2-8-7 Present Environmental Status of the Study Area

There are severe environmental problems in Monduli district (Environmental Profiles, Mbulu and Monduli Districts, NEI/IWACO/AGRIS, 1995), such as:

- Overgrazing and creeping desertification of large parts in the north and north-eastern parts;
- Intensive competition for scarce water resources (game, livestock, drinking water, irrigation);
- Destroying important wildlife habitats, due to obstruction of migrating corridors by human activities.

(1) Protected Areas

Although the Study Area does not cover any protected area, the Study Area is surrounded by several protected areas such as national parks, forest reserves, a game reserve and game controlled areas: They are:

National Parks:
- Lake Manyara
- Tarangire
- Arusha

Forest Reserves:
- Monduli
- Burko
- Lossimingori

Game Reserve:
- Mount Meru

Game Controlled Areas:
- Mto wa Mbu
- Simanjiro
- Lolkisale
- Lake Natron

(2) Protected Habitats of Animals and Birds

For the case of Masai Steppe in and around the Study Area, there is an eco-system. Almost all animals are available in every of these protected areas; however, in this IEE confirmation on the proportion of distribution in the Study Area could not be available.

According to information so far obtained from the offices concerned, the following birds could be observed in the Study Area:

- Love Bird (yellow colored Love Bird); possibly available
- Bustards; available in the whole Study Area
- Saddle Stork; available in the whole Study Area
- Violet Crested Furaco; available in the whole Study Area
- Goliath Heroin; available in the whole Study Area

(3) Cultural Places and Historic Spots

There is one historic place and two cultural locations:

- Engaruka (historic)
- Lashaine (cultural)
- Oldonyo-Lengai (cultural)

These locations are not officially alienated or leased by the Government. However, the case of the historic place, Engaruka is known as one of the oldest towns and there are remains of old buildings. Two cultural places, Lashaine and Oldonyo-Lengai are popular for the annual Masai traditional activities or visits to the areas.

(4) Water Right

The Monduli water supply project distributes water to residents, institutions and estates under five registered water rights (Table 2-13). Amount of water to Monduli Coffee Estate and Monduli town are a minimum 45,000 liters per day according to the water rights AR 983. Although various small dams are located in the surrounding villages as presented in section 2.7, water rights are not settled because water storage is not available throughout the year.

(5) Water Quality

With respect to the water quality of the Study Area, the chemical water quality of the existing water sources is generally adequate; but in some areas, i. e., conductivity values of Tukusi spring and Mswakini borehole are not acceptable; turbidity values are high in most water sources. Water in the reservoirs is found to be bacteriologically contaminated, which may be due to animal and human being contamination.

2-9 Natural Conditions

2-9-1 Topography

The Study Area is a roughly rectangular shape, being located between latitude 3 °15′ and 3 °55′ S and between longitude 35°55′ and 36°40′ E. The average axes are 70 km long in the east-west direction and 85 km long in the north-south direction. The total area is approximately 5,950 km^2 including the Study Area and its catchment area.

The Study Area is bordered on the north by the three major volcanic mountains of Monduli (2,660 mamsl), Burko (2,140 mamsl) and Essimingor (2,300 mamsl), and on the east by Arumeru district where a remarkable escarpment extends in a north-south direction on the western edge of the Engare Olmotoni river basin. On the south the Study Area is bordered by the Hill Oldonyo Lolkisale (2,130 mamsl) and on the west by the Great North Road.

The physiographic features of Monduli district are mainly related to volcanic activities, and only the southern part of the District is characterized by an elevated plateau of Precambrian rocks. The Neogene Lake Sediments were deposited in a former wide extension of Lake Manyara and occupy most of the southern part of the District.

Pronounced volcanic mountains, the Monduli, Burko and Essimingor, drains into several ephemeral rivers running toward south. These river systems join each other near Makuyuni and empty into Lake Manyara.

A major part of the Study Area is characterized by the flat plateau with associated volcanic cones. The plateaus are edged with tectonic scarps extending in a north-south direction. A remarkable fault-scrap with an east to west direction exists in the northern edge of the plateau. A large-scale broad valley exist in the north of the scrap, that is, the Ardai Basin where a bare land extends between the scrap and the Monduli mountains.

2-9-2 Geology

The Study Area is underlined with four major geological units; they are the Basement, the Older Extrusive, the Younger Extrusive and the Manyara Lake Beds.

The Basement is referred to as the Usagaran Group of Precambrian. It is composed of a varied type of gneisses, granulates, amphibolites, quartzites, meta-calc-silicates rocks, marbles and meta-igneous rocks, and occupies the southern part of the Study Area. The different types of volcanic activities have resulted in different topographical features in the northern half of the Study Area.

The Older Extrusives underlie the Monduli mountains and the faulted terrain of the lava plateau. The former forms the forest cover, dissected mountains of olivine basalt, basaltic conglomerate and trachyte rising 2,660 meters above sea level, while the latter forms lava plateaus of basaltic lava and pyroclastic beds with fault scraps in the edge of plateaus.

The Younger Extrusives are associated with the main phase of faulting. The Essimingor and the Burko are the main centers of this extrusive chiefly of nephelinitic and phonolitic lavas associated with pyroclastic beds. Small volcanic cones less than 200 m high are located in the lava plateaus.

The Manyara Lake Beds are deposited in the southwestern part of the Study Area. The beds are composed of fine-grained calcareous mudstone, marls and calcareous sandstones with horizontal beddings.

2-9-3 Hydrogeology and Groundwater

Four hydrogeological units underlie the Study Area; the Basement, the Plateau Lava, the Colluvial Deposits and the Lake Manyara Beds.

The Basement is chiefly composed of metamorphic rocks, and their weathered and fractured facies are expected as the aquifers. Depths to groundwater table experienced from the exploratory wells by RDD, Arusha are more than 60 meters deep. The results of test well drilling at Tukusi revealed that well yields were around one liter per minute from the aquifers of weathered gneiss.

The Plateau Lava is composed of alternating layers of basaltic lava, volcanic cinders (scoria), tuff and tuff breccia. Although fresh lavas underlie the plateau, they are subject to heavy weathering in broad wide valleys. Groundwater is expected to be developed in these weathered beds. An exploratory well at Mbuyuni shows that the depth to groundwater in fractured volcanic rock is more than 60 meters below the ground.

The exploratory well drilling has revealed that the Ardai and Eluanata basins are underlaid with the same lithological beds of the Plateau Lava which are composed of alternating layers of heavily weathered basaltic lava, scoriatic lava, tuff and volcanic breccia with a single bed of several meters in thikness. Five exploratory wells encountered cavern lavas rich in non-flammable, non-radioactive and non-poisonous gases. Depths to these cavern lavas range from 48 meters to 180 meters below the ground surface in the northern part of the Ardai basin.

The Colluvial Deposits underlie the foothills of the Young Extrusives at Monduli Juu and the basins of Ardai and Elianata. The deposits are composed of unconsolidated pervious and impervious beds, and have a thickness of less than ten meters in the Ardai basin and of more than 100 meters in Monduli Juu. The drilling test at Monduli Juu shows that depths to the water table, well yield, specific capacity and transmissivity are 72 meters, 20.7 liters per minute, 6.3 liters per minute per meter and ten square meters per day, respectively.

The Lake Manyara Bed is mainly composed of unconsolidated pervious beds, and groundwater potential in the beds is comparatively good according to the results of the exploratory wells at Mswakini and Makuyuni drilled by RDD, Arusha. Depths to water tables range from 24 to 31 meters, and the average specific capacity and transmissivity are 12 liters per minute and 23 square meters per day, respectively.

2-9-4 Rainfall and Surface Runoff

(1) Rainfall

The Study Area experiences distinct dry and rainy seasons. The rainy season is usually subdivided into both short and long rainy periods. The dry season lasts for five months from June to October with a mean monthly rainfall of not more than around 20 mm. Four rainfall stations with a data length of more than 20 years are selected among many rainfall stations in and around the Study Area to observe rainfall patterns in the Area as given below:

Selected Rainfall Stations

Station No.	Name of Stations	Altitude (m)	Data Length
93-36-033	Arusha Air Field	1,387	23 years : 1970-1992
93-36-014	Monduli Dist. Office	1,585	62 years : 1934-1994
93-35-024	Mbulumbulu Pr. School	1,829	50 years : 1942-1991
93-35-020	Kongoni Estate	1,676	51 years : 1941-1991

Annual rainfall fluctuates considerably between 350 mm and 1,600 mm. Mean monthly rainfall at selected stations is presented in the following table showing the average annual rainfall of 812 mm to 860 mm. The short rainy period extends from November to December, and the long rainy period lasts for three months from March to May with the peak rainfall in coming April.

Mean Monthly Rainfall in mm

Month	Arusha Air Field	Monduli Dist. Office	Mbulumbulu Pr. School	Kongigi Estate
Jan.	68	66	76	84
Feb.	70	75	71	76
Mar.	128	143	137	131
Apr.	212	219	256	214
May	88	83	112	98
Jun.	14	13	12	14
Jul.	6	3	4	7
Aug.	7	5	4	3
Sep.	6	5	7	4
Oct.	21	19	21	18
Nov.	91	84	67	67
Dec.	107	97	93	100
Annual	818	812	760	816

(2) Surface Runoff

Small rivers and many streams flow southward through the Study Area, all of which are seasonal, flowing for five to six months a year. Some of them rise locally, while others have their tributaries from other catchments outside the Study Area. No river gauging station has been established so far in the Study Area. Discharge data of two rivers at two stations in Mto wa Mbu, which are located close to the western part of the Study Area, were collected to take a general view of surface water runoff in and around the Study Area. The mean monthly runoff in terms of million cubic meters (MCM) and river yields in terms of mm of the rivers are given below:

Station No.24021
- Name of river : Simba
- Catchment area : 190 m^3
- Data length : 14 years

Station No.24031
- Name of river : Mto wa Mbu
- Catchment area : 148 m^3
- Data length : 18 years

Mean Monthly Runoff

Month	Station 24021		Station 24031	
	Runoff (MCM)	Yield (mm)	Runoff (MCM)	Yield (mm)
Jan.	2.14	11.3	1.42	9.0
Feb.	1.80	9.5	1.69	10.7
Mar.	2.30	12.1	20.9	13.2
Apr.	2.93	15.5	1.23	14.1
May	3.00	15.8	1.61	10.2
Jun.	2.54	13.4	1.50	9.5
Jul.	2.30	12.1	1.39	8.8
Aug.	2.20	11.6	1.39	8.8
Sep.	1.94	10.2	1.22	7.7
Oct.	1.98	10.4	1.18	7.5
Nov.	1.92	10.1	1.17	7.4
Dec.	2.14	11.3	1.07	6.8
Annual	27.19	143.3	17.96	113.7

The mean annual river yields are 143 mm for Simba river at station 24021 and 114 mm for Mto wa Mbu river at station 24031. Collecting runoff from mountains covered with forests, both rivers have steady annual runoff. Annual runoff coefficients at the above stations are estimated by applying rainfall data at Manyara Lake National Park. The annual runoff coefficients at the station 24021 range from 18 percent to 29 percent with an average of 24 percent, whereas the coefficients at station 24031 range from 11 percent to 32 percent with an average of 21 percent.

Table 2-1 ESTIMATE OF POPULATION IN 1994

No.	Village	Mean Annual Growth Rate (%)	Population in 1992	Population in 1994
1	Monduli Town	3.30	17,067	18,210
2	Lendikinya	4.00	2,655	2,873
3	Enguik (Monduli Juu)	4.00	3,780	4,090
4	Arkatan	3.52	1,768	1,895
5	Lossimingori	4.00	1,590	1,720
6	Lepurko	4.00	2,811	3,042
7	Meserani Juu	4.00	2,759	2,985
8	Nengungu	3.30	1,486	1,586
9	Moita Kiloriti	4.00	1,557	1,685
10	Moita Bwawani	4.00	3,636	3,934
11	Meserani Bwawani	3.99	1,065	1,151
12	Mbuyuni	4.00	3,420	3,700
13	Lolkisale	4.00	4,064	4,397
14	Tukusi	4.00	1,424	1,541
15	Makuyuni	0.69	3,554	3,604
16	Naitolia Sub-Village	0.69	1,242	1,259
17	Oltukai Sub-Village	0.25	688	691
18	Mswakini	4.00	2,210	2,391
19	Emairete	4.00	4,320	4,674
Total			61,096	65,428

Table 2-2 POPULATION DENSITY AND NUMBERS OF HOUSEHOLDS

Village	Area (km^2)	Population in 1994	Nos. of Households in 1994	Population Density per 1,000 km^2	Average Nos. of Family Member
Monduli Town	30	18,210	2,850	607.0	6.4
Lendikinya	126	2,873	660	22.8	4.4
Enguik (Monduli Juu)	54	4,090	530	75.7	7.7
Arkatan	58	1,895	214	32.7	8.9
Lossimingori	145	1,720	450	11.9	3.8
Lepurko	194	3,042	722	15.7	4.2
Meserani Juu	80	2,985	619	37.3	4.8
Nengungu	123	1,586	297	12.9	5.3
Moita Kiloriti	103	1,685	380	16.4	4.4
Moita Bwawani	139	3,934	666	28.3	5.9
Meserani Bwawani	80	1,151	548	14.4	2.1
Mbuyuni	192	3,700	783	19.3	4.7
Lolkisale	608	4,397	823	7.2	5.3
Tukusi	14	1,541	190	110.1	8.1
Makuyuni	437	4,863	1,221	11.1	4.0
Naitolia Sub-Village	(included in Makuyuni Village)				
Oltukai Sub-Village	45	691	150	15.4	4.6
Mswakini	91	2,391	526	26.3	4.5
Emairete	359	4,674	860	13.0	5.4
Total	2,878	65,428	12,489	22.7	5.2

Table 2-3 SELECTED 17 PRIMARY SCHOOLS

Name of Primary School	Year of Establishmt.	Nos. of Pupils			Nos. of Classes	Nos. of Teachers
		Male	Female	Total		
Monduli Demonst.	1975	285	338	623	8	22
Enguik	1976	149	71	220	7	6
Arkatan	1977	105	93	198	7	7
Lossimingori	1978	49	54	103	7	5
Lepurko	1977	149	95	244	7	6
Meserani Juu	1977	116	104	220	7	10
Nengungu	1963	285	281	566	7	13
Moita Kiloriti	1978	116	131	247	7	6
Moita Bwawani	1977	155	94	249	7	6
Meserani Bwawani	1977	69	38	107	7	4
Mbuyuni	1972	235	188	423	7	8
Lolkisale	1977	208	166	374	7	7
Tukusi	1991	77	65	142	7	5
Makuyuni	1970	171	154	325	7	12
Naitolia	1989	85	61	146	7	5
Mswakini	1977	112	93	205	7	9
Emairete	1975	220	117	337	7	11
Total		2,586	2,143	4,729	120	142

Table 2-4 LEARNING MATERIALS USED IN PRIMARY SCHOOLS

Name of Primary School	Teaching and Learning Materials
Monduli Demonstration	Demonstration charts, depicting human environment, flies, insects, such as cockroaches, etc.
Enguik (Monduli Juu)	Handhoes and posters
Arkatan	Posters
Lossimingori	No teaching aids except chalkboards.
Lepurko	Soaps, basins, towels, water iron-stoves, sponges lotion/cream, shoes and sandles.
Meserani Juu	Posters, textbooks and teachers' guides, handhoes, slashers, brooms and pangas.
Nengungu	Health charts and pamphlets on health care.
Moita Kiloriti	Demonstrating how to boil and conserve safe water for drinking
Moita Bwawani	Posters, relating to different nutritious dishes, textbooks.
Meserani Bwawani	Textbooks for each class which attends health and sanitation education.
Mbuyuni	Brooms made out of grass and pieces of sacks.
Lolkisale	Soap, iron-stove, tooth-brush (local), brooms made locally, slashers, and handhoes.
Tukusi	No teaching aids except chalkboards.
Makuyuni	Posters, threads, needles, clothes for sewing and brooms.
Naitolia	Textbooks and teacher's guides.
Mswakini	Posters, health charts
Emairete	No teaching aids except chalkboards.

Table 2-5 SUMMARY OF WATER SOURCE

Village	Source	Source Capacity	Remarks
TMA Pipeline		(m^3/day)	
Monduli Town	TMA Pipeline	45	TMA→Pump : 2.9 km Pump→Tank : 3.1 km
Meserani Juu	TMA Pipeline	43	L=6.7km, 4 DWP
Nengungu	TMA Pipeline	20	1 DWP
Total	1	108	
Spring		(m^3/day)	
Monduli Town	Kilimani	130	for Town use
- do -	Rasharasha	20	for Town use
Enguik	Oldeani	66	
Lolkisale	Leteti	69	
- do -	Lengolwa	35	
Tukusi	Four springs	11	
Emairete	Emairete	6	turbidity
Total	10	337	
Borehole		(m^3/day)	
Makuyuni	Borehole - 1	135	3 DWP
- do -	Borehole - 2	-	pump broken
Mswakini	Borehole - 1	75	fluoride
Total	2	210	
Shallow Well			
Lolkisale	Negligible small		
Tukusi			
Moita Kiloriti			
Oltukai			
Emairete			
Small Scale Dam	(Nos. of Dams)	(1,000 m^3)	
Lendikinya	2	157	
Enguik	1	51	
Arkatan	5	3,070	
Lepurko	2	209	
Meserani Juu	1	77	
Nengungu	3	123	
Moita Kiloriti	3	340	
Moita Bwawani	2	71	
Meserani Bwawani	2	103	
Mbuyuni	2	115	
Makuyuni	4	179	
Naitolia	2	162	
Emairete	3	355	
Total	32	5,012	

Notes: DWP = Domestic Water Point
L = Length of conveyance pipes

Table 2-6 SUMMARY OF WATER SOURCE BY VILLAGE

Village	Source Capacity				
	Small Dam (1,000 m^3)	TMA Pipeline (m^3/day)	Spring (m^3/day)	Borehole (m^3/day)	Shallow Well (m^3/day)
Monduli Town	-	45	150	-	-
Lendikinya	157	-	-	-	-
Enguik	51	-	66	-	-
Arkatan	3,070	-	-	-	-
Lossimingori	-	-	6	-	-
Lepurko	209	-	-	-	-
Meserani Juu	77	43	-	-	-
Nengung	123	20	-	-	-
Moita Kiloriti	340	-	-	-	-
Moita Bwawani	71	-	-	-	-
Meserani Bwawani	103	-	-	-	-
Mbuyuni	115	-	-	-	-
Lolkisale	-	-	104	-	0
Tukusi	-	-	11	-	0
Makuyuni	179	-	-	135	-
Naitoila	162	-	-	-	-
Oltukai	-	-	-	-	-
Mswakini	-	-	-	75	-
Emairete	355	-	-	-	-
Total	5,012	108	337	210	0

