Method for Assessment of Low Flow Conditions Caused by Abstraction

Volume 1 of 2 : Report

Scott Wilson Kirkpatrick

Project Report 237/2/T

NRA

National Rivers Authority

METHOD FOR ASSESSMENT OF LOW FLOW CONDITIONS CAUSED BY ABSTRACTION

Volume 1 of 2 : Report

Research Contractor
Scott Wilson Kirkpatrick
Scott House
Basing View
Basingstoke RG21 2JG

National Rivers Authority
Rivers House
Waterside Drive
Aztec West
Almondsbury
Bristol BS12 4UD

Project Report 237/2/T

Publisher
National Rivers Authority
Rivers House
Waterside Drive
Aztec West
Almondsbury
Bristol BS12 4UD

Tel : 0454 624400
Fax : 0454 624409

First Published 1992

Dissemination Status
Internal: Released to Regions
External: Restricted

Research Contractor
This document was produced under R&D Contract 237 by:

Scott Wilson Kirkpatrick
Scott House
Basing View
Basingstoke
Hants RG21 2JG

Tel: 0256 461161
Fax: 0256 460582

NRA Project Leader
The NRA's Project Leader for R&D Contract 237 was:

Mr Tony Jones - Thames Region

Additional Copies
Additional copies of this document may be obtained either from Regional R&D Coordinators or from the R&D Section of NRA Head Office

Project Report 237/2/T

CONTENTS

Page

Page

<u>VOLUME 2</u>

APPENDICES

LIST OF TABLES

LIST OF FIGURES

PROJECT TEAM

This study has been directed on behalf of the NRA by Thames Region. The staff involved were:

Dr Mike Owen	Topic Leader
Mr Tony Jones	Project Leader
Mr Gareth Llewellyn	NRA R&D Co-ordinator
Dr Maxine Forshaw	(from June 1991) NRA R&D Co-ordinator

The Consultants core project team consisted of:

Mr Mike Le Gouais	Project Director
Mr Shammy Puri	Project Manager (Phase 1)
Mr Steve Booth	Project Manager (Phase 2)
Dr Phil Kerrison	Aquatic Ecology Specialist
Ms Anne Knape	Landscape Specialist

EXECUTIVE SUMMARY

This report presents the results of a research contract carried out between August 1990 and November 1991 by Scott Wilson Kirkpatrick & Partners under NRA R&D Project 237, "Assessment of Low Flow Conditions".

The overall project objective was "to review low flows due to abstraction and to standardise the assessment of the condition". Phase 1 was concerned with proposing a methodology for the assessment, whilst Phase 2 coordinated a national evaluation exercise to ensure the methodology was Regionally operable.

The standard assessment method proposed, addresses the conflict between the need for minimum input of staff resources by the NRA and the need to separate low flow impacts from water quality impacts on the ecology by means of a two stage procedure comprising Preliminary Screening and Full Assessment. In practice, Regions had already carried out their own Preliminary Screening before the publication of this method.

The method is based on four Indicators and two Adjustment Factors:

Hydrological
Ecological
Landscape/Amenity
Public Perception
Size of Affected Site
Cost of Alleviation

For the Full Assessment, a 'score' is calculated for each Indicator by combining scores assigned to a number of weighted parameters within the Indicator (see Sections 7 to 10).

The Indicators can be combined in a number of ways (see Section 11) to determine for any site,

* **the severity of the condition**
* **the reliability of the assessment**
* **whether the problem is 'real' or 'perceived'**
* **the priority which the site should receive, Nationally or Regionally, for alleviation.**

For the Preliminary Screening scores are assigned directly to a chosen parameter within each Indicator (see Section 12). This stage can be used to establish approximately the severity of the condition and a rough order of priority.

It is expected that affected sites will proceed from Preliminary Screening to Full Assessment before significant capital resources are applied to alleviation.

In both cases, it is expected that only those parameters and indicators for which data are available or can be collected at minimum cost will be used.

The 'scores' and 'weights' proposed are based upon experience and on information and reports provided by NRA Regions during the study, and were amended in some cases as a result of the Phase 2 evaluation.

KEYWORDS

Abstraction, alleviation, amenity, conservation, ecology, fisheries, groundwater, hydrology, low flows, water resources

1. INTRODUCTION

The National Rivers Authority (NRA) Research & Development (R&D) programme was published in May 1990 (NRA 1990). In that program, the problem of low flows was identified as one area requiring specific attention. Following NRA Thames Region's invitation to submit a proposal, Scott Wilson Kirkpatrick were appointed Consultants on 15th August 1990, to undertake the Project 237, Assessment of Low Flow Conditions, which is part of Topic B2, Flow Regimes.

The objective of this project was to provide the NRA with the means to objectively assess the severity of , and define priority in resolving, low flows problems across the whole of England and Wales, which is under their jurisdiction. To meet these objectives, following consultations with the Regions, the Consultants have devised a relatively straightforward numerical system of assessment. Occurrences of known low flows are shown on Figure 1.1.

An Interim Report was submitted in November 1990 containing the outline of proposals which were the subject of consultations and comments received from NRA Regions in January 1991.

A final report for Phase 1 of the Project, "Proposed Methodology", was submitted in March 1991.

The Methodology was then tested by each Region by applying it to known or suspected low flow sites between July and September 1991, under a second phase of the project entitled "Evaluation of Methodology".

The results of that exercise were reviewed and discussed at a meeting between the Consultants and representatives of each Region on 29th October 1991. The methodology was then amended to take account of the feedback from that testing.

The present document constitutes the Project Report for the whole study, comprising both Phase 1 and Phase 2.

A separate R&D Note (45) has been issued, containing the instructions for applying the methodology, without all the background to the study.

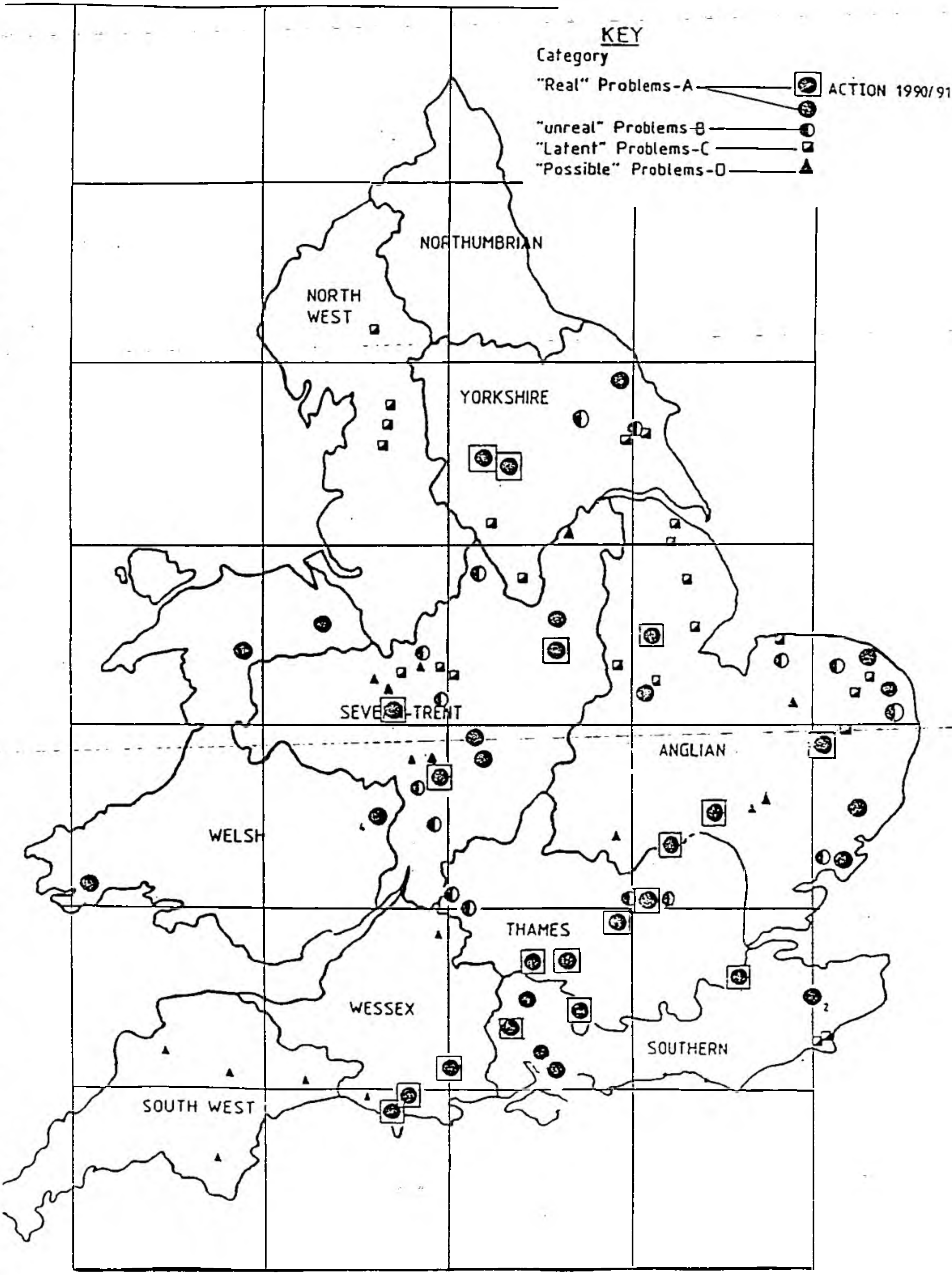
This report sets out the proposed Assessment Method, which is based upon four Indicators and two Adjustment Factors, as follows:

The Indicators are:

- **Hydrological**
- **Ecological**
- **Landscape/Amenity**
- **Public Perception**

The method as originally conceived included provision for Preliminary Screening before carrying out the Full Assessment. Some doubt has been expressed as to the value of the Preliminary Screening since the Regions have invariably carried out their own form of screening. This has been left in but amended to reflect the particular circumstances in which it might be useful.

For a rapid summary of the method, the reader is directed to Chapters 5, 6 and 11 of this report.



Known Instances of Low Flows in England & Wales

Figure 1.1

2. INTERRELATIONSHIP WITH OTHER R&D PROJECTS

At the time of submission of the Interim Report and again in the Final Report on Phase 1 the status of the relevant parts of the NRA R&D programme were reported fully.

No further review of these other projects was carried out during Phase 2 and the situation reported below is as reported in March 1991.

The following paragraphs summarise the position stated in the Interim Report and add to it the latest situation.

The newly recast project **"282, Environmentally Acceptable Flows"** is clearly one situation where the data requirements could be shared. The details of the project's aim are of such interest to this project that they are reproduced in Appendix B, to enable the staff in the Regions to refer to these while conducting the low flow assessment as recommended in this report (Section 7.5).

Figure 2.1 shows the interrelationship of the "Assessment of Low Flow Conditions" project with other relevant R&D projects. The inner ring signifies closer association with the 'Low Flow' project, and the outer ring a more distant, but relevant association.

These other R&D projects have two potential impacts on the 'Low Flows' project, namely:

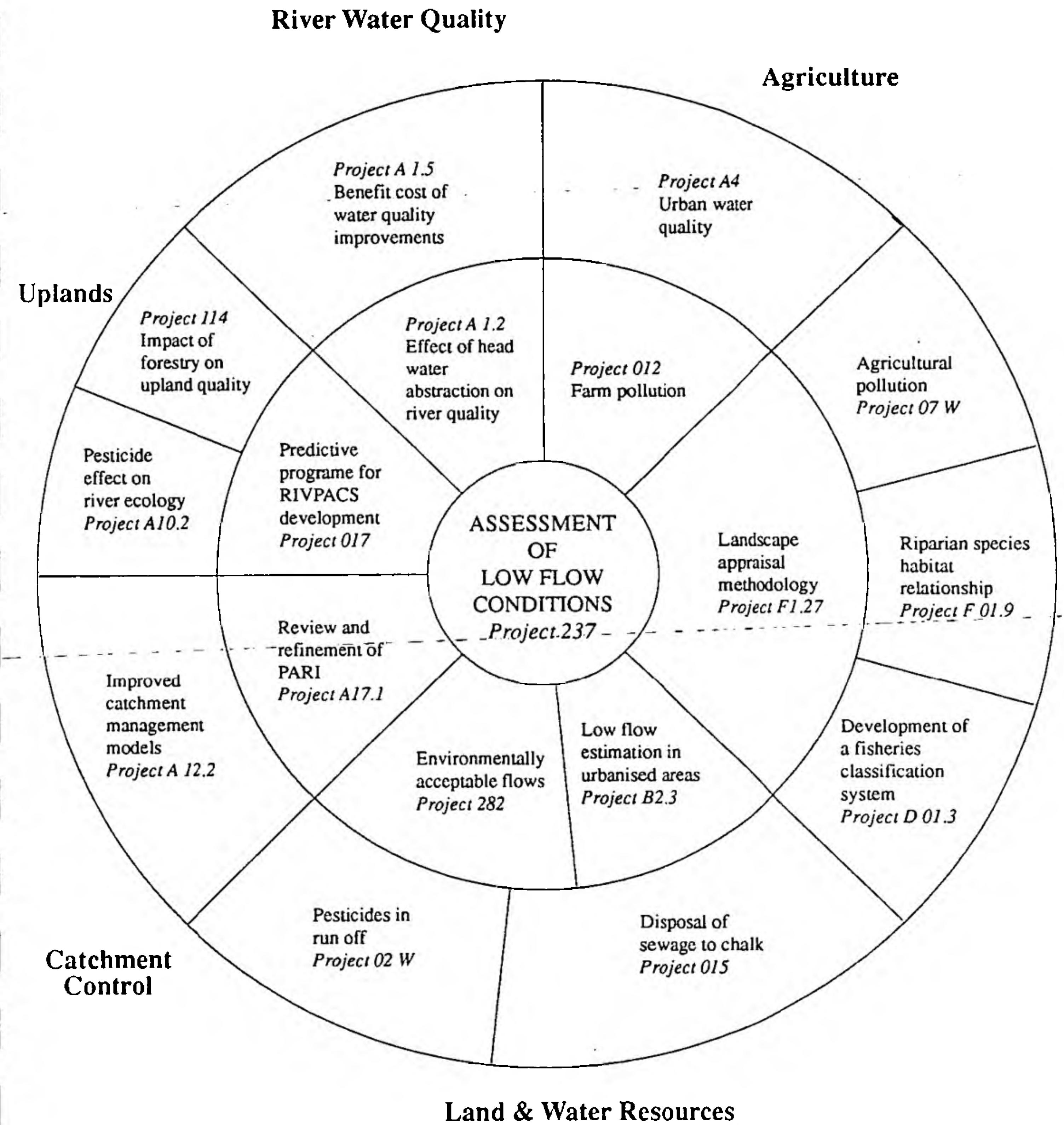
i) to provide a means of assessing specific target values for assessment parameters or alleviation objectives (e.g. Minimum Acceptable Flow, Ecologically Acceptable Flows), and

ii) to stimulate data collection or manipulation exercises, which would provide data for the assessment of low flows.

The Consultants are conscious of the fact that overall data collection within the NRA should be coordinated to serve as many purposes as possible for the minimum cost of collection. Thus in assessing which parameters to use for the low flow assessment, preference should be given to those parameters for which data are already collected or for which the data has a number of other uses within the R&D programme. It may be anticipated that the quantity and quality of data to be collected by the NRA may progressively change in the future, particularly with the objective of ensuring that the same level of data collection is achieved in all Regions.

A summary of findings to date on other R&D projects is given in Appendix D.

Many of the projects which could have a bearing on the "Low Flows" project have progressed further during Phase 2 and some have been referred to in the "feedback" from the Regions, both explicitly and implicitly. Some aspects of the methodology set out in this report will be superseded by the results of this other research but, apart from anticipating the use of Minimum Ecologically Acceptable Flows in Parameter H5, the Consultants believe that the methodology must be set up first and amended only by the final conclusions of such other research.



NRA R&D Projects Interelationship
Figure 2.1

3. REVIEW OF PREVIOUS NRA WORK

Some NRA Regions in their previous guise of the Regional Water Authorities had initiated some work on Low Flows within their respective areas but without much coordination with each other. On vesting day, the NRA took over the coordinating role, for the whole of England and Wales.

'Low Flows' as a problem was recognised in a number of Regional Water Authorities. However, the definitions, and therefore the regional perception of the problem, were viewed in a variety of differing ways in each Authority.

Following vesting day, a survey was undertaken by the NRA Anglian Region, to determine the perceptions of each region with a view to establishing the extent of the problem at a national level.
The following paragraphs review these findings which are based on Roger Cook's (Anglian Region Water Resources Manager) reports and other internal NRA reports (Appendix E). The definition of 'Categories of Problem' and summary tables from Roger Cook's Report are produced below.

Category A - "real problems"	locations where there is a clear case for action.
Category B -"unreal problems"	locations when despite public outcry there is not a clear case for action.
Category C -"latent problems"	locations which are likely to be recognised as problems if action is seen to be taken on Category A.

During the survey by Anglian Region a fourth category was identified which was described as "possible problems" i.e. those where there is perceived to be a problem which has not yet been publicly recognised but the cause and the solution have yet to be evaluated. These have been denoted "Category D".

Table 3.1 shows the number of streams by Category in each Region which are considered to have been affected.

The largest number of problem locations were identified in the Severn Trent Region, while Northumbria reported none. A total of 40 Category A problems were identified, with the largest number occurring in the Anglian Region.

Table 3.2, which was also compiled in the same survey, shows by Region and by Category the estimated costs of alleviation. Work currently underway in the Regions is aimed at better establishing these cost estimates shown in the Table 3.2.

Table 3.1 Number of Problem Locations identified

REGIONS	Number of Locations & Category				Totals
	A	B	C	D	
	Real	Unreal	Latent	Possible	
Anglian	9	4	10	4	27
Northumbria	-	-	-	-	-
North West	-	-	4	-	4
Severn Trent	6	5	3	6	20
Southern	7	-	1	-	8
South West	-	-	-	3+	3
Thames	5	4	-	-	9
Welsh	7	-	-	-	7
Wessex	3	-	-	2	5
Yorkshire	3	2	4	-	9
Total	40	15	22	15	92

The above information was provided in the Interim Report. Since that time a number of ongoing regional low flow studies have progressed. It is beyond the scope of the present report to describe all of these in detail. The Consultants are aware of two specific regions, Severn Trent and South West, where region wide studies devoted to low flow alleviation have been initiated. Investigations related to specific streams, eg the Darent (Southern) and the Slea (Anglian), are also underway.

Table 3.2

Summary of Roger Cook Survey: Budget Costs (£000)

Category	A			B			C		
Region	Capital	Operating	Compensation	Capital	Operating	Compensation	Capital	Operating	Compensation
Anglian	2775	16	-	195	6	-	710	28	5500
Northumbrian	-	-	-	-	-	-	-	-	-
North West	-	-	-	-	-	-	-	-	6100
Severn Trent	295	30	500	530	50	300	----	Not Costed	-----
Southern	20000	200	6000	-	-	-	-	-	5000
South West	-	-	-	-	-	-	28	-	-
Thames	9500	230	-	2300	60	1200	-	-	-
Welsh	500	100	1100	-	-	-	-	-	-
Wessex	4250	175	-	-	-	-	-	-	-
Yorkshire	200	-	60	500	10	50	750	10	560
Total	37520	751	7660	3525	126	1550	1488	38	17160

4. SUMMARY OF THE EXISTING SITUATION

As a first step in the study the existing situation as regards investigation and study of low flows in each NRA Region was fully reviewed by the Consultants. In order to completely appreciate the concern of the Regions, all of them were visited prior to the preparation of the Interim Report (except Northumbria). Table 4.1 summarises the dates of visits. Discussions with the Regions were aimed at establishing their concerns, their current practices and anticipated approaches to dealing with the low flow problem in their own areas. Due to the nature of the present project, detailed evaluation of every occurrence of low flows in each Region could not be made. It was therefore decided to select two contrasting occurrences of low flows and to discuss them.

