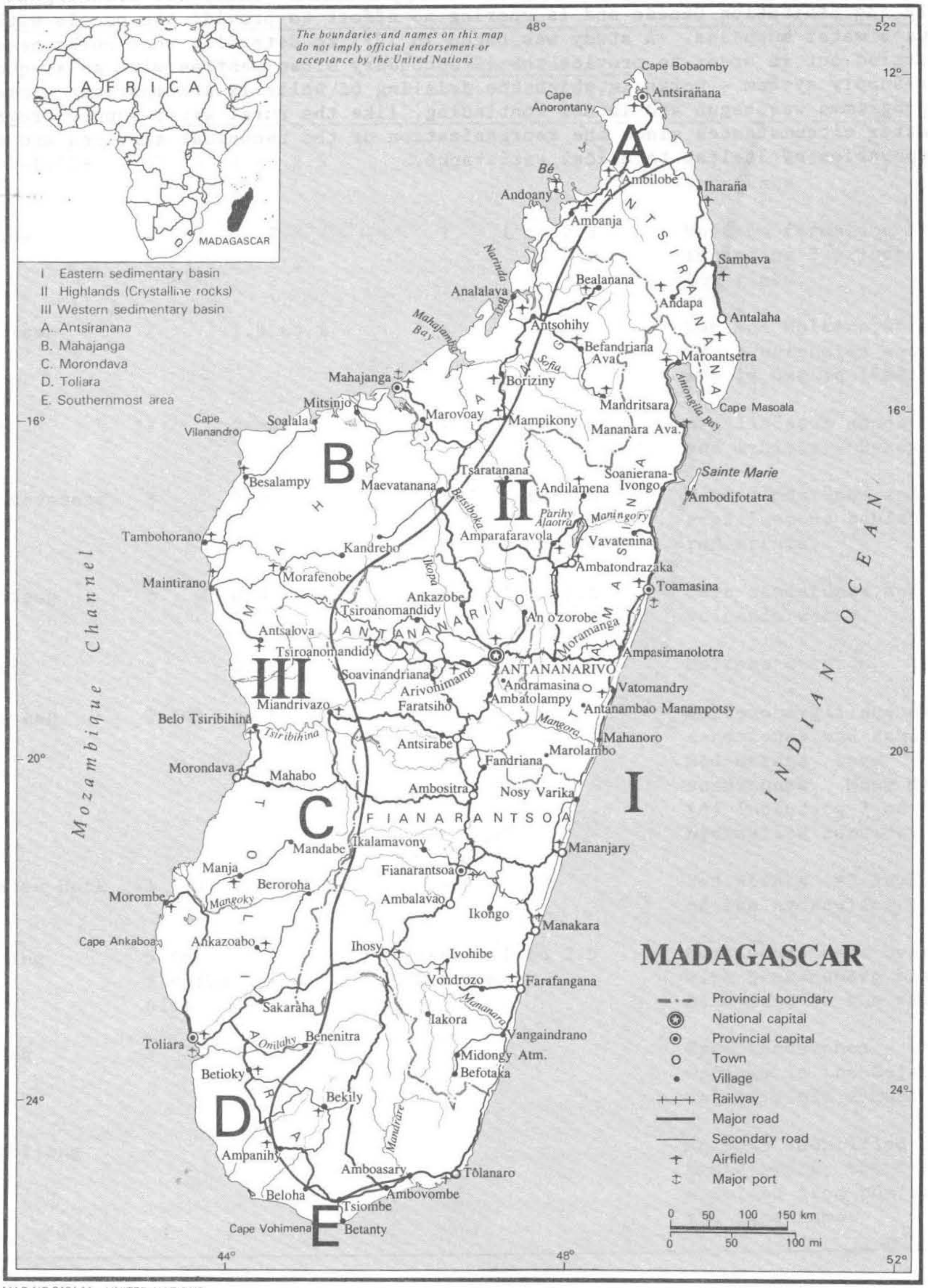
MAP 15. MADAGASCAR – MAIN MORPHOGEOLOGICAL UNITS



MAP NO.3484.11 UNITED NATIONS
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MADAGASCAR

