River Wissey Investigations: Linking Hydrology and Ecology

Summary of Recommendations for the River Wissey

1. INTRODUCTION.

This project provides a detailed examination of the ecology of the River Wissey with specific reference to relationships between flows and the flora and fauna of the river. The river is renowned as a trout stream and the study was commissioned by the National Rivers Authority in 1991, following concerns about the ecological impacts of falling flows. The project had three aims:

i) to assess the current ecological status of the Wissey and to place the current situation in an historical context;

ii) to evaluate macroinvertebrate-flow relationships for (i) environmental assessments of flow-related impacts and (ii) setting flows to meet in-river needs; and

iii) to define a Ecologically Acceptable Flow Regime for the River Wissey on the basis of all available information and approaches.

The study included intensive field surveys during 1991 and 1992 (low-flow years) and 1994 (a 'normal' flow year), supplemented by a comprehensive review of secondary sources. Macroinvertebrate and habitat data from nine Chalk streams in the Anglian were provided by the NRA for comparison with the River Wissey results. This report summarizes with findings relevant to i) and ii) above. A separate summary report reviews the information pertinent to the second aim and advances a methodology for defining the Ecologically Acceptable Flow Regime. Ouputs from the project are listed in Table 1.

Table 1 Outputs from the River Wissey investigations.

Main Report: Part I 1994:	a descriptive assessment and evaluation of ecological impacts during the 1991-92 low-flow years.
Annex A:	River corridor and wetlands: the diatom community and NRA fish survey data: water chemistry; and channel-bed sediments and surface water-groundwater interactions.
Annex B:	Aquatic macrophytes and their influence on hydraulics and sedimentation.
Annex C:	PHABSIM analyses.
Annex D:	Macroinverterates: distribution and use in habitat assessment, based on survey data from 1991-1992 and NRA data, 1964-1991.
Main Report: Part II 1995:	recommendations on physical habitat and flow management for the River Wissey and other Chalk streams in Norfolk.
Manual 1995:	the use of macroinvertebrates to assess in-river flow needs.
Summary of Investigations on Linking Hydrology and Ecology 1995	
Summary of Recommendations for the River Wissey	

1.1 Research structure.

The research followed a four-stage process:

Part 1 (Reported as Main Report 1994)

i. The *preliminary description* of the river based on both the collation of existing information and field surveys, and *classification* of the river system into sectors and reaches using a range of statistical techniques.

ii. The *comprehensive description* of the physical haitat and biota within the main sectors giving special attention to *seasonal variations*.

iiia. The *experimental assessment* of the relationships between biota and flows, using *representative* sites based upon data obtained during two low-flow years (1991-2)

Part 2. (Reported as Main Report 1995)

iiib The *experimental assessment* of the relationships between biota and flows, using *representative* sites, developing iiia by incorporating a 'normal flow' year (1994)

iv. The *critical testing* of the relationships between biota and flow, estalished for the Wissey, to other Chalk streams in the region.

2. DESCRIPTION AND CLASSIFICATION.

The review of secondary data sources included information held by the NRA on flows, groundwater levels, water quality, macroinvertebrates, river plants and fish. This was supplemented by data from other secondary sources and from a preliminary field survey. The river was found to have considerable conservation value but different parts of the drainage network were adversely affected by (i) dredging and channel works (Upper Wissey), (ii) pollution (Wissey from Swaffam through South Pickenham, and Watton Brook), and (iii) low flows (most sites; parts of the Gadder and Stringside Brook dried up during 1991-92).

The features of the ecology (Table 2) and hydrology (Table 3) of the River Wissey suggest that:-

- the River Wissey comprises some important sites for conservation of biodiversity;
- the aquatic and riparian ecosystems are adapted to the naturally regulated (i.e. groundwater-dominated) flow regime;
- the flow regime is dependent upon winter raintalls (to recharge the aquifer between November and May).

Synthesis of the information on fauna, flora, physical habitats and flows allowed division of the river into five sectors (Table 4).

Table 2 Ecological Characteristics of the River Wissey.

The river corridor has exceptional conservation value at both regional and national levels, with wet meadow and wet alluvial carr. No invasive riparian weeds were found.
The two headwater wetland sites surveyed in detail (Mill Covert near Gooderstone and Rookery Farm on the River Gadder) yielded three nationally rare and one nationally vulnerable species of diptera, all being specifically dependent on wetland habitats.
Water quality is high throughout most of the river, exceptions being on Watton Brook and on the Wissey below the Swaffham sewage treatment works outfall. During the low-flow period (1991-2) nitrogen levels were high in the upper river (>10 mgl^{-1} TON) and orthophosphate levels exceeded 1 mgl^{-1} below the Swaffham and Watton STWs.
The river channel form changes progressively downstream to a width of about 12m at the Stanford Stream confluence. However, the morphology of the river is strongly influenced by ditching and dredging, ponding behind mill weirs, and riparian management: classic gravel-ed, riffle-pool reaches (eg through Chalk Hall Farm) contrast with ponded sand-bed reaches (eg Langford Hall) and dredged reaches (eg Bodney ridge); and macrophyte-rich reaches (eg Chalk Hall Farm, to Langford Hall) contrast with heavily shaded, macrophyte-poor reaches (Langford Hall to Ickborough).
In-river flora and fauna are rich and considered to be typical of good-quality fast-flowing Chalk streams. The aquatic flora is dominated by *Ranunculus* and *Rorippa*. The inverterate fauna included more than 120 taxa but none is nationally rare. One intermittent site (Beachamwell) supported a number of locally unusual stoneflies.
Fish biomass in the main river is about 14 gm^{-2} in a 'normal' year.
'Good quality' spawning gravels for trout have a limited distribution, being restricted by (i) high proportions of sand or (ii) shallow (<15cm) depth of clean gravel.

