

I: SEYCHELLES

I.1 INTRODUCTION

Seychelles is a small island country consisting of over 110 islands located in the Indian Ocean north of Madagascar. The country was visited by Flenner Linn representing Groundwater Consultants during 25-29 April 2002.

I.2 BACKGROUND

I.2.1 Physiography and Climate

There are 115 islands that constitute The Republic of Seychelles in the Indian Ocean. The total land area is about 454 km² with a total coastline of 305 km. Some of the larger granitic islands have fairly high plateaus and hills (up to 900 m) with narrow coastal plains, while others consist of nearly flat carbonate atolls. Mahe, Praslin and La Digue are the three main islands, inhabited by 98% of the population.

The climate is humid-tropical in type and is dominated by the pattern of the monsoons. The temperature rises to 31°C during March and April and falls to 25°C during July and August. Rainfall is fairly high (2200mm) but varies from island to island and month to month. The driest period is between June and July and the wettest is in December and January.

Most of the watercourses have ephemeral flows. Due to the high relief and limited catchments, flows in most of the streams are relatively low and they often go dry, despite annual rainfall well above the world average.

I.2.2 Overall Institutional Framework of Water Sector

The Public Utilities Corporation, through an act of Parliament, is defined as the responsible authority for regulation of any "source of supply" which is defined as rivers and streams, underground strata and sea water. Aside from some limited farming being carried out on La Digue (L'Union Plantation), no significant private groundwater usage occurs on the islands.

I.2.3 Role of Groundwater in Water Sector

Total average water demand of the three main islands at 2000 level is estimated as 27,327 m³/day and is expected to rise to 31,192 m³/day by the year 2010. Present supply capacity exceeds this demand during the wet season but falls short by about 35% during the dry season, posing a challenge to water supply efforts. Since significant groundwater potential or resources have not been identified and much of the surface water potential has been developed, two desalination plants (for seawater) are being constructed.

Water supply to the three main islands is almost entirely dependent on surface water sources. Groundwater currently plays a very insignificant role in terms of volumetric contribution (approximately 2% of total water supply during dry season), although it is still an important water supply source for some of the islands in the dry season.

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

The Planning Section of the Water and Sewerage Division of the Public Utilities Corporation is responsible for all groundwater development operations in the country, including studies. Most of these studies and exploration programmes are completely or partially outsourced, as the Section does not have capacity to undertake them, mainly due to the limited level of activities in groundwater exploration and development. PUC has experienced financial difficulties in recent years to fund expansion of many of its water supply systems. External funding sources are limited and grants are not available due to the relatively high GDP. There are no separate funding commitments on groundwater development. In fact, owing to unfavourable results of earlier groundwater exploration programmes, groundwater development is not foreseen in future.

I.3 GEOLOGICAL AND HYDROGEOLOGICAL FRAMEWORK

I.3.1 Geology

Out of the total of 115 islands, 40 are granitic while the remaining are coralline. The granitic islands are believed to be associated with Gondwanaland Drift and form the tips of a large granitic mass. The age of these granites is established at 650 million years, with intrusions of Cenozoic dolerites and syenites.

The coastal plains of granitic islands consist of recent sand deposits. The bedrock is weathered granite and colluvium and at times clay layers are also found at the bottom. Many coral layers are also found within these deposits. The width and thickness of these deposits are limited. The plains are normally less than 1,000 m wide and 25 to 30 m thick (in Praslin the thickness is only 5 m) and are wedge shaped. Their thickness is almost negligible along the granite foothills and is maximum closer to the coast.

I.3.2 Hydrogeology

There are two types of hydrogeological environment; Coastal Plains and weathered/fractured granite. The Coastal Plains are narrow and limited in depth (25 to 30 m) and form unconfined aquifers. These are mainly found in the Mahe-Praslin-La Digue island group. Several limited studies have been conducted on the main islands to assess the hydrogeological characteristics, two of the main projects being in 1975 and 1987. Yields from boreholes completed in these projects were relatively low (< 2 l/s) and with high salinity in some near the shoreline. In Mahe some of the better boreholes are located in the southern area. In general, from the very limited groundwater exploration that has been conducted, overall groundwater potential is limited. However, the unconsolidated carbonate sands in coastal formations appear to have moderate potential, as indicated by the production boreholes located on La Digue island. Water levels are shallow and are often within a metre of ground level.