Area: 592,000 km^2
Population: 9.5 million (1983 estimate)

I. BACKGROUND

Madagascar is a large island or small continent; it is 1,600 km long from north to south and 600 km wide. It is situated 300 km east of the African coast in the intertropical zone. Its geomorphology consists of an area of high plateaus, with an average altitude of 2,000 m, occupying two-thirds of the territory, four coastal sedimentary basins, a broad plain sloping gently down towards the sea in the west, a narrow steep-sided region in the east, a gently undulating peneplain in the extreme south, and a basin dominated by volcanic and limestone massifs in the north.

The country has two seasons: a rainy season from November to April influenced by the north-west monsoon; and a dry season from May to October influenced by the south-east trade winds. The average annual rainfall is 1,700 mm. The wettest region, the east coast, has annual rainfall of about 3,000 mm, while the driest region, in the extreme south, has less than 400 mm.

The average annual temperature is 17.8 °C. The west coast is the hottest region, with an average maximum of 32 °C. On the high plateaus the temperature range is 16-20 °C, and at the coast temperatures average 25 °C.

The potential evapotranspiration measured by the Thornthwaite method is between 2,000 and 1,300 mm and the real evapotranspiration is between 1,300 and 300 mm.

A study of the difference between rainfall and potential evapotranspiration (R-PET) has distinguished five zones of differing wetness:

- Zone I R-PET above + 1,000 mm: hyper-wet zone
- Zone II R-PET between + 1,000 and + 200 mm: wet zone
- Zone III R-PET between + 2,000 and - 200 mm: sub-wet zone
- Zone IV R-PET below - 400 mm: arid zone.

The table below presents some typical values for the flows of Madagascar's main rivers:

Region	River	Station	Area (km^2)	Slope (m/km)	Mean annual flow (m^3/s)	Flood: 1/25 years (m^3/s)	Flow coefficient %
Tsaratanana	Sambirano	Ambanja	2,980	33.20	131.83	10,500	73.43
	Ramena	Ambodimanga	1,030	40.35	54.46	4,500	78.14
East Coast	Ivoanana	Fatihita	835	12.24	50	1,700	91.23
	Ivondro	Ringaringa	2,545	7.87	95.96	4,000	64.62
	Mananjary	Atsindra	2,260	10.14	115.6	3,200	78.05
	Namorona	Vohiparatra	445	7.53	11.7	850	37.18
	Vohitra	Rogez	1,825	11.17	66.92	3,100	59.07
High Plateaus	Sisaony	Andramasina	318	7.06	6.04	350	37.47
	Andromba	Tsinjony	350	6.72	7.73	360	55.68
	Mangoro	Mangoro	3,600	2.63	87.96	2,150	57.43
	Mangoro	Ambodimanga	4,735	2.04	131.17	2,600	59.92
	Ikopa	Fiadanana	5,203	6.71	164.66	2,500	39.4
	Sahanivotry	PK 197	427	15.20	9.04	380	50.7
	Mania	Fasimena	6,675	5.27	132.83	3,300	51.35
	Manandona	Sahanivotry	973	9.55	24	650	62.48
North-west	Isinko	Ambodiroka	600	16.68	18.6	1,500	50
Centre-South	Zomandan	Ankaramena	610	40.40	10.63	1,800	52.10
	Ihosy	Ihosy	1,500	3.35	13.66	710	28
	Mananantanana	Tsitondroina	6,510	5.82	73.77	3,200	34.63
West	Morondava	Dabara	4,650	6.08	53.9	4,600	28

II. GEOLOGY

Madagascar has two main geological systems:

