Chapter 8

Construction of GIS Database for Rural Water Supply

8 Construction of GIS Database for Rural Water Supply

8.1 General

In order to formulate a reliable water supply plan, it is necessary to correct, store and access the accurate data effectively. This is an essential process not only for the Study but also for the effective future use of available data in the Country.

The database system shall be in the form of Geographical Information System (hereinafter referred as GIS), which supports and includes the geographical data in relation with multi-sector information. The study program includes the construction and technical transfer of appropriate GIS system with reference to the existing data and database systems.

Example of output is shown in Figure 8.1-1.

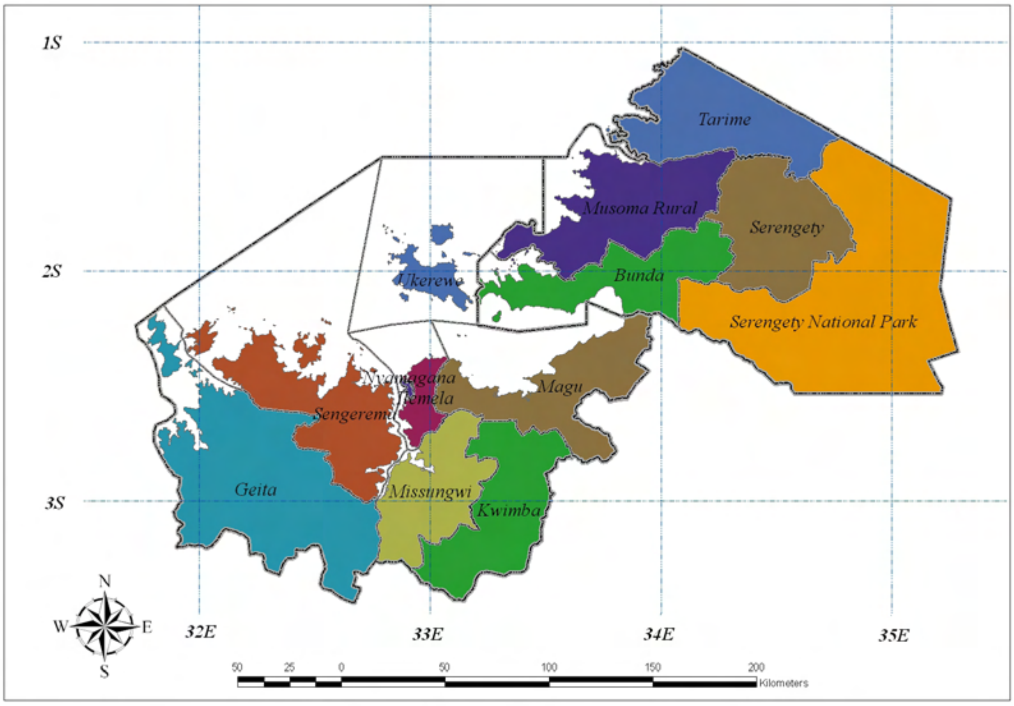

Figure 8.1-1: Region and District Map

8.2 Existing Database System

Several database systems have been constructed by the Ministry and Government Agencies and concerned Donors. In relation to the water supply services (including meteorological and hydrogeological data) the confirmed existing databases are as follows;

1) Water and Sanitation Database (Policy and Planning Department, MoW, constructed by Microsoft Access)

2) Meteorological Database (Department of Water Resources, MoW, constructed by Microsoft Access)

3) Meteorological Database (Tanzania Meteorological Agency, constructed by Microsoft Access)

4) Database for Water Supply System (MoW Data Bank of Rural Water Supply, constructed by Microsoft Access)

5) Well Inventory Database (Drilling and Dam Construction Agency, under construction, using Excel)

Other than the Ministries and Government Agencies, the following databases are confirmed.

6) DBMS designed as “WSICD (Water Supply Improvement in Coast and Dar Es Salaam Peri-Urban, JICA, Arc GIS)

7) Shinyanga -WADATA Database (RWSSP supported by Netherlands and its consultant group)

There are still a number of databases constructed by the Local Government Units and Basin Water Office with support of Donors, such as the Lake Victoria Environmental Management Program (WB, GEF), LVWR (FAO) at the local areas in Study Area. Contents of the three databases will be explained as follows.

8.2.1 MOWLD Data Bank on Rural Water Supply

GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit) has helped to develop a comprehensive database on rural water supply schemes in Tanzania. It was developed during the period of 2000 to 2002 under the project of "SUPPORT OF THE TANZANIAN WATER SECTOR". The database is located in the MoW, Dar es Salaam. In this program, more than 1500 out of about 9000 villages in Tanzania have been covered. It includes a wide range of administrative, organizational, financial, technical and resources-related data.

It was constructed as a customized Microsoft Access database system with a user friendly interface and GIS engine, i.e. GIS plug-in (MapObjects Light from ESRI) for thematic mapping of query results. This database has two interfaces, one for the Internet with limited functionality and accessibility, and the other for database management with full functionality and accessibility.

Figure 8.2-1: “Rural Water Supply Schemes” database by GTZ

The conceptual schema of the database is described as follows.

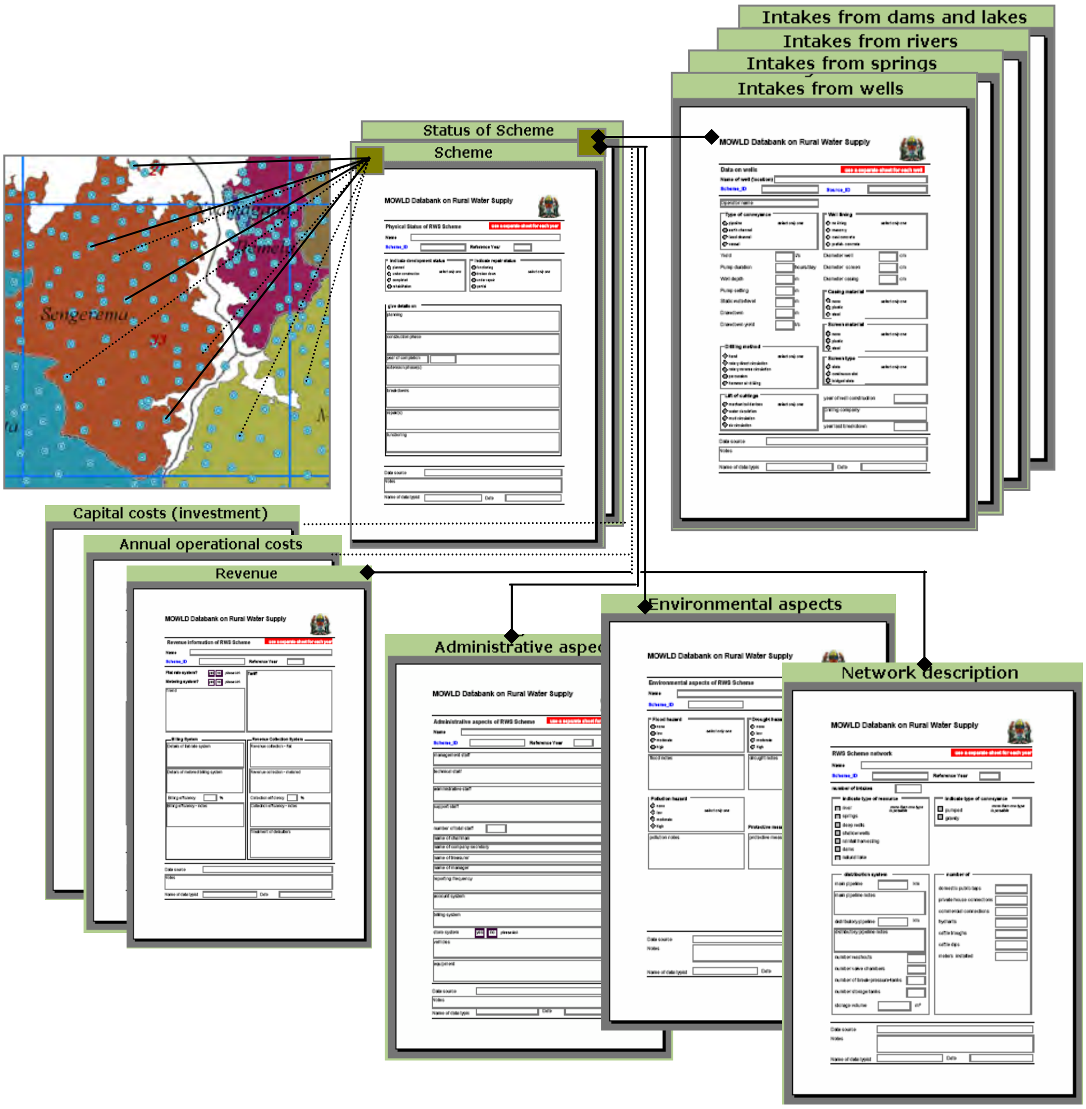

Figure 8.2-2: Conceptual Schema of "Rural Water Supply Schemes" by GTZ

The individual water scheme is the minimum unit of this database and the key to all other information, which means the descriptive information, or "Attributes", is linked to individual water schemes.

The positions of villages are geographically represented by point data, which is digitalized in the position of the village name on the topographic map. The above schemes are linked to those points, and are keys to the GIS.

The database is suitable for understanding the conditions of water schemes of Tanzania in a broad perspective, yet additional information requires analyzing of the regional conditions and planning water schemes.

The source of this database came mainly from the regional and district water engineer offices (RWE & DWE offices), which were asked to submit information for utilization.

However, the accuracy of incoming information was scarcely checked and not all the requested information was obtained; thus the reliability is not so high and the data still needs to be modified.

Also, the coordinates of individual water schemes are not taken. Thus, the extent of the impact or benefit of each water scheme is not certain. As a result, the level the need for the water supply is not so clear.

The feedback to update the constructed data is yet to be well provided because of the limited availability of IT related resources, especially the lack of personal computers and Internet services in this country.

The major items are shown as the table below.

