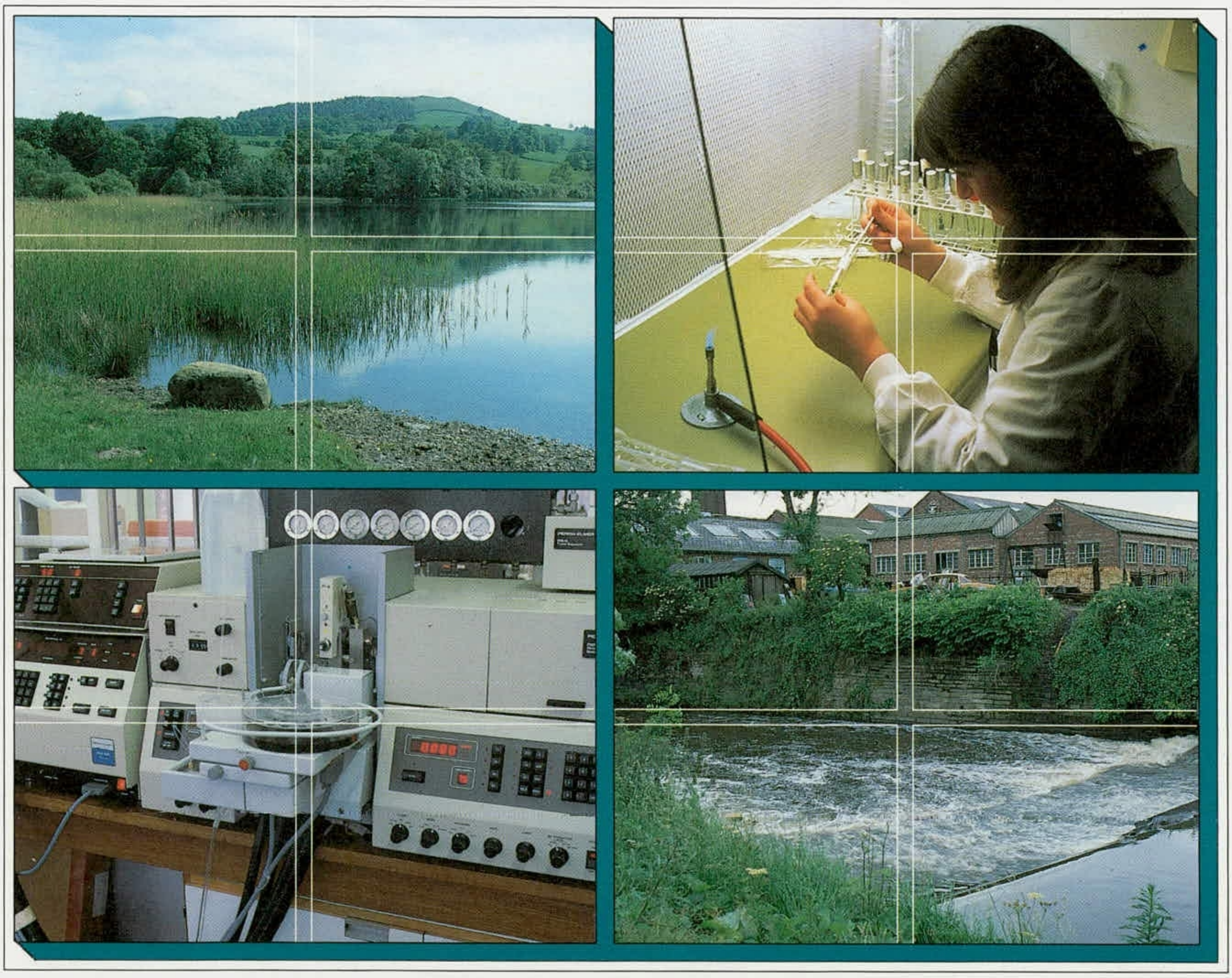
Institute of Freshwater Ecology

River Corridor Strategic Overview Feasibility Study

A report to the National Rivers Authority



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River Corridor Strategic Overview
Feasibility Study

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i) A strategic overview of conservation value and enhancement potential would bring many benefits to NRA as a whole; it is a prerequisite of policy decisions and future strategy

ii) An overview is feasible by remote sensing if combined with existing map data.

iii) The most feasible options are aerial photography at 1:10,000 or imagery by ATM or CASI supplemented with infrared; available satellite imagery is only useful in a catchment context

iv) Trial interpretations of aerial photographs have distinguished a large number of features but not always significant ones to environmental assessment

v) Aerial photographs since 1986 for half of England & Wales from a variety of sources at an estimated cost of £0.24 M; completion with new photographs may cost £0.57 M

vi) Photographs require correction, visual interpretation and digitization; the estimated minimum cost is £0.6 M

vii) Digital data are more versatile and computer processible but the technology and analysis methodology are still being developed; data can be analysed at appropriate scales in different areas. Simulated colour pictures of medium resolution can be made available

viii) The overall cost of a remotely sensed overview is estimated at £2 M which is about a tenth the cost of field RCS surveys which are also limited seasonally

ix) Estimates are based upon 45,000 km of main river and 181,000 of headwater streams, although the total could be 365,000 km

x) Photographs or computer images are of use to many NRA functions esp. as a first filter for operational work; they are a tangible asset for sale and acquisition costs could be significantly reduced by internal and external collaboration

xi) River corridor survey produce well-annotated habitat diagrams with a strong landscape component. There is no overall assessment index or national standard and no analysis of critical parameters resulting in much redundancy of data; the methodology needs improvement to match strategic and operational needs and the biological assumptions investigated

xii) Progressive validation phases are required:
An initial phase with detailed costings will be required with respect to:

- obtaining photographs, map & data sets; commission new imagery or photography
- correcting, interpreting and digitising data
- developing and validating a hierarchical classification for conservation value
- choice of a computer software & system and integration of data

A second phase extending the overview by producing a predictive system based upon layers of map and environmental data in a Geographic Information System is proposed from which to obtain estimates of biota for pristine sites prior to modification by input of remotely sensed data; interactive features allowing management scenarios to be tested following field testing

1. INTRODUCTION

The National Rivers Authority (NRA) has recognised the need for a more strategic approach to the classification and assessment of rivers with respect to conservation value and enhancement potential. A feasibility study into this strategic overview approach is therefore an essential pre-requisite to any policy considerations which will shape future NRA strategy in this field and may necessarily involve significant capital expenditure.

An assessment of the feasibility of a strategic overview of rivers in England and Wales was the main objective of this particular study. Full terms of reference are given in Appendix 2, but the specific objectives were to identify the advantages and disadvantages of the options available by establishing:

i the type, extent and sources of available information,
ii the methods required for interpretation and classification,
iii staff resources and expertise required,
iv benefits and links with other NRA core and support functions and external organisations particularly in terms of catchment management planning,
v possibilities of collaboration with external organisations,
vi timescales involved,
vii estimated costs and
viii database and data handling requirements.

1.1 Background

1.1.1 The need for an overview and its benefits

The NRA has a statutory duty under Section 16 of the Water Resources Act 1991 to further conservation. Conservation is taken to include wildlife, habitats, landscape and natural beauty and features of archaeological and historical interest. A pre-requisite, therefore, is to (1) assess and evaluate the current conservation status of inland and coastal waters and associated lands in England and Wales and (2) monitor changes in status resulting from both global and localised factors, the impact of the NRA being predominant either as a direct modifier or indirectly through granting of land drainage, abstraction or discharge consents. It is also important that, in furthering conservation, objectives for enhancing or rehabilitating degraded habitats can be identified, target dates set and actual performance measured against these criteria.

Rivers represent a major focus of NRA responsibilities. The river channel and associated lands, therefore, have become the focus for a major effort involving habitat surveys and impact assessments. However, a national strategic overview to provide planners at the national and regional level with an index of river conservation value, is still lacking.

Conservation often emphasises the protection of the best examples of habitats or rare plants and animals. As a result, developers and others, all too often, mistakenly regard features that occur outside the "ring-fence" designating an SSSI as having no conservation status.

Only 369 km of river-length in England and Wales is currently designated specifically as riverine SSSI. Although it is of paramount importance that the best rivers need to be protected, it is only right that proportionately more effort should be directed toward enhancing the conservation value of the remaining 99% of river length. All rivers have some conservation value or potential. There is an urgent need to evaluate the rivers of England and Wales so that the best stretches can be identified and protected while the remainder can be maintained or enhanced.

A strategic overview also has major potential in terms of a holistic approach to catchment management planning, incorporating other core NRA functions (Water Resources, Water Quality, Flood Defence, Fisheries, Recreation and Navigation) and outside organisations such as English Nature, Countryside Commission and English Heritage.

The methodology for a strategic overview needs to be **simple, rapid, robust** but **flexible** and readily repeatable. In terms of staffing resources, it should be entirely independent from, but complementary to, the current programme of river corridor surveys. It should also be compatible with survey methodologies used by the NRA to monitor the general and special ecosystem use-related Environmental Quality Objectives.

1.2 Method of approach

The method of approach was a desk study, literature search and contact with relevant personnel from the NRA and outside organisations. This report details existing information, outlines the options available and recommends the most appropriate methodology for the NRA. Additional emphasis was placed on conservation enhancement potential and consideration of how an overview would fit into a hierarchical classification system (Appendix 3).

This feasibility study is an essential precursor for the proposed strategic overview. It identifies cross-functional benefits and possible collaboration/cross-funding for the overview exercise.

1.2.1 Key issues

Potential methodologies for a strategic overview of the conservation value and enhancement potential of English and Welsh rivers were identified and assessed (IFE proposal, Appendix 3). Techniques needed to allow meaningful, reliable data to be obtained, made simply available and able to be analysed rapidly. The NRA would use the data as a first phase assessment, but also to underpin environmental protection, general improvement or determination of the potential for enhancement of special habitats in a cross-functional context, which would also benefit other agencies and government departments. The significance of biotic and geomorphological features such as the presence of trees on banks, the variation in river form, e.g. riffle-pool sequences, overhangs, sinuosity, in relation to fish populations but also to other biota, e.g. macroinvertebrates or plants and their diversity, has to be assessed in the context of other catchment characteristics.

One specific objective of the study is to compile a 'matrix' of the advantages and disadvantages of the different potential methodologies. This is determined by the **extent** and **quality** of the available information sources, implementation and **classification requirements,** and the benefits to both the NRA and other organisations. The best options and a recommendation for the most appropriate methodology for the NRA is the final output.

1.2.2 Detailed objectives

This report identifies and evaluates the following:

- information availability, its type, extent, sources, coverage, scale and the access costs data for sources including:
  - maps and geographic data base information;
  - satellite imagery;
  - aerial photography with interpretation from single and stereo pairs;
  - aerial video photography;
  - aerial multi-spectral and imaging scanners;
  - ground-based surveys extracts especially river corridors;
  - other potential sources or computations from databases.

- The methods required for interpretation and classification, including factors such as
  - the economic balance between survey effort versus the effort required for data elucidation and processing from the chosen media;
  - information quality and
  - reproducibility.

  The data obtained by various methods was assessed in biotic and geomorphic terms.

- the type of information that can be derived efficiently from air photography/video etc to provide data for categorising the conservation value of rivers in terms of
  - level of management from evidence of river straightening, culverts and canalization,
  - water uses, upstream and adjacent,
  - adjacent land-use, i.e. distinguish between semi-natural and intensively cultivated
  - river flow pattern;
  - potential levels of disturbance to wildlife and vegetation; presence of footpath, buildings, tow-path, building, moorings, then

- techniques to incorporate relevant data, including RCS, into a simple classification of river conservation value,

- the most appropriate format for presentation of final classification and the associated database, (e.g. GIS)

- ways in which GIS could be used as a management tool to record, display and provide figures on conservation status of rivers.

2. METHODS

2.1 Approach

The existing River Corridor Survey (RCS) method in its various draft forms, was examined. The parameters were isolated in an attempt to find those which could be satisfied from remotely-sensed data. It is obvious that the ideal RCS parameters require specialists to undertake surveys. In addition many surveys only include data on landscape and land use features combined with habitats in which plants were identified to species, and some simple morphological parameters. Although these surveys are of direct use in response to specific operational construction or maintenance work, there is no overall assessment value which puts the site-species detail into a wider sub-catchment, catchment, regional or national context. No analysis of factors or parameters, common to sites judged to be "good" or "bad" seems to have been undertaken as yet, although there is a some qualitative consensus of opinion in the general scientific community. Initial examination of photographic material indicated that several habitat and morphological parameters e.g. sinuosity, continuity of tree or bush line, etc., could be determined but there was no framework into which they could be integrated. It is therefore necessary to consider other assessments and predictive methodologies to determine if habitat quality can be assessed from parameters which could either be remotely-sensed or derived from existing data sources.

The approach has therefore been to assess:

i field survey RCS and similar (or more extensive) methodologies including the collection of physical, chemical and biotic data;

ii remotely sensed data and techniques primarily high resolution air imagery with supplementary satellite data;

iii a hierarchical approach combining both field survey and remotely-sensed data;

iv a predictive or modelling approach based on 'layers' of environmental data analysed within a data management or geographical information system (GIS) and calibrated with respect to a sample of remote sensing/field data (availability of existing map and data sets of use to predictive models).

2.2 Other potential approaches

2.2.1 Conservation status of rivers in South Africa

An expert system computer program has been implemented in S.A. for the assessment of conservation status (O'Keeffe et al 1987). The system is based upon the user supplying information about specific river attributes such as fish numbers, quantities and types of effluent etc. These parameters are then weighed against rules derived from expert opinion, and a river conservation system status (score from 0 to 100) is given as a first approximation encapsulating what are generally accepted to be the more important components of conservation status. A modified version of this approach called 'SERCON' (System for Evaluating River Conservation) is being developed by P.J. Boon (Scottish Natural Heritage) with some involvement from the NRA (P. Raven pers. comm.).

3. RIVER CORRIDOR SURVEY AND ASSOCIATED METHODOLOGIES

3.1 Comparison of RCS with other surveys

Various methodologies were compared to the River Corridor Survey (RCS) methodology whose output is descriptive and generally given as annotated, site-specific diagrams representing 500 m lengths of watercourse, despite the proposals outlined in the original NCC/Holmes draft methodology. The maps are useful in providing basic data for operational work; particularly on-site assessment between contractors and conservation personnel. Anglian NRA have been using field survey techniques to produce maps of river corridor (100 m wide?) characteristics including fauna, flora etc. along 500 m lengths, their River Environmental Database (RED).

Parameters included in the standard RCS are habitat or adjacent land-use with flora identified to determine uncommon or rare species and specific areas of plants or other features to be retained where possible.

These surveys do not have an overall assessment in simplistic form and often require considerable skill or experience to interpret. An overview is required for both strategic and operational purposes, especially at sites where decisions on development may be controversial.

Except for sinuosity, tree distribution etc., RCS survey parameters are not particularly easy to determine by several of the remote sensing methods.

The straightforward field survey technique is capable of providing a very wide range of parameters of potential interest for evaluating the environmental quality of a river. However, a number of methodological problems are present:

- Site specific; the time and costs involved in collecting such a wealth of data are very high, hence restricting survey to regions/sample areas. An intensive field survey approach is therefore more suitable for site-specific problems, e.g. in response to a specific proposal for development. In particular they are useful for providing basic data for operational work during on-site negotiations between contractors and conservation personnel, but not really appropriate for a strategic overview of the type envisaged.

- No well-defined methodology exists to translate the data collected into a simple measure of environmental quality/conservation value. Interpretation of the information requires experience and consistency is not assured.

- Data redundancy; research is required to determine which RCS parameters explain most of the variation in derived indices of river environmental quality. In this way it should be possible to determine a minimum number of parameters of importance which provide maximum discrimination between sites.

3.2 RCS costs

The overall direct costs of standard field surveys and report writing vary greatly (£50-160 per km). Surveys commissioned by North West NRA have cost £57 per km and 1.6 km per day during late spring, summer and early autumn. The cost of the Rivers Environmental database (RED) for NRA Anglian is £0.5 M for 6,000 km or £83 per km but includes more detailed ornithological surveys.

This is £13 M for 45,000 km of main river and 181,000 km of headwaters and would take 140,000 person days.

Other figures are available for the length of rivers and stream other than main river. Figures in Table 6.4 indicate that this value could be too low by a factor of two. Thus, neglecting variation in survey requirements e.g. access to sites, site quality etc., and not including standing water, **the cost of a comprehensive RCS-based survey could be as much as £21 M and take 230,000 man-days to complete;** it would need to be resurveyed at some predetermined frequency of perhaps 10-20 years.

3.3 Potential for predictive methods

Other methodologies were investigated on the assumption that a good river corridor is likely to have good aquatic or riparian biota (Table 3.1). Only one main predictive system was found to be in operational use in Britain, i.e. RIVPACS, which predicts the probability of aquatic macro-invertebrate occurrence using environmental data, although other more extensive systems are under development. In this system 8 or 12 parameters are used in predictions of macro-invertebrate fauna expected for unpolluted sites; the probabilities derived are then compared to samples to assess the degree of degradation. If this type of approach could be used (by extrapolation beyond those limits currently considered acceptable) then data on

1. positional parameters can be found from maps, e.g. altitude, bed slopes and distance from the source;
2. specialised maps of river discharge class, air temperature (and hence water temperature);
3. derived data to a lower level of detail, for water width, water depth and substratum composition (surface geology reduced/sorted by stream velocities), alkalinity of the water (retention and drift geology).

There is of course an element of a circular argument in this as, for example, river classification is also derived (but by a different method). This range of parameters may need to be altered or broadened to include all biota but could be biased in favour of a choice of map parameters for prediction of potential conservation value before downgrading this by remotely sensed data to derive enhancement potential.

