IH Report to National Rivers Authority

Data requirements and data collection procedures for application of the instream flow incremental methodology in the UK

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Part 1 Hydrological/hydraulic data requirements and data collection procedures

A guide to field data collection techniques for application of the Instream Flow Incremental Methodology using the Physical Habitat Simulation System (PHABSIM).

PREFACE

This report describes the application of the Instream Flow Incremental Methodology using the PHABSIM system to rivers in the UK. The contents of this report are based on documented material from application in the USA and from experience gained from application of the method in the UK by staff from the Institute of Hydrology, Institute of Freshwater Ecology, Institute of Terrestrial Ecology and Loughborough University. PHABSIM studies conducted by the above organisations have been commissioned as follows :

Department of the Environment : Initial model transfer and assessment of application on the rivers Gwash and Blithe.

Ministry of Agriculture Fisheries and Food : Assessment of the application of PHABSIM to river flood defence schemes. The site chosen for this study is a reach of the Poyle Channel (Middlesex)

National Rivers Authority R&D Project B2.1 Ecologically Acceptable Flows : Assessment of the application of PHABSIM at 11 study sites on rivers in England and Wales.

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ABSTRACT

The Instream Flow Incremental Methodology (IFIM) allows the quantification of a weighted measure of physical habitat available to aquatic species for the range of discharges experienced in a river. This information, when combined with hydrological data describing the flow regime may be used as a tool in the setting of flow regimes optimal for ecological management.

Under a commission from the DOE (Bullock, A., Gustard, A. and Grainger, E. S., 1991) the application of IFIM using the PHABSIM system was assessed on two British rivers, the Gwash in Leicestershire/Lincolnshire and the Blithe in Staffordshire. Hydraulic data from five sites on the two rivers was combined with habitat preference data for eight fish species (brown trout, grayling, dace, chub, roach, bream, pike and perch), five species of macroinvertebrates (Leuctra fusca, Isoperla grammatica, Rhyacophilia dorsalis, Polycentropus flavomaculatus and Sphaerium corneum) and one macrophyte species (Ranunculus fluitans Lam.). Results

of physical habitat simulations were presented as Weighted Usable Area versus discharge relationships for separate life stages of each target species.

Work is currently in progress to further assess the application of the IFIM under a three year NRA R&D commission B2.1 Ecologically Acceptable Flows which commenced in October 1990

For this commission the IFIM is being assessed through application on ten different rivers in England and Wales, chosen to lie in ten different ecological groups identified by analysis of data from the RIVPACS database.

Based on experience gained through the above applications this report outlines data requirements of the PHABSIM model and describes data collection procedures. The purpose of this exercise is to allow NRA Regions to employ their staff in the collection of hydrological and ecological data in a format compatible with the data requirements of PHABSIM. Once the application of the model has been fully assessed the availability of existing PHABSIM data sets will facilitate immediate application of the model at sites of interest to each particular region.

Executive Summary

The current high profile of low flow conditions existing in UK rivers after two years of severe drought conditions, coupled with the requirement under 1989 Water Act for the NRA to set Minimum Acceptable Flows when requested by the Secretary of State has prompted the need to develop operational tools for managing aquatic communities in British Rivers on a national scale.

Since 1974, development of the Instream Flow Incremental Methodology (IFIM) by the Aquatic Systems Branch of the U.S. Fish & Wildlife Service has allowed the quantification of species preferences for the full range of discharges experienced within a river. This quantification of habitat preferences and the relationship with river flow permits the negotiation and setting of flow regimes optimal for ecological management, paying specific regard to the physical habitat requirements of selected target species. The methodology is the standard method for determining flow requirements below major water resource schemes in 38 states of the U.S.

Aside from developments in the US the IFIM is the subject of previous studies and ongoing research in several countries world wide including Canada (**), New Zealand (Scott, D., Shirvell, C.S.), Norway (Heggenes, J.) and France (Souchon, Y., Trocherie, F., Fragnoud, E., Lacombe, C.).

Initial assessment of application of the IFIM to UK rivers was conducted by a collaborative team including staff from the Institute of Hydrology, Institute of Freshwater Ecology, Institute of Terrestrial Ecology and the Department of Geography, Loughborough University of Technology. The method was applied at five sites on the rivers Gwash and Blithe. Details are given in (Bullock, A., Gustard, A. and Grainger, E. S., 1991).

Since October 1990 work has continued in the assessment of the applicability of the IFIM for British rivers under a three year NRA R&D Project B2.1 Ecologically Acceptable Flows. For this commission the method is being assessed by application on selected study reaches on ten different rivers in England and Wales. Study rivers were selected from ten different ecological groups identified by analysis of data from the RIVPACS database.

Although the current study is intended to assess the methodology, and intentionally avoids sites with specific current operational problems, it has been suggested that individual NRA regions may wish to begin collection of data in a format compatible with the data requirements of PHABSIM, before results of the current assessment are available. The purpose of this document is to give advice, on the basis of current experience of applying the model to UK rivers, to assist in the data collection exercise.

It must be stressed that the current R&D project is still in its early stages and it is likely that the final report will identify situations in which IFIM is inappropriate as well as those in which it is appropriate. Likewise it is possible that recommendations for data collection may alter as the project evolves. Bearing this in mind the recommendations made in this document have been made such that , if followed, they will provide sufficient data for successful application of IFIM once data requirements for specific situations have been finalised. For future applications to specific problems data requirements may be reduced; the approach recommended here maximises generality at the expense of collecting some data which may prove unnecessary in certain situations. The information provided in the following chapters may be summarised thus:

* Scoping of IFIM studies
* Overview of the PHABSIM model
* Outline of PHABSIM data requirements
* Recommended procedure for application of PHABSIM
* Estimate of cost of data collection in man-days per study
* Field survey techniques and equipment

Contents

1. Introduction to the Application of the IFIM

The essence of the IFIM is concisely stated by Bartholomew and Waddle (1986):

"The IFIM is a reasoned approach to solving complex streamflow allocation problems that are often characterised by uncertainty. Application of the IFIM requires an open and explicit statement of management goals, study objectives, technical assumptions, and alternative courses of action. IFIM provides a framework for presenting decision-makers with a series of management options, and their expected consequences, in order that decisions can be made, or negotiations begun, from an informed position. IFIM exposes for the decision-makers those areas where judgement is necessary and presents the potential significance of the alternatives they might choose."

It is important to realise that the IFIM is a concept, or at least a set of ideas whereas PHABSIM is a model comprising a suite of computer programs. For some IFIM studies PHABSIM may be one of a number of different computer models used to provide information to assist in the decision making process. In some situations output from water quality models or temperature models may augment that from PHABSIM. In scoping an IFIM study it is essential to identify at the outset those factors which are likely to have significant impact on aquatic ecology and which may be limiting to aquatic populations. If, for example, a change of water temperature was identified as the principle result of some proposed development (eg. afforestation or deforestation) then a water temperature model would be the most appropriate model to employ in the IFIM study and PHABSIM would be inappropriate. If, conversely, the chief impact of a resources development was to alter the flow regime (and consequently local velocities, depth, substrate type and available cover) without significantly altering other factors such as temperature and water quality, then PHABSIM could be the sole model employed in the IFIM study.