In selecting two occurrences, the aim was to obtain a good, albeit subjective, appreciation of the problem faced by each Region. These were summarised, from the Consultant's view point, in the Interim Report. The Regions were then asked to comment on the Consultant's understanding of the situation. The revised summary of the situation within each Region is given in Appendix C.

As part of Stages 1 and 2 of Phase 1 of the Study (Figure 4.1), the following information was obtained :

* confirmed list of low flow sites previously reported.
* the basis on which the above list of sites were drawn up by each Region.
* a preliminary list of appropriate assessment parameters relevant to the sites affected by low flows.
* reports for rivers/sites which have been studied previously.

Northumbria Region was not visited since no Category A or B sites were identified. Telephone discussions with Mr David Archer of Northumbria Region have been held however.

4.1 Approach to Stage 1 and 2 Survey and Consultation (Phase 1)

Before the programme of consultation, a standard letter was issued to each Region, setting out the objectives of the study and giving a preliminary list of parameters for the assessment procedure.
At each visit the following procedure was adopted:

i) The Consultant explained the scope and objectives of the study and requested location maps of each affected site.

ii) The Consultants requested the Region to confirm that the sites listed in the returns to Roger Cook were correct or to identify any variations or additional sites.

iii) The Consultants tabled a list of possible assessment parameters (which was revised in the course of consultations) and invited the Region to nominate for discussions two of the sites identified in their Region; one for which a considerable amount of data exists and the occurrence of low flows is not in question, and another for which data are lacking and the evidence is not clear. This was to take account of the fact that the assessment procedure will be required to compare such differing sites on an equitable basis.

iv) The applicability of the list of assessment parameters was then discussed,

> a) to identify which of those or which other parameters have been used by the Region to identify the two nominated sites, and
>
> b) to seek the Regions's views on the relevance and relative importance of each parameter in their Region and Nationally.

v) Finally the Regional staff were asked for any other comments or suggestions for the study.

4.2 Staffing of Consultation (Phase 1)

Since one of the questions addressed in later stages of the study is the balance between water resources and conservation / environmental factors, the views obtained from the consultation were influenced by the officers consulted and, to a lesser extent, by the specialists fielded by the Consultants.

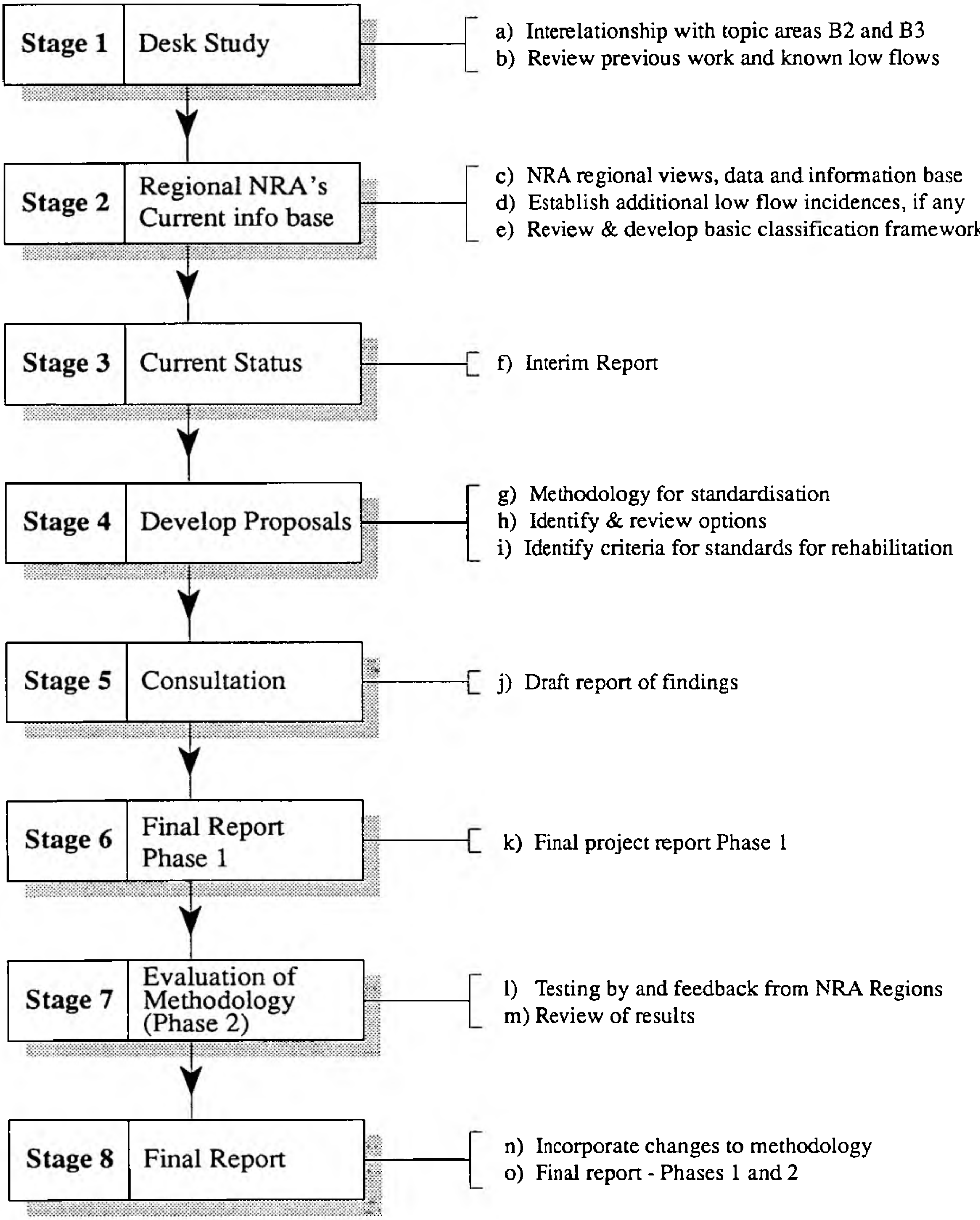
In setting up the Stage 1 and 2 meetings, this was pointed out to each Region but there was considerable variation in the range of disciplines fielded by each Region. In all cases a Water Resources officer attended the meeting but the representation of the Conservation/Environmental aspects varied. From the Consultants' side, the Water Resources aspect was dealt with by Mike Le Gouais (for predominantly surface water areas) or Shammy Puri (for predominantly groundwater areas), with both together attending meetings easily accessible to Basingstoke in order to ensure a consistent approach.

For budgetary purposes the inputs from the Consultants on environmental aspects have been limited to 3 visits each from Anne Knape and Dr Phil Kerrison, ie visits to two 'groundwater' areas and one 'surface water' area with one joint visit (to Anglian Region) to ensure co-ordination. The NRA staff also varied considerably in seniority, from those only concerned with some aspects of a few sites in one area to those at senior level who had been addressing all aspects for the whole of their Region at strategic levels.

Table 4.1

List of Liaison Meetings with NRA Regions

NRA Region	NRA Staff Met	Consultants Staff	Date of Meeting
Anglian	Mr Roger Cook Mr David Evans	S Puri Anne Knape P Kerrison	31/8/90
South West	Mr Peter Nicholson Mr Nigel Reader Dr Janet Cochrane Dr Rosanne Proome	M Le Gouais S Puri	14/9/90
Thames	Mr Nigel Hawkes Ms Maggie Pratt Mr Alastair Driver	M Le Gouais S Puri	19/9/90
Southern	Mr Steven Oakes	S Puri	24/9/90
Welsh	Ms Jean Frost Mr Richard Howell	M Le Gouais P Kerrison	24/9/90
Wessex	Dr Terry Newman Mr Richard Symonds	M Le Gouais S Puri	26/9/90
Severn Trent	Mr Elfyn Parry Mr Bob Harris Mr Roger Goodhew	S Puri P Kerrison	4/10/90
Yorkshire	Mr P Towlson Mr D Franklin Mr I Barker Mr J Pygott	S Puri Anne Knape	15/10/90
North West	Mr M Aprahamlan Mr R Ward Mr B Repton Mr R Chambers Dr M Owens	S Puri Anne Knape	18/10/90
Northumbria	Mr David Archer	M Le Gouais	(telephone discussion)



Study Workplan
Figure 4.1

This perceived imbalance was corrected when the Interim Report was circulated to the Regions in Stage 2 consultation in January 1991. A number of important contributions were made which have assisted in the final development of the assessment methodology.

4.3 Summary of Findings (Phase 1)

A broad summary of the problems and perceptions of each Region is given in Appendix C.

There is considerable variation in Regional perceptions on the problem of low flows and the objectives that any alleviation proposals should have. Basically these can be classified as follows:-

Reduction in flow (real), in some cases to zero, arising (usually) from groundwater abstraction and leading to environmental degradation and public protest.

Reduction in flow due to surface water abstraction, leading to the same problems as above.

Potential low flow problems arising from abstraction licences which cumulatively exceed the river's catchment base flow and which may have not yet been taken up to the full licensed quantity.

Other problems such as lack of 'freshets' allowing fish migration have been mentioned in one or two regions.

Public pressure (both justified and unjustified) is a major driving force in the implementation of studies in many regions but real and potential problems have also been identified by NRA regions without, or in advance of, public pressure.

The approach adopted in resolving the problem appears to the Consultants to have been biased by discipline of the NRA staff consulted. The Water Resources Staff have generally viewed the problems within the terms of essentially providing additional flow in the stream. Generally, the approach of the biological-ecological staff appears to have been governed by Water Resources aspects and as a consequence their activities have been concerned with documenting and monitoring the invertebrate data of the affected streams.

Broadly, the problem causes can be defined on water resources - hydrogeology basis as follows:

Over-abstracted and/or over-licensed Chalk (or other) aquifer

Over-abstracted and/or over-licensed surface water resources

Inadequate reservoir releases

Other reasons : e.g. impact of land use, drainage, urbanisation.

5. APPROACH TO THE ASSESSMENT

In the Interim Report it was stated that:-

> "The requirements for the method of assessment are that it should produce an equitable and reproducible assessment of the relative degree of severity of artificially-induced low flows in a wide range of watercourses, taking into account wide differences in:-
>
> i) causes and impacts
> ii) water resources and environmental aspects
> iii) quantity and quality of data available
> iv) public awareness/perception
> v) cost of alleviation measures.
>
> It was also concluded that, in addition to indicating the degree of severity, the method of assessment should indicate the level of confidence that can be placed in the assessment (ie. the quantity, quality and relevance of the data used in the assessment). In addition (and perhaps most important) the method of assessment should require the minimum appropriate commitment of resources by the hard-pressed Regions.. Thus it should be based as far as possible on data which is already collected for other purposes, or on new data which can be collected at minimum cost.
>
> A further dimension to the Classification Framework is that, in addition to assessing the relative degree of severity of the problem (on which prioritising or ranking of sites would be based) it should also describe the type or quality of problem, to enable alleviation strategies to link with overall policies for environmental improvements."

In developing the framework the Consultants have addressed the conflict between the need for minimum input of staff resources from the Regions, and the need to solve the complex problem of separating quality impacts from low flow impacts on the ecology.

The Consultants have tried not to use the need for minimum demands on staff resources as an excuse for producing a simplistic method. As a result, the proposed full assessment appears to be rather more complex than might have been hoped.

The Consultants sought to reduce the complexity of the assessment:

i) by introducing the option of a two-stage assessment comprising Preliminary Screening and Full Assessment, and
ii) by allowing the user to use only those parts of the assessment appropriate to the stage of the procedure used and the data available.

The intention was that the user would select, from a "menu" of parameters, only those for which data was available.

This concept clearly caused problems during the evaluation stage. Some Regions complained that they did not have adequate data to use all of the parameters. Others pointed out that they had already carried out a preliminary screening by their own methods and that a further such screening was unnecessary. A further point of concern was that some Regions would only use or "score" a parameter if they had accurate and full data for it whereas other Regions would make their best assessment on the basis of such data as was available.

It became clear therefore that some amendment to the approach was necessary.

5.1 Preliminary Screening

It is not proposed that either the preliminary or full assessment should be applied to every stretch of river in the country to determine if there is a low flow problem.

Nor is it proposed that all problems in rivers should be presumed to have a low flow dimension until proven otherwise. It is proposed that the assessment should be applied only to those rivers or sites for which there is some reason to believe that low flow problems are occurring. In practice this means those sites which have been shown by the Region's own preliminary screening method to be likely to be suffering a low flow problem.

Thus preliminary screening is unlikely to have any wide application but is retained in a slightly modified form as an option if required.

5.2 Principles of Full Assessment

The assessment proposed is based on three principles:

i) The assessment should indicate the degree of artificial interference with low flows (Severity Index) as well as the reliability of that assessment (Reliability Index).

ii) The evidence of low flow problems is derived from four primary Indicators, namely Hydrological, Ecological, Landscape/Amenity and Public Perception. Cost of Alleviation is relevant to the setting of priorities for alleviation but not to the assessment of the severity of the problem. A further adjustment for Size was added as a result of the Phase 2 evaluation.

iii) Because the available evidence for indicators may be different between Regions and sites there needs to be a degree of redundancy in the parameters available for use, i.e. not all parameters need to be used on any site. Another way of looking at this is as a "menu" selection of parameters. However, it has been concluded from the evaluation that some restriction should be placed on the number of parameters used.

In the Full Assessment each Indicator is 'built-up' from a number of contributing parameters to which scores are assigned by the assessor. These scores are then combined using pre-set weights for each parameter, ie. they are pre-set in the method, and are not modified by the assessor.

However, for the Preliminary Screening (Section 5.1) a single parameter for each Indicator could be used, as indeed, one Indicator from above could be used to confirm the occurrence of low flow prior to proceeding to its Full Assessment.

6. INTRODUCTION TO ASSESSMENT METHOD

The Assessment Method is based on obtaining adequate evidence from four Indicators and two Adjustment Factors, namely:-

INDICATORS:	
Hydrological	The Indicator which accounts for the hydrology of the stream system
Ecological	The Indicator which accounts for the aquatic ecology system
Landscape/Amenity	The Indicator which addresses Landscape Value and Amenity Use (or loss of Amenity)
Public Perception	The Indicator which accounts for public complaints to the NRA, both actual and potential

ADJUSTMENT FACTORS:	
Size	The Adjustment which accounts for the length and catchment area of the affected site
Cost of Alleviation	The Adjustment which addresses cost/benefit of alleviation options

Each Indicator is evaluated by combining scores assigned to a number of weighted Parameters which contribute to the Indicator. The Indicators can then be combined in a number of ways to determine for any site:

* the severity of the condition (The Severity Index)
* the reliability of the assessment (The Reliability Index)
* whether the problem is "real" or "perceived"

In order to assess the priority which each site should receive for alleviation, two **Adjustment Factors** are introduced to take account of:

* the **Size** of the affected site, i.e. the length and size of watercourse affected, and
* the **Cost**, or more correctly the benefit/cost ratio, of alleviation

The Indicators can be used at two levels:-

* **Preliminary Screening,** which requires minimum data and staff resource

* **Full Assessment,** which requires a large data base and input from staff working in a number of disciplines.

For the Preliminary Screening, scores may be assigned directly to the Indicators by the assessor. However, this level of assessment will result in a low Reliability Index, as it relies on very limited data, and may offer no advantage over the existing methods of screening used by the Regions, in which case such methods should continue to be used for Preliminary Screening.

For the Full Assessment the score for each Indicator is calculated by combining scores assigned to a number of weighted parameters related to each Indicator (see Sections 7 to 11). The Full Assessment is comprehensive and time consuming and it is expected that it will only be applied to those sites for which some form of Preliminary Screening has suggested that the stream is suffering the effects of low flows.

However, a number of points should be understood before applying the method:

i) Not all Indicators or Parameters need to be used and indeed there are restrictions placed in some cases on the number of Parameters that can be used within an Indicator. This is because there is a degree of overlap or redundancy in the parameters, so that the user can select from a "menu" of Parameters those for which data are available and/or are most relevant to the particular site

ii) The amount and quality of data used in the assessment is reflected in the **Reliability Index** of the assessment.

iii) The method will not distinguish between low flows caused by drought and those caused by long-term abstraction. The assessment must therefore be reviewed in the context of the degree of drought occurring in the years over which the data on which the assessment is made were collected.

iv) The method was developed during 1990 under the normal constraints of time and budget and was concluded before the results of some other very relevant and important research work became available, notably the evaluation by the Institute of Hydrology (IH) of the program "PHABSIM" which offers the prospect of a reasonably reproducible method of assessing minimum ecologically acceptable flows.

v) Prior to evaluation of the Indicators, the assessor must first decide whether the length of watercourse affected should be treated as one site or as a whole series of separate sites. This is of particular significance where a length of several kilometres of river is affected. The decision rests with the assessor, but if treated as several sites, it is recommended that the sites should be selected either

- to reflect natural breaks, e.g. hydraulic controls, locks, different land uses, or

- by dividing the river into (arbitrary) lengths of 1km

If divided, each length of (say) 1km can be assessed separately for Severity Index (SI) and Reliability Index (RI), with the option of taking the mean of them to produce the SI and RI for the whole of the affected length.

If the whole length is assessed as one, the assessor will, in effect, have to "average" the data for each parameter, over the whole length. Either approach should be valid.

The method is explained in more detail in the following sections and the steps involved in the assessment are shown in Table 6.1 below.

The "scores" and "weights" proposed are based upon experience and upon the results of field testing carried out in the late summer of 1991.

A Procedural Manual for the method is published in R&D Note 45.

The calculation of each Indicator is set out on sample calculation sheets and a spreadsheet-based macro, developed in Lotus 1-2-3, is also available to facilitate these calculations.

Table 6.1 The sequence of the assessment

Steps	Assessment required at each step
1	Define whether Preliminary Screening or Full Assessment required
2	Select Main Indicators of low flows (at least one for Preliminary, all for Full) Hydrological Indicator Ecological Indicator Landscape/Amenity Indicator Public Perception Indicator
3	Assign scores for the appropriate parameters of every Indicator used
4	Calculate Severity Index and Reliability Index for each of the Indicators selected
5	Combine the Indicator Indices to obtain Overall Severity Index, and Overall Reliability Index
6	Adjust Overall Severity Index to take account of: Size, and Cost
7	Decide on the further action for the stream system
8	Repeat steps 2 to 7 if more data are available

7. THE HYDROLOGICAL INDICATOR

The Consultants propose that the Hydrological Indicator should be assessed on the basis of six parameters. Each of these parameters and the system of their scoring is discussed in the following sections. Table 7.1 shows a summary of all the parameters proposed.

7.1 Groundwater Balance Parameter (H1)

This parameter, applicable to streams mainly supported by groundwater flow would be calculated for the groundwater catchment considered to be suffering low flows . It is the sum of all annual groundwater abstraction licences (ALA) divided by the calculated annual recharge (AR), for the catchment upstream of an assessment point.

$$H1 - \frac{ALA}{AR}$$

Licensed surface water abstractions (SWALA in table 7.2) and effluent returns (ER in table 7.2) would be included only if

a) parameter H2 is **not** used, **and**

b) abstraction is primarily supported by spring flow. Otherwise they would be ignored.

Scoring would be as follows:

$\frac{ALA}{AR} 10yrDrought*$	Score
>1	4
0.7 - 1.0	3
0.4 - 0.7	2
0.2 - 0.4	1
<0.2	0

Notes: * see (iii) below.

The weighting assigned is 50%.