Table 2-7 INVENTORY OF SMALL DAM

No.	Village	Name of Dam	Coordinate Long.	Coordinate Lat.	Altitude (m asl)	Dam Size (m) L	Dam Size (m) B	Dam Size (m) H	Water Depth (m)	Storage Capacity (1,000 m^3)	Catchment Area (km^2)	Water Yield (mm)	Remarks
1	Monduli Town	Ardai Lasha	3°21.6'	36°24.0'	1,330	271	4	2	2.5	113	36.7	3.08	Not working
2	-do-	Ardai No.1	3°21.8'	36°23.2'	1,365		3	2	2	5	0.8	6.25	Not working
3	-do-	Ardai No.2	3°23.5'	36°22.3'	1,345	148	3	2	3.5	45	4.3	10.47	Not working
4	Lendikinya	New Alkaria	3°20.6'	36°19.2'	1,485	210	4	6	4	142	14.8	9.59	LCT
5	-do-	Mrandawa	3°19.6'	36°23.1'	1,420	106	3	2	2	15	0.6	25.00	
6	-do-	Alkaria	3°20.7'	36°19.0'	1,485	250	4	7		-	-	-	Not working
7	Enguik	Enguik	3°13.4'	36°24.9'	1,315	112	4	6	4	51	6.4	7.97	For livestock use only
8	Arkatan	Manja	3°22.7'	36°16.6'	1,395	320	5	7	3.5	2,678	122.6	21.84	
9	-do-	Nadosoito	3°24.9'	36°22.9'	1,360	292	4	2	3	362	82.8	4.37	
10	-do-	Nongilili-2	3°24.5'	36°19.9'	1,355	100	2	4	4	19	0.5	38.00	LCT
11	-do-	Nongilili-1	3°24.6'	36°20.0'	1,360	160	3	1	1	6	0.4	15.00	Spill to Nongilili-2
12	-do-	Loikumash	3°24.3'	36°16.0'	1,385	60	3	6	3	5	10.5	0.48	
13	-do-	Ardai Ranch	3°23.9'	36°23.6'	1,340	191	5	3	2	23	27.2	0.85	Not working
14	Lossimingori	Lossimingori	3°23.0'	36°06.7'	1,390	320	4	4		81	5.1	15.88	Not working, LCT
15	-do-	Rasha Rasha	3°25.4'	36°10.7'	1,320	164	4	5		48	30.6	1.57	Not working
16	Lepurko	Lepurko	3°20.3'	36°13.5'	1,520	250	4	6	4	169	4.0	42.25	
17	-do-	Kitasho	3°21.7'	36°13.9'	1,485	150	3	2	3	40	2.0	20.00	
18	Meserani Juu	Ngoi Kumen	3°27.1'	36°29.6'	1,255	327	12	3	4	77	44.9	1.71	
19	Nengungu	Levi	3°21.6'	36°28.4'	1,405	308	4	4	1	101	2.0	50.50	
20	-do-	Hamsini	3°20.5'	36°28.7'	1,440	139	4	3	2	12	0.2	50.00	
21	-do-	Mboori	3°19.6'	36°28.0'	1,445	-	-	-	2.5	10	0.3	33.33	No embankment
22	-do-	Komesha	3°20.2'	36°28.5'	1,460	255	4	4	-		-	-	Silted
23	Moita Kiloriti	Ekivuk	3°28.4'	36°32.0'	1,300	218	4	10	4	178	8.0	22.25	LCT, DWP
24	-do-	Orngarwa	3°27.7'	36°31.1'	1,290	300	2	4	2.5	95	4.6	20.65	
25	-do-	Emao Ekivuk	3°27.6'	36°33.6'	1,310	200	3	3	2	67	5.9	11.36	
26	Moita Bwawani	Ndulele	3°33.5'	36°35.9'	1,220	160	3	4	2	61	22.4	2.72	
27	-do-	Kilimatinde	3°36.0'	36°37.1'	1,125	100	3	4	0.5	10	0.9	11.11	
28	Meserani Bwawani	Malarami	3°36.7'	36°31.2'	1,220	150	2	3	2.5	97	161.5	0.60	
29	-do-	Olnjapatwa	3°34.3'	36°26.1'	1,240	150	3	2		6	32.1	0.19	
30	-do-	Meserani	3°30.9'	36°26.4'	1,210	250	2	4		750	186.7	4.02	Not working
31	Mbuyuni	Mbuyuni-1	3°28.4'	36°13.0'	1,245	340	4	3	3	102	21.1	4.83	
32	-do-	Mbuyuni-2	3°30.2'	36°11.1'	1,245	149	4	3	1	13	18.8	0.69	
33	-do-	Mbuyuni-3	3°30.4'	36°09.2'	1,200	300	4	7		-	-	-	Silted
34	Makuyuni	Makuyuni	3°36.1'	36°06.9'	1,105	200	4	5		85	224.8	0.38	
35	-do-	J.K.T-1	3°29.0'	36°01.7'	1,145	120	2	6	1.5	65	3.4	19.12	
36	-do-	Lemiyoni	3°33.8'	36°06.5'	1,095	160	3	2	1	16	2.1	7.62	
37	-do-	J.K.T-2	3°27.8'	36°01.3'	1,155	110	3	3		13	0.9	14.44	
38	-do-	J.K.T-3	3°27.5'	36°01.6'	1,175	100	3	3		19	12.1	1.57	Not working
39	Naitolia	Nguvukazi	3°36.8'	36°03.1'	1,075	350	3	4	3	139	12.8	10.86	
40	-do-	Naitolia	3°36.3'	36°04.4'	1,085	350	3	3	2	23	3.3	6.97	
41	Oltukai	Oltukai	3°38.0'	35°55.1'	995	280	2	7		264	161.2	1.64	Not working
42	Mswakini	Mswakini-1	3°39.6'	36°04.0'	1,015	370	2	2		45	29.2	1.54	Not working
43	-do-	Mswakini-2	3°40.1'	35°57.9'	1,030	330	3	4	3	21	1.7	12.35	Not working
44	Emairete	Monduli Juu	3°14.0'	36°23.5'	1,740	164	4	8	6	271	8.1	33.46	For livestock use only
45	-do-	Soimineri	3°15.3'	36°18.1'	1,670	154	4	4		69	3.5	19.71	
46	-do-	Emairete	3°15.2'	36°23.7'	1,790	-	-	-	2.5	15	0.3	50.60	No embankment
	Total / Average									6,426	1,332.1	4.82	

Notes: L = Dam Length, W = Crest Width, H = Dam Height, DWP = Domestic Water Point, LCT = Long Cattle Trough

Table 2-8 SMALL SCALE DAMS IN USE

Village	Name of Dam	Dam Size (m)			Storage Capacity (1,000 m³)	Catchment Area (km²)
		L	B	H		
Lendikinya	New Alkaria	210	4	6	142	14.8
- do -	Mrandawa	106	3	2	15	0.6
Enguik	Enguik	112	4	6	51	6.4
Arkatan	Manja	320	5	7	2,678	122.6
- do -	Nadosoito	292	4	2	362	82.8
- do -	Nongilili No.2	100	2	4	19	0.5
- do -	Nongilili No.1	160	3	1	6	0.4
- do -	Loikumash	60	3	6	5	10.5
Lepurko	Lepurko	250	4	6	169	4.0
- do -	Kitasho	150	3	2	40	2.0
Meserani Juu	Ngoi Kumen	327	12	3	77	44.9
Nengungu	Levi	308	4	4	101	2.0
- do -	Hamsini	139	4	3	12	0.2
- do -	Mboori	No embankmt.			10	0.3
Moita Kiloriti	Ekivik	218	4	10	178	8.0
- do -	Orngarwa	300	2	4	95	4.6
- do -	Emao Ekivik	200	3	3	67	5.9
Moita Bwawani	Ndulel	160	3	4	61	22.4
- do -	Kilimatinde	100	3	4	10	0.9
Meserani Bwawani	Malarami	150	2	3	97	161.5
- do -	Olnjapatwa	150	3	2	6	32.1
Mbuyuni	Mbuyuni No.1	340	4	3	102	21.1
- do -	Mbuyuni No.2	149	4	3	13	18.8
Makuyuni	Makuyuni	200	4	5	85	224.8
- do -	J.K.T. No.1	120	2	6	65	3.4
- do -	Lemiyoni	160	3	2	16	2.1
- do -	J.K.T. No.2	110	3	3	13	0.9
Naitolia	Nguvukazi	350	3	4	139	12.8
- do -	Naitolia	350	3	3	23	3.3
Emairete	Monduli Juu	164	4	8	271	8.1
- do -	Soimineri	154	4	4	69	3.5
- do -	Emairete	No embankmt.			15	0.3
Total	32 Dams				5,012	826.5

Notes: L = Length of dam, B = Width of dam crest, H = Height of dam

Table 2-9 WATER REVENUE COLLECTION, 1994 MONDULI WATER SUPPLY PROJECT

Item	Domestic Connection	Commercial Connection	Public Tab	Total
1. Population Served	1,000		25,000	26,000
2. Nos. of Water Connections	302	25	3	330
3. Monthly Water Charge (Tsh)	200	400	-	-
4. Revenue Expected per Year (Tsh)	724,800	120,000	-	844,800
5. Actual Collection (Tsh)	289,920	84,000	-	373,920
6. Collection Efficiency (%)	40	70		44

7. District Water Department Expenditure (Tsh)

- Salaries and wages	:	6,328,000
- Recurrent Expenditures	:	7,426,000
Total		13,754,000

8. Remarks:
- Water revenue of 100 recent collection covers only 11.4 percent of recurrent expenditures.
- Water revenue of 44 percent collection covers only 5 percent of recurrent expenditures.

Table 2-10(1) SUMMARIZED WORKS OF MINISTRY OF TOURISM, NATURAL RESOURCES AND ENVIRONMENT

		Outline
TOURISM		TANZANIA TOURIST BOARD It has the responsibilities of advertising and promoting the country's tourist's attractions, both at home and abroad.
NATURAL RESOURCES	FORESTRY	TANZANIA FORESTRY DEPARTMENT This department deals with licensing affairs, growing new trees and conserving old/special species of trees. Also this department receives sensitive/important issues which might be out of the score of public corporations. Generally this department is a primary producer.
		[TAFORI] TANZANIA FORESTRY RESEARCH INSTITUTE This institute deals with all forestry research in Tanzania.
		[TWICO] TANZANIA WOOD INDUSTRIAL COOPERATION This is a secondary producer. It sells trees for wood processing.
	FISHERIES	TANZANIA FISHERIES DEPARTMENT It deals with licences. Policies - which may be national or international. It receives information deemed necessary by corporations.
		TANZANIA FISHERIES COOPERATION This cooperation deals with conservation of fishes, harvesting and selling from water bodies of the country.
		TANZANIA FISHERIES RESEARCH INSTITUTE This institute deals with all fisheries researches in water bodies of the country.

Table 2 - 10 (2) **SUMMARIZED WORKS OF MINISTRY OF TOURISM, NATURAL RESOURCES AND ENVIRONMENT**

		Outline
NATURAL RESOURCES	WILDLIFE	WILDLIFE DEPARTMENT Licensing. Policies - National and international.
		[TANAPA] TANZANIA NATIONAL PARK PARASTATAL ORGANIZATION It is the main organization running/maintaining the National Parks. In the National parks the organization supervises that there is (prohibition of or) - no agriculture - no livestock - no human activities such as settlements - no hunting
		[NCAA] NGORONGORO CONSERVATION AREA AUTHORITY This organization is limited no NGORONGORO Conservation Area. The nature of management here is different because wild animals coexist with human beings. However, hunting is not allowed. Activities such as human settlement, livestock keeping is allowed.
		[TAWICO] TANZANIA WILDLIFE COOPERATION This organization oversees all hunting activities, including chopping (reduction of wild animals). So it is a main organization dealing with wildlife.
		[MWEKA] COLLEGE OF AFRICAN WILDLIFE MANAGEMENT This college trains Tanzanian as well as foreign students. Certificate as well as diploma courses on wildlife management, payment of training is paid by individuals.
		[SWRI] SERENGETI WILDLIFE RESEARCH INSTITUTE This institute is the main supervisor of wildlife research activities in the country.
ENVIRONMENT		[NEMC] NATIONAL ENVIRONMENTAL MANAGEMENT COUNCIL To safeguard the environment responsibility of ensuring that development in any area conforms with environmental requirements. The council ensures that the environment is not polluted in any way. Any type - air, water, noise, visual
		[COSTEC] TANZANIA COMMISSION FOR SCIENCE AND TECHNOLOGY Coordinated records and controls all kinds of research in Tanzania.

Generally the government deals with game controlled and game reserved areas. Game wardens are sent to game reserves etc.

Table 2-11 REGULATIONS FOR PROTECTED AREAS

Items of Regulation	Regulation on artificial intervention						Regulation on protected animals/plants				
	People reside	Entrance in the area	Breeding of livestock	Game in the area	Game of protected animals	Camping/lodging in the area	Intentional game	Unintentional game	Use of fire	Alteration of flora, felling	Alteration of geographical features
National Park	×	△	×	×	×	×	×	×	△*	×	×
Forest Reserve	△	△	△	△	×	×	×	×	×	×	×
Game Reserve	△	△	△	△	×	×	△	△	△	△	△
Game Controlled Area	○	○	○	△*	×	×	△	△	△	○	○

×: Prohibited △: License system ○: Non licence system *: Use as management tool.

Table 2-12 PHYSICAL AND CHEMICAL DRINKING WATER STANDARDS

Group	Parameter	Unit	Criterion
Substance which may affect palatability	Total hardness (CaCo3)	mg/L	<600
	Calcium (Ca)	mg/L	n. m.
	Magnesium (Mg)	mg/L	n. m.
	Sulphate (SO4)	mg/L	<600
	Chloride (Cl)	mg/L	<800
Substance which may affect palatability	Color	mgPt/l	<50
	Turbidity	NTU	<50
	pH-Value		6.5 - 9.2
	Taste		n. o.
	Odor		n. o.
Substance which may affect palatability	Iron (Fe)	mg/L	<1.0
	Manganese (Mn)	mg/L	<0.5
	Copper (Cu)	mg/L	<3.0
	Zinc (Zn)	mg/L	<15.0
Substances which may affect human health	Fluoride (F)	mg/L	<8.0
	Nitrate (NO3)	mg/L	<100
Substances which may be toxic	Lead (Pb)	mg/L	<0.10
	Cadmium (Cd)	mg/L	<0.05
	Arsenic (As)	mg/L	<0.05
	Chromium (Cr)	mg/L	<0.05
	Cyanide (CN)	mg/L	<0.20
	Silver (Ag)	mg/L	n. m.

Note: n. m. = not mentioned n. o. = not to be rejected

Table 2-13 LIST OF WATER RIGHT

No.	Description	Water Right No.	Quantity
1	Teachers Training College water right of Lekishirti water source-spring, but seasonal water	AR 153	128,000 liters per day
2	Monduli Coffee Estate and Monduli Town	AR 983	Mini. 45,000 liters per day
3	TPDF (CTU) and Monduli Town Emaoi Etemi water source-spring at the foothills	AR 4579	3,375 liters per day
4	Monduli Pipeline	124	
5	Monduli Beunet Ltd. (TARASERO)	3393	

