NIWA

Taihoro Nukurangi

RHYHABSIM Computer Manual

I G Jowett

NIWA Science and Technology Series No 14

NIWA Library
J020787

ISSN 1173-0382

NIWA Science and Technology Series No 14

RHYHABSIM Computer Manual

I G Jowett

NIWA

Christchurch

August 1994

Cataloguing-in-publication

Jowett, I.G.
RHYHABSIM Computer Manual / I.G. Jowett -- Christchurch, NZ : National Institute of Water and Atmospheric Research Ltd., 1994. (NIWA science and technology series ; 14)

ISSN 1173-0382
ISBN 0-478-08345-9

I National Institute of Water and Atmospheric Research Ltd. II Title. III Series.

© Crown Copyright 1989, 1994

No part of this publication may be reproduced in any form without the permission of NIWA, except for the purpose of private research or study.

The *NIWA Science and Technology Series* is published by NIWA (the National Institute of Water and Atmospheric Research Ltd.), New Zealand. It supercedes *NIWA Ecosystems Publications* (Issn 1172-3726; published by NIWA Ecosystems, Hamilton, *New Zealand Freshwater Research Reports* (ISSN 1171-9842; published by NIWA Freshwater, Christchurch) and *Miscellaneous Publications, New Zealand Oceanographic Institute* (ISSN 0510-0054).

Available from:

Publications	or:	Publications	or:	Publications
NIWA		NIWA		NIWA
P O Box 8602		P O Box 11-115		Private Bag 14-901
Christchurch		Hamilton		Kilbirnie, Wellington
New Zealand		New Zealand		New Zealand
Ph 03 348 8987		Ph. 07 856 7026		Ph. 04 386 1189
Fax 03 348 5548		Fax 07 856 0151		Fax 04 386 2153

NIWA specialises in meeting information needs for the sustainable development of water and atmospheric resources. It was established on 1 July 1992.

CONTENTS Page No.

1. Introduction

1.1. River Models

RHYHABSIM was developed to provide hydrologists, engineers and resource managers with an integrated solution to some of the more common hydrometric and hydraulic computations, such as

- the calculation of flow gaugings
- computation of hydraulic parameters and slope area gaugings
- hydraulic analysis of flood flows
- determination of flood levels
- reservoir volume and area analysis and calculation of backwater curves
- changes in water depth, width and velocity with flow
- changes in instream habitat with changes in flow.

The basic stream geometrical unit for both gaugings and hydraulic modelling is a cross-section. A hydraulic model is formed by positioning a number of cross-sections so that they represent the significant channel features for the flows to be modelled. Once the geometry of a channel is defined, the model can be calibrated from field measurements and used to predict water level, velocity and habitat suitability at other flows. Calibration procedures allow actual water levels or flood marks and measured or estimated flow to be used to compute friction losses between cross-sections. For instream habitat analysis there is an additional calibration procedure to describe the velocity distribution across the section. Up to 10 instream characteristics or attributes can be described at each measurement point. Average river characteristics and the way in which these change with flow can be determined for use in resource studies. Typically, an attribute describes substrate, instream cover or water surface character however any attribute may be recorded.

Hydraulic modelling or simulation uses the Manning equation and the standard step method (refer to "Open Channel Flow", Henderson, 1966 for further details) to predict the water surface profile for a given set of flows. Each flow and profile can then be analysed to determine how volumes, depths and velocities change with flow either at a cross-section or throughout a reach or a number of reaches on a river. Instream habitat preference criteria can be applied to the simulated water depths, velocities and recorded attributes to give the weighted usable area (WUA) of instream habitat at cross-sections over reaches.

Hydraulic modelling and habitat simulation is a step-by-step procedure with each step progressing to the next. Each **RHYHABSIM** process represents one of the steps in a logical modelling procedure - checking data, calibrating the model, simulating for different flows, evaluating and plotting.

All data files are text (ASCII) to facilitate data entry and editing with any text editor. Programme operation is by menu so that little user learning or knowledge is required.

This manual is divided into three sections.

- The first section describes the types of data, the way in which these are set-out and how to start **RHYHABSIM**.
- The second describes each process, the files required, and the options available within each process.

- The third section gives detailed descriptions of some of the applications for which the programme is designed. This includes detailed comments on locating cross-sections and reaches for hydraulic modelling and procedures for calibration and modelling. Other applications and modification to those described are possible and the author should be contacted if assistance is required.

1.2. Computer Requirements and Setup

The programme runs under MSDOS or PCDOS 3.1 or higher on any IBM clone, either XT or AT, with or without a maths coprocessor. Onscreen graphic displays are provided for Hercules mono, CGA or EGA (640x350 resolution). Output is printed in an 80 column format or can be directed to a disc file. Printout from graphic displays is possible on printers which emulate the Epson MX80 (e.g. IBM graphics printer).

No special setup or configuration is required. When the programme is first run the user is prompted for a number of setup parameters which can be altered at any time using the initialisation process.

2. Data Structure

2.1. Terminology

Data is entered as cross-sections. A cross-section is a series of pairs of values of offset and level. The offset is the distance from the cross-section origin and the level may be either a water depth, height above water surface or ground level. Hydraulic modelling requires that height differences between cross-sections be known. To do this levels at each cross-section are referenced to a common datum or level. Levels in terms of a common datum are termed reduced levels or elevations. Usually hydrographic surveys use the water surface as the reference level for cross-sections and these sections can be used to form a model if level differences between sections are known. Data taken from maps or topographic surveys are usually already in terms of reduced level or elevation.

Cross-sections are usually at right angles to the direction of flow. Water velocities, if measured, can be recorded either as revolutions and time along with meter constants or as the calculated velocity. The meter constants are the coefficient and constant in the equation used to convert the measurement of revolutions/second to a velocity i.e.

velocity = coefficient x revolutions/second + constant.

Multipoint velocity measurements (e.g. at 0.2 and 0.8 or 0.2, 0.6 and 0.8 depth) are averaged to give the mean velocity in the vertical profile.

A number of cross-sections form a reach. Each cross-section is related to the next by two measurements - the distance between them and the elevation. These define the geometry of a reach.

2.2. Units

Units must be metric. Decimal points need only be entered where required.

- depth,distance - metres
- elevation, reduced level and offset - metres
- flow - cubic metres/second
- velocity - metres/second
- current meter revolutions - number
- time for revolutions - seconds
- substrate attributes - percentage
- other attributes - any unit

2.3. File names

The data file may be given any valid name of up to eight characters but must end with the extension *.HAB* or *.XSS*. Throughout this manual the symbol *$* is used to represent a name selected by the user. It is the name of the initial dataset (*$.XSS* or *$.HAB*) and name requested by the **RHYHABSIM** prompt **Name of file?:**. Neither pathnames nor extensions should be specified in response to this prompt. The programme must be operated from the directory containing the data files.

A number of files are generated automatically. Each has the same name as the initial dataset but a different extension. These files contain information which is used in subsequent processes. The following files are ASCII and can be inspected and modified at intermediate processing stages. Modification of *$.CON* and *$.OUT* is not recommended although values can be altered using a text editor if the fixed format is preserved.

File extensions used are :-

- *$.HAB* - initial data (habitat)
- *$.XSS* - initial data (cross-section)
- *$.CON* - hydraulic parameters
- *$.CNV* - data with conveyance factors
- *$.OUT* - simulation results (water surface profile)

Other machine code files created are :-

- *$.SUM* - habitat evaluation results
- *$.$$$* - cross-section data
- *$.PLT* - habitat evaluation results for plan plotting
- *$.TAB* - table of cross-section hydraulic properties.

The purpose and form of these files will be described under the appropriate processes.

There may be one or more text (ASCII) files containing habitat preference criteria. A habitat preference file may be given any valid name but must have the extension *.PRF*. The selection of preference curves generates a file *FISH.DAT* which contains those preference curves in machine code. This file is overwritten if a new set of preference curves is selected. The name of this file reflects its development as a method of assessing fish habitat although it may be used to describe the suitability of instream characteristics for any purpose.

2.4. Data Coding

Data must be entered into **RHYHABSIM** in a particular order. The order is intended to duplicate that used in the field so that entry can be directly from field sheets. To facilitate this field records should be legible with all columns completed in the correct order and units.

Numerical data must be separated by one or more blanks. Fixed format is not required but is useful for visual checking.

Certain word processing programmes can insert non-standard control characters into the text. While TAB characters are recognised, others may not be. Use text editors in non-document mode (ASCII), and check data by listing on the screen with the operating system command **TYPE**. Stray or unusual characters or unusual screen behaviour will indicate the presence of control characters.

Three types of data (gaugings, reduced level and water level referenced) are recognised and are entered with slightly different formats. The data type is identified by a key word which is the same as used by the MWD ICES **ROADS/RIVERS** programme or the Water Resources Survey **GAUGE** programme.

Identification of the dataset is by filename, however additional comments or description of the data can be entered on the data file before the keyword **(GAUGING, BED** or **BED RL)**.

Gaugings

Gauging header

The key word is **GAUGING** followed by a gauging number (1 in the following example) and 7 fields (entries) which are not used by this programme. Then the stage (1.42 in the following example) is entered followed by two more unused fields.

Data items

Water's edge and effective water's edge may be specified with or without percentages of flow. Soundings may also be specified with or without a percentage. The way in which these are used are:

- **WELB,WERB,EWE** followed by percentage - the calculation of the gauging assumes that the mean velocity between the WE and adjacent velocity measurement is the percentage times the velocity measurement. If less than 50% then a negative velocity is assumed at the edge.
- **WELB,WERB,EWE** followed by blank - calculated assuming zero velocity at the edge i.e. equivalent to an assumption of 50%.
- **S** followed by percentage - the velocity at the point of sounding is expressed as the percentage of the previous measured velocity or the next velocity if at an edge.
- **S** followed by blank - velocity interpolated i.e. sounding used to compute area only.

The data items in order are:-

0.98	**18**	**0.79**	**23**	**44**	**0.68**	**0.006**
angle	offset (m)	depth (m)	revolutions	time (sec)	meter coeff.	constants const.

Meter constants must be entered with the first velocity reading. Subsequent values need not be entered and previous values are assumed to apply. Meter constants can be altered from measurement to measurement. Only one pair of meter constants may be entered but the values may change from measurement point to measurement point.

The following example illustrates the various uses of water's edge, soundings, current angles and changing meter constants part way through a gauging.

```
GAUGING 1 101 850120 100000 02 -1 -1 U 1.42 0 L
1.0   5     0     WERB   50
1.0   5.5   .2    S
1.0   7     .79   50     40    .68   .006
1.0   8     1.    40     45    .68   .006
1.0   8     1.    30     40    .68   .006
1.0    8.9  2.7   S      150
1.0   9     1.2   10     40    .68   .006
1.0   9     1.2   20     42    .68   .006
1.0   9     1.2   30     43    .68   .006
1.0   10    1.5   44     44    .68   .006
1.0   11    2.3   S
1.0    11.3 2.3   S
1.0   12    .79   43     45    .68   .006
1.0   13    .79   43     45    .68   .006
1.0   18    .79   23     44    .68   .006
1.0   25    .4    2      45    .49   .002
1.0   30    .2    EWE    50    .49   .002
1.0   35    .1    S      0     .49   .002
1.0   40    0     WELB   0     .49   .002
END
```

This illustrates the use of soundings to define more accurately the area between the last velocity measurement and the effective water's edge. In the centre of the river soundings were used where the depth and/or velocity was too great for wading.

```
GAUGING 2 101 850121 100000 02 -1 -1 U 1.251 0 L
0.98  5     0     WERB   0
0.98  7     .79   50     40    .68   .006
0.98  8     1.    40     45
0.98  8     1.    30     40
0.98  9     1.2   10     40
0.98  9     1.2   20     42
0.98  9     1.2   30     43
0.98  10    1.5   44     44
0.98  12    .79   43     45
0.98  13    .79   43     45
0.98  18    .79   23     44
0.98   19.65 .82  EWE    50
0.98   20   0.5   S
0.98   20 .3 0.4  EWE    75
0.98   23   .39   23     40
0.98  25    .4    2      45
0.98  30    .2    EWE    50
0.98  35    .1    S      0
0.98  40    0     WELB   0
END
END
```

This example illustrates the use of effective water's edge and soundings to describe an instream obstacle which was just upstream of the gauging section. Not an ideal gauging location!

