges to monitor low and flood flow levels; the encouragement of landowners to enter agri-environment schemes in the floodplain; the identification of areas of increased silt supply and the improvement of communication between mill owners/operators and riparian owners/residents. The WLMP also provided details of potential constraints to restoration.

4.12 The WLMP (1999) is currently in the process of being rewritten and the Environment Agency is keen to dovetail the development of the WLMP with the development of the River Wensum Restoration Strategy. The prime purpose of reviewing the WLMP is to ensure that the nature conservation interests for which the River Wensum SSSI has been notified will be conserved and enhanced. Implementation of the WLMP will be one of the mechanisms for achieving the Government's Public Service Agreement target for favourable condition on the river. The boundary of the WLMP has been extended to include the majority of the floodplain in addition to the SSSI.

4.13 Although the Environment Agency is acting as the lead Operating Authority, the Wensum upstream of the confluence with the Tat, together with the Langor Drain and the Guist Drain, are managed by the Norfolk Rivers IDB, one of the members of the Water Management Alliance. Coordination between the Environment Agency and the Water Management Alliance is fundamental to the development and implementation of the new plan.

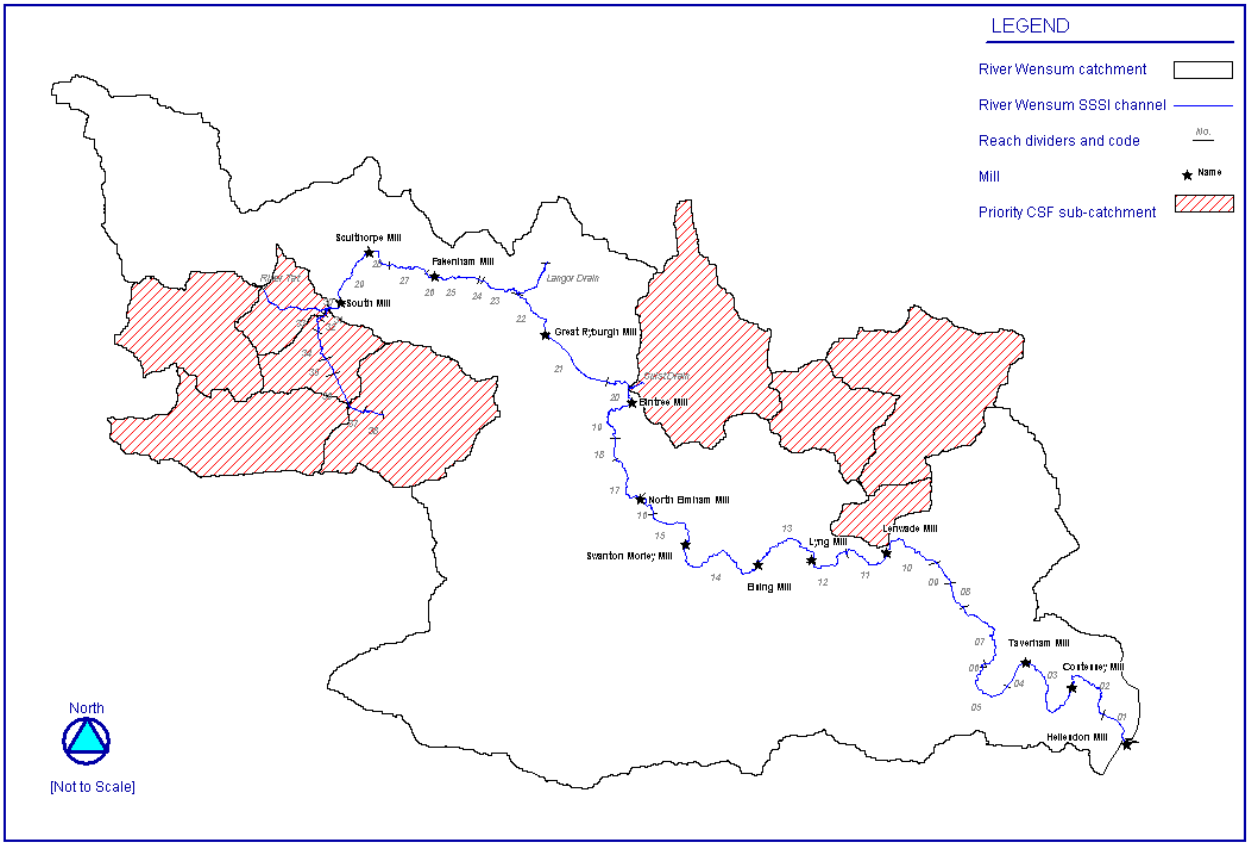
[7] URL: **www.therrc.co.uk/rrc_links.php** and URL: **www.naturalengland.org.uk**. The project website is **www.streamlife.org.uk**

# Catchment Sensitive Farming (CSF)

4.14 The England Catchment Sensitive Farming Delivery Initiative (ECSFDI) will focus on forty priority catchments (including the River Wensum) which have been identified by the Environment Agency. The ECSFDI is funded by Defra but will be delivered by Natural England working in partnership with the Environment Agency.

4.15 The aim of the ECSFDI is to raise awareness of diffuse water pollution from agriculture (for example, silt runoff) and to encourage early voluntary action by farmers to tackle the problem in priority catchments. It will contribute to the achievement of domestic and international environmental targets, in particular the PSA target for SSSIs and the longer term targets of the Water Framework Directive. Many of the indicative restoration options suggested by the Geomorphological Appraisal for the Wensum SSSI involved reducing sediment ingress to the river channel. It is intended that the River Wensum Restoration Strategy will work in parallel with and promote the work of the CSF Initiative.

4.16 As part of the initiative, officers will visit farms in the selected catchments to raise awareness of diffuse water pollution from agriculture, identify risks and pathways for pollution on the farm, and discuss and promote changes in farming practices. Technical advice will be given in the areas of land-use, soil, livestock, nutrient and manure management, as well as the protection of watercourses.




Note: Data provided by Dougal McNeill of Natural England (2006)

**Figure 13** Priority CSF sub-catchments

4.17 In the Wensum catchment there has been much progress in reducing silt pollution. The catchment has been characterised using the PSYCHIC (Phosphorus and Sediment Yield Characterisation in Catchments) model so as to predict those areas which are most vulnerable to loss of phosphate through soil erosion. A stakeholder meeting was held to identify priority sub-catchments in order to target effort (Figure 13). Monitoring of turbidity in watercourses has been established in these sub-catchments so as to identify a baseline condition. This will allow

quantification of future improvements in water quality brought about as a result of the CSF Initiative.

# Catchment Flood Management Plan (CFMP)

4.18 Catchment Flood Management Plans (CFMPs) are being developed by the Environment Agency to consider the adequacy of existing infrastructure and options for managing flood flows on a catchment basis. A 50 to 100 year perspective is considered and the impacts of climate change and changes in land-use are also considered. It is intended that CFMPs will influence local development plans, particularly with regard to the assessment of flood risk.

4.19 The Broadland Rivers CFMP includes the Wensum catchment and takes full account of the proposals for river restoration. The draft main plan began 3 months of public consultation in summer 2006. Other rivers in the Broadland CFMP include the Yare, Waveney and Bure.

4.20 Initial modelling of the upper Wensum demonstrated that flood defences in Norwich may not be sufficient to protect the city from flooding during a 1 in 100 year flood once climate change is taken into consideration. It is possible that improvements in the functioning of the River Wensum upstream of Norwich, as a result of the implementation of the River Wensum Restoration Strategy, will have an indirect benefit in terms of flood risk management for Norwich (for example, by attenuating flood peaks). Detailed modelling will be required to assess the overall impact on flood risk (refer to Sections 5.6 - 5.18 below for more details).

4.21 The River Wensum Restoration Strategy takes into account recommendations in the Broadland Rivers CFMP. Whilst one requirement of river restoration is to reconnect the river to its floodplain, restoration plans that include removal of embankments or bankside walls will only be possible where this will not result in increased flood risk to people and property.

# River Basin Management Plans (RBMP)

4.22 The Water Framework Directive is a piece of European legislation designed to integrate the way water bodies are managed across Europe. It aims to protect and enhance the water environment, promote sustainable water consumption, reduce water pollution and lessen the effects of floods and droughts. It is also designed to stop the deterioration of wetlands and improve aquatic habitats for wildlife.

4.23 Strategic planning and reporting in the Water Framework Directive is to be undertaken at the River Basin District scale. The River Wensum is in the Anglian River Basin District. River Basin Management Plans (RBMP) will set out in general terms how the water environment will be managed and will provide a framework for more detailed decisions to be made.

4.24 River basin management is based on six-year cycles of planning and action. Creation of the first Anglian RBMP will include:

- Working together consultation (statement of steps and consultation measures for producing the River Basin Management Plan) by 22 December 2006.
- A summary of Significant Water Management Issues will be produced by 22 December 2007, with consultation by July 2007.
- The first River Basin Management Plan will be drafted by 22 December 2008.
- A final version of the River Basin Management Plan will be published by 22 December 2009.

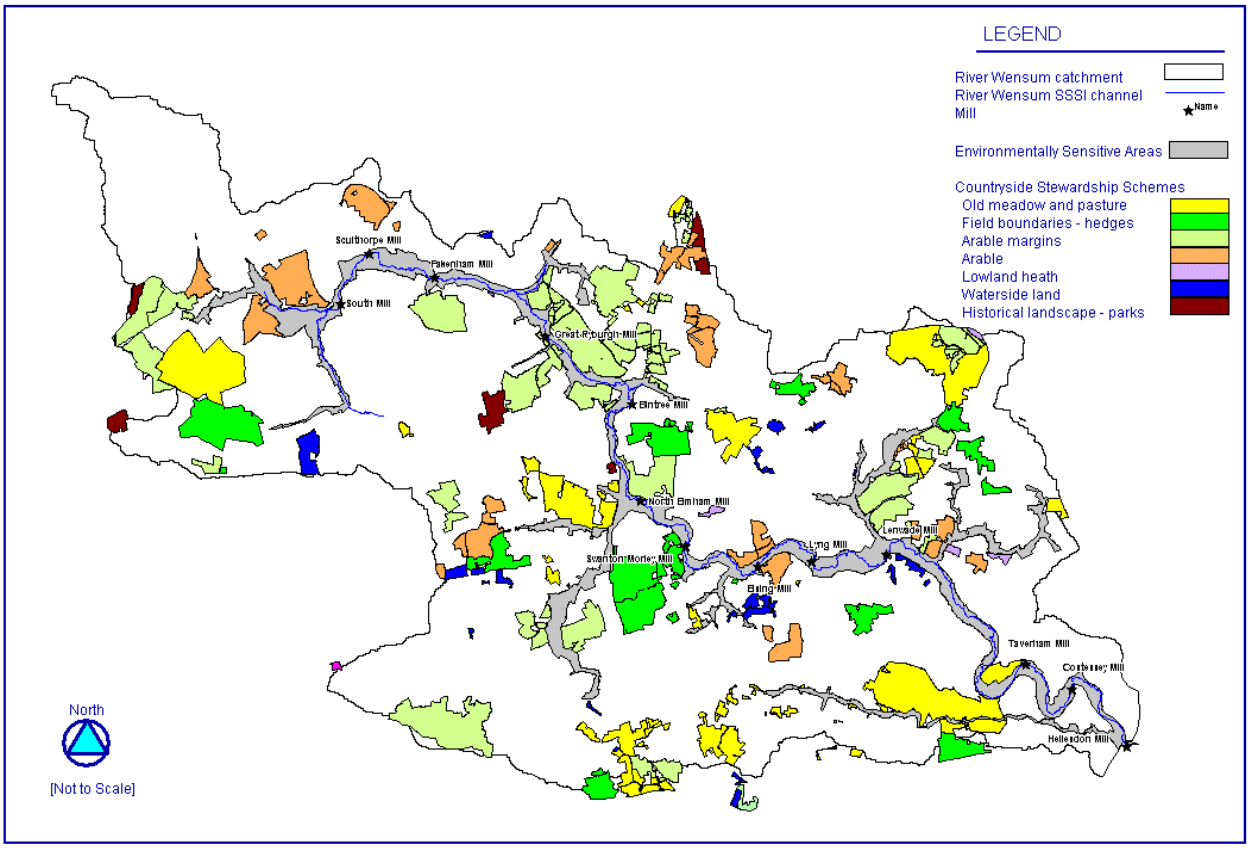
4.25 New classification schemes, environmental standards and conditions are required for use in assessing and classifying water bodies from 2009. Additional regulatory instruments (for example, guidance or regulations) may be required in England to give some of the new standards statutory status, particularly for morphological conditions.

# Agri-Environment Schemes

4.26 In their review of eastern England's Rural Development Programme , DEFRA stated that the character of the countryside in eastern England has been predominantly shaped by changing farming practices, with arable farming continuing to be the most influential factor. Grazing land and its associated landscape features (such as hedgerows and semi-natural grassland, grazing marsh and fens) provide an important contrast, such as in river valleys. The need to maintain this type of landscape lead, in the late 1980s, to the designation of Environmentally Sensitive Areas (ESA) and Countryside Stewardship Schemes (CSS). Whilst these schemes are being superseded by Environmental Stewardship Schemes (ESS), it is useful to review areas in the Wensum catchment where landowners have entered into agreement with the Government to manage their land in an environmentally beneficial way.

4.27 Figure 14 shows that there are six main areas in the Wensum catchment where CSS have been taken up by 2006. The three key prescriptions of these schemes are:

- Reversion of arable land to permanent grassland - River Tat, upstream of Lyng and at Great Witchingham (Lenwade).
- Grassland margins to reduce run-off from arable land - Guist, North Elmham and Great Witchingham (Lenwade).
- Maintenance of old meadow and pasture (farming using traditional methods) - North Elmham and between Ringland and Taverham.




Note: For larger version of this figure (A4-size), refer to Appendix 11 at back of this report. Data from Broadland Rivers CFMP (2006)

**Figure 14** Land within the Wensum catchment entered into Environmentally Sensitive Area and Countryside Stewardship Schemes (up to 2006)

4.28 The CSS scheme (up to 2006) covered much of the Wensum catchment outside the boundary of the Broads ESA schemes. The ESS is intended to build on the recognised success of the ESA and the CSS. Its primary objectives are to:

- Conserve wildlife (biodiversity).
- Maintain and enhance landscape quality and character.
- Protect the historic environment and natural resources.
- Promote public access and understanding of the countryside.
- Natural resource protection.

4.29 There are three elements to the ESS - Entry Level (ELS), Organic Entry Level (OELS) and Higher Level (HLS) Stewardships. According to the Defra website, key features of the HLS include:

- Delivery of significant environmental benefits in high priority areas.
- HLS is usually combined with ELS or OELS options.
- More complex environmental management where land managers need advice and support.
- Very wide range of management options available, targeted to support key characteristics of the different areas of the English countryside.
- Payments relate to the options chosen.
- Includes payments for capital items such as hedgerow restoration.
- Detailed application by preparing a Farm Environmental Plan.
- Unlike ELS and OELS, entry into the HLS is discretionary. Applications go through an assessment process which takes into account how the application meets the environmental priorities identified in the local area.
- Ten year agreements with payments sent out every six months.
- HLS will be administered by Natural England from regional centres with technical advice and support being provided by local Rural Development Advisers.

# Fisheries Action Plan (FAP)

4.30 The Environment Agency is developing Fisheries Action Plans (FAPs) nationally in response to recommendations in the UK Government Review of Salmon and Freshwater Fisheries. The Review Group was critical of the arrangements for local consultation and accountability on fisheries issues, and recommended the adoption of FAPs to address this. In order to trial the FAP methodology, four pilot projects were set up nationally, including the Wensum FAP. In general, FAPs aim to:

- Optimise the ecological, social, recreational and economic benefits of fisheries through the targeting and prioritisation of resources.
- Maintain, improve and develop sustainable fisheries through open consultation and partnership with local fisheries and other interests.

4.31 The River Wensum FAP brings together a partnership of fisheries and conservation interests on the river. The Wensum FAP report (2003) identified nine key fisheries issues on the river. These included poor fish recruitment, silt and nutrient pollution, the need for habitat restoration, increased access for angling, and the need to develop ecologically and socio-economically sustainable fish stocks. The FAP includes a prioritised action plan to address each of these issues.

4.32 The objectives of the River Wensum FAP (2003) run in parallel with many of the objectives of the River Wensum Restoration Strategy and there is much synergy between the two, especially in terms of the requirement to improve the physical functioning of the river and, hence, potential habitat and species diversity.

4.33 One area of possible tension relates to the fact that some members of the Wensum FAP group are promoting barbel fisheries in the lower reaches of the river. The Environment Agency considers that barbel is non-native to the River Wensum. This highly constrains the circumstances under which additional stocking could take place, so effort is being concentrated

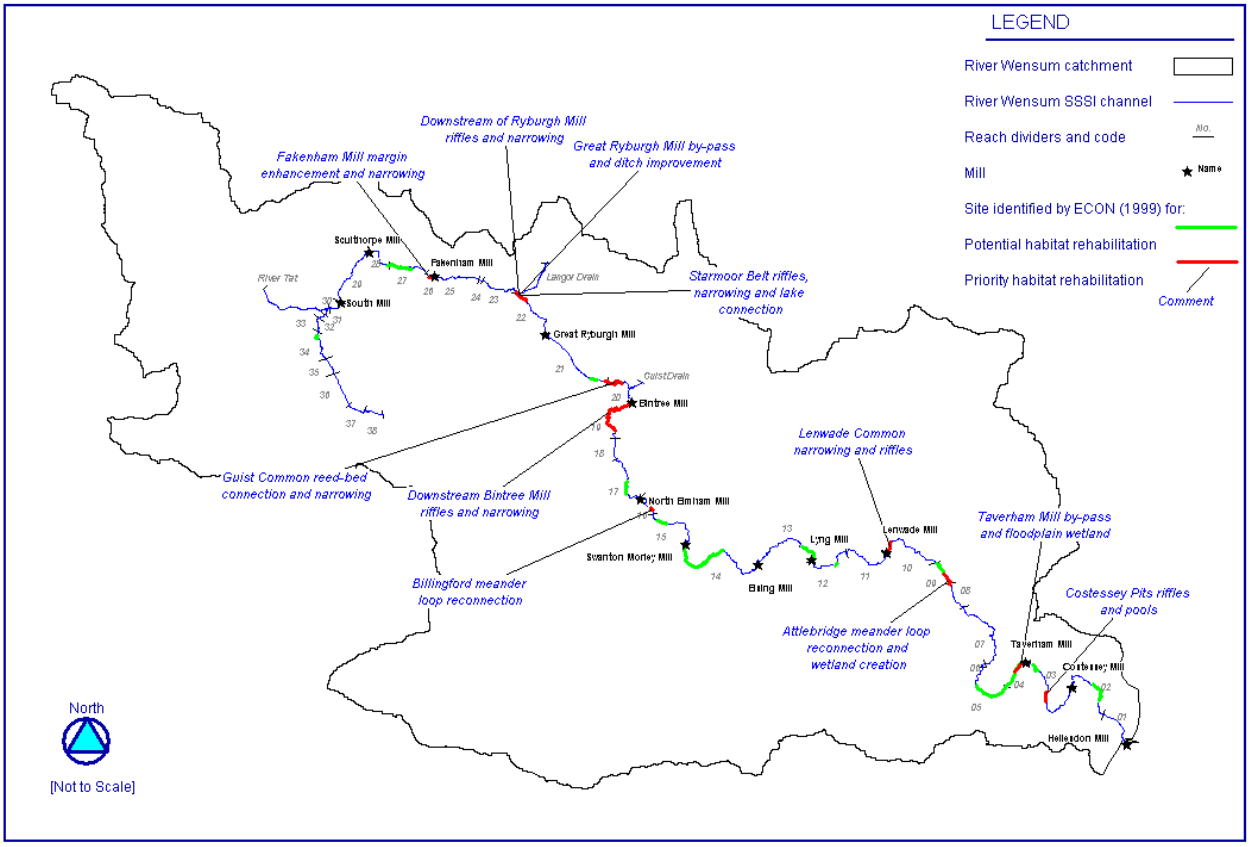
on improving habitat quality for the existing barbel populations. Natural England consider that low densities of barbel can be tolerated on the site, but that the objectives of river restoration should be to create a channel form characteristic of a chalk river in Norfolk.

# Habitat Restoration Schemes

4.34 ECON (1999) surveyed the full length of the River Wensum SSSI channel and made detailed notes about the channel geomorphology and habitat restoration requirements. The report identified 25 areas where maximum gains could be made to fisheries and conservation value. In addition, the schemes were also predicted to make generally positive contributions to the geomorphological stability and flood defence standards of the river. However, there was no attempt to consider the impact of mills, and enhancements were focussed on free flowing reaches. Eleven priority schemes were designed in some detail. The locations of the schemes proposed are shown in Figure 16. The schemes are varied in location, type, complexity and purpose.

4.35 The implementation of these schemes has been limited, primarily due to the limited funding available. However, the schemes proposed for upstream of Fakenham Mill, Bintry Mill, Billingford, Worthing and Swanton Morley have been (at least in part) implemented by the Environment Agency in partnership with local landowners and fishing interests.

4.36 Further habitat restoration has been undertaken privately in the River Wensum catchment, most notably by NACA and the Bintry Mill Trout Fishery (see Sections 4.8 - 4.10).




Note: For larger version of this figure (A4-size), refer to Appendix 11 at back of this report. Data from ECON (1999).

**Figure 16** Habitat restoration schemes recommended by ECON (1999)

# Maintenance Programmes

4.37 The Environment Agency is responsible for the management of flood risk to people and property associated with the Main Rivers, which are under its jurisdiction. Most of the River Wensum is

classified as Main River, with the exception of the Wensum upstream of the confluence with the River Tat. The sections of the River Tat which are included within the SSSI are also Main River. The Guist Drain, the Langor Drain and the upper reaches of the Wensum are classified as Main Drains and are under the jurisdiction of the Norfolk Rivers IDB. Individual field drains that link with Main River and Main Drains are managed by individual landowners.

4.38 For those sections of the River Wensum SSSI which are designated as Main River, English Nature have given assent under Section 28H of the Wildlife and Countryside Act 1981 (as amended), for the Environment Agency to carry out weedcutting provided that this is carried out within the following parameters:

- Weedcutting can commence in the 2nd week of June each year. Normally one cut is undertaken between Norwich and Doughton, with a second cut between Norwich and Lenwade if required.
- Up to 50% of the narrowed (wetted) channel is cut in sections of free flowing water.
- Up to 75% of the narrowed (wetted) channel is cut in impounded sections of channel.
- Up to 100% of the narrowed (wetted) channel is cut in the critical urban frontage in Fakenham (between Fakenham Mill and Abattoir bridge).
- Up to 100% of the wetted channel is cut in a short stretch upstream of the three gauging stations on the river (improves accuracy of flow measurement).
- Up to 1km of the designated 50% cut area can be cut in excess of 50% (up to 100% if required) where there are pinch points in the channel.
- Margins of emergent vegetation are retained along both banks. A minimum 100mm height of vegetation is retained on the bed of the river.
- No cutting of bankside vegetation is carried out, except in the immediate vicinity of gauging stations and water control structures operated by the Environment Agency.

4.39 The Environment Agency also carry out selective tree and shrub management (for example, tree trimming to allow the passage of boats for weedcutting, removal of fallen trees that might cause unacceptable flood risk, and “cut and clear” in sections which are not cut by weed-boat). They comply with their own minimum environmental standards/environmental options when carrying out this work. In addition, the Environment Agency carries out de-silting work on a selective basis.

4.40 All routine maintenance carried out by the Environment Agency is continually reviewed in the light of new information on flood risk and national priorities for expenditure. The assent for works from Natural England is subject to periodic review. Maintenance regimes may need to be amended in future so as to be consistent with the objectives of river restoration.

4.41 With regard to the management of Main Drains, the Norfolk Rivers IDB has a rolling program of channel maintenance. Maintenance is assented by Natural England on a case-by-case basis and is carried out in accordance with the Water Management Alliance booklet, ‘Standard Maintenance Operations’ (2000, currently under review).

4.42 Depending on the width of the channel or the specific requirements of a watercourse, weed cutting is carried out as follows:

- weeds are removed from the centre section of a watercourse only, leaving the margins untouched to encourage re-colonisation; or
- weeds are removed from one side of a watercourse on a two to three year rotational basis (or longer in some cases); or
- in exceptional cases or following individual site instructions, and where a watercourse is important for the drainage of residential areas, all aquatic weeds are removed on a 'need to do' basis; or
- where circumstances dictate, special treatments apply.

4.43 The removal of materials from the bed of a watercourse is carried out as follows:

- A minimum of channel de-silting is undertaken in order to promote good aquatic communities. Where de-silting is undertaken, one of two standard methods is employed:
  - De-silting across the majority of the channel width, working only from one bank and leaving a marginal fringe of silt and vegetation on the opposite side of the channel to act as a seed bank.
  - De-silting in the central section of the channel over its entire length to provide continuity of drainage, but leave the two margins untouched. This method is preferable from the land drainage standpoint as it allows a continuous, unimpeded, central flow and it assists future conservation by the creation of pools and shallows at the water's edge. Where animal poaching has taken place batters will be laid back on one side only, in any clearing cycle.
- On watercourses with less than a 2m wet width, silt will be removed from the bed of the watercourse on one side only over its entire length. Operations will be conducted where possible from the opposite bank in rotation.

4.44 On many of the classic chalk rivers of the south of England, fisheries managers have a profound impact with regard to weed cutting. This is not the case on the Wensum, where the socio-economics of fisheries do not have such a high profile. However, the profile of fisheries on the Wensum is increasing, and if this results in an increase in demand for the management of weed for fisheries, then this will need to be carried out in a way which is compatible with the objectives for river restoration.

# The Norfolk Biodiversity Partnership and Biodiversity Action Plan (BAP)

4.45 Action to conserve nationally important habitats and species is largely taken at the local level through Local Biodiversity Action Plans (Local BAPs). The BAPs provide the specific objectives and targets against which progress is measured, and are important in ensuring that national BAP targets are translated into effective action locally.

4.46 In Norfolk, implementation of BAPs is co-ordinated by the Norfolk Biodiversity Partnership. The following Norfolk local BAPs are relevant to the River Wensum Restoration Strategy:

- Chalk rivers
- Water vole
- Floodplain and coastal grazing marsh
- White-clawed crayfish
- Reedbed
- Desmoulin's whorl snail
- Otter.

4.47 River restoration proposals for each reach of the Wensum will need to consider the impacts on BAP species and habitats. In many cases river restoration will help achieve local BAP targets and objectives.

4.48 The River Wensum Restoration Strategy takes into consideration the requirements of local communities, such as access to the river by anglers, canoeists, walkers etc.

# Regional Spatial Strategy and Ecological Network Maps

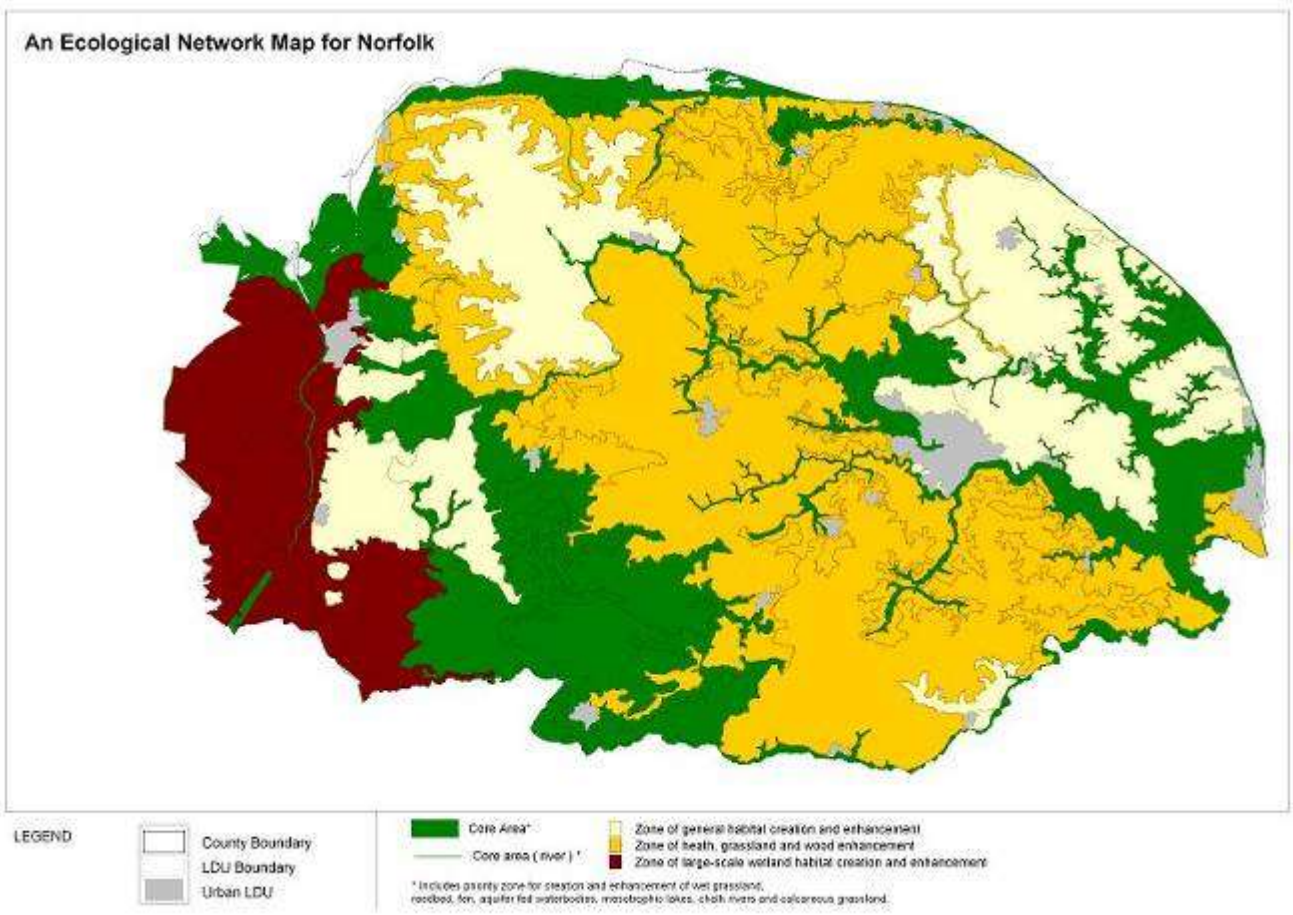
4.49 In order to secure the long term future of wildlife, it will be necessary to protect the existing wildlife resource. In addition, it is increasingly apparent that the area of wildlife habitat needs to

be greatly increased and re-connected if it is to survive in a human dominated landscape and be given a chance to adapt to climate change. The creation of an ecological network is necessary.

4.50 The Regional Spatial Strategy (RSS) for the East of England includes maps which have been drawn up by the Regional Biodiversity Mapping Project. The methodology that was used to draw up this coarse-grained map in the RSS has been applied at a finer scale by the Norfolk Biodiversity Partnership to draw up an ecological network map specifically for Norfolk to identify core areas, enhancement areas and corridors. This approach related various spatial features of SSSI, County Wildlife Sites and BAP habitat distribution to Landscape Character Units. In addition, expert opinion has been sought on the key areas for each BAP habitat, and also where habitat creation opportunities and corridors could be located at the county level.

4.51 The Norfolk Biodiversity Partnership recommends that all local authorities in Norfolk adopt the ecological network concept, and the indicative maps, and integrate them into their Local Development Frameworks. The ecological network can help with priority setting and targeting of a wide range of actions (for example, landscape characterisation studies and DEFRA Higher Level Scheme targeting statements).

4.52 The Ecological Network Map for Norfolk (Figure 16) clearly indicates that one of the most significant biodiversity corridors in the county is the floodplain of the River Wensum, running from Norwich right up to its headwaters towards the west of the county. The delivery plans that would be drawn up to implement the objectives of the River Wensum Restoration Strategy would also deliver the objectives of the Norfolk Biodiversity Partnership with regard to the biodiversity corridor of the Wensum valley.




Data from Land (2006).

**Figure 16** Ecological network map for Norfolk

# Broads Authority Sediment Management Strategy

4.53 The River Wensum feeds into The Norfolk Broads and, as such, the River Wensum Restoration Strategy could have potential implications for this unique natural resource if sediment accumulations upstream of water control structures along the Wensum are not managed correctly.

4.54 The Broads are an internationally recognised wetland, with large areas of the waterways designated under the Birds and Habitats Directives for the ecology and wildlife they support. The Broads Authority, as the navigation authority of The Broads, has adopted a strategic catchment approach to managing sediment. This approach provides long-term combined benefits to water quality, ecosystems and navigation and it also reduces the financial burden for maintenance of the navigation. The overall goal for sediment management is to achieve a balance of inputs with outputs, whilst dealing with the backlog of sediment that has accumulated more rapidly over the last six decades. To manage long-term sediment removal requirements, actions to minimise sediment inputs, particularly from banks, headwaters and algal input will be required.

4.55 The River Wensum Restoration Strategy acknowledges the requirements of the Broads Authority Sediment Management Strategy and recommends appropriate impact assessments be undertaken during the next stage of the restoration strategy (reach scale studies). Sediment that can be stabilised at the river's edge where narrowing is desired can have an important role to play in the restoration and thus can also be seen as a resource to be managed and utilised.

# 5 Catchment constraints

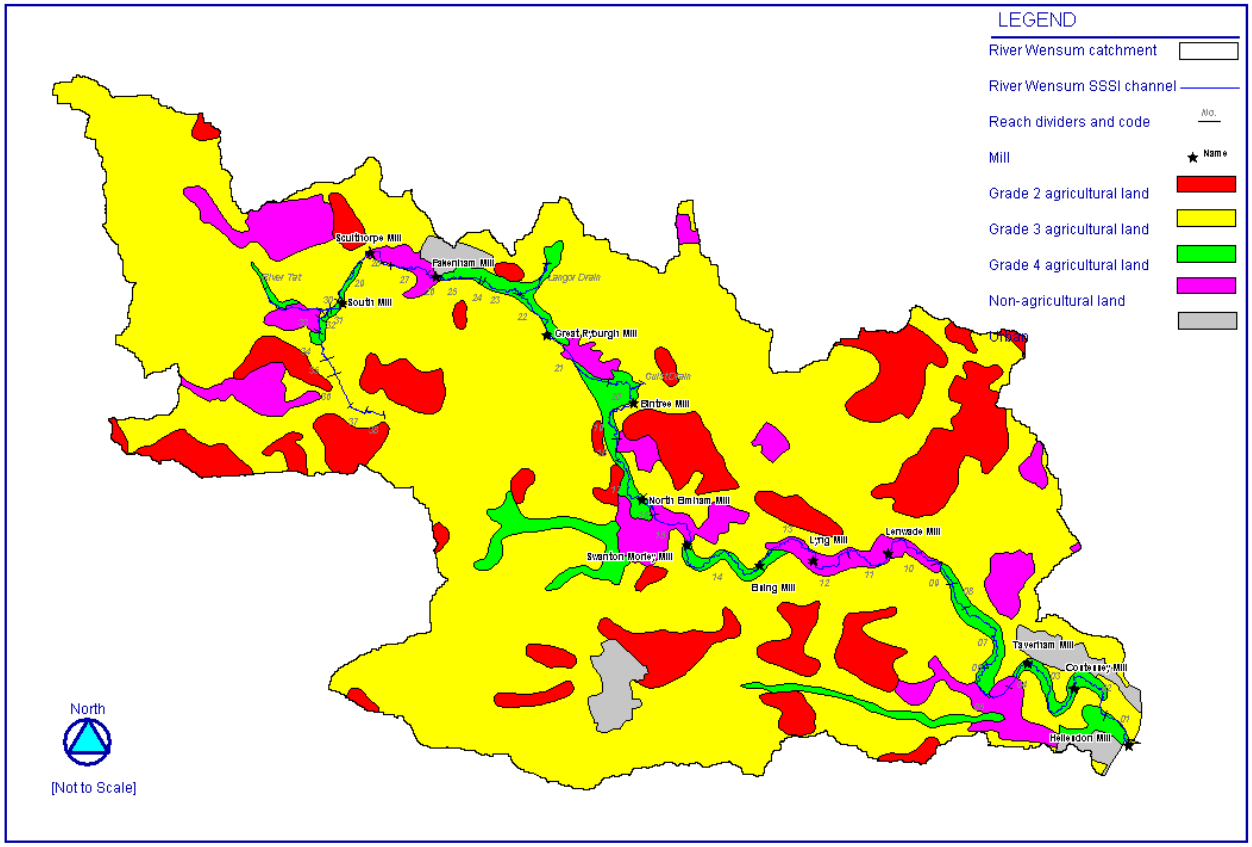
## Introduction

5.1 In order that restoration of the River Wensum SSSI is realistic, practical and likely to gain the support of local stakeholders, constraints to potential changes in the catchment have been taken into account in formulating the River Wensum Restoration Strategy.

## Land-use

5.2 The Wensum catchment is dominated by intensive arable farming. However, the Wensum floodplain is generally not suitable for arable farming, and supports a mosaic of grazing marsh, fen and woodland.

5.3 Figure 17 shows the agricultural land classification for the Wensum catchment. Almost 90% of the Wensum catchment is classified as being moderate to good/very good in quality (70% is Grade III and 17% is Grade II). There is no Grade I (excellent) agricultural land. Within the river floodplain, most of the farmland is classified as being poor (Grade IV), with some urban or non-agricultural land. This means that the farmland adjacent to the Wensum channel is not particularly versatile or suitable for arable farming.




Note: For larger version of this figure (A4-size), refer to Appendix 11 at back of this report. Data from Broadland Rivers CFMP (2006)

**Figure 17** Agricultural land classification

5.4 Although land on the floodplain is classified as poor, it supports a range of BAP habitats and species, and is a major reservoir of, and corridor for, biodiversity. This was recognised through the inclusion of floodplains of Broadland rivers in the Broads Environmentally Sensitive Area (ESA), for which farmers could secure payments for maintenance of high water levels and the practice of extensive management regimes. The Broads ESA has been superseded by the Higher Level Scheme of Environmental Stewardship, and farmers with land on the floodplain of the Wensum will be encouraged to enter into this scheme as their ESA agreements come to an end. A review of existing schemes will be necessary so as to ensure that all management regimes are compatible with river restoration. However, this is likely to be the case as ESA and HLS schemes on the Wensum floodplain have been designed so as to benefit vegetation communities and forms of management associated with hydromorphologically functioning floodplains.

5.5 The farming community has expressed concerns that restoration of the river might increase the risk of summer flooding to grazing pasture. The main concern is related to a reduction in the weed-cutting regimes and an intrinsic belief that this would result in unacceptable increases in water levels and liver fluke. Liver fluke was detected in East Anglia in the winters of 2001, 2002 and 2003. Herds were monitored for the condition, which can be controlled (refer to veterinary advice sheet 75). Land management proposals within the River Wensum Restoration Strategy complement existing agri-environment schemes, which were already in place in much of the Wensum valley at the time of the liver fluke incident. As such, it is unlikely that restoration works will contribute to any further increase in incidence of liver fluke in the Wensum catchment. However, it should be noted that restoration of the river is compatible with the habitats for which payments are being made for management under the Broads ESA scheme and, more recently, the HLS scheme.

# Flood risk

5.6 Over-bank flooding naturally occurs approximately every 2 years and channel dimensions adjust to contain this flow given adequate supplies of mobile sediment (if overly wide). Rivers, especially in lowland areas, are expected to utilize their floodplains on a regular basis. In lowland areas, high water levels in the channel are often associated with raised water levels in the floodplain and the development of seasonal wetlands or marshes.

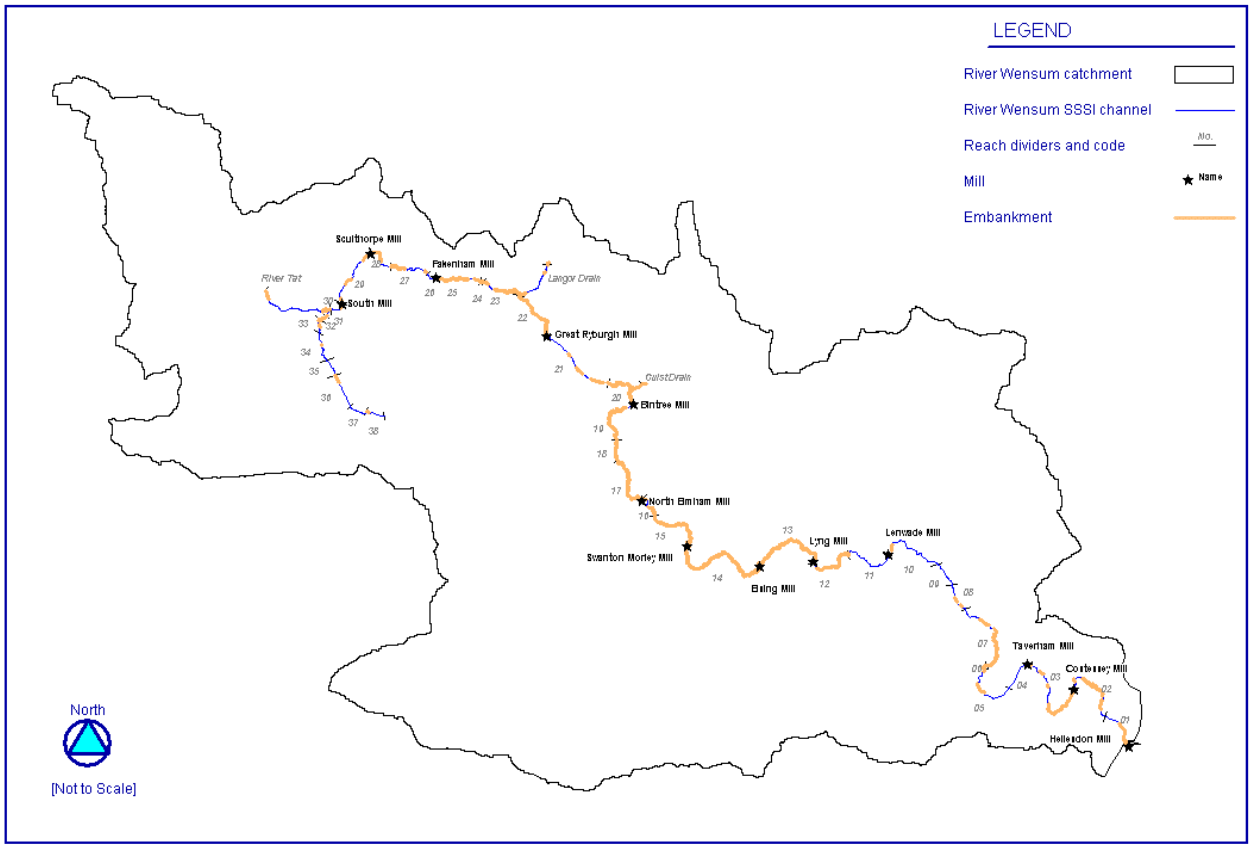
5.7 Engineering works that have been carried out on rivers to reduce flooding of residential areas or farmland, or to improve land drainage, can have serious adverse impacts which degrade the ecological value of the main channel and that of adjacent floodplain habitats. Additionally, engineering works reduce the ability of the floodplain to perform natural functions (flood control, nutrient and sediment storage).

5.8 Figure 18 shows locations along the River Wensum where embankments were identified during the Geomorphological Appraisal. Many of these embankments were not constructed explicitly for flood protection but were engineered to divert the river from its original course to power mills and to increase the storage capacity of the mill dams. In other places along the channel, low lying land is disconnected from the river by higher ground close to the river due to natural deposition of sediment or, more commonly, the spreading of river dredged materials. Embankments are not continuous upstream of Fakenham or in many areas downstream of Lyng. Since most of the embankments consist of dredged spoil, their main significance in Figure 18 is that they indicate the length of channel along which the banks are higher than the floodplain. It may be possible to repatriate this gravel to the river bed as part of river restoration.

5.9 Typically such embankments only offer limited protection appropriate for agricultural use and thus would not feature on the Environment Agency's register of flood defence assets.

5.10 Figure 19 shows properties (from the National Property Database) that lie within the Environment Agency's Flood Zone 3 outline (that is, the 1.0% Annual Exceedance Probability or less than a 1 in 100 year return period flow). The Upper Wensum Strategy Study (2003) identified 4 main areas of flood risk to properties in the River Wensum SSSI catchment:

- Fakenham (minimum standard of protection is believed to be 20 years in certain areas).
- Worthing (lower section of Wendling Beck).
- Lyng (minimum standard of protection is believed to be 13 years in certain areas).
- Lenwade.

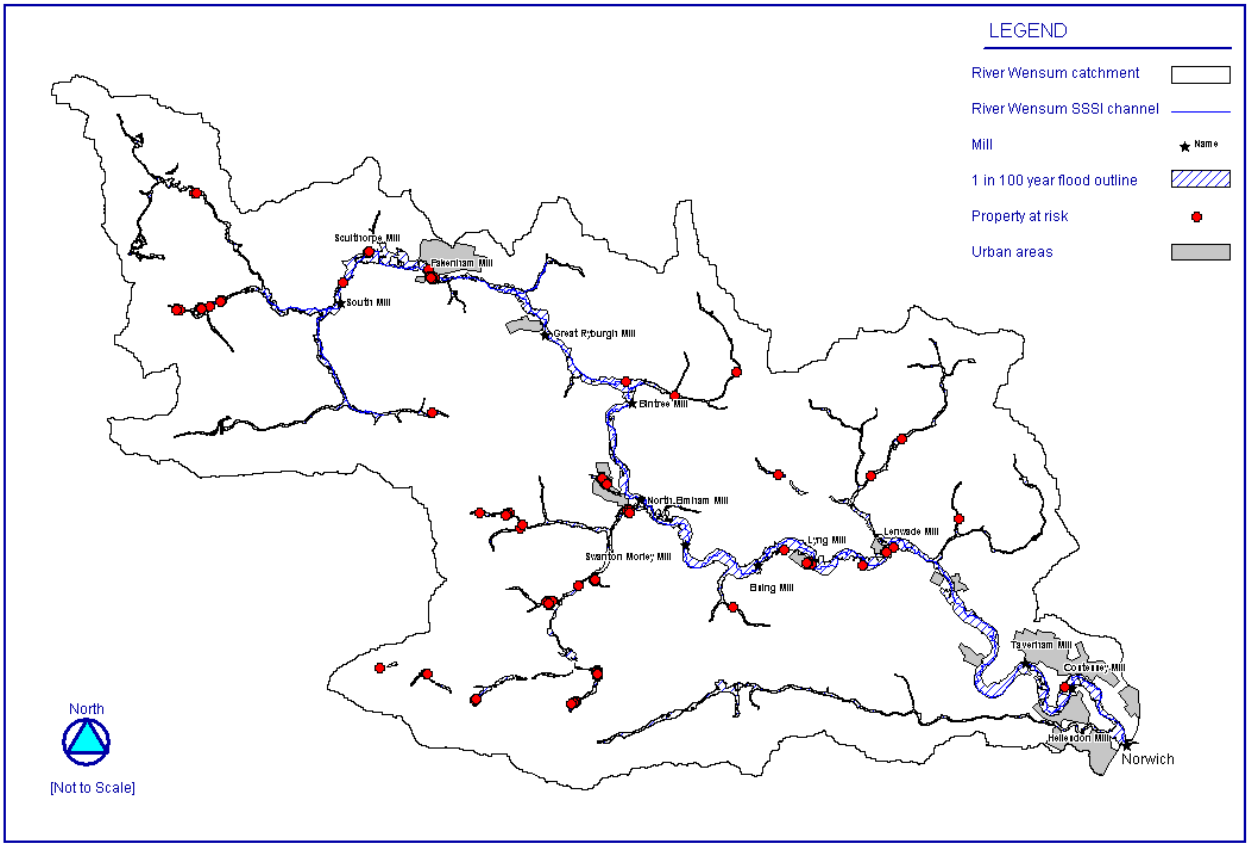



Note: For larger version of this figure (A4-size), refer to Appendix 11 at back of this report. Data from GeoData (2006).

**Figure 18** Lengths of embankments

5.11 During the Upper Wensum Strategy Study (2003), preliminary sensitivity analysis was undertaken during the hydraulic modelling of the River Wensum. The impact of climate change on flood levels was considered using the latest guidance from DEFRA that was available (Flood and Coastal Defence Project Appraisal Guidance 4 or PAG4). This required assessment of a progressive increase in peak flows by up to 20% over a 50 year design life. The study found that the potential impact of climate change on flood levels in the upper Wensum is small (that is, a mean increase of 0.09m in the 100 year return period water level). Further analysis involved modelling the impact of floodplain storage (flow attenuation) in the upper Wensum catchment. Preliminary results suggest benefits for Norwich, especially in mitigating climate change.

5.12 Halcrow Group Limited has been contracted by the Environment Agency to further the preparation of feasibility designs for the potential flood management schemes identified in the Upper Wensum Flood Strategy Study. The objectives in the River Wensum Restoration Strategy will be considered during the options appraisal and design process. Implementation of proposals to lower mill structures or to increase floodplain storage upstream of Norwich may reduce flood risk and thus reduce the need for raising defences in the future within the urban areas.



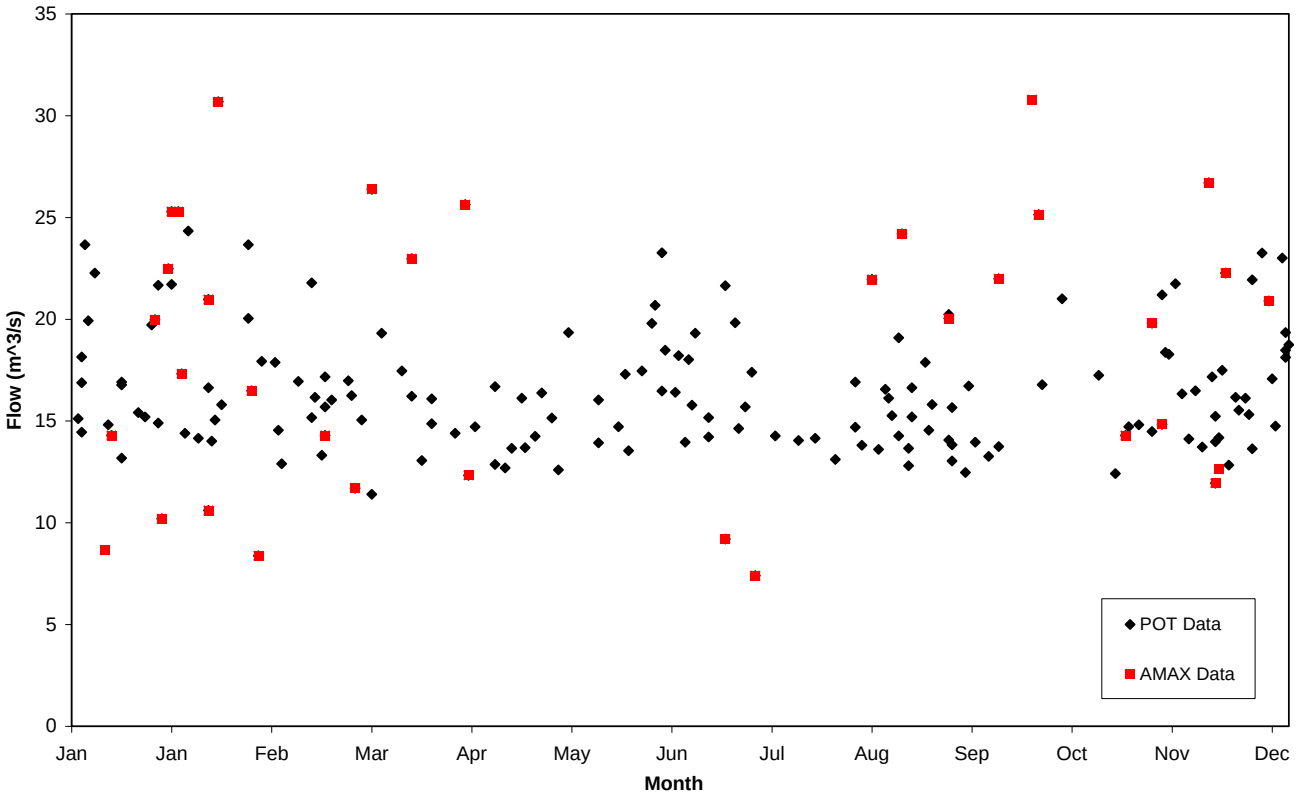

Note: For larger version of this figure (A4-size), refer to Appendix 11 at back of this report. Data from Broadland Rivers CFMP (2006)

**Figure 19** Properties in the 1 in 100 year flood outline

5.13 The current extent of river floodplain in the Wensum catchment is demonstrated in Figure 19. Much of the floodplain is managed as grazing marsh and, while the farming community accept that the floodplain should flood during the winter, they have expressed concerns about the frequency of summer inundation. To examine this concern, points over threshold (POT) and annual maximum (AMAX) data were analysed. These data are available from the Environment Agency's HiFlows website and they are plotted in Figure 20. Annual maximum values represent the maximum discharge values recorded at a gauging station each year over the period of record. POT data are the discharges over a threshold discharge value recorded at a gauging station each year over the period of record. These data show that, at Costessey gauging station, the maximum flows experienced each year since 1960 were generally between September and April. However, large flows are not absent in the summer months (POT data occurs in every month and is within the range of AMAX data).

5.14 The data show that high flows are currently possible all year round. By returning the channel to a more natural form, the flood regime will be more naturalised and bankfull flows should be expected to occur approximately every 2 years. Further, with a better connection to the floodplain in the upper reaches, flood peaks in the lower part of the system may actually decline post restoration.

