N: ZIMBABWE

N.1 INTRODUCTION

Gordon Maclear of SRK Consulting conducted the Zimbabwe country visit from the 3 to the 7 March 2002, in order to complete the visit before the national elections commencing on 9th March.

The main institutions and personnel visited are detailed below and summarised in Table 1:

- University of Zimbabwe: Department of Geology, Harare. Dr **Richard Owen** – Senior Researcher who has extensive experience in the geology and hydrogeology of Zimbabwe;

- SRK Consulting: Harare. Dr **Tony Martin** – Principal Geologist with extensive experience in the geology of Zimbabwe including map author and co-author of published geological sheets; and Mr **Alexander Mikhailov** – Senior Geologist with GIS and remote-sensing expertise.

- Ministry of Local Government, Rural and Urban Development: National Co-ordination Unit (NCU), Harare. Mr **George Nhunhama** – National Co-ordinator responsible for rural water (groundwater) supply. Board member of Zimbabwe Institute of Water and Sanitation Development and former Chief Hydrogeologist of the Groundwater Department in the Zimbabwe National Water Authority (ZINWA);

- Jeremy Prince & Associates, Harare. Mr **Tim Broderick** – Consulting Geologist and Director extensively involved in borehole siting for rural supply as well as hydrogeological investigations in Zimbabwe;

- Ministry of Mines and Energy: Department of Geological Survey, Harare. Mr **George Kwenda** – Senior Geologist in the Data Management Section with IT, GIS and cartography experience;

- ZINWA: Groundwater Department, Harare. Mr **Sam Sunguro** – Groundwater Manager and Mr **Japson Siwadi** – Hydrogeologist and database manager; responsible for custodianship of Zimbabwe groundwater resources;

- Groundwater Development Consultants, Harare. Mr **Joseph Njanike** – Director with experience in borehole siting, drilling supervision and test pumping as well as social aspects of water supply who previously worked with InterConsult;

- Ministry of Rural Resources and Water Development: Department of Water Development, Harare. Mr **Gilbert Mawere** – Chief Hydrologist responsible for water resources development, management and water policy formulation in Zimbabwe, and member of the SADC Water Resources Technical Committee.

Table 1: Contact Details of Persons Interviewed

Name	Title	Designation	Institution	Address	Telephone	Fax	E-mail
Richard Owen	Dr	Senior researcher	University of Zimbabwe – Department of Geology	PO Box MP 167, Mount Pleasant, HARARE, Zimbabwe	+263 4 303211 x1616	+263 4 333407	rowen@science.uz.ac.zw
Tony Martin	Dr	Principal Geologist	SRK Consulting	PO Box GD 773, Greendale, HARARE, Zimbabwe	+263 4 495689 +263 4 496182	+263 4 490144	amartin@srk.co.zw
Alexander Mikhailov	Mr	Senior Geologist	SRK Consulting	PO Box GD 773, Greendale, HARARE, Zimbabwe	+263 4 495689 +263 4 496182	+263 4 490144	amikhailov@srk.co.zw
George Nhunhama	Mr	National co-ordinator	National Co-ordination Unit (NCU) - Rural Water Supply and Sanitation Programme	Private Bag 7706, Causeway, HARARE, Zimbabwe	+263 4 702910 +263 11 217499	+263 4 791490	nhunhamag@iwsd.co.zw
Tim Broderick	Mr	Consulting Geologist and Director	Jeremy Prince & Associates	PO Box HG 36, Highlands, HARARE, Zimbabwe	+263 4 747382	+263 4 747382	jpaa@mweb.co.zw
George Kwenda	Mr	Senior Geologist	Ministry of Mines and Energy, Geological Survey Department	PO Box CY 210, Causeway, HARARE, Zimbabwe	+263 4 726342 /3/4	+263 4 739601	zgs@samara.co.zw kwendag@yahoo.com
Sam Sunguro	Mr	Groundwater Manager	Zimbabwe National Water Authority – Groundwater Department	PO Box 726, HARARE, Zimbabwe	+263 4 738219 +263 4 708517 +263 11 801269	-	sunguro@mweb.co.zw
Japson Siwadi	Mr	Hydrogeologist	Zimbabwe National Water Authority – Groundwater Department	PO Box 726, HARARE, Zimbabwe	+263 4 708517 +263 91 372577	-	japsiwadi@hotmail.com
Joseph Njanike	Mr	Senior	Groundwater	PO Box 1070,	+263 4 746958	+263 4 727921	gwdc@africaonline.co.

Name	Title	Designation	Institution	Address	Telephone	Fax	E-mail
		Hydrogeologist and Director	Development Consultants	HARARE, Zimbabwe	+263 4 746956	+263 4 795284	zw
Gilbert Mawere	Mr	Chief Hydrologist	Ministry of Rural Resources and Water Development, Department of Water Development	Private Bag CY 726, Causeway, HARARE, Zimbabwe	+263 4 708102 +263 4 707861	+263 4 722752	-

N.2 BACKGROUND

N.2.1 Physiography and Climate

Zimbabwe is centrally located within southern Africa, primarily on the Central African Plateau. The physiography ranges from low-lying bushveld along the Limpopo Valley and generally flat areas of the central plateau to highlands in the eastern Chimanimani area.