The keyword **END** indicates the end of a gauging and repetition of the keyword **END** indicates the end of a series of gaugings and the end of the input data.

Water level referenced data (instream habitat)

Reach header

The reach header begins with the keyword **BED** and is followed by up to 10 attribute names enclosed in quotes. The order of attribute names is the order in which the numeric values appear.

```
BED DATA 'BEDROCK' 'BOULDER' 'COBBLE'
```

If no attributes are recorded the word **BED** is sufficient.

Any attribute name may be specified but the following, in upper or lower case, are recognised as substrate descriptors to which habitat preference criteria apply. There are eight basic substrate types the keywords for which are :-

- 1 **Vegetation (aquatic macrophytes)**
- 2 **Silt (Mud)**
- 3 **Sand**
- 4 **Finegravel**
- 5 **Gravel**
- 6 **Cobble**
- 7 **Boulder**
- 8 **Bedrock (Rock)**

Minimum specifications of keywords are bold and alternatives are given in brackets.

Cross-section header

Each cross-section has a header which gives the distance upstream from the downstream section, a section name enclosed in quotes (maximum of 9 characters), the reference level of the water surface and a keyword **METER** if current meter revolutions and times are given.

The keyword **METER** can be followed by two or five meter constants. If two constants are entered the first is the slope or multiplier and the second the constant. If five are entered a double curve rating is applied the first pair of slope and constant are applied to the revs/sec and the second pair are applied when the revs/sec exceeds the third value. If the keyword is not followed by meter constants the values for the previous section will be assumed. If the keyword is not specified then data values are assumed to be velocities rather than revolutions and times.

25.0	**'xsect 2'**	**7.632**	**METER**	**0.680 0.006**
Distance (m)	'name'	water level (m)	meter	mult. and constant

or with two stage meter rating

25.0	**'xsect 2'**	**7.632**	**METER**	**0.680 0.006 .932 .725 .002**
Distance	'name'	water level	meter	mult. and constants

or if velocities are entered

25.0	**'xsect-02'**	**7.632**
Distance	'name'	water level

Data items

Data must be entered in order with one offset per line and offsets in ascending order.

The data items in order are :-

4.0	**.60**	**0.96**	**0 10 90**
offset	depth	velocity	attributes (up to 10)

or if revolutions and time is specified.

4.0	.60	40	45.6	0 10 90
offset	depth	revolutions	time	attributes (up to 10)

There may be up to 100 offset measurements to a cross-section.

Values must be entered for every data item at an offset. Velocity entries must be made when using this form of data input. The same number of attributes must be entered at every section. Negative depths represent a height above the water surface. Negative current meter counts indicate water flowing upstream i.e. eddies.

```
BED   'Gravel'   'sand'  'MUD'
0.0   'xsect 1'   7.570
-1.44  -1.30  0   0  0  100
-1.00  -0.53  0   0  0  100
0.0   0.0  0    0  50  50
1.5   0.45  0.12  0  50  50
3.0   0.54  0.64  5  55  40
...
...
101.5  .34  .14   0  10   90
102.3  0.0  0    0  0  100
105.8  -.45  0    0  0  100
108    -1.5  0    0  0  100
END
```

Water velocities entered as item 3.

Note that negative offsets can be used and that banks are described as negative depths.

```
25.0  'xsect 2'   7.632  METER  0.680  0.006
0.0  -1.5  0  0  100  0  0
1.1  -.35  0  0  100  0  0
1.5   0.0  0  0  100  0  0
2.5   .35  25  42.1  90  10  0
4.0   .60  40  45.6  0   10  90
...
...
92     0.0   0   0  0  0  100
94    -.67   0   0  0  0  100
95    -3.8   0   0 100  0  0
END OF SECTION
35.7  'XSECT 3'   7.865   METER
...
...
END OF SECTION
END OF REACH
```

The second section specifies meter constants and revolutions and time as items 3

The third section uses the same meter constants as the previous section.

The keyword **END** indicates the end of a cross-section and repetition of the keyword **END** indicates the end of a reach and the end of the input data.

Multipoint velocity measurements

Multipoint velocity measurements e.g. at 0.2, 0.6 and 0.8 of the water depth are averaged to give the mean column velocity. To enter a multipoint measurement, repeat the offset and depth measurement with the velocity reading or count at each depth. Attributes must be entered with the first velocity measurement but need not be repeated for the following multipoint measurements.

```
1.5   0.0  0  0  100 0 0
2.5   .35  25 42.1 90 10 0
2.5    .35  32 43.1
2.5   .35  12  40
4.0   .60  40 45.6 0  10 90
4.0   .60   23 39.8 0  10 90
```

Reduced level data

Reduced levels are entered like water level referenced data except that the keyword **RL** follows the word **BED**. The main difference is that only pairs of offsets and reduced levels are entered and no velocity readings are required. A reference level or datum level must be entered on each cross-section header but if all levels are to the same datum this can be zero as in the example.

```
FEB 1984 ROXBURGH SEDIMENT SURVEY - comment
BED RL
408 'XSECT-A' 0.0
0.0      133.00
0.020    133.1700
5.800    130.4800
6.300    127.8800
...
...
 63.300    87.02
 66.300    86.6800
 87.000    97.600
 124.08     129.8
end
597.  'XSECT-B' 0
     0.0      133.8400
     0.020    123.1700
    69.300    116.5400
    72.300    86.4800
    75.300    86.5400
...
    159.300    88.0200
    162.300    88.3000
    165.300    89.0100
    168.300    89.7100
    171.300    91.4000
    189.400    132.000
END
END
```

Example of cross-section data which has been taken from contour maps or has already been reduced to a common datum.

2.5. Habitat Preference Criteria

Before habitat can be evaluated a file describing the habitat preference criteria must be set up. This file can have any name but must end with the extension *.PRF*. As with the input data the file is written with a text editor using a keyword system to describe the information contained. Numeric data are separated by one or more blanks. TAB characters are acceptable but beware of other non-standard control characters.

```
Brown trout adult (Bovee)
VELOCITY    .25 .6 1.0 1.2 2.0
WEIGHT       1 .32 .1 0.05 0
DEPTH       .23 0.3 0.6 .76
WEIGHT       0 .6 .72 1
SUBSTRATE    1 2 3 4 5 6 7 8
WEIGHT      0.3 0 .95 1 1 1 .15 0
END
Brown trout juvenile (Bovee)
VELOCITY    0.0 0.1 0.73 1.0
WEIGHT       1 1 .15 0
DEPTH        0 0.2 0.9 1.0 2.0
WEIGHT       0 1 1 .35 0
SUBSTRATE    1 2 3 4 5 6 7 8
WEIGHT      .2 0 0 .5 1 1 .1 0
END
Brown trout fry (Bovee)
VELOCITY    0.0 .34 .6 1.0
WEIGHT       1 1 .3 0
DEPTH       0.0 0.2 0.55 0.9 1.5
WEIGHT       0 1 1 .35 0
SUBSTRATE    1 2 3 4 5 6 7 8
WEIGHT      .2 0 0 .5 1 .9 .2 0
END
```

The first line contains a description of the habitat preference. Only the first 41 characters are recognised.

The remaining lines contain a keyword specifying whether the numbers which follow are weighting factors, depths, velocities or substrate.

The keywords are WEIGHT DEPTH VELOCITY SUBSTRATE with the essential portion of the keywords shown bold.

Depth, velocity and substrate values on a line must increase . If a simulated depth or velocity exceeds or falls below those specified in these criteria, the habitat preference weight of the highest or lowest specified is used. Intermediate values are interpolated linearly. A maximum of 10 values can be specified.

Eight substrate types must be specified by a code number. The types and their respective code numbers are :-
1 Vegetation
2 Silt (Mud)
3 Sand
4 Finegravel
5 Gravel
6 Cobble
7 Boulder
8 Bedrock (Rock)

On the line below that specifying depth, velocity or substrate the keyword WEIGHT must be given and be followed by a set of weighting values of between 0 and 1.

The number of weights specified must equal the number of depths velocities or substrates and cannot exceed 10.

Habitat preference specification ends with the code word **END.**

If the preference specification is such that weights of only 1 and zero are interpolated, the area with ideal habitat (i.e. the area where the velocities, depths and substrate are ideal, as specified by the weight of 1) will be evaluated.

If weights of between 0 and 1 are used then the area of habitat evaluated is the weighted usable area WUA.

Up to 40 different habitat preference criteria can be specified in the *$.PRF* file but only up to 15 can be selected for evaluation at any one time.

2.6. Starting RHYHABSIM

Processes

RHYHABSIM should be operated from one directory on a hard disc system. However if a hard disc is not available you can operate either from the programme disc (where space might be limited), a twin floppy system with data files on one disc and programme files on the other (the default drive i.e. prompt, should be the data disc). To begin the programme **RHYHAB-SIM** simply type the word **RHYHAB** (in the case of a two floppy system **A:RHYHAB**). The system response is to ask for the process name.

If the first process name is appended, that process is entered directly e.g. **RHYHAB SIM** will take you straight into the simulation process.

Any of the processes available may be specified by entering at least the first three letters of the process.

Valid processes are :-

- HELP
- DOS
- INITIALISE (SETUP)
- CHECK DATA
- GAUGE (CALL *GAUGE.EXE*)
- CALCULATE GAUGINGS
- CALIBRATE HYDRAULIC MODEL
- SIMULATE
- SELECT PREFERENCE CRITERIA
- EVALUATE
- PLOT RESULTS
- END

Options

Options available for the processes can be specified by typing a slash (/) followed by the option letter after the process name e.g. **CAL /S /W**. Each process has a number of valid options.

Process	Options
INITIALISE	
DOS	
SELECT	
GAUGE	
CHECK	/P /W
CALCULATE	/P /W /N
CALIBRATE	/P /W /F /N /S /U
SIMULATE	/P /W /F /N /S /H /V
EVALUATE	/P /W /G /N /T
PLOT	/P /W /N
END	

- /P prints result summaries on the printer.
- /W writes result summaries onto *RHYHAB.LST* instead of printer.
- /F specifies that the flows vary through the reach.
- /N specifies that temporary dataset *$.$$$* should be regenerated.
- /S specifies that values of Manning's N apply to the sections rather than between sections.
- /U is used to speed execution if the channel is uniform.
- /V specifies that volume and area should be listed instead of velocity.
- /H specifies that hydraulic properties should be calculated over the full surveyed height of each cross-section rather than over twice the maximum water depth.
- /G specifies that results of the evaluation will be required for plan plotting.
- /T lists results for each transect (cross-section).