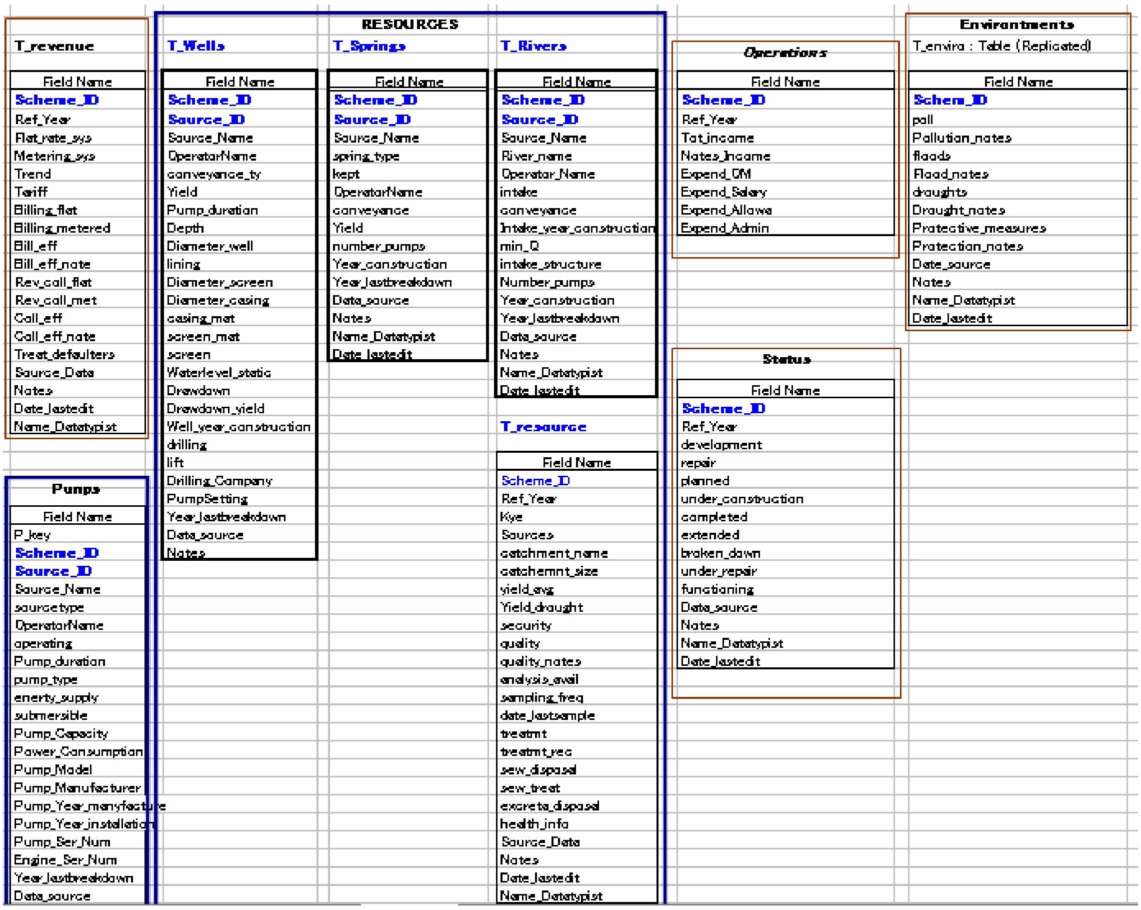

Figure 8.2-3: Major Items of “Rural Water Supply Schemes”

8.2.2 WSICD (Water Supply Improvement in Coast and Dar Es Salaam Peri-Urban)

The DBMS and GIS database was constructed for water utilization in the study of “Water Supply Improvement in Coast Region and Dar Es Salaam Peri-Urban in the United Republic of Tanzania” (hereinafter referred as WSICD).

The DBMS designed at WSICD consists mainly of five fields: water supply conditions, water resources conditions, socioeconomic conditions, environmental aspects and administrative aspects. The basic items for this database are as follows:

Table 8.2-1 Major Items of WSICD

Ward	Boundary supplied by NBS
Village	Boundary supplied by NBS
Sub-Village	Boundary supplied by NBS
Judgement of Water Supply Scheme	Boundary supplied by NBS
Population	Total Population of 2002 (Census)
	Total Population of 2015 (Projection)
	Population Served
Existing Water Source	River; coordination and attributes
	Spring; coordination and attributes
	Well; coordination and attributes
	Borehole; coordination and attributes
	Others; coordination and attributes
Sub-Village Center (position)	Latitude
	Longitude
	Ground Level (m)
Planned Machinery House (Water Source)	#. Water Source
	Latitude
	Longitude
	Ground Level (m)
Planned Storage Tank	Latitude
	Longitude
	Ground Level (m)

8.2.3 RWSSP–SHINYANGA WADATA DATABASE

The RWSSP-WADATA Database is a water Supply and Sanitation Management Database for Shinyanga Region. The need for the water database in Shinyanga was aroused by DWSP in 1990s, as the result of promotion and sensitization through meetings, seminars and workshops it came to be appreciated as an important tool for planning, monitoring and decision-making.

The data collected and entered into WADATA covers the following as in December 2005: Construction and rehabilitation of shallow and deep wells, piped water schemes, dams, rainwater tanks etc.

Table 8.2-2: Number of Well stored in WADATA

Administrative Unit	Number of WUGs	Number of Wells	Number of Pumps
Bariadi	862	862	862
Bukombe	470	470	470
Kahama	601	601	601
Maswa	521	521	521
Meatu	442	442	442
Shinyanga Municipality	248	248	248
Shinyanga District	398	398	398
Total	3542	3542	3542

The tables, which make up the WADATA database, are fifteen (15) in total. These tables are categorized into three (3) main groups namely: Administrative Units Data, Technical data and Legal and Management Data. These tables are linked together using Entity Relationship as shown by the diagram below. As the result of this link, questions can be posed based on more than one table retrieved from the database.

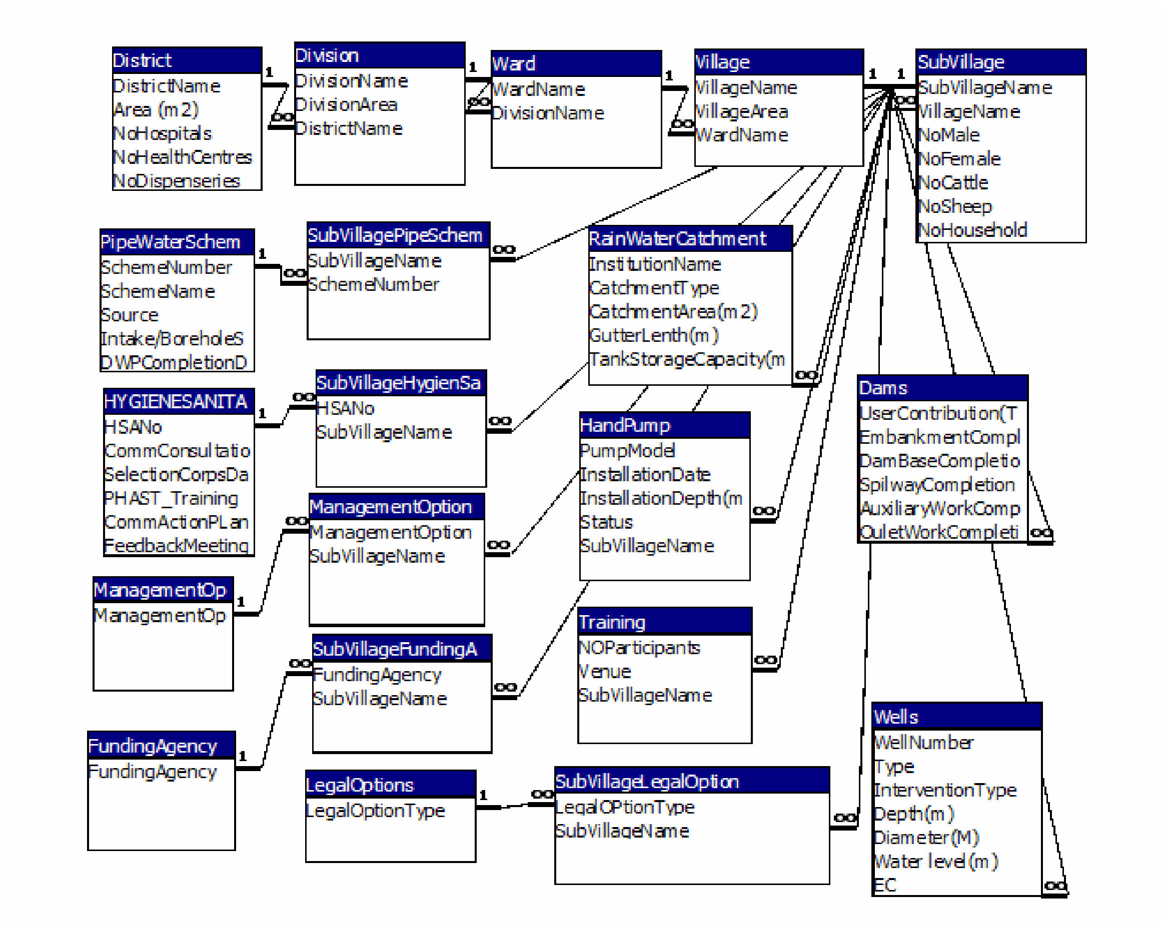

Figure 8.2-4: Entity Relationship Diagram

8.3 Evaluation of Existing Database System

The existing databases were reviewed to maximize the accumulation of the data and/or utilize the information that has been stored in the database for water supply planning purpose: That is, basically application of the similar interfaces which are most frequently used by the Tanzanian Government. This assures the availability of engineers who are familiar with the system and the easy transfer of available information.

However, most of the above mentioned databases and GIS are not well maintained and/or under the construction phase of the database.

Therefore, ArcGIS was selected to leave room for the possibility of utilizing the different databases and GIS. The database constructed at WSICD and GTZ was preliminary reviewed as a base for the database system in this study.

The study finally decided not to make the same structure of database due to the variation and availability of the data as they are deferent by the area and the purpose of the database does not always have same objectives.

But it is always possible to construct the interface between those deferent databases as most of the databases use similar interfaces and software.

8.4 Items of Database for Rural Water Supply

The contents of the database shall cover the common factors of both databases as much as possible for maximum utilization, as well as the results of field surveys (i.e. well inventory, water quality, water supply scheme information and socio-economic surveys). In the study, attribute information is directory attached to the GIS database for better maneuverability and operability and it can be linked or export to other existing database.

8.4.1 GIS software: ArcGIS v9.0 (ArvView) with customized tools

ArcGIS supplies the functionality to display maps, searching geographic objects, create thematic maps, calculation, printing, analysis based on the attribute database linked to the geographic objects.

In addition to this, for help finding or searching the attribute of the administrative boundaries like, districts, wards, villages with census values, tools are created and attached to the ArcMap as follows. Three buttons are attached to the ArcMap interface on a Tool Bar named "Mwanza & Mara Project Tools" as shown in the following figure.

Codes are written as Visual Basic for Application, and stored into M&MProject.mxd. Source codes for these tools are attached in Appendix.

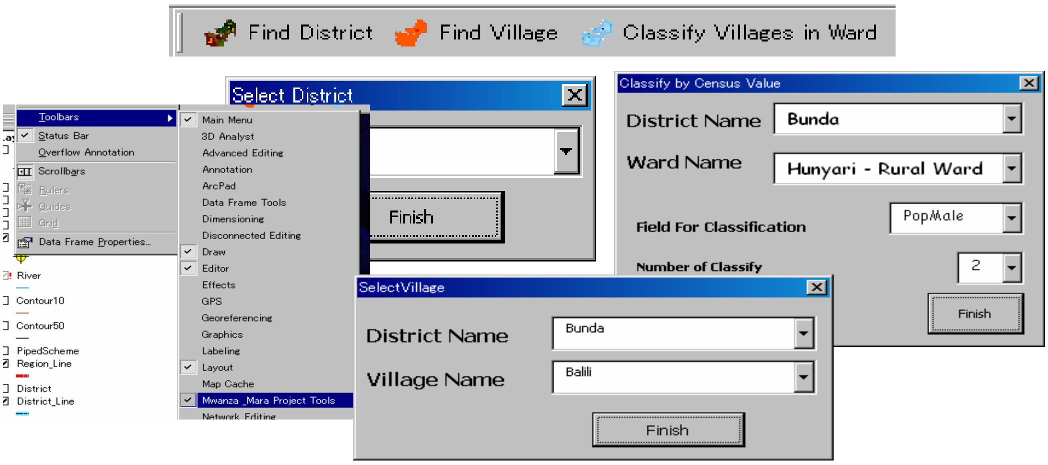

Figure 8.4-1: Menu Structure

a. Find District Button

By selecting the name of the district from the combo box, the area of the selected district will be shown and the ward within the district will be displayed.