Similar to other southern African countries, rainfall occurs in the summer months, primarily between November to April. Annual rainfall is generally consistent (between 600 and 1,000 mm) over much of the country, apart from the eastern highlands where it increases considerably (more than 1,200 mm).

N.2.2 Water Resources

Two major rivers systems are present along the borders of Zimbabwe, the Zambezi River, which forms the international border to the west and north, and the Limpopo River basin present to the south. Although major rivers are present within the country (i.e. Zambezi) there is only one major body of water, the man-made impoundment of Lake Kariba.

The Zambezi is developed extensively, primarily through the major hydro-electric dam forming Lake Kariba. Smaller rivers are also locally developed by small dams and used for water supply and irrigation.

N.2.3 Overall Institutional Framework Of Water Sector

The Zimbabwe National Water Authority (ZINWA) authority originated in 1994 as a parastatal, replacing the duties and functions of the Regional Water Authority, the Department of Water Development (DWD) and the Water River Boards, as well as other government sectors originally involved in water. The primary aspect of this re-organisation process was the de-centralisation of water management. Under the ZINWA structure the country is divided into seven catchment councils based on the major river systems. These councils carry out water resources management (both surface and groundwater).

In the past there were two primary institutions active in the development of groundwater supplies in Zimbabwe: the Department of Water Development (DWD) and the District Development Fund (DDF). The groundwater development function has now also been taken over by ZINWA.

The country has been divided into catchments and sub-catchments based on surface water basins. These form the basic unit of administration in ZINWA with Catchment Councils and Sub-Catchment Councils in charge of local water use management. The councils will be in charge of permitting of water (ground and surface) abstraction. Each Catchment Council will have a hydrogeologist to assist in decisions on granting permits.

At the national level, the main emphasis will be on resource management and planning in the water sector. Additionally, a national data archive is specified to maintain all groundwater data in the country.

NGOs are active in Zimbabwe primarily in rural water supply schemes.

N.2.4 Role of Groundwater in Water Sector

The majority of the population (70%) lives in rural areas. Agriculture, mining and tourism are main components of the economy.

Groundwater is the major source of potable supply for rural areas and many new growth areas (townships). The major cities (Bulawayo and Harare) are supplied by surface water, although a backup groundwater supply has been developed for Bulawayo due to the unreliability of the surface source during severe drought. Irrigation is important in agriculture in many areas, primarily developed on a farm scale basis with a local water source (borehole or river/stream). The majority of irrigation in the country depends on surface sources. However, in some areas irrigation schemes are present such as the Save River area in the southeast where water from alluvial aquifers developed by the Regional Water Authority is sold to individual farmers in the area.

The bulk of groundwater usage is by the agricultural sector, followed by rural water supply and to a small degree by the mining sector.

N.2.5 Groundwater Development

The formation of ZINWA will improve co-ordination in the groundwater development sector, previously carried out by DWD, DDF, NGOs and various consultants. However, both the present status and future potential (as it will not be included in ZINWA) of co-ordination with DDF appears relatively poor. DDF generally operates independently of ministry water development activities.

Groundwater development projects were carried out in the past by DWD, DDF and various consultants (under donor funded programmes), and to a more limited degree, NGOs. Both DWD and DDF responded to requests for water supply development by communities with DDF being the leading agent.

The groundwater development target is communal and resettled people, although some private work is also carried out. Boreholes are generally fitted with hand-pumps with powered pumping arrangements only occasionally used. Field operations with respect to groundwater development continue to be severely limited by lack of operating funds. As a result, private consultants are generally hired for large projects with funds derived from foreign donor support, eg UNICEF, Danish Aid, GTZ, DFID, NORAD and SIDA. Such projects often involve large numbers of boreholes.

N.3 GEOLOGICAL AND HYDROGEOLOGICAL FRAMEWORK

N.3.1 Geology

The majority of the country is underlain by Archaean igneous and metamorphic bedrock, primarily granites and gneisses. Some of Africa's oldest known rocks are present as greenstone belts within the basement complex. Various Proterozoic sedimentary units of the Umkondo, Lomagundi, Deweras and Piriwiri Groups, include limestone, shale, quartzite and phyllite lithologies with subordinate basalt and volcanic units. In the late Precambrian the Sijarira and Tengwe River Groups include conglomerates, sandstones, shales and carbonates as well as granitic intrusions. After the Pre-Cambrian, there is a hiatus until deposition of the Permo-Triassic Karoo Group. This is represented by Dwyka, Ecca, and Stormberg Groups which include tillites (Dwyka), sandstones, shales and mudstones (Ecca), grits, sandstones and basalt (Stormberg). A Cretaceous volcanic sequence (Chiswiti Volcanics) which also includes some sedimentary units is present in the north-central part of the country. The predominately unconsolidated sands and clays of the Kalahari Beds form often thick cover over much of the southwest. Additionally, several small but significant areas of alluvium (e.g. Save River valley) are also present along river valleys.