Process descriptions contain more detail of option functions.

Printing

The results of any process can be printed out or stored for printing out later in a number of ways.

The option /P on the process name will give printed results. When used in conjunction with some graphical displays, this option will produce a printed table of the data displayed on the screen.

The option /W on the process name stores the summary of results in the list file *RHYHAB.LST*. This file can be edited and printed or renamed for later use. Each time a new process is invoked the existing contents of *RHYHAB.LST* are erased and the new results of the process are stored. **Ctrl-C** should not be used to quit **RHYHABSIM** when using this option.

Printed output is limited to summaries of the calibration parameters, simulated flow profiles and hydraulic characteristics and cross-section and reach evaluations. The **Shift-PrtSc** command can be used to print out text data displayed on the screen and the complete printed record can be made if **Ctrl-P** pressed before beginning **RHYHABSIM**. Graphical displays can be printed by pressing the * key rather than **Shift-PrtSc**.

3. Processes

3.1. Initialisation - process INITIALISE

The file *RHYHAB.CFG* contains details of the configuration previously selected. If this file is deleted or does not exist, the initialisation process is begun automatically.

Drive for temporary file

IBM-AT compatibles can have a virtual disc drive installed in RAM. Reading and writing to RAM is faster so that it can be used to advantage for temporary files. When first using **RHYHABSIM** the user is asked to specify the letter of the drive on which temporary files should be written. The default is the current drive and directory.

For example the following DOS commands in the file *CONFIG.SYS* setup a 128k virtual disc as the next available drive i.e. usually the next letter after your hard disc.

DEVICE=VDISK.SYS 128 512 16

or **DEVICE=RAMDRIVE.SYS 128 512 16**

check your DOS manual to see how to utilise extended memory.

Number of levels

A table of hydraulic parameters for each cross-section is created automatically by a number of processes. The number of levels or values in the table can be set in the initialisation process. The programme then calculates parameters such as hydraulic radius and area for that number of levels starting at the lowest level in the section and finishing at a level where the height above the bed is twice the maximum surveyed water depth. If the specified water level is a datum level below the lowest point of the cross-section the table is calculated between the maximum and minimum heights of the cross- section. This can be forced by specifying the option /H in the process SIMULATE.

A large number of levels will give better accuracy but computing time is longer. The default value is 32. This will normally simulate levels to within 1mm of the levels predicted using maximum resolution.

Text and graphics display colours

If you use EGA or CGA you can set up your colour scheme for text and graphics display. With a monochrome (hercules) graphics display only normal or reverse video can be set.

3.2. Access to DOS - process DOS

This process allows DOS commands to be issued. When the prompt **C:>** appears, enter any command as if at a normal DOS prompt. Remember that you are still in the current directory. Word processing can be usefully carried out from this prompt. If *$.HAB* or *$.XSS* files are altered remember to use the /N option when CALIBRATE is used subsequently.

3.3. River Flow Gaugings - process GAUGE

This process allows gauging data to entered and saved as a text file with the extension *$.XSS* This file can be used by the processes CHECK and CALCULATE. A process within GAUGE also allows a gauging summary to be written onto disc file in a form suitable for input to **MicroTIDEDA**. If this process is used the file *GAUGE.EXE* must be present on the current directory or drive. The process prompt within GAUGE is **Which process** rather than the **RHYHABSIM - Process? :.**

For further details of the GAUGE programme see the GAUGE users manual - Water Resources Survey, Dunedin.

3.4. Checking Data - process CHECK

The process CHECK DATA (/P /W) makes a preliminary check of the input data file *$.HAB* or *$.XSS*. This process checks syntax to ensure that the reach and section headers are entered correctly and then checks that :-

- substrate descriptors (if any) are recognised and associated with substrate type
- section distances increase in order upstream
- cross-section offsets do not decrease across the section
- there are not more than 100 points in cross-section with attributes or less than 300 points in section without attributes
- there are less than 60 cross-sections
- there not more than 10 attributes specified

An attempt will be made to read the whole file, however errors in the reach or section headers and in the data can cause the error messages to have less meaning as processing proceeds.

Warning messages are issued where data may not be correct. In many instances these warnings can be ignored but they may indicate a mistake in data entry. Warnings include :-

- unreasonably high velocities
- negative velocities
- Undefined water's edge (no measurement at zero depth)
- measurements with the same offset but with different depths or attributes
- the substrate values at a point do not add to 100%

Plotting cross-sections

This is useful for data checking. Reduced levels are plotted against offset for each cross-section. If the water level has been recorded the waterway area is shaded and if velocities are recorded they are plotted to a reverse scale above the water level. All sections are plotted to the same scale and the defaults ensure that all data are plotted for all sections. Poor default scaling often results from data errors which cause unreasonably large values of reduced level, velocity or offset. Scales can be specified if required.

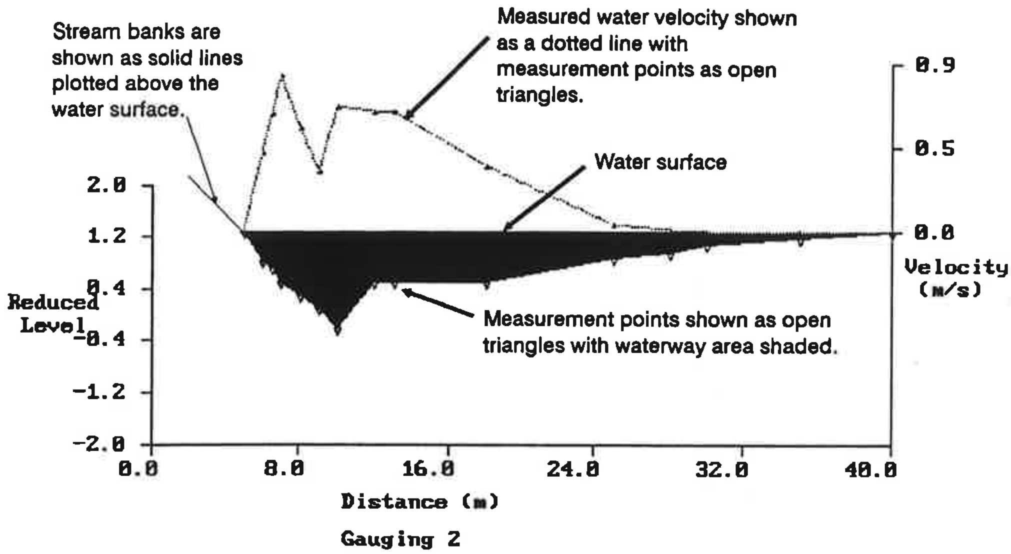


Figure 1 Example of cross-section plot

3.5. Calculation of flow gaugings - process CALCULATE

This process calculates and summarises flows for gaugings. It differs from the flow calculation in CALIBRATE in the form of the output and the ability to use soundings, current angles, different meter constants for one gauging and percentage velocity assumptions. The assumptions used in the calculation are described in Section 2.5. Up to 60 gaugings can be stored and processed on any one file.

File - GAUGE.XSS - 24 June 1989
~ ~ ~ RHYHABSIM gauging summary ~ ~ ~

Number	Gauging	Stage (m)	Discharge (cumecs)	Mean Velocity (m/s)	Cross-section Area (m2)	Hydraulic Radius	Width (m)
1.	243	1.420	8.700	.435	20.004	.514	35.0
2.	244	1.300	7.018	.390	18.000	.509	35.0
3.	245	1.251	6.186	.363	17.045	.482	35.0

Plot stage/discharge points

Gaugings can be displayed on a stage/discharge plot. Default scales are selected but can be altered if required.

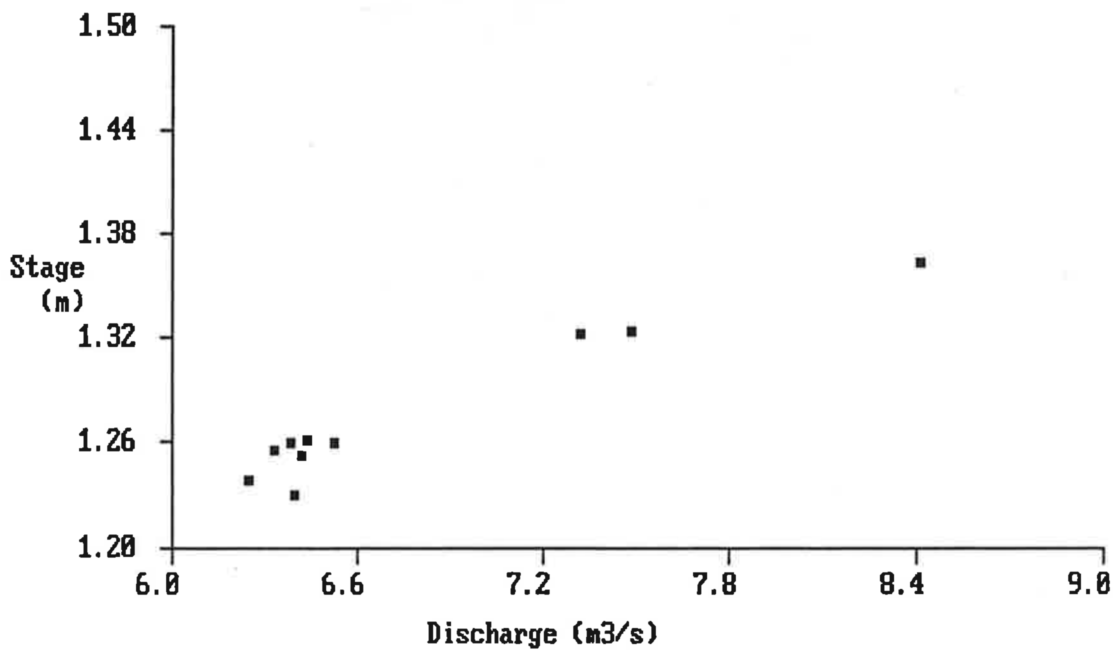


Figure 2 Example of stage/discharge plot

Plot hydraulic characteristics

The variation of cross-section area, hydraulic radius and stream width with level (stage) is displayed for each gauging.

The /P option prints a table of these values. The number of values in the table and the minimum and maximum values can be specified.

