# DRIFT USER MANUAL

# BIOPHYSICAL MODULE FOR PREDICTING OVERALL RIVER CONDITION IN SMALL TO MEDIUM SIZED RIVERS WITH RELATIVELY-PREDICTABLE FLOW REGIMES

CA Brown • C Pemberton • A Greyling •
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Water Research Commission

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## Biophysical Module for predicting overall river condition in small to medium sized rivers with relatively-predictable flow regimes

Report to the
Water Research Commission

By

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and
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# EXECUTIVE SUMMARY

### Aims of the Study

The objective of this study is the compilation of a user-friendly step-by-step guide to the biophysical components of the DRIFT methodology, including the DRIFT Hydrological Software, and the DRIFT Database. The user manual and associated software are designed to facilitate technology transfer and will ultimately lead to capacity building among environmental flow practitioners and specialists.

### Introduction

DRIFT (an acronym for Downstream Response to Imposed Flow Transformations) is an Environmental Flow (EF) assessment process that was developed by Southern Waters Ecological Research and Consulting cc (South Africa) in liaison with SMEC International (Australia), various biophysical and socio-economic specialists, and Ninham Shand Consulting Services (South Africa) who assisted with the hydrological manipulations. It is an interactive, holistic approach for advising on environmental flows for rivers. The DRIFT methodology can be used to provide flow scenarios and descriptive numerical summaries of their consequences in terms of the condition of the river ecosystem, for examination and comparison by decision makers.

DRIFT comprises four modules (biophysical, subsistence use, scenario development and compensation economics). This User Manual provides instruction for the implementation of the biophysical aspects of DRIFT, namely Modules 1 and 3. Instructions to determine the links between flow and human and livestock health (Social component – Module 2), and the calculation of compensation and mitigation cost for the Population at Risk (PAR) (Economics component – Module 4), are not included in this manual.

The activities required in DRIFT for these two modules are dealt with sequentially in the manual, as follows:

### Preparation of DRIFT hydrological data

This section of the manual deals with preparation of the DRIFT hydrological data for presentation to the specialists. It:

1. outlines the sequence in which the hydrological data should be analysed;
2. introduces DRIFT-HYDRO© and provides a guide to its application;
3. provides examples of the format of both the input hydrological data files and the output hydrological summary data to the specialists.

### Work with specialists – consequence of flow changes

This section of the manual deals with obtaining the data for population of the DRIFT biophysical database and:

1. outlines the sequence in which specialists should provide their inputs;
2. introduces some of the features that impart structure to specialist deliberations on the consequences of flow changes.

**Populate DRIFT database and generate initial scenarios**

This section of the manual deals with population of the DRIFT biophysical database and with generating scenarios that link modified flow regimes to the ecological conditions in the river that they are likely to produce. It:

1 provides an outline of the DRIFT Database;

2 explains the process of entering data;

3 outlines the steps involved in scenario generation;

4 explains some of the options available for generating scenarios;

5 highlights some of the pitfalls in generating scenarios.

**Generating the Modified Flow Regime for each Scenario**

This section of the manual deals with the generation of a modified flow regime for each DRIFT scenario, and of relevant summary hydrological data.

In addition, a list of supporting literature, and appendices contain full examples of some of the summaries given in the preceding sections, are provided. These include examples of the hydrological data presented to specialists and the calculations used in DRIFT-SOLVER©.

**Development of DRIFT**

The DRIFT methodology and associated software will continue to be upgraded and developed. The worksheets and programs provided with this manual are beta versions, and are freely available for use in determining environmental flows. While every effort has been made to ensure that they work correctly, and provide accurate results, Southern Waters Ecological Research and Consulting, Ninham Shand and the Water Research Commission do not accept any responsibility for any errors or bugs they may contain. The authors will welcome any comments on the methodology and software. A full disclaimer is provided on Page X.

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## ACRONYMS, ABBREVIATIONS, AND GLOSSARY

| | |
|---|---|
| BBM | Building Block Methodology |
| DRIFT | Downstream Response to Imposed Flow Transformations |
| DWAF | Department of Water Affairs and Forestry (RSA) |
| Ecosystem Components | Major division of the ecosystem, e.g geomorphology, water quality, vegetation, fish |
| EF | Environmental Flow |
| EFA | Environmental Flow Assessment |
| EFR | Environmental Flow Requirement |
| Elements | Individual species or chemical compounds that occur in specific Sub-components |
| FDC | Flow Duration Curves |
| Flow Categories | Divisions of the flow regime into ecologically-relevant categories, e.g., floods and low flows |
| Generic List | A list of items that will respond to a change in river flow through a change in their abundance, concentration or extent |
| MCM | Million Cubic Metres |
| PAR | Population At Risk |
| Relatively Predictable Flow Regime | Defined here as flow regimes that can be meaningfully summarised using annual averages. |
| RESOURCE UNIT | Stretches of river that are sufficiently ecologically distinct to warrant their own specification of Ecological Water Requirements |
| RDM | Resource Directed Measures |
| Screens | Display screens within DRIFT-HYDRO©. |
| SMEC | Snowy Mountains Engineering Corporation |
| Sub-components | Major divisions within the Components, such as groups of chemical components (e.g., nutrients), communities of animals (e.g., feeding guilds) or communities of plants (e.g., vegetation zones) |
| WRC | (The South African) Water Research Commission |
| Worksheets | Microsoft Excel worksheets. |

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## DISCLAIMER

***DRIFT-SOLVER©*** *AND* ***DRIFT-HYDRO©***
*WILL CONTINUE TO BE REVIEWED AND UPGRADED.*

*ACCORDINGLY, THE WORKSHEETS AND PROGRAMS PROVIDED WITH THIS MANUAL ARE BETA VERSIONS, AND ARE FREELY AVAILABLE FOR USE IN DETERMINING ENVIRONMENTAL FLOWS AT THE USER'S RISK. WHILE EVERY EFFORT HAS BEEN MADE TO ENSURE THAT THEY WORK CORRECTLY, AND PROVIDE ACCURATE RESULTS,*

*SOUTHERN WATERS ECOLOGICAL RESEARCH AND CONSULTING, NINHAM SHAND AND THE WATER RESEARCH COMMISSION DO NOT ACCEPT ANY RESPONSIBILITY FOR ANY ERRORS OR BUGS THEY MAY CONTAIN.*

*THE FOLLOWING POINTS SHOULD BE NOTED BY ALL USERS:*

- ***DRIFT-SOLVER©*** *AND* ***DRIFT-HYDRO©*** *SHOULD BE USED BY THOSE WHO HAVE EXPERIENCE IN THE FIELDS OF ENVIRONMENTAL FLOW REQUIREMENTS AND/OR HYDROLOGY;*
- *THE DRIFT METHODOLOGY IN ITS CURRENT FORMAT IS ONLY FOR USE ON RIVERS WITH REASONABLY PREDICTABLE FLOW REGIMES, AS THE BULK OF THE DATA ARE SUMMARISED PER ANNUM.*

*ALL COMMENTS AND FEEDBACK ON BOTH* ***DRIFT-SOLVER©*** *AND* ***DRIFT-HYDRO©*** *SHOULD BE SENT TO DR CATE BROWN*
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# 1. INTRODUCTION

## 1.1. BACKGROUND

DRIFT (an acronym for Downstream Response to Imposed Flow Transformations) is an environmental flow assessment process that was developed by Southern Waters Ecological Research and Consulting cc (South Africa) in liaison with SMEC International (Australia), various biophysical and socio-economic specialists, and Ninham Shand Consulting Services (South Africa) who assisted with the hydrological manipulations. It is an interactive, holistic approach for advising on environmental flows for rivers. The DRIFT methodology can be used to provide flow scenarios and descriptive summaries of their consequences in terms of the condition of the river ecosystem, for examination and comparison by decision makers and other interested parties.

In its totality, DRIFT consists of four modules (biophysical, subsistence use, scenario development and compensation economics; Figure 1.1). In the first, or biophysical module, the river ecosystem is described and predictive capacity developed on how it would change with flow changes. In the second, or subsistence module, links are described between riparian people who are common-property subsistence users of river resources, the resources they use, and their health. The objective is to develop predictive capacity of how river changes would impact their lives. In the third module, scenarios are built of potential future flows and of the predicted impacts of these on the river and the riparian people. The fourth, or compensation-economics, module lists compensation and mitigation costs (King *et al.*, 2003).

### 1.1.1. DRIFT and the Building Block Methodology

The DRIFT methodology arose from, and its initial data-collection steps closely approximate those of, the Building Block Methodology (BBM, King and Louw 1998). Like the BBM, DRIFT is a holistic approach, addressing all biophysical aspects of the river of concern. Both employ a multidisciplinary team in a workshop environment to compile one or more modified flow regimes, each of which encompasses a different volume and distribution of flows and will help maintain a different level of river condition.

There are four primary differences between the two processes:

- DRIFT is a scenario-based interactive approach, in which a database is created that can be queried to describe the biophysical consequences of a number of potential future flow regimes (scenarios). It is designed specifically for use in negotiations over water resources. The BBM is a prescriptive approach that requires identification of a single predetermined condition, after which a single flow regime is described to facilitate maintenance of that condition.
- The BBM uses the natural hydrology for a site as the basis from which the assessment is undertaken, whereas DRIFT is based on the present-day hydrology, and uses the natural flow regime for comparative purposes to assess the nature of past changes.
- The BBM "builds up" a recommended flow regime from scratch, whereas DRIFT takes the present-day flow regime as a starting point, and describes the consequences for all aspects of the river of reducing (or, if relevant, of increasing) the volume of water in the river in different ways.

- DRIFT is designed to detail and quantify the links between changing river condition and the social and economic impacts for the riparian people who rely on the river to support their rural livelihoods (Population at Risk or PAR – not dealt with in this manual). The BBM has a less-developed social component that provides less detail of social implications of flow changes.

***Note: DRIFT was developed in a semi-arid country with temperate to sub-tropical river systems and, in the form presented here, is best suited with for application in rivers with reasonably predictable flow regimes, i.e., flow regimes at can be meaningfully summarised using annual averages. Some of its operative features may need modification for other parts of the world of for rivers with unpredictable flow regimes, but this should not negate its use as a process for EF assessment.***

## 1.2. THIS USER MANUAL

This User Manual covers the biophysical aspects of DRIFT, namely Modules 1 and 3. It provides instruction for the implementation of:

- the biophysical module, and;
- the biophysical aspects of the scenario-generation module (Figure 1.1).

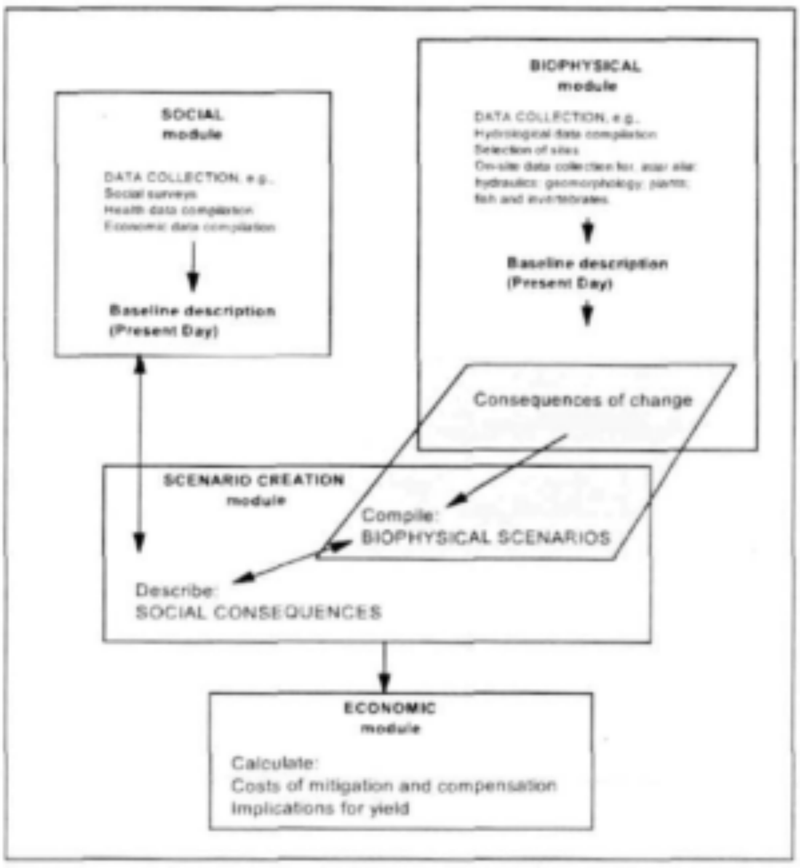



Figure 1.1 DRIFT modules (after King *et al.* 2003) and illustration of the area of focus of this manual (shaded)

The manual assumes that the reader has a working understanding of holistic approaches, such as the BBM.

The early phases of the DRIFT biophysical processes, *viz.* site selection and data collection, approximate those of the BBM, which are outlined in King and Louw (1998) and Tharme and King (1998), and given in detail in King *et al.* (2000). This manual describes the process after the data-collection phase.

### 1.2.1. Companions to this User Manual

This User Manual is intended to provide hands-one guidance on running the biophysical components of DRIFT. Readers requiring additional information of the theory and assumptions underlying DRIFT and its socio-economic components, or on further development of the methodology are directed to:

| | |
|---|---|
| Theory and assumptions: | King *et al.* (2003); Brown and Joubert (2003). |
| Social and economic: | Boehme and Hall (1999). |
| Other developments: | Arthington *et al.* (2003), Boucher (In Press). |

The DRIFT methodology has been used in the following EF studies:

- Instream Flow Requirements for the Lesotho Highlands Water Project (King et al. 2000)
- Instream Flow Requirements for the Palmiet River (Brown et al. 2000)
- Olifants/Doring Comprehensive Reserve Determination Study (Brown and Pemberton 2005)

### 1.2.2. Applicability of DRIFT to different types of rivers

This User Manual focuses on the application of DRIFT to southern African rivers, and many of the examples used, including terminology, hydrological classification, hydrological time steps and the content of the Generic Lists were derived for use in such rivers.

DRIFT can be used for environmental flow analyses for other kinds of rivers, provided the following steps are followed:

- decide on the appropriate terminology for ecologically relevant flows for the river of concern. As an example, the term "flood" may have different meanings in small rivers that remain largely within their banks and in large floodplain rivers. In the small rivers, a flood can be defined as a discrete event where, as a result of a rainfall event, the water levels in the river increase markedly over a period of days and recede again over a similar period. In large floodplain rivers an annual flood may be more relevant, where seasonal rains result in a prolonged period (several months) of higher water levels in the river;
- determine the appropriate time step for analysis of the hydrological information. For instance, in ephemeral or episodic rivers an annual time step may be inappropriate, and data may need to be averaged over much longer periods of five or ten years before the data accurately describe average conditions in the rivers;
- select a team of specialists that covers the most important ecosystem aspects of the river under consideration. For instance, for ephemeral rivers, a geohydrologist would be an essential team member;
- develop an appropriate set of Generic Lists (see Section 3) that reflects the main ways in which the river ecosystem could change with flow change.

Once the terminology, hydrological classification, hydrological time steps and the content of the Generic Lists have been decided on, some alterations to the DRIFT software may be required in order to incorporate the changes.

### 1.2.3. Layout of the manual

The activities required in DRIFT are dealt with sequentially in this manual. Thus:

| | |
|---|---|
| Section 2 | deals with the preparation of the hydrological data for use by the specialists; |
| Section 3 | deals with obtaining the biophysical consequences of changing hydrology from the specialists; |
| Section 4 | explains the steps involved in populating the DRIFT Database and generating scenarios; |
| Section 5 | involves the creation of the modified flow regime for each of the scenarios. |

In Sections 2 to 5, each sub-section is divided into two parts. These are distinguishable through the different fonts used. Essentially, the first part of each sub-section (Arial 11) is a brief description of the step, why it is required, or some summary of what is done in that step or how it links with the other steps. The second part (mainly Arial Narrow 11) provides the practical instructions, with figures, to complete the step.

Sections 6 outlines the direction expected to be followed in the future development of DRIFT and Section 7 provides supporting literature. The Appendices contain full examples of some of the summaries given in the preceding sections. These are referred to individually in the relevant sections.

## 1.3. CENTRAL RATIONALE

DRIFT is essentially a data-management tool, allowing data and knowledge to be used to their best advantage in a structured way. Within DRIFT, component-specific methods are used by each specialist to derive the links between river flow and river condition (biophysical), or between changing river condition and social and economic impact (socio-economic).

The central rationale of DRIFT is that different aspects of the flow regime of a river elicit different responses from the riverine ecosystem (e.g., Table 1.1). Thus, removal of part or all of a particular element of the flow regime will affect the riverine ecosystem differently than will the removal of some other element.

Furthermore:

- it is possible to identify and isolate these elements of the flow regime from the historical hydrological record;
- it is possible to describe the probable biophysical consequences of partial or whole removal of a particular element of the flow regime, in isolation;
- once these biophysical consequences have been described, it is possible to combine them in various ways to describe the overall impact on river condition of a range of potential flow regimes;
- once the potential changes in river condition have been described, it is possible to describe their socio-economic implications (not dealt with here).

Although the accent above (and in this manual) is on water development and removal of flow from the river, the same concepts and process can guide restoration of flows in river rehabilitation projects.

Table 1.1 Different kinds of river flow, and their importance to ecosystem functioning (King *et al.* 2003).

| Flow | Importance to ecosystem |
|---|---|
| Low flows | These are the daily flows that occur outside of high-flow peaks. They define the basic hydrological nature of the river: its dry and wet seasons, and degree of perenniality. The different magnitudes of low-flow in the dry and wet seasons create more or less wetted habitat and different hydraulic and water-quality conditions, which directly influence the balance of species at any time of the year. |
| Small floods | Small floods are ecologically important in semi-arid areas in the dry season. They stimulate spawning in fish, flush out poor-quality water, mobilise and sort gravels and cobbles thereby enhancing physical heterogeneity of the riverbed, and contribute to flow variability. They re-set a wide spectrum of conditions in the river, triggering and synchronising activities as varied as upstream migrations of fish and germination of riparian seedlings. |
| Large floods | Large floods trigger many of the same responses as do the small ones, but additionally provide scouring flows that influence the form of the channel. They mobilise coarse sediments, and deposit silt, nutrients, eggs and seeds on floodplains. They inundate backwaters and secondary channels, and trigger bursts of growth in many species. They re-charge soil moisture levels in the banks, inundate floodplains, and scour estuaries thereby maintaining links with the sea. |
| Flow variability | Fluctuating discharges constantly change conditions through each day and season, creating mosaics of areas inundated and exposed for different lengths of time. The resulting physical heterogeneity determines the local distribution of species: higher physical diversity enhances biodiversity. |

## 1.4. MAIN ACTIVITIES

The DRIFT process involves a number of river-related biophysical and socio-economic activities, which can be divided into the following major steps (Figure 1.2).

Step 1: Use of DRIFT-HYDRO© to prepare the hydrological data for use by the biophysical specialists (Section 2).

Step 2: Linkage of the hydrological statistics to cross-sectional river features at a number of representative river sites and their use by specialists to produce predictions of the biophysical consequences of flow change (Section 3).

Step 3: Population of the DRIFT Database with the flow-ecosystem predictions (Section 4).

Step 4: Use of the DRIFT Database to develop scenarios of flow change linked to ecosystem change (Section 4).

Step 5: Use of DRIFT-HYDRO© to generate modified flow regimes linked to each of the scenarios developed (Section 5).

*Step 6: Identification of the social impacts of each scenario (not dealt with here).*

*Step 7: Calculation of the economic cost of compensation and mitigation for each scenario (not dealt with here).*

*Step 8 Calculation of the impact on system yield for each scenario (not dealt with here).*

## 1.5. Biophysical Disciplines Represented in DRIFT

Ideally, a DRIFT EF assessment should take cognisance of the major ecosystem Components making up the river ecosystem of interest. In practice, the disciplines represented vary depending on the requirements of the particular project and on the budget available. In general, the biophysical specialist team for temperate rivers will consist of representatives of the following disciplines:

- Hydrology
- Hydraulics and physical habitat
- Water quality
- Geomorphology/sedimentology
- Botany
- Macroinvertebrate ecology
- Ichthyology.

Specialists in aquatic parasites, algae, aquatic and semi-aquatic mammals, water birds, plankton and herpetofauna may also be included on the biophysical team, depending on the specific requirements of the environmental flow study.

Similarly the composition of the socio-economic team is project specific, and may include specialists in sociology, anthropology, public health, animal health, water supply, resource economics, scheme economics and public participation.

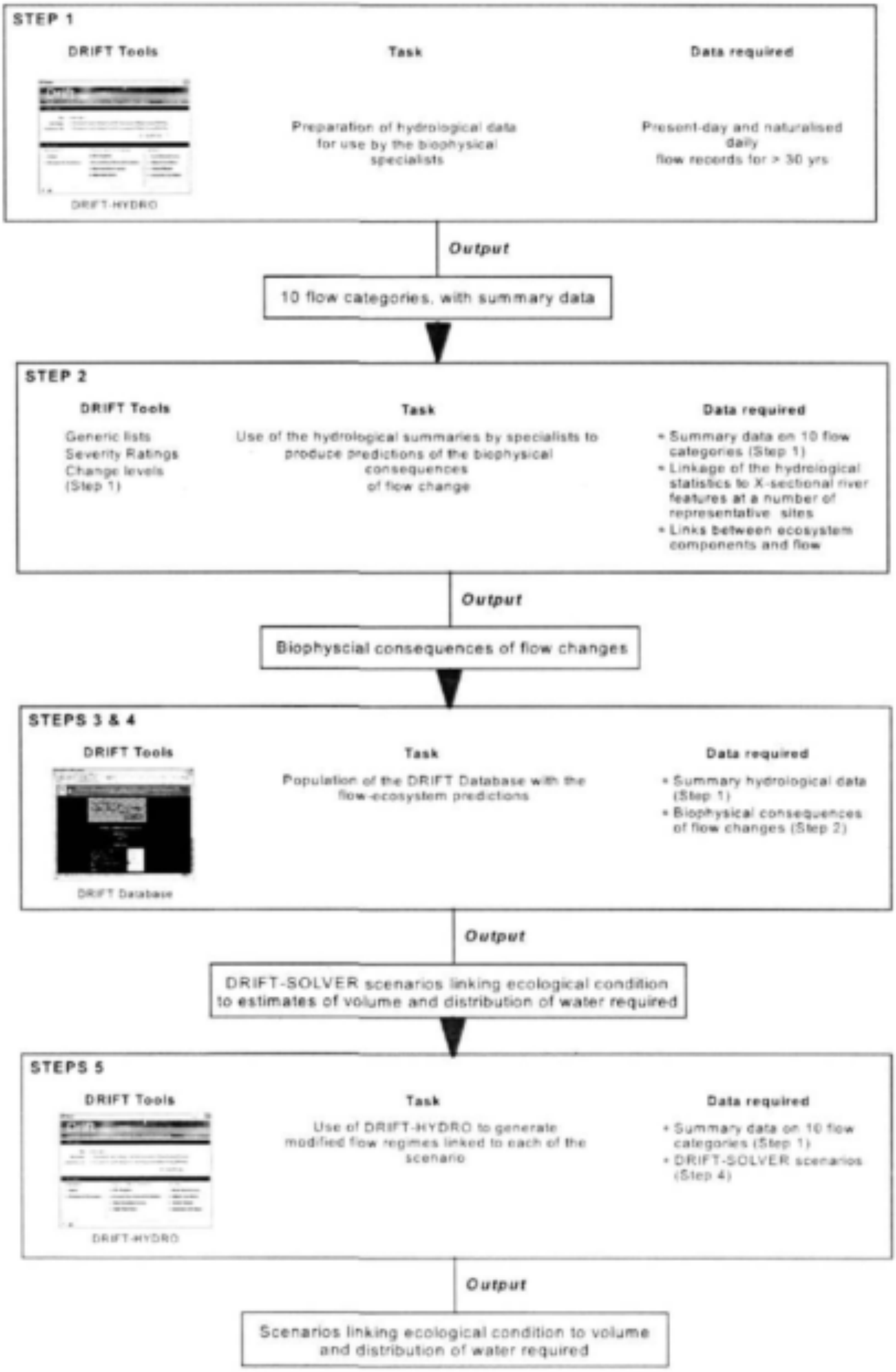



Figure 1.2 Flow diagram showing steps in DRIFT dealt with in this manual.

## 1.6. SOFTWARE PROGRAMS AND SPREADSHEETS AVAILABLE IN DRIFT

There is one hydrological software programme, DRIFT-HYDRO©, and a series of interlinked MS Excel spreadsheets, DRIFT Database, used in DRIFT. The DRIFT Database and DRIFT Hydro are separate entities, with no automated transfer of data between them. Both must be loaded, and the User must manually move data between the two.

### 1.6.1. DRIFT-HYDRO©

DRIFT-HYDRO© is a software package that has been custom-designed to enable the user to undertake all of the hydrological manipulations required in the DRIFT process. These include:

- preparation of the hydrological data, including separation of flow categories;
- generation of the required summary statistics;
- manipulation of the flow categories according to required change levels;
- generation of flow scenarios;
- generation of output tables and graphs.

**Loading DRIFT-HYDRO©**
In order to run DRIFT-HYDRO© the User will need to copy the qtintf.dll file into c:\windows\system. The Drift_#.# folder needs to be copied onto the C: drive.

File organisation and other details of DRIFT-HYDRO© are covered in Section 2.

### 1.6.2. DRIFT Database

The DRIFT Database is a series of MS Excel spreadsheets that:

- stores the matrix of flow-response couplets, predicted by the specialists, for a range of possible flow changes;
- uses this matrix to compute the ecological consequences of different volumes and distributions of water being made available for river maintenance (flow scenarios);
- summarises the ecological consequences of flow scenarios relative to the present ecological state of the river;
- allows predictions to be updated should new information become available.

*Note: In managing and manipulating the database, it is essential that effects of changes in each flow category be assessed in isolation. Thus, for each flow change assessed it should be assumed that the other flow categories would remain at their present day volume and timing.*

**Loading the DRIFT Database**
The templates for the DRIFT Database have no data links to any other programme or file and can be copied into any relevant study folder.

Please note that the DRIFT Database requires that the User be in possession of a legal copy of MS Excel 2000.

## 1.7. DRIFT AND THE SOUTH AFRICAN RESERVE PROCEDURES

DWAF's Resource Directed Measures (RDM) eight-step process is shown in Figure 1.3. This process must be followed for South African Reserve determinations (DWAF 1999). The EF assessment, as described in this manual is Steps 4 and 5. Steps 1-3 and Steps 7 and 8 require use of other methods developed by DWAF. DRIFT, BBM (King and Louw 1998) and Flow Stressor Response (O'Keeffe *et al.* 2002) can all be used in Steps 4 and 5 and do the following:

1 address the EF requirements of rivers in a holistic manner;
2 produce scenarios relating ecosystem condition to the volume and distribution of flows in the river;
3 produce the hydrological summaries and rule tables required by DWAF for Steps 7 and 8.

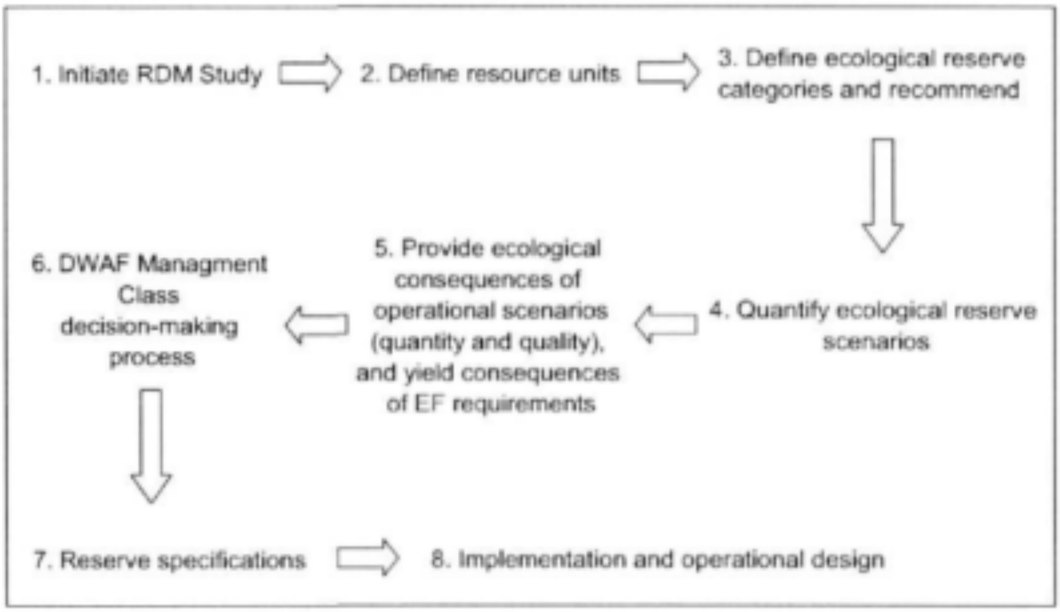



Figure 1.3 The DWAF: RDM eight-step process (Louw and Hughes 2001).

# 2. PREPARATION OF THE DRIFT HYDROLOGICAL DATA

This section of the manual deals with preparation of the DRIFT hydrological data for presentation to the specialists.

The output of this section is summary report, comprising a set of hydrological statistics that are relevant to specialists undertaking an EF assessment.

The section has three main aims:

1 to outline the sequence in which the hydrological data should be analysed;

2 to introduce DRIFT-HYDRO© and provide a guide to its application;

3 to provide examples of the format of both the input hydrological data files and the output hydrological summary data to the specialists.

The next part of the process, obtaining the predictions of biophysical consequences of changes in different components of the flow regime, is dealt with in Section 3.

## 2.1. INTRODUCTION

The first of the main assumptions underlying the DRIFT process is that it is possible to identify and isolate ecologically relevant elements of the flow regime from the historical hydrological record. Thus, one of the first steps in the process, for any river, must be to **identify the ecologically most important flow categories.** In South Africa, for the majority of rivers for which environmental flow assessments have been undertaken, the following ecologically relevant flow categories have been used:

*The low flows:* the daily flows between high-flow peaks are divided into data sets for different seasons, usually:

- wet-season low flows;
- dry-season low flows.

*The floods (or high flows):* the peak events of higher flow are allocated to one of the following:

- four size classes of intra-annual floods;
- floods with a return period of up to 2, 5, 10 and 20 years.

Summary data of these ten flow categories, based on a long-term data set of daily flows that covers wet and dry years describe:

- the *ranges* of low flows within each chosen season, and;
- the *average number per annum* of each class of flood (high-flow) event.