Units of the basement complex primarily underlie the central and southern portions of the country. The majority of the Karoo is present in the west, with a small basin preserving Karoo formations in the southwest. The bulk of the Precambrian carbonate clastic units are present in the northwest.

Dolerite and basalt dykes and other intrusions are common in most areas of the country, including the Great Dyke. The Great Dyke is a major feature of the country extending approximately north-south for 500 kilometres and with a width of up to 5 kilometres.

N.3.2 Hydrogeology

An extensive review of the hydrogeology of Zimbabwe is contained in the National Water Master Plan for Rural Water Supply and Sanitation (1985). In this report, the aquifers of the country are divided into 10 major hydrogeologic units, with one of the units (the Karoo) further sub-divided into 5 sub-units. The 10 major units are as follows:

Unit 1: Archaean granitic and Gneissic Rock
Unit 2: Greenstone Belts
Unit 3: Argillites
Unit 4: Calcareous Units
Unit 5: The Umkondo Group
Unit 6: The Karoo
Unit 7: Cretaceous Formations
Unit 8: Kalahari Beds
Unit 9: Alluvial Deposits
Unit 10: Mashonaland Dolerites

The Archaean granitic and gneissic rocks unit covers approximately 60% of the country and contains groundwater in weathered and/or fractured zones. Yields are generally low (10-50 m^3/d), but where weathering is well-developed yields of 50 to 100 m^3/d are possible. Water quality is generally good.

Greenstone belts include the Bulawayan and Shamvaian groups. The Bulawayan Group is characterised by laterally extensive aquifers with yields of 100-250 m^3/d while the Shamvaian Group has less potential with limited aquifer development and yields of the order of 10-25 m^3/d. Groundwater quality in both groups is good.

The argillites unit includes the Piriwiri, Lomagundi, Tengwe River and Sivarira Groups. Aquifers are developed in fractured, jointed and schistose zones and to a lesser extent weathered zones. Yields are in the range of 10-50 m^3/d and groundwater quality is good.

The calcareous unit includes limestone and dolomite members of the Lomagundi and Tengwe River Groups. Aquifers are present in karst features and weathered zones in shaley horizons. In general the Lomagundi Group has better potential with high yields of approximately 500-2,000 m^3/d possible. Perennial springs are also occasionally present. Groundwater quality is good.

The Umkondo Group has poorly defined characteristics with groundwater present in fractured zones, contact zones and weathered zones. Springs are common. Borehole yields are variable and in the range of 20-200 m^3/d. The highest yields are found in weathered dolerite sills and plateau areas underlain by quartzite. Water quality is acceptable.

The Karoo unit is sub-divided into 5 sub-units based on the stratigraphy:

- Unit 6a – the Batoka Basalt: groundwater occurs both weathered and/or fractured zones with yields of 20-100 m^3/d possible. Water quality is generally good;
- Unit 6b – the Forest Sandstone: with groundwater occurring under confined conditions often at considerable depth. Aquifers are laterally extensive with the sandstone consistently water bearing. Yields of 50-300 m^3/d are possible and water quality is good;
- Unit 6c – the Escarpment Grit: present only in the Hwange and Save/Limpopo basin where groundwater may occur under unconfined conditions. Yields of approximately 100-300 m^3/d are possible. Water quality is good;
- Unit 6d – the Madumabiza Mudstone: includes thin sandy intercalations where groundwater occurrence is controlled by weathering along drainage lines. Yields are low (10-25 m^3/d). Water quality is generally good although locally can have high TDS and sulphate;
- Unit 6e – the Upper and Lower Wankie Sandstone: where aquifers in these formations are generally encountered at depth under confined and in places artesian conditions. Yields are in the range of 100-300 m^3/d and water quality is generally good, although high fluoride values can be present near outcrop areas.

The Cretaceous formations of Unit 7 consist of mudstones, siltstones and sandstones and are present in the eastern Zambezi Valley. Limited data are available but average yields are of the order of 10-50 m^3/d. Water quality is variable and can have high TDS and pH values.

The generally unconsolidated formations of the Kalahari Beds form Unit 8. They are saturated over their outcrop area and aquifers are often unconfined. Exploitation has been limited because of drilling and borehole construction difficulties. Water quality is generally good and the expected groundwater potential is high.

Unit 9 consists of alluvial deposits which are locally well developed in limited portions of the country. Lithologies are highly variable, but where clean sands are present and units are thick, such as the Save valley, groundwater potential is high. Yields in these areas are in the range of 100-5,000 m^3/d. Water quality is good although the aquifers are vulnerable to pollution from surface sources.

The Mashonaland Dolerites, which are closely associated with the granite/gneisses of Unit 1, form Unit 10. Groundwater occurs in weathered and fractured contact zones with yields of 50-250 m^3/d common. Water quality is good.

N.3.3 Natural Groundwater Quality

Groundwater quality overall in Zimbabwe is good, with minor areas of quality unacceptable for human consumption related primarily to salinity and fluoride. In most of the areas underlain by the basement complex, water quality is good due to the shallow nature of aquifers with active recharge, although they are more vulnerable to pollution. As yet no large-scale problems with contamination of aquifers has been identified.