- The magmatic and metamorphic Precambrian basement, the island's skeleton, which forms the high plateaus over two-thirds of the territory;

- The coastal sedimentary basins with the following main formâtions:

Western sedimentary basin

Karroo system, consisting of continental formations dating from the Upper Carboniferous to the end of the Jurassic. It has three groups:

- Sakoa (Upper Carboniferous): illites, black schists, carboniferous sandstones, clays;

- Sakamena (Permian): micaceous schists and sandstones, grey clays with nodules, sandstones and red clays;

- Isalo (Triassic to Middle Jurassic): divided into Isalo I, Isalo II and Isalo III; poorly bonded conglomeratic coarse white sandstones with intersected stratification, clays.

Marine Middle Jurassic (marine equivalent of Isalo II and III): karstified limestones.

Upper Jurassic: limestones, marls, marly clays.

Cretaceous:

- Lower Cretaceous: marls and clays, some sandstones;

- Middle Cretaceous: mainly sandstones - coarse sandstones with intersected stratification - basaltic flows, some clays;

- Upper Cretaceous: argillaceous sandstones, marls, some basaltic flows, marly limestones.

Eocene: mainly limestones with some dolomitic limestone bands.

Oligocene: marls.

Neogene: sandstones and clays.

Quaternary: sands, sandy crust, alluviums and mangrove swamps deposits.

Diégo-Suarez basin

Permian: sandstone clays and schists.

Isalo I: continental sandstones.

Lower Jurassic: limestones and marl-limestones.

Middle Jurassic: limestones and dolomitic limestones, basaltic flows.

Cretaceous:

- Lower Cretaceous: marls, clays and sandstones;
- Middle Cretaceous: marls and sandstones;
- Upper Cretaceous: sandstones.

Eocene: limestones.

Quaternary: dunes, coral reefs, mangrove swamps, alluviums.

Eastern sedimentary basin

Cretaceous: marls, limestones, volcanic deposits, and especially sandstones.

Neogene: basaltic flows and clays.

Pliocene: clays.

Quaternary: beach sands, dunes, alluviums.

Far-south basin

Continental Neogene: clays and sandstones, argillaceous sands.

Quaternary: sand dunes and sandy surface formations.

III. GROUND WATER

The government services and other organizations concerned with water resources are:

Ministry of Industry and Trade

The Department of Mines and Energy, with:

- The Energy Service (Hydrogeology Division), responsible for ground-water prospecting, exploitation and protection;
- The Drilling and Equipment Division, responsible for drilling work.

Ministry of Transport, Supply and Tourism

The National Meteorology Service, with its Hydrometeorology Division.

Ministry of Farm Production and Agrarian Reform

The Hydraulics Service, responsible for irrigation.

JIRAMA

A state enterprise responsible for water distribution in urban areas.

Attached to the Office of the President of the Republic

The small-scale water-supply operation;
The small-scale works operation;
The water-supply operation for the south.

Private companies

SOMEAH (Hydraulic Studies and Applications Company of Madagascar) and its subsidiary SOGREAH;

SIF (drilling company).

The study and evaluation of ground water is the responsibility of the Hydrogeology Division (Energy Service, Department of Mines and Energy, Ministry of Industry and Trade).

The Division has four hydrogeologists, five technical assistants specializing in hydrogeology, boreholes and wells, four crew foremen, and about 100 workmen.

The available equipment includes hand-drilling rigs, a full set of test-pumping equipment, two sets of electrical geophysical prospecting equipment and a mechanical drill. Aerial photography is not yet used to any extent. The first hydrogeological studies began in 1910 as part of geological prospecting by technicians of the French colonial administration. This administration established a geological service to carry out geological and hydrogeological reconnaissance work.

