# Integrated Water Information Management (IWIM) System - DFID Theme W1 Water Resource Management

## KAR Project R7135

### Conceptual design specification for an Integrated Water Information Management System

**Final Report**

## Report ODTN 116
## January 2003

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HR Wallingford

**Address and Registered Office:** HR Wallingford Ltd. **Howbery Park, Wallingford, OXON OX10 8BA**
**Tel: +44 (0) 1491 835381 Fax: +44 (0) 1491 832233**

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# Contract - Research

This technical report is an output from the Knowledge and Research (KAR) Contract R7135, Integrated Water Information Management (IWIM) system. This project has been carried out by the International Development Group of HR Wallingford in collaboration with the Department of Water Development in Zimbabwe for the British Government's Department For International Development (DFID). One of the objectives of the research was to produce a conceptual specification for an Integrated Water Information Management (IWIM) system to improve the assessment and management of water resources at a catchment level.

The HR Wallingford job number was MDS 0530

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| Project title: | Integrated Water Information Management (IWIM) system |
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# ***Contract – Research*** *continued*

# Summary

Integrated Water Information Management (IWIM) System - DFID Theme W1
Water Resource Management

KAR Project R7135

Conceptual design specification for an Integrated Water Information Management System

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The project purpose is to improve integrated water resource management and strategy formulation through improved assessments of multi-sectoral water demand, allocation and use. The project has been carried out by the International Development Group of HR Wallingford in collaboration with the Department for Water Development in Zimbabwe. This report provides a conceptual design specification for an Integrated Water Information Management (IWIM) system. The conceptual IWIM system is aimed at staff working in the Department for Water Development in Zimbabwe. Although the IWIM system has been developed with Zimbabwe in mind the conceptual system is applicable to other practitioners and professionals working in the field of water resources management in southern Africa. The system would provide appropriate multi-sectoral, temporal and spatial information on water demand, use and supply to water resource and catchment managers.

The IWIM system aims to provide a visual and spatial information on aspects of demand, use and supply of water. The conceptual IWIM system, shown on the CD-ROM that accompanies this report, has been developed using the Geographical Information System (GIS) package ArcView and provides an animated demonstration of the proposed functionality of the IWIM system.

The key functions of the conceptual IWIM system include:

- Storage of water demand and use data for various sectors (e.g. industrial, domestic, environment);
- Aggregation of water use and demand data for hydrological and administrative boundaries;
- Water demand and use forecasting including various regression equations and analysis of trends;
- Water availability assessments to assist in establishing areas that are water stressed;
- Information on water abstraction licences and wastewater discharge consents;
- Comparisons with standards and targets;
- Contingency planning to assist water resources planners.

## ***Summary*** *continued*

The necessary background research and development has been accomplished under the current project to act as a foundation on which a fully functional water management tool. This research has developed a *concept*. The move from a concept to a prototype and full implementation of the system would require significant investments in both technical and institution sectors.

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# 1. INTRODUCTION

## 1.1 Background

Traditionally, water resource planning has been centred on *how much water do we need and where do we get it*. This project-by-project and sector-by-sector approach has been acceptable where there is little stress on the water resource. However, in regions such as sub-Saharan Africa where water is becoming a scarce resource, this approach leads to inefficient investment decisions, growing water conflicts, inefficient resource use, environmental degradation, and an inability to respond expediently to changing conditions (Frederick, 1992). The evident approach must now be *how much water is there and how can we best benefit from that water* (Falkenmark, 1991). In essence, water scarcity demands greater exactness in planning (FAO, 1995) to ensure it is used efficiently and effectively.

Integrated water resource planning and management relies on many factors. In the large body of literature available, institutional issues (organisational structures, management practices, policies, legislation and regulation) are widely recognised as a primary constraint to sustainable development. This is undoubtedly true, however, the importance of comprehensive assessments of water resource availability, use and allocation and the need for reliable basic information must also be recognised. Assessing the level of multi-sectoral use, demand and allocation is central to the formulation of sound water resource management policies and strategies, such as water allocation, pricing and re-use. In many developing countries, even the most basic information on water utilisation is often dissipated among a wide number of agencies with little or no interaction between them. This lack of a co-ordinated and integrated approach can lead to poor decision-making and result in inefficient water utilisation, over allocation of available resources, and disregard for in-stream uses. What is required by water resources managers and planners is a system that allows them to collate, store and analyse demand data at a catchment and sub-catchment level.

This report and accompanying CD-ROM forms part of a series of documents on integrated water resources management in southern Africa that have been produced as part of the Department for International Development (DFID) funded Knowledge and Research (KAR) Contract R7135 entitled Integrated Water Information Management system. The project has been carried out by the International Development Group of HR Wallingford in collaboration with the Department for Water Development in Zimbabwe.

## 1.2 Project overview

The main purpose of the project was to improve integrated water resource management and strategy formulation through improved assessments of multi-sectoral water demand, allocation and use. The outputs of the project included:

- A Handbook for the Assessment of Catchment Water Demand and Use;
- A conceptual design specification for an Integrated Water Information Management system.

The outputs are aimed at water resource planners responsible for allocating water across competing users. It is widely accepted by professionals and practitioners that the river catchment is the most appropriate unit for water resource planning and management. As such, the focus of the outputs is at a catchment and sub-catchment level. The Handbook for the Assessment of Catchment Water Demand and Use has been developed to draw together a range of macro-level methodologies for a variety of sectors. The Handbook is complementary to the IWIM system and can be used to produce water demand and use figures.

This report provides a conceptual design specification for an Integrated Water Information Management (IWIM) system. The conceptual IWIM system is aimed at staff working in the Department for Water Development in Zimbabwe. Although the IWIM system has been developed with Zimbabwe in mind, the conceptual system is applicable to other practitioners and professionals working in the field of water resources management in southern Africa. The generic, open-systems framework approach used for the conceptual specification allows it to be used in a wide range of country contexts, for catchments with differing characteristics, and link with other planning and analysis tools, and methodologies.

The background and the objectives of this part of the project together with the structure of this report are detailed below.

## 1.3 Structure of the report

This report has been structured as follows:

**Chapter 1** **Introduction** provides background information on the aims and objectives of an Integrated Water Information Management (IWIM) system.

**Chapter 2** **The relevance of the IWIM system to water management organisations in Zimbabwe** details the relevance of the IWIM system to water management organisations in Zimbabwe and the responsibilities of the key institution undertaking water resources management.

**Chapter 3** **Architecture of the IWIM system** outlines the structure of the IWIM system including the use of a Geographical Information System (GIS).

**Chapter 4** **Data requirements** details the data requirements of the IWIM system including the mapping data, water use, demand and supply data and other information that is required.

**Chapter 5** **Key functions of the Integrated Water Management Information (IWIM) system** discusses the key functionality that is required from the IWIM system.

**Chapter 6** **Hardware and software costs** outlines hardware and software costs of the IWIM system.

**Chapter 7** **Conclusions** provides conclusions.

**CD-ROM** **A CD ROM** accompanies the report. It provides an animated demonstration of the proposed functionality of the IWIM system.

# 2. THE RELEVANCE OF THE IWIM SYSTEM TO WATER MANAGEMENT ORGANISATIONS IN ZIMBABWE

## 2.1 Water resources management organisations in Zimbabwe

Water resources management in Zimbabwe is implemented through two statutory instruments:

- Water Act 1998;
- Water Authority Act 1998.

The main objectives of the Water Act are:

"*To develop policies to guide the orderly and integrated planning of the optimum, utilisation and protection of the country's water resources in the national interest and to ensure the availability of water to all citizens for primary purposes to meet the needs of aquatic and associated ecosystems particularly where there are competing demands for water; and to ensure the equitable and efficient allocation of the available water resources in the national interest for the development of rural, urban, industrial, mining and agricultural sectors*."

To implement the above objectives the following were set up:

- A new Department for Water;
- Zimbabwe National Water Authority (ZINWA);
- Catchment Councils.

The development of these policies is undertaken by a newly formed policy department in the new Department for Water Development. This department will formulate policies for the management of water at the national level. The purpose of ZINWA is to implement the policies via a network of catchment based water resource management units, known as Catchment Councils.

The Catchment Councils are the key institution responsible for the management of water resources in Zimbabwe. The whole of Zimbabwe has been divided into seven river catchments. These are:

- Gwayi;
- Sanyati;
- Manyame;
- Mazowe;
- Save;
- Runde;
- Mzingwane.

The new institutional structure for water management in Zimbabwe is shown in Figure 2.1.

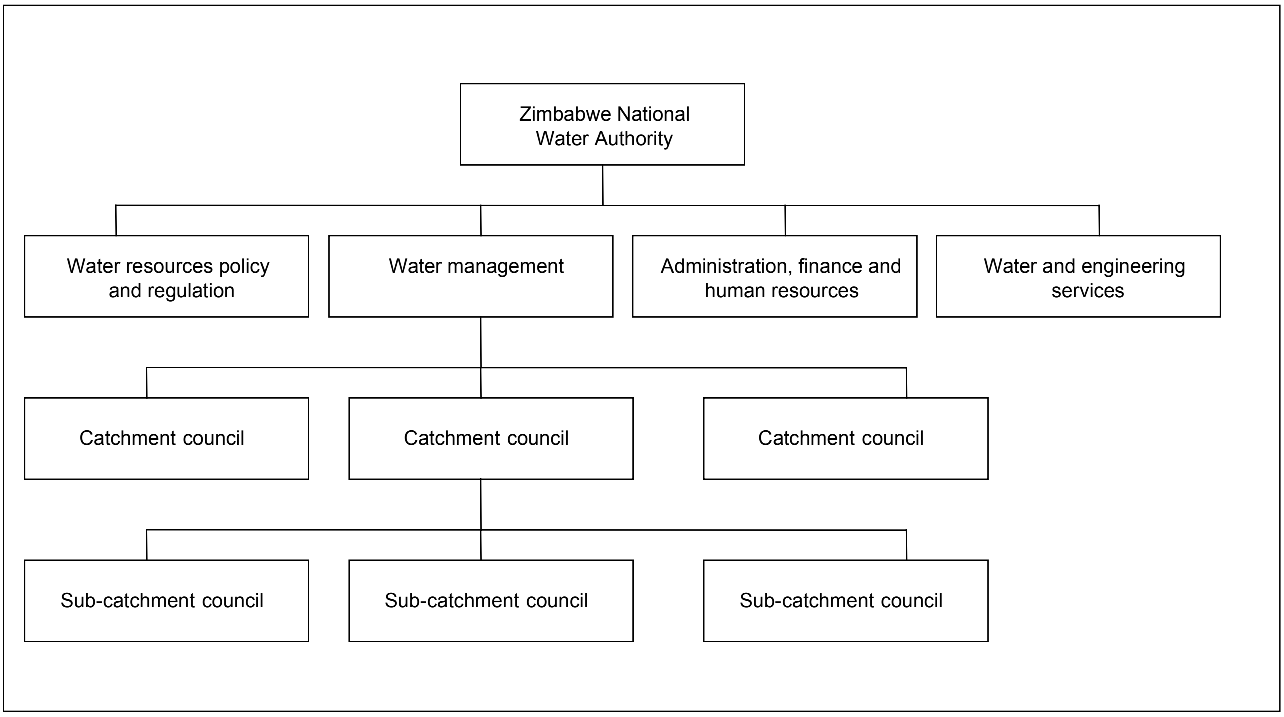


**Figure 2.1 Institutional structure for water management in Zimbabwe**

The responsibilities of the Catchment Councils include:

- Preparation of catchment management plans including:
    - Assessing and preparing inventories of water resources and water use;
    - Recommending the phasing and priority of developments;
    - Recommending water to be reserved for the future;
    - Recommending water to be reserved for the environment;
- Management of water demand and use including:
    - Monitoring water use with respect to compliance;
    - Revising, reallocating or reapportioning permits during shortages;
    - Detecting, identifying and declaring water shortage areas;
    - Determining feasibility of options for managing a water shortage area, including priority of use;
- Management of water permits including:
    - Maintaining information relating to all types of water use;
    - Monitoring, detecting and reporting on use (or waste) of water;
    - Monitoring, policing and enforcing non-compliance.

Under the Water Act of 1998 Sub-catchment Councils were established. The responsibility of the Sub-catchment Councils is to make short-term and operational decisions concerning water utilisation by permit holders. Sub-catchment Councils require the following information:

- Actual abstractions and storage of surface water within relevant river basins;
- Groundwater abstraction rates;
- Current water uses by permit holders e.g. irrigation, mining, industrial, commerce;
- Human population benefiting from each permit;
- Area under irrigation and type of crop;
- River flows;
- Groundwater levels and flows.

## 2.2 The planning process and flow of information at a catchment level

This section briefly outlines the planning process and flow of information between the various institutions responsible for water resources management in Zimbabwe. A major responsibility of Catchment Councils is the preparation of outline plans for its river system. These plans should indicate the following:

- Resources of the catchment area;
- Major water uses within the river system;
- Apportionment of water between public and private development;
- Maximum permissible levels of pollution;
- Proposals justified by the inventory of resources;
- Phasing and prioritisation of development.

The plans should also shall state the relationship of major proposals for water use with regards to how they may affect the both the catchment itself and contiguous catchments. The plans are also required to specify:

- Any potential dam sites;
- Water to be reserved for future use;
- Water for the benefit of the environment.

The flow chart for the planning process is shown in Figure 2.2.

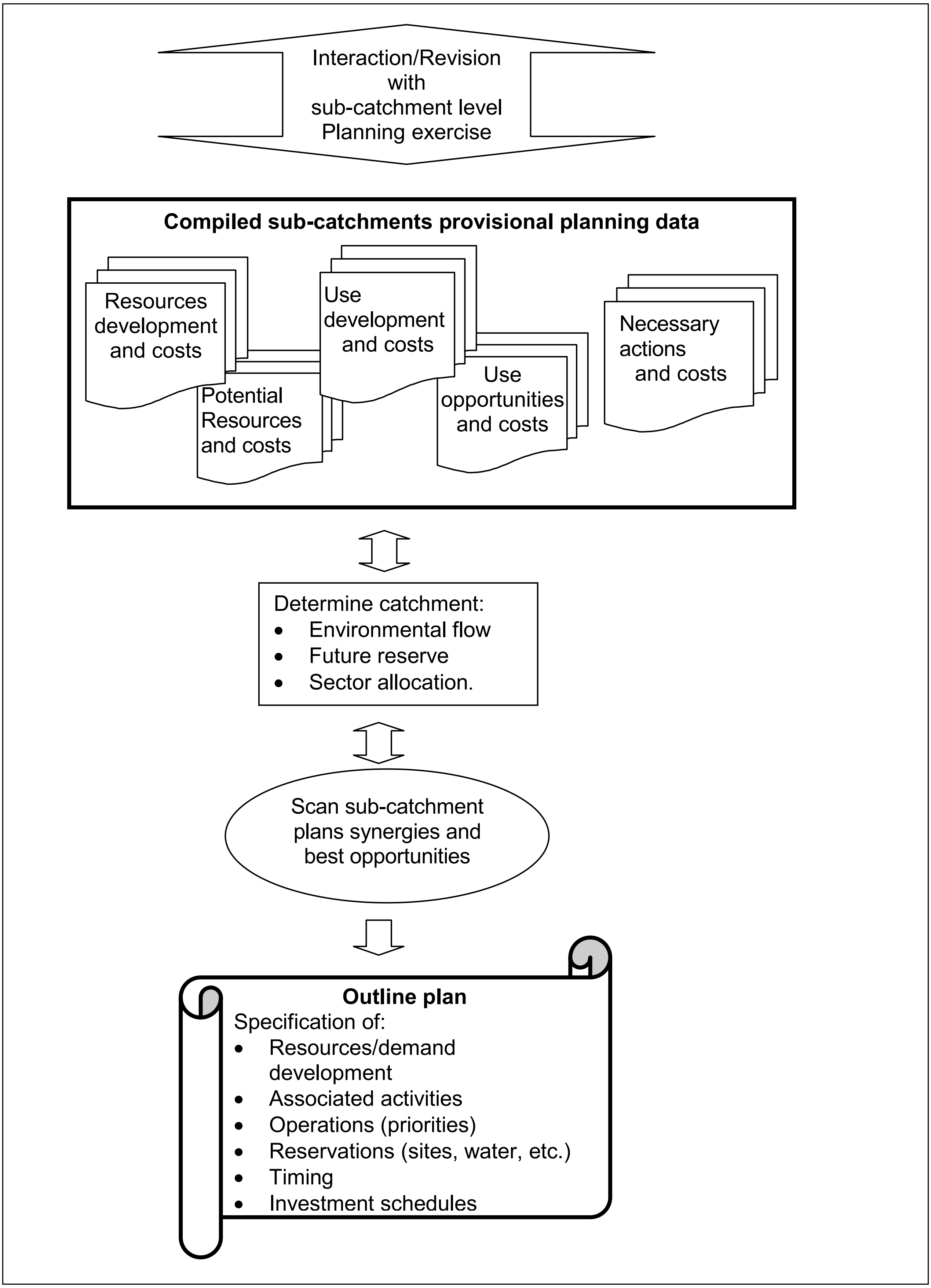


**Figure 2.2 Flowchart for the planning process at a catchment level**

The new Department for Water Development therefore requires information from ZINWA and the Catchment Councils so that it can determine:

- The available water resources at the national level;
- How water is utilised;
- The availability of water for primary purposes;
- The allocation of water with and between sectors.

