Wensum catchment description & background research document for DEFRA-EA Demonstration Test Catchments project, October 2009

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Introduction

The River Wensum rises near South Raynham in Norfolk and flows east through Norwich, joining the River Yare on the south-east side of the city. The catchment has a geographical area of approximately 651 km² (Figure 1). The River Wensum has long been renowned for its great angling and is a nationally and internationally important site for nature conservation with 71km designated in 1993 as a Site of Special Scientific Interest (SSSI) and as one of only 16 rivers to be designated as a European Special Area of Conservation. It is widely recognised as one of the most important chalk river habitats in the country.

Despite the high conservation status of the River Wensum, a condition assessment carried out by English Nature (now Natural England) in 2002 showed that the river was in unfavourable ecological condition. The main reasons were: water quality (high phosphate), siltation, and physical modifications that limit its ecological and hydrological potential to support chalk river habitat. Water quality problems are being addressed by phosphate removal at Fakenham and Dereham STWs, and other smaller works in the catchment and phosphorus in agricultural run-off is being addressed by the ECSFDI. One of the main impacts of fine sediment ingress has been a major decline in numbers of native fish species in the river requiring gravel beds to spawn e.g. dace and brown trout (Perrow and Punchard, 1998). The ECSFDI is addressing this issue through focussing on mitigation options to decrease the ingress of agriculturally derived sediment into the river channel. The River Wensum Restoration Strategy, an initiative developed by Natural England in partnership with the EA and the Water Management Alliance, aims to address the physical modifications to the river to restore a measure of hydrological functioning so that the river can sustain wildlife and fisheries characteristic of the river type (Natural England, 2009). This is one of only two ‘whole river’ restoration strategies in England.

Policy background

- 69.1 km of the River Wensum was designated as a Sensitive Area (Eutrophic) under the Urban Waste Water Treatment Directive in 1998 requiring phosphorus (P) removal at qualifying sewage treatment works (East Dereham and Fakenham).

- River Wensum SSSI - designated in 1993, the River Wensum is one of the best examples of a naturally enriched lowland calcareous river in the country. SSSI includes 71km of river channel between South Raynham and Hellesdon Mill, together with sections of two tributaries an area of 393 hectares (c. 982 acres).

- River Wensum designated a Special Area of Conservation (SAC) in 2001 under the Habitats Directive. Interest features requiring conservation objectives are: Bullhead (a fish), Brook Lamprey (a fish), White-clawed crayfish, Desmoulin’s Whorl Snail and watercourses with water crowfoot and water starwort vegetation (Ranunculus habitat). Under the Habitats Directive, appropriate river water quality standards have been set to enable Environment Agency and Natural England to assess the risk of damage to aquatic habitats or species from consented point source discharges (review of consents). See Table 1
Table 1 Targets for sites of interest features

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Feature and Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological class - GQA class</td>
<td>Bullhead, brook lamprey, white-clawed crayfish and Desmoulin’s whorl snail all &gt;='b' Also no drop in class from existing situation</td>
</tr>
<tr>
<td>River Ecosystem (RE) Class</td>
<td>Bullhead, brook lamprey, and Desmoulin’s whorl snail &gt;=RE2 white-clawed crayfish&gt;=RE3 Also no drop in class from existing situation</td>
</tr>
<tr>
<td>Suspended solids (annual average)</td>
<td>Bullhead, brook lamprey and white-clawed crayfish &lt;=25 mg/l-1</td>
</tr>
<tr>
<td>Soluble Reactive Phosphorus (annual mean)</td>
<td>An annual average phosphate concentration of 0.05mg/l from the upstream limits of the SSSI to the confluence of the River Wensum with the White Water and 0.1mg/l from that confluence to the downstream limit of the SSSI [check]</td>
</tr>
</tbody>
</table>

Despite P removal at Dereham and Fakenham STWs, and future phosphate stripping at seven small STWs under the AMP4 (2005-2010) investment programme (Bylaugh, East Rudham, Foulsham, Mattishall, North Elmham, Reepham, Sculthorpe, Swanton Morley), it is predicted that the River Wensum will have a high level of non-compliance with Habitats Directive phosphorus (P) standards (EA, 2002 – check with Louise Evans, Habitats Directive). It is predicted that introduction of P removal at all works >1000 population equivalent would only include 48% of the population due to the significant unsewered rural population. Under the Habitats Regulations there are no specific provisions for the Environment Agency on the control of unregulated and diffuse sources. However when considering management options to protect sites under the Habitats Regulations the Environment Agency must take unregulated and diffuse sources into account when assessing in combination effects. Site action plans developed under the Habitats Regulations were used to inform the River Basin Management Plans developed for the Water Framework Directive.

- **Water Framework Directive.** The River Wensum is not currently reaching the required Water Framework Directive (WFD) P target as set out by the UK’s Technical Advisory Group (UKTAG) for the WFD for SAC rivers and that this is the case upstream of the SSSI as well as through the SAC component. This means that the River’s current overall ecological status is Moderate (high confidence).