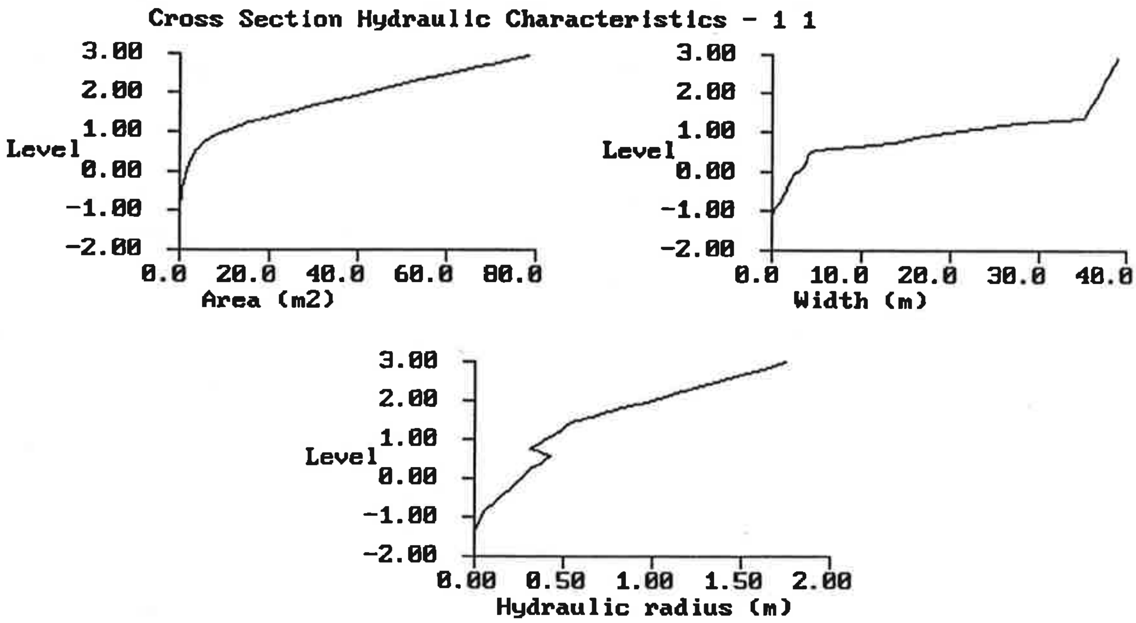


Figure 3 Plot of section hydraulic characteristics

File - GAUGE.XSS - 24 June 1989
Cross Section Hydraulic Characteristics
1 1 Distance .0

Level (m)	Area (m2)	Width (m)	Wetted Perimeter (m)	Hydraulic Radius (m)
-1.280	.00	.00	.00	.000
-1.000	.02	.17	.60	.039
-.500	.43	1.45	3.03	.143
.000	1.45	2.75	5.59	.259
.500	3.25	4.32	7.99	.407
1.000	9.33	18.58	22.42	.416
1.500	22.81	35.21	39.22	.582
2.000	40.73	36.46	41.07	.992
2.500	59.27	37.71	42.92	1.381
3.000	78.43	38.96	44.76	1.752

3.6. Calibration of Hydraulic Model - process CALIBRATE

Hydraulic modelling usually begins with the calibration of the model. The steps in the calibration of a model follow the menu choices in the process. First, flows are calculated, then values of Manning's N are fitted so that they match the flow profile. Loss coefficients can be entered or section elevations adjusted so that reasonable values of N are obtained. Back-calculated values of Manning's N can be used as a useful guide. These adjustments are incorporated in two files (*$.CON* and *$.CNV*) which are used for simulation. Options /P /W /F /U /N /S can be selected.

/P prints output while /W writes it to the file *RHYHAB.LST*.

The /F option initiates prompts for the flow at each cross- section. This can be used to calibrate reaches with tributary inflows or to analyse reaches which were surveyed with slightly varying flows.

/U can be used to decrease computing time if cross-sections are uniform in their shape or more specifically if their hydraulic radii increase monotonically with level.

The option /S applies values of Manning's N at each cross-section rather than between sections and the value at the section is assumed to be an average for a portion of the river both upstream and downstream of the section. Fitting hydraulic parameters using this option is more difficult. The use of this option in CALIBRATE and SIMULATE should be consistent.

The /N option must be used after the *$.XSS* or *$.HAB* file is altered. If this option is not specified the temporary file *$.$$$* (if it exists) is used and will contain a copy of the earlier data. Deleting the temporary file will have the same effect.

Calculate flows

The flow at each cross-section is calculated from offsets, depths and either water velocities or revolutions and times. Data entry format is described in Section 2.6.

Flow is calculated for each cross-section and averaged for the reach. The mean flow for the reach is used as the default value for the calibration process. If its value is influenced by erroneous values at some cross-sections, users may calculate a mean by hand, omitting particular sections, and use this value for calibration.

File - FICKS.HAB - 20 June 1989

Number	Section	Water Level (m)	Discharge (cumecs)	Mean Velocity (m/s)	Cross-section Area (m2)	Energy Coefficient
1.	XSECT-01	9.447	1.281	.405	3.165	1.172
2.	XSECT-02	9.453	1.211	.281	4.316	1.247
3.	XSECT-03	9.453	1.149	.155	7.426	3.027
4.	XSECT-04	9.452	1.059	.114	9.288	7.230
5.	XSECT-05	9.464	1.558	.366	4.260	2.472
6.	XSECT-06	9.475	1.500	.845	1.775	1.263
7.	XSECT-07	9.497	1.447	.251	5.766	8.779
8.	XSECT-08	9.532	1.278	.555	2.303	1.273

Average discharge for reach 1.389 cumecs

Calculate average values of Manning's N between sections

The value of Manning's N between successive pairs of cross-sections is calculated. It is a very useful guide when values are fitted to the whole reach. It also provides a check on the water level data, because a small error in level will cause a sudden increase then decrease (or vice versa) in N and a large error will result in asterisks (*****) being printed as a value of N could not be computed because the water appeared to flow uphill. Results may be stored on the file *$.CON* and, if satisfactory, no further adjustment of hydraulic parameters is required.

However usually some adjustments to levels and loss coefficients should be made so that N varies smoothly and reasonably through the reach.

No values are stored if the option /S is used and the following fitting procedures must be used.

File - FICKS.HAB - 20 June 1989
Average values of Manning's N between sections

		Distance (m)	Flow (cumecs)	Energy coef.	Stage (m)	Manning's N
1	XSECT-01	.00	1.39	1.17	9.447	
						.0204
2	XSECT-02	4.70	1.39	1.25	9.453	
						*****
3	XSECT-03	8.70	1.39	3.03	9.453	
						.1054
4	XSECT-04	12.80	1.39	7.23	9.452	
						.1727
5	XSECT-05	17.80	1.39	2.47	9.464	
						.0595
6	XSECT-06	23.40	1.39	1.26	9.475	
						.0304
7	XSECT-07	28.40	1.39	8.78	9.497	
						.0624
8	XSECT-08	39.10	1.39	1.27	9.532	

Average value of N .0780

Fit Manning's N and loss coefficients to all sections

Manning's N and hydraulic loss coefficients for bends, contractions and expansions must be estimated so that the calculated water surface profile matches that measured in the field. This process is simplified by using the measured water levels to back calculate the values of Manning's N between each pair of cross-sections. This should not be entirely automatic and loss coefficients should be estimated and water levels adjusted so that reasonable values of N are obtained.

Friction losses (Manning's N) can be applied either between cross-sections (the default) or at a cross-section (the /S option). In the former situation the friction loss is taken as an average applying between two sections with the implication that the friction loss may change at the section. Traditionally, measurement of Manning's N has been based on this assumption as water slope is calculated from the height difference between two sections.

A summary of N and loss coefficients is printed after N has been fitted to the last pair of sections.

The user is then asked whether the values of Manning's N and loss coefficients should be stored in a text file named *$.CON* for future use.

Fit Manning's N and loss coefficients from nominated cross-section

This allows hydraulic parameters to be fitted from any upstream section. Usually this option is used to amend values fitted over the whole reach using the previous menu selection. Other than this it operates in the same way as the previous menu selection.

Fit conveyance factors

This process is automatic and when complete a text file, *$.CNV*, containing conveyance factors is created. If one already exists the user is asked whether it is to be overwritten.

After fitting conveyance factors users who wish to simulate instream habitat would normally exit from **RHYHABSIM** (or use the DOS process) and use a text editor to adjust the conveyance factors calculated at the stream edges and above water level.

3.7. Hydraulic Simulation - process SIMULATE

A water surface profile is calculated using a data file and its file of hydraulic parameters (*$.CON*). Normally the data file *$.CNV* is used. If a message stating that this file does not exist is given, the process CALIBRATE should be used to fit conveyance factors and create *$.CNV*. In some circumstances the user may not wish to calculate the velocity distribution across each section (e.g. when modelling only water level) and in such cases hydraulic simulation can proceed from the *$.HAB* or *$.XSS* file. Options /P /W /S /N /F /H are available.

/P prints output while /W writes it to the file *RHYHAB.LST*.

The /S option specifies that Manning's N is to be applied at cross-sections rather than between them. Its use should be consistent with the manner in which N was fitted in CALIBRATE.

The programme calculates parameters such as hydraulic radius and area for a number of levels (specified in the initialisation process) starting at the lowest level in the section and finishing at a level where the height above the bed is twice the maximum surveyed water depth. If the specified water level is a datum level below the lowest point of the cross-section the table is calculated from the maximum and minimum values of the cross- section. This can be forced by specifying the option /H. If the water level is above the highest point surveyed then linear extrapolation is used to estimate the water's edge if the bank slope is greater than 1 in 10. If the slope is less than this a vertical bank is assumed 0.01m from the last point surveyed.

The /F option initiates prompts for the flow at each cross- section. This can be used to model tributary inflows.

The /N option specifies that the temporary file *$.$$$* should be recalculated. This need only be specified if the data file (*$.CNV*) has been altered since the last use of the of the file.

The calculation proceeds in an upstream direction using the level at the downstream section as the starting point. The user must supply a starting water level at the downstream cross-section. If a rating curve - a water level/discharge relationship - has been derived, it is simple to read off and enter the level. See the advanced applications section for hints on the calibration of the downstream section

To assist the user in the selection of the correct level for the flow at the downstream section, some relevant information is listed. This is :-

- Minimum cross-section level
- Maximum cross-section level
- Water level when surveyed
- Water level for critical flow at the section
- Water level for consistent flow

A zero level for consistent or critical flow indicates that these values were not able to be calculated.

After each flow is simulated and results tabulated the user is given the option of filing the results (in *$.OUT*) for plotting and habitat evaluation. Up to 20 simulations may be filed. When simulating high flows the predicted water level may be above the range of tabulated hydraulic characteristics. If this occurs the user will be asked whether the table should be extended. If an affirmative reply is given the table is recalculated for all cross-sections and the simulation can be repeated.

File - WAING1.HAB - 20 June 1989
- BACKWATER CURVE -

Section	Distance	Water level	Discharge	Velocity
XSECT 1	.00	8.410	4.000	.898
XSECT 2	22.10	8.504	4.000	.681
XSECT 3	47.70	8.550	4.000	.508
XSECT 4	72.50	8.568	4.000	.638
XSECT 5	97.60	8.621	4.000	.826
XSECT 6	124.40	8.749	4.000	.851
XSECT 7	153.80	8.911	4.000	.896
XSECT 8	179.10	9.035	4.000	.704
XSECT 9	195.60	9.074	4.000	.552
XSECT 10	214.60	9.189	4.000	.849
XSECT 10A	226.60	9.252	4.000	.518
XSECT 11	240.00	9.269	4.000	.720
XSECT 12	283.10	9.643	4.000	.675
XSECT 13	309.00	9.762	4.000	.635

Plot simulated flow profile

After the last simulation is filed the water surface profile, mean bed level, and simulated flow profiles can be plotted. The mean bed level is the water surface level less the mean water depth (cross-section area divided by width). The variation of width and mean velocity with discharge can also be plotted. Both displays are also available in PLOT. There is one small difference. The water surface profile and mean bed level plotted here are from the file *$.CNV* whereas in PLOT they are taken from the file *$.HAB* or *$.XSS.* If the hydraulic parameters have been accurately fitted to the measured flow profile there will be little difference.