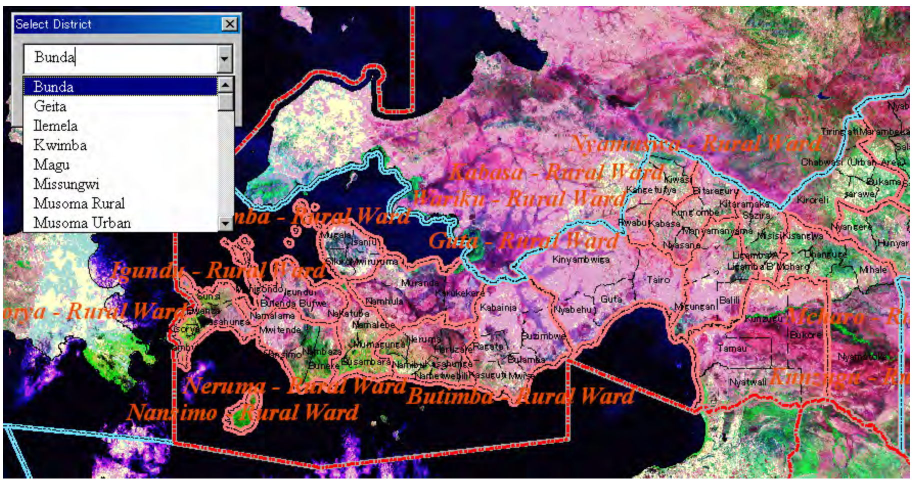

Figure 8.4-2: GIS View (District)

b. Find Village Button

By selecting the name of the district and village from the two combo boxes, the area of the selected village will be displayed and the overview window will be shown to note the area you focused on within the study area.

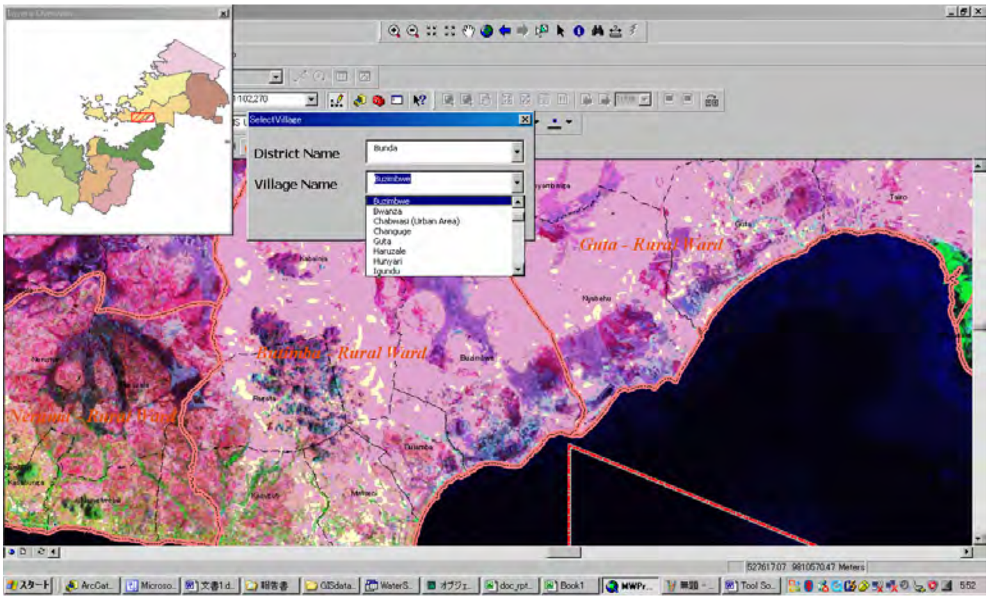

Figure 8.4-3: GIS View (Village location)

c. Classify Village Button

By selecting the name of the district and ward from the two combo boxes, the area of the selected ward will be shown and the inside of the village polygons in the ward will be colored as classified based on the selected field of census.

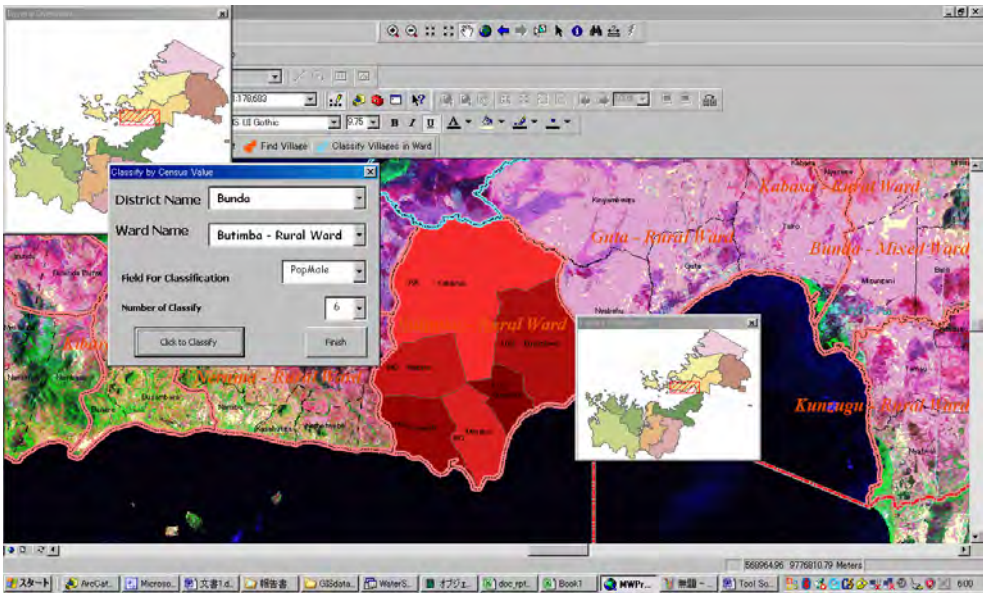

Figure 8.4-4: GIS View (Village Classification)

8.4.2 GIS Database Configuration

The GIS database for this project consists of geographic database which showing the shape of the geographic objects and attribute database which expresses the nature of geographic objects.

The database consists of 18 shape files (note, a shape file consists of multiple physical files) and a GeoTiff file which is a satellite image of the study area. The file name and contents of each file are presented in the following table. Each shape file has both geographic data and attributes data. The layer names to the respective files are shown as follows;

Table 8.4-1: List of Layers, File Name and Contents

Layer Name	Actual Name of the Shape File	Contents
WaterSamplingPoint	WaterSamplingPoint.shp	Water Sampling Points
WetSeasonLabData	WetSeasonLabData.shp	Lab data analysis results in wet season
WetSeasonFieldData	WetSeasonFieldData.shp	Field data analysis results in wet season
DrySeasonLabData	DrySeasonLabData.shp	Lab data analysis results in dry season
DrySeasonFieldData	DrySeasonFieldData.shp	Field data analysis results in dry season
Existing Well List	Well_List_Arc1960_UTM36S.shp	List of existing wells
River	River.shp	Line shape of rivers in study area
Contour10	Contour10.shp	10m contour
Contour50	Contour50.shp	50m contour
PipedScheme	PipedScheme.shp	Administrative boundaries covered by piped scheme
Social Conditions	SocialConditions.shp	SocialConditions.shp
Region_Line	Region_Line.shp	Regional boundary line
District	District.shp	District boundary polygon
District_Line	District_Line.shp	District boundary line
Ward	Ward.shp	Ward polygon
Village	Village.shp	Village polygon
VillageName	Village.shp	Village polygon (identical to above)
Region	Region.shp	Regional boundary polygon
S-36-00_loc	S-36-00_loc.TIF	Landsat 7 satellite Image of north Tanzania

Those files are stored in the “GISdatabase” folder directly under the C drive of the PC described as follow.

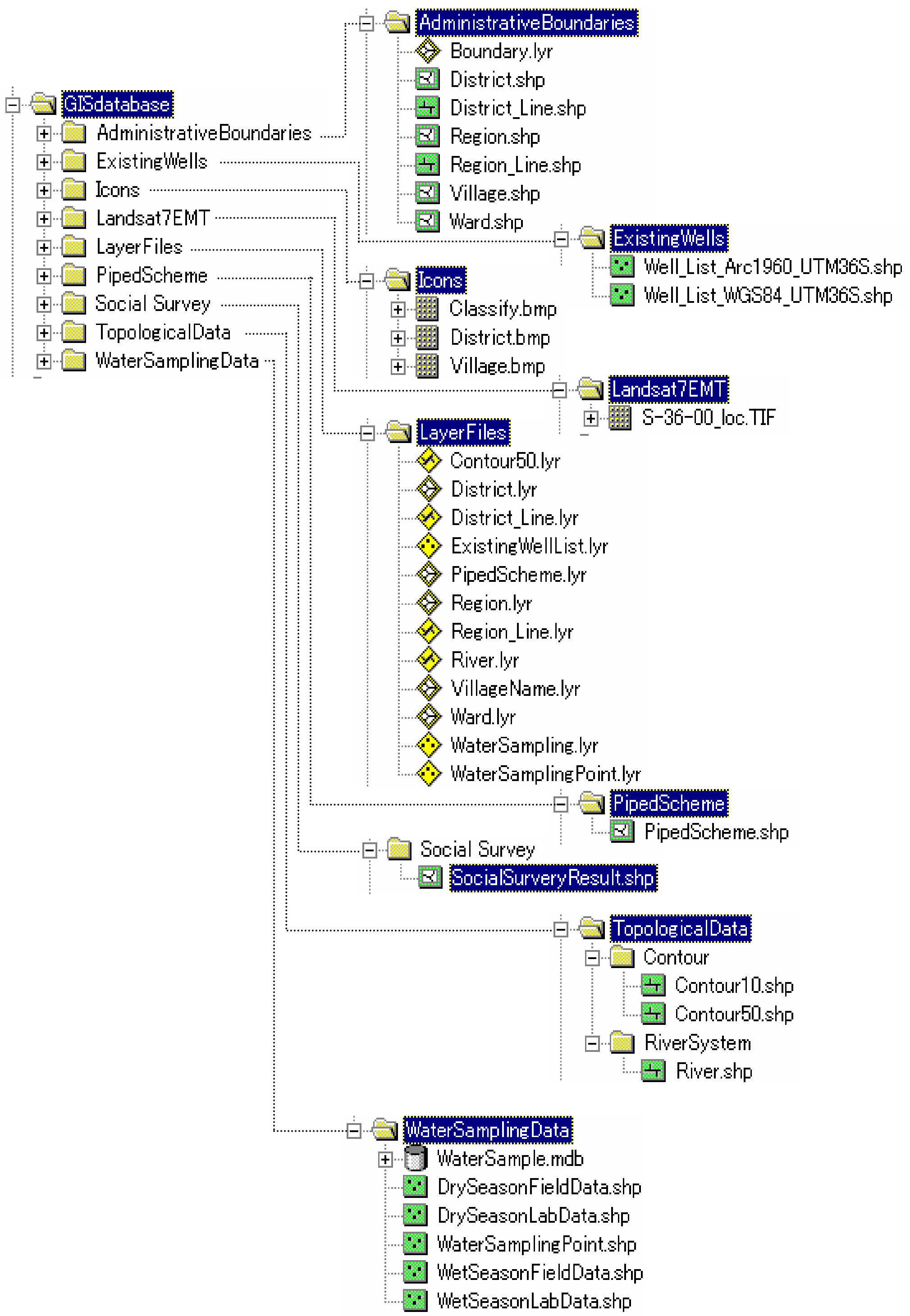

Figure 8.4-5: File Structure of GIS

8.5 Construction of GIS Database

8.5.1 Outline of GIS Database

The GIS database for the study aimed to be the platform for various types of information, with the ability to compile, update and better utilize information. For the study, the georeferencing and transforming of corrected information have been carried out to unify the separately created information. To create a solid basis of this platform, an administrative boundaries map has been created as the base map.