**Note: We have used a single hydrological dataset for illustration throughout Section 2. The data used are for EFR Site 6 on the Groot River, Western Cape (Olifants-Doring EFA study) and are used for illustrative purposes only.**

## 2.2. LAYOUT OF DRIFT-HYDRO©

The DRIFT hydrological manipulations involve several modules and processes, making it necessary to provide a structured interface. To this end, the software is arranged into three groups of processes:

**Parameters**: This section comprises all data specified by the user, e.g., the definition of seasons, sizes of flood classes and composition of scenarios. The parameters required are arranged in several groups according to the modules they appear in and processes they perform.

**Charts, Info & Statistics**: This section contains tables, charts and statistical summaries of the hydrological data for each EFR site. This information can guide the user or serve as input to DRIFT-SOLVER©.

**Actions**: This section contains the processes that require user action, e.g., definition of flood events from the daily record, selection of floods for scenarios, generation of modified flow scenarios.

Access to the modules and processes available in DRIFT-HYDRO© is provided via the main DRIFT-HYDRO© 'Dashboard' (Figure 2.1), which is the window that opens once the file organisation task (Section 2.3) has been completed and an EFR site has been selected for analysis (Section 2.4).


Figure 2.1 Main DRIFT-HYDRO© Dashboard.

## 2.3. FILE ORGANISATION FOR DRIFT-HYDRO©

A DRIFT study typically consists of analysing flow regime changes at various locations along a river or rivers. Each location is known as an EFR Site. Because a large amount of parameter and time-series data is required and subsequently generated by the DRIFT process, for each EFR site, the methodology described below helps to organise that data. Each EFR site is identified by a unique 'code' specified by the user. Filenames are then automatically generated. Consequently, all data are easily identified by the folder in which they are located and their DRIFT generated filename. This filename uses the unique EFR code.

The hydrology for a DRIFT study is organised as follows:

- Create a folder (directory) for each DRIFT study.
- In the study folder, create a subfolder for each river within that study.
- In the river folder, create a hydrology folder where all the source hydrology time-series files are located.
- In the river folder, create a subfolder for each EFR site to be studied.

Using the methodology outlined below, create the folders for each river and the subfolder for the baseline daily hydrology required at each site, e.g., C:\Wcape\EFR\Berg\Daily Flow.

For example, a study on the Berg and Breede Rivers could have the following folder structure:

C:\Wcape\EFR\Berg\Daily Flow
C:\Wcape\EFR\Berg\Site 1
C:\Wcape\EFR\Berg\Site 2
and
C:\Wcape\EFR\Breede\Daily Flow
C:\Wcape\EFR\Breede\Site 1
C:\Wcape\EFR\Breede\Site 2
C:\Wcape\EFR\Breede\Site 2.

The folder 'Daily Flow' contains files with the daily flows at each site for 'Present Day' and 'Natural' conditions. In the event that the present day flow regime is the natural flow regime, the same hydrology would need to be loaded into both the 'Present Day' and 'Natural' folders. These files can have any name, as they do not form part of the DRIFT data set.

Each EFR site is assigned a unique code, which serves to identify that site and the river on which it is located. For example, Site 2 on the Berg River could have the following code 'Berg02'. This code is then used to name all the files associated with that site, using a strict convention. This frees the User from the tedious process of tracking and organising data as well as allowing DRIFT to locate the data it requires.

**File Register**
This function provides a complete list of all the files that DRIFT uses, or creates, at the current EFR site. The file register will indicate the current status of each file, i.e., whether or not it currently exists.

On the Dashboard, in 'Charts, Info & Statistics', press 'File Register'.
Closing this window returns control to the DRIFT Dashboard.

## 2.4. SELECT A SITE FOR ANALYSIS WITH DRIFT-HYDRO©

As the hydrological information is site specific, data preparation must be done for each EFR site.

**Note: Before you can do this step you must have completed the "File organisation for DRIFT-HYDRO©" given in Section 2.3.**

Open DRIFT-HYDRO©. A screen will appear that provides an entry point to all DRIFT modules. Initially, this screen has only one button, i.e., 'Set EFR site'. Press the 'Set EFR site' button.

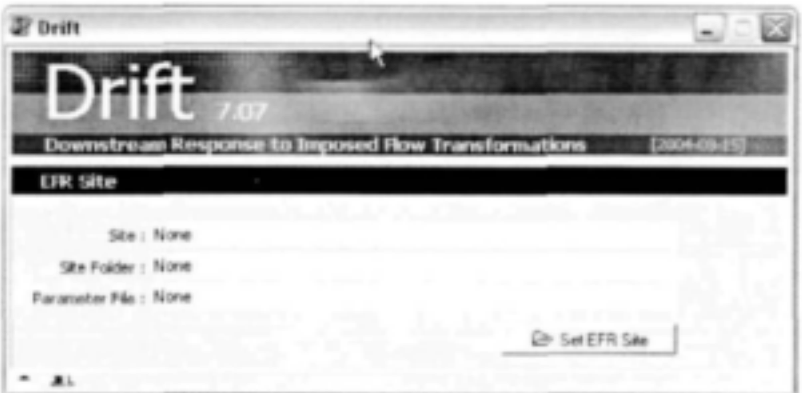



Figure 2.2 The first screen in DRIFT-HYDRO©.

A second screen will appear, comprised of two sections: 1. 'Existing Site' and 2. 'New Site' (Figure 2.3).

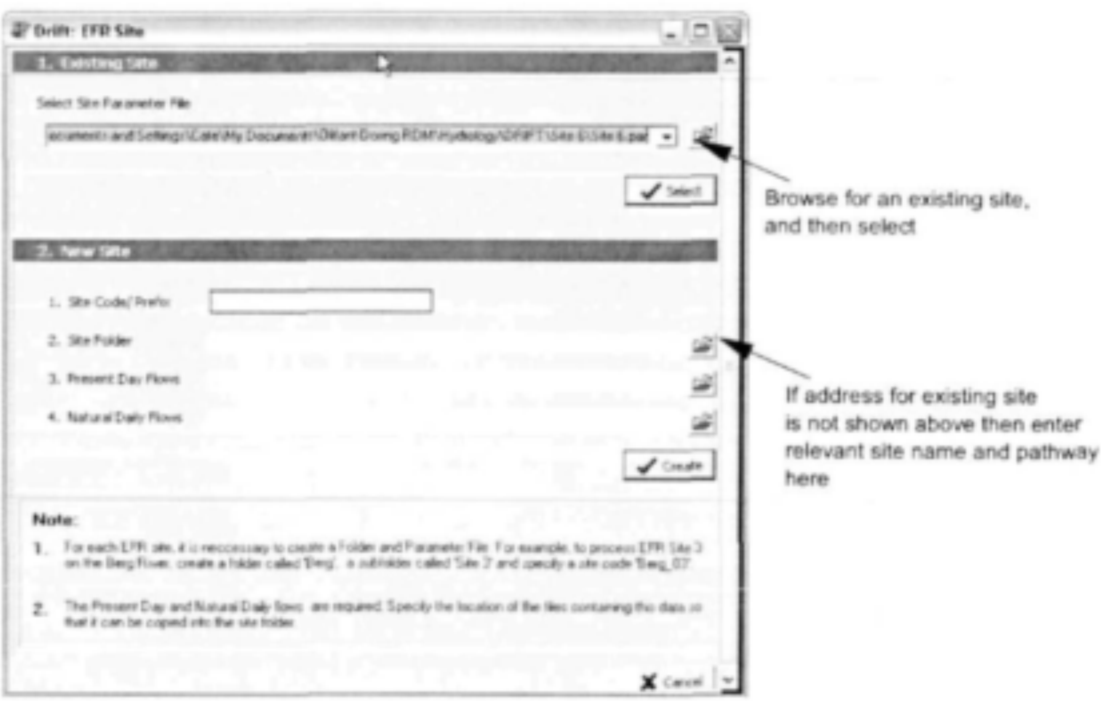



Figure 2.3 The second screen in DRIFT-HYDRO©: Define EFR Site.

If you have called up your sites during set up, then use the drop-down arrow to select a site from the list of existing sites (Figure 2.3).

For a new site, or a site for which the pathway has not been defined previously, you will need to complete the actions required for setting up a new site (Figure 2.3)[1].

Selecting or creating a site on the dialogue box in Figure 2.3 will automatically return you to the Main DRIFT Dashboard (Figure 2.1).

[1] Note: Files to be used for a new site must be in the correct format and the files that are used should be set up according to the instructions in Section 2.3.

## 2.5. SCREEN CHART DISPLAYS IN DRIFT-HYDRO©

The various screens in DRIFT-HYDRO© can be altered, resized and generally 'customised' to suit the user and the particular river/site of concern.

The options available for setting chart displays are (Figure 2.4):

**Mouse**

| | |
|---|---|
| Zooming in: | drag a rectangle with the mouse from top-left to bottom-right around the area of interest; |
| Zooming out: | drag a rectangle with the mouse from bottom-right to top-left; |
| Pan dates: | right click and drag chart to left or right; |
| Change Y maximum: | right click and drag the chart up or down. |

**Tip:** **A combination of right click and dragging in horizontal or vertical direction is effective in selecting the chart display.**

**Buttons**

If present, the buttons to the right of the chart can be used to:

- zoom to full extent;
- zoom in/out a fixed percentage;
- move a page to the left/right (usually a year or a month);
- increase/decrease Y max.

**Slider**

If present, a slider at the bottom left of the chart can be used to:

- drag chart to the left or right;
- click on the end arrows for a small left/right change (usually 1 month);
- click on the end of the slide area for a large left/right change (nearly a full page).

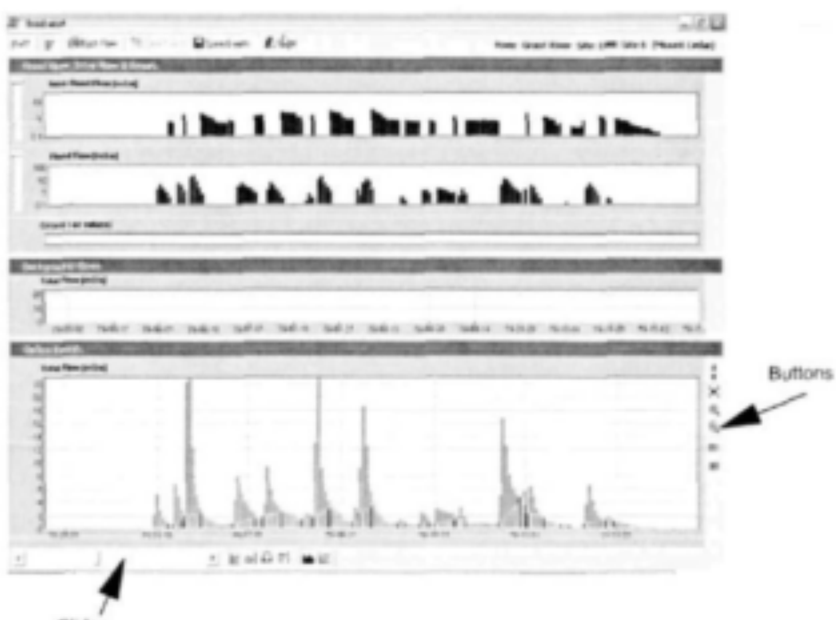



Figure 2.4 Example of a screen with buttons and slider for setting the chart display.

## 2.6. REQUIRED HYDROLOGICAL SEQUENCES

DRIFT takes as its starting point an analysis of the **present-day flow regime** of the river. This is because most river scientists base their understanding of any river on its nature and condition at the time of their studies (King *et al.* 2003). Their predictions of flow-related change describe how the river will change from present, although they may use as background any information on past characteristics of it and similar rivers. DRIFT also requires the generation of a naturalised time series as this provides the template against which flow changes over time can be assessed. Thus, the following two sets of hydrological data are required:

- simulated naturalised daily flow;
- simulated present-day daily flow.

Ideally, both sets of hydrological data should consist of at least 30 years of daily flows for each EFR site, but shorter time series can be used as long as they cover wet and dry cycles of years. These data sets are analysed within the software, to characterise natural and present flows in terms of the pre-identified flow categories.

---

Both the naturalised and the present day data sets used in DRIFT-HYDRO© are simulated data but the manner in which they are generated differs. The data for naturalised flows are comprised of the following:

1. the natural historic daily distribution of flows, i.e., in line with actual historic climatic cycles of wetter and drier years and of floods and low flows.
2. all off-stream use of water in the catchment is added back into the record for the full duration of the period under review (Figure 2.5).

Thus, the naturalised flow data are the most accurate description possible of what the flows in the river would have been like, had there been no human intervention.

The data for present-day flows are comprised of the following:

1. the present-day daily distribution of flows, i.e., taking account of changes in distribution in flows as a result of abstraction, in-channel storage, land-use changes.
2. all present-day off-stream use of water in the catchment is subtracted from the whole record – for the full duration of the period under review (Figure 2.5).

Thus, the present-day flow data are a record of what the flows in the river would have been like, had there been present-day human intervention from the start of the period of record.

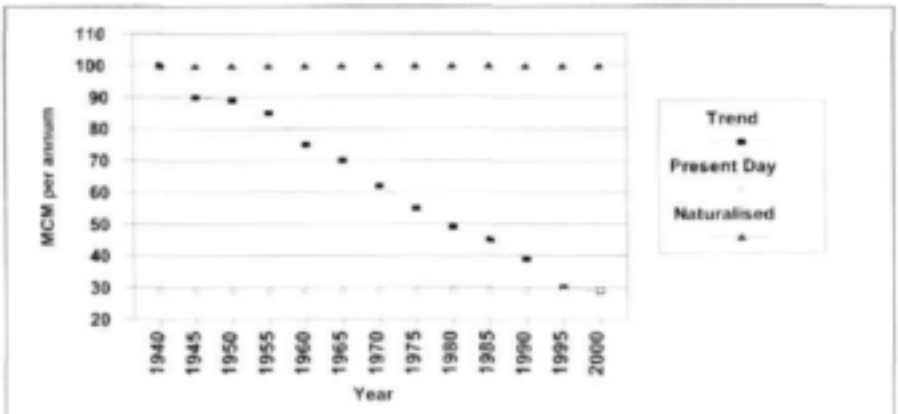



Figure 2.5 An hypothetical example of the volumetric relationships between the simulated naturalised and present-day records over a 60-year period of record.

## 2.7. WORK WITH THE HYDROLOGIST TO GENERATE THE HYDROLOGICAL TIME SERIES

It is seldom the case that the hydrological data available for an EFR site are 100% complete or accurate. This does not mean that the data cannot be used but it does mean that the importance of understanding the hydrology, its strengths, shortfalls and pitfalls cannot be overemphasised. For this reason, it is advisable that the EF facilitator liaises closely with the hydrologist generating the data, and that they undertake the DRIFT analyses together. One of the advantages of the manual manipulation of the hydrological data required in DRIFT is that it affords the EF facilitator the opportunity for detailed study of the data that have been provided by the hydrologist(s).

Key areas that should be considered in generating the hydrological data include:

- Length of the hydrological time series:
    - Did the record cover key periods of interest?
    - Was the record long enough to cover different climatic cycles and to allow summary of human-induced trends?
- Disaggregation of monthly data:
    - Which hydrological gauges were used to disaggregate the simulated monthly data for the naturalised and present day conditions?
    - Are the patterns from the gauges that were used likely to provide the best available approximation of the hydrological pattern at the EFR site?
    - How were missing data handled?
    - How were the flood events determined, and were the peaks of the very large floods recorded by the hydrological gauges that were used?

## 2.8. FORMAT OF THE HYDROLOGICAL TIME SERIES DATA

In order for the daily time series to be accepted into DRIFT-HYDRO© they must be in a standard format, which is characterised by the following (Table 2.1):

- Six header lines, starting with a dashed line.
- Header text includes site and file description, numerical units, and the date the data were simulated.
- Each set of monthly data headed by the year followed by the month (1-12).
- Data are average daily discharge data in $m^3s^{-1}$.
- Five lines of daily data (insert blank line for when February has 28 days).
- No space between the months (except for when February has 28 days).
- Each line with columns for seven days of data.

Table 2.1 Format required for the hydrological data for DRIFT-HYDRO©.

```
-----------------------------------------------------------------
Description    : EFR_Site1_PD.day
Units          : m3/s
Run Date       : February 2004
-----------------------------------------------------------------

1971 10
   4.84    4.73    4.73    4.73    4.67    4.56    4.56
   4.56    4.56    4.41    4.39    4.39    4.39    4.39
   5.69    5.90    5.50    9.15   10.57   10.54   10.25
  10.25    9.89    8.82    6.96    5.65    5.27    5.60
   6.74   11.04   25.01
1971 11
  18.45   19.00   17.36   15.45   14.01   12.90   12.09
  11.62   11.90   12.03   11.95   11.67   12.19   13.81
  12.12   10.83   13.01   12.95   11.23    9.79   10.55
  22.07   18.41   13.86   11.64   11.26   11.91   11.55
  11.50   12.93
1971 12
  12.90   12.53   78.60  134.12  101.40   65.88   51.80
  38.73   30.75   27.58   23.88   28.39   23.11   21.27
  15.76   12.82   10.88    9.43    8.57    7.75    7.31
  15.15   11.55    9.71    8.36   11.42   10.81   16.03
  18.26   14.90   45.40
1972 1
  26.94   27.24   35.79   36.54   45.05   37.27   26.70
  20.68   19.24   21.63   26.19   91.80  144.58   99.42
 176.09  290.29  313.33  193.49  147.02  125.64  114.23
 223.50  233.83  147.28  116.37  101.63   81.10   73.22
  63.16   50.20   46.67
1972 2
  48.32   45.18   32.25   31.35   29.06   22.52   18.07
  14.57   12.33   11.53    9.90    9.40    7.76    7.75
   7.70    7.75    7.75    7.75   10.19   11.13   25.83
 354.01  237.23  420.96  501.52  831.62  407.63  228.23

etc.
```

## 2.9. GENERATE BASIC STATISTICS FOR PRESENT DAY AND NATURALISED DATA

A range of basic statistics for the present day and naturalised conditions at a site are generated first as some are needed to complete other analyses.

The basic statistics are:

- mean annual runoff (MAR);
- number of years of record;
- monthly distribution of flow volumes, which is used to distinguish wet and dry seasons;
- magnitude of the 1:2, 1:5, 1:10 and 1:20 year floods (daily average peak).

The data on the inter-annual flood events, *viz.* 1:2, 1:5, 1:10 and 1:20 year floods, are generated using a partial-series analysis.

---

On the DRIFT Dashboard (Figure 2.1), under the section entitled 'Charts, Info & Statistics', press 'Present Day/Natural Statistics', and the above-mentioned statistics will be generated automatically.

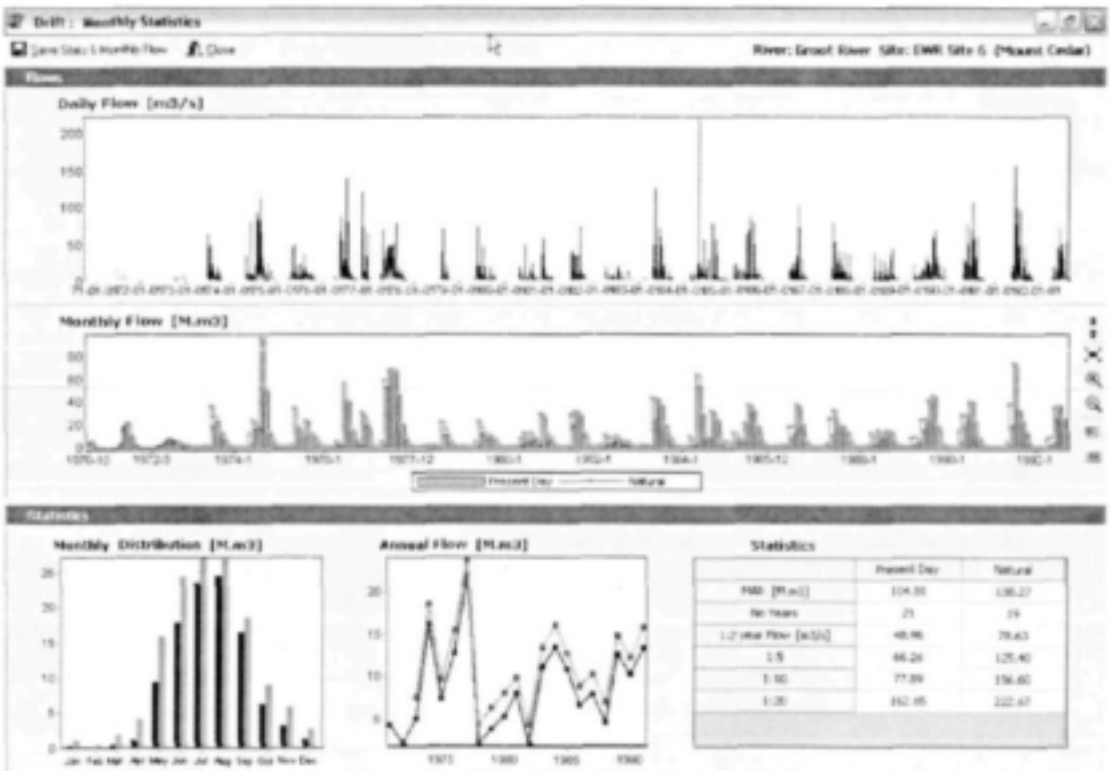



Figure 2.6 Present Day/Natural Statistics module in DRIFT-HYDRO©.

This module displays monthly and daily times-series charts as well as statistics about the hydrology of the site (Figure 2.6). This information can be used when defining seasons and flood classes, and also provides a useful check on the site's hydrology.

When zooming in on the monthly chart, the daily flow chart above it automatically adjusts to the new time period. For tips on chart navigation, see Section 2.5.

To save the summary data press 'Save Stats and Monthly Flow'. This will then ensure that the summary files are saved in the relevant folder (see Section 2.3).

Closing this window returns control to the DRIFT Dashboard.

## 2.10. SET THE HYDROLOGICAL SEASONS

Species have different tolerance ranges to the prevailing conditions and so differ in their abundances as conditions change. For instance, the different magnitudes of base flow in the dry and wet seasons create more or less wetted habitat and different hydraulic and chemical conditions, which directly influence how many individuals can survive at any time and what the balance of species will be. Thus, seasonal and annual fluctuations in environmental conditions, representing differing rainfall, and hence differing flow conditions, provide one of the first divisions of a flow regime in an EF assessment.

---

On the Drift Dashboard, under the section entitled 'Parameters', press 'Initial'.

This module sets the initial parameters pertaining to the EFR site details, seasons and flood classes. In this case, we are interested in 'seasons'.

Press the tab marked 'Seasons' (Figure 2.7).

Figure 2.7 Initial module in DRIFT-HYDRO©: Seasons screen.

Using the monthly information obtained from the basic hydrological statistics (Section 2.9), determine the number of the seasons for your EFR site. For each season, specify a name, e.g., Wet and Dry, or Summer and Winter.
Now set the months for each season – 1 indicates that the month is part of the season, 0 means the month does not form part of the season. A month can only belong to one season.

| | |
|---|---|
| Tip: | **At this stage the season number, names and months can be changed but these should not be altered once the module 'Adjust Low Flows' in 'Actions' has been run.**<br><br>**You can set as many seasons as you like, up to a maximum of 10. However you should remember that your specialists will need to analyse each season separately.** |

## 2.11. FLOW DURATION CURVES FOR NATURALISED AND PRESENT DAY DATA

It is possible to examine the Flow Duration Curves (FDCs) for any of the hydrological data you have for the site (at this stage these are naturalised and present day flows), at any time during the process.

On the DRIFT Dashboard (Figure 2.1), under the section entitled 'Charts, Info & Statistics', click on 'Flow Duration Curves'. This module (Figures 2.8a-c) can be used at any stage during the DRIFT generate and view Flow Duration Curves for any time-series.

Figure 2.8a DRIFT: Flow Duration Curves – Monthly data screen.

Use the two drop-down lists to select any two time series files to view (Figure 2.8b).

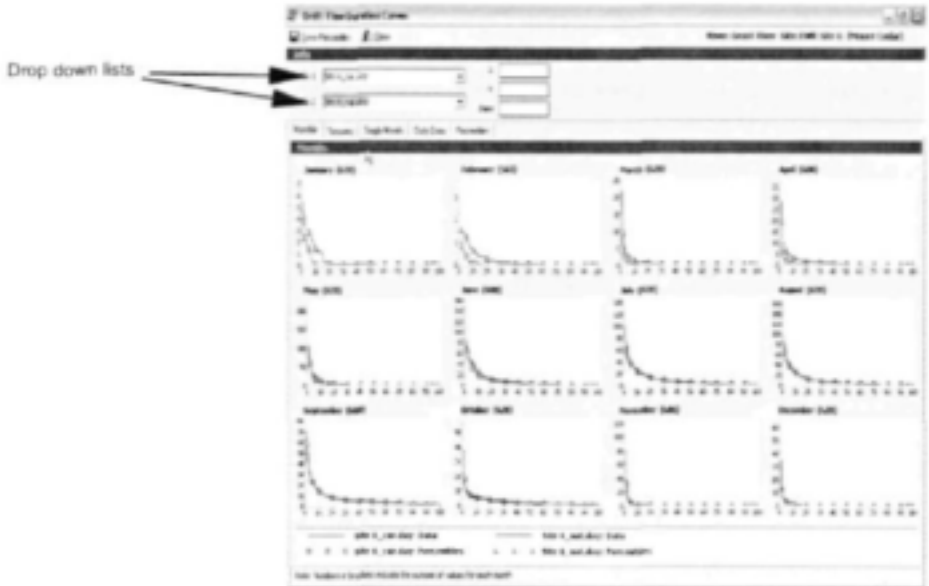



Figure 2.8b DRIFT: Flow Duration Curves – – Monthly data screen, with data displayed.

Data for a single month or season can be viewed in greater detail by clicking on the Season or Single Month tabs shown in Figure 2.8c.

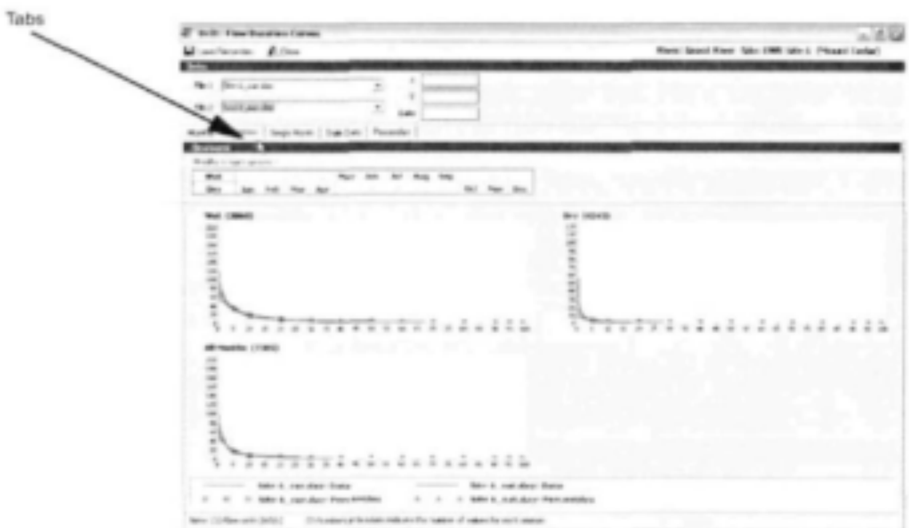



Figure 2.8c DRIFT: Flow Duration Curves – – Seasons data screen, with data displayed.

The percentile data for the files selected for display are automatically generated by DRIFT-HYDRO©, however, it is necessary to 'Save Percentiles' if you wish for these data to be stored in the site-specific percentile file (Figure 2.8d).

The site-specific data percentile file has a .prc extension, which can be read using MS Notebook, or can be imported into MS Excel.

Save percentiles

Figure 2.8d DRIFT: Flow Duration Curves – Percentile data screen, with data displayed.

Closing this window returns control to the DRIFT Dashboard.

## 2.12. SET THE FLOOD CLASSES

The high flows are separated into eight size classes:

- four intra-annual floods (i.e., floods with a return period of less than one year);
- four inter-annual floods (i.e., floods with a return period of greater than one year).

Delineation of the size classes of the intra-annual floods is dependent on the accurate estimate of the magnitude of the 1:2 year return period flood (see Section 3.5: Generating Basic Statistics). This is because the four classes of intra-annual floods are delineated based on the magnitude of the 1:2-year flood.

Halving the magnitude of an event results, in general terms, in a significant change in the sediment-moving power of the flood (King and Brown 2003). Alternatively or additionally, the discharges at which relevant channel features are inundated or exposed can be used to determine the limits of the size classes. DRIFT-HYDRO© operates under either approach.

---

On the Drift Dashboard, under the section entitled 'Parameters', press 'Initial'.

This module sets the initial parameters pertaining to the EFR site details, seasons and flood classes. This time, we are interested in "Flood Bands" (Figure 2.9).

Press the tab marked "Flood Bands".

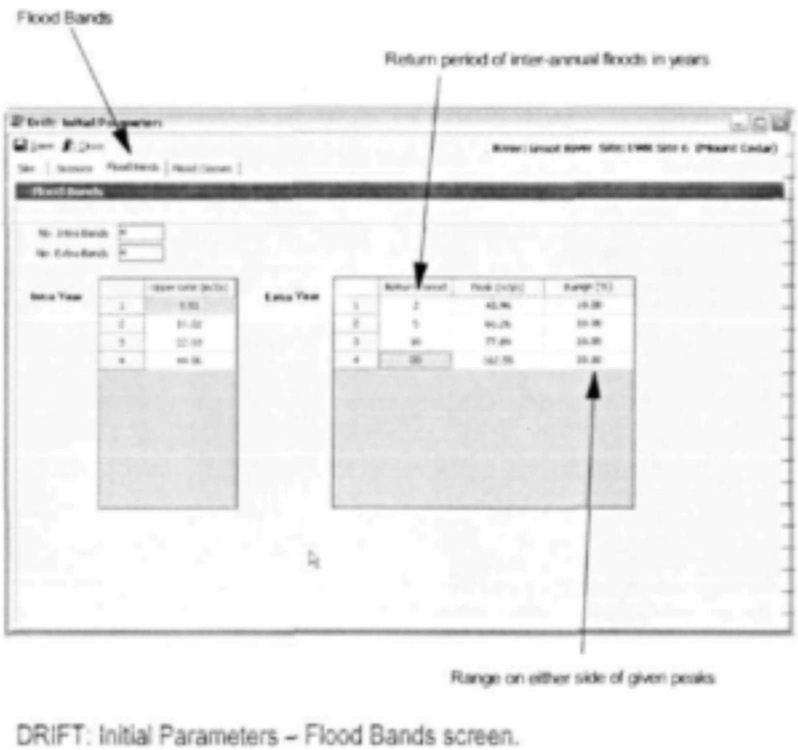



Figure 2.9 DRIFT: Initial Parameters – Flood Bands screen.

