THE UNIVERSITY
OF BIRMINGHAM

SCHOOL OF GEOGRAPHY

FINAL REPORT

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THE RIVER BABINGLEY:
a study of in-river needs
for
National Rivers Authority, Anglian Region

Volume 1: Executive Summary

Supervised by
Professor G.E. Petts

Research Associate:
M.A. Bickerton

Other Researchers:
P. Barker (diatoms)
C. Evans (temperature and technical support)
C. Ferguson (macrophytes and technical support)
E. Linton (macroinvertebrates and technical support)
I. Maddock (PHABSIM)
D. Milan (sediments)

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1 INTRODUCTION

Growing demands for water supplies, especially throughout eastern and southern England, are placing increasing pressures on water resources. The development of groundwater resources is continuing to attract intense interest, while at the same time there are growing concerns for the protection of the high ecological and amenity values that typically characterize groundwater-fed streams. The River Babingley in north-west Norfolk is underlain by the major Chalk and Greensand aquifers and groundwater flows from these aquifers play a dominant role in determining the ecological character of the river. In order to assess how much abstraction might be allowed from the aquifers, it is necessary to establish what minimum flow regime would sustain, without unacceptable deterioration, the important ecological and amenity values or the river and associated wetlands.

1.1 Aims and Objectives

This study produced two Reports: 1) the Main Report defining the 'in river needs' of the River Babingley necessary to satisfy the existing aquatic and riparian communities, and the salmonid fishery which is protected under the EC Directive (78/657/EEC), and 2) a separate report describing an approach to determine an Ecologically Acceptable Flow Regime.

Specifically, the Reports address three main objectives:

i) To establish the flora and fauna of the river and the physico-chemical attributes which support them.

ii) To indicate the sensitivity of these flora and fauna to changes in the physico-chemical environment, particularly to the following hypothetical changes in flow regime -

   A mean and 95%'ile flows reduced by (1) 10% (2) 20% and (3) 30%;
   B low flows maintained at the 95%'ile flow and mean flow reduced by (1) 10% (2) 20% and (3) 30%;
   C low flows maintained at the 98%'ile flow and mean flow reduced by (1) 10% (2) 20% and (3) 30%.

iii) To devise an approach to establish target flow regimes to meet ecological needs based upon flow-duration statistics.

Two secondary objectives are also addressed. First, the Report descibes the ecological characteristics of the main spring-heads and evaluates their values in relation to flows. Secondly, opportunities for habitat improvement are identified.

1.2 General Methodology

Full details of the approach used to assess 'instream flow needs' are given in the River Wissey Report on *Linking Hydrology and Ecology* produced for the NRA Anglian Region (Petts, 1993). In summary, application of the approach to the River Babingley involved three stages.

i) *Baseline Survey* .

a) Collation and synthesis of data on the river held by the NRA.
b) Specialist field surveys of the two main spring sites:
c) A preliminary survey of the entire length of the River Babingley and its main tributaries.

The output from this first stage is the production of a typology defining river sectors and reaches based on physical, management and biotic characteristics.

ii) *Representative Sites*

At 12 sites selected as representative of the different reaches defined in stage 1 (Figure 1), monthly surveys were undertaken to monitor flows, water chemistry, hydraulic characteristics, and distributions of sediment type and macrophyte cover. All sites were riffles or shallow runs, sites considered to be most vulnerable to declining low flows. Each site was a fixed transect and velocity, water depth, substrate types and macrophyte species were recorded at 20 points. These data allowed investigation of both longitudinal and temporal changes and provided the background data to support a specialist investigation of macroinvertebrates based upon 2-minute kick sample across each transect.

The baseline survey also identified the need for two other specialist studies:

i) investigation of diatom communities to assess water quality patterns;
ii) a detailed survey of channel-bed sediment characteristics, including trout spawning sites, using a freeze-coring technique.

iii) *Experimental Studies*

An experimental reach was located to include most of the instream habitats that characterize the river and to enable detailed investigation of the relationships between flow, temperature, hydraulic parameters, macrophytes, macroinvertebrates, and fish. Data analysis used two approaches:

a) PHABSIM (Physical HABitat SIMulation); and
b) A new approach based upon invertebrate habitat preferences.