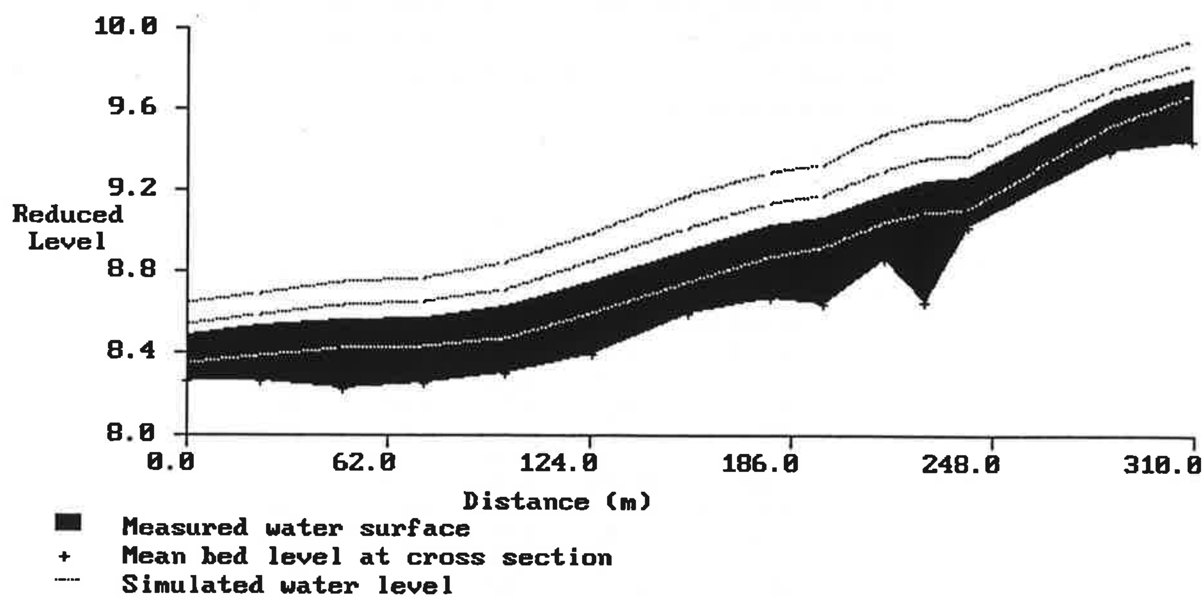


Figure 4 Measured and simulated flow profiles

3.8. Habitat Evaluation - process EVALUATE

The amount of habitat in the reach (in terms of area) is evaluated for a series (between one and twenty) of simulated flows or can be evaluated for the flow at which the survey was made. In the first case the files *$.CNV* and *$.OUT* are used and in the latter the file *$.HAB* or *$.XSS* is used. In both cases the habitat preference criteria which are applied have been selected by using SELECT and are in the file *FISH.DAT*.

/P prints output while /W writes it to the file *RHYHAB.LST*.

/G is used to prepare data for a river plan plot.

/N specifies that the temporary file *$.$$$* should be recalculated. This need only be specified if the data file (*$.CNV* or *$.HAB*) has been altered since the last use of the of the file.

/T lists results cross-section by cross- section. This usually takes some time and is only useful if there is a particular interest in one section or if an error is suspected in a section.

A number of reaches from the same river may be processed and the results incorporated into an overall summary. In this way different reaches can represent different habitat types and be averaged to represent a larger section of the river. Statistics are listed in the data summary.

While many are well known, some have been specially developed and their meaning and intended application is described in some detail below.

Hydraulic parameters

Flow, mean water depth and velocity, stream width, stream length, cross-sectional area, wetted perimeter and maximum velocity are summarised in a table. Parameters describing how water depth and velocity change across sections and throughout a reach are calculated and presented in the table.

*** Reach Summary ***
Hydraulic Parameters
File - WAING1.HAB - 20 June 1989

	Flow (m3/s)	Reach Length (m)	Area (m2)	Width (m)	Wetted Perimeter (m)	Depth characteristics Mean (m)	Maximum (m)	Coef of variation (lat.)	(long.)	Mean dep gradient	Velocity characteristics Mean (m/s)	Maximum (m/s)	Coef of variation (lat.)	(long.)	Mean vel gradient	Relative bed stability
1	2.00	333.0	3.67	14.67	14.75	.26	1.06	.498	.319	.076	.46	1.20	.455	.235	.125	.337
2	4.00	333.0	5.75	18.85	18.94	.31	1.20	.568	.237	.072	.56	1.35	.523	.157	.133	.391
3	6.00	333.0	7.64	21.94	22.06	.36	1.31	.569	.205	.071	.63	1.61	.558	.142	.141	.417
4	10.00	333.0	10.94	25.03	25.19	.45	1.48	.528	.173	.074	.70	1.95	.622	.142	.153	.426

The mean depth in a section is the cross-section area divided by the cross-section width. The mean reach depth is the sum of the mean section depths multiplied by their section lengths divided by the reach length. The mean reach depth does not necessarily equal the mean reach area divided by the mean reach width.

The mean velocity in the above output is the mean velocity across the section rather than the mean velocity within the section and the two are not necessarily the same. The mean velocity within a section is calculated by dividing the discharge by the cross-section area. The mean velocity across a section is the velocity weighted by the water surface width over which it occurs.

Coefficients of variation of depth and velocity are measures of the way in which depth and velocity vary across the sections (lateral variation) or between cross-sections (longitiudinal variation). Low values indicate uniform channels with little variation in depth or velocity whereas high values for these coefficients indicate a higher degree of variability or complexity in the channels.

Depth and velocity gradient are measures of way in which depth and velocity vary across a cross-section. The gradient is the absolute value of the change in depth or velocity between two points divided by the distance between them. Gradients are averaged across the section and through the reach. High values indicate steep banks or velocity shears while low values indicate that depth and velocity have little variation.

Relative Bed Stability is defined, for a particle, as the ratio of the water velocity which will just move the particle to the actual or predicted water velocity.

The velocity (V_c)necessary to just move a particle of diameter D is given in Design of Small Dams (USBR p 791) as;

$$V_c = 4.916\sqrt{D}.$$

The Prandtl Von Karman equation can be used to relate the velocity measured at 0.6 depth (V_m) to the velocity (V) at any height above the stream bed.

$$V = V_m(1 + 7.83N/d^{1/6}(1 + \log_e(y/d))$$

where d = depth

y = height above stream bed

and N = Manning's N

In the Prandtl Von Karman equation the bottom water velocity (V_b) is assumed to be 0.01m above the particle and the depth to be the measured water depth plus 0.5 times the particle size.

The relative bed stability (RBS) is the ratio of two velocities :-

$$RBS = V_b/V_c$$

The cross-section RBS is calculated for each substrate category present and averaged over the section by weighting for the percentages of different substrate types and the spacing of measurement points across the section.

The reach RBS is the average of the cross-section values weighted by the distances between sections.

The following particle sizes are assumed.

Substrate	Assumed size (mm)
1 Vegetation	45
2 Silt (Mud)	0.06
3 Sand	1
4 Finegravel	8
5 Gravel	45
6 Cobble	150
7 Boulder	320
8 Bedrock (Rock)	infinite

The critical velocity for vegetation is assumed to be that which will disturb gravel.

If the critical velocity exceeds the bottom velocity for any category of substrate then the relative bed stability for this category is taken as 1.

Attributes

All attributes are averaged for each flow and are summarised in a table.

*** Reach Summary ***
Recorded Attributes
File - WAING1.HAB - 20 June 1989

	Flow (m3/s)	ROCK	BOUL	COBB	GRAV	FINEG	SAND	VEGE	INVERT
1	2.00	.0	2.6	37.5	51.0	8.3	.5	.0	.3
2	4.00	.0	2.8	34.5	52.8	9.0	.8	.0	.2
3	6.00	.0	3.0	34.1	52.5	9.3	1.1	.0	.2
4	10.00	.0	3.0	33.9	52.2	9.2	1.6	.0	.2

Weighted usable area

Weighted useable area for each of the habitat criteria selected using process SELECT is evaluated and listed for each flow. The weighted usable area is calculated by evaluating the habitat suitability at a point according to the habitat sutability criteria and multiplying it by the area represented by that point.

*** Reach Summary ***
Potential Habitat (WUA)
File - WAING1.HAB - 20 June 1989
Weighting factors used are: Depth, Velocity and Substrate
Flow 2.00 m3/s Reach length 333.00 Metres

Weighting Function	WUA/m (m)	Percentage
Brown trout adult (Bovee)	1.8	12.1
Food producing (Waters)	6.6	45.2

*** Reach Summary ***
Potential Habitat (WUA)
File - WAING1.HAB - 20 June 1989
Weighting factors used are: Depth, Velocity and Substrate
Flow 4.00 m3/s Reach length 333.00 Metres

Weighting Function	WUA/m (m)	Percentage
Brown trout adult (Bovee)	2.1	11.1
Food producing (Waters)	8.4	44.5

Plotting variation of instream habitat

After evaluating instream habitat for simulated flows the results can be displayed. This option is also available in PLOT. Lines between the simulated values are fitted by quadratic interpolation.

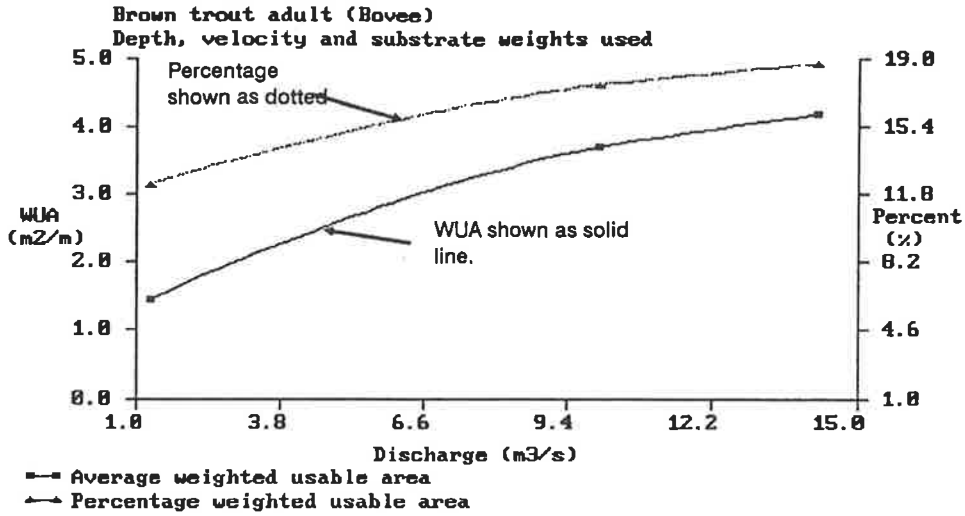


Figure 5 Example of WUA plotted against discharge

3.9. Selection of Habitat Criteria - process SELECT

The process SELECT is used to select habitat preference criteria to be used in the evaluation of habitat at measured or simulated flows. Up to 15 criteria can be selected from the preference curve file *$.PRF* (containing up to 40 sets of criteria) by listing the numbers of the preference criteria to be used. This process writes a machine code file *FISH.DAT* which is subsequently used by the evaluation process.