N.4 DATA ACQUISITION

N.4.1 Institutional Framework for Data Collection

Under the Zimbabwe Water Act of 1998, it is mandatory for all groundwater development / borehole drilling information to be submitted to ZINWA. However, this is difficult to police within the existing structure due to limited manpower. Boreholes are given temporary numbers in the field, which are then converted to official numbers for the database. The numbering system consists of first a code for the province, followed by the first four letters of the district then a four digit consecutive number. One problem is that in the field only the temporary number (non-unique) may be permanently marked on the borehole. Some drilling contractors (such as Whitbread and Jack) also maintain extensive records on their drilling operations by borehole (depth, water strike, rest water level, yield test results, casing design).

Although in the past the government (through DWD and DDF) was the primary groundwater developer for water supply, private contractors are now completing a significant proportion of water supply boreholes under the supervision of consultants on large projects.

N.5 GROUNDWATER INFORMATION SYSTEM

The ZINWA Groundwater Department is the lead institution, with respect to data collection and management and has a national groundwater information system, *viz* the National Groundwater Database that has been operating since 1996 under a Windows platform. Within the Department the following hardware is available: 1 server and ~15 PCs, running the common applications of MS Office under MS Windows operating system. The Zimbabwe National Groundwater Database is a public domain database operated and maintained by hydrogeologists within ZINWA.

N.5.1 Hardware and Software Set-up

The Zimbabwe National Groundwater Database was developed and set up using the United Nations Groundwater for Windows (GWW) software Version 1.1, 1995. The software is somewhat outdated and was designed for running under Windows 1995. Data can be exported from and imported to the Database by means of ASCII files, although the import files require detailed setting up (correct column heading nomenclature and layout) to ensure successful importation.

Version 1.1 of GWW is not particularly user-friendly and has a number of bugs resulting in the work session 'hanging' on occasion, with resultant loss of data if a routine saving procedure is not practised. As a result of this it is planned to upgrade the Zimbabwe National Groundwater Database into a more user-friendly system.

The following detailed in-house manuals regarding the use of GWW have been compiled:

- Guidelines for filling in the expanded master data – entry form 1 and 2 in the GWW Database, April 1997 (based on the Guidelines for filling in the Borehole Completion Report);
- Editing the GWW Database design, December 1996;
- How to enter the Expanded Master Data in a GWW Database, August 1996.

The procedures are carefully followed resulting in a high level of QA / QC for the data entry activities.

The graphical presentation software used is Surfer, CAD and GIS ArcView and MapInfo. Proprietary software packages, viz Aquitest, Rinvert, Resix P, RockWare and RockWorks, are utilised for data interpretation and presentation. In addition to the above graphical presentation software, GWW produces numerous graphic outputs displaying hydrogeological data such as borehole lithological logs, test-pumping curves and fits, hydrochemistry (Piper, Schoeller, Stiff), water level contours etc. These graphic outputs can, however, only be produced from within the GWW programme with no interfacing capability from GWW to other Windows applications such as cut and paste.

The hardware and software set-up of the authorities / institutions that are capable of contributing to the SADC project are summarised in Tables 2 and 3.

Table 2: Institutional Hardware Set-up (number of units indicated)

Institution	Server	Work-station	PC	Other
ZINWA – Groundwater Department	1	-	15	-
University of Zimbabwe – Department of Geology	?	1	3	-
Department of Geological Survey	1	5	?	Scanners A0 + A3
SRK Consulting	1	1	4	-
Groundwater Development Consultants	-	-	1	-

Table 3: Institutional Software Set-up (availability marked with an X)

Institution	Windows	MAC	MS Office	WP Office	GIS	In-house	Other
ZINWA – Groundwater Department	X		X		ArcView MapInfo		GWW Surfer AquiTest Rinvert Resix P RockWare RockWorks
University of Zimbabwe – Department of Geology	X		X		ArcView ArcInfo		
Department of Geological Survey	X		X		ArcView		
SRK Consulting	X		X		MapInfo		
Groundwater Development Consultants	X		X		ArcView		AquiTest Resix

The hardware and software of all the above institutions are available for the SADC mapping project.

N.5.2 Data Saved (Structure of Information System and Graphical Interface)

Data are collected by ZINWA on standard siting report and borehole completion forms, ie information is captured in paper format. These reports and forms are kept in files in the main office. One of the main functions of the recently formed sub-catchment councils is data collection thereby assisting ZINWA to collect siting, drilling and test pumping data for its projects. In the past the DDF was required to provide data to DWD for inclusion in the database, but this rarely occurred.

Under the 1998 Water Act all present and future groundwater abstraction permit holders are required to undertake monitoring as part of the permit conditions. In this way the data acquisition protocol will be formalised. In addition it is now mandatory to equip boreholes with flow meters and water level piezometers for large-scale abstraction boreholes, and for routine monitoring of water quality.