Further research and development will be required for predictive techniques before they can be used for a national strategic overview of the conservation value of rivers. Problems need to be resolved on the:

Table 3.1 Summary of parameters used in survey methodologies for watercourses (from Saunders and Dawson 1992, see also Appendix 4)

(Key: 1.. = number of classes of parameter; ∞ = identified as far as possible or measured as far as practical; * = defined by surveyor)

			1	2	3	4	5	6	7	8	9	10	11
LOCATION:													
Lat./Long. or NGR			.	∞	∞	∞	.	∞	∞	1	.	∞	∞
Dist. river source			.	∞	∞	.	.	.	.	.	.	.	.
TOPOGRAPHY:													
Altitude			∞	∞	∞	.	.	∞	.	.	.	∞	.
Channel size	Width	Water	4	∞	∞	4	∞	∞	.	∞	.	4	∞
		Bankfull	.	.	∞	4	.	.	.	.	∞	.	.
	Depth	Water	4	∞	∞	3	∞	∞	.	∞	∞	5	3
		Bankfull	.	.	∞	4	.	.	.	.	.	.	.
Channel morphology	Slope of bed		.	∞	∞	.	3	.	.	.	.	.	∞
	Substrate		9	4	7	7	5	5	.	4	6	6	3
	Shape	Bank slope	4	.	.	4	.	.	.	.	4	.	3
		Form	.	.	3	.	3	.	.	.	.	.	.
		Sinuosity	.	.	4	.	.	.	.	.	.	.	.
Shade			3	.	.	3	.	.	. .	∞	.	3	.
Erosion			.	.	5	.	3	.	.	.	.	.	.
Water velocity			?	.	∞	.	.	5	.	5	5	.	.
Discharge			.	9	∞	.	.	.	.	.	.	.	.
Water colour			.	.	∞	.	.	.	.	∞	4	.	.
Maintenance			.	.	∞	.	.	.	.	.	.	.	.
Adjacent land use			9	.	∞	∞	.	9	.	∞	6	11	7
Features u/s & d/s			.	.	∞	∞	.	9	.	.	.	.	.
WATER CHEMISTRY:													
pH			.	.	∞	.	.	.	.	.	.	.	.
Conductivity			.	.	∞	.	.	∞	.	∞	.	.	.
$CaCO_3$			.	.	∞	.	.	∞	.	.	.	.	.
Ions	Anions		.	2	6	.	.	.	.	2	.	.	.
	Cations		.	.	4	.	.	.	.	.	.	.	.
	Ion balance		.	.	∞	.	.	.	.	.	.	.	.
Temperature	Air		.	∞	.	.	.	.	.	.	.	.	.
	Water		.	∞	∞	.	.	.	.	.	.	.	.
BIOLOGY:													
Flora	present		∞	.	∞	.	4	.	∞	3	∞	7	6
	% cover		5	.	.	5	4	.	.	1	.	.	6
Fauna			.	∞	∞	.	.	.	14	.	.	10	.
Length of survey (km)			.5	.1	.2 .1	.5	*	*	?	?	.02	*	.5

1	=	RBSQ/River Corridor Survey
2	=	RIVPACS
3	=	IFE (Reconnaissance and full EIA surveys)
4	=	Faunal Richness of Headwater Streams (Land-Use Survey)
5	=	Fluvial Auditing
6	=	HABSCORE
7	=	Macrophyte and Vertebrate Survey (NRA)
8	=	Biological Survey (NRA)
9	=	Haslam Survey
10	=	Dorset Environmental Records Centre
11	=	CPI (Conservation Potential Index)

1. restricted spatial dimension in which assessment is specific to a particular stretch of river within a water catchment of specific landscape characteristics, and

2. the assumption in predictive systems based upon aquatic and riparian biota that a high score for these parameters is indicative of a river corridor with high environmental quality.

Further research is required to support this assumption and to determine which additional parameters are required to provide a reliable overall index of river corridor quality.

3.4 Summary

The standard RCS and its derivatives result in essentially well annotated diagrams of vegetation and morphological characteristics. Standard RCS methodology is best seen simply as a recording technique to show that a reach of river has been examined thoroughly, but this is not necessarily translatable into a robust and repeatable index of environmental quality. There is plenty of scope therefore for improving the methodology in both biological and landscape terms.

The high cost of a field-based approach to RCS and the methodological problems involved in translating the wealth of detailed data into simple and consistent indices of environmental quality conservation grade suggests that such an approach is neither practical nor desirable for a national survey. Sections 4 and 5 consider the contribution that remotely sensed data (air-photography, airborne scanners and satellite imagery) provide to RCS as a possible means of obtaining less detailed data but over much larger areas.

4. PHOTOGRAPHIC REMOTELY SENSED DATA

4.1 Introduction

This section describes the availability of remotely sensed photographic and video data suitable for river corridor survey assessment from aircraft. The type, extent, sources and availability of these data, together with an appraisal of other critical aspects such as the status, coverage, scale and the access cost is also presented.

4.2 Air Photography

The acquisition of air-photography in England and Wales is largely undertaken in response to specific requests from county councils, private developers for smaller areas and, more routinely, by Ordnance Survey (OS) for map revision.

Until the establishment of the Air Photographic Advisory Service (APAS) at the OS in Southampton, purchasers of air-photography in England were obliged to contact the air survey company directly, to obtain details about air-photo coverage for a particular area. Air survey companies now submit quarterly updates of flight index maps to APAS. These are available for customers to consult.

Wales has had its own central register of air-photography for a number of years, operated by the Welsh Office. The Air Photographs Unit holds an extensive collection of air photographs of Wales at various dates and scales. The unit is also responsible for indexing all air surveys flown by the RAF, OS, Government bodies and commercial air survey companies in Wales.

Within England and Wales, a variety of organisations either hold nationally important archives of air-photography, or fly new air-photography. A list of the major organisations holding existing photography or flying new air-photography is included in Appendix 1b, but a brief description of the most important within the context of the proposed River Corridor Strategic Overview, is presented in Table 4.1.

The extent of air video was not explored although data held within NRA is covered by the Air Utilisation Study Report of January 1992 (Project leader: Dave Stanley).

4.2.1 Availability of air-photography

Air-photography, in blocks greater than 250 km^2, acquired at 1:10,000 scale or greater between 1986-91 by the various air-survey organisations below, covers an estimated total area of 84,000 km^2. This represents 56% of England and Wales (151,000 km^2). **More than 50% of England and Wales is flown at large scale every 5 years**, though the distribution is variable. For example, Wales and the South of England is better covered than the north and east of England.

Table 4.1 Availability of blocks (> 250 km^2) of large-scale air-photography 1986-91

County/Region	Area (km^2)	Date	Black/white colour	Scale (1:n,000)	Company
Avon	1300	1991	C	8	AE
Beds	1200	1991	C	10	AE
Berks	1250	1986	C	10	GE
Berks	1250	1991	C	10	AE
Bucks	1900	1988/9	C	10	GE
Cheshire	2000	1988	C	10	CU
Cornwall	3600	1988	C	10	GE
Cornwall (Bodmin)	300	1986-90	B	10	MAFF
Cumbria (Eden Valley)	500	1986-90	B	10	MAFF
Durham	2400	1991	C	10	AE
Essex	3400	1990	B	12	AE
East Sussex	1800	1988	C	10	GE
Hampshire	3800	1991	C	10	GE
Hertfordshire	1600	1990	B	12	AE
Humberside	3500	1989	C	10	GE
Isle of Wight	400	1986	B	10	CU
Kent	3400	1990	C	10	GE
Lancs	3100	1988/89	C	10	GE
Leics	2500	1991	C	10	GE
Lincs (part)	400	1986-90	B	10	MAFF
London	1600	1991	C	5	AE
Manchester	1300	1988-89	C	10	GE
Merseyside	650	1989	C	10	GE
Northants	2400	1990	C	10	GE
Norfolk	5400	1988	C	10	BKS
Norfolk (coast)	800	1986-90	*FC/BW	10	MAFF
Norfolk(part) Yorks(part)			10	MAFF	
North Yorks	2100	1986-90	B	10	MAFF
Oxon	2600	1991	C	10	GE
Shropshire (part)	700	1986-90	B	10	MAFF
Somerset (part)	800	1986-90	FC	10	MAFF
Staffs	2400	1991	C	10	GE
Suffolk	3800	1986	C	10	GE
Suffolk (coast)	800	1986-90	C	10	GE

County/Region	Area (km^2)	Date	Black/white colour	Scale (1:n,000)	Company
Surrey	1700	1988	C	10	GE
S. Yorks	1600	1989	C	1	
Tyne and Wear	500	1991	C	15	GE
Wilts	3500	1991	C	10	GE
West Midlands	1600	1989	B	8	AE
West Midlands (part)	400	1986-90	B	10	MAFF
West Sussex	2000	1986	C	10	GE
2. WALES					
Dyfed (Carmarthen)	1200	1986	BW	10	MAFF
Dyfed (Cardigan)	700	1989	C	10	CU
Gwynedd					
i) Snowdonia National Park	4000	1986	C	10	GE
ii) Lleyn	300	1991	C	10	MAFF
Gwent	1400	1991	C	5/10	GE
Powys					
i)West	900	1981	BW	10	MAFF
ii) North East	900	1990	BW	10	MAFF
iii) Radnor	400	1986-89	C	10	MAFF
Mid Glamorgan	1000	1991	C	5/10	GE
South Glamorgan	400	1991	C	5/10	GE
West Glamorgan	800	1991	C	5/10	GE

Key

AE	Aerofilms Limited
GE	GEONEX UK Limited
CU	Cambridge University
MAFF	Ministry Agriculture Air Photo Unit
*	Infrared

4.3 Other sources

4.3.1 Ministry of Agriculture, Fisheries and Food Air Photo Unit

The MAFF Air-Photo Unit in Cambridge acquires photography in support of MAFF activities in agricultural research and monitoring. A flight index map of recent photography (1986 onwards) is available and regular updates are sent to APAS at OS. The Unit holds recent, medium scale (1:20,000) photography of eight of the national parks in England and Wales and regularly acquires large scale (1:10,000) air-photography within Environmentally Sensitive Areas (ESAs). In addition, since 1986 the MAFF air photo unit has flown large blocks of photography dispersed throughout England and Wales, frequently in colour and mostly at 1:10,000 scale.

MAFF air-photography is likely to provide a useful source of information for a strategic river corridor overview, in the more remote areas of England and Wales.

4.3.2 Royal Commission for Historic Monuments, Air-Photo Library

The Department of Environment (DoE) air-photo library is now housed with the Royal Commission for Historic Monuments. The library is divided into two main sections:

(a) a specialist collection of 500,000 **oblique air photographs illustrating architectural, archaeological and landscape subjects;**

(b) a general collection (various scales, dates) of 4 million vertical air photographs derived from OS, RAF and various commercial sources covering the period 1929-85.

The majority of the vertical air photography is black and white and medium scale (1:20,000). Post 1985 photography is not being added to the archive of vertical air-photographs. In the context of the NRA river corridor survey, this source of photography will only be useful in providing historical information. The patchy coverage of oblique photography makes it unsuitable for a survey of the sort envisaged unless landscape attributes are deemed important. However, it could be a useful factor in planning rehabilitation of degraded sites to previous status.

4.3.3 GEONEX UK Limited

GEONEX (formerly G.A. Storey and Partners) of Mitcham, Surrey, is a commercial air survey company with an extensive archive of air-photography of large to medium scales, often in colour. Much of this is county cover, the most recent of which (Oxfordshire, Hampshire, Wiltshire, Leicestershire, Staffordshire, West and East Sussex) was flown at 1:10,000 scale in colour to coincide with the 1991 population census.

The extensive coverage of large scale and mostly recent air-photography acquired by GEONEX represents a potentially important source of information for a river corridor overview.

4.3.4 Hunting Aerofilms Limited

Aerofilms fly a considerable amount of air-photography each year, mostly for county councils at 1:10,000 scale in colour. The regular update of county-level air-photography, means that Aerofilms is another important potential source of photography for a national overview of river corridors.

4.3.5 Other aerial photography

Other sources of aerial photographs include NRA Thames, Wessex and Southern regions. A strong landscape element is inherent in most of the source material.

4.3.6 Other platforms

Remotely controlled blimps, model planes and even kites have been used for small scale or site specific data collection. In terms of a national overview, these are unlikely to be of much value.

4.4 Aerial video

Extensive aerial video surveys have been flown by NRA Severn Trent region initially assessed on the Severn-Vyrnwy and then on the River Tame, R. Avon and the Severn Estuary (see Aircraft (and Helicopter) Utilisation Study 1992).

4.5 Cost of air-photography

The acquisition of new air-photos in England and Wales remains uncoordinated. A nationwide survey (England and Wales) as proposed for the Strategic Overview will therefore have to rely upon obtaining coverage from a number of different sources **plus** commissioning new flights of the remaining areas.

4.5.1 Air photo acquisition costs

The costs of purchasing **existing** air-photo prints vary according to the organisation and the number of prints ordered. At 1:10,000 scale each print covers approximately 5 km^2, requiring 48,000 prints (including 60 per cent stereo overlap) to cover England and Wales (151,000 km^2). **At an average cost of £10-15 per print, the total cost would be £480,000-720,000 or £3.20-4.75/km^2.**

The costs of acquiring **new** air photography are much higher, but an **average figure would be £7.50/km^2, for full stereo**, roughly twice the cost of purchasing existing photography. **It would therefore cost more than £1 M (£1,132,500) to acquire new air-photography for the whole of England and Wales.**

However, given the approximate repeat survey of 50% of England and Wales every 5 years, **a possible option would be to combine purchase of existing photography with acquisition of new photography. The costs of this option would be £3.20 km^2 for existing photography for 50% of England and Wales (£241,600) and £7.50 km^2 for the remaining 50% (£566,250) to give a total of £807,850. This option represents an investment in air-photography (existing and new) of between £0.75-1 million** over a period to be revised by NRA but which could give a frequency of five although not less than 10 years is to be recommended. The cost is estimated at approximately £5 M for 1:3,000 scale.

The cost of video photography from helicopter was estimated from NRA Severn Trent's flights at 500 and 1500 feet to be £10 km^2 or £840,000 based upon an estimated 84,000 km of watercourse.

4.6 Air photo interpretation costs

The critical factor when calculating interpretation time, apart from photo scale, is to consider the type and characteristics of each watercourse being interpreted and the variations in the density of watercourses across England and Wales. Whilst an approximate figure for main rivers (channelised and maintained) and streams (undefined) in England and Wales is 226,000 km, this fails to take into account large regional differences in drainage density. The density of the drainage network within a large area of Kent as shown by OS 1:50 000 scale maps, has been calculated from the Water Information System (see section 6.5) using new software written by the Institute of Hydrology (IH) for this specific project. The software calculates the length of river channel per 1 km square with appropriate adjustments for lakes and sea. The data, which are presented in Table 4.2 and Figure 4.3, show considerable variations in the density of the drainage network, reflecting differences in geology and especially the presence of chalk within the region.

It is extremely difficult to give more than an approximate figure for interpretation time of air-photography. Based on a trial of interpreting 1:10,000 scale air-photography of Oxfordshire, **an interpretation rate of 50 km length of watercourse per day (10 stereo pairs) is realistic. This would require 4500 days, roughly equivalent to 21 man years of effort to complete England and Wales based upon an estimate of 226,000 km of watercourse.**

Table 4.2 Variations in drainage network density (Kent) expressed by 1 km square from 1:50,000 digitised map

(a) Kent	
Squares containing a length of watercourse	25%
	km/square
Maximum length of watercourse in square	9.6
Minimum length	0.01
Average length	1.07
Standard deviation of lengths	(1.35)
(b) Extrapolation for river/stream length in England and Wales	
mean estimate	162,000
maximum estimate	365,000
(c) NRA quoted figures	km
Main river - statutory	45,000
Headwaters (post order streams estimate, Lyle & Smith)	181,000
Combined length of channel	226,000
Drains within Internal Drainage Boards and outside (Dawson 1985, report to WRc)	150-250,000

4.7 Air-photography; information content

A trial interpretation of 1:10,000 and 1:3,000 scale colour air-photography of a section of the River Kennet (Chilton Foliat - Knighton) was undertaken to determine the type and quality of river corridor information that could be interpreted from these two scales of photography (Figures 4.1 and 4.2).

This is summarised in Table 4.3, in which the type of features of interest for a river corridor survey (NCC draft, Appendix 4) are compared with those interpreted for the River Kennet. The table also includes an assessment of which features of interest in environments other than a typical lowland river, could be interpreted from air-photography. This is based partly on experience gained from interpreting air-photography for the Monitoring Landscape Change (MLC) study (HTS, 1986) in which a sample of air-photography was used to map changes in land cover in England and Wales between 1947 and 1982. There is little available information on the use of air-photography for mapping many of the smaller features of river bank and river habitat. Air-photography covering a wider range of environments would need to be evaluated during the validation stage before making definitive statements about its value for detailed river habitat mapping.

Figure 4.1 Trial interpretations (overlay) of 1:3,000 scale colour air-photography of a section of the River Kennet (Chilton Foliat - Knighton) with inset at 1:10,000

Figure 4.2 Trial interpretations (overlay) of 1:10,000, scale colour air-photography of a section of the River Kennet (Chilton Foliat - Knighton) with inset at 1:25,000 scale of similar data

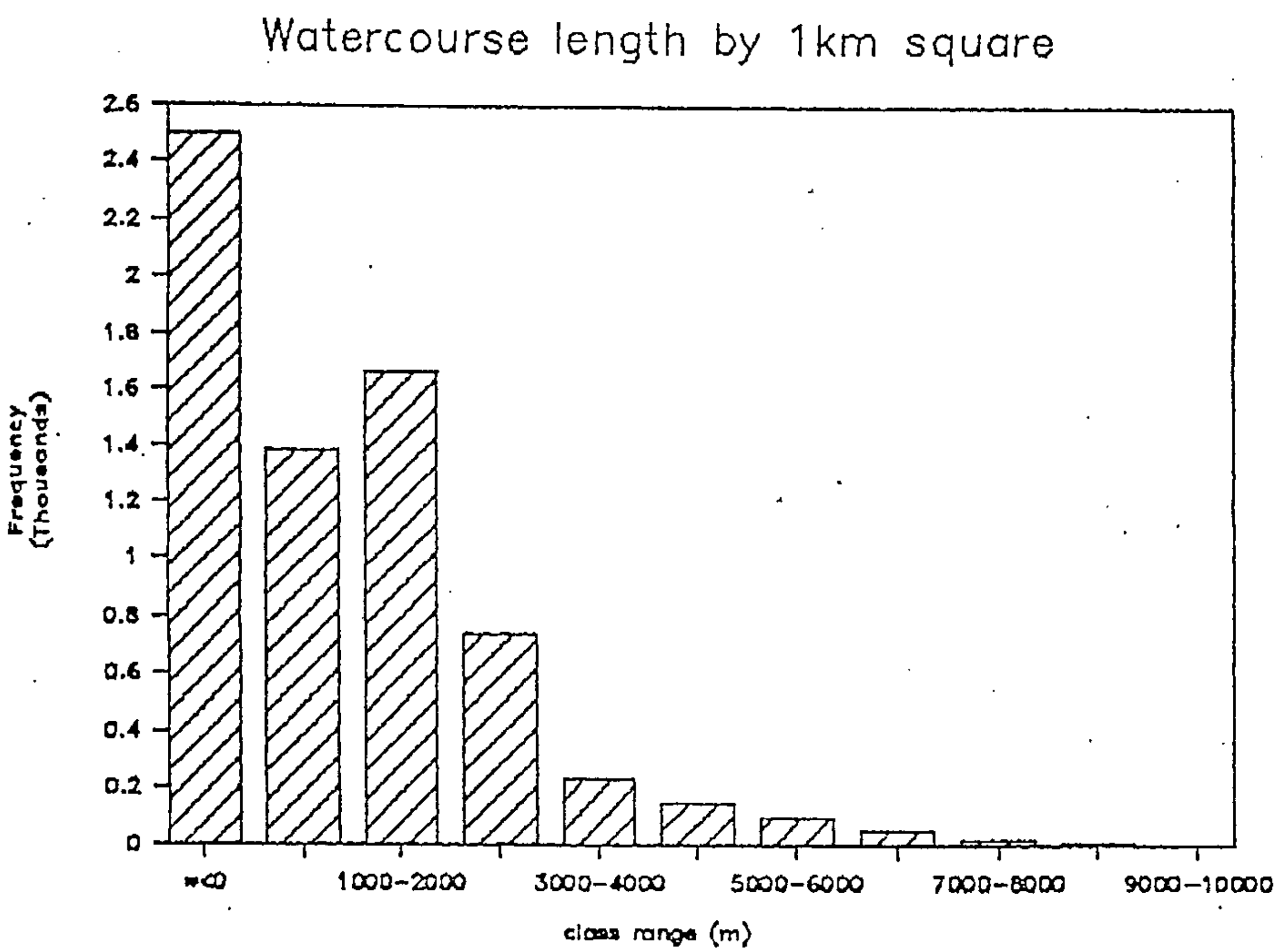

Figure 4.3 Bar chart showing frequency of length of watercourse within 1 km squares for Kent. Analysis commissioned from Institute of Hydrology for this report.