3.10. Plotting Results - process PLOT

Water surface profiles, weighted usable area (WUA), hydraulic parameters or habitat preference criteria can be displayed. The default RETURN is to plot WUA. River plan plots of hydraulic parameters, attributes or habitat suitability are printed in compressed mode (132 character) on the printer and are not displayed on the VDU. The /P option is used by some of the menu choices to print tables of the data displayed while /W will write them to the file *RHYHAB.LST*. Convenient scales are selected by default but can be specified if required.

Weighted usable area

The variation of weighted usable area (WUA) is plotted against discharge for simulated flows. Lines between simulated values are interpolated quadratically. WUA is plotted as area (m^2) and as a percentage of water surface area. An example is shown in section 3.8

Hydraulic parameters with discharge

The variation of hydraulic radius, mean water velocity and stream width with discharge is displayed. Lines between simulated values are interpolated quadratically.

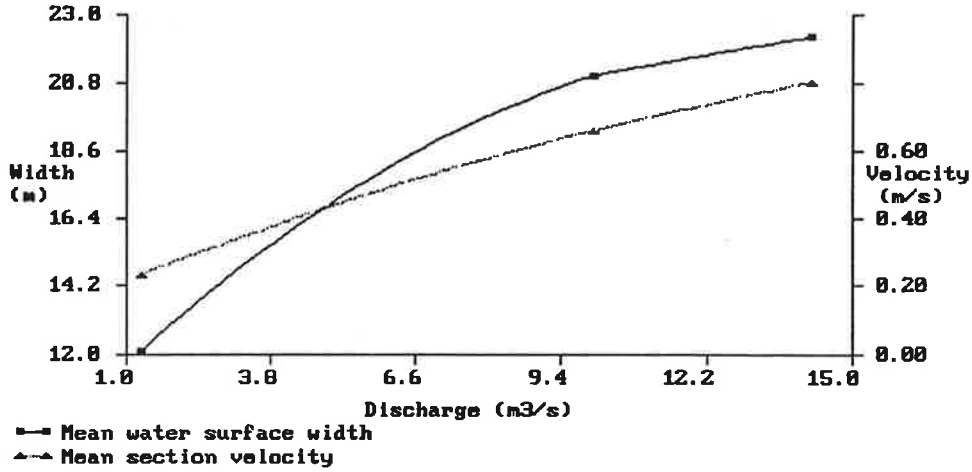


Figure 6 Variation of velocity and depth with flow

Hydraulic parameters with level

The variation of cross-section area, hydraulic radius and stream width with level is displayed for each cross-section. The number of values in the table and the minimum and maximum values can be specified. The /P option prints a table of these values. The form of the table is the same as that produced by the print option of plot hydraulic characteristics in process CALCULATE.. An example of this display and printed output is shown in section 4.5.1.

Reservoir/reach volume, area and depth

The variation of total reservoir or reach volume, surface area and mean depth with level is displayed.

The /P option prints a table of these values. The number of values in the table and the minimum and maximum values can be specified.

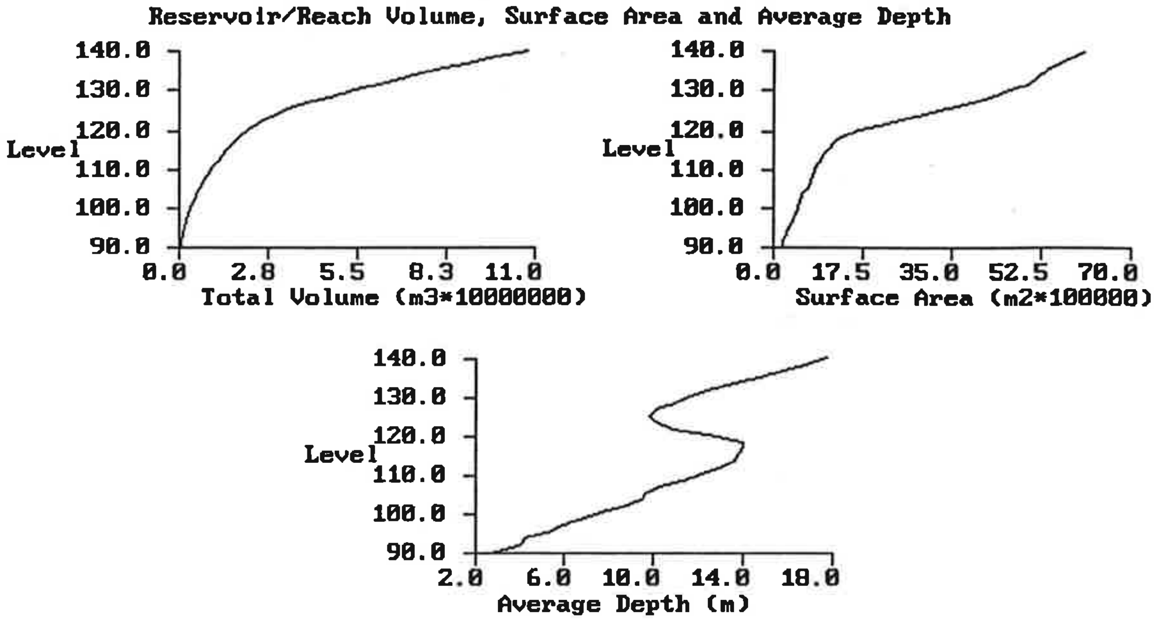


Figure 7 Reservoir area/volume/depth curve

File - DSROXB.HAB - 20 June 1989
Reservoir or River Reach Hydraulic Characteristics

Level (m)	Volume (m3)	Surface Area (m2)	Average Depth (m)
90.000	462086.2	172978.8	.00
90.000	462086.2	172978.8	2.67
95.000	1620055.0	306508.3	5.29
100.000	3575597.0	464989.9	7.69
105.000	6287055.0	650592.8	9.66
110.000	9986367.0	818924.3	12.19
115.000	14573530.0	1057956.0	13.78
120.000	20957030.0	1692085.0	12.39
125.000	33586740.0	3426501.0	9.80
130.000	53800240.0	4623350.0	11.64
135.000	79143670.0	5373826.0	14.73

Water surface profile

This plots the longitudinal water surface profile as recorded in the field as well as the mean bed level at each cross-section and any simulated flow profiles. It is useful as a check on simulated levels as well as a graphic description of the reach. The mean bed level is computed by subtracting the mean depth (cross- section area divided by width) from the water level. If the original file contained reduced levels and did not specify water levels, minimum bed levels are plotted. An example of the display is shown in section 3.7

River plan plots

Print plots of the river in plan view are produced. The user must first EVALUATE the reach using the /G option to generate a temporary data file *$.PLT*. The user can plot water depth, water velocity, relative bed stability, any of the attributes or habitat suitability weights. Scales are selected automatically but can be specified so that the same scale is used for comparative purposes. Plotted symbols represent the value of the item selected for plotting. A 10 point scale is created by dividing the range into 10 equal intervals. Alternatively the maximum and minimum values can be specified. A printer (Epsom emulation) is required.

Habitat preference criteria

Habitat preference criteria for depth, velocity and substrate can be displayed. The user chooses the preference to be plotted by listing their numbers when requested. The default RETURN is to plot all preferences.

Substrate codes used for the X-axis are :-

- V Vegetation
- M Silt (Mud)
- S Sand
- F Finegravel
- G Gravel
- C Cobble
- B Boulder
- R Bedrock (Rock)

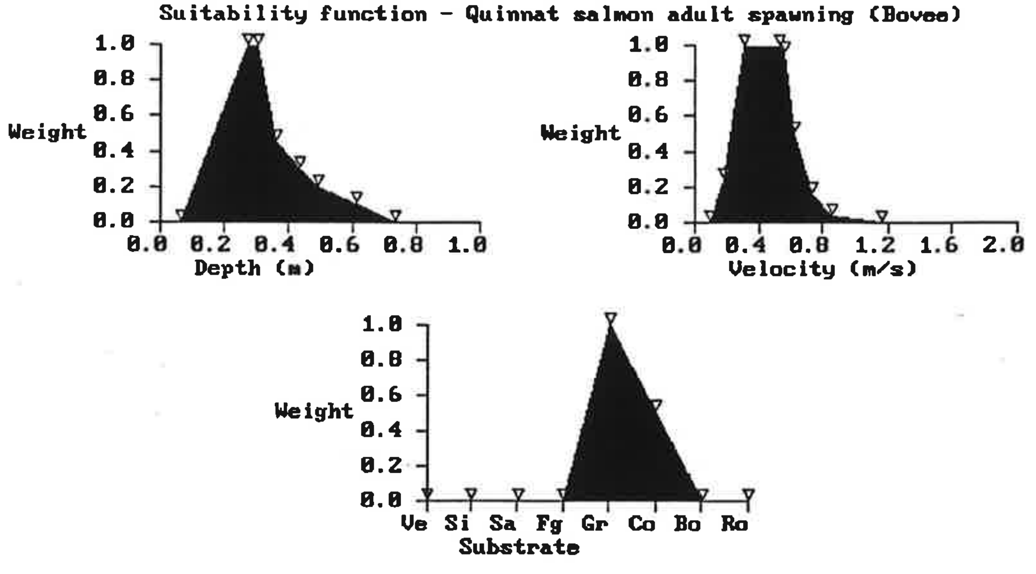


Figure 8 Example of habitat preference criteria

4. ADVANCED APPLICATIONS

4.1. Hydraulic modelling - General

After selecting the channel to be surveyed, a series of cross-sections are marked out and surveyed. The location of cross-sections will be affected by the type of modelling required. For instance low flow modelling, such as in habitat surveys will require more cross-sections than flood flow modelling where the flow is much more uniform and sections can be further apart.

Flows should not vary while water surface profiles are surveyed as varying flows complicate subsequent analysis. If a small fresh occurs during the survey, it is possible to develop an hydraulic model using varying flows throughout the reach.

Cross-section and offset location and spacing determine how realistic the hydraulic model will be. If location and spacing is appropriate there will be little difficulty in calibrating the hydraulic model.

Recording of field data (offset distances, depths, number of revolutions and times) should be accurate and systematic as any errors will cause difficulties when it comes to modelling.

Reach location

The number,location and length of reaches will depend upon the intended purpose of the hydraulic model. Usually reaches are selected so that they represent the character of a longer section of the river. Changes in river gradient and flow often indicate a change in river character.

Cross-section spacing and location

Cross-sections should be spaced so that they represent both the attributes and geometry of the river. The geometry should vary uniformly between cross-sections. Thus the cross- section spacing depends on the uniformity of the stream. Cross-section spacing should decrease where the water surface slope is changing rapidly (e.g. at heads or tails of riffles) and can increase where the water surface slope is constant. It is useful to survey the water surface profile and to plot it in the field to check that cross-sections have been located on and about changes in water surface slope. Large changes in water surface slope between pairs of cross-sections should be avoided.

The water surface across the section should be as near to horizontal as possible. The cross-section need not be in a straight line, and can curve or kink to follow features such as diagonal riffles. This should maintain a constant height difference between all points on the section and the adjacent sections. Usually cross-sections should be at right-angles to the flow but sometimes the requirement to have a horizontal water surface may mean that the flow in all or part of the section is not at right-angles. Minor deviations can be tolerated but if a large part of the flow is not at right-angles, the offset distances can be reduced according to the current angle before processing the data. Failure to do this will result in an excessively large calculated flow for the section and incorrect hydraulic characteristics for the section.