Although previously there was limited use of standards or guidelines in groundwater development and data acquisition in the country, extensive new regulations and guidelines have been formulated as part of the creation of ZINWA. Within the Groundwater Department of ZINWA, quality assurance and quality control (QA / QC) measures are in place at all stages of the data acquisition, management and data supply process, varying from full protocols (eg GWW data input) to ad-hoc / random checks (monitoring).

The Zimbabwe National Groundwater Database contains hydrogeological data (~15,000 records) from 1960, although there is a data entry backlog of >5 years in some instances, particularly for lithology and hydrochemistry information. Data are "cleaned" prior to entry to attempt to eliminate the possibility of duplication as well as correct geographic co-ordinates where possible. The database includes test pumping and hydrochemical data where available. At present there are no graphical interface facilities for linking the database, e.g. with digital photographs.

Under the 1998 Water Act that came into force in January 2000, it is required to register water use requiring a groundwater abstraction permit. From this permit all relevant detail regarding an existing borehole / well will be captured onto the National Groundwater Database. In addition, a formal application to ZINWA is required for drilling of any new boreholes / wells that must be accompanied by a hydrogeological report. In this manner it is hoped that the change in the change in the Water Law (Water Act of 1976 to Water Act of 1998) will ensure that information from all new boreholes drilled in Zimbabwe will be entered into the database.

N.5.3 Quality of Data

The quality of the hydrogeological data collected is generally good, with data collected and managed by suitably trained and qualified staff within the government, parastatal and consulting institutions. Positional accuracies of the data / monitoring points are generally in the range 10 – 100 m and field verification is routinely carried out such as field verification of borehole positions using a GPS.

Hydraulic data such as aquifer permeability, sustainable yield, however, are mostly captured on a once-off basis at the time of drilling and testing a borehole. Groundwater quality data are routinely captured in certain areas of concern with respect to population health (cholera etc) by ZINWA's Water Quality section, following a formalised operational guideline.

In areas of high groundwater use such as the Nyamandlovu Aquifer, parameters such as groundwater abstraction and water quality are routinely captured following the equipping of boreholes with flow meters and take-off points for sampling. In some instances, however, the backlog of groundwater data to be input into the database results in delays before the quality of the data can be checked and verified.

N.5.4 Available Resources for Maintenance

Within the ZINWA Groundwater Department there are only a limited number of staff available for monitoring (12), data management (7) and map production (4). This lack of staff is considered to be the most important deficiency in effective operation of the Department and hampers such activities as database maintenance and data input. In addition, the annual budget is limited: monitoring - Zim$2M, and Zim$2M for both data management and map production. Due to recent political instability in the country, international donor funding that was a regular contributor to national projects is no longer available or only available to a limited degree.

No budget is available to the Department for ongoing training and water awareness programmes for the general public. Whilst approximately Zim$25M will be budgeted to upgrade the hardware and software system within the Department over the next two years, it is uncertain whether this budget proposal will be approved. No funds are available within the Groundwater Department of ZINWA for the SADC map and atlas project.

N.6 GROUNDWATER MONITORING

N.6.1 Institutional and Legal Framework

The old Water Act (Chapter 20:22) has been replaced by a new Water Act (1998), which emphasises the integrated management of both surface and groundwater (as opposed to surface water only under the old act). The new act sets out the new structure for ZINWA (discussed earlier) and includes the emphasis on catchment level control of resources. All groundwater is now considered public water (owned by the state) enabling comprehensive management to ensure sustainable development. A major aspect of the new act is the control of groundwater abstraction, the regulation of groundwater development practices and the implementation of tariffs for commercial groundwater abstraction. Additionally, the new Water Act does away with the Priority Date, which previously (under the old act) required that the first user of the local water resource must have all of their water demands met before consideration of any other uses.

Under the new act, the Catchment and Sub-Catchment Councils will control all groundwater developments. As such, authority to drill or deepen boreholes and use groundwater will reside with catchment councils and be permitted with application fees collected. This will assist councils to co-ordinate, allocate and control groundwater abstraction. If groundwater abstraction is for some commercial use a meter will be fitted to the borehole and charges for water use levied. A general permit will be granted if the abstraction amount is within a given conservative range (based on the annual rainfall average for the region). If the applicant wishes to abstract more water, a specific permit will be required which will entail the completion of a detailed hydrogeological report, which indicates that the abstraction is sustainable within the framework of the local hydrogeology. This may include a requirement for installation of monitoring boreholes. Additionally, in the event of a drought or water shortage, the Minister has the power to suspend all permits and allow re-allocation of groundwater resources (i.e. from agriculture to towns).

The funds thus generated will be then be used for groundwater development and management in the catchment. Permits will be comprehensive for both groundwater and surface water abstraction. NGO groundwater development projects will not require permits if the sources developed are for primary use only.

N.6.2 Monitoring Network and Frequency

Groundwater monitoring is mostly confined to a few locations of strategic groundwater potential (eg the Nyamandlovu, middle Sabi and Lomagundi aquifers and areas), although ZINWA places great emphasis on monitoring and is in the process of formalising a nation-wide monitoring network.