Set the number of Intra-annual flood classes (return period < 1 year) and Inter-annual flood classes (return period > 1 year).

For each Intra-annual Class, set the 'Class Name', e.g., '1' or '2' and the Upper Limit ($m^3/s^{-1}$). In most cases, the upper limit of the Class 4 floods are calculated from the magnitude of the 1:2 year flood (provided in the Present Day/Natural Statistics module), using the following formula:

Upper limit Class 4 = Magnitude 1:2-10%[2].

Thereafter the upper limits of the Class 3, 2 and 1 size classes are arrived at by successive halving of the upper limit of the Class 4 floods, respectively.

For each Inter-annual Class, set the 'Return Period', e.g., '2' or '5' and again, the Upper Limit ($m^3 s^{-1}$). The 'Range' column determines the variation on either side of the magnitude given for the Inter-annual floods within which DRIFT will select floods for inclusion in the analysis. In other words, from Figure 2.10, the 1:20 year flood has an average daily peak ( magnitude) of 162.55 $m^3s^{-1}$, with a range of 10%. This means that DRIFT will select, from the flow record, floods with average daily peaks that range from 146.295 to 178.81 $m^3s^{-1}$.

Use the 'Save' button to save any changes.

Once the Flood Bands screen has been completed and saved, then the Flood Classes screen can be filled in using the information calculated for the Flood Bands screen.

Press the tab marked "Flood Classes" (Figure 2.10).

Figure 2.10 DRIFT: Initial Parameters – Flood Classes screen.

Use the 'Save' button to save any changes.
Closing this window returns control to the DRIFT Dashboard.

| | |
|---|---|
| *Tip:* | ***Class data can be modified but should not be altered after the module 'Select Floods' in 'Actions' has been run.*** |
| | ***The Inter-annual flood classes are sometimes referred to as Classes 5–8, with 5 = 1:2 year flood ; 6 = 1:5 year flood; 7 = 1:10 year flood and 8 = 1:20 year flood.*** |

[2] However, any suitable size delineation can be adopted.

## 2.13. SEPARATE THE HIGH FLOWS FROM THE LOW FLOWS

In DRIFT, the flow regimes of rivers with predictable perennial or seasonal flow are separated into high flows and low flows. Thus, as a first step, the present-day and naturalised flow sequences for each site must be divided into separate files comprised of the low flows and the high flows.

Highflow events are manually separated from the lowflow events as represented in the hydrological time series using the 'Mark Events' routine in DRIFT-HYDRO©. Low flows are visually distinguished from high flows using guidelines such as the rate of change of the slope of the daily hydrograph, or the discharge at which selected features of the channel become inundated.

Once a start and end day has been selected for an event, a linear interpolation is performed between them. For the days in between, any flow above the interpolated value is assigned to be 'flood flow' and any value below the line is assigned to 'low flows'. This procedure is repeated for all floods marked. Finally the separated time-series are written to file.

Each of these are later further divided (see Section 2.12):

On the Drift Dashboard, under the section entitled 'Actions', press 'Mark Flood Events'.

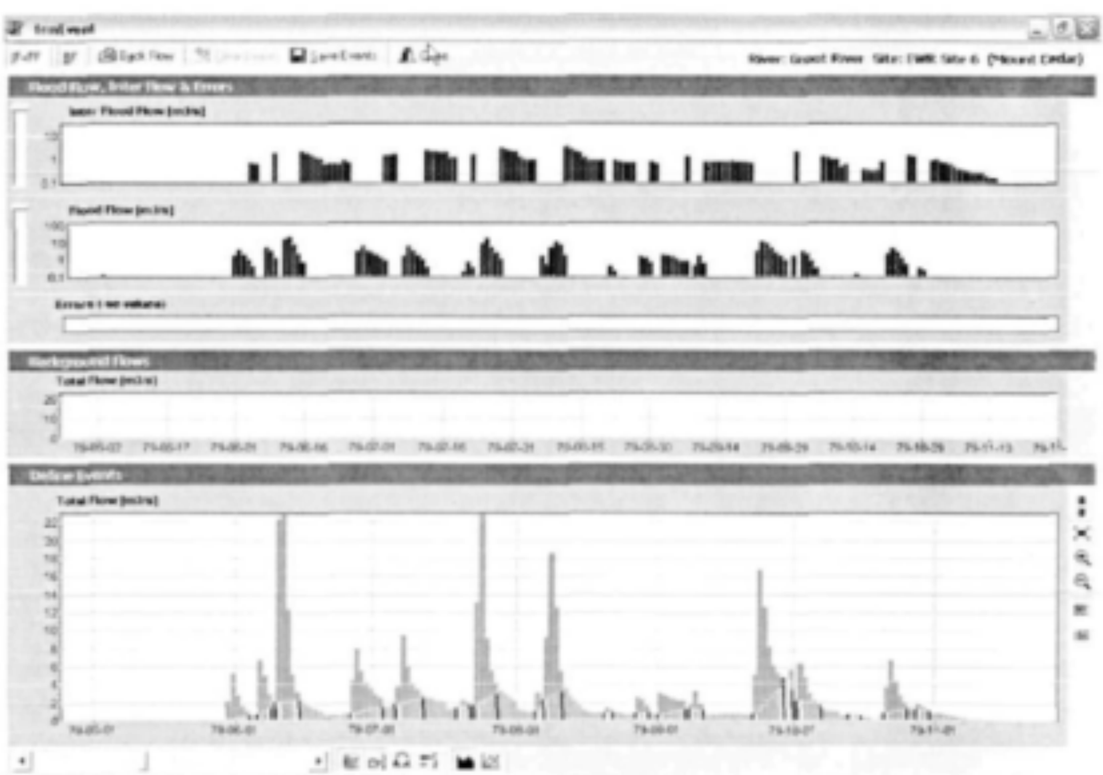


Figure 2.11 DRIFT: Mark Flood Events module, with data displayed.

This module is used to select the flood events in the daily record enabling the separation of base flow and floods (Figure 2.11). All the flood definition is done in the bottom box 'Define Events'. The other two boxes provide background information to assist in the flood definition process. These boxes can be switched off if not required or resized and moved out the way.

**Display information**

| | |
|---|---|
| Bars: | The daily flow data are depicted as discreet colours bars, comprising an average flow rate per day. These bars will change colour once they are assigned to floods (see instructions below). |
| Natural Flow: | These are shown as a line in the main box (i.e., not bars). |
| Errors: | Sometimes inappropriate selection of event boundaries results in negative flows. An error box shows these in red. |
| Background Flow: | Another box allows one to display a background time series. If this series has an associated Flood Event file, these events are also shown. |

**Note: All the boxes track the display dates of the main box. The display is totally customisable by resizing boxes or switching the various boxes on/off.**

**Chart Boxes**

The window consists of three main boxes, namely

- Flood Flow, Inter Flow and Errors;
- Background Flows;
- Define Events.

**Flood Flow, Inter Flow and Errors**

The three charts contained in this box show:

- Flood Flow;
- Interflood flow, and;
- Errors.

The Errors chart is very important and indicates negative values. This occurs when the interpolated base flow for a day exceeds the actual flow. It indicates a poor flood boundary selection.

**Background Flows**

This window allows the display of another time-series. If this series has an associated Flood Event file, these events are also shown. This can be used as a guide when selecting floods if, for example, a related site is shown for display in the background window.

**Event Display**

Various colours are used to indicate base flow, flood flow, event boundaries and event days. In addition to the display options mentioned above, another two buttons modify the 'Define Events' display.

| | |
|---|---|
| Show Area Lines | This feature is helpful when zoomed in and defining Events, but it is better to disable it when zoomed out. This helps show clearly the flood flow sitting on top of the base flow and the event boundaries. |
| Show Natural Flows | Toggles the display of Natural flow, i.e, between showing versus hidden. |

Firstly, arrange the screen so that the required level of resolution (i.e., period to be examined in a single screen) is displayed in the chart box. Moving the mouse between windows reveals a resize facility, i.e., when the cursor changes to two lines and two arrows, it is possible to resize a box by dragging the mouse.

It is advisable to retain the level of resolution in view for marking all the flood events in a season, as changing the resolution at which the data are viewed can significantly alter the definition of a flow as lowflow or highflow.

Floods are marked by sequentially clicking on the start day and end day of a 'flood event' with the left mouse button, i.e., first click the start and then the end day for each flood event. The buttons used to mark events are located at the bottom of the Define Events chart. These are (Figure 2.12):
Button 1, 'Enable Event Editing': This activates the other buttons.
Button 2, 'Mark Event'.
Button 3, 'Move Event Boundary', i.e., alter the boundaries of a marked flood.
Button 4, 'Delete Event'.

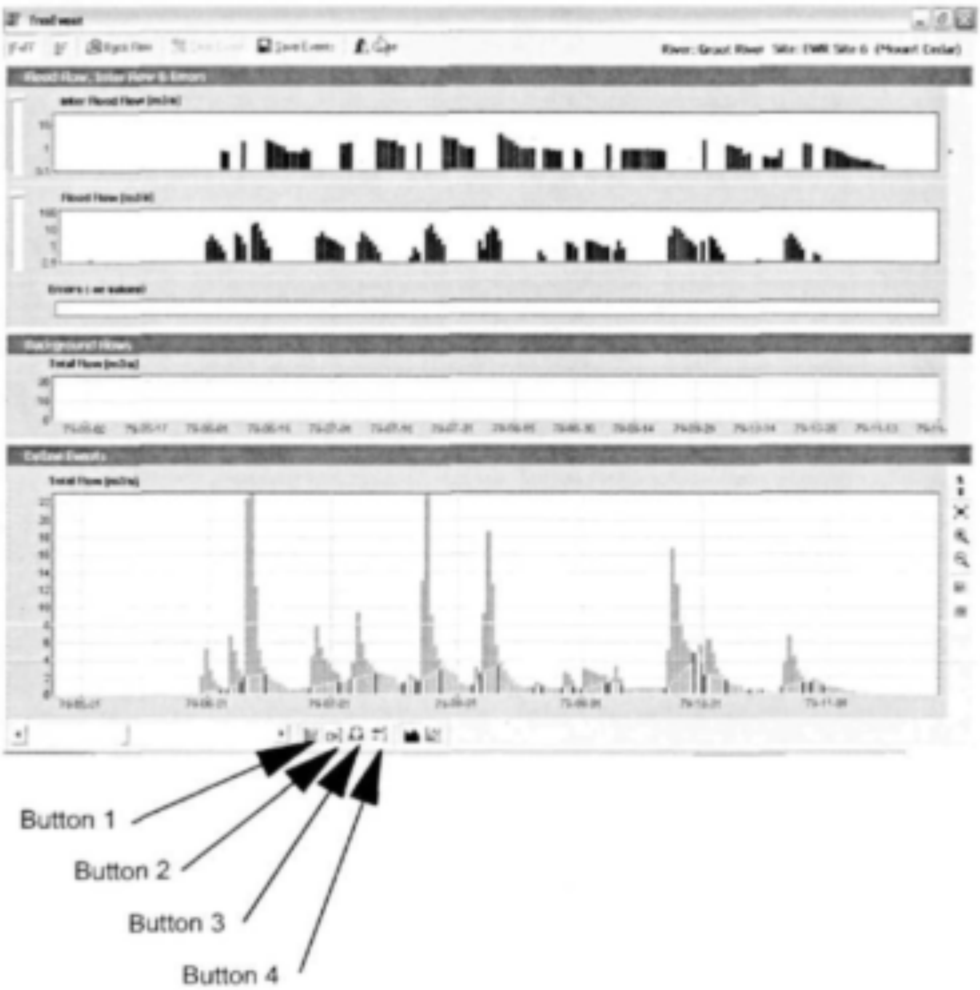



Figure 2.12 DRIFT: Mark Flood Events module, with flood marking buttons highlighted.

**Marking a single event**
Press Button 1: 'Enable Event Editing', followed by Button 2: 'Mark Event'.
A cursor with the numeral '1' appears. Click on the first day of the event. A numeral '2' appears next to the cursor – this indicates that the last day is needed. Click on the last day. Clicking a day means to click anywhere on the bar that represents that day. The cursor shows '1' again. This means that DRIFT is ready to mark the next event.

**Moving an event boundary**

Press Button 3: 'Move Event Boundary'.

The cursor shows '1'. Click on the relevant boundary (the cursor changes to '2') and then on the destination day for that boundary.

**Deleting an event**

Press Button 4: 'Delete Event'.

Click on any day within the event to be deleted. This will result in the entire event being deleted.

**Ending off**

When you have marked all the flood events, press to disengage Button 1: 'Enable Event Editing'. This disables the editing buttons.

**Save**

Press the save button to save the events defined as well as create the base flow, flood flow and inter flow time-series. The result from this step is a set of three files.

High flows (.FF file)

Low flows (.BF file)

Interflow file (.IF file).

| | |
|---|---|
| Tip: | **You cannot select a single day as both the start and the end of a flood. The software requires that, at minimum, a flood must start and end on consecutive days. Although, it will allow you to 'double-click' on a day, the next time your data are called up you will find that the programme has automatically moved the end day to the next clicked point (i.e., the start of the next flood event).** |

## 2.14. GENERATE THE HIGHFLOW STATISTICS

The highflow statistics are generated using the 'High Flow Stats' routine in DRIFT-HYDRO©.

The following information is generated for all selected high flows:

- a list of all events in the hydrological record;
- dates of occurrence, magnitude, duration, volume and days to peak for all selected floods events;
- the sizes of the four classes of intra-annual floods, with:
  - average number of floods per year in each class;
  - average monthly distribution of floods in each class;
  - average magnitude, duration and volume for each size class;
- magnitude, duration and volume of floods with return periods of 1:2, 1:5, 1:10 and 1:20 years.

---

On the DRIFT Dashboard, under the section entitled 'Charts, Info & Statistics', press High Flow Stats.

The display will show a blank box in the upper portion of the screen and the list of flood flows marked in Section 2.12: Separating high flows from low flows. These are ordered according to increasing magnitude.

Press the 'Calculate' button above the top left hand corner of the blank screen (Figure 2.13).

Calculate

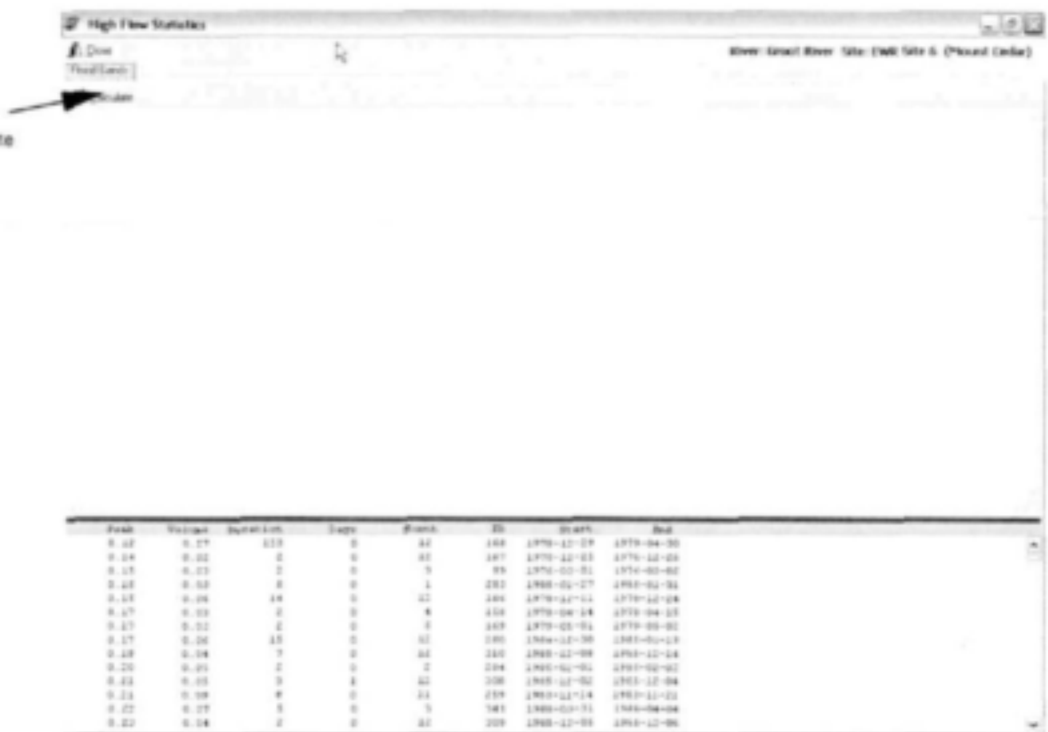


Figure 2.13 DRIFT: High Flow Stats, with Calculate button highlighted.

This will produce data in the blank screen (Figure 2.14). Use the screen toggles to navigate through the data.

| Tips: | *In High Flow Stats Intra-annual floods are referred to a < 1 year return period and the Inter-annual floods as > 1 year return period.*<br><br>*Pressing the 'Calculate' button will only generate output if 1) the high flow separation has been completed and 2) the flood classes have been specified.*<br><br>*The Inter-annual flood classes are sometimes referred to as Classes 5–8, with 5 = 1:2 year flood ; 6 = 1:5 year flood; 7 = 1:10 year flood and 8 = 1:20 year flood.* |
|---|---|

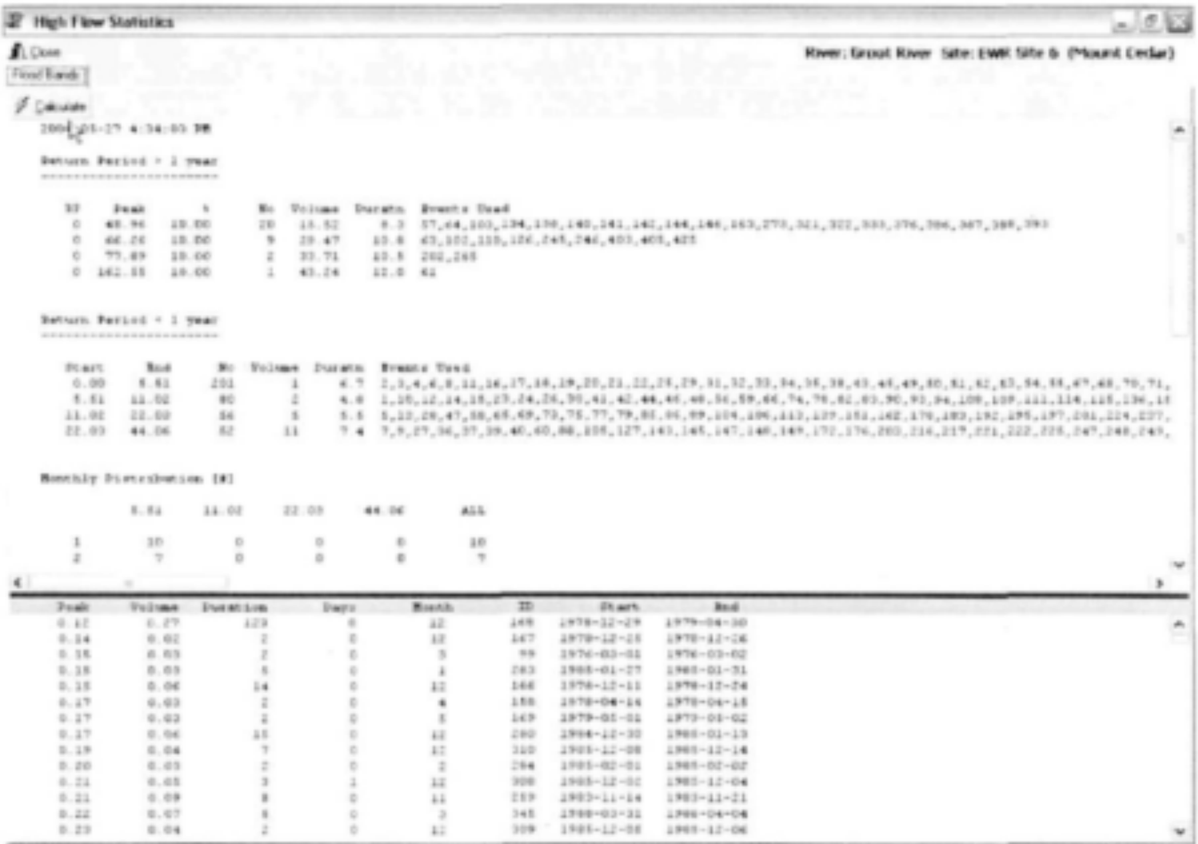



Figure 2.14 DRIFT: High Flow Stats, with data displayed.

The DRIFT-HYDRO© output for High Flows Stats is shown in Table 2.2.

Table 2.2 Example of the actual output from High Flow Stats, saved in the .fld file in the relevant site folder.

[Site 6 - nat]
2004-04-16 16:58:45

**Return Period > 1 year**

| RP[3] | Peak[4] | %[5] | No[6] | Volume | Duratn | Events Used[7] |
|---|---|---|---|---|---|---|
| 2 | 78.63 | 10.00 | 15 | 16.63 | 7.3 | 26,33,122,142,152,213,259,288,318,319,340,354, etc |
| 5 | 125.40 | 20.00 | 6 | 25.18 | 7.7 | 34,82,96,253,339,440 |
| 10 | 156.60 | 10.00 | 1 | 26.27 | 7.0 | 452 |
| 20 | 222.67 | 10.00 | 1 | 53.40 | 14.0 | 279. |

**Return Period < 1 year**

| Start | End | No | Volume | Duratn | Events Used |
|---|---|---|---|---|---|
| 0.00 | 8.85 | 237 | 1 | 3.7 | 1,2,3,11,12,13,14,17,18,19,20,22,23,27,29,36,39,40, etc. |

**Monthly Distribution [#]**

| | 8.85 | 17.69 | 35.38 | 70.77 | ALL |
|---|---|---|---|---|---|
| 1 | 11 | 0 | 0 | 0 | 11 |
| 2 | 7 | 0 | 0 | 0 | 7 |
| 3 | 9 | 2 | 3 | 0 | 14 |
| 4 | 21 | 5 | 3 | 1 | 30 |
| 5 | 29 | 9 | 9 | 6 | 57 |
| 6 | 21 | 11 | 13 | 17 | 68 |
| 7 | 16 | 13 | 19 | 15 | 68 |
| 8 | 20 | 15 | 13 | 12 | 70 |
| 9 | 33 | 14 | 16 | 5 | 70 |
| 10 | 42 | 12 | 2 | 1 | 57 |
| 11 | 19 | 4 | 1 | 1 | 26 |
| 12 | 9 | 3 | 0 | 1 | 13 |

**Monthly Distribution [#/annum]**

| | 8.85 | 17.69 | 35.38 | 70.77 |
|---|---|---|---|---|
| 1 | 1.00 | 0.00 | 0.00 | 0.00 |
| 2 | 1.00 | 0.00 | 0.00 | 0.00 |
| 3 | 0.64 | 0.14 | 0.21 | 0.00 |
| 4 | 0.70 | 0.17 | 0.10 | 0.03 |
| 5 | 0.51 | 0.16 | 0.16 | 0.11 |
| 6 | 0.31 | 0.16 | 0.19 | 0.25 |
| 7 | 0.24 | 0.19 | 0.28 | 0.22 |
| 8 | 0.29 | 0.21 | 0.19 | 0.17 |
| 9 | 0.47 | 0.20 | 0.23 | 0.07 |
| 10 | 0.74 | 0.21 | 0.04 | 0.02 |
| 11 | 0.73 | 0.15 | 0.04 | 0.04 |
| 12 | 0.69 | 0.23 | 0.00 | 0.08 |
| Total | 7.31 | 1.83 | 1.43 | 0.98 |

[3] RP = Return Period, i.e., 2, 5, 10 or 20 years.

[4] Daily average peak in $m^3s^{-1}$.

[5] Percentage on either side of the peak that DRIFT used to select flood events (see Section 2.12; Figure 2.10).

[6] Number of floods found and selected.

[7] The actual floods selected, numbered according to the .eve file.

## 2.15. GENERATE THE LOWFLOW STATISTICS

FDCs derived from the lowflow data sets for each season are used to indicate the variability of the low flows and how often any discharge is met or exceeded under present day and naturalised conditions.

The following information is generated for the low flows (Appendix A):

- number and names of seasons;
- months comprising each season;
- FDC for each season;
- FDC for each month;
- range of flows in each season (from FDCs).

The lowflow FDCs are generated using the 'Flow Duration Curve' routine in DRIFT-HYDRO©.

---

The low flow report presented in Appendix A is not produced automatically by DRIFT. The User is expected to compile the report (or similar) contained in Appendix A using the data generated by DRIFT. This entails importing data into MS Excel and generating the relevant graphs, etc.

## 2.16. PRODUCE A SUMMARY REPORT FOR THE SPECIALISTS

The biophysical specialists will require a summary of the natural and present day hydrological flow regime at each EFR site in order to provide them with an idea of past flow changes with which they can correlate changes in their component of the ecosystem. These assessments of change provide the basis from which the specialists predict the likely consequences of future flow changes.

---

The high flow report presented in Appendix B is not produced automatically by DRIFT. The User is expected to compile the report (or similar) contained in Appendix A using the data generated by DRIFT. This entails cutting and pasting the relevant information from the files generated by DRIFT, e.g., .fld files.

# 3. WORK WITH THE SPECIALISTS – CONSEQUENCES OF FLOW CHANGES

This section of the manual deals with obtaining the data for population of the DRIFT biophysical database and has two main aims:

1 to outline the sequence in which specialists should provide their inputs;

2 to introduce some of the features that impart structure to specialist deliberations on the consequences of flow changes.

The next part of the process, population of the DRIFT Database, is dealt with in Section 4.

## 3.1 INTRODUCTION

A biophysical consequence is the predicted response of a specific sub-component of the riverine ecosystem (e.g., species, community or feature) to a reduction in a single aspect of the hydrological regime. When the consequences of any flow reduction are being described, it is **assumed that all other components of the flow regime remain unchanged**.

The individual descriptions of consequences are used later in different combinations to build scenarios describing the consequences of any potential change in the whole flow regime.

Section 3.10 provides a summary of the general procedures used to derive the consequences. The methods adopted by each biophysical specialist to develop flow-related relationships for their discipline are not dealt with here.

## 3.2 FACILITATE THE SPECIALIST'S INPUTS

The descriptions of biophysical consequences of flow changes are usually built up in a sequence starting with geomorphology, then water quality and thereafter vegetation, invertebrates, fish, bird and other wildlife, with each specialist remaining responsible for her/his own area of expertise (Figure 3.1).

Traditionally, the interactions between the specialists have been facilitated through an environmental flow workshop, where each EFR site is discussed in detail. However, recently the need for, or desirability of, populating the DRIFT database in a workshop situation has come under scrutiny. There is no doubt that some form of interaction is required, where specialists can exchange ideas and discuss concepts and problems. However, current thinking is that it may be preferable to populate the database through one-on-one sessions between an EFR facilitator and individual specialists, starting with the hydraulic modeller and the sequentially moving to the geomorphologist, water chemist, botanist, macroinvertebrate ecologist and ichthyologist, with the consequences of each being completed before moving on to the next specialist. Once the DRIFT database has been populated, the specialists could come together to discuss any uncertainties or inconsistencies, and could run SOLVER (see Section 4) to check that they are in agreement with the outcomes of the model. However, at the time of writing this manual, the practice of populating the database through one-on-one sessions between an EFR facilitator and individual specialists was still in the process of being tested. Regardless of the forum adopted, the procedures outlined in this section should be followed.

Note: *If the database is to be populated in a workshop situation, then an* ***absolute*** *minimum of one day per EFR site is required. If more time is available, it can be usefully used cross-checking between specialist disciplines. However, this is normally not the case, and most DRIFT Workshops take a maximum of a day per EFR site.*

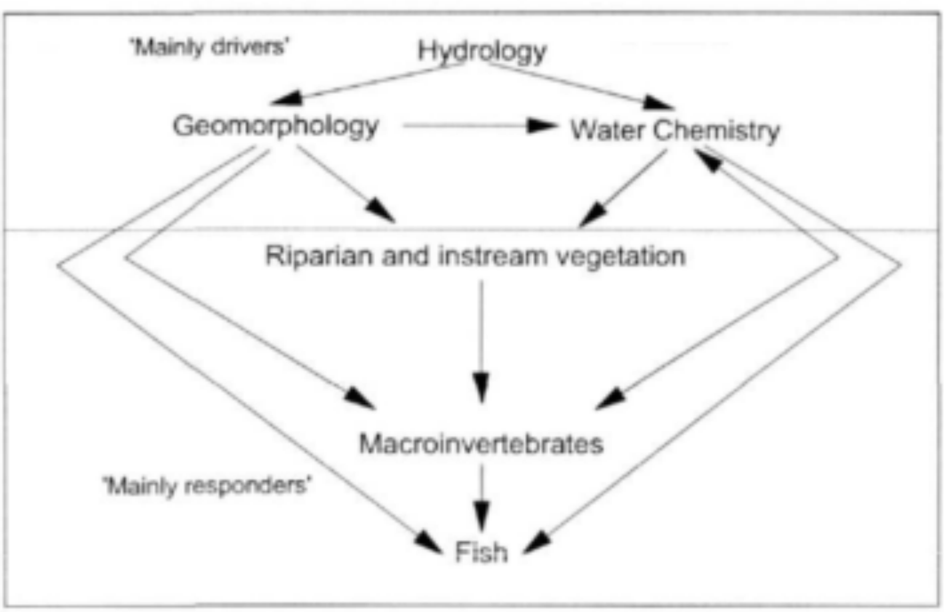



Figure 3.1 Flow chart showing the basic passage of data and information between different disciplines

## 3.3 LINK DRIFT HYDROLOGICAL STATISTICS TO CROSS-SECTIONAL RIVER FEATURES

The maximum and minimum values ($1^{st}$ and $99^{th}$ percentiles) of the dry-season and wet season lowflow FDCs are converted to water depths and marked on surveyed cross-sections of each river site (Figure 3.2). The cross-sections also contain information such as the locations of vegetation zones and of different kinds of substrata. FDCs illustrate how often any cross-section feature is exposed or inundated.