The outline of the created GIS data is described as follows:

1) Administrative boundaries

2) Georeferenced and rectified SRTM (height) data

3) Contour map calculated from SRTM

4) Georeferenced and rectified satellite Image (Landsat7)

5) Well inventory data linked to GIS

6) Socio economic information

7) River systems

8.5.2 Base Map Data

The information resources utilized for the base map of this study so far are as follows:

1) 1:50,000 topographic maps (Surveys and Mapping Division, Ministry of Lands, Housing and Urban Development Tanzania in 1976) covering the study area.

2) SRTM (Shuttle Radar Topography Mission; NASA) height information covering the study area

3) Landsat (NASA) images covering the study area

4) Administrative boundary (hand written on the 1/50,000 topographic map) supplied by NBS (National Bureau of Statistics Tanzania)

To create the base map of the Study, rectification, georeferencing of the scanned topographic maps and digitization of the administrative boundary with the interpretation and compilation of the supplied information have been carried out. SRTM and Landsat images have also been georeferenced and transformed as “ARC 1960” Datum, which is adopted in Tanzania.

The supplied information is secondary material and manually created by interpretation of A4-size handmade documents supplied by regional authorities describing the boundaries. Some of the boundaries drawn in the map were inaccurate or unclear. Therefore some boundaries are interpolated and interpreted from the topological feature of the area and regarded as an administration boundary.

Due to the separation and synoecism of the villages after the NBS’s work, as well as unclear and inaccurate hand writing on the map, the village boundaries and their correspondence to the village name shall not be quite accurate.

These inaccurate boundaries shall be corrected from time to time to maintain a good base for the upgrade of the quality of the database.

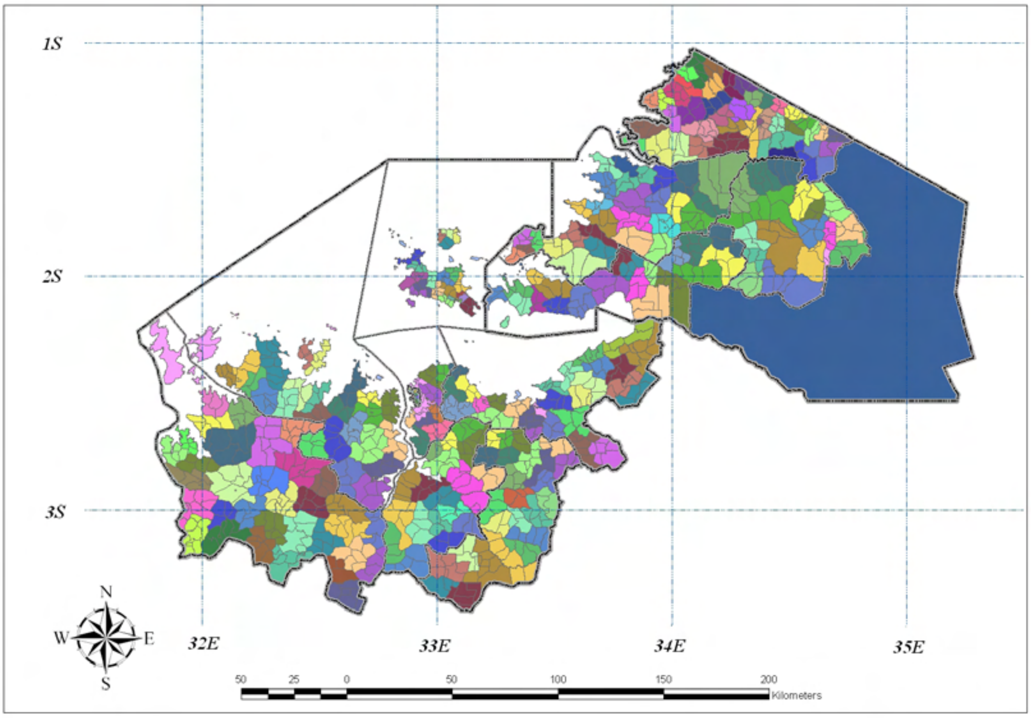

Figure 8.5-1: Results of GIS Database

8.6 Technical Transfer of GIS Database

After the construction of the basic database interfaces and related formatting and attribution of the available information such as geographical data and inventories from the survey in the study, technical transfer has been carried out to the person in charge of the maintenance of database.

As the database was formed at the Mwanza office, the C/P member for the GIS and responsible personnel from the RWSSD of MoW were invited for the training of database/GIS operation.

This is the essential part of the Study in relation to GIS, so the utilization, maintenance and upgrade shall be regularly made by the responsible person.

The technical transfer was carried out in the following steps;

8.6.1 Transfer Items

Items for technical transfer are selected as follows for enhancing the ability of information handling, including maintenance.

a. Operating GIS Application; ArcGIS v9.0 (ArcView)

- Interface
- Tools
- Data Structure
- Analysis
- Import & Export

b. Database; Relational Database Management System handling

- Import & Export
- Database Items
- Difference between RDBMS & GIS

With the given condition described in the above sections, it is essential to establish a mechanism or system for 1) accessibility of information, 2) accumulation of information, 3) enhancement of information handling, and 4) sharing of Information. For the realization and stable operation of the above mechanism or system, it is recommended that the database shall be established in the MoW office for coexistence and maximum utilization with existing resources.

8.6.2 Information handling to TANZANIA

Technical transfer training was held at the Mwanza office treating ArcGIS v9.0 ArcView. The contents of the course are described as follows. The technical manual for this course is attached in Appendix 1-5 "GIS Manual for Technical Transfer"

Table 8.6-1: Contents of the Technical Transfer Course

1	Preparation of Working Environment	Creating new folder, Connecting folder, Disconnecting folder, Copying file, Deleting file & Renaming file
2	Displaying Data	Adding data, Removing data, Saving file, Symbolizing, Labeling, Drawing & Layout
3	Geo-referencing Data	Projected coordinate system, Geographic coordinate system & Projection conversion
4	Geometric Correction for Raster Data	Adding control points, Rectification & Georeferencing
5	Data Conversion	CAD to Shape
6	Working with Attributes	Open attribute table, Creating new field, Field calculator, Table joining, Delete field
7	Query	Selecting by attribute
8	Creating Vector Data	Creating point data, Creating line data, Creating polygon data
9	Practice using actual data	Practicing Using actual data & Updating

Chapter 9

Water Resources Potential

9 Water Sources Potential

9.1 General

For the purpose of rural water supply planning, the water sources in the area are examined. The water sources can be divided into two categories:

- Surface water
- Groundwater

The surface water development potential as water sources for the water supply in the rural areas are reviewed in consideration of hydrological analysis and water quality analysis.

The groundwater development potential is examined based on the well inventory records, hydrogeological prospects, hydrological analysis and water quality analysis.

The important factors in considering water sources for the provision of water to the villages are:

- Sustainability for water use
- Availability through out the year
- Safety of water quality
- Physical distance to the source and the methods to distribute to the villages

9.2 Potential and Prospects of Use of Surface Water

The most common water sources that supply water to the villages are traditional water sources such as hand dug wells and local springs (The local springs mostly occur along rivers and small creeks as ponds, and shall not be classified as “natural springs”); however, most sources run dry or have reduced discharge in the dry season.

Therefore, villagers must fetch water from sources where water is available such as boreholes, Lake Victoria and some permanent rivers and streams.

Surface water sources that are available throughout the season include rivers, streams, ponds, and lake water. Springs are generally classified as the discharge of groundwater under specific geological conditions (such as related to the faults and fissures, some types of stratovolcano and lava, limestone area, etc.).

There are also some artificial surface water resources by use of facilities; i.e. rainwater harvesting, charcoal dam, etc. However, these are not classified as surface water sources.

The potential and its prospects for use of surface water are limited to Lake Victoria and some rivers in this study, because other artificial water sources have problems with availability and safety.

9.2.1 River Water Evaluation

The permanent rivers in the study area are the Mara and Simiyu rivers and some of the rivers at the East and South Shore (Mori River). Although some of the other rivers have water in the dry season, the water level is minimal according to the hydrological study in the area.

Table 9.2-1: River Discharge

	Monthly Average Discharge of the Main Rivers (m^3/s)												Year Total	Averages m^3/s
	January	February	March	April	May	June	July	August	September	October	November	December		
Mara	27.1	24.2	33.9	75.2	88.7	62.3	35.8	26.6	23.8	17.4	16.0	27.6	458.5	38.2
Grumeti	32.6	16.6	17.5	24.0	21.0	2.6	1.1	0.5	0.8	1.6	3.9	18.7	141.0	11.8
Mbalageti	5.4	4.5	6.6	12.9	9.1	2.0	0.6	0.4	0.4	0.8	3.2	6.3	52.1	4.3
E. Shore Streams	24.7	16.9	22.8	44.8	41.6	13.8	4.0	3.2	3.5	5.2	14.5	32.2	227.3	18.9
Simyu	64.7	45.0	62.5	84.5	54.9	22.1	15.3	12.4	10.7	9.8	26.1	69.2	477.2	39.8
Magogo-Moame	30.3	10.0	9.6	14.4	10.0	0.6	0.2	0.1	0.1	0.2	2.1	24.2	101.7	8.5
Nyashishi	3.8	1.7	1.7	2.2	2.9	0.2	0.0	0.0	0.0	0.0	0.3	7.1	19.8	1.7
Issanga	11.5	10.2	17.1	9.8	9.0	1.9	0.5	0.4	0.3	0.4	5.1	307.7	373.8	31.1
S. Shore Streams	29.0	23.6	19.5	38.6	43.9	4.0	0.5	0.4	0.4	0.4	9.9	142.6	312.8	26.1

** compiled by the LVEMP for the year of 1950 to 2000*

In this study, the river basins are subdivided into eleven river basins, namely Mori, Mara, Suguti, Ukerewe, Grumeti, Mbalageti, Ramadi, Simiyu, Magogo-Moame, Isanga and Nyaruhwa. Other small stream systems are classified as three South Shore Streams. In the table above, some of the rivers have been classified as East Shore Streams, such as the Mori River and the Suguti River. The Nyashishi and Nyaruhwa Rivers are classified as South Shore Streams. The largest basin in the study area is the Mara River Basin which occupies 13,208 km^3.

Perennial rivers shall not be included in the potential water sources, as the intake of water is not possible during the dry season. Therefore, the Mara and Simiyu rivers are the potential sources for development.