In coralline islands, which are dominated by loose calcareous sand with a very low relief and average elevation of 2.5 m, fresh water 'lenses' lie above brackish water.

I.3.3 Natural Groundwater Quality

Groundwater quality is in general excellent in all the areas that have been explored (main islands). The main issue identified to date is that the groundwater tends to be hard. Although there is a clear potential for seawater intrusion under abstraction or reduced recharge, particularly for the unconsolidated coastal terrace aquifers, there has been no indication of this yet. On La Digue, where production boreholes have been in operation continuously since 1987, there has been no consistent increase in electroconductivity.

I.4 DATA ACQUISITION

I.4.1 Institutional Framework for Data Collection

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

Table 1. Institutions and Personnel Contacted in Seychelles

COMPONENT	INSTITUTION	PERSONNEL
General GW Information Monitoring Data (SW, GW) Hydrogeological Mapping	Public Utilities Corporation (PUC)	Mr. D. Labodo, Snr. Planning Eng. Mr. S. Rousseau, Managing Director Mr. A. Alcindor, Hydrologist Mr. W. Accouche, Technician Mr A Nanjanuud, Electric. Eng.
Hydrogeological Mapping	Seychelles National Oil Corporation (SNOC)	Mr P Samson, Senior Geologist
Monitoring Data (rainfall)	Department of Meteorology	Mr. R. Lajoie, Senior Meteorologist Mr. D. Changseng, Meteorologist
Hydrogeological Mapping (GIS Expertise)	Division of Environment	Mr. J. Prosper, Senior GIS Officer
Hydrogeological Mapping (GIS Expertise, Mapping)	Ministry of Land Use and Habitat	Ms. F. Adrienne, GIS Officer
General GW Information	Water & Wastewater Engineering (Pty) Ltd.	Mr T Anderson, Engineer

GW: groundwater

SW: surface water

The Public Utilities Corporation (PUC), Water Division maintains data archives of surface water, groundwater and water quality. They also monitor rain gauges at their dam sites and river gauge stations, in addition to that collected nationally by the Department of Meteorology. Groundwater, surface water and rainfall data are maintained in a database by PUC-Water.

Groundwater Data

PUC-Water is solely responsible for both groundwater and surface water development for water supplies in the country. The only boreholes used for public water supply are present on the island of La Digue, the third most populated island in the archipelago, after Mahe and Praline. Two boreholes are operated here which provide approximately 57% of the water supply to the island. However, there are an additional 26 boreholes, located on Mahe, that are part of the PUC monitoring network. Several boreholes on La Digue are being used for irrigation of a small private estate there, but no monitoring data are provided to PUC.

Although there is very limited groundwater development, there is a standardised borehole form ("Well Register") which contains construction, testing and monitoring information. There are records of 40 boreholes drilled on Mahe and La Digue. Aside from some hand dug wells on outlying atolls these are the only groundwater developments. There is no national borehole numbering system. Interpreted test pumping data are available for some of the boreholes completed on La Digue, contained within the final report.

Surface Water Data

PUC-Water is also responsible for collection and management of surface water data. As surface water sources provide the bulk of water for supply, these data are much more extensive than groundwater data.

Water Quality Data

Water quality analyses are carried out by the PUC water quality laboratory. The majority of analyses are of treated water and wastewater. The borehole water from the two boreholes on La Digue were tested approximately yearly between 1987 and 1997. However, as no significant variation in water quality was observed, regular chemical analysis was discontinued. There is, however, monthly monitoring of EC for these boreholes.

Meteorological Data

The Department of Meteorology is responsible for national collection of meteorological data. There are 30 stations on Mahe, two in Praline and two in La Digue. The bulk of data extends from 1974, although a few stations have data from 1909.

