F: MAURITIUS

F.1 INTRODUCTION

Mauritius is a small (1,865 km^2) island nation located west of Madagascar. The country was visited by Flenner Linn representing Groundwater Consultants during 21-24 April 2002.

F.2 BACKGROUND

Some of the basic information on groundwater occurrence and institutional aspects have been taken from the country report for the 'Minimum Standards' project, updated where necessary.

F.2.1 Physiography and Climate

Mauritius is a small island located due east of Madagascar in the southwest Indian Ocean with a total area of approximately 1,865 km^2 and coastline of 330 km. The island consists of an irregular central plateau surrounded by mountain ranges and plains. The central plateau, marked by deep extinct volcanic craters and criss-crossed by rivers, streams and waterfalls, rises to a level of some 600 m in the south of the island and has a mean elevation of about 300 to 400 m. The island is almost entirely surrounded by coral reefs. The Island of Rodrigues, which is a part of Mauritius, is about 560 km east of Mauritius Island. The total area of the island is about 108 km^2.

Most of the rivers originate from the central plateau and flow radially outward to the sea. Due to the topography, heavy rainfall results in flash floods and a large proportion of the runoff is lost to the sea. There are 25 major surface water basins and 22 minor basins in the small island. Almost all the rivers are perennial and the total average surface runoff amounts to 2,340 Mm^3.

F.2.2 Overall Institutional Framework Of Water Sector

The Water Resources Unit (WRU) within the Ministry of Public Utility (MPU) is largely responsible for the assessment, development, management and conservation of water resources. The unit is the nodal organisation for the co-ordination of all activities concerning water resources management and has to liaise with all the major water user organisations, namely the Central Water Authority (CWA), the Irrigation Authority (IA), the Central Electricity Board (CEB) and the Waste Water Division (WWD). The new Water Act is in the final stages of development and, once adopted, the WRU will be converted to the Water Resources Authority (WRA).

F.2.3 Role of Groundwater in Water Sector

The population of Mauritius is 1.14 million and is spread mainly along the western part of the island. In the last two decades industrial development has taken place, particularly in the textile sector. Of total water use, 20% of good quality potable water is used for municipal water supply, 53% by the agriculture sector and 27% for hydropower generation. Groundwater is mainly used for municipal water supplies with a 50% share of the total.

Total water use is ~980 Mm^3/year. Groundwater plays a fairly significant role and at the present level, groundwater contributes 21% of total domestic and non-domestic uses (excluding hydropower uses). About 57% (112 Mm^3/year) of domestic, industrial and tourism piped water supply (i.e. water supply by CWA) is met by developed groundwater through boreholes. Almost 100% of other independent industrial supply is also met by groundwater.

There are a total of 314 production boreholes. Out of these, 109 are used for potable water supply, 104 are used by industries and the remaining 101 are used for agricultural purposes. The mean yield of boreholes used for municipal water supply is about 80 m^3/hr while the maximum yield can be as high as 300 m^3/h.

F.2.4 Institutional and Legal Framework and Funding Status for Groundwater Development

The Hydrogeology Division (HGD) remains the key organisation for the development of groundwater resources. In the last financial year, Rs 23 million was allocated to groundwater out of the total Rs 66 million budget for WRU. The CWA relies heavily on groundwater and communicates its needs for groundwater development and exploration to WRU which, in turn, carries out all the water sourcing related work, including the geophysical surveys, borehole siting, pump testing, data analysis and recommendation on pump installation as well as on pumping schedules.

HGD is responsible for all groundwater development including irrigation and industrial purposes. Authorisation for drilling of boreholes and issue/renewal of groundwater licenses is based on scientific criteria. Drilling and test pumping of private boreholes is carried out by private contractors under the supervision of the HGD. During the drilling and test pumping activities, HGD carries out spot checks to verify the quality of work and data collection. On a few occasions, these agencies also request HGD for technical expertise in difficult areas.

F.3 GEOLOGICAL AND HYDROGEOLOGICAL FRAMEWORK

F.3.1 Geology

The geology is of relatively very recent age, dating between 10 million years to 25,000 years. The island is the result of two major series of volcanic events of basaltic lava flows. The basalts are classified into three main types/series namely, the Old Series, the Intermediate Series and the Young Series.

Preliminary interpretation of geological structures suggest that, due to collapse of the Older Series lava at the centre, a caldera was formed due to normal faulting with an average throw of about 150 m. The Young Series lava intruded at the centre and flowed along the uneven erosion surface of valleys and weak zones. These zones are classified as axes of preferential lava flows. There are also some volcanic craters in the caldera.