Figure 2-1 LOCATION OF VILLAGES

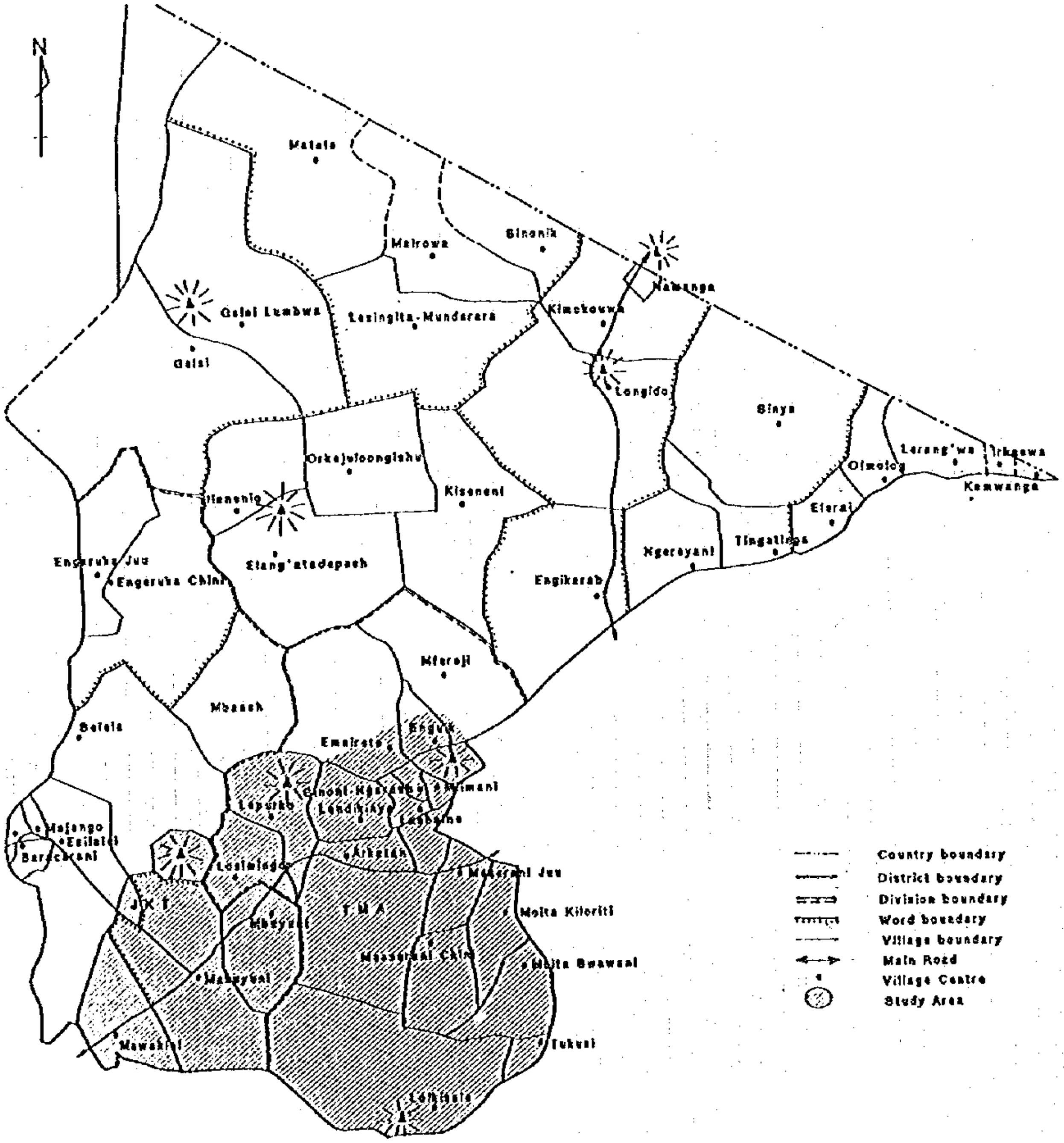


Figure 2-2 ORGANIZATION OF REGIONAL WATER DEPARTMENT

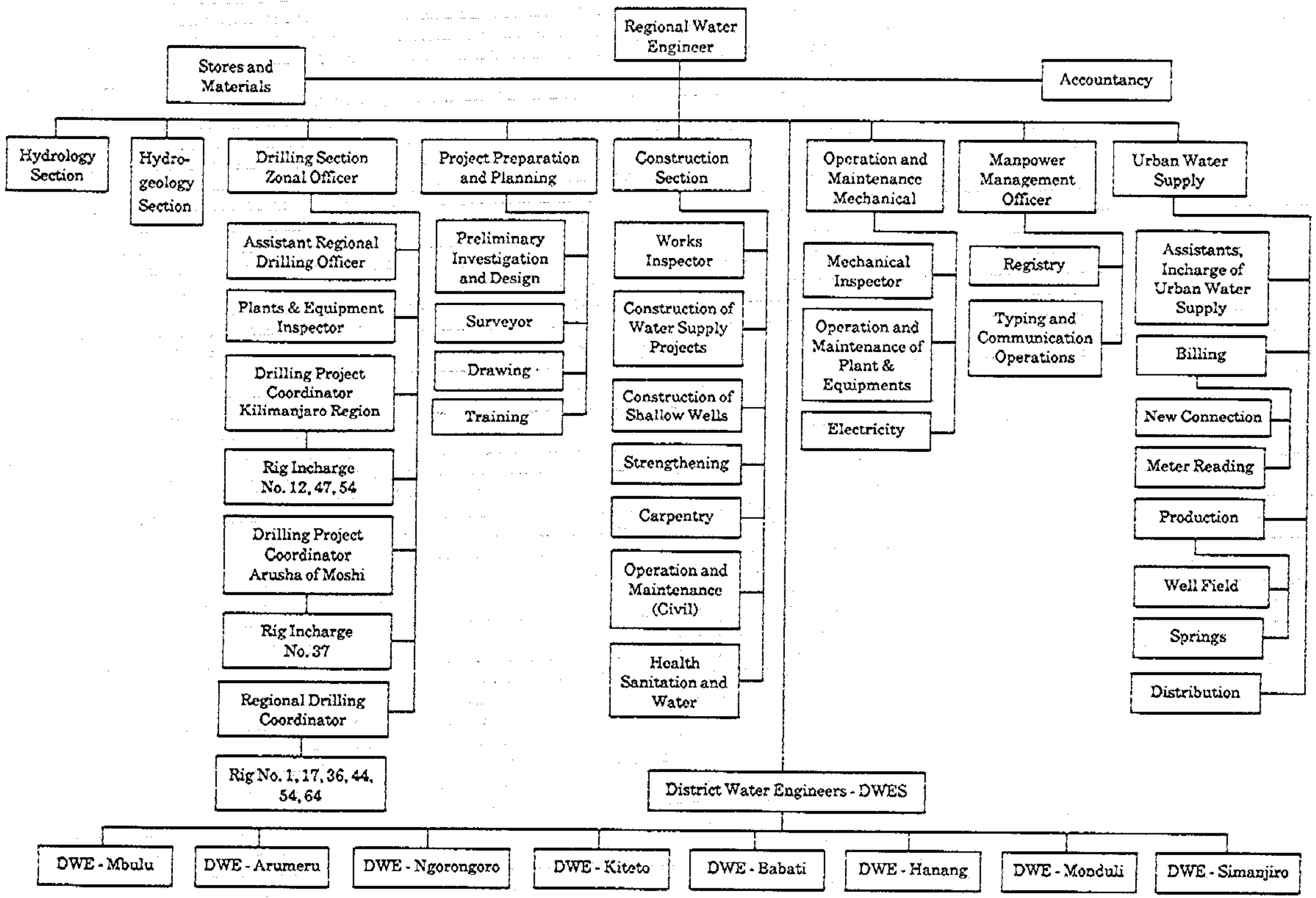
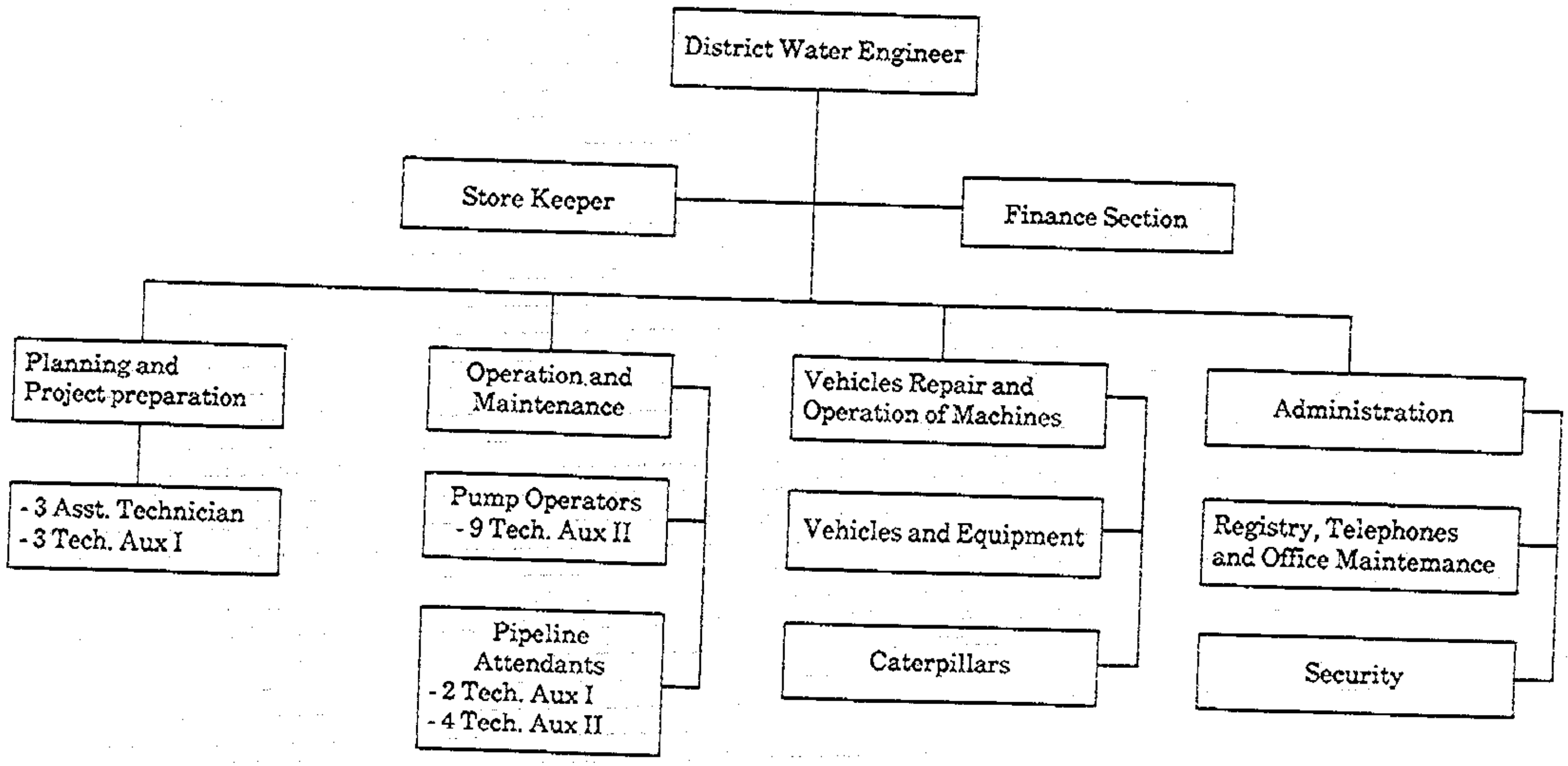


Figure 2-3 ORGANIZATION OF DISTRICT WATER DEPARTMENT



CHAPTER 3 GROUNDWATER RESOURCES

CHAPTER 3 GROUNDWATER RESOURCES

3 - 1 Hydrogeology

3 - 1 - 1 General

Prior to the commencement of geophysical prospecting and exploratory well drilling, hydrogeological surveys were conducted with the following aims:

i) to understand the general situation of the geology in the Study Area,
ii) to identify the hydrogeological units based on the geology and existing well information,
iii) to evaluate the groundwater potential of respective hydrogeological unit, and
iv) to prepare hydrogeological maps.

Locations of hydrogeological survey areas and hydrological units are presented in Figure 3-1 and 3-2 respectively.

3 - 1 - 2 Hydrologeological Units

Four hydrogeological units have been identified as a result of the field surveys. They are the Basement, Plateau Lava, Colluvial Deposits and Lake Manyara Beds as described hereinafter.

(1) The Basement

The Basement is composed of chiefly various types of gneisses associated with quartzite and meta-igneous rocks. These rocks underlay in the south of Naitolia and Tukusi in the south of the Study Area.

Main aquifers in these rocks are fractures and heavily weathered geologic materials in the upper part of the rocks. In general, granite and granitic metamorphic rocks are easily changed into loose sandy materials by superficial weathering.

The areas which are underlain by the Basement are subjected to a low rainfall regime; however, aquifers can receive recharge by the surface runoff from the forest-covered catchment areas of Lolkisale Game Controlled Area and Tarangire National Park which both experience considerably high rainfall.

(2) Plateau Lava

The geological sequence of the Plateau Lava is complex with wide varieties of volcanic lithological facies. Outcrops reveal that the lava flow consists mostly of basaltic rocks of a few meters thickness, but also contains some intercalated tuff and pyroclastic rocks. In general, the Plateau lava forms gentle undulated hills extending in a north-south direction with escarpments on both sides. Broad and shallow valleys were cut between these escarpments.

Main aquifers in the Plateau Lava seem to be of pyroclastic rocks; however, fractures in basaltic rocks are also expected to be aquifers if the rocks are heavily subjected to fracturing by tectonic movement. The areas of the Plateau Lava are located between volcanic mountains and the Basement. The aquifers are mostly subjected to recharge by surface runoff from the mountainous areas, but the magnitude of recharge depends on the distance from the mountains.

(3) Colluvial Deposits

The small-scale Colluvial Deposits underlie the Basement and the Plateau Lava areas, and thick and widely extended beds are only underlain in Monduli Juu. The records of existing wells reveal that the total thickness of unconsolidated colluvial beds which are derived from volcanic materials, exceeds 100 meters in Monduli Juu.

The Colluvial Deposits consist mostly of clay and volcanic sand with volcanic rock fragments which were derived principally from the extrusives. An expected aquifer in the Colluvial Deposits is volcanic sand according to the records of well drilling.

(4) Lake Manyara Beds

Broad flat land extends from the south of Makuyuni to the district boundaries along the highway. The distribution of the Lake Manyara Beds is in good agreement with the area of this flat land. It consists of weak consolidated calcareous mudstone, marls and calcareous sandstone with few ten centimeters thickness of single bed. Existing well records in Mswakini reveal that the total thickness of the formation is more than 100 meters.

The expected lithology of the aquifer is calcareous sandstone. The electrical conductance groundwater from this aquifer ranges from 1,000 to 1,400 μS/cm.

3 - 1 - 3 Hydrogeology of the Study Area

(1) Monduli Town

Monduli town is located in the foothills of the Monduli Mountains and is underlain by the Colluvial Deposits derived from the older extrusives of the Monduli mountains. According to the geological well logs, an unconsolidated colluvial bed of 39 meters thickness covers fractured volcanic rocks. The former acts as part of an aquifer, but does not have good potential, while the latter contains pressure gas in a caverned volcanic rock.

An interpretation of aerial photographs was made and it was estimated that the depth to the extrusives thickened abruptly to the south of the Monduli Mountains due to east-westerly faulting. The records from the exploratory well drilled near Ngarash, supports this estimate; the well did not encounter any distinct hard volcanic rocks until a depth of 150 meters below the ground surface.

(2) Monduli Juu

Geology of Monduli Juu is characterized by two calderas; inner and outer ones with diameters of three kilometers and seven kilometers respectively. The inner forms a distinct caldera, but the shape of the outer caldera is not clear due to dissected and eroded rock.

A test well was drilled to a depth of 91 meters below the ground surface in the outer caldera; but it was dry. Thick unconsolidated beds of clay with gravels and clayey rock fragments underlie in the depression and it encountered volcanic rocks at a depth of 88 meters below the ground surface where circulation mud was lost.

Drilling logs in the inner caldera show that the upper part of logs consist of Colluvial Deposits of clayey beds with a thickness of about 68 meters, and the lower part consists of medium to coarse sand with the thickness of more than 30 meters which acts as an aquifer.

(3) Surrounding Areas

a) Oltukai Sub-Village

The village is located several kilometers east of Lake Manyara, and is underlain by the Lake Manyara Beds with a thickness of more than 100 meters. A sand-floored plain slopes gently westward to Lake Manyar. The groundwater potential of the Lake Manyara Beds seems excellent, but the water has a high concentration of dissolved solids (Draft ARWMP, 1994). Results of resistivity prospecting in the village support the assessment of qualitative inferiority.

b) Mswakini Village

Being situated east of Oltukai village, the village is underlain by the Lake Manyara Beds, and the sand-floored plain slopes gently westward to Lake Manyara, the same as Oltukai village. The village is bordered on the east and southeast by the Tarangire National Park and Lolkisale Game Controlled Area which acts as part of the recharge area. Groundwater quality in the Lake Manyara Beds in the southern and eastern parts of the village has been improved with fresh water flowing from the forest-covered reserved lands.

c) Naitolia Sub-Village

The village is located in the eastern end of old lake Manyara depositional plain and is underlain by the Lake Manyara Beds in the lowland. The lake Manyara Beds are underlain by the Basement in the undulated hills. Depth to the Basement is around 80 meters. Major aquifers in the lowland are sandy materials of the Lake Manyara Beds and the water quality of the aquifers is considered to have a high concentration of total dissolved solid.

d) Makuyuni Village

The village is located in the eastern fringe of a depositional plain of the Lake Manyara Beds. The Plateau Lava surrounds the village except in the south. Major aquifers underlie the calcarreous bed of the lake Manyara Beds according to the results of test well drilling by RDD. The tested yields and static water level ranged from 37 to 76 liters per minute and 24 to 31 meters below the ground surface (RDD).

e) Mbuyuni Village

The village is located on the Plateau lava. Buani river runs through the village collecting runoff from the Essimingor catchment area. Although records of the existing well are not available around the village, it can be expected that fractured volcanic rocks and intercalated tuff and breccia possibly developed a potential aquifer. The center of Buani river course is underlain by low resistivity layers which is a sign of the existence of clayey impervious beds or highly concentrated total dissolved solids in the beds. The resistivity prospecting and geological features suggest that there is a zone of fractured volcanic rocks in the west part of the river beds.

f) Lossimingor Village

The village is located in the foothills of Mt. Essimingor and is underlain by Colluvial Deposits and volcanic rocks. An exploratory well was even drilled; but it was unsuccessful. The area receives runoff from the Mt. Essimingor which is well reserved forest lands, and groundwater potential is considered to be promising in view of the hydrogeological features of the area.

g) Lepurko Village

The village is located on the volcanic plateau, south of Mt. Burko, and is underlain by the Plateau Lava. No data on groundwater is available in and around the village; however, it may not be expectative to exploit groundwater in the Plateau Lava from a hydrogeological point of view. There is a possibility of groundwater development in the Eluanata basin being located east of the village, nevertheless drilling of test wells by RDD was unsuccessful. The basin receives runoff from the catchment areas of Mt. Burko and Mt. Kosiki. The depth to the volcanic rocks in the Eluanata basin is assumed so deep as a result of faulting along the northern edge of the plateau.

h) Arkatan Village

As the village is located on the volcanic plateau and underlain by the Plateau Lava, it is hardly expected to have developed groundwater in the Plateau; however, there is a possibility of developing groundwater in the Ardai basin which extends north of the village, but the depth to potential aquifers is estimated to be more than 200 meters.

i) Lendikinya Village

The village is underlain by the alternating beds of scoriatic volcanic rocks and pyroclastic beds. Although no data on groundwater exists for the village, the only water source available in and around the village may be the groundwater to be extracted in the Ardai basin. Estimated depth to the aquifer is more than 200 meters.

j) Nengungu Village

The village is located south of Monduli town and is underlain by the Plateau Lava. No exploratory well drilling has been tried so far by RDD. Aquifers are expected to exist in the Plateau Lava. Drilling of test wells was implemented by the Study Team near the village; however, there is no sign of groundwater to a depth of 200 meters.

k) Emairete Village

The village is located in the inner caldera and is underlain by the Colluvial Deposits. According to the results of test well drilling by RDD, static water level and yield were 5.2 meters below the ground surface and 36 liters per minute, but in the outer caldera drilling works heavy water losses were encountered at a depth of 87 meters, resulting in the abandonment of the well.

The depth to volcanic rocks is estimated at more than 100 meters below the ground surface.

l) Enguik Village

The village is located on the slopes of Mt. Monduli and is underlain by volcanic rocks. No data is available with respect to groundwater in the village. Groundwater development potential is not expected due to the hydrogeological characteristics prevailing in this area.

m) Meserani Juu

The village is situated in the lower basin of Muso river and is underlain by pyroclastic rocks. Muso river originates in Monduli mountains, and river runoff is a source of groundwater recharge in the area.

n) Meserani Bwawani

The village is located on the alluvial plain of Loolera river, a tributary of Muso river, and is underlain by unconsolidated alluvial beds and pyroclastic rocks of the Plateau Lava. Depth to volcanic rocks is more than 60 meters. The yield of groundwater of around 28 liters per minute with a drawdown of 7.3 meters was recorded by RDD at a static water level of 90 meters below the ground surface. Groundwater potential seems to be excellent in the upper part of the volcanic range.

o) Moita Kiloriti Village

The village is located in the western slopes of the volcanic plateau and is underlain by the Plateau Lava. No records on groundwater are available for the area; however, there may be a possibility of groundwater development in Nadaare river basin.

p) Moita Bwawani Village

The village is located in the eastern edge of the volcanic plateau and is underlain by pyroclastic rocks and the Plateau Lava. Although no record on groundwater is available in and around the village, it could be assumed that there is less potential for groundwater development due to the topographic features observed in the village.

q) Tukusi Village

The village is located on undulating hills and is underlain by the Basement Rocks. Depth to the Basement Rocks is about 90 meters. The development potential for groundwater in and around the village is low.

r) Lolkisale Village

The village in located in the foothills of Mt. Lolkisale and is underlain by the Basement Rocks. Groundwater yield is as low as 1.5 liters per minute at a depth of 150 meters below the ground surface according to the results of a test well drilling carried out by the Study Team. Groundwater potential of the aquifers in the fractured gneiss seems to be insufficient to warrant development.

(4) Ardai Basin

The Ardai basin, which is located south of Monduli town, covers a moderately sloping alluvial surface and wide valley floor with a total area of about 130 square kilometers. All streams rising in the Monduli and Lendikinya mountain ranges with the mean annual rainfall of more than 800 millimeters, run in a southerly direction through the Ardai basin. Part of the runoff is lost in the Ardai basin due to surface evaporation, irrigation use and infiltration from the vast area of the basin which is bounded in the south by the uplifted lava plateau. There are only two outlets to drain surface water from the basin.

Above consideration on the topographical conditions of the basin led to the inference that groundwater is recharged in the basin, transmitted and released in the Colluvial Beds and heavily fractured volcanic rock aquifers in the zone of saturated subsurface. The exploratory well drilling in the middle of the basin made during the fieldwork period has failed to reach the zone of saturated subsurface within a depth of 250 meters below the ground surface. The lithology of well logs indicates that there are several beds that can act as a potential aquifer in fractured scoriatic rocks.

The most striking feature of subsurface geology is the presence of pressure gas in the caverns of volcanic rocks. Drilling work is needed to seal the cave by cementing. The pressure gas spouted at four test wells at a depth ranging from 86 to 150 meters below the ground surface, corresponding to elevation between 1,190 and 1,390 meters above the mean sea level.

3 - 2 Geophysical Prospecting

3 - 2 - 1 Methodology

(1) Resistivity Prospecting

Two methods of electrode array, Wenner and Schlumberger, were applied to the resistivity prospecting of the Study Area. The former was applied in Monduli town and the latter to areas other than Monduli town. A maximum spacing of current electrodes for the Wenner Array was 230 meters.

The prospecting in the Ardai and Eluanata basins was conducted using the Schlumberger array with 1,000 meters of maximum AB/2 spacing for which a prospecting instrument, SYSCAL-R2, BRGM was used. The inversion analytical method was employed for interpretation of resistivity models that are approximated by the observed VES curves.

(2) Magneto-Telluric Prospecting

The Electro-Magnetic Prospecting by the VLF-MT method was initially programmed to detect rock fractures in the Study Area; however, it was not effective because the thickness of overburden is more than prospecting limits and resistivity was too low to construct models. An attempt was made to verify through the use of the VLF-MT method in Mbuyuni village where a thinner overburden was detected by the resistivity prospecting, with the result that no proper interpretation of resistivity structure was made available because of the extremely high deviation of the observed data due to the weak signals from GBR.