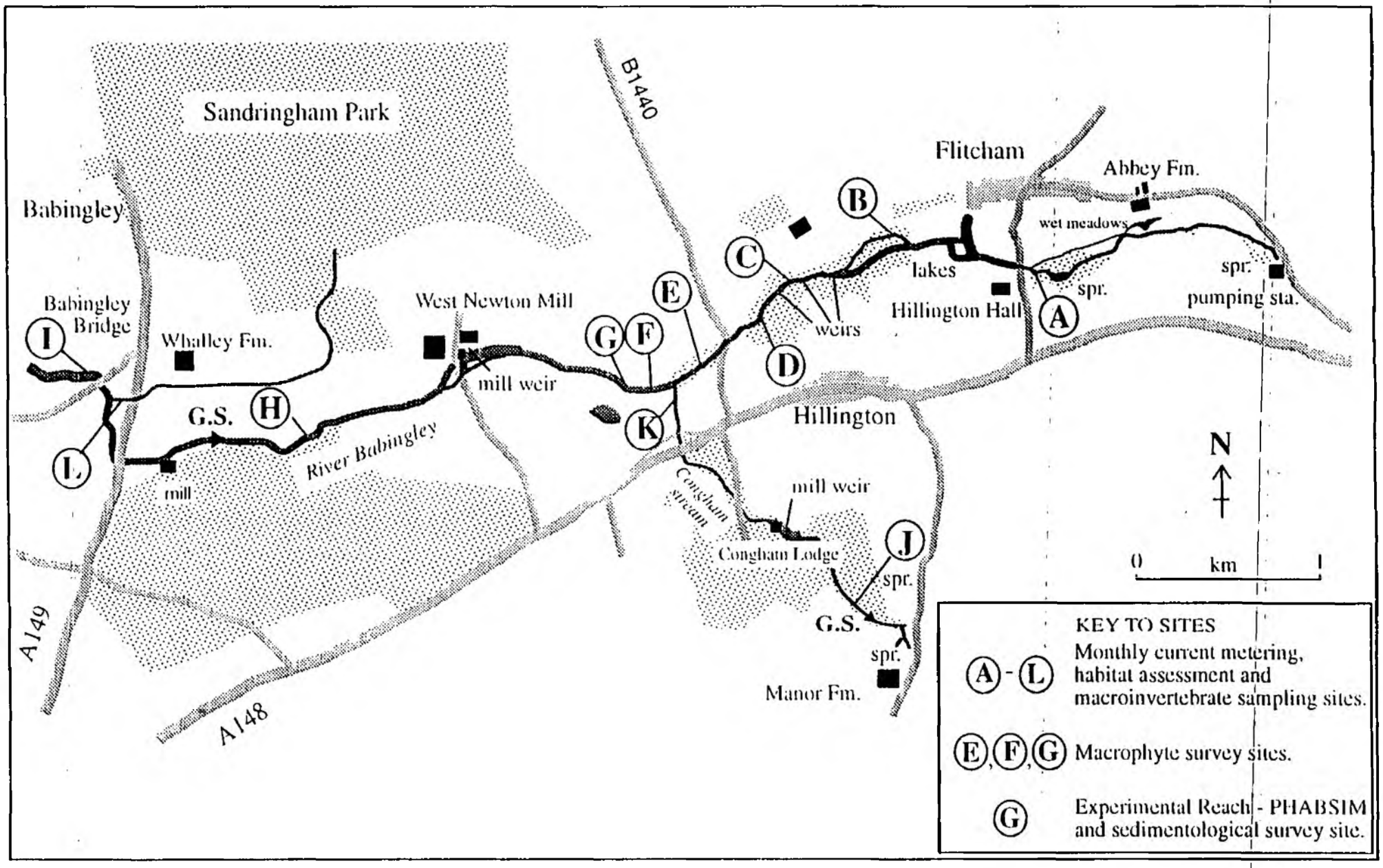

Figure 1 Map of the River Babingley and tributaries, indicating the location of survey sites.