1.5 GROUNDWATER INFORMATION SYSTEM

1.5.1 Hardware and Software

1.5.1.1 Public Utilities Corporation

The only hydrological database in the country is maintained by the PUC-Water division. The database is in Excel spreadsheet format (Table 2). The database was only implemented fully during 2002, although almost all existing data have now been entered into the database. New data are generally entered as they come in, by the responsible database technician. The data are at times presented using Arcview, but there is no direct linkage between the database and the Arcview platform.

Table 2. Summary of PUC Information System

Database / Source	In use	No. of records	Format	Useable ¹	comments
Hydrology	yes	27 (B)	Excel 97	yes	Contains separate files for each borehole, separate analysis/plot files

¹ Easily useable for the regional hydrogeologic map
B: boreholes

In terms of hardware, PUC have personal computers which are networked. They are considered to be generally enough to conduct their required activities. The Hydrological Database is located on one personal computer in the PUC-Water offices.

1.5.1.2 Division of Environment and MLUH

The Division of Environment, along with the Ministry of Land Use and Habitat are the main government institutions involved with GIS. Both are using Arcview 3.2.

1.5.1.3 Department of Meteorology

The rainfall data for the country are collected and managed by the Department of Meteorology. They maintain 30 stations on Mahe, two on Praline and two on La Digue. The bulk of data extends from 1974 although one or two stations have data from as far back as 1909. At present the data are maintained in an Excel spreadsheet (Table 3). Earlier the software CLICOM was tried but problems were encountered and it is no longer used. The Excel spreadsheet is considered to be the easiest and most effective way to maintain the rainfall data.

Table 3. Summary of Department of Meteorology Information System

Database / Source	In use	No. of records	Format	Useable ¹	comments
Rainfall	yes	34 stations	Excel 97	yes	Database is largely up to date. Most of the data is since 1974.

¹ Easily useable for the regional hydrogeologic map

1.5.2 Data Saved

1.5.2.1 Public Utilities Corporation

As groundwater is only used minimally at present, PUC is the only institution, public or private, which holds groundwater data. At present it operates only two production boreholes used as part of the public water supply on La Digue Island, which are part of 14 boreholes drilled during two projects completed in 1978 and 1987. Additionally, a series of 26 boreholes were drilled during a project undertaken by the Council of Geosciences of South Africa. Borehole logs, hydrogeological analysis and test pumping data for most of these boreholes are available in reports (paper copy). However, since there is so little groundwater data for Seychelles, extraction of these data in addition to that available in the Excel database would most likely be advisable for the regional hydrogeologic map.

Monitoring data are stored in the hydrology database mentioned in Section 1.5.1.1. In addition to groundwater data, rainfall stations are maintained at each of existing and proposed dam sites and data entered in the database. In this database, separate Excel files are saved within a defined hierarchical folder tree as indicated in Figure 1. Data entry in all segments of the database is up to date.

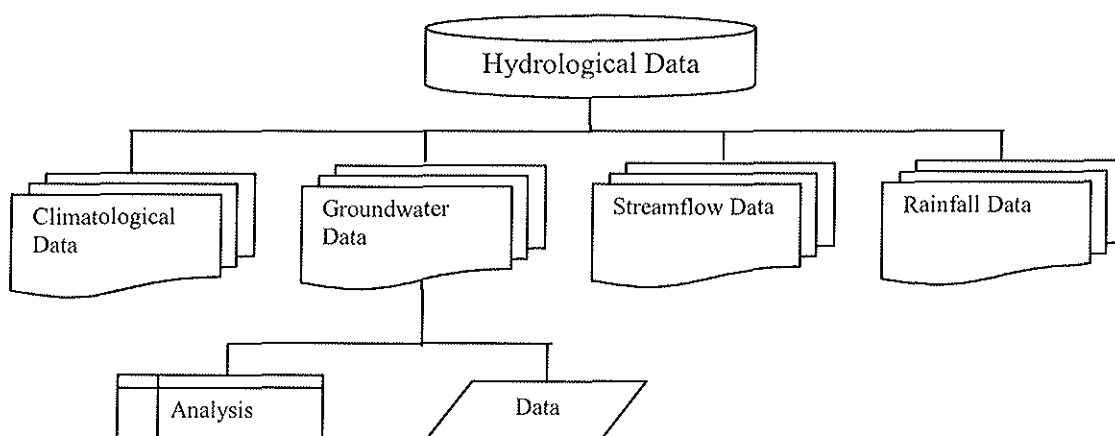


Figure 1. Directory Structure: Hydrological Database

The database has been in use since 2002 with almost all existing data now entered. In addition to borehole information, the database includes surface runoff data and water demand figures.