F.3.2 Hydrogeology

The Old Series lavas form the mountain ranges with very rugged relief and are in general considered less permeable. However, they have an important bearing on groundwater flow. Groundwater occurrence in the Old Series is limited and is of poor quality.

Compared to the Old Series, the Intermediate and Young Series are more permeable. Higher transmissivities are usually associated with fractures. The yields of boreholes vary considerably within short distances due to heterogeneity in the formation. The mean yield from boreholes in use for potable water supply is about 80 m^3/h. Yields above 300 m^3/h are also recorded under favourable conditions.

F.3.3 Natural Groundwater Quality

Groundwater quality in general is good. There are some isolated problems of saline water intrusion and the phenomenon is closely monitored by WRU. The intrusion is more common in the north and north-west of the island. At some places nitrate concentration is also high and reaches a level of 20-25 mg/l. The threat of nitrate pollution, mainly from fertilisers, is becoming a major concern, and studies are planned to assess the extent of potential contamination.

F.4 DATA ACQUISITION

F.4.1 Institutional Framework for Data Collection

The institutions and personnel contacted as part of this project are summarised in Table 1.

Table 1. Institutions and Personnel Contacted in Lesotho

COMPONENT	INSTITUTION	PERSONNEL
General GW Information Monitoring Data (GW, SW) Hydrogeological Mapping	Water Resources Unit	Dr Sharma, Director Mr. M. Mowlabacus, Senior Hydrological Officer, Mr. D. Gokool, Hydrological Technician Ms S. Bookhoo, Hydrological Officer Ms. R. Ramrekha, Hydrological Officer
General GW Information Monitoring Data (GW)	Central Water Authority	Mr. A. Pandurak, Director Mr.. J. Munbauhal, Principal Engineer Mr. R. Nizem, Engineer Mr. B. Jsowe, Engineer Mr. J. Gungadin, Engineer, Mr. L. Pem, Chemist Mr. T. Gupaule, Engineer

GW: groundwater
SW: surface water

The main repository of groundwater data is the Water Resources Unit (WRU), with some data also being acquired by the Central Water Authority (CWA). The WRU is the institution charged with management and protection of water resources. The CWA is the parastatal entity responsible for provision of public water supply for drinking and agriculture (small scale) and as such its data collection is primarily related to operational production boreholes.

F.5 GROUNDWATER INFORMATION SYSTEMS

F.5.1 Hardware and Software

F.5.1.1 Water Resources Unit

Data are acquired by the WRU through its own groundwater exploration and development activities as well as being provided by other entities, such as the CWA, private groundwater developers and users. The WRU maintains a single hydrogeological database in Excel format, although all pre-1999

data are saved in an in-house developed database. The database is not linked with any graphical interface, but is sometimes used with Autocad maps created during the national groundwater resource assessment project. Data are entered as they are received in the WRU, with recent data entry largely up to date. The CWA provides water level and abstraction monitoring data it collects to the WRU on hard copy data forms. Additionally, surface water data are still maintained in an in-house developed software.

A summary of the information system for WRU is presented in Table 2 with details provided in Section F.5.2.1.

Table 2. Summary of WRU Information Systems

Database / Source	In use	No. of records	Format	Useable[1]	comments
Hydrogeology	yes	*	Excel 97	yes	In operation since 1999, up to date as with post-1999 data
Hydrology	yes	Data from 1967	Fortran code	yes	Easily exports to Excel or other formats; only data from selected (reliable) stations are entered in database
Hydrology	no	Pre-1999 data	Fortran code	yes	Contains all older GW data, easily exported

[1] Easily useable for the regional hydrogeologic map
* Information awaited from member country

The WRU has also installed 20 pressure transducers as part of the monitoring network. Data from transducers are maintained in the Hydras3 software (provided with the transducers), which can easily export to Excel or text format.

F.5.1.2 Central Water Authority

The CWA stores some groundwater related data within two databases, one for the Mechanics and Engineering (M and E) section and one for the Water Quality Laboratory. A summary of the information system for WRU is presented in Table 3 with details provided in Section F.5.2.2.