The first summary reports on the geology of Madagascar were published in 1929 and contained information about ground water and mineral and thermomineral water. Drilling operations were carried out in the southern basin in 1952, 1953, 1955 and 1959, and in the western plains (Tuléar-Marovoay) in 1954 and 1956, and electrical geophysical prospecting was carried out in the southern basin by SIF. In 1960 we saw the creation in the Malagasy Administration of a hydrogeology office in the department responsible for geology, mines and energy in Madagascar. This body was to continue the hydrogeological study of the island, with financing from various sources. An aerial photography study was made of the southern basin. Still in the south, major deep-drilling work was carried out from 1961 to 1965 with FAC financing and from 1963 to 1965 with United States financing (IDA).

In 1968-1969 the United Nations began a large hydrogeological study project in the western basin between Tuléar and Morondava, with electrical geophysical prospecting (CGG), and drilling and test pumping (BRGM).

In 1960 the Malagasy Administration began the systematic study of ground-water resources to supply the country's towns, and in 1971 funds were made available to finance a project entitled "Specific hydrogeological studies". In addition, petroleum drilling in the western basin provided considerable hydrogeological information. Summary reports on the information obtained during these works were published, and in 1972 a project to produce a hydrogeological map of Madagascar was initiated by the Malagasy Government.

The following table presents the main data at present available on Madagascar's aquifers.

Aquifer depth Geological period	Geographic location	Well or borehole depth (m)	Yield	Hydrogeological characteristics Hydraulic conductivity K m/day	 Transmissivity T m^2/day	 Storage coefficients S %
Isalo I (from 50 m)	West-coast basin					
	Majunga basin					
	- Antsohihy	120.06	0,19			
	Toliary basin					
	- Bezaha	168	208 l/s artesian			
Upper Jurassic	Tuléar basin					
Argovian (428–572 m deep)	- Manera (Argovian sandstone)	1,300 (oil well)	240 l/s artesian			
Lower Cretaceous	Majunga basin					
Hauterivian (Sitampiky sandstone)	Tsaramandroso	20	0.7			
Middle Cretaceous	- Majaunga basin					
Aptian (continental sandstone)	Madirovalo	67	1.7			
Cenomanian - Ankarafantsika sandstone	Majunga basin					
	Mahajamba	40	66.6 l/s artesian			
	Manaratsandry	132.6	5.5 l/s artesian			
	Amboromalandy	F_1 = 51.90 F_2 = 65	23 l/s artesian 21 l/s artesian			

Aquifer depth Geological period	Geographic location	Well or borehole depth (m)	Yield	Hydrogeological characteristics Hydraulic conductivity K m/day	 Transmissivity T m^2/day	 Storage coefficients S %
Albian - Cenomanian Tsiandava sandstone (white to red coarse sandstone)	Morondava basin Manamby (Mahabo) (UN-BRGM boreholes) 1970	S 22 = 330 Borehole = 250 to 500	14 l/s artesian 4 to 7			
Upper Cretaceous						
Santonian	Majunga basin					
Continental sandstone or Marovoay sandstone	Marovoay Ambolomoty	128 40	35.5 l/s artesian 0.2			
Santonian	Morondava basin					
Manja group: Santonian sands (20-50 m)	Manja (UN-BRGM boreholes) 1968-1969	S12 = 140 S13 = 165	1	40	1,550	2.10^{-2}
Eocene	Majunga basin					
Paleocene-Ypressian Mahabibo limestone (outcropping)	Majunga (boreholes to supply the town) 30/10/69 testing	Amboaboaka well 6	63	860	5,200	
		Borehole S3 Ampombonavony 50	32	130	6,000	3.10^{-3}
		Borehole S4 Antranotakatra 27	27.6			
Lower Eocene coarse sandstone (25-300 m, east to west)	Morondava basin Dabara (Mahabo) UN-BRGM boreholes 1970	S23 = 317.52 S24 = 152.88 S25 = 70 Borehole 50 - 100	16.7 l/s artesian 3.5 l/s artesian 19 l/s artesian 4.16 to 7.5			