SUMMARY OF HYDROLOGICAL INDICATOR	
Groundwater Balance parameter H1 =	Annual Licensed Abstraction / Annual Recharge (1 in 10 yr. drought) (ALA/AR) Groundwater catchment. May need to add 'licence-exempt' abstractions, surface water abstractions and effluent returns. *Weighting = 50%.*
Riverflow Balance parameter H2 =	Daily Maximum Licensed Abstraction / Q95 "Natural" or Q95 "Natural" / Reservoir Compensation Flow Surface water catchment: Non-reservoired or Reservoired May need to add 'licence-exempt' abstractions, groundwater abstractions, effluent returns and downstream channel abstractions *Weighting = 50%.*
Groundwater Level parameter H3 =	Mean annual decline in minimum groundwater levels / Mean Seasonal Range *Weighting = 10%.*
Stream Morphology parameter H4 =	Channel Size (% of Channel) Percentage of 'normal low flow channel' occupied by low flows at end of August. Ratio of XSA(current) : XSA(normal). *Weighting = 10%.*
Flow and Ecology relationship parameter H5 =	Residual Flow / Minimum Ecologically Acceptable Flow Residual flow = (Q95 "Natural" - DMLA) for Non-reservoired catchments Residual flow = Compensation Flow (+ additions) for Reservoired catchments *Weighting = 90%.*
Movement of Springhead parameter H6 =	Change in Stream Type Length of stream reaches with changed classification (perennial - intermittent, intermittent - ephemeral). *Weighting = 10%.*

Table 7.1 : Summary of parameters related to the Hydrological Indicator

Three points should be made concerning the application of this parameter

i) As many affected sites are in the headwaters, it is likely in some (or many) cases that abstraction in adjacent catchments may affect low flows. Some judgement will be required to decide what is the appropriate catchment to be considered, or whether groups of catchments should be considered together.

ii) Some Regions stressed the occasional importance of unlicensed abstractions such as trickle irrigation, private domestic and stock watering usage. It is therefore proposed that where the assessor adjudges currently licence-exempt activities (x) to represent a significant proportion of the total annual abstraction within the catchment, an estimate is made and cumulatively accounted for in the form

$$H_1 = \frac{ALA+(x)}{AR}$$

iii) It had initially been assumed that this parameter would be calculated on the basis of the average annual recharge on the grounds that the marking system can be adjusted to allow for drought years. However, there is a strong argument for using the calculated annual recharge in the 1 in 10 year drought in order to more directly take into account drought conditions used by the Regions when setting abstraction licences.

The definition of drought in respect to groundwater resources can be based on the departure from the long term average of rainfall or recharge. Since recharge has in any case to be calculated, the case for accepting the inaccuracies inherent in using rainfall is not strong.

The calculation of annual catchment recharge is based on a monthly, preferably weekly, or even daily, budget of rainfall, runoff, evapotranspiration and soil moisture deficit. This is a time consuming process but can be simplified to a large extent by using the Meteorological Office Rainfall and Evaporation Calculation System (MORECS). For any 40 x 40km square, the 1 in 10 year minimum effective precipitation can easily be determined. The annual effective precipitation thus determined is directly correlated with, although not equal to, the groundwater recharge.

The annual recharge is usually best estimated by a weekly budget where, unlike the MORECS method, surface runoff is subtracted from rainfall before the soil moisture deficit and evapotranspiration requirements are accounted for. The balance is recharge rather than effective precipitation.

Thus it is suggested that recharge be calculated by a weekly budget using measured rainfall and runoff for the catchment, or using MORECS to assess the annual effective precipitation and then deducting the average annual surface runoff or, better still, the measured annual runoff for each year if available.

The calculation should be done for at least 10 and preferably 20 years to establish the 1 in 10 year drought by this definition. It is understood that many Regions already produce these data.

7.2 Riverflow Balance Parameter (H2)

This parameter, applicable to streams supported mainly by surface runoff, would be calculated for the surface water catchment. It is calculated differently for reservoired and non-reservoired catchments. For non-reservoired catchments, it consists of the sum of the daily maximum licensed abstraction (DMLA) divided by the naturalised 95 percentile flow (Q_{95}) assessed by the Institute of Hydrology (IH) Low Flow Study methods. Significant unlicensed abstractions and effluent returns would be added algebraically to the DMLA. In the event that parameter H1 is not used, licensed groundwater abstractions deemed to have a direct impact on low flows (e.g. within 250m of the river) would be similarly added.

Non-reservoired catchments:

$$H_2 = \frac{DMLA}{Q_{95} natural}$$

For reservoired catchments, storage usually permits the yield (i.e. reservoir abstraction) to greatly exceed Q_{95}. DMLA is not relevant, therefore, and a different approach to the calculation of the riverflow balance parameter is required. In this case, it consists of the Q_{95} natural divided by the reservoir compensation flow (COMP). Licensed abstractions from the channel downstream of the reservoir (DMLCA), significant unlicensed abstractions and effluent returns would be added algebraically to COMP. Licensed groundwater abstractions with a direct impact on low flows would again be added.

Reservoired catchments:

$$H_2 - \frac{Q_{95} natural}{COMP}$$

Scoring would be as follows:

$H2 - \frac{DMLA}{Q_{95}}$ $H2 - \frac{Q_{95}}{COMP}$	Score
>1	4
0.7 - 1.0	3
0.4 - 0.7	2
0.2 - 0.4	1
<0.2	0

The weighting assigned is 50%.

In collecting the data to assign a score to this parameter the following points should be noted:

i) There has been some discussion on the relative merits of Q_{95}, the 95 percentile flow based on the flow duration curve and MAM the Mean Annual Minimum flow based on the flow frequency curves. Both of these measures are derived from the same basic data set and may not be truly representative of the 'natural' or 'historic' conditions since this data may include some flow data affected by long term abstraction.

It is understood that neither measure is 'better' than the other but consultation with the Regions indicated that Q_{95} is more commonly used in this context.

ii) The Consultants have also considered whether the 1-day, 7-day or 10-day Q_{95} should be used. Provided that the same measure is consistently used, we do not believe it is critical which is selected. However, since current and future IH low flows work is standardising on 7-days, we would propose that the 7-day Q_{95} is used where such data are readily available.

iii) We recommend that licensed abstractions should be used in preference to actual abstractions. Where this is the case, consented effluent returns should also be added to the balance. If, however, actual abstraction figures are used, actual effluent returns must be added, and not licensed quantities.

iv) Although the parameter is calculated quite differently for reservoired and non-reservoired catchments it is not as simple as it may appear to distinguish between the two; particularly where a regulating reservoir is some way upstream of, and therefore regulates a relatively small part of the catchment to, the site to be assessed. In this case the non-reservoired catchment parameter should be used, the compensation releases should be added algebraically to DMLA and any licences upstream of the reservoir should be ignored.

The reservoired catchment parameter is only applicable where the majority of the catchment is reservoired and there is a high degree of regulation.

The interpretation of "high degree of regulation", "some way upstream" and "regulates a relatively small part of the catchment" is left to the judgement of the user, but in borderline cases both reservoired and non-reservoired parameters can be assessed and the most appropriate one used.

7.3 Groundwater Level Parameter (H3)

Originally conceived as an Aquifer Gradient Parameter, this effectively proved unworkable during evaluation by the Regions due to the sparsity of historic gradient data and the subjectivity of old contour maps.

During consultation with Regions it was consistently stated that a measure based on groundwater levels should be included, as level decline, if demonstrated, would be a clearer indication of lowering of aquifer levels.

This parameter would be calculated from the longer-term records of annual maximum and minimum groundwater levels, typically collected and tabulated as part of Regional monitoring networks, many originally instigated by the 1963 Water Resources Act.

If available, a borehole within the critical catchment under evaluation should obviously be chosen for the computation of H3. However, it is recognised that many 'upper' catchment zones and associated interfluve areas suffer from a dearth of monitoring boreholes. In such cases it is suggested that Regional hydrogeological staff utilise discretion to decide whether an alternative borehole record can be substituted. Although such a borehole may be in an adjacent catchment or downstream of the area under evaluation, it may be that similar aquifer characteristics and a comparative (radial) distance from the suspect groundwater abstraction zone may allow its utilisation.

This parameter simply aims to identify a gradual fall in aquifer storage, manifested by a decline in the annual minimum groundwater level. The annual low point (minima) of the groundwater hydrograph is noted for a sequence of at least five and preferably ten years. The mean annual decline (MAD) in the minima is then calculated over the chosen period of years.

In order to account for the natural seasonal variability in groundwater levels and allow for the significant differences in storage characteristics between the UK's major aquifers, it is suggested that the MAD is expressed as a ratio of the mean seasonal range (MSR) exhibited by the groundwater hydrograph over the same time period.

Hence

$$H3 = \frac{MAD}{MSR}$$

It is recommended that, if possible, at least 10 years of continuous records be used, to help 'average-out' individual, or an occasional sequence of climatic extremes, such as dry (low recharge) winters and summer droughts.

Scoring will be as follows:

$\frac{MAD}{MSR}$	Score
*	4
> 0.5	3
0.3 - 0.5	2
0.1 - 0.3	1
< 0.1	0

Note * Where local hydrogeological knowledge is of sufficient confidence to directly inter-relate absolute (datum) levels of the affected river stretch with groundwater - for example a fissure zone originally contributing base flow but now allowing bed leakage due to reversed groundwater gradients - a discretionary higher score of 4 may be awarded.

The weighting assigned to the parameter is 10%.

7.4 Stream Morphology Parameter (H4)

This parameter reflects the proportion of the "normal low flow channel" occupied by low flows at the end of August. It would be calculated as the mean of the ratios of current cross-sectional area of flow (XSA current) to 'normal' cross-sectional area of flow (XSA normal) at not less than 5 representative cross sections.

A suggested definition of 'normal low flow channel' is the channel occupied by the base flow at the end of the month in which a Soil Moisture Deficit first occurs.

This is based on the premise that the impact of abstraction on low flows is far greater at the end of the dry season (when storage is drawn down) than at the beginning of the dry season, when storage should be more or less full. The Consultants have considered using wetted perimeter or hydraulic radius but have concluded that cross-sectional area is most appropriate. Since this parameter is based on relative rather than absolute areas, we believe it is acceptable to calculate area as surface width x maximum depth. However, this parameter must be used with caution,

a) because following a dry winter in which full recharge does not occur, the 'normal low flow' may be abnormally low

b) it is also a measure of the 'flashiness' of the river which is dependent on other factors such as geology and land use

and

c) It must not be used where the flow is significantly influenced by backwater effects from a control i.e. it should only be used where cross-section area is approximately proportional to flow.

$$H4 = \frac{XSA(Current)}{XSA(Normal)}$$

Scoring would be:

XSA (Current)/XSA (Normal)	Score
<0.1	4
0.1 - 0.3	3
0.3 - 0.5	2
0.5 - 0.7	1
>0.7	0

The weighting assigned is 10%.

7.5 Flow and Ecology Relationship Parameter (H5)

The development of techniques to establish minimum ecologically acceptable flows (MEAF) is the subject of another NRA research project, reference 282 referred to in Chapter 2 of this Project Report.

In using the MEAF it should be noted that the ecologically acceptable flow will not be a single value for a given river but will vary with season. As the methodology has not yet been defined its application in low flow assessment is, to an extent, premature. However, when such techniques are available, the relationship between low flow occurring and MEAF will be the most important single parameter in describing the severity of the problem and in monitoring and managing low flows. The following parameter is therefore proposed.

As a measure of low flow problems in surface water areas, the proposed parameter would be calculated differently for reservoired and non-reservoired catchments.

For non-reservoired catchments:

$$H5 = \frac{Q_{95} - DMLA}{MEAF}$$

where Q_{95} = 95 percentile flow for 'natural' catchment calculated from IH Low Flows Study. In this case MAM_7 may be a better measure than Q_{95} since it is based on a consecutive run of low flows.

DMLA = as defined in H2 above

MEAF = min. ecologically acceptable flow in the critical month (Sept.)

For reservoired catchments, DMLA is often much greater than Q_{95} and therefore the parameter as given above is invalid as a low flow Indicator. The residual flow in reservoired situations is equivalent to the compensation flow (COMP) and therefore the parameter should be:

$$H5 = \frac{COMP}{MEAF}$$

Licensed abstractions from the channel downstream of the reservoir (DMLCA), significant unlicensed abstractions, effluent returns and tributary inflows (the sum of the Q_{95} for each tributary) would be added algebraically to COMP.

A possible problem is that the ecologically acceptable flow may be achieved in the month which is critical in terms of minimum flow but the (higher) ecologically acceptable flow required at some other time of year may not be achieved, ie the critical time in terms of low flows may not coincide with the critical time in terms of ecologically acceptable flows.

The compensation flow for reservoired catchments should be determined at the same time of year as the MEAF. Generally, COMP will be the minimum compensation flow and MEAF will be the "minimum ecologically acceptable flow" in the year. However, the timing of these may not always coincide.

This parameter is more difficult to quantify where the abstraction is primarily from groundwater and in such a case the measured residual flow may have to be used, instead of the compensation flow.

The scoring would be as follows:

Parameter Value $H5 = \frac{Q_{95}-DMLA}{MEAF}$ $H5 = \frac{COMP}{MEAF}$	Score
<0.6	4
0.6 - 0.8	3
0.8 - 1.0	2
1.0 - 1.2	1
>1.2	0

The weighting assigned is 90%.

7.6 Movement of Springhead Parameter (H6)

Stream reaches can be classified into 3 main types: perennial, intermittent and ephemeral. These are defined, for this project, as follows:

> Perennial reaches flow throughout the year.
>
> Intermittent reaches flow for most of the year but are dry for at least 2 weeks (in the summer).
>
> Ephemeral reaches only flow during and immediately after rainfall or snow melt.

The change in classification of a stream reach from either perennial to intermittent or intermittent to ephemeral is assumed to indicate a low flow problem. Such a change during a 1 in 10 year drought, however, is an exception to this and is not included. The "change" in stream parameter is defined as:

> The total length of reaches of a stream, upstream of the assessment point, that have changed their classification from either perennial to intermittent, or intermittent to ephemeral.
>
> **H6** = Total Length of River with Changed Classification

Scoring would be as follows:

Length of river (Km)	Score
>8	4
4 - 8	3
2 - 4	2
0 - 2	1
0	0

Equal importance is assumed for a change from perennial to intermittent, as a change from intermittent to ephemeral. Changes from perennial to ephemeral are unlikely but can be scored in exactly the same way.

The weighting assigned is 10%.

7.7 Accretion/Depletion Profiles (H7)

If available, such profiles are very descriptive of the problem but not easy to convert to a simple parameter. They measure the quality of the problem rather than its quantity. For the present it is not therefore proposed to include this in the list of assessment parameters.

7.8 Sample Calculation of Hydrological Indicator

Once all the parameters related to the Hydrological Indicator have been decided, based on data availability and suitability of the parameters for the catchment area, scores are calculated by the assessor. The score of four is the maximum that any parameter may be given. The degree of significance of each parameter is determined by a parameter weight, which is multiplied by the given score to arrive at a weighted score. The weighted scores are added together and divided by four times the sum of weights of parameters actually used, which will give the value of the Hydrology Severity Index (HSI).

Hydrology Reliability Index (HRI) is the sum of Weight of Parameters used.

Example calculation of the Hydrological Indicator

Parameter	Parameter weight	Weight of parameters used (a)	Score (out of 4) (b)	Weighted score score (a) * (b)
H1	0.5	0.5	4	2.0
H2	0.5	-	-	-
H3	0.1	0.1	3	0.3
H4	0.1	-	-	-
H5	0.9	-	-	-
H6	0.1	-	-	-
Totals		0.6 (Y)		2.3 (Z)

From the above example the following calculations may be made:

Hydrology Severity Index (HSI)

$$HSI = \frac{TotWeightedScore}{TotWeightofParms*4} = \frac{Z}{Y*4} = \frac{2.3}{0.6*4} = 0.96$$

Hydrology Reliability Index (HRI)

There are certain restrictions on the use of parameters, namely:

HRI-TotWeightofParmsUsed
-0.6

i) The total weight of parameters used must not exceed 1.0, i.e. not all of the parameters may be used.

ii) H1, H2, H5 are PRIMARY parameters.

iii) H3, H4, H6 are SECONDARY parameters.

iv) If any PRIMARY parameter is used, not more than one SECONDARY parameter may be used with it.

v) If H1 and H2 are used together, the weight of each should be reduced from 0.5 to 0.4, to reflect the overlap of these two parameters.

The purpose of these restrictions (which may appear rather complicated) is to prevent the same data being used in several parameters to produce a high score.

A complete sample calculation for a sample stream is shown on Table 7.2. Blank sheets for use of assessors when the assessment is undertaken by the Regional NRAs are given in Appendix I. The calculation has been set up on a LOTUS spreadsheet for ease of calculation.

TABLE 7.2 : SAMPLE CALCULATION

HYDROLOGICAL INDICATOR

page 1 of 2

NRA REGION: A region NAME OF STREAM: River Example DATE: 12/8/92

(see Report Chapters 7.1 to 7.8 for full explanation of the methodology)

H1 GROUNDWATER BALANCE PARAMETER – ANNUAL LICENSED ABSTRACTION / ANNUAL RECHARGE

Total Groundwater ALA =	1200	m3/a	(GWALA)	
Calculated AR (1 in 10 yr drought) =	1500	m3/a	(AR)	
Total Annual 'Licence-exempt' Abst. =	1100	m3/a	(X)	*- ONLY enter if significant*
Total Surface Water ALA =		m3/a	(SWALA)	*} ONLY enter if H2 not used and*
Licensed Effluent Returns (annual) =		m3/a	(ER)	*} ALA is supported by spring flow*

ALA/AR = (GWALA+X+SWALA-ER)/AR = 1.53

ALA/AR	Score
>1.0	4
0.7-1.0	3
0.4-0.7	2
0.2-0.4	1
<0.2	0

Assign score: H1 = 4 *PRIMARY*

H2 RIVERFLOW BALANCE PARAMETER - DAILY MAXIMUM LICENSED ABSTRACTION / Q95 "NATURAL" or Q95 "NATURAL" / RES.COMP.FLOW

Total Surface Water DMLA =		m3/d	(SWDMLA)	*- ONLY enter for non-res. catchments*
Reservoir Compensation Flow (mean daily) =	450	m3/d	(COMP)	*- ONLY enter for reservoired catchments*
Total downstream channel abstraction (daily) =	150	m3/d	(DMLCA)	*- ONLY enter for reservoired catchments*
Total 'Licence-exempt' abstraction (daily) =	50	m3/d	(X2)	*- ONLY enter if significant*
Q95(7) =	300	m3/d	(QNF)	
Total Groundwater DMLA (with direct impact) =		m3/d	(GWDMLA)	*}*
Licensed Effluent Returns (daily) =		m3/d	(ERTWO)	*} ONLY enter if H1 not used*

Non-reservoired catchments: Total DMLA/Q95 = (SWDMLA+X2+GWDMLA-ERTWO)/QNF =

Reservoired catchments: Q95/COMP = QNF/(COMP-DMLCA-X2-GWDMLA+ERTWO) = 1.20

DMLA/Q95 or Q95/COMP	Score
>1.0	4
0.7-1.0	3
0.4-0.7	2
0.2-0.4	1
<0.2	0

Assign score: H2 = 4 *PRIMARY*

H3 GROUNDWATER LEVEL PARAMETER

Mean Annual Decline in minimum groundwater levels =		m	(MAD)
Mean Seasonal Range =		m	(MSR)

MAD/MSR =

MAD/MSR	Score
*	4
>0.5	3
0.3-0.5	2
0.1-0.3	1
<0.1	0

* If MAD/MSR > 0.5, see Report Chapter 7.3 to assign score

Assign score: H3 = *SECONDARY*

TABLE 7.2 : SAMPLE CALCULATION (con't.)