Additional data of possible importance to hydrogeological mapping are the basemaps of the main islands maintained by the Electric Division of PUC. The format of these files is Arcview 3.2 and their layers include roads (major and minor), the high water level (national boundary), rivers, elevation contours (in 5, 10, and 20 metre intervals) as well as linked orthophotos (1:10,000).

1.5.2.2 Department of Meteorology

As described above, data for 34 rainfall stations are collected by the Department of Meteorology. Aside from the airport, the rain gauges are manually monitored by technicians. The airport station is a synoptic station with all the standard climatological parameters monitored. A data summary book, "The Climate of Seychelles" is under production and is expected to come out this year.

1.5.2.3 Division of Environment and MLUH

In addition to PUC Electric, both the Division of Environment and MLUH have digital (RCVIEW 3.2) mapping information for the islands. The basic digitisation (now used by both the Division of Environment and PUC Electric) was completed by MLUH and it was generally agreed that the most extensive and up to date digital mapping was available with them. However, the other institutions have carried out their own additional updating and digitisation based on their particular needs and their mapping should also be reviewed for use in a hydrogeological map.

1.5.3 Quality of Data

1.5.3.1 Public Utilities Corporation

The groundwater data, although somewhat limited, are generally of good quality. Although no set protocol is followed for quality checking of data, an informal checking of data accuracy is carried out as data are entered. The data contained in the few groundwater investigations that have been carried out appears to generally also be of good quality, although not in digital format.

1.5.4 Resources Available for Maintenance

A single hydrological technician is responsible for the hydrological database, with assistance from the hydrologist. Given the very limited amount of groundwater data present in the country, the level of resources is fully sufficient.

1.6 GROUNDWATER MONITORING

1.6.1 Institutional and Legal Framework

PUC-Water is the only entity responsible for all water resources data. Groundwater monitoring has two components: a monitoring network of groundwater levels on Mahe and water level, abstraction and EC monitoring for the production boreholes on La Digue. Water levels in the monitoring boreholes are measured manually on a weekly basis. Data are recorded in logbooks by field technicians. The bulk of data collection began in 1995. Boreholes on La Digue have been periodically monitored since 1987. However, data collection has not continued on all boreholes primarily due to some going dry or being blocked. A summary of the type of monitoring is presented in Table 4 and available data in Table 5.

Table 4. Summary of PUC Monitoring

Type and number of monitored points	Measured Parameters	Frequency	Comments
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Boreholes (27)	Water levels, EC	weekly	Data in database
Boreholes (2)	Abstraction	daily	Data in logbook (paper format); La Digue island
	Full chemistry	monthly	1987 to 1997; discontinued as no deterioration was observed

Table 5. Summary of Water Level Monitoring Data

Borehole	Location	Last data available
Mahe B11	Anse Royale	19/12/01
Mahe B11A	Anse Royale	19/12/01
Mahe B12	Anse Royale	19/12/01
Mahe B16	Anse Royale	19/12/01
Mahe B13	Anse Royale	5/4/99
Mahe B14	Anse Royale	29/8/95
Mahe B15	Anse Royale	9/9/87
Mahe B1A	Intendance	19/12/01
R1	Rochon	Blocked 29/11/00
R2	Rochon	3/4/02
R3	Rochon	3/4/02
BE17	Bon Espoir	2/4/02
AB20	Bougainville	19/12/01
HP1	La Gogue	3/4/02
HP2	La Gogue	3/4/02
HP3	La Gogue	3/4/02
LG1	La Gogue	3/4/02
LG2	La Gogue	3/4/02
LG3	La Gogue	3/4/02
LG4	La Gogue	3/4/02
LG5	La Gogue	3/4/02
LG6	La Gogue	3/4/02
FVE11	Fairview	12/6/01
FVE12	Fairview	2/4/02
TM13	Takamaka	Cover damaged 4/10/01
TM14	Takamaka	2/4/02
LD1	La Digue	15/5/00

I.6.2 Monitoring Network and Frequency

The monitoring network covers the "Inner Islands" where more than 90% of the population lives. Groundwater development has not yet occurred in the "Outer Islands". Water levels are generally measured on a weekly basis. Abstraction from production boreholes on La Digue is measured daily by the operator. The EC for the production boreholes is measured monthly in the field.