5.15 The River Restoration Centre has produced River Rehabilitation Guidance for Eastern England Rivers (2005). This guidance outlines the potential risks and impacts, as well as the benefits, associated with the most commonly used restoration and rehabilitation techniques. It is especially useful in identifying the degree of flood risk (high, medium or low) associated with particular restoration options as well as the most appropriate type of model (none, hand calculation, hydraulic model or conveyance estimation system) for determining flood risk related to rehabilitation techniques.




Note: Data from Environment Agency HiFlow Website

**Figure 20** Recorded peak flows (Costessey gauging station)

5.16 At this stage in the River Wensum Restoration Strategy, there has not been any detailed modelling of the likely effects of restoration works on flood risk. However, as specific proposals are evaluated it will be useful to simulate the potential impact on flood risk of certain measures, including:

- Embankment removal to reconnect the river to its floodplain.
- Reduction in channel capacity (narrowing, gravel bed augmentation).
- Reduced maintenance (for example, weed-cutting).
- Construction of in-channel structures (for example, gravel glides/riffles, woody debris etc.).
- Restoration of a meandering planform.

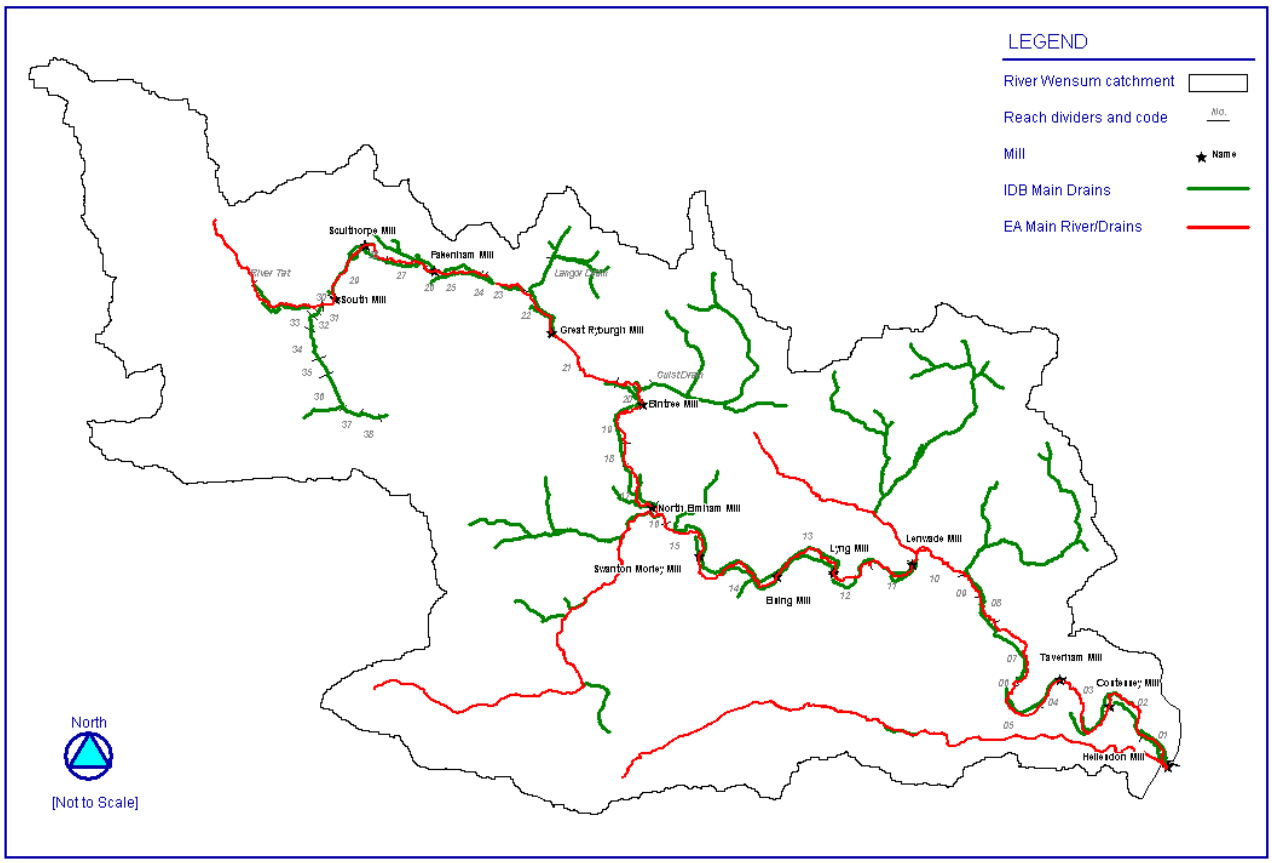
5.17 Examples of such studies which have already been completed on the Wensum include the following:

- JBA were commissioned by the Environment Agency in 2004 to undertake a hydraulic modelling study of the River Wensum at Bintry Mill. This study investigated the effect of proposed river restoration works, in the form of channel modifications, on flood risk. The study simulated changes to peak flood levels, water level recession (flooding of nearby land) and bankfull flow capacity associated with the insertion of a glide, two riffles and a weed boat channel. The proposed gravel augmentation was predicted to have no significant effect on peak levels for an extreme event.
- Mannings discharge hand calculations were undertaken by the Environment Agency to determine any change in bankfull channel capacity at Burgh Common (Swanton Morley Rehabilitation and Enhancement Study, Phase I; 2005a). The Mannings results indicated that a modified channel (that is, following riffle installation) would retain sufficient capacity to carry the 1% AEP (100 year) flow and that there would be no significant increase in out of bank flow over an average year.

5.18 The planning assumption applied in these studies to date is that flood risk should not be increased. This has been interpreted as meaning no significant loss of conveyance or increase in flood level. Changes in the thinking for flood risk management are taking place. The policy suggested by Defra as part of the 'Making Space for Water' initiative, and being proposed in the Broadland Rivers Catchment Flood Management Plan for the Wensum catchment, is to increase the use of floodplain storage where possible. This will provide benefits in terms of the flood risk management of Norwich.

# Management of main drains and field drains

5.19 Responsibilities for flood risk management and drainage of Main Drains lies with the Norfolk Rivers Internal Drainage Board, a member of the Water Management Alliance. In the Wensum valley, the Main Drains include most of the tributaries from the wider catchment, and a series of drains on the floodplain. The floodplain Main Drains tend to run parallel on either side of the river, and drain the floodplain adjacent to impounded river reaches. These drains join the Main River immediately downstream of mills (Figure 21). Some control structures are in place to regulate Main Drain input but much of the input remains gravity fed. The management of the smallest drains at field level throughout the system is carried out by individual landowners.




Note: For larger version of this figure (A4-size), refer to Appendix 11 at back of this report. Data from Broadland Rivers CFMP (2006)

**Figure 21** Norfolk Rivers IDB Main Drains and Environment Agency Main Rivers

5.20 The WMA is supportive of the River Wensum Restoration Strategy, and two members of staff are members of the Steering Group (a senior engineer and a conservation officer). However, they require that proposals take into consideration all areas in the catchment, 'north and south of the river itself'. Potential concerns include the need to maintain an efficient drainage system to prevent increases in water levels in the Main River, which could potentially increase the risk of flooding in adjacent villages serviced by IDB drains. An indication of the areas of greatest sensitivity, from the perspective of the WMA, is being sought so that further studies can focus more closely on potential impacts.

5.21 Simple analysis will be required during the pre-feasibility stage of restoration works to assess the impact of restoration proposals on river water levels and in IDB drains. An example of the type of analysis required is presented in Appendix 10.

# Nature conservation

5.22 The primary features of special interest of the River Wensum SSSI are the JNCC river types III and I and the assemblage of flora and fauna associated with the river, and these will benefit from river restoration. The River Wensum Restoration Strategy emphasises the recreation of a natural long profile, water depth/level and cross sectional form with gravel glides and occasional riffle/pool type sequences so as to reinstate the characteristic form and function of a chalk stream in Norwich. Whilst the River Wensum Restoration Strategy will not focus on improving habitat conditions for particular species, it is nonetheless expected to result in benefits for a wide range of wildlife. However, proposals for restoration practices must be assessed prior to any work on individual reaches to ensure that they are compatible with the special interests of the site.

5.23 Land parcels have been included within the boundary of the site, where these are hydrologically linked with the river and where they support communities of semi-natural vegetation characteristic of the floodplain. Although these land parcels should continue to be hydrologically linked to the river, to support semi-natural vegetation, and be managed through a regime that is compatible with the special interest of the river, the SSSI was not selected for the individual vegetation communities themselves. Tensions between river restoration and the management of the land parcels are unlikely to occur in many locations as a result of slight changes in water level that may follow restoration. After all, the land parcels support habitats characteristic of a hydromorphologically active floodplain. However, two locations where tensions may occur are:

- Guist Common - the fen communities are fed primarily from springs of high water quality, although they are inundated by river water during high rainfall events. Restoration of the hydrological relationship between the river and floodplain on this reach would result in the fen being subjected to increased inundation with water of lower quality, which might be detrimental to the communities that are currently present on this part of the SSSI.
- Broomsthorpe - the meadows support a fine example of traditionally managed floodplain with an array of habitats including M22 *Juncus subnodulosus-Cirsium palustre* fen meadow. Any work to re-establish a meandering form to the river could result in degradation of these habitats.

5.24 River restoration will provide benefits for the four European features that are confined to the channel of the river (that is, the *Ranunculus* vegetation community and populations of bullhead, white-clawed crayfish and brook lamprey). In terms of these features, river restoration can be regarded as ‘necessary for the management of the site’. It will also result in hydrological regimes in floodplain fens that will benefit populations of Desmoulin’s whorl snail.

5.25 However, some of the populations of Desmoulin’s whorl snail occupy the vegetated berms along the margins of impounded river reaches. Through river restoration and the lowering of mill structures, the habitats that support this snail may become sub-optimal. However, it is likely that as a result of slight increases in inundation elsewhere in the catchment, optimal conditions would be expected to occur elsewhere, and with good powers of colonisation, populations would adjust their pattern of distribution accordingly. Where significant areas of potentially suitable habitat are lost, it may be necessary to include the creation of appropriate habitat for Desmoulin’s whorl-snail as part of the delivery strategy for restoration on specific reaches.

5.26 In addition to the designated interests of the SSSI and SAC, the floodplain of the Wensum can be regarded as a corridor of biodiversity supporting a wide range of BAP habitats and species, many of which are found in association with chalk rivers. A large proportion of these semi-natural habitats fall within the boundary of County Wildlife Sites, many of which are hydrologically linked to the river. County Wildlife Sites represent the best wildlife habitats in Norfolk aside from statutory sites such as SSSIs. They are essential in helping to conserve the wider biodiversity

along the river corridor. An appropriate level of consideration needs to be given to these sites during development of reach based delivery plans. Restoration of the Wensum should help improve the ecological condition of many of the County Wildlife Sites along the river.

5.27 The river hosts an array of protected species including water vole, otter, white-clawed crayfish and breeding birds. During environmental assessments for the restoration of individual reaches, it will be necessary to ensure that species issues are addressed, and where necessary, mitigation included in the design. It will also be necessary to ensure that all works affecting habitats that support breeding birds are undertaken outside the breeding season.

# Mill ownership and water rights

5.28 The Environment Agency does not own all of the mills or water rights at control structures along the River Wensum SSSI (Table 6). Where private mill rights exist, the Environment Agency has limited powers to control their operational regime and retention levels. However, during initial contact with stakeholders, some mill owners were supportive of the concept of river restoration and were prepared to consider options for altering the future water management regime on impounded river reaches.

5.29 None of the mills are now used for their original purpose and only at Lenwade, Bintry and Elsing have the undershot water wheels been retained. Whilst owners can vary the retained water levels within the old milling limits, the general practice is to hold the water at a relatively high level. This is largely for aesthetic reasons (in order to maintain an expanse of water upstream of the mills) but also due to increasing levels of siltation of the mill pools.

5.30 The fragmentary nature of mill ownership is highlighted during periods of high flow. Each mill owner operates their controls to evacuate floodwaters, often without reference to owners either upstream or downstream. This emphasises the need for improved communication between mill owners/operators and riparian owners/residents. Given the significance of mills to restoration plans on the River Wensum, a potential constraint relates to the willingness of mill owners/operators to accept/implement changes in water levels, structures and channel works.

5.31 Conversely, mill owners may regard the development of the River Wensum Restoration Strategy as an opportunity for funding to modify structures that might be regarded as a liability in terms of maintenance, operation and health and safety.

**Table 6** Mill ownership and water rights

| Mill | Mill Owner | Sluice Owner | Owner of Water Rights | Gauging Station |
|---|---|---|---|---|
| Hellesdon | Environment Agency (site only - buildings demolished) | Environment Agency | Environment Agency | No |
| Costessey | Environment Agency (site only - buildings demolished) | Environment Agency | Environment Agency | Yes, HiFlows No. 34004 - continuous flow gauging station |
| Taverham | Anglian Water (site only - buildings demolished) | Anglian Water | Anglian Water | No |
| Lenwade | Private | Environment Agency | Environment Agency | No |
| Lyng | Private (site only - buildings demolished) | Private | Private | No |
| Elsing | Private | Private | Private | No |
| Swanton Morley | Environment Agency (site only - buildings demolished) | Environment Agency | Environment Agency | Yes, HiFlows No. 34114 (2 arch) and HiFlows No. 34214 (3 arch) - continuous flow gauging station |
| Elmham | Private | Private | Private | No |
| Guist | Private (site only - buildings demolished) | Private | Private | No |
| Bintry | Private | Environment Agency | Environment Agency | No |
| Great Ryburgh | Prime Life PLC. (site only - buildings demolished) | Prime Life PLC. | Prime Life PLC. | No |
| Fakenham | Private | Environment Agency | Environment Agency | Yes, HiFlows No. 34011 - continuous flow gauging station |
| Sculthorpe | Private | Environment Agency | Environment Agency | Has been used for spot gauging in the past |
| South Mill | Private (site only - buildings demolished) | Private | Private | Has been used for spot gauging in the past |

# Heritage

5.32 A number of locations in the River Wensum SSSI are important heritage sites in terms of built infrastructure and archaeological remains. Often buildings or bridges associated with mills are listed structures (generally Grade II). Details of listings are presented in the ‘mill summary sheets’ (Appendix 2). Restoration options for each section of river will need to take full account of the potential impacts on the heritage/archaeological value of the river valley.

# Recreation

5.33 The Wensum valley provides opportunities for a range of quiet recreational pursuits. However, there is generally very limited public access to the River Wensum itself. A footpath at Fakenham is the only one that runs along the banks of the River Wensum SSSI for any distance. Points at which the public has access to view the river tend to be limited to road bridges.

5.34 The Countryside and Rights of Way Act 2000 (CRoW) created new rights for people to walk on areas of open country and registered common land. The Government introduced the new access rights on a regional basis over 2004-2005 and the rights are now in force across England. A number of commons immediately adjacent to the River Wensum were identified under CRoW, including Mill Common (Waterfall Common) and Burgh Common at Swanton Morley.

5.35 The majority of land adjacent to the River Wensum is in private ownership. Stakeholders are understandably concerned about reduced access to the River Wensum, or a reduction in amenity, that may be caused by river restoration. The main recreational interests along the river include:

- Recreational boating/canoeing - there are no statutory rights of navigation within the SSSI, and so any boating and canoeing can only take place with the permission of the riparian landowners. Where boating activity does occur, areas of shallow water tend to restrict activity to short sections of the river. Canoeing is centred mainly on Fakenham, Swanton Morley and Costessey/Hellesdon, with a number of canoe clubs organising events on the river. Rowing boats are used by some riparian landowners for recreational purposes along stretches of river that they own.
- Angling - the river is of regional and national importance for angling and a large number of clubs and other organizations have fisheries interests on the river. The Wensum is a mixed fishery, supporting both salmonid (trout) and cyprinid (coarse) species. Coarse fish species include roach, dace, perch, barbel, pike, eel, gudgeon, minnow, stone loach and brook lamprey. Free fishing is available at a number of locations, including Drayton, Ringland, Swanton Morley and Fakenham. There are a large number of still waters within the floodplain (mainly flooded gravel pits) which are also of value for angling.
- Walking - access to the river for walkers is mainly restricted to the many road bridges which span the river. Footpaths along the banks occur at Fakenham, Drayton and Lenwade.

# 6 Components and implementation

## Overview

6.1 The River Wensum Restoration Strategy is intended to provide a high level framework that can subsequently be translated into a programme of work to restore the River Wensum to favourable condition. The strategy focuses on the main issues affecting the form and function of the river as a whole. The approach is strategic, identifying and prioritising key elements that must be considered during restoration of the 71km of river channel in the SSSI.

6.2 The River Wensum Restoration Strategy is supported by a significant amount of analysis but cannot provide a complete 'recipe' or exact specification to what is required in individual river reaches, due to weaknesses in the data available and uncertainties in the effectiveness of certain river restoration techniques. When applied at the local level, issues will arise that influence the practicality of what can be achieved, and staged changes in water level control may be desirable. When drawing up delivery plans for restoration of individual river reaches, consultation with all interested parties will be essential to ensure that stakeholders are in agreement with the proposed actions, and to secure the relevant permissions that will be required. Further study will also be required before detailed designs are produced, including surveys of protected species and flood risk modelling.

6.3 The restoration could be implemented in a number of ways, such as:

1) Through the contracting of works by a central body (for example, the Environment Agency) with continued input from a steering group.
2) Through coordination of local groups by a centralised project. This would ease planning issues and raise part of the funds required through national funding and available grants, as well as taking advantage of opportunities to carry out work in line with the strategy wherever possible.
3) Through local efforts and private initiatives (similar to the previous initiatives on the Wensum, such as NACA and EA, and on the Little Ouse, such as the Little Ouse Headwaters Project).

6.4 It should also be recognised that some of the changes envisaged in the restoration strategy go further than has been attempted elsewhere in the UK, both in extent and impact. Because of this there are uncertainties about the best practices to adopt. An important aspect of implementation of the strategy will be lessons learnt during initial pilot schemes and at demonstration sites. Adaptation of the methods prior to their re-use at new sites may be needed. To date, monitoring of the success or otherwise of previous schemes on the Wensum (as well as elsewhere) has been weak.

6.5 A case in point is the changes proposed at the former mills along the River Wensum. Whilst structures have been removed before from rivers in the UK, the driver has usually been flood risk management for people and property. Lowering or removal of a water control structure as part of a restoration scheme is rare and, for the most comparable case on the River Kennet, the water level was reduced only marginally (by 0.3m). In Denmark, for example, there have been larger changes made at weir structures but generally on smaller streams. The techniques used there will need to be adapted before they can be applied to a Norfolk chalk stream.

6.6 The reason that river restoration at mills has been identified as a priority is that lowering or removing mill structures and associated channel works will alter the gradient of the water level in the channel in the zone of influence of the structure. Engineering works at mills will inevitably

involve some form of silt management and bed re-grading in the impounded reach and will, therefore, influence the extent and type of restoration required in neighbouring reaches. It would be inappropriate to restore a section of channel up or downstream of a mill without reference to the proposed programme of work at the mill.

# Timeline for restoration

6.7 In order that the River Wensum Restoration Strategy is realistic and practical, a timeframe needs to be defined for completion of the recommended works (Table 7). The Government's (PSA) target is for 95% of SSSIs by area to be in favourable or unfavourable recovering condition by 2010. Provided that the River Wensum Restoration Strategy is in place and work is progressing, the 2010 target does not constrain the programme for completion of work, although there clearly needs to be a reasonable timetable for completion of physical changes. The actual attainment of favourable condition may take some years after completion of the physical works.

6.8 The Water Framework Directive provides another driver for river restoration. This gives a requirement for all rivers to be working towards and, except where heavily modified or economically disproportionate, to achieve 'good ecological status' by 2015. However, this does not apply to SAC rivers, and River Basin Management Plans should adopt the conservation objectives of designated sites (Appendix 6).

6.9 Elements of the River Wensum Restoration Strategy that may involve hard engineering (such as works at mill structures) or that are unlikely to be resolved through natural processes (such as recovery of gravel bed materials or the re-meandering of straightened lengths of channel) will require early intervention. However, where possible, natural processes will be encouraged to restore channel form and function over time, either through enhancement or assistance of natural recovery. Only in reaches where it is considered unlikely that the channel will recover its natural form in a reasonable timeframe (that is, very wide reaches that would not narrow down within the next 10 to 15 years), will additional forms of intervention be programmed into the reach based delivery plans. As the way the strategy is implemented and funded will influence its feasibility, a staged timeline of works is considered and the cooperation of stakeholders and partners and the integration with local initiatives is encouraged.

6.10 It is also worth highlighting the need to consider climate change in the River Wensum Restoration Strategy. A supplementary note to the Flood and Coastal Defence Project Appraisal Guidance provided by Defra for economic appraisal (PAG3) was produced in October 2006. This suggests that climate change should be considered during the planning of flood defence works by undertaking sensitivity analysis during the flood modelling process. The recommended indicative sensitivity ranges for peak river flow volumes (in relatively large catchments) are +10% (for 1990 to 2025) and +20% (2025 to 2115). The influence of climate change on the River Wensum Restoration Strategy could be wide ranging, from an influence on flood levels and flood risk management requirements, to an influence on the frequency of extreme flood flows and, in turn, river channel stability, characteristic bankfull channel dimensions, habitat stability and evolution. The sensitivity of the hydrology, hydraulics, geomorphology and ecology should all be considered with respect to climate change at the project level to ensure its sustainability.

**Table 7** Timeframe for restoration

| Date | Target | Monitoring & assist natural recovery | Works at mills* | Restoration & enhancement | Bed raising | Narrowing |
|---|---|---|---|---|---|---|
| 2006 | Complete River Wensum Restoration Strategy | | | Interim management advice as to how mill structures should be maintained until full scale restoration is carried out. | | |
| 2007 | Formulate Project Organisation | Monitoring of pilot schemes should be on-going (prior to works, during and after) and should be adaptive. Monitoring will inform decision on whether additional works must be commissioned. Monitoring data can be shared between project teams so that lessons learnt during pilot scheme can be adopted by other projects. | Lower water levels at mills through alteration of existing operational regime - no physical modification of water level control structures. | Works at mills to be accompanied by local channel enhancements and improvements in floodplain connectivity. Restore original planform at priority sites. | Works at mills to be accompanied by bed raising and riffle creation as required. | Works at mills to be accompanied by silt management, which may include the creation of berms (re-distribution of silts) along channel margins in locations where the channel is currently over wide. Other narrowing techniques to be implemented where appropriate. |
| 2008 | | A catchment wide maintenance plan must be agreed between stakeholders and partners prior to works commencing. The aim of the maintenance plan should be to assist natural recovery wherever possible (refer to Appendix A). The strategy will have to balance conflicting requirements. | Further reduce water levels at mills through physical modification of water level control structures. | | | |
| 2009 | | | | | | |
| 2010 | PSA target | | Review monitoring data and undertake additional works at mills as and when required. | Where identified on reach summary sheets (Appendix A), restoration of meanders and enhancement works. | Where identified on re ach summary sheets (Appendix A), other bed raising works. | Take advantage of local initiatives and stakeholder/partner input wherever possible to narrow over-wide reaches or encourage natural berm accumulation.<br><br>Later on, and where required to speed up process of channel narrowing in very over-wide reaches, commission rehabilitation works. |
| 2011 | | | | | | |
| 2012 | | | | | | |
| 2013 | | | | | | |
| 2014 | | | | | | |
| 2015 | WFD target | | | Review monitoring data and undertake works as and when required. | Review monitoring data and undertake works as and when required. | Review monitoring data and undertake works as and when required. |
| 2016+ | | | | | | |

Time

* See Table 9 for recommended action at each water level control structure.

# Summary sheets

6.11 Whilst generic information about the Wensum catchment as a whole is provided in this technical report, specific information relating to particular locations in the catchment is summarised in a series of tables, presented as appendices to this report (Appendices 1 and 2). These 'summary sheets' represent data collected from a wide range of sources and they present the River Wensum Restoration Strategy at the reach scale. The aim of the sheets is to collate data for future ease of reference and to make the designation of management options, and the reasoning behind recommendations, transparent for future studies at the local scale.

6.12 Through original analysis, and taking into account the site descriptions and recommendations of the Geomorphological Appraisal, previous river restoration initiatives/schemes and potential constraints to restoration, the river was divided into reaches. 38 reaches were identified on the River Wensum and one on each of the River Tat, the Langor Drain and the Guist Drain. 'Reach Summary Sheets' include information for each reach related to its location, possible constraints to restoration and previous works or studies (Appendix 1). The following recommendations are also presented for each reach:

- summary of requirements
- reference channel dimensions
- management class
- specific actions recommended.

6.13 It is important to note that works at weirs/mill structures are slightly different in character to the work in the channel but are considered an essential element of a 'whole river' restoration. Without change at the mills, improvements elsewhere on impounded reaches can only achieve a limited effect and will not result in the change in ecological condition of the river that is required. Summary sheets for each mill (Appendix 2) are given in a similar form to those prepared for the river reaches.

# Management class

6.14 As a first step towards quantifying the magnitude of restoration work needed, it is important to define the different types of 'restoration' being considered for each reach of the River Wensum. This is helpful as there is no universally accepted nomenclature to distinguish between relatively minor restoration measures, like the introduction of riffles, and major changes such as the cutting of a new river course. Broad definitions of management classes used in this study are given in Table 8.

6.15 Designation of management classes on a reach-by-reach basis was dependant on an assessment of restoration requirements, as listed on the reach summary sheets. Generic statements were used to define these requirements on the reach summary sheets. The requirements are based, in part, on the degree of variation of the current channel form (width and depth) from that of a semi-natural channel in Norfolk. Discussions with Natural England, the Environment Agency and local landowners suggest that narrowing can take place at the rate of 5m in 5 to 10 years along parts of the river. It is assumed that physical narrowing and bed raising (rehabilitation) will be required in reaches where narrowing of greater than 5m and bed raising of more than 0.3m is necessary. More details of the decision making process involved in designating management classes are provided in Figure 22.

**Table 8** Management classes for 'Restoration' actions

| Management Class | Definition |
|---|---|
| Works at water level control structures | This is a pivotal and necessary component of the River Wensum Restoration Strategy. It is necessary for works at water level control structures to be completed prior to restoration works up/downstream if the strategy is to be sustainable. Backwater or impounded river sections upstream of mill structures dictate the current form and function of the Wensum in the majority of reaches. |
| Restoration | The re-cutting of an old meander/river course and complete alteration of the current regime. The planform to which the river is restored should ideally be a former course that can be identified in the floodplain. Only recommended where it was considered that this would provide tangible benefits to the functionality of the river. |
| Rehabilitation | Physical modification of the channel to re-create self-sustaining physical habitats (for example, riffles, side berms), generally where the channel is currently substantially over deep and/or over wide. |
| Enhancement | Measures undertaken to help improve physical habitat where this is identified as lacking, such as where riparian vegetation is not in a good condition (for example, woody debris structures, tree planting & re-vegetation to encourage the formation of vegetated berms). |
| Assist natural recovery | Amplification of existing processes to encourage natural recovery (for example, reduction of maintenance to allow the accumulation of woody debris where appropriate and the development of berms where riparian vegetation is already in good condition). |
| Monitor | This should be considered at all sites at the earliest opportunity to check that the current condition does not degrade further, and to ensure that the geomorphological response to management works is as anticipated. A distinction is made between adaptive management and post project appraisal. Adaptive management allows for changes to the management approach or techniques if, for example, during implementation of engineering works or a period of natural recovery, the approach is causing deterioration in condition or negative impacts elsewhere in the catchment. Post project appraisal often involves repeat surveys of the restoration site (topographic, ecological or geomorphological etc.) to allow the outcome of the project to be monitored against its original aims. |

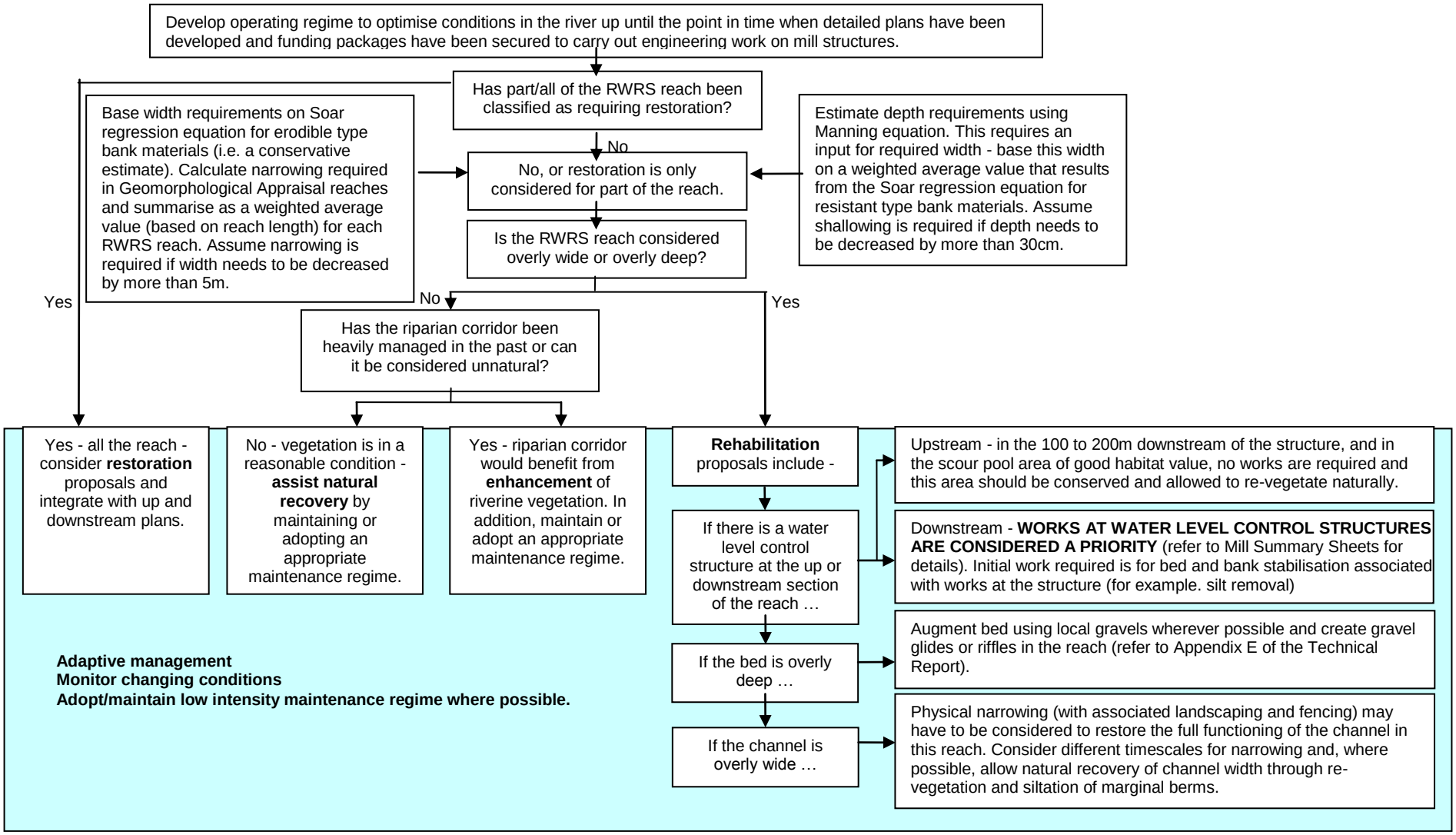



**Figure 22** Decision process in management class designation

### Mills

6.16 The mill structures have a profound influence on the river system in the Wensum catchment. If high retained water levels continue upstream of the mills, they would form a significant constraint on the effectiveness of river restoration. Physical modifications at mill sites should aim to restore a more natural longitudinal profile to the river and to remove or reduce physical barriers to the movement of fish and wildlife. Whilst historically a number of mills have been in existence for centuries these have always very actively stored and released water and the cessation of working of the mills in combination with dredging has had a significant impact.

6.17 The recommended actions at mill structures are shown in Table 9. At a number of sites there is no mill building and removal of water level control structures would be the desired course of action. However, often there are multiple channels at a mill site and it is likely that some hydraulic controls would be needed to maintain a split of flows to all channels. These would probably take the form of a fixed crest and a natural chute that would allow the passage of fish and woody debris. At locations where the water level control structures are part of the historic mill building, there is often a variety of passageways and the best way to lower levels will need to be identified using more detailed survey. Initial action can be taken at low cost by merely adjusting operating levels using the available gates and stop boards. The reduction in head that could be achieved at a typical dry weather flow is also summarised in Table 9. The estimated maximum reduction in backwater length through changing the operational level of the sluices (that is, without the need for major engineering works) is 18km. This would reduce the length of the River Wensum SSSI affected by backwater from mills from 67% to 40%. To achieve this it would be necessary to ensure that no channels downstream of gates or fixed weirs are affected, but this could be a cost effective start to the Wensum restoration.

6.18 It is likely that at some locations, where the channel course has been altered and the mill channel is significantly higher than the natural channel, the main flow could be diverted upstream of the current mill location. Maintaining some flow to the original mill weir is likely to be preferable for aesthetic and heritage reasons, so by-passing is likely to be required in conjunction with lowering of the mill weir. Sites where such a solution is envisaged are at Great Ryburgh and Lyng.

6.19 The control structures at Costessey, Swanton Morley and Fakenham are used for flow gauging by the Environment Agency. Lowering these weirs may mean that the existing gauging arrangements will need to be replaced by other methods, such as ultrasonic techniques. The weir on the main channel at Swanton Morley has a two stage drop and a significant reduction in water level could be achieved there without affecting flow gauging through the bridge.

6.20 A former mill known as Gogg's Mill near to Fakenham was removed as part of the drainage improvement works of the 1950s. The channel upstream of the mill has narrowed significantly through the accretion of silt berms, and provides a good case study of the extent to which natural recovery can help restore natural river form and function.

6.21 As part of the River Wensum Water Level Management Plan being prepared by Entec (2007) the views of some private owners on changes in operating level have been canvassed. In broad terms this is not opposed, but there is concern to maintain an attractive setting incorporating some mill pond in line with the historical context particularly at:

1) Elsing
2) Great Ryburgh
3) Bintree
4) North Elmham
5) Lenwade.

6.22 A reduction in the retained water level at mills may constrain the ability to direct water through all the existing channels at mill sites, should this still be required, there may be a need to carry out physical modifications to some of the subsidiary water level control structures.

**Table 9** Potential changes at water level control structure

| Mill | Proposed Ultimate state | Potential for initial adjustment of operating levels | Amount of lowering possible by changes in sluice operation only/ reduction in backwater (km) | Requirement for structural works |
|---|---|---|---|---|
| Hellesdon | Remove gates | Good. Initial changes can be made by removing boards and changing sluice operation. | 0.52m<br>1.5km | Total removal of obstruction requires some structural modifications, but is possible. |
| Costessey | Lower fixed measuring weir | Low. Initial changes can be made by changing sluice operation, however limited by need to retain flow in different channel. | Small | Modification of EA fixed measuring weir will be necessary to reduce operating levels. Existing fish pass may also need modification. |
| Taverham | Remove gates | Good. Gates can be kept open but distribution of flow to different channels may need to be maintained. | 0.3m<br>0.5km | Anglian Water are assessing options for modification of gate controls as currently unsatisfactory to operate. |
| Lenwade | Lower operating levels | Good. Automatic gate can be programmed or even used to simulate traditional mill operations. | 0.99m<br>2.04km | Fish pass may be needed. |
| Lyng | Lower level and create new bypass | Limited. But proposals for change being considered and link to flood protection and angling proposals. | 0.47m<br>0.25km | Lowering of fixed weir will be needed to maintain flow in mill channel. |
| Elsing | Lower | Limited. Operation of sluices to a lower level is possible. | 1.36m<br>2.51km | |
| Swanton Morley | Lower, remove older mill weir | Limited - lowering of old mill weir possible. Other controls are fixed weirs used by EA for flow measurement. | 0.14m<br>Negligible | Significant change in control levels will require modification of modern concrete weirs. |

**Table continued…**

| Mill | Proposed Ultimate state | Potential for initial adjustment of operating levels | Amount of lowering possible by changes in sluice operation only/ reduction in backwater (km) | Requirement for structural works |
|---|---|---|---|---|
| Bintree | Lower | Good. Operating levels could be adjusted by sluices. | 1.12m<br>3.75km | Mill sluices may need modification. |
| North Elmham | Lower | Good. Operating sluices to a lower level is possible. | 0.72m<br>3.25km | |
| Great Ryburgh | Bypass/reconnect to meander | Limited. Gates already kept open. | 0.82m<br>2.75km | Reconnection of old meander will require connection to channel upstream of mill, possibly through existing bypass. |
| Fakenham | Lower | Limited, but easily achieved. EA operated gate could be kept open during summer | 0.1m<br>1.5km | Structural work required to lower gauging weirs. |
| Sculthorpe | Lower | Limited due to fixed weirs. | 0.3m<br>Negligible | Fixed openings beneath mill will need structural modification. |
| South | Remove sill | None | | Fixed sill below bridge may be lowered. |

6.23 The details of how best to modify the operating level thus needs more detailed study as part of the implementation planning.

### Reaches

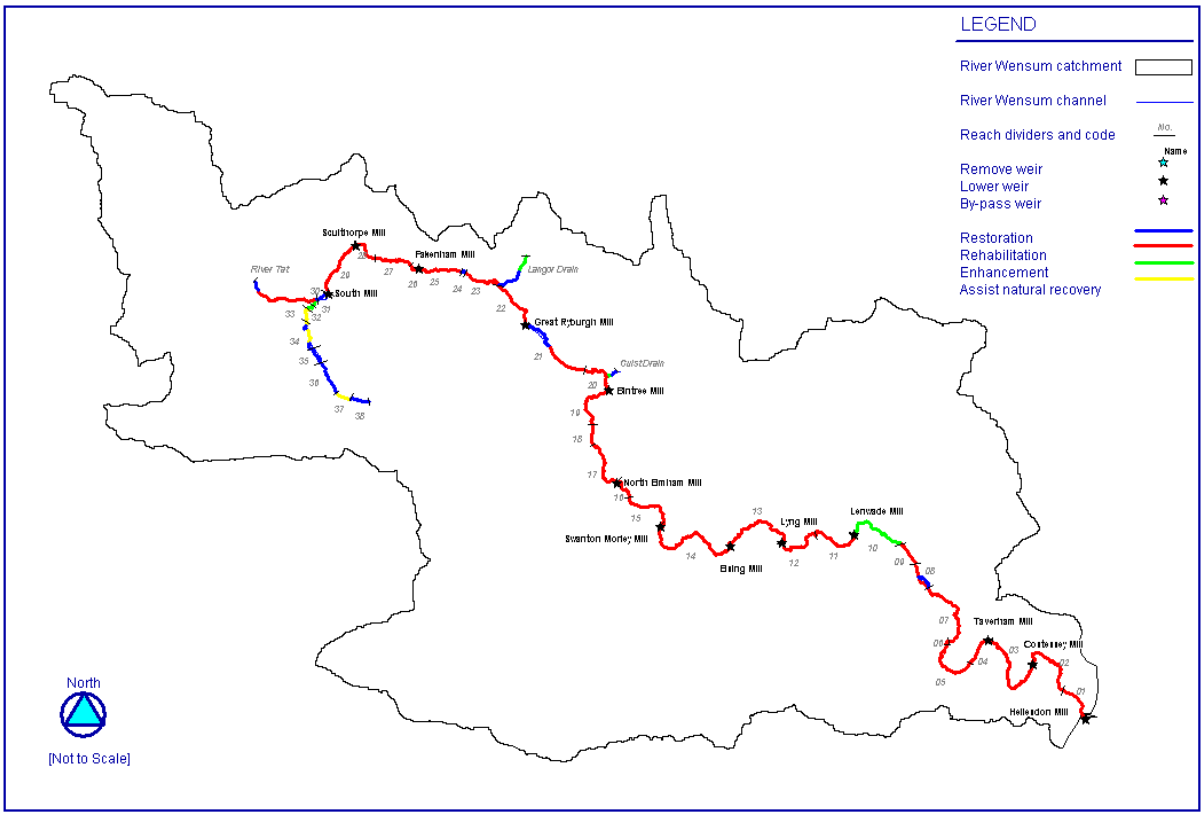
6.24 The location of river reaches and the distribution of restoration management classes are presented in Figure 23 and summarised in Table 10. The majority of river reaches on the River Wensum SSSI fall within the management class of rehabilitation, generally on account of their requirement for channel narrowing and/or bed raising and riffle or glide re-establishment (refer to Appendix 1 for details of requirements in each reach and Sections 6.14 - 6.15 for details of the management class decision making process). In total, 27 reaches are classed as in need of ‘rehabilitation’, covering about 63km of the River Wensum SSSI, which is almost 85% of the river channel Table 11). Due to local variability, it is unlikely that rehabilitation (for example, through narrowing/depth reduction) would be required over the whole reach length and, for costing purposes, it is assumed that 75% of the total reach length will be restored.

6.25 Bed raising is required over 45km of channel. Gravels will be placed to form riffles and glides but it is expected that, on average, there will have to be a 0.5m decrease in bankfull depth throughout the catchment. Some gravels may be won by the on-site processing of spoil heaps (that is, former dredged material) and this will reduce the need to import material.

6.26 About 5.5km are classed as ‘enhancement’ reaches (where the channel is not overly wide but where the littoral margin is lacking or requires enhancing) and 3km are classed as ‘assist natural recovery’ (where narrowing is expected to occur naturally, and where there is a good littoral margin to encourage this if maintenance is reduced or maintained at a low level).

6.27 In a small number of reaches (4 along the River Wensum), opportunities for full meander restoration are thought to be desirable. The reaches on the River Tat, the Langor Drain and Guist Drain also have some sections of channel where restoration would be desirable. However, in most reaches along the River Wensum where re-meandering is considered appropriate to restore the full functioning of the river, only a small part of the total reach length would be affected. The remaining part of the reach length was classified as rehabilitate, enhance or assist natural recovery. Initial proposals are for just over 3km of the current channel to be cut-off by 'restoration' and used as off-river supplementary units. Restoration itself would create nearly 8km of new channel length (mainly in the upstream reaches of the catchment). In most locations the course of the former channel is readily identifiable and can be reconnected to the existing channel. Apart from establishing the new channel, it will be necessary to provide diversion and cut-off at the existing channel, and environmental mitigation works (for example, for water voles).

6.28 No reaches are in a sufficiently favourable state to be classed as requiring 'monitoring' alone, although sections of some of the reaches (such as those where successful previous restoration work has taken place) will warrant this and monitoring will be a key requirement during and following restoration works, particularly at pilot scheme sites.




Note: For larger version of this figure (A4-size), refer to Appendix 11 at back of this report.

**Figure 23** The River Wensum Restoration Strategy: classification of reaches by management class

**Table 10** Summary of reach classification and requirements

| RWRS reach code | RWRS reach length (km) | Management class | Length of restoration (km) | Amount of narrowing required over 75% reach length (km) | Amount of bed raising required over 75% reach length (km) |
|---|---|---|---|---|---|
| 1 | 1.65 | Rehabilitate | | 10.7 | 0.6 |
| 2 | 3.16 | Rehabilitate | | 9.8 | 0.4 |
| 3 | 3.91 | Rehabilitate | | 5.2 | 0.3 |
| 4 | 1.49 | Rehabilitate | | 9.4 | 0.7 |
| 5 | 2.56 | Rehabilitate | | | 0.5 |
| 6 | 0.23 | Rehabilitate | | 11.8 | |
| 7 | 3.62 | Rehabilitate | | | 0.5 |
| 8 | 1.25 | Rehabilitate with restoration | 0.8 | | 0.4 |
| 9 | 1.11 | Rehabilitate | | | 0.6 |
| 10 | 2.94 | Enhance or assist | | | |
| 11 | 2.43 | Rehabilitate | | 7.0 | 1.0 |
| 12 | 2.15 | Rehabilitate | | | 0.4 |
| 13 | 3.68 | Rehabilitate | | | 0.6 |
| 14 | 4.83 | Rehabilitate | | 10.1 | 1.2 |
| 15 | 2.52 | Rehabilitate | | | 0.4 |
| 16 | 1.17 | Rehabilitate | | | 0.5 |
| 17 | 2.60 | Rehabilitate | | 12.9 | 1.5 |
| 18 | 0.86 | Rehabilitate | | 5.6 | 0.7 |
| 19 | 2.67 | Rehabilitate | | | 0.7 |
| 20 | 2.01 | Rehabilitate | | 14.6 | 0.8 |
| 21 | 3.31 | Rehabilitate with restoration | 1.44 | | 0.9 |
| 22 | 2.38 | Rehabilitate | | 5.2 | 0.8 |
| 23 | 1.98 | Rehabilitate | | | 0.5 |
| 24 | 0.18 | Restoration | 0.33 | | 0.5 |
| 25 | 1.96 | Rehabilitate | | 5.2 | 0.4 |
| 26 | 0.46 | Rehabilitate | | 14.2 | 1.4 |
| 27 | 1.72 | Rehabilitate | | 8.8 | 1.0 |

**Table continued…**

| RWRS reach code | RWRS reach length (km) | Management class | Length of restoration (km) | Amount of narrowing required over 75% reach length (km) | Amount of bed raising required over 75% reach length (km) |
|---|---|---|---|---|---|
| 28 | 1.25 | Rehabilitate | | | 0.6 |
| 29 | 2.63 | Rehabilitate | | | |
| 30 | 0.67 | Restoration | 0.5 | | 0.7 |
| 31 | 0.48 | Enhancement | | | |
| 32 | 0.32 | Enhancement | | | |
| 33 | 0.72 | Assist natural recovery | | | |
| 34 | 1.57 | Assist natural recovery with restoration | 0.63 | | |
| 35 | 0.71 | Restoration | 0.75 | | |
| 36 | 1.41 | Restoration | 0.75 | | |
| 37 | 0.72 | Assist natural recovery | | | |
| 38 | 0.85 | Restoration | 0.75 | | |
| Tat | 3.28 | Rehabilitate with restoration | 0.5 | | |
| Guist | 0.33 | Enhancement with restoration | 1.2 | | |
| Langor | 1.43 | Enhancement with restoration | 0.3 | | |
| **Total** | **75.1** | | **7.9** | **20.4** | **45.3** |

**Table 11** Management requirements

| | Length (km) | Percentage of total length |
|---|---|---|
| Restoration | 3km | 5% |
| Rehabilitation | 63km | 84% |
| Enhancement | 5.5km | 7% |
| Assist natural recovery | 3km | 4% |

# Initial cost estimates

6.29 The main components of work required during implementation of the River Wensum Restoration Strategy fall into one of the following five categories:

- Modification/removal of mill structures.
- Restoration.
- Bed raising and riffle/glide creation.
- Narrowing.

- Miscellaneous improvements such as landscaping, fencing, construction of backwaters, fry refuges, vegetation establishment and planting.

6.30 To give a preliminary costing for the River Wensum Restoration Strategy, a wide range of costs and unit rates were assembled from previous projects, including a number of projects that have already been completed on the Wensum. In addition, costs derived from the River Restoration Centre's examples of previous works and standard civil engineering cost rates were also considered. Typically, the quoted unit rates for river restoration do not include overheads and project management costs and do not include a contingency (as required by Defra for project assessment). Table 12 provides a summary of the rates used in this strategy. The preliminary costings of each component of work and initial estimates of total project costs have been calculated.

**Table 12** Typical unit costs of restoration works

| | **Unit rate** |
|---|---|
| Mill weirs | Varies (see description below) |
| Restoration | £150,000/km |
| Bed raising, riffles and glides | £180,000/km |
| Narrowing (5-10m) | £200,000/km |
| Narrowing (>10m) | £400,000/km |
| Landscaping | £1,000/km |
| Fencing | £6,000/km |

6.31 The total cost of implementing the restoration as one large construction project let to a commercial contractor would be high. If all costs are considered and the restoration is tackled as a major project to a given completion deadline, normal commercial rates and contingencies must be assumed and the total scheme costs would be in the range of £25-£50m.

6.32 Conversely, a great deal could be achieved at very low cost by focussing on changes at weirs and through projects promoted and carried out by local community action, and through the linking to other developments such as green infrastructure planning and flood risk management schemes. The cost of installing bank protection for narrowing is a significant component and, for example, the adjustment of river width in many places could be realised over a longer time period (observed accumulations of berms take 10-15 years) by natural processes influenced by the regime of weed cutting and channel maintenance.

6.33 The total costs of restoration are thus very dependent on the way that work is implemented. When a small scale scheme is implemented costs are kept low through donation of companies' and individuals' time and enthusiasm. Whilst it is highly desirable to continue to involve the community and tap into local resources, the **full implementation** of such a major project within a deadline of 2010 or 2015 would not be possible by these means.

6.34 The best solution for taking the restoration forward may be a compromise between these two approaches. For example, an initial pilot project could be set up covering a number of restoration reaches and changes needed at mills, incorporating measures which will be required to stabilise the river banks and recreate the original form and depth of river bed in the immediate vicinity of the structures. At other locations, taking opportunities for simple changes to mill sluice operation, and monitoring of the results would add little cost. Further bed raising, installation of riffles and glides, together with secondary works and narrowing might then follow, managed by and using local resources. Designs can be adapted to those found most acceptable. A central coordinating body would be desirable to ensure that the changes in river condition are monitored so that past

mistakes are not repeated. This body could also assist in securing the necessary consents and permissions for projects to proceed.

6.35 Where possible, natural recovery of channel width will be induced over the short term (10 to 15 years) and should be sufficient in numerous locations along the River Wensum. Because the estimated cost of narrowing is a large component of the total cost, a number of options for this have been considered. Narrowing of the channel will include some element of natural bank protection and some work to backfill behind. Cost rates are higher where there is a need to narrow significant lengths of river channel as more backfilling will be required.

# Initial schedule and funding

6.36 A schedule for implementation of the River Wensum Restoration Strategy has not yet been derived but already there are clear opportunities that would be ideal to advance as pilot projects (Plate 8).

6.37 One potential opportunity is at Taverham Mill. Taverham Mill is owned by Anglian Water Services Ltd., who are keen to reduce overheads related to gate maintenance, and to resolve health and safety issues in relation to the operation of the structures. They are also planning environmental enhancements to their landholding, for example by improving the connectivity between the Wensum and its floodplain and by introducing woody debris into the channel. Restoration at Taverham Mill represents a significant opportunity to establish 'best practice' for alteration of water level control structures and for channel modification.

6.38 Upstream of Lyng, Norfolk Anglers Conservation Association are proposing a partnership river restoration project aimed at improving the fisheries and conservation value of the channel (Plate 8). Initial proposals include connection of the parallel drain, which was probably the original course of the river before it was diverted, to the Wensum upstream of the mill. At the same location, the Environment Agency is interested in developing a scheme to reduce flood risk to property in the village. This project has the potential to demonstrate how flood risk management can be incorporated in a reach based Delivery Plan, as well as linking new improvements with some previous enhancement works (for example, the NACA riffles downstream).

6.39 At Great Ryburgh, a scheme was undertaken in the early 1990s to reconnect the original meandering watercourse downstream of the mill to a downstream mill cut that is straight and of low diversity. The challenge here would thus be restoration of the channel planform, as well as in-channel features, through restoring the connection upstream of the mill (Plate 8).

6.40 Funding for the development of reach delivery plans based upon the framework of the River Wensum Restoration Strategy may be available from a number of sources, including the Environment Agency (for example, grant in aid for flood risk management capital schemes, fisheries improvements and the Water Level Management Plan), Natural England and the Norfolk Rivers IDB. Some elements of the strategy may also be funded through agri-environment schemes such as Environmental Stewardship. As the Wensum is acting as a significant pilot for other rivers throughout the UK and Europe, there may also be opportunities to apply for European Union funding for some elements of the work. The development of local partnership projects with landowners, angling interests and conservation organisations is also likely to provide funding opportunities. The Aggregates Levy Sustainability Fund may also be an appropriate source of funding, given the impact of the aggregates industry in the Wensum valley.

# Implementation

6.41 The River Wensum Restoration Strategy has set out a challenging vision for restoration in the River Wensum SSSI and this section has discussed the outputs of the strategy. These include the main elements of work required at the catchment scale using a strategic and phased approach, a possible timeline of works and preliminary costings. It has also suggested a number of pilot schemes that could be used to develop methodologies and to provide examples of cooperative work between stakeholders, project partners and the community as a whole.

6.42 To take the strategy forward, reach scale restoration works must be considered in more detail. Initially, a prioritisation of sites is required to pinpoint where works are required, are desirable and are expected to be practicable and sustainable. Local studies must then be commissioned to describe reach scale objectives, highlight any constraints and, where appropriate, to produce a delivery plan. There will need to be consideration of the initiatives, strategies and schemes described in Section 4. Restoration on individual river reaches is likely to affect the Environment Agency's level thresholds for flood warning, which will therefore need to be reviewed post restoration.

6.43 An important element of restoration will be monitoring of project sites. Ideally, this will include survey of the study site prior to any works to provide a baseline understanding of the issues, and the setting of clear objectives for geomorphic change and habitat creation. There should also be an assessment of the study site during the works to ensure that they do not have any detrimental impacts either at, upstream or downstream of the study site. Management should also be adaptive to allow for change in techniques where unforeseen circumstances develop. Post-project monitoring is necessary to ensure that the objectives of the work have been met and that ecological conditions are recovering.