Cross-sections need not be parallel to each other. The distance between cross-sections is measured along the thalweg, however for convenience this is usually taken as the distance between cross-sections or when not parallel, the average of the distance between cross-sections measured along each bank.

Simulation is made easier if the downstream cross-section is located at an hydraulic control which is typically the head of a steep riffle or rapid, a waterfall or a severe constriction. A control is a section where the water level is governed by the flow and geometry at that section alone - the influence from further downstream is minimal. This is a section where the relationship between water level and discharge can be calculated theoretically.

Offset spacing

A series of measurements are made along each cross-section. It is advisable to make measurements at fixed intervals (usually one or two metres depending on the river width) with additional measurements at the water's edge and abrupt changes in section.

The offset is the distance along the cross-section from some origin. If the origin is a straight baseline parallel to the general direction of the river the plan plot will resemble the layout of the river. Usually the origin is zero but negative values are acceptable.

The spacing of offsets is based on similar principles to the spacing of cross-sections.

Section geometry should vary uniformly between offsets. Variable geometry means that offsets should be more closely spaced.

Offset positions should be such that the depths describe the bank, as well as instream, geometry. The bank geometry should be surveyed to or above the water level of the highest flow to be simulated. Heights above water level (a negative value of water depth) can be measured from a taut horizontal tagline using wading rods, can be levelled or can be estimated.

Offsets should be measured at the actual water's edge. An offset at the effective water's edge should also be recorded with a value for the depth and a velocity of zero.

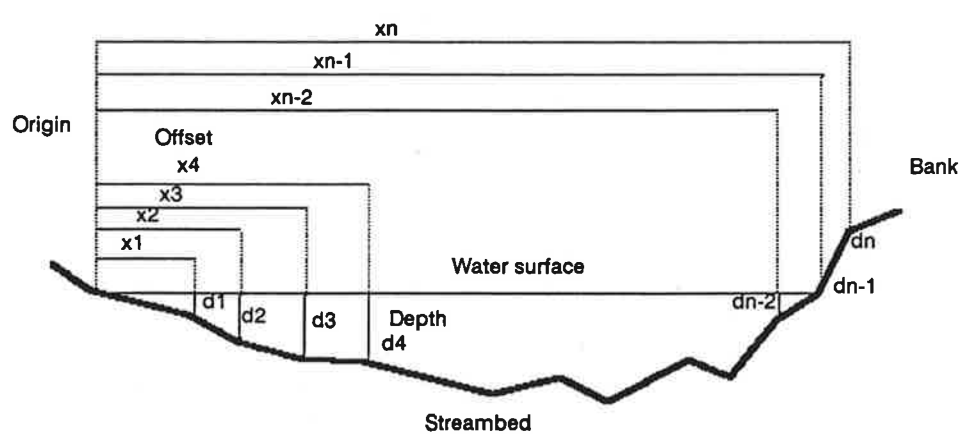


Figure 9 Offset and depth measurements along section

Calibration of downstream section

The relation between water level and discharge at the downstream cross-section gives starting levels from which the upstream water surface profile can be calculated. It is best established by recording water levels for a number of flows in the same way as ratings are established for water level recorders or staff gauges (see hydrology texts such as "Applied Hydrology" by Linsley, Kohler and Paulhus). A fixed peg or staff should be left at the downstream transect so that the level at other flows can be measured. If the range of flows is not sufficient the rating can be extrapolated by a number of methods. Hydraulic calculations using the simulation part of **RHYHABSIM** can assist particularly if the downstream section is at an hydraulic control. The water level for zero flow can be determined from the lowest point on the cross-section (if a control) or from the lowest point on the downstream riffle which would control the water level at very low flows.

To assist the user in the selection of the correct level for the flow at the downstream section, some relevant information is listed. This is :-

- Minimum cross-section level
- Maximum cross-section level
- Water level when surveyed
- Water level for critical flow at the section
- Water level for consistent flow

The first two levels specify the range of acceptable levels.

The third, the water level when surveyed, would be the starting level if simulating the flow at which the survey was made. If a flow higher than this is simulated the starting level should be higher than the surveyed level and if lower the starting level should be lower.

The fourth level is the level at which the flow will be critical. If the downstream section has been located on a control such as the head of a riffle or a narrow constriction then the flow at the section will approach critical. Even if the section is considered to be a control section it is rare to find that the water level as low as the computed critical level. However if the critical level is computed for a number of flows, the general shape of the rating curve can be derived and fitted through the known point - the level and flow at which the survey was made.

The fifth level is the level which would occur if friction alone controls the water level between the two downstream cross- sections. This situation occurs in uniform reaches where there are no obvious controls further downstream. At times it is impossible to compute a level for consistent flow. This indicates that some other form of control, often critical, exists and is commonly encountered if the downstream section has been located at a critical control section. The warning message should be ignored. Simulation of a number of flows can be used to develop a consistent flow rating curve for the downstream section in the same way as the critical levels can be used. Normally an actual rating curve will be a little below the curve for consistent flow (and above the curve for critical flow). Depending upon the type of control (friction or critical) a rating curve can be fitted through the known point (the measured flow and level) with the shape of the consistent or critical flow rating.

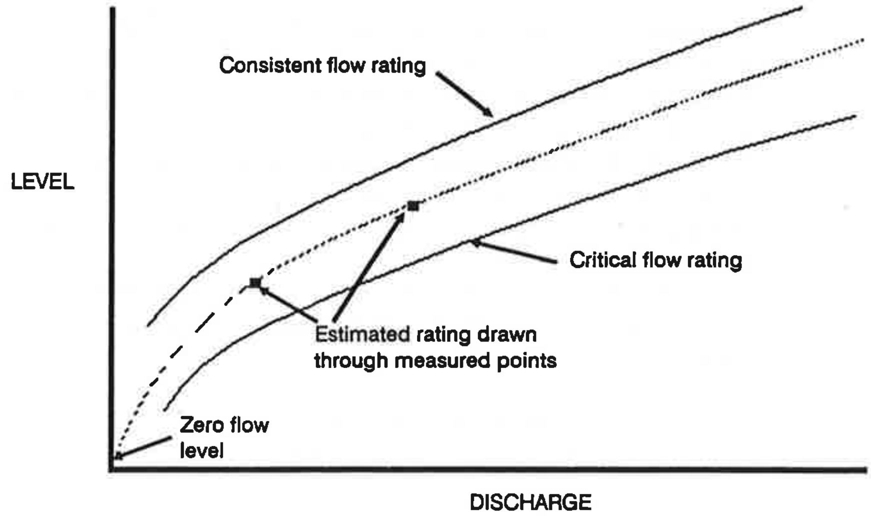
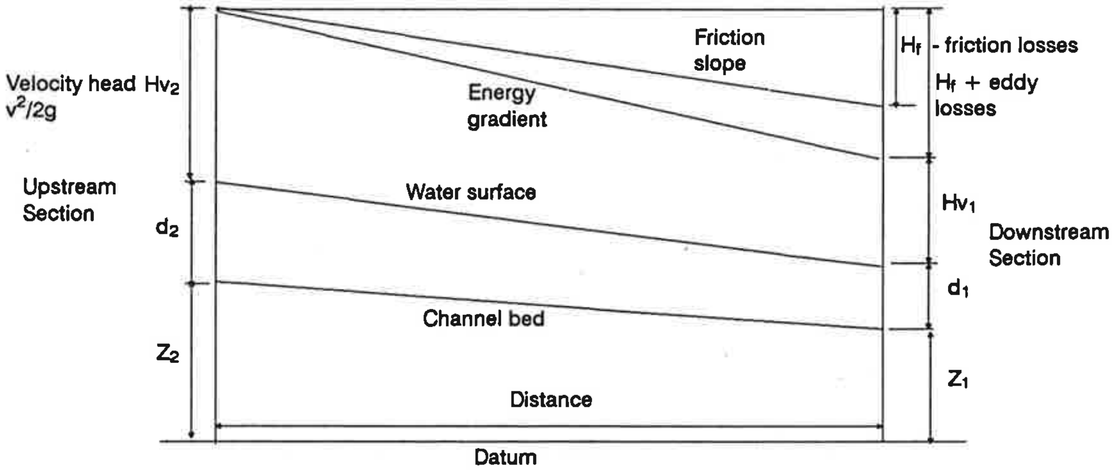


Figure 11 Estimation of rating at downstream control

Estimation of friction and other energy losses

The theoretical base of uniform flow hydraulics and the empirical process of fitting or estimating values of N and loss coefficients is one of energy conservation. The theory is described in various hydraulic texts such as Henderson's "Open Channel Flow" and Ven Te Chow's "Open Channel Hydraulics" and is not repeated in great detail here. CIFG's Instream information paper No 5 gives many practical hints on techniques used.



Total energy at section 2 = total energy at section 1 + losses
$Z_2 + d_2 + Hv_2 = Z_1 + d_1 + Hv_1 + H_f$ + eddy losses

Figure 10 Stream flow energy conservation

When fitting values there are several principles of which the user should be aware :-

- Between any two sections there is a difference in water level and velocity head ($velocity^2/2g$). The total hydraulic losses - friction (Manning's N) , bend , expansion and contraction - must equal the difference in level plus change in velocity head.
- Values of Manning's N should not alter erratically through the reach. Usually values tend to be between 0.025 and 0.08 and to vary gradually through the reach with higher values in riffles and lower values in pools or runs.
- The friction loss is computed from the arithmetic average of the hydraulic properties of the upstream and downstream section. When option /S is specified the friction loss is composed of two parts - a friction loss due to the lower cross-section and its value of N and a friction loss due to the upper cross-section and its different value of N.
- If the head difference (water level + velocity) between the sections is negative, a value of N cannot be calculated. The same situation can arise when option /S is specified and the friction loss due to the lower section exceeds the head difference between the two sections. Such situations should not be possible hydraulically if cross-section locations were placed according to the criteria set out earlier. The inability to calculate a value for N suggests an error in either the measured water levels or the value of N for the lower section (when using option /S).
- If a value for N at the upper section cannot be calculated the user should attempt to reduce hydraulic losses by setting all bend, expansion and contraction coefficients to zero. If this fails the user may either assume that the upstream water level was underestimated and enter a new value or assume that the downstream water level was overestimated and go back to the previous pair of sections to adjust its value. A cross-section can be raised or lowered and normally this should be within the range of measured left, right and mid-stream water levels.
- When using option /S, hydraulic losses can be reduced by reducing the value of N at the downstream section. To reduce N at the downstream section the fitting process must be begun again from a downstream section and new values of water level, N or loss coefficients used so that a lower value of N is calculated for the problem section.

Photographs of the reach often help in the analysis when trying to remember or visualise features such as bends and contractions and other unusual features which might cause problems in the hydraulic modelling. With experience such features could be noted on the field data sheets.

4.2. Instream habitat surveys

The system is similar to that developed by the Cooperative Instream Flow Group (CIFG) in Colorado and for more detailed explanations of the method the user should consult some of their publications such as 'A guide to stream habitat analysis using the instream flow incremental methodology' and 'Hydraulic simulation in instream flow studies - theory and techniques', Instream Flow Information Papers 12 and 4 respectively.