HYDROLOGICAL INDICATOR

NRA REGION: A region **NAME OF STREAM:** River Example **DATE:** 12/8/92

(see Report Chapters 7.1 to 7.8 for full explanation of the methodology)

H4 STREAM MORPHOLOGY PARAMETER

Cross Section	Current XSA of flow (m2)	Normal XSA of flow (m2)	Current / Normal
1	8	35	0.23
2	9	44	0.20
3	15	49	0.31
4	22	63	0.35
5	14	66	0.21
		Mean =	0.26

Current/Normal	Score
<0.1	4
0.1-0.3	3
0.3-0.5	2
0.5-0.7	1
>0.7	0

Assign score: H4 = 3 *SECONDARY*

H5 FLOW AND ECOLOGY RELATIONSHIP PARAMETER - RESIDUAL FLOW MINIMUM ECOLOGICALLY ACCEPTABLE FLOW

Q95(7) =		m3/d	(QNF)	} *ONLY enter for non-res. catchments*
Total DMLA (see H2) =		m3/d	(DMLA)	}
Reservoir Compensation Flow (mean daily) =		m3/d	(COMP)	}
Total downstream channel abstraction (daily) =		m3/d	(DMLCA)	}
Total 'Licence-exempt' abstraction (daily) =		m3/d	(X2)	} *ONLY enter for reservoired catchments*
Licensed Effluent Returns (daily) =		m3/d	(ERTWO)	}
Tributary Inflows (sum of Q95s) =		m3/d	(TRIB)	}
MEAF (critical month) =		m3/d	(MEAF)	*(Note: MEAF is under development as part of NRA R&D Project 282 and is as yet undefined)*

(Q95-DMLA)/MEAF or COMP/MEAF	Score
<0.6	4
0.6-0.8	3
0.8-1.0	2
1.0-1.2	1
>1.2	0

Non-res. catchments: (Q95-DMLA)/MEAF =

Res. catchments: (COMP-DMLCA-X2+ERTWO+TRIB)/MEAF =

Assign score: H5 = *PRIMARY*

H6 MOVEMENT OF SPRINGHEAD PARAMETER

Total length of reaches changed from perennial to intermittent = km

Total length of reaches changed from intermittent to ephemeral = km

Sum = km

Sum of reaches (km)	Score
>8	4
4-8	3
2-4	2
0-2	1
0	0

Assign score: H6 = *SECONDARY*

CALCULATION OF HYDROLOGICAL INDICATOR

Parameter	Param. weight		Weight of params. used	Score	Weight x Score
H1	0.5	*} if H1 & H2 are BOTH used,*	0.4	4	1.6
H2	0.5	*} set both weights to 0.4*	0.4	4	1.6
H3	0.1				0
H4	0.1		0.1	3	0.3
H5	0.9				0
H6	0.1				0
		SUM1 =	0.9 (max.1)	SUM2 =	3.5

Hydrology Severity Index = SUM2/(SUM1x4) = 0.97

Hydrology Reliability Index = SUM1 = 0.90

8. THE ECOLOGICAL INDICATOR

The Consultants propose that the Ecological Indicator should be assessed on the basis of five parameters. Each of these parameters and the system of their scoring is discussed in the following sections. Table 8.1 shows a summary of all the parameters proposed. It should be noted that during the development and testing of the Method, the Ecological Indicator proved to be the most complex and was the subject of most debate.

It is important therefore that the assessor should read the Overview of Parameters (8.3 below) and Section 17 "Summary and Conclusions" before applying the method.

8.1 <u>Philosophy behind the Ecological Indicator</u>

The Ecological Indicator generates scores which reflect the extent to which low flows are jeopardising the channel and riparian communities which depend on groundwater or a surface watercourse. To generate valid scores, the Ecological Indicator must first define the function of flowing water to the channel and riparian communities, and secondly, assess the extent to which this function is being fulfilled.

The function of running water for aquatic communities is to generate and maintain the habitat features the constituent populations require and to provide physico-chemical conditions within the range they can tolerate. There is a complex inter-relationship between water chemistry, habitat structure and instream plant, fish and benthic macro-invertebrate community structure, which is central to the design of the Ecological Indicator.

Where food resources are adequate, habitat is sufficiently diverse and physico-chemical conditions lie within a particular range, a stable, diverse and well-balanced stream community will develop. This may include macro-invertebrates, submerged aquatic vascular plants and game or coarse fish. Changes in habitat or water chemistry caused by low flows, effluents, channel engineering or any other stresses will displace the delicate balance between the channel environment and colonising communities. This invariably causes a restricted species assemblage to adopt the habitat.

For example, cold, good quality, flowing water is important in generating the eroding habitats and physico-chemical conditions required by game fish and certain macro-invertebrate species. If these conditions change, the community will alter, as species adapted to exploit the newly established environment gain prominence. This change in community structure may occur as a direct response to changes in water chemistry and habitat structure, or may be the indirect effect of water quality on habitat structure.

Low flows affect both habitat generation and water quality, so the problem when developing the assessment methodology was to separate low-flow-induced effects from those caused by other factors affecting water chemistry and habitat, such as enrichment with sewage effluent and channel maintenance.

Flow decreases may derogate habitat by increasing sediment deposition and temperature, which in turn encourages the establishment of surface dwelling and emergent plants.

Decreases in water quality may debilitate sensitive species directly or may cause sediment or colonial algae/bacteria to accumulate at the channel surface thus altering the substrate available for colonisation.

Engineering activities may remove habitat features, alter flow regime/sedimentation and alter water chemistry.

By studying community structure, the condition of the stream ecosystem can be assessed. The aim of the community structure aspects of the macro-invertebrate, fisheries and plant parameters was to establish target communities, which, provided flows have been adequate, should have been achieved. If these targets are not met, then the shortfall is likely to be the result of low flows, which may be reducing water quality or affecting habitat or both. The method must be able to take account of the effects non-low-flow-related changes in water quality, channel engineering and river type have had on community structure up to the time of sampling. This is much the same as the 'tare' function on a laboratory balance which accounts for the weight of the beaker in order to display the weight of its contents.

8.2 Long-term NRA-funded research to develop methods of determining Minimum Ecologically Acceptable Low Flow - MEAF

Research in North America and New Zealand during the late 1970's and early 1980's aimed to quantify the flow needs of the various stream communities. To protect the welfare of these fisheries, the Co-operative Instream Services Group of the US Fish and Wildlife Service developed the 'Incremental Flow Method' (IFM) in 1976. This system enables the amount of physical habitat available for various lifestages of fish to be estimated at different flows. Suitable habitat features must include the presence of sufficient water depth for the fish populations and the presence of eroding riffles (redds) in which eggs can be laid.

Similar habitat management methodology (Physical HABitat SIMulation - PHABSIM, NRA R&D topic 2.1) is presently being funded by the NRA and will eventually enable MEAF's to be determined for UK rivers. When this research is complete the MEAF may provide a benchmark against which low flow derogation can be measured. This may then eliminate the need for a methodology to assess the extent of habitat and community derogation by low flows.

8.3 Overview of parameters comprising the Ecological Indicator

Five ecological parameters are proposed (Table 8.1), of which the first four will measure the impact of existing flow conditions and the fifth, conservation, will be used only if there is other evidence (hydrological or ecological) that low flows are occurring. The reasons for this are explained below. Data on invertebrates and fisheries will be used as measures of low flow conditions because they respond to sustained periods of low flows. These invertebrate and fish parameters may appear to be complicated, but this is essential so that the effects of low flows can be differentiated from effects of water quality and engineering. Bankside plants may contribute some limited information about the lowering of the water table.

Macro-invertebrate community parameter - It was decided to use average score per taxon (ASPT) as an index of macro-invertebrate community structure, and to down-weight the index to take account of non low-flow-induced factors such as water quality and engineering influences. The suitability of ASPT for this purpose is discussed further in Section 8.4.2.

Angling and Fishery parameter - There was no convenient summary fish-community index, so the method had first, to specify the changes in community structure which might be caused by water quality and habitat changes, and secondly to suggest the extent to which community change resulted from low flows. To attach factors to down-weight the effects of effluents, channel engineering and geographical location to the classification would have made it complex and cumbersome. For this reason, the implementation of the fishery parameter requires a fishery scientist to judge the extent to which low flows are responsible for changes in the fishery.

A further aim of this parameter was to incorporate information on 'fishing interests' as well as 'the fishery', which are not necessarily congruous. For example, trout spawn in gravel redds up tributaries and in headwaters, so if these habitats are lost due to low flows, the stream's 'fishing' could be made up by ensuring adequate water depth, and restocking with mature fish. This, however, would derogate 'the fishery'. So, satisfying the immediate needs of the angler does not necessarily ensure a successful fishery. However, it was felt that the parameter should take account of fishing interest, and respond to short- term effects such as the loss of fishing due to acute low flow incidents, as well as responding to long-term changes in community structure.

Fish stocks parameter - Low base flows affect community structure by reducing water quality and altering the eroding nature of the habitat. Low flows caused by river abstraction in contrast, are likely to reduce fish production and displace the age structure of the community in favour of young fish. In other words, although spawning may still occur, fewer fish will survive to develop the older year classes. Non-low-flow-related changes in water chemistry and habitat destruction may also affect fish stocks, so, as with other parameters, it is necessary to separate the influence of channel modifications and sewage effluents on fish stocks from that caused by flows. This will be done by introducing a scoring procedure similar to that suggested for the macro-invertebrate community. Alternatively, the fishery scientist may assess the extent to which low flows are contributing to the decline and allocate a score.

The aim was to develop a methodology which was adaptable enough to incorporate whatever data was considered by the fishery scientists in the Regions to reflect their low flows problem. For this reason, the framework of the methodology has been kept simple and flexible.

Plant parameter - There is a dearth of data concerning plant distribution in the Regions but a plant parameter was included in the method to ensure that data which was available, could contribute to the low flows assessment. Again an informed judgement must be made by biologists in the Regions as to the extent to which low flows were responsible for the changes.

Conservation parameter - The final section of the Ecological Indicator, scores a catchment according to the presence of nationally or locally important conservation features. However, because the presence of conservation and landscape features provides no direct indication of the severity of low flows in the catchment, the conservation parameter should be used only when there is direct evidence that low flows are a problem. This is to avoid the accumulation of high scores on the basis of strong public perception of a problem in an area of outstanding conservation value with high water quality, but for which there is no direct evidence that low flows are causing the problem. In other words, the fact that a stream is of high water quality or supports a valuable wetland habitat or contains rare plant, fish or animal species is relevant only when there is hydrological or ecological evidence that low flows are threatening the catchment.

8.4 Invertebrate community parameter (E1)

8.4.1 Development of the macro-invertebrate community parameter

There are various tools available to the NRA for analysing macro-invertebrate community structure. Most however have been developed for water quality monitoring purposes and must be specifically adapted for use in low flows assessment. The aim of the ecological assessment is to generate a target community; the community which would have existed at the site before the present low flows had influenced the habitat. If the present community fails to meet this target, then derogation will be indicated, for which low flow is likely to be the cause.

It is cumbersome to adapt a system such as **RIVPACS*** for this purpose, as it predicts community structure from the physico- chemical conditions associated with the low-flow derogated habitat rather than that at the site under 'natural' conditions. The former is adequate when considering water quality because although the predicted fauna may be restricted, it can be concluded that water quality is not limiting when this fauna has been achieved. However, the latter is needed when considering low flows, as it is necessary to show that the community is below potential, is unbalanced and that the site probably supports smaller populations of fish than would otherwise be the case.

Unless historic physico-chemical data are available, adapting RIVPACS for low flows assessment would involve estimating the conditions (substrate size, alkalinity, depth, width, distance from source, gradient) which existed at the site before low flows became a problem. RIVPACS could then use these to predict the 'natural' assemblage for the site, which could then be compared with the present assemblage to give a measure of habitat derogation.

However, for the present assessment methodology, it was decided to adopt a simpler approach and to modify biological quality indices to generate macro-invertebrate community targets.

(*RIVPACS - River invertebrate prediction and classification system - was developed from research carried out by IFE - Institute of Freshwater Ecology - in the 1980's. Macro-invertebrate communities associated with a range of unpolluted streams throughout the UK were investigated in co-operation with the water industry. Species lists were manipulated with the multivariate statistics packages 'TWINSPAN' - TWo-way INdicator SPecies ANalysis - and 'DECORANA' - DEtrended COrrespondence ANAlysis - to cluster sites with similar community structure. These site clusters were then correlated with physico-chemical variables by Multiple Discriminant Analysis. When this information had

SUMMARY OF ECOLOGICAL INDICATOR	
E1 Invertebrate Community Parameter (potential : measured ASPT)	Based on Average Score Per Taxon (ASPT). Ratio of measured ASPT : potential ASPT *Weighting = 40%.*
E2 Fishery parameter (Non-tidal, Tidal, Access to migratory fish)	Decline in fish community from Game species through to Coarse species; also declines in tidal fisheries and access to migratory fish, all primarily due to low flows. Also loss of fishing in short-term. *Weighting = 20%.*
E3 Fish Stocks parameter (present/potential fish stock)	Ratio of present fish stock : 'potential' fish stock. *Weighting = 30%.*
E4 Plant parameter	Seasonal change in terrestial plants in channel and long-term change in bankside flora *Weighting = 10%.*
E5 Conservation parameter	Assessed on basis of formally designated sites and conservation value of non-designated sites. *Weighting = 30%.*

Table 8.1 : Summary of parameters related to the Ecological Indicator

been assembled it was possible to develop a package (RIVPACS) to operate in the reverse direction - in other words to predict the assemblages which might be expected at sites displaying a given set of physico-chemical characteristics.)

8.4.2 The ASPT-based macro-invertebrate community parameter

The indices of macro-invertebrate community structure which are most widely used for water quality purposes are the Biological Monitoring Working Party score (BMWP) and the related Average Score Per Taxon (ASPT). Unlike diversity indices, they do not rely on equating individuals per species with total number of species per site and are not greatly influenced by temporal changes. BMWP score and ASPT reflect biological quality by scoring the presence or absence of particular invertebrate types at a site. Both indices may vary in different geographical regions, scores at lowland sites being generally lower than those at upland sites.

ASPT differs consistently between sites in upland and lowland areas and this effect is removed in the methodology by applying a factor of 0.8. The factor was developed from the IFE's analyses of the performance of BMWP score and ASPT at 268 sites in 41 catchments in the early 1980's (Armitage et al., 1983). Unpolluted upland site had maximum ASPT's of around 6.8, whereas lowland sites could have ASPT's as low as 5.4.

The following points were considered when developing the low flows assessment methodology around ASPT rather than BMWP.

a) BMWP score increases with sampling effort and is not a particularly useful index when comparing data between Regions, as the data will have been collected in different ways. ASPT suffers less in this respect.

b) BMWP will be greater at a habitat-diverse site (where there are many types of invertebrate, each adapted to exploit a particular habitat niche) than at a site with a relatively homogeneous habitat. Differences in ASPT between sites with diverse and homogenous habitats is less extreme.

c) Both BMWP score and ASPT decline as habitat structure at a site changes from predominantly eroding to more depositing (beetles, bugs and species adapted to quiescent conditions score lower than lotic species). This decline in habitat may be caused by low flows or by increases in effluent discharge or by a combination of the two.

d) Both BMWP score and ASPT decline as the organic component (from sewage effluent, run-off etc) of the channel flow increases. This may be caused by low flows or by increases in effluent discharge or by a combination of the two.

It has been argued that at sites with relatively homogeneous habitat structure comprising habitat niches containing high scoring invertebrates (such as small mountain streams in Cumbria), the loss of some of these niches due to low flows will not alter ASPT but would alter species diversity. However, on a national scale, flows which reduce the number of habitat niches in a channel but do not destroy the eroding nature of the channel are far less severe than those which severely alter the nature of the habitat. The ASPT-based method would rightly score streams displaying habitat loss higher than those that do not.

If the high current velocities in mountain streams declined sufficiently to severely disadvantage the stoneflies, mayflies and caddisflies that compete effectively under such conditions, then other less-high-scoring species would increase in dominance. This would then reflect in ASPT.

The maximum achievable ASPT might therefore be a useful starting point from which to adapt water quality data for low flows application. The Consultants proposal is to successively down rate the index to take account of stresses due to water quality, channel engineering, and location (ie whether the source is in an upland or a lowland, and whether the site is in a headstream, mid-reach or lower reach). The product would be a coarse estimate of the ASPT potential of a stretch of river. If the ASPT measured for the stretch failed to reach this value, then it would indicate derogation, for which flow is likely to be the cause. The procedure would start with the question:

1) Are macro-invertebrate data available?

If the answer is 'NO' then the algorithm ends but if the answer is 'YES' then proceed to 2

2) Generate potential ASPT, as shown on flow chart in Figure 8.1.

This would score the invertebrate communities in fast flowing eroding headwaters with various proportions of sewage effluent differently from those in slower flowing more depositing reaches with similar sewage effluent components. In the same way, ponded depositing or 'heavily-managed' lower river reaches could be scored.

3) Relate the measured ASPT to the potential ASPT, and generate a score for the river stretch from the table below:

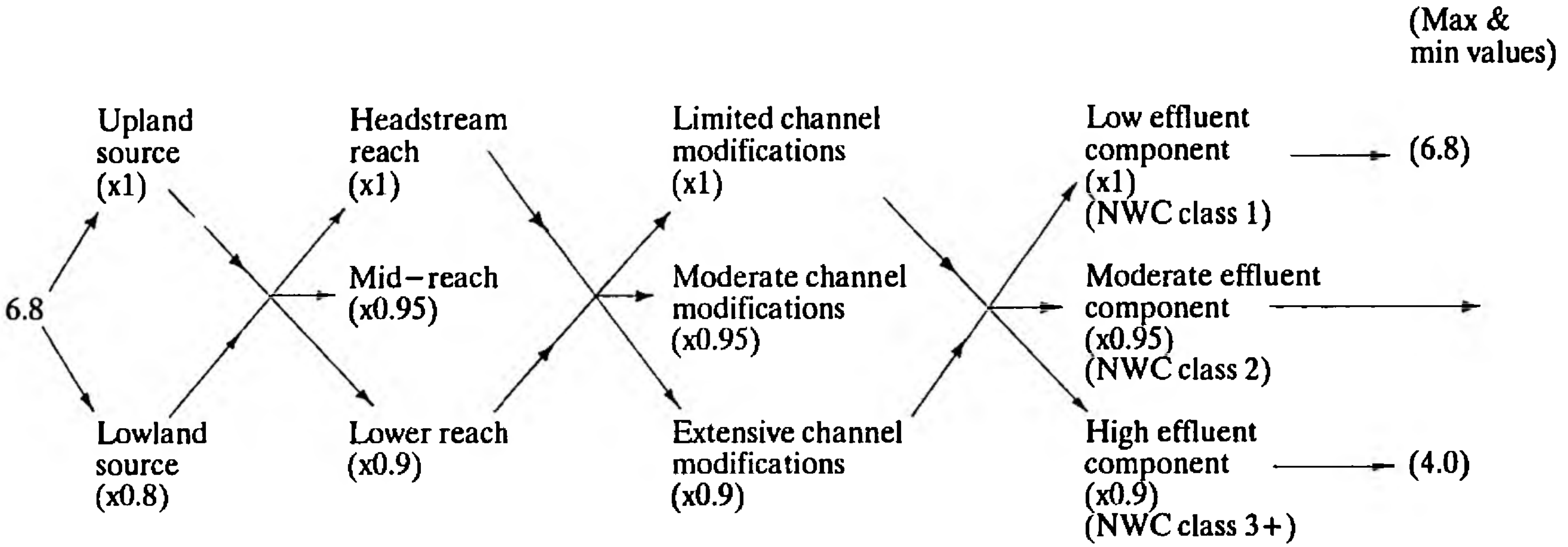


Figure 8.1. Flow Chart to Generate Potential ASPT

Measured ASPT	Potential ASPT					
	<4.5	4.5-5.0	5.1-5.5	5.6-6.0	6.1-6.5	>6.5
<4.5	0	1	2	3	4	4
4.5-5.0		0	1	2	3	4
5.1-5.5			0	1	2	3
5.6-6.0				0	1	2
6.1-6.5					0	1
>6.5						0

Thus, the maximum score of 4 would be allocated where potential ASPT was high, and the ratio of measured to potential ASPT was low.

The weighting for this invertebrate community parameter, (E1) is 40%

8.5 Fishery parameter (E2)

The fishery parameter is based on the fact that a river can be divided into the following zones on the basis of fish community structure:

1) Trout-salmon zone

2) Grayling zone

3) Barbel-chub-dace zone

4) Bream-roach-tench zone

A change from one zone to another reflects changes in habitat and water chemistry and our assumption is that low flows affect fisheries primarily by altering these variables.