**Plate 8** Potential pilot sites for restoration - Top Left: Upstream of Lyng Mill - present channel, Top Right: Upstream Lyng Mill - old course Bottom Left: Downstream Great Ryburgh Mill - old course, Bottom Right: Taverham Mill - sluice

# 7 Recommendations and conclusions

## Conclusions

7.1 All riverine units of the River Wensum SSSI are in unfavourable condition, due in part to high levels of siltation and previous channel modifications which result in a loss of geomorphological functioning.

7.2 The higher than necessary inflow of sediment from the catchment is being addressed through Defra's 'Catchment Sensitive Farming' project and changes in the agricultural support system to encourage environmentally sensitive land use practices.

7.3 Changes in water management and physical changes to the channel are required to return the river to a more naturally functioning system.

7.4 The River Wensum Restoration Strategy provides a framework that can be used to deliver major improvements in the River Wensum SSSI in line with government targets of restoring the river to favourable condition. The strategy has specified changes in bed level, river width, redevelopment of meanders and changes at mill weirs, as well as ancillary aspects such as planting and use of woody debris.

7.5 The strategy indicates that the majority of the SSSI river channel would benefit from improvements which, building on work begun in an earlier geomorphological appraisal (Geodata, 2006) have been defined in four classes (restoration, rehabilitation, enhancement and assist habitat recovery - see Sections 6.24 - 6.28). Mills currently affect two-thirds of the entire river and changes to the operating levels at mills are essential for successful river restoration.

7.6 During preparation of the strategy there has been only limited consultation with stakeholders outside of the Steering Group. Though generally supportive, some stakeholders have expressed concerns regarding specific aspects of the restoration such as impacts on drainage and flooding. These concerns will be addressed during detailed feasibility studies for individual projects. The benefits of river restoration to flood risk management at a catchment scale are recognised in the Environment Agency's Broadlands Rivers Catchment Flood Management Plan and river restoration has a key role in future adaptation to climate change, offering advantages for flood peak reduction in Norwich in particular.

7.7 The costs of river restoration have been quantified, with these varying greatly depending on how the strategy is implemented. Much can be achieved at low cost (for example, the operating levels of mills could be reduced, and as a result backwater affected reaches would reduce by up to 18km).

7.8 There are important local complexities that must be addressed in the delivery phase of the restoration strategy. Detailed feasibility and design studies, and wider stakeholder consultation, will be carried out during the preparation of reach based delivery plans.

## Recommendations

### Strategy implementation

1) The River Wensum Restoration Strategy Steering Group should now take forward the project to an implementation stage. It is important to select the optimal delivery mechanism, identify funding sources and identify the organisation(s) which would best lead the project.

2) More detailed consultation with stakeholders is needed early in the next stage, both to promote the overall vision, and to discuss how local changes would be implemented.
3) Discussions with stakeholders that want to implement works on the river in the very near future, including Anglian Water, NACA (angling club) and the Environment Agency flood risk management team should be continued at the earliest opportunity.
4) Further study is required into how to implement the proposed changes in water levels at mills. It would seem appropriate that this should be progressed as part of the implementation of the River Wensum Water Level Management Plan, but this aspect must remain an integral part of the River Wensum Restoration Strategy.
5) Plans should be made for a demonstration site where the operating level at a mill can be progressively lowered. The changes in the river should be monitored to establish how lowering of water level can be achieved without creating unsightly muddy banks, or causing silts to be deposited on high quality gravel bed downstream of the mill.
6) During the development of the restoration strategy there were uncertainties in the methods used for calculating reference river widths and depths. Monitoring of the initial works under the plan should be undertaken to refine the prediction techniques and the most effective way of achieving river improvements.
7) The effects of potential restoration works on the flooding regime should be studied in more detail.
8) The River Wensum Restoration Strategy could be promoted as a pilot for improvement of river condition under the Water Framework Directive.

### Future restoration strategies

9) Future fluvial audits carried out for other SSSI rivers should focus closely on the work needed for restoring and improving the river condition. Ideally they should compare the channel size at bankfull flow with expected values and recommend where interventions are geomorphologically desirable. The recording of depth in a typical fluvial audit should use a reference condition, such as bankfull depth, to allow easy interpretation of the data.
10) There is a need to research and set out clearly the characteristic features of rivers, such as natural width and depth variations, glides and riffle and pool sequences to help refine techniques for restoration.
11) The backwater effect at mills has been shown to have a major influence on river condition. This is a very common situation that has received little attention in the past. More research is needed on the best way to reduce the impacts of impoundments, and so restore river form and ecology, whilst taking into account the impacts on amenity, recreation and heritage.
12) Personal accounts of observed changes in the river (such as in Appendix 4) have been useful to this study. Effort should be made to collate similar accounts for other rivers.

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# Appendix 1 Reach summary sheets

## Summary of data sources & analysis

**Table Aa1** Reach data summary

| | |
|---|---|
| Location: | The river channel was split into reaches of varying length based on Geomorphological Appraisal (2006) reach information. The Appraisal identified about 120 reaches and each reach was described using generic statements related to management requirements (for example, works at structures, fix sediment ingress points etc). Where neighbouring reaches were similar in requirements, the reaches were amalgamated. This produced a more manageable number of reaches for study in the River Wensum Restoration Strategy (RWRS) (that is, 38 reaches on the Wensum and one on each of the lower Tat, the Langor and Guist Drains). |
| NGR: | National Grid References, from OS maps, for up/downstream limits of each reach. |
| Total Reach Length: | Total length along channel centreline between up/downstream limits of each reach. |
| Geomorphological Appraisal (2006) Reaches: | List of Geomorphological Appraisal reaches included in each RWRS reach (described using the Geomorphological Appraisal reach codes). |
| Associated Mill Summary Information: | Refers to any mill structures (and associated Mill Summary Sheet from Appendix 2) at the up/downstream limits of each reach. Works at mills are considered a priority and reach requirements must integrate with restoration plans at mill structures. |

**Table Aa2** Current reach condition

| | |
|---|---|
| Description: | Summary of all relevant information related to reach-scale geomorphology, including a description of the channel and its floodplain, influencing factors etc. Information from a variety of sources, including the Geomorphological Appraisal database (for example, on embankments), ECON report (1999; general description, state of vegetation, river bed, habitat diversity etc.), OS maps (planform, drainage and general land-use etc). |
| Natural England Assessment: | The assessment unit code, type and condition of river units that are associated with each reach. Data from the English Nature (2002) Condition Assessment, with a review by Natural England (Agricultural Heartlands Team). |
| Upstream Catchment Area: | Upstream catchment area calculated from the upstream reach extent. The catchment area at each mill was estimated using the Flood Estimation Handbook. For reaches between mills, catchment area was estimated by integration using reach length. |
| Channel Dimensions (Bankfull): | Bankfull width was measured in each Geomorphological Appraisal reach. A range of widths is given for each RWRS reach.<br>Maximum bankfull depth was estimated for Main River using cross sectional data in the ISIS model (Upper Wensum Strategy Study, 2003). A representative ISIS node was identified for each RWRS reach. For the River Tat and Wensum upstream of the Tat confluence, topographic survey data for a proposed (1980) dredging scheme upstream of Fakenham was used. |
| Length Affected by Backwater: | The existing ISIS model was run for an average flow and the upstream extent of backwater effects were identified on a long profile of the channel, mapped on an OS map and compared to the location of each RWRS reach. The length of each reach affected by backwater was then measured. |
| Maintenance Regime: | Information provided by the Environment Agency and the Norfolk Rivers IDB relating to the extent and intensity of weed cutting and tree management in each reach. |

**Table Aa3** Constraints

| | |
|---|---|
| Flood Risk: | Flood Zone 3 map outlines available from the Environment Agency (extent of flooding expected in a 1 in 100 year return period flood event) were compared to the National Property Database (residential properties in the Wensum catchment). The number of properties perceived to be at risk of flooding was recorded and classified (low risk = no properties; moderate = 1 to 5 properties; high = 6 or more properties). |
| Land Use: | Information provided by Natural England (North East Norfolk & Broads Team) relating to the type of floodplain and valley side land-use. |
| Amenity Value: | Information provided by the Environment Agency (Fisheries, Recreation and Biodiversity Team) and Natural England (Agricultural Heartlands Team) relating to the type of amenity value in the RWRS reach. |
| Other: | Additional notes of relevance (for example, gauging station, high conservation value, potential flood risk management capital scheme etc). |

**Table Aa4** Previous works or recommendations

| | |
|---|---|
| Previous Measures (Consented): | Information provided by the Environment Agency about the types of work and locations where the Environment Agency have consented to works in the Wensum catchment since the 1990s (see Figure 12 in Technical Report), including works related to Environment Agency flood risk management. |
| Potential Schemes for Habitat Restoration (ECON): | Information taken from the ECON report (1999). The report identified 25 areas where maximum gains could be made to fisheries and conservation value (see Figure 16 in Technical Report). |
| Geomorphological Appraisal (2006) Options for Restoration:<br>Reach Code<br>Reach Status<br>Management Class | The Geomorphological Appraisal classified its reaches based on 'reach status' and 'management class' (refer to Sections 3.7 - 3.9 in the Technical Report). A summary of the information provided in the Geomorphological Appraisal for those reaches included within each RWRS reach is provided in this section. |
| Work related to weir<br>Re-establish former channel or dimensions<br>Reconnect river to floodplain<br>Narrow<br>De-silt<br>Augment gravel or bed or water levels<br>Monitor<br>Reduce maintenance<br>Improve flow & habitat diversity<br>Establish riparian vegetation<br>Create or maintain backwater<br>Fix sediment ingress points | The Geomorphological Appraisal also suggested a range of 'indicative management options' at each reach. These were represented by a number of generic statements (listed on the left). A table of tick boxes was used to identify which options were suggested for those Geomorphological Appraisal reaches included within each RWRS reach. |

**Table Aa5** Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Description of requirements or major factors that may influence works in the RWRS reach. The most important influences identified are mill structures and any works that may need to be tackled at these locations before plans are made for works elsewhere in the reach. | | | |
| Reference Channel Dimensions: | Width: | Reference Channel Dimensions: | Width: | Reference Channel Dimensions: |
| Revised Management Class: | Classify as restoration, rehabilitation, enhancement or assist natural recovery (refer to Table 8 in Technical Report). Classification is based on the decision rule outlined in the Technical Report (Figure 22). | | | |
| Specific Actions Recommended: | Related to recommendations associated with works at water control structures (that is, the need for integration of works in reaches up and downstream of the mill structures), shallowing or narrowing requirements in overly deep or wide reaches, and a general requirement for adaptive management and adoption/maintenance of a low intensity maintenance regime. Approximate number of glide/riffle features was estimated roughly using reach length divided by a typical riffle spacing (that is, 6 times the required bankfull width, after Brookes, 1990). | | | |

**Table Aa6** Summary of reach information

| Reach code (RWRS) | Reach length (km) | Mill at downstream end of reach | Overall reach classification | Length of restored channel (km) | Narrow width by (m)* | Reduce depth by (m)* | Maximum number of riffles or glides* | Notes |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.65 | Hellesdon - remove | Rehabilitate | | 10.7 | 0.6 | 16 | Coordinate plan with channel stabilisation upstream of mill |
| 2 | 3.16 | | Rehabilitate | | 9.8 | 0.4 | 32 | 3 new riffles installed by NACA |
| 3 | 3.91 | Costessey - lower | Rehabilitate | | 5.2 | 0.3 | 42 | Coordinate plan with channel stabilisation upstream of mill |
| 4 | 1.49 | Taverham - remove | Rehabilitate | | 9.4 | 0.7 | 16 | Coordinate plan with channel stabilisation upstream of mill Anglian Water have expressed interest |
| 5 | 2.56 | | Rehabilitate | | | 0.5 | 28 | |
| 6 | 0.23 | | Rehabilitate | | 11.8 | | 2 | |
| 7 | 3.62 | | Rehabilitate | | | 0.5 | 40 | |
| 8 | 1.25 | | Rehabilitate with restoration | 0.80 | | 0.4 | 14 | |
| 9 | 1.11 | | Rehabilitate | | | 0.6 | 13 | |
| 10 | 2.94 | | Enhance | | | | | Co-ordinate with EA capital works |

**Table continued…**

| Reach code (RWRS) | Reach length (km) | Mill at downstream end of reach | Overall reach classification | Length of restored channel (km) | Narrow width by (m)* | Reduce depth by (m)* | Maximum number of riffles or glides* | Notes |
|---|---|---|---|---|---|---|---|---|
| 11 | 2.43 | Lenwade - lower | Rehabilitate | | 7.0 | 1.0 | 31 | Coordinate plan with channel stabilisation upstream of mill |
| 12 | 2.15 | | Rehabilitate | | | 0.4 | 28 | Previous improvements in this reach |
| 13 | 3.68 | Lyng - Lower and create by-pass | Rehabilitate | | | 0.6 | 48 | Co-ordinate EA capital works and NACA proposals<br>Landowner has expressed support |
| 14 | 4.83 | Elsing - lower | Rehabilitate | | 10.1 | 1.2 | 66 | Coordinate plan with channel stabilisation upstream of mill |
| 15 | 2.52 | Swanton Morley - lower | Rehabilitate | | | 0.4 | 34 | Coordinate plan with channel stabilisation upstream of mill<br>Some existing works upstream |
| 16 | 1.17 | | Rehabilitate | | | 0.5 | 20 | |
| 17 | 2.60 | Elmham - lower | Rehabilitate | | 12.9 | 1.5 | 45 | Coordinate plan with channel stabilisation upstream of mill |
| 18 | 0.86 | | Rehabilitate | | 5.6 | 0.7 | 15 | |
| 19 | 2.67 | | Rehabilitate | | | 0.7 | 47 | Extend previous works at Bintree |

Table continued…

| Reach code (RWRS) | Reach length (km) | Mill at downstream end of reach | Overall reach classification | Length of restored channel (km) | Narrow width by (m)* | Reduce depth by (m)* | Maximum number of riffles or glides* | Notes |
|---|---|---|---|---|---|---|---|---|
| 20 | 2.01 | Bintree - lower | Rehabilitate | | 14.6 | 0.8 | 40 | Coordinate plan with channel stabilisation upstream of mill |
| 21 | 3.31 | | Rehabilitate with restoration | 1.44 | | 0.9 | 68 | Old course of river in floodplain |
| 22 | 2.38 | Great Ryburgh - bypass | Rehabilitate | | 5.2 | 0.8 | 51 | |
| 23 | 1.98 | | Rehabilitate | | | 0.5 | 45 | |
| 24 | 0.18 | | Restoration | 0.33 | | | | |
| 25 | 1.96 | | Rehabilitate | | 5.2 | 0.4 | 47 | |
| 26 | 0.46 | Fakenham - lower | Rehabilitate | | 14.2 | 1.4 | 11 | Co-ordinate with EA capital works |
| 27 | 1.72 | | Rehabilitate | | 8.8 | 1.0 | 43 | |
| 28 | 1.25 | | Rehabilitate | | | 0.6 | 33 | |
| 29 | 2.63 | Sculthorpe - lower | Rehabilitate | | 9.1 | 0.5 | 70 | Coordinate plan with channel stabilisation upstream of mill<br>Known area of dredging in 1950s |
| 30 | 0.67 | South - remove sill | Restoration | 0.50 | | | | Coordinate plan with channel stabilisation upstream of mill |

Table continued…

| Reach code (RWRS) | Reach length (km) | Mill at downstream end of reach | Overall reach classification | Length of restored channel (km) | Narrow width by (m)* | Reduce depth by (m)* | Maximum number of riffles or glides* | Notes |
|---|---|---|---|---|---|---|---|---|
| 31 | 0.48 | | Enhancement | | | | | |
| 32 | 0.32 | | Enhancement | | | | | |
| 33 | 0.72 | | Assist natural recovery | | | | | |
| 34 | 1.57 | | Assist natural recovery with restoration | 0.63 | | | | |
| 35 | 0.71 | | Restoration | 0.75 | | | | Raynham Lake and highly modified channel |
| 36 | 1.41 | | Restoration | 0.75 | | | | Wensum diverted around lake |
| 37 | 0.72 | | Assist natural recovery | | | | | |
| 38 | 0.85 | | Restoration | 0.75 | | | | |
| River Tat | 3.28 | | Rehabilitate with restoration | 0.50 | | | | |
| Langor Drain | 1.98 | | Enhancement with restoration | 1.20 | | | | |
| Guist Drain | 0.74 | | Enhancement with restoration | 0.30 | | | | |
| **Total** | **76.1** | | | **8.0** | | | | |

* Refers to rehabilitation reaches only

# River Wensum Restoration Strategy - reach summary sheets

## REACH CODE: RWRS 01

**Table Ab1** RWRS 01 Reach data summary

| | |
|---|---|
| Location: | Wensum Mount Farm to Hellesdon Mill |
| NGR: | 618930, 310520 to 619830, 310520 |
| Total Reach Length: | 1,645m |
| Geomorphological Appraisal (2006) Reaches: | W51 to W50 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for Hellesdon Mill, which is located at the downstream end of RWRS01. |

**Table Ab2** RWRS 01 Current reach condition

| | | |
|---|---|---|
| Description: | Channel becomes impounded upstream of Hellesdon Mill and widens towards the mill. Channel has been straightened and is managed close to residential areas. Some riparian trees exist in this reach. Embankments mainly on right bank in downstream half of reach. | |
| Natural England Assessment: | Part of the SSSI River Unit 54 (Taverham Mill to Hellesdon Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. River flows are adversely affected downstream of the Costessey Public Water Supply.<br>River Unit adjacent to Terrestrial Site Units 40 to 44 - 18.7ha supporting a mosaic of grazing marsh, and fen (including MG8 and M27). Mostly on the right bank of the river in downstream section of RWRS01. | |
| Upstream Catchment Area: | 630km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 20-34m<br>2.27m |
| Length Affected by Backwater: | All reach affected by backwater from Hellesdon Mill. | |
| Maintenance Regime: | 75% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Ab3** RWRS 01 Constraints

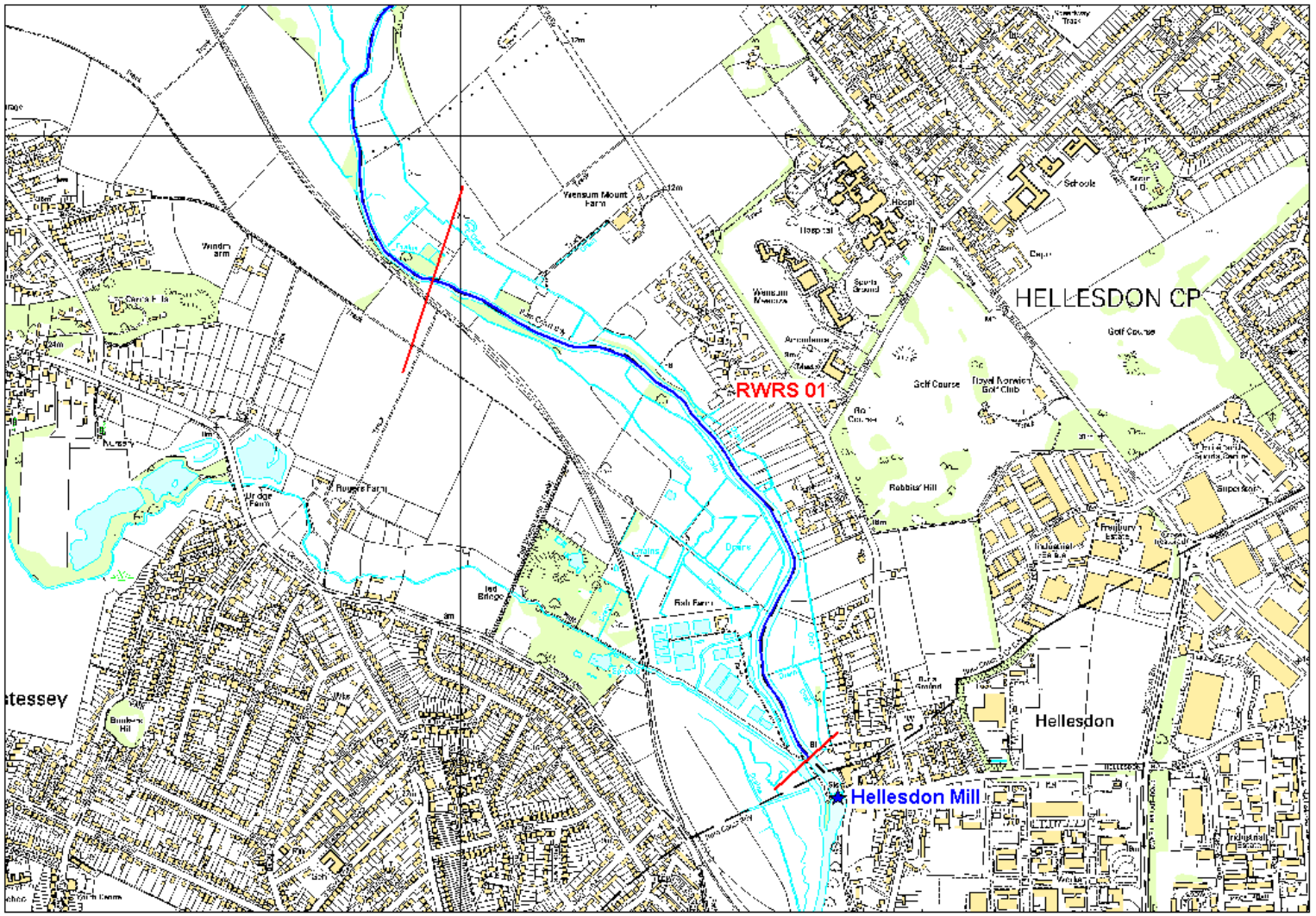
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Floodplain dominated by grazing marsh (ESA tiers 1,2 & 3) with IDB drain on both sides of the river, semi-improved apart from SSSI described above. North-eastern valley side dominated by curtilage and gardens that come right down to the river bank. South-western valley side dominated by arable farmland. Fish farm (now disused) at downstream end. |
| Amenity Value: | Canoeing at Hellesdon Mill. Angling leased to club. Also fished by riparian owners. |
| Other: | None |

**Table Ab4** RWRS 01 Previous works or recommendations

| | | |
|---|---|---|
| Previous Measures (Consented): | Hellesdon Mill - River Tud sluice automated (1999) - associated with Environment Agency flood risk management works. | |
| Potential Schemes for Habitat Restoration (ECON): | None | |
| Geomorphological Appraisal (2006) Options for Restoration: | | |
| Reach Code | W50 | W51 |
| Reach Status | Damaged | Damaged |
| Management Class | Assist | Restore |
| Work related to weir | | ✓ |
| Re-establish former channel or dimensions | | |
| Reconnect river to floodplain | | |
| Narrow | ✓ | ✓ |
| De-silt | | ✓ |
| Augment gravel or bed or water levels | | |
| Monitor | | |
| Reduce maintenance | | |
| Improve flow & habitat diversity | | |
| Establish riparian vegetation | | ✓ |
| Create or maintain backwater | | |
| Fix sediment ingress points | ✓ | |

**Table Ab5** RWRS 01 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with removal of structure at Hellesdon Mill and associated river works. De-silt channel just upstream of the current water control structure and augment the bed using gravels. Given the often wide nature of the channel, physical narrowing is required. Remove embankments to reconnect river to its floodplain and improve marginal/bankside vegetation. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 11.1-11.3m<br>Erodible banks: 16.8 -17.1m | Depth: | Resistant banks: 1.69m<br>Erodible banks: 1.43m |
| Revised Management Class: | Rehabilitate | | | |
| Specific Actions Recommended: | Initial work required is for bed and bank stabilisation associated with removal of Hellesdon Mill structures at downstream end of reach. Appropriate measures required to manage silt deposits upstream of the mill. Augment bed on average by 0.6m using local gravels wherever possible and create up to 16 gravel glides or riffles in the reach. The channel is on average 10.7m 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. Adopt/maintain 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. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Ab** RWRS 01 Location Plan

## REACH CODE: RWRS 02

**Table Ac1** RWRS 02 Reach data summary

| | |
|---|---|
| Location: | Costessey Mill to Wensum Mount Farm |
| NGR: | 617700, 312700 to 618930, 310520 |
| Total Reach Length: | 3,155m |
| Geomorphological Appraisal (2006) Reaches: | W57 to W52 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for Costessey Mill, which is located at the upstream end of RWRS02. Note that reach is affected by backwater from Hellesdon Mill. |

**Table Ac2** RWRS 02 Current reach condition

| | | |
|---|---|---|
| Description: | Generally, a sinuous channel but with poor riparian cover alongside meadows. Extensive drain system that is mainly disconnected from the river. High spoil banks indicate previous dredging along Drayton Low Road. Short, free flowing reach downstream of Costessey Mill. | |
| Natural England Assessment: | Part of River Unit 54 (Taverham Mill to Hellesdon Mill) - Ranunculus vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. River flows are adversely affected downstream of the Costessey Public Water Supply. | |
| Upstream Catchment Area: | 560km2 | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 17-50m<br>2.10m |
| Length Affected by Backwater: | All but upstream 0.5km of reach affected by backwater from Hellesdon Mill. | |
| Maintenance Regime: | 75% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Ac3** RWRS 02 Constraints

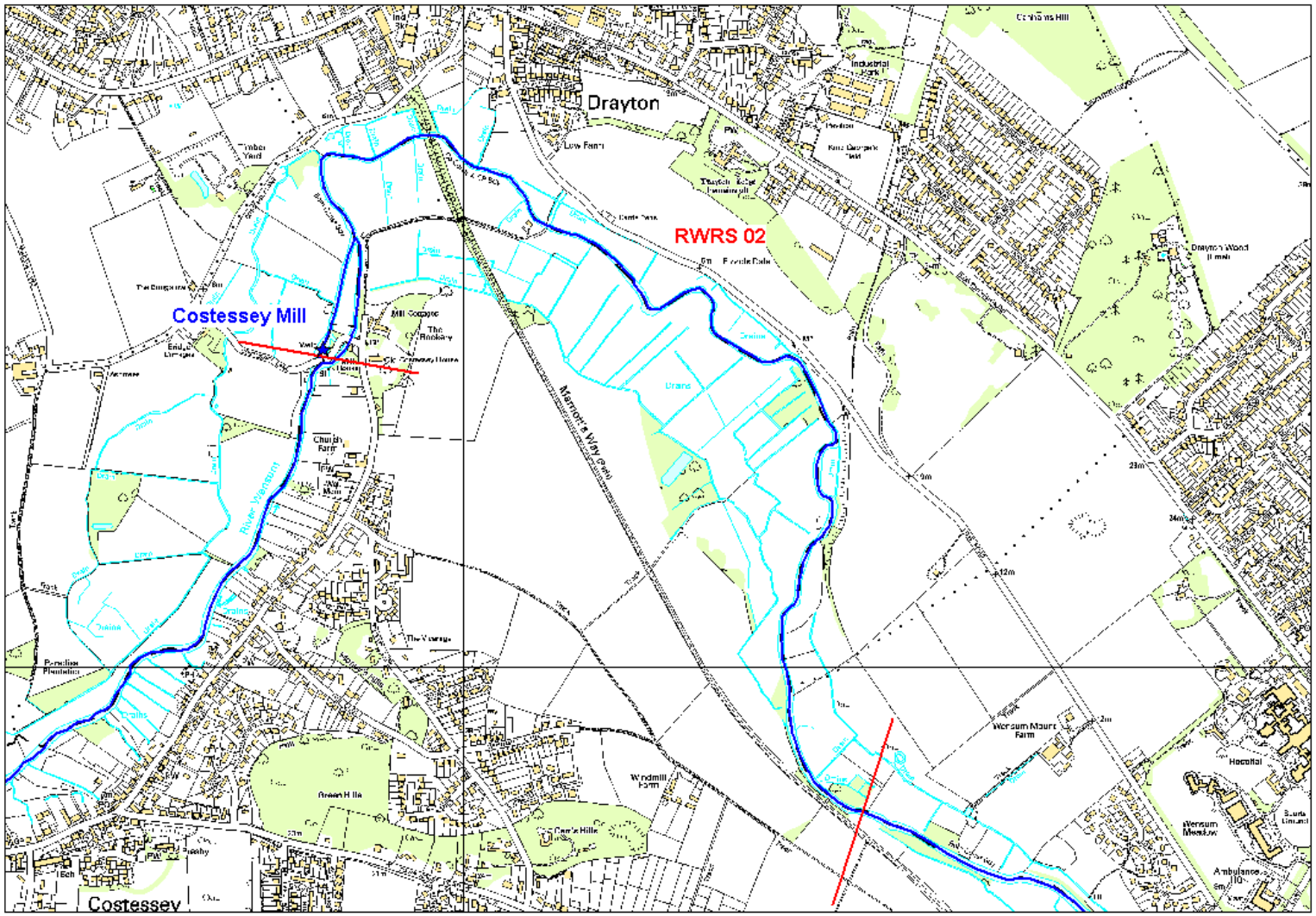
| | |
|---|---|
| Flood Risk: | Moderate (1 property in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Floodplain dominated by semi-improved grazing marsh (ESA tier 1) with lengths of IDB drain on both sides of the river. Some arable farmland on the floodplain to the north of the river. Low Road Meadows on S. side is under ESA fen tier. Both valley sides dominated by arable farmland. |
| Amenity Value: | Angling (day permits, fishing syndicates, free fishing). Public access to river at Drayton Green Lanes and CRoW access land associated with this. |
| Other: | Legal requirement of Environment Agency to maintain minimum water level of 5.3m ODN upstream of Costessey Mill. |

**Table Ac4** RWRS 02 Previous works or recommendations

| | | | | | | |
|---|---|---|---|---|---|---|
| Previous Measures (Consented): | Costessey Point - river restoration, gravel riffles, 2-stage channel, fish refuges, fencing (2004; refer to NACA website). | | | | | |
| Potential Schemes for Habitat Restoration (ECON): | Drayton drain reconnection and floodplain wetland creation. | | | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | | | |
| Reach Code | W52 | W53 | W54 | W55 | W56 | W57 |
| Reach Status | Damaged | Damaged | Damaged | Damaged | Degraded | Severely degraded |
| Management Class | Restore | Restore | Restore | Restore | Rehabilitate | Rehabilitate |
| Work related to weir | | | | | | ✓ |
| Re-establish former channel or dimensions | | | | | | |
| Reconnect river to floodplain | | | | | | |
| Narrow | ✓ | ✓ | ✓ | ✓ | ✓ | |
| De-silt | | | | | | |
| Augment gravel or bed or water levels | ✓ | ✓ | ✓ | ✓ | | |
| Monitor | | | | | | |
| Reduce maintenance | | | | | | |
| Improve flow & habitat diversity | | | | | | |
| Establish riparian vegetation | | ✓ | ✓ | ✓ | | |
| Create or maintain backwater | | | | | | |
| Fix sediment ingress points | ✓ | ✓ | ✓ | ✓ | ✓ | |

**Table Ac5** RWRS 02 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with removal of structure at Hellesdon Mill and lowering of structure at Costessey Mill and associated river works. Restoration must link with the existing scheme at Costessey Point. Physically narrow the channel and augment bed using gravels. Remove embankments along both banks downstream of Marriott's Way and improve marginal/bankside vegetation, such as by tree planting. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 10.3-11m<br>Erodible banks: 15.6-16.6m | Depth: | Resistant banks: 1.66m<br>Erodible banks: 1.40m |
| Revised Management Class: | Rehabilitate | | | |
| Specific Actions Recommended: | In the 100 to 200m downstream of Costessey 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. Augment bed on average by 0.4m using local gravels wherever possible and create up to 32 gravel glides or riffles in the remainder of the reach. The channel is on average 9.8m 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. Adopt/maintain maintenance regime and riparian management to allow channel to create natural variations in local channel width and habitat niches. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4



**Figure Ac** RWRS 02 Location Plan

## REACH CODE: RWRS 03

**Table Ad1** RWRS 03 Reach data summary

| | |
|---|---|
| Location: | Taverham Mill to Costessey Mill |
| NGR: | 615900, 313700 to 617700, 312700 |
| Total Reach Length: | 3,910m |
| Geomorphological Appraisal (2006) Reaches: | W61 to W58 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheets for Taverham Mill and Costessey Mill, which are located at the upstream and downstream ends of RWRS03, respectively. |

**Table Ad2** RWRS 03 Current reach condition

| | | |
|---|---|---|
| Description: | Often straightened between meander bends. Bendways have deep pools. Channel is generally over wide. Substantial drainage network on both banks, although right bank tends to be largely residential and left bank downstream of Transportation Plantation is embanked. Previously labelled the 'highest quality impounded section above all mills along the Wensum' (ECON, 1999). | |
| Natural England Assessment: | Part of River Unit 54 (Hellesdon Mill - Taverham Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. River flows are adversely affected downstream of the Costessey Public Water Supply.<br>River Unit adjacent to Terrestrial Units 38 to 39 support a mosaic of mesotrophic grassland, and rush pasture (including MG8 and M22). Neutral on the right bank of the river opposite. | |
| Upstream Catchment Area: | 550km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 16-24m<br>1.91m |
| Length Affected by Backwater: | About half reach affected by backwater from Costessey Mill. | |
| Maintenance Regime: | Generally, up to 50% and 75% of weeds cut on free-flowing and impounded reaches, respectively by the Environment Agency (100% in the short reach upstream of the gauging station). Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Ad3** RWRS 03 Constraints

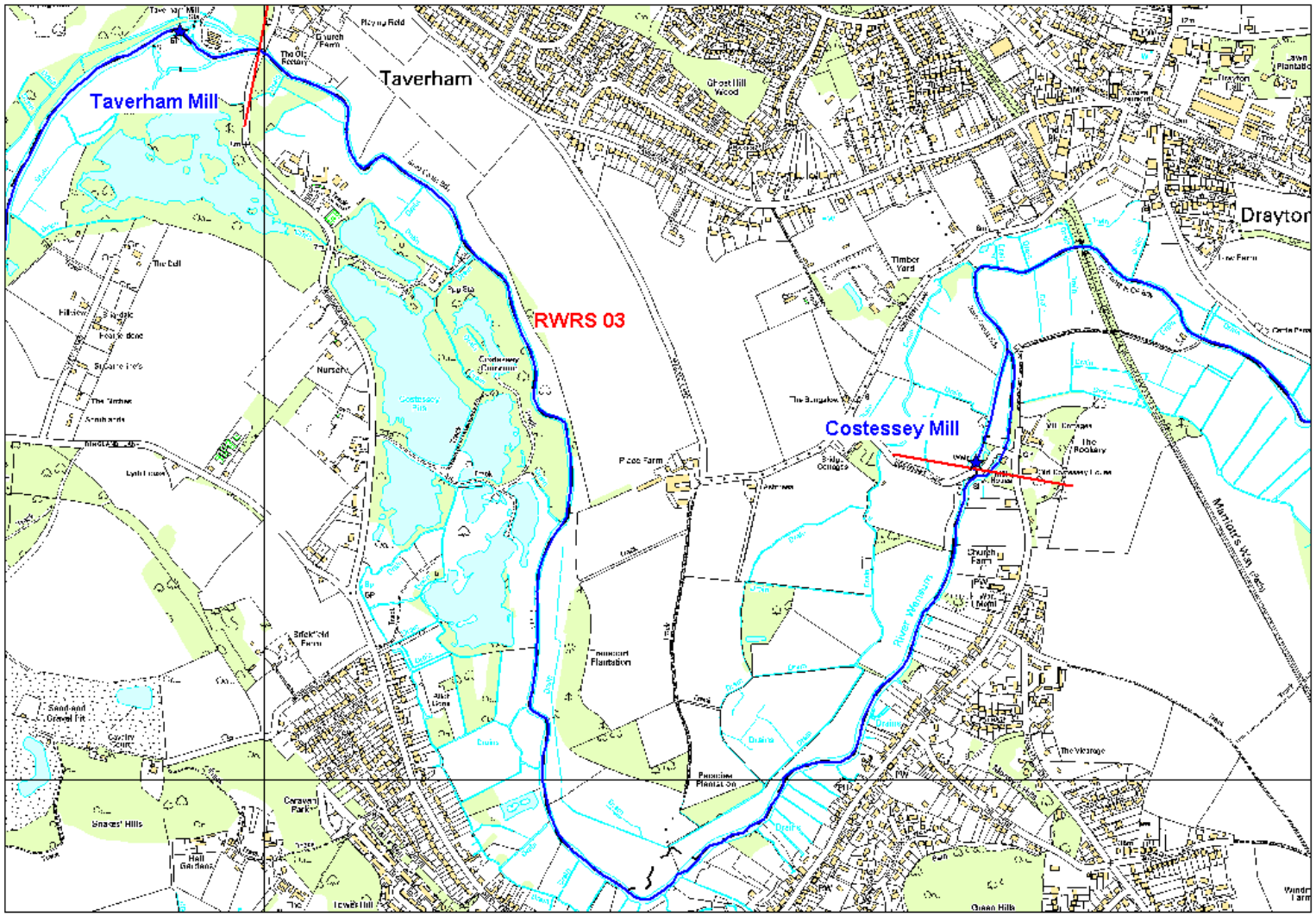
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Urban curtilage along much of the southern side of the river at Costessey. Costessey gravel pits on south side of river upstream of Costessey. On north bank of river, the floodplain is dominated by grazing marsh (mainly ESA tier 1) at the downstream end of the reach with arable on the floodplain toward Taverham Mill. Northern valley side dominated by arable. |
| Amenity Value: | Angling (Norwich and District Angling Association, some day permits). |
| Other: | Legal requirement of Environment Agency to maintain minimum water level of 5.3m ODN upstream of Costessey Mill.<br>Need to maintain reliable intake point for the public water supply abstraction at Costessey.<br>Consider Environment Agency gauging station at Costessey Mill. |

**Table Ad4** RWRS 03 Previous works or recommendations

| | | | | |
|---|---|---|---|---|
| Previous Measures (Consented): | None | | | |
| Potential Schemes for Habitat Restoration (ECON): | Tree planting downstream of Taverham Mill. Costessey pits riffles and pools. | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | |
| Reach Code | W58 | W59 | W60 | W61 |
| Reach Status | Degraded | Degraded | Damaged | Damaged |
| Management Class | Rehabilitate | Rehabilitate | Assist | Assist |
| Work related to weir | ✓ | | | |
| Re-establish former channel or dimensions | | | | |
| Reconnect river to floodplain | | ✓ | | |
| Narrow | | ✓ | ✓ | ✓ |
| De-silt | | ✓ | ✓ | |
| Augment gravel or bed or water levels | | ✓ | ✓ | ✓ |
| Monitor | | | | |
| Reduce maintenance | | | | |
| Improve flow & habitat diversity | | | | |
| Establish riparian vegetation | | | ✓ | ✓ |
| Create or maintain backwater | | | | |
| Fix sediment ingress points | | | | |

**Table Ad5** RWRS 03 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with removal of structure at Taverham Mill, lowering of structure at Costessey Mill and associated river works. De-silt channel just upstream of Costessey mill and augment the bed using gravels. Physically narrow channel where substantially over wide. Reconnect river to its floodplain by removing embankments. Develop marginal/bankside vegetation, for instance by planting trees at meander bends. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 10.2-10.3m<br>Erodible banks: 15.4-15.5m | Depth: | Resistant banks: 1.58m<br>Erodible banks: 1.35m |
| Revised Management Class: | Rehabilitate | | | |
| Specific Actions Recommended: | In the 100 to 200m downstream of Taverham Mill structure 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. Elsewhere, initial work required is for bed and bank stabilisation associated with lowering of Costessey Mill structures at downstream end of reach. Appropriate measures required to manage silt deposits upstream of Costessey mill. Augment bed on average by 0.3m using local gravels wherever possible and create up to 42 gravel glides or riffles in the reach. The channel is on average 5.2m 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. Adopt/maintain 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 structure. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Ad** RWRS 03 Location Plan

## REACH CODE: RWRS 04

**Table Ae1** RWRS 04 Reach data summary

| | |
|---|---|
| Location: | Northfields (Ringland Lane) to Taverham Mill |
| NGR: | 615050, 312780 to 615900, 313700 |
| Total Reach Length: | 1,490m |
| Geomorphological Appraisal (2006) Reaches: | W202 to W200 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for Taverham Mill, which is located at the downstream end of RWRS04. |

**Table Ae2** RWRS 04 Current reach condition

| | | |
|---|---|---|
| Description: | Channel straight, wide and relatively open, especially towards Taverham Mill as woodland retreats on right bank. Flow is slow and bed silted due to modification and impoundment at mill. IDB drain runs parallel to Wensum on left bank and numerous drainage channels in floodplain just upstream of mill. | |
| Natural England Assessment: | Part of River Unit 53 (Lenwade Mill - Taverham Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 550km$^2$ | |
| Channel Dimensions (Bankfull): | Width: | 22-26m |
| | Depth: | 2.17m |
| Length Affected by Backwater: | All reach affected by backwater from Taverham Mill. | |
| Maintenance Regime: | 75% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Ae3** RWRS 04 Constraints

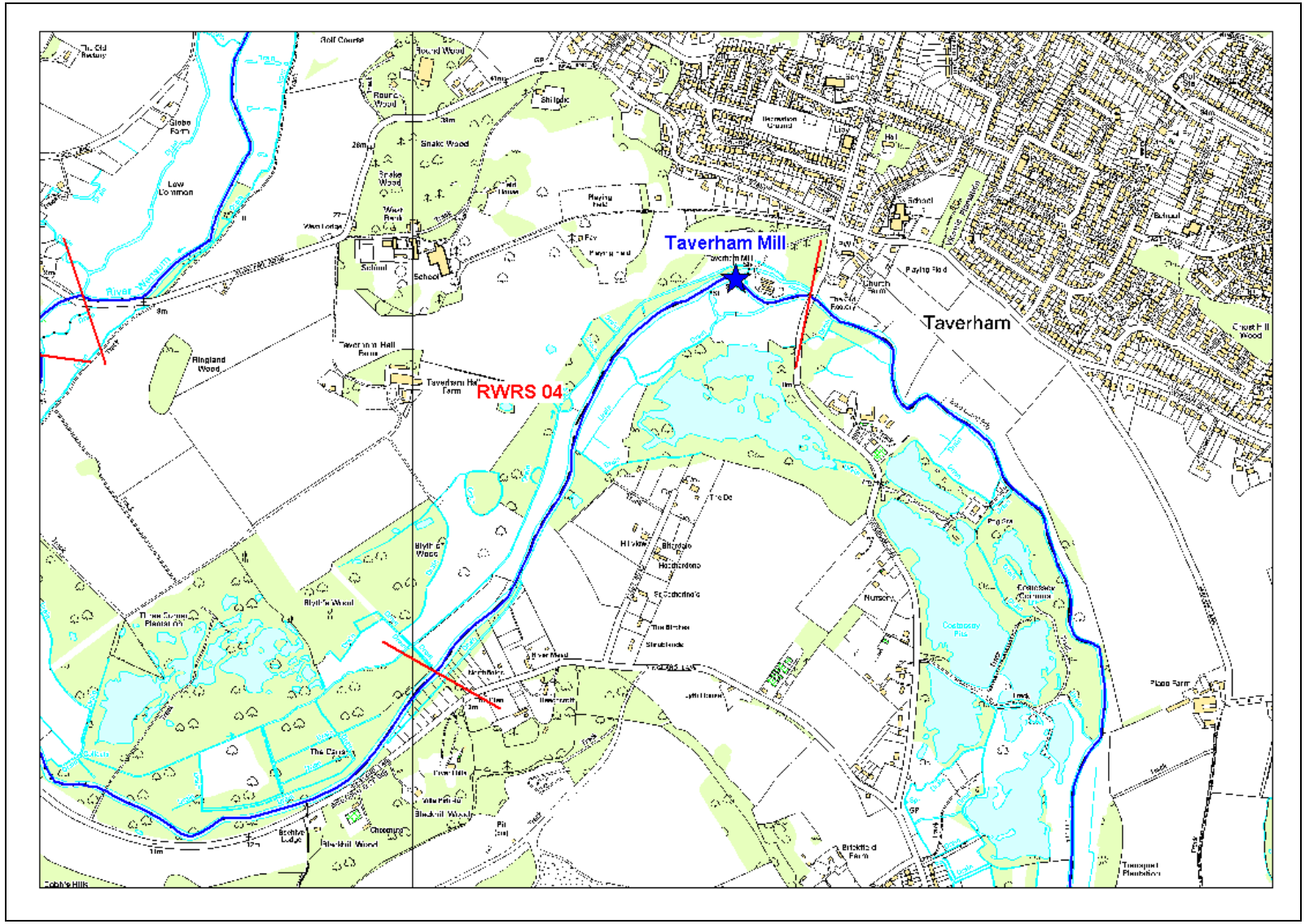
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Floodplain dominated by semi-improved grazing marsh (ESA tier 2), scrub and plantation, with IDB drain running along northern side of river. On the floodplain to the south of the river, there are also the Costessey Pits at the downstream end of the reach and a cluster of cottages at the upstream end of the reach. North valley side dominated by plantation and southern side by arable fields. |
| Amenity Value: | Commercial fishery (Anglian Water) upstream and downstream of Taverham Mill and in floodplain lakes.<br>Playing fields on left bank at Taverham |
| Other: | Environment Agency weed pullout upstream of Taverham Mill. |

**Table Ae4** RWRS 04 Previous works or recommendations

| | | | |
|---|---|---|---|
| Previous Measures (Consented): | None | | |
| Potential Schemes for Habitat Restoration (ECON): | Ringland Drain connection<br>Taverham Mill by-pass and floodplain wetland | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | |
| Reach Code | W200 | W201 | W202 |
| Reach Status | Damaged | Degraded | Damaged |
| Management Class | Assist | Rehabilitate | Assist |
| Work related to weir | ✓ | ✓ | ✓ |
| Re-establish former channel or dimensions | | | |
| Reconnect river to floodplain | | | ✓ |
| Narrow | | | ✓ |
| De-silt | | | ✓ |
| Augment gravel or bed or water levels | ✓ | ✓ | ✓ |
| Monitor | | | |
| Reduce maintenance | | | |
| Improve flow & habitat diversity | | | |
| Establish riparian vegetation | | | ✓ |
| Create or maintain backwater | | | |
| Fix sediment ingress points | ✓ | ✓ | ✓ |

**Table Ae5** RWRS 04 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with plans to remove structure at Taverham Mill and associated river works. Possibility to divert flow through previous channel or drainage system upstream of mill is being investigated in conjunction with Anglian Water. De-silt channel just upstream of the current structure, physically narrow and augment bed with gravels. Develop marginal/bankside vegetation. Use coarse woody debris structures to exacerbate sinuosity in wooded areas. | | | |
| Reference Channel Dimensions: | Width: | Reference Channel Dimensions: | Width: | Reference Channel Dimensions: |
| Revised Management Class: | Rehabilitate | | | |
| Specific Actions Recommended: | Co-ordinate with Anglian Water regarding works at Taverham Mill as they have expressed support for the River Wensum Restoration Strategy. Initial work required is for bed and bank stabilisation associated with removal of Taverham Mill structures at downstream end of reach. Appropriate measures required to manage silt deposits upstream of the mill. Augment bed on average by 0.7m using local gravels wherever possible and create up to 16 gravel glides or riffles in the reach. The channel is on average 9.4m 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. Adopt/maintain 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 structure. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Ae** RWRS 04 Location Plan

## REACH CODE: RWRS 05

**Table Af1** RWRS 05 Reach data summary

| | |
|---|---|
| Location: | Downstream Ringland to Northfields (Ringland Lane) |
| NGR: | 614070, 313550 to 615050, 312780 |
| Total Reach Length: | 2,555m |
| Geomorphological Appraisal (2006) Reaches: | W204 and W203 |
| Associated Mill Summary Information: | No mill at up or downstream end of RWRS05 |

**Table Af2** RWRS 05 Current reach condition

| | | |
|---|---|---|
| Description: | Much of channel straightened. Floodplain is woodland and pasture, with an extensive drain network and some embankments upstream and in centre of reach. Channel side stock fenced and so there is rank marginal/bankside vegetation. | |
| Natural England Assessment: | Part of River Unit 53 (Lenwade Mill - Taverham Mill) - Ranunculus vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 545km$^2$ | |
| Channel Dimensions (Bankfull): | Width: | 18-22m |
| | Depth: | 1.93m |
| Length Affected by Backwater: | All reach affected by backwater from Taverham Mill. | |
| Maintenance Regime: | 75% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Af3** RWRS 05 Constraints

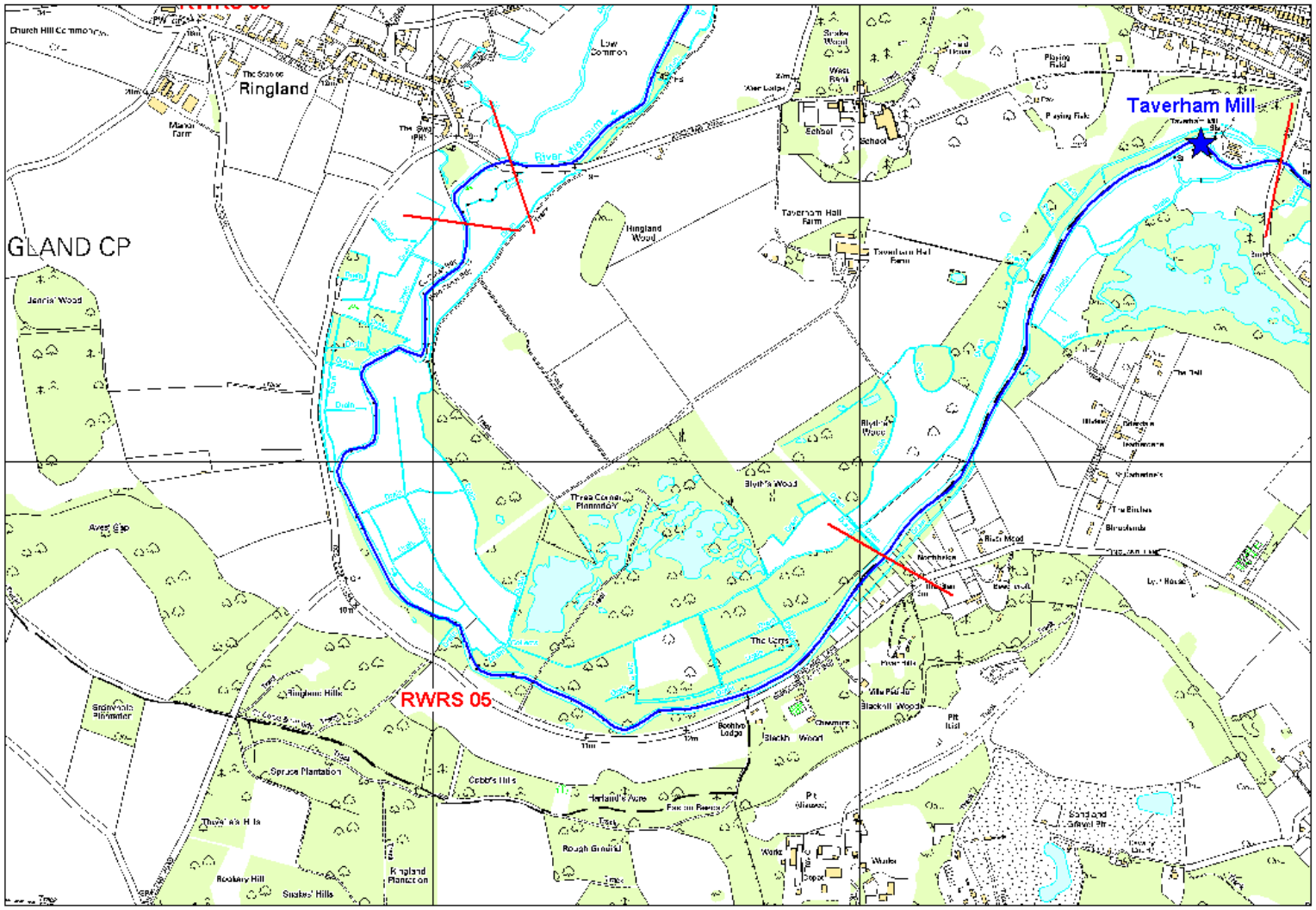
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Floodplain is managed as grazing marsh (ESA tiers 1 & 2) upstream and woodland downstream and Ringland Pits to the north of the river. An IDB drain runs through the floodplain to the north of the river. |
| Amenity Value: | Angling (riparian owners). River visible from Costessey Lane reach. CRoW access land at Ringland Hills is located above the road and does not have a riparian margin. |
| Other: | None |

**Table Af4** RWRS 05 Previous works or recommendations

| | | |
|---|---|---|
| Previous Measures (Consented): | None | |
| Potential Schemes for Habitat Restoration (ECON): | Ringland Drain Reconnection | |
| Geomorphological Appraisal (2006) Options for Restoration: | | |
| Reach Code | W203 | W204 |
| Reach Status | Damaged | Damaged |
| Management Class | Assist | Assist |
| Work related to weir | | |
| Re-establish former channel or dimensions | | |
| Reconnect river to floodplain | | ✓ |
| Narrow | ✓ | ✓ |
| De-silt | ✓ | |
| Augment gravel or bed or water levels | ✓ | |
| Monitor | | |
| Reduce maintenance | | |
| Improve flow & habitat diversity | | |
| Establish riparian vegetation | ✓ | |
| Create or maintain backwater | | |
| Fix sediment ingress points | | ✓ |