It is clear that in conducting an IFIM study an ideal goal would be to relate changes in populations to change in the flow regime.

Although some studies have successfully demonstrated that PHABSIM may be capable of achieving this goal it must be appreciated that PHABSIM is not in general capable of this task since it predicts change in a weighted measure of physical habitat area (WUA) available to aquatic species and does not predict change in biomass. In some instances a linear relationship between biomass and WUA has been demonstrated (**S) but it is clear that this is not generally the case since factors other than change in WUA may be limiting to populations. It is essential that, in the absence of equivalent population models, one accepts the limitation of using WUA as the key variable and attempts to take into account as best as is possible factors which are likely to influence the relationship between WUA and populations. Gore and Nestler (1988) make the following statement with regard to this issue:

" PHABSIM is a vehicle for presenting biological information in a format suitable for entry into the water resources planning process. It is not, nor was it ever intended to be, a replacement for population studies, a replacement for basic research into the subtleties of fish or benthic ecology, nor a replacement for biological innovation or common sense. As such, PHABSIM has been found to be a defensible technique for adjudicating flow reservations".

2. Introduction to the PHABSIM Model

In this section we will briefly describe the structure and flow of information through the PHABSIM model. For details of the basic concepts and assumptions underlying the model please refer to the Project Inception Report, to Bullock & Gustard (1991) or to Bovee (1982). Here we shall restrict our attention to identifying the data requirements of particular models contained within the PHABSIM suite of programs.

2.1 HYDRAULIC MODELLING

The hydraulic models contained within PHABSIM are calibrated with observed field data and used to simulate depths and velocities at different discharges selected by the user. The study reach is represented by a grid of cells whose boundaries are defined by a number of transects placed along the reach, perpendicular to the direction of flow, and a number of points positioned laterally across each transect (see Fig 1). Hence the simulated depths and velocities predicted at a particular point across a transect are assigned to a cell area whose boundaries are defined by the mid-points of the distances to adjacent points on the cross section and the mid points of the distances to the next up and downstream transects. PHABSIM hydraulic simulation programs assume that the hydraulic variables measured at a transect extend halfway to adjacent transects up and downstream.If this is not the case, upstream weighting factors should be applied. Weighting factors are used by the habitat simulation programs, not the hydraulic simulation programs. Details of the assignment of these weights is discussed in section 4.8 below.

PHABSIM contains three basic hydraulic simulation programs; IFG4, MANSQ, and WSP. For the simulation discharges IFG4 predicts the water surface elevation using a simple stage/discharge relationship. As is the case with all three models the water surface profile is assumed to remain constant across each transect. IFG4 predicts velocities on a cell-by-cell basis using Mannings equation and a simple mass balance adjustment. MANSQ uses the solution of Mannings equation to predict water surface elevations but does not predict velocities. MANSQ may be used when IFG4 fails to predict sensible water surface elevations. WSP is a standard step backwater model which predicts water surface elevations. WSP requires the stage/discharge relationship at the most downstream section to be known-this may be supplied using IFG4. WSP uses an energy balance model to project water levels from the most downstream transect to all transects upstream.

Like MANSQ, WSP predicts water surface elevations only and cannot be used to simulate velocities. An important difference in the structure of the three models is that in IFG4 and MANSQ each transect is modelled independently of its neighbours whereas WSP treats simulation variables at each transect as being dependent upon corresponding values at the next up and downstream transects. IFG4 performs well in high gradient streams where there is no variable backwater effect. For lower gradient streams where backwater effects are present it is necessary to use a combination of the IFG4 and WSP models. As the hydraulic models remain to be thoroughly tested for a range of different types of UK rivers our recommendation at this stage is to collect sufficient field calibration data to satisfy the data requirements of all three models in order that the user maintains the maximum available choice of hydraulic models.

2.2 HABITAT MODELLING

IFIM is based on the assumption that aquatic species exhibit discrete and quantifiable preferences for a range of the microhabitat variables depth, velocity, available cover and substrate type. The principle habitat model available within PHABSIM is the HABTAT model. For each selected target species HABTAT requires a numerical representation of the suitability to the species of values of these microhabitat variables over the whole range of values predicted by the hydraulic modelling programs. The basic form of this representation is in the form of a habitat suitability curve, also referred to as a preference curve. For each of the microhabitat variables depth, velocity, substrate and cover a preference curve must be supplied for each life stage of the selected target species. The development and validation of preference curves is discussed in further detail in Part II of this report.

The most recent version of PHABSIM requires habitat suitability information for depth, velocity and "channel index". Here, the channel index can be a coded measure of available cover, a coded observation of substrate type or any other habitat suitability index designed by the user. One of the main limitations to the user is that the HABTAT program uses only one channel index, thus cover or substrate may be used independently, but a simulation cannot simultaneously incorporate preference information for cover and substrate. The development of PHABSIM to simultaneously incorporate measures of cover and substrate is seen as a high priority and will be one of the areas of focus for the current R&D project. Until the form of channel indices describing cover and substrate characteristics has been finalised we recommend following the procedure described in section 4.6 below in the data collection exercise. in some situations it may not be deemed necessary to use all of this data in the simulation, but following this approach will ensure that sufficient data is available, at the expense of gathering some data which may later prove redundant.

Another requirement of the habitat simulation procedure is the assignment of weighting factors to each transect. Basically these weights are defined to describe the relative distribution of areas of differing habitat types between adjacent transects. Values of weights are assigned after field observation of the distribution of areas of different habitat types. This topic is discussed in more detail in section 4.8 below.

The recognition of the distribution of areas of different habitat types is also important in the process of mapping results from simulations using data from the representative study reach to a larger portion of the stream being studied. Once again this matter is discussed in section 4.8 below.

2.3 HYDROLOGICAL MODELLING

The basic output from PHABSIM simulations is the weighted usable area vs discharge relationship. This relationship allows the user to identify an "optimal" discharge by locating the peak of the weighted usable area curve, and gives a measure of the relative reduction in weighted usable area for non-optimal discharges. However, in an IFIM study, we are generally interested in how the availability of physical habitat varies over the whole flow regime experienced, or perhaps over the range of flows experienced within a particular season. In order to conduct analyses of this type it is clear that we must also have available as input to the modelling process a description of the flow regime. Hence, in the choice for a study site for application of IFIM an important consideration is the availability of historical flow data.

In the current R&D study we have selected study sites so that they are within approximately 10 km of a gauging station. It is preferable that the gauging station should have a continuous record of flow data for five years or more.

The availability of flow data is also very useful in the modelling process as it may be used in the verification of discharge estimates made in the field by current metering. It is important to recognise the necessity to approximate any inflows between the study site and the nearest gauging station.

3. PHABSIM Data Requirements

In this section we define the minimum data requirements for the hydraulic and habitat models contained within PHABSIM. Detailed description of the data collection procedure is given in section 4.