Aquifer depth Geological period	Geographic location	Well or borehole depth (m)	Yield	Hydrogeological characteristics Hydraulic conductivity K m/day	 Transmissivity T m^2/day	 Storage coefficients S %
Eocene limestone (30-90 m)	Morondava basin					
	Befandriana plain	S2 bis = 152	2.92 (relative specific yield)			
		S3 = 160	5			
	UN-BRGM boreholes, 1969	S4 bis = 128	4.37			
		S9 = 75	18.7 (relative specific yield)		725	2.10^{-4}
Eocene limestone, more or less marly (30-100 m)	Beravy plateau (UN-BRGM boreholes) 1969	S10 = 172 S11 = 100.40				
Eocene limestone (outcropping)	Tuléar basin					
	Toliary (boreholes to supply the town)	Miary boreholes				
		F_1 = 34	83.3			
		F_3 = 41.90	14.5			
		F_4 = 41.20	66.3			
Post-Eocene						
(Neogene-Quaternary surface formations)	Majunga basin					
(a few metres) Surface sand formations, sand-sandstone crust	Majunga area	2 to 15	0.46			
Alluviums	Mampikony	10 to 20	8.5			
Neogene-Quaternary	Morondava basin					
Medium-coarse sand, argillaceous in places	Mahabo (UN-BRGM boreholes)	S16 = 167.38	0.24		70	
		S18 = 164.78	0.04		35	
		S19 = 164.78	0.30		600	
		S27 = 30	2			

Aquifer depth Geological period	Geographic location	Well or borehole depth (m)	Yield	Hydrogeological characteristics Hydraulic conductivity K m/day	 Transmissivity T m^2/day	 Storage coefficients S %
<u>Quaternary</u>	<u>Toliary basin</u>					
Alluvial terraces,	Toliary	Star borehole = 50	0.8			
Quaternary dunes			0.6	12.96	500	2 - 4.5 10
Fine to medium clay-marl			0.7			
sands (3-6 m)		SNHU borehole				
		38.20	1			
		37.80	1	11.75	300	
Quaternary calcareous		Sumatex borehole				
sands (7 m)		60	3.5	8.64	4	
Medium, slightly		Miary borehole				
argillaceous, alluvial		12.80	1.7	24.18	200	
sands (4 m)		14.80	2.5	28.99	300	
	<u>Far-South Basin</u>					
<u>Neogene</u>						
Sand-sandstone clays	Ankatrafay	104.7	1.55			
(20-50 m)	Beantsiva	36	1.33			
	Ankilibeara	16.25	0.04			
	Ambaro	40.10	0.0027			
	Erada	127.50	0.019			
	Masina	46.50	0.13			
	Etrobeke		0.55			
	Antreaky		0.58			
	PK 328.5 (Bemamba)	15.50	0.03			
<u>Quaternary</u>						
(a few metres)						
clay-limestone sands	Soalara		0.79			
	Antsirafaly		0.33			

Aquifer depth Geological period	Geographic location	Well or borehole depth (m)	Yield	Hydrogeological characteristics		
				Hydraulic conductivity K m/day	Transmissivity T m^2/day	Storage coefficients S %
Recent dunes	Anakao		2.6			
Alluviums	Ampotaka-Menarandra	20	11.8	131.7	2,160	0.05
Quaternary: sands	Saodona	22	1.16			
and sandstones with	West Melaindoza		0.42			
limestone bonding	East Melaindoza		0.62			
	Ionka		1.19			
	Egaha		2.23			
	South-West Elanga	10.30	0.9			
	Ankitry	164.7	0.043			
	Benonoka	166	0.55			
Argillaceous sands (first aquifer at 7-10 m)	Ambovombe	10-15	0.016 0.033 0.56			
Argillaceous sands (second aquifer at 20-25 m)	Ambovombe	25-30	0.34 to 4	8.64 to 5.76	129.6 to 86.4	
Surface eolian sands (6-10 m)	Beloha	6 to 8	0.17	0.50	2.16	
(6-20 m)	Ambondro	9 to 20	0.29	1.7	8.64	
	<u>East Coast Basin</u>					
<u>Cretaceous</u>						
Sandstone-clay sands (7-30 m)	Vatomandry	40	0.2			
<u>Quaternary</u>						
Surface beach-sand formations (0-30 m)	Tamatave	15 to 30	1.5 to 6	70	432	
(0-30 m)	Vatomandry	15	0.5		52	