Table 9.2-2: Water Quality of River Water

DRY SEASON

District	Name of Location	SN	T. Coliform	Esc. Colif	Pb	As	Se	Cr	CN	Cd	Ba	Hg	F	NO3	Color	Turbidity	pH	TSS	TDS	T-Hardness	Ca	Mg	SO4
			count/100ml	count/100ml	mg/l	μg/l	μg/l	mg/l	mg/l	mg/l	mg/l	μg/l	mg/l	mg/l	mg Pt/l	NTU		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Magu	Simiyu River Bridge	RV1	26	38	<0.01	<1	<1	<0.01	0.006	<0.001	0	1	1.2	3	59	12	8.26	252.20	355.00	146.0	94.00	12.64	18.60
Bunda	Rubana River Bunda	RV2	11	18	<0.01	<1	<1	<0.01	0.009	<0.001	0	1	0.8	4	117	541	7.1	584.00	95.60	55.0	42.00	3.16	24.10
Tarime	Ryamisanga Mara River	RV3	14	25	<0.01	<1	<1	<0.01	0.002	<0.001	0	3	1.0	4	67	16	7.13	485.30	94.70	45.0	26.00	4.62	0.00
Tarime	Randa Mori River	RV4	24	38	<0.01	<1	<1	<0.01	0.003	<0.001	0	<1	1.0	4	141	31	7.2	369.60	110.40	72.5	52.00	4.98	21.00
Serengeti	Ft. Ikoma River Grumeti	RV5	17	28	<0.01	<1	<1	1.00	0.001	<0.001	0	2	1.7	3	0	0	8.5	558.00	642.00	190.0	67.00	29.89	48.90

District	Name of Location	SN	Cl	Fe	Mn	Cu	Zn	BOD	NH4	B	Ni	Sb	Mo	NO2	Residue Cloride (mg/l)	Temp	EC	K	PO4	COD	HCO3	Na	Organic Phosphate (mg/l)
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		°C	μS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	
Magu	Simiyu River Bridge	RV1	87	0.26	0.0	<0.01	<0.01	0	0.54	0.06	<0.01	<0.001	<0.01	0.06	0.0	25.6	707.00	9.96	1.21	0	423	101.30	0.33
Bunda	Rubana River Bunda	RV2	13	3.45	0.0	<0.01	<0.01	10	1.21	0.01	<0.01	<0.001	<0.01	0.00	0.0	25.8	191.30	11.05	2.38	31	87	15.10	0.67
Tarime	Ryamisanga Mara River	RV3	26	1.67	0.0	<0.01	<0.01	21	0.57	0.01	<0.01	<0.001	<0.01	0.03	0.0	25.9	189.20	8.35	0.49	61	74	23.60	0.07
Tarime	Randa Mori River	RV4	22	1.08	0.0	<0.01	<0.01	16	0.48	0.01	<0.01	<0.001	<0.01	0.02	0.0	25.9	221.00	6.23	0.92	31	40	17.00	0.11
Serengeti	Ft. Ikoma River Grumeti	RV5	144	0.21	0.0	<0.01	<0.01	0	0.46	0.06	<0.01	<0.001	<0.01	0.05	0.0	25.5	1281.00	18.45	0.81	10	556	222.40	0.2

WET SEASON

District	Name of Location	SN	T. Coliform	Esc. Colif	Pb	As	Se	Cr	CN	Cd	Ba	Hg	F	NO3	Color	Turbidity	pH	TSS	TDS	T-Hardness	Ca	Mg	SO4
			count/100ml	count/100ml	mg/l	μg/l	μg/l	mg/l	mg/l	mg/l	mg/l	μg/l	mg/l	mg/l	mg Pt/l	NTU		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Magu	Simiyu River Bridge	RV1	14	5	<0.01	<0.05	0.07	<0.01	0.001	<0.001	1	<0.05	7.9	0	176	38	8.07	413.00	187.20	107.0	77.00	7.29	20.00
Bunda	Rubana River Bunda	RV2	0	0	0.04	<0.05	0.07	<0.01	0.002	<0.001	0	<0.05	0.6	4	584	162	7.35	404.00	95.80	58.0	43.00	3.65	30.70
Tarime	Ryamisanga Mara River	RV3	0	0	<0.01	<0.05	0.04	<0.01	0.000	<0.001	0	<0.05	1.1	2	132	29	6.7	157.00	82.70	42.0	25.00	4.13	13.80
Tarime	Randa Mori River	RV4	0	0	<0.01	<0.05	0.08	<0.01	0.001	<0.001	0	<0.05	0.7	5	374	78	7.7	7.00	73.30	48.0	30.00	4.37	25.20
Serengeti	Ft. Ikoma River Grumeti	RV5	0	0	<0.01	<0.05	0.06	<0.01	0.001	<0.001	0	<0.05	0.9	0	59	11	8	204.00	115.70	70.0	49.00	5.10	14.50

District	Name of Location	SN	Cl	Fe	Mn	Cu	Zn	BOD	NH4	B	Ni	Sb	Mo	NO2	Residue Cloride (mg/l)	Temp	EC	K	PO4	COD	HCO3	Na	Organic Phosphate (mg/l)
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		°C	μS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	
Magu	Simiyu River Bridge	RV1	47	0.00	0.0	<0.01	0.128	0	0.00	0.28	<0.01	<0.001	<0.01	0.07	0.0	24.5	374.00	1.54	1.06	10	174	57.68	0.33
Bunda	Rubana River Bunda	RV2	21	0.22	0.0	<0.01	<0.002	17	0.03	1.13	<0.01	<0.001	<0.01	0.13	0.0	24.6	191.70	5.16	1.76	51	68	7.23	0.02
Tarime	Ryamisanga Mara River	RV3	19	0.94	0.0	<0.01	<0.002	16	0.51	0.55	<0.01	<0.001	<0.01	0.03	0.0	24.9	165.40	2.43	0.69	41	56	29.01	0.02
Tarime	Randa Mori River	RV4	12	1.40	0.0	0.01	<0.002	28	0.34	0.20	<0.01	<0.001	<0.01	0.06	0.0	24.9	146.70	0.70	0.62	75	51	23.45	0.04
Serengeti	Ft. Ikoma River Grumeti	RV5	21	0.11	0.0	<0.01	0.011	0	0.00	0.20	<0.01	<0.001	<0.01	0.03	0.0	24.7	115.70	1.55	0.82	0	84	61.45	0.02

> Tanzania Upper Limit > Tanzanian Allowavle Value > WHO GV & ACV > Tanzanian Allowavle Value

The water quality of river water is represented by high color, turbidity, Hg, Fe, BOD and NH_4. Coliform and bacteria are high in the dry season, but concentrations are reduced to a drinkable level in the wet season. Treatment and filtering are required for potable purposes.

Still, river water can be used as a general water source instead of for drinking and cooking. However, river water is not considered as a source of rural water supply in the study due to the following reasons:

1) High fluctuation of the river water level by season makes it difficult.

2) The water quality of the river is risky due to the content of toxic metal such as Hg and high bacteriological contamination.

3) Although permanent rivers such as the Mara River exist, a treatment and filtering plant is required. Additional works for the intake structure will also be required such as a river stream dividing to the canal or an infiltration gallery. The capital and maintenance costs would be quite high for a village water supply.

9.2.2 Potential of Lake Victoria

Lake Victoria is the world's second largest freshwater lake, covering an area of 67850 sq km. The water level has varied within two meters in the past three decades but the fluctuation tends to retain the water level every ten years. Therefore, it can be categorized as a stable water source. The lake water is one of the highest potential surface water sources in the area.

As the lake is an international water source, the possible intake amount cannot be calculated based only on data from the Tanzanian side.

The Lake Victoria Environmental Management Project (LVEMP) has calculated the overall average inflow and outflow using the meteorological data available in Kenya, Uganda and Tanzania.

The data consisted of rainfall over the lake and discharges from the three countries as inflow, and evaporation and runoff into the Victoria Nile (river) as outflow.

Table 9.2-3: Mass Balance of Lake Victoria

Average 1950 -2000	**Flows (m^3/s)**	**Percent (%)**
Inflows		
Rain Over Lake	3631	82
Basin Discharges	778	18
Outflows		
Evaporation from Lake	-3330	76
Victoria Nile	-1046	23
SUM	33	

* *Integrated Water Quality/Limnology Study for Lake Victoria Part II (2002, LVEMP)*

Groundwater interaction and human consumption is not included. However, the calculated Mass Balance has a good alignment with the lake water level.

The $33m^3/s$ of water equals 2,851,200 m^3/day. The water demand in this study for planning the rural water supply from Lake Victoria is $32{,}435m^3$/day in the year 2015, with a maximum intake of $46708m^3$/day.This is 1.6% of the total water balance (positive value) of the lake.

However, in general, the amount of water intake is increasing parallel to the development of the lakeside areas, such as the water demand of factories and the increasing demand of human consumption by the growing population. In addition to the increasing demand for lake water, pollution at the lakeshore is also an issue of concern. During recent years, the water level of Lake Victoria has been declining as shown in the following figure.

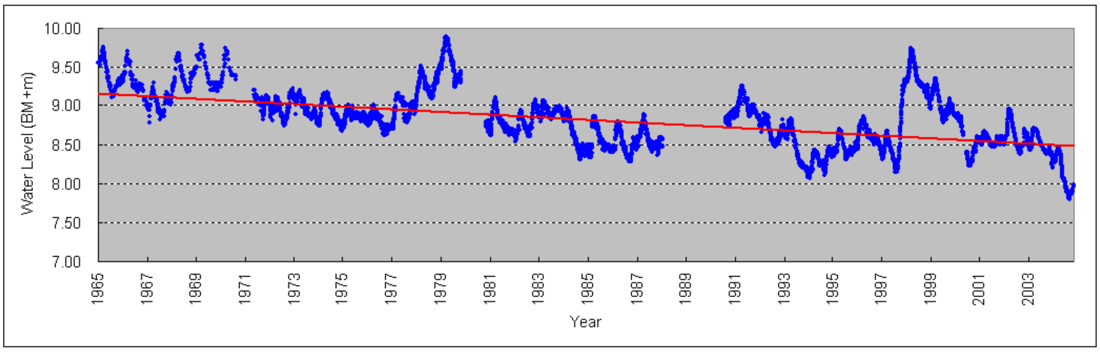

Figure 9.2-1: Water Level Fluctuation of the Lake Victoria

Although only a small portion of the positive inflow of Lake Victoria is to be used based on the plan of this study, management of the lake water is essential to maintain the total mass balance.

The LVEMP approaches water quality issues based on non point and point source pollution loads of BOD, total nitrogen and total phosphorus (ton/year).

Table 9.2-4: Nutrient Pollution Loads to Lake Victoria

Source	BOD	Total Nitrogen	Total Phosphorus
	(tons/year)	(tons/year)	(tons/year)
Catchment	0	49510	5690
Atmosphere	0	102150	24400
Industrial	5610	410	340
Municipal	17940	3510	1620
Total	23550	155580	32050

* *Integrated Water Quality/Limnology Study for Lake Victoria Part II (2002, LVEMP)*

The result indicates that the BOD as well as the total nitrogen and phosphorus loads are high from industrial and municipal sources.

The results concerning the water quality of Lake Victoria in this study are shown in the following table. The analysis revealed that the water is high in coliforms and general bacteria at the lake shore. The result also indicates high values of turbidity, color, BOD and NH_4 throughout the year. There are some areas high in Ba, Fe, and NO_2. These facts indicate that the water itself should be filtered and treated for potable purposes.

Compared with the LVEMP study, the Coliform, BOD, NH_4 and PO_4 loads of the lake are a result of human activity.