3.1 HYDRAULIC DATA REQUIREMENTS

Hydraulic Simulation Programs: Minimum Data Requirements

IFG4

(i) Survey of x,y coordinates of the bed elevation for each transect (maximum 100 points per transect). The x,y coordinates represent the horizontal distance and the vertical elevation difference from the headpin representing the start of the transect. Within PHABSIM these are converted to a cross-sectional profile of channel bed elevations. It is a convention within PHABSIM that the most downstream transect be labelled transect number 1 and that x distances across the transect be measured moving from left to right looking upstream. Coded observations of cover and substrate must be recorded for each surveyed point. The transect which represents the most downstream end of the study reach should be located at a hydraulic control, upstream of which there is a unique stage-discharge relationship.

(ii) Measurement of inter-transect distances and assigned upstream weighting factor (see sections 4.7, 4.8 for details)

(iii) Measurement of water surface elevation and discharge at a minimum of three calibration flows. The measurement of velocity at each surveyed point across the transect during at least one of the calibration flows, preferably at the highest of the three calibration discharges.

MANSQ

(i) As (i) above

(ii) As (ii) above

(iii) Measurement of discharge and water surface elevation at a minimum of one calibration flow.

WSP

(i) As (i) above

(ii) As (ii) above

(iii) Measurement of discharge at all transects for one calibration flow and at the most downstream section only for a minimum of thee calibration flows.

3.2 HABITAT DATA REQUIREMENTS

Habitat simulation program: minimum data requirements

HABTAT

For each target species life stage HABTAT requires the following data:

(i) Set of suitability indices for one or more of the following:
depth
velocity
substrate
cover

(ii) Set of hydraulic information describing the depth and velocity characteristics for each cell as a function of discharge. This information is supplied as output from the hydraulic simulation programs

(iii) Coded observation of cover and substrate at every survey point. These values are supplied by field observation and are assumed to be independent of discharge. In order to account for seasonal variability separate seasonal observations of substrate and cover may be made and corresponding simulations run.

3.3 HYDROLOGICAL DATA REQUIREMENTS

Hydrological data is required if one is to interpret the weighted usable area vs discharge relationship in the context of the historical flow regime. we recommend the following as sufficient data for such an exercise:

(i) Record of daily flows of at least five years duration

(ii) Record of daily stage of at least five years duration

The stage record is not necessary for the interpretation of output but is useful for verifying stage-discharge relationships predicted by the hydraulic simulation programs.

4. Data Collection Procedure for Application of PHABSIM

In this section we describe in detail a step-by-step procedure for collection of field data in the application of IFIM using PHABSIM.

4.1 STUDY REACH SELECTION

In the process of scoping an IFIM study we must identify a length of river over which we require conclusions drawn from the IFIM study to be valid. Clearly the more homogeneous the river is in terms of its hydrological and ecological characteristics, the more easily we may extrapolate results from simulations over the selected study reach. Depending upon the goal of the IFIM study we may wish the study reach to be representative of the larger length of river, or we may wish to focus on a location we consider to be of critical importance to the study. Consequently we shall discuss two approaches to study site selection, the critical reach approach and the representative reach approach:

(1) Critical Reach Approach

This approach is appropriate in a situation where it is possible to identify, through existing data, an area of the river which is known to be most sensitive to changes in flow and critical to the success of a particular species life-stage. If for example it is believed that the availability of spawning area is the limiting factor to recruitment of a particular fish species then the selection of a reach covering the known spawning area would be most appropriate as the study reach for an IFIM study designed to specify a flow regime optimal for recruitment of the species. The critical reach should meet two basic criteria:

a) The reach should be highly sensitive to changes in stream flow. The rate of change of width, depth and velocity with respect to discharge should be greater for the critical reach than for other portions of the river. Generally the most sensitive reaches with respect to discharge are elevated portions of the channel such as riffles and gravel bars.

b) The critical reach must also act as a biological control. The target species in the IFIM study must be known to be directly limited by the type of habitat present in the critical reach for a particular life stage. For example if the availability of spawning area is known to be limiting to trout populations then a convex gravel bar would be an appropriate choice of critical reach for the IFIM study.

(2) Representative Reach Approach

If it is not possible to identify the availability of a particular habitat type to a particular species life-stage as the limiting factor to success of the species we must sample the relationship between the flow regime and all of the different habitat types present in the length of river to which IFIM conclusions are to be applied. For a single species different habitat types may be limiting to different life stages at different times of the year, and if the IFIM study addresses more than one target species different habitat types may be limiting to populations of the different species. In either case it becomes imperative that our study site represents the full range of habitat types present in the larger length of river.

The process of selecting a representative reach requires the identification of the variety of different habitat types present in the larger stretch of river. In addition to identifying different geomorphological features, eg. pools and riffles, we must identify the distribution of areas having cover,eg. overhead cover, undercut banks, or floating aquatic plants, and areas thought to be of special ecological importance,eg. backwater refuges.

The level of detail in which this surveillance is undertaken will obviously be limited by the availability of resources for the study. Clearly a full topographical survey, species distribution maps and aerial photography are all desirable, but in practice we may limit input at this stage to visual surveillance from bridges and from the bankside where access is possible. Existing data and expert local opinion may be used to supplement the visual survey when resources are limited.

Having identified the variety of different habitat types present in the larger stretch of river we proceed to choose a reach within the stretch which contains examples of all of these habitat types. Clearly the more homogeneous the larger stretch of river the easier this task will become and the shorter the length of the nominated representative reach.

An extra consideration in selecting the exact location of the study reach is the requirement of the hydraulic models within PHABSIM that the most downstream transect be placed at a hydraulic control, upstream of which there is a unique stage-discharge relationship. Whilst it is highly desirable to fulfil this consideration to aid success in the modelling process it may not always be possible to do so without the reach becoming unrepresentative, eg. a reach immediately upstream of a weir may not be representative of those areas further up and downstream.

Having selected the reach for study we next proceed to choose the locations of the transects at which we will sample microhabitat variables.

4.2 TRANSECT PLACEMENT

The first step in the establishment of a PHABSIM study site is the selection of locations to position transects for the measurement of microhabitat variables. The placement of transects must reflect the data requirements of both the hydraulic models and habitat models used in the PHABSIM simulation. Transects must be placed such that they are perpendicular to the direction of flow. To achieve this goal the following procedure is recommended:

(i) Locate most downstream transect

The hydraulic models within PHABSIM require the most downstream transect to be placed at a hydraulic control, upstream of which there is a unique stage-discharge relationship. A hydraulic control is defined as a physical feature, natural or man-made, upstream of which there is a unique stage-discharge relationship. Typical examples are weirs, riffle sections or channel constrictions. Controls are reflected by a break or inflection in the water surface. It is important to recognise that a control will not always be orientated at right angles to the channel banks. If a control runs diagonally across the channel a transect should be placed diagonally along the control, not at right angles to the channel banks.

(ii) Locate most upstream transect

The representative reach is chosen such that it contains all of those habitat types present in the larger stretch of interest. The extent of the reach will thus be dictated by the requirement that all of these habitat types are sampled by the placement of transects within the reach. Thus the most upstream transect should be chosen so as to minimise the total length of the reach whilst satisfying the demand that all habitat types are sampled.