2 RESULTS

This study represents a continuing development of our understanding of the links between hydrology and ecology and of ways to evaluate instream flow needs. The River Babingley was shown to be of high ecological interest and the springheads are of considerable conservation value.

2.1 Typology

A typology of sites for the River Babingley has been established. The main river comprises only two major sectors: A, the Chalk stream sector from the Flitcham Abbey Farm springhead to Babingley Bridge (Figure 1), and B a fenland section from Babingley Bridge downstream to the tidal sluice. Within the first sector five reaches have been differentiated on the basis of physical habitat and water-quality characteristics:

A) CHALK STREAM
- Ai) Upstream of the Hillington stream confluence
- Aii) Hillington stream confluence to the B1440
- Aiii) B1140 to the Congham stream confluence
- Aiv) Congham stream confluence to West Newton Mill
- Av) West Newton Mill to Babingley Bridge

B) FENLAND STREAM

Sector A is a trout stream of high ecological interest but Sector B has little ecological value although sustaining a fair cyprinid fishery. During the period of survey, a period of extreme low flows, neither the Congham stream nor the Park Pool stream (lower section) contained fauna or flora of special interest.

2.2 The Chalk Springheads

There are two main springheads, below Flitcham Abbey Farm and Manor Farm. A field survey of these two sites showed that both provide habitat for nationally notable species of Diptera.

The permanent springhead and associated wet-meadowland on the Babingley below Flitcham Abbey farm is shown to be of particular conservation value: defined both by its largely unmanaged geomorphological and ecological setting and by the associated species of fauna and flora.

At the time of survey, the Manor Farm springhead showed less of interest than Abbey Farm, probably because of its contrasting topographic setting and management history. The main contrast is the lack of trees around the Manor Farm springhead to provide shade and diversify habitat.

2.3 Flows

Flows over the 1988-92 period are shown to be the lowest sequence of flows on a record that extends back to 1963, although a new gauging station was established in 1976. For example, the median flow for 1992 of 0.191 m^3s^{-1} compares with the median value for the 1976-85 period of 0.533 m^3s^{-1}.

Flows in the Babingley appear to be relatively high in comparison to neighbouring streams but this is shown to be an artifact of the inaccurate definition of the catchment area. The defined topographic catchment area is shown to underrespresent the effective catchment area of the groundwater system by a factor of between 1.6 and 2.3; the effective catchment area appears to be about $80km^2$.

Flows in the Babingley are dominated by discharges from the permanent springhead at Flitcham Abbey Farm. Up to 90% of the river flow comes from the springs at Flitcham and Hillington, although a higher springhead, now dry in most years, may have contributed important flows to a 'winterbourne' sector above Flitcham.

2.4 Water quality

Being dominated by springflows, conductivity (about 640 $uScm^{-1}$) varied little during the year, increasing slightly downstream in winter and decreasing slightly downstream in summer. pH ranged between 7.5-8.3. The flows have moderate nutrient loadings with Total Oxidized Nitrogen exceeding $10mgl^{-1}$ but the water quality of the upstream reaches is generally good. Invertebrate scores were: BMWP 100<140 and ASPT averaged 5.3. Biological monitoring using a diatom assay demonstrated that water-quality declines downstream being poorest in Sector B.

2.5 Macrophytes

Sites unaffected by shading from riparian trees have a good macrophyte development dominated by *Hippuris* and *Rorippa* with *Ranunculus* important only in the lower reach Av. However, the development of the dominant species during the year varied considerably between sites.

2.6 Morphology

Channel width is greatest in reach Ai immediately below the Flitcham Abbey Farm springhead and then remains at about 5-6m downstream. Reaches Aii and Aiii are gravel-bed, pool-riffle channels with the substrate comprising more than 20% gravel coarser than 28mm. Below the Congham stream confluence, the substrate is dominated by sand; the gravelly-sand substrate being overlain by a thin gravel armour layer. Reach Av and Sector B have largely artificial channelized forms.

2.7 Instream hydraulics.

In terms of the hydraulic geometry, the river includes a diversity of channel types: upstream sites being dominated by changes of velocity and downstream sites being dominated by changes of depth. The importance of macrophyte growth in sustaining patches of high velocity and clean gravel substrate during severe low flows is demonstrated for reaches Aiv and Av.