I.7 HYDROGEOLOGICAL MAPPING

I.7.1 Existing Hydrogeological mapping

There are no hydrogeologic maps for the Seychelles.

I.7.2 Existing Geological Maps

There are two geologic maps for the main islands of the Seychelles contained in a report on the geology of the islands (Baker, 1963). There is a colour map including Mahe, Praline, La Digue and nearby islands and a black and white map including Silhouette, Ile du Nord and Aldabra Atoll. The maps are at a scale of 1:50,000. A summary of the legend is provided in Table 6.

Table 6. Geologic Maps Legend Summary

Legend	Details of legend
Geologic units	Colored or numbered polygons Dolerite dikes
Geologic boundaries	Straight line: observed Dashed line: approximate Dotted line: gradational
Other geologic features	Faults, quartz veins, shear zones
Topography	250 ft. interval contours
Other features	Springs and water supply head works Rivers and streams Margin of reefs, boat passages Sandy beaches Fresh water and saline swamps Trig stations Principal points and numbers: air photos Tarred roads, tracks, footpaths

The geology of Mahe has been digitised from this map (Autocad format) and is available from the Ministry of Land Use and Habitat.

I.7.3 Existing Topographic and other Mapping

The Department of Surveys and Mapping sells topographic and orthophoto maps for all of the islands at scales ranging from 1: 2,500 to 1:100,000. Most of these maps date from the 1960s and are considerably out of date.

Digital topography and other physical features have been prepared by the Ministry of Land Use and Habitat GIS Section. The features have been created as shape and drawing (Autocad) files in Arcview, version 3.2. Although some information needs to be updated, the quality of these features is considered to be good. The type of features, in addition to topography, that are available include roads and tracks, forests, wetlands, rivers, high water mark. Contours are available for the main islands at 5, 10 and 20 m intervals.

An Arcview format digital map of Mahe, Praline and La Digue is also maintained by the PUC-Electric Division. It contains the above features and is also linked to 1:10,000 georeferenced orthophotos.

The GIS Section of the Ministry of Environment is in the process developing an Atlas of coastal sensitivity, focussed mainly on the vulnerability in relation to oil spills.

1.8 DATA AVAILABLE FOR A SADC HYDROGEOLOGICAL MAP

As there is no existing hydrogeological map for Seychelles, a national map would have to be developed as part of the SADC hydrogeological map. Most likely this could be based largely on the existing geological maps. These maps are in digital format. Given the relatively simple geology of the islands, a hydrogeological map could be based on, for example, the definition of four aquifer units:

1. Aquifers in fractured and/or weathered bedrock (granitic areas of main islands)
2. Aquifers associated with fractured intrusions and country rock (mapped dykes)
3. Aquifers associated with extensive carbonate coastal plateaus (a unit demarcated on the geologic map)
4. Limited aquifers present in unconsolidated or weakly consolidated sands (atoll islands)

The few existing boreholes could easily be plotted and some characteristics of each of these units defined. The main derivative map possible for Seychelles would be rainfall. Topography, infrastructure, roads, boundaries, etc. are present in digital form and could then be overlaid.

1.9 COMMITMENTS AND CONCERNS

1.9.1 Commitments on Contribution to the Regional Mapping Project

Public Utilities Corporation

Assistance in accessing and compiling hydrological data can be provided.

Ministry of Environment

The GIS Section of the Ministry of Environment would like to be involved and may be able to provide GIS and map preparation assistance, depending on the exact timing and requirements.

1.9.2 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 the Seychelles.