Table 9.2-5: Water Quality of Lake Victoria

DRY SEASON

District	Name of Location	SN	T. Coliform	Esc. Colif	Pb	As	Se	Cr	CN	Cd	Ba	Hg	F	NO3	Color	Turbidity	pH	TSS	TDS	T-Hardness	Ca	Mg	SO4
			count/100ml	count/100ml	mg/l	μg/l	μg/l	mg/l	mg/l	mg/l	mg/l	μg/l	mg/l	mg/l	mg Pt/l	NTU		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Magu	Pump-H Kalemelala I Lake-Vic	LV1	33	46	<0.01	<1	<1	<0.01	0.001	<0.001	0	<1	0.9	1	36	8	8	388.40	51.60	43.0	19.00	5.83	0.00
Magu	Lake Victoria Bulima	LV2	22	41	<0.01	<1	<1	<0.01	0.000	<0.001	0	<1	1.0	1	14	3	8.9	548.60	51.40	28.0	12.00	3.89	0.00
Magu	Pump-H Kalemelala I Lake-Vic	LV3	36	49	<0.01	<1	<1	<0.01	0.000	<0.001	0	<1	0.7	4	44	12	9.1	771.00	53.90	275.0	182.00	22.60	6.60
Mwanza	Milongo Lake-Vic Mwanza	LV4	2	5	<0.01	<1	<1	<0.01	0.001	<0.001	1	<1	0.7	10	0	0	7.64	669.00	171.00	195.0	71.00	30.13	19.30
Tarime	Shirati Lake Victoria	LV5	11	25	<0.01	<1	<1	<0.01	0.000	<0.001	0	<1	0.7	1	22	8	8.9	269.40	50.60	30.5	21.00	2.31	3.30
Sengerema	Buyagu - Lake Victoria	LV6	12	4	<0.01	<1	<1	<0.01	0.005	<0.001	0	<1	0.9	3	67	16	9.43	319.70	80.30	47.0	31.00	3.89	10.00
Sengerema	Nyakahako	LV7	5	1	<0.01	<1	<1	<0.01	0.016	<0.001	0	<1	0.3	0	411	171	5.71	797.40	22.60	14.0	13.00	0.24	0.00
Sengerema	Lushamba-kanyara	LV8	18	11	0.07	<1	<1	<0.01	0.001	<0.001	0	<1	0.3	2	0	75	8.6	976.80	43.20	33.0	18.00	3.65	0.00
Geita	Katoma lake victoria	LV9	5	2	<0.01	<1	<1	0.01	0.001	0.001	0	<1	0.3	2	0	0	9.79	471.10	48.90	28.0	17.00	2.67	6.60
Ukerewe	Chabilungo Lake Victoria	LV10	8	5	<0.01	<1	<1	0.02	0.001	0.001	0	<1	0.3	2	7	3	7.98	674.20	45.80	34.0	20.00	3.40	0.00
Musoma	Musoma Lake Victoria	LV11	18	9	<0.01	<1	<1	<0.01	0.001	<0.001	0	<1	0.3	2	22	8	8.32	477.80	42.20	28.0	13.00	3.65	1.60
Musoma rural	Bukima Lake victoria	LV12	29	11	<0.01	<1	<1	<0.01	0.001	<0.001	0	<1	0.4	2	0	2	7.93	356.50	43.50	28.0	13.00	3.65	0.00

District	Name of Location	SN	Cl	Fe	Mn	Cu	Zn	BOD	NH4	B	Ni	Sb	Mo	NO2	Residue Cloride (mg/l)	Temp	EC	K	PO4	COD	HCO3	Na	Organic Phosphate (mg/l)
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		°C	μS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	
Magu	Pump-H Kalemelala I Lake-Vic	LV1	16	0.12	0.0	<0.01	<0.01	0	1.55	0.01	<0.01	<0.001	<0.01	0.04	0.0	25.8	103.50	3.02	0.33	0	46	7.90	0.07
Magu	Lake Victoria Bulima	LV2	15	0.09	0.0	<0.01	<0.01	5	1.68	0.01	<0.01	<0.001	<0.01	0.04	0.0	25.9	103.50	2.96	0.28	20	44	7.50	0.02
Magu	Pump-H Kalemelala I Lake-Vic	LV3	9	0.18	0.0	<0.01	<0.01	0	0.30	0.08	<0.01	<0.001	<0.01	0.09	0.0	25.5	107.80	3.35	0.72	10	45	8.50	0.05
Mwanza	Milongo Lake-Vic Mwanza	LV4	55	0.28	0.0	<0.01	<0.01	57	0.61	0.01	<0.01	<0.001	<0.01	1.23	0.0	25.8	342.00	12.07	0.76	117	103	27.60	0.35
Tarime	Shirati Lake Victoria	LV5	11	0.08	0.0	<0.01	<0.01	12	0.31	0.01	<0.01	<0.001	<0.01	0.02	0.0	25.7	101.30	2.75	0.55	41	40	7.20	0.03
Sengerema	Buyagu - Lake Victoria	LV6	13	0.07	0.0	<0.01	<0.01	7	0.41	0.15	<0.01	<0.001	<0.01	0.03	0.0	24.9	201.00	3.06	0.18	20	81	30.60	0.01
Sengerema	Nyakahako	LV7	18	4.00	0.0	<0.01	<0.01	18	1.26	0.08	<0.01	<0.001	<0.01	0.00	0.0	24.7	47.80	4.55	0.34	51	26	7.10	0.02
Sengerema	Lushamba-kanyara	LV8	20	0.03	0.0	<0.01	0.2	0	0.37	0.06	<0.01	<0.001	<0.01	0.03	0.0	25.2	93.90	2.37	0.17	10	40	6.50	0.01
Geita	Katoma lake victoria	LV9	18	0.04	0.0	0.16	<0.01	0	0.74	0.07	<0.01	<0.001	<0.01	0.02	0.0	24.7	96.70	2.28	0.01	10	49	5.50	0
Ukerewe	Chabilungo Lake Victoria	LV10	12.5	0.08	0.0	0.37	<0.01	10	0.35	0.06	<0.01	<0.001	<0.01	0.30	0.0	25.1	101.50	2.43	0.07	31	49	5.90	0.01
Musoma	Musoma Lake Victoria	LV11	13	0.10	0.0	<0.01	<0.01	17	0.31	0.14	<0.01	<0.001	<0.01	0.01	0.0	24.6	104.10	2.80	0.10	41	53	5.80	0
Musoma rural	Bukima Lake victoria	LV12	13	0.06	0.0	<0.01	<0.01	3	0.84	0.09	<0.01	<0.001	<0.01	0.07	0.0	24.7	94.10	4.20	0.07	10	54	4.20	0.01

WET SEASON

District	Name of Location	SN	T. Coliform	Esc. Colif	Pb	As	Se	Cr	CN	Cd	Ba	Hg	F	NO3	Color	Turbidity	pH	TSS	TDS	T-Hardness	Ca	Mg	SO4
			count/100ml	count/100ml	mg/l	μg/l	μg/l	mg/l	mg/l	mg/l	mg/l	μg/l	mg/l	mg/l	mg Pt/l	NTU		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Magu	Pump-H Kalemelala I Lake-Vic	LV1	3	0	<0.01	<0.05	<0.05	<0.01	0.001	<0.001	0	<0.05	0.3	0	0	3	8.84	3.00	46.90	27.0	17.00	2.43	3.30
Magu	Lake Victoria Bulima	LV2	0	0	<0.01	<0.05	0.06	<0.01	0.000	<0.001	0	<0.05	0.3	2	14	5	9.48	296.00	43.90	28.0	13.00	3.65	1.60
Magu	Pump-H Kalemelala I Lake-Vic	LV3	3	1	<0.01	<0.05	<0.05	<0.01	0.001	<0.001	0	<0.05	0.4	0	14	3	8.66	72.00	468.00	24.0	16.00	1.94	1.60
Mwanza	Milongo Lake-Vic Mwanza	LV4	0	0	0.02	<0.05	0.05	<0.01	0.001	<0.001	0	<0.05	0.3	52	0	2	7.14	20.00	50.40	31.0	18.00	3.16	1.60
Tarime	Shirati Lake Victoria	LV5	10	4	<0.01	<0.05	0.09	<0.01	0.000	<0.001	0	<0.05	0.3	0	29	3	7.8	16.00	44.30	27.0	14.00	3.16	1.60
Sengerema	Buyagu - Lake Victoria	LV6	26	37	<0.01	<1	<1	<0.01	0.001	<0.001	0	<1	0.9	4	91	16	8.98	30.00	73.10	47.0	21.00	6.32	14.50
Sengerema	Nyakahako	LV7	10	17	<0.01	<1	<1	<0.01	0.001	<0.001	0	<1	1.0	2	456	63	5.68	400.00	19.00	14.0	5.00	2.19	28.10
Sengerema	Lushamba-kanyara	LV8	32	49	<0.01	<1	<1	<0.01	0.001	<0.001	0	<1	0.6	5	7	0	8.1	150.00	43.50	21.0	14.00	1.70	0.00
Geita	Katoma lake victoria	LV9	7	16	<0.01	<1	<1	<0.01	0.001	<0.001	0	<1	0.6	3	14	5	9.75	20.00	39.40	24.0	12.00	2.92	6.60
Ukerewe	Chabilungo Lake Victoria	LV10	11	22	<0.01	<1	<1	<0.01	0.001	<0.001	0	<1	0.6	5	67	12	6.68	20.00	27.10	20.0	8.00	2.92	14.50
Musoma	Musoma Lake Victoria	LV11	16	25	<0.01	<1	<1	<0.01	0.001	<0.001	0	<1	0.6	3	7	5	9.38	160.00	42.20	27.0	13.00	3.40	3.30
Musoma rural	Bukima Lake victoria	LV12	51	93	<0.01	<1	<1	<0.01	0.001	<0.001	0	<1	0.6	6	14	5	8.14	200.00	39.30	29.0	12.00	4.13	3.30

District	Name of Location	SN	Cl	Fe	Mn	Cu	Zn	BOD	NH4	B	Ni	Sb	Mo	NO2	Residue Cloride (mg/l)	Temp	EC	K	PO4	COD	HCO3	Na	Organic Phosphate (mg/l)
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		°C	μS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	
Magu	Pump-H Kalemelala I Lake-Vic	LV1	11	0.00	0.0	<0.01	<0.002	6	1.89	0.09	<0.01	<0.001	<0.01	0.03	0.0	24.5	93.80	0.27	0.04	31	46	32.01	0.01
Magu	Lake Victoria Bulima	LV2	13	0.00	0.0	<0.01	<0.002	28	1.09	0.16	<0.01	<0.001	<0.01	0.02	0.0	24.7	87.90	0.55	0.19	61	39	5.01	0.15
Magu	Pump-H Kalemelala I Lake-Vic	LV3	14	0.00	0.0	<0.01	<0.002	11	0.20	0.19	<0.01	<0.001	<0.01	0.03	0.0	24.6	93.70	0.49	0.31	31	45	29.93	0.05
Mwanza	Milongo Lake-Vic Mwanza	LV4	10	0.00	0.0	<0.01	<0.002	34	0.01	0.18	<0.01	<0.001	<0.01	0.03	0.0	25.3	100.80	0.44	0.33	117	34	21.06	<0.01
Tarime	Shirati Lake Victoria	LV5	8	0.00	0.0	<0.01	<0.002	4	0.00	0.18	<0.01	<0.001	<0.01	0.03	0.0	24.5	44.30	0.43	0.1	10	32	10.30	0.01
Sengerema	Buyagu - Lake Victoria	LV6	14	0.32	0.0	<0.01	0.05	10	0.57	0.06	<0.01	<0.001	<0.01	0.05	0.0	25.8	146.10	2.06	0.08	31	86	24.50	0.13
Sengerema	Nyakahako	LV7	17	1.03	0.0	<0.01	0.06	18	3.01	0.10	<0.01	<0.001	<0.01	0.44	0.0	26.0	38.00	3.41	0.35	51	18	10.00	0.49
Sengerema	Lushamba-kanyara	LV8	11	0.00	0.0	<0.01	0.02	0	0.35	0.03	<0.01	<0.001	<0.01	0.05	0.0	25.4	86.90	2.03	0.38	10	48	9.10	0.05
Geita	Katoma lake victoria	LV9	12	0.00	0.0	<0.01	<0.01	0	0.54	0.03	<0.01	<0.001	<0.01	0.04	0.0	25.8	78.80	1.42	0.20	10	39	8.80	0.05
Ukerewe	Chabilungo Lake Victoria	LV10	13	0.00	0.0	<0.01	0.06	10	0.41	0.01	<0.01	<0.001	<0.01	0.07	0.0	25.2	54.10	1.46	0.79	31	29	9.20	0.03
Musoma	Musoma Lake Victoria	LV11	11	0.07	0.0	<0.01	<0.01	27	0.57	0.07	<0.01	<0.001	<0.01	0.09	0.0	25.8	84.30	1.62	0.31	61	40	9.80	0.05
Musoma rural	Bukima Lake victoria	LV12	28	0.00	0.0	<0.01	<0.01	10	0.31	0.04	<0.01	<0.001	<0.01	0.03	0.0	24.7	78.60	1.48	0.35	31	46	9.20	0.05

> Tanzania Upper Limit; > Tanzanian Allowavle Value; > WHO GV & ACV; > Tanzanian Allowavle Value

A comprehensive management system for Lake Victoria should be considered to prevent pollution in order to maintain reasonable water quality.