**Table Af5** RWRS 05 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with removal of structure at Taverham Mill and associated river works. Remove embankment. Augment bed with gravels. Assume reach will narrow naturally in time. Use coarse woody debris structures to exacerbate sinuosity in wooded areas where channel is straight. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 10.1m<br>Erodible banks: 15.3m | Depth: | Resistant banks: 1.47m<br>Erodible banks: 1.25m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | Reduce depth by an average of 0.5m and raise bed using up to 28 gravel glides or riffles in the reach. Adopt/maintain maintenance regime and riparian management to allow channel to narrow naturally. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Af** RWRS 05 Location Plan

## REACH CODE: RWRS 06

**Table Ag1** RWRS 06 Reach data summary

| | |
|---|---|
| Location: | Ringland Road at Ringland to Downstream Ringland |
| NGR: | 614190, 313700 to 614070, 313550 |
| Total Reach Length: | 225m |
| Geomorphological Appraisal (2006) Reaches: | W205 |

**Table Ag2** RWRS 06 Current reach condition

| | | |
|---|---|---|
| Description: | Short reach that has embankments along both banks throughout (except at ford) but that is naturally sinuous with pools at the outerbends. Whilst largely unmanaged, banks are vertical and contain non-native poplars. Channel is wide but fairly shallow. | |
| Natural England Assessment: | Part of River Unit 53 (Lenwade Mill to Taverham Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 540km$^2$ | |
| Channel Dimensions (Bankfull): | Width: | 27m |
| | Depth: | 1.08m |
| Length Affected by Backwater: | Downstream part of reach affected by backwater from Taverham Mill. | |
| Maintenance Regime: | Generally, up to 50% and 75% of weeds cut on free-flowing and impounded reaches, respectively, by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Ag3** RWRS 06 Constraints

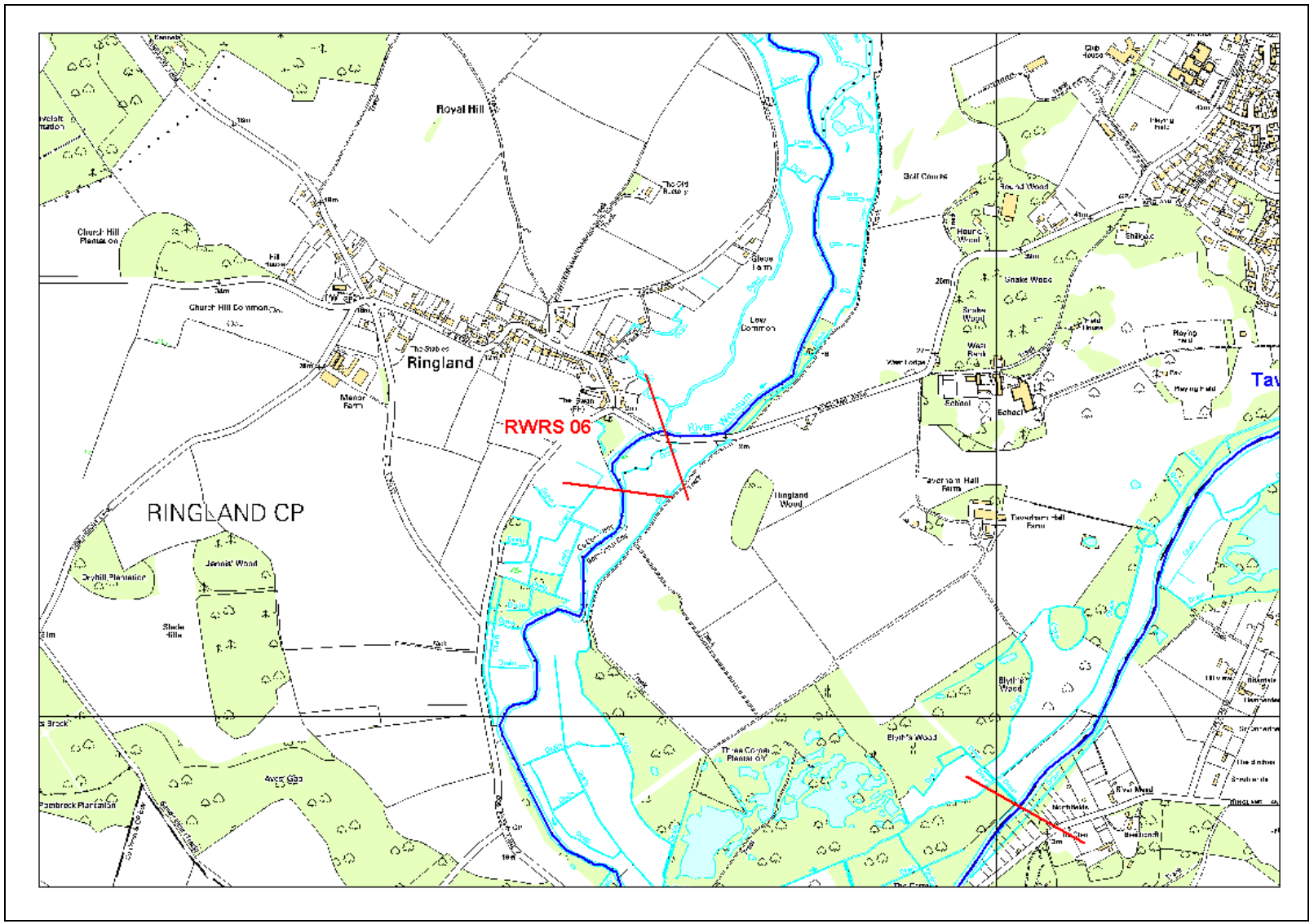
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | The floodplain is managed as grazing marsh, with short IDB drains on both side of the river. The valley sides are dominated by arable crops. |
| Amenity Value: | Angling (free fishing). Small area of Low Common mapped as CRoW land, opposite the Swan public house, in immediate vicinity of ford. |
| Other: | None |

**Table Ag4** RWRS 06 Previous works or recommendations

| | |
|---|---|
| Previous Measures (Consented): | None |
| Potential Schemes for Habitat Restoration (ECON): | None |
| Geomorphological Appraisal (2006) Options for Restoration: | |
| Reach Code | W206 |
| Reach Status | Semi-natural |
| Management Class | Protect and monitor |
| Work related to weir | |
| Re-establish former channel or dimensions | |
| Reconnect river to floodplain | |
| Narrow | |
| De-silt | |
| Augment gravel or bed or water levels | |
| Monitor | ✓ |
| Reduce maintenance | |
| Improve flow & habitat diversity | |
| Establish riparian vegetation | |
| Create or maintain backwater | |
| Fix sediment ingress points | |

**Table Ag5** RWRS 06 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Physical narrowing required in this very wide reach, although any works must ensure that existing ecological communities are conserved. Remove embankments to reconnect the channel to its floodplain. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 10.1m<br>Erodible banks: 15.2m | Depth: | Resistant banks: 1.44m<br>Erodible banks: 1.22m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | Create up to 2 gravel glides or riffles in the reach, possibly by re-using gravels from shallow sections of the bed, although little overall change in depth is required. The channel is on average 11.8m 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. Adopt/maintain maintenance regime and riparian management to allow channel to create natural variations in local channel width and habitat niches. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Ag** RWRS 06 Location Plan

## REACH CODE: RWRS 07

**Table Ah1** RWRS 07 Reach data summary

| | |
|---|---|
| Location: | Upstream Attlebridge Hall to Ringland Road at Ringland |
| NGR: | 613320, 315970 to 614190, 313700 |
| Total Reach Length: | 3,615m |
| Geomorphological Appraisal (2006) Reaches: | W207 (part) and W206 |

**Table Ah2** RWRS 07 Current reach condition

| | | |
|---|---|---|
| Description: | Generally, channel is fairly wide but relatively shallow and there are a number of naturally meandering sections. There are riffles downstream of the footbridge at Ringland and these cause some upstream flow impoundment. High spoil banks exist along both banks, especially downstream of Taverham golf course. Extensive drainage network on floodplain. | |
| Natural England Assessment: | Part of River Unit 53 (Lenwade Mill - Taverham Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 540km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 18-19m<br>1.94m |
| Length Affected by Backwater: | Downstream part of reach (about 100m) affected by shallow water upstream of ford and Ringland riffles. No part of reach affected by mill backwater. | |
| Maintenance Regime: | 50% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Ah3** RWRS 07 Constraints

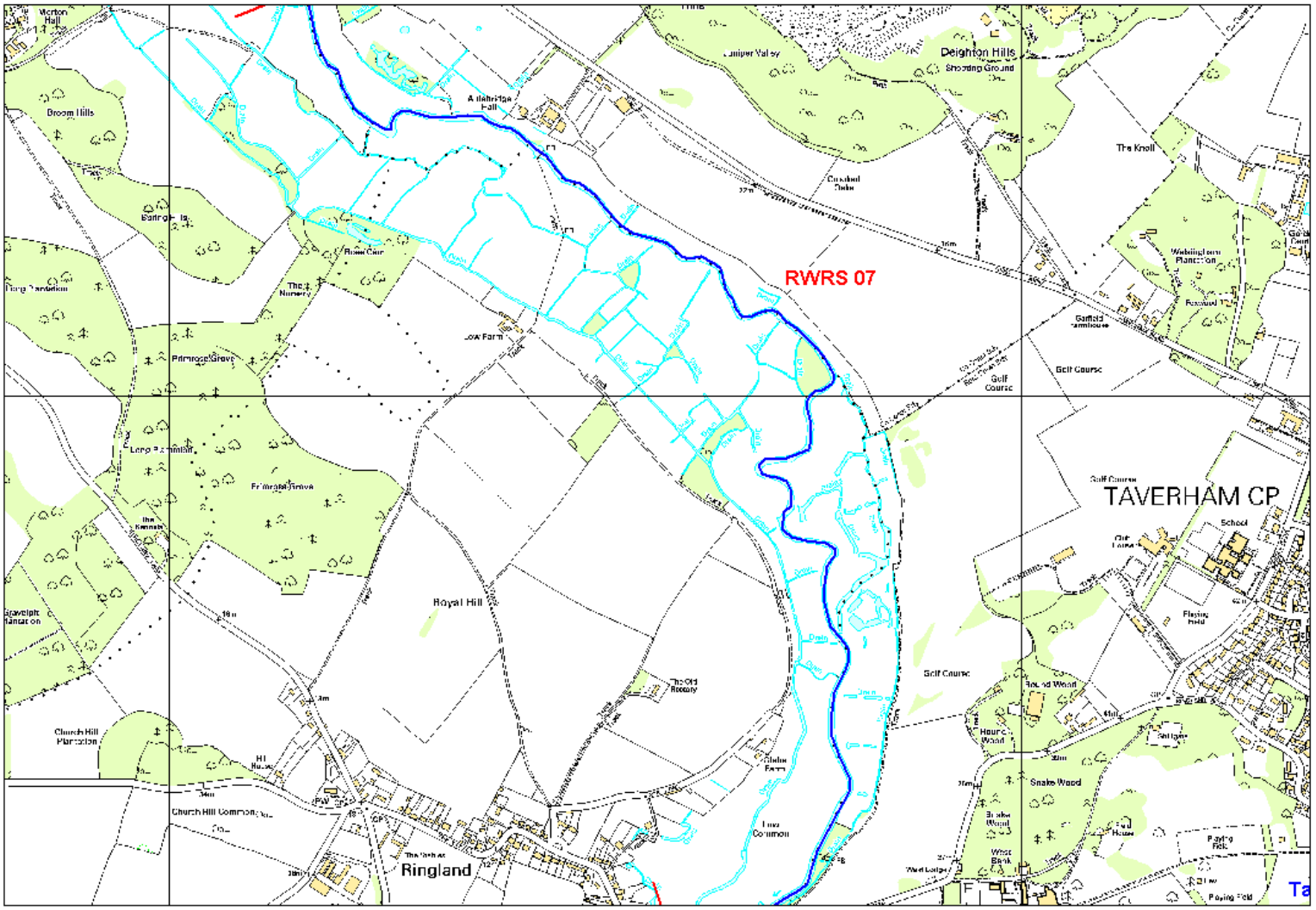
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Golf course and associated management dominates the floodplain and valley side on the eastern side of the river. On the western side of the river, the floodplain is dominated by semi-improved grazing marsh (entirely ESA tier 1), with an IDB drain running through it and arable cropping on the valley side. |
| Amenity Value: | Angling (free fishing, commercial trout and course fishery, syndicate). CRoW access land present at Low Common. River visible from footpath on the western edge of the floodplain. |
| Other: | Riffles downstream bridge, wet woodland. |

**Table Ah4** RWRS 07 Previous works or recommendations

| | | |
|---|---|---|
| Previous Measures (Consented): | None | |
| Potential Schemes for Habitat Restoration (ECON): | None | |
| Geomorphological Appraisal (2006) Options for Restoration: | | |
| Reach Code | W206 | W207 |
| Reach Status | Damaged | Damaged |
| Management Class | Assist | Assist |
| Work related to weir | | |
| Re-establish former channel or dimensions | ✓ | ✓ |
| Reconnect river to floodplain | ✓ | ✓ |
| Narrow | ✓ | ✓ |
| De-silt | | |
| Augment gravel or bed or water levels | ✓ | |
| Monitor | | |
| Reduce maintenance | | |
| Improve flow & habitat diversity | | |
| Establish riparian vegetation | ✓ | ✓ |
| Create or maintain backwater | | |
| Fix sediment ingress points | | |

**Table Ah5** RWRS 07 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Remove embankments to reconnect river to floodplain. Augment bed with gravels. Assume reach will narrow naturally in time. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 10-10.1m<br>Erodible banks: 15.2m | Depth: | Resistant banks: 1.43m<br>Erodible banks: 1.21m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | Reduce depth by an average of 0.5m and raise bed using up to 40 gravel glides or riffles in the reach. Adopt/maintain maintenance regime and riparian management to allow channel to narrow naturally. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Ah** RWRS 06 Location Plan

## REACH CODE: RWRS 08

**Table Ai1** RWRS 08 Reach data summary

| | |
|---|---|
| Location: | Upstream Morton Bridge (near Attlebridge) to upstream Attlebridge Hall |
| NGR: | 612750, 316940 to 613320, 315970 |
| Total Reach Length: | 1,250m |
| Geomorphological Appraisal (2006) Reaches: | W208 and W207 (part) |
| Associated Mill Summary Information: | No mill at up or downstream end of RWRS08 |

**Table Ai2** RWRS 08 Current reach condition

| | | |
|---|---|---|
| Description: | Velocity is increased at bridges and gravel bed is retained as a result. Channel is relatively straight but becomes more sinuous downstream, where there are pools on the outer bends. Generally, poor marginal/bankside vegetation, local bank collapse and some small lengths of embankment. Drainage network on right bank floodplain. | |
| Natural England Assessment: | Part of River Unit 53 (Lenwade Mill - Taverham Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 500km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 18-20m<br>1.78m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | 50% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Ai3** RWRS 08 Constraints

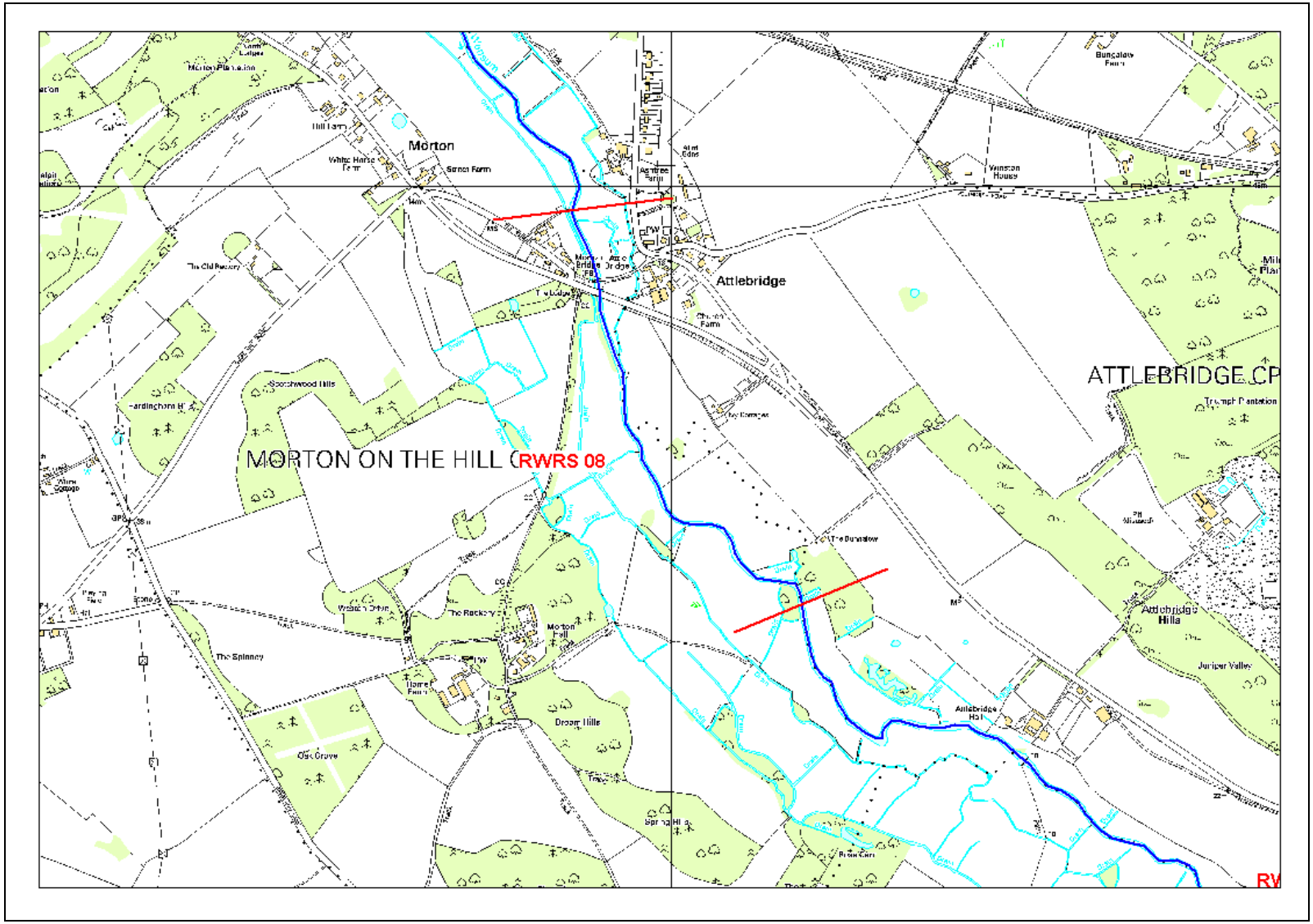
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Semi-improved grazing marsh (ESA tiers 1 & 2), with IDB drain running through. Some residential property at Attlebridge. |
| Amenity Value: | Angling (leased). |
| Other: | Riffles associated with bridges and pools on outerbends. |

**Table Ai4** RWRS 08 Previous works or recommendations

| | | |
|---|---|---|
| Previous Measures (Consented): | None | |
| Potential Schemes for Habitat Restoration (ECON): | Attlebridge meander loop reconnection and wetland creation. | |
| Geomorphological Appraisal (2006) Options for Restoration: | | |
| Reach Code | W207 | W208 |
| Reach Status | Damaged | Damaged |
| Management Class | Assist | Assist |
| Work related to weir | | |
| Re-establish former channel or dimensions | ✓ | |
| Reconnect river to floodplain | ✓ | ✓ |
| Narrow | ✓ | ✓ |
| De-silt | | |
| Augment gravel or bed or water levels | | |
| Monitor | | |
| Reduce maintenance | | ✓ |
| Improve flow & habitat diversity | | |
| Establish riparian vegetation | ✓ | |
| Create or maintain backwater | | |
| Fix sediment ingress points | | |

**Table Ai5** RWRS 08 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Restore old course of the river on the left bank following the boundary identifiable on the OS map. Link channel bed/water levels with those that have naturally developed at the bridge. Infill current channel or retain as a backwater. Integrate restoration scheme with bed levels upstream and downstream - requires augmentation of bed with gravels and development of marginal/bankside vegetation. Assume remainder of reach will narrow naturally in time. There is no known reference channel in this part of the catchment and restoration channel dimensions should be determined using hydraulic geometry. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 9.6-10m<br>Erodible banks: 14.4-15.2m | Depth: | Resistant banks: 1.38m<br>Erodible banks: 1.17m |
| Revised Management Class: | Rehabilitation with restoration (restored section expected to be approximately 800m between Ivy Cottages and The Bungalow). | | | |
| Specific Actions Recommended: | Restore meandering section of channel. Reduce depth of current channel upstream of the restoration by an average of 0.4m and raise bed using up to 14 gravel glides or riffles in the full reach. Adopt/maintain maintenance regime and riparian management to allow channel to narrow naturally. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Ai** RWRS 08 Location Plan

## REACH CODE: RWRS 09

**Table Aj1** RWRS 09 Reach data summary

| | |
|---|---|
| Location: | Marriots Way near Slade Plantation to Upstream Morton Bridge (near Attlebridge) |
| NGR: | 612210, 317780 to 612750, 316940 |
| Total Reach Length: | 1,105m |
| Geomorphological Appraisal (2006) Reaches: | W209 |

**Table Aj2** RWRS 09 Current reach condition

| | | |
|---|---|---|
| Description: | Downstream Swannington Beck tributary, channel becomes wider and sediment volume increases. Channel meanders gently but there is little marginal/bankside vegetation. There is a large backwater upstream of the first bend. At the very downstream end of the reach the channel narrows after a sharp bend to a more natural width and velocity increases as a result. Drain system on the floodplain. | |
| Natural England Assessment: | Part of River Unit 53 (Lenwade Mill to Taverham Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 495km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 18m<br>1.98m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | 50% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Aj3** RWRS 09 Constraints

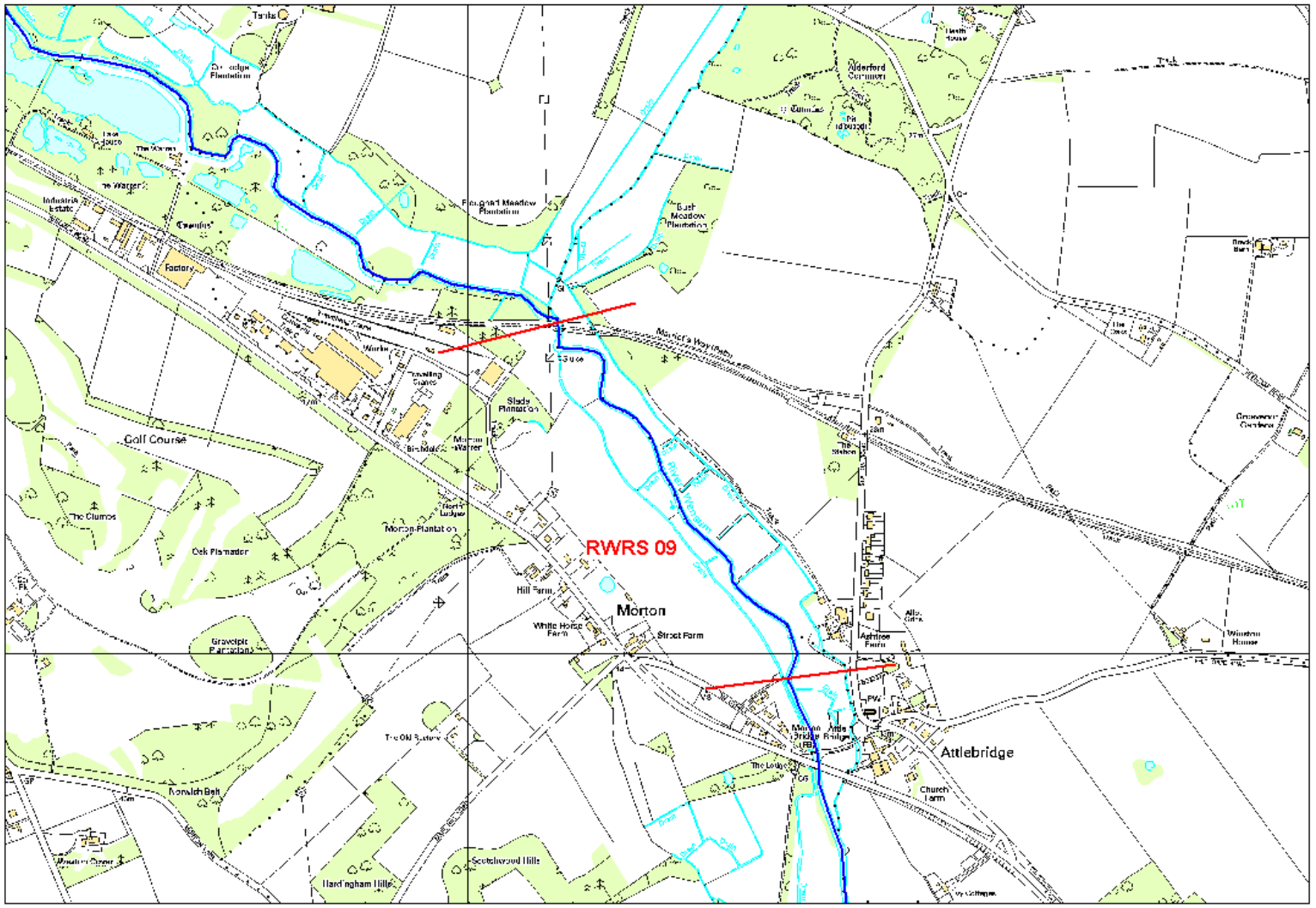
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Narrow strip of permanent drained pasture (ESA tier 1) on left (N) bank. Grassland and arable farmland on right (S) side. |
| Amenity Value: | Angling (riparian owners). Public footpath crosses the river at Attlebridge Hall. |
| Other: | None |

**Table Aj4** RWRS 09 Previous works or recommendations

| | |
|---|---|
| Previous Measures (Consented): | None |
| Potential Schemes for Habitat Restoration (ECON): | Morton channel riffles and re-profiling to narrow and meander;<br>Morton drain connection. |
| Geomorphological Appraisal (2006) Options for Restoration: | |
| Reach Code | W209 |
| Reach Status | Semi-natural |
| Management Class | Protect and monitor |
| Work related to weir | |
| Re-establish former channel or dimensions | |
| Reconnect river to floodplain | |
| Narrow | |
| De-silt | |
| Augment gravel or bed or water levels | |
| Monitor | |
| Reduce maintenance | ✓ |
| Improve flow & habitat diversity | |
| Establish riparian vegetation | ✓ |
| Create or maintain backwater | |
| Fix sediment ingress points | |

**Table Aj5** RWRS 09 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Assume reach will narrow naturally in time. Improve marginal/bankside vegetation. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 9.5m<br>Erodible banks: 14.3m | Depth: | Resistant banks: 1.36m<br>Erodible banks: 1.16m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | Reduce depth by an average of 0.6m and raise bed using up to 13 gravel glides or riffles in the reach. Adopt/maintain maintenance regime and riparian management to allow channel to narrow naturally. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Aj** RWRS 09 Location Plan

## REACH CODE: RWRS 10

**Table Ak1** RWRS 10 Reach data summary

| | |
|---|---|
| Location: | Lenwade Mill to Marriots Way near Slade Plantation |
| NGR: | 610160, 318200 to 612210, 317780 |
| Total Reach Length: | 2,935m |
| Geomorphological Appraisal (2006) Reaches: | W303 (part) to W210 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for Lenwade Mill, which is located at the upstream end of RWRS010. |

**Table Ak2** RWRS 10 Current reach condition

| | | |
|---|---|---|
| Description: | Lenwade Common - riffles in channel but grass cut short so little littoral margin. Downstream - flow is rapid (with some exposed gravels) but uniform as channel has been straightened. Presence of bridge and alders increases flow diversity locally.<br>Bernard Matthews Estate - six, low-flow, mainly horseshoe shaped weirs provide flow diversity especially at bendways. Grass mowed short giving the channel an open appearance, with some alders downstream. | |
| Natural England Assessment: | Part of River Unit 53 (Lenwade Mill - Taverham Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 430km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 14-20m<br>1.34m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | Environment Agency - no weedcutting or other routine maintenance work in Bernard Matthews's estate. | |

**Table Ak3** RWRS 10 Constraints

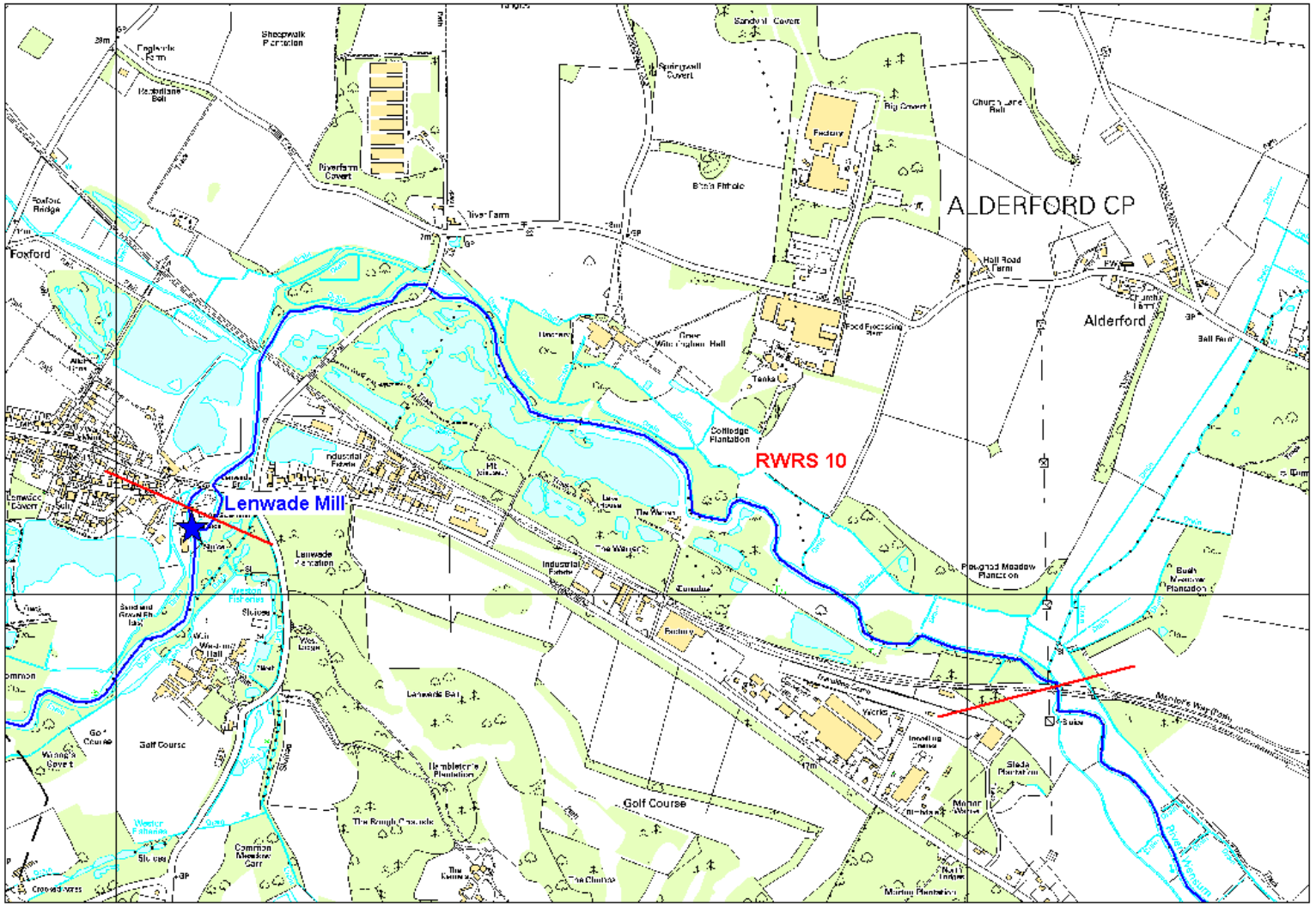
| | |
|---|---|
| Flood Risk: | Moderate (2 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Predominantly large, mature gravel pits, particularly along right (S) side of valley. Narrow strip of semi-improved pasture (ESA tiers 1 & 2) on left (N) side. Residential/industrial properties at Lenwade. Some plantations. |
| Amenity Value: | Aesthetic. Angling (commercial coarse fishery, private trout fishery), Canoeing in pits by Lenwade Mill. Marriotts Way public access near the river. |
| Other: | Conserve area downstream Lenwade Common to Porters Lane Road Bridge.<br>Potential flood risk management capital scheme. |

**Table Ak4** RWRS 10 Previous works or recommendations

| | | | | | |
|---|---|---|---|---|---|
| Previous Measures (Consented): | Lenwade Mill sluice automated (2004) - associated with Environment Agency flood risk management works. | | | | |
| Potential Schemes for Habitat Restoration (ECON): | Lenwade Common narrowing and riffles | | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | | |
| Reach Code | W210 | W300 | W301 | W302 | W303 |
| Reach Status | Damaged | Semi-natural | Semi-natural | Damaged | Severely degraded |
| Management Class | Assist | Protect and monitor | Protect and monitor | Assist | Rehabilitate |
| Work related to weir | | | | ✓ | ✓ |
| Re-establish former channel or dimensions | | | | | |
| Reconnect river to floodplain | | | | | |
| Narrow | | | | | |
| De-silt | | | | | |
| Augment gravel or bed or water levels | | | | | |
| Monitor | | ✓ | ✓ | | |
| Reduce maintenance | ✓ | | | ✓ | ✓ |
| Improve flow & habitat diversity | | ✓ | ✓ | | |
| Establish riparian vegetation | ✓ | | | | |
| Create or maintain backwater | | | | | |
| Fix sediment ingress points | ✓ | | ✓ | | ✓ |

**Table Ak5** RWRS 10 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with lowering of structure at Lenwade Mill and associated river works. Encourage less intensive stocking of livestock and develop marginal/bankside vegetation. Allow channel to narrow and de-silt naturally.<br>In Bernard Matthews Estate, replace weirs with coarse woody debris structures. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 8.6-9.2 m<br>Erodible banks: 13.1-13.9m | Depth: | Resistant banks: 1.35m<br>Erodible banks: 1.14m |
| Revised Management Class: | Enhancement | | | |
| Specific Actions Recommended: | In the 100 to 200m downstream of Lenwade Mill structure 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. Co-ordinate with potential flood risk management capital scheme - proposed works include installing a bank to protect industrial property and a lake (or a wall to protect also Porters Lane main road) from flooding up to 150m downstream of the mill. There may be potential to co-ordinate this work with proposed lowering of mill controls/raising of the bed and to mitigate against the effects of this on flood risk. Discussions underway between Environment Agency and Natural England/JBA. Enter into discussions with Bernard Matthews Estate.<br>Adopt/maintain maintenance regime and riparian management to allow channel to develop a more natural form. However, assume reach will narrow naturally in time and that no bed raising is required. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Ak** RWRS 10 Location Plan

## REACH CODE: RWRS 11

**Table AI1** RWRS 11 Reach data summary

| | |
|---|---|
| Location: | Walsis Hill to Lenwade Mill |
| NGR: | 608590, 318130 to 610160, 318200 |
| Total Reach Length: | 2,430m |
| Geomorphological Appraisal (2006) Reaches: | W306 to W303 (part) |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for Lenwade Mill, which is located at the downstream end of RWRS11. |

**Table AI2** RWRS 11 Current reach condition

| | | |
|---|---|---|
| Description: | Impounded upstream of Lenwade Mill. Flow is very slow and channel wide. Banks are steep and have little marginal/bankside vegetation. | |
| Natural England Assessment: | Part of River Unit 52 (Elsing Mill - Lewnade Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 425km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 15-25m<br>2.30m |
| Length Affected by Backwater: | All reach affected by backwater from Lenwade Mill. | |
| Maintenance Regime: | 75% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table AI3** RWRS 11 Constraints

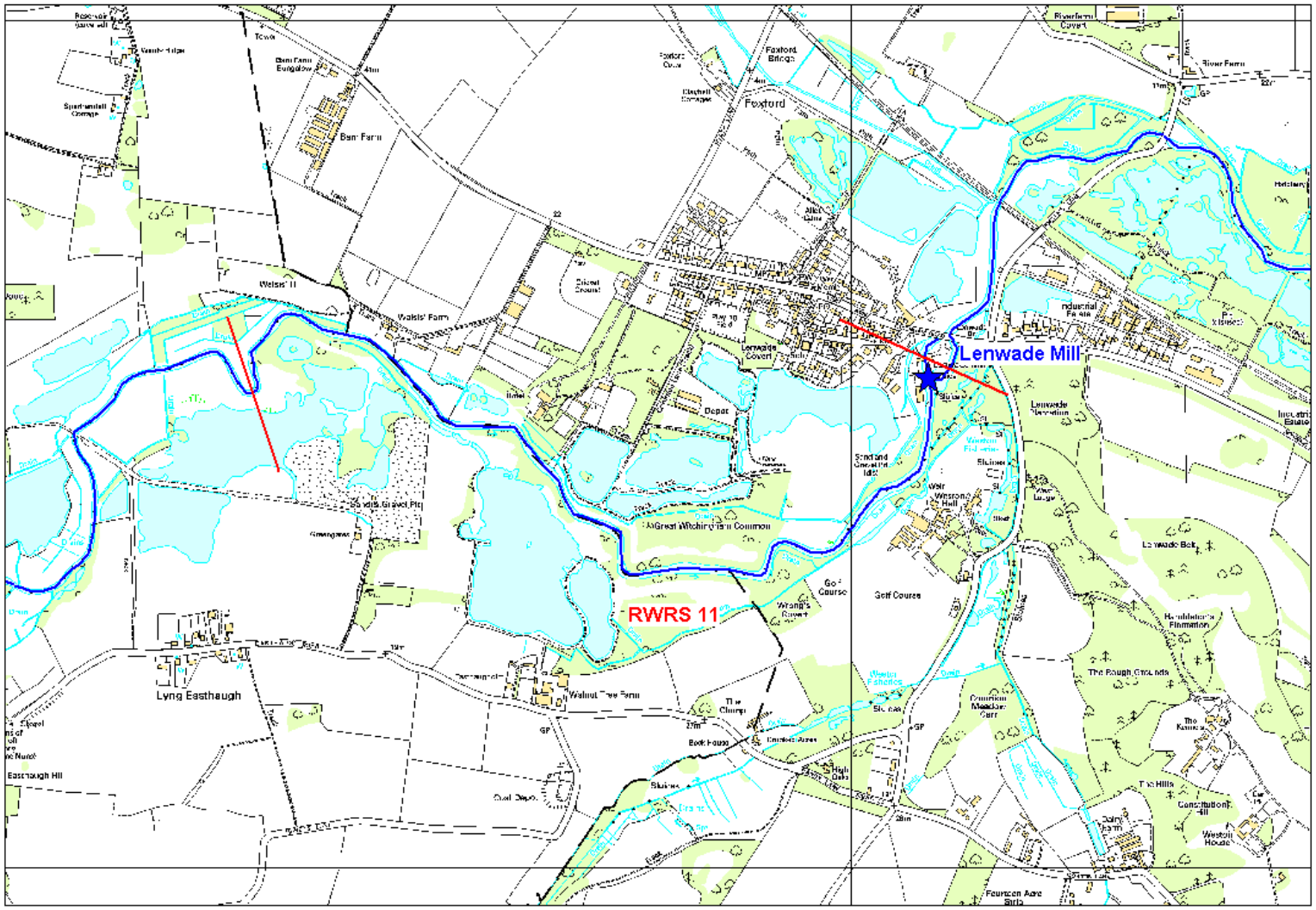
| | |
|---|---|
| Flood Risk: | Moderate (2 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Predominantly disused gravel pits/angling lakes, wet woodland. More industrial, business and residential properties on north side towards Lenwade, including hotel complex by river. Some improved permanent grassland. |
| Amenity Value: | Angling, (Catch 22 fishery, Lenwade Common Lakes, day permits). Canoeing in pits by Lenwade Mill. Great Witchingham Common has public access and a public footpath adjacent to the river at the foot of Walsis' Hill. |
| Other: | None |

**Table AI4** RWRS 11 Previous works or recommendations

| | | | | | |
|---|---|---|---|---|---|
| Previous Measures (Consented): | Lenwade Mill sluice automated (2004) - associated with Environment Agency flood risk management works. | | | | |
| Potential Schemes for Habitat Restoration (ECON): | None | | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | | |
| Reach Code | W302 | W303 | W304 | W305 | W306 |
| Reach Status | Damaged | Severely degraded | Damaged | Damaged | Damaged |
| Management Class | Assist | Rehabilitate | Assist | Assist | Restore |
| Work related to weir | ✓ | ✓ | | | |
| Re-establish former channel or dimensions | | | | | |
| Reconnect river to floodplain | | | | | |
| Narrow | | | ✓ | ✓ | ✓ |
| De-silt | | | | | |
| Augment gravel or bed or water levels | | | ✓ | ✓ | ✓ |
| Monitor | | | | | |
| Reduce maintenance | ✓ | ✓ | ✓ | ✓ | ✓ |
| Improve flow & habitat diversity | | | ✓ | ✓ | ✓ |
| Establish riparian vegetation | | | | | |
| Create or maintain backwater | | | | | |
| Fix sediment ingress points | | ✓ | | | ✓ |

**Table AI5** RWRS 11 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with lowering of structure at Lenwade Mill and associated river works and also with the flood risk management capital project proposed for Lenwade. De-silt channel just upstream of Lenwade Mill sluices. Physical narrowing and augmentation of the bed with gravel required. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 8.6 m<br>Erodible banks: 13-13.1m | Depth: | Resistant banks: 1.34m<br>Erodible banks: 1.14m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | Initial work required is for bed and bank stabilisation associated with lowering of Lenwade Mill structures at downstream end of reach. Appropriate measures required to manage silt deposits upstream of the mill. Augment bed on average by 1.0m using local gravels wherever possible and create up to 31 gravel glides or riffles in the reach. The channel is on average 7.0m 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 sluices. Adopt/maintain 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. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AI** RWRS 11 Location Plan

## REACH CODE: RWRS 12

**Table Am1** RWRS 12 Reach data summary

| | |
|---|---|
| Location: | Lyng Mill to Walsis Hill |
| NGR: | 617180, 317780 to 608590, 318130 |
| Total Reach Length: | 2,145m |
| Geomorphological Appraisal (2006) Reaches: | W309 to W307 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for Lyng Mill, which is located at the upstream end of RWRS12. Note that this reach is affected by backwater from Lenwade Mill. |

**Table Am2** RWRS 12 Current reach condition

| | | |
|---|---|---|
| Description: | Gravel bed downstream of Lyng Mill for about 100m and two gravel riffles between Sparham Pools and Bailey Bridge. Downstream, there is extensive siltation due to impoundment and increased channel width. Exceptions are where trees encroach on the channel (for example, upstream Bailey Bridge). Channel is straight over lengthy sections between meander bends. Extensive drain system on the floodplain and floodplain pools - tend to be disconnected from the main channel due to embankments that often exist on both banks downstream of Sparham Pools. | |
| Natural England Assessment: | Part of River Unit 52 (Elsing Mill - Taverham Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river.<br>River Unit adjacent to Terrestrial Unit 37 supports 2.8 ha of mesotrophic grassland and swamp (including MG9 and S5) towards the downstream half of RWRS12 on the left bank of the river. | |
| Upstream Catchment Area: | 415km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 13-15m<br>1.71m |
| Length Affected by Backwater: | Just under half reach affected by backwater from Lenwade Mill. | |
| Maintenance Regime: | Generally, up to 50% and 75% of weeds cut on free-flowing and impounded reaches, respectively, by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. Some management of riparian trees by fishing syndicate. | |

**Table Am3** RWRS 12 Constraints

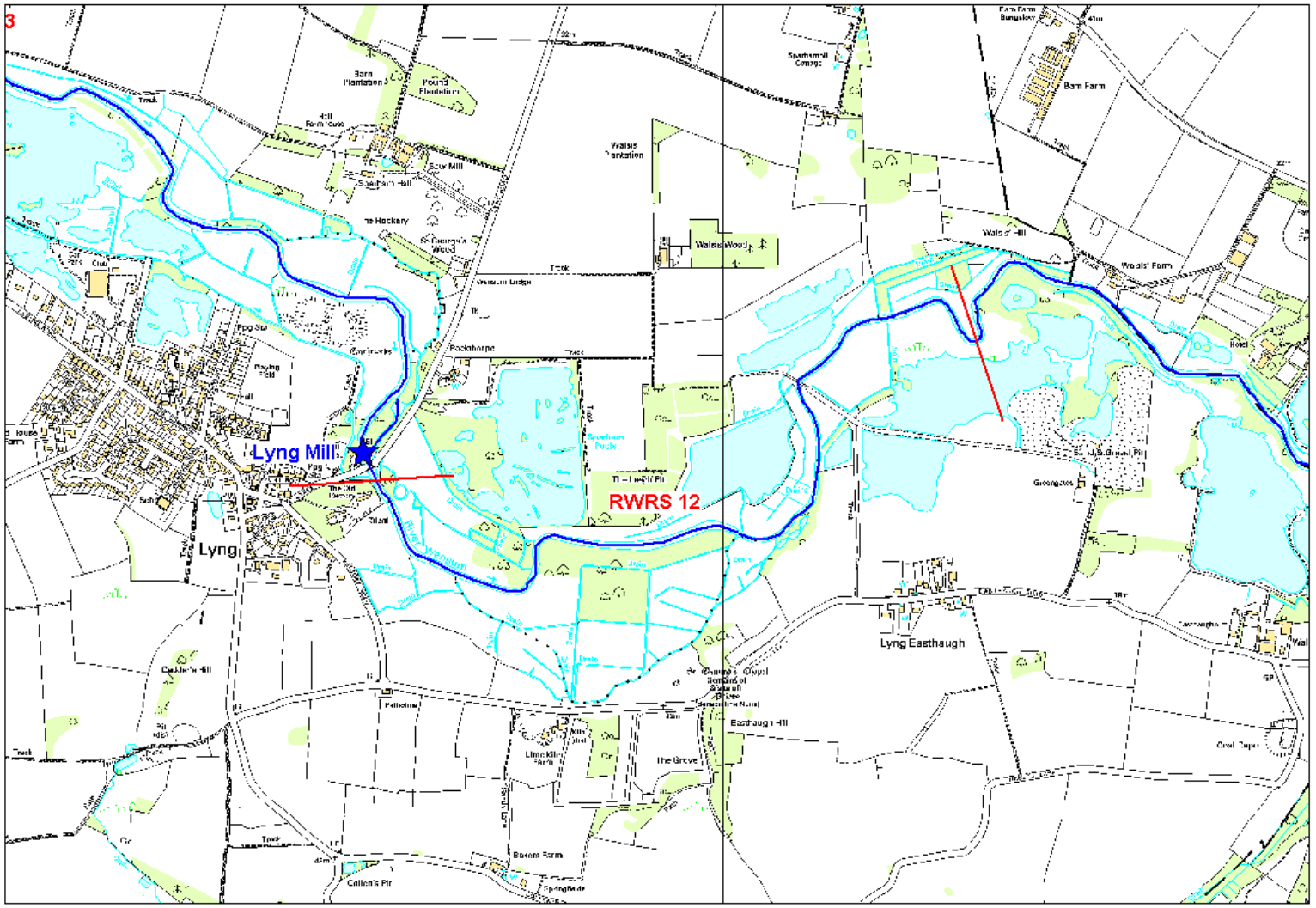
| | |
|---|---|
| Flood Risk: | Moderate (1 property in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Flooded former gravel workings on left (N) bank, partly occupied by Sparham Pools nature reserve. Permanent drained and damp pasture (ESA tiers 1 & 2) on both sides. Some woodland. |
| Amenity Value: | Angling (Norfolk Anglers Conservation Association, angling club); Nature reserve with access (Norfolk Wildlife Trust). |
| Other: | None |

**Table Am4** RWRS 12 Previous works or recommendations

| | | | |
|---|---|---|---|
| Previous Measures (Consented): | Downstream Lyng Mill - riffle creation, excavation of pools, channel narrowing, connection of backwater (1999; refer to NACA website). Downstream Lyng Mill to Lenwade Mill - tree management (2003) - associated with Environment Agency flood risk management works. Downstream Lyng Mill - excavation of pools (2004). | | |
| Potential Schemes for Habitat Restoration (ECON): | Lyng connection of gravel pit and fish pond using drains.<br>A scheme of riffle installation is also suggested by NACA - an alternative scheme upstream of Lyng Mill is to reuse the old channel on the left bank. | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | |
| Reach Code | W309 | W308 | W307 |
| Reach Status | Damaged | Damaged | Damaged |
| Management Class | Rehabilitate | Rehabilitate | Rehabilitate |
| Work related to weir | | | |
| Re-establish former channel or dimensions | | | |
| Reconnect river to floodplain | | | |
| Narrow | | ✓ | ✓ |
| De-silt | | | |
| Augment gravel or bed or water levels | ✓ | ✓ | ✓ |
| Monitor | | | |
| Reduce maintenance | ✓ | ✓ | |
| Improve flow & habitat diversity | ✓ | ✓ | ✓ |
| Establish riparian vegetation | | | ✓ |
| Create or maintain backwater | | | |
| Fix sediment ingress points | ✓ | ✓ | |

**Table Am5** RWRS 12 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | In the 100 to 200m downstream of Lyng Mill structure 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. All works must integrate with lowering of structures at Lenwade and Lyng mills and associated river works and must link with previously implemented schemes. Generally, channel is overly wide but not excessively so and has shown propensity to narrow where conditions are conducive. Allow channel to narrow naturally by removing embankments and encouraging growth of marginal/bankside vegetation. Use coarse woody debris structures to exacerbate sinuosity in wooded areas where channel is straight. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 8.5 m<br>Erodible banks: 12.8-12.9m | Depth: | Resistant banks: 1.33m<br>Erodible banks: 1.13m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | Reduce depth by an average of 0.4m and raise bed using up to 28 gravel glides or riffles in the reach. Adopt/maintain maintenance regime and riparian management to allow channel to narrow naturally. Assume reach will narrow naturally in time. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Am** RWRS 12 Location Plan

## REACH CODE: RWRS 13

**Table An1** RWRS 13 Reach data summary

| | |
|---|---|
| Location: | Elsing Mill to Lyng Mill |
| NGR: | 614940, 317710 to 617180, 317780 |
| Total Reach Length: | 3,675m |
| Geomorphological Appraisal (2006) Reaches: | W357 (part) to W310 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheets for Elsing Mill and Lyng Mill, which are located at the upstream and downstream ends of RWRS13, respectively. |

**Table An2** RWRS 13 Current reach condition

| | | |
|---|---|---|
| Description: | Channel is wide and has extensive silt deposits due to impoundment upstream of Lyng Mill. It is straight between pronounced bendways, some of which have outer bank pools and it is embanked along both banks throughout the reach. The floodplain is grazed by livestock and it has poorly developed littoral margins. IDB drains run parallel along both banks. Section of channel between Elsing Mill and road bridge at Mill Street has gravel bed and is of high conservation value. | |
| Natural England Assessment: | Part of River Unit 52 (Elsing Mill - Taverham Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 390km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 8.1-40m<br>1.87m |
| Length Affected by Backwater: | Virtually all reach is affected by backwater from Lyng Mill. | |
| Maintenance Regime: | 75% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table An3** RWRS 13 Constraints

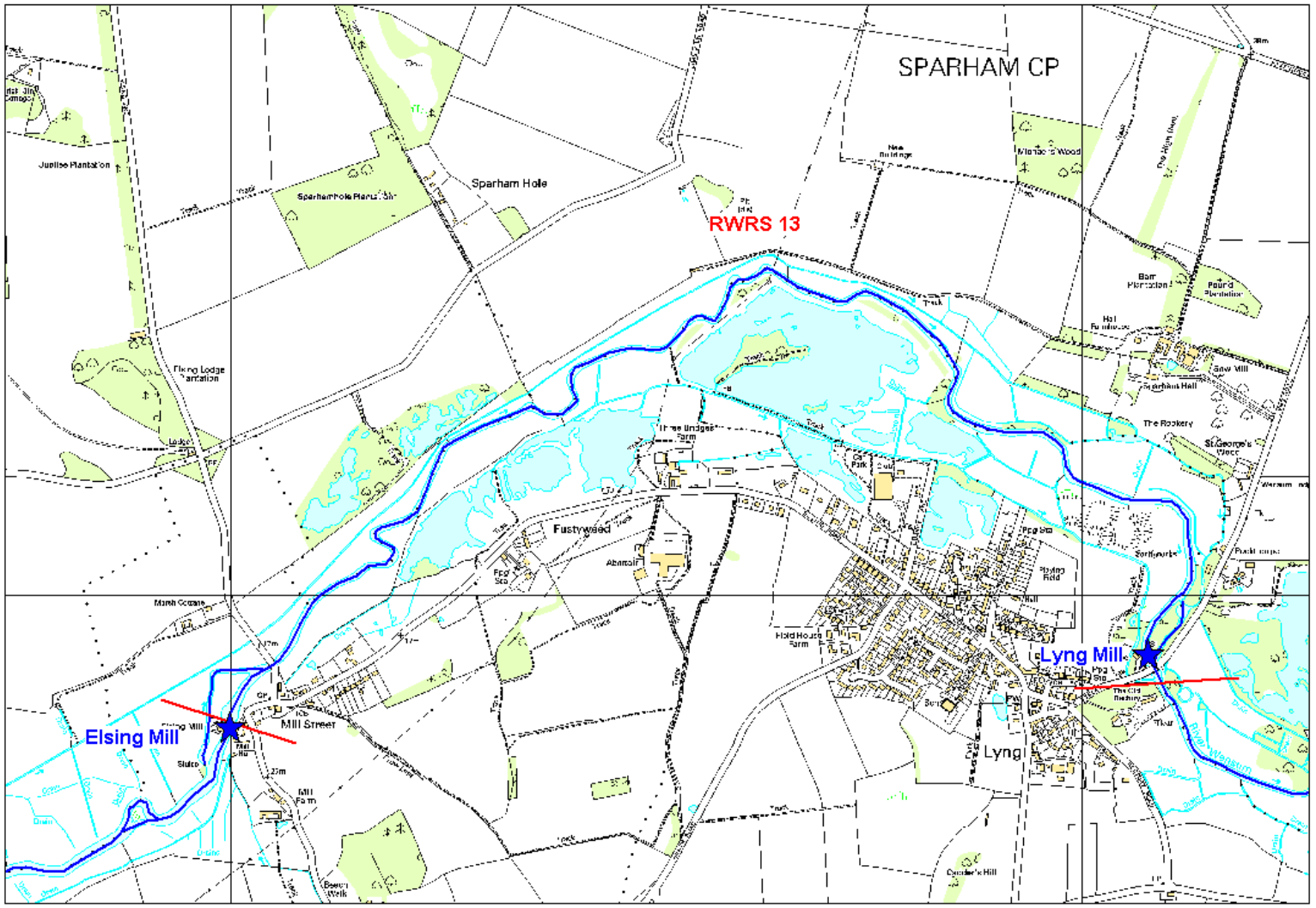
| | |
|---|---|
| Flood Risk: | High (6 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Extensive disused gravel pits on right (S) bank. Drained, semi-improved permanent pasture (ESA tier 1) on both sides of river. Arable farmland on valley sides. |
| Amenity Value: | Angling (Norfolk Anglers Conservation Association, fishing club, Kingfisher Fishing Lakes, fishing syndicate). |
| Other: | Conserve good pool habitats.<br>Archaeological interest adjacent to right bank.<br>Potential flood risk management capital scheme. |