Figure 2.3 shows the flow of information between the two new Department for Water, ZINWA and the Catchment Councils.

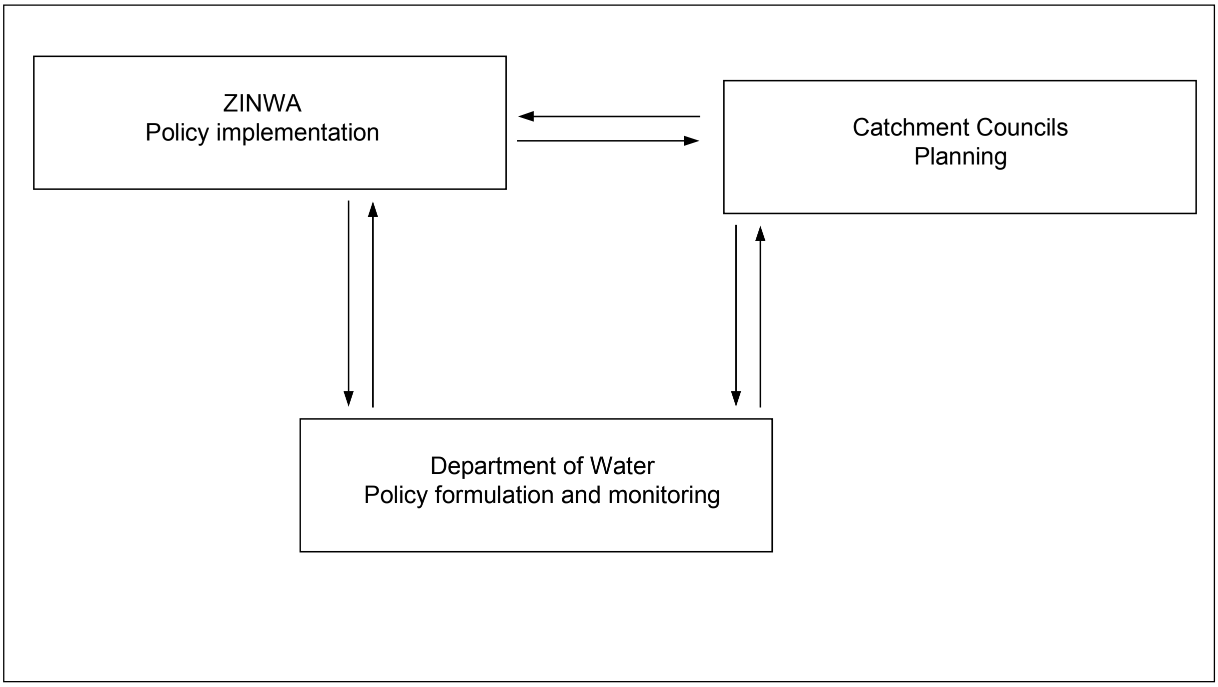


**Figure 2.3 Information flows between Department of Water, ZINWA and the catchment councils**

A Sub-catchment Council will obtain most the required information from:

- ZINWA;
- Water users;
- Catchment Councils;
- Local authorities;
- Agritex.

Figure 2.4 shows the flow of information between the catchment and sub-catchment level.

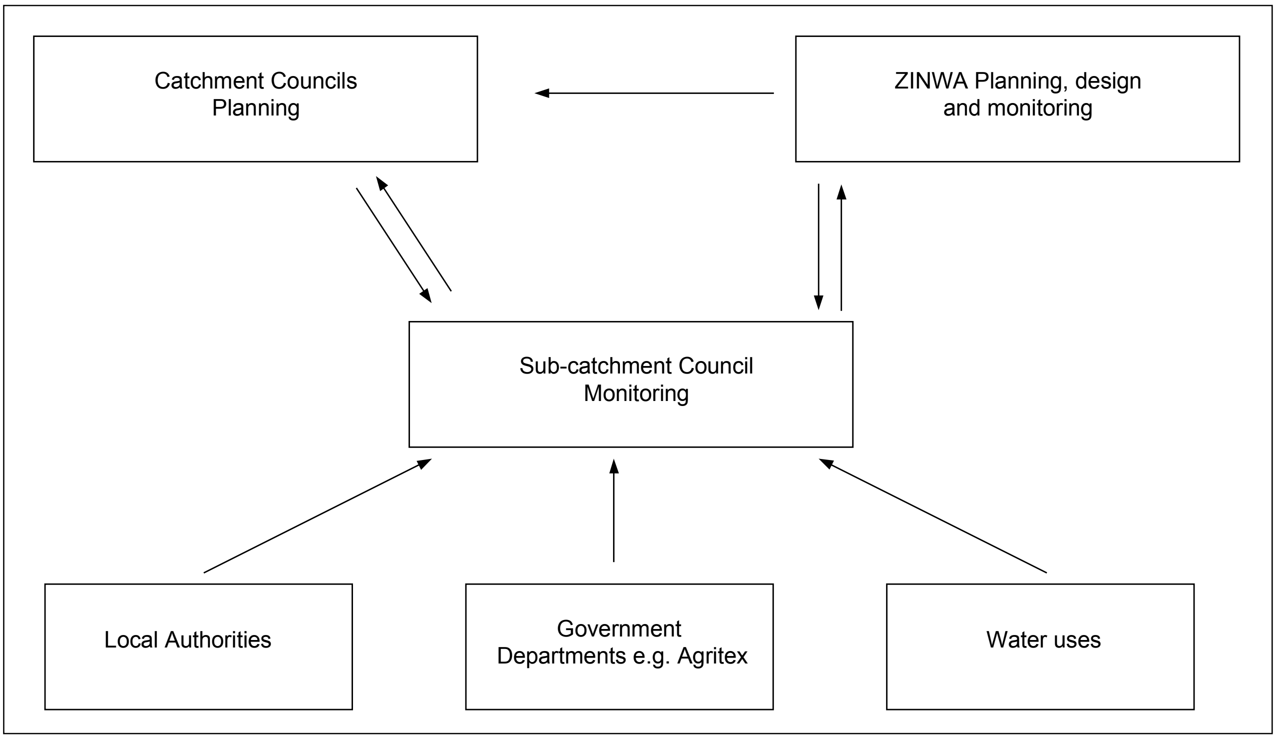


**Figure 2.4 Information flows at the catchment and sub-catchment level**

Figure 2.5 shows the relationships between Catchment Councils and various stakeholders and the flow of information between them.

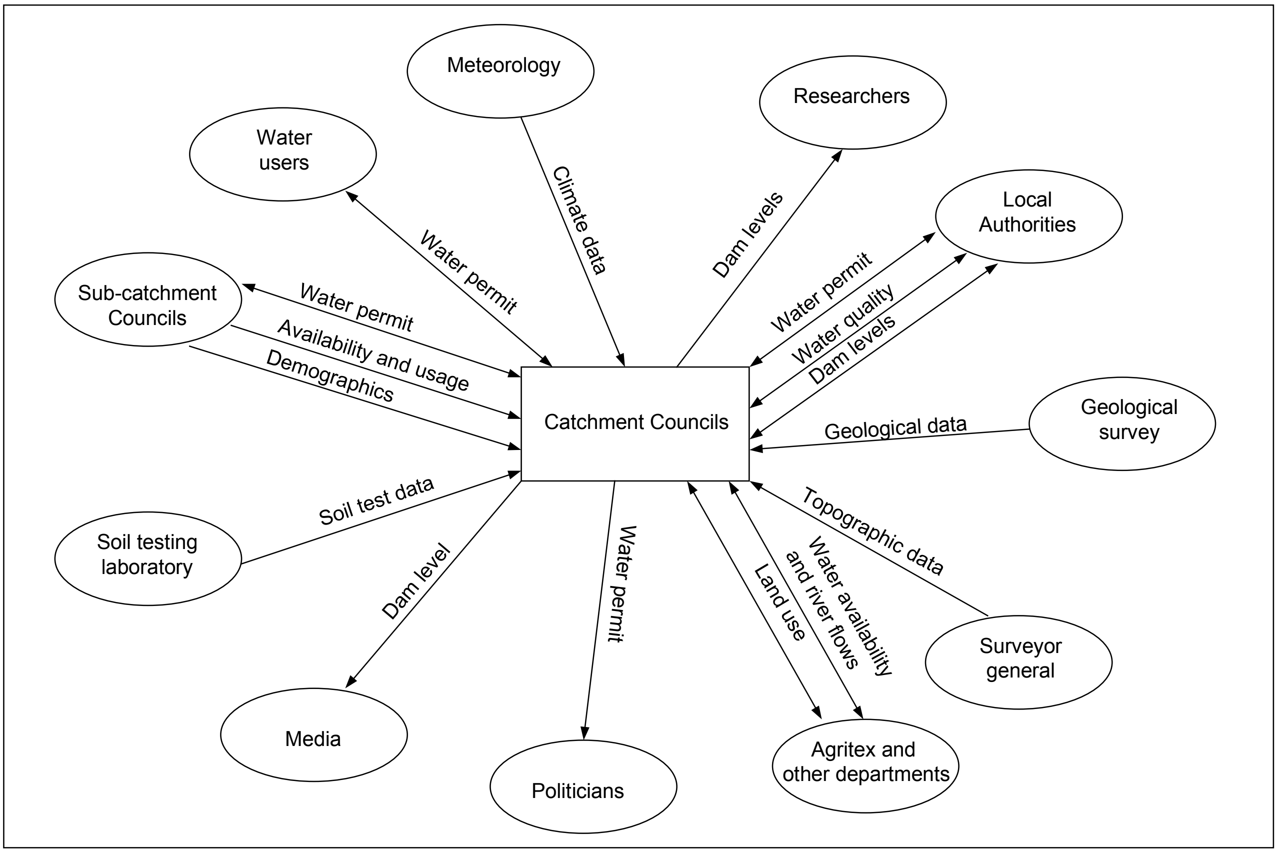


**Figure 2.5 Catchment council stakeholders and the flow of information**

## 2.3 Stakeholder participation in the development of the IWIM system

A series of consultation workshops were held at key stages of the project to provide a forum for water professionals and practitioners to contribute to the detailed formulation of the research. The objectives of the workshops were:

- To identify stakeholder responsibilities and water management functions and their relationship to water demand and water use information requirements;
- To identify relevant data sources, data availability and constraints (e.g. quality, quantity and frequency) in meeting their respective needs;
- To identify information flows and information management requirements to achieve integration across different stakeholders and stakeholder water management functions.

Participants included:

- Members of various sections of the Department for Water Development including:
  - Hydrology
  - Planning;
  - Pollution control;
  - Catchment planning team;
- Members of the Catchment Councils;
- Members of Sub-catchment Councils;
- Agricultural Extension services (Agritex);
- Water Resources Management Strategy Technical Secretariat;
- Ministry of the Environment;
- Confederation of Zimbabwean Industry;
- Town Engineers Forum;
- District Development Fund.

## 2.4 Responding to stakeholder participation

Catchment planners are mainly concerned with the economic and social development of the catchment and are not normally directly involved with water management. However, in planning the development of a catchment the potential changes in water use and demand, as well as the changes in the water resource, must be considered. Any change in the land use or activities in the catchment affects the water situation and requires decisions to be made about whether and how those changes can be incorporated into the water management strategy for the catchment.

Increasingly, water has become the limiting factor to development either on a catchment level or a national level. Future development and certainly further growth will, in these cases, rely on the location of a new source (such as through inter-basin transfers) or water saving either through increases in water use efficiency or a change in the catchment development strategy toward less water-intensive economic activities.

Those responsible for catchment planning are usually not directly involved with, or expert in, water management and require support information to make informed development decisions. Catchment planning is also a dynamic process where development priorities are constantly changing. Consequently, the impact of the development plans on water use are also constantly changing and affect water demands.

The philosophy behind the Integrated Water Information approach emphasises that effective management of water must be fully incorporated within the planning and decision making process for the development and growth of the catchment. Good catchment planning supports effective water management if water management needs are fully considered in the planning process because difficult or impossible water supply situations are avoided. Along with the catchment planning strategy, there are strategies for water allocation and water management which the planner must be fully aware of.

The primary components of catchment planning where water management is concerned are:

- To ensure that planned developments do not have an adverse effect on either the hydrology or water quality of the catchment
- To ensure that adequate water resources are available to all water users in all sectors over the development horizon

To implement these primary components, the catchment planner requires knowledge in several areas common to water managers. These include:

**(i) Catchment water resources**

Catchment development is only feasible if there is sufficient water to support it. Water resources are often now the limiting factor to future development. The potential for new sources or increased storage either within or outside the catchment may also be considered to improve the resource potential if warranted. The schedule for the development of these and other water resources infrastructure must also be considered to ensure that the infrastructure is in place when needed. This should be part of the planning process.

**(ii) Water demand forecasts**

Water demand forecasts are tied directly with catchment planning and their relationship should be cyclical, as the forecasts are based on expected development and growth in the catchment. As part of demand management, the potential for improving efficiency in distribution or otherwise reducing demands must be assessed as this can make significant differences in the resource potential of the catchment.

**(iii) Water allocation policies and strategies**

Water allocation policies are directly linked to development planning and may also be cyclical because water allocation policies may result from development policies or vice-versa. Development plans may highlight the need to reconsider allocation policies. For example, where catchment plans lean toward industrial development this may conflict with agricultural water demands and may lead to a reassessment of water allocation to these sectors.

**(iv) Reliability requirements**

Different economic activities have varying reliability requirements and both the reliability needs of the industries and the ability of the catchment and its water infrastructure to meet the required levels of reliability. The impact of drought and drought alleviation strategies are an aspect of this.

**(v) Costs of supplying water and expected returns of the planned development**

Especially where water is becoming a limiting factor, the cost of supplying additional water for a development may be prohibitive. These costs may be offset if the value of the industry to the catchment is high. Such costs must be included in the overall catchment plan. Water quality must also be considered within these costs both in terms of supplying water of adequate quality and ensuring that the resulting effluent is acceptable. Water quality standards must also be met.

**(vi) Hydrological impacts of planned developments**

The hydrological impacts of the development must be fully considered, not just looking at the impacts of a single development, but for the combined effect of all planned development over the entire planning horizon period and including the impact of drought.

### (vii) Environmental considerations

The basic flow requirements for rural communities and other unregulated use must be considered in terms of meeting these demands as well as ensuring that the hydrological impacts on these are acceptable. Similarly, minimum flow requirements for environmental or aesthetic needs are also important. Sustainability is the key.

### (viii) Source and quality of the information used

The source of the information used and its quality is of great importance. Planning decisions must be based on the best information available and the risks inherent in using that information must be well understood and incorporated into the decision making process. Future monitoring needs should also be considered at this time.

### (ix) Water permits

Whatever the planned development for the catchment, water users will need permits for water use and the plans must fit with current permitting policy (though permit policy can also be flexible to accommodate changes in development plans).

The roles and responsibilities of these Catchment Councils have directed the functionality of the conceptual IWIM system. This is discussed further in Section 2.5.

## 2.5 Objective and management functions of the IWIM system

Optimal development of water resources requires appropriate policies and strategies to allocate and manage water in an integrated and sustainable manner. Integrated planning of water resource development and management is essential but without basic information on all aspects of the water cycle there can be little confidence in the output of resource management studies that focus on efficient use. In the past, support for hydrological assessments of the water resource availability has been high and a number of associated tools have been developed. However, little has been done to develop tools and methodologies related to improving assessments of water allocation, use and demand within a multi-sectoral context.

The IWIM system would assist in improving the capture, quality control and synthesis of information as well as being a support tool for strategy formulation and integrated planning studies. By focusing on the 'user' or 'demand' end of the water cycle, the system would complement existing 'supply' side information systems such as hydrological databases and provide vital information for use in the application of water resource systems analysis models. The primary objectives of the IWIM system are:

- To support assessments of issues related to water demand and use, through provision of current and forecast information;
- Identify information requirements including gaps in data sets;
- To provide integrated multi-sectoral information;
- To provide appropriate information to assist water managers to answer questions on the level and performance of water related systems;
- To enable the comparison of observed data against prescribed targets and standards;
- To provide information by which the performance of water resources infrastructure can be assessed including:
    - equitability of water distribution;
    - efficiency of water use;
    - effectiveness of water use;
- Storage and management of water abstraction licences or permits;
- Planning for future developments;
- Demand forecasting;

- To provide a tool by which the spatial and temporal information can be presented and analysed at different scales and time steps.

An overview of the IWIM system in relation to catchment management organisations is shown in Figure 2.6 below.