2.1 Flows.

The hydrological characteristics of the River Wissey are summarised in Table 3. The flows recorded at Northwold gauging station, illustrated in Figure 1, clearly show the droughts of 1975-76 and 1988-92 , but there is no long-term pattern of decline. For example, considering the two 15 year periods winter 1961-2 to 1975-6 and 1976-7 to 1991-2, the first period included 6 years during which mean monthly flows failed to reach 3 cumecs and the latter included 7 years during which this threshold was not exceeded. The 1988-92 drought appears to be unusual because the seven low winter flow years occured in a sequence broken only by the wet winter of 1987-88.

Table 3 Hydrological characteristics of the River Wissey.

Water Balance 1956-88:	Rainfall (653mm)=Runoff (218mm)+ Losses (435mm) (Losses are mainly by evapotranspiration).			
Rainfalls during years of survey:	1991	1992		1994
Streamflows as gauged at Northwold (Drainage area 275 km², 1956-1988:				
Monthly average flows:	High	-	February (2.8 cumecs)	
	Low	-	September (0.8 cumecs)	
Highest recorded daily mean flow:			12.86 cumecs.	
Mean daily flow			1.9 cumecs	
95%'ile flow:			0.58 cumecs	
Mean flows during years of survey	1991 - 1992: 0.479 cumecs		1994: 2.15 cumecs	
Minimum flow at Northwold during 1988-1992: 0.149 cumecs in September (lowest flow on record).				
Groundwater levels:				
Watershed borehole levels strongly related to winter rainfall				
Valley bottom borehole levels related to river levels				
River shows major gains from groundwater between North Pickenham and Hilborough				
Stanford tributary shows strong positive gradient from groundwater to stream between Sturston Carr and Buckenham Tofts				

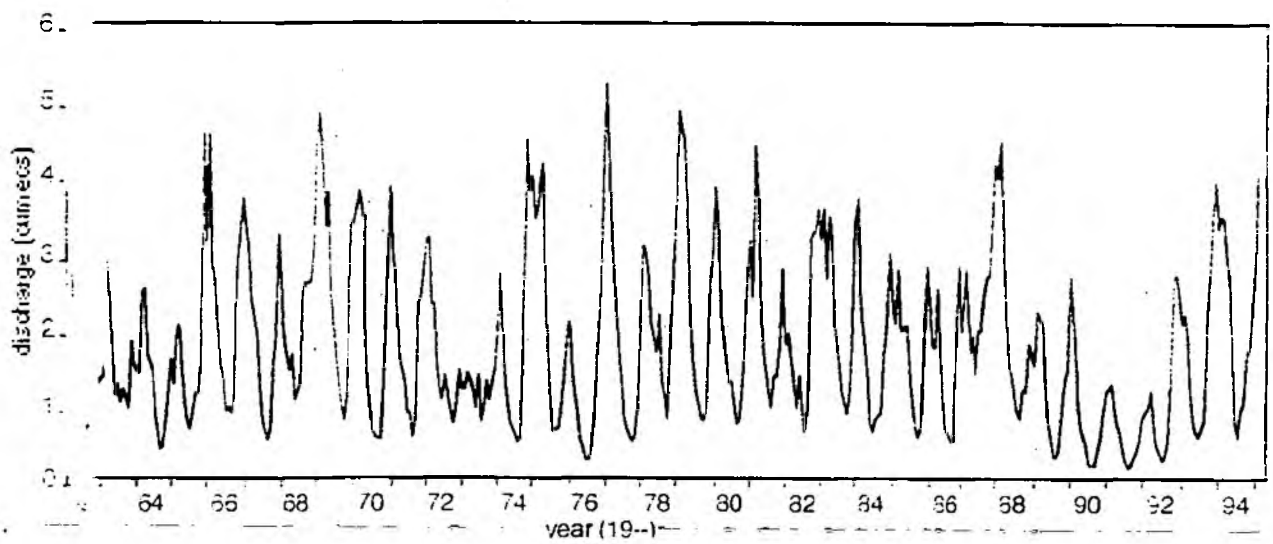

Figure : Mean monthly flows recorded at Northwold gauging station, 1962-1994.

2.2 Aquatic invertebrates.

Analysis of long-term macroinvertebrate records (1962-1994) demonstrated highest diversity in the mid 1980s and reduced faunas in the 1970s and 1989-92 a pattern which integrates (a) long-term improvements in water-quality, (b) responses to variations in flow and (c) physical habitat degradation. A highly significant relationship was found between the number of taxa and flows, specifically the deviation of the 7-day low flow for the month of survey from the long-term average. Several taxa were shown to be highly sensitive to flow levels.

The impact of the extreme low flows during drought years is illustrated by data for October 1991, having a monthly mean flow of 0.20 cumecs, in comparison with the 'normal' flow year of 1994 (mean flow of 0.91 cumecs - slightly above the long-term average). Total abundance of macroinvertebrates was reduced by 36% and there was a 30% reduction in species and 26% reduction in families. Macrophyte cover was reduced by 36% but *Ranunculus* cover declined dramatically, by 88%.

Detailed analyses of the development of aquatic macrophytes and of their influence on local hydraulic conditions (velocities and depths) allowed formulation of significant relationships of the form:

site median depth (or velocity) = a + (b x discharge) + (c x macrophyte cover)

Thus, heavily shaded sites with limited macrophyte growth demonstrated contrasting hydraulic conditions to exposed sites. Maximum macrophyte cover varied between years from 10% (1991-2) to 100% (1994).

Table 4 **Sectors along the River Wissey** (see also Figure 2).