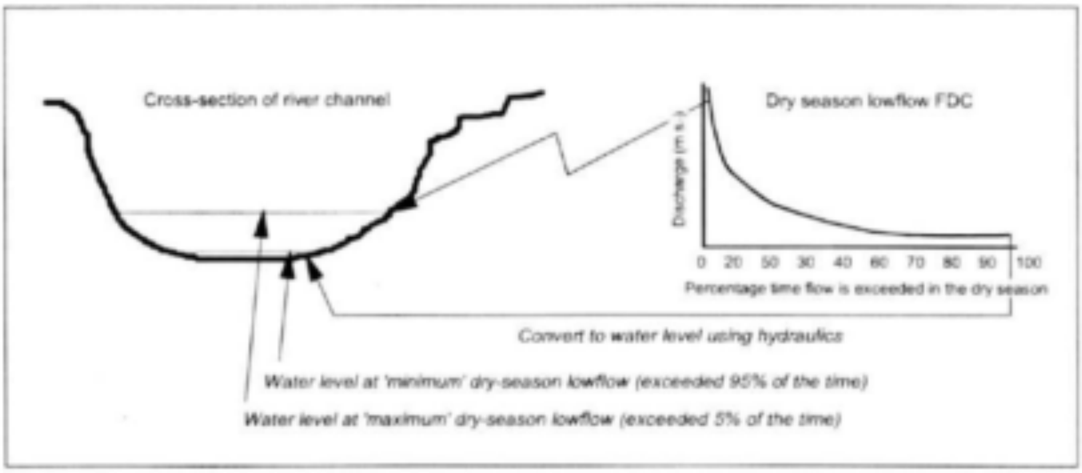



Figure 3.2 The range of hypothetical lowflow discharges that occur during a dry season, expressed as water depths shown on one or more cross-sections of the river channel at each EFR site. The amount of time that the water level was at or above a particular level may be derived from the FDC.

The water depths corresponding to the boundaries of each of the eight flood classes are also marked on the cross-sections (Figure 3.3). Pertinent hydraulic statistics associated with each size class, such as average water depth, average velocity, wetted perimeter and wetted area are derived by the hydraulic modeller.

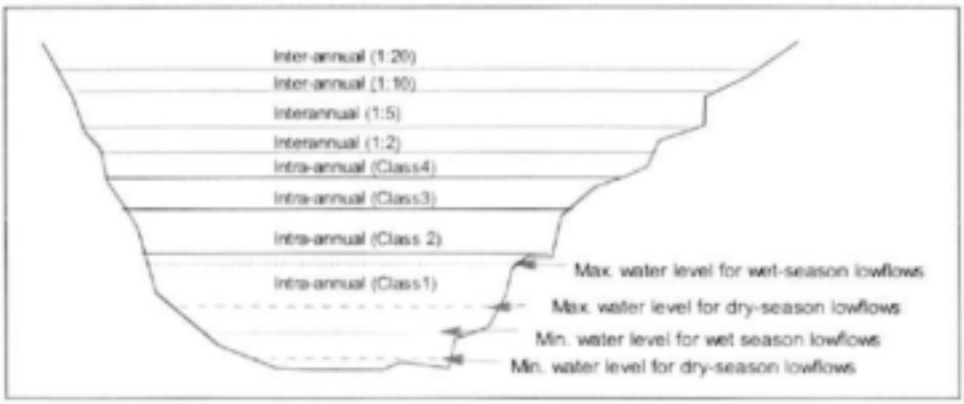



Figure 3.3 An hypothetical example of the water depths delineated by the various hydrological statistics, shown on a cross-section of river channel.

## 3.4 SET CHANGE LEVELS FOR EACH FLOW CATEGORY

The essence of DRIFT is that a range of changes is posed for each of the (10) flow categories, and for which the specialists together predict how the ecosystem will change from its present condition. The changes for high and low flows are presented to specialists in different ways. Low flows are changed in their **range and/or percentile distribution** and thus **variability**, whilst high flows are reduced in their **numbers**, i.e., frequency.

The number of change levels in each flow category provided for in DRIFT are thus:

| | |
|---|---|
| Wet season low flows: | four change levels comprising changes in range and/or percentile distribution; |
| Dry season low flows: | four change levels comprising changes in range and/or percentile distribution; |
| Class 1 intra-annual floods: | one to four changes in the number of events per year; |
| Class 2 intra-annual floods: | one to four changes in the number of events per year; |
| Class 3 intra-annual floods: | one to four changes in the number of events per year; |
| Class 4 intra-annual floods: | one to four changes in the number of events per year[8]; |
| 1:2 year inter-annual floods: | two levels, *viz*. present or absent; |
| 1:5 year inter-annual floods: | two levels, *viz*. present or absent; |
| 1:10 year inter-annual floods: | two levels, *viz*. present or absent; |
| 1:20 year inter-annual floods: | two levels, *viz*. present or absent; |

Various factors will determine the change levels selected for consideration by the specialists. The most important of these are:

1. Defining Change Level 1. Change Level 1 for each flow category is defined as the change (either increase of decrease) that (specialists agree) could occur without undue change to the riverine ecosystem, i.e., 'minimum change' (from present-day) level.
2. Reflecting flow-related management concerns in the catchment. Ultimately, the change levels chosen for each flow category will comprise the matrix from which the biophysical consequences of future flow scenarios will be described. It is therefore essential that they reflect the sorts of flow changes that are likely to occur in/be proposed for a river.

---

On the DRIFT Dashboard, under the section entitled 'Parameters', press 'Changes & Scenarios'. Select the tab 'Change Levels'.

**High Flows**

It is necessary to specify the number of floods events in each flood class required for each change level. As a guide, insert the present day (PD) situation as change level 1. Below this fill in the user-defined change levels, with up to ten levels for each category. In most cases, the maximum number of flow changes (after PD) assessed is four, but in some cases even four change levels are neither needed nor appropriate.

---

[8] The number of highflow change levels will depend on:

- the number of floods in a size class in the present day hydrological time series;
- whether management proposals encompass an increase or decrease in the frequency of floods in that size class.

For instance, if there are only two floods per annum (on average) in a particular size class, and water-resource developers predict that there will be less in future, then only two change levels can be described, viz: 1) a reduction from two to one flood per annum and 2) a reduction from two to zero floods per annum.

For instance, in assessing Class 4 floods in Figure 3.4, if PD close to the natural situation and is 1 then if floods are reduced, only one change level is possible, viz. 0. Thus, in this example, if scenarios involving addition of water are not envisaged, consequences need only be described for one change level. The dark grey squares indicate undefined change levels, and show a value of -1. These values are not used. To add new levels, type over this grey area. To define a change level, complete all the cells within a row, using any number ≥ 0.

Figure 3.4 DRIFT: Change Levels screen.

**Low Flow**

For low flows, specify the number of change levels for each season. This will result in the creation of time-series of low flows for each change level for each season, which can be manipulated to describe the required flow change (Section 3.5).

| | |
|---|---|
| Note: | **This step must be completed (and change levels set) BEFORE the low flows can be adjusted (see next step in Section 3.5).** |

## 3.5 GENERATE CHANGE LEVEL DATA FOR LOW FLOWS

Change levels for low flows are made by adjusting the shape of the flow duration curve for each season (Figure 3.5). Using DRIFT-HYDRO©, a separate time-series is created for each season and associated change level. Each of these time-series can be 'customised' to produce the required characteristics.

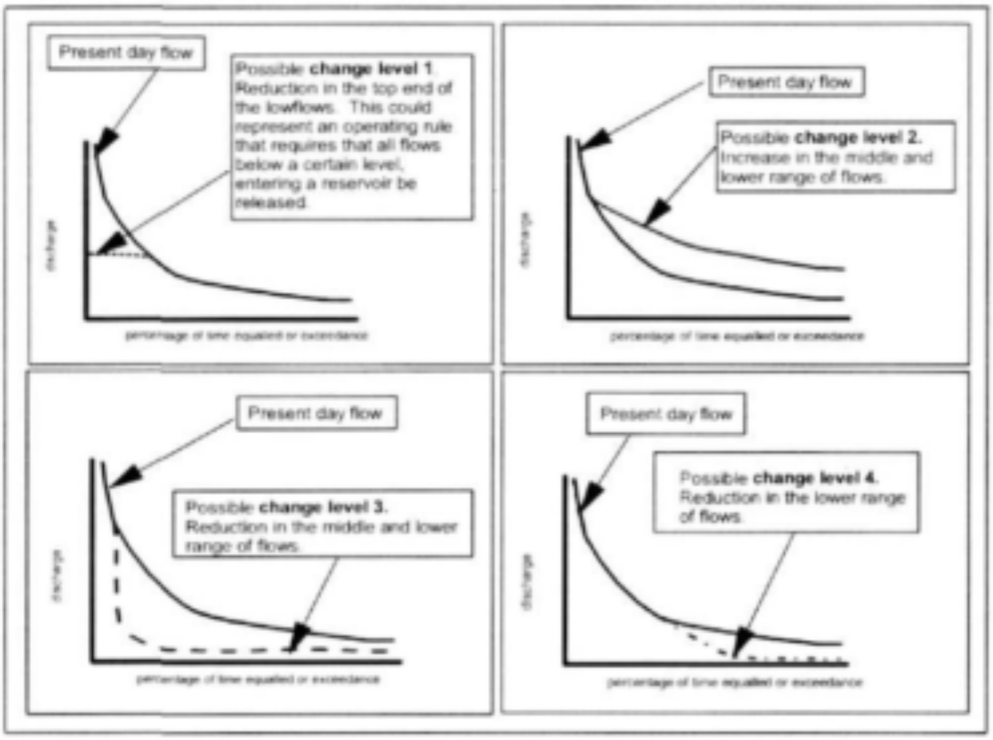



Figure 3.5 Schematic representation of possible alterations to a lowflow FDC, each of which would represent one change level, with an accompanying annual volume and daily distribution.

The adjustments required for each lowflow change level are done using the 'Adjust low flows' routine in DRIFT-HYDRO©.

On the DRIFT Dashboard, under the section entitled 'Actions', press 'Adjust Low Flows'.

The page shows several tabs (Figure 3.6):

- 'Monthly' – Allows the user to modify the lowflow FDCs month by month.
- 'Seasons' – Allows the user to modify the lowflow FDC for an entire season.
- 'Single Month' – Allows the user to view a single month or season.
- 'Daily Data' - Allows the user to view the time-series behind the FDC.
- 'Percentiles' – Allows the user to view the percentile tables for the time-series.

All the charts and tables show the original data (*viz.* present day) as well as the modified data (Figure 3.7).

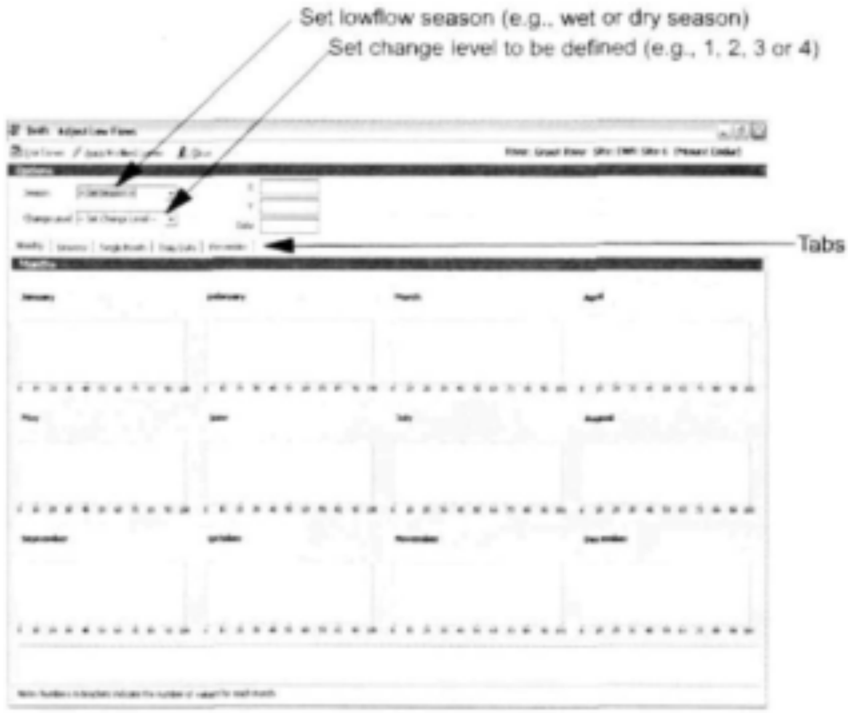



Figure 3.6 DRIFT: Adjust low flows (monthly) opening screen, without data.

**To modify a time-series**

In the drop-down boxes select a 'Season' and a 'Change Level' (Figures 3.7).

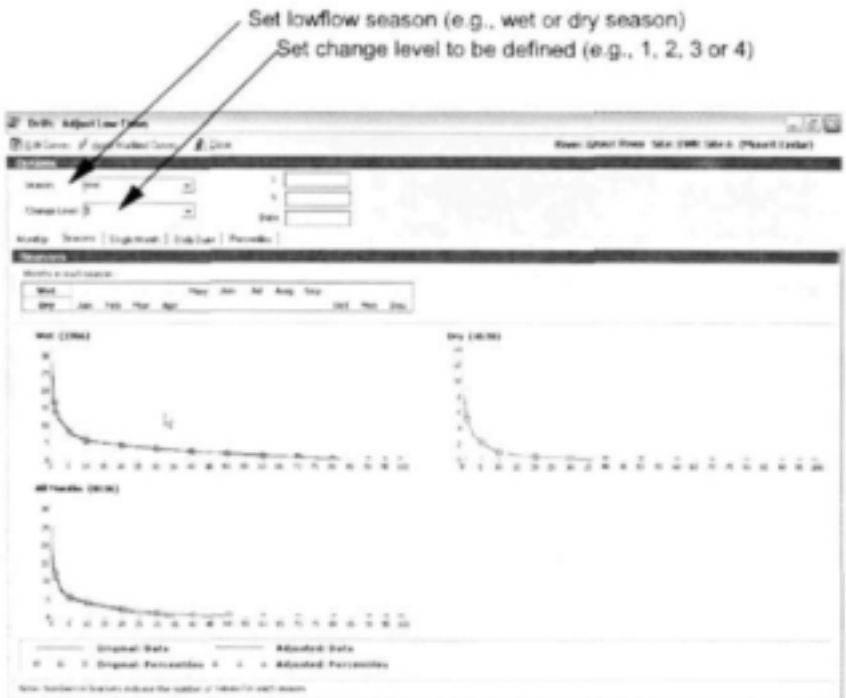



Figure 3.7 DRIFT: Adjust low flows (seasons) screen, after selection of season and change level, with unmodified, i.e., present day, data.

*Note: The chart for the months not included in the current season, are darker and disabled. This also applies to the seasons not currently selected.*

To modify the FDCs, press 'Edit Curves' to pop up the 'Modify FD Curve' screen. Select a month or season to edit by pressing the appropriate tab (Figure 3.8). Modifications are performed by entering new data in the 'Mod Flow' box at the base of the window. As data are entered, the points on the curve are raised or lowered and the resulting change is automatically converted to an actual time-series. Modifications can be performed on individual months or for the entire season.

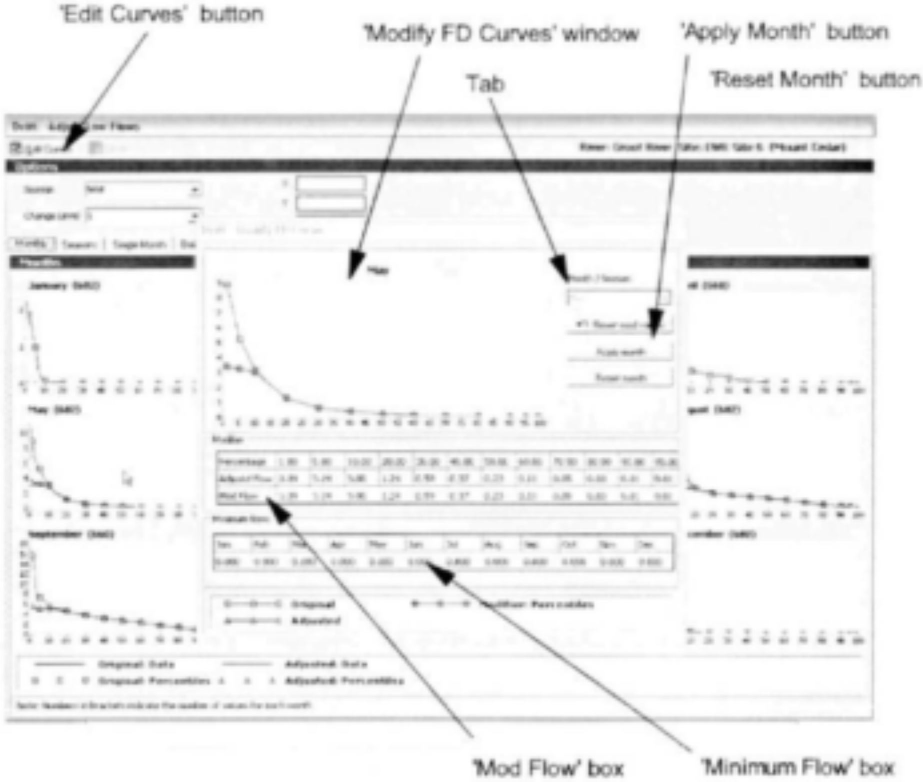



Figure 3.8 DRIFT: Adjust low flows (seasons) screen, with data and showing the 'Modify FC Curves' window.

The month/season can also be selected in the drop-down box inside the 'Modify FC' Curve window. To adjust the FD curve, change the numerical values in the row titled 'Mod Flow'. Changes are indicated on the 'Modify FC Curve' chart (Figure 3.8). However, the time-series is only changed when the button 'Apply Modified Curved' is pressed.

To implement a minimum flow, in cases where the flows are zero, type the minimum flow required in the 'Minimum Flows' row.

In all Edit curve charts the actual data as well as the percentile values themselves are shown for both the original and modified time-series.

To save any changes to a FDC press the 'Apply Month' Button.

To start again press the 'Reset Curves' button (careful, this step is irreversible).
To close the Edit Window press the same button used to open it i.e. 'Edit Curves'.

*Note: The FDCs **must** be adjusted (and saved) for each of the lowflow change levels set for each month in each season.*

**Minimum-change Change Level**

The first Change Level is routinely set as the change that could be effected to the wet or dry season low flows without resulting in a marked change to the present day condition of the ecosystem (see Section 3.4).

The specialists use the marked cross-sections to assess how much, if at all, the volume and distribution of flows could be changed without significant effects on the functioning of the riverine ecosystem. Thereafter, three additional levels of reduction are considered.

**General 'rule-of-thumb' for reductions in lowflows**

In general, if the focus of the assessment is to predict the consequences of additional abstractions from a river, the following reduction levels (from present day) are used:

- Capped at $20^{th}$ percentile on the Present Day FDC.
- Capped at $50^{th}$ percentile on the Present Day FDC.
- Capped at $70^{th}$ percentile on the Present Day FDC.
- Capped at $90^{th}$ percentile on the Present Day FDC.

## 3.6 GENERATE CHANGE LEVEL DATA FOR HIGH FLOWS

High flows are reduced in their **frequency**. For each reduction level, the **timing** of the remaining floods must also be decided. The timing of floods in each flood category is provided as part of the summary statistics for high flows and should be used as a guide for deciding on the timing of future floods, i.e., floods should not be requested in months where they did not occur naturally.

---

The highflow statistics (Section 2.14) provided the average magnitude, duration and volume of each flood category (Figure 3.9). The values are used to calculate the volume of water that would be needed to generate a flood event in each category. Thus, the change level data for a flood category are automatically calculated as the volume of water needed to generate a flood event in that category, multiplied by the number of events in each change level (see Section 3.4: Setting change levels for each flow category).

There is thus no need to do anything more to generate the highflow data.

**Minimum-change Change Level**

As for low flows, the first Change Level for each Flood Class is routinely set as the change in the number of floods that would not result in a marked change to the present day condition of the ecosystem, i.e., maintain *status quo* (see Section 3.4).

## 3.7 FORMAT FOR BIOPHYSICAL CONSEQUENCES: SEVERITY LEVELS, UNCERTAINTY, LIKELIHOOD OF CHANGE AND DATA SOURCES

DRIFT requires that specialists use a standard format for describing the consequences of flow change.

**Generic Lists**

For each discipline, a list of items that is likely to change with flow changes is required. Generic Lists are dealt with in more detail in Section 3.8.

**Direction of change**

For each prediction, specialists are asked to describe the direction of predicted change (if any) for every item on their Generic List. The direction of change represents an increase or decrease in the ***abundance, concentration or extent*** of a Generic List item.

**Severity Ratings**

For each consequence, the specialists will be asked to describe the ***severity*** of the predicted change (if any) using a Severity Rating between 1 and 5 (Table 3.1) for every item on their Generic List.

Table 3.1 Severity Ratings for each prediction of flow-related change. Severity Ratings convert directly to Integrity Ratings by adding a + (toward natural) or a – (away from natural).

| Severity Rating | Severity of change | Equivalent loss (abundance/concentration) | Equivalent gain (abundance/concentration) |
|---|---|---|---|
| 0 | None | no change | No change |
| 1 | Negligible | 80-100% retained | 1-25% gain |
| 2 | Low | 60-79% retained | 26-67% gain |
| 3 | Moderate | 40-59% retained | 68-250% gain |
| 4 | Severe | 20-39% retained | 251-500% gain |
| 5 | Critically severe | 0-19% retained; includes local extinction | 501% gain to ∞: up to pest proportions |

**Integrity Ratings**

For each prediction described, specialists are also be asked to give an indication of whether the change represents a move towards or away from the natural condition of the river. This move away from or towards natural is illustrated by a positive (+) or negative (-) sign before the Severity Rating.

The addition of the sign changes the Severity Rating to an Integrity Rating.

**Expression of uncertainty**

Uncertainty is expressed through the range of Severity Ratings given for an item. As shown in Table 3.1, each rating already encompasses a range of change. In addition, if uncertainty is greater than that already contained in the Severity-Rating range, this may be expressed as a range of Severity Ratings, e.g., 2-4. This effectively increases the spread of predicted percentage change, e.g., if rating 2 = 5-24%, and rating 4 = 51-75%, then ratings 2-4 would translate to an expected change of anywhere between 5 and 75%.

### Likelihood

Likelihood is an expression of the probability of the predicted change occurring and is expressed as high (H), medium (M) or low (L). This is different from expressing confidence in a prediction (which is expressed as uncertainty above) – and is an assessment of the ecological likelihood of the predicted change occurring.

### Data source

The quality of the data supporting each prediction must be provided. The data quality is rated as high (H), medium (M) or low (L), according to the following criteria:

H The prediction is supported by studies that have been published in peer-reviewed papers, books or reports. The studies should be directly applicable to the river in question. For instance, in the case of a motivation for a flow to support a particular species, the quality of the supporting data should only be listed as high if there is a peer-reviewed paper, book or report on the relevant aspect of that species' life-history.

M The prediction is supported by one or more of the following:
- studies in peer-reviewed papers, books or reports on similar species and/or processes
- unpublished data on the same species and/or processes
- direct observations in the study river.

L The prediction is made on the basis of:
- anecdotal information
- 'gut-feel'.

## 3.8 FORMAT FOR BIOPHYSICAL CONSEQUENCES: GENERIC LISTS

The worksheets containing the specialist data are arranged according to the format for the DRIFT Generic Lists. These Generic Lists are compiled for each discipline participating in the EF assessment.

It is important that the specialists adhere to the structure of these lists as they form the basis upon which the DRIFT Database is built.

**Contents of the Generic Lists**

DRIFT Generic Lists are comprised of items that will respond to a change in river flow through a change in their:

- abundance;
- concentration;
- extent (area).

The lists should not include processes. While it is accepted that changes in flow result in changes in processes, it is important that the implications of these process changes are described rather than the processes themselves. For example, a reduction in wet season low flows may result in a deduction in the **process** of downstream movement of invertebrates (downstream drift), which in turn may lead to a drop in recolonisation of downstream reaches. The implication of this would be a reduction, in the downstream reaches, in the abundance of macroinvertebrate species that rely on drift as a means of recolonisation. Thus, the Generic List item of interest would be a species that is a representative of all or many of the species that rely on drift as a means of recolonisation.

**Structure of the Generic Lists**

The Generic Lists comprise three levels in a hierarchical structure, as follows (Figure 3.9):

Level 1: Ecosystem Components, e.g., geomorphology, water quality, vegetation, fish.

Level 2: Sub-components. Major divisions within the Components, such as groups of chemical components (e.g., nutrients), communities of animals (e.g., feeding guilds) or communities of plants (e.g., vegetation zones).

Level 3: Elements. Individual species or chemical compounds that occur in specific Sub-components.

The actual Sub-components and Elements addressed for each Component are at the discretion of the specialist responsible for that Component. The number of entries allowed in each is limited, however, to allow for database design and more efficient operation.

For any Component, specialists may elect to describe changes as a result of flow changes for a maximum of ten (10) Sub-components, and four (4) Elements per Sub-component, i.e., a maximum of 40 elements. For all of the elected elements, the likely consequences will be described for all of the flow change levels. Thus, if the total allowable elements are used, this could result in predicted changes in 40 elements being described for up to four flow change levels in ten flow categories for each EF site.

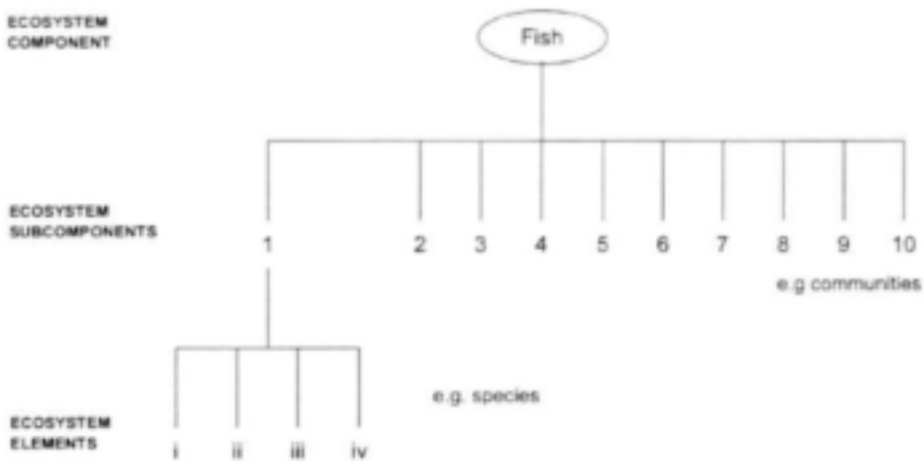



Figure 3.9 Structure of data entry worksheets showing the relationship between Component, Sub-components and Elements.

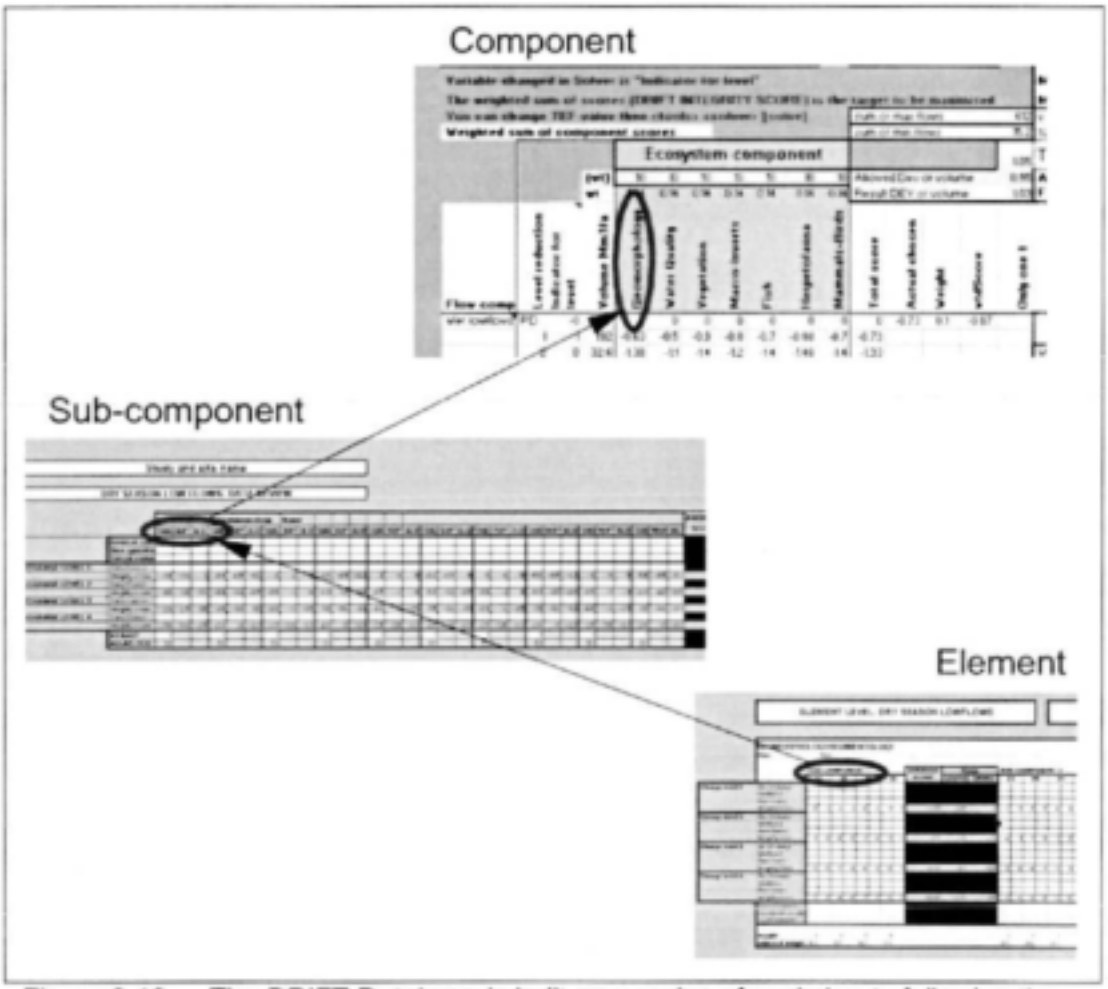



Figure 3.10 The DRIFT Database is built as a series of worksheets following the hierarchical structure outlined in Figure 3.9.

**Liaison between specialists in compiling their Generic Lists**

When compiling their Generic Lists, in addition to the hydrological and hydraulic information, specialists (in particular those responsible for describing the biological consequences of flow changes) may request information from other specialists.

For instance, before a specialist can predict the consequences of a reduction in summer low flows for a fish, they may wish to consider the EFFECT of the resultant flow on the following (Figure 3.11):

- depth and wetted area (from hydraulic specialist);
- water velocity (from hydraulic specialist);
- temperature (from the WQ specialist);
- salinity concentrations (from the WQ specialist);
- habitat quality (e.g., riffle embeddedness; from the geomorphologist);
- inundation of marginal vegetation (from the botanist);
- extent of instream vegetation (from the botanist);
- potential food for the fish (from the macroinvertebrate specialist).