The River Wensum is part of the Anglian River Basin District under the Water Framework Directive. Significant water management issues identified in the Anglian River Basin Management Plan consultation were:
- **diffuse pollution from rural areas** (nitrates, phosphorus and sediment)
- **diffuse pollution from urban areas** and transport (nitrates, phosphorus and sediment)
- **point source pollution** (abstraction and other artificial flow pressures, nitrates, phosphorus and sediment)
- **flow problems** (abstraction and other artificial flow pressures, alien species, physical modifications (rivers and lakes) and sediment)
- alien species
- physical modifications (abstraction and other artificial flow pressures, physical modifications (rivers, lakes, estuaries and coasts) and sediment).

Catchment Sensitive Farming (CSF)

The River Wensum was designated as a priority catchment under the ECSFDI in 2006 with two target areas being identified south of Fakenham (Upper Wensum) and around Reedham (North Wensum). The two areas total approximately 25% of the total area of the catchment which is 63000 hectares and holds approximately 180 holdings. The CSF project in these areas focuses on reducing sediment and phosphate diffuse pollution. The target areas were selected because: (i) Soil type, generally light (sandy loam) or medium (sandy clay loam or clay loam); (ii) High predicted P and sediment loss to watercourses and (iii) anecdotal evidence of sedimentation of watercourses from diffuse agricultural pollution. Subsequently, the Wensum has been identified as high priority for pesticides.

In 2006, the objective for the Wensum was to have 13,000 ha under catchment sensitive farming management with 70% land in target area to have an approved SMP. By the end of March 2008 there had been: 8 ‘events’ held; 78 1:1 advice visits covering 75 holdings; 81 holdings engaged covering an area of 10,350 ha (equates to 57% of the target area/16% of the total Wensum priority catchment area). Also, by the end of March 2008, approximately 200 ‘counts’ of planned/implemented DWPA mitigation methods were recorded covering land use change, soil management and livestock management (see Appendix 1).

In the Wensum catchment the Capital Grant Scheme funding priority statement (2009/10) states that Natural England are particularly interested in funding applications which aim to reduce sediment, nutrient and pesticide run-off from agricultural holdings. A list of capital items which will assist in delivering these aims is provided in order of priority (item codes in brackets):

- Yard works for clean and dirty water separation (CSF014)
- Lined biobeds (off-set or drive-over) (CSF022)
- Roofs for slurry and silage stores (CSF026)
- Roofing of manure storage and livestock gathering areas (CSF023)
- Livestock and farm machinery tracks (CSF021)
- Resurfacing of gateways (CSF016)
- Relocation of gates (CSF001)
- Watercourse fencing (CSF003)
- Cross drains on or in farm tracks (CSF011)
- Pesticide sprayer loading and wash-down areas (CSF027)
- Sediment ponds and traps (CSF012)
- Livestock troughs with associated pipework (as an alternative to livestock drinking from watercourses) (CSF010)
- Hard bases for livestock drinkers and feeders (CSF007)
- Fencing for buffer strips, marshes, wet grassland, wet woodland, ponds (CSF004)
- Livestock drinking bays (CSF006)
- Watercourse crossings (CSF024)
- Rainwater storage tanks, first-flush rainwater diverters and downpipe filters (CSF017)
- Installation of piped culverts in ditches (CSF015)
- Swales with check dams (CSF013)
- Pasture pumps and associated pipework (CSF008)
- Ram pumps and associated pipework (CSF009)
- Solar-powered electric fence kits for seasonal fencing (CSF005)
- Installation of livestock drinking troughs in draining pens for freshly dipped sheep (CSF020)
- Sheep dip drainage aprons with residue sumps (CSF019)
- Relocation of sheep dips/pens (CSF018)
- Water gates (CSF002)
Catchment description

Geology & hydrogeology
The River Wensum catchment is predominantly Senonian (Upper Cretaceous) chalk solid geology overlain by quaternary drift deposits (<10m thickness) of mixed origin (chalk boulder clay, glacial sand and gravel) (Figure 2a and 2b). In the west the chalk bedrock is close to the surface and the flow is derived primarily from the ground waters of the chalk aquifer. As the river progresses east the depth of the glacial sediments overlying the chalk increase, and the proportion of flow derived from surface waters also increases. The River Wensum, therefore, is not typical of a chalk river catchment as many of the tributary headwaters are not winterbournes (streams or rivers that are dry through the summer months), but flow from clay.

Soil & topography
In the central area of the catchment the soils are of low permeability where coarse loams overlie clay (Figures 3a and 3b). Lighter sandy loam soils are extensive in the western headwaters and also in the eastern part of the catchment between Reepham and Norwich. The soils exhibit high local variability and can vary from medium clay loams to light sandy loams within a very small area.

The catchment does not rise above 95m (Bradedham Hill) (Figure 4). The River Wensum drains in an easterly direction with a low gradient, particularly downstream of Fakenham. The majority of the catchment (78%) has slope of 0-3 degrees, with only a small percentage of land area with slope 3-7 degrees and greater (Figure 5 - slope). The steeper valley sides and the lighter sandy/sandy-loam soils are sensitive to water and wind erosion (Hodge et al., 1984).