2.8 Macroinvertebrates

Analysis of NRA records and field survey data indicate that the river contains a reasonably rich macroinvertebrate community typical of a moderately sized, macrophyte rich, unpolluted Chalk stream, although clear differences exist between sector A (typical gravel bed, upland fauna) and other sites having faunas typical of lowland and silted conditions. Correlation with a range of environmental variables demonstrated the importance of flow velocity and substrate. Important seasonal differences are also shown with the fauna in May being different to that in October and February.

2.9 Fish

Sector A is a typical small Chalk stream, with a trout fishery. Despite the drought that has severely limited habitat availability for brown trout for four consecutive years, trout biomass in February 1993 was 3.8gm^{-2}. Although few adults were captured, there were large numbers of juveniles indicating that, although suitable habitat was severely limited, spawning had been successful in 1991/2. The major problem for adult fish is the lack of deep pools with good flow, probably because sedimentation by sand has largely infilled former pools in the absence of high, flushing flows.

2.10 Linking hydrology and ecology

A summary of the analyses of biological responses to changing flow are given in Table 1. However, the volume of water that is required to meet the needs of biological targets is dependent upon channel size, the 'naturalness' of the channel morphology, especially its bedform, and upon whether any artificial structures (such as fish weirs) have been introduced to mitigate against the adverse effects of low flows or historic channel 'improvement' works. Along the Babingley there are a number of weirs designed to sustain habitat for adult trout during low flows (see Plate 3 in the Main Report). These structures sustained refuge habitats for trout during the severe 1989-92 drought when flows fell to below 0.1 m^{3}s^{-1}.

As a result of these observations, a 'drought' flow regime has also been proposed assuming that the weirs will be maintained or other habitat management works introduced to provide the necessary refuge habitat.

Table 1 Summary flow data for the River Babingley (as gauged at Castle Rising)

Method	Record	Discharge (m^3s^{-1})
95%'ile flow	1977-92 (naturalized)	0.246
Mean flow	1977-92 (naturalized)	0.640
PHABSIM - minimum flows		
Trout - Adult		0.280
Spawning		0.280
Juveniles		0.170
Fry		0.090
Invertebrates		0.127
Invertebrate Sensitivity Analysis		
	February	0.30
	May	0.30
	October	0.12

3 DEFINING A TARGET ECOLOGICAL FLOW REGIME

3.1 The approach

Three fundamental principles provided the basis for the approach:-

- seasonally variable flows (at least 'winter' and 'summer') minimum flows, defined to meet specified ecological targets, must be defined for different life stages or ecosystem functions;
- wet years and drought years are important features of natural ecosystems and play important roles in sustaining the ecological integrity of a river;
- high flows (bankfull or above) with a moderate frequency (once in every 1-5 years) are required to maintain physical habitat diversity.

3.1.1 Benchmark flows

The approach used five benchmarks to establish a flow regime to meet a specific objective, ie to maintain usable habitat for trout. The benchmarks are:

- the Channel Maintenance Flow (CMF), which may be used to define a Habitat Maintenance Flow (HMF=0.6CMF)
- an Optimum Ecological Flow (OEF),
- a Desirable Ecological Flow (DEF) or 'normal winter minimum flow',
- an Acceptable Ecological Flow (AEF) or 'normal summer minimum flow',
- a Threshold Ecological Flow (TEF).

The TEF is the flow below which habitat for the ecological target is eliminated.

The magnitudes of these benchmark flows were defined using field observations, a simulation model (PHABSIM), and comparison with the more detailed study of the River Wissey. Acceptable frequencies were then given to these flows to enable the construction of flow duration curves. Two scenarios were used: with and without fish weirs to improve habitat under low-flow conditions.

Having established the magnitude of the benchmark flows and their *acceptable* durations and frequencies, an Environmentally Acceptable Flow Regime (EAFR) was generated by defining:-

i) a series of typical minimum monthly flows including the DEF and AEF having an average frequency of once in every two years.

ii) a series of wet-winter flows, which include the CMF and HMF, and the acceptable frequency of occurrence (1:3 years).

iii) a series of dry-year minimum flows, including the TEF, and the acceptable frequency of occurrence (1:5 years).