Two sets of aerial photography were acquired in different months during 1991. The 1:3,000 scale photography acquired under winter vegetation conditions in March gave much better discrimination between certain land cover types, e.g., rough pasture and marshy grassland. At full summer growth in September, these differences were much less apparent on the 1:10,000 scale air-photography. An additional problem is deriving information on watercourse characteristics along stretches which are fringed with trees.

In general, both the 1:10,000 scale and 1:3,000 scale air photos could be used to map area features (Table 4.3) but the larger scale (>1:5,000) photography facilitates interpretation of more detailed river bank and habitat features. It will be important to interpret different types (black and white/colour) scales (1:20,000-1:3,000) and dates of air-photography for a range of environments to establish a workable classification. This will require a limited amount of fieldwork to validate interpretation.

Processing potential

(a) Aerial photographs

It is now feasible and relatively cheap to digitise air-photography, enabling the image to be processed using standard image processing techniques and should be explored as part of a validation exercise. The cost of digitising (perhaps £10-20 per print) and the large quantities of data involved, may mean that this is impractical except for priority areas. For example, a standard (23 cm x 23 cm) 1:10,000 scale photograph digitised at 50 microns (i.e. 0.5 m on ground) represents more that 20 Mb of data or 700 Gb per colour for England and Wales; the data produced by this process could be reduced by only digitising, at this high resolution, the corridor within say 100 m either side of watercourses or by computer within say 150 m from the Ordnance Survey blue-line watercourse digitised data.

Existing image classification software fails to utilise important pattern, context and texture parameters that are essential for successful classification of very high resolution imagery such as air-photography. However, in the medium it may be feasible to mosaic a large number of air-photo prints for a region of interest and store the imagery on optical disc, enabling the user to display an area of interest for detailed interpretation on a colour monitor. Interpretation would be assisted by overlaying ancillary vector map information (drainage, woods, settlements etc.) onto the photo image.

(b) Aerial video

The apparently high resolution of aerial video data is primarily related to interpretation by the human eye. Despite the use of good quality (broadcast) video cameras with 450 line resolution, spatial correction techniques for captured frames and density enhancement, the data content is relatively low and all the above mentioned problems of image classification remain.

4.8 Air-photography; information capture

Whatever method is adopted, there will be a basic requirement for the data to be rectified to a base map. This can be achieved at different levels of precision depending upon the type of data and the extent of the relief.

Table 4.3 A trial comparison of photo interpretation of air photography from River Kennet into NCC RCS classification classes

River corridor habitat classification	Identified on R. Kennet air-photography	Possible to identify from colour air-photography
AREA FEATURES		
A. Woodland Scrub		
1.Woodland:		
-semi-natural (broadleaf)	yes	yes
-plantation	no	yes
2.Scrub	yes	yes
- carr	no	no
3.Parkland	no	yes
4.Recently felled woodland	no	yes
B. Grasslands		
1.Unimproved	yes	yes
2.Semi-improved	no	difficult
3.acidic	no	)
		) unenclosed
4.neutral	no	) rough
		) pasture
5.calcareous	no	)
6.improved	yes	yes
7.marshy grassland	yes	yes
C. Tall Herb and Fen		
1.Bracken	no	yes
2.Upland mixed	no	no
3.Tall ruderal and ephemeral	no	no

River corridor habitat classification	Identified on R. Kennet air-photography	Possible to identify from colour air-photography
D. Heathland		
1.Dry dwarf-scrub	no	yes
2.Wet dwarf-scrub	no	yes
3.Lichen and bryophyte heath	no	) upland) heath
4.Mountain heath	no	)
5.Heath/grass moor	no	yes
E. Mire, Flush and Spring		
1.Bog/fen	no	yes
2.Bog flushes	no	yes
F. Swamp inundation communities		
1.Swamp	yes	yes
G. Open Water		
1.Canals	no	yes
2.Ditches	yes	yes
3.Ponds, pools, cut-off meanders	yes	yes
4.Lakes (lochs/llyns)	no	no
5.Gravel pits	no	yes
6.Reservoirs	no	yes
7.Streams	yes	yes
H. Coastland		
I. Rock		
1.Natural rock	no	yes
2.Quarries/mines	no	yes
J. Miscellaneous		
1.Arable	yes	yes
2.Amenity grassland	yes	yes
3.Ephemeral/short herb		no difficult
4.Hedges	yes	yes

River corridor habitat classification	Identified on R. Kennet air-photography	Possible to identify from colour air-photography
BANK FEATURES		
A. Bank morphology		
1.Shelves	no	yes
2.Earth/rock cliffs	yes	?
3.Artificial banks	no	yes
4.Canalised	yes	yes
5.Flood banks	no	yes
6.Bank height	no	large scale
7.Bank width	no	large scale
8.Bank slope	no	no
B. Bank Composition		
1.Mud	no	yes
2.Sand	no	yes
3.Earth	no	yes
4.Bare shingle	no	yes
5.Vegetated shingle	no	yes
6.Natural cobbles/boulders	no	yes
C. Bank vegetation		
1.Conifers	no	yes
2.Broadleaf	yes	not to species
3.Scrub	yes	yes
4.Reed	yes	yes
5.Ruderals, herbs, grasses (dense cover)	yes	yes
RIVER HABITATS		
1. Inlets	yes	yes
2. Depth	no	no
3. Width	yes	yes

River corridor habitat classification		Identified on R. Kennet air-photography	Possible to identify from colour air-photography
4.	Substrates		
	- bed rock	no	no
	- boulders	no	no
	- cobble/pebble/gravel	no	no
	- mud/silt/clay	no	no
	- peat	no	no
5.	Flow		
	- pool/slack	yes	yes
	-riffle	yes	yes
	-run	no	no
	-rapids	no	yes
	-waterfall	no	yes
	-protruding rocks	no	difficult
	-margins (shingle, mud, sand)	yes	yes
FLORA			
1.	Emergent marginal fringe	yes	yes
2.	River flora	no	no
3.	Algal cover	no	possible if dense

4.8.1 Photogrammetric mapping

A standard photogrammetric plotter or more advanced analytical plotter (approx. £100,000), is used to create a 3-D model of the surface from pairs of stereo air-photographs from a set of ground control points (GCPs). The interpreter is then able to map directly onto a base, e.g., 1:10,000 scale. The results can be encoded into a GIS simultaneously or digitised subsequently. A comparison of the two methods will be necessary especially with respect to accuracy.

The high precision attainable from photogrammetric mapping is achieved at a relatively high cost compared with other methods, but in areas of very steep terrain this may be the only method that provides results of acceptable accuracy. This was the conclusion of the Nature

Conservancy Council (now English Nature) National Countryside Monitoring Scheme (NCMS), which used a sample of air-photography to map habitats in selected counties of England and Wales and for Scotland.

Zoom Transferscope

A lower cost option is to match the air-photo interpretation to a base map using a zoom transferscope (cost of machine £10,000). This instrument allows the user to match two maps (i.e. interpretation and base map) of different scale and plan. With some instruments digital encoding can be accomplished at the same time. The advantage of including the base map at the interpretation stage is that the river network from Ordnance Survey is visible to assist with interpretation as some OS maps are not entirely accurate with respect to rivers, especially at 1:50,000 scale.

Rectification of digital maps

A correction for scale distortion in digital air-photography is relatively straightforward in areas of gentle relief. GCPs identifiable on both the digitised air-photography and the base-map are recorded, enabling the air-photo data to be rectified to the base by re-sampling the image data (£10-£20 each). To correct for distortion introduced by topography would require a digital terrain model (DTM). Whilst DTMs of the UK exist (see section 6), the costs of purchasing high resolution data (5 m contour interval) to give sufficient accuracy are unlikely to justify the additional accuracy (or to be available).

A more practical technique would be to rectify interpretation maps derived from air-photography within the GIS. Different riverine attributes, e.g., bank morphology, riparian vegetation, stream-bed substrate, could be digitised as separate files and analysed within the GIS using a model that relates these and other attributes from ancillary data, e.g., soils, adjacent land cover to river corridor quality.

Rectification, for example, of oblique video frames is required and various techniques continue to be developed by The Geodata Unit at Southampton University.

4.9 Date of baseline survey

(a) Establishing a baseline

The variable dates for which air photographs are likely to be acquired across England and Wales means that the date of the baseline survey will have to cover a specified number of years. For example, for a survey commencing in 1993, the baseline could be 1990-94, with a repeat every 5-10 years. Alternatively as recent data already exists for half the county then a frequency of 10 years could be used if the remaining half could be flown within five years. It may be advantageous to undertake the survey progressively over an extended period, with a repeat survey of each county, catchment, etc., every 5-10 years depending upon monitoring requirements. This would simplify the acquisition of new air photography which could then be spread over a longer period. This is an important logistical point given that one air survey company is unlikely to be able to fly more than four or five counties (5-10% of county) in each season under typical weather conditions.

(b) Monitoring requirements

It is also likely that the conservation status of particular reaches of river will change more quickly in areas subject to greater human pressure. The repeat cycle should therefore be shorter in these areas. Similarly, more effort should be concentrated on these stretches of river possibly involving a range of survey techniques from air photography to detailed field sampling including flora, fauna, fish and water chemistry. The larger rivers and their floodplains would be included in this category, especially those where the potential impact of flood defence activities is large and which may also be important for fisheries, recreation, navigation etc.

A hierarchical system is therefore envisaged involving different intensities of monitoring in both time and space based upon a range of techniques. Consideration will need to be given to the sampling problems associated with selecting rivers for more intensive monitoring, their distribution within England and Wales and the repeat frequency of surveys.

5. MULTI-SPECTRAL IMAGERY

This section describes the type, availability, extent, sources, and the acquisition of remotely sensed multi-spectral and satellite digital imagery from aircraft and satellite, for river corridor survey, including an appraisal of other critical aspects such as the status, coverage, scale and the access cost. Imagery may also be available from project orientated studies by commercial companies (e.g. Shell), but these have not been included.

5.1 Satellite imagery

Two electro-optical sensors, SPOT and Landsat Thematic Mapper (TM) have sufficient spatial and spectral resolution to provide accurate land cover maps of the UK.

Table 5.1 The spectral and spatial characteristics of the two sensors

	Landsat TM	SPOT
Sensor Type	Scanner	Pushbroom
No. of spectral bands	7	3 (MSS), 1(PAN)
Band width		
1	0.42 - 0.52 blue	MSS
2	0.52 - 0.60 green	0.50 - 0.59 green
3	0.63 - 0.69 red	0.61 - 0.68 red
4	0.76 - 0.90 nr InfraRed	0.79 - 0.89 nr Infra Red
5	1.55 - 1.75 mid Infra Red	PAN
6	10.40 - 12.40 thermal IR	0.51 - 0.51
7	2.08 - 2.35 Mid IR	
Scene coverage	185 x 185 km	60 x 60 km
pixel size	30 m (120 m in band 6)	20 m in MSS 10 m in PAN
Repeat cycle	16 days	26 days

The advantages of satellite imagery include:

- large area coverage (Landsat 185 km x 185 km),
- repeat imaging (typically 16 days under cloud-free conditions),
- digital image data with wavelengths ranging from visible blue (TM1; 0.45 - 0.52 microns) to thermal infrared (TM7; 10.4 -12.5 microns),
- good geometric properties
- relatively low cost

All these attributes need to be assessed in relation to information content compared with higher resolution airborne photographic and scanning systems.

The digital nature of the image data enables scenes to be contrast-enhanced for maximum brightness and contrast to facilitate interpretation and for each scene to be rectified geometrically, for example to the GB National Grid. Multi-spectral image data can also be classified using rapid computer-assisted techniques into broad land cover types over large areas. For these reasons satellite imagery is a valuable tool for mapping at regional level notably river catchment, county, national park and national level.

5.1.1 LANDSAT Thematic Mapper (TM)

The TM sensor was launched in 1982 on-board the Landsat series of satellites. With 7 spectral bands, including near and middle infrared and a spatial resolution (pixel size) of 30 m, this sensor represented a major improvement on the earlier multi-spectral scanner (MSS). The 30 m pixel size appears to be optimal for mapping landcover in UK, given typical field size (Townshend, 1984). **The inclusion of a mid-infrared waveband** (TM5: 1.55-1.75 microns) **provides considerable additional discriminatory power for vegetation mapping.**

The sensor has been used for a number of land cover mapping projects in the UK. The current land cover map of the UK being produced by ITE (Monkswood) is the most important of these. Hunting Technical Services Limited (HTS, 1986) produced a land cover map from classified TM data as part of the Monitoring Landscape Change (MLC) project. These data are summarised by county and a copy of the land class map is archived with the Rural Areas Database (RAD), at the University of Essex. Particularly relevant in the context of river corridor survey is the project undertaken by the National Remote Sensing Centre (NRSC, 1990) for IFE, to map land cover change in two water catchments (River Hodder and River Axe). A land cover map for each catchment was produced at two dates from computer-assisted classification of the multi-spectral image data and the results presented by parish, sub-catchment and river corridor. GIS software was used to delimit a 100 m zone around each watercourse and this buffer was intersected with each class map to show change in land cover adjacent to each watercourse over a 12 year period.

Once the ITE satellite land cover map is completed (1993) and incorporated into a data base or geographical information system, land cover adjacent to each watercourse in England and Wales could be determined by integrating the land cover map with a digitised drainage network.

5.1.2 SPOT

SPOT 1 was launched in 1986, and SPOT 2 in 1990. With a 20 m pixel size in multi-spectral (XS) mode and a 10 m pixel size in panchromatic (Pan) mode, a considerable improvement in spatial detail was obtained. However, by adopting solid state array (CCD) technology, the number of wavebands is limited to 3 (visible green, visible red and near-infrared), thereby limiting discrimination of vegetation types. Each scene is only 60 x 60 km, compared with 185 km x 185 km for Landsat, resulting in an increase in cost per square kilometre.

The most important development available from SPOT imagery is the interpretation of relatively large scale (1:25,000) hard-copy imagery based on combining the spectral information of the multi-spectral data (XS) with the spatial detail of the panchromatic (pan) data. This SPOT image integration technique has been used recently by Hunting Technical Services to produce enhanced hard-copy imagery of Cambridgeshire. Whilst spatial detail is considerably enhanced, allowing for very accurate interpretation of land cover features, resolution is not sufficient to map river corridor habitats in the detail shown in Table 5.1.

5.1.3 Other satellite sensors

ERS-1

Data from this satellite, which carries a range of microwave remote sensing equipment, is just beginning to become available. The main instrument is the Active Microwave Instrument (AMI) which can operate as a Synthetic Aperture Radar (SAR) which produces high quality radar images over a 100 km swath width and can operate through heavy cloud cover. Uses are expected to be include land use surveys, ice or oil slick movements at sea and warm/cool air front movements plus seawater temperature from the Along Track Scanning Radiometer and a radar altimeter for ice sheet and sea level variation. The SAR (image mode) has a 30 m pixel size providing data suitable for land cover mapping. The advantage of the system is all-weather capability but techniques for derivation of land cover information are less advanced than for optical sensors.

5.1.4 Satellite costs; data and processing

Approximately 15 Landsat TM scenes are needed to cover England and Wales. At a cost of £2000 per scene, total cover would cost £30,000. In addition, image rectification to the national grid, computer classification and summary of results by, for example water catchment, would probably cost a further £150,000. However, much more accurate results can be obtained by classifying two scenes acquired at different times in the growing season. This is the technique adopted successfully by ITE Monk's Wood to classify TM data of UK into a maximum of 22 land classes. The additional accuracy is obtained by effectively obtaining two spectral signatures from each land parcel, but the penalty is a doubling in data costs.

It would be possible to buy from ITE the TM derived land class map of England and Wales to correspond to the first strategic River Corridor Overview. However, future surveys would need to update this database from additional Landsat scenes.

Experience with SPOT suggests that despite its superior spatial resolution, the absence of a mid-infrared channel is a major disadvantage compared with TM for land classification. The alternative, integration of SPOT XS/Pan to produce enhanced hard-copy imagery for visual interpretation is a feasible but costly alternative. A minimum of 50 SPOT scenes is required to cover England and Wales. At £1300 for XS data and £1550 for SPOT Pan data, total cost is £65,000 for XS and £77,500 for Pan, to give a total of £142,000 for the cost of raw data alone.

SPOT data can be acquired in stereo but there is very little available for the UK.

5.2 Airborne imagery

5.2.1 Airborne thematic mapper (ATM)

The Daedalus AADS 1268 is an 11-channel, digital airborne scanner recording various band widths of approx. 0.05-.3 micron in the 0.42-13.00 micron region. With a fixed instantaneous field of view (IFOV) of 2.5 milli-radians, pixel size is a function of flying height. At 1000 m for example, pixel size is 2.5 m and swath width is 716 pixels x 2.5 m (1790 m). The advantage of this electro-optical scanner compared with conventional air-photography is the availability of spectral channels from the visible, near-infrared, short and long wavelength infrared, providing potentially much greater discrimination of surface features.