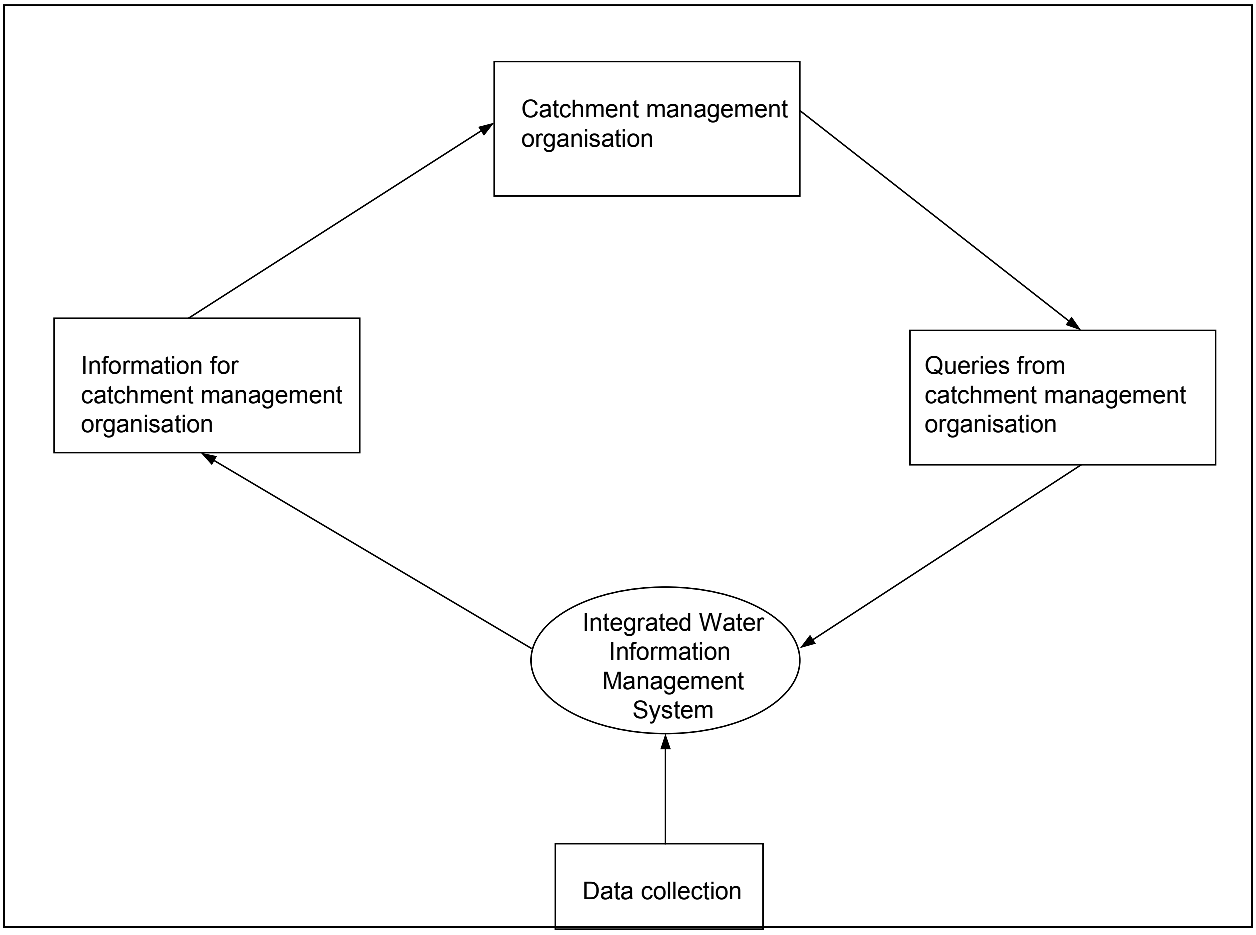


**Figure 2.6 Structure of the IWIM system in relation to a catchment management organisation**

The core of the IWIM system is based on a Geographical Information System (GIS). The architecture of the IWIM system is discussed in Chapter 3.

# 3. ARCHITECTURE OF THE IWIM SYSTEM

The core of the IWIM system comprises a Geographical Information System (GIS) linked to a database. The IWIM system is to be developed as a generic system so that it is possible to transfer it to any country, providing the relevant data, in the correct format, are available. An overview of the structure of the IWIM system is shown in Figure 3.1 below.

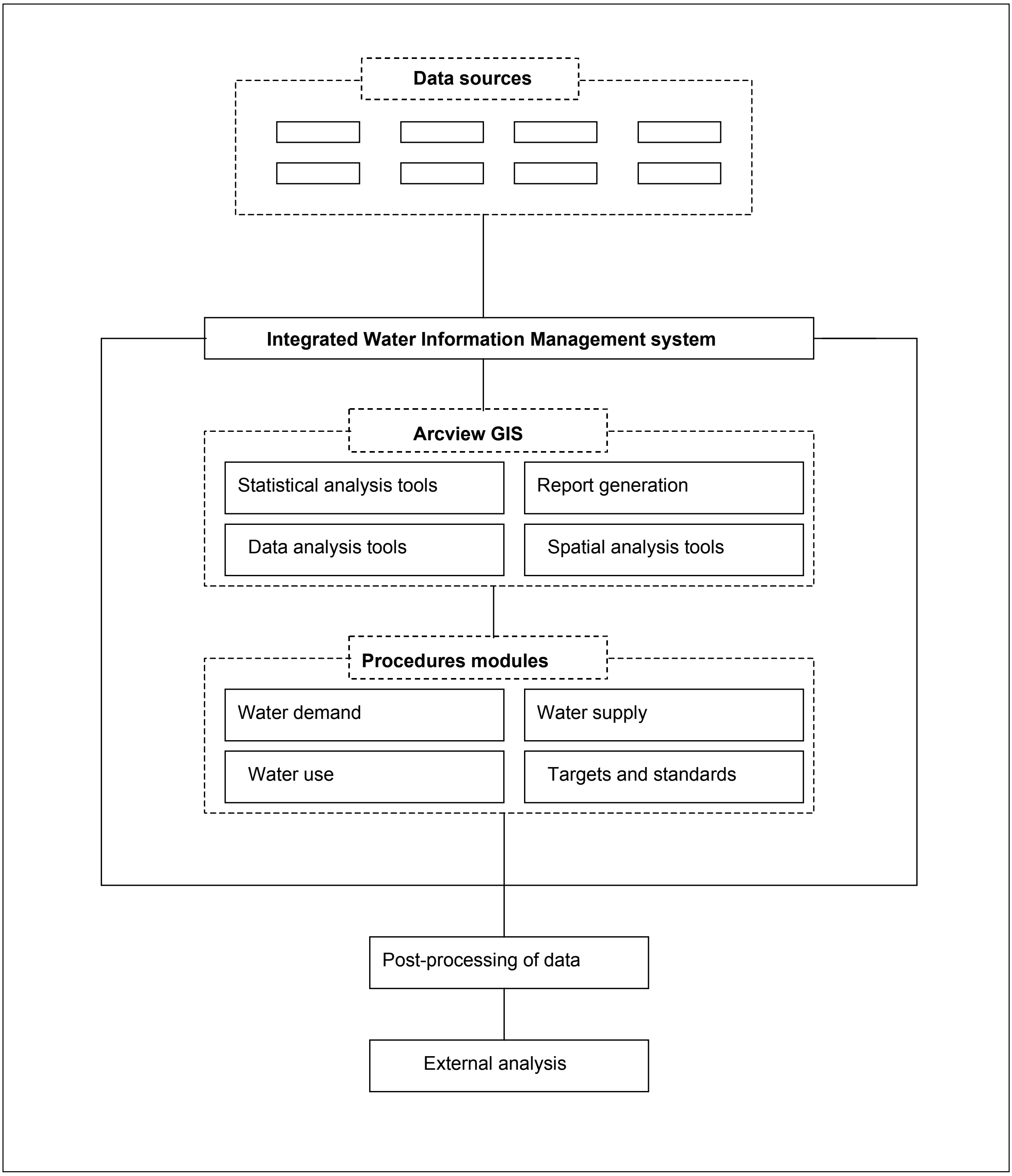


**Figure 3.1 Overview of the IWIM system**

## 3.1 Use of a Geographical Information System (GIS)

The IWIM system aims to provide a visual and spatial information on aspects of demand, use and supply of water. It is appropriate that computational tools that can encompass aspects of these should be used. In the last decade, wide use of relational database technology has occurred, however, considerable limitations on creating the structures for large databases have been found. In parallel to these developments has been increasing power and sophistication of computers and associated with that more powerful and flexible Geographical Information System (GIS). The last few years have seen all these developments culminating in the availability of GIS which directly link to database tables and structures. The use of a GIS linked with an open architecture has the following advantages:

- It allows data to be displayed visually at a number of different scales;
- Improved management of data from variable sources including various databases;
- Improved decision making within the water management system;
- It possible to link, or integrate, information that is difficult to associate through any other means. This allows combinations of mapped variables to build and analyse new variables.

The conceptual IWIM system, shown on the CD-ROM that accompanies this report, has been developed using the ArcView package. ArcView is one of the most widely used GIS packages in the world. ArcView was chosen for the development of the conceptual IWIM system because:

- An ArcView system funded by DFID was already being used by the Department for Water Development in Zimbabwe to manage hydrological data;
- There was a linkage to mapping that had been developed by the Zimbabwean Department of Water Development. These include:
  - Access to the water quality data currently being mapped for the whole country;
  - Access to the water rights data base being developed and the functions written to aggregated them for locations through out the river network;
- Linkage to other Zimbabwean government agencies including the Department of Natural Resources and Agricultural Technical Extension Service (Agritex).

## 3.2 Temporal resolution of the IWIM system

The temporal resolution of the IWIM system is dependent on the information requirements of the end user. The IWIM system is primarily focused on the management of water demand and use data at a macro-level. As a consequence the IWIM system has the ability to operate at two different temporal scales. These are

- Monthly;
- Annually.

The IWIM system allows the user to generate annual data from the monthly data stored in the system.

## 3.3 Spatial resolution of the IWIM system

The importance of using hydrological boundaries as the basis for water resource planning and management is now widely recognised. The spatial definition of the IWIM system is thus centred on catchments and sub-catchments.

There is generally a need within water management institutions to view and manage information at a variety of different spatial scales (e.g. local, regional, national, multi-country or international). The scale at which information has to be integrated is dependent upon the nature of the decisions to be made and is a function of the following:

- User requirements;

- Size of the country;
- Administrative and political boundaries;
- Availability of data and information;
- Catchment boundaries.

Water management organisations and agencies generally require information at a number of different spatial scales ranging from a national level to a sub-catchment scale or even lower. Figure 3.2 below illustrates some of the levels for which spatial information may be required. The number and type of spatial levels required by the IWIM system will be country dependent.

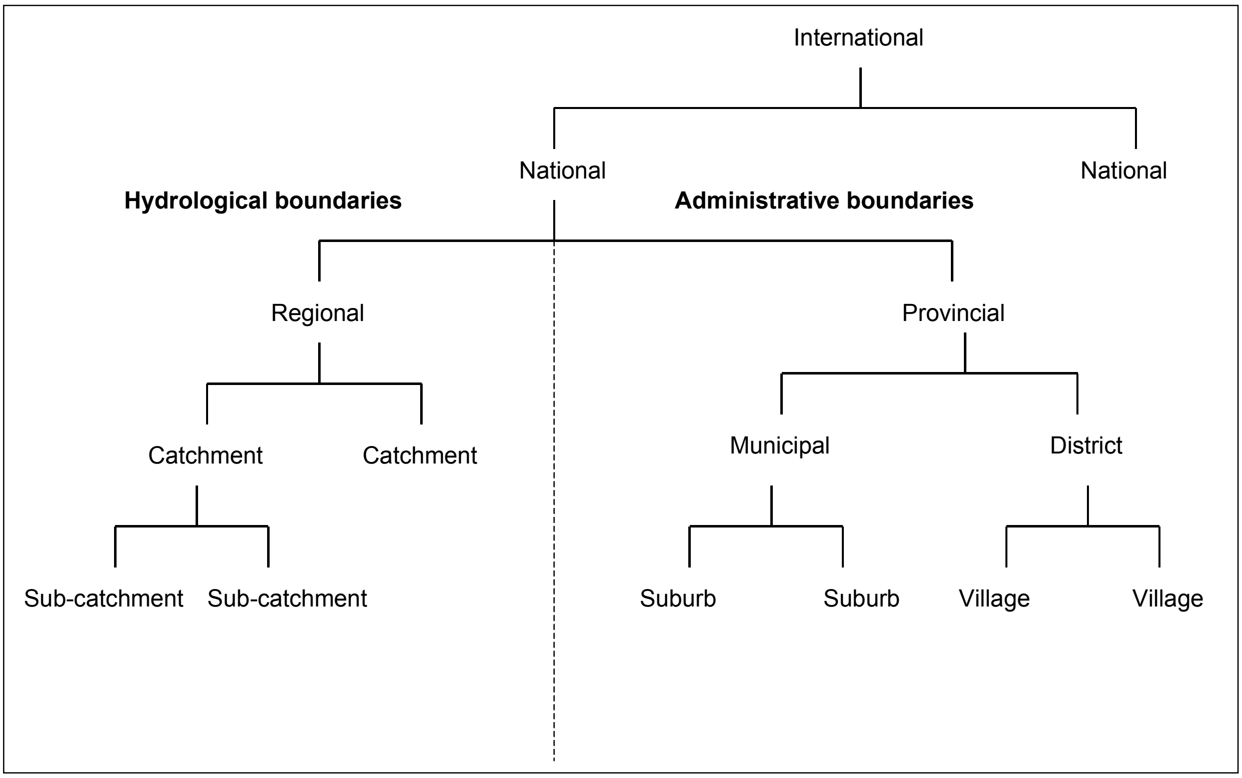


**Figure 3.2 Examples of the spatial levels that may be required by an IWIM system**

In most countries political boundaries are generally not coincidental with hydrological boundaries. One of IWIM's strengths is that the use of a GIS allows spatial data to be manipulated in order to answer specific queries at various hydrological levels (e.g. catchment and sub-catchment), and various administrative and political levels (e.g. provincial and district).

# 4. DATA UTILISED BY THE IWIM SYSTEM

The IWIM system utilises a wide variety of data including:

- Spatial data;
- Water use data;
- Water supply data;
- Information on water abstraction licences and wastewater discharge consents.

An overview of the various types of data is discussed below

## 4.1 Spatial data

Spatial data is integral to the functionality of the IWIM system. There are two main forms of spatial data that are required by IWIM, these are:

- Mapping;
- Geo-referenced objects.

The mapping and geo-referenced objects used by the IWIM system are described below.

### 4.1.1 Mapping

The majority of the mapping required by the IWIM system is thematic mapping. Thematic maps contain information about a single subject or 'theme'. Various types of thematic mapping that may be required by an IWIM system include:

- Watercourses;
- Aquifers;
- Catchment and sub-catchment boundaries;
- Administrative and political boundaries e.g. districts, regional and international boundaries;
- Land use boundaries including:
    - Safari and game parks;
    - Large farming areas;
    - Irrigation schemes;
- Soil types.

In many cases the above mapping will be available in digital format, however, in some cases the mapping required will have to be digitised from base mapping.

### 4.1.2 Geo-referenced objects

Geo-referenced objects represent data that are point based and which are oriented to a particular point in space. Examples of geo-referenced objects that may be included in the IWIM system are:

- Water supply infrastructure data e.g. details of reservoirs, boreholes, river intakes;
- Water abstraction licences and permits;
- Wastewater discharge consents;
- Water use centres e.g. cities, towns, villages and major industries.

The geo-referenced objects in the IWIM system would, in some cases, include additional information in the form of tables that can be called up by the user when the object is selected.

## 4.2 Water demand and use data

The IWIM system allows the user to analyse and store data for a number of key water demand and use sectors. It is recommended that the key water use sectors used are as follows:

- Industry;
- Urban;
- Agriculture;
- Rural water supply;
- Environment;
- Miscellaneous.

The above key water use sectors are broken down into sub-sectors as shown in Figure 4.1. The sum of the water uses for the sub-sectors should equal the total water use for the sector. It is important to note that the IWIM system gives the user the flexibility to define their own key water use sectors. However, when setting up the IWIM system it is important that each of the water use sectors and sub-sectors is well defined. It is essential that the user defines the key water use sectors and sub-sectors such that:

(i) Double counting of water use does not occur. For example, if not correctly defined the urban commercial water use sub-sector may include a water use already counted under the light industrial water use.

(ii) It is important to ensure that all water uses are included.