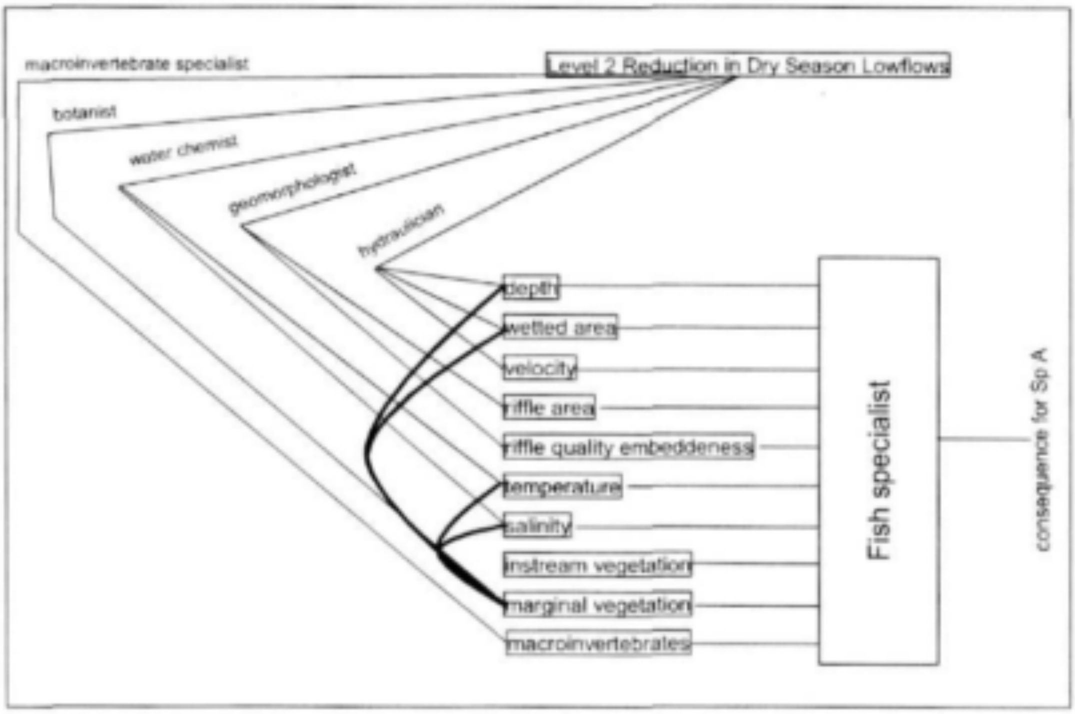



Figure 3.11 Schematic giving hypothetical example of information that needs to be assimilated by a fish specialist in order to predict the consequences of a change in wet season low flows for fish species A.

If the DRIFT Generic Lists compiled by any of the specialists do not contain items that might be required by specialists later in the sequence, then the predictions made will be based on fewer data than are potentially available. It is thus vital that the compilation of Generic Lists is a structured interactive exercise involving all the specialists.

**Focusing of flow related issues and 'indicator' items in the Generic Lists**

All specialists (and thus all disciplines) are limited to four elements per Sub-component, and a maximum of ten Sub-components, regardless of whether or not they are generating data that another specialist will need.

Before requesting data from another specialist, a specialist should thus ensure the following:

1. The information can be used: For instance, salinity data should not be requested by the fish specialist if there are no data on the salinity tolerances of any of the fish species in the study.
2. The main factors affecting the Generic List items are concentrated on.
3. The route that input data will take to get to them is understood. Specialists should not make predictions on behalf of another discipline. For instance, a fish biologist considering siltation of riffles and possible loss of invertebrates as a food sources for fish, should rely on the geomorphologist for information on the riffle and the macroinvertebrate specialist for information on the impact of riffle siltation on invertebrate abundances. The appropriate consideration for the fish biologist is the effect on the fish of any predicted change in invertebrates.

**Developing models of responses to flow**

Predictions will be based on conceptual or quantitative models of the relationship between each Generic List item and flow. These models will describe current understanding of the relationships. For instance, reductions in the number of Class 1 floods may affect the abundance of a macroinvertebrate species through (Figure 3.12):

- reduction in the number of cues for emergence (direct response);
- changes in water quality (indirect response);
- changes in food availability, e.g., leaf litter (indirect response).

It is important that the specialists make a first attempt at providing at least a conceptual model for each Generic List item, for refinement over time (e.g., Figure 3.12).

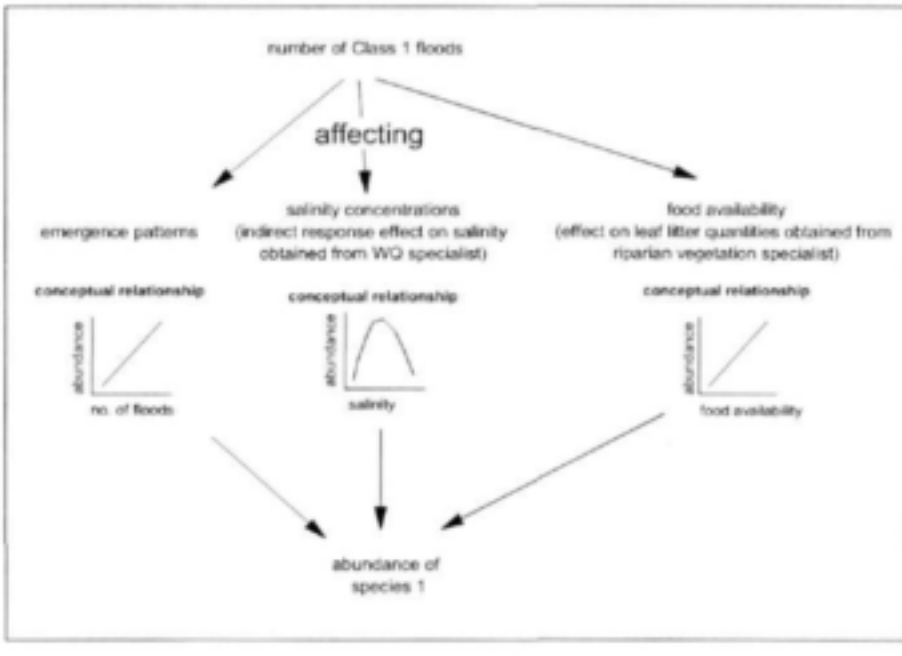



Figure 3.12 Schematic outlining a simple conceptual model for the response of a macroinvertebrate species to changes in the number of Class 1 floods.

## 3.9 SPECIALIST REPORTS

Specialists involved in an EF assessment using DRIFT each write a report of their findings prior to the population of the DRIFT database. The Terms of Reference for each report should require that it contains at least the following:

1 The full Generic List for that discipline.
2 A list of the data required from other disciplines.
3 Conceptual or detailed models of the relationship between each Generic List item and flow.
4 A description of how high flows in each size class affect ecosystem functioning, with specific reference to that discipline.
5 A literature review supporting the above, and on any relevant flow-linked phenomena of similar rivers.
6 Collation and analysis of all data collected at the EFR sites during the project.

---

**Example: Table of Contents for DRIFT Report**

Contents:

1 Introduction
2 Literature search: Discipline-specific background information available on the study rivers
3 Study approach and limitation
4 Division of the catchment into representative reaches
5 Site specific results of data collection activities
6 Discipline-specific Generic List
7 Information required from other specialists to inform flow-related changes to the items on the Generic List
8 Flow-related ecological profiles for ecosystem elements included in the Generic List
9 Expected generic responses of ecosystem elements included in the Generic List to modification of different parts of the hydrological flow regime
10 Literature cited

## 3.10 OBTAIN SPECIALISTS' PREDICTIONS OF THE BIOPHYSICAL CONSEQUENCES OF FLOW CHANGES

Once the specialists' reports are written, and usually in a workshop situation, the specialists provide their predictions on how the items on their generic lists are likely to change with the changes in flow (see set flow changes in Sections 3.5 and 3.6).

For each selected change level the hydraulic modeller provides information on how water depth, velocity and inundated area vary over key habitats at different discharges. Similarly, the hydrological change levels provide an indication of the temporal distribution of discharges for each flow category. Each specialist is asked to link this information to data, specific to their ecosystem Component, that have been collected along the same cross-sections, or elsewhere at the sites, to predict how the considered flow changes might cause ecosystem change.

For low flows, the summary data for each change level, such as the $5^{th}$ and $99^{th}$ percentile discharges, the shape of the FDC and the timing of the flows are used to provide information against which specialists can relate their particular Component.

For high flows, the specialists initially describe how the high flows in each size class affect ecosystem functioning. These effects can be biological, physical or chemical in nature. For instance, whereas the large 1:20 year events may dictate the shape of the channel, the smaller within-year events may act as biological cues and have much less effect on channel shape. Once they have described the effects of each size-class flood, they then describe the consequences of a reduced frequency of events in each size class and of such events no longer occurring. Thus, if six Class 3 floods occur on average per year, the specialists could describe the consequences for, for example:

- five events (on average per annum) instead of six;
- three events instead of six;
- one event instead of six;
- no events instead of six.

At each change level the remaining events are allocated to one or a range of calendar months, with reasons.

On presentation of the hydrological data, and a description of the flow changes that will be addressed, each specialist will use their own data, and their own methods to determine the likely consequences for each item on their Generic List.

The consequences of the change levels for the various flow categories are then entered into the DRIFT Database (Section 4), either by the specialists or by the facilitator.

# 4. POPULATE THE DRIFT DATABASE AND GENERATE INITIAL SCENARIOS

This section of the manual deals with population of the DRIFT biophysical database and with generating scenarios that link modified flow regimes to the ecological conditions in the river that they are likely to produce. It aims to:

1 provide an outline of the DRIFT Database;

2 explain the process of entering data;

3 outline the steps involved in scenario generation;

4 explain some of the options available for generating scenarios;

5 highlight some of the pitfalls in generating scenarios;

6 aid the user in interpreting and understanding the anticipated outputs from the database.

## 4.1 INTRODUCTION

The DRIFT biophysical database template is a site-specific framework designed to receive information from specialists and to use this to predict the ecological consequences of future (altered) flow regimes. Once populated, the database provides a permanent record of flow-related information provided by the specialists for that particular system, and the pathway used to develop the flow scenarios is transparent, from information provided by the specialists through to the final scenarios (Brown and Joubert 2003).

The flow scenarios are generated, and evaluated in terms of river condition, using multi-criteria analysis (MCA).

### 4.1.1 Software requirements

In order to run the DRIFT biophysical database you will need to be in possession of a legal copy of MS Excel 2000, and you will need to ensure that the 'Solver' routine (available in "Add-ins" in MS Excel 2000) is loaded.

Double-clicking on the Excel icon labelled "DRIFT" will open the database. Upon opening the database a dialogue box will appear warning the user about Macros in Excel. Click on the "Enable Macros" icon to continue.

***Tip: The DRIFT database is provided as a read-only file and needs to be renamed prior to use. The DRIFT database is not write-protected because of the need to add data in order to be able to create and view scenarios. Consequently there is the danger of accidentally overwriting important data and formulae. Please keep a backup copy of the database to refer to at all times.***

## 4.2 STRUCTURE OF THE DRIFT BIOPHYSICAL DATABASE

The database is divided into a series of worksheets. In order to access a worksheet click on one of the tabs on the bottom of the screen (Figure 4.1).


Figure 4.1 Cover Page of the DRIFT Database. Arrows point to the tabs that can be used to access the various worksheets.

The worksheets are arranged into six main groups on the basis of their functions (Figure 4.2). These are:

| | |
|---|---|
| Introduction: | *Cover Page and User Guide worksheets* |
| Hydrology: | *Summary of volumes and flow change information.* |
| Data Storage: | *Data Entry and Review worksheets, including Severity Ratings, Integrity Ratings, and other information from the specialists* |
| Scenario Creation: | *DRIFT-SOLVER© worksheet* |
| Scenario Evaluation: | *DRIFT-CATEGORY worksheet* |
| Checks and Balances: | *Integrity Effects, Solver Upper and Lower worksheets.* |

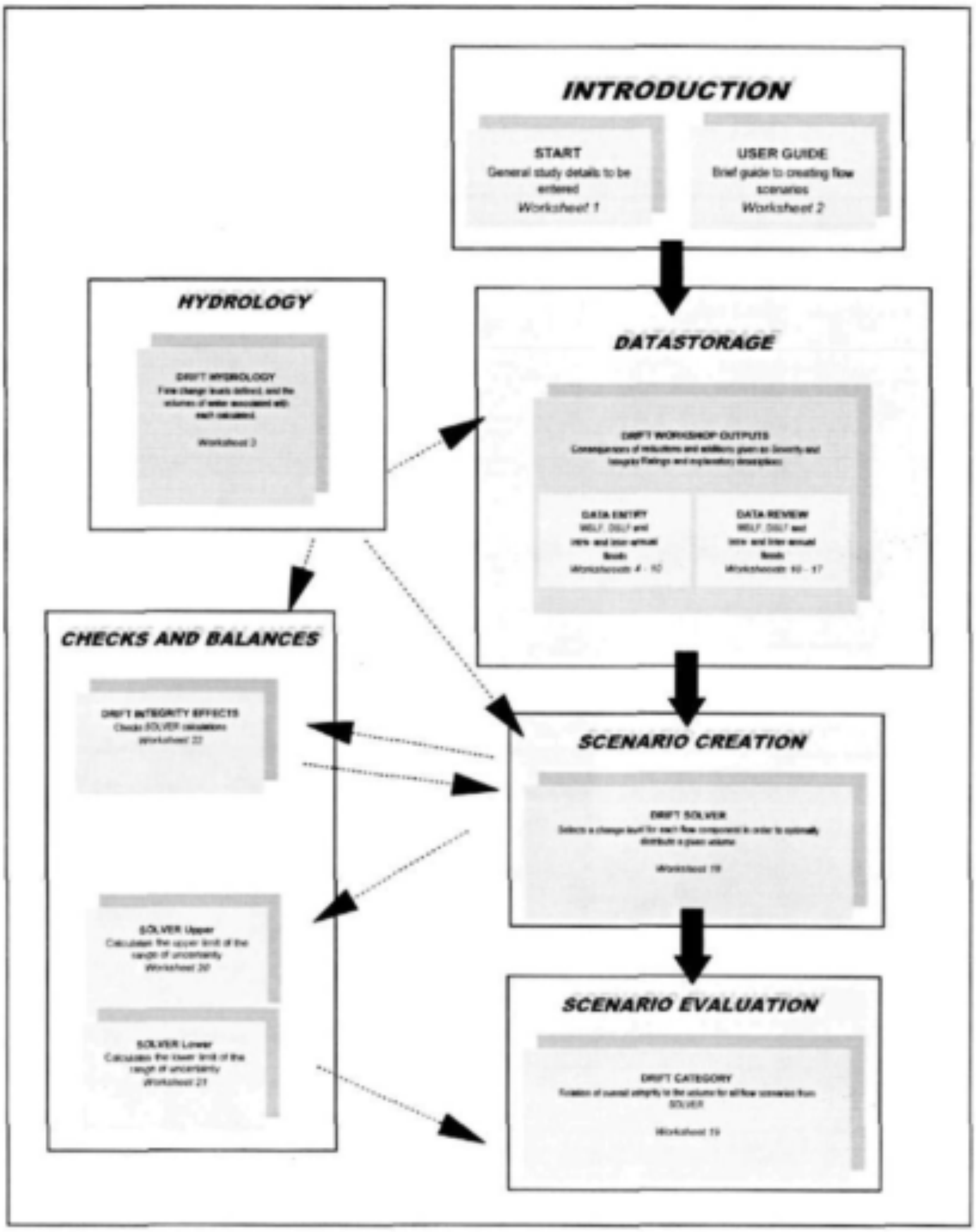



Figure 4.2. The Excel worksheets within the DRIFT database.

## 4.3 INTRODUCTORY WORKSHEETS

There are two Introductory worksheets, namely:

START: which forms the cover page to the DRIFT Database. General information regarding the study, such as the river and site names, period of study, client name and study team details, is entered into the assigned spaces. Each database is site specific and pertains to only one EFR site;

USER GUIDE: which is a short user guide describing the types of worksheets found in the database, outlines the software requirements of the database and provides various tips and warnings for users. Brief instructions on how to run DRIFT-SOLVER© and DRIFT-CATEGORY, along with tips on interpreting their outcomes are listed. A section on interpreting Consequence Data, using the 'Wet-low Review' worksheet as an example is also provided.

### START

Accessing worksheet: Click on the START Tab (Figure 4.1).

Entering data: The cells with white text can be altered and the appropriate study information entered (Figure 4.3).


Figure 4.3. The Start Worksheet, with the information that is required to be entered by the user circled in white.

**Links to other worksheets**

The study and site name will appear as a heading on each of the successive worksheets in the database. The names of the specialists will be carried through to the data-entry and data review worksheets and appear alongside their associated ecosystem Components.

## USER GUIDE

| | |
|---|---|
| Accessing worksheet: | Click on the USER GUIDE Tab (Figure 4.1). |
| Entering data: | No data should be entered on this worksheet. |

**Links to other worksheets**

Not linked.

## 4.4 HYDROLOGY WORKSHEET

There is one hydrology worksheet. This provides a summary of the different reductions and additions of flow assessed, and the volumes of water associated with each.

| | |
|---|---|
| Accessing worksheet: | Click on the SUMMARY HYDROLOGY Tab (Figure 4.1). |
| Entering data: | Volumes for each flow category and change level are obtained from the DRIFT-HYDRO© (see Section 2), and should be copied across manually into this worksheet (Figure 4.4). |


Figure 4.4. The Summary Hydrology Worksheet.

**Links to other worksheets**

Flow volumes for each flow category and change level are automatically fed to the scenario-creation worksheet (DRIFT-SOLVER©) page. The naturalised MAR is also linked to the SOLVER page.

## 4.5 DATA ENTRY

Data entry is done at the level of the Generic List element. The data entry group of worksheets for any one EFR site contains, for any one EFR site, ten worksheets, one for each of the ten different flow categories:

| | |
|---|---|
| WSLF – ELEMENT: | Wet Season Low Flow. |
| DSLF – ELEMENT: | Dry Season Low Flow. |
| CLASS 1 – ELEMENT: | Class 1 Floods. |
| CLASS 2 – ELEMENT: | Class 2 Floods. |
| CLASS 3 – ELEMENT: | Class 3 Floods. |
| CLASS 4 – ELEMENT: | Class 4 Floods. |
| CLASS 5 – ELEMENT: | Class 5 Floods. |
| CLASS 6 – ELEMENT: | Class 6 Floods. |
| CLASS 7 – ELEMENT: | Class 7 Floods. |
| CLASS 8 – ELEMENT: | Class 8 Floods. |

The worksheets are for the entry and storage of raw data on the predictions of change for all Generic-List items (see Section 3.9), at the element level, for up to four levels of change in flow volume.

The data entries consist of the Severity and Integrity Ratings (see Section 3.10) together with written explanations. Sub-component Integrity Ratings are then automatically calculated from the Element worksheets using the weighted sum of the relevant elements.

---

| | |
|---|---|
| Accessing worksheet: | Click on the *-ELEMENT[9] Tab (Figure 4.1). |
| Entering data: | Data can be entered into cells with a white background. The data in cells with a coloured fill are common to all sites and studies, and should not need to be changed. |
| Labelling data: | The four elements making up each Sub-component have default labels A – D, and the ten Sub-components default labels 1 – 10. These must be replaced with labels from the specialists' Generic Lists. |

a. Sub-component labels may be the names of communities, groups of species, groups of chemical compounds or important features.

b. Element labels will be the names of individual species, chemical compounds or aspects of important features.

*Figure 4.5 shows an example of an element worksheet, with data entered for the macroinvertebrates. Sub-component one has been relabelled 'Riffle Community' (Figure 4.5, red circle), and the four elements have been relabelled individual genera (Figure 4.5, purple circles).*

[9] Where * = acronym for one of the ten flow categories.

Figure 4.5. A section of the Wet Season Low Flow Element worksheet (WSLF-Element) showing completed data for the four elements making up the Sub-component 'Riffle Community', for the Component 'Invertebrates'.

| | |
|---|---|
| Severity Rating: | After considering the flow-category change, and with reference to their own data and analyses, the specialists enter Severity Ratings of change into the appropriate cells. Two Severity Ratings can be entered for each prediction, allowing the expression of uncertainty (Section 3.10). Each element has two assigned columns, for an upper, and a lower value, respectively. |
| Direction of change: | Specialists note whether the change described will constitute an increase (I) or a decrease (D) in abundance/concentration of the assessed element. |
| Likelihood: | The probability of the change occurring is reflected by its 'Likelihood'. Likelihood is expressed as high (H), medium (M) or low (L), and is the ecological likelihood of the specialist's prediction happening. |
| Data Source: | The quality of the data supporting each consequence is entered. The 'Data Source' is rated as high (H) medium (M) or low (L) according to the criteria outlined in Section 3.9. |
| Integrity Rating | An assessment is entered of whether the predicted change represents a move towards (+), or away from (-), natural by re-entering the Severity Rating values with a prefix + or -. |

The Integrity Ratings are the last line of data entered for each element at each flow change level. Once entered, an 'Average' score (weighted sum; see Appendix C for an explanation of calculations), as well as an 'Upper' and 'Lower' value will be automatically calculated for each Sub-component. The blue lines in Figure 4.5 indicate the data cells used in the calculations of the 'Average', 'Upper' and 'Lower' scores.

Note: *Not all Sub-components will be represented by four elements, and some may comprise only a single element. If the number of elements in each Sub-component is less than four, the relative weights of the elements should be adjusted to compensate for missing data i.e. the weights for those elements which are not being used should be set to zero. The weights that can be set by the user are circled in light blue in Figure 4.5.*

**Additional comments**

Below the change level data there are three comment boxes for each element, titled 'General Comments', 'Site-specific Comments' and 'Social Comments' (grey circle in Figure 4.5). An example of each, using fish data, is given below (Metsi 2002).

- General comment: It is expected that a reduction of the lowflow wet period, will have a major impact on habitat quality and quantity. These changes would significantly alter the prediction for this critically endangered species at this site, as availability and quality of spawning and incubation habitat will be reduced.
- Site-specific comment: It is also likely that negative affects on the Maloti Minnow will result from the physical presence of the weir preventing connectivity and thus gene-flow between up and downstream reaches. The species may be lost from this reach.
- Social Comment: Red data species that is not commonly caught or utilised for food by people.

**Links to other worksheets**

The average, and upper and lower Integrity Values for each Sub-component are automatically fed into the data review worksheets. The values for flow change 1 of the Sub-component illustrated in Figure 4.5, which will be fed into the WSLF-Review worksheet, are circled in green.

## 4.6 DATA REVIEW

The 'Review' worksheets use the Sub-component Integrity values to compute an Integrity Value for each Component. A separate Component Integrity Value is computed for each change level of each of the ten flow categories. There are four review worksheets: for the wet-season low flows, for the dry season low flows, for the intra-annual floods and for the inter-annual floods.

| | |
|---|---|
| Accessing worksheet: | Click on the '*-REVIEW'[10] Tab (Figure 4.1). |
| Entering data: | The relative weights of the Sub-components are the only data other than comments that should be entered into the review worksheets (turquoise circles in Figure 4.6). These weights are selected and entered by the relevant specialists, with the default being equal weighting. |

**Links to other worksheets**

The Sub-component Integrity Ratings are automatically updated from the scores calculated in the element worksheets, and no predictive data need to be entered manually into the review worksheets. For example, the green circles in Figure 4.6 indicate the Sub-component Integrity Ratings that were calculated in the 'WSLF-Element' worksheet and circled in green in Figure 4.5. Specialists' comments and data sources can be entered alongside the appropriate Integrity Ratings.

Component Integrity Ratings (weighted sum of the Sub-component Integrity Ratings for each change level) are calculated in the review worksheets and are fed into DRIFT-SOLVER© (Section 4.7). Only the 'Average Score' for each Component is fed into DRIFT-SOLVER© (red circle, Figure 4.6). The 'Upper' and 'Lower' scores picked up from the data entry worksheets are fed into the 'SOLVER UPPER' and 'SOLVER LOWER' worksheets (Figure 4.6: dark blue and purple circles, respectively) and are used to provide the 'confidence limits' in the predictions. The specialists' names associated with each Component are linked to the cover page.

[10] Where * = acronym for one of the four flow groupings listed above.

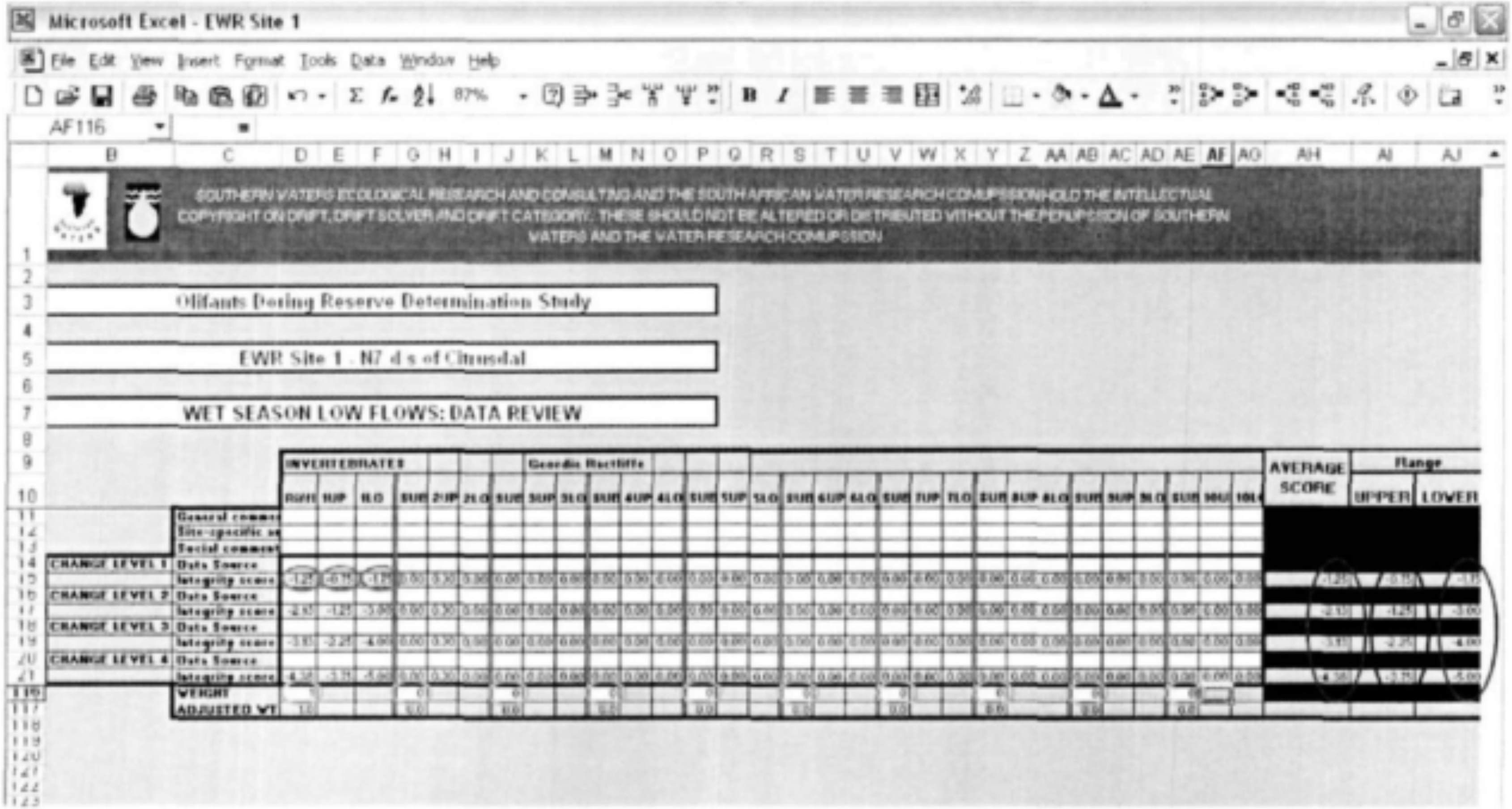



Figure 4.6. A section of the Wet Season Low Flow Data Review worksheet, showing the Component 'Invertebrates'.

## 4.7 SCENARIO CREATION WORKSHEET

There is one scenario creation worksheet, called DRIFT-SOLVER©. In DRIFT-SOLVER©, the predictive data, represented by the Integrity Ratings are combined in a range of permutations to create scenarios. Each scenario consists of a flow regime (one change level from each of the flow categories) together with its predicted ecosystem changes.

Integrity Ratings for each Component linked to the flow change levels (from the Review Worksheets) are summed, taking into account their positive and negative values, to produce an Overall DRIFT Integrity Score for each scenario (Figure 4.6: score in the green block).

The objective of SOLVER is to maximise the Overall DRIFT Integrity Score, and in doing so describe the distribution of flows, within an available volume of water, that would result in the best possible condition of the riverine ecosystem.

There are three starting points for the generation of such flow scenarios, referred to here as TYPES 1 – 3.

TYPE 1: A SPECIFIED VOLUME OF WATER AVAILABLE FOR ENVIRONMENTAL FLOWS. The scenario will describe the predicted condition of the river when a given volume of water is distributed ***optimally*** to achieve the best possible ecosystem condition.

TYPE 2: A SPECIFIED CONDITION IN WHICH THE RIVER SHOULD BE MAINTAINED. The scenario will describe the ***amount of water and optimal distribution*** required to facilitate maintenance of the river in the desired condition.

TYPE 3: MANAGEMENT LIMITATIONS: TYPE 1 OR TYPE 2 scenarios with modifications on the basis of limitations imposed by management or design constraints. The scenario will describe the volume and condition of the river resulting from the non-optimal distribution of water available.