Reach and cross-section location

The reach usually represents an average section of the stream and contains a range of habitat types or attributes. A number of disconnected reaches may be surveyed either to represent the conditions in the section of the stream better or to represent the different characters of sections of the stream. A number of reaches can be summed and averaged in the process EVALUATE. In some instances critical rather than representative reaches can be selected. An example is the shallowest riffles which can be modelled to determine the flow at which the depth falls below a critical level for the passage of fish.

The principles of cross-section location and offset spacing for hydraulic modelling, i.e. that the spacing of measurements decreases as the variability of the geometry increases, also applies to instream attributes. The spacing of cross-sections and offsets reflects the variation in both instream habitat and geometry - fortunately these two things are usually closely related. Surveys should extend above water level and usually the bank should be described to at least one metre above the water surface. Waterproof data sheets are an advantage. An example of a typical field sheet is shown.

Instream Habitat Survey

River		Date		Water Surface Elevation (m)	
Reach		Time		Left bank	
Section no.		Current meter		Midstream	
Distance (m)		Table no.		Right bank	
		constants		mean	

Offset (m)	Depth (m)	Revs	Time secs	Substrate R	B	C	G	F	S	M	V			Comments

Figure 12 Typical instream habitat data sheet

Velocity Measurements

Velocity measurements should be made at all instream offset points and very small velocities should not be ignored. Reverse currents should be recorded as a negative number of revolutions. Velocity or revolutions and time measurements (at 0.6 depth below water surface or at 0.2 and 0.8 if the depth exceeds 1.2m or there is an unusual vertical velocity distribution) are recorded. Water velocities can be measured with 20 second counts rather than the more standard 40 second count. If this is done the actual count and time should be recorded rather than doubling a 20 second count to make it appear as a 40 count. Attributes (substrate etc.) are recorded for every offset both instream and on bank.

Calculation of flows

Flows calculated at each cross-section should be examined closely as excessive variation could indicate data errors. Usually flows at individual cross-sections should not be more than 10% different from the mean. If they are, and are not due to data errors, it is usually because the flow was not at right angles to the section with the result that the flow is overestimated. If this occurs the offset spacing should be adjusted by multiplying by the cosine of the current angle. However there are other possible explanations as cross-sections locations are not ideal flow gauging sections.

Conveyance factors

Conveyance factors, ratios of actual measured velocities to calculated velocities, are fitted automatically. The user should edit the resulting file of conveyance factors adjusting the zero values at the stream edge and above water level.

The conveyance file *$.CNV* is a replica of *$.HAB* except that water velocities measurements are replaced by conveyance factors and the water levels are the adjusted values rather than those originally entered. The conveyance factor is the third item on the data line and follows the offset and depth values.

If a measured water velocity is zero, such as in a backwater, at the water's edge or above the water surface then the conveyance factor will be zero.

When simulating flows, calculated water velocities are multiplied by the conveyance factor to give a simulated water velocity. This will reproduce the measured velocity distribution when the measured flow is simulated. Simulated velocities will always be zero at points with zero conveyance factors. Thus the conveyance factors at the water's edge and banks must be changed from zero to an estimated value if flows higher than measured are to be simulated.

Usually conveyance factors vary across a section in a regular pattern. Adjustments to points should attempt to emulate this pattern.

Flow profile

The water surface at each cross-section is levelled. The water level should be measured at three positions across the section - left bank, right bank and at a mid point - and averaged. When levelling the water surface at the banks, the staff should be held clear of any instream obstructions which are likely to influence the water level locally. The flow profile is the level at each cross-section plotted against the distance upstream and should be a smooth curve with no anomalies such as water flowing uphill. All levelling should be closed and carefully checked. Errors in levelling water surfaces are difficult to detect retrospectively and there is rarely any opportunity to repeat the levelling run.

Weighted usable area

The usable area within a river is the area instream where the physical character (water depth, velocity and substrate, if required) meets the criteria specified in the habitat preferences.

If the preferences are specified so that only weights of 0 or 1 are interpolated for all depths, velocities and substrates, the area is the usable area in m^2.

If the curves are specified so that weights of between 0 and 1 can be interpolated then the area, WUA, is an index of suitability rather than a measure of physical area.

Weighted usable area can be expressed in three ways :-

area (square metres)

width (metres)

percentage stream area or width

It is useful to use WUA in terms of area to identify the flow which maximises habitat whereas WUA in terms of percentage is more useful for comparisons between rivers and for identifying the 'most efficient flow' - that is the flow where the highest proportion of the stream is "usable".

4.3. Instream Habitat surveys without hydraulic modelling

The hydraulical modelling of rivers for low flows is difficult and requires a degree of experience and judgement. Even then there are times and situations where hydraulic simulation is not feasible. **RHYHABSIM** can be used to evaluate changes in instream habitat for flows without a full hydraulic simulation. Although this is a favoured method in the US there has been little demand for such methods in New Zealand and the processes involved in this type of calculation have not yet been linked together in a friendly fashion. The basis of habitat evaluation without hydraulic simulation is to develop stage/discharge relationships for every cross-section surveyed independently rather than by hydraulic modelling. This means that distances between sections and the relative levels between them are not important. Sections can be located anywhere, although free use of this feature can lead to biased surveys. The steps in carrying out such as survey are to locate and survey each cross-section (offsets, velocities, substrate etc.) and then to carry out a series of stage/discharge measurements at each cross-section so that rating curves can be derived. If required curves can be extrapolated using standard hydrological techniques such as logarithmic extension. In this method sections usually represent a particular type of habitat so that section distances can be adjusted to record the average proportions of that type of habitat. Conveyance factors must be estimated for each measurement point on sections. This can be done by entering the data as if it were a reach of high gradient and then fitting hydraulic parameters to this ficticious geometry (these values are not used at any stage but must exist to allow subsequent processes to run). Once a model is developed conveyance factors can be fitted. These conveyance factors depend only on the measured velocities and the surveyed cross-section geometry. After this, the required flows can be simulated to generate the file *\$.OUT*. Examination of this file will show a table of values, one column of which is predicted water level at each section. This column is then replaced by the values taken from the independently derived rating curves. Alternatively, the simulation step can be omitted and a text editor used to generate the *\$.OUT* file. The files containing the conveyance factors *\$.CNV* and the water levels and discharges, file *\$.OUT*, are used to calculate instream habitat in EVALUATE. This may sound complicated but it is possible and relatively easy. It is suggested that intending users contact the author for assistance.

The technique described above can also be used to modify the results of simulations where the flow profile indicates unsatisfactory hydraulic modelling. Small adjustments to predicted water levels can be used to improve the accuracy of habitat evaluations.

4.4. Development of stage/discharge rating curves

At times it is necessary to calculate stage/discharge relationships at points on or along a river without the assistance of stage and discharge measurements taken over a longer time.

Water levels are normally controlled by conditions which prevail downstream. Two types of control are recognised, the critical control of a feature such as the riffle, rapid, constriction or sharp bend and friction control where the friction along a section of the river controls the level. In reality, control is by a combination of friction and critical type controls further downstream.

Stage/discharge relationships can be developed by modelling a reach of the river hydraulically. The survey should begin some distance downstream of the area of interest - usually 4 or so cross-sections are sufficient. A hydraulic survey is setout into the region of interest and cross-sections and water levels surveyed. Hydraulic parameters are estimated from the surveyed flow profile. The downstream section is calibrated by the approximate methods described in the preceding section and flow profiles predicted for the required range of flows. Because the effect of error in the estimated downstream level reduces rapidly as the calculation progresses upstream, it is possible to develop rating curves for the cross-sections which are beyond significant influence of the downstream section. The extent of this influence can be investigated by trying a few levels and plotting the resulting flow profiles.

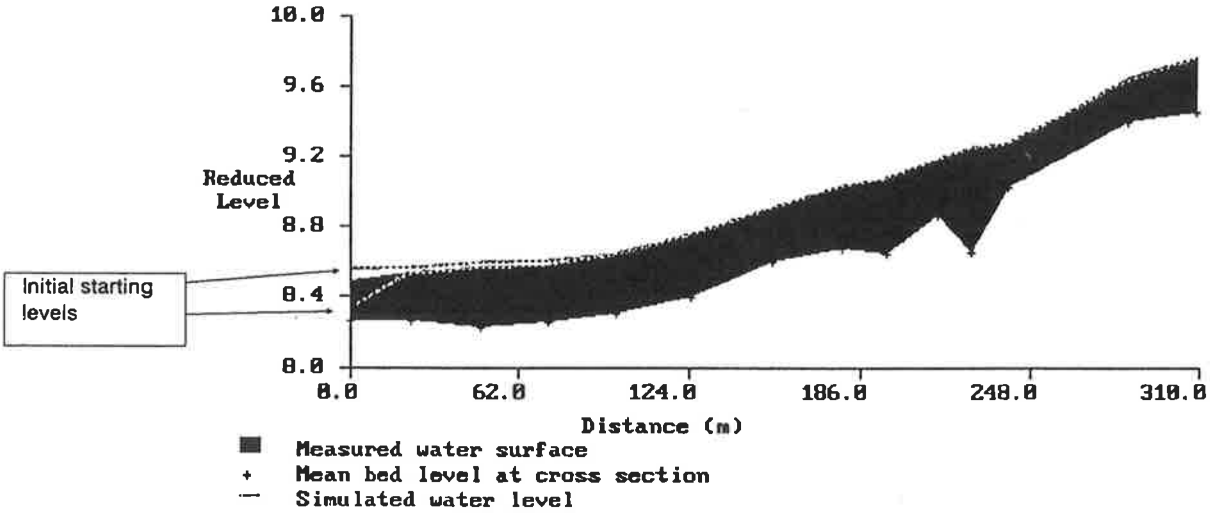


Figure 13 Flow profiles with initial level errors

4.5. Design flood levels and slope-area gaugings

Design flood levels along a river and discharges for slope-area gaugings can be derived.

Flood levels are often determined by modelling hydraulically the section of river being designed. The survey data are usually measured at very different flows to that being modelled. Cross-sections are spaced at greater distances than for low flow modelling but it is still essential that the controlling features such as constrictions and bends be identified. Data may be entered either as reduced levels (if taken from maps) or referenced to water level. In both circumstances one of the most useful features of **RHYHABSIM** is the ability to use past records of flood level and discharge to estimate actual values of Manning's N during floods. This process is similar to the calibration process in low flow modelling except that the recorded flood levels and discharge are entered into the "Calculate average values of Manning's N between sections" menu choice of process CALIBRATE. A similar process is used to calculate a slope-area gauging. The two or more cross-sections and their recorded water levels are entered in the normal manner as RL data. CALIBRATE and the menu choice to "Calculate average values of Manning's N" is used to determine the discharge which gives the estimated value of Manning's N.

4.6. Reservoir volumes and areas

Reservoir volumes, surface areas and mean depths are easily calculated within PLOT /P. Survey data are entered using the reduced level format. If the number of cross-sections exceeds 60 the reservoir can be divided into two or more sections and the totals computed afterwards. Individual section areas can also be tabulated within PLOT /P if required.

The calculation of volume assumes that the end cross-sections extend a distance upstream and downstream equivalent to half the distance between them and the adjacent sections. If the end section is a wall or dam face then the product of the end section cross-section area and half the distance to the next section should be subtracted from the total. Widths and depths should be similarly amended if appropriate.

Differences between volumes calculated for successive surveys can give accumulated volumes of sediment.