On the other hand, the PLMT method was introduced to investigate large scale resistivity structures in the Ardai basin where a potential aquifer system is expected to exist. The PLMT method is to explore subsurface electrical resistivity distribution by measuring both electric and magnetic fields generated by electric power lines.

3-2-2 Resistivity Prospecting

Resistivity prospecting was carried out at 205 sites to cover the Study Area, details of which are given in the Supporting Report.

Resistivity Prospecting

Location	Nos. of Sites	Max. AB/2 (m)	Array
Monduli Town	17	230	Wenner
Monduli Town	37	200	Schlumberger
Monduli Juu	30	200	-do-
Ardai Basin	21	200	-do-
Tukusi	4	200	Wenner
Tukusi	12	200	Schlumberger
Naitolia	15	200	-do-
Mbuyuni	15	200	-do-
Arkatan West	17	200	-do-
Arkatan East	18	200	-do-
Oltukai	2	140	-do-
Mswakini	5	100	-do-
Makuyuni	5	200	-do-
Ardai and Eluanata	7		
Total	205		

3-2-3 PLMT Prospecting

Prospecting was conducted in the Ardai and Eluanata basins. 95 prospecting sites were selected on a grid at an interval of around 2,000 meters. The interpreted resistivity model is composed of three different resistivity layers; low resistivity of less than 50 Ω-m, middle resistivity of 50 to 500 Ω-m and high resistivity of more than 500 Ω-m. The results of PLMT prospecting are presented in the Supporting Report.

Iso-resistivity contour lines are mapped at a depth of 1,000 meters below the ground surface. A contour line of more than 500 Ω-m which probably indicates solid volcanic rocks, distributed in accordance with the mountain slopes from the north of Monduli town to Mt. Kosiki via Lendikinya. Another 500 Ω-m contour line runs on the Plateau Lava along the route of the Arusha-Dodoma highway. It is the most striking feature that 500 Ω-m contour lines are underlaid on the divide between the Arkatan basin and Eluanata basin.

3-3 Exploratory Well Drilling

3-3-1 General

Exploratory well drilling has been carried out to learn the hydrogeological conditions of the Study Area, more specifically with the following aims:

i) to set up hydrogeological units,
ii) to obtain the vertical/horizontal extent of aquifers,
iii) to grasp the characteristics and potential of aquifers, and
iv) to test groundwater quality.

Eleven drilling sites were selected around the Study Area after consideration of the results of hydrogeological surveys and resistivity prospecting. Drilling depth ranged from 100 meters to 250 meters. Of 11 test wells, nine drilling works were operated by the Study Team by using truck mounted rotary drilling rigs owned by the Ministry of Water, Energy and Minerals; T-64HB and T-985 of Schramm. Drilling works of the other two wells were carried out by a Tanzanian contractor with his own rigs of Super Rock-1994.

Although full the column of borehole logging was not conducted due to heavy circulation losses, results of resistivity logging were analyzed to locate aquifers and aquicludes after the drilling works had been completed. The interpretation of the lithologic logs assisted in determining locations of screens with the above borehole loggings.

After completion of the drilling works, fiberglass reinforced pipe (FRP) casings of 150 mm diameter and horizontal slotted screens of FRP with 12 percent openings were installed in the boreholes.

3-3-2 Results of Drilling

The results of drilling (Table 3-1) have shown that two wells out of 11 wells yielded measurable amounts of groundwater and five wells were dry as far as water yields are concerned, and are summarized as follows:

Summary of Exploratory Wells

Well No.	Location	Drilled Depth (m)	S. W. L. (mbgs)	Yield (ℓ/min)	Lithology of Screen	Remarks
EX-1	Natiolia	84	65	dry	calcar. sand	
EX-2	Mbuyuni	70	57	dry	fract. basalt	
EX-3	Tukusi	100	55	1.0	weth. basement	
EX-4	Monduli Town	154	129	*	volcnc. sand	
EX-5	Lashaine	192	-	*		gas
EX-6	Lendikinya	250	-	dry		
EX-7	Monduli Juu	102	72	20.7	volcnc. sand	
EX-8	Monduli Town	126	-	dry	fract. basalt	gas
EX-9	Arkatan West	48	-	dry		gas, avandnd.
EX-10	Arkatan East	152	-	dry	scrt. vl. rock	gas
EX-11	Monduli Town	153	-			cave in 153 mbgs

Notes: S.W.L. = Static Water Level, mbgs = meters below the ground surface
ℓ/min = liters per minute, calcar. = calcareous, fract. = fractured
weth. = weathered, volcnc. = volcanic, scrt.vl. = scoriatic volcanic
* shows that groundwater yield is negligible small.

(1) EX-1 in Naitolia

Drilling was aimed to detect aquifer potential in the Lake Manyara Beds. The lithology of well up to a depth of 58 meters is composed of alternative beds of clay, sand and gravel with calcareous fragments which are correlative with the Lake Manyara Beds. The hole is underlain by weathered granite from a depth of 58 meters to the bottom. Preliminary pumping tests were made by air lift at a static water level of 65 meters below the ground surface, but resulting in a negligible quantity of water.

(2) EX-2 in Mbuyuni

The well was drilled to a depth of 70 meters to obtain data on groundwater potential of the Plateau lava. The well was developed by jetting and the static water level was obtained at a depth of 57 meters below the ground surface. Pumping was preliminarily tried by air lifting; but not enough water was extracted.

(3) EX-3 in Tukusi

Drilling aimed to investigate the potential of aquifers in the Basement Rocks. The drilling works were stopped at a depth of 100 meters below the ground surface on the weathered gneiss of the Basements. The well was developed by jetting and a static water level was obtained at 54.56 meters below the ground surface. Preliminary pumping tests by air-lifting resulted in a water yield of one liter per minute.

(4) EX-4 in Ngarasi, southwest on Monduli Town

In order to investigate the potential for aquifers in the pyroclastic rocks and fractured volcanic rocks, a well was drilled to a depth of 154 meters. The static water level was 122 meters below the ground surface. Preliminary pumping tests were made by air lifting; but not enough water was extracted.

(5) EX-5 in Lashaine, south of Monduli Town

The drilling site is located on the northern edge of the Ardai basin. The depth of drilling is 192 meters below the ground surface. A heavy circulation loss was encountered in a dry cave with gas at a depth of 67 meters in fractured volcanic rocks. The hole was plugged with cement and drilling continued to a depth of 198 meters using an air drilling method; however, there was no trace of groundwater during the drilling procedure.

(6) EX-6 in Ardai Basin for Lendikinya

The drilling site is located in the middle of the Ardai basin. A heavy circulation loss took place at depths of from 128 to 138 meters where formations change from thick clayey bed to fractured volcanic rocks. Drilling works were halted at a depth of 250 meters; the well was dry.

(7) Ex-7 in Emairete, Monduli Juu

The test well is located on the Colluvial Beds in Monduli Juu caldera with the drilling depth at 102 meters. Casings were installed up to 100 meters below the ground surface with 200 meters long screens. Static water level is 72.5 meters below the ground surface. Constant yield tests were conducted to evaluate well potentials. The yield and maximum drawdown by 24 hours continuous pumping were 20.66 liters per minute and 3.26 meters respectively.

(8) EX-8 in Sinon, Monduli Town

Drilling aimed to investigate aquifer potentials in the pyroclastic rocks and fractured volcanic rocks. Drilling works continued to a depth of 126 meters, and encountered a heavy circulation loss at the above depth where formation changes from thick scoriatic breccia to fractured volcanic rocks. The loss took place in a dry cave with gas, and the hole was plugged with cement. Preliminary pumping tests were conducted by air lifting; but the well was dry.

(9) EX-9 in Arkatan West

The drilling site was located in the southern part of the Eluanata basin to investigate aquifer potentials in the fractured volcanic rocks in the Plateau Lava. The drilling works stopped at a depth of 48 meters below the ground surface where a heavy circulation loss in fractured volcanic rocks was encounterd. The loss was caused by pressured gas in a dry cave. The well was dry.

(10) EX-10 in Arkatan East

The drilling site was located in the southern part of the Ardai basin to investigate aquifer potentials in the pyroclastic and fractured volcanic rocks in the plateau Lava. The well was drilled to a depth of 152 meters, and encountered a heavy circulation loss at a depth of 85 meters in tufaceous pyroclastic rocks. The loss was caused by the pressured gas in a dry cave. The well was dry.

(11) EX-11 in Monduli Town

The drilling works aimed to investigate aquifer potentials in the fractured volcanic rocks of the Younger Extrusives. The site was selected in the northeast of Monduli township. A heavy circulation loss took place at a depth of 150 meters below the ground surface due to presence of a dry cave. The cave was plugged with cement and casing was installed to a depth of 122 meters at a interval of from 35 to 51 and 106 to 100 meters below ground surface. Preliminary pumping tests were conducted by air lifting; but resulting in negligible quantity of water.

3-3-3 Pumping Tests

(1) Methodology

In order to obtain groundwater potentials, aquifers are tested by three kinds of pumping tests; preliminary test, constant yield test, and recovery test. Tests were carried out on two wells; EX-7 exploratory well in Monduli Juu and the existing well (10/52) in Makuyuni drilled by RDD. The discharge rates in the constant yield test are usually determined based on the maximum discharge in the preliminary test. Water is continuously pumped for 24 hours, and when pumping is stopped, recovery of the water level is measured until it attains the static water level. A submersible pump was used for the pumping tests, the capacity of which is 15 Kw, 300 liter per minute and at 150 meters of TDH.

(2) Results of Test

The transmissivity was determined from an analysis of drawdown data by the two methods of Jacob and recovery. The transmissivity from each formation is consistent with the lithologic characteristics of the formation.

The Lake Manyara Beds, in which aquifers are subject to recharge by surface runoff of rivers and rainfall over the wide alluvial plains on the Lake Manyara Beds, have comparatively good transmissivity. The transmissivity of the Colluvial Beds in Monduli Juu underlaid by the Colluvial Beds is eight m^2/day in the volcanic sand.

Summary of Pumping Test

Well	Location	Static W. Level (m)	Yield (ℓ/min)	Draw-down (m)	Specific Capacity (ℓ/min/m)	Transmissivity (m^2/day)	
						Jacob	Recovery
10/52	Makuyuni	19.33	78.2	7.53	7.53	11	7
EX-7	Emairete	72.25	20.7	3.26	3.26	8	10

3 - 4 Water Quality

3 - 4 - 1 Water Quality Analysis

Water quality analyses were carried out by means of an in-situ test and a laboratory test with the following objectives:

i) to interpret the hydrochemical evolution of groundwater, and
ii) to evaluate surface and groundwater sources for water supply planning.

The in-situ test covers the parameters of Electrical conductance, pH, Water Temperature and Bacteriological Examination, and the laboratory test covers the following 25 physical and chemical parameters; Color, Turbidity, Taste, Odor, Bacteria, pH, EC, TDS, NO_2, NO_3, Cl, Fe, Mn, NH_3, $CaCO_3$, Cu, Cr^{6+}, Ca, Mg, SO_4, Na, HCO_3, K, Ps and F.

3 - 4 - 2 In-Situ Test

Twenty-nine water samples were collected from springs, boreholes, rivers and other water sources. The results of the analyses are presented in Table 3-2.

(1) Electrical Conductance

The electrical conductance ranges from 75 to 8,750 μS/cm; the highest was recorded from the water sample of the Lake Manyara and the lowest from the water sample of a spring on the northern slopes of Mt. Monduli. The groundwater samples taken from the boreholes in Mswakini and Makuyuni indicate the electrical conductance of 1,406 and 1,032 μS/cm respectively. The high values of the lake water of Manyara may be due to heavy evaporation over the surface of the lake in its expanding time. Spring water collected in the northern volcanic mountains shows low electrical conductance ranging from 75 to 802 μS/cm with an average of 260 μS/cm.

(2) pH

The pH values are rather high ranging from 7.4 to 10.0. The water samples from reservoirs and surface runoff show higher values from 7.8 to 9.1 μS/cm with an average of 8.5 μS/cm. The values of water samples from springs are rather low ranging from 7.4 to 8.5 μS/cm with the average of 7.9 μS/cm. The water samples from boreholes indicate almost the same pH values as spring water.

3-4-3 Laboratory Test

(1) General

The water samples were analyzed at the laboratory of Arusha Water Department by using a Hach test kit, Spectrophotometer DR 2000, digital titrator and in some instances, a drop pipette. The water samples were assessed for drinking purposes, based on the maximum permissible level of the WHO Drinking Water Standards, The results of the laboratory tests are presented in Table 3-3. The results of the laboratory test are plotted on Trilinear Diagram (Piper Diagram), Pattern Diagram (Stiff Diagram) and Wilcox Diagram in order to interpret the hydrochemical characteristics.

(2) Water Quality Assessment for Drinking Purpose

a) pH

The pH value of a water sample expresses its tendency to accept or release hydrogen ions characterized by a scale from 0 (very acidic) to 14 (very basic or alkaline). An acceptable range of pH level for drinking water quality is between 6.5 and 9.2. Except the water sample from the Manyara Lake with a pH value of 10.3, all water samples are of pH values within the permissible limit.

b) Turbidity

The turbidity test measures the optical property of the water sample which results from the scattering and absorbing of light by the particular matter present. High levels of turbidity can protect microorganisms from the effect of disinfection, stimulate the growth of bacteria and exert a significant chlorine demand. The recommended value of turbidity is less than five NTU.

High turbidity values were recorded mostly from water of river surface flows, reservoirs and lakes. Samples from Lashaine reservoir, Makuyuni river and the Manyara Lake show extremely high values of turbidity; however, turbidity is highly variable under the influence of rainfall intensity apart from in Lake Manyara. Most water sources of springs and boreholes meet the standard.

c) Color

Color in drinking water may be due to the presence of colored organic matters, e.g. humic substances, metals such as iron and manganese, or highly colored industrial wastes. High levels of color were recorded from the water samples with the high turbidity. The water sample of Makuyuni river has the highest value of 98,000 NTU, whereas the lowest was recorded to be zero from the water sample of Mto wa Mbu river. Except EX-3 and Burko BH-4 boreholes, color for the water samples collected from boreholes is within the limitation of the standard.

d) Total Dissolved Solid (TDS)

Only the water sample from Lake Manyara exceeds this standard.

e) Total Hardness

Total hardness is a measure of the polyvalent metallic cations present, usually calcium and magnesium. None of the samples recorded levels in excess of the Tanzanian Standard of 600 mg/l.

f) Calcium and Magnesium

No limits have been defined in the Tanzanian Rural Water Health Standard, but taking into consideration the WHO Standard, allowable values of 200 mg/l calcium and 150 mg/l have been applied. None of the samples recorded levels in excess of the maximum permissible levels of Calcium and Magnesium.

g) Iron

Iron in domestic water supply stains laundry and porcelain, thus causing a nuisance rather than a potential health hazard. A bitter or astringent flavor is felt by some people when the level of iron in drinking water exceeds 1.00 mg/l. As for six water samples from reservoirs and dug wells, Iron exceeded the limitation. The highest content of recorded was 6.00 mg/l at Oltukai dug pit.

h) Nitrate

Nitrate represents the most completely oxidized state of nitrogen commonly found in water. Many granular commercial fertilizers contain nitrogen in the form of Nitrate. Four water samples have high concentrations of Nitrate exceeding the Tanzanian Rural Health Standard of 100 mg/l; they are the Lake Manyara, Nanja swamp, Lashaine reservoir and Makuyuni river.

i) Chloride and Sulphate

Except for the water samples from Lake Manyara, the Chloride concentration is lower than the Tanzanian Standard of 800 mg/l. Two water samples from Lake Manyara and the Lashaine reservoir exceed the permissible values.

j) Fluoride

Fluoride occurs naturally in some groundwater and one to two mg/l level is normally maintained in public drinking water supplies for the prevention of dental caries. Three water samples have high values exceeding the Tanzanian Standard for Drinking Water of 8.0 mg/l; they include the Lake Manyara, Moita Kirolite reservoir and Mswakini boreholes.

k) Electrical Conductivity (EC)

The Electrical Conductivity of water varies directly with the concentration of salts in solution and gives a general indication of the total dissolved solids (TDS) in the water. The measurement of this parameter is very important because it gives a quick approximate guide to the physico-chemical quality of a water source.

Electrical Conductivity values of more than 1,200μS/cm at 25 °C were taken as a reference figure, above which the water quality would probably not conform to the standard. Four water sources have higher Electrical Conductivity which exceed 1,200μS/cm, including Tukusi spring, Lake Manyara, Mswakini borehole and Burko BH-14 borehole.

(3) Bacteriological Characteristics

Out of 14 water samples, only four water samples, all of which are collected from boreholes, are safe from bacteriological contamination (Table 3-4). This may be due to animal and/or human contamination. Most sources are open, i.e. not fenced off and therefore entrance of people and animals to water sources might be the major cause of pollution.

(4) Hydrochemical Interpretation

Hydrochemistry greatly contributes to the understanding of groundwater flow. In an interpretation of the water quality data, analyses must correlate with one another and related information. As the surface flow begins from shallow to deeper artesian groundwater, the water quality is altered by three modifications: dissolution reduction, base exchange, and concentration. These changing processes of water quality are called the "hydrochemical evolution of groundwater".

Groundwater flows may be traced chemically in highly different scales ranging from a distance of a few meters to several hundred kilometers. Regardless of scale, chemistry is always a detective tool of research. As groundwater flows in aquifers over long distances, so increases in the ratio of HCO_3 to the total anion and Na+K to the total cation take place due to an acceleration of dissolution and base exchange. Therefore, it is easy to understand the hydrochemical evolution of each sample when they are plotted on a graph showing the relation between the two ratios.

The Piper Diagram is a useful representation to indicate differences or similarities in water, i.e. classification of water in terms of elapsed time after it has been recharged by the surface water system. The diagram can be divided into the following hydrochemical areas: carbonate hardness, carbonate alkali, non-carbonate hardness, non-carbonate alkali, and intermediate.

The carbonate alkali zone is generally represented by the water quality of surface river water and shallow groundwater and the carbonate alkali zone is represented by it of deep groundwater. In general, the hydrochemical evolution of groundwater is directed from carbonate hardness to carbonate alkali, except for salt-contained and mineralized groundwater. Interpretation of the water quality data may be worked out based on graphical plotting (Figure 3-3 and 3-4) as follows:

Group 1: Area of Carbonate Hardness zone

Rivers, Springs and Reservoirs

- Lolkisale spring, Tukusi spring, Kilimani spring Lossimingor spring, Mto wa Mbu river, Kirurumo river and Ingulpan river.

Boreholes

- Mswakini 10/29, Tukusi EX-3, Makuyuni 23/68 and Monduli Juu EX-7.

Group 2: Area of Carbonate Hardness, but close to Carbonate Alkali zone

Rivers, Springs and Reservoirs

- Monduli Juu spring, Mbuyuni reservoir, Lendikinya reservoir Meserani Bwawani reservoir, Lepurko reservoir, Enguik spring and Oltukai dug well.

Boreholes

- Selian and Burka BH-14.

Group 3: Area of Carbonate Alkali zone

Rivers, Springs and Reservoirs

- Meru spring (Emaoi spring), Makuyuni river, and Moita Kiloreti reservoir.

Boreholes

- Makuyuni 10/52 and Burko BH-2

Group 4: Area of Non-carbonate Alkali zone

- Nanja swamp and Lashaine reservoir

3 - 5 Evaluation of Aquifer Potential

3 - 5 - 1 Aquifer Potential in the Study Area

Well yields for respective hydrological units and basin-wide groundwater potential have been evaluated through the data analyses collected from the existing wells drilled by RDD (Table 3-5) and the exploratory wells drilled by the Study Team (Table 3-1). Well yields for respective hydrogeological units are presented in Table 3-6.