Rainfall & Hydrology
The Wensum catchment long-term average annual rainfall is 650-700mm. This compares to the average for England and Wales of 920mm. [Figure 6a]

Environment Agency flow gauging stations in the catchment are shown in Figure 7. They are largely located at the inflows of the principal tributaries: River Tat, Langor Drain, Guist Drain, Wendling Beck (Whitewater/Blackwater), Penny Spot Beck, Blackwater, Swannington Beck and River Tud. The principal hydrological pathway to the river network is through slow percolation into the underlying aquifer and subsequent discharge via springs. The river hydrograph displays a damped response to rainfall events due to the catchment permeability and runoff storage in the chalk aquifer, although the influence of overlying drift deposits is increasingly obvious downstream. This is reflected by a base flow index (BFIHOST) ranging from 0.93 on the River Tat to 0.53 at the gauging station on Wendling Beck (Table 1). It is also reflected in the CERF estimate of slow response flow (>three days) as a proportion of Hydrologically Effective Rainfall (Figure 6c and 6d). The flow regime is typified by a progressive seasonal rise in water levels, peaking in March/April (Geodata, 2006).

The rivers flow regime is heavily modified by water level management (mainly abstraction and effluent discharge), 14 water mills and an extensive drainage network. The water mill structures generate a stepped bed and water profile where the bed tends to be steeper downstream of the mills and less steep in the ponded stretch upstream of the mills.
Land Use
Agricultural land use makes up 75% of the catchment area (broken down as 35% cereals, 25% other crops, 15% grassland), with the remaining land split approximately evenly between urban and woodland (Figure 8). The main urban centres in the catchment are Norwich, Fakenham and East Dereham with populations of 250,000, 10,000 and 20000, respectively (Figure 10a). Intensively farmed arable land dominates the valley sides and the flood plain is characterized by a mix of semi-improved grassland, scrub, gravel pits, wetlands and scattered woodland. Unusual for a lowland river, grassland in the catchment is still traditionally managed by cattle grazing; although animal numbers are decreasing. Livestock farming is dominated by poultry and pig rearing, although there is also sheep and cattle grazing. There were over 48,000 pigs in the catchment in 2005 though the British Pig Executive suggests numbers have dropped in the last five years. Average farm size is relatively small (69 ha), with 459 out of 824 farms under 10 ha. There are 174 farms included in the Entry Level Scheme covering a total of 43,000 of the 63,000 hectares of farm land in the catchment.

Documented land-use changes since the early 1900’s which are largely responsible for the large quantity of fine sediments deposited in the river system include:
- Loss of floodplain meadows in the river corridor.
- 40% increase in surface water drainage network since 1904
- Intensive programme of land drainage in the 1940s to enable the expansion and intensification of cultivation.
- Decrease in permanent grassland and heath
- Increase in sand and gravel extraction in the Wensum valley
- Increase in free range pig units on sandy soils.
- Expansion of urban areas (locally around Norwich, Dereham, Fakenham) and infrastructure.

Source: Geodata, 2006

Catchment pressures

Water Resource Use [need to add map of major water abstraction points]
The Broadland Rivers Catchment Abstraction Management Strategy (CAMS) was published in March 2006. It set out how water abstractions would be managed until 2011, outlined where water is available, and also, if relevant, where current rates of abstraction need to be reduced. The Wensum catchment is divided in to a series of 3 water resources management units ((WRMU’s), Wensum, Tud and Blackwater) to which the same licensing strategy can be applied due to their resource availability status and or the protection of a downstream critical Assessment Point. The Environment Agency published the Broadland Rivers CAMS Annual Update in March 2008 as the resource status and restrictions had changed since the CAMS was originally published. The update gives an indication of how much water is available for further abstraction and the associated restrictions that may apply to new or varied abstraction licences. The resource status for WRMU D (Wensum SAC) is to remain within the status of Over Licensed. The resource availability status for WRMU D remains at Over Licensed. There has however been an improvement with approximately 0.9ML/d of licensed resources recovered. The resource status for WRMU E (Lower River Wensum and River Tud) is to remain within the status of Over Licensed. The resource availability status for WRMU E remains at Over Licensed. The resource status target for WRMU F (Upper River Bure and Blackwater) is to move from Over Licensed to No Water Available.
Agricultural pressures
There is considerable spatial variation in the vulnerability of agricultural land to nutrient and sediment loss [Figures 9a-f], due to a range of factors such as rainfall patterns, soil type, slope, stream density and road/track networks. The form and timing of this loss, in ecological terms, is also significant (Jarvie et al., 2005; Withers & Jarvie, 2008).