**Table An4** RWRS 13 Previous works or recommendations

| | | | | | |
|---|---|---|---|---|---|
| Previous Measures (Consented): | Upstream Lyng Mill - reduction in silt berms (2002/3) and de-silting (2005/6) - associated with Environment Agency flood risk management works. | | | | |
| Potential Schemes for Habitat Restoration (ECON): | Lyng Mill by-pass using drains | | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | | |
| Reach Code | W310 | W351 | W352 | W354 | W355 |
| Reach Status | Degraded | Degraded | Recovered | Recovered | Damaged |
| Management Class | Rehabilitate | Rehabilitate | Conserve and monitor | Conserve and monitor | Restore |
| Work related to weir | | ✓ | ✓ | ✓ | ✓ |
| Re-establish former channel or dimensions | | | | | |
| Reconnect river to floodplain | | | | | |
| Narrow | | ✓ | | | |
| De-silt | | | | | |
| Augment gravel or bed or water levels | | ✓ | | | |
| Monitor | ✓ | | ✓ | ✓ | |
| Reduce maintenance | | ✓ | | | |
| Improve flow & habitat diversity | | ✓ | | | |
| Establish riparian vegetation | | ✓ | | | |
| Create or maintain backwater | | | | | ✓ |
| Fix sediment ingress points | ✓ | | | | |

**Table An5** RWRS 13 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with lowering of structures at Lyng and Elsing Mills and associated river works and with flood risk management capital project (see below). De-silt channel just upstream of the current sluices at Lyng and augment bed with gravels. Remove embankments to reconnect the river to its floodplain and encourage development of marginal/bankside vegetation. Connect the IDB system to the channel. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 8.1-8.4 m<br>Erodible banks: 12.3-12.7m | Depth: | Resistant banks: 1.32m<br>Erodible banks: 1.12m |
| Revised Management Class: | Rehabilitation (one option that has been considered at this location by landowner is restoration of by-pass/drainage channel). | | | |
| Specific Actions Recommended: | Co-ordinate with potential flood risk management capital scheme - proposed works include a cut-off wall and bank in the vicinity of the mill house upstream of the structure. This seems unlikely at present to be the preferred solution and there is a good prospect of tying in works with restoration proposals. Discussions underway between Environment Agency and Natural England/JBA. Co-ordinate with landowner who has expressed support for the River Wensum Restoration Strategy.<br>In the 100 to 200m downstream of Elsing Mill structure 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. Initial work required is for bed and bank stabilisation associated with lowering/by-pass of Lyng Mill structures at downstream end of reach. Appropriate measures required to manage silt deposits upstream of the mill. Reduce depth by an average of 0.6m and raise bed using up to 48 gravel glides or riffles in the reach. Assume reach will narrow naturally in time. Adopt/maintain maintenance regime and riparian management to allow channel to narrow naturally. Post-project monitoring is required, especially in association with works at the mill sluices. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure An** RWRS 13 Location Plan

## REACH CODE: RWRS 14

**Table Ao1** RWRS 14 Reach data summary

| | |
|---|---|
| Location: | Swanton Morley Mill to Elsing Mill |
| NGR: | 602050, 318550 to 614940, 317710 |
| Total Reach Length: | 4,830m |
| Geomorphological Appraisal (2006) Reaches: | W403 to W400 (excluding W404) plus w359 to w 357 (part) |
| Associated Mill Summary Information: | Refer to Mill Summary Sheets for Swanton Morley and Elsing Mill, which are located at the upstream and downstream ends of RWRS14, respectively. |

**Table Ao2** RWRS 14 Current reach condition

| | | |
|---|---|---|
| Description: | Engineered channel at Swanton Morley. Generally in reach, channel is wide and has extensive silt deposits due to impoundment upstream of Elsing Mill. It is straight between pronounced bendways, such as at Castle Farm, and it is embanked along both banks throughout much of the reach (exception is by sewage treatment works). The floodplain is grazed by livestock and the channel has poorly developed littoral margins. Floodplain drains run parallel to both banks. | |
| Natural England Assessment: | Part of River Unit 51 (North Elmham Mill - Elsing Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river.<br>River Unit adjacent to Terrestrial Units 34 and 36-3 support 3.4 ha of mosaics of rush pasture, fen, swamp and wet woodland (including M22, S7, S5, and W6) mostly on the right bank of the river between White House and Castle Farms.<br>River Unit adjacent to Terrestrial Unit 35 supports 0.25ha of woodland (including W8 and W2). | |
| Upstream Catchment Area: | 390km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 11.3-35.4m<br>2.46m |
| Length Affected by Backwater: | All but upstream 250m of reach affected by backwater from Elsing Mill. | |
| Maintenance Regime: | 75% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Ao3** RWRS 14 Constraints

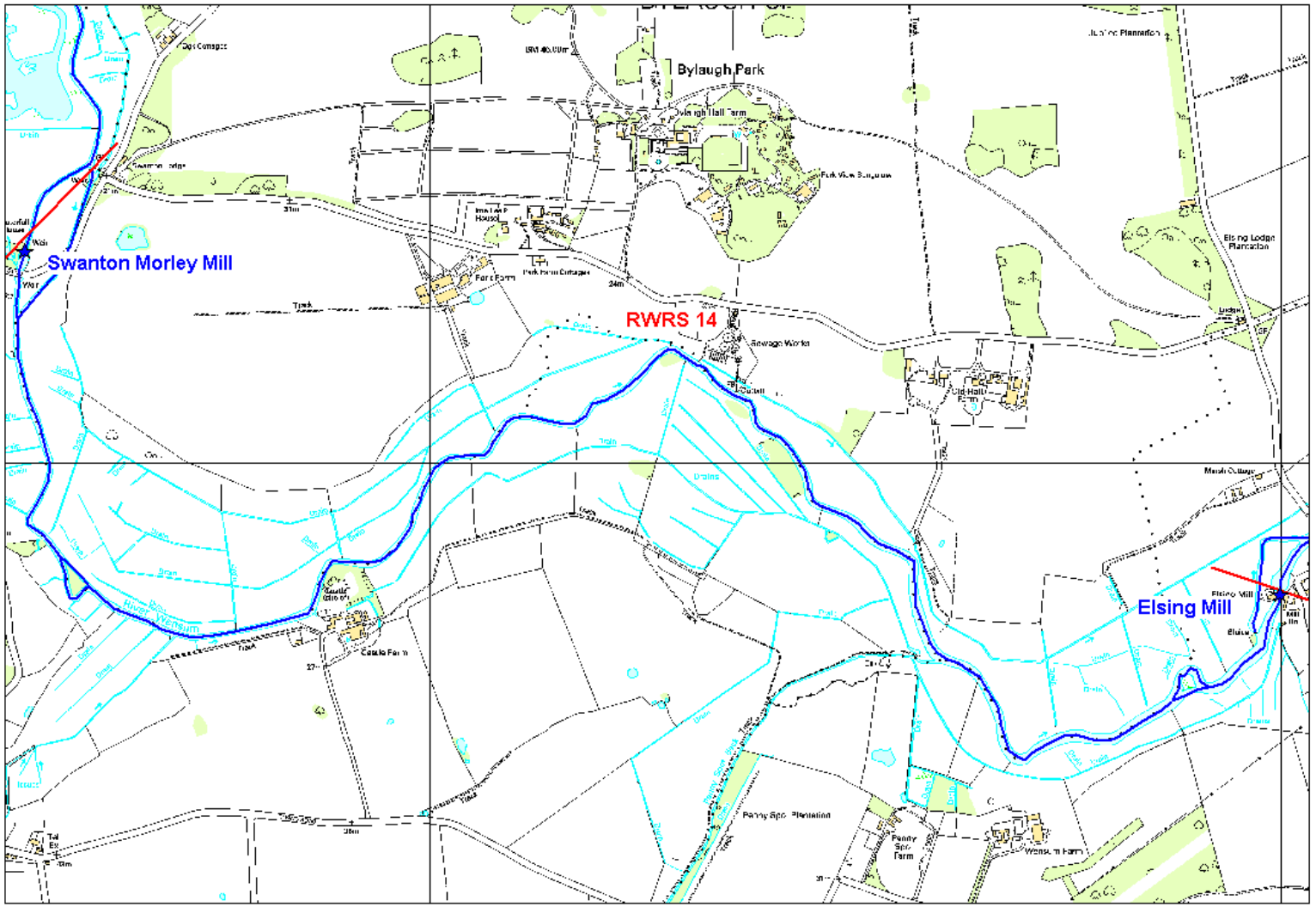
| | |
|---|---|
| Flood Risk: | Low (0 property in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Drained and damp permanent pastures (ESA tiers 1 & 2) on both sides of the valley with some arable reversion. Damp pasture/fen/woodland SSSI units as described above, near Swanton Morley. Some residential property close to river at Elsing. Arable farmland on valley sides. |
| Amenity Value: | Angling (free fishing, Dereham and District Angling Club), Canoeing at Swanton Morley Mill. Terrestrial SSSI Unit 35 is recognised as CRoW access land. |
| Other: | Sewage Treatment Works. Archaeological interest at Castle Farm. |

**Table Ao4** RWRS 14 Previous works or recommendations

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Previous Measures (Consented): | Upstream Castle Farm - reduction in vegetated berms (2004) - associated with Environment Agency flood risk management works. | | | | | | | |
| Potential Schemes for Habitat Restoration (ECON): | Castle Farm channel restoration | | | | | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | | | | | |
| Reach Code | W355 | W356 | W357 | W358 | W359 | W400 | W401 | W402 |
| Reach Status | Damaged | Damaged | Damaged | Damaged | Damaged | Damaged | Damaged | Damaged |
| Management Class | Restore | Restore | Restore | Restore | Restore | Restore | Restore | Monitor |
| Work related to weir | ✓ | ✓ | ✓ | | | | | |
| Re-establish former channel or dimensions | | | | ✓ | | ✓ | | |
| Reconnect river to floodplain | | | | | ✓ | ✓ | ✓ | |
| Narrow | | | ✓ | | ✓ | ✓ | ✓ | |
| De-silt | | | ✓ | | ✓ | ✓ | | |
| Augment gravel or bed or water levels | | | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Monitor | | | | | | | | ✓ |
| Reduce maintenance | | | | | | | | |
| Improve flow & habitat diversity | | | | | ✓ | ✓ | ✓ | |
| Establish riparian vegetation | | | ✓ | | | ✓ | | |
| Create or maintain backwater | ✓ | | | | | | | |
| Fix sediment ingress points | | | ✓ | ✓ | ✓ | ✓ | ✓ | |

**Table Ao5** RWRS 14 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with lowering of structures at Elsing and Swanton Morley Mills and associated river works. De-silt channel just upstream of Swanton Morley structures, physically narrow and augment bed with gravels. Remove embankments to reconnect the river to its floodplain and encourage development of the marginal/bankside vegetation. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 8.1m<br>Erodible banks: 12.2-12.3m | Depth: | Resistant banks: 1.29m<br>Erodible banks: 1.10m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | In the 100 to 200m downstream of Swanton Morley Mill structure 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. Initial work required is for bed and bank stabilisation associated with lowering of Elsing Mill structures at downstream end of reach. Appropriate measures required to manage silt deposits upstream of the mill. Augment bed on average by 1.2m using local gravels wherever possible and create up to 66 gravel glides or riffles in the reach. The channel is on average 10.1m 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. Adopt/maintain 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 structure. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Ao** RWRS 14 Location Plan

## REACH CODE: RWRS 15

**Table Ap1** RWRS 15 Reach data summary

| | |
|---|---|
| Location: | Upstream Riverside Farm to Swanton Morley Mill |
| NGR: | 600770, 319730 to 602050, 318550 |
| Total Reach Length: | 2,520m |
| Geomorphological Appraisal (2006) Reaches: | W404 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for Swanton Morley Mill, which is located at the downstream end of RWRS15. |

**Table Ap2** RWRS 15 Current reach condition

| | | |
|---|---|---|
| Description: | Character of river changes downstream of Riverside Farm. Channel is wide, with a poorly developed littoral margin and, despite being sinuous, there is little flow diversity. Embankments exist throughout the reach along both banks and there is an extensive drain network on the left bank. Engineered channel at Swanton Morley. Condition of channel greatly improved by recent river restoration scheme (Swanton Morley Phases I, II and III). | |
| Natural England Assessment: | Part of River Unit 51m (North Elmham Mill - Elsing Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river.<br>River Unit adjacent to Terrestrial Unit 33 supports 4ha of mesotrophic grassland and fen (including MG8, M22, and S7) on the right bank of the river by Waterfall Farm/Swanton Lodge. | |
| Upstream Catchment Area: | 390km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 13.8m<br>1.69m |
| Length Affected by Backwater: | All reach affected by backwater from Swanton Morley Mill. | |
| Maintenance Regime: | 75% of weeds cut by the Environment Agency (100% in the short reach upstream of the gauging station). Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Ap3** RWRS 15 Constraints

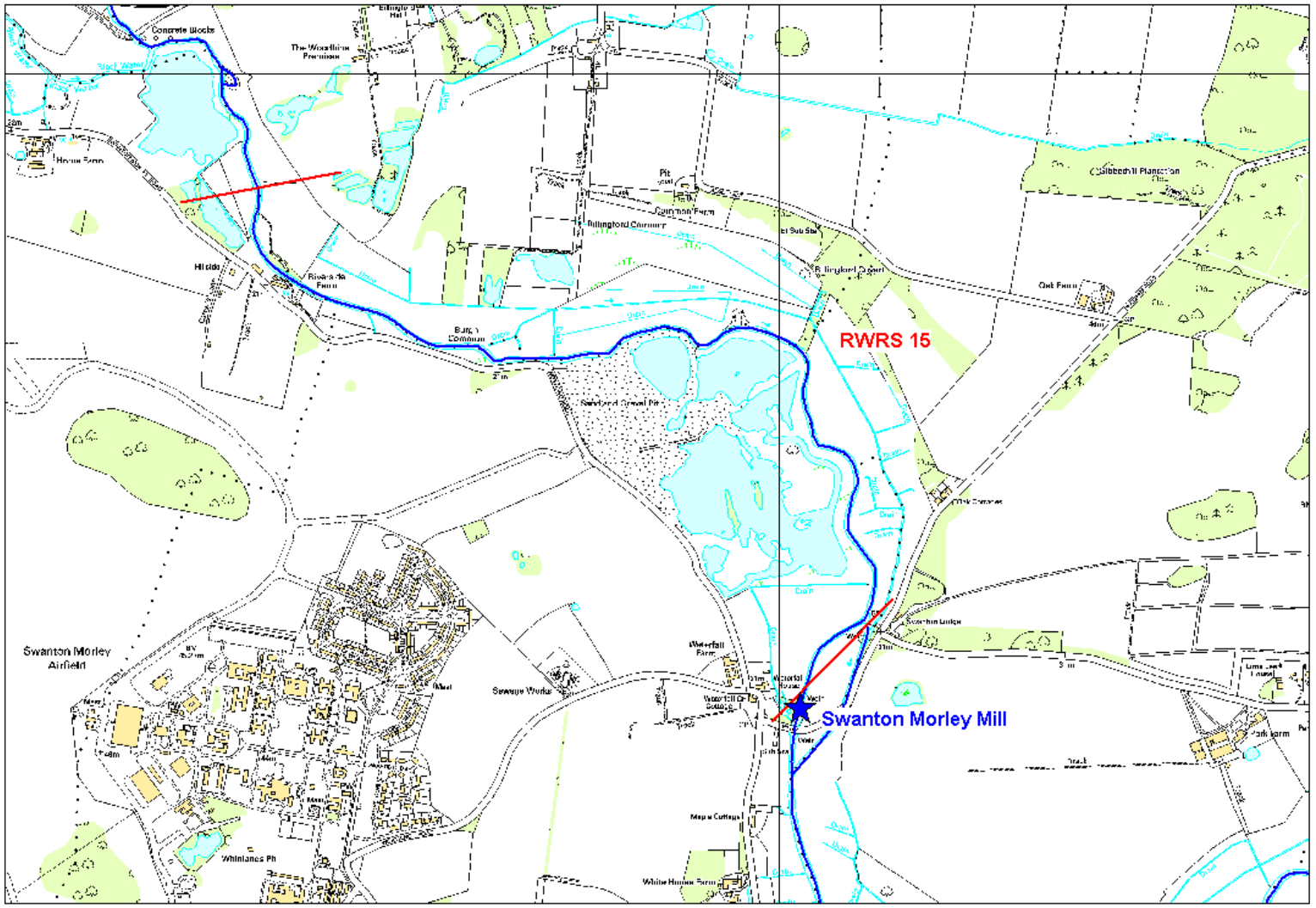
| | |
|---|---|
| Flood Risk: | Low (0 property in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Drained permanent pasture (ESA tier 1) and other semi-improved grassland on left (N) side occupying former Billingford and Burgh Commons. Disused gravel pits (now fishing lakes) on both banks. Arable farmland on valley sides. |
| Amenity Value: | Angling (free fishing, Dereham and District Angling Club, Norfolk Flyfishers Club). Trout and coarse fishing in lakes. Canoeing at Swanton Morley Mill. Mill Common and Burgh Common lie immediately adjacent to the river and have been mapped as CRoW access land. Further CRoW land is mapped at the edge of the floodplain on the valley side opposite Burgh Common. |
| Other: | Removal of embankments may increase risk of escape of non-native fish species to the river. Consider Environment Agency gauging station at Swanton Morley Mill. |

**Table Ap4** RWRS 15 Previous works or recommendations

| | |
|---|---|
| Previous Measures (Consented): | Swanton Morley - river restoration, 4 riffles, 3 fish fry bays and berm construction (2005).<br>Swanton Morley - river restoration, 2 off-river refuges, margin re-profiling (2006). |
| Potential Schemes for Habitat Restoration (ECON): | Worthing riffles and narrowing;<br>Swanton Morley channel narrowing and margin enhancement |
| Geomorphological Appraisal (2006) Options for Restoration: | |
| Reach Code | W404 |
| Reach Status | Degraded |
| Management Class | Rehabilitate |
| Work related to weir | |
| Re-establish former channel or dimensions | |
| Reconnect river to floodplain | ✓ |
| Narrow | ✓ |
| De-silt | |
| Augment gravel or bed or water levels | ✓ |
| Monitor | |
| Reduce maintenance | |
| Improve flow & habitat diversity | |
| Establish riparian vegetation | ✓ |
| Create or maintain backwater | |
| Fix sediment ingress points | |

**Table Ap5** RWRS 15 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with lowering of structure at Swanton Morley Mill and associated river works and must link with previously completed schemes. De-silt channel just upstream of Swanton Morley structures and augment bed with gravels. Encourage channel to narrow naturally by developing marginal/bankside vegetation. Plant trees on outer bends to prevent breaching into gravel pits. Introduce coarse woody debris structures in the downstream section of the reach to encourage scour. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 8.1 m<br>Erodible banks: 12.2m | Depth: | Resistant banks: 1.28m<br>Erodible banks: 1.09m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | Initial work required is for bed and bank stabilisation associated with lowering of Swanton Morley Mill structures at downstream end of reach. Appropriate measures required to manage silt deposits upstream of the mill. Reduce depth by an average of 0.4m and raise bed using up to 34 gravel glides or riffles in the reach. Assume reach will narrow naturally in time. Adopt/maintain maintenance regime and riparian management to allow channel to narrow naturally. Post-project monitoring is required, especially in association with works at the mill structures. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Ap** RWRS 15 Location Plan

## REACH CODE: RWRS 16

**Table Aq1** RWRS 16 Reach data summary

| | |
|---|---|
| Location: | North Elmham Mill to Upstream Riverside Farm (Swanton Morley) |
| NGR: | 600270, 320370 to 600770, 319730 |
| Total Reach Length: | 1,170m |
| Geomorphological Appraisal (2006) Reaches: | W501 (part), W500 and W407 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for North Elmham Mill, which is located at the upstream end of RWRS16. Note reach is affected by backwater from Swanton Morley Mill. |

**Table Aq2** RWRS 16 Current reach condition

| | | |
|---|---|---|
| Description: | River and by-pass channel for Elsing Mill fast flowing with a gravel bed downstream. Riffles at confluence with Blackwater (Wending Beck) but channel embanked on both banks downstream of confluence. Old meander loop used as an off river supplementation unit (ORSU). | |
| Natural England Assessment: | Part of River Unit 51 (North Elmham Mill - Elsing Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 270km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 12.5-16.6m<br>1.70m |
| Length Affected by Backwater: | All but upstream 350m of reach affected by backwater from Swanton Morley Mill. | |
| Maintenance Regime: | Generally, up to 50% and 75% of weeds cut on free-flowing and impounded reaches, respectively, by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Aq3** RWRS 16 Constraints

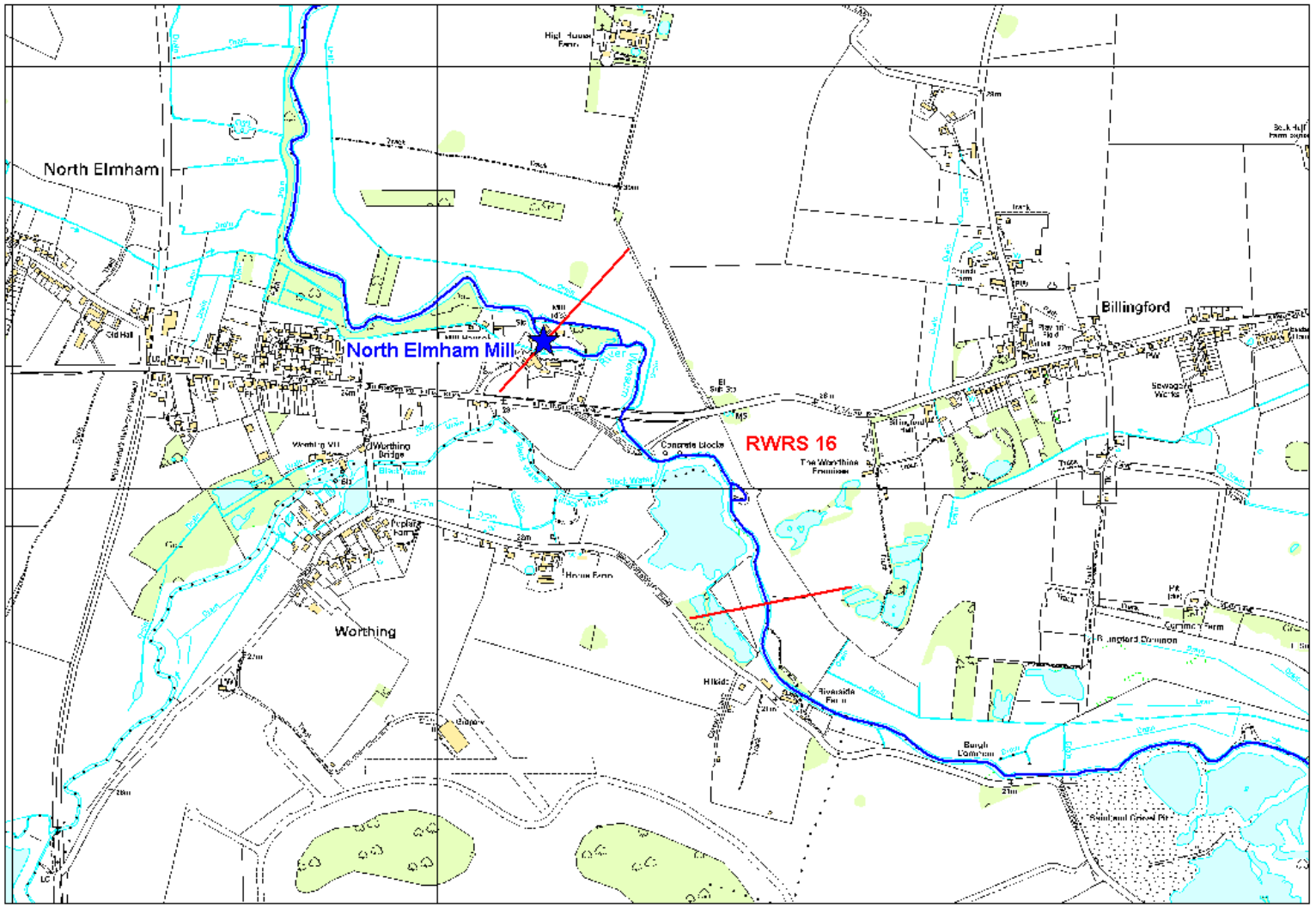
| | |
|---|---|
| Flood Risk: | High (10 properties in the 1 in 100 year return period flood outline - Flood Zone 3 in tributary) |
| Land Use: | Mainly drained, semi-improved permanent pasture (ESA tier 1) on left (N) side of valley, and also around lower reach of the Blackwater tributary. Also some arable reversion under ESA tier 4. Some residential property at North Elmham. |
| Amenity Value: | Angling (syndicate) |
| Other: | Ecological communities - for example, at ORSU and confluence |

**Table Aq4** RWRS 16 Previous works or recommendations

| | | | | |
|---|---|---|---|---|
| Previous Measures (Consented): | Billingford meander loop reconnection (2000). | | | |
| Potential Schemes for Habitat Restoration (ECON): | Billingford meander loop reconnection. | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | |
| Reach Code | W407 | W500 | W501 | W515 |
| Reach Status | Recovering | Damaged | Degraded | Degraded |
| Management Class | Assist | Assist | Rehabilitate | Restore |
| Work related to weir | | | ✓ | ✓ |
| Re-establish former channel or dimensions | | | | |
| Reconnect river to floodplain | | | | |
| Narrow | ✓ | ✓ | | |
| De-silt | | | | |
| Augment gravel or bed or water levels | ✓ | ✓ | | |
| Monitor | ✓ | | | |
| Reduce maintenance | | ✓ | | |
| Improve flow & habitat diversity | ✓ | | | |
| Establish riparian vegetation | ✓ | | | |
| Create or maintain backwater | | | | |
| Fix sediment ingress points | | | | |

**Table Aq5** RWRS 16 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with lowering of structures at Swanton Morley Mill and North Elmham Mill and associated river works. Also must link with the completed meander loop connection at Billingford and take flood risk into consideration. Develop marginal/bankside vegetation and augment bed with gravels. Preferably, remove embankments to reconnect river to its floodplain. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 6.3-6.7m<br>Erodible banks: 9.6-10.2m | Depth: | Resistant banks: 1.16m<br>Erodible banks: 0.99m |
| Revised Management Class: | Rehabilitate | | | |
| Specific Actions Recommended: | In the 100 to 200m downstream of North Elmham 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. Augment bed on average by 0.5m using local gravels wherever possible and create up to 20 gravel glides or riffles in the reach. Assume reach will narrow naturally in time. Adopt/maintain maintenance regime and riparian management to allow channel to narrow naturally. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Aq** RWRS 16 Location Plan

## REACH CODE: RWRS 17

**Table Ar1** RWRS 17 Reach data summary

| | |
|---|---|
| Location: | Bintree Woods to North Elmham Mill |
| NGR: | 599270, 321950 to 600270, 320370 |
| Total Reach Length: | 2,600m |
| Geomorphological Appraisal (2006) Reaches: | W503 to W501 (part) |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for North Elmham Mill, which is located at the downstream end of RWRS17. |

**Table Ar2** RWRS 17 Current reach condition

| | | |
|---|---|---|
| Description: | Relatively sinuous but impounded, silted and overly wide. Vertical earth banks restrict connectivity with floodplain - embankments on left bank in downstream half of reach and on both banks in upstream half of reach. Extensive drain network on the floodplain upstream of North Elmham. | |
| Natural England Assessment: | Part of River Unit 50 (Bintree Mill - North Elmham Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river.<br>River Unit adjacent to Terrestrial Unit 32 supports a 7ha mosaic of mesotrophic grassland and rush pasture (including MG8 and M22) on the right bank of the river opposite the Sewage Works at North Elmham. | |
| Upstream Catchment Area: | 265km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 12.5-20.6m<br>2.51m |
| Length Affected by Backwater: | All reach affected by backwater from North Elmham Mill. | |
| Maintenance Regime: | 75% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Ar3** RWRS 17 Constraints

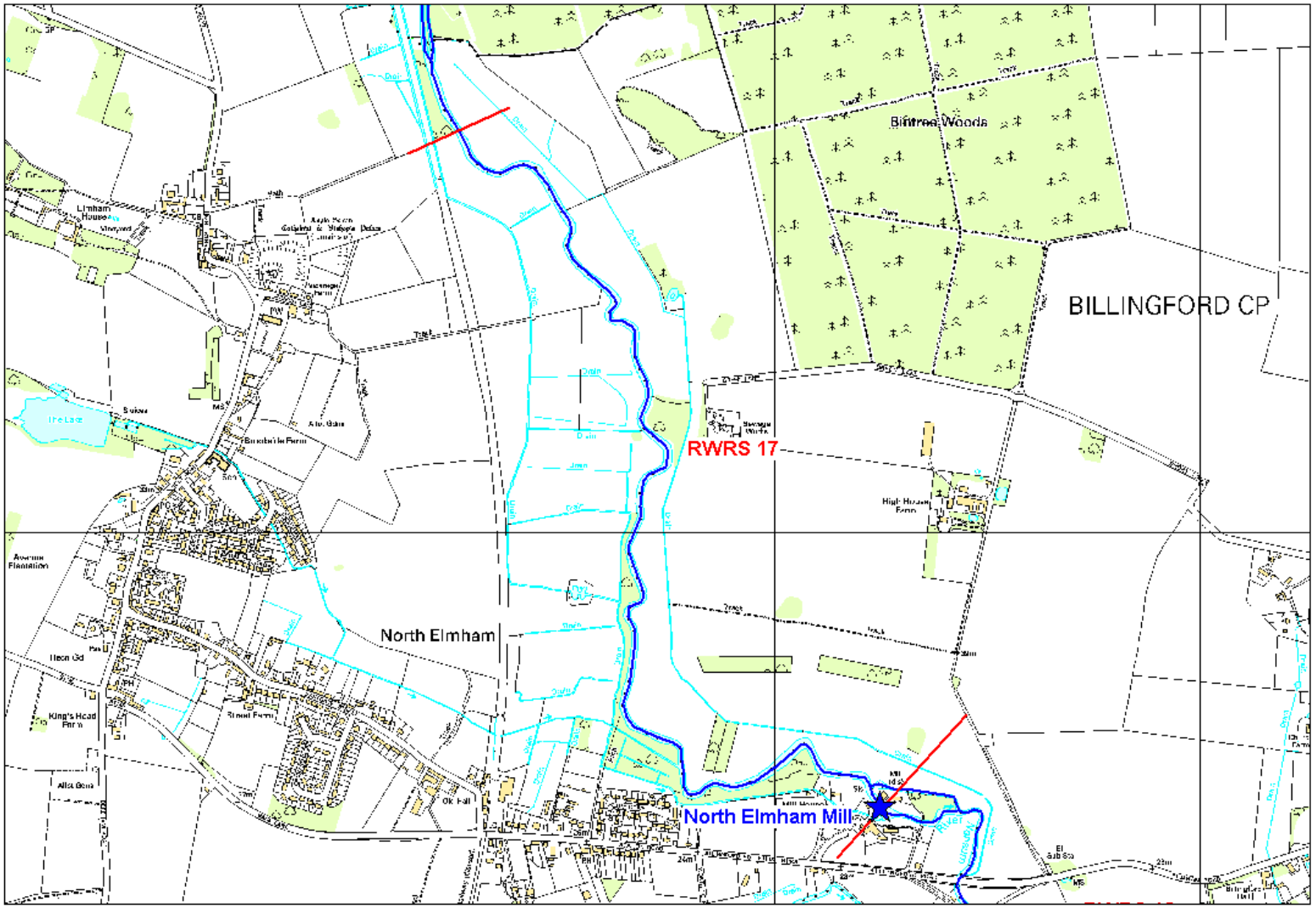
| | |
|---|---|
| Flood Risk: | High (17 properties in the 1 in 100 year return period flood outline - Flood Zone 3 in tributary) |
| Land Use: | Mainly drained permanent pasture both sides of river (mainly ESA tier 1, but also damper meadows under tier 2), including SSSI grassland as described above. Residential properties near river at North Elmham. |
| Amenity Value: | Angling (Bintry Mill Trout Fishery). Bintree Woods are mapped as CRoW access land and includes the river bank below Bintree Hills. |
| Other: | None |

**Table Ar4** RWRS 17 Previous works or recommendations

| | | | |
|---|---|---|---|
| Previous Measures (Consented): | None | | |
| Potential Schemes for Habitat Restoration (ECON): | North Elmham floodplain reed-bed connection, creation of anastomising section and narrowing | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | |
| Reach Code | W501 | W502 | W503 |
| Reach Status | Degraded | Degraded | Degraded |
| Management Class | Rehabilitate | Rehabilitate | Rehabilitate |
| Work related to weir | ✓ | | |
| Re-establish former channel or dimensions | | | |
| Reconnect river to floodplain | | ✓ | |
| Narrow | | ✓ | ✓ |
| De-silt | | ✓ | |
| Augment gravel or bed or water levels | | ✓ | ✓ |
| Monitor | | | |
| Reduce maintenance | | | |
| Improve flow & habitat diversity | | | |
| Establish riparian vegetation | | | |
| Create or maintain backwater | | | |
| Fix sediment ingress points | | | |

**Table Ar5** RWRS 17 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with lowering of structure at North Elmham Mill and associated river works. De-silt channel just upstream of North Elmham Mill, physically narrow and augment bed with gravels. Remove embankments to reconnect the river to its floodplain and encourage development of marginal/bankside vegetation. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 6.3 m<br>Erodible banks: 9.5-9.6m | Depth: | Resistant banks: 1.04m<br>Erodible banks: 0.89m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | 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 1.5m using local gravels wherever possible and create up to 45 gravel glides or riffles in the reach. The channel is on average 12.9m 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. Adopt/maintain 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. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Ar** RWRS 17 Location Plan

## REACH CODE: RWRS 18

**Table As1** RWRS 18 Reach data summary

| | |
|---|---|
| Location: | Dell View Farm to Bintree Woods |
| NGR: | 599230, 322780 to 599270, 321950 |
| Total Reach Length: | 855m |
| Geomorphological Appraisal (2006) Reaches: | W505 and W504 |
| Associated Mill Summary Information: | No mill at up or downstream end of RWRS18 |

**Table As2** RWRS 18 Current reach condition

| | | |
|---|---|---|
| Description: | Channel straightened and wide. Where banks are steep or trees shade the bank line, reducing the growth of emergent vegetation, the channel remains wider, silt has accumulated in the channel and flow diversity is reduced. Embanked on one bank throughout - right bank upstream and left bank downstream. Some drains on floodplain where fields exist but land-use beside river is mainly woodland. | |
| Natural England Assessment: | Part of River Unit 50 (Bintree Mill - North Elmham Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 265km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 14.5-16.5m<br>1.70m |
| Length Affected by Backwater: | All reach affected by backwater from North Elmham Mill. | |
| Maintenance Regime: | 75% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table As3** RWRS 18 Constraints

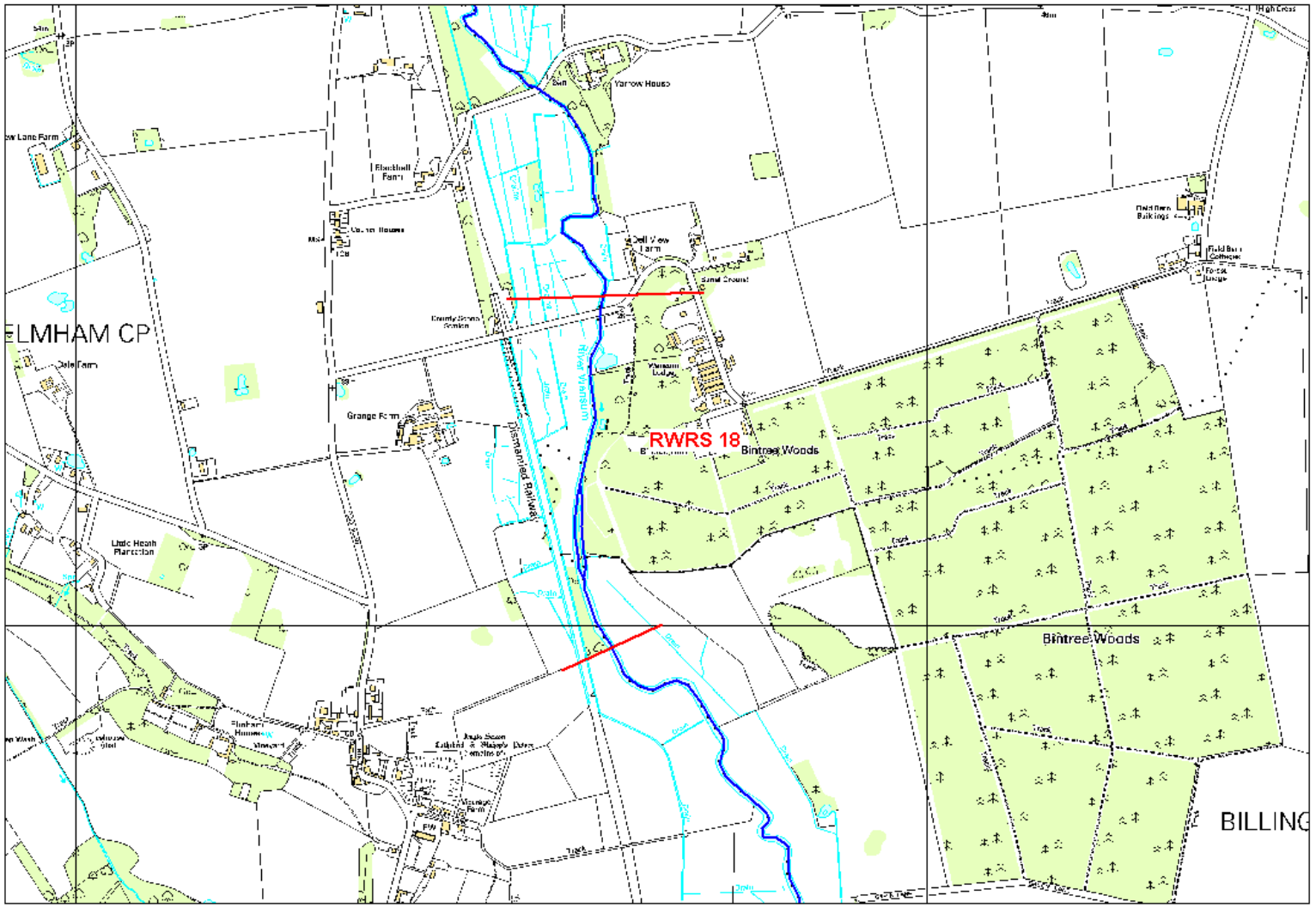
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3 in tributary) |
| Land Use: | Woodland on left (E) bank - Bintree Woods; drained permanent pasture (ESA tier 1) bisected by disused railway line on right (W) bank. |
| Amenity Value: | Angling (Bintry Mill Trout Fishery). Bintree Woods are mapped as CRoW access land and includes the river bank below Bintree Hills. |
| Other: | None |

**Table As4** RWRS 18 Previous works or recommendations

| | | |
|---|---|---|
| Previous Measures (Consented): | None | |
| Potential Schemes for Habitat Restoration (ECON): | None | |
| Geomorphological Appraisal (2006) Options for Restoration: | | |
| Reach Code | W404 | W405 |
| Reach Status | Degraded | Degraded |
| Management Class | Rehabilitation | Rehabilitation |
| Work related to weir | | |
| Re-establish former channel or dimensions | | |
| Reconnect river to floodplain | | |
| Narrow | ✓ | ✓ |
| De-silt | | |
| Augment gravel or bed or water levels | ✓ | ✓ |
| Monitor | | |
| Reduce maintenance | | |
| Improve flow & habitat diversity | | |
| Establish riparian vegetation | | |
| Create or maintain backwater | | |
| Fix sediment ingress points | | ✓ |

**Table As5** RWRS 18 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with lowering of structure at North Elmham Mill and associated river works. Physically narrow channel and augment bed with gravel. Remove embankments to reconnect river to its floodplain. Develop marginal/bankside vegetation and use coarse woody debris structures to exacerbate sinuosity. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 6.3 m<br>Erodible banks: 9.5m | Depth: | Resistant banks: 1.04m<br>Erodible banks: 0.89m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | Augment bed on average by 0.7m using local gravels wherever possible and create up to 15 gravel glides or riffles in the reach. The channel is on average 5.6m 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. Adopt/maintain maintenance regime and riparian management to allow channel to create natural variations in local channel width and habitat niches. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure As** RWRS 18 Location Plan

## REACH CODE: RWRS 19

**Table At1** RWRS 19 Reach data summary

| | |
|---|---|
| Location: | Bintry Mill to Dell View Farm |
| NGR: | 599860, 324240 to 599230, 322780 |
| Total Reach Length: | 2,670m |
| Geomorphological Appraisal (2006) Reaches: | W510 to W506 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for Bintry Mill, which is located at the upstream end of RWRS19. Note that this reach is affected by backwater from North Elmham Mill. |

**Table At2** RWRS 19 Current reach condition

| | | |
|---|---|---|
| Description: | Just downstream of Bintry Mill, channel is fairly straight and fast flowing with a gravel bed and some exposed chalk. Downstream, channel becomes naturally sinuous with a number of pools at bendways and is embanked (mainly on right bank, for example, adjacent to Turf Common). Towards end of reach, channel straightened once again and wide. Where banks are steep or trees shade the bank line, reducing the growth of emergent vegetation, the channel remains wider, silt has accumulated in the channel and flow diversity is reduced. Some drains on the floodplain, especially towards downstream end of reach. | |
| Natural England Assessment: | Part of River Unit 50 (Bintree Mill - North Elmham Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river.<br>River Unit adjacent to Terrestrial Unit 31 supports a 20 ha mosaic of mesotrophic grassland, rush pasture, swamp and wet woodland (including M22, S5, W2, S5, and W6). On the right bank of the river in the upstream half of RWRS19. | |
| Upstream Catchment Area: | 260km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 13-15.2m<br>1.72m |
| Length Affected by Backwater: | About half affected by backwater from North Elmham Mill. | |
| Maintenance Regime: | Generally, up to 50% and 75% of weeds cut on free-flowing and impounded reaches, respectively, by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table At3** RWRS 19 Constraints

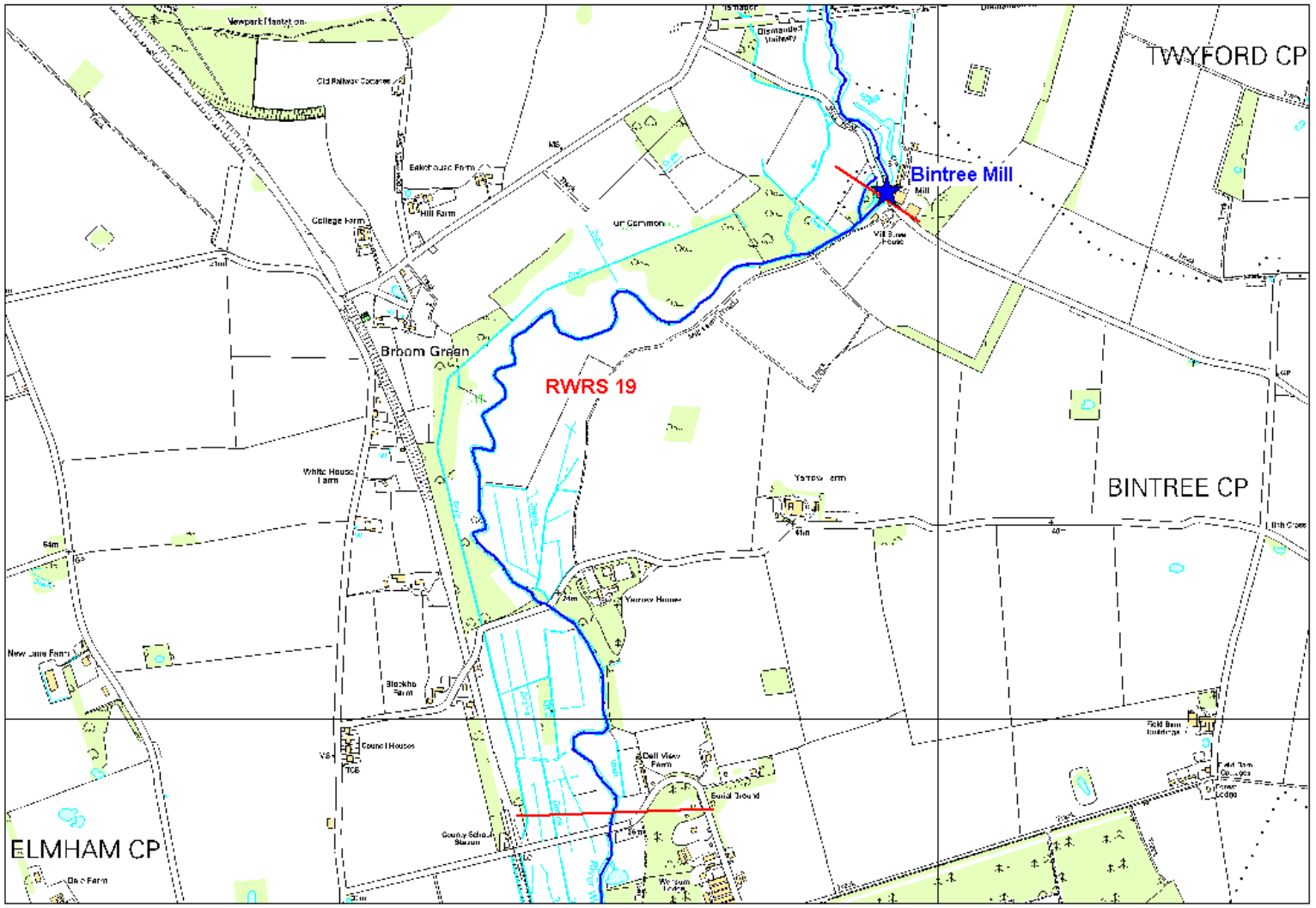
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3 in tributary) |
| Land Use: | Drained permanent pasture (ESA tier 1) on left (E) side. Drained and wet permanent pasture, rush pasture, scrub, and wet woodland, majority of which is SSSI as described above on right (W) side of valley, with ESA tier 2 at S. end. Arable reversion under ESA near Bintry Mill. Arable farmland on valley sides. |
| Amenity Value: | Angling (Bintry Mill Trout Fishery). |
| Other: | None |

**Table At4** RWRS 19 Previous works or recommendations

| | | | | | |
|---|---|---|---|---|---|
| Previous Measures (Consented): | Bintry Mill - sluice automated (1999) - associated with Environment Agency flood risk management works.<br>Downstream Bintry Mill - riffles/gravel glides, channel narrowing, fencing/tree planting (2000).<br>Downstream Bintry Mill - fisheries deflectors (2001).<br>Downstream Bintry Mill - Bacton to King's Lynn pipeline - open cut and channel restoration (2003).<br>Downstream Bintry Mill - 3 gravel glides, including remedial work to pipeline crossing (2004). | | | | |
| Potential Schemes for Habitat Restoration (ECON): | Downstream Bintry Mill riffles and narrowing | | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | | |
| Reach Code | W506 | W507 | W508 | W509 | W510 |
| Reach Status | Degraded | Semi-natural | Damaged | Semi-natural | Recovered |
| Management Class | Rehabilitate | Enhance | Protect & monitor | Rehabilitate | Protect & monitor |
| Work related to weir | | | | | |
| Re-establish former channel or dimensions | | | | | |
| Reconnect river to floodplain | | | | | |
| Narrow | ✓ | ✓ | | ✓ | |
| De-silt | | | | | |
| Augment gravel or bed or water levels | | | | ✓ | |
| Monitor | | | ✓ | | ✓ |
| Reduce maintenance | | | | | |
| Improve flow & habitat diversity | ✓ | ✓ | | ✓ | ✓ |
| Establish riparian vegetation | | | | | |
| Create or maintain backwater | | | | | |
| Fix sediment ingress points | ✓ | | ✓ | | |

**Table At5** RWRS 19 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with plans to lower structure at North Elmham Mill, lower structure at Bintry Mill and associated river works. They must also link in with the schemes already completed at this site. Some sections of this reach have emergent vegetation that is naturally narrowing the channel and this should be encouraged to continue. Augment bed with gravels towards the lower section of the reach and remove embankments to reconnect the river to its floodplain. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 6.2m<br>Erodible banks: 9.4m | Depth: | Resistant banks: 1.03m<br>Erodible banks: 0.88m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | In the 100 to 200m downstream of Bintry 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. Reduce depth by an average of 0.7m and raise bed using up to 47 gravel glides or riffles in the reach. Assume reach will narrow naturally in time. Adopt/maintain maintenance regime and riparian management to allow channel to narrow naturally. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure At** RWRS 19 Location Plan

## REACH CODE: RWRS 20

**Table Au1** RWRS 20 Reach data summary

| | |
|---|---|
| Location: | Upstream Guist Common to Bintry Mill |
| NGR: | 598890, 325080 to 599860, 324240 |
| Total Reach Length: | 2,010m |
| Geomorphological Appraisal (2006) Reaches: | W550, W513 to W511 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for Bintry Mill, which is located at the downstream end of RWRS20. |

**Table Au2** RWRS 20 Current reach condition

| | | |
|---|---|---|
| Description: | Upstream, sinuous but wide with silt deposits accumulating in the channel. Floodplain is marshy (reedbed and fen) at Guist Common. In the centre of the reach is the confluence with Guist Drain. This occurs just downstream of where the course of the river bends and takes a more southerly route. Floodplain contains a network of drains on the right bank and Guist Carr on the left bank in this central section. Channel remains sinuous but becomes wide as flow begins to slow in impounded section upstream of Bintry Mill. Throughout most of reach channel is embanked on both sides. | |
| Natural England Assessment: | Part of River Unit 49 (Great Ryburgh Mill - Bintree Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river.<br>River Unit adjacent to Terrestrial Units 23 to 24 support a mosaic of mesotrophic grassland and rush pasture (MG8 and M22) on right bank upstream of Guist Drain confluence. Terrestrial Units 25, 27 and 30 supports a mosaic of mesotrophic grassland, rush pasture and fen (including MG8, M7, and M22) on left bank downstream of confluence. 33.6ha.<br>Terrestrial Units 22 and 29 support 16ha of swamp (including S4 and S29) on left bank of river; Overall status is unfavourable recovering and favourable, respectively. Unit 22 is one of the largest areas of reedbed in Norfolk, outside the Broads.<br>Terrestrial Unit 28 supports 1.6ha of woodland (W2) at Guist Drain confluence. | |
| Upstream Catchment Area: | 210km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 12-27m<br>1.82m |
| Channel Dimensions (Bankfull): | Width: Depth: | |
| Length Affected by Backwater: | All reach affected by backwater from Bintry Mill. | |