(1) Lake Manyara Beds

As shown in Table 3-6, the yields from wells drilled in the Lake Manyara Beds range widely from 37 to 527 liters per minute. The calculated transmissivity in Makuyuni borehole is 23 square meters per day. Screens were installed in calcareous beds on top of the basement. The static water levels are

24 meters below the ground surface at Makuyuni borehole 23/68 and 52 meters below the ground surface at borehole 78/86 drilled near the Lake.

The yields of wells from the unconsolidated aquifers of the Lake Manyara Beds are generally excellent among the respective hydrogeological units identified in the Study Area. Nevertheless, the exploratory well EX-1 drilled at Naitolia to a depth of 76 meters, the southern edge of the Beds, was dry. This may imply that the yield of a well in the Lake Manyara Beds depends on its location whether it is drilled nearby the outlet of river channels under which groundwater is flowing from recharging areas.

(2) Colluvial Beds

Ex-7 test well was drilled to a depth of 102 meters in the Colluvial Beds at Monduli Juu. Continuous pumping tests were tried for 24 hours, resulting in 21 liters per minute of well yield, 3.3 meters of maximum drawdown and 72 meters below the ground surface for a static water level. Lithology of major aquifers is quartzose volcanic sand which is located from 68 to 100 below the ground surface, and screens with a total length of 20 meters were installed in the Beds.

There is a possibility to increase the screenable length of permeable beds when the drilling depth is extended to 150 meters, according to the results of resistivity prospecting at Monduli Juu.

(3) Plateau Lava

Most test wells planned for water development in Monduli town were located to identify aquifers in the Plateau Lava. EX-11 test well was drilled in the foothills of Mt. Monduli where the Younger Extrusives probably underlie; however, drilling encountered pressure gas in a volcanic rock cavern at a depth of 150 meters below the ground surface. As is well-known, Plateau Lava is characterized by the presence of pressure gas in cavern lava.

The yield of the RDD well 2/36 at Tarsero was 38 liters per minute at a static water level of 26 meters below the ground surface; drawdown was not recorded. The lithology of the aquifer is the Colluvial Beds which overlie the Younger Extrusive. According to the data from the RDD well 7/82 at Meserani

Bwawani located in the south of Ardai basin, the well yield was 28 liters per minute with a maximum drawdown of 7.3 meters. The static water level was 90 meters below the ground surface.

Several exploratory wells were drilled in the Ardai basin; however, no pumping test has so far been carried out. The results of resistivity prospecting done by the Study Team have revealed that a high resistivity layer which can be correlated with massive volcanic rocks, was not detected within the prospecting limit of 1,000 meters with some exceptions.

(4) Basement

Basement aquifers are of particular importance in the southern part of the Study Area because of their wide spread extent in the Arusha region. The aquifers are developed within the weathered overburden and fractured bedrocks of crystalline rocks of intrusive and/or metamorphic origin which are mainly of Precambrian age.

The results of ARWMP drilling indicate that the average static water levels and well yields from 97 wells are 31 meters below the ground surface and eight cubic meters per hour respectively. Exploratory well EX-3 at Tukusi, which had a drilled depth of 100 meters, yielded one liter of water per minute by air lifting at a static water level of 62 meters below the ground surface, and the RDD test well 54/55 yielded 18 liters of water per minute and had a static water level of 104 meters below the ground surface.

3 - 5 - 2 Aquifer Potential in Engare Olmotoni Area

RDD organized a study group led by the Regional Water Engineer to investigate supplemental water sources for Monduli town water supplies. The investigation has been ongoing for several years covering Lakilaki Coffee Estate, Kisongo and Arusha Air Field. Main works include hydrogeological surveys and resistivity prospecting. Prior to the study, several exploratory wells were drilled by RDD in the drainage areas of the Engare river, the southwestern slopes of Mt. Meru. Table 3-6 gives general information on the test wells.

The Engare Olmotoni area is underlain by Mt. Meru volcanic lava and is covered by volcanic debris. The thickness of the lava is more than 50 meters at the borehole site of BH 142/79. The lava has been subject to heavy weathering and fracturing, and is interbedded with coarse volcanic sand, which may indicate that the lava could act as a part of aquifer.

As presented in Table 3-6, the static water levels range from 30 to 45 meters below the ground surface except BH 142/79, and the average water yield is 33 cubic meters per hour. The calculated maximum specific capacity and transmissivity are 15.8 cubic meters per hour per meter and 752 square meters per day, respectively. The data are highly fluctuating; however, this may not be due to the location of well sites but the inadequate well completion techniques and mis-location of screen intervals.

3-6 Potential Well Yields

3-6-1 General

Based on the specific capacities obtained through the examination of exploratory well drilling and data on the existing wells, the optimum well yields for respective hydrogeological units has been assessed as given in Table 3-7. Specific capacities are applied for calculation of a particular well yield. Depths of proposed wells are determined based on the results of borehole loggings and geological well logs of the exploratory wells drilled in the Study Area. The optimum well yields are finally determined on condition that screens of a minimum 20 meters be installed, minimum drawdown is 10 meters, and pumping is operated for 10 hours a day. Table 3-8 presents the results of evaluation of well yields.

3-6-2 The Study Area

(1) Lake Manyara Beds

The Lake Manyara Beds overlying the Basement occur in the southern part of the Study Area. Four villages are located on the lake Manyara Beds; they are Oltukai, Mswakini, Naitolia and Makuyuni, of which the two villages of Naitolia and Oltukai have no groundwater development potential because of low potential together with inferior water quality due to high electrical conductivity. The possible well yield of one production well is 135 cubic meters per day for Makuyuni Village and 144 cubic meters per day for Mswakini village.

(2) Colluvial Beds

Large-scale Colluvial Beds underlie the Monduli Juu Caldera. The possible groundwater yield of one production well is 36 cubic meters per day at Emairete village. The relatively low yield is due to the small scale of the well's recharge area.

(3) Younger Extrusive

Three major mountains are underlaid by the Younger Extrusives. Geological boundaries are not clear between the Plateau Lava on the northern edge of the Ardai and the Eluanata basin. EX-7 test well in Tarorero was planned to be located in the Younger Extrusives, but drilling encountered pressured gas in a lava cavern. This may suggest that the volcanic rock encountered probably belong to the Plateau Lava.

(4) Plateau Lava

Groundwater potential in these volcanic rocks vary from place to place according to their lithology. One of the major problems with respect to groundwater development, especially for rural water supplies, is deeper static water levels. In many cases, water cannot be lifted by a manual pump. The possible groundwater yield of one production well is 50 cubic meters a day in and around Meserani Bwawani village and Monduli town.

(5) Basement Rocks

The groundwater potential in the Basement Rocks is variable according to the thickness of the weathered rocks of the Basement. The possible groundwater yield of one production well is 12 cubic meters per day at Naitolia village, east of the Lake Manyara Beds.

3 - 6 - 3 Engare Olmotoni Area

The data from seven test wells are so far available to evaluate the groundwater yields of Engare volcanic rocks extending north of Arusha Air Field. No exploratory well drilling was conducted here under the Study. The average groundwater yield of the above seven wells is 630 cubic meters per day (Table 3-5).

Table 3 - 1 SUMMARY OF EXPLORATORY WELLS

Will No.	Location	Depth		Tested Data		Lithology of Aquifer
		Drilled (m)	Cased (m)	S. W. L. (mbgs)	Yield (1/min)	
EX - 1	Natiolia	76	73	65.00	negligible small	calcareous sand
EX - 2	Mbuyuni	64	60	58.00	dry	fructured basalt
EX - 3	Tukusi	98	79	54.56	1.00	weathered basement
EX - 4	Ngarasi Monduli Town	154	144	122	negligible small	volcanic sand
EX - 5	Lashaine	198	not cased		negligible small	
EX - 6	Lendikinya	250	not cased		dry	
EX - 7	Emairete Monduli Juu	102	100	72.25	20.66	voalcanic sand
EX - 8	Sinon Monduli	126	100		dry	fractured basalt
EX - 9	Arkatan-West	48	not cased		dry abandoned	
EX - 10	Arkatan-East	152	140	135.91	dry	scoriatic vol. rocks
EX - 11	Tarosero Monduli Town	200				

Table 3-2 RESULTS OF IN-SITU WATER QUALITY TEST

No.	Location		Altitude (mamsl)	Type of Sources	Date	EC (μS/cm)	pH	Temp (°C)	Bacteria	Coliform	Color	Turbid'y
	Village	Log./Lat.										
1	Lake Manyara	3°38.714' 35°52.285'	985	Lake	Dec. 22, 94	8,750	10.0	28.4	3	-	+	+ +
2	Arkatan Ardai Dam	3°21.760' 36°24.054'	1,315	Reservoir	Jan. 17, 95	558	8.8	30.9	-	-	+ + +	+ + +
3	Emairete Monduli Juu	3°14.066' 36°22.921'	1,780	Reservoir	Feb. 16, 95	274	8.1	24.2	5	5	+ + +	+ + +
4	Lepurko	3°20.146' 36°13.369'	1,520	Reservoir	Dec. 15, 94	311	8.2	26.5	-	+ + +	+	+ + +
5	Monita Bwawani	3°33.470' 36°35.829'	1,170	Reservoir	Dec. 26, 94	347	8.7	29.2	30+	20	+	+ +
6	Monita Kileriti	3°28.736' 36°32.014'	1,290	Reservoir	Dec. 26, 94	426	8.8	25.8	20+	0	+	+ +
7	Naitolia	3°36.210' 36°04.981'	1,100	Reservoir	Dec. 14, 94	150	8.7	28.7	0	0	+ + +	+ + +
8	Essimingor	3°25.320' 36°10.722'	1,325	Surface river	Dec. 15, 94	669	8.7	28.8	10	20+	+	+ +
9	Mbuyuni	3°28.179' 36°12.774'	1,320	Surface river	Dec. 13, 94	381	8.3	30.0	0	0	+	+ +
10	Meserani Bwawani	3°29.425' 36°26.541'	1,240	Surface river	Dec. 23, 94	559	9.1	30.7	+ + +	+ + +	+ +	+ +
11	Oltukai	3°37.853' 35°55.581'	1,020	Surface river	Dec. 14, 94	423	7.8	29.1	-	-	-	+ + +
12	Ardai River	3°25.345' 35°25.791'	1,440	Surface river	Mar. 14, 95	119	8.7	20.4		+ + +	+ + +	+ + +
13	Makuyuni River	3°33.532' 36°05.538'		Surface river	Mar. 14, 95	291	9.0	25.2		+ + +	+ +	+ +
14	Kirarumo River	3°22.117' 35°50.427'	1,080	Surface river	Mar. 14, 95	344	8.8	25.5		0	clear	none
15	Monduli Urban	3°17.148' 36°26.926'	1,625	Tank Rasharasha	Dec. 16, 94	106	8.3	19.8	5	2	clear	none
16	Monduli Urban	3°17.148' 36°26.926'	1,625	Tank Kiliman	Dec. 16, 94	103	8.3	18.4	10	10+	clear	none
17	Monduli Mountains	3°15.513' 36°28.035'	1,950	Spring	Dec. 30, 94	126	8.4	17.5	11	0	clear	none
18	Emairete Monduli Juu	3°15.085' 36°23.432'	1,765	Spring	Dec. 16, 94	364	7.4	18.9	+ + +	+ +	+ + +	+ + +
19	Enguik Monduli Juu	3°13.902' 36°25.703'	1,905	Spring	Dec. 16, 94	75	7.5	21.2	-	-	clear	none
20	Essimingor	3°24'43.85" 36°06'05.4"	1,615	Spring	Feb. 13, 95	642	7.6	21.2	+ + +	0	clear	none
21	Mungu Crater	3°31.351' 36°36.108'	1,160	Spring	Dec. 26, 94	400	8.5	25.7	50+	20+	+	+
22	Tukusi	3°41.066' 36°36.237'	1,130	Spring	Dec. 29, 94	802	7.5	28.2	15	20+	clear	none
23	Tukusi	3°42.237' 36°34.682'	1,180	Spring	Dec. 29, 94	1,145	7.7	26.5	50+	50+	clear	none
24	Lashaine Pump Station	3°19.324' 36°27.027'	1,410	Pipe from Meru Spring	Feb. 27, 95	226	8.2	25.3	50+	0	clear	none
25	Mt. Meru TMA source	3°18'26.4" 36°43'27.3"	1,860	Spring	Mar. 08, 95	177	8.1	18.5	5	0	clear	none
26	Lolkisare	3°22.097' 36°50.422'	960	Spring	Mar. 15, 95	308	8.4	21.6	50+	30+	clear	none
27	Arkatan Nanja Swamp	3°22.703' 36°16.757'	1,390	Dug pit	Jan. 17, 95	1,892	7.7	23.1	+ + +	0	clear	+
28	Mswakini	3°40.775' 36°00.553'	1,055	Borehole 110/79	Feb. 13, 95	1,406	7.4	28.1	50+	0	clear	none
29	Makuyuni	3°33.302' 36°05.461'	1,050	Borehole 10/52	Feb. 09, 95	1,032	7.5	27.1	+ + +	+ + +	clear	none

Table 3-3 RESULTS OF WATER QUALITY ANALYSES

1) Surface River, Spring & Lake

No.	Name of Village	Kind of Sources	Turb'ty (NTU)	Colour (mg/ℓ Pt)	Odour	Taste	pH	EC (μS/cm)	TDS (mg/ℓ)	Alkali. (mg/ℓ)	Ca (mg/ℓ)	Mg (mg/ℓ)	Fe (mg/ℓ)	Mn (mg/ℓ)	Cr (mg/ℓ)	PO4 (mg/ℓ)	Cu (mg/ℓ)	Na (mg/ℓ)	K (mg/ℓ)	Hard. (mg/ℓ)	HCO3 (mg/ℓ)	NO3 (mg/ℓ)	NO2 (mg/ℓ)	SO4 (mg/ℓ)	Cl (mg/ℓ)	F (mg/ℓ)	KMnO4 (mg/ℓ)	NH3 (mg/ℓ)
QS-1	Kilimani	Spring	2	20	nil	good	8.00	123	62	100	8	19.52	0.34	0.10	0.04	0.48	0.21	3	1	60	100	14.08	0.10	0	5	0.45	0.30	0.00
QS-2	Losimingor	Spring	5	30	nil	good	7.80	690	345	320	64	17.08	0.15	0.60	1.78	0.04	0.23	30	4	230	320	17.16	0.17	36	15	0.72	1.73	0.02
QS-3	Monduli Juu	Spring	160	1,020	humic	poor	6.80	425	263	205	20	12.20	5.70	19.00	0.39	2.95	2.54	19	11	70	205	39.06	0.40	40	5	3.51	54.72	0.20
QS-4	Nanja	Swamp	250	1,500	organic	muddy	8.20	385	193	160	40	12.20	3.15	9.50	0.15	2.01	0.95	95	20	150	160	299.20	3.00	80	70	2.51	27.36	0.60
QS-5	Lashaine	Reservoir	12,000	97,000	organic	obj'ble	8.00	384	192	190	12	7.32	0.40	0.20	2.75	6.50	18.00	50	150	60	190	275.00	2.60	200	10	7.58	0.30	2.00
QS-6	Tukusi	Spring	3	19	nil	sl.sali.	7.70	1,374	687	730	28	100.00	0.12	0.00	0.06	0.03	0.31	64	15	480	730	5.72	0.30	52	30	2.10	0.00	0.00
QS-7	Neru	Spring	2	12	nil	good	8.10	175	89	130	2	3.66	0.10	0.00	0.02	0.18	0.12	20	5	20	130	7.48	0.06	0	3	4.32	0.00	0.00
QS-8	Makuyuni	River	14,000	98,000	nil	obj'ble	8.90	294	147	100	8	19.52	0.34	0.10	1.00	1.48	1.21	37	48	60	100	114.08	1.10	5	5	1.45	0.30	2.00
QS-9	Manyara	Lake	12,000	97,000	organic	saline	10.34	12,400	6,200	11,000	80	63.44	2.34	5.10	1.04	0.68	0.34	130	70	460	8,000	364.08	3.64	1,200	2,500	35.45	14.67	3.52
QS-10	Kirurumo	River	12	50	nil	good	8.34	365	182	184	24	17.80	0.05	0.20	0.03	0.04	0.01	10	3	480	184	6.16	0.03	5	9	0.62	0.58	0.00
QS-11	Lolkisale	Spring	3	17	nil	good	8.40	308	154	70	24	9.76	0.05	0.70	0.06	0.03	0.31	13	2	100	70	7.48	0.03	22	25	0.65	2.00	0.00
QS-12	Mto Wa Mbu	River	0	0	nil	good	7.40	360	180	240	36	24.40	0.05	0.30	0.01	0.01	0.01	11	4	190	240	14.52	0.14	0	5	0.38	1.15	0.00
QS-13	Ingulupani	River	2	12	nil	good	8.20	369	189	240	36	21.96	0.00	0.00	0.00	0.01	0.00	15	7	180	240	14.52	0.14	0	5	0.63	0.00	0.00
QS-14	Tukusi	River	10	49	nil	good	9.14	991	496	430	36	63.44	0.04	0.00	0.03	0.15	0.07	22	5	350	430	5.28	0.05	28	45	1.66	0.00	0.00
QS-15	Enguik	Spring	12	63	nil	good	8.12	237	119	100	12	12.20	0.70	0.08	0.02	0.34	0.08	28	8	80	100	7.04	0.07	1	1	0.60	0.23	0.01
QS-16	Lepurko	Reservoir	67	351			7.5	425	213	190	16	2.44	0.73	1.40	0.08	0.79	0.10	16	7	50	190	14.08	0.14	13	10	6.16	4.03	0.19
QS-17	Lendikinya	Reservoir	5,475	21,500	smell	unobj.	7.53	130	65	210	12	4.90	1.34	9.60	0.43	0.74	0.15	14	4	50	210	11.00	0.10	27	5	2.29	27.65	0.42
QS-18			13	71	nil	good	7.63	216	108	100	4	2.44	0.01	0.10	0.04	0.43	0.08	12	2	20	100	4.83	0.50	1	3	3.63	0.30	0.00
QS-19	Mfereji	River	12	64	nil	good	8.17	136	68	60	10	6.10	0.03	0.10	0.02	0.18	0.07	32	9	50	60	7.04	0.07	0	3	0.56	0.30	0.00
QS-20	Meserani B.	Reservoir	1,060	5,800	smell	unobj.	7.78	360	180	60	16	2.44	0.65	4.15	0.44	1.35	0.08	20	8	50	60	14.52	0.15	14	5	4.17	11.95	0.40
QS-21	Mbuyuni	Reservoir	1,100	5,960	smell	unobj.	8.33	669	335	340	16	9.76	1.29	3.04	0.58	2.21	0.09	18	6	80	340	7.04	0.08	27	10	6.60	8.76	0.35
QS-22	Moita K.	Reservoir	226	1,360	smell	unobj.	8.02	642	321	300	12	4.90	0.54	5.01	0.25	1.76	0.10	34	12	80	300	11.00	0.11	12	10	14.12	14.43	0.10
QS-23	Oltukai	Oug well	79	444	nil	good	6.95	1,103	560	750	24	0.85	6.00	0.03	1.27	1.27	1.50	180	24	430	750	8.80	0.05	19	5	1.20	17.28	0.08

Note: QS-1 to QS-13 tested on March, 1995 and QS-14 to QS-23 stested on Aug. to Oct., 1995

2) Borehole

No.	Name of Borehole	Location	Turbidit (NTU)	Colour (mg/ℓ Pt)	Odour	Taste	pH	EC (μS/cm)	TDS (mg/ℓ)	Alkali. (mg/ℓ)	Ca (mg/ℓ)	Mg (mg/ℓ)	Fe (mg/ℓ)	Mn (mg/ℓ)	Cr (mg/ℓ)	PO4 (mg/ℓ)	Cu (mg/ℓ)	Na (mg/ℓ)	K (mg/ℓ)	Hard. (mg/ℓ)	HCO3 (mg/ℓ)	NO3 (mg/ℓ)	NO2 (mg/ℓ)	SO4 (mg/ℓ)	Cl (mg/ℓ)	F (mg/ℓ)	KMnO4 (mg/ℓ)	NH3 (mg/ℓ)
QB-1	110/29	Mswakini	3	18	nil	sl.sali.	7.09	1,400	700	620	60	70.76	0.11	0.30	0.04	0.69	0.16	70	13	440	620	6.60	0.07	120	5	9.54	0.86	0.00
QB-2	10/52	Makuyuni	4	24	nil	good	7.09	813	407	450	20	21.96	0.04	0.20	0.55	0.02	0.14	71	12	140	450	12.32	0.12	1	15	1.99	0.58	0.03
QB-3	EX-3	Tukusi	93	498	nil	good	8.83	796	398	410	40	73.20	0.08	0.30	0.04	0.11	0.46	60	12	400	410	6.16	0.60	34	30	2.20	0.86	0.00
QB-4	23/68	Makuyuni	15	77	nil	good	8.85	864	432	500	16	31.72	0.02	0.10	0.03	0.30	0.10	31	3	170	500	4.84	0.05	0	6	1.31	0.30	0.00
QB-5	EX-7	Emairete	12	59	nil	good	7.61	491	246	240	24	43.90	0.04	0.00	0.04	0.36	0.08	13	11	160	240	5.28	0.05	0	5	1.90	0.00	0.00
QB-6	Burko BH-2	Buka Est.	5	30	nil	good	7.67	705	360	50	6	3.66	0.44	0.10	0.03	0.44	0.10	20	7	30	50	4.84	0.05	18	10	6.30	0.30	0.00
QB-7	Selian BH	Selian	3	21	nil	good	8.54	987	494	210	22	8.54	0.04	0.00	0.02	0.24	0.06	21	4	90	210	10.56	0.12	27	15	4.57	0.00	0.01
QB-8	Burko BH-14	Buka Est.	16	86	nil	good	7.22	1,262	631	510	20	4.89	0.01	0.10	0.03	0.36	0.15	23	2	70	510	10.20	0.11	110	35	5.30	0.30	0.01
WHO Drinking Standard			25	50			6.5-9.2		1,500		200	150.00	1.00	0.50			1.50			500				150	600	8.00		

Note: QB-1 to QB-3 tested on March, 1995 and QB-4 to QB-8 stested on Aug. to Oct., 1995
WHO Standard is limitation of maximum permissibl level.