TYPE 2 and 3 scenarios require that a TYPE 1 scenario creation be undertaken first, followed by manual manipulation of the results.

| | |
|---|---|
| Accessing worksheet: | Click on the DRIFT-SOLVER© Tab (Figure 4.1). |
| Entering data: | The Target Environmental Flow (TEF) is the most important value to be entered in DRIFT-SOLVER© (Cell U9) (Figure 4.7: dashed red rectangle). The TEF is the annual volume of water made available for the river in a particular scenario, and it is this volume that is distributed between the different flow categories. The maximum amount of water that can be stipulated is the naturalised Mean Annual Runoff (MAR; cell U7). The present day MAR (PD MAR) is displayed in Cell X7 and the percentage PD MAR is shown in Cell X8. When the % PD MAR used is greater than 100 %, then water is being added back into the river relative to its present condition. |

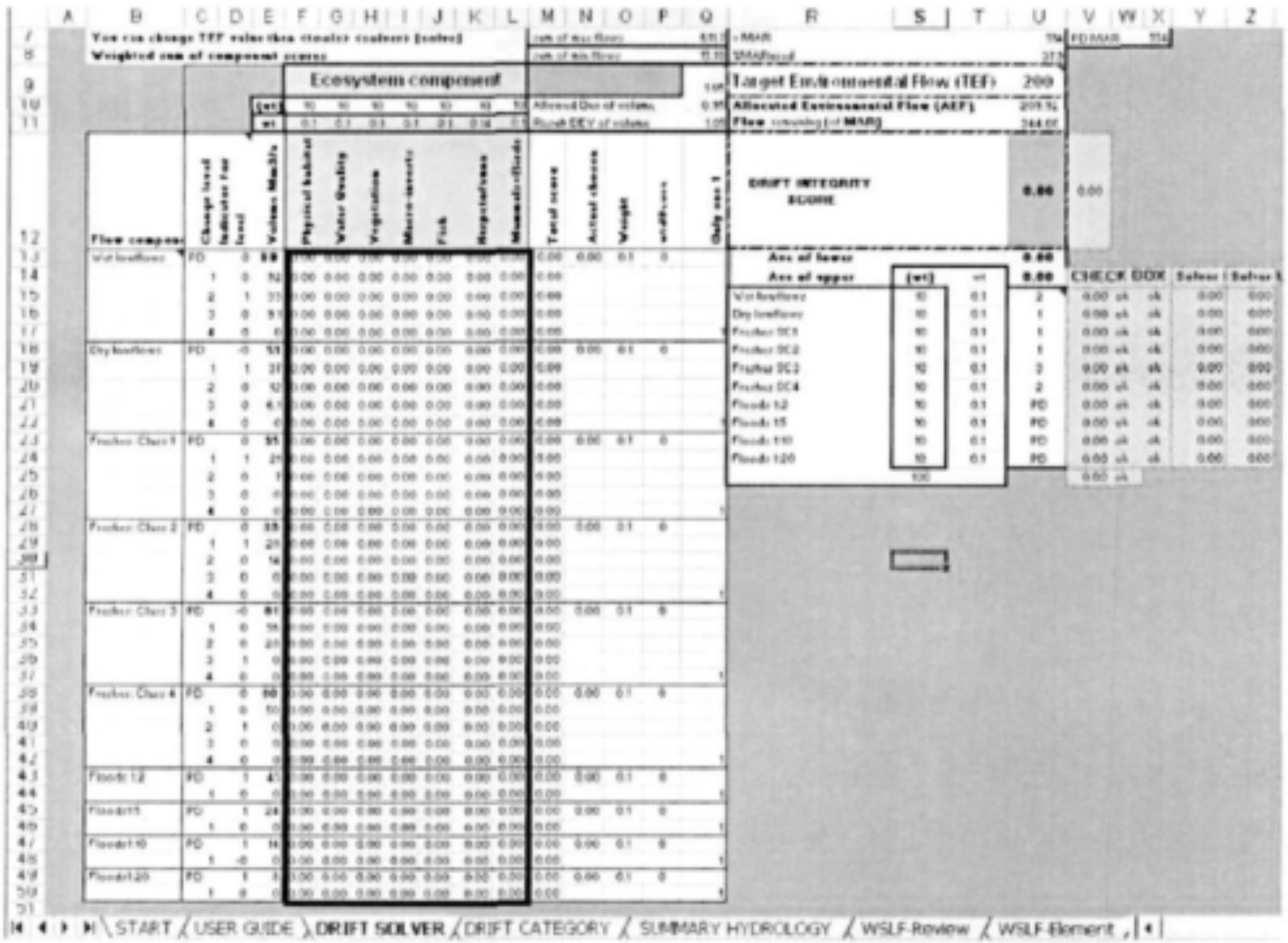



Figure 4.7 A section of the 'DRIFT SOLVER' worksheet.

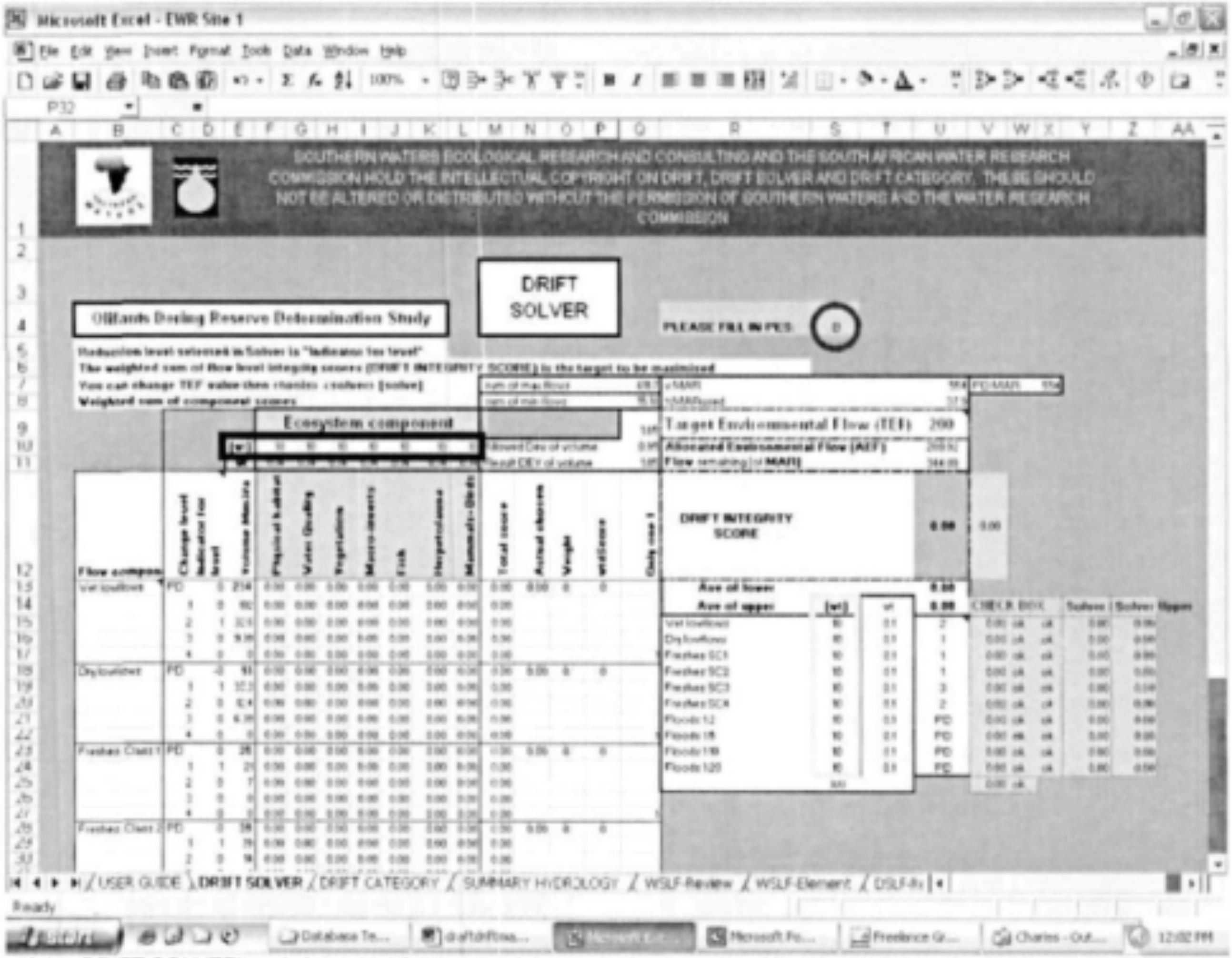



Figure 4.8 A section of the 'DRIFT SOLVER' worksheet, highlighting the data required to be entered into the worksheet by the user.

Other than the TEF, the weights for each Component and Present Ecological Status (PES; see Appendix X) of the river site in question are the only data that should be entered/altered in DRIFT SOLVER (but see also TYPE 2 and 3 scenarios below). The Component weights are displayed in Cells F10-L10 (default is equal weighting) (Figure 4.8: blue rectangle), and the flow category weights in Cells S15-24, with (default is equal weighting) Figure 4.8: yellow rectangle). The PES is entered into Cell S4 (Figure 4.8: green circle).

**Links to other worksheets**

The Component Integrity Ratings are automatically updated from the scores calculated in the review worksheets, and no prediction data are manually entered into DRIFT-SOLVER©.

Flow volumes from the 'Summary Hydrology' worksheet and the naturalised and PD Mean Annual Runoffs are automatically displayed on the SOLVER page.

The results from DRIFT-SOLVER© are automatically transferred to the table in DRIFT-CATEGORY entitled 'Input Sheet for Data from DRIFT-SOLVER©'.

**TYPE 1 SCENARIOS: A SPECIFIED VOLUME OF WATER AVAILABLE**

The specified volume of water is the Target Environmental Flow (TEF). Type the TEF into Cell U9 and press Enter.

Select 'Tools' on the main Excel menu, followed by 'Solver'. When the Solver pop-up box (called Solver Parameters) appears, select 'solve' (Figure 4.9: red circle). Solver will search for the solution that maximises the DRIFT Integrity Score for the volume of water entered (see Appendix C for the calculations). The Solver parameters (see Figure 4.9) are preset and should not be changed.

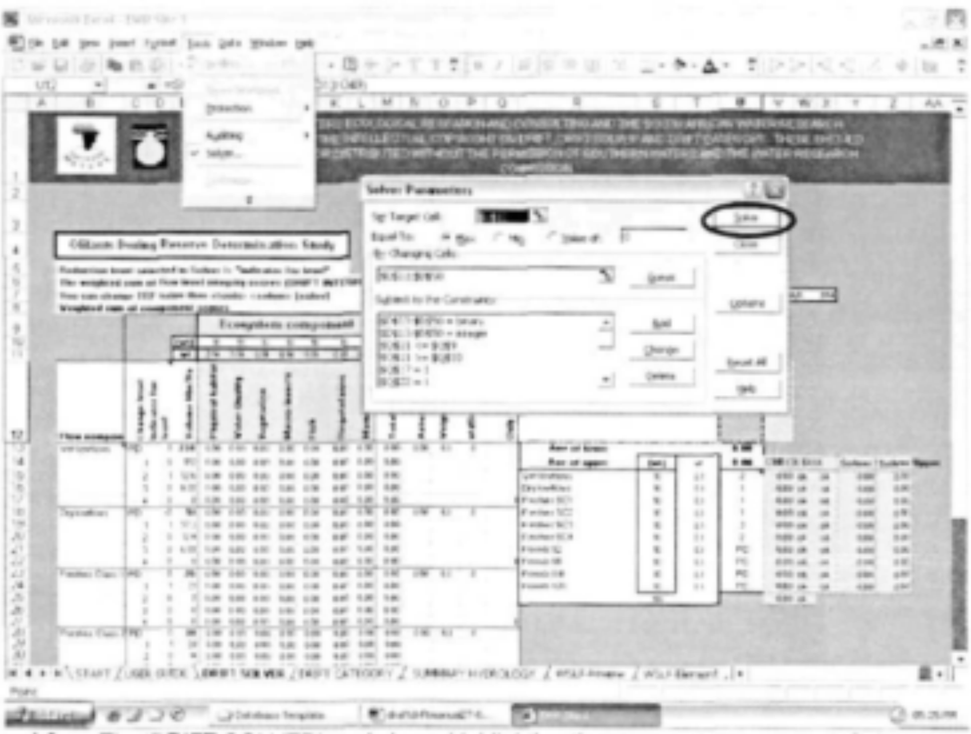


Figure 4.9 The 'DRIFT SOLVER' worksheet, highlighting the steps necessary to run Solver.

If Solver finds a solution, choose 'keep Solver solution' to view the scenario, or 'Restore original values' to cancel. If Solver indicates that it could not find a solution this is probably because the TEF volume is either too low or too high to find a suitable combination of volumes from the ten flow categories.

Additional scenarios can be created by entering different TEF volumes in Cell U11, and rerunning Solver (see also Section 4.8: Scenario Evaluation Worksheet).

Note: *When DRIFT-SOLVER© selects a new flow regime based on the TEF, this may not exactly equal the TEF because it has to use whatever volumes are available in the flow-change levels. SOLVER is given leeway of a 5% deviation from the TEF on either side. The volume of water it selects is called the Allocated Environmental Flow (AEF) (Cell U10). Cells Q9-10 state the allowed and resultant deviations; while Cell Q11 displays the resultant percentage deviation from the TEF i.e. the AEF divided by the TEF. The % naturalised MAR used (Cell U8) is calculated as the AEF divided by the naturalised MAR (Cell U7), and the flow remaining (Cell U11) is the difference between the v MAR and the AEF. The present day (PD) MAR is displayed in Cell X7 and the % PD MAR used is displayed in X8.*

**Interpreting a scenario**

Flow volumes for all flow categories for the present day (PD) and for the assessed change levels are displayed in Cells E13-50.

In column D (Cells 13-50), a binary code indicates which change level was selected for each flow category by Solver. A "1" indicates that the level was selected (Figure 4.10) and a "0" that it was not selected.

Column M ("Total Score") displays the Flow Level Integrity Score for each change level of each flow category, i.e., the weighted sum of the Component scores for that change level.

Column N displays the Integrity Score for the selected change level.

Column O displays the weights for each of the flow categories (adjusted in Cells S15-24).

Column P represents the weighted score for the flow category, i.e., weight x Flow Level Integrity Score. The sum of the weighted scores in column P is the DRIFT Integrity Score (Cell U12).

Column Q is a check that ensures that only one change level is selected per flow category - a "1" must appear in this column otherwise Solver has miscalculated (Figure 4.10).

The 'Ave of lower' and 'Ave of upper' in Cells U13 and 14 respectively are the DRIFT Integrity Scores calculated on the SOLVER UPPER and LOWER worksheets (see Section 4.9).

**Checks and balances**

*All cells with a pale blue background provide checks on the calculations undertaken on the SOLVER worksheet. It is important to take note of the check boxes, as the SOLVER page is not write-protected, and there is always the chance that formulae or data can be mistakenly changed or deleted.*

Cells V14-24 (Figure 4.11: red rectangle) are the weighted flow change level integrity scores, and cells W14-24 (Figure 4.11: yellow circle) and X14-24 (Figure 4.11: purple circle) compare these scores to those calculated on the SOLVER LOWER and SOLVER UPPER worksheets respectively. If each flow level integrity score is within the two limits, "ok" will appear, otherwise "wrong" will appear.

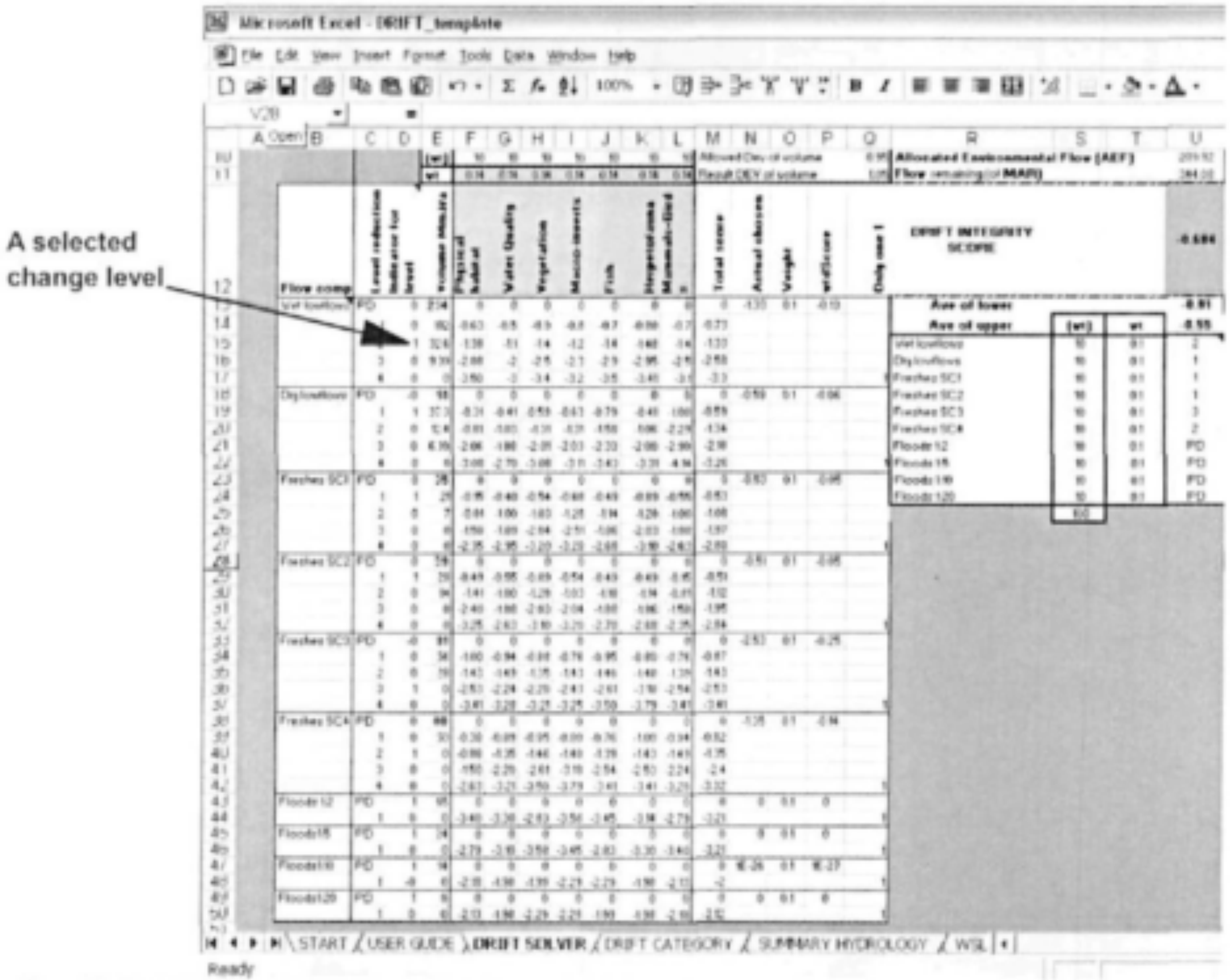



Figure 4.10 The section of the 'DRIFT SOLVER' worksheet described in the section 'interpreting a scenario'.

Cell V25 (Figure 4.11: green rectangle) recalculates the DRIFT integrity score by summing the values in cells V14-24. If this total in cell V25 is equal to the DRIFT integrity score in cell U12 (Figure 4.10), then "ok" will appear in cell W25 (Figure 4.11: grey circle), otherwise "wrong" will appear.

The DRIFT Integrity Score is recalculated in Cell V12 as a crosscheck with the score calculated in U12. If these two scores do not equal each other, the user needs to backtrack and check the relevant calculations.

A full description of the calculations and processes behind the creation of the Overall Integrity Score is outlined in Appendix C.

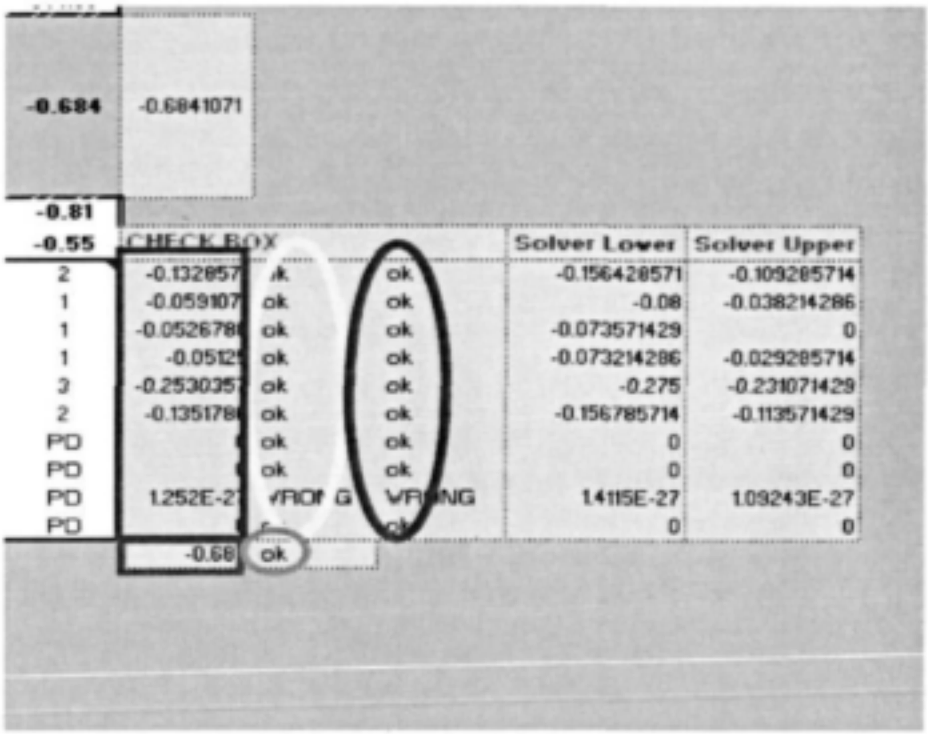



Figure 4.11 The 'Check Box' from the 'DRIFT SOLVER' worksheet.

**TYPE 2 SCENARIOS: A SPECIFIED CONDITION FOR THE RIVER**

There are three mechanisms for determining the volume and distribution of water required to maintain a specific river condition:

1. create the DRIFT-CATEGORY plot (Section 4.8) and use that to determine the volume and distribution of water required to maintain the desired or target DRIFT Integrity Score;
2. adjust the TEF and run Solver as described for a TYPE 1 scenario until the desired or target DRIFT Integrity Score is obtained.
3. determine a target DRIFT Integrity Score for a specific species and set the scores for all other species to zero.

**TYPE 3: MANAGEMENT LIMITATIONS**

If some of the flow categories required for optimal distribution cannot be released, perhaps because of design or operational constraints, then it is possible to manually adjust the distribution by changing the position of any of the "1" in Column D.

The volume of water used to produce the scenario (Cell U12) will drop if flow categories are eliminated or selected at a lower change level. If possible, that volume of water should be redistributed to other categories.

| | |
|---|---|
| *Tip:* | ***DRIFT-SOLVER© cannot be write protected because of the need to change values in order to be able to create scenarios. This means that there is a danger of accidentally overwriting important data. Please ensure that you retain backup copies for reference in the event of an accidental overwrite.***<br><br>***The levels of flow change available for a scenario are dependent on the Change Levels used to populated the database. Thus, the change levels should be selected upfront to reflect the scenarios of interest.***<br><br>***It is important to check that seasonal reversals of low flows do NOT occur. At low % MAR DRIFT has a tendency to choose a wet season lowflow that is lower than dry season lowflow. This must be assessed and, if seasonal reversal occurs, changed manually.*** |

## 4.8 SCENARIO EVALUATION WORKSHEET

There is one scenario evaluation worksheet, called DRIFT-CATEGORY.

The purpose of DRIFT-CATEGORY is to display the relationship between the volume of water remaining in the river and river condition. This is displayed in two plots where the volume of water is shown as MCM or as % MAR.

Accessing worksheet: Click on the DRIFT-SOLVER© Tab (Figure 4.1).

**Creating the DRIFT-CATEGORY Plots**

The results from DRIFT-SOLVER© are automatically transferred to the table entitled 'Input Sheet for Data from DRIFT-SOLVER©' (cells B-T; 30-55; Figures 4.12 and 4.13). The results will appear in cells B33-T33 (cells with a white background). These results are over-written each time SOLVER is run. *In order to keep these results, the Integrity Scores, flow volumes (i.e., in cells B33-T33) and other data in the white cells need to be copied down into the yellow portion of the table* *__before__* *SOLVER is rerun.* When pasting the data it is essential that the 'Paste Special' command, followed by ticking the 'Values' box, is used. The yellow portion of the 'Input Sheet for Data from DRIFT SOLVER' table contains the data used to create the CATEGORY plots.

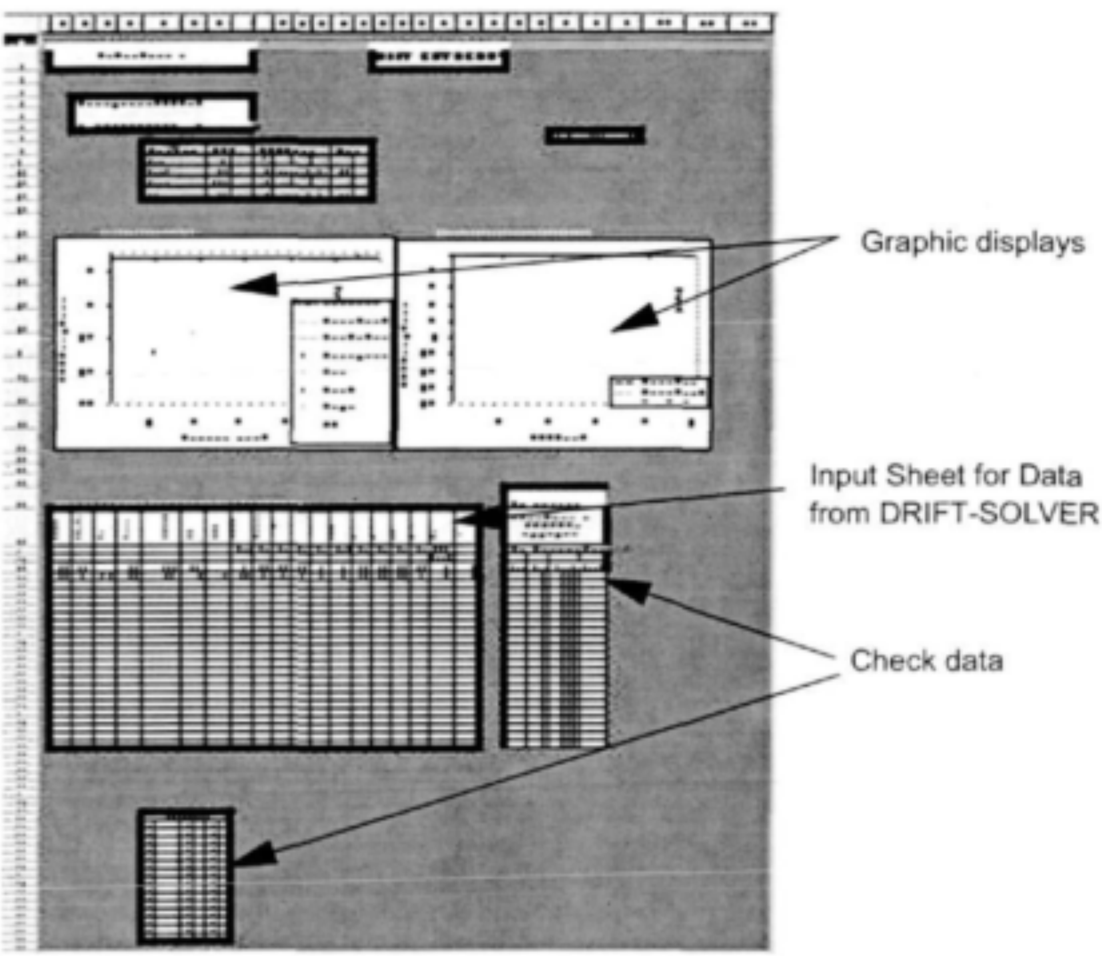
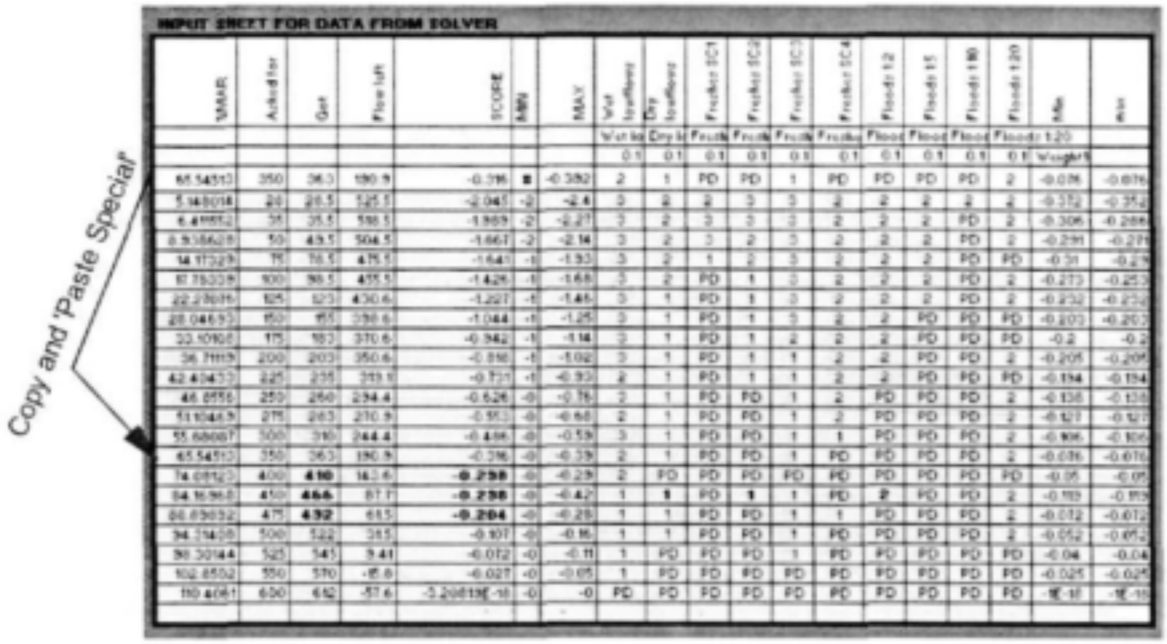



Figure 4.12 The DRIFT-CATEGORY Worksheet.




| VMAR | Asked for | Got | Flow left | SCORE | MIN | MAX | Wet lowflows | Dry lowflows | Freshes SC1 | Freshes SC2 | Freshes SC3 | Freshes SC4 | Floods 1:2 | Floods 1:5 | Floods 1:10 | Floods 1:20 | Min | Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Wet lo | Dry lo | Fresh | Fresh | Fresh | Freshe | Flood | Flood | Flood | Floods 1:20 | | |
| | | | | | | | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | Weight | |
| 65.54513 | 350 | 363 | 190.9 | -0.316 | [illegible] | -0.382 | 2 | 1 | PD | PD | 1 | PD | PD | PD | PD | 2 | -0.076 | -0.076 |
| 5.148018 | 25 | 28.5 | 525.5 | -2.045 | -2 | -2.4 | 3 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | -0.352 | -0.352 |
| [illegible] | 35 | 35.5 | 518.5 | -1.989 | -2 | -2.27 | 3 | 2 | 3 | 3 | 3 | 2 | 2 | 2 | PD | 2 | -0.306 | -0.288 |
| [illegible] | 50 | 49.5 | 504.5 | -1.667 | -2 | -2.14 | 3 | 2 | 3 | 2 | 3 | 2 | 2 | 2 | PD | 2 | -0.291 | -0.271 |
| 14.17329 | 75 | 76.5 | 475.5 | -1.641 | -1 | -1.93 | 3 | 2 | 1 | 2 | 3 | 2 | 2 | 2 | PD | PD | -0.31 | -0.29 |
| [illegible] | 100 | 98.5 | 455.5 | -1.426 | -1 | -1.68 | 3 | 2 | PD | 1 | 3 | 2 | 2 | 2 | PD | 2 | -0.273 | -0.253 |
| [illegible] | 125 | 123 | 430.6 | -1.227 | -1 | -1.46 | 3 | 1 | PD | 1 | 3 | 2 | 2 | 2 | PD | 2 | -0.232 | -0.232 |
| 28.04693 | 150 | 155 | 398.6 | -1.044 | -1 | -1.25 | 3 | 1 | PD | 1 | 3 | 2 | 2 | PD | PD | PD | -0.203 | -0.203 |
| 33.10108 | 175 | 183 | 370.6 | -0.942 | -1 | -1.14 | 3 | 1 | PD | 1 | 2 | 2 | 2 | PD | PD | PD | -0.2 | -0.2 |
| [illegible] | 200 | 203 | 350.6 | [illegible] | -1 | -1.02 | 3 | 1 | PD | 1 | 1 | 2 | 2 | PD | PD | 2 | -0.205 | -0.205 |
| 42.40433 | 225 | 235 | [illegible] | [illegible] | -1 | -0.93 | 2 | 1 | PD | 1 | 1 | 2 | 2 | PD | PD | PD | -0.194 | -0.194 |
| [illegible] | 250 | 260 | 294.4 | -0.626 | -0 | -0.76 | 3 | 1 | PD | PD | 1 | 2 | PD | PD | PD | 2 | -0.138 | -0.138 |
| [illegible] | 275 | 283 | 270.9 | -0.553 | -0 | -0.68 | 2 | 1 | PD | PD | 1 | 2 | PD | PD | PD | 2 | -0.127 | -0.127 |
| [illegible] | 300 | 310 | 244.4 | [illegible] | -0 | -0.59 | 3 | 1 | PD | PD | 1 | 1 | PD | PD | PD | 2 | -0.106 | -0.106 |
| 65.54513 | 350 | 363 | 190.9 | -0.316 | -0 | -0.39 | 2 | 1 | PD | PD | 1 | PD | PD | PD | PD | 2 | -0.076 | -0.076 |
| [illegible] | 400 | **410** | [illegible] | **-0.298** | -0 | -0.29 | 2 | PD | PD | PD | PD | PD | PD | PD | PD | PD | -0.05 | -0.05 |
| [illegible] | 450 | **466** | 87.7 | **-0.298** | -0 | -0.42 | 1 | **1** | PD | **1** | 1 | PD | **2** | PD | PD | 2 | [illegible] | [illegible] |
| [illegible] | 475 | **492** | [illegible] | **-0.204** | -0 | -0.28 | 1 | 1 | PD | PD | 1 | 1 | PD | PD | PD | 2 | -0.072 | -0.072 |
| [illegible] | 500 | 522 | 31.5 | -0.107 | -0 | -0.16 | 1 | 1 | PD | PD | 1 | PD | PD | PD | PD | 2 | -0.052 | -0.052 |
| 98.30144 | 525 | 541 | 3.41 | -0.012 | -0 | -0.11 | 1 | PD | PD | PD | 1 | PD | PD | PD | PD | PD | -0.04 | -0.04 |
| 102.6502 | 550 | 570 | [illegible] | -0.027 | -0 | -0.05 | 1 | PD | PD | PD | PD | PD | PD | PD | PD | PD | -0.025 | -0.025 |
| 110.4061 | 600 | [illegible] | -57.6 | -3.20819E-16 | -0 | -0 | PD | PD | PD | PD | PD | PD | PD | PD | PD | PD | -1E-16 | -1E-16 |

Figure 4.13 Close-up of the 'Input sheet for data from SOLVER' sheet from DRIFT-CATEGORY (see Figure 4.12).