**Table Au3** RWRS 20 Constraints

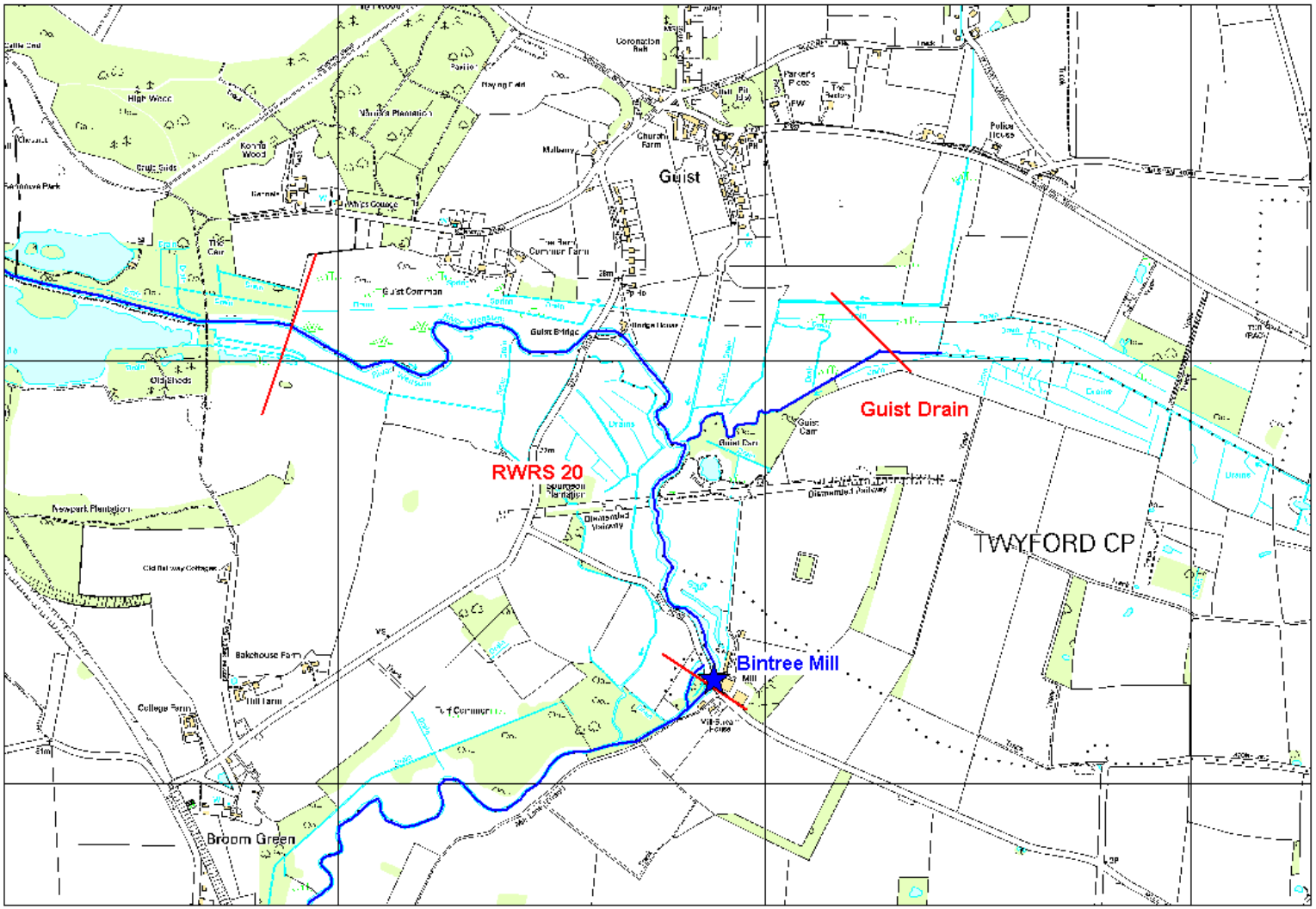
| | |
|---|---|
| Flood Risk: | Moderate (1 property in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Permanent, predominantly wet pastures (ESA tiers 1, 2 & 3), reedbed, fen, woodland and scrub, majority of which comprises SSSI units as described above. |
| Amenity Value: | Angling. Open access land. |
| Other: | Reedbed and fen at Guist Common to be conserved (spring fed and water is of higher quality than that in river). |

**Table Au4** RWRS 20 Previous works or recommendations

| | | | | |
|---|---|---|---|---|
| Previous Measures (Consented): | Bintry Mill - sluice automated (1999) - associated with Environment Agency flood risk management works.<br>Upstream Guist Bridge - removal of silt/berm reduction (2003/4) - associated with Environment Agency flood risk management works.<br>Scrub control, water level control and dyke management at Guist Common (2000). | | | |
| Potential Schemes for Habitat Restoration (ECON): | Guist Common reed-bed connection and narrowing | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | |
| Reach Code | W511 | W512 | W513 | W550 |
| Reach Status | Recovered | Degraded | Damaged | Degraded |
| Management Class | Conserve & monitor | Conserve & monitor | Rehabilitate | Rehabilitate |
| Work related to weir | | | ✓ | ✓ |
| Re-establish former channel or dimensions | | ✓ | ✓ | |
| Reconnect river to floodplain | | | | ✓ |
| Narrow | | | | ✓ |
| De-silt | | | ✓ | |
| Augment gravel or bed or water levels | | | ✓ | ✓ |
| Monitor | | | | |
| Reduce maintenance | | | | |
| Improve flow & habitat diversity | | | | |
| Establish riparian vegetation | | | | ✓ |
| Create or maintain backwater | ✓ | | | |
| Fix sediment ingress points | | | ✓ | ✓ |

**Table Au5** RWRS 20 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with lowering of structure at Bintry Mill and associated river works. De-silt channel just upstream of Bintree Mill. Physical narrowing and augmentation of the bed with gravel required. Remove embankments to reconnect river to its floodplain. Develop marginal/bankside vegetation. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 5.4-6.2 m<br>Erodible banks: 8.2-9.3m | Depth: | Resistant banks: 1.03m<br>Erodible banks: 0.88m |
| Revised Management Class: | Rehabilitate | | | |
| Specific Actions Recommended: | Initial work required is for bed and bank stabilisation associated with lowering of Bintry Mill structures at downstream end of reach. Appropriate measures required to manage silt deposits upstream of the mill. Consider effect of lowering Bintry structure on water levels at the previous site of Guist mill (will the structure at Guist (sill) then hold an impoundment and what effect could this have on upstream water levels etc.) Augment bed on average by 0.8m using local gravels wherever possible and create up to 40 gravel glides or riffles in the reach. The channel is on average 14.6m 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. Adopt/maintain 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. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Au** RWRS 20 Location Plan

## REACH CODE: RWRS 21

**Table Av1** RWRS 21 Reach data summary

| | |
|---|---|
| Location: | Great Ryburgh Mill to upstream Guist Common |
| NGR: | 596400, 326980 to 598890, 325080 |
| Total Reach Length: | 3,310m |
| Geomorphological Appraisal (2006) Reaches: | W554 to W551 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for Great Ryburgh Mill, which is located at the upstream end of RWRS21. Note that this reach is affected by backwater from Bintree Mill. |

**Table Av2** RWRS 21 Current reach condition

| | | |
|---|---|---|
| Description: | Channel diverted from original course, is very straight and wide with steep banks. Old channel remains in the left bank floodplain just downstream of Great Ryburgh Mill, with a small section, less well defined, further downstream on the right bank floodplain. Downstream, in wooded area there are woody debris accumulations in the channel, causing the bed to vary between silt accumulations upstream of debris to exposed gravels downstream. Where there is little patchy shade, the channel can become very wide due to bank erosion and the poor growth of emergent vegetation. | |
| Natural England Assessment: | Part of River Unit 49 (Great Ryburgh Mill - Bintree Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 200km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 9-11m<br>1.87m |
| Length Affected by Backwater: | About half reach affected by backwater from Bintry Mill. | |
| Maintenance Regime: | Generally, up to 50% and 75% of weeds cut on free-flowing and impounded reaches, respectively, by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Av3** RWRS 21 Constraints

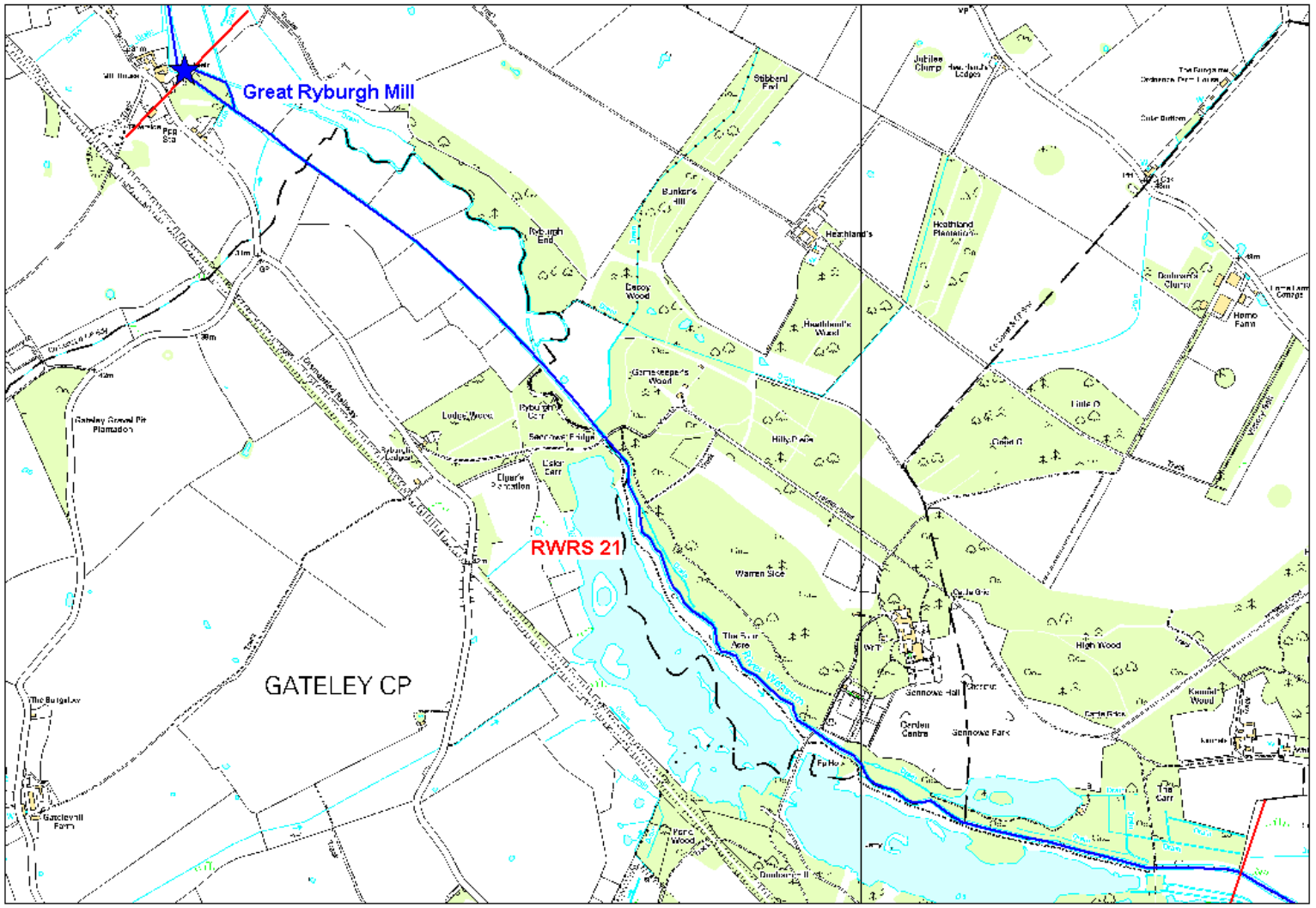
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Permanent pasture (mainly well-drained) including part of Sennowe Park, on either sides of the valley, extensive woodland and forestry plantations on N valley-side down to river. Large disused gravel pits on right (S) side of valley partly enclosed by woodland. Arable farmland on valley-side to south. |
| Amenity Value: | Angling (riparian owner) |
| Other: | None |

**Table Av4** RWRS 21 Previous works or recommendations

| | | | | |
|---|---|---|---|---|
| Previous Measures (Consented): | Downstream Great Ryburgh Mill - connection to former river channel (1995) and gravel point bar in main channel. Flow no longer passes down the former channel, which is still evident in the field. | | | |
| Potential Schemes for Habitat Restoration (ECON): | Connection of lake at Sennowe Park and introduction of sinuosity; Downstream of Ryburgh Mill riffles and narrowing - an alternative to this ECON scheme is to restore the old course of the Wensum (still largely intact within the floodplain); Great Ryburgh Mill by-pass and ditch improvement. | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | |
| Reach Code | W551 | W552 | W553 | W554 |
| Reach Status | Damaged | Degraded | Severely degraded | Recovering |
| Management Class | Enhance | Enhance | Rehabilitate | Assist |
| Work related to weir | ✓ | | | |
| Re-establish former channel or dimensions | | | ✓ | ✓ |
| Reconnect river to floodplain | | | | |
| Narrow | ✓ | | | |
| De-silt | | | | |
| Augment gravel or bed or water levels | ✓ | | | |
| Monitor | | | | |
| Reduce maintenance | | ✓ | | |
| Improve flow & habitat diversity | | | | |
| Establish riparian vegetation | | | | |
| Create or maintain backwater | | | | |
| Fix sediment ingress points | ✓ | | ✓ | |

**Table Av5** RWRS 21 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with lowering of structure at Bintry Mill, by-passing of structure at Great Ryburgh Mill and associated river works. Re-meander through old course of river that can be seen on the OS map, and in the field, and restore gravel bed. Restoration channel dimensions to be based on dimensions of channel existing in the floodplain and hydraulic geometry. Remove embankments to reconnect river to its floodplain. Continue low level of maintenance in wooded area to allow woody debris accumulations and natural creation of channel sinuosity. Ensure that tree line is not continuous - this will encourage the growth of emergent vegetation and will naturally narrow the channel, especially in lower reaches that are affected by backwater from Bintry Mill. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 5.2-5.4 m<br>Erodible banks: 7.8-8.1m | Depth: | Resistant banks: 0.99m<br>Erodible banks: 0.84m |
| Revised Management Class: | Rehabilitation and restoration (restored section expected to be approximately 1,440m upstream Sennowe Bridge). | | | |
| Specific Actions Recommended: | In the 100 to 200m downstream of Great Ryburgh Mill structure 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. Restore section of channel upstream of Sennowe Bridge (existing channel should be retained as a backwater area and majority of Wensum flow should pass through restored reach to ensure it remains functional). In remainder of reach, reduce depth by an average of 0.9m and raise bed using up to 68 gravel glides or riffles in the reach. Assume reach will narrow naturally in time. Adopt/maintain maintenance regime and riparian management to allow channel to narrow naturally. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Av** RWRS 21 Location Plan

## REACH CODE: RWRS 22

**Table Aw1** RWRS 22 Reach data summary

| | |
|---|---|
| Location: | Downstream Pensthorpe Wildfowl Park to Great Ryburgh Mill |
| NGR: | 595294, 328621 to 596400, 326980 |
| Total Reach Length: | 2,375m |
| Geomorphological Appraisal (2006) Reaches: | W556 and W555 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for Great Ryburgh Mill, which is located at the downstream end of RWRS22. |

**Table Aw2** RWRS 22 Current reach condition

| | | |
|---|---|---|
| Description: | Straight sections between sinuous sections of channel. In sinuous sections, some gravel exposures where channel is narrowed by vegetated berms. Downstream, flow deep and sluggish due to impoundment upstream of Great Ryburgh Mill. Embankments exist along both banks in much of the reach. Some drains on floodplain. | |
| Natural England Assessment: | Part of River Unit 48 (Fakenham Mill - Great Ryburgh Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 195km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 10-14m<br>1.68m |
| Length Affected by Backwater: | All reach affected by backwater from Great Ryburgh Mill. | |
| Maintenance Regime: | 75% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Aw3** RWRS 22 Constraints

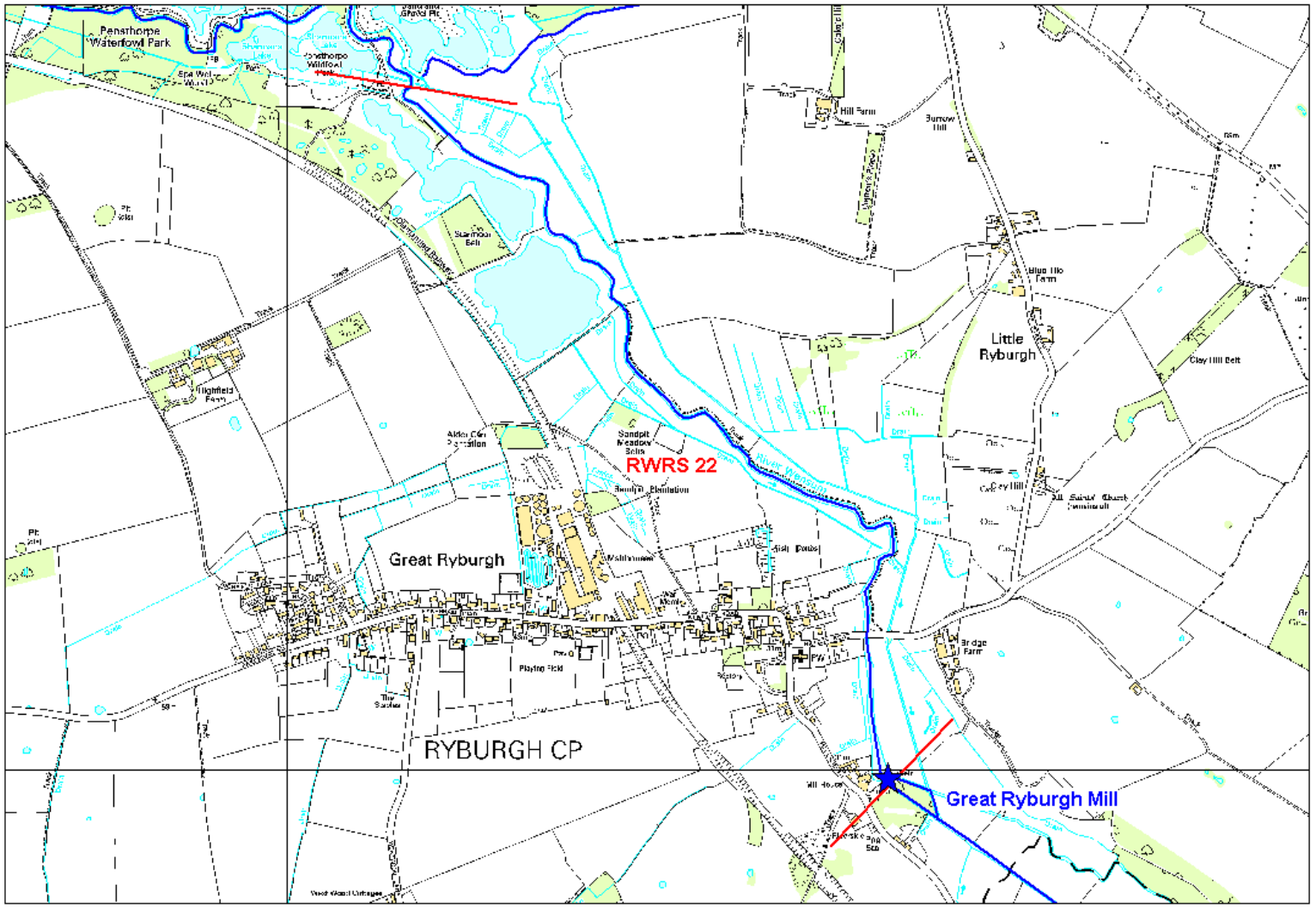
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Disused gravel pits and plantations on right (S) bank, part of Waterfowl park. Drained permanent pasture (ESA tier 1) .Some residential property at Great Ryburgh. Arable farmland on valley sides. |
| Amenity Value: | Angling (riparian owners). . |
| Other: | Archaeological interest at Great Ryburgh (ancient fish ponds). |

**Table Aw4** RWRS 22 Previous works or recommendations

| | | |
|---|---|---|
| Previous Measures (Consented): | Downstream of Pensthorpe - selected berm reduction and tree management (2002).<br>Upstream Great Ryburgh Mill - silt removal (2004/5).<br>Both associated with Environment Agency flood risk management works. | |
| Potential Schemes for Habitat Restoration (ECON): | Starmoor Belt riffles, narrowing and lake connection | |
| Geomorphological Appraisal (2006) Options for Restoration: | | |
| Reach Code | W555 | W556 |
| Reach Status | Damaged | Degraded |
| Management Class | Restoration | Rehabilitation |
| Work related to weir | | |
| Re-establish former channel or dimensions | | ✓ |
| Reconnect river to floodplain | ✓ | ✓ |
| Narrow | | ✓ |
| De-silt | | ✓ |
| Augment gravel or bed or water levels | | ✓ |
| Monitor | | ✓ |
| Reduce maintenance | | |
| Improve flow & habitat diversity | | |
| Establish riparian vegetation | | |
| Create or maintain backwater | | ✓ |
| Fix sediment ingress points | | |

**Table Aw5** RWRS 22 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with plans to by-pass the structure at Great Ryburgh Mill and associated river works. De-silt channel just upstream of the current structure (if required following de-silting in 2004/5). Physical narrowing and augmentation of the bed with gravel required. Remove embankments to reconnect river to its floodplain. Develop marginal/bankside vegetation. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 5.1-5.2m<br>Erodible banks: 7.8m | Depth: | Resistant banks: 1.86m<br>Erodible banks: 0.73m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | Initial work required is for bed and bank stabilisation associated with by-passing of Great Ryburgh Mill structures at downstream end of reach. Appropriate measures required to manage silt deposits upstream of the mill. Augment bed on average by 0.8m using local gravels wherever possible and create up to 51 gravel glides or riffles in the reach. The channel is on average 5.2m 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. Adopt/maintain 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. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Aw** RWRS 22 Location Plan

## REACH CODE: RWRS 23

**Table Ax1** RWRS 23 Reach data summary

| | |
|---|---|
| Location: | Downstream Great Ryburgh Common to Pensthorpe Wildfowl Park |
| NGR: | 593890, 329140 to 595294, 328621 |
| Total Reach Length: | 1,980m |
| Geomorphological Appraisal (2006) Reaches: | W558 (part) and W557 |
| Associated Mill Summary Information: | No mill at up or downstream end of RWRS23 |

**Table Ax2** RWRS 23 Current reach condition

| | | |
|---|---|---|
| Description: | Initially straight in Starmoor Plantation but latter part of reach is highly sinuous, not significantly overly wide and has riffles. Littoral margins not well developed due to maintenance and dredging and spoil banks. | |
| Natural England Assessment: | Part of River Unit 48 (Fakenham Mill - Great Ryburgh Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river.<br><br>River Unit adjacent to Terrestrial Units 15 & 16 support a 3.6 ha mosaic of mesotrophic grassland, rush pasture and scrub (including M22) upstream of Pensthorpe Waterfowl Park. | |
| Upstream Catchment Area: | 175km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 10-12m<br>1.35m |
| Length Affected by Backwater: | About 600m reach affected by backwater from Great Ryburgh Mill. | |
| Maintenance Regime: | Generally, up to 50% and 75% of weeds cut on free-flowing and impounded reaches, respectively, by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Ax3** RWRS 23 Constraints

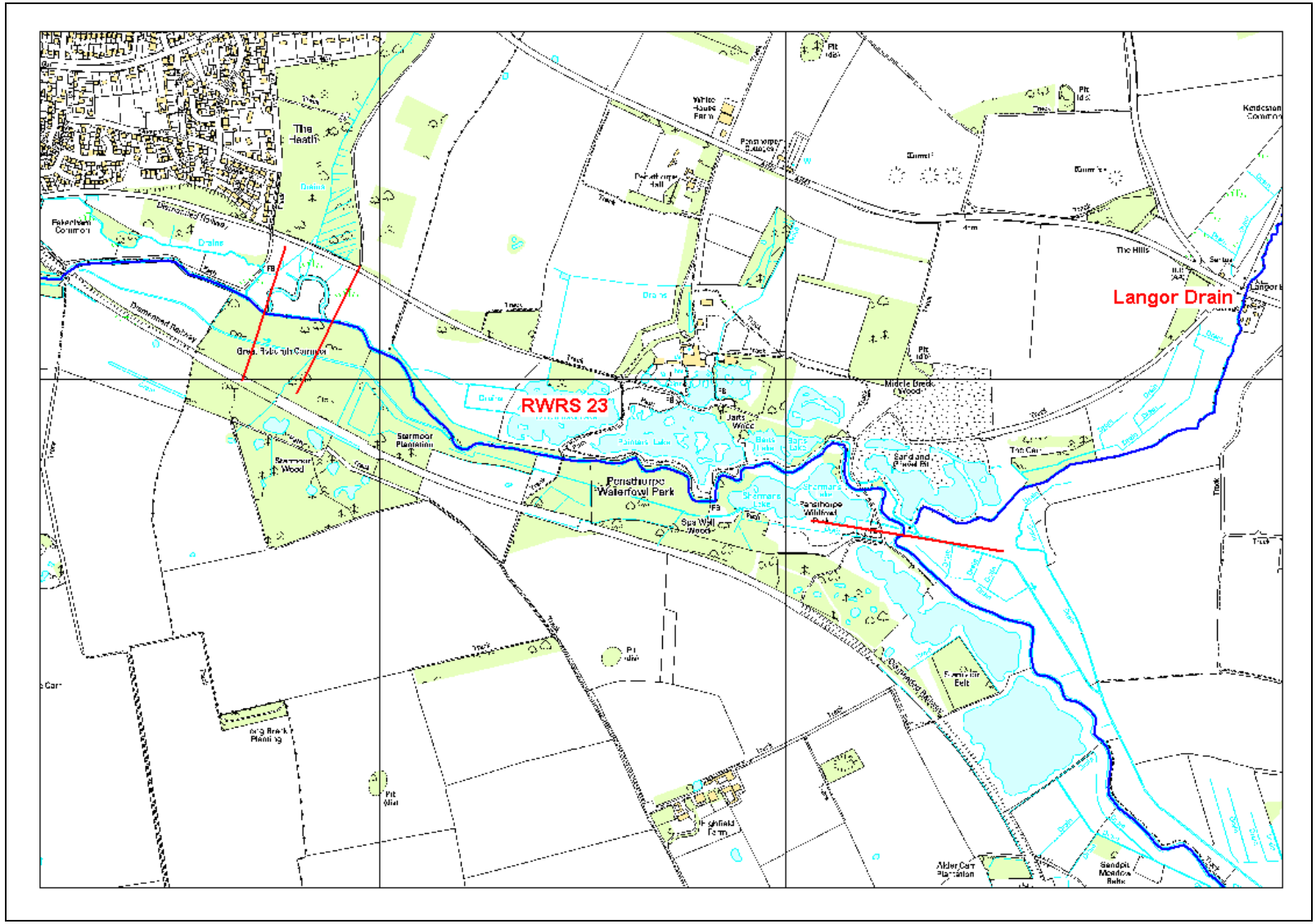
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Grazing marsh and pasture (ESA tiers 1, 2 & 3), woodland and former gravel pits (some of which form part of waterfowl park and nature reserve). |
| Amenity Value: | Angling (riparian owners). Waterfowl Park |
| Other: | None |

**Table Ax4** RWRS 23 Previous works or recommendations

| | | |
|---|---|---|
| Previous Measures (Consented): | Upstream of Pensthorpe - selected berm reduction and tree management (2002) - associated with Environment Agency flood risk management works. | |
| Potential Schemes for Habitat Restoration (ECON): | None | |
| Geomorphological Appraisal (2006) Options for Restoration: | | |
| Reach Code | W557 | W558 |
| Reach Status | Recovering | Degraded |
| Management Class | Assist | Rehabilitate |
| Work related to weir | ✓ | |
| Re-establish former channel or dimensions | | ✓ |
| Reconnect river to floodplain | | |
| Narrow | ✓ | ✓ |
| De-silt | | |
| Augment gravel or bed or water levels | ✓ | ✓ |
| Monitor | | |
| Reduce maintenance | | |
| Improve flow & habitat diversity | | |
| Establish riparian vegetation | | |
| Create or maintain backwater | | |
| Fix sediment ingress points | | ✓ |

**Table Ax5** RWRS 23 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with plans to by-pass the structure at Great Ryburgh Mill and associated river works. Upstream reach - use coarse woody debris structures to exacerbate sinuosity in wooded areas where channel is straight. Encourage narrowing through improvements to the marginal/bankside vegetation. Augment bed with gravel. Remove embankments to connect river to its floodplain. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 4.8-4.9m<br>Erodible banks: 7.2-7.4m | Depth: | Resistant banks: 0.83m<br>Erodible banks: 0.71m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | Reduce depth by an average of 0.5m and raise bed using up to 45 gravel glides or riffles in the reach. Assume reach will narrow naturally in time. Adopt/maintain maintenance regime and riparian management to allow channel to narrow naturally. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Ax** RWRS 23 Location Plan

## REACH CODE: RWRS 24

**Table Ay1** RWRS 24 Reach data summary

| | |
|---|---|
| Location: | Great Ryburgh Common |
| NGR: | 593720, 329140 to 593890, 329170 |
| Total Reach Length: | 175m |
| Geomorphological Appraisal (2006) Reaches: | W558 (part) |
| Associated Mill Summary Information: | No mill at up or downstream end of RWRS24 |

**Table Ay2** RWRS 24 Current reach condition

| | | |
|---|---|---|
| Description: | Straight, embanked section of channel downstream of Fakenham. Old channel available on left bank for reinstatement. | |
| Natural England Assessment: | Part of River Unit 48 (Fakenham Mill - Great Ryburgh Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river.<br>River Unit adjacent to Terrestrial Units -15 support a 7.4ha mosaic of Fen and woodland (including W2, W5, W10 and S25) on the right bank of the river. | |
| Upstream Catchment Area: | 170km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 12m<br>1.33m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | 50% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Ay3** RWRS 24 Constraints

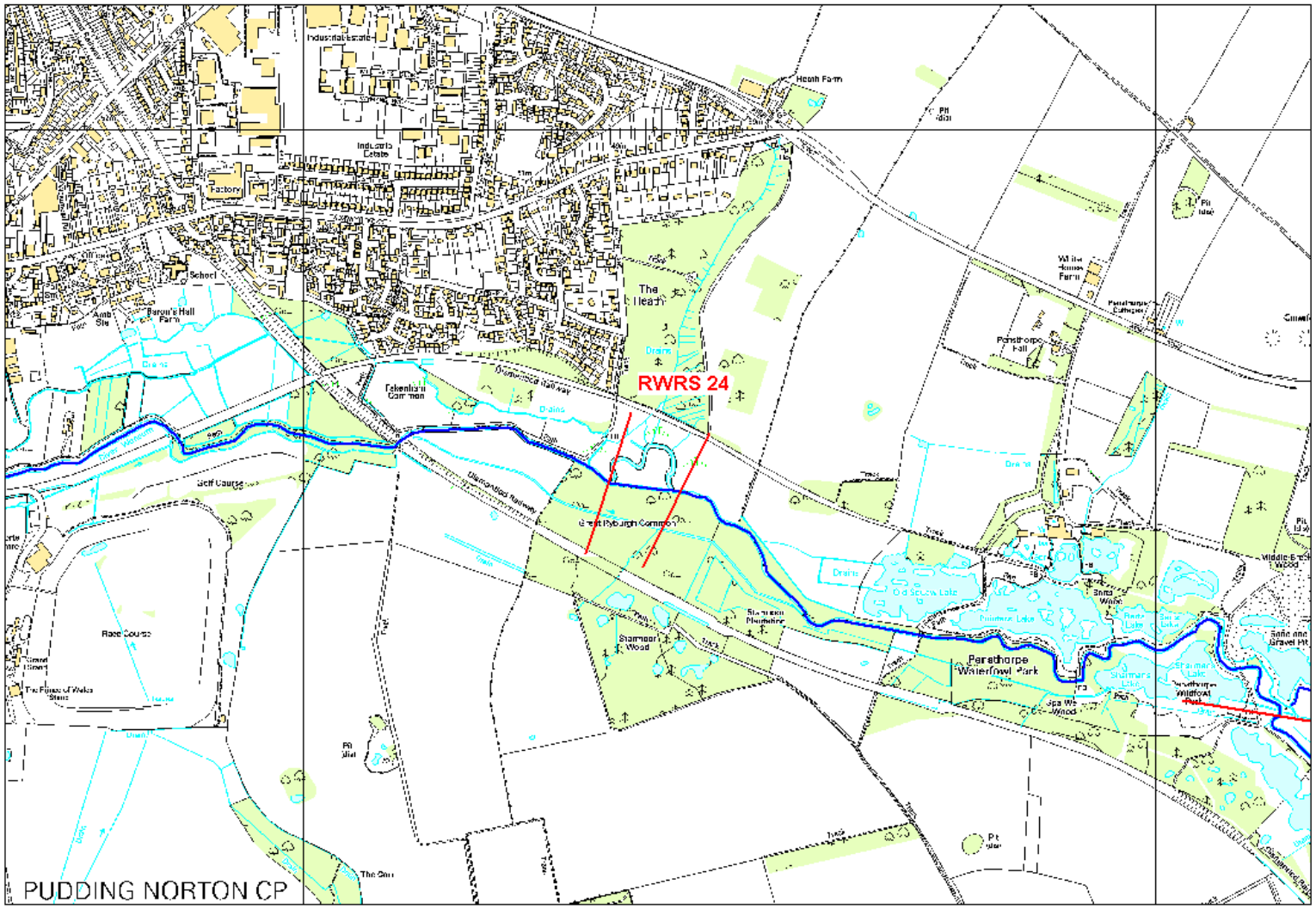
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Permanent pasture (ESA tier 1) on left (N) bank; fen and woodland on Great Ryburgh Common SSSI as described above on right (S) bank. Woodland and plantation on adjacent valley sides. |
| Amenity Value: | Angling |
| Other: | None |

**Table Ay4** RWRS 24 Previous works or recommendations

| | |
|---|---|
| Previous Measures (Consented): | None |
| Potential Schemes for Habitat Restoration (ECON): | None |
| Geomorphological Appraisal (2006) Options for Restoration: | |
| Reach Code | W558 |
| Reach Status | Degraded |
| Management Class | Rehabilitate |
| Work related to weir | |
| Re-establish former channel or dimensions | ✓ |
| Reconnect river to floodplain | |
| Narrow | ✓ |
| De-silt | |
| Augment gravel or bed or water levels | ✓ |
| Monitor | |
| Reduce maintenance | |
| Improve flow & habitat diversity | |
| Establish riparian vegetation | |
| Create or maintain backwater | |
| Fix sediment ingress points | ✓ |

**Table Ay5** RWRS 24 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Possibility to restore channel by redirecting flow through previous section of channel and reinstating channel dimensions and structure. Location of previous channel is not obvious in the field, but is visible on an OS map. Use hydraulic geometry to define channel conditions in absence of reference site at this location in the catchment. Infill existing channel or retain as a backwater. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 4.8m<br>Erodible banks: 7.2m | Depth: | Resistant banks: 0.80m<br>Erodible banks: 0.68m |
| Revised Management Class: | Restoration (restored section expected to be approximately 325m - along old course of channel). | | | |
| Specific Actions Recommended: | Restore section of channel. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Ay** RWRS 24 Location Plan

## REACH CODE: RWRS 25

**Table Az1** RWRS 25 Reach data summary

| | |
|---|---|
| Location: | Fakenham Mill to Great Ryburgh Common |
| NGR: | 591940, 329330 to 593720, 329140 |
| Total Reach Length: | 1,955m |
| Geomorphological Appraisal (2006) Reaches: | W563 to W559 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for Fakenham Mill, which is located at the upstream end of RWRS25. |

**Table Az2** RWRS 25 Current reach condition

| | | |
|---|---|---|
| Description: | Engineered channel that is mainly straight and embanked with a drain network on the floodplain upstream. Sections of channel have narrowed naturally downstream of Fakenham Mill, causing flow to be fast and gravels to be exposed locally. Wooded area lacks emergent vegetation growth and is wide with extensive siltation as a result. Downstream of woods, channel narrows again where emergent vegetation grows. | |
| Natural England Assessment: | Part of River Unit 48 (Fakenham Mill - Great Ryburgh Mill) - *Ranunculus* vegetation variant CB1; Eutrophic lowland river community covering JNCC River Types 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 160km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 9-30m<br>1.16m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | 50% of weeds cut by the Environment Agency (although up to 100% of vegetation cut in wetted channel immediately downstream of Fakenham Mill to the footbridge and just upstream of gauging station). Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table Az3** RWRS 25 Constraints

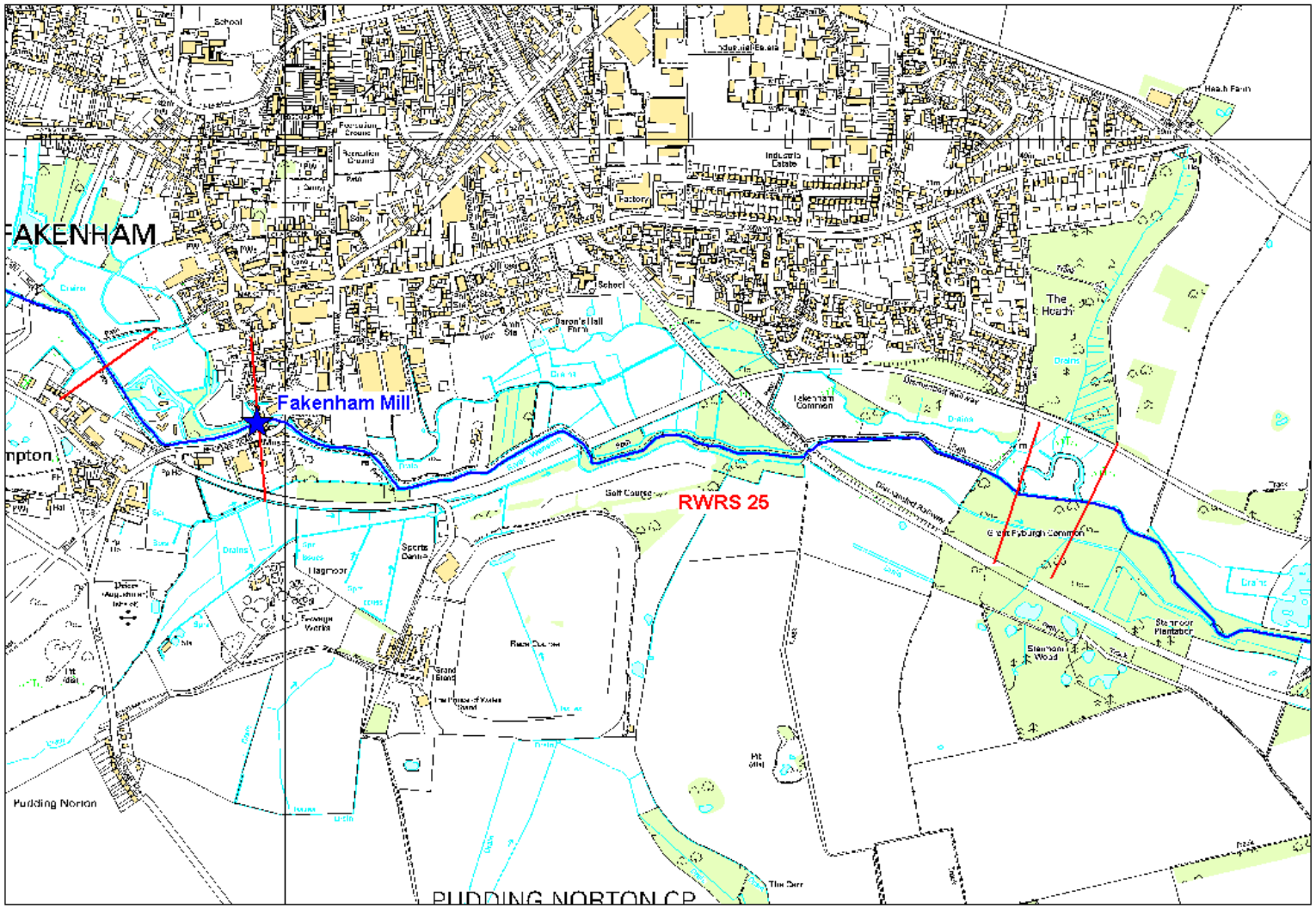
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Drained permanent grassland (ESA tier 1) at Flagmoor, Fakenham and Great Ryburgh Commons, with ESA tier 2 at Baron's Hall Farm. Race course and golf course S of river. Some woodland. Residential and industrial areas of Fakenham. |
| Amenity Value: | Angling (free fishing). Canoeing at Fakenham Mill |
| Other: | Consider Environment Agency gauging station at Fakenham Mill. |

**Table Az4** RWRS 25 Previous works or recommendations

| | | | | | |
|---|---|---|---|---|---|
| Previous Measures (Consented): | Downstream Fakenham Mill - berm reduction (1996).<br>Fakenham Mill sluice automated (2005).<br>Both associated with Environment Agency flood risk management works. | | | | |
| Potential Schemes for Habitat Restoration (ECON): | None | | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | | |
| Reach Code | W559 | W560 | W561 | W562 | W563 |
| Reach Status | Damaged | Damaged | Damaged | Damaged | Degraded |
| Management Class | Assist | Assist | Assist | Assist | Rehabilitate |
| Work related to weir | | | | | |
| Re-establish former channel or dimensions | | | | | |
| Reconnect river to floodplain | | | | | |
| Narrow | ✓ | ✓ | ✓ | ✓ | |
| De-silt | | | | | |
| Augment gravel or bed or water levels | | ✓ | | ✓ | |
| Monitor | | | | | |
| Reduce maintenance | ✓ | ✓ | ✓ | | |
| Improve flow & habitat diversity | ✓ | | ✓ | ✓ | |
| Establish riparian vegetation | | | | | ✓ |
| Create or maintain backwater | | | | | |
| Fix sediment ingress points | | | | ✓ | |

**Table Az5** RWRS 25 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with lowering of structure at Fakenham Mill and associated river works. Enhance margins to encourage continued narrowing and reduction in silt content of main channel. Physically narrow the channel, augment bed with gravel and develop marginal/bankside vegetation. Use coarse woody debris structures to exacerbate sinuosity in wooded areas where channel is straight. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 4.5-4.7m<br>Erodible banks: 6.8-7.1m | Depth: | Resistant banks: 0.80m<br>Erodible banks: 0.68m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | In the 100 to 200m downstream of Fakenham 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. Augment bed on average by 0.4m using local gravels wherever possible and create up to 47 gravel glides or riffles in the reach. The channel is on average 5.2m 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. Adopt/maintain maintenance regime and riparian management to allow channel to create natural variations in local channel width and habitat niches. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure Az** RWRS 25 Location Plan

## REACH CODE: RWRS 26

**Table AAa1** RWRS 26 Reach data summary

| | |
|---|---|
| Location: | Hempton to Fakenham Mill |
| NGR: | 591580, 329470 to 591940, 329330 |
| Total Reach Length: | 464m |
| Geomorphological Appraisal (2006) Reaches: | W564 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for Fakenham Mill, which is located at the downstream end of RWRS26. |

**Table AAa2** RWRS 26 Current reach condition

| | | |
|---|---|---|
| Description: | Engineered channel that is impounded and wide with extensive siltation upstream of Fakenham Mill. Urban development of the floodplain. Fluvial Audit shows no embankments. | |
| Natural England Assessment: | Part of River Unit 47 (Confluence of Wensum & Tat - Fakenham Mill) - Transition Reach *Ranunculus* vegetation variant CB2 to CB1; Chalk/base rich lowland river community to Eutrophic lowland river community covering JNCC River Types IIIa/b to 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 160km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 21m<br>2.15m |
| Length Affected by Backwater: | All reach affected by backwater from Fakenham Mill. | |
| Maintenance Regime: | Up to 100% of vegetation cut by the Environment Agency in wetted channel due to high flood risk to people and property. Bankside vegetation cut on urban fringes (by local authority). | |

**Table AAa3** RWRS 26 Constraints

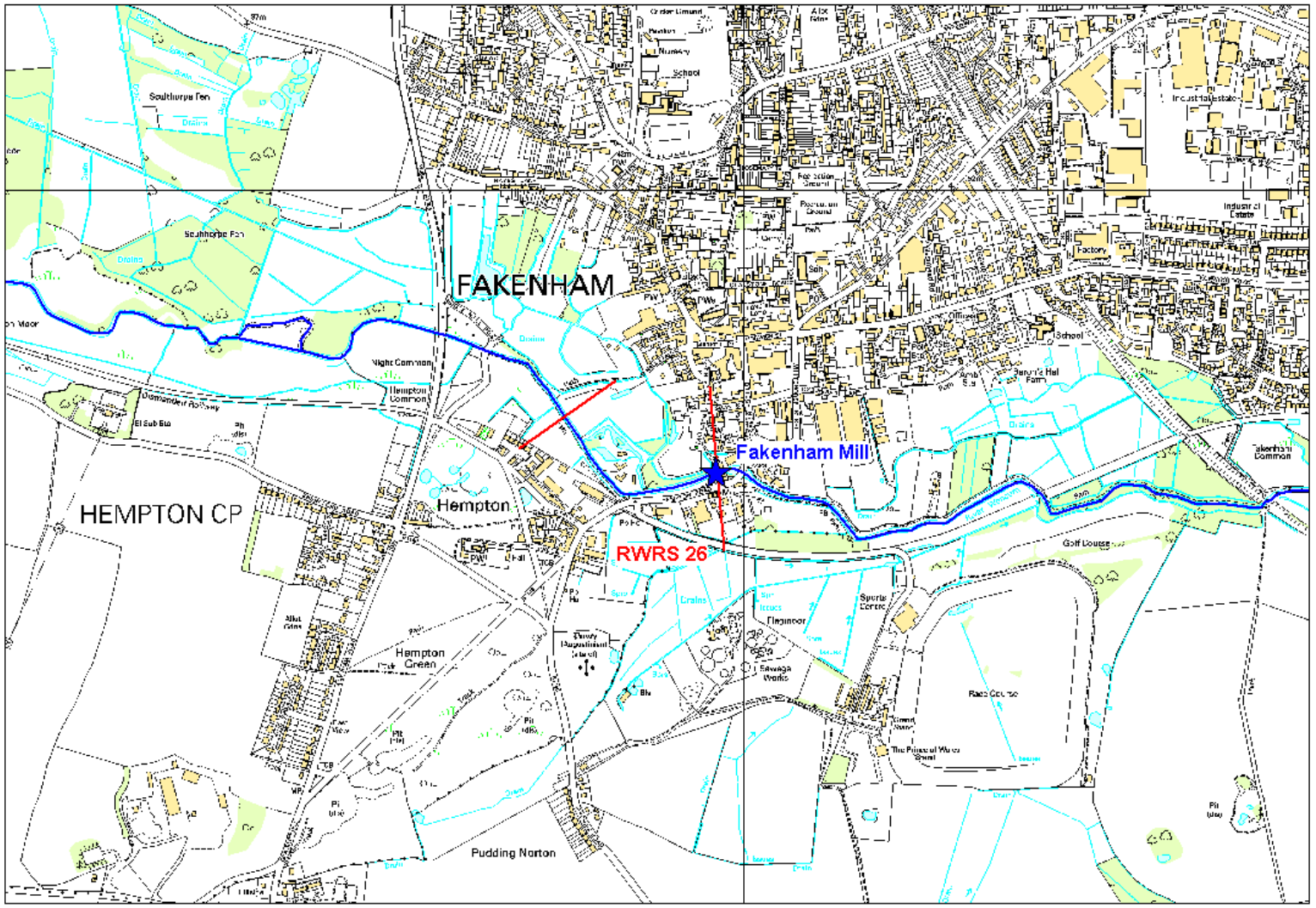
| | |
|---|---|
| Flood Risk: | High (8 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Some small areas of permanent grassland (some ESA tiers 1 & 2) and woodland in urban fringe to the N of the river, but mainly residential, business or light industrial use. |
| Amenity Value: | Angling (free fishing), Canoeing at Fakenham Mill. Riverside footpath. Night Common has been mapped as CRoW access land. |
| Other: | Consider Environment Agency gauging station at Fakenham Mill.<br>Potential flood risk management capital scheme. |

**Table AAa4** RWRS 26 Previous works or recommendations

| | |
|---|---|
| Previous Measures (Consented): | Fakenham Mill sluice automated (2005) - associated with Environment Agency flood risk management works.<br>Upstream Fakenham Mill - river restoration, channel narrowing, silt removal (2000). |
| Potential Schemes for Habitat Restoration (ECON): | Fakenham Mill margin enhancement and narrowing |
| Geomorphological Appraisal (2006) Options for Restoration: | |
| Reach Code | W564 |
| Reach Status | Recovering |
| Management Class | Assist |
| Work related to weir | ✓ |
| Re-establish former channel or dimensions | |
| Reconnect river to floodplain | |
| Narrow | ✓ |
| De-silt | |
| Augment gravel or bed or water levels | |
| Monitor | |
| Reduce maintenance | |
| Improve flow & habitat diversity | ✓ |
| Establish riparian vegetation | |
| Create or maintain backwater | |
| Fix sediment ingress points | |

**Table AAa5** RWRS 26 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with lowering of structure at Fakenham Mill and associated river works. Must also integrate with proposed flood risk management capital project and link with existing enhancements. De-silt channel just upstream of Fakenham Mill, physically narrow and augment bed with gravels. Encourage development of marginal/bankside vegetation. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 4.5m<br>Erodible banks: 6.8m | Depth: | Resistant banks: 0.77m<br>Erodible banks: 0.66m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | Co-ordinate with flood risk management capital scheme - proposed works include raising of bank (for example, raised footpath) along Hempton Road on right bank immediately upstream of mill and individual protection of isolated properties on the left bank. There is clearly potential to co-ordinate this work with proposed lowering of mill controls. Discussions underway between Environment Agency and Natural England/JBA. Initial work required is for bed and bank stabilisation associated with lowering of Fakenham Mill structures at downstream end of reach. Appropriate measures required to manage silt deposits upstream of the mill. Augment bed on average by 1.4m using local gravels wherever possible and create up to 11 gravel glides or riffles in the reach. The channel is on average 14.2m 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. Adopt/maintain 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. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAa** RWRS 26 Location Plan

## REACH CODE: RWRS 27

**Table AAb1** RWRS 27 Reach data summary

| | |
|---|---|
| Location: | Sculthorpe Moor to Hempton |
| NGR: | 590090, 329760 to 591580, 329470 |
| Total Reach Length: | 1,720m |
| Geomorphological Appraisal (2006) Reaches: | W568 to W565 |
| Associated Mill Summary Information: | No mill at up or downstream end of RWRS27.<br>However, reach is affected by backwater from Fakenham Mill. |

**Table AAb2** RWRS 27 Current reach condition

| | | |
|---|---|---|
| Description: | Influenced by impoundment upstream of Fakenham Mill. Channel is slow flowing, wide and has extensive siltation, with some vegetated berms. Some exposed gravels associated with road bridges. Channel is contained within embankments beside Hempton Moor. Downstream, former pond of Gogg's Mill has narrowed naturally. | |
| Natural England Assessment: | Part of River Unit 47 (Confluence of Wensum & Tat - Fakenham Mill) - Transition Reach - *Ranunculus* vegetation variant CB2 to CB1; Chalk/base rich lowland river community to Eutrophic lowland river community covering JNCC River Types IIIa/b to 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river.<br>River Unit adjacent to Terrestrial Units 9 - 11 supports 5.1ha of mesotrophic grassland and fen (including MG8 and M27) towards the end of RWRS27 on the left bank of the river.<br>Terrestrial Unit 8 supports a 13.2ha mosaic of fen and scrub woodland (including extensive stands of S25c, W2 & W6) upstream end of RWRS27. | |
| Upstream Catchment Area: | 150km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 12-22m<br>1.76m |
| Length Affected by Backwater: | All reach affected by backwater from Fakenham Mill. | |
| Maintenance Regime: | 75% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table AAb3** RWRS 27 Constraints

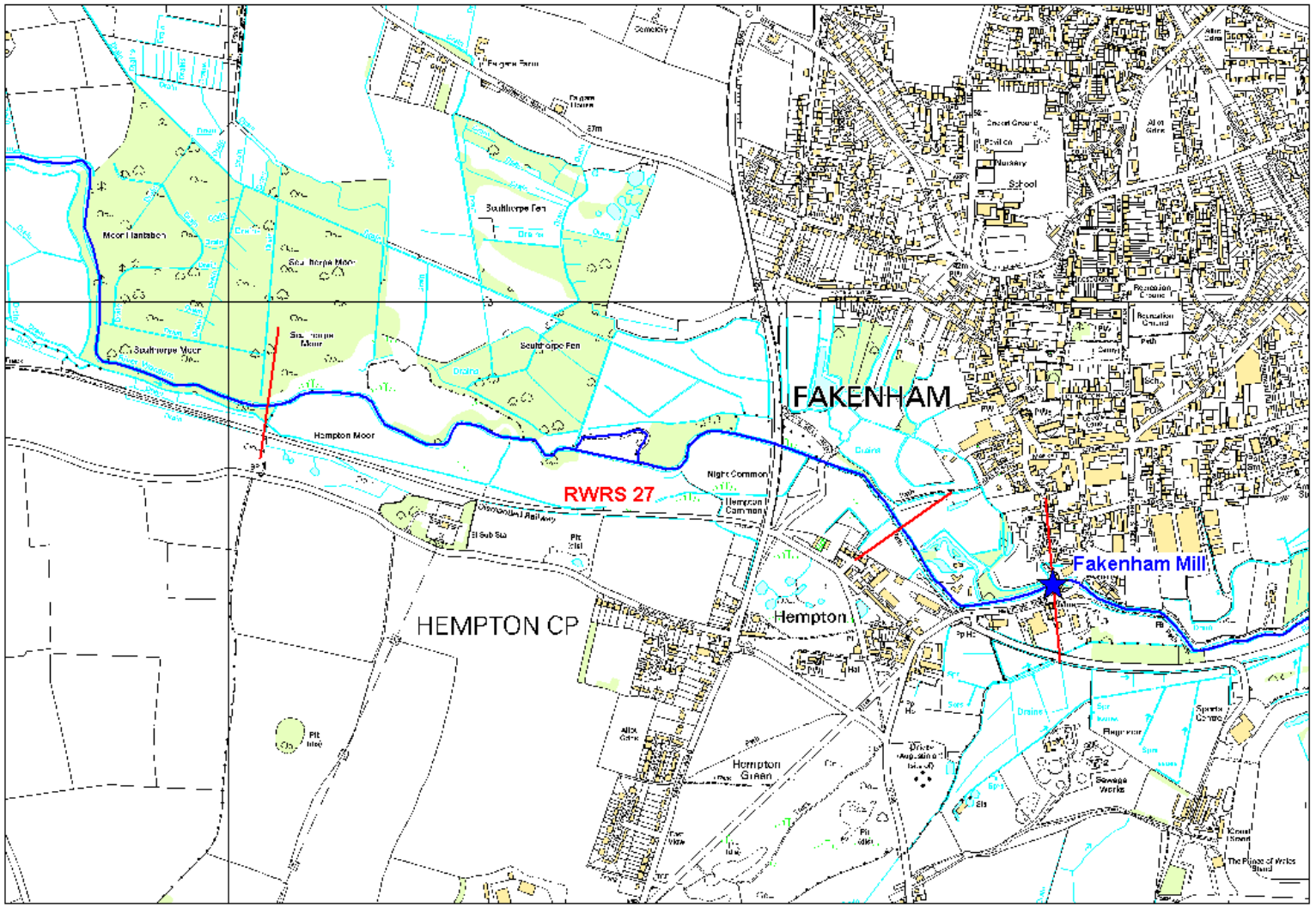
| | |
|---|---|
| Flood Risk: | Moderate (1 property in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Wet pasture (ESA tiers 2 & 3), fen, woodland and reedbed on left (N) side, associated with the Hawk & Owl Trust and NOA reserves, and part SSSI as described above. Mainly ungrazed grassland on right (S) side, some of which is ESA tier 1. Disused railway line separates arable farmland on valley-side to south. |
| Amenity Value: | Angling (Fakenham Angling Club, free fishing). Hawk and Owl Trust Reserve at Sculthorpe Moor. Norfolk Ornithologist's Association reserve at Hempton. Public access to river/riverside footpath at Gogg's Mill. Night Common and Hempton Moor have been mapped as CRoW access land. |
| Other: | Wetlands and fen have high conservation value.<br>Environment Agency weed pull-out at Hempton. |