Table 3 - 4 BACTERIOLOGICAL TEST

Village	Source and Location	Date sampled	Expressed as Bacteria/100mL of sample	
			Faecal coliform	Comments.
Moita Kiloriti	dam	18/9/1995	TNTC	Unsatisfactory
Mbuyuni	dam	18/9/1995	TNTC	Unsatisfactory
Meserani Chini	dam	18/9/1995	TNTC	Unsatisfactory
Tukusi	borehole	02/8/1995	0	Satisfactory
Makuyuni	borehole	15/7/1995	0	Satisfactory
Mfereji	Engos-Emotispring	16/9/1995	43	Unsatisfactory
Emairete	BH No. 2	08/9/1995	1	Unsatisfactory
TMA	Emaoi spring	16/9/1995	18	Unsatisfactory
Lendikinya	dam	11/9/1995	TNTC	Unsatisfactory
Lepurko	dam	10/9/1995	TNTC	Unsatisfactory
Enguik	spring	10/9/1995	20	Unsatisfactory
Burka Estate	borehole 14	20/9/1995	0	Satisfactory
Selian	borehole	20/9/1995	1	Unsatisfactory
Burka Estate	borehole 2	20/9/1995	0	Satisfactory

Note: TNTC Means Too Numberous to Count

Table 3-5 SUCCESSFUL BOREHOLES OF RDD IN AND AROUND THE STUDY AREA, MONDULI DISTRICT

BH. No.	Depth (m)	SWL (mbgs)	DWS (mbgs)	Yield (m^3. hr)	D/d (m)	S. C. (1/min/m)	Dep. to H. Rock	Aquifer	Location	Alt. (mamsl)	Long. Lati.
2/36	72.2	26.1	36.4	2.30	-	-	-	W. lava	Tarasero	1,546	3° 16.816' 36° 26.305'
3/36	73.2	26.2	36.6	2.30	-	-	-	W. lava	Tarasero	1,530	3° 16.816' 36° 26.305'
10/52	103.6	31.1	34.1	4.50	-	-	-	W. dike	Makuyuni	1,095	3° 33.302' 36° 05.461'
54/55	155.4	104.0	152.7 154.0	1.10	-	-	-	W. gneiss	Naitolian	1,105	3° 38.195' 36° 07.331'
23/68	144.6	24.0	95.0	2.20	-	-	-	W. basement v. ash	Makuyuni	1,105	3° 32.362' 36° 04.262'
110/79	103.7	30.0	42.7 85.4	31.60	43.0	12.2	103.0	calcareous	Mswakini	1,055	3° 40.775' 36° 00.553'
7/82	106.8	89.9	-	1.70	7.3	3.9	-	c. sand grav, granu.	Meserani * Bwawani	1,220	3° 32.071' 36° 25.900'
112/84	29.0	5.2	9.5 20.1 25.0	2.18	-	-	28.9	soft soil clay	Engwiki	1,730	3° 15.040' 36° 23.453'
78/86	-	51.6	-	11.30	-	-	-	w. basalt	Manyara ranch	1,030	3° 32.976' 36° 00.841'

Remark : DWS = Depth water struck SWL = Static water level D/d = Drawdown
SC = Specific capacity Alt = Altitude

Table 3-6 SUMMARY OF EXPLORATORY WELLS IN ENGARE OLMOTONI AREA

BH. No.	Depth (m)	Well Dia (mm)	Screen (m-m)	SWL (mbgs)	Yield (m^3. hr)	D/d (m)	Duration (hrs)	S. C. (1/min/m)	Aquifer	Location	Alt. (mamsl)	Long. Lati.
AR 75/86	119.0	200	52-57, 61-72 81-91, 101-111 =36m	40.6	10.30	13.54	8.7	0.76	fractured basalt	Burka Coff. Estate	1,385	3° 20.661' 36° 36.991'
AR 70/77	97.6	150	total=19.5m	30.1	33.77	8.05	-	4.19	-	Magereza Air port	1,375	3° 22.041' 36° 37.375'
AR 142/79	94.6	168	40-69.3 =29.3m	1.5	89.10	10.75	6.0	8.29	sand & gravel	Kirany Mission	1,385	3° 21.216' 36° 40.068'
AR 37/80	152.5	219-156	21-30, 49-59 71-81, 119-124 =34m	45.7	47.88	3.03	18.0	15.80	sand & gravel	Arusha Seed Farm	1,500	3° 18.475' 36° 38.066'
AR 47/80	127.2	219	37-49, 61-73 85-98 =24m	38.0	6.01	8.80	5.0	0.68	basalt	Arusha Seed Farm	1,495	3° 18.425' 36° 37.943'
AR 79/80	91.5	168	44-63 = 19m	42.7	5.08	25.30	4.3	0.20	fractured basalt	Arusha Seed Farm	1,495	3° 18.580' 36° 37.995'
AR 96/80	140.0	200	57-72, 90-105 =30m	31.7	39.60	12.44	14.0	3.18	sand & gravel	Arusha Seed Farm	1,480	3° 18.665' 36° 37.875'

Note: W.D.= Well diameter SWL=Static water level D/d=Drawdown Duration=Tested duration
S. C.= Specific capacity T= transmissivity Alt=Altitude

Table 3-7 GROUNDWATER POTENTIAL IN RESPECTIVE HYDROGEOLOGICAL UNITS

Hydrogeological Unit	BH. No.	Depth of Well (m)	SWL (mbgs)	DWS (mbgs)	Yield (ℓ/min)	D/d (m)	S.C. (ℓ/min)	T (m^2/d)	Aquifer	Location
Lake Manyara Bed	10/52	104	31.0	34	78	7.5	10.4	23	calcareous	Makuyuni
Lake Manyara Bed	23/68	145	24.0	95	37	-			w. basement v. ash	Makuyuni
Lake Manyara Bed	110/79	104	30.0	43 85	527	43.0	12.3		calcareous	Makuyuni
Lake Manyara Bed	78/86	-	51.6	-	188	-			w. basalt	Manyara ranch
Colluvial Beds Monduli Juu	112/84	29	5.2	10, 20 25	36	-			soft soil clay	Emairete
Monduli Juu	EX-7	100	72.3	-	21	3.3	6.4	8	vol. sand	Emairete
Younger Extrusive	2/36	73	26.1	36	38	-			w. lava	Tarasero
Younger Extrusive	3/36	73	26.2	37	38	-			w. lava	Tarasero
Plateau Lava	7/82	107	89.9	-	28	7.3	3.8		c. sand grav, granu.	Meserani Bwawani
Basement	54/55	155	104.0	153 154	18	-			w. gneiss	Naitolia

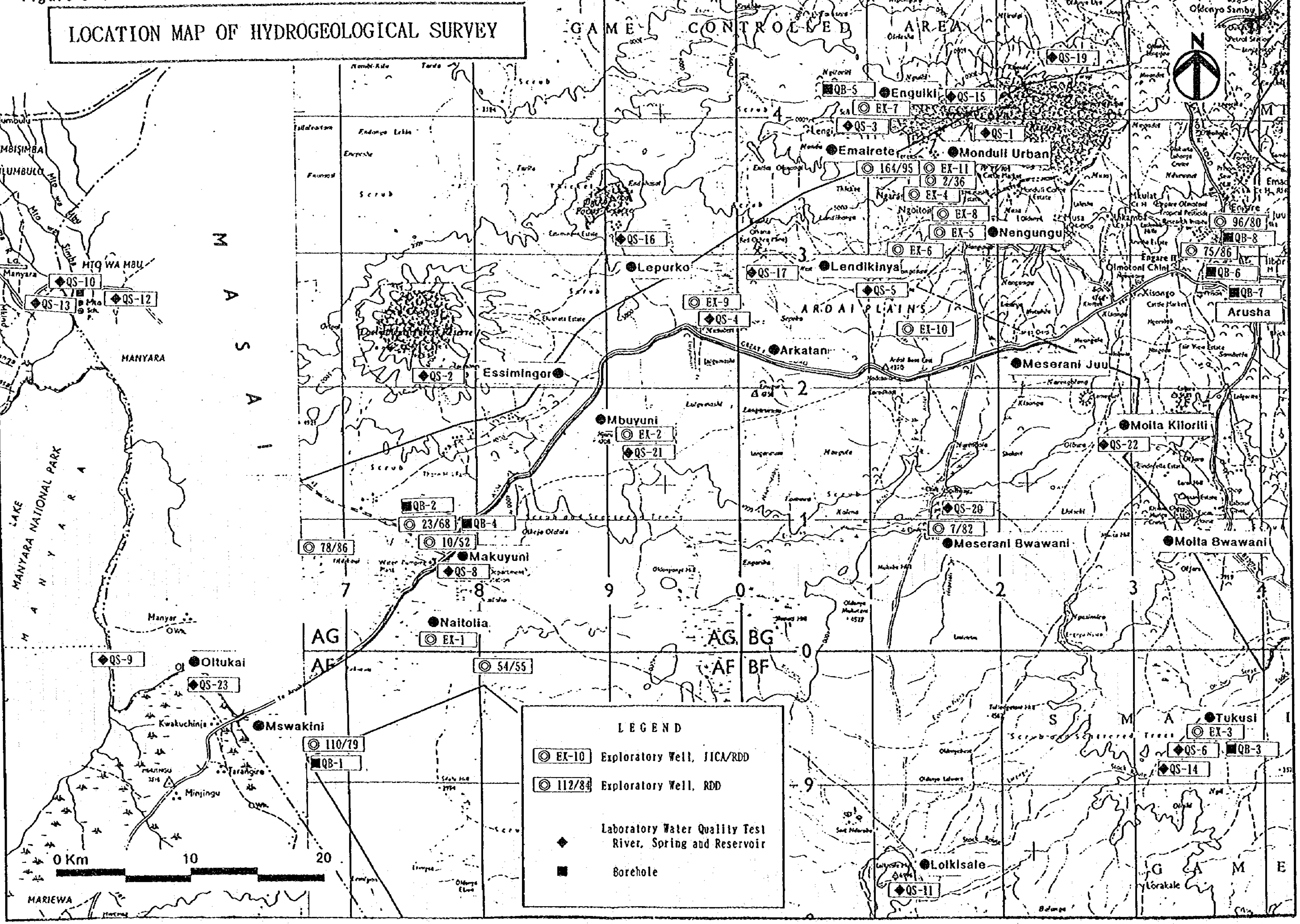
Remark: SWL = Static Water Level DWS = Depth Water Struck D/d = Drawdown
S.C. = Specific Capacity T = Transmissivity

Table 3-8 EVALUATION OF WELL YIELD FOR DEVELOPMENT PLAN

Formation/Village	Proposed Well Depth (m)	Aquifer Thickness (m)	S.W.L (mbgs)	Specific Capacity (ℓ/min/m)	Possible Drawdown (m)	Well Yield		Evaluated Wells	Major Constraint
						(ℓ/min)	(m^3/d)		
Lake Manyara Beds Makuyuni Mswakini	 100 120	 20 50	 30 30	 15 12	 15 20	 225 240	 135 144	10/52, 23/68 110/79, 82/79, 74/79	none E.C. = 1,400 μS/cm Fluorite = 9.54 mg/ℓ (limit. = 8.0)
Colluvial Beds Emaireti	150	25	75	6	10	60	36	EX-7, 107/79, 87/79	Small recharge area
Younger Extrusive Monduli Town	100	20	30	4	10	40	24	3/36	
Plateau Lava Monduli Town								EX-11, 164/95	
Basement Naitolia	200	20	30	2	10	20	12	54/55	Deep SWL & low potential
Engare Volcanics Engare Olmotoni	150	25	40	70	15	1,050	630	75/76, 70/77, 37/80, 47/80, 79/80, 96/80	Densely drilled production wells for private estates

Remark: Well yield in m^3/d is calculated based on 10 hrs pumping per day

Figure 3-1 HYDROGEOLOGICAL MAP OF THE STUDY AREA



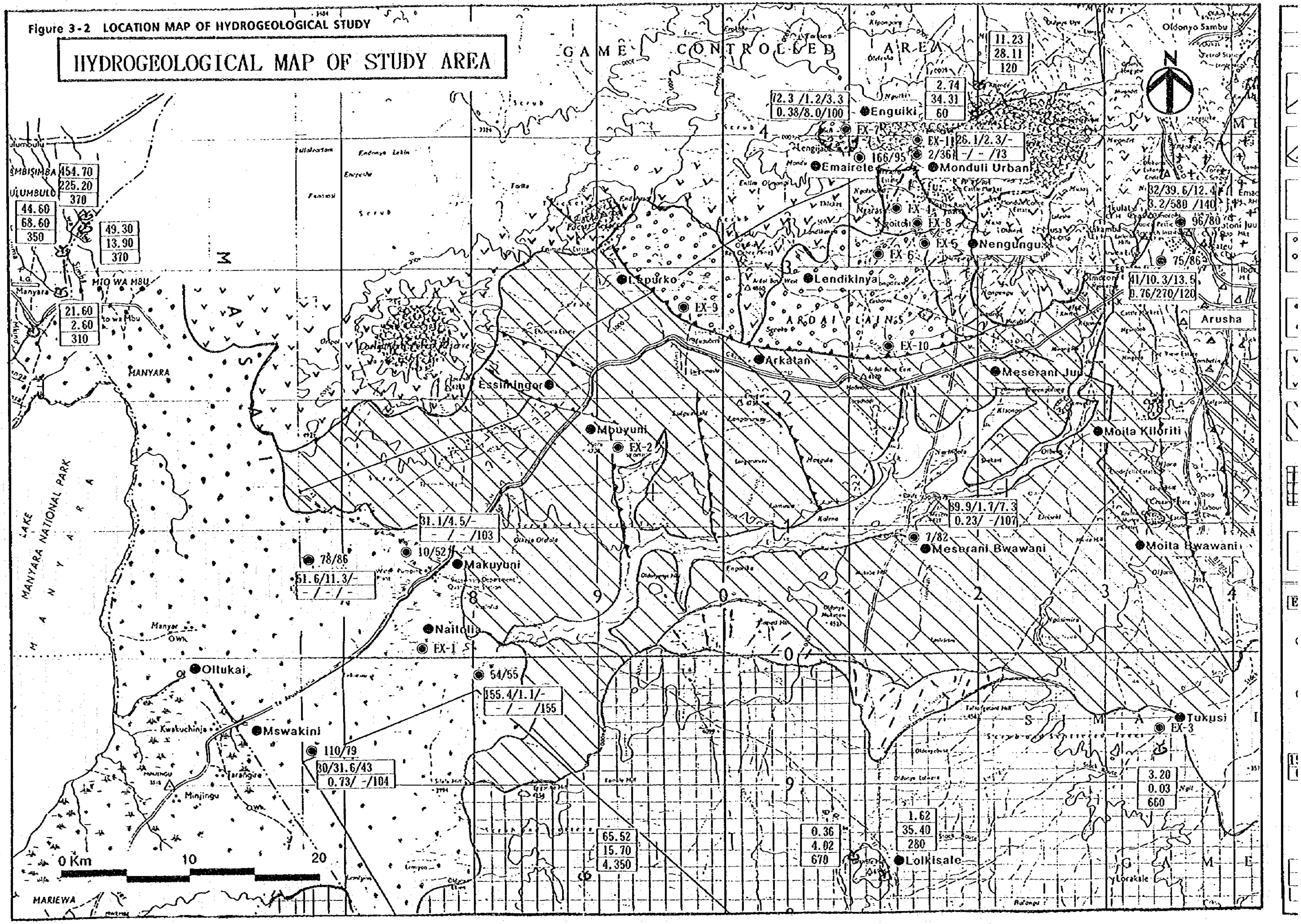
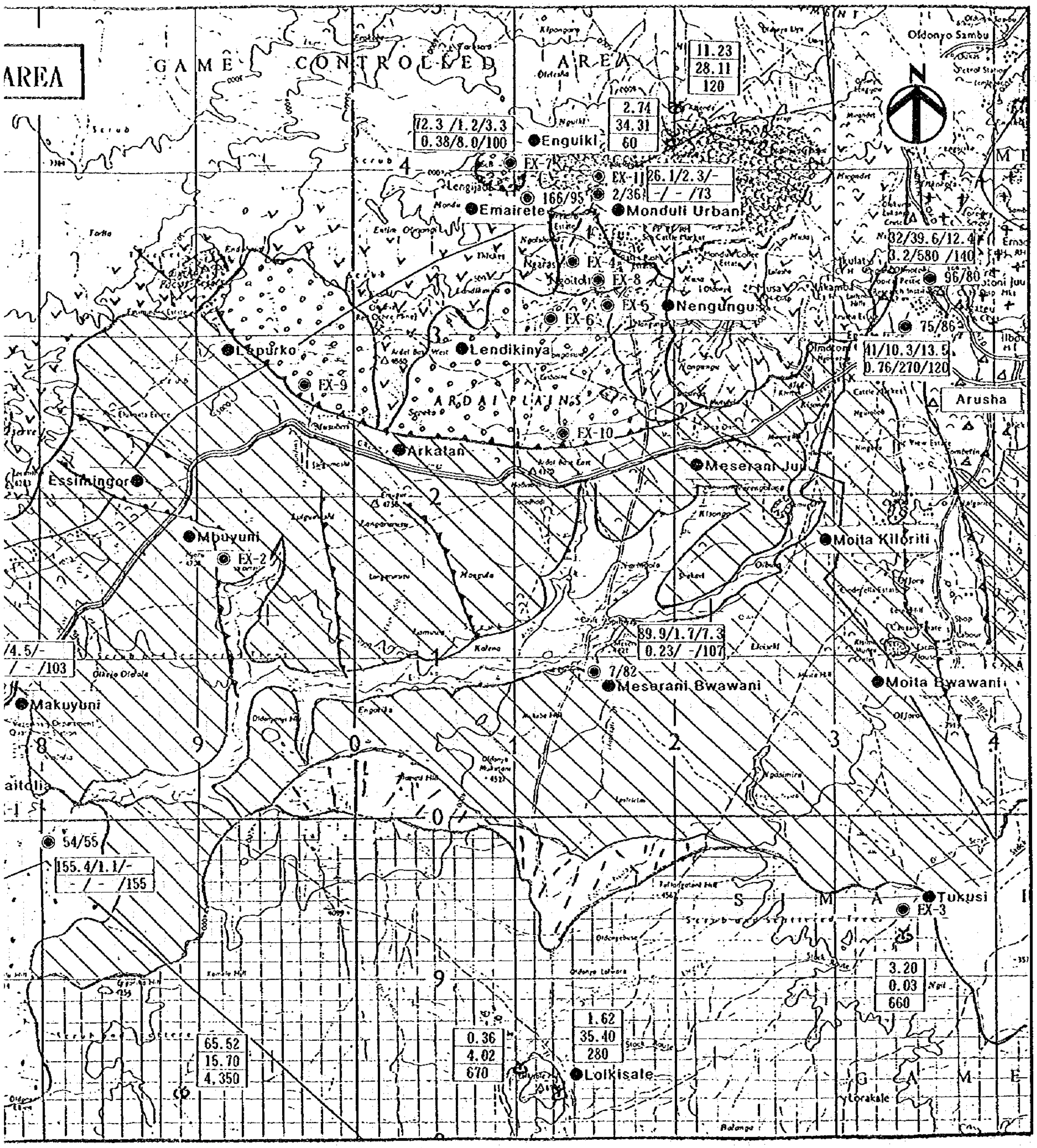