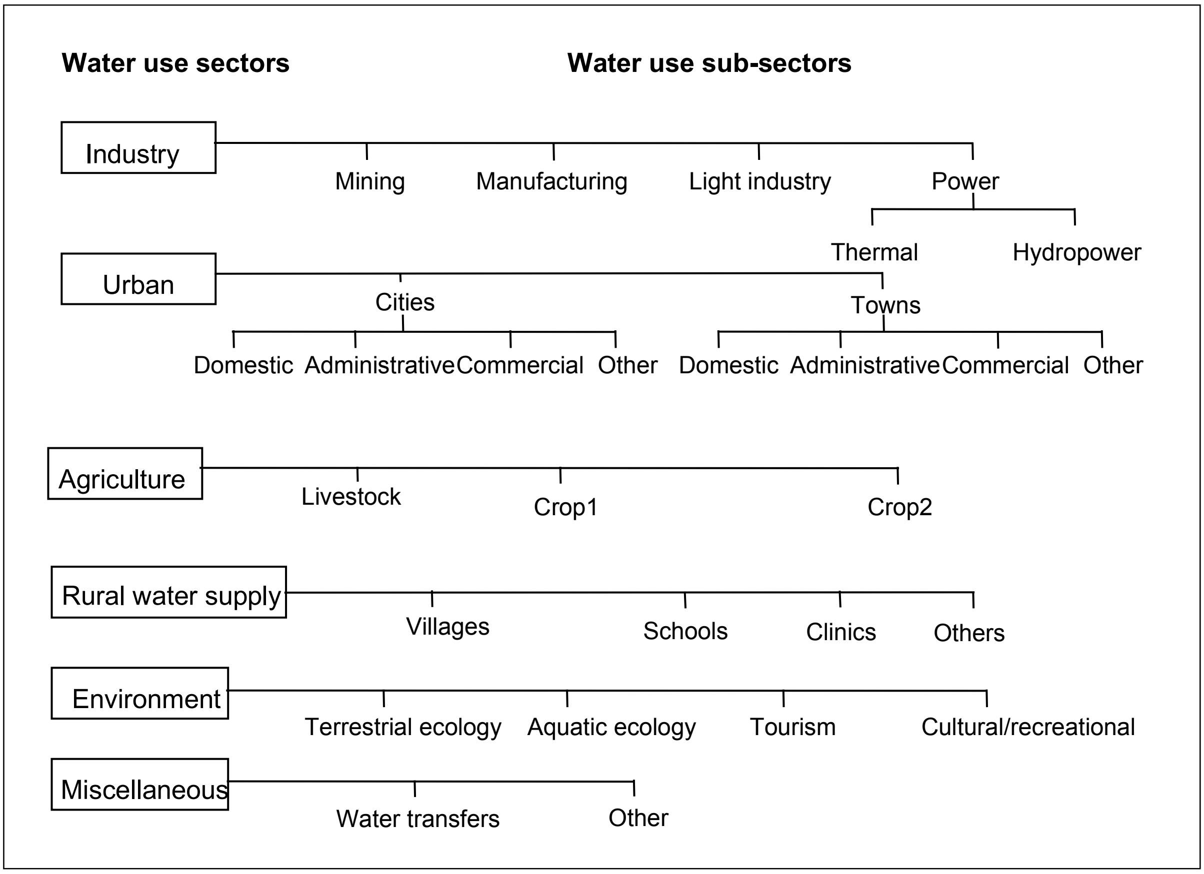


**Figure 4.1 Examples of water use sectors and sub-sectors**

Brief details of the various key water use sectors are given below.

### 4.2.1 Industry
This sector includes water used for industrial purposes, such as fabrication, processing, washing, in-plant conveyance, and cooling, and includes such industries as steel, chemicals, paper, and petroleum refining. The water may be obtained from a public water supply or may be self supplied. Industrial water use data for the various sub-sectors should, where possible, be taken from bulk water metering of water supplies. In some countries power may be classified as a separate water use sector.

### 4.2.2 Urban
The majority of the urban sector will comprise domestic use. It is recommended that where possible metered data are used to collate domestic water use data. The level at which the water use data is collated is dependent upon the following:

- The needs of the user;
- The resolution of the water metering system.

### 4.2.3 Agriculture
Agricultural water use is often difficult to estimate. Even large irrigation schemes are often unmetered. Should metered data on agricultural water use be unavailable, in some cases agricultural water use may be made from abstraction licences. Where this information is not available crop water use can be calculated using the following information:

- Crop area;
- Estimates of crop evapotranspiration made from meteorological data and the crop type;
- Estimated conveyance and application efficiencies of the irrigation schemes.

### 4.2.4 Rural water supply
In the rural areas of many developing countries there is often a paucity of metered water use data available. In many cases rural water use will have to be estimated from population figures to which a per capita water use figure is applied.

### 4.2.5 Environment
Environmental water use is probably the most difficult water use to quantify. Instream flow requirements for aquatic ecology are dependent on the baseline conditions. The water use for terrestrial ecology can be estimated by establishing the carrying capacity of the land and calculating the volume of water required to support this.

### 4.2.6 Miscellaneous
Miscellaneous water uses may include water transfers that in many cases will be metered.

## 4.3 Water supply data
Although the IWIM system is primarily focused on the management of demands on a sub-catchment and catchment scale, the system also utilises recorded water supply data to allow catchment managers and planners to ascertain the following:

- Imbalances between water supply, use and demand at various levels;
- Quantities of unaccounted for water;
- How improvements in water use efficiency and improve water supply and demand imbalances;

IWIM incorporates the following information in the water supply database:

- Source name;
- Existing and planned withdrawal information where available;
- Yield of water source (if available);
- Source type (i.e. surface water, reservoir) and details (e.g. dam height, borehole depth);
- Type of water use;
- Inter-basin transfer information (if applicable);
- Well data (if applicable).

The IWIM system incorporates data on the three main sources of raw water supply. These are:

- Dams;
- Diversion structures;
- Boreholes and wells.

The information that is incorporated in the IWIM system for each of these is discussed below. The safe yield of a raw water supply system is the demand that it can meet under specified drought conditions. For example, a 30 year safe yield is the demand that a system can support under drought conditions that would occur on an average of once every 30 years, or have a one in 30 chance of occurring in any single year.

### 4.3.1 Dams

The IWIM system holds the following information on reservoirs:

- Dam height and type;
- Type and capacity of spillway;
- Full, operating and minimum supply level;
- Live storage volume;
- Sedimentation rate;
- Safe yield;
- Date of the last safety inspection
- Uses.

Each reservoir in the IWIM system is geo-referenced. When selected a table is produced illustrating the above information.

### 4.3.2 Diversion structures

Where watercourses are used as a source of water supply, the IWIM system provides the following information to the user:

- Name of the river;
- Capacity of the intake;
- Date of construction
- Uses.

### 4.3.3 Boreholes and wells

The IWIM system holds information on the following regarding groundwater water supply sources:

- Depth of borehole or well;
- Type of casing and screen;
- Type and capacity of pumping system;
- Yield of borehole;

- Uses.

## 4.4 Water abstraction licence data

A water abstraction licence or water right is usually a legally protected right, often granted by law, to take possession of water from a source of water such as a watercourse, reservoir or aquifer and to divert that water and put it to commercial use. The water abstraction licence data included in the IWIM system includes the following:

- Name of the water abstraction licence or permit holder;
- Source from which water is abstracted i.e. borehole, watercourse or reservoir;
- Rate of abstraction;
- Period of the year for which the abstraction is valid;
- Date when the abstraction licence expires;
- The population, number of livestock, crop area, industrial production that is supplied by the water right.

## 4.5 Wastewater discharge consent data

A wastewater discharge consent acts as a licence or permit to discharge effluent to a ‘controlled water’ such as a watercourse, lake, reservoir or aquifer, providing the wastewater is within specified limits. The IWIM system stores information on wastewater discharge consents including the following:

- Name of the discharge consent holder;
- Maximum quantity of effluent to be discharged to the controlled water;
- Date at which the discharge consent expires;
- Maximum limits of discharge (e.g. maximum biochemical oxygen demand (BOD) limit);
- Receiving watercourse or aquifer;
- History of non-compliance and fines.

## 4.6 Units of measurement

The IWIM system is to be set up as a generic water management system, and as such there are no explicitly defined units in which the data must be provided. However, to limit the complexity of the system it is recommended that the user standardises the units of measurement for each particular data type. For example the user may decide to define domestic water use in Ml/day and agricultural water use in l/s. However, for calculation purposes the IWIM system will convert the data into one consistent unit.

## 4.7 Data availability

The availability of data is crucial to the successful implementation of the IWIM system. Problems can often be encountered with not only the availability of data, but also in terms of quality, format, completeness and ownership. For example data availability and its format can dictate the format of the hardware and software to be used. The data required and available for the IWIM system has been assessed via number of workshops with the relevant stakeholders in Zimbabwe. This section details the following:

- Available base data for the IWIM system;
- The Water Rights data required;
- The other data that is required for the IWIM system.

### 4.7.1 Available base data for the IWIM system

There has already been a significant quantity of GIS base data that has been digitised for use in ArcView for a hydrological GIS-based system that is already in use. This includes:

- River system;
- Catchment Council and Sub-catchment Council boundaries;

- Surface water gauging stations;
- Administrative boundaries;
- Towns;
- Land class;
- Communications links such as roads and railways.

These data are readily available to form the base maps for the IWIM system

### 4.7.2 Water rights data

There is an existing comprehensive database detailing the 17,000 water rights on rivers in Zimbabwe. The information in this database includes:

- Name of the water rights holder;
- Name of the property;
- Name of the river from which the water is abstracted;
- Location of the abstraction;
- Status of the water right (e.g. application, temporary, provisional, final);
- Type of water right (e.g. storage or flow right);
- Rate of abstraction and total volume to be abstracted if applicable;
- Total volume of water to be stored if applicable;
- Period when abstraction can take place if applicable.

### 4.7.3 Other data

There still remains data that is not available in digital format suitable for use in the IWIM system. This includes:

- Climate data including:
    - Rainfall;
    - Temperature
    - Humidity;
    - Wind;
    - Light intensity or day length;
- Cropped areas and type of crop;
- Population including the location, numbers and future growth rates of:
    - Humans;
    - Farm animals;
    - Wild life;
- Physical infrastructure including:
    - Dams;
    - Industrial plants;
    - Mines;
- Information on wastewater discharge consents;
- Water demand and use data for the following sectors:
    - Urban domestic;
    - Rural domestic;
    - Industrial;
    - Agriculture;
    - Environmental requirements.

Climate, population and physical infrastructure data are available at a reasonable spatial resolution. Such data needs to be digitised for use in the IWIM system. This can be a laborious and time-consuming task. Water demand and use data are not currently available. Sub-catchment Councils will use recommended procedures to collect this information

# 5. KEY FUNCTIONS OF THE INTEGRATED WATER INFORMATION MANAGEMENT SYSTEM

This chapter discusses the key functions of the IWIM system. As previously stated the primary function of the IWIM system is to provide an integrated approach to the assessment of water demand at various spatial levels ranging from a sub-catchment level to a national level. The key functions of the IWIM system include the ability to carry out the following:

- Aggregation of data which allows the user to interrogate the system concerning demand information on various spatial scales varying from a sub-catchment level to a national level, and on various temporal scales ranging from daily to annually;
- Proximity analyses;
- Demand forecasting using a number of different methods;
- Comparison of forecast demands against required targets and standards;
- Water availability assessments which allow the user to ascertain and predict 'hotspots' where demand may outstrip the available supply;
- Various water resources planning functions including:
    - Assessments of when drought restriction orders should be put in place on the holders of water abstraction licences;
    - Allow a comparison to be made between different demand forecasting methods;
    - Assessments of where improvements can be made to water use efficiency;
    - Simplify the production of catchment management plans and reporting;

Details of the various functions of the IWIM system are given below.

## 5.1 Aggregation of data

The IWIM system allows users to interrogate the system at a number of temporal and spatial levels. Mean daily supply and demand data will be held in a database management system for the various sources of water supply, water use and water demand sectors. The IWIM system allows the user to aggregate the data sets as follows:

- Temporally e.g. the user will be able to aggregate data on a monthly or annual basis;
- Sectorally e.g. the system will allow the user to aggregate data for various demand sectors and sub-sectors, together with supply sources;
- Spatially e.g. data can be aggregated using either hydrological boundaries (e.g. at a sub-catchment, catchment or national level) or using administrative and political boundaries (e.g. at a national, provincial, or district level);
- Combinations of the above.

Examples of temporal and spatial aggregation of data are given in the sections below.

## 5.2 Proximity analyses

The IWIM system allows the user to carry out proximity analyses. For example the user may wish to answer the following queries:

- How many water abstraction licences are there within 10 km of the village of Nyanyadzi?;
- How many boreholes are there within 2 km of the town of Chimanimani?;
- Display many industrial sites are there with a water use of greater than 20 Ml/day within 20 km of the city of Mutare?
- Provide details of all the reservoirs with a live storage capacity of greater than 20 million $m^3$ that are within 50 km of the city of Gweru?

Details of the how the IWIM system would provide information to the user to answer the final two queries above are shown in Figures 5.1 and 5.2.

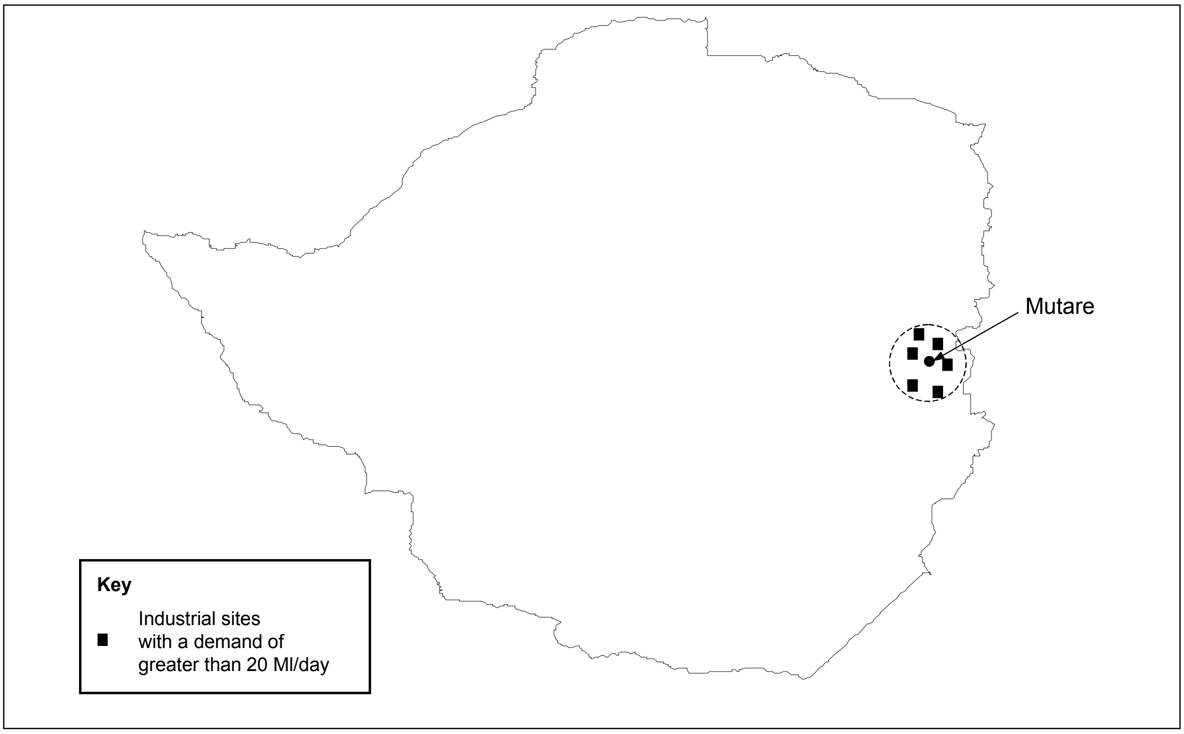


**Figure 5.1 Industrial sites with a water use of greater than 20 Ml/day within 20 km of Mutare**

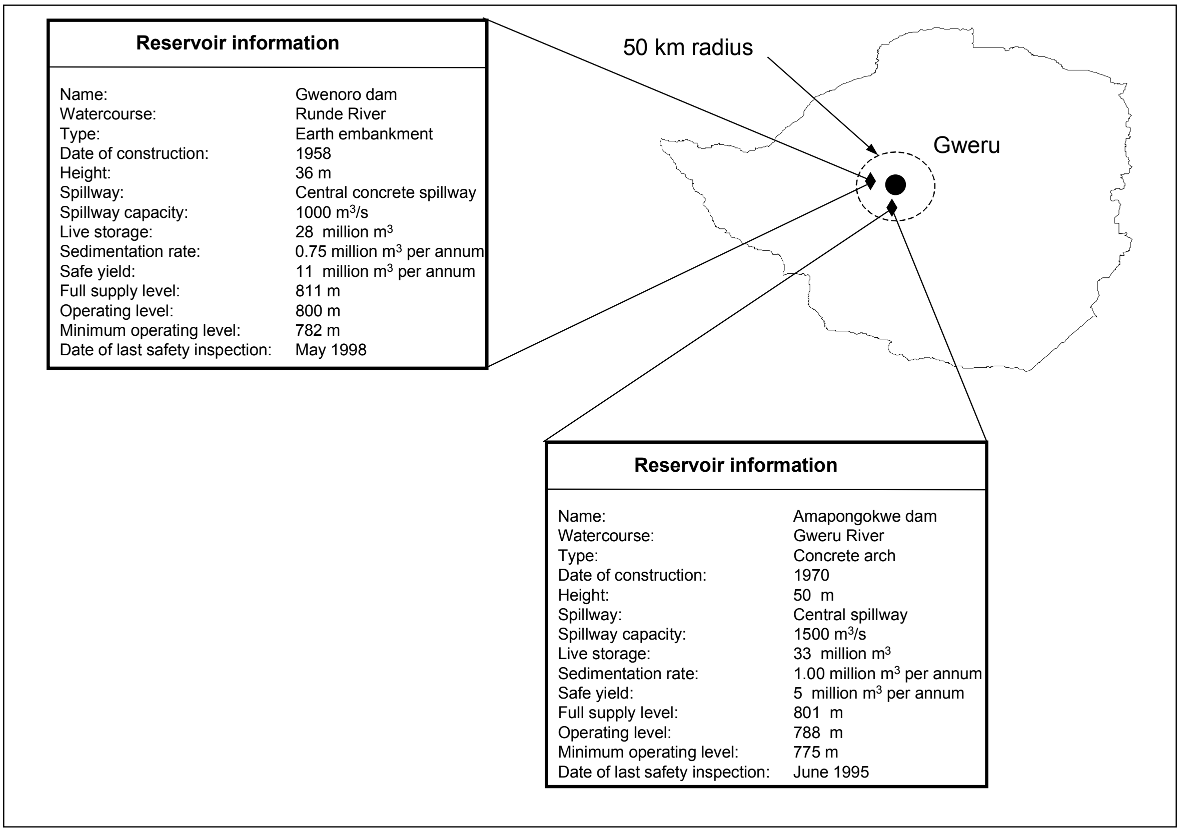


**Figure 5.2 Example of a proximity analysis to establish the details of all the reservoirs with a live storage of grater than 20 million $m^3$ within 50 km of the town of Gweru**

## 5.3 Water use and demands

The IWIM system is primarily aimed at assisting catchment and water resources managers in managing demands and water use. The IWIM system allows information on water use and demand to be compiled on a number of different spatial scales. For example the user may wish to establish the answers to the following:

- How does water use in Harare vary over a typical year?;
- Which population centres have a water use of greater than 150 litres per person per day?;
- For each catchment show the percentage water use of each key water use sector;
- For each province show the quantity of water used on an annual basis in Mega-litres for each key water use sector.