**Table AAb4** RWRS 27 Previous works or recommendations

| | | | | |
|---|---|---|---|---|
| Previous Measures (Consented): | Upstream Fakenham Mill - weeds transplanted by fishing club (1997).<br>Night Common - willow hurdles installed by fishing club (1998).<br>Hempton - meander reinstated as mitigation for flood defence works upstream (2003) - previous channel was also retained - ecological enhancement (in mitigation for flood risk management works).<br>Hempton - riffles instated as mitigation for flood defence works upstream (2004) - ecological enhancement (in mitigation for flood risk management works).<br>South Mill to Fakenham Mill - berm reduction, silt removal and tree removal (2002) - associated with Environment Agency flood risk management works. | | | |
| Potential Schemes for Habitat Restoration (ECON): | Hempton Moor floodplain reconnection & narrowing | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | |
| Reach Code | W565 | W566 | W567 | W568 |
| Reach Status | Degraded | Degraded | Degraded | Severely degraded |
| Management Class | Rehabilitation | Rehabilitation | Rehabilitation | Enhance |
| Work related to weir | ✓ | ✓ | ✓ | ✓ |
| Re-establish former channel or dimensions | | | | |
| Reconnect river to floodplain | | | | |
| Narrow | ✓ | ✓ | ✓ | ✓ |
| De-silt | ✓ | | | ✓ |
| Augment gravel or bed or water levels | | ✓ | ✓ | ✓ |
| Monitor | | | | |
| Reduce maintenance | | | | |
| Improve flow & habitat diversity | ✓ | ✓ | ✓ | ✓ |
| Establish riparian vegetation | | | | |
| Create or maintain backwater | | | | |
| Fix sediment ingress points | ✓ | | ✓ | ✓ |

**Table AAb5** RWRS 27 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with lowering of structure at Fakenham Mill and associated river works and must link with the existing enhancement schemes. Physically narrow and augment bed with gravels and develop marginal/bankside vegetation. Remove embankments to reconnect river to its floodplain. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 4.3-4.4m<br>Erodible banks: 6.5-6.7m | Depth: | Resistant banks: 0.76m<br>Erodible banks: 0.66m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | Augment bed on average by 1.0m using local gravels wherever possible and create up to 43 gravel glides or riffles in the reach. The channel is on average 8.8m 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. Adopt/maintain maintenance regime and riparian management to allow channel to create natural variations in local channel width and habitat niches. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAb** RWRS 27 Location Plan

## REACH CODE: RWRS 28

**Table AAc1** RWRS 28 Reach data summary

| | |
|---|---|
| Location: | Sculthorpe Mill to Sculthorpe Moor |
| NGR: | 589310, 330320 to 590090, 329760 |
| Total Reach Length: | 1,245m |
| Geomorphological Appraisal (2006) Reaches: | W570 and W569 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for Sculthorpe Mill, which is located at the upstream end of RWRS28. |

**Table AAc2** RWRS 28 Current reach condition

| | | |
|---|---|---|
| Description: | Downstream of Sculthorpe Mill are gravel shallows for about 200m. Channel is relatively straight for lengthy sections between meander bends. Upstream Sculthorpe Moor, channel is embanked on both sides and there is an extensive drain system on the floodplain. | |
| Natural England Assessment: | Part of River Unit 47 (Confluence of Tat and Wensum - Fakenham Mill) - Transition Reach - *Ranunculus* vegetation variant CB2 to CB1; Chalk/base rich lowland river community to Eutrophic lowland river community covering JNCC River Types IIIa/b to 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 145km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 8-11m<br>1.32m |
| Length Affected by Backwater: | Virtually none of reach is affected by backwater from Fakenham Mill. | |
| Maintenance Regime: | 50% of weeds cut by the Environment Agency. Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk. | |

**Table AAc3** RWRS 28 Constraints

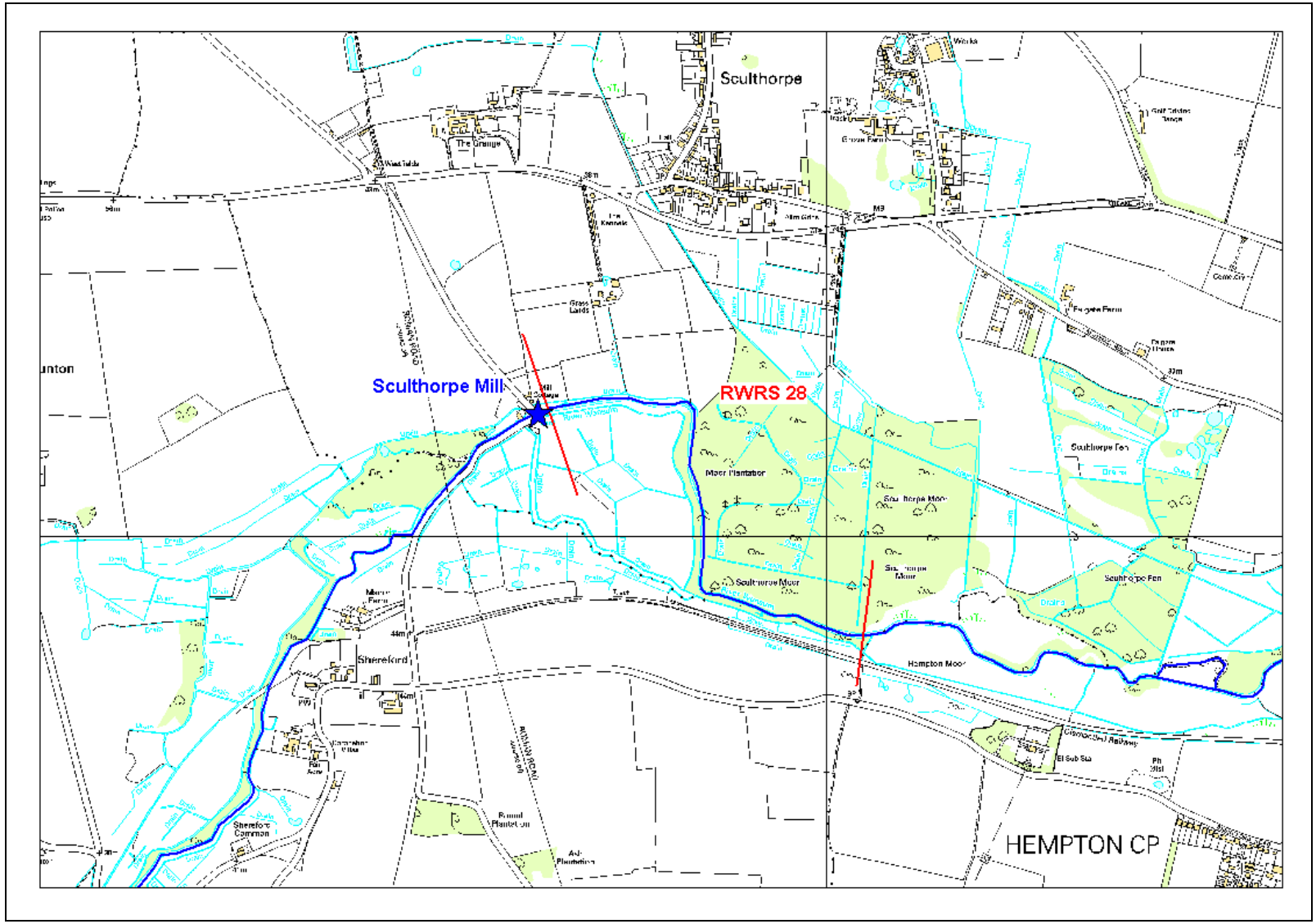
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Plantations, reedbed, grazing marsh (ESA tier 1), fen and woodland on left (N) side associated with the Hawk & Owl Trust reserve. Extensive wet pasture (ESA tiers 2 & 3 and part SSSI) at Sculthorpe Mill Meadows on S side. Arable farmland predominates on valley sides. |
| Amenity Value: | Angling (Fakenham Angling Club); Hawk & Owl Trust reserve at Sculthorpe Moor. |
| Other: | None |

**Table AAc4** RWRS 28 Previous works or recommendations

| | | |
|---|---|---|
| Previous Measures (Consented): | South Mill to Fakenham Mill - berm reduction, silt removal and tree removal (2002) - associated with Environment Agency flood risk management works. | |
| Potential Schemes for Habitat Restoration (ECON): | None | |
| Geomorphological Appraisal (2006) Options for Restoration: | | |
| Reach Code | W569 | W570 |
| Reach Status | Severely degraded | Recovering |
| Management Class | Rehabilitate | Assist |
| Work related to weir | ✓ | |
| Re-establish former channel or dimensions | | |
| Reconnect river to floodplain | | |
| Narrow | ✓ | |
| De-silt | ✓ | |
| Augment gravel or bed or water levels | ✓ | |
| Monitor | | |
| Reduce maintenance | | |
| Improve flow & habitat diversity | ✓ | ✓ |
| Establish riparian vegetation | | |
| Create or maintain backwater | | |
| Fix sediment ingress points | ✓ | |

**Table AAc5** RWRS 28 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Use coarse woody debris structures to exacerbate sinuosity in wooded areas where channel is straight. Remove embankments to reconnect river to its floodplain and augment bed with gravel. Develop marginal/bankside vegetation to encourage channel to narrow naturally. Potential to use wood from poplar plantations. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 4.2m<br>Erodible banks: 6.3-6.4m | Depth: | Resistant banks: 0.75m<br>Erodible banks: 0.64m |
| Revised Management Class: | Rehabilitation | | | |
| Specific Actions Recommended: | In the 100 to 200m downstream of Sculthorpe 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. Reduce depth by an average of 0.6m and raise bed using up to 33 gravel glides or riffles in the reach. Assume reach will narrow naturally in time. Adopt/maintain maintenance regime and riparian management to allow channel to narrow naturally. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAc** RWRS 28 Location Plan

## REACH CODE: RWRS 29

**Table AAd1** RWRS 29 Reach data summary

| | |
|---|---|
| Location: | Downstream South Mill Farm to Sculthorpe Mill |
| NGR: | 588120, 328290 to 589310, 330320 |
| Total Reach Length: | 2,630m |
| Geomorphological Appraisal (2006) Reaches: | W1004 to W1000 and W571 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheets for Sculthorpe Mill and South Mill, which are located at the downstream and upstream ends of RWRS29. |

**Table AAd2** RWRS 29 Current reach condition

| | | |
|---|---|---|
| Description: | Change in channel width and depth downstream of River Tat confluence. Channel larger in size and has been straightened over lengthy sections. Often silt deposits on the bed (upstream of this reach). Some areas fenced and with riparian trees. Extensive tree cover, especially on left bank. Upstream Sculthorpe Mill, channel has narrowed naturally due to high silt deposition and growth of emergent vegetation but flow is sluggish. Localised embankments and extensive drain network on the floodplain. | |
| Natural England Assessment: | Part of River Unit 47 (Confluence of Wensum and Tat - Fakenham Mill) - Transition Reach - *Ranunculus* vegetation variant CB2 to CB1; Chalk/base rich lowland river community to Eutrophic lowland river community covering JNCC River Types IIIa/b to 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river.<br>River Unit adjacent to Terrestrial Unit 7 supports a 2.6 mosaic of mesotrophic grassland and fen, including MG8 & S26) on right bank at upstream end of RWRS29.<br>Terrestrial Units 5 & 6 supports an 8.1 ha mosaic of fen and scrub woodland (including S25, S26, W2 & W6) on left bank of river upstream of Unit 7. | |
| Upstream Catchment Area: | 135km2 | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 6.8-36m<br>1.20m |
| Length Affected by Backwater: | Just over half reach affected by backwater from Sculthorpe Mill. | |
| Maintenance Regime: | Generally, up to 50% and 75% of weeds cut on free-flowing and impounded reaches, respectively, by the Environment Agency up to Dunton Bridge (TF 882 290). Tree management where required to allow passage of weedboat or to remove obstacles causing unacceptable flood risk.<br>Upstream of Dunton Bridge, Environment Agency operates a cut and clear type regime (annual walk through to trim trees and remove obstacles causing unacceptable risk). | |

**Table AAd3** RWRS 29 Constraints

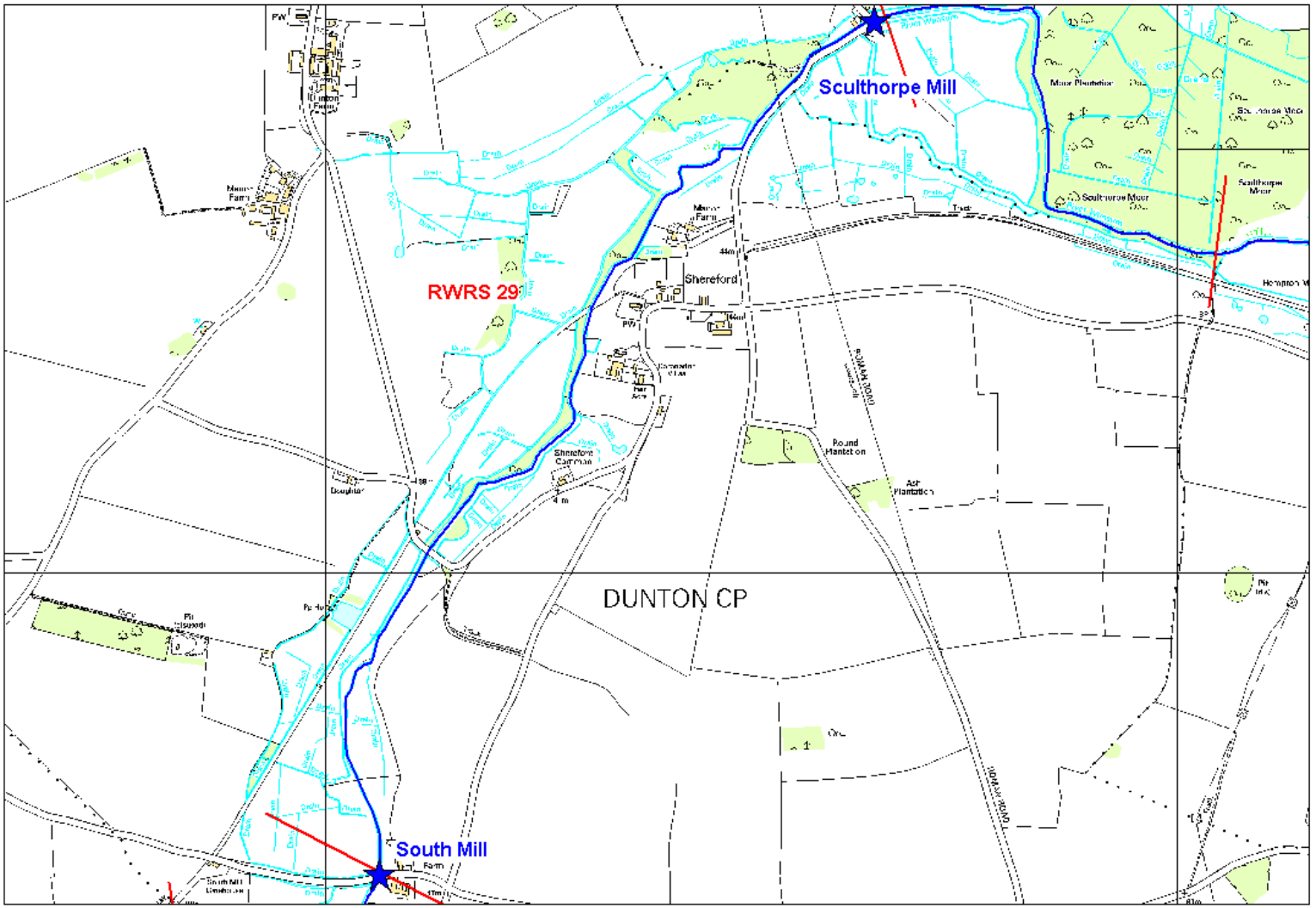
| | |
|---|---|
| Flood Risk: | Moderate (3 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Mainly damp/wet permanent pasture (ESA tiers 1, 2 & 3), apart from SSSI fen and woodland as described above. Scattered residential properties. Arable farmland predominates on valley sides. |
| Amenity Value: | Angling (leased trout fishery). Shereford Common has been mapped as CRoW access land. |
| Other: | None |

**Table AAd4** RWRS 29 Previous works or recommendations

| | | | | | | |
|---|---|---|---|---|---|---|
| Previous Measures (Consented): | South Mill to Fakenham Mill - berm reduction, silt removal and tree removal (2002).<br>South Mill to Sculthorpe Mill - tree trimming and vegetation control (2000).<br>Both associated with Environment Agency flood risk management works. | | | | | |
| Potential Schemes for Habitat Restoration (ECON): | None | | | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | | | |
| Reach Code | W571 | W1000 | W1001 | W1002 | W1003 | W1004 |
| Reach Status | Degraded | Damaged | Damaged | Recovering | Damaged | Recovering |
| Management Class | Rehabilitate | Assist | Restore | Assist | Restore | Assist |
| Work related to weir | ✓ | ✓ | ✓ | ✓ | | |
| Re-establish former channel or dimensions | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Reconnect river to floodplain | | | | | | |
| Narrow | | | | | | |
| De-silt | ✓ | ✓ | ✓ | | | |
| Augment gravel or bed or water levels | | ✓ | | | ✓ | |
| Monitor | | | | | | |
| Reduce maintenance | | | | | | |
| Improve flow & habitat diversity | | | | | | |
| Establish riparian vegetation | | | | | ✓ | |
| Create or maintain backwater | | | | | | |
| Fix sediment ingress points | | ✓ | ✓ | | ✓ | ✓ |

**Table AAd5** RWRS 29 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with lowering of structure at Sculthorpe Mill and associated river works. De-silt channel just upstream of Sculthorpe Mill, physically narrow and augment bed with gravels. Remove scrub to open up the channel and encourage development of marginal/bankside vegetation. Use coarse woody debris structures to exacerbate sinuosity in wooded areas where channel is straight. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 4.1-4.2m<br>Erodible banks: 6.1-6.3m | Depth: | Resistant banks: 0.74m<br>Erodible banks: 0.63m |
| Revised Management Class: | Rehabilitate | | | |
| Specific Actions Recommended: | Initial work required is for bed and bank stabilisation associated with lowering of Sculthorpe Mill structures at downstream end of reach. Appropriate measures required to manage silt deposits upstream of the mill. Augment bed on average by 0.5m using local gravels wherever possible and create up to 70 gravel glides or riffles in the reach. The channel is on average 9.1m 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 Sculthorpe Mill. Adopt/maintain 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 structure. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAd** RWRS 29 Location Plan

## REACH CODE: RWRS 30

**Table AAe1** RWRS 30 Reach data summary

| | |
|---|---|
| Location: | Upstream River Tat confluence to South Mill Farm |
| NGR: | 587660, 328070 to 588120, 328290 |
| Total Reach Length: | 665m |
| Geomorphological Appraisal (2006) Reaches: | W1051 and W1050 |
| Associated Mill Summary Information: | Refer to Mill Summary Sheet for South Mill, which is located at the downstream end of RWRS30. |

**Table AAe2** RWRS 30 Current reach condition

| | | |
|---|---|---|
| Description: | Straight section of channel that is wide and deep downstream of River Tat confluence and upstream of South Mill. Potentially receives large amount of sediment from River Tat sources. Diversion of river and embankments associated with mill. | |
| Natural England Assessment: | Part of River Unit 47 (Confluence of Wensum and Tat - Fakenham Mill) - Transition Reach - *Ranunculus* vegetation variant CB2 to CB1; Chalk/base rich lowland river community to Eutrophic lowland river community covering JNCC River Types IIIa/b to 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 60km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 12m<br>1.46m |
| Length Affected by Backwater: | Reach expected to be affected over a short length by backwater at remains of South Mill (sill across the bed by road bridge). | |
| Maintenance Regime: | Cut and clear type regime operated by the Environment Agency (annual walk through to trim trees and remove obstacles causing unacceptable risk). | |

**Table AAe3** RWRS 30 Constraints

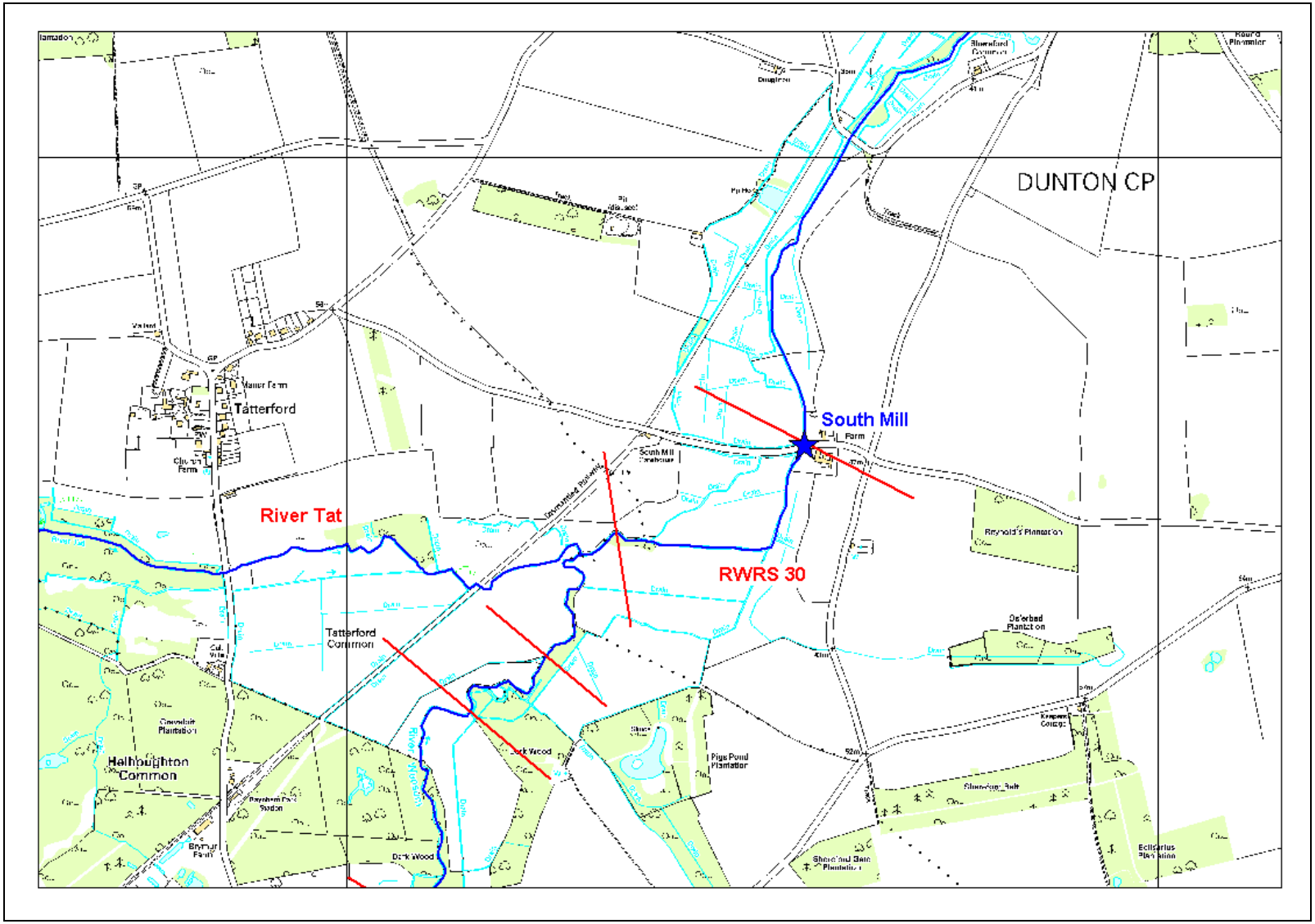
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Permanent pasture (ESA tiers 1 & 2) on both sides of river. Arable farmland on valley sides. |
| Amenity Value: | Angling (leased trout fishery) |
| Other: | None |

**Table AAe4** RWRS 30 Previous works or recommendations

| | | |
|---|---|---|
| Previous Measures (Consented): | None | |
| Potential Schemes for Habitat Restoration (ECON): | None | |
| Geomorphological Appraisal (2006) Options for Restoration: | | |
| Reach Code | W1050 | W1051 |
| Reach Status | Severely degraded | Severely degraded |
| Management Class | Rehabilitate | Rehabilitate |
| Work related to weir | | |
| Re-establish former channel or dimensions | ✓ | ✓ |
| Reconnect river to floodplain | | |
| Narrow | ✓ | |
| De-silt | | |
| Augment gravel or bed or water levels | | |
| Monitor | | |
| Reduce maintenance | | |
| Improve flow & habitat diversity | | |
| Establish riparian vegetation | | |
| Create or maintain backwater | | |
| Fix sediment ingress points | ✓ | ✓ |

**Table AAe5** RWRS 30 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | All works must integrate with removal of sill-type structure at South Mill and any associated river works. Reinstate meandering channel with appropriate sinuosity and fill in the existing channel that was created as a diversion when South Mill was in use. The original channel is not evident on the floodplain, although a drain seen on the OS map along the left bank of the Wensum may represent a previous river course. Further, as there are no suitable reference reaches at this location in the catchment, restoration channel dimensions should be based on hydraulic geometry calculations. It would be suitable to reconnect the restoration channel with the existing channel at the road bridge by South Mill. Develop marginal/bankside vegetation, with some riparian trees. Connect to drains or create off-river refuges. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 2.3-2.4m<br>Erodible banks: 3.5-3.6m | Depth: | Resistant banks: 0.72m<br>Erodible banks: 0.62m |
| Revised Management Class: | Restoration (restored section expected to be approximately 500m). | | | |
| Specific Actions Recommended: | Restore section of channel. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAe** RWRS 30 Location Plan

## REACH CODE: RWRS 31

**Table AAf1** RWRS 31 Reach data summary

| | |
|---|---|
| Location: | Wensum/Tat confluence zone |
| NGR: | 587490, 327760 to 587660, 328070 |
| Total Reach Length: | 475m |
| Geomorphological Appraisal (2006) Reaches: | W1052 |
| Associated Mill Summary Information: | No mill at up or downstream end of RWRS31 |

**Table AAf2** RWRS 31 Current reach condition

| | | |
|---|---|---|
| Description: | Sinuous and slightly over wide reach upstream of River Tat confluence. Silt has accumulated over the gravel bed. Few in-stream features or littoral vegetation. Sheep trampling and bank erosion. Localised embankments only. | |
| Natural England Assessment: | Part of River Unit 47 (Confluence between Wensum and Tat - Fakenham Mill) - Transition Reach - *Ranunculus* vegetation variant CB2 to CB1; Chalk/base rich lowland river community to Eutrophic lowland river community covering JNCC River Types IIIa/b to 1a-c & IIa; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 60km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 6m<br>0.52m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | Cut and clear type regime operated by the Environment Agency (annual walk through to trim trees and remove obstacles causing unacceptable risk) downstream of the River Tat confluence with the River Wensum.<br>Upstream of the Tat confluence, Norfolk Rivers IDB maintenance is undertaken on a tri to bi-annual basis by weed cutting carried out in accordance with the IDB Standard Maintenance Operations document (King's Lynn Consortium of IDBs, 2000). | |

**Table AAf3** RWRS 31 Constraints

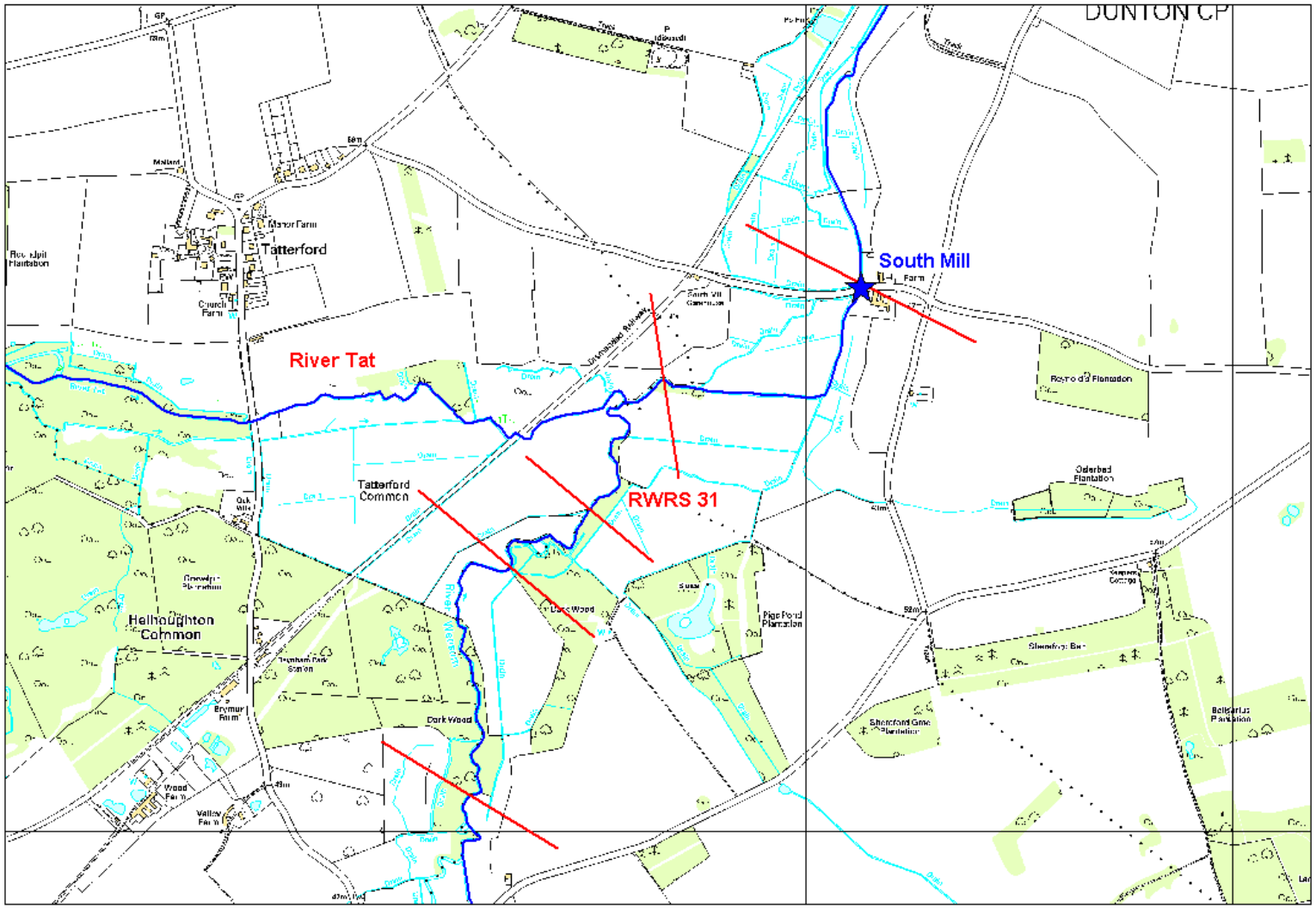
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Drained permanent pasture (ESA tier 1) on both sides of river with some woodland. Adjacent land at Tatterford Common is wet pasture mainly under ESA tier 3. |
| Amenity Value: | Angling (leased trout fishery, riparian owner) |
| Other: | None |

**Table AAf4** RWRS 31 Previous works or recommendations

| | |
|---|---|
| Previous Measures (Consented): | None |
| Potential Schemes for Habitat Restoration (ECON): | None |
| Geomorphological Appraisal (2006) Options for Restoration: | |
| Reach Code | W1052 |
| Reach Status | Recovered |
| Management Class | Conserve and monitor |
| Work related to weir | |
| Re-establish former channel or dimensions | |
| Reconnect river to floodplain | |
| Narrow | |
| De-silt | |
| Augment gravel or bed or water levels | |
| Monitor | ✓ |
| Reduce maintenance | ✓ |
| Improve flow & habitat diversity | |
| Establish riparian vegetation | |
| Create or maintain backwater | |
| Fix sediment ingress points | |

**Table AAf5** RWRS 31 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Encourage less intensive stocking of livestock and develop marginal/bankside vegetation. Allow to narrow and de-silt naturally. Remove embankments to reconnect the river to its floodplain. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 2.3m<br>Erodible banks: 3.5m | Depth: | Resistant banks: 0.5m<br>Erodible banks: 0.43m |
| Revised Management Class: | Enhancement | | | |
| Specific Actions Recommended: | Adopt/maintain maintenance regime and riparian management to allow channel to develop a more natural form. However, assume reach will narrow naturally in time and that no bed raising is required. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAf** RWRS 31 Location Plan

## REACH CODE: RWRS 32

**Table AAg1** RWRS 32 Reach data summary

| | |
|---|---|
| Location: | Tatterford Common/Dark Wood |
| NGR: | 587300, 327630 to 587490, 327760 |
| Total Reach Length: | 320m |
| Geomorphological Appraisal (2006) Reaches: | W1053 |
| Associated Mill Summary Information: | No mill at up or downstream end of RWRS32 |

**Table AAg2** RWRS 32 Current reach condition

| | | |
|---|---|---|
| Description: | Sinuous, very wide and generally embanked. Few in-stream features or littoral vegetation. Sheep trampling and bank erosion. | |
| Natural England Assessment: | Part of River Unit 45 (Pear Tree Corner - Confluence of Wensum and Tat) - *Ranunculus* vegetation variant CB2; Chalk/base rich lowland river community covering JNCC River Types IIIa/b; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 55km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 8m<br>0.48-0.6m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | Norfolk Rivers IDB maintenance is undertaken on a tri to bi-annual basis by weed cutting carried out in accordance with the IDB Standard Maintenance Operations document (King's Lynn Consortium of IDBs, 2000). | |

**Table AAg3** RWRS 32 Constraints

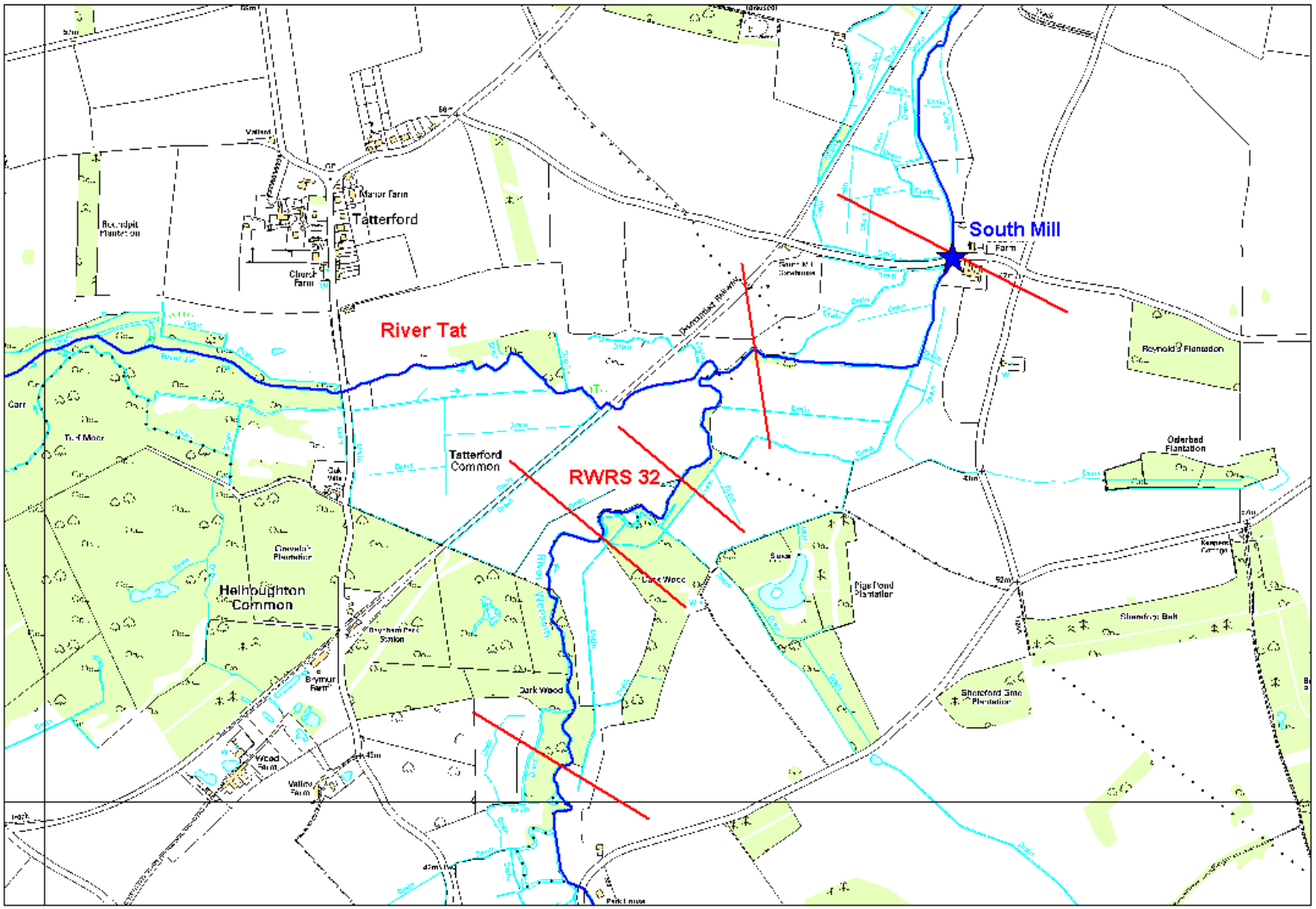
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Semi-improved permanent pasture (ESA tier 1) on both sides of the river and woodland. |
| Amenity Value: | Angling (leased trout fishery, riparian owner) |
| Other: | None |

**Table AAg4** RWRS 32 Previous works or recommendations

| | |
|---|---|
| Previous Measures (Consented): | None |
| Potential Schemes for Habitat Restoration (ECON): | None |
| Geomorphological Appraisal (2006) Options for Restoration: | |
| Reach Code | W1053 |
| Reach Status | Severely degraded |
| Management Class | Rehabilitate |
| Work related to weir | |
| Re-establish former channel or dimensions | ✓ |
| Reconnect river to floodplain | ✓ |
| Narrow | ✓ |
| De-silt | |
| Augment gravel or bed or water levels | ✓ |
| Monitor | |
| Reduce maintenance | ✓ |
| Improve flow & habitat diversity | ✓ |
| Establish riparian vegetation | |
| Create or maintain backwater | |
| Fix sediment ingress points | ✓ |

**Table AAg5** RWRS 32 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Encourage less intensive stocking and develop marginal/bankside vegetation. Allow to narrow naturally. Remove embankments to reconnect the river to its floodplain and open up the ox-bow. Use coarse woody debris structures to exacerbate sinuosity in wooded area, such as to encourage flow into entrance of ox-bow. Allow channel to restore the ox-bow naturally. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 2.2m<br>Erodible banks: 3.4m | Depth: | Resistant banks: 0.5m<br>Erodible banks: 0.43m |
| Revised Management Class: | Enhancement | | | |
| Specific Actions Recommended: | Adopt/maintain maintenance regime and riparian management to allow channel to develop a more natural form. However, assume reach will narrow naturally in time and that no bed raising is required. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAg** RWRS 32 Location Plan

## REACH CODE: RWRS 33

**Table AAh1** RWRS 33 Reach data summary

| | |
|---|---|
| Location: | Helhoughton Common to Tatterford Common |
| NGR: | 587210, 327080 to 587300, 327630 |
| Total Reach Length: | 720m |
| Geomorphological Appraisal (2006) Reaches: | W1055 and W1054 |
| Associated Mill Summary Information: | No mill at up or downstream end of RWRS33 |

**Table AAh2** RWRS 33 Current reach condition

| | | |
|---|---|---|
| Description: | Channel sinuous and wide, with relatively uniform character. Little emergent vegetation is able to grow in woods. Localised embankments. | |
| Natural England Assessment: | Part of River Unit 45 (Pear Tree Corner - Confluence of Wensum and Tat) - *Ranunculus* vegetation variant CB2; Chalk/base rich lowland river community covering JNCC River Types IIIa/b; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 50km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 8m<br>0.56-1.27m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | Norfolk Rivers IDB maintenance is undertaken on a tri to bi-annual basis by weed cutting carried out in accordance with the IDB Standard Maintenance Operations document (King's Lynn Consortium of IDBs, 2000). | |

**Table AAh3** RWRS 33 Constraints

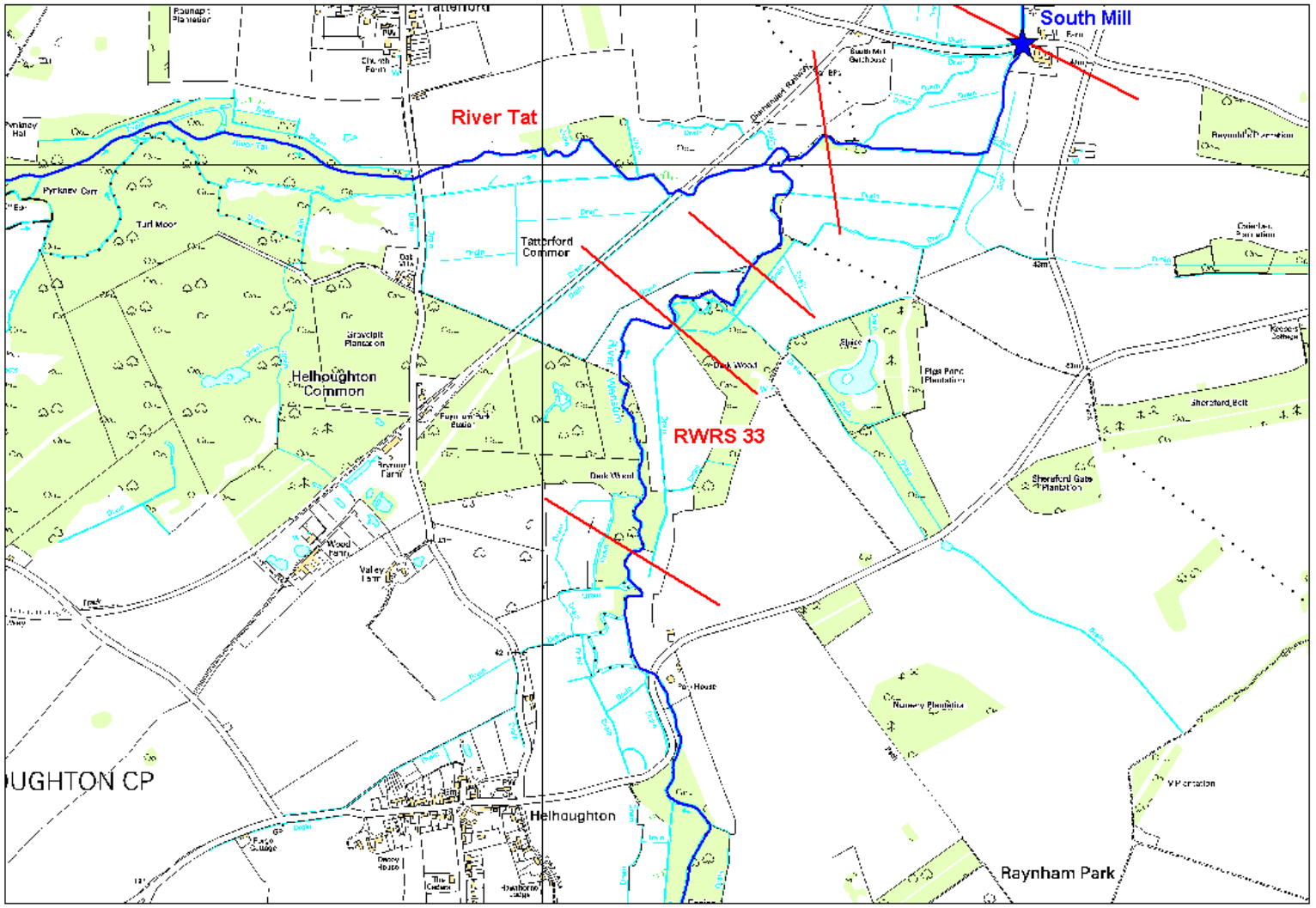
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Woodland/semi-improved pasture (ESA tier 1) on both sides of the river. Arable farmland, extensive semi-natural woodland and plantation woodlands in surrounding areas. |
| Amenity Value: | Angling (leased trout fishery) |
| Other: | None |

**Table AAh4** RWRS 33 Previous works or recommendations

| | | |
|---|---|---|
| Previous Measures (Consented): | None | |
| Potential Schemes for Habitat Restoration (ECON): | None | |
| Geomorphological Appraisal (2006) Options for Restoration: | | |
| Reach Code | W1054 | W1055 |
| Reach Status | Degraded | Damaged |
| Management Class | Rehabilitate | Assist |
| Work related to weir | | |
| Re-establish former channel or dimensions | | |
| Reconnect river to floodplain | | |
| Narrow | ✓ | ✓ |
| De-silt | | |
| Augment gravel or bed or water levels | | |
| Monitor | | |
| Reduce maintenance | ✓ | ✓ |
| Improve flow & habitat diversity | ✓ | ✓ |
| Establish riparian vegetation | | |
| Create or maintain backwater | | |
| Fix sediment ingress points | ✓ | ✓ |

**Table AAh5** RWRS 33 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Allow to narrow naturally by creating gaps in the tree line and allowing growth of emergent vegetation. Remove embankments to reconnect the river to its floodplain. Use coarse woody debris structures to exacerbate sinuosity in wooded area. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 2.1-2.2m<br>Erodible banks: 3.2-3.3m | Depth: | Resistant banks: 0.5m<br>Erodible banks: 0.43m |
| Revised Management Class: | Assist natural recovery | | | |
| Specific Actions Recommended: | Adopt/maintain maintenance regime to allow channel to develop a more natural form. However, assume reach will narrow naturally in time and that no bed raising is required. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAh** RWRS 33 Location Plan

## REACH CODE: RWRS 34

**Table AAi1** RWRS 34 Reach data summary

| | |
|---|---|
| Location: | Brickkiln Plantation (Helhoughton) to Helhoughton Common |
| NGR: | 587500, 326000 to 587210, 327080 |
| Total Reach Length: | 1,570m |
| Geomorphological Appraisal (2006) Reaches: | W1059 to W1056 |
| Associated Mill Summary Information: | No mill at up or downstream end of RWRS34 |

**Table AAi2** RWRS 34 Current reach condition

| | | |
|---|---|---|
| Description: | Through woodland, channel is a relatively natural width at certain locations. Upstream is wooded and downstream there is an extensive drain network on the floodplain. A number of sections in this reach have been straightened/cut-off in the past. | |
| Natural England Assessment: | Part of River Unit 45 (Pear Tree Corner - Confluence of Wensum & Tat) - *Ranunculus* vegetation variant CB2; Chalk/base rich lowland river community covering JNCC River Types IIIa/b; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 45km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 6-8m<br>0.48-0.78m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | Norfolk Rivers IDB maintenance is undertaken on a tri to bi-annual basis by weed cutting carried out in accordance with the IDB Standard Maintenance Operations document (King's Lynn Consortium of IDBs, 2000). | |

**Table AAi3** RWRS 34 Constraints

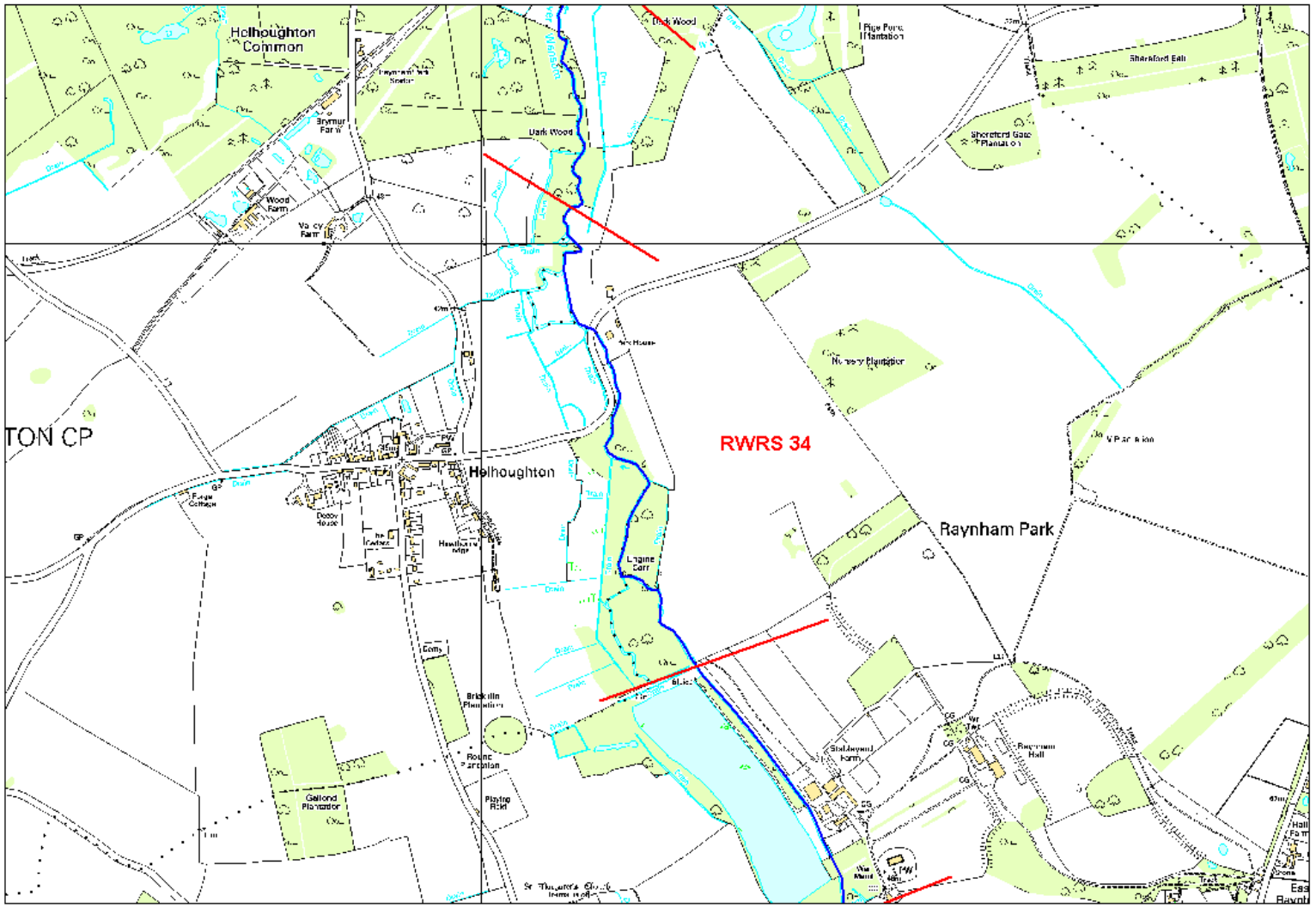
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Mainly woodland adjacent to the river. Permanent pasture on both sides in part (ESA tiers 1 & 2). Raynham Park to east. |
| Amenity Value: | Angling (leased trout fishery). Public Footpath crosses the Wensum immediately downstream of the Raynham Lake. Public Footpath intersects with the river at the road bridge at Helhoughton Common. |
| Other: | Conserve ecological communities |