The most recently published user's guide for PHABSIM (Milhous 1990) advises that the most upstream transect also be located at a hydraulic control, although this is not a specific requirement of the hydraulic models within PHABSIM.

(iii) Locate all additional controls

Having defined the upper and lower limits of the study reach it is essential that transects are placed at all hydraulic controls present within the reach. This is necessary to aid success in the hydraulic simulations. It is also recommended that a transect be placed at any bends which occur in the reach.

(iv) Locate additional habitat types

Clearly the transects placed in steps (i) and (ii) will sample some of the different habitat types present within the reach, but rarely will all types be sampled. The next step is, therefore, to place a number of additional transects so as to sample any habitat types which are not sampled by those transects placed in steps (i) and (ii).

(v) Transects for discharge measurement

When running PHABSIM simulations we require the best estimate of discharge for each of the calibration flows. When measuring the discharge in the field using a current meter we expect that the best estimate of discharge will be at a transect through which the flow is steady, parallel to the channel banks, with a fairly uniform depth of water about 0.5 to 1.0 metres, ie. in a run (or glide) section. Having placed transects following steps (i) to (iv) we recommend ensuring that at least two transects are placed in positions where we can expect a good estimate of discharge, by addition of extra transects if necessary.

(vi) Head of pools

For reaches containing pool-riffle sequences it is recommended that transects be placed at the head of pools, well into the transition zone toward the pool, since the head of the pool will migrate upstream with decreasing flow. This is to assist in ensuring a good hydraulic representation of the reach.

Clearly the number of transects which will be required to satisfy the criteria outlined in steps (i)-(vi) will vary with the complexity of the study reach in terms of hydraulics and habitat types. From experience gained in UK PHABSIM studies to date around ten transects is generally the minimum number with fifteen to twenty being required in a more complex than average situation.

4.3 HEADPIN ELEVATION SURVEY

Positions of the transects selected for sampling should be marked on both banks with permanent headpins. In order to establish the relative elevations of the headpins it is necessary to carry out a standard levelling loop. We only require this information for one headpin at each transect hence it is advisable to carry out this survey from whichever bank it is easiest. It is advisable to tie in the elevations of the headpins to a fixed datum level (eg. a nail driven into a tree or a point marked on a bridge) so that it is possible to check for any disturbance to the headpins over time.

4.4 REACH LENGTHS

Once the transects have been located and their positions marked with headpins the distances between adjacent transects must be measured. Taking these measurements at an early stage in the field study is advisable as it can assist greatly in the relocation of headpins. The distances between headpins at adjacent transects must be measured on both banks of the channel. Distances on the left and right banks are then averaged and assigned to the appropriate transect. The reach length value assigned to a particular transect is defined as the averaged distance to the next transect downstream. Hence the reach length assigned to the most downstream transect (No 1 by PHABSIM convention) is zero.

4.5 BED ELEVATION SURVEY

Bed elevations relative to some fixed datum level must be surveyed at every sampling point across each transect. The first step in this process is the selection of the positions of the sampling points at each transect. Points are chosen to satisfy, as well as is practically possible, the following criteria :

(i) The profile of the channel bed must be adequately described. Points should be chosen to coincide with breaks in the slope of the channel bed.

(ii) Variation in substrate/cover across the channel must be adequately described. Points should be placed at points where there is a noticeable change in substrate/cover type.

(iii) Sufficient points must be used to give a reliable estimate of discharge through the transect. It is recommended that no more than ten per cent of the total discharge should pass through any of the cells defined by the mid-points between adjacent sampling points. Points should be added such that all cells satisfy this criterion, using a visual estimate of discharge through each cell.

It is important to remember that these criteria should be satisfied at all of the calibration flows. If, as is often the case for ease of working, the initial survey is conducted at a low summer flow, sufficient points must be placed outside the stream to ensure that higher flows can be modelled with comparable accuracy. Headpins must be located above the anticipated bank full level.

It is a convention within PHABSIM that the horizontal x distances of the sampling points be measured moving from left to right looking upstream, ie. the x coordinate of the left headpin looking upstream is 0.0. Bed elevations at each point may be measured relative to any fixed datum level-the elevation of one of the headpins is a convenient datum level for this purpose.

4.6 MEASUREMENT OF DISCHARGE

We require the mean column velocities at the sampling points at a number of calibration flows in accordance with the data requirements of the hydraulic models within PHABSIM. Technical details are discussed in section 5.2 below. In order to satisfy the minimum data requirements of all of the models it is necessary to measure velocities at all sampling points within the stream at every transect for one of the calibration flows. It is recommended that this flow be the highest of the set of calibration flows. In order that the data set be as consistent as possible this complete set of velocities should be measured over as small a time period as is practically possible. Certainly it is recommended that velocities at different transects be measured on the same day and that the order of measurement is recorded.

Since we require,in the hydraulic modelling process, the development of a stage-discharge relationship at the most downstream transect, it is advisable to measure discharge at this transect for every calibration discharge (minimum of three).

At every calibration flow we require a best estimate of discharge. If a complete set of velocities is not being recorded at a particular calibration flow then velocities should be measured at those transects identified (see 4.3 above) as the most likely to yield reliable discharge estimates.

4.7 WATER SURFACE ELEVATIONS

The water surface elevation relative to some fixed datum level must be measured at each of the calibration flows. At each transect the water surface elevation should be measured at the left side, centre and right side of the stream. These values are then averaged to give an average water surface elevation for each transect. It is recommended that a full set of water surface elevations be measured before measurement of discharge is commenced. Once discharge measurement is completed water surface elevations should be re-measured so that any variation over time can be recognised. This is particularly important when a complete set of velocities is measured over a number of hours or if there is a possibility of flow being altered ,eg. by the altering of sluice gate settings.

4.8 OBSERVATION OF COVER AND SUBSTRATE

As mentioned above the most recent version of PHABSIM available from the U.S. Fish & Wildlife Service uses a single channel index which the user can define to be either substrate or cover. Incorporation of both indices simultaneously is the subject of current research. The current version of PHABSIM gives the user flexibility in the choice of channel index and the choice of coding system used to record the characteristics of the channel index. Essentially any coding system may be used as long as coded observations are in the form of real numbers. When designing such a code the necessity of developing a corresponding preference curve, relating species preference to the discrete coded observations , must be recognised. A coding system which is too simple may not adequately describe changes in the channel index, but if the code is too complex an enormous amount of resource input may be necessary to develop corresponding species preference curves. The coding systems for observation of cover and substrate characteristics used in the initial UK application of PHABSIM were developed by Trihey and Wegner (1981) and are described in tables 1 and 2 below :