Table 5.2 Swath width and flying height for AADS-1268 ATM

Scan angle	Flying height (m)				
	500	1000	2000	4000	10 000
85^0	900 m	1800 m	3600 m	7300 m	18 000 m
72^0	720 m	1450 m	2900 m	5800 m	14 500 m

N.B. Resolution is 2.5 milliradians (1.25 mrad optional)

Table 5.3 Spectral response of AADS-1268 ATM channels

AADS-1268 Spectral Bands	AADS-1268 ATM Channels Wavelength μm	Landsat 4 TM Bands
1	0.42 - 0.45	
2	0.45 - 0.52	1
3	0.52 - 0.60	2
4	0.605 - 0.625	
5	0.63 - 0.69	3
6	0.695 - 0.75	
7	0.76 - 0.90	4
8	0.91 - 1.05	
9	1.55 - 1.75	5
10	2.08 - 2.35	7
11	8.50 - 13.00	6

A comparison of three different ATM waveband combinations including,

- ATM 2, 3, 5 (simulated true colour)
- ATM 3, 5, 7
- ATM 9, 10, 11

flown with a 5 m pixel size (nominal) over Bourton-on-the-Water (River Windrush and River Dickler) reveals considerable variation in land cover information identifiable on 1:10,000 scale hard-copy imagery. In particular, **water bodies are displayed more clearly on the imagery containing middle and thermal infrared channels** (ATM 9, 10, 11), **whilst differentiation of marsh/swamp vegetation is more apparent on imagery containing visible and near-infrared** (VNIR) **channels** (ATM 3, 5, 7).

Research would be required to determine the optimal combination of spectral channels required for specific riverine habitats. Hooper (1990) has used various band combinations of ATM data (7, 10, 5; 11, 5, 3) with a 2 m pixel size to develop relationships between biophysical and spatial characteristics of vegetation and fluvial processes.

The following vegetative and morphological attributes could be identified:

1. Vegetation
   - graminaceous species separable from tree and herbaceous species on the basis of vigour and texture
   - aquatic plants on riffle sequences
   - large monospecific stands of some submerged and emergent aquatic species

2. Hydrogeomorphic features
   - over-topping level inferred from vegetation characteristics
   - longitudinal and point bars: separable on the basis of vegetation and substrate characteristics
   - pool/riffle sequences
   - bank slope

One potential advantage of using scanner data is the scope for rapid classification of features from digital multi-spectral data. Contextual classification systems i.e. analysis of the spatial arrangement of pixels, can considerably aid classification but the software is currently primitive and misclassification, especially of mixed pixels, and the absence of contextual information within the classification procedure, considerably reduces the level and accuracy of detail that can be obtained from classification of ATM data.

A major problem with scanner data is its poor geometric properties. In the turbulent lower atmosphere, variations in aircraft altitude and attitude induce major geometric errors in the scanner data. The Natural Environment Research Council (NERC) in collaboration with the University of Cambridge (Bernard Devereaux, Department of Geography), is investigating the possibility of using a calibrated video camera on the aircraft nose to identify GCPs on both video image and corresponding map to enable the precise orientation of the aircraft to be reconstructed. This information can be used to calculate the appropriate correction to the image data.

5.2.1.1 ATM costs

In the UK, the Daedalus scanner is operated by Global Earth Sciences. The system is hired on a day rate, the amount dependent upon the number of days of hire. It is not possible, without consulting the operator directly, to calculate data costs for a region. The NRA recently commissioned flying of the south coast of England. However, the enormous amounts of data generated by the scanner suggest that flying selected areas is the only practical option, possibly along the course of a number of rivers of contrasting flow and environmental characteristics.

5.2.2 Imaging spectrometry - CASI

The Compact Airborne Spectrographic Imager (CASI) is an imaging spectrometer operating in the pushbroom sampling mode, that is, being solid state matrix of charged couple device (CDD) detectors (288 x 576). It receives reflected visible light continuously and samples a line of these data simultaneously across a swath of 512 columns. The field of view is $30/45^0$ in width and therefore the size of pixels are dependant on the flying height. In contrast to the 11 relatively broad bands of the Daedalus ATM, the spectral response of CASI is divided into 288 channels of 1.8 nm band width spectral resolution over the more limited 400-900 nm band width without full infra-red. CASI can be programmed for specific requirements which can be changed in-flight.

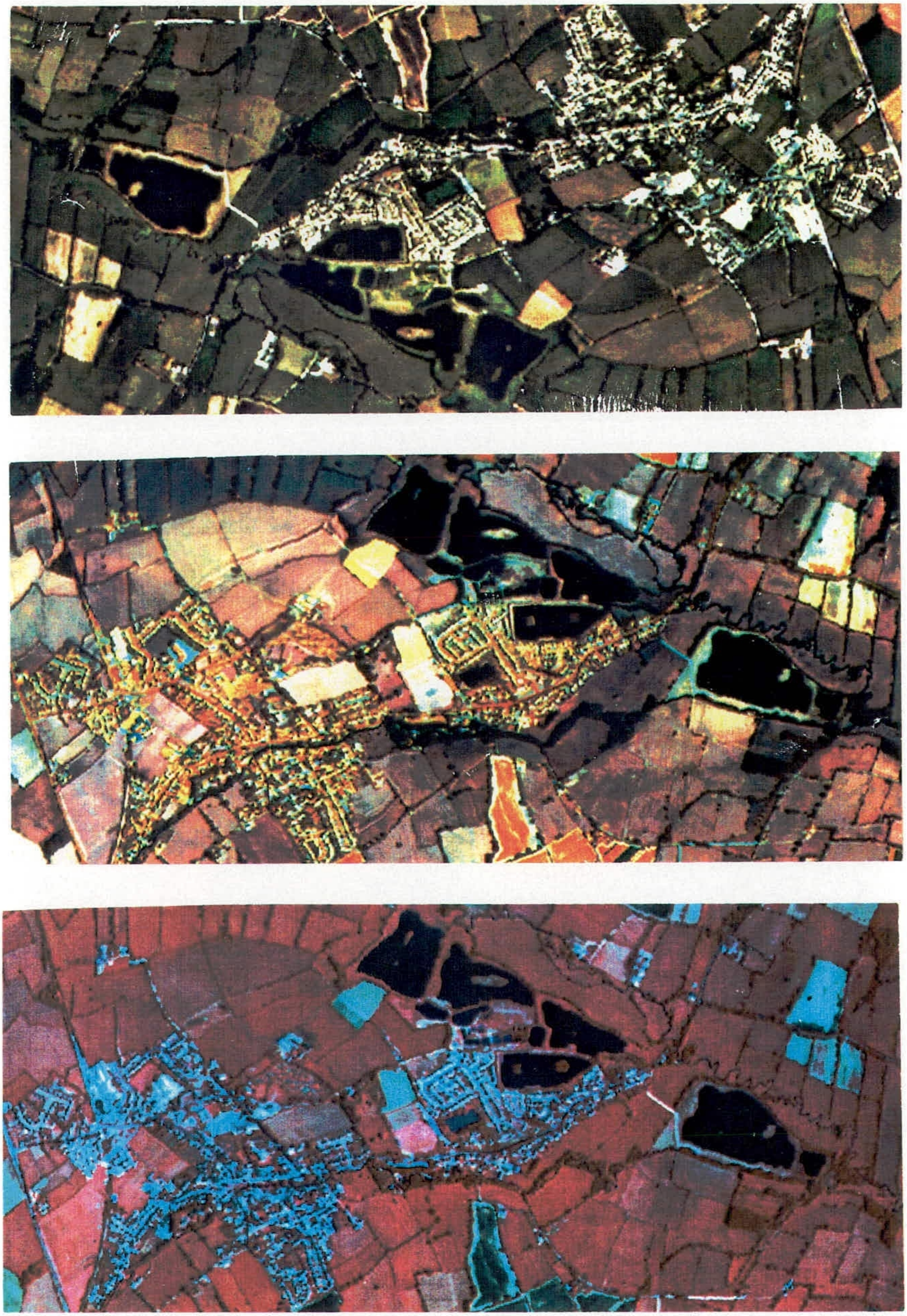

Figure 5.1 A comparison of three different waveband combinations (simulated true colour, with near infrared and with thermal bands) from digital Airborne Thematic Mapper data (see text); the original sheets have been reduced from 1:10,000 to approx. 1:20,000 to show the range of variation in colour and thus interpretation, available.

A demonstration of CASI data output was arranged at Chilworth Manor on 8 January 1992. This comprised survey flight data by ATM over the three mile coastal zone of Southern Britain from London to Bristol together with examples of CASI data; this was funded by the NRA and project lead by Dave Palmer of NRA Wessex Region as a feasibility study under the auspices of the Chief Scientist, Jan Pentraeth.

5.2.3 Other scanners

Other systems include:

(a) GER (Geophysics Environmental Research) high resolution and radiometric resolution scanners. It has two scanner systems; the first combines 63 channels, 24 channels of 25 nm-wide in the visible/near infra-red in the 0.5-1.08 micron region, 7 of 120 nm width in the near infra-red and 32 of 16 nm width in the infra-red 2-2.5 micron region; the second scanner system has 24 channels of various widths in the 0.4-14 micron range.

(b) ATTA Advanced Terrain Tracking Radar Altimeter. This was available for test by NERC in 1990 on behalf of Rutherford Appleton Laboratory, for significant wave-height measurements.

The choice of an imaging spectrometer-based survey technique for rivers is less straight-forward than for marine coastal use because of the significance of geometric corrections and the objectives of coastal surveys. The possible selection and ordering of a CASI scanner with its modified ancillary thermal spectrometer must in economic terms bias the choice especially as the proposed quarterly flights of the English and Welsh coasts will only utilise half the potential flight time. This may allow flying the land area of England and Wales within a five year period presuming that the NRA has total control of the use of the aircraft.

Sideways microwave scanners could be investigated for use in the assessment of geomorphological features.

5.2.4 Other data

- NERC Register of imagery

- ESA landsat LEDA data base on ESA Information Retrieval System, Frascati, Italy.

5.3 Comparative summary of photographic and digital imagery

Rapid developments in remote sensing technology, both in data acquisition and analytical techniques, makes it difficult to specify a particular technique for all areas. However, a number of factors are important when comparing the potential contributions of different imaging systems for a national survey of river corridors including:

i) data availability; stereo air-photography is available and continues to be flown for large areas of England and Wales. By contrast, data from airborne scanners/imaging spectrometers is restricted in coverage and likely to remain so;

ii) data resolution; air-photography is very high resolution but is limited spectrally to the visible wavelengths. Alternatively, airborne scanners have a relatively coarse spatial resolution compared with air-photography but acquire data in the middle and thermal infrared giving considerably greater discriminatory power.

The spectral range of imaging spectrometers varies (CASI is restricted to the visible and near-infrared) but their very narrow bandwidths may assist with vegetation species discrimination and assessment of water quality. Detailed research is required to demonstrate this; there has been very little substantive work published to date.

The spatial resolution of current satellite systems is too coarse for detailed river corridor studies, but the large area coverage and frequent image acquisition is ideally suited to mapping land cover change at the regional, especially catchment, level;

iii) data processing; air-photography requires time-consuming visual interpretation and manual digitising of interpretation results prior to machine processing and analysis. Digital data from scanners etc. are in a machine compatible format but the techniques for information extraction are primitive compared with the very detailed level of information that can be interpreted by the human eye from high resolution air-photography. It is unlikely that substantial improvements in information extraction procedures from digital imagery will be developed in the short-term; this will have to await developments in knowledge-based systems.

Rectification to a map base of all imagery, including from satellites and air-photography, is needed prior to data entry into a GIS for analysis and display. The procedures for digital rectification of satellite imagery and air-photography are well-established and relatively straightforward, although expensive for air-photography in areas of steep topography where high precision is required. Although the geometric properties of imaging spectrometer data are superior to airborne scanner data, considerable research is required to develop accurate techniques and practical techniques for both types of system;

iv) data costs; satellite imagery is the cheapest option but information content is considerably lower compared with airborne systems. Acquisition of large-scale air-photography (existing and new) for England and Wales is less than £1 M. It is difficult to estimate costs for airborne scanner/imaging spectrometer data but full coverage (England and Wales) would be expensive.

In summary, it is clear that the basic data source should be large scale (e.g. 1:10,000-1:3,000) colour air photography. Interpretation of this photography should be supplemented by data from the airborne scanner and imaging spectrometer at a number of contrasting sample sites during the validation stage of the project to assess the potential of these systems for deriving information, especially for detailed species mapping of aquatic and riparian vegetation, not visible on colour air-photography.

6. ENVIRONMENTAL DATA SOURCES AND INFORMATION SYSTEMS

6.1 Introduction

A major task during the validation stage of the project will be to examine the possibility of incorporating various 'layers' of environmental data into a GIS as the first step towards establishing a predictive system for measuring environmental quality/conservation value of river corridors. This will require firstly, a consideration of the databases available and secondly, the information systems available for analysis of environmental data, including data derived from air-photography/field survey specifically for the national RCS.

A number of national environmental databases and information systems are described below, with comments on status, data content, coverage, resolution, cost and applicability of the system for river corridor survey.

6.2 Environmental data sources

6.2.1 Ordnance Survey (OS)

A wide variety of digital map data are available from Ordnance Survey but, apart from the methodology of collection, data are constrained by the positional requirements of printed map production. For example, the position of watercourses are displaced when in proximity to roads.

Map data of interest include:

- Scale digital height data as 1:10,000 height, 1:50,000 contours/DTM with accuracy to 3 m, in 5/20 km squares
- Boundary record data at 1:10,000 for county, district, parish and constituencies (from March 1992)

  (Bartholomew GB digitised height)

6.2.2 Institute of Hydrology (IH)

Hydrological data are kept in the Surface Water Archive on an ORACLE database at IH. Rainfall and discharge data on some 1750 sites over the last two decades together with a record of number of years and their completeness are regularly updated.

6.2.3 SSLRC Land Information System - LANDIS

The aim of the Soil Survey and Land Research Centre (SSLRC), Land Information System (LandIS) is to organise existing soil data to facilitate its effective use. SSLRC has used LandIS to capture soil data and maps in a digital form for statistical, tabular and graphical output via a relational database management system.

The type and resolution (cell size) of data held within LANDIS are given in Table 6.1. A **number of these parameters, particularly soil type, rainfall and temperature could provide valuable inputs for the prediction of the environmental quality of a watercourse at a given site.**

6.2.4 ITE land classification system

The ITE Land Classification System provides a framework for sampling variability in the landscape. The system incorporates a wide range of environmental variables, including climate, topography, human geography, solid and superficial geology. **The principle behind the land classification is that the significant ecological variables are associated with environmental variables,** e.g. altitude. A statistical procedure is then used to allocate one of 32 Land Classes to each 1 km square in Great Britain.

The land classes show well-defined geographical distributions which reflect combinations of environmental features, thereby providing a convenient sampling frame for ecological survey. The classification has been used as the basis for three major national surveys; 1978, 1984, 1990. In the most recent survey, 508 squares of 1 km were visited and sampled, spread proportionately across the 32 Land Classes, with information recorded on plant species along streams in addition to other habitats.

The robust nature of the Land Classification System sampling frame, enables regional and national predictions of these surveyed parameters to be made. In the context of the proposed strategic River Corridor Overview, **the ITE Land Classification System provides both a suitable sampling frame for selecting river sample areas and a potentially useful data-set on land use and plant species in stream habitats.**

6.2.5 ITE satellite land cover map of Great Britain

The Environmental Information Centre (EIC) of ITE Monkswood, is producing a land cover map of Great Britain from Landsat Thematic Mapper Satellite data. The multi-temporal satellite data is being classified into 22 land cover classes (Table 6.3) using computer assisted techniques, with a minimum mappable area of approximately 1 ha. **The output gives the land cover of each 25 metre cell of the British National Grid. The project is due for completion in mid-1993, although all fieldwork and 70% of England and 30% of Wales has been completed.**

6.2.6 National Park land cover data

The Countryside Commission for England and Wales and DoE funded a project at Silsoe College to map change in land cover within each of the National Parks. **This is a potential useful data-set, providing relatively detailed information on land cover within areas of high conservation value and covering approximately 10% of the land area of England and Wales.** The most recent interpretation data is for the period 1986-88 and the data are held within a raster-based GIS (Spatial Analysis System - SPANS).

Table 6.1 Spatial data held in LANDIS in raster form

Data	Resolution	Cost £/km^2
Soil map of England and Wales (1:250 000)	100 m	0.44
	1 km	0.055
Selected detailed soil maps (1:25 000 and 1:50 000)	50 m	
	5 km	
Altitude (m)	5 km	
Local Authority boundaries of England and Wales	1 km	
Mean annual monthly, summer and excess winter rainfall totals (with standard deviations)	5 km	
Accumulated temperature (day °C above 0, 5.6 and 10.0; day °C below 0)	5 km	
Growing season - start and end dates	5 km	
Potential soil moisture deficit (PSMD)	5 km	
Crop adjusted soil moisture deficit for cereals, sugar beet and potatoes	5 km	
Field capacity start and end dates	5 km	
Machinery work days and safe grazing days	5 km	

Table 6.2 Spatial data from Institute of Hydrology (January 1992)

Data set	Type	Source	£/km^2	Notes
WRAP	1 km grid	IH	0.02	Winter rainfall acceptance potential
SAAR	1 km grid	IH	0.02	Currently 1941-70 average annual rainfall
PE	1 km grid	IH	0.01	Potential evaporation (1941-70) - grass
2 day M5	1 km grid	IH	0.01	(FSR - rainfall statistic)
2 hr rain	1 km grid	IH	0.01	(FSR)
24 hr rain	1 km grid	IH	0.01	(FSR)
2 day M5/SAAR	1 km grid	IH	0.01	(FSR)
25 day M5/SAAR	1 km grid	IH	0.01	(FSR)
SMD bar	1 km grid	IH	0.01	(FSR)
snowmelt	1 km grid	IH	0.005	(FSR)
r	1 km grid	IH	0.01	(FSR)
monthly rainfalls	12 x 1 km grids	IH+MetO	0.02 /year	plus commission to Met Office (where applicable)
1:50 k rivers	vector	IH+OS	1.00	
DTM grids and rivers	4 x 50 m grids + vector	IH+OS	3.00	plus licence fee to OS
LF grids	3 x 1 km grids	IH	0.33	

Table 6.3 Range of land cover classes for the satellite and cover map produced by ITE

1. Woodland
   - deciduous
   - evergreen
   - scrub

2. Semi-natural vegetation
   - dwarf shrub heath (lowland)
   - dwarf shrub heath (upland)
   - grass/shrub heath (lowland)
   - grass/shrub moor (upland)
   - bracken
   - grass heath (lowland)
   - grass moor (upland)
   - bog (upland)
   - marsh/rough grass
   - meadow (unimproved)

3. Arable
   - pasture (incl. amenity grassland)
   - arable
   - natural (fallow)

4. Development
   - suburban/rural development
   - industry/urban

5. Water
   - inland
   - coastal/sea

6. Bare ground
   - beach
   - bare

6.2.7 Other digitised data

Other data sources with subject details and scale or form include:

- Boundaries of Sites of Special Scientific Interest (SSSI) from JNCC together with other data of conservation interest
- Research Council data bases and systems EIC, NUTIS, and for classification and ground-truth comparisons
- Smaller databases of river data eg IFE/Southampton University survey of management on main rivers (Brookes et al 1987)
- GIS databases within the Research Councils and elsewhere;
- National rivers water quality surveys 1980, 1985, 1990

6.3 Ancillary map information

A potentially valuable source of information are maps, both contemporary and historical. Contemporary mapping (1:10,000, 1:25,000 and 1:50,000 scale OS) provide important thematic information on the distribution of built-up areas, woodland and semi-natural vegetation and a pattern of drainage including cut-off meanders. Cover information is only available in digital form for England and Wales at small scale (1:250,000) but digital mapping at very large scale (1:1250/urban plan scale) is available for most urban areas. Restricted areas are digitised at 1:10,000 scale. **The 1:50,000 scale maps (Landranger series) are being raster digitised and can be displayed as an image backdrop to other data sets. These could include the distribution of sites of Special Scientific Interest, areas of Outstanding Natural Beauty and Statutory landscape/conservation designations.** A potentially useful application of this technique is the coincidence of public rights of way adjacent to rivers as a possible way to evaluate levels of wildlife disturbance. Historical maps, e.g. pre-war at 1:25,000 scale, may provide useful information on former courses of rivers.