**Table AAi4** RWRS 34 Previous works or recommendations

| | | | | |
|---|---|---|---|---|
| Previous Measures (Consented): | None | | | |
| Potential Schemes for Habitat Restoration (ECON): | Helhoughton meander loop re-connection | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | |
| Reach Code | W1056 | W1057 | W1058 | W1059 |
| Reach Status | Damaged | Damaged | Damaged | Semi-natural |
| Management Class | Assist | Assist | Assist | Protect and monitor |
| Work related to weir | | | | |
| Re-establish former channel or dimensions | ✓ | | | |
| Reconnect river to floodplain | | | | |
| Narrow | | | | |
| De-silt | | | | |
| Augment gravel or bed or water levels | ✓ | | | |
| Monitor | | | | ✓ |
| Reduce maintenance | | | | ✓ |
| Improve flow & habitat diversity | | | ✓ | |
| Establish riparian vegetation | | ✓ | ✓ | |
| Create or maintain backwater | ✓ | | | |
| Fix sediment ingress points | ✓ | | | |

**Table AAi5** RWRS 34 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Restore cut-off meander bend to east of Helhoughton (still evident in floodplain and known to retain some flow). Check current channel dimensions using hydraulic geometry and remove silt/shape as appropriate. Infill current straight channel or use as backwater. Create off-river refuge unit at downstream smaller meander that can be observed on OS map or use woody debris in the channel to encourage flow through this meander if it is functional.<br>Also, restore channel downstream of Raynham Lake through to upstream end of Engine Carr. A restoration is required at this location to extend and, therefore, assist reconnection of the channel restoration in RWRS35. Use drainage channel observed on OS map to determine new river course. Use hydraulic geometry and the size of the channel in Helhoughton meander loop to inform dimensions. Infill existing channel or use as backwater.<br>Elsewhere, de-silt. Introduce gaps in the tree line to encourage growth of macrophytes or develop marginal/bankside vegetation. Maintain coarse woody debris in the channel through wooded areas to encourage sinuosity. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 2-2.1m<br>Erodible banks: 3-3.1m | Depth: | Resistant banks: 0.48m<br>Erodible banks: 0.42m |
| Revised Management Class: | Assist natural recovery and restoration (restored sections expected to be approximately 335m downstream of Park House and 335m upstream of Raynham Lake in Engine Carr, respectively). | | | |
| Specific Actions Recommended: | Restore sections of channel where straightening has occurred in the past. Adopt/maintain maintenance regime to allow channel to develop a more natural form. However, assume that the remainder of the reach will narrow naturally in time and that no bed raising is required. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAi** RWRS 34 Location Plan

## REACH CODE: RWRS 35

**Table AAj1** RWRS 35 Reach data summary

| | |
|---|---|
| Location: | West Raynham to Brickkiln Plantation (Helhoughton) |
| NGR: | 587860, 325400 to 587500, 326000 |
| Total Reach Length: | 705m |
| Geomorphological Appraisal (2006) Reaches: | W1060 (part) |
| Associated Mill Summary Information: | No mill at up or downstream end of RWRS35 |

**Table AAj2** RWRS 35 Current reach condition

| | | |
|---|---|---|
| Description: | Straightened reach where channel has been diverted beside artificial lake associated with Raynham Hall. Diverted channel wide and has little littoral margin. Outlet at the lake is under investigation by the Norfolk Rivers IDB. Inspections suggest that there is a sluice outlet to the lake and a number of culverts (under footpath to Engine Carr and as a possible outlet for the lake). Also, poplar logs are placed against the bridge at the downstream end of the lake, acting as water control structures on the river. | |
| Natural England Assessment: | Part of River Unit 45 (Pear Tree Corner - Confluence of Wensum & Tat) - *Ranunculus* vegetation variant CB2; Chalk/base rich lowland river community covering JNCC River Types IIIa/b; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 40km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 7m<br>0.23-0.39m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | Norfolk Rivers IDB maintenance is undertaken on a tri to bi-annual basis by weed cutting carried out in accordance with the IDB Standard Maintenance Operations document (King's Lynn Consortium of IDBs, 2000). | |

**Table AAj3** RWRS 35 Constraints

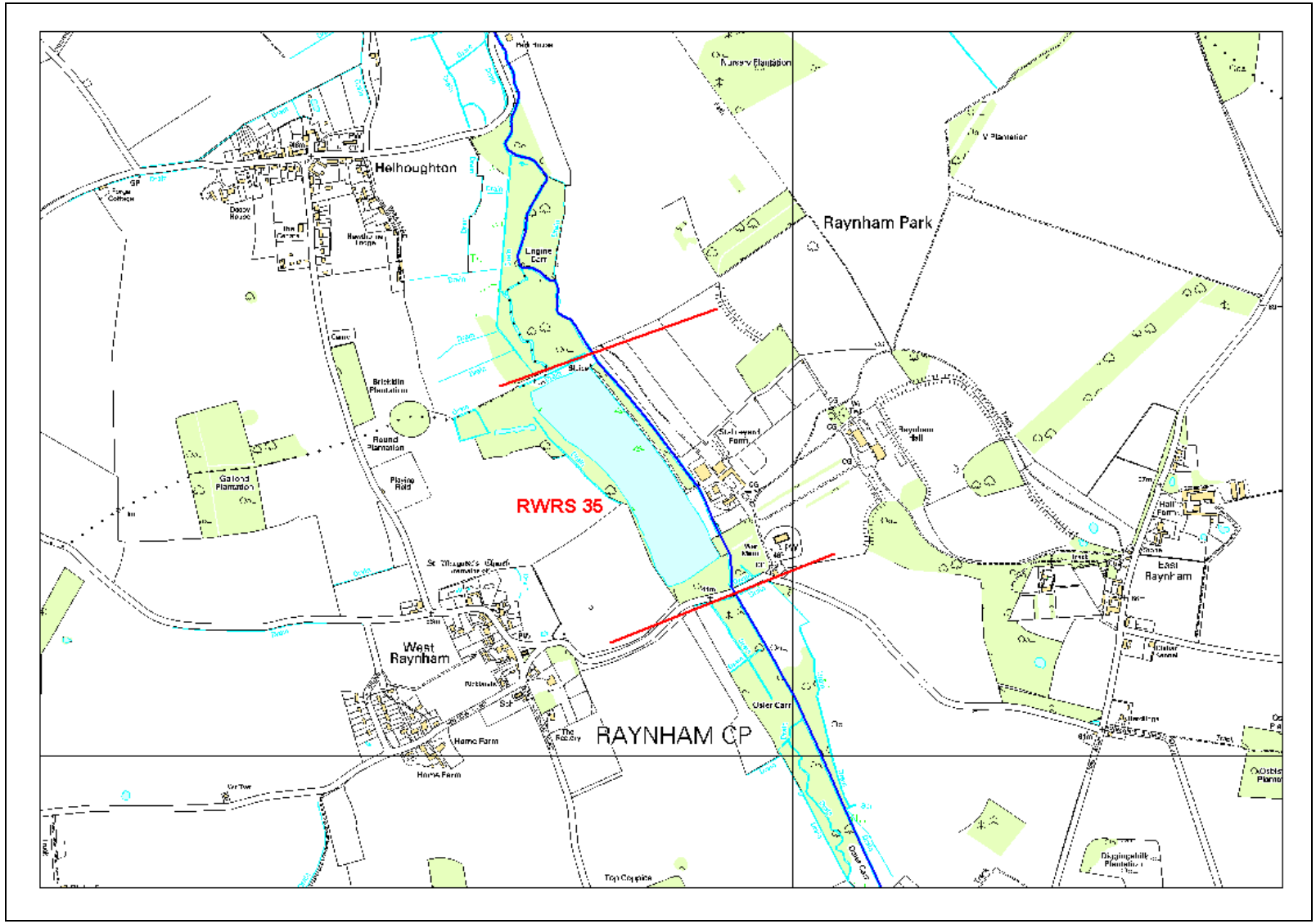
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Reedbed, lake, and woodland in immediate vicinity, with Raynham Park to east. |
| Amenity Value: | Angling (leased trout fishery). Landscape feature (lake). Public Footpath runs along river bank and crosses the river immediately downstream of the lake. |
| Other: | Lake may provide wader habitat. |

**Table AAj4** RWRS 35 Previous works or recommendations

| | |
|---|---|
| Previous Measures (Consented): | Recent IDB maintenance |
| Potential Schemes for Habitat Restoration (ECON): | None |
| Geomorphological Appraisal (2006) Options for Restoration: | |
| Reach Code | W1060 |
| Reach Status | Degraded |
| Management Class | Enhance |
| Work related to weir | |
| Re-establish former channel or dimensions | |
| Reconnect river to floodplain | |
| Narrow | ✓ |
| De-silt | |
| Augment gravel or bed or water levels | ✓ |
| Monitor | |
| Reduce maintenance | |
| Improve flow & habitat diversity | ✓ |
| Establish riparian vegetation | |
| Create or maintain backwater | |
| Fix sediment ingress points | ✓ |

**Table AAj5** RWRS 35 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Drain lake and re-cut channel, augmenting bed with gravel. Plant occasional trees but ensure gaps in the tree line to encourage growth of macrophytes. Channel dimensions should be estimated using hydraulic geometry in comparison with existing channel dimensions in the Helhoughton meander loop downstream. Planform should also be based on hydraulic geometry relations and natural channel sinuosity in the vicinity of this reach, although there is limited scope due to constriction in the valley bottom. Reconnect downstream with restoration planned in RWRS34 towards Engine Carr. Infill current channel or retain as a backwater. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 1.8m<br>Erodible banks: 2.8m | Depth: | Resistant banks: 0.48m<br>Erodible banks: 0.42m |
| Revised Management Class: | Restoration (restored section expected to be approximately 750m). | | | |
| Specific Actions Recommended: | Drain lake and restore channel throughout this reach. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAj** RWRS 35 Location Plan

## REACH CODE: RWRS 36

**Table AAk1** RWRS 36 Reach data summary

| | |
|---|---|
| Location: | South Raynham Bridge to West Raynham |
| NGR: | 588440, 324130 to 587860, 325400 |
| Total Reach Length: | 1,410m |
| Geomorphological Appraisal (2006) Reaches: | W1062 (part) to W1060 (part) |
| Associated Mill Summary Information: | No mill at up or downstream end of RWRS36 |

**Table AAk2** RWRS 36 Current reach condition

| | | |
|---|---|---|
| Description: | Artificial channel that is straight and embanked in its lower reaches. Upstream of the meadow the channel is beginning to narrow naturally through the development of vegetated berms. Downstream, the wood has extensive silt deposition but where reeds grow and narrow the channel, gravels can be exposed. | |
| Natural England Assessment: | Part of River Unit 45 (Pear Tree Corner - Confluence of Wensum & Tat) - *Ranunculus* vegetation variant CB2; Chalk/base rich lowland river community covering JNCC River Types IIIa/b; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 35km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 5-7m<br>0.85-0.6m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | Norfolk Rivers IDB maintenance is undertaken on a tri to bi-annual basis by weed cutting carried out in accordance with the IDB Standard Maintenance Operations document (King's Lynn Consortium of IDBs, 2000). | |

**Table AAk3** RWRS 36 Constraints

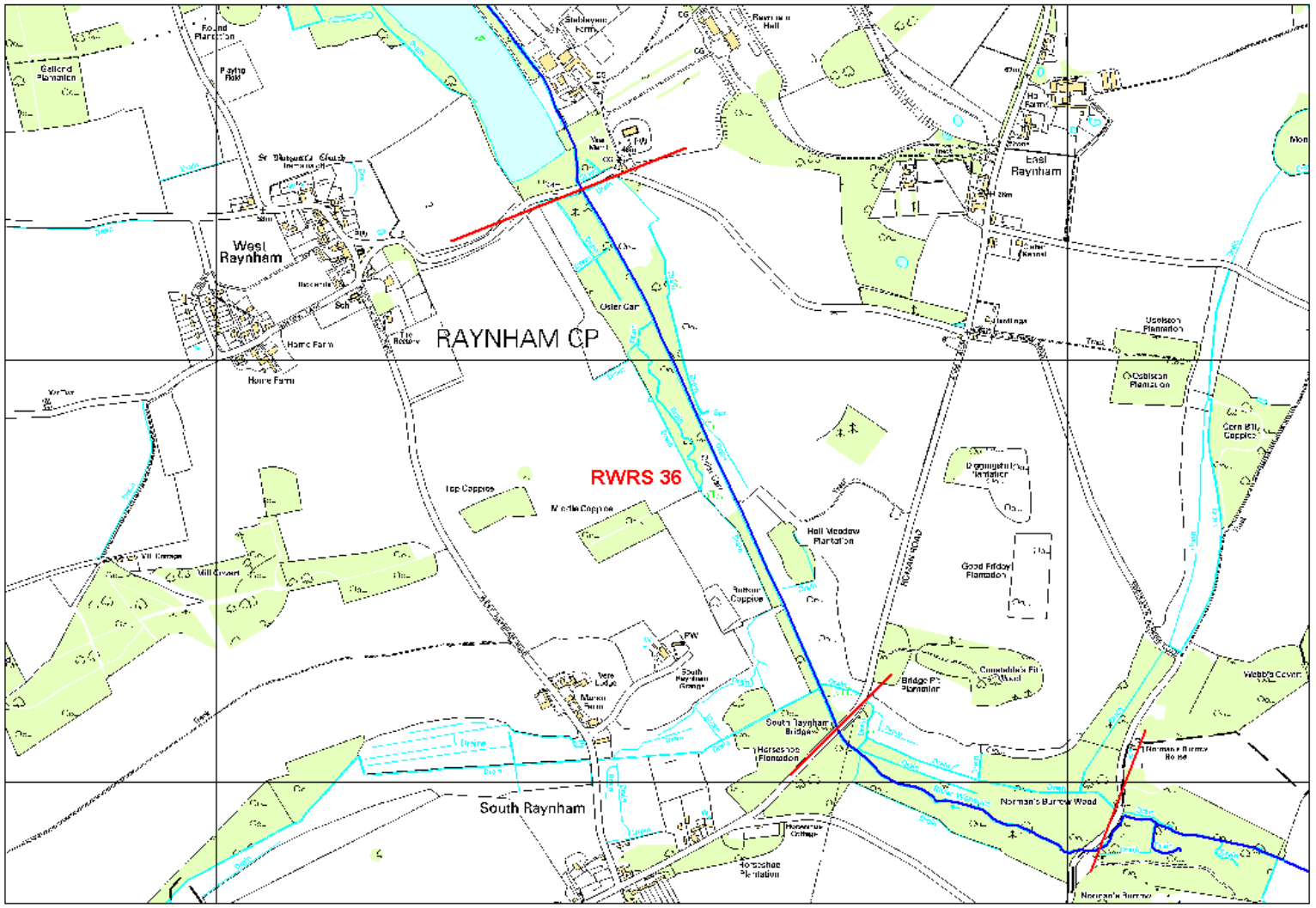
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Water meadows (ESA tier 1) on left (W) side, otherwise predominantly woodland fringing river. Mainly arable on surrounding farmland. |
| Amenity Value: | Angling (leased trout fishery). Public footpaths run parallel with the river at the edge of woodland. |
| Other: | None |

**Table AAk4** RWRS 36 Previous works or recommendations

| | | | |
|---|---|---|---|
| Previous Measures (Consented): | Late 1990s de-silting. | | |
| Potential Schemes for Habitat Restoration (ECON): | None | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | |
| Reach Code | W1060 | W1061 | W1062 |
| Reach Status | Degraded | Severely degraded | Recovering |
| Management Class | Enhance | Enhance | Assist |
| Work related to weir | | | |
| Re-establish former channel or dimensions | | ✓ | |
| Reconnect river to floodplain | | | |
| Narrow | ✓ | | |
| De-silt | | | |
| Augment gravel or bed or water levels | ✓ | | |
| Monitor | | | |
| Reduce maintenance | | | ✓ |
| Improve flow & habitat diversity | ✓ | | ✓ |
| Establish riparian vegetation | | ✓ | ✓ |
| Create or maintain backwater | | ✓ | |
| Fix sediment ingress points | ✓ | ✓ | ✓ |

**Table AAk5** RWRS 36 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Re-cut channel and augment bed with gravel. Channel dimensions should be estimated using hydraulic geometry in comparison with existing channel dimensions in the Helhoughton meander loop downstream/dimension in RWRS35. Planform should also be based on hydraulic geometry relations and natural channel sinuosities within the reach (refer to OS map and drain on left bank in mid section of the reach which may have been an original course of the Wensum). Reconnect downstream with restoration planned in RWRS34 and RWRS35 towards Engine Carr. Remove spoil banks and infill current channel or retain as a backwater. Introduce gaps in the tree line to encourage growth of macrophytes. Maintain coarse woody debris in the channel. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 1.6-1.8m<br>Erodible banks: 2.5-2.8m | Depth: | Resistant banks: 0.47m<br>Erodible banks: 0.41m |
| Revised Management Class: | Restoration (restored section expected to be approximately 750m). | | | |
| Specific Actions Recommended: | Restore straight channel in this reach. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAk** RWRS 36 Location Plan

## REACH CODE: RWRS 37

**Table AAI1** RWRS 37 Reach data summary

| | |
|---|---|
| Location: | Norman's Burrow Wood to South Raynham Bridge |
| NGR: | 589090, 323850 to 588440, 324130 |
| Total Reach Length: | 720m |
| Geomorphological Appraisal (2006) Reaches: | W1062 (part) |
| Associated Mill Summary Information: | No mill at up or downstream end of RWRS37 |

**Table AAI2** RWRS 37 Current reach condition

| | | |
|---|---|---|
| Description: | Channel widens and, where gradient is reduced, there has been extensive deposition of silt on the bed. Some macrophyte growth in the channel through the woods where trees have fallen (encourages development of vegetated berms and narrowing). | |
| Natural England Assessment: | Part of River Unit 45 (Pear Tree Corner - Confluence of Wensum & Tat) - *Ranunculus* vegetation variant CB2; Chalk/base rich lowland river community covering JNCC River Types IIIa/b; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 35km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 5m<br>0.52m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | Norfolk Rivers IDB maintenance is undertaken on a tri to bi-annual basis by weed cutting carried out in accordance with the IDB Standard Maintenance Operations document (King's Lynn Consortium of IDBs, 2000). | |

**Table AAI3** RWRS 37 Constraints

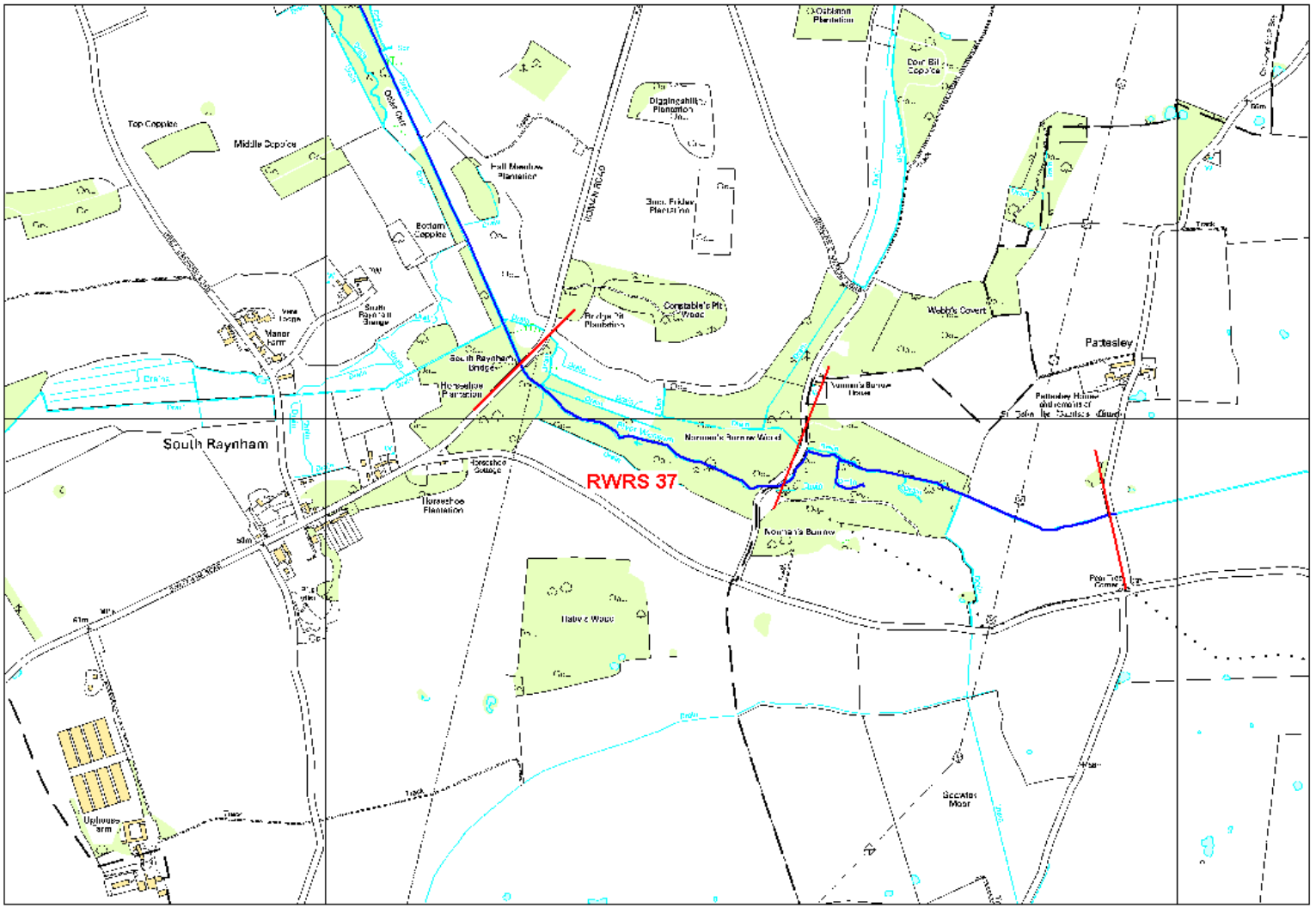
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Woodland fringing river, surrounded by arable farmland. |
| Amenity Value: | Public Footpaths run parallel with the river at the edge of woodland and one public footpath crosses the river. |
| Other: | None |

**Table AAI4** RWRS 37 Previous works or recommendations

| | |
|---|---|
| Previous Measures (Consented): | None |
| Potential Schemes for Habitat Restoration (ECON): | None |
| Geomorphological Appraisal (2006) Options for Restoration: | |
| Reach Code | W1062 |
| Reach Status | Recovering |
| Management Class | Assist |
| Work related to weir | |
| Re-establish former channel or dimensions | |
| Reconnect river to floodplain | |
| Narrow | |
| De-silt | |
| Augment gravel or bed or water levels | |
| Monitor | |
| Reduce maintenance | ✓ |
| Improve flow & habitat diversity | ✓ |
| Establish riparian vegetation | ✓ |
| Create or maintain backwater | |
| Fix sediment ingress points | ✓ |

**Table AAI5** RWRS 37 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Introduce gaps in the tree line to encourage growth of macrophytes. Maintain coarse woody debris in the channel to encourage sinuosity, erosion of silt bed and creation of flow diversity. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 1.6 m<br>Erodible banks: 2.5m | Depth: | Resistant banks: 0.46m<br>Erodible banks: 0.41m |
| Revised Management Class: | Assist natural recovery | | | |
| Specific Actions Recommended: | Adopt/maintain maintenance regime to allow channel to develop a more natural form. However, assume reach will narrow naturally in time and that no bed raising is required. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAI** RWRS 37 Location Plan

## REACH CODE: RWRS 38

**Table AAm1** RWRS 38 Reach data summary

| | |
|---|---|
| Location: | Pear Tree Corner to Norman's Burrow Wood |
| NGR: | 589850, 327770 to 589090, 323850 |
| Total Reach Length: | 850m |
| Geomorphological Appraisal (2006) Reaches: | W1064 to W1063 |
| Associated Mill Summary Information: | No mill at up or downstream end of RWRS38 |

**Table AAm2** RWRS 38 Current reach condition

| | | |
|---|---|---|
| Description: | Artificial channel that is often straight and deep, but with a steep gradient that exposes gravel on the bed locally. Fallen trees and woody debris. Embankment upstream of Norman's Burrow Road. | |
| Natural England Assessment: | Part of River Unit 45 (Pear Tree Corner - Confluence of Wensum & Tat) - *Ranunculus* vegetation variant CB2; Chalk/base rich lowland river community covering JNCC River Types IIIa/b; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river. | |
| Upstream Catchment Area: | 25km$^2$ | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 5-6m<br>0.62-1.33m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | Norfolk Rivers IDB maintenance is undertaken on a tri to bi-annual basis by weed cutting carried out in accordance with the IDB Standard Maintenance Operations document (King's Lynn Consortium of IDBs, 2000). | |

**Table AAm3** RWRS 38 Constraints

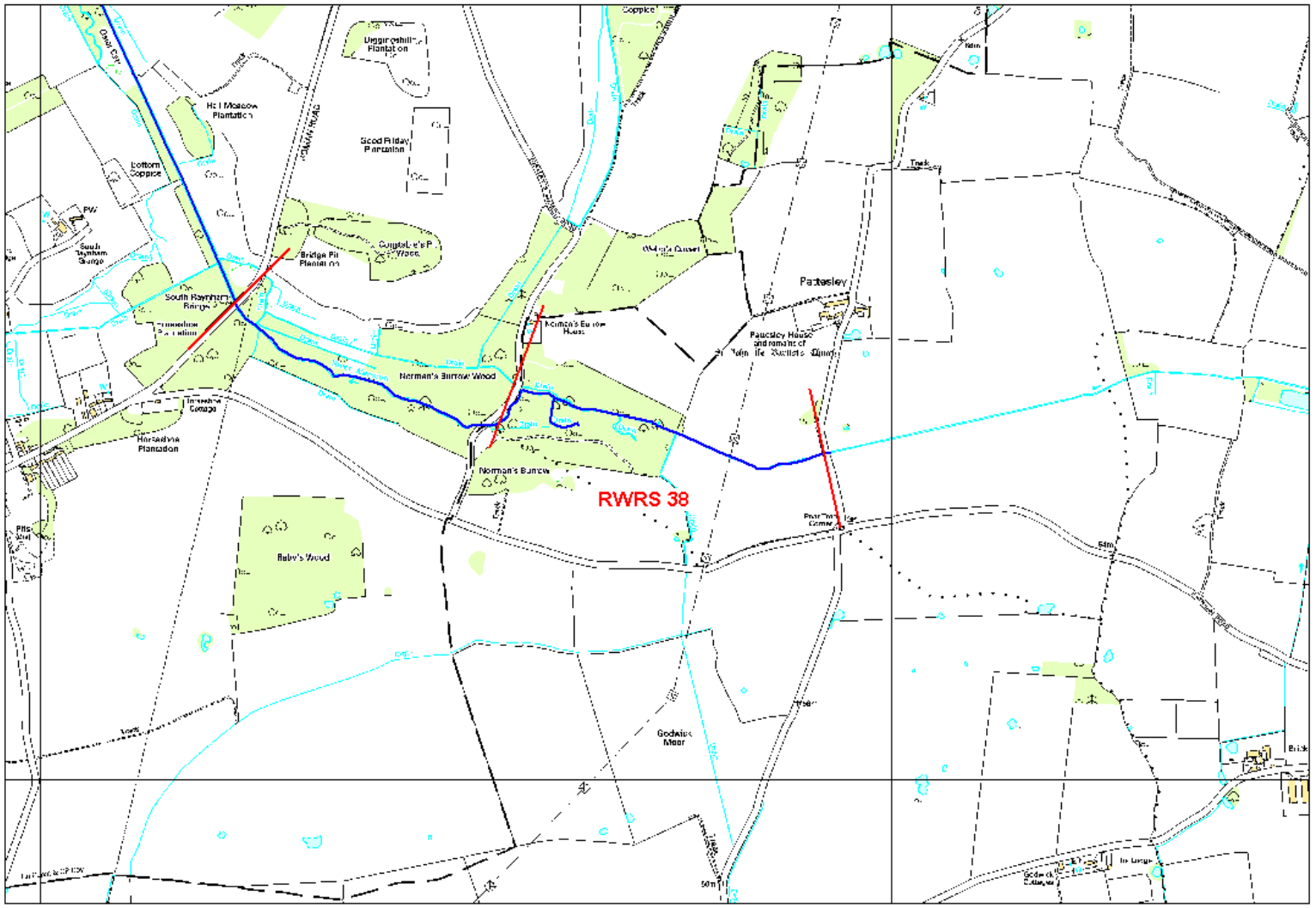
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Arable and woodland |
| Amenity Value: | |
| Other: | None |

**Table AAm4** RWRS 38 Previous works or recommendations

| | | |
|---|---|---|
| Previous Measures (Consented): | None | |
| Potential Schemes for Habitat Restoration (ECON): | None | |
| Geomorphological Appraisal (2006) Options for Restoration: | | |
| Reach Code | W1063 | W1064 |
| Reach Status | Damaged | Degraded |
| Management Class | Assist | Enhance |
| Work related to weir | | |
| Re-establish former channel or dimensions | | ✓ |
| Reconnect river to floodplain | | |
| Narrow | | |
| De-silt | ✓ | |
| Augment gravel or bed or water levels | ✓ | ✓ |
| Monitor | | |
| Reduce maintenance | ✓ | |
| Improve flow & habitat diversity | ✓ | |
| Establish riparian vegetation | | ✓ |
| Create or maintain backwater | | |
| Fix sediment ingress points | ✓ | ✓ |

**Table AAm5** RWRS 38 Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Re-cut channel and augment bed with gravel. Channel dimensions should be estimated using hydraulic geometry and knowledge of channel dimensions downstream (especially in restoration reach RWRS36). Planform should also be based on hydraulic geometry relations and natural channel sinuosities within the reach (refer to OS map and drain on left bank in mid section of the reach which may have been an original course of the Wensum). Reconnect downstream with channel in RWRS37 at Norman Burrows Road. Maintain coarse woody debris in the channel. Develop marginal/bankside vegetation. Infill current channel or retain as a backwater. | | | |
| Reference Channel Dimensions: | Width: | Resistant banks: 1.3-1.4m<br>Erodible banks: 1.9-2m | Depth: | Resistant banks: 0.33m<br>Erodible banks: 0.29m |
| Revised Management Class: | Restoration (restored section expected to be approximately 750m). | | | |
| Specific Actions Recommended: | Restore section of channel. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAm** RWRS 38 Location Plan

## REACH CODE: RWRS Tat

**Table AAn1** RWRS Tat Reach data summary

| | |
|---|---|
| Location: | Downstream Coxford to River Wensum confluence |
| NGR: | 585040, 328800 to 587580, 328020 |
| Total Reach Length: | 3280m |
| Geomorphological Appraisal (2006) Reaches: | W2000 to W2005 |
| Associated Mill Summary Sheet: | No mill at up or downstream end of RWRS Tat |

**Table AAn2** RWRS Tat Current reach condition

| | | |
|---|---|---|
| Description: | Straightened along much of its course. Embankments in upper and lower sections. | |
| Natural England Assessment: | Part of River Unit 46 (Broomsthorpe - Confluence of Wensum &I Tat) - *Ranunculus* vegetation variant CB2; Chalk/base rich lowland river community covering JNCC River Types IIIa/b; Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river.<br>River Unit adjacent to Terrestrial Units 14 support 33.3 ha of mosaics of mesotrophic grassland, rush pasture, fen and scrub (including M22, S7 and W6) towards the upstream end of the River Tat reach.<br>Terrestrial Unit 4 supports woodland - 3.8ha towards the middle of the River Tat reach on the right bank. | |
| Upstream Catchment Area: | 40km$^2$ (70km$^2$ at downstream end and confluence with River Wensum) | |
| Channel Dimensions (Bankfull): | Width:<br>Depth: | 7-8m<br>2.06 to 0.62m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | Cut and clear type regime operated by the Environment Agency (annual walk through to trim trees and remove obstacles causing unacceptable risk). | |

**Table AAn3** RWRS Tat Constraints

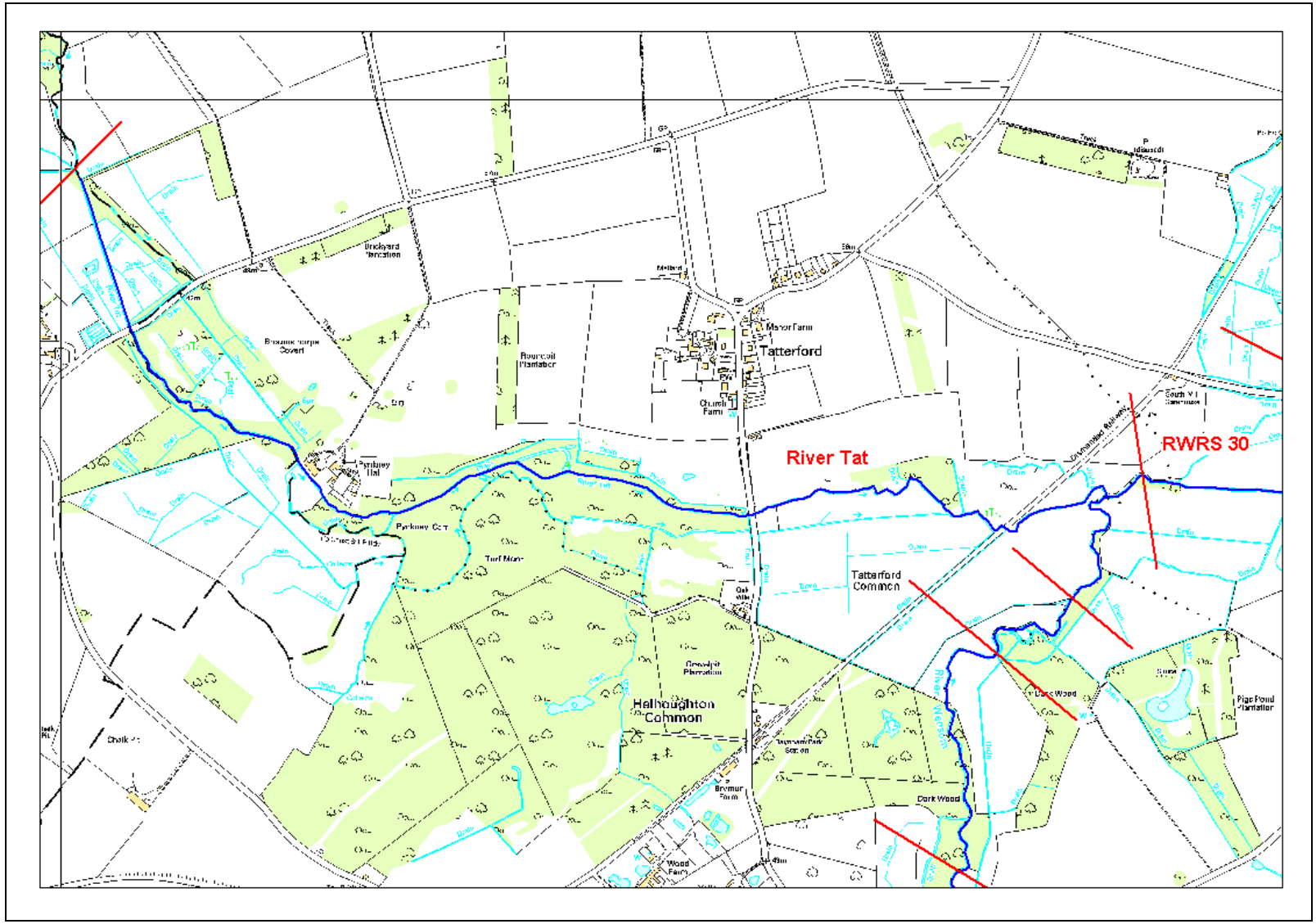
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Grazing meadows under ESA tiers 1, 2 & 3 include Tatterford Common, Tat Meadows, Pynkney Meadows and Tattersett Marsh, parts of which are SSSI units as described above. These are interspersed with fen, scrub, extensive woodland, and plantations either side of the river. Arable farmland predominates in surrounding area. |
| Amenity Value: | Angling (riparian landowner). Footpath through part of site unit 25 |
| Other: | Terrestrial compartments support particularly fine mosaics of mesotrophic grassland and rush pasture. Archaeological interest associated with environs of Coxford Abbey adjacent to the river. |

**Table AAn4** RWRS Tat Previous works or recommendations

| | | | | | | |
|---|---|---|---|---|---|---|
| Previous Measures (Consented): | None | | | | | |
| Potential Schemes for Habitat Restoration (ECON): | None | | | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | | | |
| Reach Code | W2000 | W2001 | W2002 | W2003 | W2004 | W2005 |
| Reach Status | Recovering | Degraded | Severely degraded | Severely degraded | Damaged | Severely degraded |
| Management Class | Conserve and monitor | Rehabilitate | Rehabilitate | Rehabilitate | Assist | Rehabilitate |
| Work related to weir | | | | | | |
| Re-establish former channel or dimensions | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Reconnect river to floodplain | ✓ | | | | | |
| Narrow | | | | | | |
| De-silt | | | | | | |
| Augment gravel or bed or water levels | | ✓ | | | ✓ | |
| Monitor | ✓ | | | | | |
| Reduce maintenance | ✓ | | | | | |
| Improve flow & habitat diversity | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Establish riparian vegetation | | ✓ | ✓ | ✓ | | ✓ |
| Create or maintain backwater | | | | | | |
| Fix sediment ingress points | | | ✓ | ✓ | | ✓ |

**Table AAn5** RWRS Tat Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Restore channel, particularly upstream, to its original course and dimensions and augment bed with gravel. Remove embankments. Develop marginal/bankside vegetation. Maintain coarse woody debris in the channel. A section of the original watercourse forms part of the IDB drain and further investigation would determine the potential for restoring full river flow to this reach and rationalising the drainage upstream of Main River and Main Drain. | | | |
| Reference Channel Dimensions: | Width | Resistant banks: 1.8-2.7m<br>Erodible banks: 2.8-4.0m | Depth: | Resistant banks: 0.54m<br>Erodible banks: 0.47m |
| Revised Management Class: | Rehabilitation and restoration (particularly upstream - restored section expected to be approximately 500m). | | | |
| Specific Actions Recommended: | Restore section of channel upstream. Use up to 210 gravel glides or riffles in the reach. Adopt/maintain maintenance regime and riparian management to allow channel to narrow naturally. Once shallowing works have been completed, allow channel (that is on average 4.7m over wide) to narrow naturally and begin programme to improve riparian vegetation. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAn** RWRS Tat Location Plan

## REACH CODE: RWRS Langor Drain

**Table AAo1** RWRS Langor Drain Reach data summary

| | |
|---|---|
| Location: | Along Langor Drain upstream of River Wensum confluence to Foxhills Wood |
| NGR: | 596470, 329930 to 595290, 328630 |
| Total Reach Length: | 1980m |
| Geomorphological Appraisal (2006) Reaches: | W1080 to W1083 |
| Associated Mill Summary Sheet: | No mill at up or downstream end of RWRS Langor Drain |

**Table AAo2** RWRS Langor Drain Current reach condition

| | | |
|---|---|---|
| Description: | Possibly straightened in its lower section but highly sinuous upstream of A1067 main road. Sand and gravel pits on Wensum floodplain at confluence. Woodland/plantations upstream. | |
| Natural England Assessment: | River Unit 46 (Langor Drain) - Overall status is unfavourable with wide range of reasons for adverse condition, including the form and function of the river.<br>River Unit adjacent to Terrestrial Units 17 & 18, support a mosaic of mesotrophic grassland and rush pasture (including M22 & M23) on either side of the Langor Drain, between the river and the A1067.<br>Terrestrial Units 19, 20 & 21 support a mosaic of rush pasture, fen and scrub (including M22, S25, and W6) on either side of the Langor Drain upstream of the A1067. | |
| Upstream Catchment Area: | 16.5km$^2$ upstream of Wensum confluence | |
| Channel Dimensions (Bankfull): | Width: | 3-6m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | Norfolk Rivers IDB maintenance is undertaken on a tri-annual basis and is a mixture of weed cutting and silt removal carried out in accordance with the IDB Standard Maintenance Operations document (King's Lynn Consortium of IDBs, 2000). | |

**Table AAo3** RWRS Langor Drain Constraints

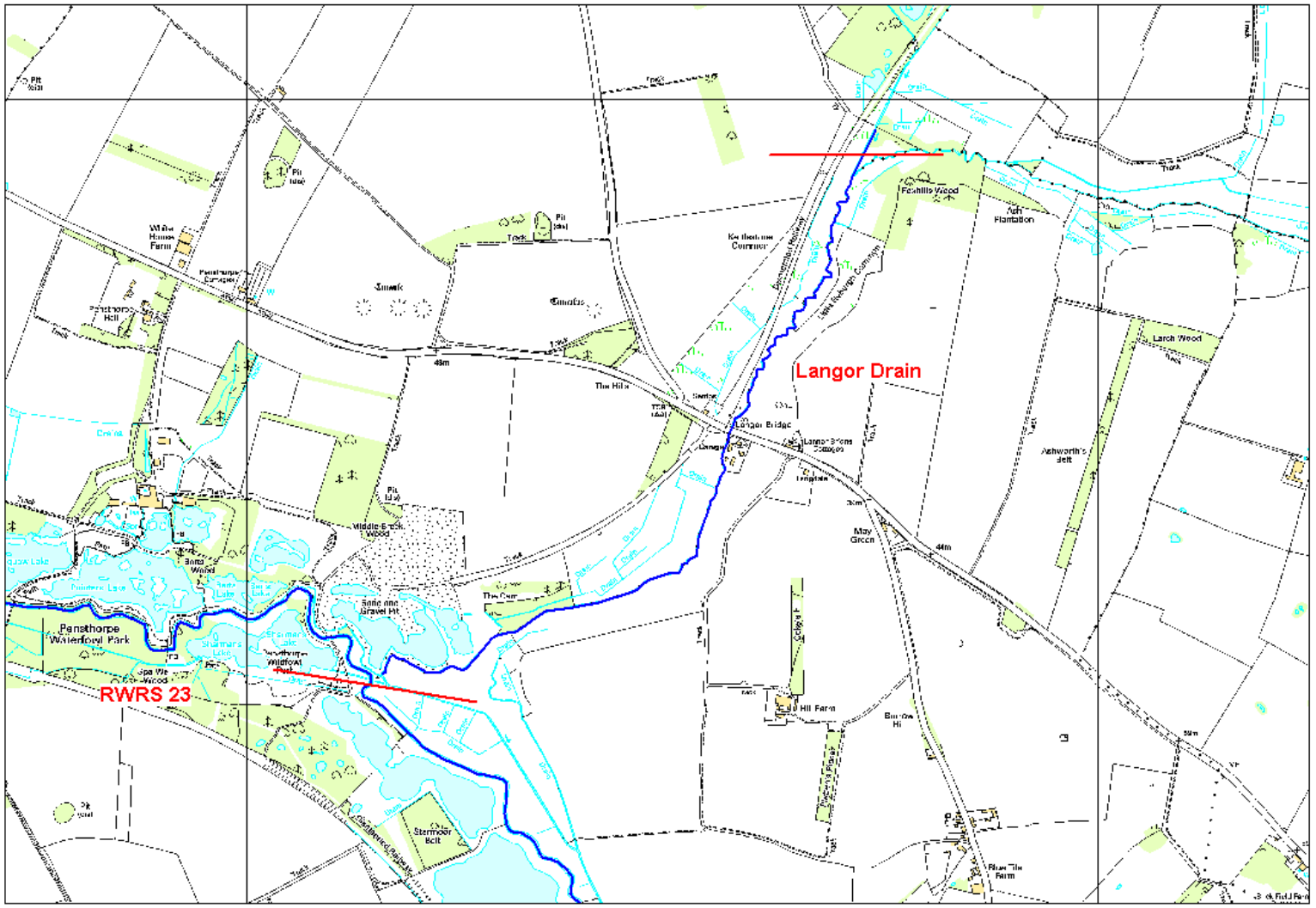
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Little Ryburgh and Kettlestone Commons (SSSI units) occupy either side of the drain upstream of Langor Bridge and comprise unimproved pasture under ESA tier 2, fen and scrub, Downstream more open semi-improved permanent pasture predominates (ESA tiers 1 & 2) continuous with the main valley, with disused gravel pits on the north bank near the confluence with the River Wensum. Open arable farmland predominates on the valley sides, some of which is undergoing reversion to grassland, with small scattered woodland blocks/plantations. |
| Amenity Value: | A public footpath runs through Kettlestone Common. |
| Other: | None |

**Table AAo4** RWRS Langor Drain Previous works or recommendations

| | | | | | |
|---|---|---|---|---|---|
| Previous Measures (Consented): | None | | | | |
| Potential Schemes for Habitat Restoration (ECON): | None | | | | |
| Geomorphological Appraisal (2006) Options for Restoration: | | | | | |
| Reach Code | W1080 | W1081 | W1082 | W1083 | W1084 |
| Reach Status | Damaged | Damaged | Damaged | Damaged | Damaged |
| Management Class | Restore | Restore | Assist | Assist | Restore |
| Work related to weir | | | | | |
| Re-establish former channel or dimensions | | | | ✓ | ✓ |
| Reconnect river to floodplain | | | | | |
| Narrow | | | | | |
| De-silt | | | | | |
| Augment gravel or bed or water levels | | ✓ | ✓ | ✓ | ✓ |
| Monitor | | | | | |
| Reduce maintenance | | | | | |
| Improve flow & habitat diversity | | | | | |
| Establish riparian vegetation | | | | ✓ | |
| Create or maintain backwater | | | | | |
| Fix sediment ingress points | | | | | ✓ |

**Table AAo5** RWRS Langor Drain Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Towards downstream end of the reach, restore channel to its original course and dimensions and augment bed with gravel. Remove embankments. Develop marginal/bankside vegetation. Maintain coarse woody debris in the channel. | | | |
| Reference Channel Dimensions: | Width | Resistant banks: 0.7-1.0m<br>Erodible banks: 1.0-1.5m | Depth: | Resistant banks: 0.28m<br>Erodible banks: 0.25m |
| Revised Management Class: | Enhancement and restoration (particularly in lower sections - restored section expected to be approximately 1200m). | | | |
| Specific Actions Recommended: | Restore section of channel downstream. Adopt/maintain maintenance regime and riparian management to allow channel to develop a more natural form. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAo** RWRS Langor Drain Location Plan

## REACH CODE: RWRS Guist Drain

**Table AAp1** RWRS Guist Drain Reach data summary

| | |
|---|---|
| Location: | Along Guist Drain upstream of River Wensum confluence |
| NGR: | 600410, 325010 to 599810, 324800 |
| Total Reach Length: | 740m |
| Geomorphological Appraisal (2006) Reaches: | W1070 to W1071 |
| Associated Mill Summary Sheet: | No mill at up or downstream end of RWRS Guist Drain |

**Table AAp2** RWRS Guist Drain Current reach condition

| | | |
|---|---|---|
| Description: | Straightened along much of its course, except just upstream of the Wensum confluence. Floodplain contains an extensive network of drainage channels. Embanked on right bank throughout. | |
| Natural England Assessment: | Terrestrial Unit 28 supports 1.7ha of woodland (W2) towards the Wensum confluence on the right bank.<br>Terrestrial Unit 25, 26 & 27 supports a mosaic of mesotrophic grassland rush pasture and fen (including M22 and S7) mainly associated with RWRS 20.<br>Terrestrial compartments 28 & 29 support wet woodland (W2) and fen (S26). | |
| Upstream Catchment Area: | 35km$^2$ upstream of Wensum confluence | |
| Channel Dimensions (Bankfull): | Width: | 4m |
| Length Affected by Backwater: | None | |
| Maintenance Regime: | Norfolk Rivers IDB maintenance is undertaken on a need-to-do basis and is carried out in accordance with the IDB Standard Maintenance Operations document (King's Lynn Consortium of IDBs, 2000). | |

**Table AAp3** RWRS Guist Drain Constraints

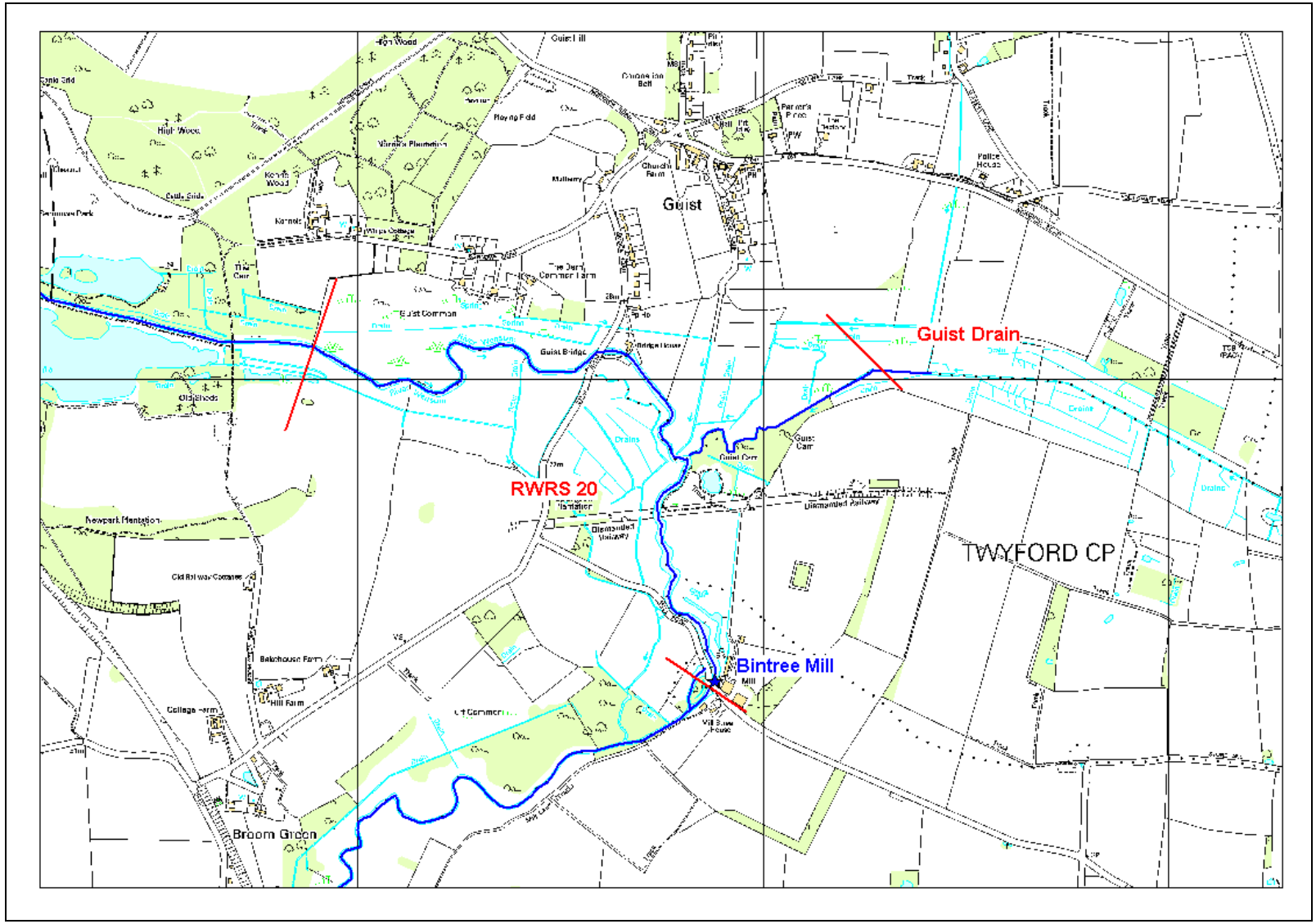
| | |
|---|---|
| Flood Risk: | Low (0 properties in the 1 in 100 year return period flood outline - Flood Zone 3) |
| Land Use: | Drained and wet semi-improved pasture (ESA tiers 1 & 2) occupy the floodplain, including SSSI units described above, with woodland/scrub (Guist Carr) at the confluence with the river. Arable farmlands, with scattered plantations, predominate in the surrounding areas. |
| Amenity Value: | Public footpath through part of site unit 25 |
| Other: | None |

**Table AAp4** RWRS Guist Drain Previous works or recommendations

| | | |
|---|---|---|
| Previous Measures (Consented): | None | |
| Potential Schemes for Habitat Restoration (ECON): | None | |
| Geomorphological Appraisal (2006) Options for Restoration: | | |
| Reach Code | W1070 | W1071 |
| Reach Status | Degraded | Damaged |
| Management Class | Restore | Enhance |
| Work related to weir | | |
| Re-establish former channel or dimensions | | ✓ |
| Reconnect river to floodplain | | |
| Narrow | | |
| De-silt | | |
| Augment gravel or bed or water levels | | ✓ |
| Monitor | | |
| Reduce maintenance | | |
| Improve flow & habitat diversity | | |
| Establish riparian vegetation | | ✓ |
| Create or maintain backwater | | |
| Fix sediment ingress points | ✓ | |

**Table AAp5** RWRS Guist Drain Reach restoration strategy

| | | | | |
|---|---|---|---|---|
| Summary of Requirements: | Towards upstream end of the reach, restore channel to its original course and dimensions and augment bed with gravel. Remove embankments. Develop marginal/bankside vegetation. Maintain coarse woody debris in the channel. | | | |
| Reference Channel Dimensions: | Width | Resistant banks: 1.9m<br>Erodible banks: 2.9m | Depth: | Resistant banks: 0.39m<br>Erodible banks: 0.35m |
| Revised Management Class: | Enhancement and restoration (particularly upstream - restored section expected to be approximately 300m). | | | |
| Specific Actions Recommended: | Restore section of channel upstream. Adopt/maintain maintenance regime and riparian management to allow channel to develop a more natural form. | | | |




Blue star is approximate location of main mill sluice; Blue line is River Wensum centre line; Red lines are RWRS reach dividers. Map scale is 1:10,830 at A4.



**Figure AAp** RWRS Guist Drain Location Plan