Five sectors were defined on the basis of (i) hydrology, (ii) water quality, (iii) geomorphology, (iv) in-river biota and (v) riparian habitats.
Sector 1: Upper Wissey to North Pickenham. Ditched, moderately eutrophic, spring-fed stream, characterised by disturbance tolerant riverine flora and an impoverished inverterate fauna. Channel is cut into non-alluvial clay.
Sector 2: North Pickenham to the Watton Brook confluence. This sector is degraded both physically (channel and bank management) and chemically (Swaffham STW discharge) and this is reflected by the instream flora and fauna, and riparian habitats.
Sector 3: Between the Watton Brook and Stanford Stream confluences. Despite the poor quality of flows from the Watton Brook, this sector is particularly important (especially below Bodney Bridge, comprising a wide range of in-river and riparian habitats. The rich flora and diverse invertebrate community are typical of fast-flowing, calcareous streams with a diversity of physical habitats. Dominant fish species: eel with brown trout (stocked) and dace (coarse fish are selectively removed).
Sector 4: Stanford Stream confluence to Oxborough. Another important sector with similar characteristics to sector 3, but dominated by deeper in-river habitats with sandy runs and shallow, fine gravel riffles. Dominant fish species: eel with brown trout (stocked) and dace (coarse fish are selectively removed).
Sector 5: Oxborough and downstream. A canalized, fenland river, with typical diverse fauna and flora. Dominant fish species: eel with dace, pike and chub.

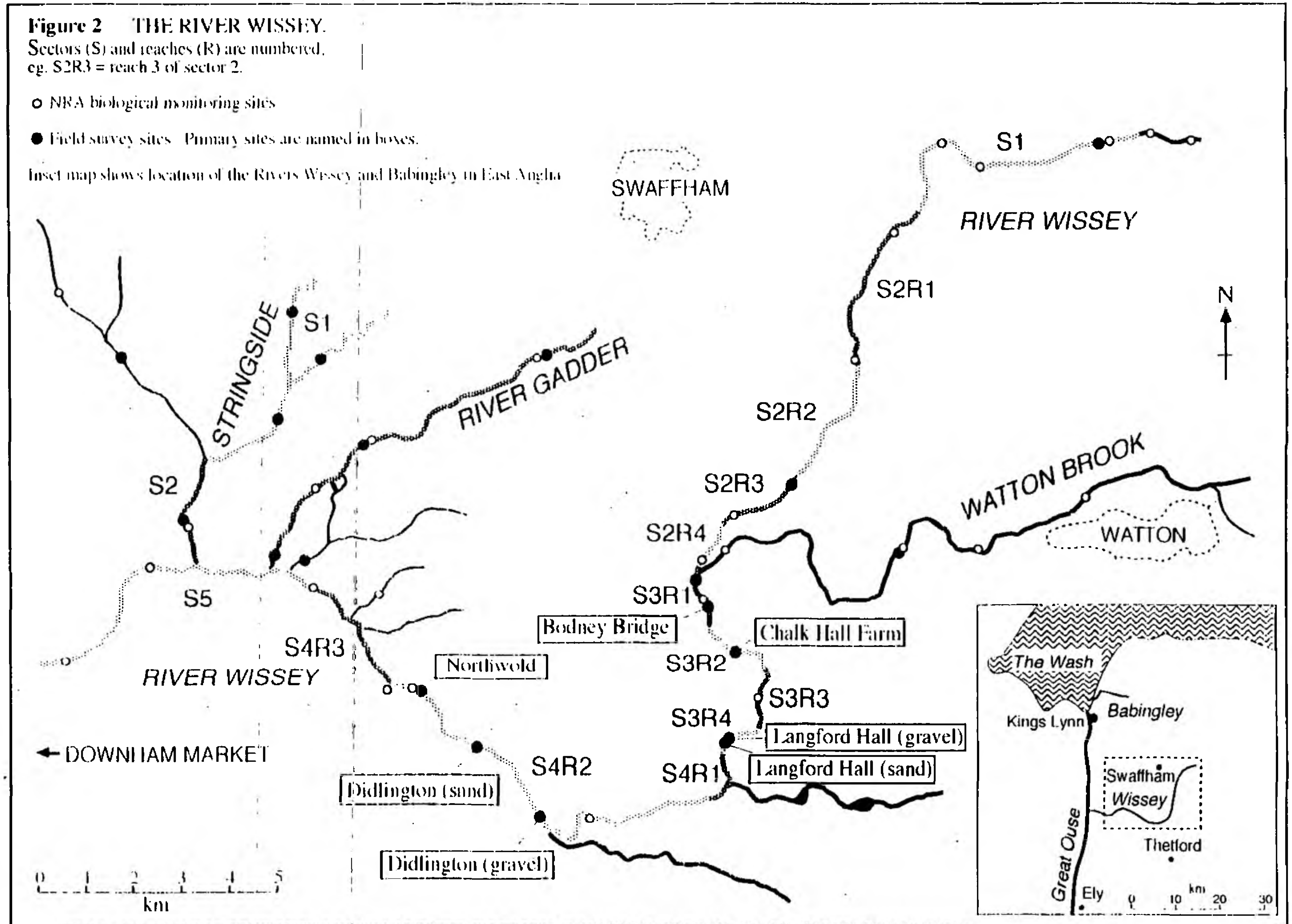

Figure 2 THE RIVER WISSEY.
Sectors (S) and reaches (R) are numbered, eg. S2R3 = reach 3 of sector 2.

o NRA biological monitoring sites

● Field survey sites. Primary sites are named in boxes.

Inset map shows location of the Rivers Wissey and Babingley in East Anglia

3. ASSESSMENT OF BIOTA-FLOW RELATIONSHIPS.

3.1 Methods.

The assessment of in-river flow needs utilised the methodology summarized in Figure 3 and focussed on two sectors (3 and 4). Summary of the results are given in Table 5. Hydrological indices were obtained from the literature, mainly from work in USA.