Data on species composition, population density and biomass is variously collected in the NRA regions, so the aim of the fishery parameter is to use these available data to score any changes in community structure and/or fishing potential which result from low flows. As with the invertebrate parameter, the main task is to separate low-flow-induced changes in water quality and habitat from those produced by effluents and channel modifications.

As there is no convenient summary index of fish community structure, the method must first, specify the changes in community structure which might be caused by water quality and habitat changes, and secondly, suggest the extent to which community change results from low flows. To incorporate a system to down-weight the effects of effluents, channel engineering and geographical location would have made the classification system complex and cumbersome, so the implementation of the fishery parameter requires the fishery scientists in the Regions to judge the extent to which low flows are responsible for changes in their fisheries.

A further aim of this parameter is to incorporate information on 'fishing interests' as well as 'the fishery', which, as mentioned in the overview of the Ecological Indicator, are not necessarily congruous. By responding to fishing interests, the method is able to make use of data on the short-term loss of fishing due to acute low flow incidents, as well as data on longer-term changes in community structure.

If there is evidence that a decline in fish community is due to low flows, then scores will be assigned from the appropriate table below. Decline might occur in, headstream, non tidal or tidal reaches. In non-tidal reaches the decline may involve deterioration in the quality of a game fishery, a coarse fishery or a conversion from a game to a coarse fishery. There might also be a loss of access for migratory species.

Thus the scoring of this parameter may be on the basis of

- Decline in fish community:
  by scoring from Table 8.2

OR - Short term impact on angling:
  by scoring from Table 8.3

OR - Loss of access for migratory species:
  by scoring from Table 8.4

This assessment must be carried out by a fisheries scientist on a semi-quantitative or qualitative basis, assessing the species affected and the degree of reduction in access based upon local knowledge of the particular river.

It is suggested that the highest score from any of the tables is carried forward for use in calculating the Ecological Indicator.

The weighting of the fishery parameter (E2) is 20%.

Table 8.2 Changes in fish community due to low flows

Non Tidal Fisheries	Fish community under 'normal' flow conditions	Decline due to low flows (b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
Game	Headstream:								
	(a) Trout,salmon	2	3	4	-	-	-	-	-
	(b) Small trout only (+ loss of older year classes)	-	2	3	-	-	-	-	-
	(c) Minor species only (loss of spawning habitat)	-	-	2	-	-	-	-	-
	(d) Complete loss lower reaches	-	-	-	-	-	-	-	-
	Lower Reaches:								
	(e) Trout	2	3	4	-	1	2	3	4
Coarse	(f) Barbel,chub,dace perch, pike	-	3	4	-	-	1	2	3
	(g) Small populations of species (f) (+ loss of older year classes)	-	2	3	-	-	-	1	2
	(h) Bream, perch roach, tench	-	3	4	-	-	-	-	1
	(i) Small populations of species (h) (+ loss of older year classes)	-	2	3	-	-	-	-	-

Tidal Fisheries		Decline due to low flows (a)	(b)	(c)
	(a) No reduction in Game or Coarse	-	2	4
	(b) Seasonal decline to euryhaline spp	-	-	2
	(c) Permanent decline to euryhaline spp	-	-	-

Table 8.3 Short-term impact on angling

Score	Description
4	No fishing was possible during a season due to low flows
3	
2	
1	
0	No evidence of short-term impact of low flows on angling

Table 8.4 Reduction in access to migratory fish

Score	Description
4	60% reduction in access
3	45% reduction in access
2	30% reduction in access
1	15% reduction in access
0	No evidence of reduction in access

8.6 Fish Stocks Parameter (E3)

Low base flows affect community structure by reducing water quality and altering the eroding nature of the habitat. This may cause a succession from a game to a coarse fishery, or result in the survival of only ubiquitous bottom-feeding species. In contrast, low flows caused by river abstraction are likely to reduce fish production and displace the age structure of the community in favour of younger fish. In other words, although spawning may still occur, fewer fish will survive to develop the older year classes.

The loss of older year classes is incorporated in the community structure table in the above section but the methodology should also be able to detect low-flow-related declines in production. This is the function of the fish stocks parameter.

As with other parameters, non-low-flow-related declines in water chemistry and habitat destruction may affect fish stocks, so, it is necessary to separate the influence of channel modifications and sewage effluents from that caused by low flows. This will be done by introducing a scoring procedure similar to that suggested for the macro-invertebrate community. Alternatively, the fishery scientist may assess the extent to which low flows are contributing to the decline and allocate a score accordingly.

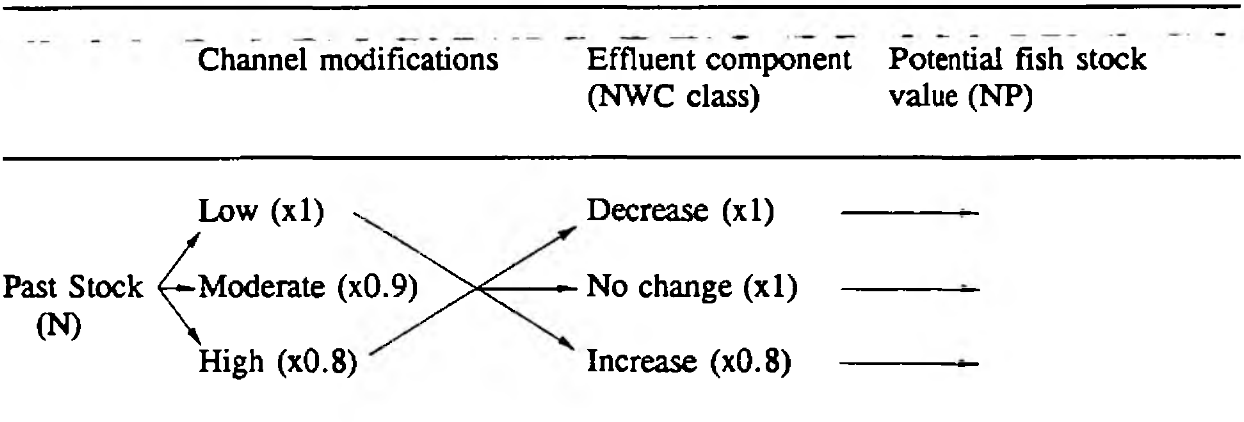
The fish stocks parameter is based on a comparison of present fish stocks and the 'potential' fish stock. Potential fish stock would be derived by down-weighting fish stock measured before the low flow were a problem, to take account of subsequent adverse impacts of sewage effluents and channel modifications. An algorithm similar to that used for macro-invertebrates for this purpose is shown below.

This parameter (E3) may be calculated where present and archive data on fish stocks are available, or where the fishery scientist can reasonably predict the potential fish stock of a stretch of river. This system is flexible in that data in various forms can be used. These might include population density, biomass or which ever variable is measured in the individual Regions.

The procedure on the flow chart below would start with the question:

1) Are data on fish stock available for the period before low flows were perceived as a problem (or can a reasonable estimate of such fish stocks be made)?

   If the answer is 'No', then the algorithm ends, but if the answer is 'Yes' then use the flow chart below to generate potential fish stocks.



2) Compare the measured present fish stock (NM) with the potential fish stock (NP) as the ratio:

$$\frac{NM}{NP}$$

A value of less than 1.0 indicates that a decline in fish stocks has occurred and may result from low flows. The greater the stock depletion, the more serious the effects of low flows. A value greater than 1.0 indicates that there is probably no decline in fish stocks due to low flows.

3) A scoring system for this parameter is suggested below.

Score	Value to which fish stock has declined	Severity of low flow related decline in fish stock
4	<0.4	Serious decline
3	0.4 - 0.59	Large decline
2	0.6 - 0.79	Moderate decline
1	0.8 - 1.00	Slight decline
0	>1.0	None

The weighting of this Fish Stock (E3) parameter is 30%

8.7 Plant Parameter (E4)

In upland reaches, high flows and current velocities erode and scour the channel, and encourage the colonisation of submerged, well attached algae and thin-leaved vascular plants. Thin leaves reduce the risk of dislocation during spates but at the same time protect against burial during periods of sediment deposition. In contrast, low flows may increase sediment deposition and temperature and cause surface dwelling, strap-leaved and emergent plants to establish. The establishment of this community may then encourage further sediment deposition, leading eventually to the establishment of riparian species within the channel.

Algal and aquatic vascular plant data are not widely available in the Regions. However, abnormal short-term invasion of the channel by riparian species during summer months, and the longer-term changes in herbs, shrubs and trees on the river banks should be scored. As in the fishery parameter, an informed judgement must be made by biologists in the Regions as to the extent to which low flows are responsible for the changes.

Score	Description
4	Bankside flora has changed or is changing due to a lower water table
2	Abnormal invasion of the river channel in summer by marginal terrestrial plants.
0	No change, other than normal seasonal variation in channel or bankside flora

The plant parameter (E4) weighting is 10%.

8.8 Conservation parameter (E5)

This parameter (E5) assesses the value of river corridors in conserving natural habitats and wildlife. The assessment is based on two sources of information. First, it takes account of the formal designation of conservation areas which rely on groundwater or surface water to maintain their character. Secondly, this parameter incorporates the duty of the NRA to conserve the whole river system, including groundwater levels and springs.

The Water Resources Act 1991 states that priority should be given to the conservation of SSSI's and sites of national importance. SSSI's based on fisheries assets have not been widely designated but English Nature is undertaking that task at present. Assessments for this parameter should be made by Conservation Officers in the Regions who will have access to English Nature's list of designated sites and the data from river corridor surveys commissioned by the NRA.

After liaison with the NRA it has been decided to include the water quality standard of a river stretch in this parameter. However, the presence of good quality water and conservation/landscape features provides no direct measure of the severity of low flows in the catchment, so the conservation parameter should be used only when there is direct evidence that low flows are a problem. The conservation parameter will then assist in prioritising sites for support. This is to avoid the accumulation of high scores based on strong public perception of a problem in an area of high conservation value with high water quality, but for which there is no direct evidence that low flows are causing a problem.

The scores apply to ponds and open water as well as flood plain meadows, marshlands, swamps, fens, carrs, mires, flushes and river banks and islands. Formally designated sites should be awarded scores as outlined in the upper section of the table below. Sites within the river system should be awarded scores as indicated in the lower table and the two scores added together. Cumulative scores should be divided by 2 to calculate this ecological parameter. A maximum score of 4 can be generated.

The conservation parameter (E5) should be given a weighting of 30%.

Score	Channel, riparian or other habitats depending on surface or groundwater for their character
5	RAMSAR Sites, National Nature Reserves (NNR's) Marine Nature Reserves (MNRs') Special Protection Areas (SPA's). Sites of Special Scientific Interest (SSSI's) Habitat of species protected by EC Directive or Wildlife and Countryside Act
4	Conservation sites of regional or county importance (eg Naturalist Trust Reserve, RSPB reserve)
3	Local nature reserve*
0	No formal designation

Note * 'Local nature reserve' is an umbrella term for features referred to variously as Heritage sites, c-sites, local nature reserves and sites of historic interest.

Score	Instream and riparian habitat
3	High conservation value, eg a diverse, natural and typical habitat of a viable size and containing species sensitive to disturbance. NWC class 1 stretch
2	Moderate conservation value, eg a smaller or less diverse site; or a site with natural or typical habitat but no particularly threatened species. NWC class 2 stretch
1	Site of minor conservation value NWC class 3 stretch
0	Site of no conservation value. NWC class 4 stretch

8.9 Sample Calculation of Ecological Indicator

Certain restrictions have been placed on the use of parameters as follows:

i) The total weight of parameters used must not exceed 1.0, i.e. not all of the parameters may be used.

ii) Parameter E5 should not be used unless there is other firm evidence of low flows, from at least two of parameters H1, H2, H5, E1, E2, E3.

A full sample calculation for the Ecological Indicator is shown in Table 8.5. Blank calculation sheets to use in NRA Regions are attached in Appendix I.

The calculation of the Fishery Parameter, E2, at first glance appears complex due to the possible use of a total of four tables. However, the following explanation of how this parameter has been scored in the Sample Calculation of the Ecological Indicator (Table 8.5) is provided as an aid to understanding the scoring procedure.

For the hypothetical river (River Example), the reach in question is in the non-tidal lower reaches. Information is available to the Fisheries Scientist on the changes in fish species from the previous year. This reveals that where Trout were previously present in the reach, only small populations of Barbel, Chub and Dace are now to be found. On the Non-Tidal Fisheries table (Lower Reaches section), this decline in the fish community is awarded a score of 2 since it has declined from (e) (i.e. Trout in Lower Reaches) to (g) (i.e. small populations of species (f)).

Additional information, however, is available on the fishing activities in the reach during the latest fishing season. Although fishing activities continued more or less the same as in the previous season, reports reveal that during a one-week period when the river was running particularly low, normal fishing was unable to continue. This indicates a short-term impact on fishing due to low flows which, having only a limited effect, is assessed as minor and awarded a score of 1 on the Short-term Impact table.

No reliable information is available on the access of migratory fish to the reach and so this table is not used in the scoring procedure.

The Fishery Parameter score to be used in the calculation of the Ecological Indicator is the highest score from any, or all, of the tables used in the scoring procedure. This means that, in this case, E2 is awarded a final score of 2.

TABLE 8.5 : SAMPLE CALCULATION

ECOLOGICAL INDICATOR

page 1 of 2

NRA REGION: A region **NAME OF STREAM:** River Example **DATE:** 12/8/92

(see Report Chapters 8.1 to 8.9 for full explanation of methodology)

E1 INVERTEBRATE COMMUNITY PARAMETER

Generate potential ASPT:

Select multipliers:

SOURCE =	1.00	SOURCE: Upland = 1; Lowland = 0.8
REACH =	0.95	REACH: Headstream = 1; Mid = 0.95; Lower = 0.9
CHAN.MODS. =	0.95	CHANNEL MODIFICATIONS.: Limited = 1; Moderate = 0.95; Extensive = 0.9
EFF.COMP. =	1.00	EFFLUENT COMPONENT: Low (NWC class 1) = 1; Moderate (NWC class 2) = 0.95; High (NWC class 3) = 0.9

Potential ASPT = 6.14

Measured ASPT = 4.80

Score		Potential ASPT					
		<4.5	4.5-5.0	5.1-5.5	5.6-6.0	6.1-6.5	>6.5
	<4.5	0	1	2	3	4	4
	4.5-5.0		0	1	2	3	4
Measured	5.1-5.5			0	1	2	3
ASPT	5.6-6.0				0	1	2
	6.1-6.5					0	1
	>6.5						0

Assign score: E1 = 3

E2 FISHERY PARAMETER

Non-Tidal Fisheries:

Score	Fish community under 'normal' flow conditions	Decline due to low flows							
		b)	c)	d)	e)	f)	g)	h)	i)
Game	Headstream								
	a) Trout, salmon	2	3	4	-	-	-	-	-
	b) Small trout only (+ loss of older year classes)	-	2	3	-	-	-	-	-
	c) Minor species only (loss of spawning habitat)	-	-	2	-	-	-	-	-
	d) Complete loss	-	-	-	-	-	-	-	-
	Lower reaches								
	e) Trout	2	3	4	-	1	2	3	4
Coarse	f) Barbel, chub, dace, perch, pike	-	3	4	-	-	1	2	3
	g) Small populations of species f) (+ loss of older year classes)	-	2	3	-	-	-	1	2
	h) Bream, perch, roach, tench	-	3	4	-	-	-	-	1
	i) Small populations of species h) (+ loss of older year classes)	-	2	3	-	-	-	-	-

Tidal Fisheries:

	Decline due to low flows		
	a)	b)	c)
a) No reduction in Game or Coarse	-	2	4
b) Seasonal decline to euryhaline spp	-	-	2
c) Permanent decline to euryhaline sp	-	-	-

OR: **Access to migratory Fish:**

Description	Score
60% reduction in access	4
45% reduction in access	3
30% reduction in access	2
15% reduction in access	1
No evidence of reduction in access	0

OR:

Short-term impact parameter	Score
No fishing was possible during a season due to low flows	4
or any assessed score in-between	
No evidence of short-term impact of low flows on angling	0

Assign score: E2 = 2

TABLE 8.5 : SAMPLE CALCULATION (cont'd)

ECOLOGICAL INDICATOR

page 2 of 2

NRA REGION: A region **NAME OF STREAM:** River Example **DATE:** 12/8/92

(see Report Chapters 8.1 to 8.9 for full explanation of methodology)

E3 FISH STOCKS PARAMETER

Generate potential fish stock: Past fish stock (N) = [ ]

Select multipliers: CHAN.MODS.= [ ] CHANNEL MODIFICATIONS: Low = 1; Moderate = 0.9; High = 0.8

EFF.COMP. = [ ] EFFLUENT COMPONENT: Decrease = 1; No Change = 1; Increase = 0.8

Potential fisk stock (NP) = N x multipliers = [ ] Measured present fish stock (NM) = [ ]

Present/Potential Fish Stock = [ ]

Present/Potential	Decline related to low flows	Score
<0.4	Serious decline	4
0.4-0.59	Large decline	3
0.6-0.79	Moderate decline	2
0.8-1.00	Slight decline	1
>1.0	None	0

Assign score: E3 = [ ]

E4 PLANT PARAMETER

Description of changes	Score
Bankside flora has changed or is changing due to a lower water table	4
Abnormal invasion of the river channel in summer by marginal terrestrial plants	2
No change, other than normal seasonal variation in channel or bankside flora	0

Assign score: E4 = 2

E5 CONSERVATION PARAMETER

Only use this parameter if there is direct evidence that low flows are a problem (i.e. from 2 of parameters H1,H2,H5,E1,E2,E3)

Formally designated sites:

Channel, riparian or other habitats depending on surface or groundwater for their character	
RAMSAR Sites, National Nature Reserves (NNRs), Marine Nature Reserves (MNRs), Special Protection Areas (SPAs), Sites of Special Scientific Interest (SSSIs), Habitat of species protected by EC Directive or Wildlife and Countryside Act	5
Conservation sites of regional or county importance (eg Naturalist Trust Reserve, RSPB Reserve)	4
Local nature reserve (including Heritage sites, C-sites, and Sites of historic interest)	3
No formal designation	0

Sites within the river system:

Instream and riparian habitat	Score
High conservation value, eg a diverse, natural and typical habitat of a viable size and containing species sensitive to disturbance. NWC class 1 stretch	3
Moderate conservation value, eg a smaller or less diverse site; or a site with natural or typical habitat but no particularly threatened species. NWC class 2 stretch	2
Site of minor conservation value. NWC class 3 stretch	1
Site of no conservation value. NWC class 4 stretch	0

Add scores from both tables and divide by 2 to give final E5 score. Assign score: E5 = 2

CALCULATION OF ECOLOGICAL INDICATOR

Parameter	Param.weight	Weight of params. used	Score	Weight x Score
E1	0.4	0.4	3	1.2
E2	0.2	0.2	2	0.4
E3	0.3			0.0
E4	0.1	0.1	2	0.2
E5	0.3	0.3	2	0.6
		SUM1 = 1.0 (max.1)	SUM2 =	2.4

Ecology Severity Index = SUM2/(SUM1x4) = 0.60

Ecology Reliability Index = SUM1 = 1.00

9. THE LANDSCAPE AND AMENITY INDICATOR

This Indicator incorporates parameters describing the overall importance of the river in the landscape and also the impact of low flows on the visual outlook and on the recreational and amenity use of the river. A summary of the parameters included in this Indicator is given in Table 9.1. This Indicator provides an assessment of the value of the river and river corridor, as perceived by people. The wider implications of the landscape must be established first, in order that the seriousness of any problems associated with low flows can be assessed. Secondly, this Indicator assesses the extent to which the amenity of the river/river corridor is affected by low flows during the summer months.