The ZINWA structure within the new Water Act will focus on national level monitoring as well as be a permit requirement of any permits issued. As part of the special permits, installation of boreholes specifically for water level monitoring may be required under certain conditions. This will greatly improve the level of monitoring in the country.

At this stage the existing groundwater monitoring networks exist on a regional scale as well as groundwater supply scheme-based scale. The monitoring network boreholes are generally protected and marked (yet still prone to vandalism) with monitoring frequency varying from ad-hoc to monthly or quarterly.

The hydrogeological parameters most routinely measured are water levels (taken manually, with autographic recorders and digitally) and pumping rates, with data generally collected in the field and transferred to the office by pen and paper, and digital downloading via telemetry in areas of high groundwater abstraction. Hydraulic parameters (K and T) are usually measured on a once-off basis only following drilling and completion of aquifer tests.

Groundwater quality is routinely monitored in selected areas only by ZINWA's Water Quality Section with analyses conducted both in the field and laboratory. There is as yet no comprehensive national groundwater quality monitoring system and dedicated database.

Monitoring frequency of physical parameters (rainfall, flow, water quality and water levels) is mostly monitored on at least a quarterly basis in areas of high abstraction, whereas aquifer productivity and hydraulics are measured on an ad-hoc basis only following drilling and testing of the borehole as mentioned.

The Zimbabwe groundwater monitoring networks are detailed in Table 4.

Table 4: Monitoring Network Detail

Name	No of boreholes	Purpose of monitoring	Parameters monitored	Recording method	Monitoring frequency	Monitoring period
?	?	?	?	?	?	?
?	?	?	?	?	?	?

(Detail above to be filled in by Mr S Sunguro (ZINWA Groundwater Section) during July workshop?)

N.6.3 Quality of Monitoring Data

The quality of monitoring data is accurate where data exists for identified monitoring network boreholes, with positional accuracies ranging from 10 to 100 m. ZINWA's Groundwater Section has QA / QC measures in place during the various stages of monitoring / sampling, data management and map production / GIS, thus ensuring best data quality, although a shortage of experienced senior staff / mentors results in logistical problems with checking of all field data. The QA / QC protocols of other institutions involved in random monitoring programmes, such as drilling contractors and consultants, is, however, not formalised and field verification of the data may thus be required.

Detailed, operational guidelines exist for water quality monitoring as part of water pollution control measures, ensuring that the quality of the monitored data is acceptable.

N.7 HYDROGEOLOGICAL MAPPING

N.7.1 Existing Hydrogeological Maps

A national hydrogeological map was published in January 1986. This map was prepared by InterConsult A/S Consulting Engineers as part of the then National Master Plan for Rural Water Supply and Sanitation of Zimbabwe. A grant from NORAD (Norwegian Agency for International Development) funded the preparation and production of the map.

The Map, viz: *The Zimbabwe Regional Hydrogeological Map, 1 : 500 000, Ministry of Energy and Water Resources and Development, Harare 1986*, was based primarily on the national geologic map. A second countrywide hydrogeological map was compiled under the Sub-Saharan Africa Hydrological Assessment Study (MacDonald and Partner, 1990). The map was produced at a scale of 1:1,500,000 and serves rather as a reconnaissance map presenting the available hydrogeological information.

The regional Map was produced solely for groundwater development planning purposes and illustrates major hydrogeological units only. Within each unit the occurrence of groundwater and generalised aquifer development potential is indicated. The Map is intended for use to highlight suitable areas for suggested future study and development and is not intended for use as a borehole siting tool.

The Map comprises four 1 : 500 000 scale sheets displaying the land surface where the geological units on the main geological map of Zimbabwe were simplified and arranged according to rock types (lithology) to prepare a base for the hydrogeological map.

There are no insert / derivative maps displaying hydrogeological features included on the Map sheets.

The following features are displayed on the Map:

- Hydrogeological unit and groundwater development potential;
- Topography, showing political boundaries, roads, towns including hydrology features such as rivers and dams;
- Geology features such as lineaments, dykes and lithological boundaries, as well as the source of the geology data as a small inset map.

The cartographic projection detail of the Map (as per the geology map) is summarised in Table 5.

Table 5: Zimbabwe Hydrogeological Map Cartographic Projection Detail

Projection	UTM zone 35K + 36K
Units	Metres
Spheroid	Clarke 1856

The most important source of data for the compilation of the thematic data layers related to groundwater, was the National Groundwater Database operated by ZINWA. The second main thematic layer displaying the lithological units is predominantly based on the existing geological map of the Geological Survey at a scale of 1 : 1 000 000.

The detail of the hydrogeological map legend is summarised in Table 6.