3.1.1 PHABSIM.

PHABSIM is a set of computer models, developed in the United States, that are used to relate changes in discharge to habitat availability for target species or life stages. The PHABSIM analyses used field data from the seven representative sites (primary sites) and microhabitat suitability curves as published for UK conditions, but not specifically Chalk streams. Surveys were undertaken in May and October 1991 and Ferbuary 1992. Each site survey involved a minimum of 140 hydraulic measurements within a reach of 10 times channel width in length. Differences between sites reflected channel form, substrate and macrophyte cover. Under low flow conditions, habitats are sustained in reaches having a riffle-pool bedform; conversely, habitat is lost first from channelized and deep run reaches lacking morphological diversity.

Habitat time-series for average flow conditions and actual flows during the 1988-92 drought demonstrated that:

- suitable habitat for adult trout was virtually eliminated during the late summers of 1989-1992;
- spawning habitat was severely reduced in 1990 and 1991;
- habitat for juvenile trout was available throughout the drought.

3.1.2 Macroinverterate-flow relationships.

Macroinvertebrate-flow relationships were based on data from the 7 primary sites in sectors 3 and 4, supplemented by 14 secondary or tertiary sites on smaller streams. Samples were collected in May and October 1991 and February, May and October 1992; with additional surveys at three primary sites in February, May and October 1994. From each of the primary sites, twelve samples were obtained from each site on each survey. Fewer samples were otained from the minor sites. The 700 samples yielded over 120 taxa having abundances ranging from less than 10 to more than 1500 per sample.

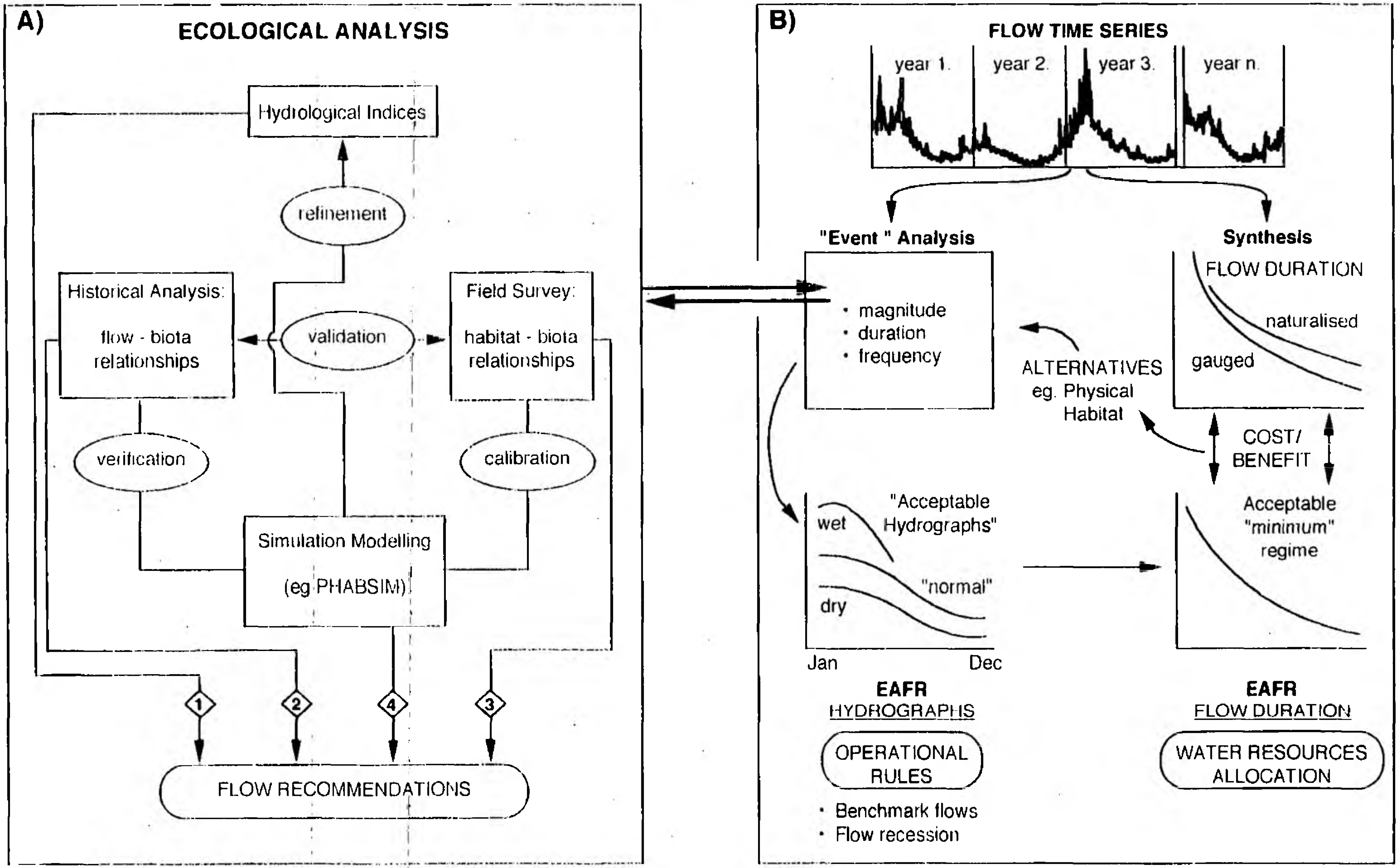

Figure 3 Methodology for the determination of Ecologically Acceptable Flow Regimes (EAFRs), based on integrated investigation of hydrology and ecology. A) The Wissey study and B) the input of the Wissey study to determining the Ecologically Acceptable Flow Regime (EAFR) following the Babingley recommendations (Petts, 1995).