Aquifer depth Geological period	Geographic location	Well or borehole depth (m)	Yield	Hydrogeological characteristics: Hydraulic conductivity K m/day	Transmissivity T m^2/day	Storage coefficients S %
Alluviums, medium - coarse sands (to 5 m)	Ademaka Lopary	16.50 3.40	30 10	180 450	1,555 60	
	High Plateaus					
Recent formations						
Alluviums, medium - coarse sands (4-6 m)	Antananarivo Moramanga	25 18	3 to 6 5	113.6 to 40 75	2,160 to 43 700	3 to 8.7 10^{-4}
Alteration stratum coarse sands (5-10 m)	Antananarivo (Mabitsy)	9.80	0.4	0.4	3	
	Diégo-Suarez basin					
Alluviums	Anamakia plain	S_2 = 16.00 S_3 = 18.80	0.2	30	250	
Sand dunes	Orangea	S_2 = 22.60	0.01			

Chemical properties of the water

The water can be divided into three main groups with respect to its chemical properties:

- Water with very low mineral content: resistivity at 18° over 10,000 cm (crystalline high plateaus);
- Water with average mineral content: resistivity at 18° between 1,000 and 10,000 cm (west and east coasts);
- Water with high mineral content: resistivity at 18° below 1,000 cm (for south: Ancient Neogene and Quaternary sand aquifers; sometimes surface water and alluvial aquifers, probably examples of contamination with Neogene water).

Madagascar's water generally has a high bicarbonate content. It often has a high iron content, especially in alluvial aquifers, the Cretaceous aquifer and the aquifers in Recent formations.

The water of the Eocene and Jurassic periods and sometimes the water of Recent formations has calcium and magnesium facies. The Neogene aquifer is rich in $NaCl$ and KCl. Heavy pumping from the coastal aquifers can cause increased salinity.

Since its creation, the technical department responsible for hydrogeology in Madagascar has tried to acquire the basic knowledge needed for the rational exploitation of the country's ground water, i.e. general data about the aquifers, their geological characteristics, their geographical distribution, the depths of the installations required, the available yields, and the quality of the water of the aquifers.

At present (1985) the efforts are being concentrated on research and the development of installations suited to the conditions found in Madagascar, especially with a view to the exploitation of the alluvial and sand aquifers. The technical data is still insufficient, and additional more detailed studies are required in order to establish the specific hydrogeological characteristics of the various aquifers inventoried. Hydrogeological study programmes are therefore to be undertaken, including test pumping to calculate the permeability, transmissivity and storage coefficients of the aquifers.

III. EXPLOITATION OF THE GROUND WATER

Surface-water and ground-water resources are exploited by the State through the following technical bodies:

- The Hydrogeology Division, which is responsible for construction of tapping installations (wells and boreholes up to 25 m deep, wells with horizontal drains). The Division comes under the Energy Service, Department of Mines and Energy, Ministry of Industry and Trade.

  This Division is fully equipped to construct wells, with five hand-drilling rigs, and one Tone Boring 200 rig which can drill 6 to 8 inch boreholes, 150 m deep. The staff, whose numbers and qualifications are given above, includes engineers who provide basic hydrogeology training with courses in water drilling, and technicians specializing in all aspects of well and borehole work;

- The Drilling and Equipment Division, another section of the Department of Mines and Energy, Ministry of Industry and Trade, which is responsible for deep-drilling work.