Data collected in a consistent manner and recorded in a standard form, will produce consistent and comparable results. The assessment is 'built up' by applying the method to each 1000m length of river. Where the length of river to be assessed is in excess of this length, the total score for the full length is divided by the number of sections (of 1000m) surveyed. The component parts of the landscape, such as trees, landforms and artifacts, will be recorded and their importance to the landscape as a whole will be assessed. All landscape assessments should take place at a specified time of year. This could possibly correspond with the timing of the first sampling of river invertebrates in spring/early summer. This assessment could be carried out by the same ecological/conservation survey team, after an introduction to the specialist techniques required. Alternatively, personnel trained in landscape assessment techniques could be employed.

9.1 Landscape Designation and Rarity Parameter (L1)

This parameter L1, assesses the importance of the landscape through which the river flows. It will be important in prioritising competing projects for low flow alleviation, but since it is not a measure of low flows as such, it should be only used if there is other evidence that low flows occur. The parameter L1 is derived from two components, the landscape designation and landscape rarity.

Landscape Designation

The value of the landscape to people has already been established by the designation of tracts of landscape into categories such as National or Country Parks. These categories indicate the importance of a piece of landscape in the national and local context and have been allocated scores accordingly:

Score	Description
2	Important in a national context, ie National Parks and Areas of Outstanding Natural Beauty.
1	Important in a local context ie Areas defined as Country Parks/Special Value etc within local or structure plan context.
0	Landscape has no official designation.

An additional score may be awarded as follows:

+1	Areas which are undergoing environmental improvements (either national or local) and where finance exists to support such improvements ie landscapes within Development Corporation Areas, Local Initiative Areas.

Landscape Rarity

The importance of a river or river corridor within its wider landscape is assessed by this score for rarity. A higher score is awarded to a river or river corridor which is rare in a national context - as opposed to a local context - as this reflects the greater sensitivity with which these landscapes have to be treated.

Score	Description
2	Where river/river corridor landscape is "the only" or "one of the best examples of ...." in the national context.
1	Where river/river corridor landscape is "the only" or "one of the best examples of ...." in the local context.
0	The river has no rarity value.

The score for Parameter L1 is the sum of the scores assigned under Landscape Designation and Landscape Rarity, with a range of 0 to 4 ie a score of 5, which is possible, would be counted as 4.

Landscape designation and rarity parameter (L1) weighting is 20%.

9.2 The Importance of the River as a Landscape Feature and its Impact on Adjacent Land (L2)

This parameter (L2) is also derived from two components:

The Importance of the river as a landscape feature

This component establishes how visually important the river is within the landscape, regardless of any planning designation. The assessment should be made from places which are accessible to the public, such as footpaths, roads and local vantage points within the river corridor. Where several access points exist, the dominant overall impression should be recorded.

Score	Description
3	High importance - dominant landscape feature, due to associated artifacts such as weirs, bridges etc.
2	Medium importance - only stretches of the river are visible, or the course is only noticeable because of bankside vegetation being visible.
1	Low importance - the river is barely noticeable.

Impact of River on Adjacent Land

In many areas the river has had a considerable impact on the adjacent landscape. Many towns grew because the adjacent river was navigable or was used as an energy source for mills etc. In addition the 'management' of the river either allowed the adjacent land to be drained or to flood so changing its agricultural use. It is important within this parameter that only the present day use is recorded, as the historical element is allowed for in L5.

The scoring is based on the principle that the greater the score assigned to each parameter, the greater the 'problem'. However within this parameter there are both positive and negative impacts in relation to the river and its effect on adjacent land. Consequently the score for 'importance' above is reduced by a negative mark where the overall impact is attractive in order to reduce the overall score and vice versa. For example, a score of 3 for 'importance' would be followed by -1 for impact if the drainage of the adjacent land had resulted in better agricultural land or reduced flooding.

SUMMARY OF LANDSCAPE AND AMENITY INDICATOR		
L1	Landscape Designation and Rarity parameter (Designation + Rarity Score)	Designation: Nat.Parks & Areas of Outstanding Natural Beauty/Country Parks/no desig Rarity: 'National' and 'Local' Rarity. *Weighting = 20%.*
L2	Importance of the river as a landscape feature and its impact on adjacent land parameter	Importance: Visual importance of river. Impact: Attractive or degraded adjacent land use. (Importance + Impact) *Weighting = 30%.*
L3	Recreation parameter	Number of water-contact activities unable to take place in certain time periods. (Not Fishing or Angling - see E2). *Weighting = 30%.*
L4	Amenity parameter	Based on Odour at channel, Visual problems in channel, and Visual problems on river bank/adjacent land. *Weighting = 10%.*
L5	Historical and Cultural Associations parameter	Importance of historical and archaeological interest sites. *Weighting = 10%.*

Table 9.1 : Summary of parameters related to Landscape and Amenity Indicator

Score	Description
-1	Where an attractive adjacent land-use (within 500m) is primarily as a result of man's impact on or management of the river
+1	Where a degraded or unsightly adjacent land use is primarily as a result of man's impact on or management of the river which could be remedied if remedial action were taken to the river

The two scores are added to produce a score with a range of 0 to 4. The weighting of this parameter (L2) is 30%.

9.3 Recreation Parameter (L3)

The parameter L3, assesses the impact of low flows on water-based recreational activities. As the impact of low flows on fishing is assessed in parameter E2, fishing and angling are excluded from the following assessment of water-contact recreational activities.

Recreational use may be passive or active. In general active use is associated with sports which require direct contact with water, such as: canoeing; sailing; rowing; boating; swimming; diving; water-skiing and wind surfing. These sports should have a higher score than passive recreational use, as any reduction in water quantity or quality as a result of low flows, can seriously affect participation in the sport. The scores should be awarded if the activity has been affected by a reduced volume or flow of water or a change in water quality due to low flows has occurred within the specified time period.

Score	Description
4	When three or more water contact recreational activities were unable to take place sometime in each year during a 5 year period.
3	Three or more water-contact recreational activities were unable to take place at any time in any one twelve month period.
2	One or two water-contact recreational activities were unable to take place at any time in any twelve month period.
1	Any water-contact recreational activity was affected by low flows within the last five years. This also includes a reduction in enjoyment of a sport, resulting from low river flows.
0	No change has been noted.

Fishing and angling are not included in the score of recreational activities in the above table.

The above score takes into account the present (and potential) use of the river for recreation. However, if historical evidence exists, which can be authenticated, that an active water-contact activity was possible on the river in the past (say 25 years) and there is a demand for that sport nationally or locally an additional score of +1 may be awarded as follows, up to a maximum total of 4 for this parameter.

Score	Description
+1	The river was able to support a water-contact recreational activity within the past 25 years, but this activity is no longer possible due to lower river flows.

The weighting of the recreation parameter (L3) is 30%.

9.4 Amenity Parameter (L4)

This parameter L4 assesses the impact of low flows on the general amenity of the river by reference to bank-side recreational pursuits and access to the river. Although low flows do not prevent walking, birdwatching, sightseeing and picnicking from taking place, the enjoyment of these recreational pursuits may be affected. Odour and visual impact are based on pollution and nuisance, as measured in some NRA regions. These will need to be recorded during the summer months at specified times, which it is suggested should be in the first week of August.

The parameter score is derived from the sum of scores, up to a total of 4, based on the following three components of the parameter.

Odour

Score	Description
2	Strong odour at channel edge eg sludge, sewage, chemical or farmyard wastes and noticeable at a distance of more than 10 metres from the channel.
1	Noticeable odour at the channel edge.
0	No noticeable odour.

Visual - River Channel

This includes unnatural water colour, farm wastes, foam, sewage, fungus, crude sewage, visible solids, rotting vegetation and also where refuse and litter are exposed or if no water is present.

Score	Description
3	Three or more of the above elements which persist over a period of several months, as a result of low flows or three or more of the above elements which occur intermittently.
2	One to three of the above elements which persist over a period of several months, as a result of low flows.
1	Two of the above elements which occur intermittently, as a result of low flows.
0	No visual problem.

Visual - River Bank and Adjacent Land

An additional score of 1 can be awarded where the general public are encouraged to have access to the river as part of a wider planning designation such as: a public open space; or the provision of a long-distance footpath or nature trail.

Score	Description
+1	Where planning designation encourages public use.

The weighting of the amenity parameter (L4) is 10%

9.5 <u>Historical and Cultural Associations (L5)</u>

This parameter allows the evaluation of impact on the river within a wider context, eg does the name of a building or a town derive from the name of the river or is the landscape character particularly influenced by water mills, designed parkland or particular bankside vegetation. If so, such associations reinforce the requirement to maintain appropriate water levels.

Score	Description
4	Sites of national historical/archaeological interest ie.National Monuments, National Trust sites.
3	Sites of regional historical/archaeological interest generally within 500m.
2	Sites which have national cultural associations such as paintings and literature.
1	Sites of local historical archaeological, cultural or literary interest, such as place names.
0	No historical or cultural associations.

The weighting of this historical and cultural parameter (L5) is 10%.

9.6 Sample Calculation of Landscape and Amenity Indicator

It is repeated here for emphasis that parameters L1, L2, L4, L5, are not direct evidence of low flows and should not be used unless there is other firm evidence of low flows from at least two of parameters H1, H2, H5, E1, E2, E3.

A full sample calculation for the Landscape/Amenity Indicator is shown on Table 9.2. Blank calculation sheets for use by NRA Regions are attached in Appendix I to this Report.

TABLE 9.2 : SAMPLE CALCULATION

LANDSCAPE AND AMENITY INDICATOR

NRA REGION: A region   NAME OF STREAM: River Example   DATE: 12/8/92

(see Report Chapters 9.1 to 9.6 for full explanation of methodology)

Note: Do not use L1,L2,L4 or L5 unless there is other firm evidence of low flows from at least 2 of parameters H1,H2,H5,E1,E2,E3

L1 LANDSCAPE DESIGNATION AND RARITY PARAMETER

For Landscape Designation:

Description	Score
Important in a national context, ie National Parks and Areas of Outstanding Natural Beauty	2
Important in a local context, ie Areas defined as Country Parks/Special Value etc. within local or structure plan context	1
Landscape has no official designation	0
An additional score may be awarded as follows:	
Areas which are undergoing environmental improvements (either national or local) and where finance exists to suport such improvements, ie landscapes within Development Corporation Areas, Local Initiative Areas	+1

For Landscape Rarity:

Description	Score
Where river/river corridor landscape is "the only" or "one of the best examples of..." in the national context	2
Where river/river corridor landscape is "the only" or "one of the best examples of..." in the local context	1
The river has no rarity value	0

Add scores to a maximum of 4.   Assign score: L1 = 3

L2 IMPORTANCE OF THE RIVER AS A LANDSCAPE FEATURE AND ITS IMPACT ON ADJACENT LAND PARAMETER

For Importance:

Description	Score
High importance - dominant landscape feature, due to associated artifacts such as weirs, bridges etc.	3
Medium importance - only stretches of the river are visible, or the course is only noticeable because of bankside vegetation being visible	2
Low importance - the river is barely noticeable	1

For Impact:

Description	Score
Where an attractive adjacent land use (within 500m) is primarily as a result of man's impact on, or management of, the river	-1
Where a degraded or unsightly adjacent land use is primarily as a result of man's impact on, or management of, the river, which could be remedied if remedial action were taken to the river	+1

Add scores to a range of 0-4   Assign score: L2 = 3

L3 RECREATION PARAMETER

Description (do not include fishing/angling)	Score
When 3 or more water-contact recreational activities were unable to take place sometime in each year during a 5 year period	4
3 or more water-contact recreational activities were unable to take place at any time in any one 12 month period	3
1 or 2 water-contact recreational activities were unable to take place at any time in any 12 month period	2
Any water-contact recreational activity was affected by low flows within the last 5 years. This also includes a reduction in enjoyment of a sport, resulting from low river flows	1
No change has been noted	0
If historical evidence exists, an additional score may be awarded where:	
The river was able to support a water-contact recreational activity within the past 25 years, but this activity is no longer possible due to lower river flows	+1

Add scores to a maximum of 4.   Assign score: L3 = 2

TABLE 9.2 : SAMPLE CALCULATION (cont'd)

LANDSCAPE AND AMENITY INDICATOR

NRA REGION: A region **NAME OF STREAM:** River Example **DATE:** 12/8/92

(see Report Chapters 9.1 to 9.6 for full explanation of methodology)

Note: Do not use L1,L2,L4 or L5 unless there is other firm evidence of low flows from at least 2 of parameters H1,H2,H5,E1,E2,E3

L4 AMENITY PARAMETER

For Odour:

Description	Score
Strong odour at channel edge, eg sludge, sewage,chemical or farmyard wastes and noticeable at a distance of > 10m from the channel	2
Noticeable odour at the channel edge	1
No noticeable odour	0

For Visual Impairment at the river channel:

(Elements include unnatural water colour, farm wastes, foam, sewage, fungus, crude sewage, visible solids, rotting vegetation, and also where refuse and litter are exposed or if no water is present)

Description	Score
3 or more of the above elements which persist over a period of several months, as result of low flows, or 3 or more of the above elements which occur intermittently	3
1 to 3 of the above elements which persist over a period of several months, as result of low flows	2
2 of the elements which occur intermittently, as a result of low flows	1
No visual problem	0

For Visual Impairment on the river bank and adjacent land:

Description	Score
Where planning designation encourages public use	+1

Add scores to a maximum of 4. **Assign score: L4 = 3**

L5 HISTORICAL AND CULTURAL ASSOCIATIONS PARAMETER

Description	Score
Sites of national historical/archaeological interest, ie National Monuments, National Trust sites	4
Sites of regional historical/archaeological interest, generally within 500m	3
Sites which have national cultural associations such as paintings and literature	2
Sites of local historical/archaeological, cultural or literary interest, such as place names	1
No historical or cultural associations	0

Assign score: L5 = 3

CALCULATION OF LANDSCAPE AND AMENITY INDICATOR

Parameter	Param.weight	Weight of params.used	Score	Weight x Score
L1	0.2	0.2	3	0.6
L2	0.3	0.3	3	0.9
L3	0.3	0.3	2	0.6
L4	0.1	0.1	3	0.3
L5	0.1	0.1	3	0.3
		SUM1 = 1.0		SUM2 = 2.7

Landscape and Amenity Severity Index = SUM2/(SUM1x4) = 0.68

Landscape and Amenity Reliability Index = SUM1 = 1.00

10 THE PUBLIC PERCEPTION INDICATOR

The Public Perception Indicator is based on two parameters, the proximity of the river to urban areas and the extent of complaints received by the NRA. The parameters are summarised in Table 10.1.

10.1 Proximity of River to Centres of Population Parameter (P1)

This parameter assesses the number of people within reasonable proximity of the river who might be affected by low flows in the river and who might be disadvantaged if alleviation work is not undertaken. Recreation and amenity are assessed by parameters L3 and L4 and parameter P2 assesses complaints from the public.

Score	Description
4	River flows through a large centre of population ie. a town.
3	River flows through a small centre of population ie. a village.
2	River flows within 1km of a town.
1	River flows within 1km of a village.

The distinction between a town and a village is usually evident in a given Region but where this is not the case a suitable guideline might be to classify a town as any conurbation with more than 10,000 population.

The weighting of the proximity of river to centres of population parameter (P1) is 30%.

10.2 Complaints Received from the Public Parameter (P2)

Public pressure is an important factor in highlighting perceived 'problems' of low river flows, whether the problems are real or not. It is therefore important to allow for this factor within the framework, although it is recognised that not all complaints are factually correct. Scores will be awarded where complaints about low river flows have been received over a number of years, and not in relation to a single incident of a particularly severe drought.

SUMMARY OF PUBLIC PERCEPTION INDICATOR			
P1	Proximity of River to Centres of Population	Based on size of pop. and proximity.	*Weighting = 30%.*
P2	Complaints received from the Public	Number and source of complaints.	*Weighting = 70%.*

Table 10.1 : Summary of parameters related to Public Perception Indicator

Score	Description
4	Written complaints received from national organisations (e.g. English Nature, CLA, CPRE, Salmon and Trout Association, etc) in support of local pressure groups formed specifically to deal with problems affecting the river and its environment.
3	Press coverage or written complaints received from national organisations or local clubs or pressure groups.
2	A moderate number (over 5 per annum on average) of written complaints received from individuals about problems related to low river flows over a period of years.
1	Up to 5 written complaints received on average per annum from individuals about problems related to low river flows over a period of years.
0	No complaints received about problems related to low river flows.

The weighting of the Complaints Received from the Public parameter (P2) is 70%.

10.3 Sample Calculation of Public Perception Indicator

A full sample calculation of the Public Perception Indicators is shown in Table 10.2. Blank calculation sheets are included in Appendix I for use by the NRA Regions.

TABLE 10.2 : SAMPLE CALCULATION

PUBLIC PERCEPTION INDICATOR

page 1 of 1

NRA REGION: A region **NAME OF STREAM:** River Example **DATE:** 12/8/92

(see Report Chapters 10.1 to 10.3 for full explanation of methodology)

P1 PROXIMITY OF RIVER TO CENTRES OF POPULATION PARAMETER

Description	Score
River flows through a large centre of population, ie a town	4
River flows through a small centre of population, ie a village	3
River flows within 1km of a town	2
River flows within 1km of a village	1

(If unsure of town/village distinction, use: Town = > 10,000 pop.)

Assign score: P1 = 4

P2 COMPLAINTS RECEIVED FROM THE PUBLIC PARAMETER

Description	Score
Written complaints received from national organisations (e.g. English Nature, CLA, CPRE, Salmon & Trout Assoc. etc.) in support of local pressure groups formed specifically to deal with problems affecting the river and it's environment	4
Press coverage or written complaints received from national organisations or local clubs or pressure groups	3
A moderate number (> 5/annum on average) of written complaints received from individuals about problems related to low river flows over a period of years	2
Up to 5/annum on average written complaints received from individuals about problems related to low river flows over a period of years	1
No complaints received about problems related to low river flows	0

Assign score: P2 =

CALCULATION OF PUBLIC PERCEPTION INDICATOR

Parameter	Param.weight	Weight of params.used	Score	Weight x Score
P1	0.3	0.3	4	1.2
P2	0.7			0
		SUM1 = 0.3		SUM2 = 1.2

Public Perception Severity Index = SUM2/(SUM1x4) = 1.00

Public Perception Reliability Index = SUM1 = 0.30

11. COMBINING THE INDICATORS

Having established 'scores' in the form of Severity Index and Reliability Index for each Indicator, they can be combined in a number of ways. Table 11.1 shows this for the sample calculations used in previous chapters.

11.1 Overall Severity Index

The Severity Index (SI) calculated as the sum of the (weighted) SI's for each of the Indicators as follows:-

	Indicator SI (a)	Weight % (b)	Weighted SI (a) * (b)
Hydrology HSI		40%	
Ecology ESI		30%	
Landscape/Amenity LSI		20%	
Public Perception PSI		10%	

$$TotalSI=\sum(a*b)$$

It should be noted that the weights are fixed but all other spaces are filled in by the assessor. A further discussion of weights is given in Chapter 13 of this report.

11.2 Overall Reliability Index

The Overall Reliability Index is calculated in a similar way as the Overall Severity Index, but the Public Perception Indicator does not contribute to the Reliability Index and the weights used are amended to:

Hydrology HRI	40%
Ecology ERI	35%
Landscape/Amenity LRI	25%

During the evaluation, a number of Regions "scored" parameters on the basis of informed judgements by experienced staff, rather than hard data, whereas others would only assign a score on the basis of hard data.