Pasting the data for sequentially increasing or decreasing TEF values into the yellow blocks will generate the two DRIFT-CATEGORY plots (Figure 4.14). Once they have been created, they can be altered by changing the data in the yellow blocks, by rerunning SOLVER.

The small yellow box on the top left of the screen (Cells C–I; 6-8) links the PES value and Present Day MAR given on the 'SOLVER' page. The current PES value is shown on the left hand CATEGORY plot and is given an Integrity Score of 0.

**Creating the boundaries for the Ecological Condition Categories**

Boundaries between categories of ecological condition are per force artificial. Ecological categories are human imposed distinctions, which are useful for management, but in many cases there may not be a marked threshold between one condition category and the next.

In the absence of a clear definition of when a river shifts from one category to the next, the following set of 'rules' has been adopted in DRIFT to distinguish between different condition categories.

***Scenarios that shift an ecosystem back toward natural***

If, for a given scenario, the final score of all the Integrity Ratings for all Sub-components (i.e., Overall Integrity Score) is positive and:

- if at least 85% of the sub-component Integrity Ratings are ≤ 1, then the condition of the ecosystem will remain in the present category;
- if at least 85% of the sub-component Integrity Ratings are ≤ 2, then the condition of the ecosystem will shift from the present category to the next highest category;

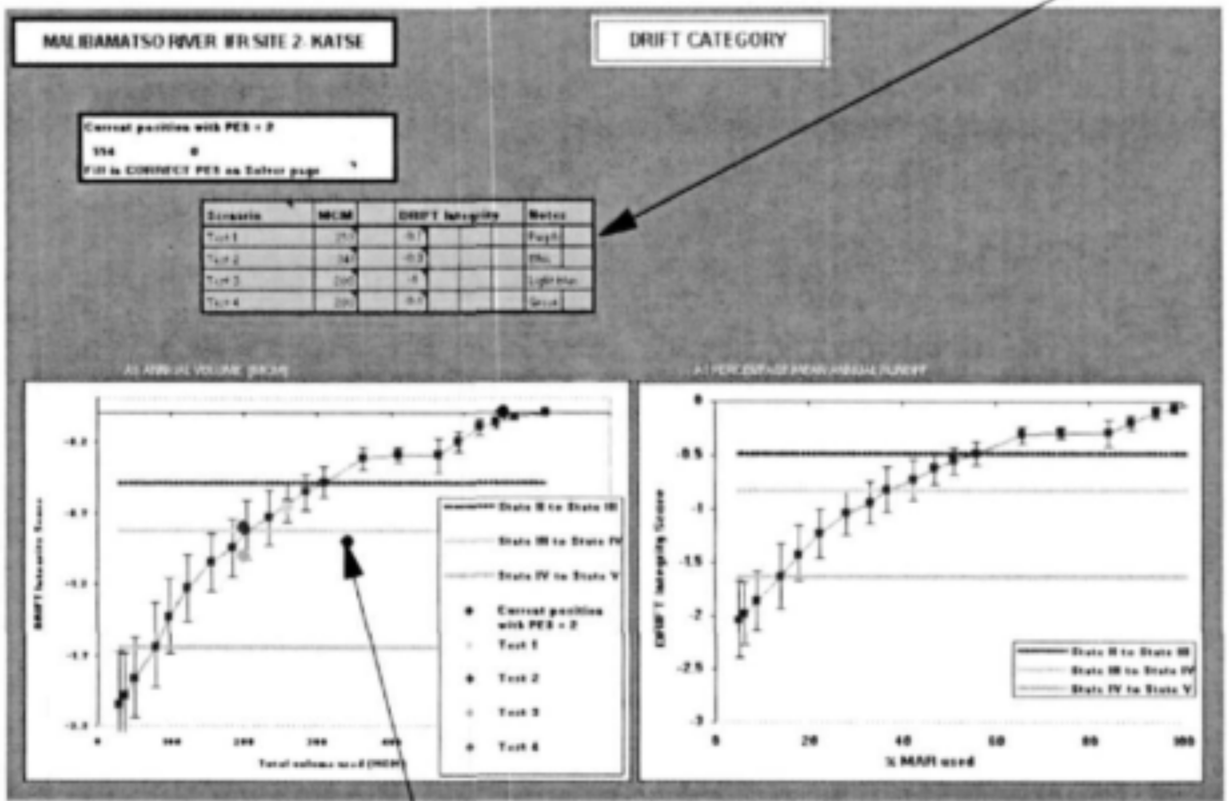



Figure 4.14 The two DRIFT-CATEGORY plots (see explanation below).

- if at least 85% of the sub-component Integrity Ratings are ≤ 3, then the condition of the ecosystem will shift to two categories higher;
- if at least 85% of the sub-component Integrity Ratings are ≤ 4, then the condition of the ecosystem will shift to three categories higher.

***Scenarios that shift an ecosystem away from natural***

If, for a given scenario, the Overall Integrity Score is negative and:

- if at least 85% of the sub-component Integrity Ratings are ≥ -1, then the condition of the ecosystem will remain in the present category;
- if at least 85% of the sub-component Integrity Ratings are ≥ -2, then the condition of the ecosystem will shift from the present category to the next lowest category;
- if at least 85% of the sub-component Integrity Ratings are ≥ -3, then the condition of the ecosystem will shift to two categories lower;
- if at least 85% of the sub-component Integrity Ratings are ≥ -4, then the condition of the ecosystem will shift to three categories lower.

**Viewing a new scenario**

One to four new scenarios can be plotted on the CATEGORY curves by entering the relevant data into the light green 'Scenario' box (Cells F-O; 10- 14, Figure 4.14). New scenarios should be named (Cells F11-14). The volume of water used to produce each scenario (from Cell U12 in DRIFT-SOLVER©) should be entered in Cells H11-14, and the DRIFT Integrity Score (from Cell U14 in DRIFT-SOLVER©) should be entered into Cells J11-14. The positions of the new scenarios will appear on the left hand CATEGORY plot. Scenario 1 = purple circle. Scenario 2 = dark blue circle. Scenario 3 = light blue circle. Scenario 4 = dark green circle.

**Interpreting a scenario**

If a scenario falls on or near the curve then the distribution of flows is close to optimal for the volume entered. If however, it is not possible to release some of the required flow categories, then the distribution of flows may be less than optimal and the position of the new scenario will tend to fall well below the curve.

**Links to other worksheets**

The CATEGORY worksheet is linked to the SOLVER worksheet as described above. It is also linked to the Integrity Effects worksheet (Section 4.9), which calculates the position of the river condition categories, i.e., when a change in river condition from one category to the next occurs.

| | |
|---|---|
| *Tip:* | ***DRIFT- CATEGORY cannot be write protected because of the need to change values in order to be able to create and view scenarios, respectively. This means that there is a danger of accidentally overwriting important data. Please ensure that you retain backup copies for reference in the event of an accidental overwrite.*** |

## 4.9 'CHECKS AND BALANCES' WORKSHEETS

There are two types of Checks and Balances worksheets. These are:

- SOLVER LOWER and SOLVER UPPER, which express the range of uncertainty in specialists' predictions. The SOLVER LOWER and SOLVER UPPER worksheets appear and function in the same manner as the DRIFT-SOLVER© page, but instead of using an average of the range of Integrity Ratings, uses either the lower or upper value. The resulting scores from these worksheets are used to produce the error bars on the DRIFT-CATEGORY plot.
- CATEGORY RULES, which calculates the condition classes that are depicted on the DRIFT-CATEGORY plot (see Section 9).

### SOLVER UPPER AND SOLVER LOWER

| | |
|---|---|
| Accessing worksheet: | Click on the SOLVER UPPER or SOLVER UPPER Tabs (Figure 4.1). |
| Entering data: | No values should be entered manually into these worksheets. The upper and lower scores are automatically calculated when SOLVER is run on the DRIFT-SOLVER© page. |

**Links to other worksheets**

All lower and upper values are automatically linked to SOLVER LOWER and SOLVER UPPER from the Data Review worksheets. The output values from the SOLVER LOWER and SOLVER UPPER worksheets are fed automatically into DRIFT-CATEGORY and used to create the error bars on the DRIFT-CATEGORY plot.

### CATEGORY RULES

| | |
|---|---|
| Accessing worksheet: | Click on the CATEGORY RULES Tab (Figure 4.1). |
| Entering data: | No data are entered into this worksheet. With each successive running of DRIFT SOLVER, data in Cells E9:16 and E22:29 are to be copied and pasted (using 'paste special', 'values') into the adjacent yellow section (Figure 4.15). These data represent cumulative percentages of scores in the categories defined in Section 4.8. These categories are depicted in the red and purple circles in Figure 4.15. Once all scenarios in DRIFT SOLVER have been run, the rules stipulated in Section 4.8 will need to be applied to the data in the yellow portions of the worksheet, in order to determine the Overall Integrity Scores at which changes in river condition occur. The Overall Integrity Scores, at which changes in river condition occur, needs to be copied onto the DRIFT CATEGORY worksheet, in order to create the boundaries for Ecological Condition categories. Three changes in river condition can be added to the DRIFT CATEGORY plots, the titles of which need to be inserted in Cells V33, W33 and X33. The Overall Integrity Score at which each change occurs needs to be inserted into Cells V34:59, W34:59 and X34:59. |

**Links to other worksheets**

Linked to DRIFT-SOLVER© and DRIFT-CATEGORY.

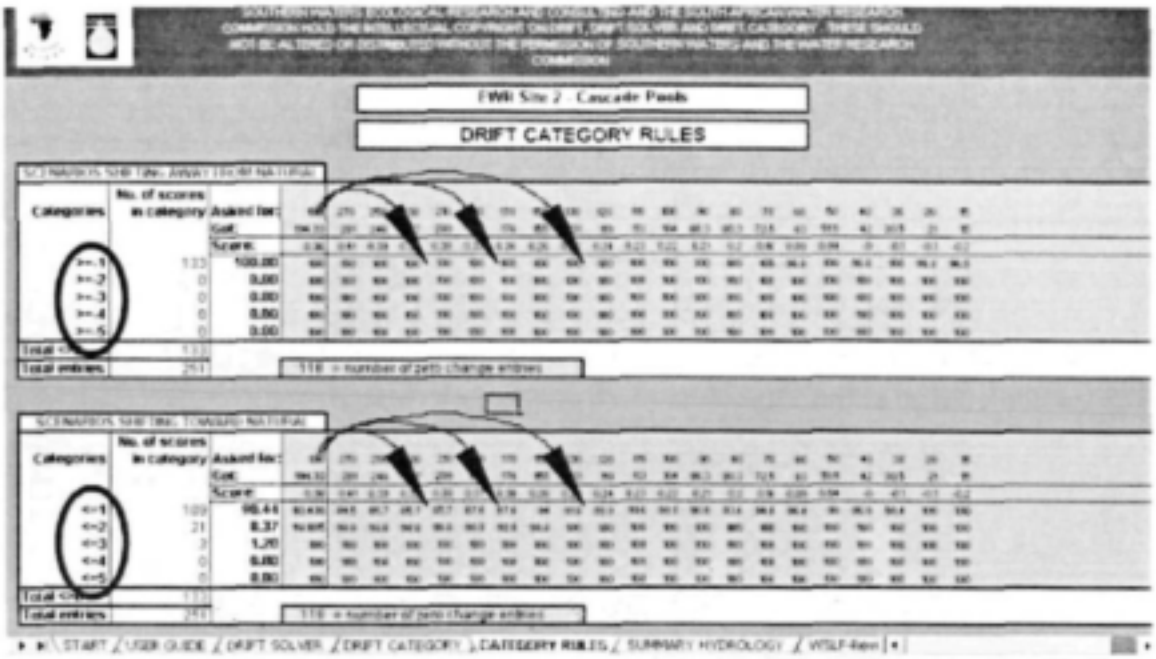



Figure 4.15 The Category Rules worksheet. See above for explanation.

# 5. GENERATING THE MODIFIED FLOW REGIME FOR EACH SCENARIO

This section of the manual deals with the generation of a modified flow regime for each DRIFT scenario, and of relevant summary hydrological data.

Once the DRIFT Database has been populated with the specialists' predictions, and DRIFT SOLVER and DRIFT CATEGORY have been run, it is possible to reconstruct a complete flow regime for any of the flow scenarios that were generated. These complete flow regimes are required for input to various Yield, and other Water Resource Models, and for determining the long-term average flow requirements for the scenario[11].

In this stage of the DRIFT process, the aim is to generate the detailed hydrological output for any DRIFT scenario selected. This will comprise:

1. A complete flow regime for each scenario. This flow regime is compiled by combining the relevant hydrological data sets constructed (see Sections 3.5 and 3.6) for each of the flow changes selected by DRIFT for each flow category. The process of generating the modified flow regime for a scenario is explained in Sections 5.2, 5.3 and 5.4.
2. An EFR Summary Table, which summarises the DRIFT requests, i.e., those directly from DRIFT-CATEGORY for each scenario. This is explained in Section 5.5.
3. Rule Tables for each scenario. These are the exceedance tables for the flow regime constructed in 1 above. This is explained in Section 5.5.

## 5.1. INTRODUCTION

Much of the scenario generation is done in the DRIFT Database, using the summary hydrological statistics. These summary statistics provide sufficient basic data to allow for the selection of one or more key scenarios for further more detailed investigation or for selection as the chosen scenarios. However, while useful for decision-making, the monthly and annual averages generated in DRIFT-SOLVER© are not particularly useful in implementing a selected scenario. Thus, once one or more scenarios have been selected for possible implementation, more detailed hydrological data need to be generated of the flow regime linked to each.

[11] As a general rule, the volumes given in DRIFT Category are higher than the final volumes that would be arrived at through detailed calculations for particular releases from a dam, or run-of-river abstraction, when floods are capped and/or are not cued by climatic events.

## 5.2. CREATE THE MODIFIED FLOW REGIME IN DRIFT-HYDRO©

Each run of DRIFT-SOLVER© produces a scenario that the user can give a name to, and for which SOLVER has produced flow change levels. To create the full modified flow regime for a scenario, its name and flow change levels are entered into DRIFT-HYDRO© according to the procedures described below.

As a general rule, the volumes given in DRIFT Category will be higher than the final volumes that would be arrived at through detailed calculations for a particular scenario, when floods are capped and/or are not cued by climatic events[12].

---

Restart DRIFT-HYDRO©. On the Drift Dashboard, under the section entitled 'Parameters', press 'Changes & Scenarios'.

Then select 'Scenarios' (Figure 5.1).

Figure 5.1 Define-Scenarios window in DRIFT-HYDRO©.

Creation of a modified flow regime for a given scenario is started by entering its name and corresponding flow change levels produced by DRIFT-SOLVER© into the Scenarios window (Figure 5.1). These should include:

- a specified change level for each lowflow season (from DRIFT-SOLVER©);
- a specified change level for each Flood Class (from DRIFT-SOLVER©).

It is only necessary for the user to enter the change level for each flow category, the other information such as the volume of water associated with a change level, and the number of floods associated with the chosen inter- or intra-annual flood change level, will be filled in automatically by DRIFT-HYDRO© using the information provided earlier (see Section 3.4). For instance, the 'High Flows' box at the

[12] For example, if DRIFT requests 5 floods of a particular Class, then if 5 floods occur naturally in the season they are requested they will be supplied. If, however, only 2 floods occur then only 2 will be supplied. If more than 5 floods occur naturally, e.g., 7, then only the requested 5 floods will be supplied.

bottom of the Scenarios window (Figure 5.1) will indicate the number of floods associated with a change level.

Only valid change levels are accepted, i.e., only those change levels for which the USER has specified that there are data will be available for selection (see Section 3.4). In the event of an erroneous selection, such as entry of a change level for which no data exist, the lower 'High Flows' box will display a red cell (Figure 5.2). The Low Flows box will not allow erroneous edits and the previous entry will remain unchanged.

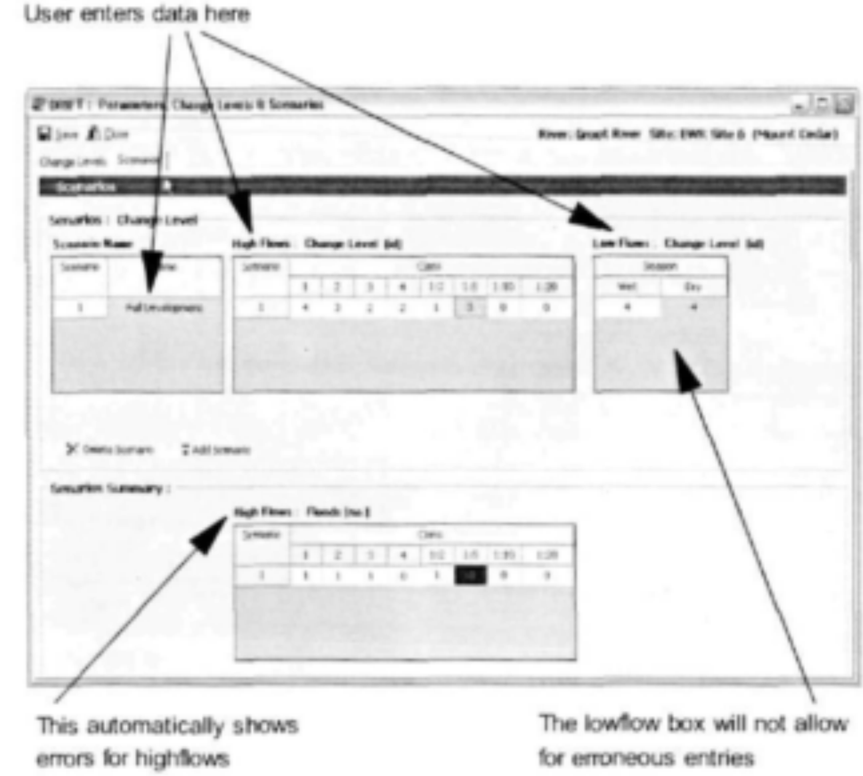



Figure 5.2 Define-Scenarios module in DRIFT-HYDRO©, showing scenario selection, with an incorrect choice for 1:5 year floods (Class 6).

When the flow details of a scenario have been entered, press the Save button to save the change levels chosen. The flow change levels entered are then transferred automatically to 'Select Floods' (Section 5.3) and to the 'Generate EF' (Section 5.4) windows in DRIFT-HYDRO©.

Additional scenarios can be added at any time, and any number of scenarios can be specified. Use the 'Add' button to add a new scenario. Scenarios can be deleted at any time, but one scenario must always remain.

*Note: The DRIFT reported volumes for a modified flow regime usually include the volume contained in the floods with a return period of 1:2, 1:5, 1:10 and 1:20 years or more. Results reported using other methods, for instance the Building Block Methodology (King and Louw 1998), usually exclude this volume, as it is assumed that inter-annual floods will pass through the system, and cannot be managed. Thus, any comparison between the results obtained using these different EF assessment methods will need to ensure that this is corrected for.*

## 5.3. SELECT FLOOD EVENTS FOR INCLUSION IN EACH SCENARIO

Usual practice is to impose future flow modifications on the past hydrological records This requires a *post-hoc* selection of the floods that would form part of the EFR had it been in operation, which is done using the 'Floods' screen in DRIFT-HYDRO©.

The process for this flood selection is as follows:

1. Start with the largest floods required, e.g., Class 7 or 8, and work backwards towards the smallest floods required, e.g., Class 1.
2. For each flood class allocate the number that that scenario allows per year, taking account of the timing stipulated for each class.
3. In some cases the full number of floods allowed by a scenario will not be available in the record, e.g., during dry or drought years. In these cases, one of two options should be exercised:
    a. The record can be explored to determine whether any floods in a larger size class have not already been assigned to a scenario, and are thus available for selection for a smaller flood class.
    b. If no larger floods are available for reassignment, then the flood requirements for that year remain unallocated. This reflects the basic approach that floods that do not occur naturally should not be provided.
4. Once the required floods have been selected for each year where they are available, DRIFT-HYDRO© will automatically cap the floods selected for each flood class in terms of their magnitude or duration, i.e., only the portion of that flood required to meet the actual magnitude or duration will be calculated as part of the EF scenario. If floods selected for a specific class have a magnitude or duration less than those required, they remain unchanged.

The default hydrological record for use in this exercise is the simulated present-day hydrological dataset (see Section 2.6 for the hydrological sequences generated for DRIFT). Should a scenario require flows to be added to the present-day flow regime, there is an option for using the simulated naturalised hydrological dataset.

---

On the Dashboard, under 'Actions', press 'Select Floods'.

The actual flood events for a scenario are selected from the hydrological record in the DRIFT: Floods module. Briefly, the flood selection process comprises:

- select a scenario, using the drop-down list (Figure 5.3)[13];
- select a Flood Class, using the drop-down list or the appropriate class button
- select the floods required using the grids or the charts.

**Selecting the floods required for each Flood Class**

You will need to work through each flood class, allocating the number that scenario allows per year.
To begin flood selection:

1. select the scenario for which you are going to select floods;
2. select the flood class for which you are going to select floods;

13 Note: The parameters for each scenario have to be set (Section 5.2) before this step can be undertaken.

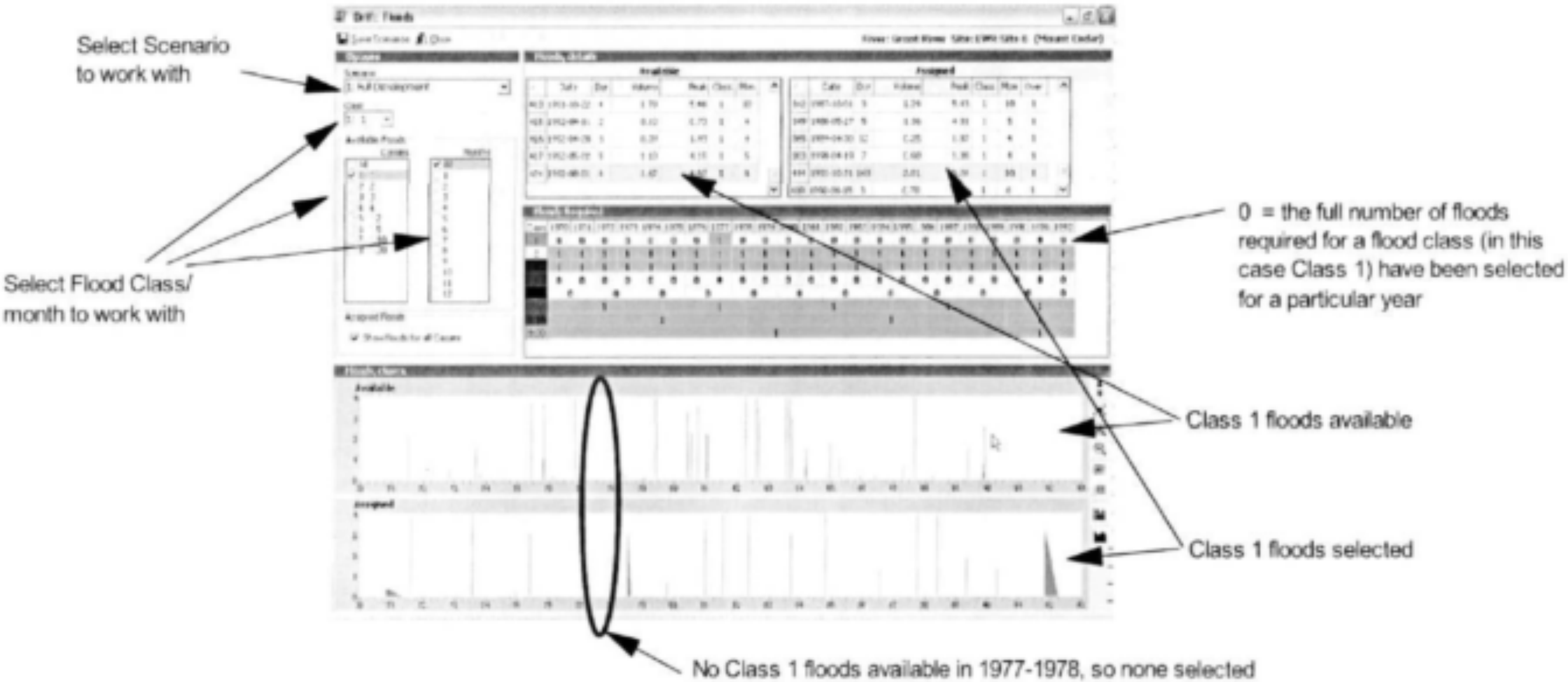



Figure 5.3 Floods module in DRIFT-HYDRO©, showing selection of Class 1 floods.

This is done using the 'Options' panel, which also contains filters to alter the display of available floods, by class and individual months (see below).

These two steps will result in the following being displayed on the screen:

1. For any one flood class selected, the number of floods that occurred in the record and that are thus available for selection in the 'Floods Available' panel. This information will include details of the timing and magnitude of the available floods.
2. The number of floods in the selected Flood Class required to meet the Change Level selected for the scenario (Section 3.2). This is in the 'Floods Required' panel, which shows the number of floods required for each year/period and class.

To make the screen live, press 'Edit' in the top left hand corner.


Floods can be selected in one or two ways:

1. by clicking on the required flood in the available column at the top of the page[14], or;
2. by clicking on the available floods in the charts[15] at the bottom of the page.

A flood is initially categorised as 'Available'. Once selected for a scenario it becomes 'Assigned', and no longer appears as 'Available', so that it cannot be selected more than once.

As floods are assigned, the numbers in the 'Floods Required' panel drop to reflect the number of floods still required. A zero value indicates that all the required floods have been assigned. A negative value indicates that too many floods have been assigned within a particular period.

Once all the floods in one category required for a scenario have been selected, the coloured cells in the column 'Class' can be clicked on to change the class selection.

[14] **Details:** This panel contains two grids listing the Available and the Assigned floods. Clicking a row in either grid will move it across to the other grid. The change is reflected in the 'Floods Required' panel. The 'Assigned' grid has an extra column, 'Over'. This indicates the class to which a flood has been assigned.

[15] **Charts:** This panel contains two charts containing the Available and the Assigned floods. A flood can be moved from one box to the other by clicking on it. The display can be changed in the normal way (see Setting Chart Display in Section 2.5). In addition, two buttons beneath the standard ones toggle the display of floods from vertical lines to triangles. The vertical line is located at the date of the flood peak, it's height representing the flood peak. The triangle is located between the flood start and end date. It's peak is located at the date of the flood peak and it's height represents the peak size.

When selecting floods it is important to bear in mind the timing requirements stipulated by the specialists. This can be done by either double-checking the timing of each flood selected, or by adjusting the display, using the 'Options' panel so that only floods available in the relevant months are displayed (Figure 5.3).

**Override floods**

DRIFT will only allow the selection of floods that are represented in the flow record under consideration. If a flood does not occur naturally, it should not be supplied by artificial means. In the example shown in Figure 5.3, for example there were no Class 1 floods in 1977-78, thus none could be assigned to the modified flow regime.

Because the scenarios usually encompass a sub-set of the actual floods available however, it is possible that floods from one class can be selected to make up the required numbers in a smaller size class. For instance, in the case of the example in Figure 5.3, if a scenario required more Class 1 floods than appeared in the dataset being used, Class 2 floods could be used instead (Figure 5.4). In this situation, the Override Class for that Class 2 flood will be Class 1 (orange circle in Figure 5.4).