Table 3. Summary of CWA Information Systems

Database / Source	In use	No. of records	Format	Useable[1]	comments
M and E	yes	*	Excel 97	yes	Includes SWL, DWL, yield; data since 2000; each BH has a separate file
Water Quality	yes	120 boreholes	Excel 97	Yes	Contains only selected (important) BHs; data since 1993
Water Quality	yes	*	paper	no	BHs considered not important; data since 1993

[1] Easily useable for the regional hydrogeologic map
* Information awaited from member country

F.5.2 Data Saved

F.5.2.1 Water Resources Unit

The bulk of groundwater data available for both Mauritius and Rodrigues has come out of a long term groundwater research project carried out between 1995-1999. The study greatly advanced the understanding of the hydrogeology of both islands, including delineation of specific aquifer units,

location of greater groundwater reserves (primarily through deeper drilling) and definition of groundwater flow paths and trends. Data generated through this study are available in reports and in digital format at WRU. Complete groundwater and surface water data are periodically compiled and published as Hydrology Data Books. A 1992-95 data book has been published and the 1996-2000 data book is being prepared. At present there are 337 boreholes in use distributed throughout Mauritius, roughly evenly divided between potable water supply, industrial and agricultural uses. Most of these boreholes have excellent records from drilling and construction to testing and monitoring.

As part of the permit to drill, private drillers are required to provide all drilling and construction data to the WRU. Whenever possible a WRU technical staff member or hydrogeologist observes on site activities during drilling to ensure that acceptable procedures are followed and required data collected. Data on test pumping are also provided to WRU by private contractors for analysis as part of the abstraction licensing procedure. Regular water level data are available from 1997, although only data for 2000-2001 are entered in the computer.

The WRU maintains the national hydrological database. The database is in Excel spreadsheets. The database is comprehensive and includes drilling, test pumping and monitoring data. The database was implemented in 1999, with data previously entered in an in-house developed database written in Fortran code. Only approximately 35% of the data from the old Fortran database have been imported into the new database, although the old database can still be used if older data are required.

F.5.2.2 Central Water Authority

The role of the CWA is to provide public water supply as well as small garden irrigation water. There are no hydrogeologists on the staff of CWA, so it primarily acts in acquiring various groundwater data which are then passed to the WRU for analysis and archiving. Only groundwater monitoring data are collected by the CWA, i.e. water level measurements, abstraction rates and water quality analyses.

A copy of all groundwater data collected by CWA is passed to WRU, so that in general, CWA water level and abastraction monitoring data would be more easily accessed for hydrogeologic mapping from WRU. The digital database that contains borehole data at CWA is that maintained by the M and E section, while water quality data for selected boreholes is kept in the Water Quality database. The databases are summarised in Table 4.

Table 4. Summary of Data Fields: CWA Databases

M and E Database		**Water Quality Database**
Field	**Units**	**Parameter**
Site no.		Sample code
Site (name)		Date of sampling
Code (borehole no.)		Appearance
Borehole dia.	Millimeters	Odour
Casing dia.	Millimeters	Colour
Depth	Meters	PH
SWL	Meters	Conductivity
DWL	Meters	Turbidity
Yield	m3/hr	Nitrate (as N)
Ground level	m amsl	Phosphate (as P)
Make (pump)		Ammonia (as N)
Capacity (pump)		COD
Installed depth	Meters	Sodium
Clearance under pump	Meters	Potassium
Motor make		TSS

M and E Database		Water Quality Database
Date installed		TDS
Riser type		Chloride
Age of pumpset		Sulphate
Remarks		BOD
		TOC
		Nitrite

Water quality analyses generally involve basic hydrochemical parameters. There are regular data from 1997, with the total data record extending from 1993. Water quality analyses are made of raw (including boreholes) and treated water.

CWA also occasionally participates in projects related to groundwater. Projects include the 1995-99 groundwater resource assessment and an on-going project funded by the Mauritius Sugar Research Institute on the fate of agriculturally generated nitrate in groundwater.

F.5.3 Quality of data

F.5.3.1 Water Resources Unit

Specified QA/QC procedures are not established in data collection and data management in WRU. Random visual checks of data are carried out as they are entered in the database. However, because of the well controlled nature of groundwater development and the relatively few role players involved, the quality of groundwater data appears to be very good. Very little data are not captured by the WRU, aside from some drilling data when private drilling (rarely) proceeds without notification of WRU. The most significant limitation of groundwater data is that much of the data only extends back to approximately 1995, although extensive groundwater development began in the early 1970's.