3.1.2 Application of the EAFR

The EAFR should be regarded as a guide to meet the desired ecological targets. Different EAFRs may be derived for different targets. On some rivers, especially those that have been channelized, for a single target, different EAFRs may be developed if other structural habitat enhancements are introduced and maintained. Thus, this approach may be used in the decision-making process to examine the relative costs and benefits of different flow-management alternatives in relation to habitat management options.

3.2 The Babingley

3.2.1 Ecological objectives

The upper Babingley, Sector A and the permanent springhead at Abbey Farm are considered to be of high ecological value and conservation interest. It is recommended that this sector should be conserved and managed to enhance its high conservation value. The primary target used in this study is to sustain the river for adult trout.

3.2.2 The benchmark flows

The recommended monthly flows and the derived flow duration curves (Figure 2) are based on the following benchmarks:

Flow	Benchmark	Without weirs	With weirs
m^3s^{-1}		EAFR1	EAFR2
1.8	CMF	Q0.3	Q0.3
1.2	HMF	Q1.5	Q1.5
0.93		Q5	Q5
0.70	OEF	Q10	Q10
0.45	DEF	Q27	Q27
0.30		Q58	Q50
0.28	AEF1	Q87	Q55
0.20	TEF1 AEF2	Q100	Q87
0.10	TEF 2	Q100	Q100

Other percentiles have been fixed arbitrarily to provide a smooth curve.

A precautionary approach is recommended, using the EAFR1 as the basis for water resources management on the River Babingley.

3.2.3. Water resources implications

The above results indicate that after allocating water for in-river needs (EAFR1), the volumes available for abstraction represent about 40% of the gross resource. With regard to the specific scenarios (section 1.1), Options B (1) and (2) would be ecologically acceptable. The recommended flow duration curve to sustain usable habitat for trout includes a 25% reduction of the mean and median flows but an increase in the gauged 95th percentile flow is required.

If there is a need for additional abstractions, consideration should be given to surface water abstraction from the Fenland sector which requires lower flows to maintain habitat for biota.