Table 1 Conditional cover classification scheme

Cover	Description
0.	No physical cover
1.	0 - 25% of the cell affected by object cover
2.	25 - 50% of the cell affected by object cover
3.	50 - 75% of the cell affected by object cover
4.	75 - 100% of the cell affected by object cover
5.	0 - 25% of the cell has overhanging vegetation
6.	25 - 50% of the cell has overhanging vegetation
7.	50 - 75% of the cell has overhanging vegetation
8.	75 - 100% of the cell has overhanging vegetation
9.	0 - 25% of the cell has undercut bank
10.	25 - 50% of the cell has undercut bank
11.	50 - 75% of the cell has undercut bank
12.	75 - 100% of the cell has undercut bank
13.	0 - 25% of the cell affected by object cover combined with overhanging vegetation
14.	25 - 50% of the cell affected by object cover combined with overhanging vegetation
15.	50 - 75% of the cell affected by object cover combined with overhanging vegetation
16.	75 - 100% of the cell affected by object cover combined with overhanging vegetation
17.	0 - 25% of the cell affected by object cover combined with undercut bank
18.	25 - 50% of the cell affected by object cover combined with undercut bank
19.	50 - 75% of the cell affected by object cover combined with undercut bank
20.	75 - 100% of the cell affected by object cover combined with undercut bank
21.	0 - 25% of the cell has a combination of undercut bank and overhanging vegetation
22.	25 - 50% of the cell has a combination of undercut bank and overhanging vegetation
23.	50 - 75% of the cell has a combination of undercut bank and overhanging vegetation
24.	75 - 100% of the cell has a combination of undercut bank and overhanging vegetation
25.	0 - 25% of the cell has a combination of object cover, undercut bank and overhanging vegetation
26.	25 - 50% of the cell has a combination of object cover, undercut bank and overhanging vegetation
27.	50 - 75% of the cell has a combination of object cover, undercut bank and overhanging vegetation
28.	75 - 100% of the cell has a combination of object cover, undercut bank and overhanging vegetation

SOURCE: Trihey E.W. and Wegner D.L. 1981

Table 2 Substrate classification scheme

1.	Plant
2.	Mud
3.	Silt (<0.062 mm)
4.	Sand (0.062 - 2 mm)
5.	Gravel (2 - 64 mm)
6.	Rubble (64 mm - 250 mm)
7.	Boulder (250 mm - 4000 mm)
8.	Bedrock (solid rock)

SOURCE: Trihey E.W and Wegner D.L. 1981

In the course of the current R&D project a new substrate and cover classification has been developed by the authors in association with Dr Bob Milhous of the U.S. Fish & Wildlife Service, Dr Patrick Armitage and Dr Mike Ladle of IFE Riverlab.

The scope of the current R&D program is extremely broad- to assess the methodology for application to UK rivers with a wide range of different hydrological and ecological characteristics for a number of fish, macroinvertebrate and macrophyte species. In order to devise a code which can be applied successfully in this variety of different conditions it was necessary to maximise generality at the expense of collecting some data which may prove unnecessary in certain situations. If an IFIM study were addressing a more specific problem it may be desirable to simplify the code and thus reduce data collection resource input. This is particularly likely if the study focuses on a particular species life-stage; having identified those elements of the channel indices which are important in defining the species habitat requirements the code may be simplified accordingly. Unless particular reasons have been identified for using a more simple coding system we recommend recording field observations of substrate and cover using the new codes defined below.

Since PHABSIM assumes the channel index to be independent of flow it is only necessary to observe cover and substrate characteristics once during the IFIM study. However, if seasonal variability of these characteristics is pronounced, and considered important to the study, repeat observations and separate simulation runs for different seasons would be appropriate.

Some of the observations required in the coding system require estimates in terms of percentage presence of a particular characteristic over the given area of observation. The cell areas to which PHASBSIM will ultimately assign these values are determined by the assignment of weights (see 4.9 below). For the purpose of field observation we suggest that the area over which observation is made is restricted to the area "close" to the survey point at which the observation is being made. We regard this area as extending approximately 1 metre around the survey point. Careful placement of transects, survey points and assignment of weights should ensure that the habitat characteristics in the reach are realistically described by this "point sampling" approach. Directly observing channel index characteristics over the whole area of cells implicitly defined within the PHABSIM habitat simulation programs is practically almost impossible considering the physical dimensions of these cells.

Thus, for each survey point the following characteristics should be estimated:

Small object cover (<200 mm)	percent	0 to 100
Large object cover (>200 mm)	percent	0 to 100
Overhanging vegetation cover	percent	0 to 100
Instream vegetation	index	0 to 100.00
Undercut bank (Y or N)	existence	0 or 1
Substrate	index	0 to 12000.00
Substrate packing	index	0 to 100

Note, that when making the above measurements that percentages should only be taken in units of 10 percent (it is unrealistic to expect a greater accuracy than this when taking visual measurements).

(i) Vegetation Index.

The instream vegetation index is derived from the following:

No instream vegetation = 0
Streaming type vegetation = 1
Reed type vegetation = 2
Floating vegetation = 3
Streamer & reed vegetation = 4
Streamer & floating vegetation = 5
Reed & floating vegetation = 6

The index is written as XYD.Z, where X is the dominant vegetation type; Y is the subdominant; D is the total coverage of vegetation in units of ten percent (range = 0 to 9), and Z is the percentage of the total vegetation taken up by the dominant. For example, a cell with 30% of the stream bed area covered by vegetation, of which most (60%) is streaming and the remainder is floating, would have the following values: X=1, Y=3, D=3, and Z=60 producing an index of 133.60. If there is only one type of vegetation, and therefore Z would equal 100%, then it should be recorded as X0D.00 rather than X0D.100.

(ii) Substrate Index.

The substrate index is derived from the following:

Plant detritus/organic material		= 11
Clay	(<0.02 mm)	= 2
Silt	(<0.06 mm)	= 3
Sand	(0.06-2.0 mm)	= 4
Fine gravel	(2-8 mm)	= 5
Medium gravel	(8-24 mm)	= 6
Coarse gravel	(24-60 mm)	= 7
Cobble	(60-200 mm)	= 8
Boulder	(200-4000 mm)	= 9
Bedrock	(4000 mm+)	= 10
Terrestrial vegetation		= 11
Man made bank material		= 12

As an approximate guide clay and silt may be distinguished in the field since clay grains stick together and silt does not, also clay has a rather more 'buttery' feel that silt does when rubbed between the fingers. The index should be written in the form X0Y.Z; where X is the number of the most prelevant grain size and Y is the second most common, the two being separated by a zero. Z is the percentage of the total bed surface covered by the most prelevant material. As with the vegetation index, if there is only one type of substrate then it is written as X00.00 rather than X00.100.

4.9 ASSIGNING WEIGHTS

The habitat modelling programs within PHABSIM require the assignment of weights which describe the relative distribution of different types of habitat through the reach. In order to assign values of these weights it is necessary first to identify the major habitat types (eg. pool,riffle,run etc.) present in the study reach. Having completed this task it is then necessary to estimate what proportion of the stream between transects is made up of each of these habitat types. The assignment of these weights to values of habitat variables sampled at each transect in effect defines a grid of cells over which these values are assumed to apply. Unlike in the hydraulic simulation programs these cells do not have boundaries mid-way between adjacent transects. Only in the case where all weights are defined as 0.5 do the boundaries of the cells used in the hydraulic and habitat simulations coincide.