  This Division has 2 drilling engineers, 15 drilling technicians trained in Malagasy technical schools, and about a 100 workmen. The available equipment includes: 2 hand-drilling rigs of 30 m capacity; 2 Failing Walker Neer FW N 30 combined rotary-percussion rigs of 150 m capacity (1,000 m per year); 1 Walker Neer WS 31 percussion rig of 150 m capacity (500 m per year); and 1 Walker Neer WS 21 percussion rig of 100 m capacity (400 m per year). The Division's present problem is the lack of spare parts for maintenance of the rigs.

  Private enterprise is represented by only one drilling company (SIF-Bachy).

The following towns are supplied with pumped ground water:

Town	Number of inhabitants (1981 estimate)	1981 consumption (m^3/year)	Aquifers
Majunga	82,000	5,961,640	Eocene limestone
Toliary	47,000	2,603,810	Eocene limestone
Marovoay	25,000	547,446	Cretaceous sandstone
Morondava	23,000	429,683	Quaternary sands
Antalaha	20,000	439,368	Alluviums
Mananjary	17,000	338,553	Alluviums
Antsohihy	12,000	356,439	Isalo sandstone
Morombe	10,000	70,297	Quaternary limestone
Maintirano	10,000	147,778 (1980)	Quaternary sands
East Fenerive	9,000	101,436	Alluviums
Maevatanana		89,402	Alluviums
Ambanja		209,899	Alluviums
Mampikony		32,461	Alluviums
Betroka		58,686	Alluviums
Madirovalo		68,101	Cretaceous sandstone
North Befandriana		72,031	Alluviums
Ambato-Boeni		54,701	Quaternary sand-sandstone
Bezaha		21,747	Isalo sandstone
Mahabo		43,287 (1980)	Alluviums
Bekily		24,128	Underflow
Beloha		1,831 (6 months, 1982)	Recent Eolian sands
Tsihombe		14,763	Underflow
Mitsinjo		22,169	Eocene limestone
Total		11,709,656	

The following large towns have mixed water supplies (surface and ground water):

Town	Number of inhabitants, 1981	1981 consumption (m^3/year)	Water resources used
Fianarantsoa	67,287	1,916,565	Surface water and springs rising from sand aquifers
Antsirabe	44,071	1,428,001	Springs rising from fissured basalt stratum and lake water (100 m^3/h).
Total	111,358	3,344,566	

Little is yet known about the use of ground water to supply rural dwellers. However, a rough estimate of the volume of ground water drawn off can be made on the following bases:

- 266 village wells and boreholes have been listed. Assuming an average unit exploitation rate of 1.5 m^3/h and 10 hours of pumping per day, the annual volume drawn off by these installations will be about one and a half million cubic metres;
- A water distribution system in one of the southern regions of Madagascar uses six wells yielding 76 m^3/day. Thus, over a year the volume drawns off will be about 30,000 m^3
- In the high plateaus region the villagers are able with their own means to dig wells to tap the sand aquifer. Unfortunately, these wells have not been listed and the volume of water drawn off is not known.

The following are the main factories supplied with ground water:

Company name	Business	Aquifers exploited
Kafema (Diégo-Suarez)	Torrefaction	Alluvial sands
Sotema (Majunga)	Textiles	Eocene limestone
Sumatex (Toliary)	Textiles	Quaternary sands
Toly (Toliary)	Mechanical engineering	Quaternary sands
Star (Toliary)	Brewing	Quaternary sands
Zema (Amboasary)	Fertilizers	Alluvial clay sands
Solima (Toamasina)	Oil refining	Beach sands

Company name	Business	Aquifers exploited
Zeren (Toamasina)	Fertilizers	Beach sands
Ramanandraibe (Toamasina)	Clove processing	Beach sands
Kobama (Antsirabe)	Flour milling	Surface clay sands