Recovery was rapid after the 1988-92 drought. By October 1994, at three sites in sector 3, the number of taxa had increased from 61 in 1991 and 71 in 1992 to 87 in 1994; and abundances had increased from 150,000 15,200 in 1991 to 19,700 in 1992 and to 23,700 in 1994. Analyses of relationships between the abundance of the more frequent taxa (occuring in >20% of the 501 samples from the primary sites) and environmental variables revealed:

- both seasonally and between years, the primary variables explaining the distribution of invertebrate taxa was flow and macrophyte growth, these two variables determining the spatial pattern of velocities, depths and silt accumulation;
- season-specific relationships must be developed;
- data from a single spatial survey of a range of hydraulic habitats may be used to estimate changes with flow between years only for the end-of-summer, low flow period (here, October);
- family-level identification gives almost identical results to species level;
- 4 flow-sensitive taxa have been isolated -

Baetidae	Gammaridae
Ephemeridae	Simuliidae

- methods for developing habitat preference curves (eg Figure 4A) have been evaluated and, for the Wissey, multiple regression on three variables (velocity, depth and macrophyte cover) was demonstrated to be most appropriate;
- suitability surfaces (eg Figure 4B) have been developed to provide a look-up guide for assessing flow-related habitat quality.

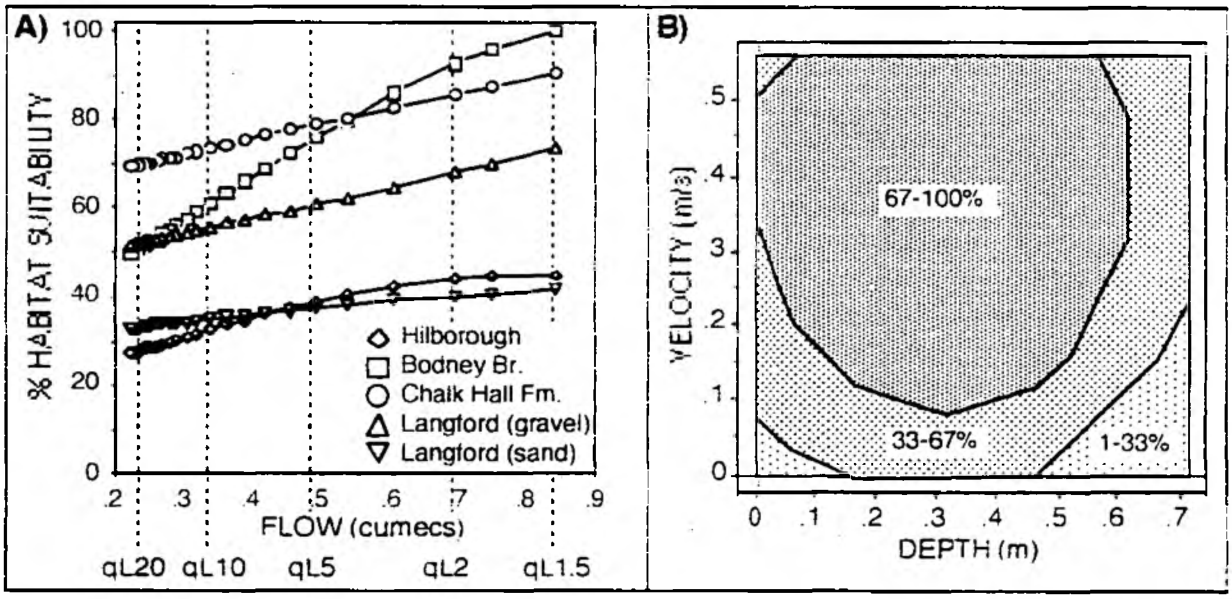

Figure 4 Habitat preference curves and surfaces for one indicator taxon (Baetidae) in the River Wissey, Sector 3. A) Habitat preference curves, showing habitat suitability with discharge relationships for 5 sites in Sector 3. B) Suitability surface, showing habitat suitability under different depth/velocity combinations.

4. APPLICATION OF FLOW-BIOTA RELATIONSHIPS TO OTHER CHALK STREAMS.

Flow-biota relationships established for the River Wissey were tested on a dataset for 21 sites on 9 rivers, based on a survey in 1992/3 using the same field survey procedures as adopted herein. The rivers included were: Cam, Gaywood, Heacham, Ingol, Kennett, Lark, Nar, Sapiston and Thet. At several sites, the hydaulic data was outside the range encountered on the Wissey whilst water-quality differences between rivers was reflected by significnat differences in the macroinvertebrate communities. Following a detailed analysis, it was concluded that:

- habitat suitability relationships must be developed for each river, and ideally for each sector independently:
- habitat suitability relationships for one river cannot (normally) be transferred to another river:
- habitat suitability relationships developed from a single spatial survey in a sector may be used to predict summer flow-related between-year changes in the fauna at a sector: such a spatial survey should include a range of representaive mesohabitats covering a wide range of velocity-depth-macrophyte-substrate combinations.

5. THE RIVER WISSEY: IN-RIVER FLOW NEEDS.

Results of the detailed analyses of data for the River Wissey focused on two sectors (Sectors 2 and 3, Table 3) of particular importance both as trout fisheries, and more generally because of their high conservation value. The ecological significance of a range of flows was established (Table 5). The chosen targets included: trout and dace (adult, juvenile and spawning habitat), and invertebrates (changes in abundance of flow sensitive taxa and predictions on number of taxa from long-term records). These were used to define three sets of monthly minimum flows (Table 6): for invertebrates; invertebrates and dace; and invertebrates, dace and trout. For each, four regimes were defined: wet-year, 'normal' year, drought year, and severe drought year, and these were given appropriate frequencies, chosen subjectively, but guided by the historical series of flows. Each set of four regimes was then combined to define Ecologically Acceptable Flow Regimes (Table 7). Once established, the EAFR was used to define:

(i) abstractable volumes,
(ii) prescribed flows (hands-off flows) that may be attached to abstraction licences, and
(iii) maintained flows requiring river support.