5. Field Survey Techniques and Equipment

The guide to fieldwork techniques given below shows the standard methods used in data collection for this type of study. In the course of the current R&D project some of these methods are being refined and developed. As these methods are not completely proven yet the advice below relates to the most tried and tested field survey techniques. For information on the latest methodologies or using equipment not described here please contact the authors.

5.1 FIELDWORK PLANNING

When beginning field data collection for a PHABSIM study it is vital to start by carefully planning the work that one is about to do. This will pay dividends by ensuring that the work runs as smoothly as possible and minimises time that may be wasted through having incorrect equipment etc. In the inial stages, then it is essential to consider the site that you are to work on and examine any previous work that may have taken place there and to study existing data.

Access to data concerning the flora and fauna found at a site may be very useful not only when selecting the target species for the study, but also in the further development of the suitability indices for those species. In addition to this it is important to consider this information when planning the survey work. For example, if studies involving flora in a river channel have shown that a site is particularly affected by seasonal weed growth then the work must take this into account as it will have major implications for the stage/discharge relationship through the year. Hence, it is advantageous, to select study reaches in areas where much relevant data has been collected in the past, for example sites sampled for macroinvertebrates during the RIVPACS survey can be found on many rivers throughout the U.K. and the data obtained would be useful in this work. Other sources of useful information include Universities, other research institutes etc. as well as from within the regional NRAs.

Another important factor to consider during the initial reach selection process is the size of the catchment at a prospective site. This has quite large implications in the expense and time taken to study a site. If the catchment size is much over 150 km^2 then it is likely that the survey work will involve the use of a boat and/or a cableway system at some point, especially when measuring high flows, with a consequent increase in manpower requirements and thus expense. If a reach is marginal as far as this is concerned then it is worthwhile examining the hydrological records and walking or wading the reach to check what equipment and manpower investment will be needed (see 5:7 for advice on working on large rivers).

Having selected the river copies of detailed maps of the area (such as the OS 1:2500 scale) should be obtained to provide details of nearby benchmarks, site accessibility, hazards such as power lines etc. They may also give one further information concerning the size of the river channel etc. and will be an invaluable aid when producing sketch maps of the location of transects and so on.

Before embarking on a field survey make sure that you have the correct equipment (see 5.8 for the equipment check list), with duplicate gear as back up if any parts of the apparatus is easily broken or is liable to break down. Remember it is better to be over equipped than to have to abandon work, or to put survey staff in physical danger, through the lack of proper equipment.

5.2 LEVELLING

It is assumed that the user of this guide will have levelling experience. However, it is useful to know the type of work that will be required and the necessary accuracy needed to complete the work satisfactorily.

Perhaps the best type of level for this work is the 'automatic' level as these are highly accurate, quick to set up and use and inaccuracies caused by slight movements of the tripod during the survey etc. are minimised. The level should have a vertical accuracy of + or - 1.5 mm over a double levelling run of 1 km or better (as is achievable with most modern levels) and it is advantageous if it is waterproof. The levelling staff should be at least 4 m in length, as light as possible and narrow in section so that gusts of wind will affect it as little as possible. The staff should either incorporate a permanently attached bulls eye spirit level bubble or a separate hand held bulls eye bubble should be provided.

Levelling is used to obtain headpin elevations, channel cross-sections, and water surface elevations. Each of these measurements require slightly different approaches as outlined below:

A: Headpin elevations. The purpose of this is to provide a point of known elevation on each of the transects so that the ground elevations of each point on the cross sections may be calculated. This is achieved by running a simple levelling loop incorporating all of the headpins on the most convenient side of the river. Headpin elevations should be taken to at least 0.5 cm nd the misclosure should be within normally acceptable limits, ie. + or - 12 $(k)^{0.5}$ where k is the length of the circuit in km. When the survey loop has been completed the misclosure should be calculated as soon as possible so that any mistakes can be quickly and easily corrected.

B: Channel cross section survey. This provides the channel cross-section profile data. In this case it is best to set up the level close to the headpin (but not so close that its elevation cannot be read), where it is easy to communicate to the person holding the staff. The elevation of the headpin is taken first and then the elevation of each point along the transect is measured so that there relative heights may be obtained. Horizontal distances are measured by using a tape measure in the usual way. Horizontal distances should be measured to the nearest 30 cm at least and vertical distances should be measured to a minimum accuracy of + or - 5.0 cm.

C: Water surface elevations. For these measurements the level should be set up as in B above, ie. where communication between the surveyors is easy. Firstly, the headpin elevation is taken. Then the water surface height is measured relative to the pin in the following manner:

1: The staff person moves to a suitable measuring point and holds the staff upright just above the water.
2: The level operator focuses the level on the staff and indicates that he or she is ready.
3: The staff person then slowly lowers the staff until it just penetrates the water (a meniscus is just formed between the base of the staff and the water), then holding the staff as steady as possible, shouts 'ready' to the level operator.
4: The level operator takes the reading.

This process may require some practise and it helps if the staff involved are experienced at surveying in general. The measurements should be repeated approximately three times at both banks and in the middle of the river. If the measurements at each point are widely different then it is advisable to take more readings, although one should expect some variation in the water height from one side of the river to the other. The water surface elevations should be measured to the nearest 0.5 cm at least.

When taking the water surface elevations and velocity readings it is important to have a stage board of some kind sited near or within the reach so that any variation in the flow during the survey can be seen and noted.

5.3 CURRENT METERING

It is assumed that, once again, the user of this guide does not require an all encompassing guide to current metering. Consequently, all the usual prerequisites to accurate current metering apply in addition to any advice given here.

Measurement of the water velocities is, perhaps, the most time consuming part of the data collection procedure. There should, therefore, be more than one person in the team current metering at any one time. This obviously requires more than one current meter. Ideally all of the current meters used in the study should be of the same type and should have been recently calibrated so that all of the meters give accurate readings. Perhaps the best type of current meter for this study are those which use electromagnetic induction to get velocity readings rather than the normal 'impellor' type. This is because they are unaffected by weeds etc. that may be growing in the channel. They also tend to be calibrated for life, they are much less difficult to maintain and less prone to breakage.

For each cell only the mean velocity is required, therefore, current meter readings are usually taken at 0.6 of the depth (from the water surface) usual averaged over 30 seconds. Often, though, this may not give an accurate enough representation of the mean velocity due to turbulence or the presence of weeds etc. In this case, readings at other depths may be taken at the surveyors discretion and the mean velocity calculated from these. At each point both the depth of the water and the velocity should be noted.

5.4 APPLICATION OF COVER/SUBSTRATE CODE

The cover and substrate coding system as given in (4.8) should be applied in the following manner.

As stated in (4.8) it should only be applied to an area of 1 meter surrounding each survey point. To avoid confusion when taking the measurements it is suggested that the same staff carry out all of the readings in a survey. This aids consistency in the measurements and also saves time as the staff involved should develop a routine. It will also help if the readings are taken in a consistent order like that given on the survey sheets (appendix A). Readings should be taken for all of the cells, both those in the water and those which may be submerged at higher flows. Further information concerning each characteristic is given below:

A: Small object cover. This refers to any small objects (<200 mm approximately house brick size or less) which lie on the river bed and banks, and may give cover to small fish and invertebrates. Readings are taken as a percentage in units of 10%.