6.4 Environmental data summary

Databases which may be required are various but most are of suitable scale, format, type and are available for purchase if not already available or previously implemented for NRA within its regions. The choice of database or geographical information is of prime importance particularly in view of the current IS review within the NRA but cannot be decided upon without testing its input requirements, its capability, versatility, simplicity, and output. Information sources have therefore been assembled to show the potential range (or gaps) of data available for use if the RCS strategic overview is taken further.

NRA produced or commissioned ground based surveys of river corridors will be importance in testing the approach proposed in this report but will need to be integrated or transferred into the information system selected. Surveys are however selective in being produced for the better quality sites or as a brief operational assessment in response to a proposed change eg dredging, development, etc. The current estimate of strategic field RCS completed is 13% of main river or at minimum 2% of a total estimated length of all watercourses (Table 6.4).

This section therefore aims to determine the information available, its type, extent and sources together with other critical aspects such as the status, coverage, scale and the access cost.

Table 6.4 Length of strategic River Corridor Surveys undertaken in main river in each NRA region to May 1991

NRA region	Length of river (km)	Length of strategic RCS	Percentage of main river surveyed
Anglian	4453	3000	67
Northumbria	2785	350	13
North-West	5900	nil	0
Severn-Trent	7055	900	13
Southern	2010	nil	0
South-West	2788	80	3
Thames	3748	1000	27
Welsh	4802	12	<1
Wessex	2548	200	8
Yorkshire	6034	nil	0
England and Wales	42,123	5542	13

6.5 Geographic and other information systems

6.5.1 Water Information System (WIS)

The water information system (WIS) has been developed by the Institute of Hydrology (IH), Wallingford more intensively since 1989, with recent collaboration from International Computers Limited (ICL) for potential use by NRA North West.

The system has been designed to assist with national requirements for water management, planning and research. A geographical information system (GIS) approach has been adopted to handle both spatial and time-series data.

The first component of the system is based on a digital network of watercourses derived from O.S. map 1:50,000 scale. A denser drainage network is represented with greater accuracy on larger scale maps (e.g. 1:25,000 scale), but the expense of recoding contour errors and joining gaps in the drainage network on the original O.S. map sheets, precluded digitising at larger scales, except in restricted areas (e.g. North West National Rivers Authority Region).

The second important component of the system is the raster-based digital terrain model (DTM). IH have purchased contour data from the O.S., captured originally from 1:50,000 scale maps with a 10 m contour interval and converted to a grid of heights with a 50 m cell size. **A major task has been to ensure compatibility between the DTM and watercourse network, requiring a very high level of accuracy during data capture of watercourses. Given the relatively coarse resolution of the DTM, considerable time has had to be devoted to ensure that watercourses drain downslope along the lowest part of a valley at all points on the river.** By combining the watercourse network and DTM, the user can derive a number of important parameters of importance for hydrological modelling and for the management and planning of water resources in catchments. These include mapping catchment boundaries and measuring areas, and calculating flow directions and slope of steepest descent.

The third component of the system is the database of River Quality Survey (RQS) data derived from a network of sample points across the country. The system allows the user to output results on water characteristics (chemical, biological) at a given location and for a specified period. By combining spatial data (drainage network) with time-series data (pollution levels) the system can be used to draw river quality survey maps. These maps show a river network with the width of the river related to flow, and the colour to the degree of pollution. **The river quality survey data provides a potentially important data-set for combination with other environmental data** (soils, climate, vegetation) **for the development of models to predict the overall environmental quality of rivers.**

WIS provides a useful model for the development of a similar system for river corridor survey overview for both strategic and operational uses. This system could incorporate the DTM/watercourse network developed by IH, which represents a major investment in software development and data compilation.

River network density is needed to assess the cost basis for interpretation of aerial and this has been commissioned (within the contract) from IH using the WIS data base (Table 4.2 and Figure 4.3).

6.5.2 Other Information Systems (IS) or Geographical Information Systems (GIS) in use/planned and contacts

ROD Yorkshire Water plc

CORINE information system of EC. The use of GIS was explored for a variety of purposes but was nearly confounded by requirements for the large geographic content (2.3,000,000 km^2) with the requirement for a relatively fine resolution (< 1 km^2) and the wide range of data sets not thematically or spatially related but also on time and resources (Briggs 1991). Data on biotopes, areas designated for wild birds, water resources, soil, climate, slopes, coastal erosion, soil erosion risk and other related parameters but mostly at a scale of 1:100,000 or greater.

Germinal, Lausanne, Switzerland

a Dutch system, Prof Verheyen, Holland

NRA GIS task group (Keith Annand, Thames NRA) Final Report

NRA Head Office (Phil Rees)

GIS Software systems available include:

ARC/INFO, vector based industry standard, can handle large data sets but only two plane direct comparisons possible; £30,000 pa in commercial environment

Laser-Scan, another major standard

Spans

SysScan

Intergraph

Antec - Datascape (currently in use at NRA Severn-Trent and Southern Regions)

Jazzmaps

ILWIS Integrated Land and Water Information System. Developed by ITC (International Training Centre) Netherlands

IDRISI Raster-based low-cost system

GRASS US Corp of Army Engineers raster-based GIS with vector capabilities

7. DISCUSSION

This object of this report was to assess the feasibility of a strategic overview of the conservation status and enhancement potential of English and Welsh rivers. The terms of reference required that methodologies should be explored which are simple, rapid, robust yet flexible and repeatable. However current standard River Corridor Survey (RCS) methodology embody much detail and could be described as well annotated diagrams of vegetation with some morphology and other features. This immediately raises the problem of the enormity of the size of data sets required in order to provide site data in sufficient detail, to assess the conservation status for the length of watercourse in England and Wales of some quarter of a million kilometres distributed over 151,000 square kilometres of land. A balance therefore needs to be established between the large volume of data and the requirement for sufficient site specific detail to allow the conservation status to be determined in full consideration of the known range of differences at the regional and topographical level but also the nature of human interactions with the water environment.

An initial examination of a potential methodology, remote data sources, availability of geographic data and systems for data management, particularly Geographic Information Systems (GIS), a possible strategy has become apparent. This basically comprises a proposal to examine the prediction of pristine quality for sections of river from existing data, then degrading this by real data from interpretation of remotely sensed data before classifying sections of watercourse at a suitable level. To achieve this, alternative survey methodologies have been examined, sources of data assembled, alternative methodologies of remote data capture examined, trial interpretations undertaken, and possible methods of integration of remotely sensed data sources with existing map data examined to allow the establishment of some classification of output of conservation status.

7.1 River Corridor Survey (RCS)

There are several RCS methodologies used for routine operational work or part of strategic surveys, not just within the NRA but elsewhere in conservation and commerce. The standard RCS and its derivatives result in essentially well annotated diagrams of vegetation with some site morphology and other features; they have a strong landscape component but do not seem fully integrated. Standard RCS are undertaken by specialists and need specialist interpretation, and as such are not easily or directly transferable. Standard RCS methodology is best seen simply as a recording technique to show that a reach of river has been examined thoroughly and assessed. There is plenty of scope for improving the methodology in both biological and landscape terms. Indeed, the basis as originally produced in draft form (NCC) contained elements not now incorporated. The standard RCS output is not very amenable to handling or processing in any machine compatible form. The following actions are required:

1) a sensitivity analysis to allow quality assessment or grading of output for strategic, operational and site specific uses. This should enable regional and topographical aspects to be compatible with remotely sensed data.

2) The biological basis of inputs especially flora should be closely examined and set in a national and sound ecological context. Problems of rare biota and local occurrences must be confronted.

3) Aquatic faunal data should be incorporated on a nationally agreed basis.

4) RCS diagrams should be produced in a standard machine readable and storable form for easy handling and display.

Ground truth data will be required in support of remote sensed data, and existing surveys will naturally be a first choice. A representative selection across the range of RCS will be required. However, consideration will need to be given to developing an appropriate conservation classification of rivers and optimising methods of data capture compatible with other NRA functions. Landscape should have a higher priority than at present.

7.2 Remotely sensed data

The technology is currently available to provide data at many levels of detail from satellite to low overflights by aircraft. **The cost can be viewed as high but it is likely to be less than one tenth of ground-based RCS.** The acquisition of remotely sensed data is only the start of the process whether by photography or multi-spectral or full spectral means. The images need to be processed in a single or resampling process, to standard co-ordinates (National Grid Reference), the data captured and then integrated into a processing and retrieval system for use.

Available satellite data gives sufficient detail for general adjacent land or catchment classification use. The costs of buying, flying or interpreting the full cover of England and Wales are relatively high, but seems to represent a sound multi-use investment in an organisation with an annual budget of over £450 M. Coordination of flights and a register of flight requirements within NRA is currently needed to minimise costs. External cooperation should be considered. However, **a complete organised set of aerial images does have considerable commercial value by itself.** Seasonal flights to allow interpretation of rivers banks under deciduous vegetation may be needed. If integration is not possible then a sampling procedure would be required, possibly based on ITE land class system but the need for site specific information is known to exist. **Remote sensed images can supply a good first level approach suitable for operational requirements.** As a quick reference, this is particularly cost-effective in terms of decision-making.

The current choice is apparently between:

i) **large scale colour air-photography** which is the most practical and proven tool for a survey of this type having very high resolution, relatively low cost and available in colour and stereo; (at 1:10,000 scale or the intermediate option of 1:25,000 acquisition flight enlarged to 1:10,000). However, data will need to be digitised and exists only in three visible broad bands; or

ii) **imaging spectrometry**, particularly by CASI, at a similar scale to above. This technique is however prone to problems relating changes in attitude during in flight and in addition NERC has found the addition of an upward facing spectro-radiometer of use with imaging data acquisition interpretation. Imaging spectrometry has or will have, greater versatility in processing and automatic classifying; pictures can be directly produced in simulated real colour; data is available in digital form to a much extended density range than by photography.

The less complex older technology multi-spectral broad band ATM has more disadvantages particularly of resolution but does take measurements in the infra-red region which have been reasonable successful in identifying groups of riparian vegetation. The human eye is very efficient at interpreting riparian and similar features but with the expected advances in textural analysis programs automatic classification may be possible. Such distinction based upon resolution by photography or from images, may be considered academic as unless in the unlikely event seasonal flights are undertaken for the better sites partially vegetated by trees, little will be seen of the bank in any case. **It is therefore recommended that these two systems are compared over a wide range of conditions before a decision is made. This may include validation of photo interpretation from ground truth surveys or from over flights of previously surveyed sites, determination of time required for validation over the full range of habitats and at various scales, for direct transfer to raster or vector single class files in the data management system.**

The recent NRA aircraft utilisation survey (Jan 1992) summarises the need for proper analysis to evaluate the need, extent and image format for RCS, together with observations that regions are undertaking flights on a piecemeal basis in a variety of formats, that they are unaware of the technical options and that formats should be compatible with GIS and WAMS. There is also the need to make data compatible with other functions especially coastal and flood defence.

No estimate of cost has been made for interpretation of video data although a figure equivalent those above is likely. However a solution to the major problems of rectification, resolution of captured frames and data transfer to a database needs to be addressed and costed in detail during the validation phase.

7.3 Availability of data

There are many and various sources of data available both for construction of a framework for an overview system and for use in the proposed predictive part of the system (Table 7.1). Several obvious sources have already been explored and are in the process of being made more useful or corrected for use in the water environment; these should obviously be considered in the first instance.

Other sources can be used in the prediction of pristine quality values for sites or by with further development the prediction of degraded values by, for example, the input of water chemistry. One example already in use for use as a standard with which to compare field samples, is RIVPACS. It is interesting to see that eight of the input variable required can be directly found from a range of map data, two or three more can be determined with lesser accuracy, leaving one variable with only a low accuracy of prediction and another optional variable not frequently used. The resultant of this is the prediction for the probability of occurrence of tens of macroinvertebrate species or taxa but whilst it should strictly not be used in this manner it is likely to be of use incorporated in a five or ten point conservation scale. **Other similar systems and more extensive systems are under development for prediction of general aquatic or riparian biota (e.g. IFE 'plantpacs' or biomorpho-pacs or NCC systems.**

Table 7.1 Summary of parameters needed, available or potentially computable/derivable for use in RCS assessments and indices

LOCATION:			map
Latitude, longitude or NGR			map
Dist. river source			map, data base or calculate from OS blue line
TOPOGRAPHY:			
Altitude			map (satellite radar?)
Channel size	Width	Water	remote, deduce from river class data
		Bankfull	
	Depth	Water	deduce?
		Bankfull	
Channel morphology	Slope of bed		from contour map
	Substrate		possibly deduce from geology map and discharge class (or rain)
	Shape	Bank slope	possible from hydrographic range and geological data
		Form	
		Sinuosity	remote, map
Shade			remote
Erosion			(as shape above?)
Water velocity			deduce
Discharge			class from map (+ NRA harmonised sampling)
Water colour			occasionally possible e.g. peat land classes
Maintenance			remote, historical data base
Adjacent land use			available from satellite or sample based classification
Features u/s & d/s			remote
WATER CHEMISTRY:			
pH			from remote and geology?
Conductivity			from remote and geology?
$CaCO_3$			from remote and geology?
Ions	Anions		unlikely
	Cations		unlikely
	Ion balance		(as conductivity)
Temperature	Air		available as equations (Met.Office)
	Water		from air temps
BIOLOGY:			
Flora	present		under development (by IFE and JTNC?)
	% cover		from shade estimate from remote data
			RIVPACS etc.
Soils			available
land use and cover			available

7.4 Data management systems

The most challenging part of the proposed overview is integrating and modelling the data, e.g from remote sensing, fieldwork, biological and chemical samples etc. within the data management system to derive a single, practical environmental quality grade for a specific stretch of river before classifying its conservation status and the potential to improve its status. This may not be able to operate in a truly interactive way without considerable effort but must be considered in specifying the parameters of the data management system.

Firm recommendations are difficult in light of continually changing or upgrading of computing hardware and software, technologies and methodologies. However, **several items should be given serious consideration:**

- **compatibility of output tape formats** not just physical size are very important to efficient transfer of data.
- **determine best GIS** to allow integration of 6,000 NRA National River Quality samples with remotely sensed data
- compromise situation - major rivers by ATM/CASI rectified to OS-blue line 1;50,000 and filled-in with colour stereo-pair photography at 1:10,000; a feasible and cost effective system but technically difficult to fit data into raster data base.
- **choice of workstations** for testing would need say with 250-500 mb and 1-5 Gb tape server (Sun, HP, Dec, micro-VAX, IBM)
- a main GIS work station at Bristol could be regularly updated and data kept semi-permanently or circulated in a reduced or interpreted form to regions or catchments together with real or simulated site images using optical disc technology in preference to magnetic tapes but again there is much updating of technology in hand.
- Distribution on a type of CD-ROM optical disc (644 mb) to each of the 10 regions, or 30 subregions or divisions, 50 hydrometric areas, or the 150 main catchments
- GIS information data layers need to be transferable between industry standard machines

As improvements in both methodology, software and hardware are continually being made, such choices should be made during the next or test phase but incorporate the selection of industry standard hardware GIS systems, actual trials in both compatibility of handling overflight data from digitized photographic and imaging spectrometry and commercial map data expected to be used.

7.5 Assessment of the potential for an hierarchical classification

The assessment of the extent, derivation and determination to which a hierarchical classification could be taken is currently difficult on the extent of coverage of the survey (full or sampled) and the degree of inclusion of regional, topographical and other sources of data eg chemical. However, a regional five point scale or ten point national scale seems quite feasible from full overflight data. However realistic consideration must be given to a range of sampling strategies and integration of other NRA functions. This will be addressed in a forthcoming NRA research project on conservation classification.

The costs of (i) purchasing existing and acquiring new photography to ensure countrywide cover and interpreting the large number of prints are high. This suggests that the feasibility of a sample-based survey should be considered from a comparison with the costs and benefits of a census survey (ie strategic *versus* operational requirements). The overwhelming advantage of a census survey is that site specific information is provided, e.g. the conservation value of every stretch of river is coded based upon a set of observations. The sampling approach only provides a prediction of river conservation value based on a sample of observations, but with the advantage of considerably lower costs. This would be a better option for repeat surveys to monitor change.

If a sample-based survey were adopted, England and Wales could be stratified by some environmental parameter (ITE land class, soil type, etc.) to improve sampling efficiency. A 10 per cent sample (8,400 km) of watercourses in England and Wales would require entirely new flying, but given the much reduced area this could be undertaken at large scale (1:5,000 or greater) within one flying season. Interpretation time would be less than 200 days enabling the whole survey to be completed within one year and repeated as required.

A sample-based survey would enable national predictions of river conservation quality, with confidence limits, to be made for each category of the sampling system. Repeat surveys would show the extent to which the river had improved or degraded over the intervening period.

This project has been complex due to a variety of factors including absence of interpretation of RCS results, variation in both RCS methodology and overview techniques between regions. Thus although a hierarchical classification system, together with some suggestions for its levels, could be proposed, its potential degree of reliability it is a yet unclear.