Differences between the results presented in the final reports and those published in the 1994 reflect: (a) the completion of the Babingley Report which proposed the approach for defining the EAFR; (b) the inclusion of data for 1994 (a 'normal' flow year) as well as the drought years of 1991-92, and (c) improvements in the invertebrate methodology

5.1 Abstractable Volumes.

The results allow specification of the acceptable maximum volume of abstractions:

Runoff - Environmental needs = Abstractable volumes

Thus, for the Wissey (based on the EAFR for trout, dace and invertebrates in Table 7), having an average in-river flow requirement of 1.5 cumecs, equivalent to 172 mm of runoff, the **acceptable maximum abstraction is 0.4 cumecs which equates to 46 mm of runoff.** By using different series of monthly flows to meet in-river flow needs for 'wet' and 'dry' years (Table 6) the potential volume available for abstraction in specific years has been determined, for example:

i) in 1987, using the wet year in-river flow need: 262 mm - 212 mm = 50 mm
ii) in 1990, using the one-in-twenty year drought requirement: 116 mm - 53 mm = 63 mm

In reality, this potential cannot be realized only in hindsight. Furthermore, it is unlikely that the complex flow control rules which would be required to exploit the full water resources potential, involving monthly prescribed flows that also vary between years, could be operated successfully. Practicable rules are suggested below.

Table 5 The ecological significance of flows determined for the River Wissey (sectors 3 and 4, having 4 and 3 reach types, respectively). MDF=mean daily flow.

Hydrological index	Flow - cumecs	Ecological Target	Bench-mark
	0.16	Juvenile dace habitat sustained at 67% of standard in one reach in both sectors	AEF
10% MDF	0.19		
	0.20	Juvenile trout habitat sustained at 67% of standard in one reach of one sector	TEF
	0.20	Severe loss of invertebrate habitat	TEF
	0.20	Trout spawning habitat eliminated throughout both sectors	
	0.30	Threshold flow to sustain some habitat for adult trout in one reach of one sector	TEF
	0.30	Juvenile trout habitat sustained at or above 67% of standard in both sectors	AEF
	0.33	Threshold flow to sustain habitat for adult dace at or above 67% of standard in one reach of one sector	TEF
	0.34	Threshold end-of-summer flow to sustain habitat for macroinvertebrates at 67% of standard in one sector	AEF
	0.35	Trout spawning habitat eliminated in one sector	TEF
20% MDF	0.38		
	0.40	Threshold flow to sustain some habitat for adult trout in at least one reach type in both sectors	AEF
	0.40	Adult dace habitat sustained at 67% of standard in at least one reach in both sectors	AEF
	0.51	Habitat for adult dace sustained at 67% of standard in all reach types in both sectors	DEF
	0.53	Habitat for most sensitive macroinverterate (Simuliidae) sustained at 67% of end-of-summer standard	DEF
30% MDF	0.57		
95%'ile flow	0.58		
	0.60	Threshold flow to sustain adult trout habitat in all reaches of one sector	DEF
	0.68	Dace spawning habitat sustained at 67% of optimum in one reach in one sector	TEF
	0.72	Trout spawning habitat sustained at 67% of optimum in one reach in one sector	
Aquatic baseflow	0.79		
	0.84	End-of-summer *Standard flow* - high macroinverterate diversity and biomass	
	0.85	Optimum habitat for juvenile trout in both sectors	OEF
	0.90	May: two 'indicator' invertebrate taxa reduced below 67% of standard for month	AEF
	0.90	Threshold flow to sustain habitat for adult trout in all reach types of both sectors	DEF
	0.90	Trout spawning habitat sustained at 67% of optimum throughout sector 3 and in one reach in sector 4	AEF
	1.00	Dace spawning habitat sustained at 67% of optimum in at least one reach in both sectors	AEF
	1.41	Dace spawning habitat at optimum in at least one reach in both sectors	DEF
	1.41	Trout spawning habitat at optimum in one sector	DEF
	1.41	Optimum habitat for adult dace	OEF
	1.50	May: most sensitive inverterate taxa (Simuliidae) sustained at 67% of standard for month	DEF
	2.00	Optimum habitat for adult trout in one reach of each sector	OEF
	2.50	Four 'indicator' macroinvertebrate taxa sustained at 67% of standard for February.	DEF
	3.00	Optimum habitat for adult trout	OEF
10%'ile flow	3.50	Flushing flow	HMF
Q2.33	8.60	Channel riparian flow	CMF

Table 6 Recommended minimum-flow regimes for the River Wissey. All flows are cumecs. Benchmark flows are given in bold. R=flow back estimated from end-of-summer low flow using the dry-weather recession. Figures assume no surface-water abstractions. Winter flows are 'indicators' of groundwater levels to sustain summer flows. Control rules allow exploitation of winter runoff (see text).