Nitrate: The Environment Agency’s risk assessments for the Water Framework Directive based on modelled pressures indicate that 6 of the 19 waterbodies within the Wensum catchment are at risk of failing the 50 mg l\(^{-1}\) threshold for nitrate, or 11.3 mg l\(^{-1}\) as nitrate-N (Wendling Beck, Blackwater Drain, Tat and the tributary inputting at Twyford, Figure 9a). The main stem of the River Wensum is classified as probably not at risk from nitrate pressure, and the River Tud is classified as probably at risk. It is important to note that the WFD pressure assessments include nitrogen loss from agricultural land use, consented sewage treatment works, and areas of urban land use. Predictions of nitrate loss from agriculture only using the NEAP-N nitrate leaching model at the 1km\(^2\) scale show greater spatial variation across the catchment (Figure 9b). The highest losses are in from the Blackwater drain and Swannington Beck. It is important to note that the NEAP-N model does not represent the hydrological processes that transport nitrate from the base of the soil profile to the river.

Phosphorus: The Environment Agency’s diffuse pollution risk from agriculture assessments for the Water Framework Directive show the majority of the River Wensum catchment is at risk or probably at risk from phosphorus(excluding the River Tat and Swannington Beck). The main stem of the River Wensum, Wendling Beck and the River Tud are predicted to be at risk from phosphorus (Figure 9c). Using the PSYCHIC decision support system, phosphorus losses reflected the soils and hydrology, with highest losses in the central area of the catchment where the soils are of low permeability and the dominant hydrological pathway is quick flow (Figure 9b, Figure 6c). The lowest phosphorus losses were predicted to be in: (i) the north west of the catchment (River Tat and headwaters of the Wensum) where the chalk bedrock is close to the surface and the flow is derived primarily from the ground waters of the chalk aquifer, and (ii) the lower reaches of the catchment where there are free draining soils in unconsolidated sands and gravels with high storage.

Sediment: The latest Water Framework Directive characterisation maps show that the whole of the Wensum catchment is at risk or probably at risk from the direct effects of sediment (Figure 9e). PSYCHIC model predictions of sediment loss show a more spatially differentiated pattern with the highest losses coinciding with highly erodible soils in the Tud, Wendling Beck, Swannington Beck and the Blackwater drain (Figure 9f). The Geomorphological Appraisal undertaken by Geodata (2006) also provides maps of sediment sources and sinks in the River Wensum catchment using a system of scores and weights. Highly erodible soils are found in the lower reaches of the Wensum (downstream of Lenwade), the Blackwater from Reepham, Swannington Beck and the lower reaches of the Tud. In the upper reaches of the Wensum, ‘hotspots’ occur south of Fakenham, at Doughton and around the headwaters of the Tat. The catchment (steep valley sides and lighter sandy/sandy loam soils), channel banks, and the bed surface were identified as potential sources of sediment. Clay to coarse sand sized sediments were found to be the main source of materials from the catchment, derived from runoff from:
Erosion of bare or arable fields and pasture (especially where fields have no buffer zone and are adjacent to the channel
- Roadside verges by traffic, tracks and footpaths
- Trampling of the floodplain or banks by livestock
- Pig farm units
- Recently cleared drains

Sediment management options were identified, focussing on both the sources and hydrological pathways (hillslope runoff, springs that connect to the main channel, tracks that cross the main channel, IDB or road drains that discharge in to the main channel etc.).

Non-agricultural pressures
Rivers in the catchment receive treated domestic effluent from 12 sewage treatment works (Figure 10b) and Table 3. Given the predominantly rural nature of the catchment, there are also a significant number of single dwelling or small community discharges within the areas, some of which are consented (Figures 10c and d). There are also a significant number of consented agricultural activities including intensive pig rearing units, and Bernard Matthews poultry farms and food processing units. Further details of these activities are available from the Environment Agency’s ‘what’s in your backyard’ webpage.

Table 3: Summary information for major (>2000 PE) STWs in the Wensum catchment [Ask for Area staff help to populate table. Unsure if STW highlighted in blue are correctly named]

<table>
<thead>
<tr>
<th>STW</th>
<th>Receiving water</th>
<th>Population equivalent</th>
<th>Target concentration</th>
<th>Phosphorus load* (kg/day)</th>
<th>P removal date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fakenham</td>
<td>Wensum</td>
<td>13439</td>
<td>2.00</td>
<td></td>
<td>31/12/2004</td>
</tr>
<tr>
<td>East Dereham</td>
<td>Wensum</td>
<td>17475</td>
<td>2.00</td>
<td></td>
<td>31/12/2004</td>
</tr>
<tr>
<td>Syderstone</td>
<td>Rudham stream</td>
<td></td>
<td>2.00</td>
<td></td>
<td>31/03/2008</td>
</tr>
<tr>
<td>East Rudham</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stibbard</td>
<td>Foulsham beck</td>
<td>1.00</td>
<td></td>
<td></td>
<td>31/03/2008</td>
</tr>
<tr>
<td>North Elmham</td>
<td>Wensum</td>
<td>1.00</td>
<td></td>
<td></td>
<td>31/03/2008</td>
</tr>
<tr>
<td>Swanton Morley</td>
<td>Wensum</td>
<td>2.00</td>
<td></td>
<td></td>
<td>31/03/2008</td>
</tr>
<tr>
<td>Mill Street</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swannington</td>
<td>River Tud</td>
<td>1.00</td>
<td></td>
<td></td>
<td>31/03/2008</td>
</tr>
<tr>
<td>Mattishall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Tuddnham</td>
<td></td>
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</tbody>
</table>

Water Quality
Environment Agency surface and groundwater monitoring locations in the River Wensum catchment are identified in Figure 12.