8. SUMMARY AND PROPOSALS

8.1 Summary

A River Corridor Strategic Overview is feasible by remote sensing if the approach of including existing map data and utilising a geographic information system is included. River Corridor Surveys (RCS) are essentially well annotated diagrams of vegetation with some site morphology and other features; they have a strong landscape component. **Remote sensing can supply a good first level approach suitable for operational requirements.** RCS data are prepared by specialists and need specialist interpretation but as such are not easily or directly transferable for strategic overviews. To satisfy this component **a predictive element is proposed** to produce, in RIVPACS style, a probability of quality for aquatic environment and biota. This value for pristine quality for sites can then be modified by remotely sensed data before hierarchically classifying the stretch of watercourse. Image scale is important as the watercourse only occupies a minute part of any image but interpretation require a minimum size.

The cost of a strategic overview by on-site survey for the 45,000 km of main river and 181,000 km of headwater, is estimated to cost at least £13,000,000 and require 140,000 person-days (Table 8.1) excluding the incorporation of the data in an machine accessible format (£1-2,000,000 ?). In contrast, the estimated cost of a remote survey may vary from around £1,500,000 at 1:10,000 scale to almost ten times this for 1:3,000 scale. A first aerial survey at 1:10,000 would be less as half the photography is available but interpretation etc. will still be required. A set of detailed images would be available for initial filtering for operational needs and a tangible asset would be available for sale. Mixed scales are envisaged but the costs balance out and a combined figure of £2,000,000 including some purchase or hire of data sets is the current best estimate.

The next (validation) phase needs to address several aspects of the overview survey, particularly economics and data compatibility. It should include consideration of:

1) changes to current RCS methodology to improve its compatibility for use at all levels from local operational to strategic overview level including examining the biological assumptions being made;

2) the choice of image acquisition and processing between colour stereo photography versus imaging spectrometry. 50% of England and Wales has been overflown within the last 5 years. Image spectrometry is more versatile and has greater potential depth of interpretation but is newer technology; full integration of image acquisition throughout the NRA is essential but cost savings may limit the choice of method;

3) data sets, their compatibility and detailed supply costs, for prediction of pristine quality of sites e.g. land-use, soils, geology, river channels and catchment or other boundaries;

4) data handling and integrating systems available to accommodate both the large quantities of map and image data, current and historical photographic data. These are needed to facilitate useful interaction of differing types of data **and** to produce output

Table 8.1 Comparison of methodologies with current costs and effort for surveys of 45,000 km main river plus 181,000 km of headwater streams and for a maximum of 365,000 km of watercourse

Methodology	Cost, £ M	Time person-days
On-site field based RCS (10 or 20 year cycle) integration of survey into machine readable and accessible form	13-21 (1-2)	150,000-230,000
Air photography - colour stereo		
1:10,000 scale existing	0.24	
new	0.57	
full reconnaissance	1.1	
rectification and interpretation	0.3	4,500
digitization and classification	(0.3-0.5?)	?
1:3,000 new survey	5-8	40,000-60,000
interpretation	5?	
Imagery		
1:25,000 equivalent		
Satellite SPOT (10 x 10 m - 60 x 60 m pixel size, land use only)	0.07-0.2	
1:10,000 equivalent		
ATM with rectification and classification, e.g. 1 x 1 m pixel size	1?	
CASI as above	1-2?	

for distribution for strategic but also operational work at useful levels ie from reaches and catchments to regional level; and,

5) fully integrating RCS methodology and data gathering into other NRA functions, data acquisition especially images, interpretation and distribution or access systems

8.2 The way forward - progressive stages

In view of:

- The requirement for the collection of large amounts of data and production of very detailed annotated diagrams of vegetation and river morphology characteristics resulting from existing standard techniques for river corridor survey;

- It is clear that such a methodology is neither feasible nor appropriate, given the size of England and Wales (>250,000 km of watercourse distributed within a land area of 151,000 km^2) and the requirement for a strategic overview of the current and potential conservation status.

- A balance therefore needs to be established between the large volumes of data required for site-specific information and the need to implement a national monitoring system with sufficient detail to be useful for strategic planning at national and regional levels. Thus

- Following an initial examination of the existing methodologies for river corridor survey, an analysis of the potential of remote sensing, especially large scale colour air-photography and other environmental data-sets, two separate but not exclusive options have been identified.

Stage 1 - Air-photography with field-based RCS validation

This option is a relatively simple, low technology route based on the interpretation of a national coverage of air-photography with derivation and validation of a simple index of river conservation grade (1-5) using the standard, field-based RCS methodology. **This would be the preferred option at the start of the implementation stage, providing data and methodological procedures for incorporation into the second more sophisticated predictive system.**

i) Establish period for baseline survey, e.g. 1990-94 or 1986-95.
ii) Obtain existing photographic or spectral images for this baseline period; commission flying of new air-photography to ensure full national coverage (preferably on a collaborative basis.
iii) Develop a classification system based on interpretation of photographs/images in selected study areas for contrasting landscape types.
iv) Validate classification with reference to field-based standard RCS methodology by a detailed investigation of the relationship between parameters mapped from air-photography and detailed RCS measurements with other biotic and physicochemical

data available.

v) Refine classification to derive a standard, consistent, repeatable index of river corridor conservation value and apply to entire data-set (air-photography and sample of airborne scanner/imaging spectrometer data) for England and Wales.

vi) Assess validity of index from sample of new RCS sites

vii) Incorporate index of conservation into GIS, with facilities for rapid display and interrogation of data and ancillary information including:
- designated conservation areas, e.g. SSSI, national park boundaries
- water catchment boundaries, and probably
- water chemistry

Sub-stage 1: Sample-based survey

See 7.5).

Stage 2: Development of a predictive system: modelling approach

The development of a predictive system with the capability to determine the consequences, possibly at the catchment level, of changes in land use/cover, new discharge consents, persistent low flow etc. for river corridor quality.

i) Develop a model to predict the 'pristine' status of a watercourse under contrasting conditions of scale, geology, climate, soil, altitude. This is analogous to the RIVPACS approach and the model would need to be implemented within a GIS incorporating national environmental data-sets.

ii) Integrate and relate different data-sets, including interpretation from air-photography, to derive an index of river corridor environmental quality. Determine the parameters explaining most of the variation in river corridor quality in order to minimise data requirements. **The development of the predictive system and integration of remotely sensed data with other national environmental data-sets may, in the longer term therefore, considerably reduce data needs.**

iii) Test under field conditions including
- assessment of watercourse degradation;
- analysis of the departure of watercourse from predicted status based on standard field-based RCS methodology and sampled air-photography; and
- prediction of the consequences of new development, e.g. drainage, land use change, agricultural change etc. on river conservation value.

9. ACKNOWLEDGEMENTS

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(Roger Moore, Isabella Tindell, David Melvis)

Dept of Oceanography, Southampton University - demonstration of ATM & CASI for coastal regions (Simon Boxall)

Hunting Aerofilms (Peter O'Connell)

Global Earth Sciences (Chris Jewett)

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ITE monkswood Steven Briggs/Andrew Wilson (04873-381/8) Editors & authors of remote sensing review for NRA (Gareth Llewllyn) with IS/CASI data (+ATM?) and with a review on aquatic aspect of remote sensing freshwaters by Glen George of IFE (+Paul Carling?)

APPENDIX 1a Addresses of organisations with RCS, GIS or related interests contacted during project (in Bold)

	Telephone	Fax
Alconbury Consultants (Nigel Holmes)		
Prof. J.A. Allen Centre for Near & Middle African Studies School of Oriental & African Studies University of London, Thornhaugh Street, Russell Square, London WC1H 0XG Vice chairman Remote Sensing Society	071-637-2388 (-323-6159)	-436-3844
British National Space Centre Remote Sensing Applications Development Unit NERC Monks Wood Experimental Station Abbots Ripton, Huntingdon PE17 2LS	04873-381	-467
Virginia Carter US Geological Survey		
Countryside Commission		
Countryside Council for Wales		
CSIR Water Technology Water Quality Information Systems PO BOX 395 Pretoria 0001 South Africa (Nicholas King)	-12-841-4794	-4785
English Nature Nature Conservancy Council for England Northminster House Peterborough PE1 1UA (Mark Felton)	0733-340345	
Hunting Technical Services Limited Thamesfield House, Boundary Way Hemel Hempstead, Herts HP2 7SR. (Graham Deane, Geoffrey Griffiths, Sally Bishop)	0442-231800	-219886

	Telephone	Fax
Institute of Hydrology Wallingford (Roger Moore, Isabella Tindall, T12057a5)		
MAFF		
National Remote Sensing Centre Space Dept. R190 Building Royal Aerospace Establishment, Farnborough, Hants GU13 6TD	0252-541464	
National Rivers Authority		
- Head Office Rivers House, Waterside Drive, Aztec Park, Almondsbury, Bristol BS12 4UD (Dr K O'Grady Head of Fisheries, Recreation, Conservation & Navigation) (Dr Paul Raven, Conservation Officer, 4343) (Mervyn E. Bramley, Head, R & D; Gareth Llewellyn) (Lindsay Pickles, Flood Defence Officer) (Richard Streeter, Water Resources Officer) (John Seager, -Water Quality)	0454-624400	-624409
- Anglian (David Stanley, Project manager -Remote sensing Techniques) (Peter Barham, Conservation Officer))		
- Northumbria (John Hogger, Conservation Officer)		
- North West (Mark Diamond, Conservation Officer)		
- Severn Trent (David Hickie, Conservation Officer -aerial video)		
- Southern (Mike Beard) (John Morgan, Conservation Officer)		

	Telephone	Fax
- South West (Peter Nicholson, Conservation Officer) (Jeff Bateman)		
- Thames (Alistair Driver, Conservation Officer) (Keith Annand, NRA GIS Working Group Co-ordinator)		
- Welsh (Richard Howell, Conservation Officer)		
- Wessex (David Palmer, Nick Holden, Sheila Conway) (Lyn Jenkins, Conservation Officer)	0278-457333	
- Yorkshire (John Pygott, Conservation Officer)		
Natural Environment Research Council - National Computing Service GIS project manager, NCS Keyworth (Sam Boote)		
The Landscape Overview (Bud Young)		
Soil Survey and Land Research Centre T.R.E. Thompson, Silsoe Campus, Cranfield Silsoe, Bedford MK45 4DT (Dick Thompson)	0525-60428	
University of Southampton Southampton SO9 5NH	0703-595000	
Dept. of Oceanography (Simon Boxall)	0703-592744	593059
Dept of Geography (K.J.Gregory, Ted Milton) Geodata Unit (Mike Clarke, Chris Hill, Angela Gurnell)	0703-592216 -593260 -592204 -592719	
Welsh Office		

APPENDIX 1b Addresses of air photographic organisations

Central Register of Air Photography for Wales Cartographic Services Welsh Office Room G-003 Crown Offices, Cathays Park, Cardiff CF1 3OQ	0222-823815
Ordnance Survey Air Photo Sales Romsey Road, Maybush, Southampton SO9 4DH	0703-792584
Royal Commission on the Historical Monuments of England National Monument Record National Library of Air Photographs Alexander House, 19 Fleming Way, Swindon, Wilts SN1 2NG	0493-414100
Geonex UK Limited 92-94 Church Road Mitcham, Surrey CR4 3TD	081-640-1971 081-685-9393
ADAS Aerial Photography Unit Block B, Brooklands Avenue Cambridge CB2 2DR	0223-455780
BKS Surveys Limited Ballycairn Road Coleraine County Londonderry BT51 3HZ	0265-52311/7
Committee for Aerial Photography University of Cambridge Mond Building, Free School Lane Cambridge	0223-334577
Hunting Aerofilms Gate Studios Station Road, Borehamwood, Herts WD6 1EY	081-207-0666
Clyde Surveys Limited Clyde House, Reform Road, Maidenhead Berkshire SL6 8BU	0628-21341

APPENDIX 2 TERMS OF REFERENCE FOR A REPORT ASSESSING THE FEASIBILITY OF A STRATEGIC RIVER CORRIDOR OVERVIEW OF RIVERS IN ENGLAND AND WALES from NATIONAL RIVERS AUTHORITY

1. Overall objectives

To evaluate the feasibility of a strategic overview of the conservation status and enhancement potential or rivers of England and Wales.

2. Specific objectives

The study should identify advantages and disadvantages of the options available for a strategic overview by establishing:

i the type, extent and sources of available information

ii the methods required for interpretation and classification

iii staff resources and expertise required

iv benefits and links with other NRA core and support functions and external organisations particularly in terms of catchment management planning

v possibilities of collaboration with external organisations

vi timescales involved

vii estimated costs

viii database and data handling requirements

3. Background

The NRA gas a statutory duty under Section 8(1) of the Water Act 1989 to 'further' conservation. A pre-requisite is therefore to (1) assess and evaluate the current conservation status of inland and coastal waters and associated lands in England and Wales and (2) monitor changes in status resulting from both 'global' and 'localised' factors, predominant being the impact of the NRA either as a direct modifier or indirectly through granting of land drainage, abstraction or discharge consents. It is also important that, in furthering conservation, objectives for enhancing/rehabilitating degraded habitats can be identified, target dates set and actual performance measured against these criteria.

River represent a major focus of NRA responsibilities. The river channel and associated lands have therefore become the focus for a major effort involving habitat surveys and impact assessments. However, a national strategic overview is still lacking.

Conservation often emphasises the protection of the best examples of habitats or rare plants and animals. As a result, all too often, developers and others regard habitats that occur outside the ring-fence line designating an SSSI or National Nature Reserve as fair game, because they apparently have no conservation status.

Only 369 km of river-length in England and Wales is currently designated specifically as riverine SSSI. Although it is of paramount importance that the best rivers in conservation terms need to be adequately protected, it is only right that proportionately more effort should be directed toward enhancing the conservation value of the remaining 99% of the rive-length. All rivers have some conservation value however low. There is an urgent need to evaluate the rivers of England and Wales so that the best stretches can be identified and protected while the remainder can be maintained or enhance.

A strategic overview also has major potential in terms of a holistic approach to catchment management planning, incorporating other core NRA functions such as Water Resources, Water Quality, Flood Defence, Fisheries, Recreation and Navigation.

A Phase I strategic overview of the conservation value and enhancement potential of rivers in England and Wales is required. The method needs to be simple, rapid, robust but flexible and readily repeatable. In terms of staffing resources, it should be entirely independent from, but complementary to, the current programme of river corridor surveys.

It also needs to be compatible with survey methodologies which will be used by the NRA to monitor the general and special ecosystem use-related Environmental Quality Objectives.

4. Method of Approach

i Desk study/literature search

ii Contact with relevant personnel from the NRA and outside organisations (e.g. English Nature, Countryside Council for Wales, MAFF)

5. Timescale

The deadline for a completed report is 31 January 1992.

6. Output

Report detailing existing information, outlining the options available and recommending the most appropriate methodology for the NRA.

The contents of the report shall be the sole property of the National Rivers Authority.

7. Benefits

This feasibility study is essential for the strategic overview. It will identify cross-functional benefits and possible collaboration/cross-funding for the overview exercise.

8. Additional Terms of Reference

More emphasis will be placed on conservation enhancement potential.

Consideration of how an overview would fit into a hierarchical classification system will be taken into account.

The NRA would be agreeable if, under the auspices of IFE project management, specific expertise on geomorphic and other aspects related to interpretation of aerial photographs is undertaken by another party, provided this is included within the quoted budget.

APPENDIX 3 PROPOSAL from THE INSTITUTE OF FRESHWATER ECOLOGY to NATIONAL RIVERS AUTHORITY

1. Introduction

Within the NRA's statutory responsibility to further conservation in England and Wales, it is clear that an essential prerequisite is to assess and evaluate the conservation status of inland and coastal waters together with the associated land, and to monitor changes in status brought about by both local and more general factors. It is however necessary to identify the factors which enhance habitat and to avoid or minimise those leading to degradation. One major problem is the sharp division between designated reserves and adjacent land which apparently have no conservation status but are integral to the former.

Only a minute proportion of rivers (369 km) have so far been specifically designated as riverine SSSIs and although it is most important that such rivers should be protected, it is equally important that effort should be given to enhancing the conservation value of the remainder as all rivers have some conservation value no matter how low. There is an urgent need by NRA to evaluate the rivers of England and Wales in order to identify and protect the best stretches and to maintain or enhance the remainder. It has been a source of puzzlement to IFE staff during surveys that some rivers are protected whereas others of even better quality are not. Thus it is apparent that an overview is necessary. However as Phase I specifies, such work must pragmatically use a methodology which is both simple, rapid, robust but also flexible, repeatable and compatible with existing survey methodologies.

2. The Institute of Freshwater Ecology

The IFE has not only a wide and probably unparalleled experience in fundamental biological research into habitat and community relationships in UK rivers but an established familiarity with survey work for such projects as RIVPACS and in Environmental Assessment for major international companies. Such surveys have not only been based on the ground but at various levels in the air. Current projects include the use of multi-spectral scanners mounted on aircraft to identify aquatic and riparian vegetation while other projects utilise satellite imagery particularly in land-water use interactions.

In order to ensure that the broadest possible experience is available for this project, the Institute of Freshwater Ecology (IFE) has associated with Hunting Technical Services Limited (HTS) who have a broad base in aerial and remotely sensed data collection and interpretation.

HTS was formed in 1953 with the aim of providing services to land resources development, particularly in the developing world. HTS is now one of the largest independent land resource companies in the world employing over 100 graduate specialists and having worked in over 100 countries. The main activities of HTS are the survey of renewable and non-renewable resources, land use planning, agricultural management, rural development and environmental conservation. HTS staff cover a wide range of disciplines and the company has access to many specialist consultancy companies and independent specialists, some associated on a retainer basis.

Resident specialists and permanent staff of HTS can offer expertise including the following:

- land resource evaluation
- environmental planning and management
- irrigation and drainage
- remote sensing and geographic information systems
- cartography, reports and map production
- livestock
- agriculture
- marine and aquatic resources
- environmental impact
- monitoring and evaluation
- geology

HTS services include:

- acquisition/procurement (satellite imagery can be acquired or procured with all necessary processing carried out in house)
- image processing (all forms of image processing can be performed - image restoration, geometric correction, image enhancement and information extraction)
- precision hard copy
- geographic information systems from various sources of data; ground data, mapped information and remotely sensed data
- digital cartography (GIS, digitise thematic or base maps)
- micro-computer for image processing and GIS with integrated remote sensing projects on renewable resource applications
- geological and mineral services and research for the European research and space agencies

HTS has undertaken a number of projects in which a combination of satellite imagery, air-photography and ground survey have been used to collect information on landscape features of conservation value.

The Monitoring Landscape Change Project, commissioned jointly be DoE and Countryside Commission in 1980, used a sample of multi-date air photographs to map change in area and linear features in England and Wales. The project demonstrated the feasibility of obtaining national statistics on changes in small scale landscape features, many of conservation value, as well as providing a summary of changes in land use.