The way in which the IWIM system could respond to these queries is shown in Figures 5.3, 5.4, 5.5 and 5.6 below.

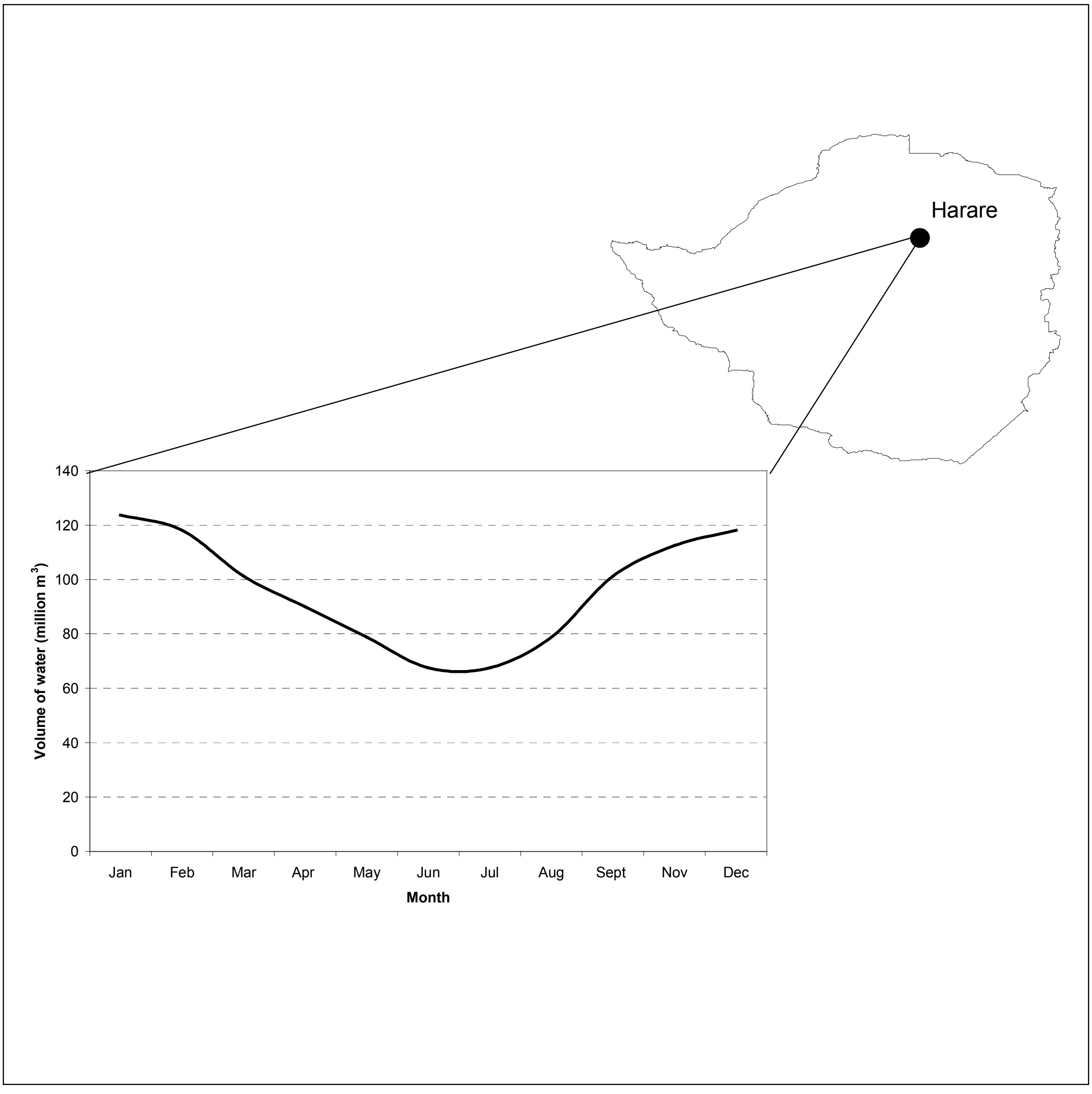


**Figure 5.3 Water use for a typical year for the city of Harare**

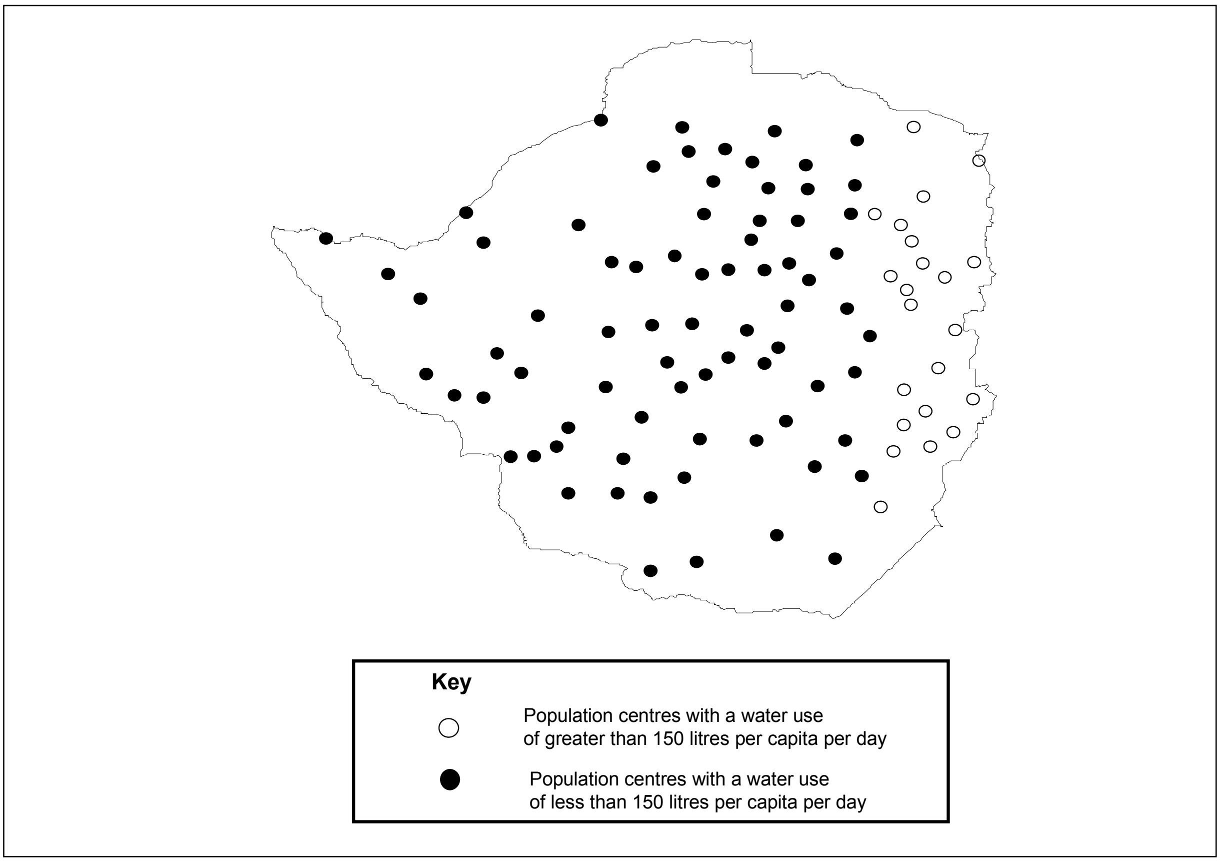


**Figure 5.4 Population centres with a water use of greater than 150 litres per capita per day**

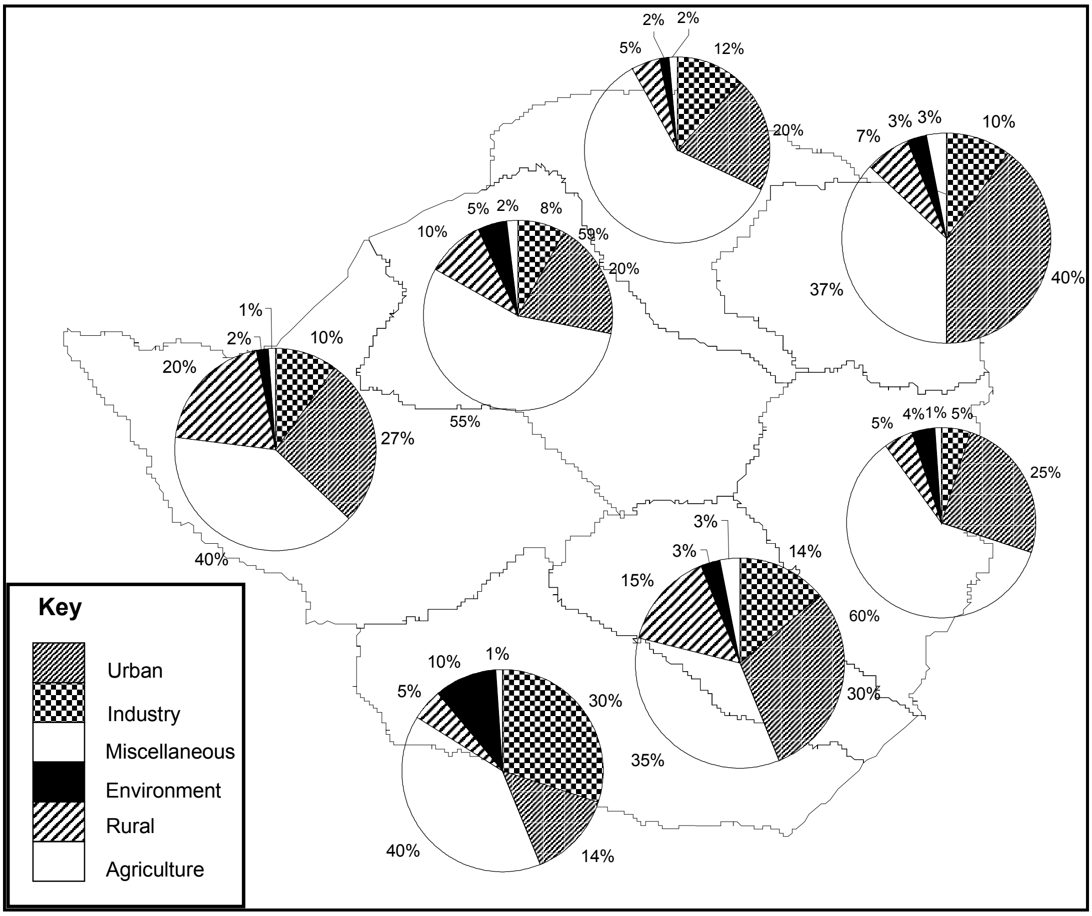


**Figure 5.5 Percentage water use for each key water use sectors by catchment**

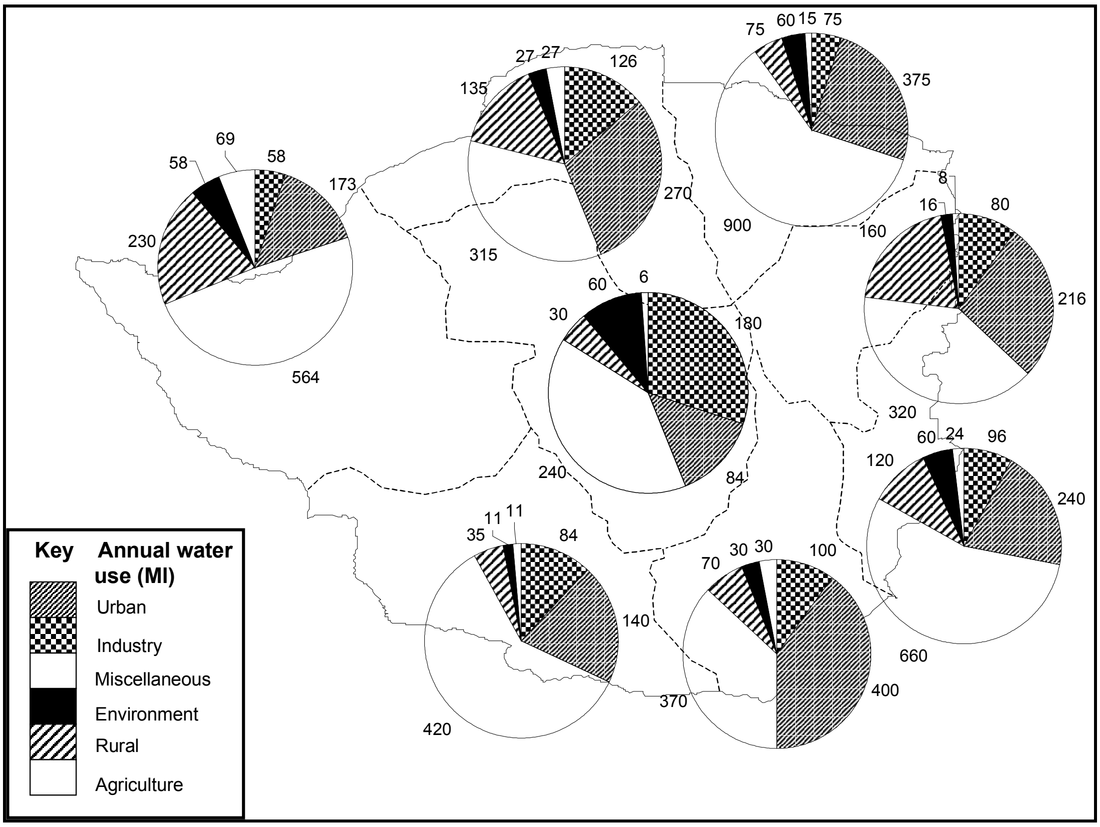


**Figure 5.6 Annual water use in Mega-litres by province**

## 5.4 Demand forecasting

The IWIM system will allow water management organisations to forecast water demands for the various defined spatial levels and water use sectors. There are numerous influences on water demand, some of the most commonly cited include:

- Population growth;
- Tariff levels;
- Changes in the efficiency of water domestic, industrial and agricultural water use;
- Socio-economic factors;
- Climate change.

Forecasting changes in water demand is, at best, an inexact science owing to the uncertainties in the lack of knowledge concerning the future. It is important that these uncertainties are reflected in the demand forecast carried out. The IWIM system allows a number of demand forecasting techniques to be applied for the various planning horizons that are of interest. The demand forecasting methods available with the IWIM system are:

- Extrapolation based on population growth;
- Analysis of trends;
- Multiple regression analysis;
- User defined methods.

The demand forecasting method that the user chooses to apply will be primarily dependent upon the quality and availability of the historical water demand data. As more water demand data becomes available IWIM system provides the user with the option of using more sophisticated and data intensive demand forecasting methods. The demand forecasting methods available within the IWIM system are outlined below.

### 5.4.1 Extrapolation based on population growth

This method should only be used where data are limited. The forecast demand is estimated by the IWIM system using project population growth figures and multiplying by an estimated per capita consumption figure. Data used for this method by the IWIM system may include the following:

- Water usage data available from public water supply organisations;
- Population data from the latest census.