Phosphorus: Phosphorus levels in the Wensum have been an issue for a long time (eg Boar, 1994) with levels increasing markedly from 1975 in association with effluent from STWs. Phosphate stripping at Fakenham and Dereham STWs under AMP3 and seven smaller works under AMP4 (in addition to phosphate stripping at the Bernard Matthews poultry processing factory at Great Witchingham) have reduced phosphorus loads entering the watercourse, however there are still high levels of phosphorus stored in the sediment (Geodata, 2006). Chalk rivers are characterised by naturally low levels of phosphate, so for this reason, the following water quality targets for annual average orthophosphate have been set for the Wensum SSSI: 0.04 mg l⁻¹ from the upstream limits.
of the SSSI to Sculthorpe; 0.06 mg l\(^{-1}\) from Sculthorpe to Taverham Bridge; and 0.1 mg l\(^{-1}\) from Taverham Bridge to the downstream limit of the SSSI. From the maps shown in Figure 13c and 15b, it is evident that these targets are being exceeded in certain tributaries, in particular Wendling Beck, Blackwater and certain stretches of the River Tud. Phosphate levels in the groundwater are elevated between 0.05 and 0.1 mg l\(^{-1}\) in the Tat and Swannington beck.

**Nitrate**: Moderate nitrate levels were measured in 2007 in surface water (>8.0 mg l\(^{-1}\) as nitrate-N) in the Tat, Blackwater, Wendling beck and a small part of the Tud river subcatchments are evident from Figure 13a. These coincide with the GQA classifications (based on a 3-year monitoring programme) for 2006 given in figure 15. Mean borehole concentrations for 2005-2008 shown in Figure 14a also show elevated levels (> 10 mg l\(^{-1}\) as nitrate-N) in the Tat subcatchment. Consequently, only certain parts of the catchment are within an NVZ (refer to DEFRA website).

**Sediment**: Due to the impact of silt on the fisheries and wider ecology of the River Wensum, under the ECSFDI an enhanced monitoring programme focussing on sediment has been established. Do we have any information from ECSFDI to input here? The build up of silt deposits has been widely reported due to the heavily modified flow regime.

**WFD classifications**

In 2007 the Environment Agency made a change to the way the status of water bodies is assessed. For twenty years, a General Quality Assessment (GQA) scheme had been used to assess river water quality in terms of chemistry, biology and nutrients. Figure 15 shows the results of the GQA assessment for 2006, with stretches of water graded from poor to very good. However, the Water Framework Directive requires a more comprehensive way of assessing the whole water environment to help direct action to where it is most needed. For surface waters there are two separate classifications for water bodies, ecological and chemical. For a water body to be in overall ‘good’ status both ecological and chemical status must be at least ‘good’.

The Environment Agency website holds the river basin management plans for England and Wales, and a range of other information about the environment, river basin management planning and the Water Framework Directive. [www.environment-agency.gov.uk/wfd](http://www.environment-agency.gov.uk/wfd). Maps are available showing the current state of waters, including:

- Ecological status or potential for rivers, canals and surface water transfers
- Chemical status for rivers, lakes, estuarine and coastal waters
- Chemical status and trends for groundwater
- Quantitative status for groundwater

Information related to the plans can be retrieved by using ‘What's In Your Backyard’ [http://www.environment-agency.gov.uk/maps](http://www.environment-agency.gov.uk/maps). Note: these pages represent the data for the draft river basin management plans which were published for public consultation between December 2008 and June 2009. The River Basin Management Plans have been submitted to the Secretary of State and Welsh Ministers for approval. Once approval is received in December 2009, the data on What's in Your Backyard will be updated to reflect the data contained in these plans.

Figure 16 [contact Area staff to get Figure A.2 Ecological status or potential for rivers, canals and surface water transfers, Environment Agency River Basin Management Plan, Anglian River Basin District 6 Annex A: Current state of our waters December 2009] shows the current ecological status of rivers, canals and surface water transfers in the Wensum catchment. The main stem of the Wensum is classified as bad ecological status,
the Blackwater tributary is poor, and the remainder of the catchment is moderate ecological potential (Heavily Modified Water Body classification). Then main stem is failing to achieve good chemical status and the whole catchment has poor groundwater chemical status.

**Completed and on-going research and other initiatives**

Due to its high conservation status, the Wensum is an extremely well studied catchment. In Annex 2, we have attempted to identify some of the key research projects, internal Environment Agency projects and wider catchment initiatives which will contribute to the Demonstration Test Catchments initiative. This is by no means an exhaustive list.