More recently HTS staff on secondment to the National Remote Sensing Centre, were involved with the IFE to map change in land cover in two water catchments (River Hodder and River Axe) from satellite imagery. Geographical Information System (GIS) techniques were used to output the land cover data by river corridor (eg within a zoom zone) and by sub catchment. Land cover adjacent to a river or stream is an important determinant of 'naturalness' and could be incorporated into a scheme to assess the conservation value of a particular length of drainage channel.

HTS has recently been involved in the development of remote sensing and GIS techniques for environmental impact assessment. This has involved producing maps of landscape 'quality', enabling the impact of new developments on the landscape to be evaluated. Similar techniques, involving mapping and measurement of important riverside features (riverine vegetation characteristics, level of management, adjacent land cover, soils and geology) could be used to develop a simple classification of stream conservation value, similar to that proposed by NRA.

The Project

Methodologies which are feasible for a strategic overview of the conservation value and enhancement potential of English and Welsh rivers will be studied. Such techniques will need to allow meaningful reliable data to be repeatedly obtained, made simply available and able to be assessed rapidly for use in NRA activities as a first phase, but also later to underpin environmental protection, general improvement or determination of potential for enhancement of special habitats. The role of cross-function benefits between the various agencies and government department will also be investigated as would the biotic and geomorphological significance of data obtained in these various ways. Such factors would need to include not just the presence of trees on banks but the variation in river form, eg riffle-pool sequences, overhangs, sinuosity, in relation to fish populations but also to other biota, eg macroinvertebrates or plants and their diversity.

Specific objectives of the study include an overview or 'matrix' of the advantages and disadvantages of the different potential methodologies together with determining the extent and quality of the information sources available, implementation and classification requirements, and the benefits to NRA activities both internally and in its interaction with organisations, together with the best options and a recommendation for the most appropriate methodology for the NRA.

The project will be undertaken as a desk study with appropriate contacts being established to determine

i) information available, its type, extent and sources, which will be appraised together with other critical aspects such as the status, coverage, scale and the access cost. It is proposed to investigate data sources including:

    - maps and geographic data base information particularly from Ordnance Survey, databases of river data eg IFE/Southampton University survey of management on main rivers and GIS databases within the Research Council and elsewhere;
    - satellite imagery including data for land use surveys by MAFF and possibly Countryside Commission data, together with the possibilities of sideways scanners for assessment of geomorphological features, data held by the former Rural Areas, ESRC/NERC Data Archive, Institute of Hydrology and Research Council databases;
    - aerial still photography with interpretation from single and stereo pairs from such sources as the NRA Thames, Wessex and Southern regions, but probably including others such as, from the Welsh Office, some County Councils and commercial registers and centres;
    - aerial video photography from NRA regions such as Severn Trent, but also

from project orientated studies by commercial companies eg Shell, as available;

- aerial multi-spectral scanners such as flow by NERC for river corridor studies, and for lake studies (with and without image enhancement);
- ground based surveys extracts especially river corridors, Research Council data bases and systems EIC, NUTIS, and for classification and ground-truth comparisons; and
- other potential sources or computations of databases.

It is assumed that access for appraisal will be available to examples of NRA regional information such as held on video tape by Severn Trent and Riparian Corridor Survey data.

ii) The methods required for interpretation and classification which includes factors such as the balance between survey effort versus the effort required for data elucidation and processing from the chosen media, information quality and reproducibility. In-house expertise on interpretation and usefulness of the data obtained by various methods will be assessed in biotic and geomorphic terms.

Thus the proposal will also

a) investigate the type of information that could be derived efficiently from air photography/video etc to provide data for categorising the conservation value of each stretch of river such as

- level of management from evidence of river straightening, culverts and canalization,
- water uses, upstream and adjacent,
- adjacent land cover, ie distinguish between semi-natural and intensively cultivated (satellite imagery could be used to achieve this mapping),
- river flow pattern; fast (pool and rapid), slow,
- probable levels of disturbance to wildlife and vegetation; presence of footpath, buildings, tow-path, building, moorings, then

b) investigate techniques to incorporate these data, including RCS data, into a simple classification of river conservation value,

c) consider the most appropriate format for presentation of final classification and the associated database, probably using GIS; and,

d) suggest ways in which GIS could be used as a management tool to record, display and provide figures on conservation status of rivers.

iii) Staff resources and expertise required

In view of the breadth of the objectives, the time-scale required and the varying breadth of experience of specialists, it is proposed that scientists will investigate their own specialisation but the whole will be coordinated, integrated and assessed by the project leader. The latter will, in addition, be the main contact with relevant NRA and non-NRA personnel including English Nature, Countryside Council for Wales, MAFF.

Expertise is available within the consultancy group, IFE and HTS, on all aspects of section (i) above. IFE will provide senior and principal scientists with experience in remote sensing survey by the above techniques, computer analysis, and ground-truth survey whilst this will be supported by senior consultants from HTS.

iv) Benefits and links with other NRA care and support functions and external organisations especially re catchment planning will be investigated, particularly the links at local level but also broader planning issues with Countryside Commission, MAFF and DoE.

v) The time-scale currently proposed will be in accordance with a final report date of 31 January 1992 with intermediate deadlines from an assumed acceptance of quote 11.11.91:
end of November for first joint meeting with detailed proposals for investigation;
end of December (pre-Christmas) for second joint discussion meeting with results of internal searches and discussion of emergent problems, data or technique shortfall;
end of second week of January, draft reports for integration and emergent proposals for further investigation;
third week of January, draft report available for comment;
fourth week of January, final report preparation and distribution.

vi) Costs for the project are estimated at £12,000 (excluding VAT) based upon

	$£d^{-1}$	day	£k
Senior and Principal day rates	250-435	35	10.4
Typing and report preparation	135-215	3	0.5
Consumables			0.3
Travel and subsistence (final presentation, coordination and data status and quality visits)			0.8
		Total	12.0

This does not include purchase or use of trial sets of information as may be available already within or outside NRA. No intermediate meetings with NRA have been included in this costing.

vii) Database and data handling requirements will be available in house, at minimal cost outside or exist within NRA regions.

The contents of the report are acknowledged as the sole property of the NRA although the report may contain data etc as examples from many sources and the property of others.

APPENDIX 4 Survey parameters from River Corridor Survey and similar surveys of fluviatile habitats (from Saunders and Dawson 1992)

CONTENTS

A.4.1 **RBSQ (River and bank, selected species, quantitative analysis)/River Corridor Survey**
(Holmes, 1983)

	Units:
Information from maps:	
1. Geology	?
2. Altitude	m
3. Slope	?
4. Hydrology	?
Information from morphological survey of site:	
5. Substrate:	
5.1 Bed rock	% cover
5.2 Boulders	% cover
5.3 Cobbles	% cover
5.4 Pebbles	% cover
5.5 Gravel	% cover
5.6 Sand	% cover
5.7 Silt/mud	% cover
5.8 Clay	% cover
5.9 Peat	% cover
6. Water depth:	
6.1 < 0.25 m	%
6.2 0.25-0.5 m	%
6.3 0.5-1.0 m	%
6.4 > 1.0 m	%
7. Water velocity	?
8. River width:	
8.1 < 5 m	%
8.2 5-10 m	%
8.3 10-20 m	%
8.4 > 20 m	%
9. Bank slope	
9.1 < 30°	%
9.2 30-60°	%
9.3 60-90°	%
9.4 > 90°	%
10. Bank type	
10.1 Shelf	%
10.2 Solid earth cliff	%
10.3 Soft earth cliff	%
10.4 Rock cliff	%
10.5 Artificial	%
10.6 Flood bank adjacent	%
10.7 Levee set back	%
11. Habitats within river:	
11.1 Pool	%
11.2 Slack	%
11.3 Riffle	%

11.4	Rapid	%
11.5	Run	%
11.6	Waterfall	%
11.7	Exposed rock	%

12. Shade:

12.1	None/little	%
12.2	Moderate	%
12.3	Heavy	%

13. Adjacent habitats (each subdivided: see attached site survey sheet)

13.1	Woodland & scrub	% cover
13.2	Grassland & marsh	% cover
13.3	Tall herb & fern	% cover
13.4	Heathland	% cover
13.5	Mire, flush & spring	% cover
13.6	Swamp/inundation	% cover
13.7	Open water	% cover
13.8	Rock	% cover
13.9	Miscellaneous	% cover

Information from botanical survey of site: [1]

14.	List of plant species in river [2]	present/absent
15.	List of plant species on banks [3]	present/absent

16. Percentage cover of bank vegetation:

16.1	Conifers (mature)	% cover
16.2	Conifers (recent)	% cover
16.3	Broadleaf (mature)	% cover
16.4	Broadleaf (recent)	% cover
16.5	Thick scrub/shrubs	% cover
16.6	Sparse scrub/shrubs	% cover
16.7	Reed/sedge	% cover
16.8	Dense open	% cover
16.9	Sparse open	% cover
16.10	Reseeded or mown	% cover
16.11	Exposed tree roots	% cover
16.12	Bare mud/clay	% cover
16.13	Bare sand/shingle	% cover
16.14	Bare stones/rocks	% cover

17. Plant cover:

17.1	Bryophytes	% cover
17.2	Emergents	% cover
17.3	Submerged	% cover
17.4	Floating	% cover
17.5	Filamentous algae	% cover

Notes

[1] recorded over two 500 m lengths.

[2] submerged for more than 85% of the time.

[3] submerged for more than 50% but less than 85% of the time.

N.B. variants of the above survey system utilise four grades of percentage cover in place of estimated percentages, as follows: 1 = < 5%; 2 = 5-25%; 3 = 25-50%; 4 = > 50%.

4.2 **RIVPACS**
(Wright et al 1984; Furse et al 1987; Moss et al 1987)

	Units
Information from maps: [1]	
1. Latitude of site	° N/S
2. Longitude of site	° E/W
3. Altitude of site	m
4. Distance of site from source	km
5. Slope [2]	m km^{-1}
Information from site:	
6. Mean width of water	m
7. Mean depth of water	cm
8. Substratum composition	phi (ϕ) [3]
8.1 boulders + cobble (≥ 65 mm)	% cover
8.2 pebbles + gravel (2.1-64 mm)	% cover
8.3 sand (0.06-2.0 mm)	% cover
8.4 silt + clay (0.004-0.06 mm)	% cover
9. Discharge category [4]	categories 1-9 [5]
Information from chemical analysis of water:	
10. Alkalinity [2]	mg $CaCO_3$ l^{-1}
11. Chloride [2]	mg Cl l^{-1}
Information derived within RIVPACS program:	
12. Mean annual air temperature [2, 6, 7]	°C
13. Mean annual air temperature range [2, 6, 8]	°C

Notes

[1] determined from 1:25,000 O.S. maps.

[2] use of variable optional.

[3] derived from the following four phi values, weighted by percentage composition of the substratum:

boulders + cobble = -7.75
pebbles + gravel = -3.25
sand = 2.0
silt + clay = 8.0

[4] average daily flow.

[5] 1 ≤ 0.31 cumecs; 2 ≤ 0.62; 3 ≤ 1.25; 4 ≤ 2.50; 5 ≤ 5.0; 6 ≤ 10.0; 7 ≤ 20.0; 8 ≤ 40.0; 9 ≤ 80.0.

[6] derived using information from Climatological Memorandum (Meteorological Office, 1975).

[7] mean of January, April, July and October means.

[8] July mean-January mean.

A.4.3 **IFE (Reconnaissance and Full EIA surveys)**

	Units
Information from maps: [1]	
1. Latitude of site [2]	° N/S
2. Longitude of site [2]	° E/W
3. National Grid Reference [2]	-
4. Distance from source of watercourse	km
5. Altitude of survey section	m (to *ca* 5 m)
Physical characteristics of channel:	
6. Mean width of water (at time of survey)	m
7. Mean depth of water (at time of survey) [3]	m
8. Mean width of channel (bankfull)	m
9. Mean depth of channel (bankfull)	m
10. Water velocity (estimated mean)	$m\ s^{-1}$
11. Water discharge	$m^3\ s^{-1}$
12. Slope of channel bed over survey length	° (to *ca* 1°)
13. Type of bed or water flow	7 categories [4]
14. Relative stream power	estimated 1-10 [5]
15. Channel form in plan	3 categories [6]
16. Channel sinuosity [7]	4 categories [8]
17. Channel section	4 categories [9]
18. Erosion as percentage of stream bank of section	5 categories [10]
19. Substratum:	
19.1 Bedrock or outcrops	% cover, or proportion [11]
19.2 Boulders (> 256 mm)	% cover, or proportion [11]
19.3 Cobbles (65-255 mm)	% cover, or proportion [11]
19.4 Pebbles and gravel (2.1-64.0 mm)	% cover, or proportion [11]
19.5 Sand (0.06-2.0 mm)	% cover, or proportion [11]
19.6 Silt and clay (0.004-0.06 mm)	% cover, or proportion [11]
19.7 Organic or peat	% cover, or proportion [11]
20. Colour & nature of water (*e.g.* presence of particles)	description
Characteristics of adjacent land:	
21. Land use on watercourse banks, and visual features within 0.5 km	description
22. Upstream features	description
23. Downstream features	description
24. Maintenance	description
25. Fishery interest	description
Biological information:	
26. List of all macroinvertebrate families [12] or genera [13] in the watercourse [14]	list
27. List of all plant genera [12] or species [13] growing in channel and adjacent land	list
28. Sketch map, detailing position and degree of cover of the various plant stands [13, 15]	-

Water chemistry:

29. Water temperature	° C
30. pH (hydrogen ion)	pH value
31. Conductivity (total salts)	µs cm^{-1}
32. Calcium carbonate	mg l^{-1}
33. Major anions present:	
33.1 Alkalinity (as bicarbonate)	m.e.l.
33.2 Chloride	mg l^{-1}
33.3 Sulphate	mg l^{-1}
33.4 Nitrate-nitrogen	mg l^{-1}
33.5 Phosphate-phosphorus (soluble/orthophosphate)	mg l^{-1}
33.6 Silicate/silicon	mg l^{-1}
34. Major cations present:	
34.1 Calcium	mg l^{-1}
34.2 Magnesium	mg l^{-1}
34.3 Sodium	mg l^{-1}
34.4 Potassium	mg l^{-1}
35. Ion balance, derived from (33) & (34), (expressed as a ratio)	m.e.l.

Scoring:

Environmental data on physical parameters, flora and animals are summarised together with a score for environmental quality based on scales of 0-10 for flora and invertebrates together with a correlation for management. Maintenance effects were scored on a -2 to +2 scale broadly based on:
-2 for channel resectioning and realignment;
-1 for either channel realignment or for channel resectioning of both banks;
-½ for either channel realignment or for channel resectioning of one bank;
0 a neutral score, for possible or historical management;
+1 for unmanaged but agricultural banks especially rough grazing *etc.*;
+2 for near natural conditions.
(Combinations of these scores are also used).

The overall score is calculated by adding floral and invertebrate scores, correcting for maintenance score, and dividing by two.

Notes

[1] determined from 1:25,000 O.S. maps.
[2] use of latitude/longitude *or* National Grid Reference optional.
[3] mean depth of pools noted in parentheses if present.
[4] waterfall; stepped; long riffle; riffle-pool with sequence distance (in m); glide or run; smooth; or static or ponded.
[5] 0-3 indicates bed and bank stable rivers and streams; 4-5 indicates rivers or large streams with some bed scour or bank erosion or lateral migration; 6-8 indicates active rivers with rock or worked gravels and erosion or migration or both. Comment should be included.
[6] Straight; meandering; or braided.

[7] Current and previous where the situation may have changed.

[8] Straightened; slight; moderate; or extreme. Value (in m) should be included to indicate actual and previous amplitude.

[9] Slope; steep; vertical; or trapezoidal if managed, dredged or resectioned.

[10] Incising; flake or slab; slump or slide; undercut or block fall; or depositions (with type of material and position).

[11] Proportion represented by asterisks, where * ≈ 20%.

[12] In reconnaissance surveys.

[13] In full surveys.

[14] Samples taken by pond net sweeps in deep water and kick sampling in shallow water.

[15] Accuracy of maps achieved by stretching a 100 m tape measure along the river bank.

A.4.4 Faunal Richness of Headwater Stream (Land-Use Survey)

The various land-use categories are coded alphanumerically (see land-use survey sheets).

A4.5 Fluvial Auditing

		Units
1.	Reach length	m
2.	Planform	3 categories [1]
3.	Gradient	3 categories [2]
4.	Width [3]	m
5.	Depth [4]	m
6.	Ration width/depth	-
7.	Riffle spacing	m (or N/A)
8.	Number of points in reach (measured)	-
9.	Number of points in reach (estimated)	-
10.	Sediments:	
10.1	Boulder	%
10.2	Cobble	%
10.3	Gravel	%
10.4	Sand	%
10.5	Silt/clay	%
11.	Position of photographs of 1 m quadrats	Description
12.	Amount of mineral material exposed in banks	% of reach
13.	Bank materials:	
13.1	Boulder	%
13.2	Cobble	%
13.3	Gravel	%
13.4	Sand	%
13.5	Silt/clay	%
14.	Stratification of bank materials	yes [5]/no
15.	Bank vegetation categories:	
15.1	Trees	%
15.2	Herbs	%
15.3	Grass	%
15.4	Crop	%
16.	Type of bank erosion where occurring	3 categories [6]
17.	Structures inspected in reach that are causing bed erosion/deposition	description, with N.G.R.
18.	Signs of river incising bed	description
19.	Signs of 'fresh' deposition	description
20.	Remarks/other notes	description

Notes

[1] Braided, meandering or straight.

[2] Steep (fall/pool); moderate (riffle/pool); or low (no obvious natural steps).

[3] Bank to bank at bankfull flow.

[4] Bankfull, avoiding pools.

[5] If yes, provide sketch to show how.

[6] Flake, slide or block.