For the purpose of rural water supply in the study, the lake water shall be used for the scheme based water supply system, consisting of intake facilities, pump facilities, a processing plant, a storage tank and a distribution pipe. The harmful substances from the lake shall be treated and processed. The cost effectiveness shall be carefully examined with the borehole distribution (Level II) system for the actual use of the water for the rural area.

9.2.3 Examination of Surface Water

The potential surface water distribution covers a wide portion of the study area. However, in the inland area, the ponds and rivers are not suitable for use as potable water sources due to the seasonal effect, water quality and cost of facility construction. Lake water is considered as a potential source of water for villages within some 9 km from the lake.

However, the necessity of a treatment and filtering plant requires higher cost in terms of construction and operation and maintenance. Operation and maintenance will be an important factor for facilities with a treatment system.

River water is not considered for use as a rural water supply because of its unreliability due to seasonal variations in water volume, risks for the water quality and the high cost of the water supply facility.

9.3 Groundwater Potential

In general, the two groundwater sources identified in the area are stratum aquifers and fissure water. Stratum aquifers can be divided into two categories: shallow aquifers and medium aquifers.

The **shallow aquifer** is a common water source in the area and is used through shallow wells and traditional water sources, such as dug wells and local springs. It is easy to identify this type of aquifer. However, it is affected seasonally due to a change in groundwater level (most of them are dry in the dry season) and based on the water quality analysis results, it is easily polluted by contamination from the surface.

The **medium aquifer** is distributed in the secondary deposits and weathered zone of the Precambrian rock units. This aquifer is much safer, more productive than the shallow aquifer and the seasonal fluctuation is less than that of shallow wells.

The **deeper water** source (aquifer), the fissure type water, is generally distributed at the joints and fissures. Provided with good water quality, this type of aquifer is the safest and most sustainable.

The groundwater potential in this study mainly focused on the medium aquifers and fissure type water, which have a more sustainable and safer nature based on the results of surveys conducted in this study.

9.3.1 Classification of Aquifer Unit

The groundwater in the study area can be classified into three forms:

1) Stratum aquifer: unconfined aquifer within 10m below ground surface (bgsl) in the Neocene alluvial, lacustrine, terrestrial, fluvatile and marine deposits

2) Stratum aquifer: unconfined, semi-confined aquifer at a depth range of 20-50m bgsl in the decomposed (weathered) or secondary deposited Precambrian hard rocks (mainly granite)

3) Fissure water: semi-confined, confined aquifer at a depth range of 20–150m bgsl in the fractures and fissures distributed in the hard rocks.

The study area is widely occupied by granite and its members (hard rocks). Therefore, the major water to be extracted from the ground will be water from medium stratum aquifers and fissure water. There are also shallow stratum aquifers in the area, but most of them dry up or the discharge is minimal in the dry season.

The geological map of the area is presented in Figure 2.2-1 as a reference of the distribution of the geological units.

A well inventory survey was conducted to interpret and analyze the hydrogeological characteristics of the area. The field well inventory survey identified 229 functioning wells including both shallow and deep wells (hereinafter, “shallow well” means a well with a depth of less than 20m bgsl) among 515 villages. The survey identified 67 functioning deep boreholes, with only limited specification data of the well.

A follow up survey has been conducted to obtain additional information for the interpretation of the hydrogeological condition; follow up field survey and existing data compilation.

As a result, 338 wells were investigated in total, including eight holes from the field survey, and 101 from the past drilling records and their positioning works.

Figure 9.3-1 presents the geological formation of the 294 sites from the well inventory survey which has the well depth records. The area is largely occupied by Precambrian rock units, of which the composition is 86 %, and granitic rock, such as granite and its decomposed members, accounts for 76%. Eleven percent of the sites are in the geological formation of Neocene Deposits.

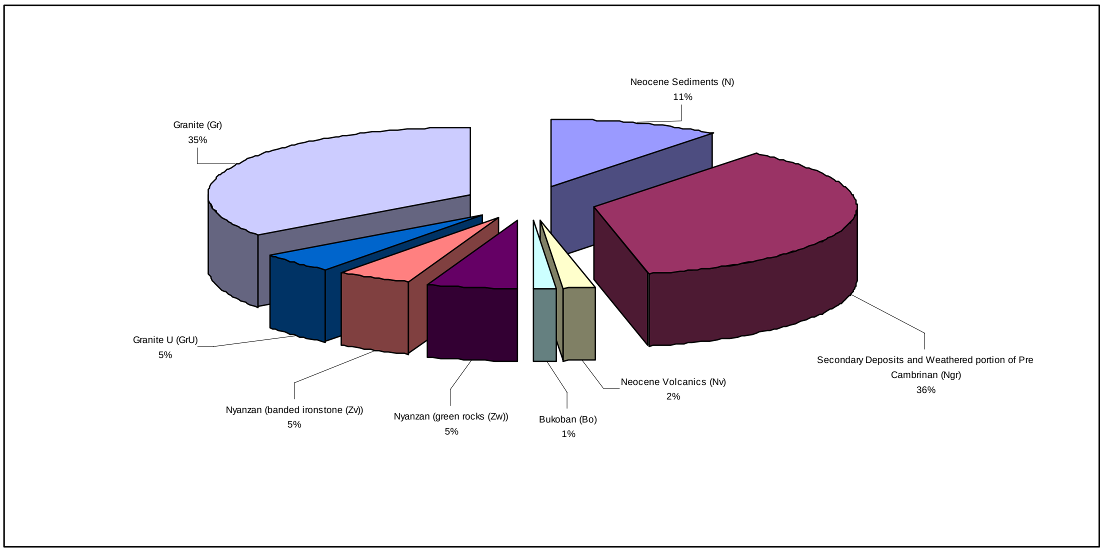

Figure 9.3-1: Composition of Extracting Aquifer (Geology) by Well

Most of the well inventory could not retrieve the specific aquifer formation from the available data and screen depth. Therefore, the aquifers of some of the wells were estimated from the geological map and/or site survey.

a. Relationship between Well Depth and Yield (Discharge)

The capability of the aquifers is reviewed based on the yield and well information. Figure 9.3-2 shows the relationship between well depth and yield (liters per minute) as well as static water level.

The high yielding (more than 70 liters/min) depth ranges from 30m to 180m, but holes at these depths include a lot of low yielding wells as well.

This is much due to its geological nature. The wells are highly affected by the existence of fissures and/or fractures as the aquifer, and the discharge (yield) depends on the storage capacity and continuity of the fissures and fractures.

b. Relationship between Aquifer (Geology Type) and Yield

The known yields are extracted by the geology of the aquifer. The average, minimum and maximum yields by the geology of the aquifer are shown in Table 9.3-1.

Table 9.3-1: Aquifer and Yield, Depth

	Yield (litre/min)				Depth (GL-m)			
	sample no	maximum	minimum	average	sample no	maximum	minimum	average
Neocene	11	60.0	0.1	11.8	31	105.5	3.0	25.7
Secondary Deposits and Weathered portion of Pre Cambrinan (Ngr)	53	267.8	0.1	28.7	106	195.3	4.0	35.5
Volcanics	1	2.4	2.4	2.4	6	91.0	7.0	33.8
Bukoban	0	0.0	0.0	–	4	86.0	7.0	32.5
Nyanzan (green rocks)	8	151.7	0.1	38.0	16	93.0	6.0	54.0
Nyanzan (banded ironstone)	8	11.9	0.3	4.4	14	90.2	6.0	49.7
Granite U	7	1.7	0.1	0.6	14	40.0	5.0	9.4
Granite	71	335.0	0.1	45.7	103	214.6	1.6	51.7

Granite has the highest average yield at 53 l/min, followed by Nyanzan green rocks (38 l/min) and Decomposed Precambrian rocks (36 l/min). But the figures vary from less than 1 l/min to over 300 l/min. The average itself is highly affected by the large numbers of more than 100 l/min.

However, this fact indicates that potential aquifers exist in these rock units, and the potential for the development of water sources is relatively higher than other rock members.

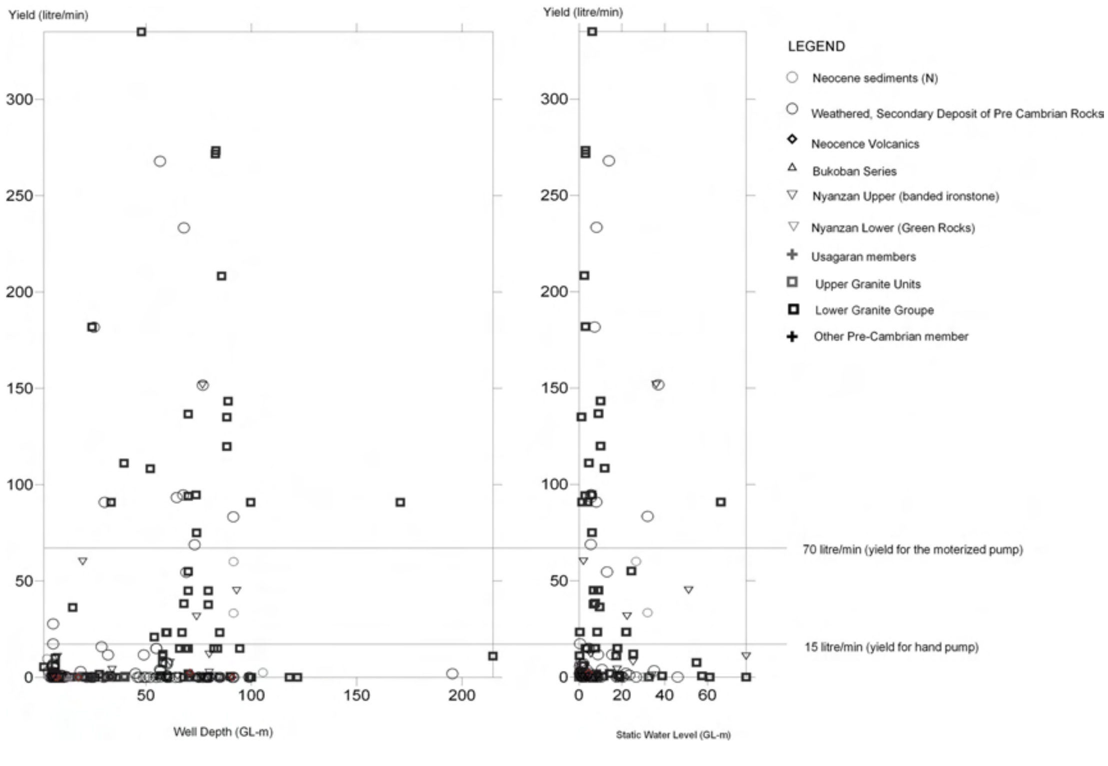

Figure 9.3-2: Relation between Yield (litres/min) and Well Depth, Static Water Level by Geology

High potential aquifers can be confirmed in Figure 9.3-2. Although the yield in each aquifer varies, granite, decomposed Precambrian rocks and some of the Nyanzan rock groups produce a good yield of water.

The yield distribution map is indicated in Figure 9.3-3. The high yielding area is distributed from the north to the south of Kwimba, the lakeside of Musoma and west of the boundary between Sengerema and Geita.

c. Relationship between Well Depth and Water Level

The relationship between well depth and water level is examined in Figure 9.3-4.