Table 6: Hydrogeological main Map Summary

Legend	**Details of Legend**
Hydrogeological Unit simplified from the geology of Zimbabwe	10 units shown as a unit number (1 – 10) with Units 1, 2, 4 and 6 divided into sub-units according to variations in the lithology of the main unit; eg Unit 6 (Karoo) subdivided into 5 units ranging from Unit 6A: Upper Karoo basalts to Unit 6E: Lower Karoo sandstones.
Groundwater Development Potential Classification shown as three colour shades in the main map sheet	Classification of groundwater development potential: ➢ High: Blue ➢ Moderate: Yellow ➢ Low: Red ➢ No data available left blank
Lithology of each Hydrogeological Unit	Rock types described in the legend (text) and represented on the map by various patterns, symbols, hatching and combinations. Each Hydrogeological Unit has its own specified lithology
Aquifer hydraulics of each Hydrogeological Unit described in text in the legend	Classification: ➢ **Average Transmitting Properties** – 'High', 'Moderate', 'Low', 'Moderate to High', 'Moderate to Low'

Legend	Details of Legend
	➢ **Type of Permeability** – 'Primary', 'Secondary' or 'Mixed' ➢ **Average depth to Water Table** – value in metres ➢ **Average Specific Capacity and Yield Range** – values in $m^3/d/m$ and m^3/d respectively
Geological Symbols	Lithological boundaries and approximate extent of African Surface shown as polygons; with photo-linear traces (faults, fracture) and dykes indicated with as black lines
Source of Geology Depicted	Inset map showing 3 zones of Zimbabwe with different geological sources: 1 – geological base from Aquater (1984) 2 – photo-geological base from LANDSAT imagery with limited field checking 3 – photo-geological base from LANDSAT imagery interpretation
Topographical Symbols	Common topographic symbols used are:- ➢ Roads: shown as different patterned and thickness lines divided into major, secondary and other; ➢ Railway: dashed line; ➢ Cities and towns: grey shaded polygons; ➢ River or water-course: solid and dashed blue lines respectively, brown line for dry river; ➢ Lake or dam: blue polygons with varying pattern in-fills; ➢ International boundary: black dash-dot line

N.7.2 Derivative maps

There are no insert / derivative maps displaying hydrogeological features included on the Map sheet.

N.7.3 Classification and Legend of Maps

The groundwater development potential of each hydrogeological unit is mapped and portrayed according to a simplified legend that is not based on an international standard such as the UNESCO Legend. The hydrogeological legend uses a colour scheme that subdivides the hydrogeological unit into high (green), moderate (yellow), and low (red) groundwater potential.

The following aquifer parameters are described or quantified in the legend opposite each hydrogeological unit:

- Average transmitting properties: as low, moderate of high;
- Type of permeability: as primary, secondary or mixed;
- Average depth to water table: in metres below surface;
- Average specific capacity: in $m^3/d/m$;
- Yield range: in m^3/d.

N.7.4 Existing Geological Maps

The sources of geological information are from published and un-published field mapping, and photo-geology from Landsat imagery interpretation. Geology is presented on a published 1 : 1 000 000 Geological Map of Zimbabwe, currently in its 7th edition (1999), printed by the Department of

Geological Survey. The occurrence of economic minerals is indicated on the geological map in addition to the formation type.

Smaller scale geological maps produced by the Geological Survey are available (1:100,000 scale) for 60% of the country both in paper and in digital form (vectorised and scanned). Geologic maps also include borehole locations and general information if available. Short reports or bulletins accompanying the geologic maps may include a hydrogeology section.

A range of digital data type and format is commercially available from the Department of Geological Survey. These data are provided on CD for geological information such as bulletins and short reports, electromagnetic and aeromagnetic data and stream sediment geochemical data.

The detail of the Zimbabwe Geological Map legend is summarised in Table 7.

Table 7: Geological Map Summary

Legend	Details of Legend
International Period	International format Geological period in text, sub-divided into Geological **System or Group**
Table of Formations	➢ Each formation allocated a specific colour, together with some hatching as well as letter denoting sub-division within a specific formation ➢ Textual description of each formation
Economic Minerals	Type of economic mineral occurring in each formation listed in text, with predominant mineral in upper case and subordinate mineral in lower case
Topographical Explanation	Topographic symbols shown as per international cartographic standards

N.7.5 Existing Physiographic Maps

The topography is presented on a 1 : 1 000 000 scale map, 6th edition, published by the Surveyor-General, Harare, 1970, with amendments 1977. This map forms the base map for the geological map, which in turn forms the base to the hydrogeological map.

In addition to the main topographic map sheet, there is coverage of the majority of the country by 1 : 50,000 scale maps sheets.

N.8 DATA AVAILABLE FOR SADC HYDROGEOLOGICAL MAP

The contributions of each of the institutions contacted with respect to the SADC Map and Atlas project is summarised in Table 8.

Table 8: Contributions of the Institutions to the SADC Project

Institution	General groundwater information	Monitoring / time dependant data	Map production
ZINWA	X	X	X
University of Zimbabwe	X		X
Department of Geological Survey			X
SRK Consulting			X

Institution	General groundwater information	Monitoring / time dependant data	Map production
National Co-ordination Unit	X		
Jeremy Prince & Associates	X		
Groundwater Development Consultants	X	X	

The availability of the individual data sets / maps for the SADC project map is indicated in Table 9.