This method should only be used where data are limited and can only be applied at a macro level i.e. it is not possible to forecast water demand for individual water use sectors.

### 5.4.2 Analysis of trends

The IWIM system allows an analysis of water demand trends to be made. The IWIM system utilises time as the independent variable and allows the user to fit a variety of mathematical functions to historical water demand data to allow future water demands to be estimated.

This method is limited by its primary assumption that historical trends indicate what future water demand will be. The future demand, predicted by the IWIM system, using this method is dictated by the mathematical function that is fitted to the data by the user. The IWIM system provides the user with a library of functions that can be fitted to historical data. If the relevant demand data are available the user can carry out demand forecasting on a sector by sector basis.

### 5.4.3 Multiple linear regression analysis

The IWIM system allows the user to carry out multiple linear regression analysis. Users can use one of more independent functions. The values found can be determined by ordinary least square analysis. The method can be used to investigate to forecast demands for different sectors. However, similar to the analysis of trends this method assumed that the fitting a regression to historical data will adequately predict future demands.

### 5.4.4 Multiple non-linear regression analysis

The IWIM system also provides the user to carry out non-linear regression analysis. This method is relatively data intensive and the results produced may be no more accurate than trend analysis.

### 5.4.5 Component demand forecasting

Component demand forecasting allows estimates of water demand to be based on individual demand components e.g. household appliances, industrial machinery crop and the extent of the usage or the production of that individual component. Additional usage outside of the aggregated components, (depending on the coverage of the components), can be assigned to miscellaneous uses and system losses.

This method of demand forecasting can be useful in determining the present distribution of uses and production technologies. It can also identify key areas of use, predict areas of use that my increase or decrease and how these may affect the total water usage. However, this method requires large quantities of data as well as detailed analysis.

### 5.4.6 User defined methods

The IWIM system allows the user to input their own user defined equations for the forecasting of water demands.

### 5.4.7 Examples of demand forecasting

As previously stated the IWIM system allows the user to carry out demand forecasts using a number of different methods for a number of different spatial and temporal scales. Figure 5.7 below illustrates an example where the user has carried out demand forecasting over a 20 year planning horizon for each of the key water use sectors for the whole of Zimbabwe. The planning horizon, number of key water use sectors and the spatial level at which the demand forecasts is carried out are determined by the user. For example the user could forecast water demands for a particular catchment or sub-catchment over a planning horizon of ten years.

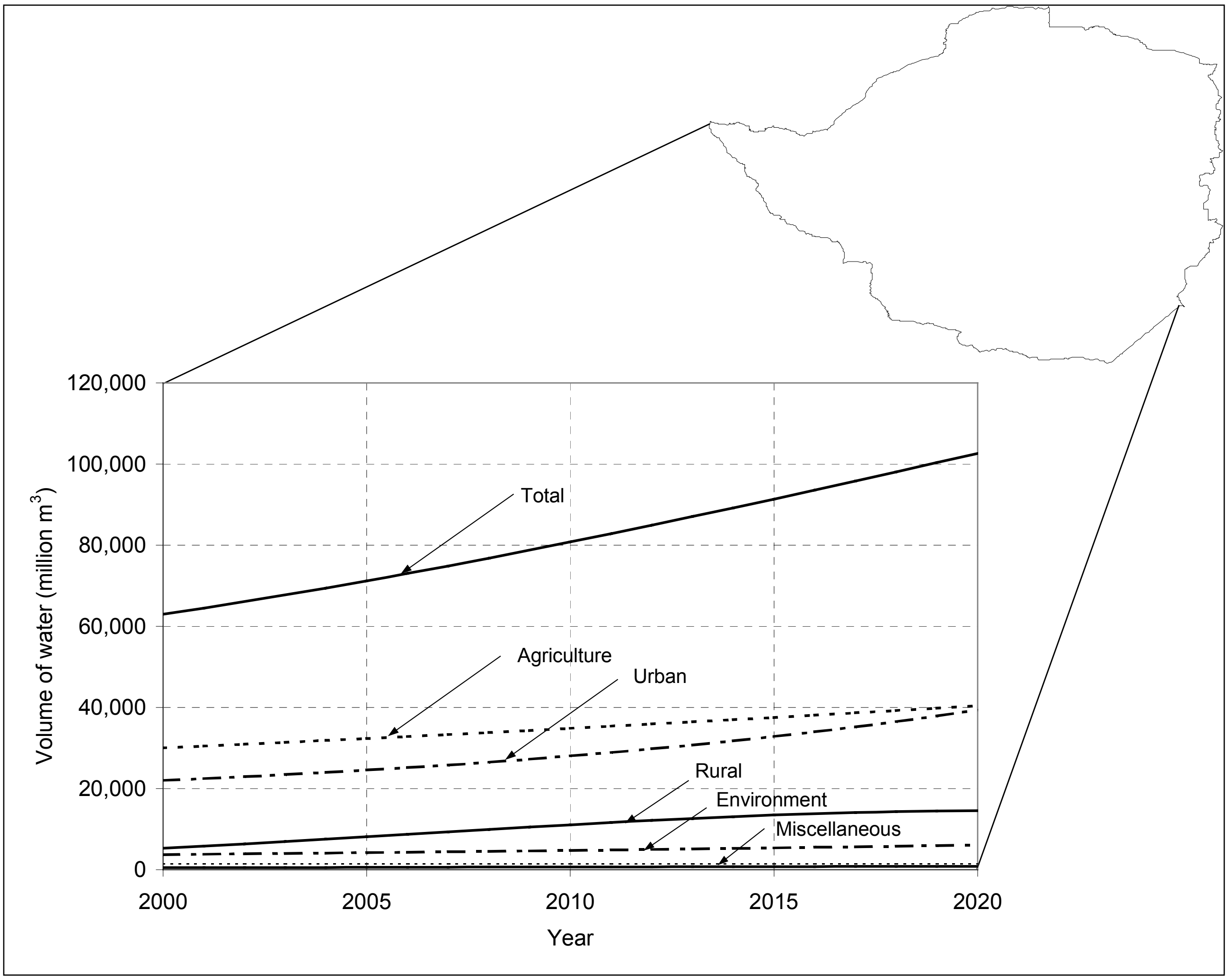


**Figure 5.7 Demand forecasts for a 20 year planning horizon for each of the key demand sectors for the whole country**

The example shown in Figure 5.8 illustrates the ability of the IWIM system to compare different the results of different demand forecasting methods for a specific catchment. In the example shown in Figure 5.7 the user has carried out demand forecasting using an analysis of trends, a multiple non-linear regression equation and a method based purely on population growth. The IWIM system allows the user to compare the results of each of these methods graphically over the user's chosen planning horizon, in this case 20 years.

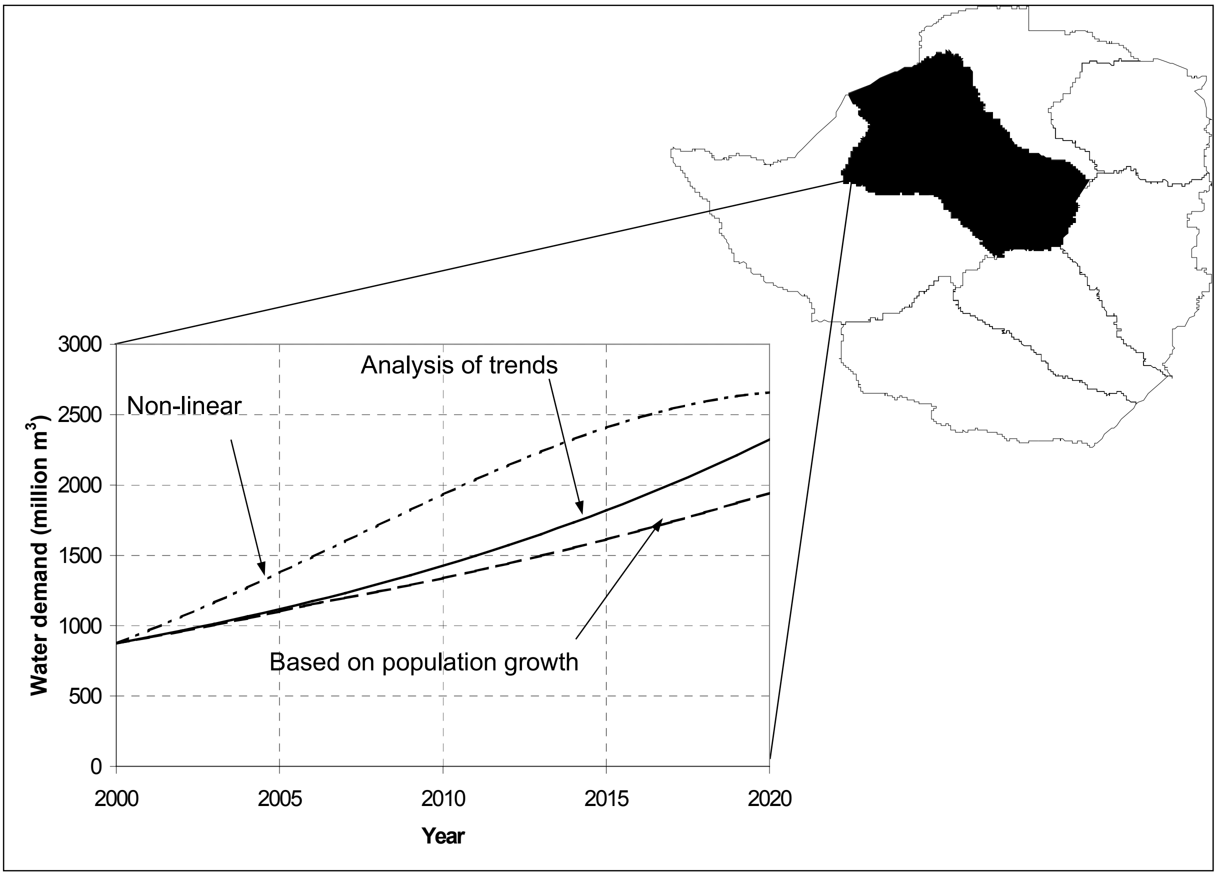


**Figure 5.8 Three demand forecasts using different methods for a specified catchment**

## 5.5 Water availability assessments

The IWIM system allows users to assess the water availability in terms of water stress. Water stress is defined as a country's estimated volume of water used per annum expressed as a percentage of the estimated available water resource. A water scarcity index is used as detailed below. Four levels of stress are identified by the IWIM system as follows:

- **Low water stress.** Areas that are estimated to use less than 10% of their available water resource and that in general do not experience pressures on their water resources.
- **Moderate water stress.** Where the use of water is estimated to be in the range 10% to 20% of the available resource and water is becoming a factor that is limiting development.
- **Medium to high water stress.** Here water use is in the range of 20% to 40%. In these areas careful management is needed to ensure that uses remain sustainable.
- **High water stress.** Use of more than 40% of the available resource indicates a position of scarcity and often the use of water at a rate faster than the natural replenishment.

The IWIM system also allows users to specify their own water stress criteria e.g. the IWIM system allows the user to query where water use outstrips supply. The example shown in Figure 5.9 below shows an example of a water stress query carried out by a user at sub-catchment level in Zimbabwe.

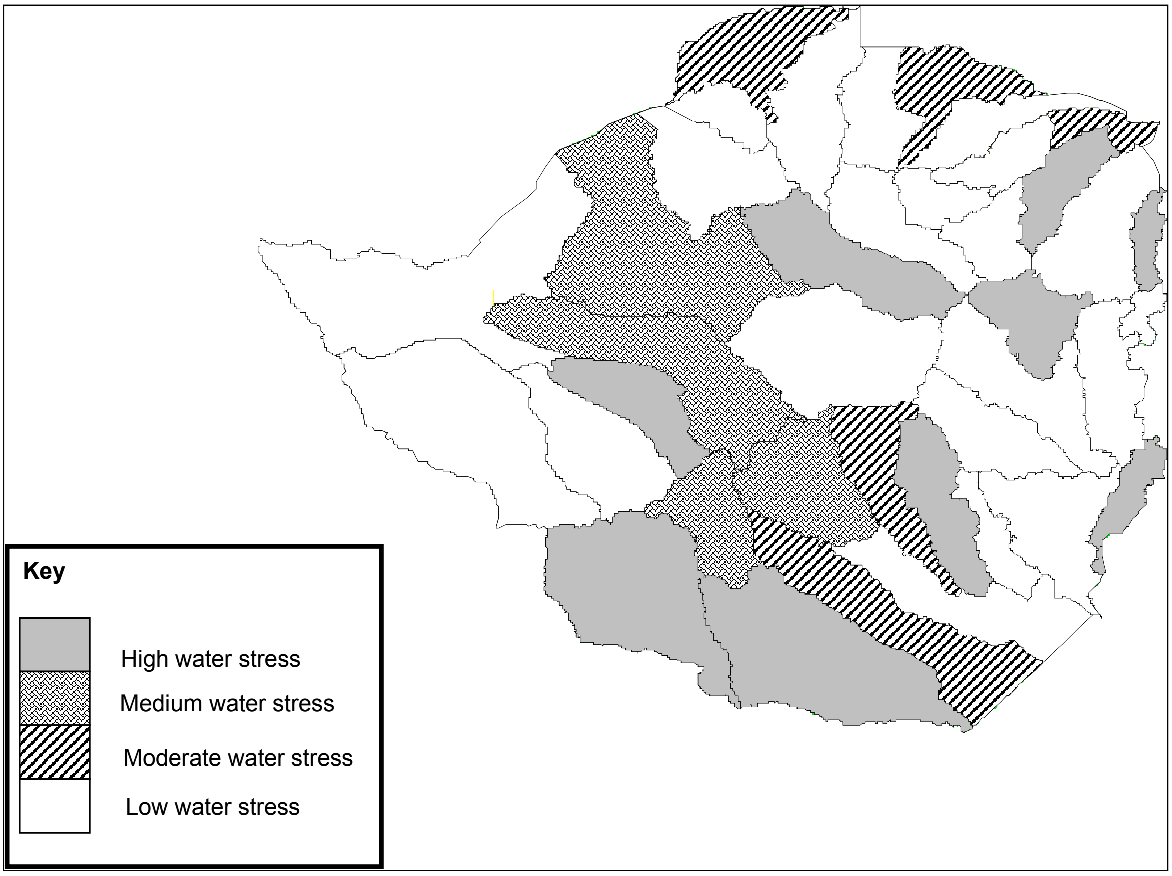


**Figure 5.9 Levels of water stress at a sub-catchment level**

The IWIM system also allows the user to compare water supply and demand information at a sub-catchment, catchment and national level. Figure 5.10 shows a comparison of supply and demand information carried out for the various sub-catchments that form the Mazowe catchment in Zimbabwe. Such an analysis also allows catchment managers to ascertain the unaccounted for water for each catchment. Where unaccounted for water is defined as water supplied from a public water supply that has not been account for as being distributed to domestic, commercial, industrial, agricultural users or other users. It includes unmetered water uses such as illegal connections, leakage (i.e. conveyance losses in the distribution system), and meter-errors.

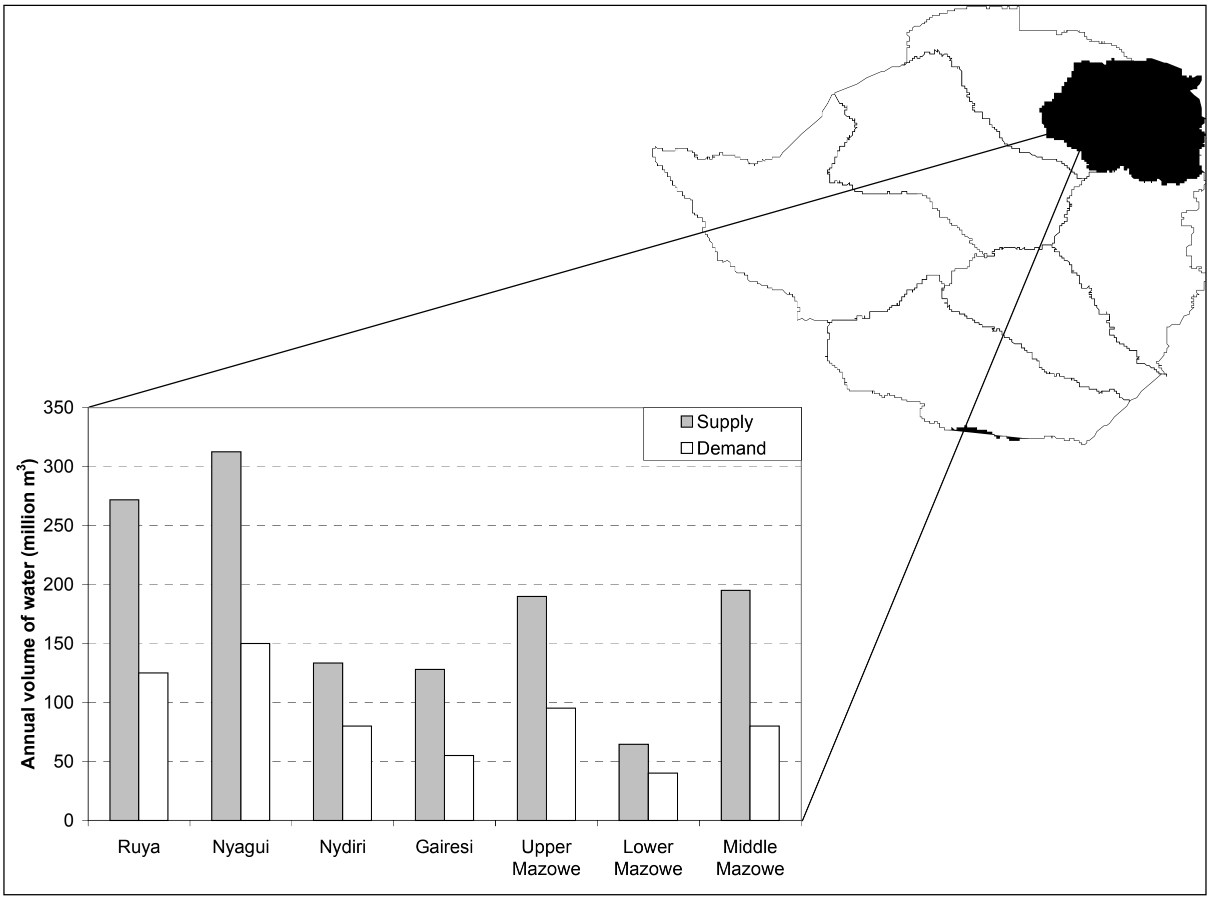


**Figure 5.10 Comparison of supply and demand information for the Mazowe sub-catchments**

## 5.6 Water supply information

The IWIM system acts as a database for water supply information. The IWIM system allows catchment managers to interrogate details concerning various water supply infrastructure including reservoirs, river intakes and boreholes. Information that is held by IWIM at a sub-catchment level is shown in Figure 5.11 below.