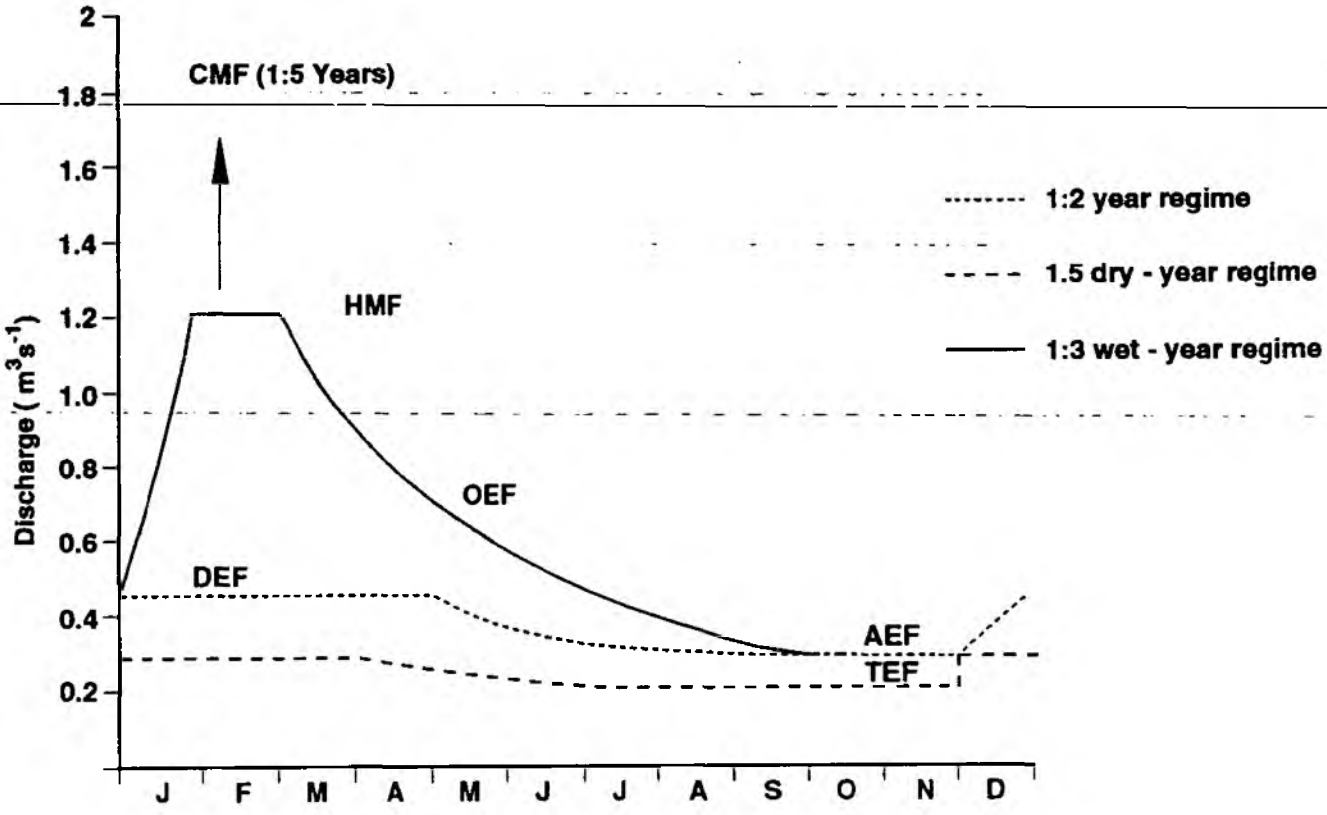

Figure 2a Flow Hydrographs used to construct the EAFR for the River Babingley

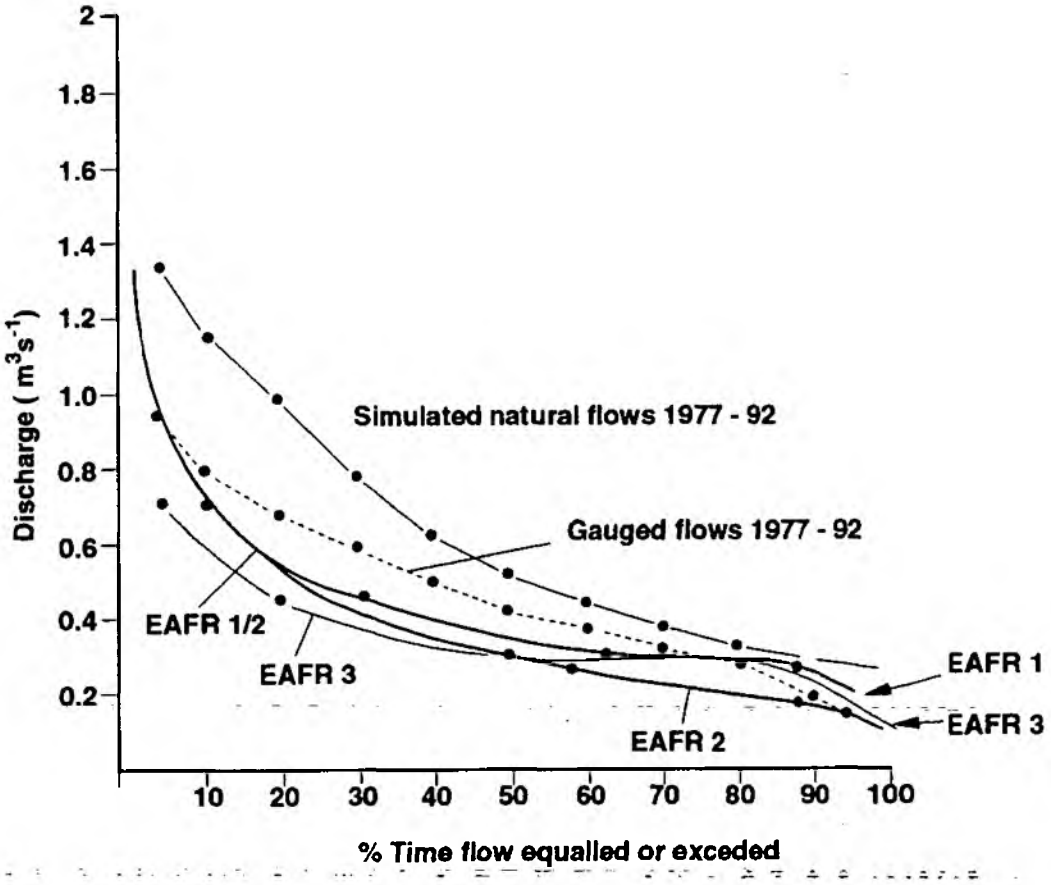

Figure 2b flow duration curves for three EAFR scenarios defined in the text in comparison to the gauged air simulated return data

4 MANAGEMENT OPTIONS

4.1 Flow management

It is Recommended that the Ecologically Acceptable Flow Regime (EAFR1) is applied to the upper Babingley as a matter of priority. However, the middle river below West Newton Mill is of less value and here flows over Greensand. Options include:

i) Restore flows at the Babingley springhead by reducing abstractions from the Chalk (but note the expanded effective catchment area over which such a policy would have to apply);

ii) Introduce river support from groundwater pumping to maintain flows during periods of drought.

The loss of abstractable volume from the Chalk groundwater may be replaced:

iii) by a surface water abstraction at or below the Castle Rising gauging station;

iv) by increased abstraction from the Greensand, the effects of which are likely to be restricted to the lower reaches;

v) by increased abstractions from the catchment of the Manor farm spring (but note that although the spring and stream have little ecological value at present, better management could enhance the ecolgical quality of this part of the catchment).

4.2 Habitat needs

The flow recommendations are made with the provision that the existing habitat quality is maintained or enhanced.

i) In the absence of floods to flush the channel, pools should be dredged of sand and hydraulic diversity maintained by flow narrowing structures.

ii) The only source of gravel to the river is from bank erosion; periodically gravel could be introduced to the river below Hillington lakes to allow 'natural' downstream replenishment during floods, or individual riffles in reaches Aii and Aiii especially could be directly supplemented.