**References:**


Annex 1


Land use change
- Use forestry and set aside schemes to good effect, Either whole field or tactically in landscape (14)

Soil Management
- Add compost, sewage sludge, paper waste or other off-farm organic matter source as a soil conditioner (1)
- Adopt minimal cultivation systems where soils are suitable (8)
- Adopt recognised soil management plan (60)
- Avoid high risk crops on fields at high risk of erosion (2)
- Check for and deal with capping and sub-surface compaction (28)
- Cultivate and drill across the slope where it is safe to do so (12)
- Cultivate land for crop establishment in spring rather than autumn (2)
- Establish in-field grass buffer strips, including valley bottom (22)
- Leave autumn seedbed as rough as is consistent with herbicide program (21)
- Maintain and enhance soil organic matter (2)
- Plough in crop residues/green manure as a soil conditioner (1)
- Retain over wintering stubble (4)
- Harvest high risk fields or medium risk fields with high risk crops early in autumn and introduce a cover crop (1)
- Use low pressure tyres for farm machinery to minimise compaction (3)

Livestock management
- Avoid poaching (6)
- Move feed and watering troughs at regular intervals or install onto permanent hard standing (1)
- Reduce field stocking rates when soils are wet (3)
- Where soil and weather conditions are unfavourable, reduce the length of the grazing day or grazing season (2)

[No information available on (i) Fertiliser management (ii) Manure management (iii) Farm infrastructure (iv) Pesticide management]

Supporting Figures
Note: All maps in this document are covered by the following:
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Figure 1. Wensum catchment
Figure 2. Bedrock and superficial geology (major tributary catchments shown)

a) bedrock geology

b) superficial geology
Figure 3. Soil series (NATMAP soil vector data) and a simplification of Hydrology of Soil Types (HOST) classification (major tributary catchments shown).

a) Soil series

Free draining permeable soils over chalk with moderate storage
Free draining soils in unconsolidated sands and gravels with high storage
Seasonally waterlogged soils
Drained lowland peaty soil, groundwater controlled by pumping
Slowly permeable, seasonally waterlogged soils

b) Simplified HOST classification
Figure 4 Elevation
Figure 5. Slope
Figure 6. a) Long-term average annual rainfall (mm); b) CERF estimate of annual hydrologically effective rainfall (HER) (mm); c) CERF estimate of quick flow (<three days) as proportion of HER and flow; and d) CERF estimate of slow response flow (>three days) as proportion of HER.
Figure 7. Location of flow gauging sites that have coincident water quality sampling

Table 1 Flood Estimation Handbook parameters for Wensum gauging sites

<table>
<thead>
<tr>
<th>Site name</th>
<th>AREA (km²)</th>
<th>POT</th>
<th>Qmed (cumecs)</th>
<th>BFI HOST (%)</th>
<th>SPR HOST (%)</th>
<th>Prop Wet</th>
</tr>
</thead>
<tbody>
<tr>
<td>River Tat @ Tatterford Common</td>
<td>70.8</td>
<td>1.5</td>
<td>0.93</td>
<td>9.9</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>River Tud @ Costessey Park Bridge</td>
<td>72.2</td>
<td>5.3</td>
<td>0.60</td>
<td>32.6</td>
<td>0.31</td>
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<tr>
<td>River Wensum @ Black Lane Worthing</td>
<td>18.1</td>
<td>1.6</td>
<td>0.67</td>
<td>28.5</td>
<td>0.31</td>
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<td>River Wensum @ Great Witchingham Bridge</td>
<td>499.2</td>
<td>20.1</td>
<td>0.67</td>
<td>27.0</td>
<td>0.3</td>
<td></td>
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<td>River Wensum @ Helhoughton Bridge</td>
<td>55.4</td>
<td>2.9</td>
<td>0.76</td>
<td>20.4</td>
<td>0.3</td>
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<td>River Wensum @ Sculthorpe Mill</td>
<td>143.0</td>
<td>3.9</td>
<td>0.86</td>
<td>14.3</td>
<td>0.29</td>
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<td>River Wensum @ Swanton Morley Bridge</td>
<td>377.4</td>
<td>16.4</td>
<td>0.69</td>
<td>25.4</td>
<td>0.3</td>
<td></td>
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<tr>
<td>River Wensum @ Sweet Briar Road Bridge</td>
<td>650.3</td>
<td>23.4</td>
<td>0.68</td>
<td>26.6</td>
<td>0.3</td>
<td></td>
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<tr>
<td>Wendling Beck @ Pear Tree Corner Bridge</td>
<td>100.7</td>
<td>10.5</td>
<td>0.53</td>
<td>35.6</td>
<td>0.31</td>
<td></td>
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</tbody>
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Abbreviations:
- POT: Peaks Over a Threshold
- QMED: Median Annual Flood (with return period 2 years)
- BFIHOST: Base Flow Index derived using the HOST soil classification
- SPRHOST: Standard percentage runoff derived using the HOST soil classification
- Propwet: FEH index of proportion of time that soil is wet
Figure 8 a) Simplified classification of CEH LandCover2004; and Defra 2004 head km$^2$ b) beef; c) dairy; d) sheep; e) pigs; and f) poultry
Figure 9. Mapped Water Framework Directive pressure classes and NEAPN and PSYCHIC estimates of nutrient and sediment export (25%iles) for a typical climatic year (1961-90)