The information held by the IWIM system allows catchment managers to assess the following:

- Number and total storage capacity of reservoirs in a certain area;
- Date when a dam safety inspection is required;
- Date when the infrastructure was constructed;
- Yields of water supply sources.

The IWIM system allows the user to carry out a number of queries on the water supply information. For example the user may wish to know the number of dams higher than 15 m in a particular sub-catchment, together with their total live storage volume and safe yield. The IWIM system allows such queries to be undertaken. Such a query is shown in Figure 5.12. Other queries such as the number of boreholes deeper than 50 m and their total yield could also be carried out. Such a querying facility allows catchment managers to make comparison between the yields of boreholes deeper than 50 m and boreholes less than 50 m deep to establish which type of borehole provides ‘best value’ in terms of water supply per unit cost.

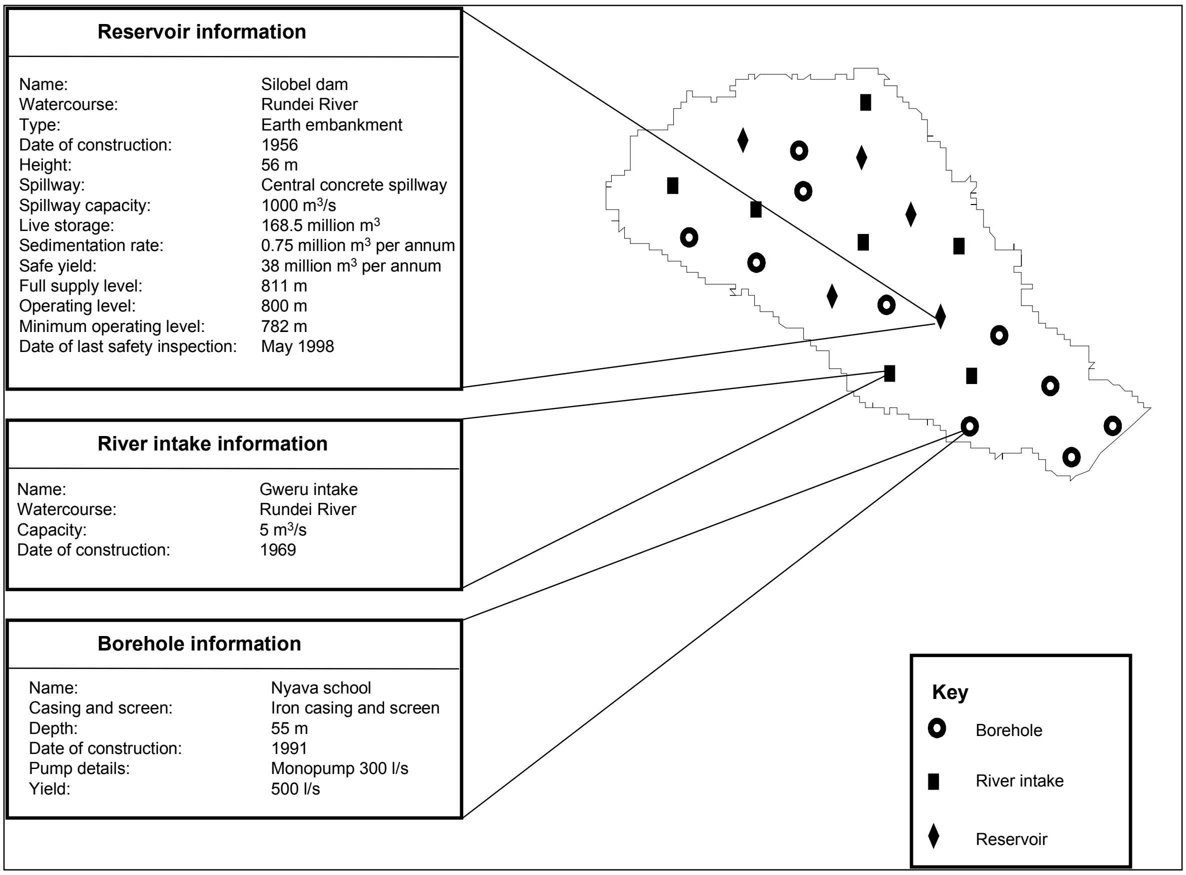


**Figure 5.11 Details of water supply infrastructure held by the IWIM system**

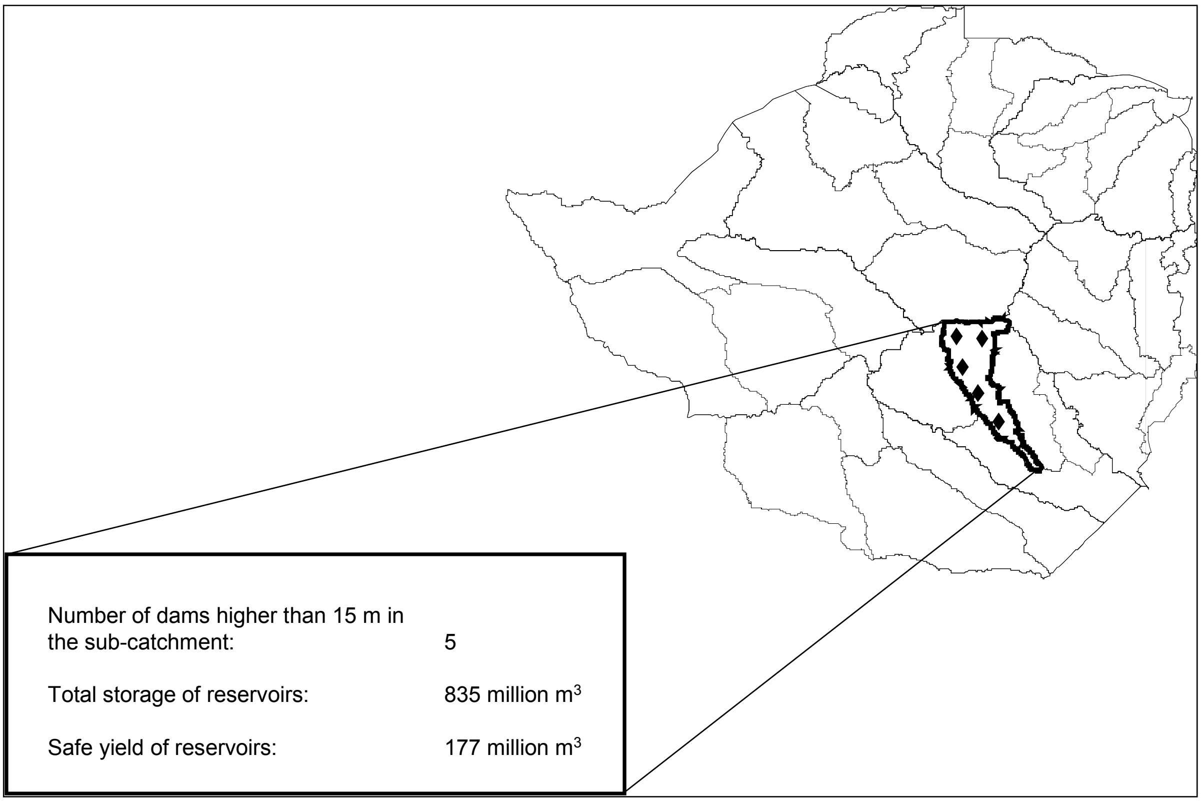


**Figure 5.12 Query to establish all dams higher than 15 m in a particular sub-catchment**

## 5.7 Water abstraction licences and wastewater discharge consents

The IWIM system acts as a database for the storage information for water abstraction licences and wastewater discharge consents to controlled waters. The selection of a water abstraction licence or wastewater discharge consent by the user displays various information concerning the licence or permit. The information held by the IWIM system is shown in Figure 5.13 below.

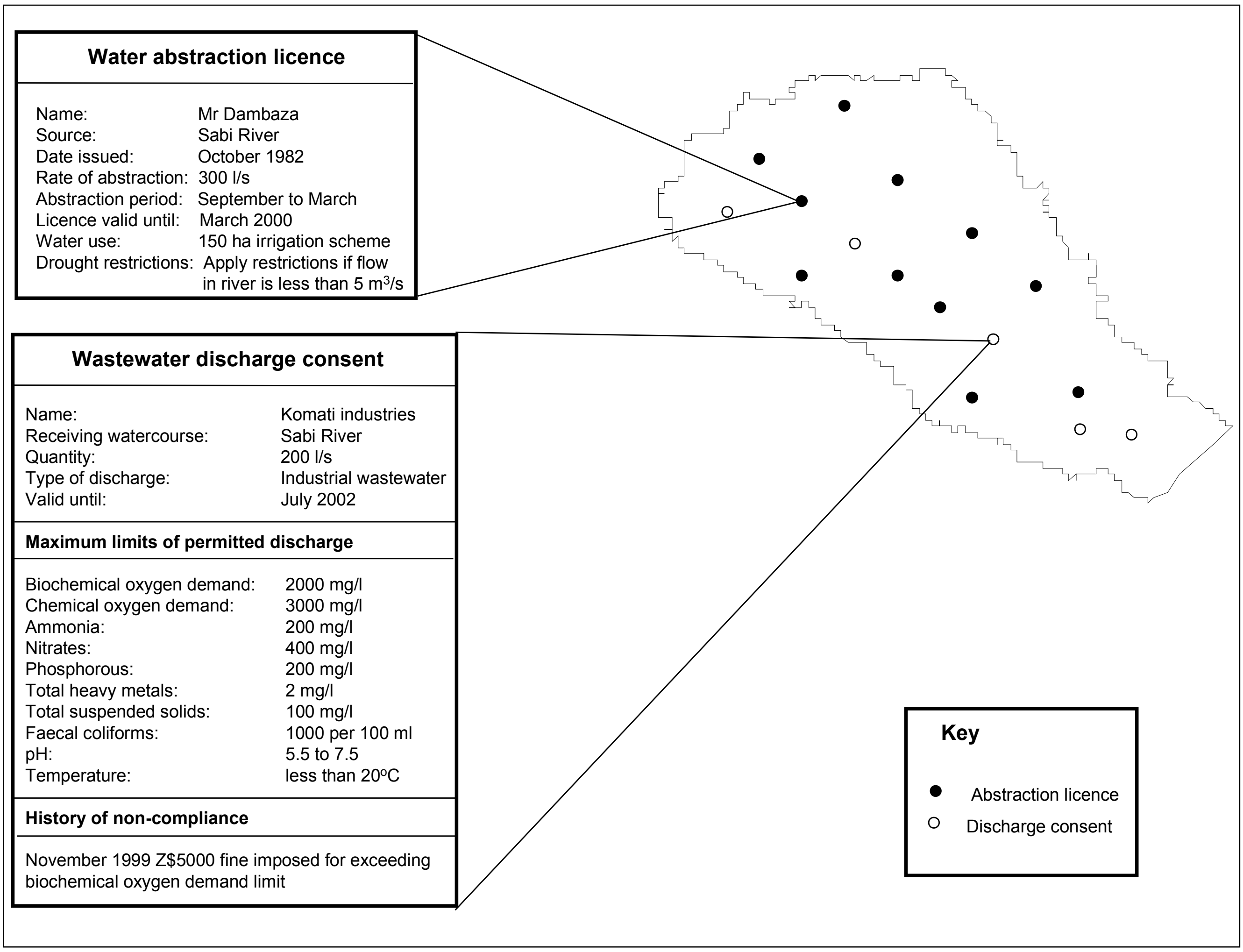


**Figure 5.13 Information on water abstraction licences and wastewater discharge consents held by the IWIM system**

The IWIM system would also allow catchment managers to carry out the following queries:

- Display all wastewater discharge consents with a history of non-compliance;
- Display all wastewater discharge consents located on the Lunde River;
- Display all holders of water abstraction licences who are allowed to abstracted more than 5000 l/s;
- Display all water abstraction licences that are used to supply industrial sites;
- Display all water abstraction licences issued between October 1991 and May 1997;
- Display all water abstraction licences located on the Zambezi River and give the total maximum quantity of water that can be abstracted by the licence holders.

The final query is displayed in Figure 5.14.

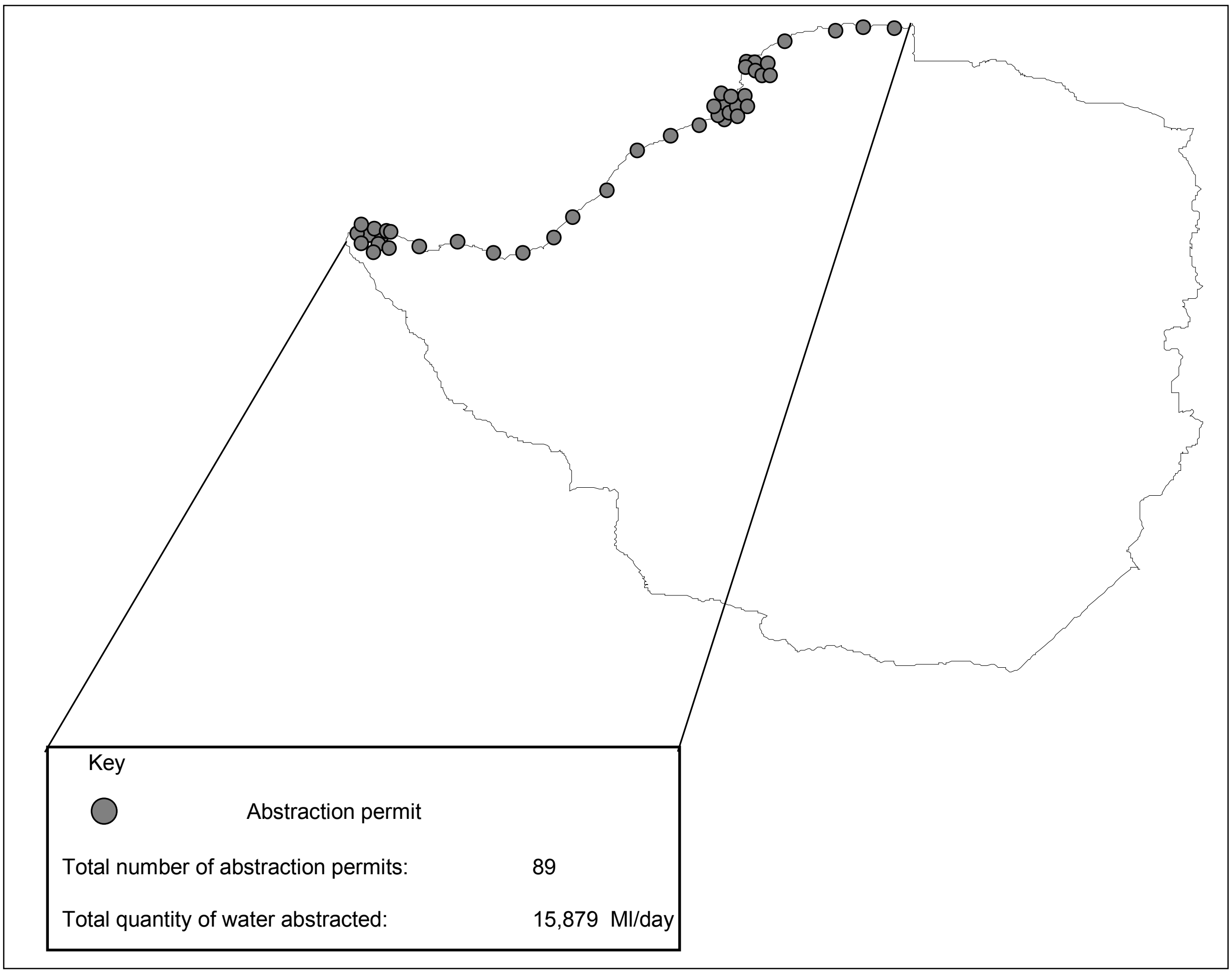


**Figure 5.14 Abstraction licences located on the Zambezi River and the total quantity that can be abstracted from these licences**

## 5.8 Comparison of water use and water demands with targets and standards

The IWIM system allows catchment planners to carry out comparisons between particular standards and targets. Standards and targets can be defined as follows:

### 5.8.1 Standards

As previously stated an important aspect of water management is to balance supply and demand. However, in addition it is important that that the water supplied meets a minimum water quality requirement, dependent on the demand. In most countries standards exist for water quality in terms of prescribed parameters that water has to achieve to meet.