	Wet year	Normal low	Drought	Severe drought
Frequency flow equalled or inceeded	1.5	2.0	5.0	20.0
a) Invertebrates and habitat. (including Dace)				
January	2.80	1.50	0.50	0.35
February	**3.50**	2.50	1.00	0.90
March	2.85	2.30	1.50	1.20
April	2.35R	2.00R	1.30R	1.10R
May	1.70	**1.50**	**0.90**	0.75
June	1.30	0.95	0.75	0.50
July	1.00	0.75	0.55	0.35
August	0.90	0.65	0.45	0.25
September	**0.85**	**0.55**	**0.35**	**0.2**
October	**0.85**	**0.55**	**0.35**	**0.2**
November	1.35	**0.55**	**0.35**	**0.2**
December	2.00	0.75	**0.35**	**0.2**
Mean	1.82	1.30	0.75	0.59
b) Invertebrates. Dace and Trout				
January	2.80	2.00	0.6	0.40
February	**3.50**	2.50	**0.90**	**0.90**
March	2.85	2.30	1.50	1.00
April	2.50R	2.00R	1.30R	**0.90**R
May	1.80	1.50	**0.90**	0.75
June	1.30	0.95	0.75	0.55
July	1.10	0.75	0.55	0.45
August	1.00	0.65	0.45	0.35
September	**0.90**	**0.55**	**0.4**	**0.3**
October	**0.90**	**0.55**	**0.4**	**0.3**
November	**1.50**	**0.9**	**0.4**	**0.3**
December	2.00	1.25	0.5	**0.3**
Mean	1.88	1.4	0.78	0.58

5.2 Control Rules.

The information gained from in-river flow analyses (see Table 6) may be used to recommend flow control rules including 'hands-off' flows (HOF) for surface-water abstraction licenses and maintained flows (MF) to protect in-river needs.

To sustain the Wissey as a trout stream:

Winter HOF (November to June inclusive) = 1.5 cumecs

but a 30-day flow of more than 3.5 cumecs must be spared each year and a 15 day flow of more than 8 cumecs should be spared at least once every 5 years. The time-period (November-June), has been chosen to protect the river during the key months (Novemer, May, and June).

Summer HOF (July to October inclusive) = 0.90 cumecs

In a drought year (with an acceptable frequency of no shorter than 1:5 years) the controls on surface water abstractions may be relaxed:

If flow on 1st February has not reached 1.5 cumecs,
the HOF for February through June may be reduced to 1.0 cumec and
the summer HOF may be lowered to 0.6 cumecs.

Maintained flows may also be specified:

Flows should normally be maintained, by groundwater support if necessary, at a minimum of 0.4 cumecs. Exceptionally, under 1:20 year drought conditions, the minimum maintained flow may be reduced to 0.30 cumecs.

The above rules allocate a 1.42 cumecs to in-river needs, equivalent to 163 mm of runoff, on average, allowing up to 55 mm for abstraction (on the basis of the historical mean gauged flow).

Table 7 EAFRs (flow duration percentiles) to meet different Ecological Objectives for the River Wissey. Based on data in Table 6. Percentiles - flows equal to or greater than. * Assumes high flows unaffected but the duration of these flows could be reduced if winter surface-water abstractions are allowed; rules for such abstractions are given below, and the impact of maximum winter surface-water abstractions on the estimated mean flow is given in the last two rows of the table. T=trout, D=dace, ad=adult, spn=spawning, juv=juvenile, inerts.=invertebrates, inv.H.=historical analyses of inverterates.

Flow (cumecs)	Percentiles 1956-88 (gauged)	Invertebrates and Dace	Invertebrates, Dace, and Trout	Benchmark Flow
10*	0.1	0.1	0.1	CMF
4.33*	5	5	5	
3.5*	10	10	10	HMF OEF (T.ad.)
1.5		37	32	OEF (D.ad.) DEF (T.spn)
1.0	74	48	47	AEF (D.spn)
0.9		52	69	DEF (T.ad.) AEF (T.spn)
0.8		54	72	
0.7		64	78	AEF (D.ad.)
0.6	96	70	86	
0.5	92	86	93	DEF (Inverts.)
0.4		92	98	AEF (T.ad.) AEF (D.ad.) DEF (Inv.H.)
0.35		97.5	98.3	AEF (Inverts.) TEF (T.spn)
0.3		98	100	AEF (T.juv.) TEF (T.ad.) AEF (Inv.H.)
0.2		100		TEF (T.juv) TEF (Inv.H.)
Estimated mean (cumecs)	1.9	1.34	1.5	
Runoff (mm)	218	154	172	
*Mean (cumecs)		1.07	1.29	
* Runoff (mm)		123	150	

5.3 Use of Q95.

The tradition of using the 95th percentile flow (Q95), based on historical data, to determine 'in-river' needs under-estimates the volume required to protect the river ecosystem in 'normal' and, especially, wet years, but over-estimates the in-river needs during severe droughts.

Thus, for the Wissey where Q95 is 0.58 cumecs:

i)	in an average year:	218 mm - 67 mm = 151 mm
ii)	in 1987:	262 mm - 67 mm = 195 mm
iii)	in 1990:	116 mm - 67 mm = 49 mm

On the River Wissey Q95 was shown to approximate the minimum acceptable end-of-summer flow in a 'normal' year, but is higher than the recommended end-of summer minimum for the 1:5 low-flow year (0.40 cumecs) and lower than that required during the 1:3 wet year (0.90 cumecs).

6. OTHER RECOMMENDATIONS.

In addition to the flow recommendations detailed above, the study has provided a catchment perspective on the Wissey. The conservation value, potential for enhancement and recommendations for management of the Wissey and its tributaries are summarized in Table 8. Specific attention should be given to:-

- creating buffer zones along most of the headwater streams to reduce nutrient and fine sediment inputs from agricultural land: control instream macrophyte growth by shading, thus reducing maintenance costs and ecologically-damaging dredging activities; and improving the conservation value of the river corridor.
- from Hilborough to the Buckenham Tofts weir ensure that no works are undertaken to degrade the channel form and riparian areas.
- from Buckenham Tofts weir downstream, habitat diversity should be improved along the channel margins by creating eddies, backwaters, and marginal cover: the careful location of dead trees would be advantageous, and gravel accumulation and limited bank erosion should not be revented.
- during dry summers, management of macrophytes should be limited to the maintenance of a few, fast-flowing runs.
- monitoring of water quality and flows should be undertaken at Hilborough, below the Watton Brook confluence (an important control point in the stream network) in order to monitor long-term trends and short-term incidences.
- monitoring of groundwater levels surveyed into river levels is recommended between North Pickenham and Hilborough, an important reach for groundwater discharge maintaining flows during dry periods.