- **a)** WFD nitrate
- **b)** NEAPN nitrate kg ha\(^{-1}\) yr\(^{-1}\)
- **c)** WFD agricultural phosphorus
- **d)** PSYCHIC diffuse phosphorus kg ha\(^{-1}\) yr\(^{-1}\)
- **e)** WFD sediment
- **f)** PSYCHIC sediment kg ha\(^{-1}\) yr\(^{-1}\)
Figure 10 Non-agricultural pressures on water quality
Figure 11 Road and rail networks

- **M way**
- **Primary road**
- **A road**
- **B road**
- **Minor road**
Figure 12. Monitoring a) ECSFDI water quality and flow monitoring points; b) Agency surface water and groundwater water quality monitoring points; and c) river flow gauging points

a) coincident flow and WQ  
b) surface and groundwater WQ points

c) flow

- ECSFDI coincident WQ and flow
- Surface water WQ monitoring point
- GQA chemistry
- GQA biology
- Groundwater WQ monitoring point
- ECSFDI flow gauge
- Flow gauge in operation
Figure 13 Mean surface water concentrations from Agency monitoring 2007

a) nitrate mgL-1
- 5.5 - 6.4
- 6.5 - 7.2
- 7.3 - 8.1
- 8.2 - 8.9
- 9.0 - 9.8

b) suspended solids mgL-1
- 4.3 - 7.0
- 7.1 - 9.7
- 9.8 - 12.4
- 12.5 - 16.0
- 15.1 - 17.7

c) orthophosphate mgL-1
- 0.05 - 0.07
- 0.08 - 0.09
- 0.10 - 0.11
- 0.12 - 0.13
- 0.14 - 0.15

d) total phosphorus mgL-1
- 0.06 - 0.08
- 0.09 - 0.11
- 0.12 - 0.13
- 0.14 - 0.15
- 0.16 - 0.18
Figure 14 Mean borehole concentration for 2005-08: a) nitrate and b) phosphate

a) nitrate mgL-1

b) phosphate mgL-1
Figure 15 General Quality Assessment

a) GQA nitrate

b) GQA phosphate

c) GQA biology

Legend:
- **Very good**
- **Good**
- **Fairly good**
- **Fair**
- **Poor**
- **Bad**
- **Ungraded**
Figure 16 Water quality trend analysis
### PROJECT | ORGANISATIONS INVOLVED | INFORMATION DELIVERABLE TO DTC | RELEVANT DATES | FURTHER INFORMATION
--- | --- | --- | --- | ---

Baseline hydrochemical data | UEA | Wensum surface water and Chalk groundwater survey by PhD student Sarah Wexler conducted during 2007-09 | 2007-2009 | S.Wexler@uea.ac.uk  
Tel: +44 (0)1603 59 3990

Baseline Report Series: 21. The Chalk and Crag of north Norfolk and the Waveney Catchment | EA and British Geology Society | Characterises the major aquifers in the Wensum catchment and identifies long term trends in water quality at representative localities in the aquifer | Published 2006 | Groundwater Systems and Water Quality Commissioned Report CR/06/043N  
Science Group: Air, Land & Water  
Technical Report NC/99/74/21