Standards are also often defined in terms of water quantity. Minimum quantities of water with an associated reliability for different demand sectors may be defined by government organisations. The World Health Organisation established a minimum figure of 150 litres per day per household for water use in order to provide for adequate health and sanitation. The World Bank quotes a figure of 50 litres per person per day for water use. The IWIM system allows a comparison to be between actual use and forecast use and the minimum standards required to provide for adequate health and sanitation. Figure 5.15 illustrates how the IWIM system can be used to compare the actual water use in a particular sub-catchment against the water use to meet the World Bank water use requirement of 50 litres per person per day.

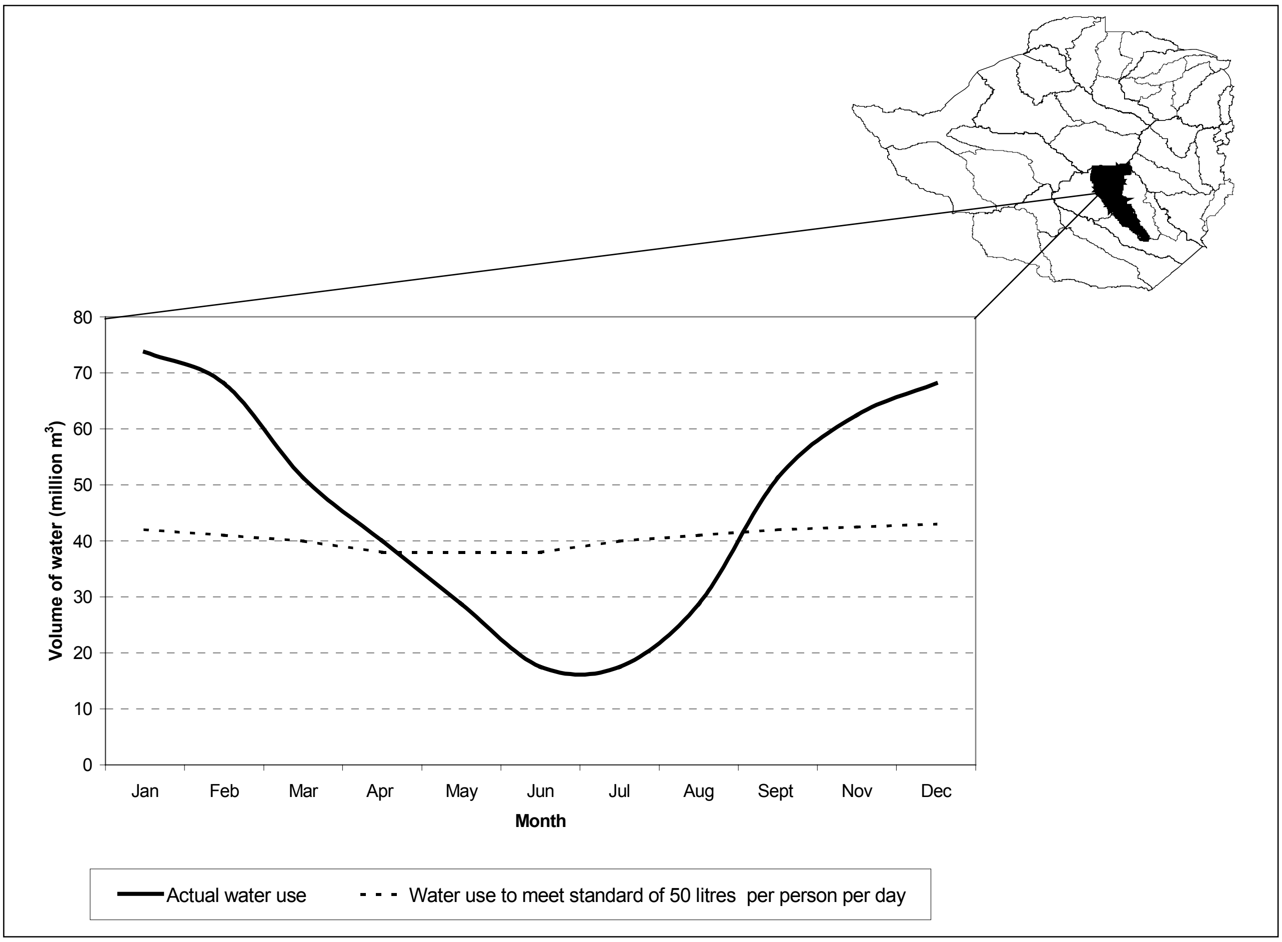


**Figure 5.15 Comparison between actual water use and water required to meet a standard of 50 l/c/day for a particular sub-catchment**

## 5.8.2 Targets

Many countries have development targets based on five or even ten yearly development plans. Development of targets for water use requirements to meet the planning targets proposed by central and local government organisations could be based on changes in the following sectors:

- Agricultural production. Increases in water use owing to multiple cropping and expansion of agricultural areas;
- Industrial production;
- Domestic water use. Demographic and socio-economic factors (i.e. a larger, more affluent population) will have a bearing on water use;
- Environmental requirements.

The IWIM system allows the user to compare demand forecasts against development and planning targets. Figure 5.16 shows how the IWIM system can be used to compare forecast supply against a forecast target demand required to meet a particular development requirement for a particular sub-catchment in Zimbabwe.

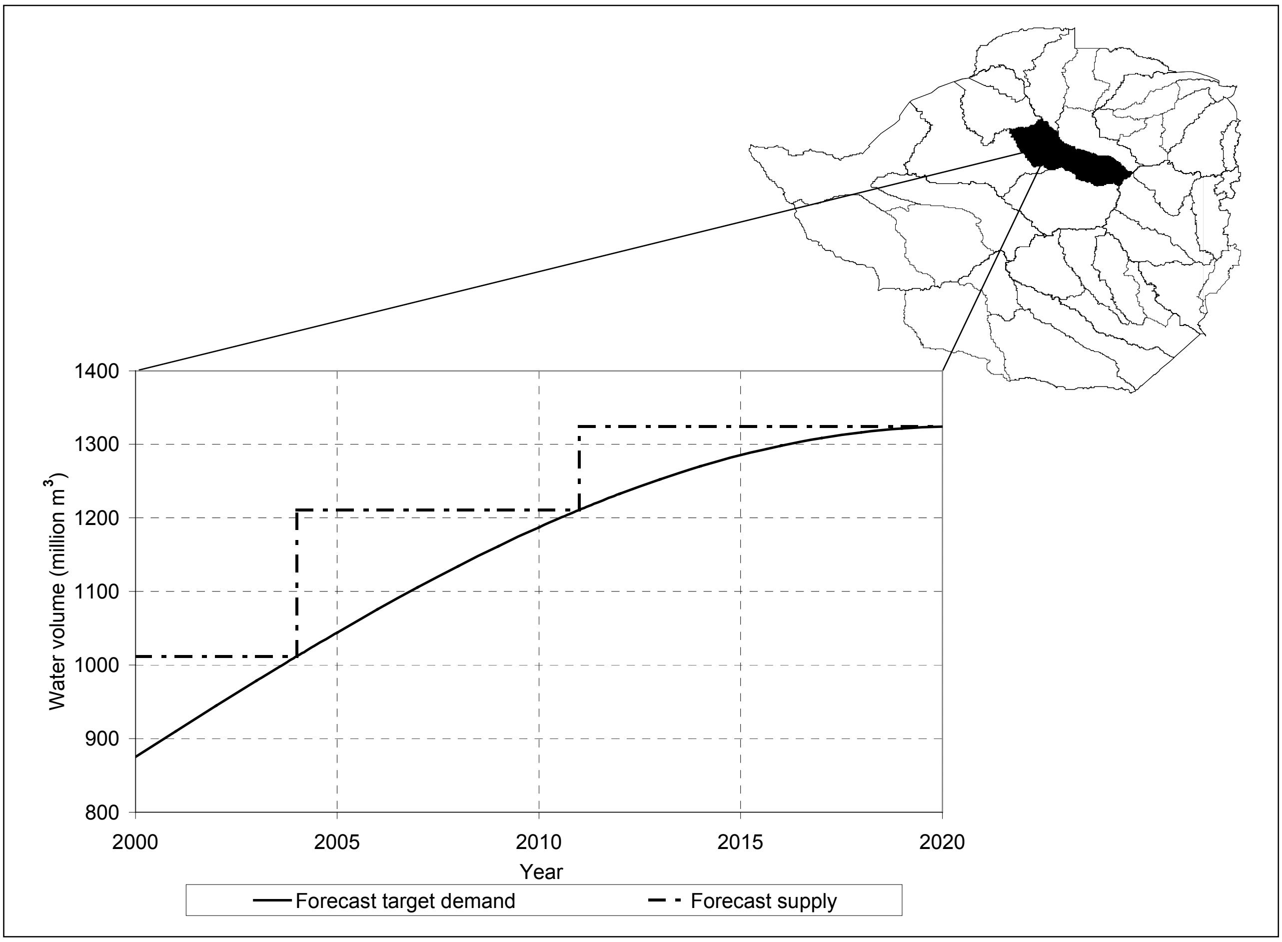


**Figure 5.16 Comparison of forecast supply against forecast target demand**

## 5.9 Contingency planning

An important facet of the IWIM system is the ability to carry out water contingency planning is ensuring that adequate alternative sources of water will be available should a prolonged drought occur or a source of water become contaminated. This function will allow planners to implement necessary measures to have alternative water sources available in the event of emergency water shortfalls. For example the IWIM system will allow planners to evaluate which water abstraction licences should have a drought restriction imposed on them and which areas are worst affected by water shortages. If a drought occurs in a particular catchment water resources managers may wish to place drought restriction orders on all abstraction licences that supply water for uses with a low priority. The IWIM system allows users to interrogate the catchment in which the drought has occurred to establish all the abstraction licences used to supply tourist sites. This example is shown in Figure 5.17.

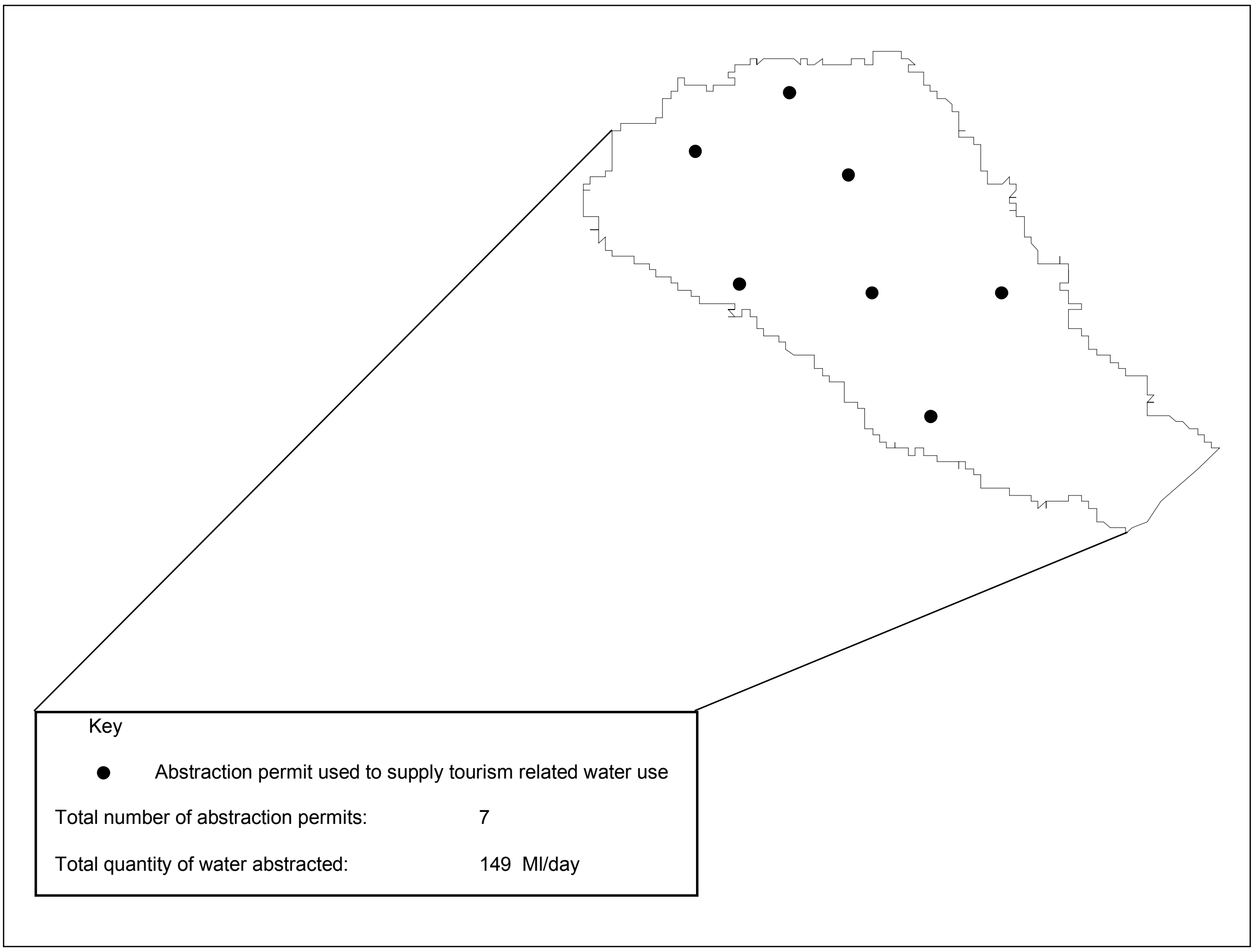


**Figure 5.17 Establishment of non-essential water uses for a particular sub-catchment**

## 6. HARDWARE AND SOFTWARE COST ESTIMATES FOR THE IWIM SYSTEM

This section details the hardware and software that are required to support the IWIM system.

### 6.1 Hardware

The hardware requirements and outline costs for the IWIM system are given in Table 6.1.

**Table 6.1 Hardware requirements and costs**

| Description | Quantity | Unit cost (US$) | Total cost (US$) |
|---|---|---|---|
| | | | |
| Pentium IV 600 MHz processor 256 MB RAM | 10 | 2,500 | 25,000 |
| A0 digitiser | 1 | 5,000 | 5,000 |
| A0 plotter | 1 | 7,500 | 7,500 |
| Other miscellaneous equipment | - | 5,000 | 5,000 |
| **Total** | | | **42,500** |

### 6.2 Software

The software requirements and costs for the IWIM system are outlined in Table 6.2.

**Table 6.2 IWIM software requirements and costs**

| Description | Quantity | Unit cost (US$) | Total cost (US$) |
|---|---|---|---|
| GIS software | | | |
| ArcView | 8 | 3,000 | 24,000 |
| Spatial analyst | 1 | 4,500 | 4,500 |
| 3D analyst | 1 | 4,500 | 4,500 |
| Microsoft Office | 10 | 600 | 6,000 |
| Other miscellaneous software | - | - | 5,000 |
| **Total** | | | **44,000** |

### 6.3 Collation of data and recurrent costs

Although much of the data required by the IWIM system is available some of it may not be able to be used directly owing to its incompleteness and/or it is in an incompatible format e.g. hardcopy that may have to be digitised. The collation and upgrading of data will be an annual task. The cost of the initial data collation and upgrading exercise has been estimated to be between US$100,000 and US$150,000. Other recurrent costs are given in Table 6.3.

**Table 6.3 IWIM recurrent costs**

| Description | Total cost (US$) |
|---|---|
| Operation and maintenance of the hardware and software costs | 5,000 to 10,000 |
| Recurrent data collation and upgrading costs | 20,000 to 25,000 |
| **Total** | **25,000 to 35,000** |

# 7. CONCLUSIONS

This report and accompanying CD-ROM are designed to demonstrate the potential for an Integrated Water Information Management (IWIM) system to improve the way in which water is managed at a catchment and sub-catchment level in southern Africa. This research has developed a *concept*. The necessary background research and development has been accomplished under the current project to act as a foundation on which to build.

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