Table 8 Conservation value, potential for enhancement and recommended management for the River Wissey and tributaries.

Sector/reach.	Character	Present conservation value.	Potential for enhancement.	Recommendations.
Wissey, Sector 1. Bradenham to Ernford Hse.	Heavily managed, ditched through arable areas. Part intermittent.	Low. Some organic pollution; high-nutrient arable runoff.	Good. A relatively natural, attractive stream could be achieved with moderate investment in management.	Introduce buffer zones / reduce frequency of dredging to encourage riparian flora. Any measures to improve channel diversity.
Wissey, Sector 2. Ernford Hse. to Watton Bk. confl.	Moderate/low intensity managment: pasture/wet meadow. Silty runs with few gravel riffles.	Mixed. Some excellent wet meadows of very high value. Instream habitat moderate-poor. Organic pollution problems.	Good. Riparian habitat already quite good, instream habitat could be improved.	Preserve & extend wet meadow areas. Reduce access for stock to riparian margins. Address organic pollution problem - at source or through root exclusion zones / ponds.
Wissey, Sector 3. Watton Bk. confl. to Buckenham Tofts	Semi-natural, typical Chalk stream. Good pool-riffle structure; some ponding from weirs.	Excellent. Instream habitat good, especially Reach 2, with diverse substrate, flora and invertebrate and fish fauna. Riparian woodland of moderate value.	Moderate. Instream habitat requires preservation rather than enhancement. Riparian alluvial woodland could be significantly improved.	Preserve instream habitat. Replace riparian plantation trees with native species and let understory develop naturally.
Wissey, Sector 4. Buckenham Tofts to College Fm.	Semi-natural, with deep run habitat predominating in-stream. Mainly plantation surrounding.	Moderate. Moderate habitat for invertebrates and flora, due to predominance of deep runs. Good adult trout habitat.	Good. Instream habitat fulfills function as adult trout habitat; fry habitat and riparian flora could be greatly improved.	Improve marginal habitat for fry / invertebrates by increasing diversity. Develop backwater areas. Replace riparian plantation trees with native species.
Wissey, Sector 5 College Fm. to Whittington	Heavily managed, fenland section.	Moderate. Habitat typical for this sector type; good coarse fishery. Riparian zone is poor.	Moderate. Natural character and drainage function limits potential for instream improvements.	Introduce buffer zones. Create adjacent fish fry habitats - backwaters areas. Any measures to increase habitat diversity.
Upper Gadder. Cockley Cley to Gooderstone.	Intermittent in upper section with artificial lakes; perennial in lower section with wet woodland / meadow.	Good. Intermittent, thus limited instream habitat above spring-head. Wet meadows at Mill Covert identified as extremely valuable for invertebrates.	Moderate. Intermittency of upper reach limits instream improvements. However, wet meadow areas could be extended.	Preserve and extend wet meadow areas around the springs. Wildfowl lakes are being created at Gooderstone Water Gardens: suggest removal of willows and extension of wetlands.
Lower Gadder. Gooderstone to Wissey confl.	Mainly run-type instream habitat through pasture and arable land; dense emergent flora controlled by cutting.	Moderate-low. Grazing and arable cultivation limit riparian vegetation in most parts. A Brown Trout population existed prior to 1990.	Moderate. Riparian flora could be improved.	Limit stock grazing of banks in pasture areas to allow regeneration of riparian zone. Develop buffer zone in lower reach and improve channel management for fish fry habitat.
Stringside Str. Upstream of Barton Bendish and Beachamwell tributaries	Intermittent headwaters through arable land.	Low. Heavily dredged	Good. Intermittent, limiting potential instream improvement. However, in these intensive arable areas streams/ditches provide valuable damp refugia for invertebrates, birds and mammals, and landscape interest.	Anything to improve riparian zone - both in extent and diversity. Plant buffer zones, aim to reduce dredging/cutting in the medium-term.
Stringside Str. Beachamwell to confl. with Barton Bendish str	Intermittent, wooded stream u/s Oxboro'Wood; perennial, spring-fed stream through wood/ arable land d/s Eastmoor.	Mixed. Interesting intermittent stream invertebrate fauna at Beachamwell; lower section of lesser interest.	Moderate. The perennial section could be improved by measures to improve riparian and instream flora.	Oxborough Woods are already under management to improve the conservation value of the woodland. Instream flora through the Woods may be improved by selectively reducing shading.
Stringside Str Confl. with Barton Bendish stream to confl. with Wissey	Ponded by G.S. in upper section and from main river in lower. Heavily dredged except immediately d/s G.S..	Poor, except for immediately d/s the G.S. where flow is faster and trees limit access for dredging. Coarse fish proliferate in the lower section - probably a good refuge from the main river during high flows.	Poor. Ponding and necessary drainage work limit possibilites for enhanement.	Extension of buffer zone above and below G.S.
Watton Brook	Gravel bed, naturally riffle-pool stream but dredged and cultivated up to banks. Organic pollution problems	Poor. Very little interest.	Good. Instream habitat could drastically improve if water quality was raised. Potential also for improving riparian flora.	Buffer zones. Improve / reduce effluent entering stream. Reduce cutting and manage channel to increase instream and riparian macrophytes which will also improve water quality.