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<tr>
<td>Nitrogen species and stable isotope data</td>
<td>UEA</td>
<td>Seasonal surface water sampling along the length of the River Wensum to determine controls on inorganic chemistry with special emphasis on the processing of nitrogen species as revealed by dual-isotope (nitrogen and oxygen isotopes of nitrate) . Sarah Wexler PhD thesis with completion in mid-2010.</td>
<td>2007-2009</td>
<td><a href="mailto:S.Wexler@uea.ac.uk">S.Wexler@uea.ac.uk</a> Tel: +44 (0)1603 59 3990</td>
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<tr>
<td>Tracing the sources and fate of diffuse nitrate contamination in a lowland agricultural catchment using a dual-isotope method</td>
<td>UEA, Sarah Wexler, Kevin Hiscock, Paul Dennis</td>
<td></td>
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<tr>
<td>Modelling Soil Erosion and Runoff Risk</td>
<td>UEA</td>
<td>Catchment Governance, stakeholder engagement, modelling of erosion risk based on field to regional models</td>
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<td>Current RELU project modelling the economic costs and benefits of WFD implementation. New ESRC project on land use change and ecosystem services starting in 2010.</td>
<td>UEA social sciences, ask sean for name - Presented at Wensum workshop</td>
<td>3D Visualisation tools, very powerful for engagement</td>
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| River Wensum restoration strategy (NECR010) | Funded by Natural England. | The focus of the restoration strategy is to address the physical modifications to the river to restore a measure of hydrological functioning so that it can sustain wildlife and fisheries characteristic of the river type. The restoration strategy was finalised in November 2007. The restoration plan identified several key influences on hydrological functioning:  
  • 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. 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.  
  • channel dredging; straightening; and the presence of embankments (only about 20% of the surveyed channel remains largely unmodified)  
  • intensive agriculture in the upper catchment, generating run off of silt and nutrients,  
  • an extensive network of artificial drainage channels in the floodplain, affecting flows and water levels | Ongoing | (Coombes, M., Curini, A., Howard Keeble, A., Green, T. and Soar, P. 2009. River Wensum Restoration Strategy. Natural England Research Reports, Number 024)  
http://naturalengland.etraderstores.com/NaturalEnglandShop/NECR010 |
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<tr>
<td>River Wensum Special Area of Conservation (SAC) Geomorphological Appraisal</td>
<td>Commissioned by English Nature, funded by EN, EA and King’s Lynn Consortium of Internal Drainage Boards. Produced by GeoData</td>
<td>Aim: to develop, through an understanding of the physical processes of sediment transport, a vision for river restoration for the River Wensum, whilst balancing these against the constraints imposed by flood risk management. Three approaches were used: Fluvial Audit; Geomorphological dynamics assessment; and multi-criteria analysis to classify the river network into river modification, management and sediment system categories.</td>
<td>2005</td>
<td>English Nature Research Report 685 – A Geomorphological Appraisal of the River Wensum Special Area of Conservation</td>
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<tr>
<td>River Wensum – Catchment and Sediment Management</td>
<td>Broads Forum and Natural England</td>
<td>This report describes the objectives and achievements of two initiatives on the River Wensum SSSI – the ECSFDI and the Wensum Restoration Strategy.</td>
<td>September 2008</td>
<td><a href="http://www.boads-authority.gov.uk/%5Brepor">www.boads-authority.gov.uk/%5Brepor</a> t%5D%20River%20Wensum%20e28093</td>
</tr>
<tr>
<td>Assessment of the impact of nutrient removal on eutrophic rivers (P2-127/TR)</td>
<td>EA funded project undertaken by Leicester University</td>
<td>River Wensum was studied to determine the effects of P-stripping from effluents discharging from Fakenham and East Dereham STWs. Recommendations are made for conservation, management and policy issues related to eutrophication in lowland rivers. Key relevant findings: (1) Phosphorus control led to a decrease of 64% and 76% total phosphorus at Dereham and Fakenham, respectively, with a significant decrease of SRP which may have been due to the high flow regime of the year 2000-2001. (2) Aquatic plants were not found to be an indicator of nutrient levels in the rivers studied since all the rivers were enriched at concentrations beyond those at which plants might show a response. Other factors, particularly alkalinity (geology) and river power (river size) were major determinants of macrophyte communities.</td>
<td>1998-2002</td>
<td>Demars, B. and Harper, D. Water Column and Sediment Phosphorus in a Calcareous Lowland River and Their Differential Response to Point Source Control Measures. Water, Air, and Soil Pollution, Volume 167, Numbers 1-4, October 2005, pp. 273-293(21) B O L Demars and D M Harper. 2002. Assessment of the impact of nutrient removal on eutrophic rivers. Environment Agency report No. P2-127.</td>
</tr>
<tr>
<td>Appraisal of phosphorus and sediment transfer in three pilot areas identified for the catchment sensitive farming initiative in England: application of the prototype PSYCHIC model</td>
<td>DEFRA funded. ADAS contractors</td>
<td>Modelled annual total P export was 0.9kg P ha⁻¹ year⁻¹ from the Wensum catchment. Corresponding sediment export is predicted to be 70 kg ha⁻¹ year⁻¹, respectively. The findings highlight the importance of factors including P application rates, soil types and the increased connectivity provided by assisted drainage in determining pollution 'hotspots'. Model output was used to engage stakeholders and devise abatement strategies as part of the ECSFDI.</td>
<td>Undertaken in 2006</td>
<td>Collins, A.L., Strömqvist,J., Davison, P. S., Lord, E. I. 2007. Soil Use and Management, Volume 23, Supplement 1, pp. 117-132(16)</td>
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<tr>
<td>Water Resources Associates has undertaken a new modelling study of the River Wensum using INCA software, to assess the potential for reducing nitrate and phosphorus in the river systems.</td>
<td>Water Resources Associates and Reading University</td>
<td>The INCA-N and INCA-P models were used to investigate a range of possible nutrient reduction measures. The results show that it will be difficult to reduce phosphorus significantly because of the store of phosphorus available in the soils and the sediments.</td>
<td>2009</td>
<td>Paul Whitehead (<a href="mailto:pw04@watres.com">pw04@watres.com</a>). Water Resource Associates – Bulletin - Issue No 19 July 2009</td>
</tr>
<tr>
<td>A modelling-based approach to support a reduction in diffuse source pollution</td>
<td>Funder: Anglian Water. Contractor: Cranfield University</td>
<td>The SWAT model was applied to the Wensum catchment to investigate the utility of such a modelling tool for identification of potential source areas of water, sediment, nitrate and phosphate</td>
<td></td>
<td>Professor Sue White Email: <a href="mailto:sue.white@cranfield.ac.uk">sue.white@cranfield.ac.uk</a></td>
</tr>
</tbody>
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