B: Large object cover. This refers to any large object (>200 mm larger than house brick size), as above, which may give cover it larger fish etc. Readings are taken as above.

C: Overhanging vegetation cover. This refers to vegetation external to the river, which may provide shade or cover. The most common example of this is overhanging trees. Readings are taken, again, in percentage terms as in A and should provide a measure of the shading of the cell by the vegetation.

D: Instream vegetation. This refers to the presence of aquatic vegetation that may be growing in the river. In the cells that are outside the river there will probably be no aquatic veg. therefore readings of 0 should be entered. The possibility of all three types of vegetation existing at a point is catered for by taking the dominant two together, such as streamers and reeds (index of 4) and then the least common, in this case floating veg. (index of 3). Streaming vegetation refers to plants growing on the river bed or sides, that is not emergent (unless the plants are very prolific and the river flow very low). Reed type vegetation refers to emergent vegetation (not just reeds) as are usually found growing on the channel margins. Floating vegetation is that which may grow from the bed or banks of the river and forms floating vegetation "mats" with open water underneath.

E: This refers to the presence or not of undercutting of the banks at the channel margin. If the banks are too vegetated to easily recognise this then a suitable stick should be used to determine if the bank is undercut. This is best done by wading and not from the bank, where the ground may collapse underfoot if undercutting has occurred.

F: Substrate index. It is recommended that the person taking the substrate measurements has some experience of sediment size analysis. It is also valuable to predetermine the sizes of each sediment size band. If in doubt physically measure the sediment with a suitable implement. The term plant detritus/organic material refers to dead vegetation such as leaves etc. Terrestrial vegetation refers to such things as grass, stinging nettles and trees which may be found within the cells. Man made bank material refers to situations where the channel structure has been altered by man through the use of concrete etc.

G: Substrate packing. This is an estimation of the amount of packing of the sediment in percentage terms. It is not necessarily dependant on grain size, although clay and silts are likely to be more loosely packed than boulders. It is estimated by moving the substrate by kicking etc. If the substrate is solid then its packing would be in the 90-100% band if the substrate had the consistency of a liquid (ie. was very loosely packed) then its index would be close to 0%.

5.5 RECORDING DATA

It is essential that data is collected in a clear, orderly, fashion so that it may easily be utilised by staff other than those who collected it. Pencil should be used for writing on data sheets as it is unaffected if the record sheet gets wet. Mistakes should be clearly crossed out and corrections made alongside. Notes of any non-routine procedures should be made at the time of the survey. If in doubt clearly note everything as it is surprising what may be forgotten by the time the data is processed. The use of standard data sheets is strongly recommended and examples of these are given in appendix A. The collected data should be logically filed on return from the field visit and processed as soon as possible. A note should also be taken of the person who wrote down the data so that any inconsistencies, for example in handwriting, can hopefully be corrected. The importance of good record keeping cannot be over-emphasised and it is impossible to take too many notes, even if they are not all used in the end.

5.6 FIELDWORK ON LARGE RIVERS

Work on large rivers leads to many problems and often requires different approaches to the data collection than outlined above. The size of the river affects fieldwork in three main ways:

1: Channel width

If the channel is very wide (eg. > 50 m) the accuracy of readings taken with a level may decrease to a point that is unacceptable. It will also become very difficult or impossible to get accurate distance measurements using a tape measure. In this type of situation it is recommended that more accurate type of surveying equipment such as a Total Station Electronic Distance Measuring equipment (EDM) is used for surveying heights and distances. This has the benefit that highly accurate readings may be taken over long distances and that all of the measurements required to locate a survey point are taken at one time. However, the use of this type of equipment will require a computer and the correct software to analyze the data and to calculate variables, such as the distance between survey points, required in the course of the remaining fieldwork. It will also require improved methods of communication between survey staff (such as the use of hand-held CB radios) as they may be more than shouting distance apart.

2: Channel depth

If the channel is deeper than may be safely wadeable then the use of a dry-suit and/or boat may be necessary. It is expected that the user of this guide will have experience of using small boats, and will therefore not require instruction here. The usual method for positioning a boat (usually a small rubber dinghy) is to place a rope or wire across the river and then to use this to move the boat to the required point on the transect. For this it is best to have two people in the boat, one to hold the boat in position and the other to operate the relevant measuring equipment. In high flow conditions it may be necessary to combine this with the use of an outboard motor. In these circumstances great attention must be payed to safety to ensure that the field staff are not endangered.

Where the channel is not particularly wide and a level is being used, it may become apparent that the surveying staff is not long enough to be read at the channel thalweg. In this situation it is possible to firstly measure the water depth using the staff, and then take a reading of the water surface level (as above) and from this calculate the bed elevation. Where an EDM is being used it is possible to obtain extensions for the target prism staff to ensure that it is long enough, although a similar approach to the above may be possible by using a levelling staff to measure the water depth and then surveying the water height using the EDM.

The measurement of cover and substrate will also be difficult in deep water as it is usually impossible to see the river bed. In this case it may be possible to estimate the readings by probing with staff or rod. Alternatively it may be necessary to use a corer/grab to take samples from the bed.

3: Water velocities

It is recommended that the main, initial, channel survey is undertaken at low velocities. However, when measuring calibration flows it may be necessary to work when the river is at a high flow. In this case work should be undertaken from a boat or portable cableway system. Do not attempt to wade the river. Current metering may be undertaken using a cable suspension system, from which the current meter may be lowered into the water. Again in these circumstances pay close attention to safety.

5.7 EQUIPMENT CHECKLIST

Below is a list of equipment required to conduct a PHABSIM study:

General:

Waders (both thigh and chest waders).
Wellington boots.
Waterproofs.
Maps.
Clipboard.
Survey sheets and notebooks.
Polythene bags to keep notebooks and survey sheets in.
Pencils and sharpener.
Tent pegs (for securing tape measure end).
Barrier cream (to protect the hands of people working in the river, it also helps to protect against Wiles disease)
Antiseptic soap.
Water container and fresh water (to wash hands afterwards).
First aid kit.
Puncture repair kit for waders and dry suits etc.
Sledgehammer.
Metal detector.
Carrying bag or rucksack.
Safety line.
Hand held 2 way radios.
Dry suit.
Knife.
Life Jackets (even when not working from a boat it is advisable to have lifejackets available for wading).

Surveying Equipment:

Level (preferably automatic type)

Tripod.
Surveying staff.
Bulls eye bubble spirit level for staff.
At least two 30 or 50 m Tape measures.
Marker flags.
Marker stakes (eg. Permamarks).
EDM, target prism, tripod, staff, data logger/portable computer (for working on large rivers or for producing highly accurate site maps).
Batteries for above.

Current metering.

At least two current meters (preferably electromagnetic).
Wading rods for above.
Batteries for above.
Portable cableway system (for large rivers).