TABLE 11.1 : SAMPLE CALCULATION OF THE OVERALL INDICES

CALCULATION OF OVERALL INDICATORS

page 1 of 1

NRA REGION: A region   **NAME OF STREAM:** River Example   **DATE:** 12/8/92

(see Report Chapters 11.1 to 11.6 for full explanation of methodology)

OVERALL SEVERITY INDEX (SI)

SI type	SI	Weight	Weighted SI
Hydrological SI	0.97	40.0%	0.39
Ecological SI	0.60	30.0%	0.18
Landscape and Amenity SI	0.68	20.0%	0.14
Public Perception SI	1.00	10.0%	0.10
		Total SI (SIi) =	0.80

OVERALL RELIABILITY INDEX (RI)

RI type	RI	Weight	Weighted RI
Hydrological RI	0.90	40.0% *	0.36
Ecological RI	1.00	35.0% *	0.35
Landscape and Amenity RI	1.00	25.0% *	0.25
		Total RI =	0.96

** Use only a proportion of indicator weight if "judgemental scoring" has been carried out (see Report Chapter 11.2)*

POSSIBLE ACTION

SI	RI	Action
High	High	Put in Capital Programme for Alleviation
High	Low	Further studies required
Low	High	No action unless strong public pressure, in which case mount public relations campaign
Low	Low	No action unless strong public pressure, in which case initiate minimum cost further studies and mount public relations campaign

SIZE ADJUSTMENT

Length of watercourse affected (L) =	5	km
Catchment area to mid-point of length affected (CA) =	12	km2
Adjusted Severity Index (SIa) = SIi x L^{13} x CA^{13} =	3.15	

COST ADJUSTMENT

Benefit:		
Increase in low flow resulting from alleviation scheme =	0.5	Ml/day
Benefit (or Value) = (approx.)	£0.50	million
Cost:		
Net Present Value of costs of alleviation scheme = *(discount rate = 6% over 100 years, or as recommended by the DoE)*	£0.45	million
Benefit/Cost ratio =	1.11	
Adjusted Severity Index (SIa) =	3.15	
Total Severity Index (TSI), taking account of Benefit/Cost ratio =	3.32	

Such "judgemental" scoring carried out by suitably experienced staff can make a valuable contribution to the assessment but should be reflected in the assessment of Reliability Index.

It is proposed therefore that in assessing the Reliability Index, the assessor should use a proportion only of the Indicator weight to reflect the degree of confidence which he or she has in the assessment.

11.3 Suggested Action

Having assessed the Severity Index and the Reliability Index the action arising from this assessment is categorised as shown in Table 11.2.

Table 11.2 Suggested action resulting from assessment of low flows

Severity Index	Reliability Index	Action Required
High	High	Put in NRA Capital Works programme for alleviation
High	Low	Further study and data collection required
Low	High	No action unless strong public pressure in which case mount a public relations campaign to explain that there is no problem.
Low	Low	No action unless strong public pressure in which case initiate minimum cost studies and mount public relations campaign

Detailed action by the NRA following the assessment is beyond the scope of this project and therefore it has not been considered further. However, during the formulation and evaluation of the methodology, various points of discussion emerged which might aid or influence the NRA in allocating priority for action between high-scoring sites. These Factors, and the way in which they might be applied, are discussed below.

11.4 Real or Perceived Problem

The assessment of whether there is a real problem or a problem only in the public's perception is based upon a qualitative comparison of the Hydrological and Ecological Indicators with the Public Perception Indicator. In the case where the Public Perception Severity Index is high but the other Indicators show a low Severity Index with a medium to high Reliability Index then the problem can be categorised as a perceived problem only.

In all other cases, the Public Perception Indicator is most unlikely to change the conclusion drawn from the other Indicators but may influence the likely order of priority.

11.5 Size Adjustment

Up to this stage in the assessment procedure, a short length of headwater stream could score the same as perhaps tens of kilometres of the middle course of a large river. The importance of the two low flow conditions could be expected to be quite different, however.

A Size Adjustment factor is therefore required, to reflect the length and size of watercourse affected. This, like the Cost Adjustment factor discussed below, would be applied as an adjustment to the SI (but not RI) assessed from the four basic Indicators.

However, unlike Cost, the Size Adjustment should influence the ranking by severity of problem and not only the rehabilitation/alleviation priorities. It should therefore be applied, in all cases, before the application of the Cost/Benefit adjustment.

It is proposed that an adjusted Severity Index (SIa) should be calculated from the initial Severity Index (SIi) from the following formula:

$$SIa = SIi \times L^{1/3} \times CA^{1/3}$$

where L is the length of watercourse affected (km)
CA is the catchment area to the mid-point of the length affected (km^2).

The indices of "⅓" have been selected (rather than "½") on the basis that the greater length of affected channel usually (but not always) means a greater catchment area.

11.6 Cost Adjustment

The cost, or more correctly the Benefit/Cost Ratio of an alleviation scheme, does not affect the severity of the problem but should have some influence on the order of priority assigned to schemes. Recognising this, the NRA have initiated a further R&D Project, Proposal No. B03(91)5, to evaluate the costs and benefits of low flow alleviation.

As an interim procedure, until this new research reaches conclusions, the Cost Adjustment is based on the following:-

i) The cost of 'buying out' an existing licence has been quoted in a number of Regions as approximately £1 million per Ml/day.

ii) Any alleviation scheme will have an effect equivalent to a reduction in licensed abstraction. For example, if a re-circulation scheme or groundwater support scheme produces an increase in low flow of 0.5 Ml/day without affecting the available abstraction, this can be considered as having the same value as buying out abstraction licences of this magnitude, ie. a Value or Benefit of £500,000.

iii) The cost of the alleviation scheme can be expressed as a commuted sum (Net Present Value of Costs). It is suggested that should this be calculated at a discount rate of 6% over 100 years, or as recommended by the DoE for public sector projects.

Thus the Cost Adjustment could be expressed as the Benefit/Cost ratio with the Benefit calculated as in ii) above and the Cost calculated as in iii) above.

This is only an approximate adjustment as the Consultants have not investigated the accuracy of the quoted cost of buying out licences, and the relationship between the increase in low flow achieved by alleviation measures and the corresponding availability of licensed abstraction is, in some cases complex. However it does give some guide to the viability of alleviation options.

In principle, no alleviation scheme should proceed if its Benefit/Cost Ratio is less than 1 since this means that it would be more cost-effective to 'buy-out' licences.

In practice, however, alternative sources may not be available or may only be available at higher cost. In reality, the cost of alternative sources and hence of buying out licences will vary but the figure quoted above may be taken as a starting point.

If, in order to mitigate the effects of 1Ml/d abstraction, an alleviation scheme in one area costs 10 times as much as an equivalent scheme in another area, the latter should be moved up the list of priorities. That is not to say that the schemes should be ranked solely on the basis of benefit/cost ratio. Following the rules:-

i) increasing Benefit/Cost ratio should increase priority and

ii) increasing Severity Index should increase priority - one obvious way of taking account of the Benefit/Cost (B/C) ratio is to multiply the Adjusted Severity Index as calculated under 11.5 above by the B/C ratio.

Intuitively, however, this is likely to give too much significance to the B/C ratio and a suggested multiplier would be

$$(1+0.5(\frac{B}{C}-1))$$

A full sample calculation of the cost adjustment is shown in Table 11.1. Blank calculation sheets are included in Appendix I for use by the NRA Regions.

12. PRELIMINARY SCREENING

In the Phase 1 Report it was proposed that in order to 'focus' the assessment effort on those sites which have a low flow problem there should be a preliminary screening of sites using the Primary Indicators.

As a first stage, it was suggested that only those rivers or sites for which there is some reason to believe that there may be a problem would be considered. This reason could be minimal at this stage, e.g. one complaint or known problems in an adjacent catchment, but is much more likely to be based upon a Preliminary Screening already carried out by the Region.

For such rivers or sites it was proposed that one parameter should be selected from each Indicator as representing that Indicator. Any parameter can be selected but it was thought most likely that the parameters chosen would be those which are the easiest to evaluate, and which will give the highest (most severe) mark in that particular area.

For each Indicator, the Severity Index is taken as

$$\frac{MarkforChosenParm}{MaximumMarkforParm}$$

The overall preliminary Severity Index would then be the sum of the SI's calculated for the Indicators used.

It was proposed that if the Preliminary SI exceeds 1 (ie at least two Indicators with a Severity Index of 0.5 or more) then the site would be considered to be suffering a low flow problem of sufficient magnitude to warrant the full assessment procedure.

However, during the Evaluation of the methodology, it became apparent that this form of preliminary screening would add little to the methods already in use.

In most cases a further method of Preliminary Screening is unnecessary and it is suggested that for any further Preliminary Screening to be worthwhile it should be based only on the Hydrological and/or Ecological Indicator.

13. WEIGHTING - NATIONAL OR REGIONAL

13.1 Introduction

A key issue is the weight to be assigned to each Indicator.
The discussions with the Regions have focused this issue into two questions :

i) how much weight should be given to Public Perception or 'pressure' compared to other, more objective Indicators?

ii) should the same weights be used in every Region or should the Regions set their own weighting?

Although these are quite separate questions, the suggestion that Regions should set their own weighting usually arises in Regions which are experiencing considerable public pressure over low flow sites and are concerned that a national weighting system would not give as much weight as they would to public pressure.

Taking the two questions in turn :

13.2 Public Perception

In the Interim Report the question was set out as follows :

> "A dichotomy within the Regions, which this study must address and resolve, is the relative importance of Public Pressure, and other "subjective" or "judgemental" Indicators in comparison with the Hydrological and Ecological Indicators.
>
> On the one hand there is an argument that since the investigation of low flows has been largely driven by public pressure and since this pressure is based upon the public's subjective and judgemental assessment of landscape and amenity, these Indicators should be given a high priority as part of NRA policy to be responsive to public concern.
>
> On the other hand there is an argument that it would be wrong simply to seek the public's perception of a problem and alleviate the problem, thus perceived. This would amount to tackling the symptom rather than the cause, and would be unlikely to prevent further problems. In addition, public perception, and recreation-amenity- landscape aspects often reflect the proximity of a site to centres of population or the activities of pressure groups. These factors may negatively bias the assessment of isolated habitats and it is argued that such a bias would be wrong. "

In further consultation, some Regions have pointed out that public pressure is not necessarily subjective and can be based on 'hard' objective data. It may also be concluded that there is a degree of linkage between the Landscape Indicator and Public

Perception. Indeed the classification of sites such as SSSI and AONB could be considered as "**Official**" public perception.

Therefore, although separately assessed, it is also worth looking at these two Indicators together.

It has been suggested that the weight should be roughly one third each for :

> **Hydrology, Ecology, and**
> **[Landscape/Amenity + Public Perception].**

The latter two Indicators could also be considered as the 'Subjective' Indicators as they measure the impact on man rather than on the natural environment.

13.3 National v. Regional Weights

The question of whether weights should be set Nationally or Regionally is linked to whether funding for alleviation measures is to be Nationally or Regionally allocated.

It is understood that the objective of this research project is to develop a National assessment procedure, implying that weights should be set Nationally. If weights were set Regionally it is unlikely that there would be a consistency of assessment between Regions.

It was therefore proposed, in Phase 1, that Indicator weights should be set Nationally but that a limited proportion (say 10% of the overall weight) should be at the discretion of the Region. Parameter weights would be set Nationally i.e. they would be the same in every Region. However, as discussed in 13.4 below, the option of Regional discretion has now been removed.

13.4 Proposed Weights

The following table shows the Indicator Weights proposed in the Phase 1 Report and the weights adopted after the Evaluation (Phase 2) was completed.

Indicator	More 'Subjective'	Proposed in Phase 1 report	More 'Objective'	Adopted
Hydrology	35%	40%	40%	40%
Ecology	25%	30%	35%	30%
Landscape/Amenity	15%	10%	15%	20%
Public Perception	25%	20%	10%	10%

In all cases, the greatest weight is given to the Hydrological Indicator which is the most direct measurement of the problem and is an independent Indicator, whereas all the others are dependent, ie they measure consequences of low flow. Ecology is probably the next most important Indicator since it suffers the most direct consequences.

In the Phase 1 Report Landscape/Amenity was given the lowest weight, because it 'overlaps' with ecology and public perception and in particular, because public perception is likely to be based upon landscape/amenity aspects.

Public perception was given a relatively high weight because in the real world, it is an important driving force of the need to identify and alleviate low flows.

It was also proposed to provide a Regional discretion in weighting by allowing the Region to add a 10% 'discretionary weight' to any Indicator weight and then divide the resulting overall SI and RI by 1.1 to correct it to a total weight of 100%.

Following the meeting on 29th October 1991 between the Consultant, the Topic Leader, Project Leader and representatives from all Regions it was agreed that the Landscape/Amenity weight should be increased to 20% and Public Perception reduced to 10%. This is to prevent pressure groups from being able to raise a particular site in the 'rankings' on the basis of lobbying where there is little or no objective evidence, while still giving the same total weight to the "Subjective" Indicators.

It was also agreed that there should be no Regional discretion.

14. ALLEVIATION OPTIONS

The TOR for this project require an overview of the options that are available for alleviation of the low flows. It would be beyond the scope of this report to review them in terms of a full benefit assessment, as these would require considerable local data in each case, as well as the results of field investigations. The review, therefore is qualitative in approach and provides a series of options which, either in combination, or singly, could be applied to specific low flow instances.

Most NRA Regions have already given some degree of consideration to the alleviation options available to them to mitigate the impact of low flows. For historical reasons, the options can be broadly grouped into two categories :

* fire fighting, interim alleviation option
* long term resource management option

Previous administrative constraints necessitated the above categorisation and to some extent the solutions proposed to the water authorities by their Consultants were to resolve local problems with localised solutions. In the present circumstances with the NRA taking a far wider view of water resource conservation in terms of environmental enhancement, more long term and permanent options can be seriously considered. This does not imply that immediate solutions that are urgently required should be abandoned but that rather they should be seen as temporary solutions.

Table 14.1 shows a list of options that are available, as well as an indication of whether the options falls into the category of "local and short term" or "regional and long term". The table also indicates the applicability of the option in terms of possible difficulties in its implementation.

Many of the options listed in the table have either already been investigated in the UK or have been tested at pilot scheme scale. Some of the previous augmentation schemes promoted by the Anglian, Southern, Thames and Severn Trent Water Authorities should be re-reviewed in the light of the new objectives that have been assigned to the NRA by the Water Act of 1989. Although those schemes do not directly apply to the present list of cases affected by low flows, the experience gained can be put to good use in evaluating how the alleviation options could be applied.

The alleviation options available in the context of the above categorisation are considered next.

14.1 <u>Localised, fire fighting options</u>

i) **Flow augmentation :**
this is the most common and obvious option. Ground water from boreholes located close to the affected streams can be used to provide stream support in localised conditions.

Options 1 to 3 listed on Table 14.1 are a variation of this principle. These options can only be used where aquifers provide the stream base flow. The stream bed permeability is a critical factor in utilising such options. Options 8 and 9 are similar to these but there is the added water quality constraint.

ii) Localised bed lining :

this option, usually combined with augmentation, would be effective in many Chalk aquifer type situations. The earliest tests of this approach were used in Gussage Brook in 1970/71 by the then Avon and Dorset River Authority.

Options 4 and 5 would be used for this type of alleviation. Because of cost constraints, and to an extent ecological factors these options have been used on relatively short stretches of streams. There are certain technical difficulties associated with the bed lining approach, concerned with the possible build up of hydraulic pressure below the lining causing rupture - solutions to reduce this are available but would require testing in any given solution.

iii) Localised artificial recharge :

given appropriate conditions recharge through wells could support springs or limited stream sections. Trials of this type were carried out by the Anglian Water Authority at Ashwell springs in 1978/79.

Options 6 to 8 on Table 14.1 indicate the variations of artificial recharge, as enhanced recharge - sewage spreading has been tested in Hampshire on the chalk aquifer and other localised examples are known. However, these need to be reevaluated in the content of their providing support to the river, affected by low flows.

iv) Engineered landscape :

an option with some promise where conditions have so altered from the 'natural' that the only solutions would be to fully 'engineer' the stream and its immediate environment.

Options under this heading are listed under 4, 20 and 21 in Table 14.1. Generally the capital costs of these schemes would make them prohibitive, as also the running costs subsequently including the need to allocate NRA staff resources. However, where appropriate, local volunteer and special interest groups may well wish to run these type of schemes. A similar situation has occurred on the Blackwater Canal where an embankment and the associated works have been reconstructed and are maintained by a committed local volunteer organisation.

14.2 <u>Long term resource management option</u>

i) Relocation of major abstractions :

boreholes which are known to closely impact spring flows and river flows could be relocated to other more remote sites.

Options 2 and 11 are sub sets of this approach. A number of investigations related to this approach have been studied in the UK principally in the Chalk aquifer and some pilot scale testing was carried out. During extreme droughts some such schemes have been implemented though mainly to provide public supply rather than to provide low flow alleviation. Experience gained from operating these schemes and further evaluation of them would provide adequate information to undertake preliminary pre-feasibility study of potential for low flow alleviation.

ii) Revocation of Licences :

an option similar to that above, would require shut downs of boreholes.

Options 12, 13 and 14 on Table 14.1 are variations of this approach. Some negotiations are already underway between the NRA and Water Plc's to consider how best this could be achieved within the context of Environmental Statements being prepared by the Water Plc's.

iii) Integrated catchment resource management:

an option based on a combination of the two above, involving relocation of some sources combined with revocation of others.

iv) Conjunctive use :

conjunctive use option of considering multiple sources, if available, would be an attractive option.

The two categories in iii) and iv) are listed as options 15, 16 and 17 on Table 14.1. To implement any one of these, or a combination will require negotiation with major licence holders ie mainly the Water Plc's and Water Co's. Some other users eg the electricity industry also have large licences which should be included for possible negotiation.

v) Remote and new river sources :

seasonal abstraction depending on river flows and ground water levels.

Options 1, 2 and 11 would apply under this category. This category has been listed separately in spite of the possible duplication above to stress how adding or removing options to proposed alleviation can subtly change the emphasis and would require a completely new level of field trials and pre-feasibility investigation. Previously option 11 was mentioned under category 14.2.(i), in the context of relocation, here however it is mentioned in the context of manipulation of the aquifer storage.

vi) Artificial recharge :

an option (within catchment management) which has in the past been considered uneconomic. With the current suggestions of environmental impact costs, it may be appropriate to reconsider artificial recharge in appropriate aquifers.

This category includes options 6 to 8 and 10, with emphasis on 10. The option may be unacceptable from quality viewpoint in situations where contaminants could be introduced eg road surface run off, run off from urbanised areas, etc.

vii) Ecological engineering:

an alternate approach to alleviating the impact of low flow by restoring them could be to accept the reduced flows but to 'engineer' the ecological habitat into an acceptable but artificial balance. This would include options 21 and 22 but they would only be applicable in exceptional situations.

Table 14.1 SUMMARY OF ALLEVIATION OPTIONS

Alleviation Option	Option	Applicability
AQUIFER FED STREAMS		
1. Flow augmentation from near stream boreholes	Localised, short term	Streams with low bed permeability
2. River support from distant boreholes	Localised, short term	Stream with bed permeability similar to aquifer
3. River support from aquifer not in contact with stream	Localised, short term	Stream not underlain by the aquifer providing the support
4. Stream bed lining with 'engineered' flora, fauna, landscape and amenity	Localised, short term	Lining material compatible with underlying aquifer system eg puddled chalk on chalk aquifer
5. Stream bed lining coupled with 2 or 3 above	Localised, long term	As above, 4, and where bed material is permeable
6. Artificial recharge to maintain spring head or environmentally sensitive ponds	Localised, medium term	Aquifer of medium tranmissivity and storage
7. Aquifer recharge by partly treated sewage effluent	Localised, medium term	Medium transmissivity aquifer of good buffer capacity to improve quality as it travels towards stream
8. Discharge of treated sewage effluent to streams	Regional, long term	Sewage treatment works located close to, or at headwater of streams
9. Recirculation of stream flow by pumping back to headwaters	Localised, long term	Treatment by aeration to minimise quality deterioration
10. Regional aquifer recharge enhancement from storm run off storage ponds	Regional, long term	Appropriate storage ponds, appropriately sited, aquifer of moderate transmissivity

Table 14.1 Continued.