Figure 3-2 LOCATION MAP OF HYDROGEOLOGICAL STUDY

HYDROGEOLOGICAL MAP OF STUDY AREA



LEGEND

Symbol	Lithology	Hydrogeology
	RECENT River beds Clay, sand and gravels	Small scale shallow groundwater
	Fan, Talus Clay, volcanic sand & fragments	Small scale shallow groundwater
	Volcanic talus Clay, volcanic sand & fragments	Large scale groundwater in Engare Olmoton
	Colluvium Clay, volcanic sand & fragments	Large scale groundwater only in Monduli Juu
	NEOGENE Lake Nanyara Bed	Large scale groundwater, but inferior quality in EC and fluorine
	Younger Extrusive	Fractured aquifer with small scale quantity
	Plateau Lava	Fractured aquifers and pressure gas in volcanic caves. Depth to water level is more than 250 m
	PRECAMBRIAN Basement Rocks Gneiss, migmatite, granulite and metaigneous	Aquifer in weather part of Basement rocks
	Escarpments	

Explanation of Symbol and Figure		Remark
◉ 7/82	Exploratory Well of RDD	SWL=S. W. L. in mbgs Q =Well discharge in m3/hr Dd =Drawdown in m SC =Specific capacity in m3/hr/m T =Transmissivity in m2/day WD =Well Depth in m S. R=Specific discharge
◉ EX-10	Exploratory Well of JICA/RDD	
19.3 /4.7/7.5 0.62/10 /36	Well Potential SWL/Q/Dd SC/ T/WD	
	Spring	
3.2 0.032 300	Spring discharge Q (m3/hr) S. R(mm/ann) E. C. (μS/cm)	

CHAPTER 4 DEVELOPMENT PROPOSAL

CHAPTER 4 DEVELOPMENT PROPOSAL

4 - 1 Needs for Development

The existing water supplies covering about 65,000 of residents in the Study Area range from traditional hand-dug wells to modern boreholes. Water supplies for the surrounding 18 villages rely mainly on stored water in small-scale dams. Surface runoff of streams and rivers is seasonal and of very short duration. The present production of groundwater, which is a most suitable water source for rural water supplies for its stable yield and water quality, is estimated at 210 cubic meters per day. This could accommodate only 32 percent of the water demand to meet the minimum drinking water of 10 liters per capita per day when the pumping stations are operated as planned; however, operation is often interrupted by power failures or engine troubles.

The present water consumption is less than the minimum requirement; 9.5 liters per capita per day for Monduli town and 8.0 liters per capita per day for the surrounding villages. Water resources development is an urgent matter in order to meet the minimum water requirement for the time being and then to meet the increasing water requirement anticipated in the near future.

In many villages where water supplies rely on small scale-dams, water is not available in the dry season since surface runoff goes dry and proper water management is not put into practice. As a result of the unreliability of water sources, the villagers have to walk long distances in search of water. 95 percent of the households spend three hours a day collecting water for their families. Women and children undertake the responsibility of water collection, which is laborious work. For reduction in carrying distances, water sources development needs to be distributed over the entire Study Area.

The groundwater development potential in the Study Area is not adequate to fulfill the estimated water demand, though every effort was made to exploit groundwater. In spite of relatively high annual rainfall of not less than 800 millimeters in the catchment area extending behind the Ardai basin which is deemed to be an important groundwater recharge area, the results of exploratory well drilling have revealed less groundwater potential mainly due to complicated geological structures caused by volcanic activities.

Accordingly efforts shall be attempted to develop surface water by means of construction of small dams with well-designed water control structures. For stable water supplies throughout the year, water management should be introduced in operating reservoirs. In conformity with the national water policy, rural water supplies should be operated and maintained by the villagers as well as water charge collection. To this end, the functions of village water committees should be strengthened.

4-2 Objectives and Components of the Project

The main objective of the Project is to provide safe water throughout the year in adequate quantities for drinking, food preparation, and personal hygiene with a target year of 2014. Furthermore, in due consideration of the importance of livestock keeping to the villagers in the Study Area together with contribution of the livestock sector to the regional economy, water provision for livestock has been proposed within the limits of available water resource.

The Project proposes development of water resources including provision of water source facilities and public standpipes; distribution systems with house connections have not been planned as a part of this Project because of the very low population density (around 17 person per square kilometer) prevailing in the surrounding areas and economic consideration in-keeping with the low economic level of the communities. It is expected that the system will be expanded from standpipes to individual house connections as the community becomes more prosperous.

To accomplish the above objective, the Project proposes to implement the following projects, with minimal investment, serving all villagers.

Groundwater Development

1) Existing Monduli Water Supply Project
- Construction of boreholes with power pumps in Engare Olmotoni area, north of the Arusha airfield.
- Construction of transmission pipelines with booster pumps from the proposed boreholes to the existing water tank in Monduli town.

2) Existing Village Water Supply Projects

- Rehabilitation of Makuyuni water supply project
- Rehabilitation of Mswakini water supply project
- Rehabilitation of Emairete water supply project

Surface Water Development

1) New Construction of Small-Scale Dams

- 29 dams in Monduli town and 15 other villages

2) Rehabilitation of Small-Scale Dams

- six dams in Lossimingori and four other villages

4 - 3 Projection of Numbers of Inhabitants and Livestock

4 - 3 - 1 Planning Period

The planning period has been fixed at 20 years, from 1995 to 2014, according to the planning criteria established by the Ministry of Water, Energy and Minerals. The numbers of inhabitants and livestock are projected for the planning period as presented in the following sections.

4 - 3 - 2 Population

The population is projected for the planning period of 20 years based on the 1994 population and the mean annual population growth rates at the village level as presented in chapter 2-3 of this report. The total population of 65,428 in 1994 is expected to increase to 131,635 by 2014, about 2.01 times the present population (Table 4-1).

Projection of Population

Items	1994	1999	2004	2009	2014	2014/1994
Monduli Town	18,210	21,415	25,203	29,628	34,854	1.91
18 Villages	47,218	56,319	67,300	80,638	96,781	2.05
Total	65,428	77,734	92,503	110,266	131,635	2.01

4-3-3 Livestock

While livestock contributes more to the regional economy, there are many bottlenecks for improving livestock production. The number of livestock should be decreased and the quality of livestock improved. This is the basic position held by the Planning Commission of Monduli district. The major reason is that there is not and will not be enough water for livestock at present and in the near future. What is more important is to provide water for human consumption in the District. Under the above situation, the Project has assumed that the number of livestock remains stationary during the planning period owing to water scarcity in the dry season; the number of livestock is 99,166 livestock units (Table 4-2). One livestock unit is equivalent to one head of cattle, or five goats, or five sheep, or two donkeys.

4-4 Water Demand

The present daily water consumption level is as low as 8.5 to 9.0 liters per capita, lower than the minimum drinking water requirement recommended by WHO. The first step in the water supply program is to provide the villagers with the minimum water supply of 10 liters per capita per day in order to meet basic human needs. The per capita water demand will increase to some extent when water is made available. This Project has estimated that daily water requirement will increase to 30 liters per capita during the planning period. The planned water requirements are given below:

Unit Water Requirement

Items	Unit	Water
Domestic Use	person/day	30 ℓ
School	pupil/day	10 ℓ
Hospital	bed/day	88 ℓ
Government Office	person/day	10 ℓ
Hotel, Restaurant	person/day	70 ℓ
Livestock Use	Livestock Unit/day	25 ℓ

Based on the projection of population, the number of livestock and others, the water demand has been estimated for the planning period. In the calculation of water demand, 15 percent of water losses are added. The water demand in 2014 will amount to 7,905 cubic meters per day (Table 4-2 and 4-3) as given below:

Water Demand in 2014 (m^3/day)

Items	Domestic	Livestock	School/Others	Losses	Total
Monduli Town	1,046	91	78	182	1,397
18 Villages	2,904	2,389	365	850	6,508
Total	3,950	2,480	443	1,032	7,905

4-5 Water Resources Development Planning

4-5-1 Groundwater Resources

Groundwater is generally of better quality than surface water. The development of groundwater should be planned according to the following guidelines:

- Facilities for groundwater development will consist of boreholes, pumping equipment with drainage facilities to protect wells from surface water infiltration, and storage tanks; distribution systems will not be provided.

- Pumping systems shall be of manual operating when static water levels are less than 30 meters below the ground surface, otherwise power generating systems will be provided, but discussions are required for affordability of operation and maintenance costs.

- Although the daily water consumption of 30 liters per capita is proposed as the target, the consumption level will be modified so as to meet the minimum requirements only at the initial stage of the Project depending on the capacity of well yields.

- Boreholes shall be located within a reasonable distance from the center of the village, as far as possible.

- Water quality should be tested to confirm whether or not it meets the requirements of Drinking Water Standard established by the Government.

- Locations of boreholes will be selected within the public lands like schools, village offices, dispensaries and others.

4-5-2 Surface Water Resources

There are 46 small-scale dams, of which 32 are in operation for domestic and livestock uses. Water yields of 46 existing reservoirs expressed in millimeters as rates of total storage capacities to their catchment areas, range from 0.2 to 50.6 with an average of 4.8 millimeters, compared with the mean annual rainfall of 800 millimeters. Topography of the Study Area allows of construction of small-scale dams.

Development of surface water where groundwater is not available shall be planned according to the following guidelines:

- The live storage capacities of dams shall be sufficient to meet water demand under drought conditions with a return period of 10 years. The gross storage capacities are obtained by adding sediment volumes to be estimated for the planning period to the live storage capacities.

- The intake facilities and spillways will be properly located in consideration of topographic conditions.

- Where surface water treatment is necessary, a simple process should be employed to permit village operation of the facilities.

- Selected materials should be used for the embankment crossing river channels, and embankment will be well compacted. Foundation treatment will be done for the river crossings; failure of the existing dams mainly took place at river crossings.

- Reservoir operation rules should be prepared so as to make water available all year round through examination of water balances.

4 - 6 Sanitary Education Programme

4 - 6 - 1 Introduction

Sanitary education should focus on the following areas of sanitation and water:

- Definition of Sanitation and Water as a concept and as a programme.

- Why Sanitation and Water as a programme

- Experiences gained from the current sanitation and water situation.

What is sanitation and water?

Sanitation and Water is a concept based on the need to supply safe clean water for improved sanitary conditions of the beneficiaries of this programme. The concept is based on the following assumptions:-

- Community mobilization and participation in the planning, implementation and evaluation of the sanitation and water situation are essential elements to ensure sustainability of these programmes.

- The concept emphasizes human resource development as a major component of the programme as opposed to technical aspects which has been the traditional approach to water schemes. The programme aims at sensitizing and empowering communities to control their own development using their local institutional structures. The concept emphasizes the bottom-up approach in planning, giving the communities opportunities to develop plans based on their own problems, identified by themselves and develop implementation plans and evaluate the outcome against set objectives.

Sanitation and water as a concept has proved to be a workable concept in attempts to integrate needs in water for drinking, food preparation, personal hygiene and others as a focus for improved health conditions of the beneficiary communities. The process is essential and programmes addressing these need have been developed.

Why sanitation and water as a programme ?

Development efforts in providing clean, safe water have been given strong emphasis with the national target of accessibility for all the population to safe clean water at a distance of 400 meters by the year 2000. However, past experiences have shown that provision of safe, clean water alone was not sufficient to assist in an improvement of health of the beneficiaries because sanitary conditions remained poor and lack of sanitary education facilitated health problems. Therefore, integration of sanitation and water is a positive approach to effective utilization of water resources for improved quality of life. The second major component is the process orientation to enable the communities to own these programmes for sustainability.

4-6-2 School Environment and Sanitary Education

(1) School Environment

The environment of the school is important for the health of the schoolchildren. If schools do not have good provisions for sanitation, clean water and facilities for hygienic preparation of food, children cannot be expected to take seriously the sanitary education they receive in the classroom.

Clean, safe water is needed both for drinking and washing hands. The school environment should be kept clean with bins and pits for storing rubbish. Classrooms must be kept clean and dry with adequate lighting and ventilation. Moreover, it is important to ensure that pit-latrines in schools are kept clean. School meals can have an important role in the nutrition of the schoolchildren and many countries have set up feeding programmes. Food should be prepared in clean conditions by properly supervised cooks.

(2) Sanitary Education in Primary School

The most important task in developing a curriculum is to plan the content to match the level and age of the child as he /she progresses through the school. This involves taking into account the various stages of development (social/emotional, intellectual and physical). The primary school is a good place for laying the foundations of health that can be built upon in later schooling.

However, in early primary schooling the child can only grasp simple concepts and ideas. It is only in later stages that a child is able to handle more complex and abstract arguments. Therefore, the spread of contents across the different ages may have to be modified for practical reasons. Since in Tanzania only a few children manage to go on to secondary schools, sanitary education in primary schools must aim to be as comprehensive as possible to prepare the child for future life.

4-6-3 Approach of Teachers to Participatory Training

The experiential learning approach advocates involvement of learners in the process of practicing or the integration of action and reflection. The learners participate in certain activities and analyse them in order to gain insights on what happened, why it happened or rather the root causes of what happened so that they can go on to find out what they have learnt through the experience and plan future action based on their insights.

In a nutshell, the approach should emphasize active learning rather than passive lecture-oriented processes. Responsibility for learning is shared between learners and trainers. It is assumed that knowledge is shared because there is no expert and that everyone has something to contribute to the learning process. Hence training experiences should be designed to deal with the learners/ participants' "Back home" situation.

4-6-4 Water, Sanitation and Diseases

The World Health Organization (WHO) has estimated that 60% of all sickness in the world is due to poor water and sanitation and that five million children die each year from diarrhea. Hence the provision and utilization of a safe water supply and proper sanitation arrangements are not enough to bring about improvement in a community's health status.

It is imperative to address the relationship between water and diseases and water and sanitation. This can be done in the following manner:

- Inform the individuals and the community as a whole on how to enjoy better health through proper water use and sanitation.

- Assist individuals and the community as a whole to adopt the concept.

This approach, therefore, calls for the formation of Village Health Committees which are non-existent in the majority of villages in Monduli District to oversee improved implementation of community initiatives with regard to sanitary education. According to the environmental classification of water-related diseases, some of the infections are passed through drinking water as water-borne diseases.

However, many of these diseases are transmitted through contamination during water collection and storage as well as from contamination of hands, fingers and food. As water for practising hygiene is often the limiting factor, the above-mentioned diseases are called-water washed diseases. In water-related diseases such as schistosomiasis, part of the parasite life-cycle is in water. In the water-related insect vector diseases such as malaria and filariasis, transmission of diseases is by an insect that breeds in water.

4-6-5 Prevention of Excreta-Disposal and Water Related Diseases

Prevention of excreta-disposal and water related diseases based on:

- Proper human waste disposal
- Water collection and transportation
- Water storage, and
- Personal hygiene

(1) Human Waste Disposal

One of the most important actions which families can take to prevent the spread of germs is to dispose faeces safely. Human waste is very dangerous because it always carries disease germs. Diseases that human waste can spread include hookworms, typhoid fever, dysentery, cholera, bilharzia, roundworms and others. People can swallow these germs if the germs get into water, on to food, on the hands or utensils and surfaces used for preparing food:

The above listed diseases can be prevented by having latrines and using them. If it is not possible to have latrines, adults and children should defecate away from houses, paths, water supplies and anywhere that children play. After defecating the faeces should be buried. Faeces of babies and young children are also more dangerous than those of adults. Therefore even small children should be taught how to use latrines. If they defecate without using latrines then their faeces should be cleared and buried or put into the latrine.

(2) Water Collection and Transportation

Research data from the surveyed area in Monduli district shows that most of the households collect their water from dams, ponds, or gullies. All these water sources are exposed to all sorts of contamination both at the water sources, and transportation stage. Similarly the data show that about 77 % of the respondents spend more than three hours a day fetching water and more than three people are involved in the process. The research findings show that water source management is a community responsibility.

Measures to prevent contamination of water during collection and transportation include;

- The source of water should be protected to prevent dirt from getting in. For example wells and springs should be fenced in, in order to prevent animals from contaminating the source.

- Water which spills around the source should be drained.

- Animals and human beings should not share the same sources. Animals should be given water away from the point where human beings collect their water.

- Personal hygiene of the people who collect water is very important. They should always use clean hands.

- Clean containers with clean covers should be used.

- Clothes and utensils should be washed away from the source of water.

(3) Water Storage

The Research data in Monduli district focusing on water availability indicates that water is only obtained during rainy seasons. This situation, therefore, emphasizes the need for a water storage system. Similarly, the sanitary situation data reveals that most of the families do not have latrines hence human disposal is done in the bush. This situation encourages contamination of water storage and collection utensils.

The following measures are essential against contamination:

- Water storage facilities should be kept clean and covered with clean covers.

- Domestic animals should not have access to these water storage containers because they could contaminate the water.

- Whenever communities draw their water from a well by using buckets, strings or scooping containers, these containers should be kept clean and hanged on a rack near the well.

- Water obtained from streams, wells, ponds should be allowed to settle down by using a three-pot system. This system is recommended as a simple way of purifying water because some of the dirt will settle own and some of the living organisms die. This system, however, is not a hundred percent safe.