iii) Large amounts of sand enter the river from cultivated fields. Throughout reaches Aii and Aiii the river gains some protection from sedimentation by the existing wooded buffer strip. This should be retained. Reach Aiv and the Congham stream are ploughed to the river bank and these reaches would benefit from the creation of a buffer strip although care should be taken not to create a closed canopy over the stream in order to sustain macrophyte growth.

iv) Habitat-diversity throughout the lower reaches of Sector A is significantly and beneficially influenced by the seasonal pattern of macrophyte growth; instream management should develop a sensitive approach to weed management.

4.3 Recommendations for further investigations and improved monitoring procedures

4.3.1 Macroinvertebrate monitoring

In the light of the perceived high conservation value of the upper River Babingley, and the diversity of habitat types along the length of the river, the number of routine sampling sites is probably inadequate. In particular, it appears that only two sites are currently being monitored: Babingley Bridge and North Wooton, and that the whole of the upper section is being ignored. In order to maintain a satisfactory record of the biological quality of the whole river it is recommended that routine monitoring is at least resumed at the Flitcham site. Ideally, a new site should be introduced upstream or downstream of the B1440 (between sites D and E of this survey).

4.3.2 Manor Farm Springs

Any test pumping in the vicinity of Manor Farm springs should be accompanied by a further ecological survey to assess the impacts of draw-down on the spring margins, and more importantly the adjacent wet woodland, which have been shown to support some nationally notable invertebrate taxa.

4.3.3 Park Pool Stream

Increased abstraction from the Greensand could adversely affect the Park Pool stream which rises, apparently from the geological map, from Greensand springs on the Sandringham estate. It is recommended that further detailed ecological survey is undertaken of these springs to assess their ecological value and likely impacts. Note however, that during this survey the contribution of the Greensand, and the Park Pool stream in particular, to the flows in the Babingley was negligible during summer.

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