The use of ground water for irrigation is confined to the following cases:

Location	Farming activity	Aquifers exploited	Type of exploitation
High plateaus	Rice-growing	Sand	Springs and dams between hills
Morondava plain	Rice-growing	Cretaceous	Artesian boreholes
Majunga plain	Tobacco-growing	Alluvial	Pumping

The following are two examples of the use of ground water for livestock-raising:

Location	Activity	Aquifers exploited	Type of installation
Majunga plain	State zebu farm (Fafifama), Private livestock-raisers	Surface Neogene and Quaternary	Several wells
Far-south basin	Private zebu farms	Surface sands	Several wells and ponds

The water requirements of industry and agriculture have not yet been evaluated. However, there has been no difficulty in finding surface-water and ground-water solutions for the water-supply problems of industry and agriculture.

The following problems have been encountered in the exploitation of ground water:

- The relative under-exploitation of known ground-water aquifers;
- Intrusion of salt water in the deep aquifers of the semi-arid zone in the far south, which imposes a constraint on proposed solutions to the people's water-supply problems;
- The excessively high iron content of the water of the alluvial aquifers and sometimes of the Cretaceous aquifers;
- Intrusion of salt water in the coastal aquifers following excessive pumping.

IV. CONCLUSION

Ground water is of great economic and social importance in Madagascar:

- Several towns are supplied from ground-water resources;

- In the high-plateaus and east-coast regions a large part of the rural population obtains its water from wells tapping the sand or coastal sand aquifers;

- The water of the sand aquifers is tapped by various means and used to irrigate the rice fields in the alluvial valleys between the hills on the high plateaus;

- The largest factories in the Majunga and Tuléar regions obtain their water from ground-water aquifers;

- Cattle farming in the Majunga, Morondava and Tuléar regions depends on the ground water drawn off from wells and boreholes of medium depth;

- In the semi-arid region of the far south, ground water is often the only resource available to guarantee the survival of the people and their animals.

The cost of ground water, including construction and annual operating costs, drawn from a well with an estimated life of 20 years and an average yield of 40 m^3/h, is about one Malagasy franc per cubic metre. This is an average price, for in the southern region where the water is drawn from the wells by hand, water vendors sell the water at 1,200 to 4,000 Malagasy francs per cubic metre, while the State water distribution corporation (JIRAMA) sells it to the consumer at about 40 Malagasy francs a cubic metre.

Given the increase in water requirements and the limitations on use of surface water, the exploitation of ground water is expected to increase in Madagascar. The major technical difficulties have been removed and now the exploitation of the aquifers seems to depend only on the material means and availability of financing, especially with respect to the use of ground water in rural areas and the management and maintenance of the installations in particular. The effort will therefore have to be focussed on strengthening the ground-water development organizations by furnishing them with sufficient material and financial means and establishing an adequate structure for the management and maintenance of water-supply installations in rural areas.

V. REFERENCES

The documents on Madagascar's ground water available in the archives of the Hydrogeology Division (Ministry of Industry and Trade) include:

- An AY catalogue, containing 1,091 documents;

- An HY catalogue, containing at present 733 reports on the hydrogeological works carried out in Madagascar by the technicians of the Hydrogeology Division;

- An inventory of water points and maps indicating their location on scale 1:500,000 and 1:100,000.

- Unpublished maps:

  - Map of water resources on scale 1:2,000,000;

  - Maps of aquifers on scale 1:500,000:

    - Majunga region;
    - Tuléar region;
    - Far-South region;
    - Morondava region;

  - Maps of isopiestic curves on scale 1:500,000:

    - Morondava region;
    - Far-South region;

  - The Majunga Eocene aquifer of the Morondava sedimentary basin in the Tuléar coastal plain;

- Study on the Mahafaly Eocene limestone plateau;

- Study on the Far-South sedimentary basin;

- Study on the Antananarivo alluvial plain.