F.5.3.2 Central Water Authority

The CWA collects extensive data on abstraction, water levels and water quality in production boreholes it operates as part of the water supply programme as well as some piezometers adjacent to production boreholes. However, it does not have the capacity to review or analyse the data as it comes and merely passes it straight to the WRU. Standard data forms are used to collect water level and abstraction volumes (using in line flow meters). Water quality analyses are conducted following relevant international standard procedures.

F.5.4 Available Resources for Maintenance

The groundwater database (Excel) for the WRU has a dedicated hydrological technician who is responsible for data input and assisting users. Data input is generally up to date and no major concerns have been noted regarding manpower for data management and data entry.

F.6 GROUNDWATER MONITORING

The CWA is primarily responsible for groundwater monitoring, with data provided to the WRU. Monitoring carried out by private groundwater users is generally provided directly to the WRU. The WRU also monitors observation boreholes which form a national monitoring network. The Water Act sets out the regulations for groundwater monitoring and these are implemented through the permitting of drilling and licensing of abstractions. Penalties are specified for non-compliance, but these (MR5,000) are considered too small to act as a significant deterrent.

F.6.1 Groundwater Monitoring Network and Frequency

F.6.1.1 Water Resources Unit

The national monitoring network, monitored by the WRU, consists of 200 manually monitored boreholes and 20 transducers. The objective of the monitoring network is primarily resource management and protection. Protection includes pollution monitoring and prevention, as well as monitoring of seawater intrusion. Seawater intrusion has occurred in the northern plains area, but the fresh/saline interface has been stabilised. The network covers all parts of the island and all aquifer units. Manually monitored boreholes are measured monthly. Transducers are set to collect data at 15 minute intervals. Additionally, 20 rainfall stations are monitored by the WRU. Groundwater samples are taken from selected boreholes for analysis on a monthly basis as well. Monitoring is summarised in Table 5.

Table 5. Summary of WRU Monitoring

Type and number of monitored points	Measured Parameters	Frequency	Comments
Boreholes (200)	Water levels	monthly	Manual monitoring
Boreholes (*)	chemistry	monthly	Selected boreholes are sampled monthly
Boreholes (20)	Water levels	15 minutes	transducers

* Information awaited from member country

F.6.1.2 Central Water Authority

The CWA monitors production boreholes as well as associated piezometers that are part of the supply source. The objective of monitoring is protection of the resource to ensure supply. Licensed abstraction rates are reviewed in relation to water level trends on a monthly basis and abstraction reduced if required. Monitoring is summarised in Table 6.

Table 6. Summary of CWA Monitoring

Type and number of monitored points	Measured Parameters	Frequency	Comments
Boreholes (120)	Water levels	monthly	Manual monitoring
	chemistry	7 - 10 days	

F.6.1.3 Private Users

Private users of groundwater include industry and agriculture (sugar estates). As part of the abstraction license private users are required to measure water levels and water chemistry, and provide the data directly to WRU. A summary of the prescribed private monitoring is provided in Table 7.

Table 7. Summary of Prescribed Monitoring for Private Boreholes

Type and number of monitored points	Measured Parameters	Frequency	Comments
Boreholes (227)	Water levels	monthly	Manual monitoring
	chemistry	monthly	Frequency may be increased if any deterioration is observed

F.6.2 Quality of Monitoring Data and QA/QC

There are no set QA/QC procedures for data collection or data management. Informal checking occurs as data are entered and reviewed as part of monthly assessments. However, all monitored points (public and private) have been located with GPS. Although no set protocols exist, since the data are used by hydrogeologists in WRU very regularly, monitoring data quality should be good.

F.7 HYDROGEOLOGICAL MAPPING

F.7.1 Existing Hydrogeological Maps

The Hydrogeologic Maps for both Mauritius and Rodrigues are published by the WRU. Both maps and their accompanying reports were completed in 1999 at the conclusion of the groundwater resource assessment project. A main hydrogeologic map (Carte Geologique, Schema hydrogeologique) has been prepared for each island with an associated series of derivative maps as well as a detailed summary report.

The hydrogeologic map for Mauritius is produced in colour at a scale of 1:50,000 and comes in two sheets. The hydrogeologic map for Rodrigues is produced in colour at a scale of 1:25,000. The base of the maps is the geology with topographic contours. The accompanying text gives a detailed description of the climatological and physical features of the island, the structural evolution, stratigraphy, hydrogeology and recharge dynamics. The hydrogeologic map and associated derivative maps are also digitally available as Autocad drawing files.