Boat Work.

Rubber dinghy (preferably with wooden floor).
Pump and puncture repair kit.
Outboard motor & fuel.
Oars.
Lifejackets.
Rope (at least 50 m depending on river size)
Anchors and chain.
Anchor stakes.
Cable anchoring system (put across the river to help position the boat).

6. Estimate of Cost of Data Collection for IFIM Studies

Below is an estimate of the cost of data collection expressed in man hours. As a guide to the effect of river size on necessary expenditure the cost has been estimated for both a small river and a large river. It must be stressed that this is only an approximate guide based on the authors experience. Unless otherwise stated each time is calculated for a site with 10 transects in it, each transect having 15 points.

	Small River	Large River	No. of Staff
Initial site visit and reach selection	7 hrs	7 hrs	2
Transect placement and installation of markers	4 hrs	4 hrs	4
Headpin elevation survey inc. reach length survey	3 hrs	4 hrs	4
Bed elevation survey per transect)	½ hr	1 hr	2
Measurement of velocities and water surface elevation (per transect)	1 hr	2 hrs	3
Observation of cover and substrate (per transect)	½ hr	1 hr	2
Site record note taking, eg. sketch maps, video, photographic records etc.	3 hrs	3 hrs	2

Note that some of the measurements may be combined thus saving some time. For example the bed elevation survey could be done simultaneously with the observation of cover and substrate requiring 3 people for approximately 1 or 2 hours for small and large rivers respectively.

7. Guide to Fauna Sampling For IFIM Studies

It is still too early in the project to provide specific guidelines for acquiring data. The aims of this study have included the need to assess the feasibility of using PHABSIM to predict invertebrate responses to habitat loss. With this in mind only broad recommendations can be made.

At each site an assessment of the habitat variability should be made and invertebrate samples collected from each microhabitat. This will provide data on the typical faunal community of each microhabitat. In the present study 5 habitat types have been recognised. Guidance notes on sampling are given below.

7.1 INVERTEBRATE SAMPLING

Identify five micro-habitats which fit as near as possible, into the following categories:

A - SLACK, an area with no flow.
B - MARGINAL, often in marginal plants or in their roots, flow is usually minimal.
C - RIFFLE.
D - WEED, often varies between rivers, sample the weed only not the substrate but record the nature of the substrate and the type of weed.
E - DEEPER/SLOWER, an area within the reach where deposition occurs.

Each sample was taken in a fifteen second period, the depths were recorded in centimetres. **Surface flow velocity** was most easily measured in seconds per meter then converted to standard flow velocities according to the following tabulation.

Velocity category	secs. per meter	cm per sec.
1	> 10	< 10
2	4 - < 10	< 10 - 25
3	2 - < 4	< 25 - 50
4	1 - < 2	< 50 - 100
5	< 1	< 100

Substrate type was recorded according to the following categories:

Boulders	> 256 mm
Cobbles	> 64 - 256 mm
Pebbles	> 16 - 64 mm
Gravel	> 2 - 16 mm
Sand	> 0.0625 - 2 mm
Silt	> 0.004 - 0.0625 mm
Clay	</= 0.004 mm

Percentage substrate cover for each micro-habitat was noted as was the composition of the substrate of the whole reach.

To record the **compaction** of the substrate the following categories were composed according to the effort required to disturb it, this gives a general idea of the compaction over the whole reach.

1 - Very loose, minimum effort required to disturb the substrate.
2 - Loose.
3 - Medium, some effort needed.
4 - Compact.
5 - very compact, very difficult to disturb the substrate.

The sample data (after processing) can be used to supplement data on habitat preferences of various taxa and also assess the possible affects of discharge changes on faunal communities. For example, if the marginal area is likely to be exposed due to abstraction it could be assumed that the marginal community will be displaced. Riffle areas may be reduced and species associated with such areas could be affected. However, this can be a gross simplification and the strongly dynamic nature of invertebrate communities means that there will be a continued adjustment to conditions and frequently local hydraulic conditions are more important determinants of faunal composition than the proportion of flow abstracted. The effects will therefore be very river or site specific. Thus, generalisations may not be applicable in the case of invertebrates. However until it is shown conclusively that invertebrate data are not relevant, samples should be collected in the manner described. They will provide useful data on the "importance" of different microhabitats and add to the bank of knowledge on habitat preferences. In addition they can be used to test the predictions made by PHABSIM which will be based on habitat suitability curves for selected species, characteristic of different microhabitat conditions.

7.2 FISH SAMPLING

At each site an estimate will need to be made of fish population numbers. The most suitable method for achieving this is the multiple catch method. The reach should be fished sufficient times to ensure an adequate drop off in catch to occur; this will normally be at least three times. For each species to be modelled this population will need to be subdivided into adult and juvenile fish. The age structure will, therefore, also need to be determined.

The area to be electrofished should be chosen with regard to the practicalities of electrofishing. Suitable electric fishing methods should be used to ensure a constant and relatively large proportion of the fish present in the reach are caught at each fishing. The reach should be isolated by setting stop nets at the top and bottom of the reach to be fished.

If fish location maps (FLMs) are to be produced, disturbance along the bank of the reach to be fished should be kept to a minimum, especially before the first fishing. Again if FLMs are to be produced the fishing team should try - within the constraints of efficient fishing - not to drive the fish ahead of the anodes. This can be avoided by not having the anodes continually energised, but instead energising them intermittently, if possible targeting likely fish habitats/locations.

Where large numbers of minor fish species are present they may be subsampled by catching them in a short section of the reach only. An estimate of minimum species density can then be calculated for that area and extrapolated to the section as a whole. Fish lengths (fork length) of each fish from each fishing should be recorded. Whilst it may be possible to determine the ages of smaller fish from length-frequency distributions, scales should be taken from all the larger fish and a selection of smaller fish and ages determined in order to verify such assumptions.

Fish should be returned alive to the river at the end of the last fishing.

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Appendices

A: Survey sheet for channel cross section curves and current metering.

SITE: DATE:

CROSS SECTION No. SHEET No. OF:

WATER ELEVATIONS:	LEFT			
STAFF INVOLVED:	CENTRE			
R OR L BANK (PEG Nos)	RIGHT			

LEFT PEG HT: RIGHT PEG HT:

No OF POINT	DIST.ACROSS TRANSECT	ELEVATION (STAFF)	DEPTH	VELOCITY	NOTES

CURRENT METER TYPE:

VELOCITY READING DURATION:

LEVEL TYPE: No:

B: Survey sheet for substrate and cover measurements.

SITE:	DATE:
CROSS SECTION No:	SHEET NO: OF:
STAFF INVOLVED:	

POINT No.	DIST.	SMALL OBJ.%	LARGE OBJ.%	O.H. VEG %	INST. VEG INDEX	U.C. BANK	SUBST INDEX	PACK INDEX

C: Survey sheet for levelling.

SITE:

SHEET No. OF:

DATE:

STAFF INVOLVED:

SURVEY NOTES:

POINT No	BACKSIGHT	FORESIGHT	NOTES