Alleviation Option	Option	Applicability
11. Seasonal abstraction from near river and more distant boreholes, including induced recharge from river beds.	Regional, long term	Appropriate aquifer conditions and stream bed conditions
12. Revocation of unused licences in affected area	Local, long term	Appropriate legal powers
13. Renegotiation of licences to reduce licence to a lower (probably the actual) limit	Local, long term	Cordial conditions for negotiation and legal powers
14. Renegotiation of licence conditions requiring, eg, river support discharge	Local, regional, long term	Appropriate negotiations and aquifer-stream interaction
AQUIFER PLUS SURFACE FED STREAMS		
15. Integrated catchment resource management	Regional, long term	Coordinates in water resources, ecology and conservation, including amenity and landscape
16. Conjunctive use: combining surface and aquifer abstraction	Regional, long term	Needs full evaluation of all catchment abstraction, discharge and stream flow
17. Increase storage of surface reservoirs to provide additional 'resource' for stream support	Localised, long term	Appropriate conditions to increase storage and provide releases

Table 14.1 Continued

Alleviation Option	Option	Applicability
SURFACE FED STREAMS		
18. Modify reservoir releases to provide additional discharge during low flows	Localised, long term	Appropriate conditions to modify existing weirs
19. Install checks in stream to provide water depth in low flow periods	Localised, long term	Acceptable conditions on ecological and quality grounds
20. Revoke licences not in use of those that are over licenced	Localised, long term	Appropriate legal power
ECOLOGICAL AND LANDSCAPE ENGINEERING		
21. Introduction of new ecological balance in streams irrevocably degraded	Localised, long term	Acceptance by ecological and conservation interests
22. Managed landscape and habitat, water garden	Very localised, long term	Economics may be prohibitive, solution could be unacceptable to public

15. CRITERIA FOR REHABILITATION STANDARDS

15.1 Introduction

In setting the criteria for rehabilitation standards the objective is to answer the following questions:

i) Which parameters should be used to define the level of rehabilitation to be achieved?

ii) to what extent should rehabilitation seek to restore the 'historic' or 'natural' conditions, or better? (ie quantitative criteria).

iii) Should rehabilitation be to the same standards in all cases and, if not, on what grounds should different standards be applied?

iv) To what extent should cost influence the rehabilitation standards?

The most obvious solution is to use the Standard Assessment Method and to assign target reductions in the Severity Index to be achieved by rehabilitation.

The Standard Assessment Method encompasses the most comprehensive criteria, based on the assessment parameters. However, some of the parameters are much more relevant to rehabilitation standards than others and in any given case, rehabilitation should perhaps be focused on the particular impact or impacts which are causing most concern.

In previous work in the Regions, rehabilitation standards have been identified at two levels:-

a) flow required to achieve full species diversity - ie full restoration of habitat, although this does not necessarily mean full restoration of flows.

b) (lower) flow required to satisfy visual and amenity aspects.

Two other criteria which affect these standards and have been considered in previous work are:

c) water depth (relevant to visual/amenity aspects)

d) water quality, which is not a parameter in the Standard Assessment Method but becomes significant in considering recirculation options for rehabilitation.

15.2 Full Restoration of Habitat

The criteria for full restoration of habitat are being developed under NRA Research Project B2.1 through the development of techniques to establish Ecologically Acceptable Flows using PHABSIM.

When these techniques are in place, they can be used to establish target flows throughout the year (or perhaps, more correctly expressed as target base flows).

These target ecologically acceptable flows can be compared with 'natural' low flows less licensed abstraction, or compared with actual flows.

They might also be used as the basis of 'conditioning' future licences to maintain an ecologically acceptable minimum flow or in negotiating the revocation of existing licences and replacement with 'conditional' licences.

It is worth repeating that full restoration of habitat does not mean full restoration of historic flow quantities. The physical parameters affecting habitat include flow velocity, depth, turbidity or sediment load and other physical and chemical characteristics.

In addition to restoring flows, it may be necessary to restore the channel, ie the restoration of flows may well not, per se, restore the habitat.

It is important therefore when considering restoration, to ensure that a flow **regime** is provided which is appropriate to the channel being restored.

Gradients associated with the riffle/pool sequence in the dry bed should be re-established so that restoration can re-instate these habitats. Gravel should be introduced at appropriate points to assist riffle formation and thereby raise semi-fixed heads to enhance downstream pool formation.

In addition the works necessary to restore flows (eg channel lining) must be done in such a way as to preserve or provide a suitable habitat. Care should be taken to preserve plant-colonised margins through boggy areas of botanically diverse meadow land. In such stretches an underlining technique which causes minimal disturbance should be employed.

Where channels are being restored for recolonisation by plants and invertebrates rather than to preserve surviving communities, measures should be taken to ensure that the lining does not inhibit the development of plants or become damaged as they grow. In such cases, a puddled clay and/or bentonite liner would be recommended as appropriate.

Until project B2.1 reaches conclusions, it is proposed that Ecological Parameters E1 (Invertebrates) and E2 or E3 (Fisheries) be used as the basis for criteria for rehabilitation with a target mark of 0 or, exceptionally, 1.

In order to establish target flows from any of these parameters it is necessary at this stage to relate the flow to that in similar watercourses or downstream reaches of the same watercourse which achieve the required target mark (ie are not suffering low flows to the extent that ecological damage is caused).

15.3 Restoration of Visual Amenity

For visual and amenity aspects we propose that parameters H4 (Stream Morphology) or H6 (Movement of Springhead) should be used with a target mark of 0 or, exceptionally, 1.

Parameter L4 (Amenity) may also be used but it is an indirect method of assessing target flows and therefore only be used by reference to similar watercourses to assess target flows.

15.4 Cost or Benefit/Cost

Although **target** rehabilitation standards may be independent of cost, the standards achievable are unlikely to be:

The Cost Adjustment may be taken into account in setting priorities between rehabilitation schemes achieving the **same** standards in the manner set out in paragraph 11.6.

However, the Cost Adjustment is a measure of the cost of restoring a given quantity of flow and on a different watercourse, the same quantity of flow may rehabilitate quite different lengths of watercourse.

Another way of looking at this is that different quantities of flow may be needed to rehabilitate the same length of watercourse at different sites.

Thus an alternative cost Indicator might be the cost per kilometre of watercourse restored to

a) full habitat or
b) visual/amenity requirements only.

'Cost' in this case would be the NPV of costs as set out in Section 11.6(iii).

Thus 'typical' or 'average' costs per km could be established nationally for each of the two levels of rehabilitation and each proposed scheme compared with these 'typical' costs.

This whole question is being addressed under an NRA R&D Project (Proposal No B03(91)5), to evaluate the costs and benefits of low flow alleviation.

16. TESTING AND DEVELOPMENT

Phase 1 of this study, completed in March 1991, proposed a standard assessment methodology for low flow conditions. The methodology, based upon a system of scoring and weighting a selection of certain key parameters and Indicators was developed on the basis of experience, information and results collated by the Consultants from all the Regions.

However, given the complexity of the problems the assessment sought to address, it was imperative that the methodology was 'field-tested' by the Regions, to ensure the suggested parameters were realistic and workable (with existing data), providing sensible answers that could be applied in a practical manner on a national basis.

Accordingly, the Phase 2 evaluation of the methodology was undertaken within the Regions between July-October 1991. All of the Regional responses are detailed in Appendix F. During this phase, nine Regions eventually proffered a total of twenty separate watercourses for evaluation. Much useful feedback was generated by this exercise and the relative degree of parameter utilisation between Regions is clearly highlighted in Table 1 of Appendix G.

The collation and synthesis of the evaluation exercise by the Consultants resulted in the issue of a Consultation Paper (Appendix G) to all Regions on 22nd October 1991. This paper formed the basis for discussion at a round-table meeting at Kings Meadow House, Thames Region on 29th October 1991, attended by the Regional personnel and Consultants' team detailed in Appendix H.

The Regional representations presented during the meeting have subsequently been carefully considered by the Consultants and duly amalgamated within the Framework of the final assessment methodology.

As a result of this exercise, one parameter was changed and a number were adjusted to further accommodate Regional wishes. However, the basic framework of the Phase 1 assessment methodology survived intact and the Consultants feel justified that the assessment system now proposed within this Final Report has been fairly developed and tested. This evaluation currently represents the best inter-consensus of Regional opinion within a field of study suffering from a wealth of personal, often subjective, perception of the problems and a relative dearth of objective, hard evidence.

However, some measure of the severity of the low flow problem is now available for inter-Regional comparison. When used thoughtfully with the Reliability Index, the Consultants believe the assessment methodology provides a viable comparative tool to aid allocation of priorities for remedial measures/works, as well as providing the NRA with a system capable of withstanding public scrutiny.

17. SUMMARY AND CONCLUSIONS

17.1 Context of Method

The NRA inherited problems of low river flows arising from over-abstraction under existing licences which would not now be granted under present legislation and practice.

The NRA also inherited from a number of Regional Water Authorities (RWAs) proposals for capital schemes to alleviate specific low flow problems. There is increasing public pressure to alleviate low flow problems, the intensity of which is not necessarily related to the severity of the problem. The NRA therefore commissioned R&D Project 237 to develop a means to objectively assess the severity of, and assign priorities between, low flow sites.

An important objective was to develop a method as soon as possible since some alleviation works were already under way and the NRA needed to ensure that resources would be targeted where they would be most cost effective. Consequently the method was developed in advance of other, relevant, research projects and within the following constraints:-

1) There was to be a minimum requirement for data collection, so the system should be based on established methods and incorporate historical data.

2) The methodology should be able to incorporate a wide range of data, collected by the various Regions in a non-uniform way, and usually for purposes other than low flows assessment.

3) The methodology should be simple and non-time-consuming and should be understandable by non-specialists.

4) The methodology should extract as much information as possible from the data, which were likely to be scarce.

5) The methodology should be applicable to watercourses and river types in different geographical regions.

These constraints were particularly important when considering the ecological factors involved in low flows assessment, as biological data have been traditionally collected in an unstandardised way by the water industry, for water quality monitoring rather than habitat assessment and conservation purposes.

17.2 Summary of Method

The method developed is based on the use of four Indicators and two Adjustment Factors as follows:-

- an overall Severity Index
- an overall Reliability Index

each of which will lie between 0 and 1.

The possible actions arising from the assessment are set out in Table 11.2, based on whether each Index is assessed as High or Low. Where Indices are between, say, 0.45 and 0.55, they should be looked at critically to determine whether they should be treated as high or low.

17.8 Adjustment Factors and Adjusted Indices

Adjustment Factors which are applied to the Severity Index only are provided to take account of:

- the Size of the affected site
- the Cost/Benefit of alleviation proposals

The adjusted Severity Index will no longer necessarily fall between 0 and 1 and may, in fact, be 100 or more. Thus the unadjusted Severity Index cannot be compared in any meaningful way with either of the Adjusted Severity Indices and three "Severity Indices" should be assessed, namely:

- Unadjusted Severity Index
- Severity Index adjusted for size only
- Severity Index adjusted for size and cost/benefit

The Reliability Index remains the same in each case.

The first assessment of Action Arising would be based on Table 11.2 using the Unadjusted SI and this would then be reviewed and modified as necessary in the light of the Adjusted SIs.

17.9 Sample Calculation and Spreadsheet

To facilitate the assessment, which may be rather time-consuming, sample calculations and blank calculation sheets are provided.

A spreadsheet-based macro developed in Lotus 1-2-3 is also available to facilitate the calculations.

REFERENCES

Armitage P.D., Wright J.F. and Furse M.T. (1983). The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. Water Res., 17, 333-347.

Cox R., Furse M.T., Wright J.F., and Moss D. (1991) RIVPACS II - A User Manual. Institute of Freshwater Ecology, River Laboratory, East Stoke, Wareham, Dorset.

LOTUS v3.1 MACRO-DRIVEN SPREADSHEET

(3½" disk & manual)

Project Report 237/2/T

Landscape & Amenity I. S.: *land1, land2, land3, land4, land5, calc_land*

Public Perception I. S.: *public1, public2, calc_public*

It is important that the correct selection is made otherwise the Macro may be corrupted. If this happens repeat initial instructions to load the Macro but all changes to project spreadsheet will be lost.

4. If the Macro has stopped due to an error press [CTRL]-[BREAK]. If the User wishes to move between different Indicator Spreadsheets (e.g. from the Ecological to the Hydrological Indicator Spreadsheet so Macro can restarted in one of the Hydro. Parameters), then use *[Ctr]l-[pageup]* and *[Ctrl]-[pagedown]* keys.

5. When editing Parameter values within a spreadsheet, <*return*> should not be used to skip a cell with a value in it. This will replace the value with a blank. Instead, the value to be retained must be typed in again.

Error Trapping

The Macro-Driven Spreadsheet has been "error-trapped" as far as is possible at the time of writing of this manual. Should any errors or problems become apparent please refer to: H. Wong, N. Evans or M. Le Gouais at Scott Wilson Kirkpatrick (0256 461161).

NRA LOW FLOWS ASSESSMENT MACRO

LOTUS v3.1 MACRO-DRIVEN SPREADSHEET

USER MANUAL

(March 1992)

Introduction

This User Manual summarises the instructions needed to operate the NRA Low Flows Assessment Macro-Driven Spreadsheet. The Macro has been compiled in Lotus 1-2-3 Release 3.1 with the "Wysiwyg" add-in and this program must first be loaded before running the Macro.

Note: It is assumed that the User has at least a basic knowledge of Lotus 1-2-3 R3.1 using "Wysiwyg".

Load Lotus 1-2-3 and start Macro

NOTE: Lotus 1-2-3 R3.1 must be resident in the "123R3" directory of the hard disk. The Indicator Spreadsheets are all stored on the floppy disk which also houses the Macro.

From the root directory type: *CD 123R3 <RTN>*

Insert the Macro floppy disk in the A: drive

Type: *123 <RTN>*

In Lotus 1-2-3:

[ALT-F10] [LOAD] [WYSIWYG.PLC] <*RTN*> *[QUIT]*

/[FILE] [RETRIEVE] [NRA_MACR.WK3]
and the Title screen will appear with the menu prompt.

When starting the assessment for a new river: *[NEW]*

When continuing an assessment previously started: *[EDIT]*

After entering the data, a file may be *[SAVED]* and *[PRINTED]* from this menu.

[QUIT] will exit from Lotus 1-2-3.

Each Low Flow Indicator (Hydrological, Ecological, Landscape and Amenity, Public Perception) is based on a separate spreadsheet in the same format as the 'Blank Calculation Sheets' in the Project Report. After hitting *[NEW]* (and entering the NRA Region and Stream Name) or *[EDIT]* (and retrieving the appropriate file) the menu prompts should be used to get into each of these spreadsheets in any desired order.

Within each spreadsheet, user-friendly instructions and guidance are provided to facilitate the calculation of the Indicators. However, it is recommended that the Procedural Manual (R&D Note 45) is read prior to the operation of the Macro.

Points to be aware of during Macro operation

1. Before running the Macro, always make a back-up copy of the Low Flows Macro disk (Lotus 1-2-3 R3.1 can call more than one file into active memory, therefore the files can be easily corrupted when trying to save).

2. If an error is made during data entry, continue entering the remaining values of the Parameter, return to the Parameter menu, then select the same Parameter and make the necessary changes.

3. If the Macro stops prematurely, press the folowing keys:

   [Alt-F3] [left arrow once] <rtn> *[F3]*

   ... a list of range names is given - choose the range name which applies to your current spreadsheet, e.g. if you are in the Hydrological Indicator Spreadsheet then choose one of the following range names that applies to the Parameter you wish to return to). Important range names are:

   Macro Menu: *\M, Macromenu, Sprdsht_menu, Hydro_menu, Ecol_menu, Lndspe_menu, pp_menu*

   Hydrological Indicator Spreadsheet: *hydro1, hydro2, hydro3, hydro4, hydro5, hydro6, calc_hydro*

   Ecological Indicator Spreadsheet: *ecol1, ecol2, ecol3, ecol4, ecol5, calc_ecol*

Landscape & Amenity I. S.: *land1, land2, land3, land4, land5, calc_land*

Public Perception I. S.: *public1, public2, calc_public*

It is important that the correct selection is made otherwise the Macro may be corrupted. If this happens repeat initial instructions to load the Macro but all changes to project spreadsheet will be lost.

4. If the Macro has stopped due to an error press [CTRL]-[BREAK]. If the User wishes to move between different Indicator Spreadsheets (e.g. from the Ecological to the Hydrological Indicator Spreadsheet so Macro can restarted in one of the Hydro. Parameters), then use *[Ctrl]-[pageup]* and *[Ctrl]-[pagedown]* keys.

5. When editing Parameter values within a spreadsheet, <*return*> should not be used to skip a cell with a value in it. This will replace the value with a blank. Instead, the value to be retained must be typed in again.

Error Trapping

The Macro-Driven Spreadsheet has been "error-trapped" as far as is possible at the time of writing of this manual. Should any errors or problems become apparent please refer to: H. Wong, N. Evans or M. Le Gouais at Scott Wilson Kirkpatrick (0256 461161).

NRA LOW FLOWS ASSESSMENT MACRO

LOTUS v3.1 MACRO-DRIVEN SPREADSHEET

USER MANUAL

(March 1992)

Introduction

This User Manual summarises the instructions needed to operate the NRA Low Flows Assessment Macro-Driven Spreadsheet. The Macro has been compiled in Lotus 1-2-3 Release 3.1 with the "Wysiwyg" add-in and this program must first be loaded before running the Macro.

Note: It is assumed that the User has at least a basic knowledge of Lotus 1-2-3 R3.1 using "Wysiwyg".

Load Lotus 1-2-3 and start Macro

NOTE: Lotus 1-2-3 R3.1 must be resident in the "123R3" directory of the hard disk. The Indicator Spreadsheets are all stored on the floppy disk which also houses the Macro.

From the root directory type: *CD 123R3 <RTN>*

Insert the Macro floppy disk in the A: drive

Type: *123 <RTN>*

In Lotus 1-2-3:

[ALT-F10] [LOAD] [WYSIWYG.PLC] <*RTN*> *[QUIT]*

/[FILE] [RETRIEVE] [NRA_MACR.WK3]
and the Title screen will appear with the menu prompt.

When starting the assessment for a new river: *[NEW]*

When continuing an assessment previously started: *[EDIT]*

After entering the data, a file may be *[SAVED]* and *[PRINTED]* from this menu.

[QUIT] will exit from Lotus 1-2-3

Each Low Flow Indicator (Hydrological, Ecological, Landscape and Amenity, Public Perception) is based on a separate spreadsheet in the same format as the 'Blank Calculation Sheets' in the Project Report. After hitting *[NEW]* (and entering the NRA Region and Stream Name) or *[EDIT]* (and retrieving the appropriate file) the menu prompts should be used to get into each of these spreadsheets in any desired order.

Within each spreadsheet, user-friendly instructions and guidance are provided to facilitate the calculation of the Indicators. However, it is recommended that the Procedural Manual (R&D Note 45) is read prior to the operation of the Macro.

Points to be aware of during Macro operation

1. Before running the Macro, always make a back-up copy of the Low Flows Macro disk (Lotus 1-2-3 R3.1 can call more than one file into active memory, therefore the files can be easily corrupted when trying to save).

2. If an error is made during data entry, continue entering the remaining values of the Parameter, return to the Parameter menu, then select the same Parameter and make the necessary changes.

3. If the Macro stops prematurely, press the folowing keys:

[Alt-F3] [left arrow once] <rtn> [F3]

... a list of range names is given - choose the range name which applies to your current spreadsheet, e.g. if you are in the Hydrological Indicator Spreadsheet then choose one of the following range names that applies to the Parameter you wish to return to). Important range names are:

Macro Menu: *\M, Macromenu, Sprdsht_menu, Hydro_menu, Ecol_menu, Lndspe_menu, pp_menu*

Hydrological Indicator Spreadsheet: *hydro1, hydro2, hydro3, hydro4, hydro5, hydro6, calc_hydro*

Ecological Indicator Spreadsheet: *ecol1, ecol2, ecol3, ecol4, ecol5, calc_ecol*