F.7.2 Derivative maps

A series of derivative maps are provided accompanying the hydrogeologic maps. For Mauritius these maps consist of the following:

- A principal aquifer distribution map (1:230,000) showing the five primary aquifer units;
- A structural map (1:250,000)
- An isohypses map for ancient formations (1:200,000)
- An isohypses map for recent formations (1:200,000)
- A piezometric map (1:200,000)
- A map of the principal craters (unknown scale)

On the hydrogeologic map itself inset maps are provided with annual rainfall and piezometric contours. Additionally, there are four hydrogeologic cross sections (2 at 1:50,000, 2 at 1:25,000).

The Rodrigues hydrogeologic map has only two derivative maps provided as insets on the main map, showing annual rainfall and the delineation of the principal aquifers.

F.7.3 Classification and Legend of Maps

Both maps, for Mauritius and Rodrigues, have the same legend type. Although aquifer units are delineated, borehole yield data are not indicated. The details are summarised in Table 8.

Table 8. Hydrogeological Reconnaissance Maps Legend Summary

Main Geologic Map	
Legend	**Details of legend**
Geology The different geologic units are shown as colour filled polygons, with the basalt divided based on age into Recent, Intermediate and Ancient sequences.	Sub categories (i.e. scoreaceous, pyrochlastic units) are provided within each basalt group. Supeficial formations are divided into alluvium and carbonates.
Groundwater Features	Springs
Structure	Faults Limits of calderas Effrondremonts
Volcanic features	Lava tunnels and pits Craters
Surface Water Features	Rivers, perinial and ephemeral; blue solid and broken line Dams canals
Topography	100 m contour interval
Other features	Towns Roads
Derivative Maps	
Rainfall	Contours: 0-1000, 1,000-2000, 2,000-3,000, 3,000-3,600, and >3,600 mm/year
Principal Aquifers	Colour filled and label polygons; Principal Aquifer: • Curepipe • Phoenix, Beau Bassin, Albion/Moka, Coromandel • Nouvelle Decouverte, Plaines des Roches/Midlands, Trou d'Eau Douce • Northern Plains Secondary Aquifers: • Chemin Grenier, Frederica • Alluvium and colluvium • Carbonate formations • Fractured aquifers
Piezometry	Contours; 50 meter contour interval, meters amsl

F.8 DATA AVAILABLE FOR A SADC HYDROGEOLOGICAL MAP

Based on the existing data sets and mapping, Table 9 summarises the data available for specific legend items that may be desirable to portray on a regional hydrogeologic map. However, since very few existing legend entries are associated with ranges of values, and given the recent date of the map, the map as it stands could be used directly as a base for the SADC hydrogeologic map of Mauritius. Principal aquifers are defined primarily by structure which compartmentalise the aquifers. Secondary aquifers have also been identified, which tend to be small.

Since some component of borehole yield or abstraction rate will likely be of interest for the SADC hydrogeological map, these two parameters (and data sources) are included on the table.

Table 9. Hydrogeological Map Legend Summary

LEGEND	SOURCE DATA	PROCESSED DATA	NOT AVAILABLE
Geology		Autocad (v.12) drawing files with WRU	
Groundwater Features		Springs: as indicated in drawing files (WRU)	
Structure		Autocad (v.12) drawing files with WRU	
Volcanic features		Autocad (v.12) drawing files with WRU	
Surface Water Features		Autocad (v.12) drawing files with WRU	
Topography		Autocad (v.12) drawing files with WRU	
Other features		Autocad (v.12) drawing files with WRU	
Rainfall	WRU GW database	Autocad (v.12) drawing files with WRU	
Principal Aquifers		Autocad (v.12) drawing files with WRU	
Piezometry	WRU GW database; CWA database	Autocad (v.12) drawing files with WRU	
Additional possible legend entries			
Borehole yield	WRU GW database		
Groundwater usage	CWA M&E database; WRU GW database		
Groundwater Chemistry (EC, TDS, etc.)	CWA chemistry database; WRU GW database		
Areas of Seawater Intrusion	WRU GW database		

F.9 COMMITMENTS AND CONCERNS

F.9.1 Commitments on Contribution to the Regional Mapping Project

Water Resources Unit

Assistance in data compilation.

F.9.2 Concerns

Although there is enthusiasm for the project objectives and SADC-WSCU activities in general, there is a general feeling that the regional hydrogeologic map and atlas will be of little use for Mauritius.