Such an arrangement is possible because each flood selected for a particular class, but which has a magnitude or duration that exceeds those required, will be 'capped' in terms of its magnitude or duration, i.e., only the portion of that flood required to meet the actual magnitude or duration will be calculated as part of the EF scenario. Floods selected for a Class, but which have a magnitude or duration less than those required, however, will remain unchanged. Once again, this reflects the basic approach that floods that do not occur naturally should not be provided in an EF.

| | |
|---|---|
| *Tip:* | ***When selecting override floods, it is advisable to begin with the biggest floods, and to preferentially select override floods that are as similar as possible in size to those making up the class for which selection is being done.*** |

**Press the 'Save' button to save the flood selection to file.**

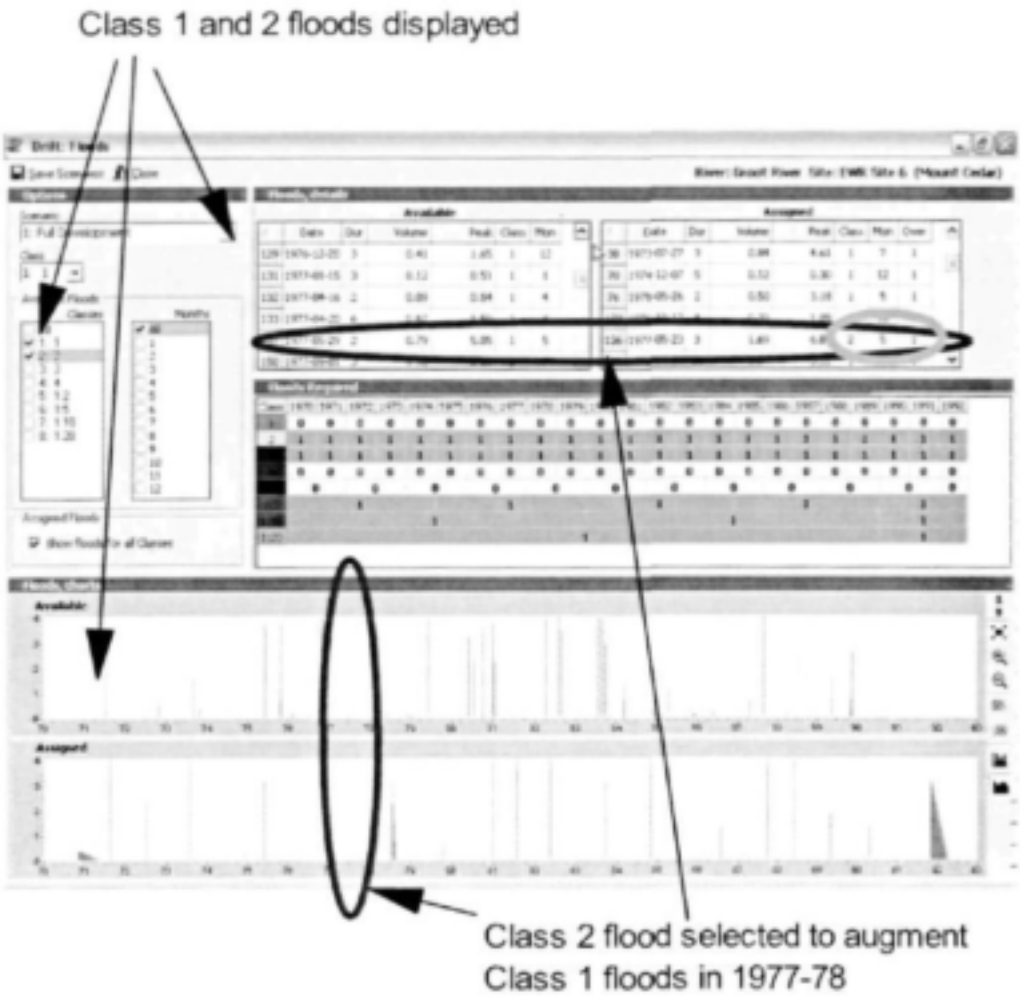



Figure 5.4 Floods module in DRIFT-HYDRO©, showing selection of Class 1 floods, with an override selection of a Class 2 flood.

## 5.4. COMPLETE GENERATION OF EF SCENARIO FLOW REGIME

Once all of the relevant Change Levels for ALL of the flow categories, as stipulated by DRIFT-SOLVER©, have been entered into DRIFT-HYDRO©, and the floods required to meet the flood change levels have been selected, then a modified flow regime representing the flows in the river under that scenario can be generated by recombining all of the different flow categories at their relevant Change Levels.

This is done using the Generate EFR module in DRIFT-HYDRO©.

---

On the Dashboard, in 'Actions', press 'Generate EFR Flows'.

The generation of EFR flows is automatic, but this module can be used to check and assess the characteristics of each scenario.

The window contains several charts, one for each scenario (Figure 5.5). The time-series are shown as a combination of solid and line graphs representing:

- the time-series used as a historical record (default is present-day);
- the final EFR flow for the scenario
- the constituents of that flow, i.e., the low flows and the high flows.

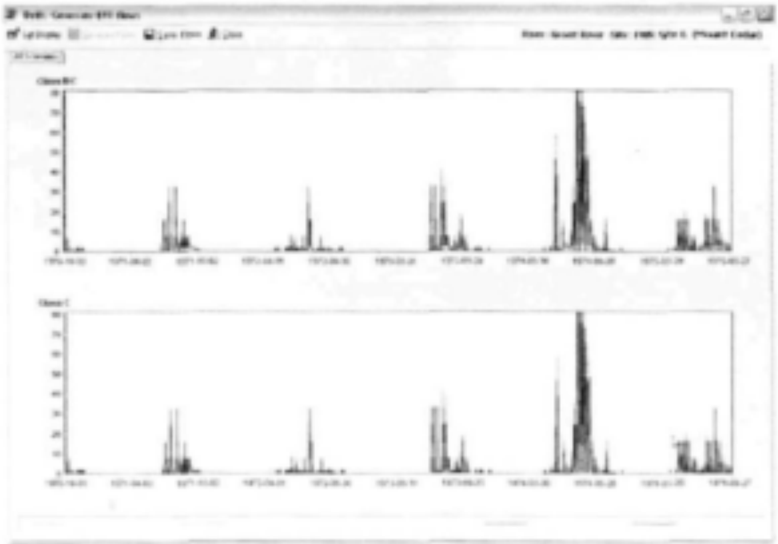


Figure 5.5 Generate EFR window in DRIFT-HYDRO©.

The original flow is in the background and is coloured blue. Thus, any blue showing indicates flow unassigned to the scenario.

The EFR flow is a red line that is the combination of low flow (yellow) and high flow (lime) lines.

Any combination of the scenarios that have been generated for a site can be displayed at once by selecting the required scenarios using the 'Set Display' button in the top left hand corner of this screen. **Press the 'Save' button to save the EFR time-series to file.**

## 5.5. GENERATE EFR TABLES

Once an EF scenario has been generated by DRIFT-HYDRO© and saved to file, the resultant modified time series is available in the site folder. The scenarios are numbered according to the order in which the scenarios are listed in 'Parameters/Scenarios'. DRIFT-HYDRO© can then be used to provide the necessary summary statistics for the EF time series.

| | |
|---|---|
| Note: | **At this stage, the EFR Table and the Rule Tables need to be constructed manually, using the appropriate data from the DRIFT Database and DRIFT-HYDRO©.** |

### 5.5.1 EF flow regime

The flow regime associated with an EF scenario is generated automatically by pressing 'Generate EFR Flows' (see Section 5.5).

The resultant time series is saved to the relevant hydrology folder, *viz.*:
C:\Wcape\EFR\Berg\Site 2\Site 2_s1.day.

The notation refers to the order of the scenarios as they were entered in 'Parameters/Changes and Scenarios'\'Scenarios' (see Section 5.2).

Each time the 'Generate EFR Flows' button is pressed DRIFT-HYDRO© will regenerate the scenarios according to whatever change levels have been stipulated (Section 5.2) and whatever floods have been selected (Section 5.3), and **overwrite the relevant .day file**.

To protect the .day file from being over-written, it must be renamed (using, e.g., Windows Explorer) as for example:
C:\Wcape\EFR\Berg\Site 2\Site 2_Category_B.day.

### 5.5.2 EFR Summary Table

At minimum, an EFR Table should contain the following information:

- Name of the river.
- Name of the EF site.
- Natural Mean Annual Runoff (nMAR; MCM).
- The condition the EF is intended to maintain, e.g., near-natural/Category B.
- Median (maintenance) discharge for low flows in each calendar month.
- Drought discharges for low flows in each calendar month. These are usually taken as the 90$^{th}$ percentile on the naturalised low flow Flow Duration Curves, and usually do not include floods.
- The magnitude (daily peak; $m^3s^{-1}$), duration (days), volume (MCM) and return-period (1:years) of the flood requirements in each calendar month.

An example of a completed EF Table is provided in Table 5.1.

### 5.5.3 Rule Tables

Flow Duration Curves and percentiles for the EF time series are obtained using 'Charts, Info & Statistics'/ 'Flow Duration Curves'. See instructions in Section 2.11.

**Low flow Rule Tables**

Flow Duration Curves and percentiles for the lowflow component of the EF time series can be generated by combining the relevant lowflow change levels for the wet and dry season lowflows. The hydrological data comprising the lowflow change levels are those that were generated in Section 3.5.

The Flow Duration Curves and percentiles for these change levels can be generated by following the same procedures described for generating the Flow Duration Curves for Naturalised and Present Day Data (Section 2.11), and selecting the relevant change levels from the drop down lists.

For example, if the DRIFT scenario selected require the following combination of low flows:

| | |
|---|---|
| Wet season lowflows: | change level 3 |
| Dry season lowflows: | change level 3 |

Then the low flow Flow Duration Curves would be constructed by selecting Dry_1.BF and Wet_3.BF from the drop down list (see Figure 5.6), and then pressing the 'Percentiles' button to generate the two (separate) FDCs (Figure 5.7).

Press 'Save Percentiles' to save these to file.

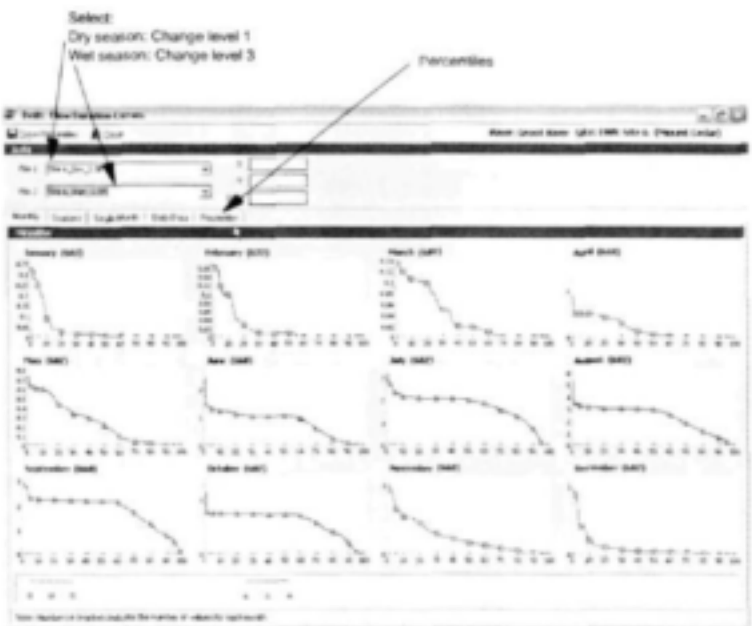



Figure 5.6 DRIFT: Flow Duration Curves. Monthly data screen.

Table 5.1 An example of a typical EF Summary Table.

| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | VOL ($X10^6\ m^3$) | nMAR % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RIVER NAME: TEST ONE** | | | | | | | | | | | | | | |
| **TEST ONE SITE 1: EMC = B. nMAR= 527.14 MCM** | | | | | | | | | | | | | | |
| **MAINTENANCE** | | | | | | | | | | | | | | |
| **LOW FLOWS Q $m^3s^{-1}$ [16]** | 1.8 | 2.4 | 3.1 | 3.7 | 4.2 | 3.9 | 3.7 | 3.2 | 2.7 | 2.1 | 1.8 | 1.7 | **89.824** | **17.04** |
| **FLOOD Peak[17] $m^3s^{-1}$** | 7.3 | 14.0 | 1)14.0<br>2)28.0 | 1)14.0<br>2)28.0 | 1)28.0<br>2)55.0<br>3)86.5 | 55 | 7.3 | 7.3 | - | - | | 7.3 | **65.391** | **12.40** |
| **Duration (in days)** | 2 | 5 | 1) 5<br>2) 5 | 1) 5<br>2) 5 | 1) 5<br>2) 6<br>3) 6 | 6 | 2 | 2 | - | - | | 2 | | |
| **Return period (years)** | 1:1 | 1:1 | 1) 1:1<br>2) 1:1 | 1) 1:1<br>2) 1:1 | 1) 1:1<br>2) 1.1<br>3) 1:2 | 1:1 | 1:1 | 1:1 | - | - | | 1:1 | | |
| **MAINTENANCE TOTAL (Volume)** | | | | | | | | | | | | | **155.215** | **29.44** |
| **DROUGHT** | | | | | | | | | | | | | | |
| ***LOW FLOWS[18] $m^3s^{-1}$*** | *0.3* | *0.3* | *0.5* | *0.7* | *0.8* | *0.7* | *0.6* | *0.5* | *0.4* | *0.4* | *0.3* | *0.3* | *14.756* | *2.8* |
| ***FLOOD Peak $m^3s^{-1}$*** | - | - | - | - | - | - | - | - | - | - | - | - | | |
| ***DURATION in days*** | - | - | - | - | - | - | - | - | - | - | - | - | | |
| ***DROUGHT TOTAL*** | ***(Volume)*** | | | | | | | | | | | | ***14.756*** | ***2.8*** |

[16] Figures rounded-off to the nearest one decimal place.

[17] Daily average peak

[18] $90^{th}$ percentile on the naturalised low flow Flow Duration Curves

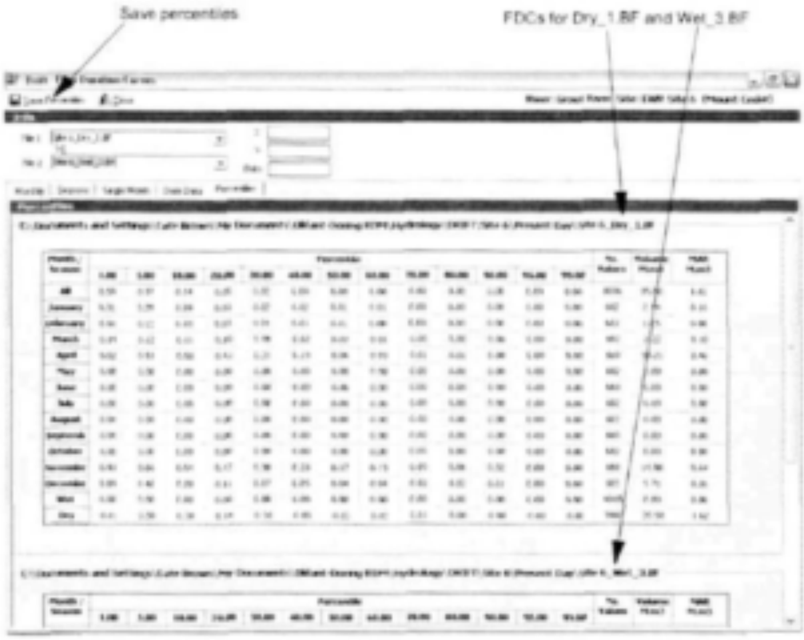



Figure 5.7 DRIFT: Flow Duration Curves. Percentiles screen.

Each FDC will contain data for only one season, either Wet or Dry, with the other season given as zeros. These are saved as .prc files, and can be imported into MS Excel, and combined to produce a monthly low flow FDC for the flow regime of interest.

| | |
|---|---|
| ***Tips:*** | ***The lowflow change-level Flow Duration Curves for the different seasons may require some adjustment, in order to ensure that there is a smooth transition between seasons. Remember that the change levels are essentially hypothetical and artificial divisions of the flow regime (which are extremely useful when trying to understand the river's response to flow change at different times of the year) and recombining the wet and dry season flow may result in some discrepancies in the transition months, e.g., spring and autumn. These are best dealt with 'at source', i.e., by returning to 'Actions'/'Adjust Low Flows' in DRIFT HYDRO and 'smoothing' out the transition months.***<br><br>***Often mistakes made earlier on in the process only become apparent at the report writing stage, i.e., generating EF time series and EF Summary Tables. Therefore, adjustments to the hydrological data are catered for in DRIFT HYDRO, at certain points. For instance, lowflow change level curves can be adjusted or the flood requirements for a scenario can be altered and the flood events for that scenario reselected, and EF scenarios regenerated.*** |

# 6. FUTURE DEVELOPMENTS

The development of DRIFT, and the tools that support it, is ongoing, linked to the availability of research/development funds such as those from the WRC that supported the writing of this manual, and to opportunities for development and improvement that present themselves during environmental flow consultancies.

At present, key focus areas for future development are:

- creation of simpler version of DRIFT that can be used in areas where data availability is extremely low, and which focuses on valued resources provided by ecosystems. Development is linked to current projects on the Mekong (S.E. Asia), Zambezi (Mozambique) Pangani (Tanzania) and Blue Nile (Ethiopia) Rivers;
- development of the socio-economic 'SOLVER' templates;
- development of a version of DRIFT specifically tailored to environmental flow assessments for intermittant and ephemeral rivers.

*Note: Queries and suggestions arising from the use of this User Manual will be dealt with by Southern Waters on a case-by-case basis.*

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# APPENDIX A
## EXAMPLE OF THE DRIFT-HYDRO© LOWFLOW DATA PRESENTED TO SPECIALISTS

**LOW FLOWS: PRESENT-DAY RECORD**

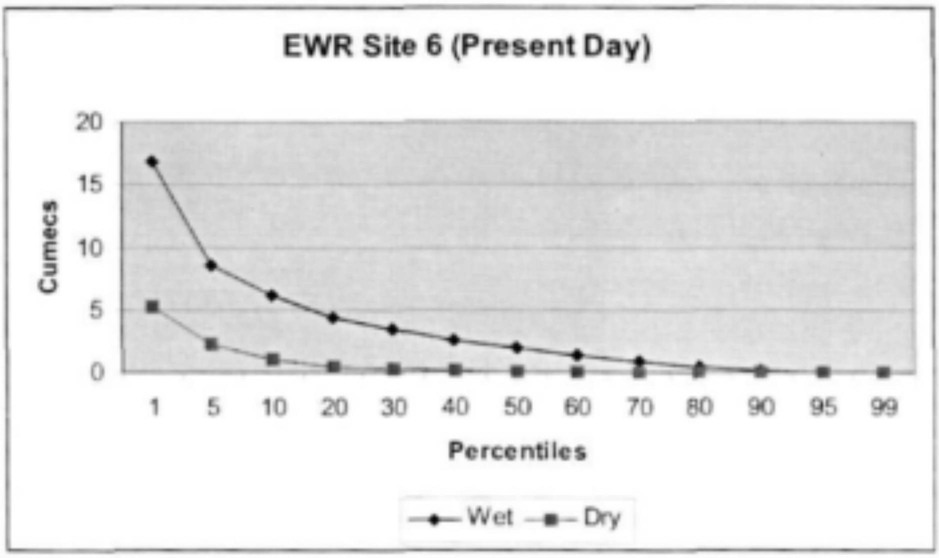
MAR and seasonal distribution
MAR 104.810 MCM

Monthly Flow [M.m3]

| | |
|---|---|
| Jan | 0.403 |
| Feb | 0.135 |
| Mar | 0.557 |
| Apr | 1.151 |
| May | 9.285 |
| Jun | 17.775 |
| Jul | 23.466 |
| Aug | 24.490 |
| Sep | 16.481 |
| Oct | 6.385 |
| Nov | 3.293 |
| Dec | 1.389 |

Wet season: May – September
Dry season: October – April.

Lowflow distributions



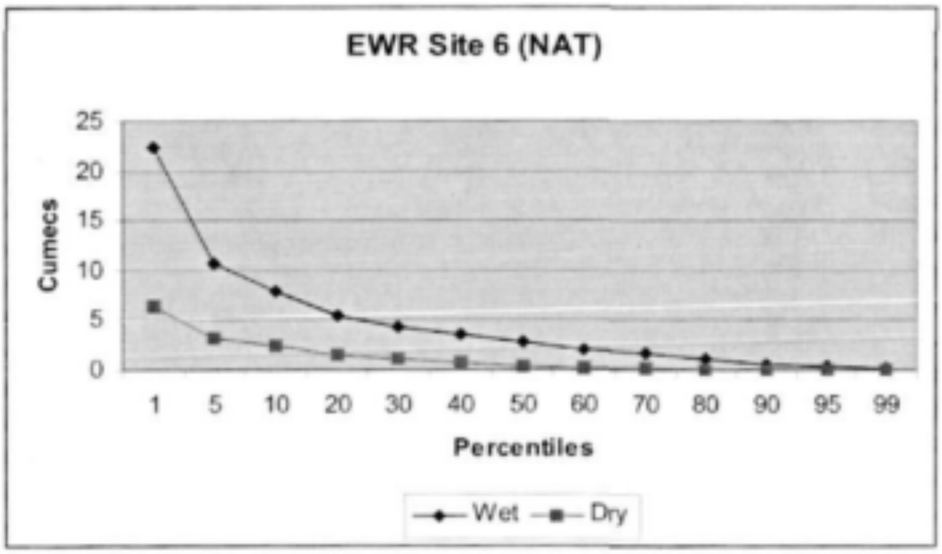
**LOW FLOWS: NATURALISED RECORD**

MAR and seasonal distribution
MAR 138.272 MCM

Monthly Flow [M.m3]

| | |
|---|---|
| Jan | 1.180 |
| Feb | 0.521 |
| Mar | 1.925 |
| Apr | 4.102 |
| May | 15.939 |
| Jun | 24.389 |
| Jul | 27.157 |
| Aug | 26.834 |
| Sep | 18.525 |
| Oct | 9.004 |
| Nov | 5.904 |
| Dec | 2.792 |

Wet season: May – September
Dry season: October – April.



# APPENDIX B

## EXAMPLE OF THE HIGHFLOW DATA PRESENTED TO SPECIALISTS

### INTRA-ANNUAL FLOODS: PRESENT DAY

1= Jan; 12 = Dec.

| Class | I | 2 | 3 | 4 |
|---|---|---|---|---|
| Upper limit (cumecs) | 5.51 | 11.02 | 22.03 | 44.06 |
| 1 | 1.00 | 0.00 | 0.00 | 0.00 |
| 2 | 1.00 | 0.00 | 0.00 | 0.00 |
| 3 | 0.80 | 0.10 | 0.10 | 0.00 |
| 4 | 0.87 | 0.09 | 0.00 | 0.04 |
| 5 | 0.59 | 0.08 | 0.18 | 0.03 |
| 6 | 0.32 | 0.24 | 0.17 | 0.08 |
| 7 | 0.19 | 0.23 | 0.16 | 0.33 |
| 8 | 0.23 | 0.18 | 0.21 | 0.23 |
| 9 | 0.41 | 0.31 | 0.15 | 0.08 |
| 10 | 0.60 | 0.31 | 0.07 | 0.02 |
| 11 | 0.83 | 0.00 | 0.04 | 0.04 |
| 12 | 0.88 | 0.00 | 0.00 | 0.06 |

Total of each class per annum 7.72 1.53 1.09 0.92

### INTER-ANNUAL FLOODS: PRESENT DAY

| Return period (in years) | Daily Average Peak (in cumecs) |
|---|---|
| 2 | 48.9 |
| 5 | 66.2 |
| 10 | 77.9 |
| 20 | 162.7 |

**INTRA-ANNUAL FLOODS: NATURALISED**

| Class | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Upper limit (cumecs) | 8.85 | 17.69 | 35.38 | 70.77 |
| 1 | 1.00 | 0.00 | 0.00 | 0.00 |
| 2 | 1.00 | 0.00 | 0.00 | 0.00 |
| 3 | 0.64 | 0.14 | 0.21 | 0.00 |
| 4 | 0.70 | 0.17 | 0.10 | 0.03 |
| 5 | 0.51 | 0.16 | 0.16 | 0.11 |
| 6 | 0.31 | 0.16 | 0.19 | 0.25 |
| 7 | 0.24 | 0.19 | 0.28 | 0.22 |
| 8 | 0.29 | 0.21 | 0.19 | 0.17 |
| 9 | 0.47 | 0.20 | 0.23 | 0.07 |
| 10 | 0.74 | 0.21 | 0.04 | 0.02 |
| 11 | 0.73 | 0.15 | 0.04 | 0.04 |
| 12 | 0.69 | 0.23 | 0.00 | 0.08 |
| Total of each class per annum | 7.31 | 1.83 | 1.43 | 0.98 |

**INTER-ANNUAL FLOODS: NATURALISED**

| Return period (in years) | Daily Average Peak (in cumecs) |
|---|---|
| 2 | 78.6 |
| 5 | 125.4 |
| 10 | 156.6 |
| 20 | 222.7 |

# APPENDIX C

# CALCULATIONS USED IN DRIFT-SOLVER©

The text below, which outlines the calculations and processes involved in DRIFT-SOLVER©, is taken mainly from Brown and Joubert (2003). Slight adjustments have been made in order for the text to be compatible with the addition of the element level.

**Compiling a TYPE 1 Flow Scenario Using Integer Linear Programming**

The DRIFT-SOLVER© routine uses the Solver tool in Excel, which provides the necessary ("branch and bound") algorithm (Microsoft, 1985-1997). An integer linear program (e.g., Winston, 1994) optimises the distribution of a given total volume of water among different change levels of flow categories in a way that results in the lowest aggregate impact on the riverine ecosystem according to the Integrity Ratings. It does this by summing the Integrity Ratings of all the Elements and Sub-components, taking into account all the negative or positive signs, to produce combinations of high and low flows that return the highest possible Overall Integrity Score for that volume.

The Overall Integrity Score for a particular flow scenario is obtained by summation in four steps. The mathematical notation used is given in Table C.1.

Table C.1. Mathematical notation used in this manual.

| Notation | Designation | Range |
|---|---|---|
| **i** | Flow classes | 1 to 10 |
| **m** | Ecosystem Components | 1 to ≥ 5 |
| **k** | Ecosystem Sub-component | 1 to 10, for each **m** |
| **j** | Change level for each flow class | 0*, 1, 2, 3, or 4 for each **i** |
| **l** | Ecosystem element | -5 to +5, for each **k** |
| $\mathbf{x}_{ijk}$ | Sub-component Integrity Rating, i.e., the effect on integrity of flow class **i** at change level **j**, on ecosystem Sub-component **k** | -5 to +5 |
| $\mathbf{X}_{ijm}$ | Component Integrity Rating, i.e., the effect on integrity of flow class **i** at change level **j**, on ecosystem Component **m** | -5 to +5 |
| $\mathbf{y}_{ijl}$ | Element Integrity Rating, i.e. the effect on the integrity of flow class **i** at change level **j**, on ecosystem element **l**. | |
| $\mathbf{z}_{ij}$ | Flow Level Integrity Score, i.e., the effect on integrity of flow class **i** at change level **j**, on the whole riverine ecosystem | -5 to +5 |
| **Z** | Overall Integrity Score, i.e., expected river condition for a flow scenario | 0 = Present Day, +ve = rehabilitation; -ve = degradation |
| $\mathbf{I}_{ij}$ | Binary code used to denote the change level chosen for a particular flow class. | 1 if flow reduction level *j* is chosen for flow class *i*, if not = 0 |

* Present day levels.

**STEP 1** The element Integrity Ratings ($y_{ijkl}$) for a flow change level are aggregated (weighted sum) for each ecosystem Sub-component to give a score for that Sub-component ($x_{ijk}$). Example?

$$x_{ijk} = \sum_{l=1}^{4} b_l y_{ijl} \tag{1}$$

**STEP 2** The Sub-component Integrity Ratings ($x_{ijk}$) for a flow change level are aggregated (weighted sum) for each Component to give a score for that Component ($X_{ijm}$). Example?

$$X_{ijm} = \sum_{k=1}^{n} w_k x_{ijk}\,, \tag{2}$$

where $w_k$ is the weight of ecosystem Sub-component $k$

**STEP 3** The five ecosystem Component scores are aggregated to arrive at the Flow Level Integrity Scores ($z_{ij}$) for each flow class change:

$$z_{ij} = \sum_{m=1}^{5} W_m X_{ijm}\,, \tag{3}$$

where $W_m$ is the weight of ecosystem Component $m$

**STEP 4** The Flow Level Integrity Scores ($z_{ij}$) for all 10 flow classes are aggregated to give an Overall Integrity Score $Z$ for a particular flow scenario, e.g., $Z_{scenarioA}$:

$$Z_{scenarioA} = \sum_{i=1}^{10} \omega_i\ z_{ij}\,, \tag{4}$$

where $\omega_i$ is the weight of flow class i

The flow levels $j$ that are selected for each flow class $i$ are denoted by the indicator variable ($I_{ij}$). The problem can then be expressed as maximising the Overall Integrity Score $Z$:

$$Z = \sum_{i=1}^{10} I_{ij} \omega_i z_{ij}\,, \tag{5}$$

where $I_{ij}$ is either 0 or 1 for the particular flow change j.

The $I_{ij}$ are binary (or 0-1 integer) variables, and DRIFT-SOLVER© is set up to maximise the aggregate score $Z$ by choosing the $I_{ij}$ for each flow class (i.e., choosing which flow change is selected for each flow category). Only one $I_{ij}$ = 1 is allowed for each flow class $i$ by setting the constraint:

$$\sum_{j=1}^{4} I_{ij} = 1 \tag{6}$$

For change levels that are not selected as part of the flow regime $I_{ij}$ =0 and the contribution to equation 4 is zero.

For TYPE 1 scenario analyses, a total volume (Q) is specified, which must be distributed between the flow classes. DRIFT-SOLVER© runs through each of the possible flow changes and either accepts or rejects it by setting $I_{ij}$ to 1 or 0. DRIFT-SOLVER© sums the volumes used ($q_{ij}$) by each flow change level and checks that the summed volume Q* is within a user-specified range of the given total volume Q (e.g. 90% Q ≥ Q* ≤ 110% Q). There is therefore an overall constraint that:

$$Q \times a \geq Q^* \leq Q \times b, \tag{7}$$

where $Q^* = \sum_{i=1}^{10} \sum_{j=1}^{4} I_{ij} q_j$ and *a* and *b* are allowed deviations from the allocatable total Q.

Acceptance or rejection of a change level for a flow class is therefore based on a trade-off between the volume required and the score $z_{ij}$ for that flow class $i$ level $j$.

In summary, DRIFT-SOLVER© solves the following problem:

Maximise: $Z$ (Equation 4), where $Z$ is built up from equations 1, 2, 3 and 4;

subject to the constraints of equations 6 and 7, and all $I_{ij}$ = 0,1.