4-6-6 Hygiene

(1) Personal Hygiene

Several diseases can be prevented by hygienic habits such as washing hands with soap and water after contact with faeces and before handling food. Washing hands with soap and water stops germs from getting into food or mouths. It is essential to wash hands after defecating, before handling food and after cleaning the bottom of a baby or a child who has just defecated.

i) Children often put their hands into their mouths. Therefore it is important to wash a child's hands, especially before giving food.

ii) For good personal hygiene the following are basic elements

(2) Domestic Hygiene

a) Safe Handling of Food

People can get sick from eating dirty food. They can protect themselves from disease by taking these measures:

i) Washing their hands before they prepare or eat food. The health educator can give them a demonstration on how to wash their hands properly.

ii) Raw fruits and vegetables should be washed before they are eaten.

iii) In areas where there is no inspection of meat, the meat should be thoroughly cooked to avoid tapeworm infestation.

iv) If a person is sick or has sores on his hands, he should not be allowed to handle food. The germs can be passed to other people.

b) Utensils

Most families in Monduli district attempt to clean their utensils using clean water. It is important for the animator/sanitary worker to alert the target group that utensils may look clean and but still may be contaminated.

Utensils should be washed with clean water; be dried with clean cloth or be put on a dish rack to dry in the sun or wind so as to prevent flies from landing on them. In cases of places where the winds are strong, utensils can be put on a dish rack inside the house to dry.

(3) Environmental Hygiene

From recent findings regarding sanitary conditions in Monduli, particularly in the villages, there is a need to do the following in order to improve the health conditions of the members of the community:

i) Areas surrounding houses should be cleared of grass, bush, and rubbish in order to get rid of snakes which can cause death, and rats which can cause plague.

ii) All rubbish should be burnt in order to decrease the number of flies, cockroaches, and other infectious diseases which flourish in dirty areas.

iii) There should be running drainage furrows in order to cut down accumulation of water around houses which are for mosquito breeding.

iv) In other places, chicken and other animals sleep in the same houses an human beings. Chicken can transmit diseases when they play with soil that has been contaminated by the faeces of domestic animals.

v) Rubbish pits should be constructed at appropriate sites.

vi) All faeces of domestic animals should be cleared away from houses because young children can be infected when playing with soil that has been contaminated by faeces of domestic animals. (This is a delicate issue which should be discussed carefully. The sanitary educator should always remember that he/she must never dictate solutions to the community).

4-6-7 Proposal for Sanitary Education Programme

(1) Approach to Sanitary Education

To stimulate attention and comprehension about sanitary education, education programmes should be prepared through pretesting, two way-communication, and the social network approach as follows:

Pretesting:

Apart from school pupils, the majority of the population in the Study Area are either semi-literate or illiterate. It is therefore important that the messages to them are in their own language and written texts should be minimized. Pretest of educational materials like posters is important to ensure the intended effect with respect to attention, comprehension, credibility of the source, e.g., by use of their natural leaders and feasibility of implementation.

Two way-Communication:

The Masai people are very open and would like to exchange views with even strangers. Educational inputs should take advantage of this quality. Two-way communication, compared to one-way communication, has a much higher chance of achieving successful communication. In a two-way communication the receiver can ask questions, ask for elaboration and the source can ask for confirmation of the message to correct misunderstandings. Mass media campaigns should therefore be supported by interpersonal communication. Among the Masai tribe, this can take place during age-group meetings where conversations can take place in a friendly manner.

Social Network Approach:

Sanitary education approaches and strategies should be done using existing social networks. Here the community has its traditional leaders and ways of communication. These means should be utilized to enable them to communicate in their own way using their own methodologies. Messages could start from their tribal and government leaders and such messages could be disseminated through the traditional leaders to youth groups. Their ceremonies, discussions, songs and symbols should be used.

People should be told if the desired outcome is difficult and ways of supporting each other should be devised. Support from leaders and solidarity within different age groups could be used to facilitate this.

(2) Moral, Cultural Issues and Acceptance of Programme

The objective of sanitary education involves sensitive issues some of which can be difficult to reconcile with culture, religion or community concerns. The Masai tradition of youth gathering at night and the religious restriction on the use of condoms are clear examples of this potential conflict. The programme should certainly take account of customs and culture of the community and base it on the realistic assessment of risk behaviors and the situations that arise in the community.

Programme planners should involve the community, religious leaders, as well as education authorities and youth organizations in some aspects of programme design. There can be an arrangement to have a centrally designed curriculum with some allowance for local alterations. School administrators, teachers, parents, students and religious groups should be invited to review meetings, and, by providing them with frequent reports, gaining acceptance of the programme may result.

The parents could be educated with the children and parents should be invited as teachers. This will further acknowledge the role of parents and will ensure consistency of ideas both at school and home. There will be added communication between parents and their children with the ultimate benefit of conferring credibility on the programme.

(3) Contents of Education

The contents of sanitary education should include the following:

i) Awareness of the general public as regards sanitary education;
ii) Knowledge on causes of waterborne diseases.
iii) Changing pupils' attitudes, social norms and self efficacy in relation to sanitary education.
iv) Maintenance of behavior change in order to motivate family members and fellow villagers.
v) Taking care of people who are sick and advising villagers where to go when they are indisposed.

There are basic issues which can be included in the content of most school health and sanitation education curricula. However, it is important for local facilitators to, as much as possible, make the content culture specific. They may select or add to the list of suggestions below covering knowledge, attitude, skills domains as well as support aspects. The following are topics which could be included:

Knowledge:

- Definition of Health and Sanitation Education
- Causes of waterborne diseases and outbreaks of diseases related to sanitation.
- Use of toilet facilities
- How can one be infected with any of the top 10 diseases?
- Prevention of infection
- Role of Traditional Birth Attendants (TBAs)

Attitudes:

- What are attitudes and beliefs?
- Pupils attitudes towards health and sanitation education
- Attitudes in the community towards disease. Are diseases avoidable? Who is responsible when one becomes sick?
- Pupils self concept and their worth, and how those feelings affect them when they make decisions.
- Pupils attitudes towards other people regarding care.
- Pupils attitudes and those of others towards people with HIV/AIDS and those who are regarded at risk.

- What values within society and within groups promote unhygienic behavior?
- Which types of behavior promote the success of health and sanitation education ?

Skill:

- How communication skills contribute in promoting health and sanitation education.
- Decisions students must make on health and sanitation education.
- How they can protect themselves and others from contracting diseases.
- How can pupils assist fellow villagers and promote solidarity?

Support:

- What can people in the society do to help promote health and sanitation education ?
- How do economic issues contribute to unhygienic behavior ?
- How can villagers support each other in making their decisions with regard to promoting better health, clean surroundings and partaking of nutritious foods ?

(4) Context of Education

The teaching of influencing attitudes and behavior requires a participatory approach in addition to the traditional didactic approach. Clearly the programme requires a variety of teaching resources and teaching strategies. The following is a list of resources and strategies:

Teaching Resources:

- Manuals and texts for students and teachers' guide
- Films and video
- Slides, posters, pamphlets, photographs
- Flip charts
- Handouts and work sheets

Teaching Strategies:

- Small group discussions
- Large group discussions
- Panel discussions
- Role plays and games
- Case studies and brain storming
- Talks, lectures and quizzes
- Play, writing and reading

In order for health and sanitation education to succeed, there needs to be an appropriate school and classroom environment. The environment should promote interaction for participatory teaching for example, the arrangement of chairs in a circle encourages people to talk more freely and to each other. However, if the school cannot provide an environment for discussion of personal issues, alternative facilities may be created within or outside school such as youth organizations. There should also be training of trainers.

4 - 6 - 8 Comments by Panelists and Teachers

With respect to sanitary education in primary schools, manuals for teachers and learning materials for pupils were prepared by four writers who were appointed by the Study Team. Preparation of manuals and learning materials is an attempt to integrate the three concepts: health, sanitation and water as a response to the current communication challenge in development process. The manual focuses on an integrated multisectoral approach in the dissemination of information related to health, sanitation and water problems.

Prior to seminars for teachers and education trials at primary schools, a two-day panel discussion comprising four panelists from Monduli district, District Academic Master, District Community Development Officer, District Medical Officer and the District Water Engineer, took place.

Two-day seminars for teachers and two-day education trials for pupils were conducted by writers who solicited the involvement of teachers and pupils at the three selected schools of Monduli Demonstration Primary School, Arkatan Primary School and Makuyuni Primary School in September/October,

1995. The seminars and trials were based on the experiential and participatory approach.

Teachers were asked to evaluate the teachers' sessions as well as pupils' trials on a daily basis. Pupils were requested to give written comments on what they would do next in order to meet the objective of the trials. The exercise was well done and there are great hopes that the sanitary education programme which is being designed will be well received by the schools. The comments on the seminars and education trials made by the teachers and pupils are summarized in Table 4-7.

Table 4-1 PROJECTION OF POPULATION

Village	Population				
	1994	1999	2004	2009	2014
Monduli Town	18,210	21,415	25,203	29,628	34,854
Lendikinya	2,873	3,496	4,252	5,174	6,295
Enguik (Monduli Juu)	4,090	4,978	6,053	7,366	8,961
Arkatan	1,895	2,253	2,678	3,184	3,786
Lossimingori	1,720	2,093	2,546	3,098	3,769
Lepurko	3,042	3,702	4,502	5,479	6,665
Meserani Juu	2,985	3,633	4,418	5,376	6,540
Nengungu	1,586	1,865	2,195	2,580	3,036
Moita Kiloriti	1,685	2,051	2,494	3,035	3,692
Moita Bwawani	3,934	4,788	5,822	7,085	8,619
Meserani Bwawani	1,151	1,400	1,702	2,069	2,517
Mbuyuni	3,700	4,503	5,476	6,664	8,107
Lolkisale	4,397	5,351	6,508	7,919	9,634
Tukusi	1,541	1,875	2,281	2,775	3,376
Makuyuni	3,604	3,830	3,860	3,997	4,134
Naitolia Sub-Village	1,259	1,303	1,348	1,396	1,444
Oltukai Sub-Village	691	700	708	717	726
Mswakini	2,391	2,910	3,539	4,306	5,239
Emairete	4,674	5,688	6,918	8,418	10,241
Total	65,428	77,734	92,503	110,266	131,635

Table 4-2 PROJECTION OF NUMBER OF LIVESTOCK

Unit: livestock unit equivalent

Village	Numbers of Livestock Unit				
	1994	1999	2004	2009	2014
Monduli Town	3,622	3,622	3,622	3,622	3,622
Lendikinya	5,503	5,503	5,503	5,503	5,503
Enguik (Monduli Juu)	1,936	1,936	1,936	1,936	1,936
Arkatan	5,458	5,458	5,458	5,458	5,458
Lossimingori	5,158	5,158	5,158	5,158	5,158
Lepurko	9,176	9,176	9,176	9,176	9,176
Meserani Juu	5,555	5,555	5,555	5,555	5,555
Nengungu	1,761	1,761	1,761	1,761	1,761
Moita Kiloriti	5,740	5,740	5,740	5,740	5,740
Moita Bwawani	11,249	11,249	11,249	11,249	11,249
Meserani Bwawani	3,628	3,628	3,628	3,628	3,628
Mbuyuni	2,226	2,226	2,226	2,226	2,226
Lolkisale	8,252	8,252	8,252	8,252	8,252
Tukusi	1,228	1,228	1,228	1,228	1,228
Makuyuni	6,212	6,212	6,212	6,212	6,212
Naitolia Sub-Village	4,413	4,413	4,413	4,413	4,413
Oltukai Sub-Village	5,189	5,189	5,189	5,189	5,189
Mswakini	8,062	8,062	8,062	8,062	8,062
Emairete	4,798	4,798	4,798	4,798	4,798
Total	99,166	99,166	99,166	99,166	99,166

Notes: - 1 livestock unit = 1 head of cattle, or 5 goats, or 5 sheep, or 2 donkeys.
- Numbers of livestock are assumed not to increase during the planning period.

Table 4-3 WATER DEMAND FOR DOMESTIC USE

Unit: m^3/day

Village	Water Demand				
	1994	1999	2004	2009	2014
Monduli Town	546	642	756	889	1,046
Lendikinya	86	105	128	155	189
Enguik (Monduli Juu)	123	149	182	221	269
Arkatan	57	68	80	96	114
Lossimingori	52	63	76	93	113
Lepurko	91	111	135	164	200
Meserani Juu	90	109	133	161	196
Nengungu	48	56	66	77	91
Moita Kiloriti	51	62	75	91	111
Moita Bwawani	118	144	175	213	259
Meserani Bwawani	35	42	51	62	76
Mbuyuni	111	135	164	200	243
Lolkisale	132	161	195	238	289
Tukusi	46	56	68	83	101
Makuyuni	108	112	116	120	124
Naitolia Sub-Village	38	39	40	42	43
Oltukai Sub-Village	21	21	21	22	22
Mswakini	72	87	106	129	157
Emairete	140	171	208	253	307
Total	1,965	2,333	2,775	3,309	3,950

Note: 0.33 m^3/day/capita

Table 4-4 WATER DEMAND FOR LIVESTOCK USE

Unit: m^3/day

Village	Water Demand				
	1994	1999	2004	2009	2014
Monduli Town	91	91	91	91	91
Lendikinya	138	138	138	138	138
Enguik (Monduli Juu)	48	48	48	48	48
Arkatan	136	136	136	136	136
Lossimingori	129	129	129	129	129
Lepurko	229	229	229	229	229
Meserani Juu	139	139	139	139	139
Nengungu	44	44	44	44	44
Moita Kiloriti	144	144	144	144	144
Moita Bwawani	281	281	281	281	281
Meserani Bwawani	91	91	91	91	91
Mbuyuni	56	56	56	56	56
Lolkisale	206	206	206	206	206
Tukusi	31	31	31	31	31
Makuyuni	155	155	155	155	155
Naitolia Sub-Village	110	110	110	110	110
Oltukai Sub-Village	130	130	130	130	130
Mswakini	202	202	202	202	202
Emairete	120	120	120	120	120
Total	2,480	2,480	2,480	2,480	2,480

Note: 0.025 m^3/day/livestock unit

Table 4-5 WATER DEMAND FOR SCHOOLS

(1) Day School

Unit: m^3/day

Village	Water Demand				
	1994	1999	2004	2009	2014
Monduli Town	22	27	33	40	48
Lendikinya	2	3	3	4	5
Enguik (Monduli Juu)	2	2	3	3	4
Arkatan	3	4	5	5	6
Lossimingori	3	4	5	6	7
Lepurko	3	3	4	5	6
Meserani Juu	3	4	5	6	8
Nengungu	2	2	2	3	3
Moita Kiloriti	2	3	4	4	5
Moita Bwawani	3	3	4	5	6
Meserani Bwawani	2	2	3	4	4
Mbuyuni	7	8	10	12	15
Lolkisale	4	5	6	8	9
Tukusi	2	2	2	3	4
Makuyuni	12	12	13	13	14
Naitolia Sub-Village	-	-	-	-	-
Oltukai Sub-Village	-	-	-	-	-
Mswakini	2	3	3	4	5
Emairete	4	5	5	7	8
Total	78	92	110	132	157

(2) Boarding School

Village	Water Demand				
	1994	1999	2004	2009	2014
Monduli Town	37	46	55	67	82
Total	37	46	55	67	82

Note: 0.010 m^3/day/student for day school.
0.070 m^3/day/student for boarding school.

Table 4-6 PROJECTION OF NUMBER OF PUPILS

(1) Day School

Village	Numbers of Pupils				
	1994	1999	2004	2009	2014
Monduli Town	2,205	2,683	3,263	3,971	4,832
Lendikinya	261	317	386	470	572
Enguik (Monduli Juu)	236	287	349	425	517
Arkatan	322	383	455	541	643
Lossimingori	325	396	481	585	712
Lepurko	278	338	411	501	609
Meserani Juu	346	421	512	623	758
Nengungu	159	187	220	259	304
Moita Kiloriti	247	301	366	445	541
Moita Bwawani	283	344	419	510	620
Meserani Bwawani	195	237	288	351	426
Mbuyuni	687	836	1,017	1,237	1,505
Lolkisale	423	515	626	762	927
Tukusi	168	204	249	303	368
Makuyuni	1,185	1,226	1,269	1,314	1,359
Naitolia Sub-Village	-	-	-	-	-
Oltukai Sub-Village	-	-	-	-	-
Mswakini	233	284	345	420	511
Emairete	370	450	548	666	811
Total	7,923	9,409	11,204	13,383	16,105

(2) Boarding School

Village	Numbers of Pupils				
	1994	1999	2004	2009	2014
Monduli Town	534	650	790	962	1,171
Total	534	650	790	962	1,171

Table 4-7 COMMENTS ON SANITARY EDUCATION PROGRAMME MADE BY PANELISTS AND TEACHERS

1. Teachers' Comments

(Arkatan Primary School)

i) Sanitary education subject should be taught as an independent subject with its own curriculum.

ii) Teachers would like to use village governments to do the following:

- To start with, teachers will sensitize members of the School Board during Board meetings.
- Teachers will use songs, poems and drama in order to convey the message about sanitary education to parents during PARENTS DAYS and whenever teachers, parents and pupils will congregate.
- Teachers will sensitize and also use the Village Health Committee members to disseminate knowledge about sanitary education; because one of the duties of this committee is to educate villagers with regard to health and sanitation aspects.
- Teachers will also sensitize and use religious leaders resident in the village to convey the sanitary education message to the members of their denominations.

iii) Seminars on sanitary education for teachers should be held regularly.

iv) The next seminar for teachers should be given more hours/time to enable teachers to receive, read through and evaluate the seminar papers before making any meaningful suggestions for improvement or otherwise.

(Makuyuni Primary School)

i) Teachers think it will be advisable to apply the mobilization approach by using poems, drama, songs in classes and public places.

ii) To invite teachers to attend village government meetings in order to provide teachers with the opportunities to convey messages on sanitary education.

(Monduli Demonstration Primary School)

i) Teachers unanimously agreed that the subject of sanitary education should be taught in primary schools, dispensaries, health posts and in mother and child health clinics. Apart from primary school pupils and teachers; major emphasis should be placed on women who are better placed to disseminate this knowledge to the whole community through the assistance of teachers groups.

ii) Sanitary Education should be extended to cover the entire community especially parents of school children.

iii) Sanitary education should be taught as an independent subject.

iv) A national "SANITATION WEEK" should be held along similar lines as those pertaining to national ROAD SAFETY WEEK.

v) Regular seminars for teachers should be held.

2. Panelists' Comments

The panel concluded that the sanitary education program being planned for primary schools is a good idea; but the panelists recommended the following:

i) Sanitary education should be disseminated through village government leaders, village health committees, traditional leaders such as Laigwanak, Loibons, Traditional Birth Attendants.

ii) Sanitary education to be conducted in schools as well.

iii) Sensitization of the masses (villagers).

iv) Bye-laws should be enacted to oblige every villager to build a pit latrine and use it effectively.

v) Posters and other visual aids should be used in the campaign for WATER IS LIFE.

vi) There should be organized study tours to enable the Masai to learn from neighboring districts.

vii) The villages committees should be involved in all stages of the planning, implementation, monitoring and evaluation.

viii) A sanitary education program should be conducted for the parents-cum-villagers in order to sensitize them to be able to reciprocate to what the pupil-cum-sons and daughters tell then.

ix) The other component of the sanitary education program should focus on pupils who are the future generation and who can transmit to their parents what they are taught at school. Furthermore, the draft manuals and learning materials will be revised according to the recommendations of the teachers, pupils and panelists. The question of gender relationship will also be given prominence during the revision of the manuals and teaching materials.