Table 9: Data-set / Map availability

Data-set / Map	Source data available	Processed data available	Not available
Boreholes	X	X	
Geology	X	X	
Physiography	X	?	

The Zimbabwe National Groundwater Database is created and owned by ZINWA's Groundwater Section, and its use is restricted to ZINWA. As such, it is protected by a licence agreement, and access to and use of the database is conditional.

N.9 CAPACITY AND COMMITMENT FOR THE PROJECT

N.9.1 Existing Capacity

The Groundwater Department of ZINWA have limited capacity at a national level for their own mapping programme and information system. From all the interviews held, the major and predominantly identified deficiency related to data collection, management and map production was related to a lack of staff as well as lack of political will and available funding.

In addition, since the manpower resources available to the Groundwater Department are limited, the mentorship process is restricted thus limiting the chance of development within the department.

N.9.2 Commitments on Contribution to Regional Mapping Project

The commitments made by individuals and institutions towards the SADC project are summarised below:

- ZINWA – undefined number of staff at senior hydrogeologist level with related experience for a maximum 20% time commitment for the project. Whilst this commitment is genuine, and the hydrogeologists within ZINWA are eager to contribute towards this SADC project, the number and availability of the limited staff for the SADC project would need to be formally verified. Funds are not available within ZINWA's budget for the SADC map and atlas project ;
- Zimbabwe Geological Survey (ZGS) – 2 members of staff, at senior geologist level with cartography and database management skills for a 5 – 10% time commitment for the duration of the project. This commitment would require verification with management of the Geological Survey;

- National Co-ordination Unit (NCU of Ministry of Local Government) – 1 staff member with hydrogeological experience and skilled in national co-ordination possibly available on a full-time basis, dependent on restructuring of the NCU;
- Mineral Resources Centre (MRC of University of Zimbabwe) – 2 to 3 members of senior staff with hydrogeological, hydrochemical, modelling, geophysics and data management skills available for a 50% time commitment on a consulting basis ranging from US$140 to US$200 per day. This is considered to be a firm and feasible commitment;
- Jeremy Prince and Associates (JPAA) – 4 staff members skilled in hydrogeology, geology and geophysics with local knowledge and experience available on a consulting basis at US$300 per day. The specific commitment to the SADC project will depend on the total consulting work-load of the firm;
- Groundwater Development Consultants (GDC) – 4 staff members with local hydrogeological experience available on a consulting project basis at US$200 – 300 per day. The availability of the staff member/s would require verification prior to commencing with the project since they may be committed to another project.

N.9.3 Country Expectations and Policy Concerns with the SADC Project

The needs and expectations of the hydrogeologists interviewed, with respect to the SADC project, are summarised in Table 10 below:

Table 10: Overview of the SADC Map and Atlas Project – Map and Information Expectations

Institution	ZINWA	NCU	MRC	JPAA	GDC
Scale	Country scale	-	Continent and regional	1 : 1 Mill	1 : 2.5 Mill
Legend	IAH	-	-	UNESCO	-
Map format	Main map + inset maps	-	-	Atlas with detail maps on smaller scale	Same format for each country
Commitment	Manpower	Manpower	Manpower	Manpower	Manpower

In general the respondents were very positive about the project and considered it to be long overdue. A major benefit of the project was seen to be a better understanding of trans-boundary / regional groundwater resources.

According to the majority of people / institutions interviewed, the following policy issues need to be urgently addressed before the SADC atlas is applied regionally:

- Aspects of data ownership, distribution, copyright and access need to be formalised. Following from this an expectation is that the data must be freely accessible;
- Concern was expressed regarding the ongoing maintenance / upgrading of the SADC Region database that will be formed for the project. In addition there was concern regarding the inherent changes in software and hardware with the technological advances experienced today with the result that the system / database may become defunct if it is not correctly designed initially and then maintained;
- The expectation amongst all the respondents was that the database formed for the SADC Map and Atlas Project must be freely available;
- There must be a commitment, both within each member country as well as the SADC Region, to release available groundwater information and data for compilation into a SADC Groundwater Map and Atlas;

- There must be a very strong commitment, both on a SADC Region and local country level, to the project in order to ensure success;
- Communication aspects for the project require consultation on a top-down approach, thereby ensuring political support at top level for the project;

N.10 REFERENCES

Ministry of Water Resources, 1985, National Master Plan for Rural Water Supply and Sanitation, InterConsult (Norway) and E. Martinelli and Associates (Zimbabwe).

Ministry of Health, 1995, Upgraded Well Manual for Field Workers, Mvuramanzi Trust, 27 pp.

Standards Association of Zimbabwe, 1997, Zimbabwe Standard Specification for Water for Domestic Supplies, Zimbabwe Standard No. 560:1997, ICS 13.060.20, ISBN 0-86928-469-X.

Standards Association of Zimbabwe, 1995, Zimbabwe Standard Specification for Natural Mineral Water, Zimbabwe Standard No. 457:1995, ICS 13.060.10, ISBN 0-86928-310-3.

The Zimbabwe National Water Authority, 2001, Accessing Water Under the New Water Act (Water Act Chapter 20:24), 8 pp.