A4.6 HABSCORE, NRA (Welsh Region)

	Units
General:	
1. National Grid Reference	-
2. Flow conditions	Description
3. Site length	m
4. Site comments (*e.g.* fish stocking, pollution, barriers, *etc.*)	Description
Tributary:	
5. Principal riparian land use (within 200 m upstream):	9 categories [1]
6. Mean water conductivity	$\mu s\ cm^{-1}$
7. Mean water hardness	mg $CaCO_3\ l^{-1}$
Reach:	
8. Altitude	m
9. Vegetation:	
9.1 Herbaceous vegetation	categories A, S, C, F or D within ≤0.5 m and >0.5 m of surface [2]
9.2 Deciduous woody vegetation	categories A, S, C, F or D within ≤0.5 m and >0.5 m of surface [2]
9.3 Coniferous trees	categories A, S, C, F or D, within ≤0.5 m and >0.5 m of surface [2]
Sections:	
10. Section lengths	m (to the nearest 1 m, for each section, downst. to upstream).
11. Wetted widths	m (to nearest 0.1 m)
12. Depths:	
12.1 Right bank	cm
12.2 Left bank	cm
13. Substrate:	
13.1 Bedrock	categories A, S, C, F or D [3]
13.2 Boulders (> 25.6 cm)	categories A, S, C, F or D [3]
13.3 Cobbles (6.4-25.6 cm)	categories A, S, C, F or D [3]
13.4 Gravel (0.2-6.4 cm)	categories A, S, C, F or D [3]
13.5 Sand, silt & clay (< 0.2 cm)	categories A, S, C, F or D [3]
14. Flow:	
14.1 Cascade/torrential	categories A, S, C, F or D [3]
14.2 Turbulent/riffle/broken	categories A, S, C, F or D [3]
14.3 Glide/run - deep (> 30 cm)	categories A, S, C, F or D [3]
14.4 Glide/run - shallow (< 30 cm)	categories A, S, C, F or D [3]
14.5 Pool - deep (> 30 cm)	categories A, S, C, F or D [3]
14.6 Pool - shallow (< 30 cm)	categories A, S, C, F or D [3]

15. Fish cover:

15.1	Boulders/bedrock	categories A, S, M, C or F [4]
15.2	Tree-root systems	categories A, S, M, C or F [4]
15.3	Branches/logs	categories A, S, M, C or F [4]
15.4	Undercut banks (not incl. above)	categories A,S, M, C or F [4]
15.5	Instream vegetation	categories A,.S, M, C or F [4]
15.6	Deep water (not included above) [5]	categories A, S, M, C or F [4]
15.7	Other (specify)	categories A, S, M, C or F [4]

Notes

[1] Moorland/heathland; rough pasture; improved pasture; arable; deciduous woodland; coniferous woodland; urban; industrial; or tips/waste.

[2] percentage of water surface overhung by vegetation types, estimated as follows:
Absent = 0%; Scarce = 1-5%; Common = 6-20%; Frequent = 21-50%; Dominant = > 50%

[3] percentage of stream bed area, estimated as follows:
Absent = 0%; Scarce = 1-5%; Common = 6-20%; Frequent = 21-50%; Dominant = > 50%.

[4] percentage of stream bed area that provides cover suitable for 10-20 cm trout, estimated as follows:
Absent = 0%; Scarce = < 1%; Moderate = 1-10%; Common = 11-20%; Frequent = > 20%.

[5] For sections less than 5 m wide, deep water is > 50 cm; for sections greater than 5 m wide, deep water is > 10% of width.

A4.7 Macrophyte and Vertebrate Survey, NRA (South West Region)

For subdivisions of each category, see attached field check-list.

Botanical species list: [1]

1. Broad-leaved plants of the waters edge
2. Tall emergents (including grasses)
3. Floating plants
4. Submerged fine-leaved plants
5. Submerged broad-leaved macrophytes
6. Liverworts
7. Mosses
8. Benthic algae
9. Branched filamentous algae
10. Net-forming algae
11. Unbranched filamentous green algae

Vertebrates present: [1]

12. Fish
13. Birds
14. Mammals

Notes

[1] Presence/absence of species/higher taxa

A4.8 **Biological Survey, NRA (Southern region)**

	Units
1. National Grid Reference	-
2. Width (mean and range)	m
3. Depth (mean and range)	cm
4. Clarity	description
5. Macrophyte cover	%
6. Substrate:	
6.1 Boulders/cobbles	%
6.2 Pebbles/gravel	%
6.3 Sand	%
6.4 Silt/clay	%
7. Habitat:	
7.1 Pool	+/-
7.2 Slack	+/-
7.3 Riffle	+/-
7.4 Run	+/-
7.5 Depositing	+/-
7.6 Eroding	+/-
7.7 Canalised	+/-
7.8 Detritus	+/-
8. Flow	5 categories [1]
9. Influences	?
10. Land use:	
10.1 Left bank (primary)	description
10.2 Left bank (secondary)	description
10.3 Right bank (primary)	description
10.4 Right bank (secondary)	description
11. Shading:	
11.1 Left bank	description
11.2 Right bank	description
12. Bank vegetation	3 categories [2]
13. Alkalinity	$mg\ l^{-1}$
14. Chloride	$mg\ l^{-1}$
15. Conductivity	$\mu s\ cm^{-1}$
16. BMWP:	
16.1 Score	-
16.2 Predicted score	-
17. ASPT:	
17.1 Score	-
17.2 Predicted score	-

Notes

[1] Slack, slow, moderate, fast or spate.

[2] Trees, bushes, low plants.

A4.9 **Haslam Survey**
(Haslam & Wolseley, 1981)

	Units
Physical characteristics:	
1. Channel width	m
2. Average depth of channel centre	cm (can be estimated to nearest 25 cm).
3. Substrate	6 categories [1]
4. Main flow types	5 categories [2]
5. Water clarity	4 categories [3]
6. Bank slope	4 categories [4]
7. Possible sources of damage other than pollution	20+ categories [5]
8. Landscape	8 categories [6]
Botanical characteristics:	
9. Plants above normal water level	species
10. Plants of the channel	species

Notes

[1] Boulder; stone; gravel; sand; silt (including mud); or peat.

[2] Negligible (water barely moving); slow (water obviously moving, water surface calm, and trailing plant parts still); moderate (water surface somewhat disturbed and swirling, trailing plant parts moving); fast (water surface disturbed, trailing plant parts moving vigorously); or rapid (water surface broken by boulders or stones, much swirling and disturbance).

[3] Very turbid (bed cannot be seen over 30 cm down); turbid (bed visible between 30 and 75 cm); clear (bed visible at over 75 cm down); or shallow clear (sites which appear clear but are too shallow to determine whether they should be rated as somewhat turbid or as clear.

[4] Gentle (< 30°); moderate (30-60°); steep (60-90°); or vertical/undercut.

[5] Presence/absence of each of the following potential sources of damage: substantial shade at sides or over whole channel; visitor trampling, paddling or swimming; cattle disturbance, trampling or grazing; boats; recent dredging; recent weed cutting; herbicides sprayed on emerged (or floating) species; aquatic herbicides used in the water of the channel; roadworks affecting channel or temporarily causing extra mud, *etc*., to wash into channel; bed made of concrete, boulders or other coarse substrates; bed of man-made unstable substrate; undue turbulence or deep water caused by bridge piers or other structures; unduly steep banks for the type of channel; unduly shallow or wide (if flow swift enough to cause scour), or unduly deep; in dykes, *etc*., particularly, substantial lowering of water level during previous year; summer drying; fierce spates; very swift normal flow; regulation of flow; any other obvious source of damage.

[6] Alluvial plains; lowland farmland; upland; mountain; very mountainous; lowland moorland; bog and hill; or blanket bog plains.

A4.10 Dorset Environmental Records Centre

Boxes on card marked as appropriate for parameters on detailed survey card.

AQUATIC HABITAT CARD — **DORSET ENVIRONMENTAL RECORDS CENTRE**

SITE NAME						GRID REF.	SU SY ST SZ		
OWNER	AREA (or length of river/stream)	acres hectares ft/m	ALTITUDE ft m			Freshwater	Brackish	Tidal	
	ACCESS	Public footpath/, bridleway	Road	No public access					
TENANT	FLOWING WATER	Streams & ditches < 2ft wide	Slow moving ditches, streams & rivers 2 - 10'	Fast streams & rivers > 2ft wide	Rivers > 10ft wide		Water flowing throughout year	Usually dry in summer	
	STILL WATER	Small ponds up to 20yd²	Larger ponds (< 1 acre)	Lakes (> 1 acre)			Standing water throughout year	Usually dry in summer	
STATUS Nature reserve	MAXIMUM DEPTH OF WATER (Approx)	< 6in.	6in - 1ft	1 - 2ft	2 - 5ft	> 5ft			
SSSI	SUBSTRATUM	Shingle	Sand	Mud/Silt	Clay	Rock	Organic detritus		
Forestry Commission National Trust Private	WATER MARGIN	Bank higher than 2ft	Bank less than 2ft	No bank		Wide belt of marginal aquatic veg. > 5ft	Narrow belt of marginal aquatic veg. < 5ft	No marginal belt	
Other	TREE SHADE	> 50% shaded by trees	< 50% shaded by trees	No shade					
USE	ASSOCIATED VEGETATION	Submerged vegetation	No or very little vegetation in water	Reeds (Phragmites)	Pond sedges (Carex riparia C. acutiformis)	Reed Mace (Typha)	Other dominant vegetation specify		
		Willow/ sallow	Alder	Other trees/ shrubs specify					
RECORDER Name:	ADJACENT LAND USE	Arable/ley	Permanent pasture	Wet/water meadows	Scrub	Woodland	Carr	Heathland	Marsh/bog
Address:		Road/ railway	Houses/ industrial	Waste ground (urban)					
Date:	OUTSTANDING INTERESTS	Flowering plants	Other plants specify		Mammals	Birds	Amphibia	Fish	
No. of visits to site		Odonata (dragon & damselflies)	Ephemeroptera (mayflies)	Plecoptera (stoneflies)	Trichoptera (caddisflies)	Coleoptera (Beetles)	Other animals specify		

A4.11 CPI (Conservation Potential Index)

Score assessments for each parameter given in square brackets.

I. ASSESSMENT OF CURRENT STATUS.

	Units
Site details:	
1. N.G.R. (upstream and downstream points)	-
2. Width of stretch	m
3. Gradient [1]	m km^{-1}
Habitat diversity:	
4. Spatial flow diversity	low [1], moderate [6] or high [12]
5. Substrate diversity	low [1], moderate [7] or high [14]
6. Sinuosity	low [1], moderate [6] or high [12]
7. Bankslope variability	low [1], moderate [6] or high [12]
8. Depth variability	low [1], moderate [6] or high [12]
Naturalness:	
9. Bank type as proportion of bank length [2]:	
9.1 Concrete	0 [0], 1/3 [0], 2/3 [0] or 1 [0]
9.2 Reinforced	0 [0], 1/3 [1], 2/3 [2] or 1 [3]
9.3 Natural	0 [0], 1/3 [4], 2/3 [6] or 1 [10]
10. Flow	regulated [3] or unregulated [6]
11. Channel form:	
11.1 Straightened	yes [0] or no [5]
11.2 Overwidened	yes [0] or no [5]
12. Vegetated riparian buffer zone:	
12.1 As a proportion of channel width	0 [0], 1/3 [1], 2/3 [5] or > 1 [10]
12.2 As an absolute width (m) < 1	[1], 1-10 [3], 11-20 [6] or > 20 [10]
13. Artificial obstructions to migratory fish [3]:	
13.1 Weir	yes [0] or no [2]
13.2 Dam	yes [0] or no [2]
13.3 Flow diversion	yes [0] or no [2]
14. Water quality	1A [10], 1B [8], 2 [5], 3 [2] or 4 [0]
15. Adjacent land use [4]:	
15.1 Rough pasture	0 [0], 1/5 [2], 2/5 [4], 3/5 [5], 4/5 [6] or 1 [6]
15.2 Improved pasture	0 [0], 1/5 [1], 2/5 [1], 3/5 [2], 4/5 [3] or 1 [4]
15.3 Urban	0 [0], 1/5 [0], 2/5 [0], 3/5 [0], 4/5 [0] or 1 [0]
15.4 Arable	0 [0], 1/5 [0], 2/5 [0], 3/5 [1], 4/5 [1] or 1 [2]
15.5 Coniferous plant	0[0], 1/5 [0], 2/5 [1], 3/5 [1], 4/5 [2] or 1 [2] **15.6**
Broadleaf wood	0 [0], 1/5 [2], 2/5 [4], 3/5 [6], 4/5 [7] or 1 [7]
15.7 Other (specify)	

Vegetation:

16. Vegetation type [4]:	
16.1 Bankside:	
16.1.1 Trees/shrubs	0 [0], 1/5 [3], 2/5 [4], 3/5 [5], 4/5 [6] or 1 [8]
16.1.2 Long sward	0 [0], 1/5 [3], 2/5 [4], 3/5 [5], 4/5 [6] or 1 [8]
16.1.3 Short sward	0 [0], 1/5 [2], 2/5 [3], 3/5 [4], 4/5 [5] or 1 [6]
16.2 Emergent	0 [0], 1/5 [5], 2/5 [8], 3/5 [8], 4/5 [5] or 1 [4]
16.3 Floating	0 [0], 1/5 [5], 2/5 [6], 3/5 [4], 4/5 [3] or 1 [2]
16.4 Submerged	0 [0], 1/5 [5], 2/5 [6], 3/5 [6], 4/5 [8] or 1 [8]
17. Diversity:	
17.1 Bankside	low [2], moderate [7] or high [17]
17.2 Emergent	low [1], moderate [3] or high [6]
17.3 Floating	low [1], moderate [2] or high [5]
17.4 Submerged	low [1], moderate [3] or high [6]

II. SCORE FOR ENHANCEMENT.

18. Water quality	low [2], moderate [14] or high [32]
19. Physical habitat characteristics:	
19.1 Instream:	
19.1.1 Flow diversity	low [0], moderate [2] or high [5]
19.1.2 Sinuosity	low [0], moderate [1] or high [4]
19.1.3 Depth variability	low [0], moderate [3] or high [6]
19.1.4 Substrate variability	low [0], moderate [2] or high [5]
19.2 Bank:	
19.2.1 Slope variability	low [0], moderate [3] or high [6]
19.2.2 Substrate variability	low [0], moderate [1] or high [4]
19.3 Adjacent land use (type)	low [0], moderate [2] or high [6]
20. Vegetation:	
20.1 Buffer width	low [1], moderate [6] or high [12]
20.2 Instream management	low [1], moderate [4] or high [9]
20.3 Bankside management	low [1], moderate [5] or high [11]

Notes

[1] derived using OS 1:50,000 or 1:10,000 maps.

[2] long established flood defence schemes using earth and even reinforced banks taken as 'natural'.

[3] provision of 'fish pass' passable by all migratory fish (including coarse stocks) scores 2. Passes easily accessible only to more agile species (*e.g.* salmonids) scores 1.

[4] estimated as proportion of bank length.

[5] assessments made on the potential (low, moderate or high) for improvements to water quality, physical habitat and vegetation.

A4.12 ICID (International Commission on Irrigation and Drainage) (Bolton & Dawson, in press).

Appendix 5

INSTITUTE OF FRESHWATER ECOLOGY

Progress report on River Corridor Strategic Overview Feasibility Study

To: National Rivers Authority Project Director, Dr P Raven, Conservation Officer, Head Office

This study evaluating the feasibility of a strategic overview of the conservation status and enhancement potential for the rivers of England and Wales has concentrated upon the specific objectives of identifying the advantages and disadvantages of the options available.

Following an extensive period attempting to evaluate the correct philosophy behind the methodology proposed, data are being gathered on:

i the type, extent and sources of available information
ii the methods required for interpretation and classification
iii staff resources and expertise required
iv benefits and links with NRA and external organisations
v possibilities of collaboration with external organisations
vi timescales involved
vii estimated costs and
viii database and data handling requirements especially Geographic Information Systems.

The availability of large scale air-photography between 1986-91 has been tabulated for England and Wales together with air photography from:

(a) The Ministry of Agriculture, Fisheries and Food air photo unit at medium scale (1:20,000) photography of eight of the national parks in England and Wales and large scale (1:10,000) air-photography within Environmentally Sensitive Areas and since 1986 large blocks dispersed throughout England and Wales, frequently in colour and in the majority of cases at 1:10,000 scale.

(b) Royal Commission for Historic Monuments, a specialist collection of 500,000 oblique air photographs and a general collection (various scales, dates) of 4 million vertical air photographs. The majority of the vertical air photography is black and white and medium scale (1:20,000) but 1985 photography is not being added to the archive.

(c) Geonex which much of this is county cover (6), the most recent of which was flown at 1:10,000 scale in colour to coincide with the 1991 census; this represents a potentially important source of information for river corridor analysis.

(d) Hunting Aerofilms fly a considerable amount of air-photography each year, mostly for county councils at 1:10,000 scale in colour. However, the acquisition of new air-photos in England and Wales remains uncoordinated. Air photo acquisition costs are being assessed but at 1:10,000 scale and at an average cost of £10 per print (£3.20 km^2), the total cost to cover England and Wales would be £480,000.

To determine information content for river corridors, a trial interpretation of 1:10,000 and 1:3,000 scale colour air-photography of a section of the River Kennet (Chiltern Foliat - Knighton) is being undertaken.

Satellite imagery

SPOT and Landsat Thematic Mapper (TM) have sufficient spatial and spectral resolution to provide accurate land cover maps of UK but the resolution must be assessed in view of developing enhancement techniques.

The Landsat Thematic Mapper (TM) has a 30 m pixel size optimal for mapping landcover in UK, given typical field size and includes a mid-infrared waveband (TM5: 1.55 - 1.75 microns) which provides considerable additional discriminatory power for vegetation mapping.

SPOT 2 launched in 1990 has a 20 m pixel size in multispectral (XS) mode and a 10 m pixel size in panchromatic (Pan) mode, but the choice of adopting solid state array (CCD) technology, limits to 3 (visible green ( ), visible red ( ) and near-infrared ( ), limiting discrimination of vegetable types.

Airborne thematic mapper (ATM) records 11-channel in the 0.43 - 13.00 micron region. Depending upon flying height, pixel size varies between 1-20 m and has the advantage of the scanner compared with conventional air-photography is the availability of spectral channels from the visible, near-infrared, short and long wavelength infrared.

Databases of environmental information systems include

(a) Soil Survey and Land Research centre (SSLRC), Land Information System (LandIS) on soil data and is available in raster format for England and Wales (1:250,000) with less at 1:24,000 and 1:50,000 plus altitude, local authority boundaries, mean annual monthly, summer and excess winter rainfall totals, temperature, soil moisture deficit;

(b) the ITE Land Classification System incorporates a wide range of environmental variables, including climate, topography, human geography, solid and superficial geology, with the land classes showing well-defined distributions;

(c) ITE satellite land cover map of Great Britain with a range of land cover classes for the ITE satellite land cover including woodland, semi-natural vegetation, arable, development, water, bare ground, often subdivided several times.

The Water Information System (WIS) developed by the Institute of Hydrology (IH), has been assessed, as have river corridor and associated surveys including RBSQ/River Corridor Survey, RIVPACS, IFE (Botany), Faunal Richness of Headwater Streams (Land-Use Survey), Fluvial Auditing, HABSCORE, Macrophyte and Biological Survey, Haslam Survey, Dorset Environmental Records Centre, ICID and other miscellaneous ones.

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