The static water level by well depth shows no significant relationship. Some deep holes have deep static water levels, while others have shallow static water levels. Some deep aquifers are confined aquifers, although the well depth is more than 80 meters, and there exists a static water level of less than 5 meters.

However, there is a tendency for the static water level to be less than 10 meters until a depth of between 40 to 50 meters. The aquifer unit in this range is weathered Precambrian and granite members. This may indicate that unconfined – semi confined aquifers are present until a depth of around 50 meters, and as the depth increases, the variation of yield increases. The deeper holes are exploiting water from semi confined-unconfined water in fractures or fissures, and wells which intersect good yielding fissures or fractures will have static water of less than 20 m bgsl. It should be noted that the difference of massive rocks and the decomposed zone can hardly be identified from the surface. Therefore, from the depth of 30m to 80m bgsl, the two rock units interfuse.

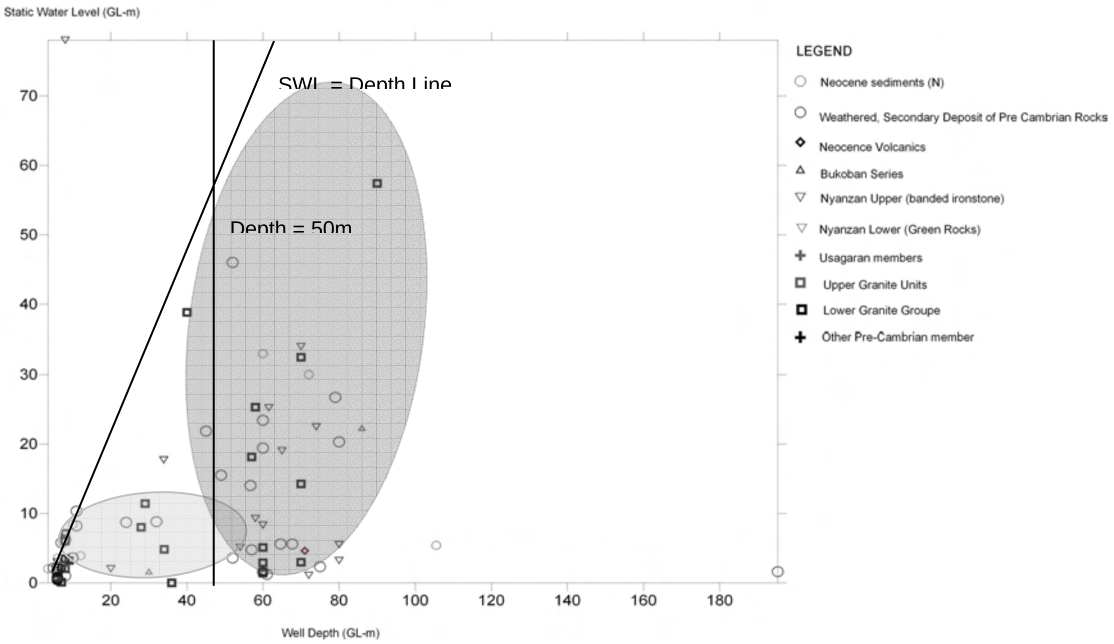

Figure 9.3-4: Well Depth and Static Water Level

9.3.2 Character of Aquifer Unit and Wells

In evaluating the existing data and survey data, the following points are revealed:

- Potential (productive) aquifers can be divided into two types: stratum aquifers in the weathered or secondary deposits of Precambrian rock units and fracture type aquifers.
- High yield areas or aquifers are not identified as a zone, but some limited locations

- There is quite a high variation of yield by depth and type of aquifer.
- Granite and Nyanzanian metasedimentary rocks are the main fissure water sources and productive aquifers in the area.
- The static water level varies even in aquifers of the same geology.

Considering these findings, the potential targets for groundwater development shall be limited to two types:

1) The granite and Nyanzan metasedimentary rock distributed area for the fissure type aquifers (more than 45 meter in depth).
2) Medium aquifers in the decomposed Precambrian rocks (up to 50 m).

Determination of the target depth and the location shall highly depend on the fissures for the deep aquifers. Therefore, a detailed lineament interpretation is essential to determine the water source development points.

However, even if the drilling intersects the fissure or fracture zone, it is very difficult to predict its yield until the drilling strikes a certain aquifer.

The difficulty of water source development in the area is also indicated in the SIDA Report, 1979. Only 31% of the total drilling holes could get a yield of more than 1 m^3/h, which is 17 l/min.

The hydrogeological analysis of aquifer parameters is described in the test drilling results, such as the specific capacity and storability by individual holes. However, these parameters are not discussed in regard to the whole study area, as there is not sufficient information to discuss the results as representative aquifers.

The groundwater flow mechanism is also not described. The nature of the flow is not clearly identified in cases where productive holes and dry holes are found at a close distance. The static water level of the individual holes is presented in the preliminary water availability map.

a. Water Quality of the Groundwater

A series of water quality results has been achieved, and from the results, the nature of groundwater can be summarized as follows:

Shallow Wells: large variation by area. The shallow well at Bunda (Tamau Borehole) is extracting water from an aquifer in the Neocene deposits; it has an extremely high concentration of Cl, SO_4, Cd, Na, and K, and the EC value exceeds 40,000 μ S/m. The well shall not be used as a drinking water source. Shallow wells also have high contaminations of coliform and bacteria, and indicate a high EC value. This largely depends on the well structure and nature of the aquifer.

Deep wells: not so much affected by bacteria but it contains a series of metal ions such as Fe, Pb, Cr, Se, Ba and F. Based on the water quality standards of Tanzania and WHO, some of the parameters exceed the allowable value. The granite fissure type aquifer at **Kwimba and Magu** indicated a high content of F. This fact indicates a similar tendency with the SIDA report, 1979.

The examined shallow wells are extracting water from subsurface shallow aquifers with a depth of less than 20m. The chemical composition of the shallow wells (Hexa and Trilliniar Diagram) indicates that the nature of its composition is similar to surface water, but some of it contains toxic substances originated from the soil. Neocene sediments are composed of fine grained silt or mud of various origins (i.e. alluvial, lacustrine, terrestrial, fluvatile and marine deposits of the Precambrian rock origin). Therefore, various chemicals are distributed by location and depth, and the permeability is generally low.

Through the study, it is recommended not to extract water from shallow aquifers, such as the Tamau borehole, if high concentrations of toxic substances are found. This is largely due to the concentration of heavy materials. Therefore, areas where Neocene deposits are distributed are not recommended as potential aquifers as it they are not always safe.

Deep wells include medium boreholes and deep boreholes with a depth of more than 20 meters bgsl. Some wells contain heavy metal ions and fluoride, of which the content is higher than the upper limit of the Tanzanian standard. However, with careful examination of water quality, the water itself, without any treatment, is safer than other water sources.

Therefore, in terms of water quality, the following aquifers are considered potential groundwater sources for the water supply:

- Medium depth stratum aquifers in the decomposed Precambrian rock unit (mainly secondary deposits or weathered granite (from 20m to 50m in depth from the surface)
- Deep fissure water of granite, Nyanzan rock units (from 20 m to 100m)

The distribution of EC in relation to the geology is presented in Figure 9.3-5.

b. Geological Structure and the Groundwater

It was revealed that one of the potential aquifers is fissure water extracted from the fissures and fractures distributed in the Precambrian hard rock formations.

Therefore, the potential area for the extraction of fissure water largely depends on the existence of fissures in the rocks. These structures are examined by the interpretation of geological maps (faults, fractures, lineaments and geological boundaries), aerial photograph interpretation, and SRTM data and images. Figure 9.3-6 presents the interpreted structures (such as lineaments, faults and fissures). The yield of the wells from the well inventory survey is also marked in Figure 9.3-7, which shows the density of the lineaments in a 4km grid. The high density area is shown in dark gray.

The interpretation of the maps, especially in reference to the yield, will provide the information on the potential water bearing structure.

The direction of the lineaments is not constant. The character of the lineaments is described as follows:

- The major trend of lineaments in Geita, Sengerema, Ukerewe, West of Misungwi and Mwanza rural area is in a WNW-ESE direction, intersected by several lineaments in a NNE-SSW direction. Some of the lineaments are also confirmed in the NNW-SSE direction. The area is basically segmented into small fragments of rock mass.
- Low lying hills and flatland are abundant in the area of Kwimba, and part of Magu. Strong lineaments cannot be seen, but lineaments in a WE-SW, WNW-ESE direction have developed. Lineaments in a NNE-SSW and WNW-ESE direction intersect in the

north-eastern part of Magu.

- South of Bunda is the flatland of the river terrace. Major lineaments in a NW-SE direction can be found at the boundary with Musoma District.
- The major trend of lineaments in the Musoma, Tarime and Serengeti areas is in NW-SE, NE-SW and EW directions, but the irregularity of the lineaments is high in the area. They also intersect each other, and are fragmented. The large fault structure is well identified by aerial photograph at the boundary of Tarime, Serengeti, and Musoma.

The high density area and its trend (direction) can be described as follows with reference to the direction of the lineament:

- West of Sengerema – Geita (NNE-SSW, WNW-ESE)
- East Sengerema – West Mwanza, Misungwi (NNW-SSE)
- Small spot of high density area at East Magu-North Kwimba (NE-SW)
- Small spot of high density area at West Bunda-Musoma (NW-SE)
- Central Musoma (WNW-ESE)
- Small spot of high density area at Tarime (along the fault line), Serengeti

In these areas, high yield wells are mainly on the following lineaments:

- NNE-SSW, WNW-ESE lineaments in Sengerema and Geita.
- NW-SE lineaments in Misungwi and Kwimba
- WNW-ESE lineaments in Bunda and Musoma
- NNW-SSE lineaments in Musoma, Serengeti and Tarime
- EW to WSW-ENE lineaments in Tarime

Recognizing that the well inventory data is disorganized in the study area, further well inventory information will provide a more accurate interpretation of the water bearing structure from the lineament maps.

However, in reference with the SIDA report and our test drilling record, the possibility of intersecting the water bearing fissures and structures is low, even in areas which have high yield well records.

Further organization of past data, such as location of the yielding area, its geological and structural interpretation, pumping test results and hydrological parameters, is required.

9.3.3 Aquifer Potential Evaluation

The potential area for groundwater development is examined. The potential water extracting zone (groundwater availability map) is shown in Figure 9.3-8.

Two types of aquifers are considered as potential groundwater sources based on the yield, geological structure and water quality.

a. Medium depth stratum aquifer

Type of Rock: Decomposed Precambrian rock units (mainly secondary deposits or weathered granite.

Target Depth: From 20m to 50m in depth from the surface

Distribution:

- Hillside of Geita, East Sengerema, West Misungwi, East Kwimba and Magu, Ukerewe Island in Mwanza Region
- Hillside of North Bunda, Central Tarime, South Tarime and West Serengeti in Mara Region

Estimated Yield: Between 5 to 15 l/min is most common. High values of more than 70 l/min can be achieved if it captures the coarse grained fissure zone.

Parameters from Test Wells

Specific Capacity (m2/day): ranges from 0.044 to 8.804
Transmissivity (m2/day): ranges from 0.0085 to 3.72

Remarks: The yield of the aquifer largely depends on the local topographical features (catchment area, valley). The lineaments are also targeted as additional potential for the aquifer. Coarse grained granite and other Precambrian rocks in the local area are an advantage.

Water Quality: Good in general. Some wells are sensitive to the rain and seasonal fluctuation of the quality can be observed.

b. Deep depth fissure water

Type of Rock: Granite, Nyanzan rock units (Precambrian rock units)

Target Depth: From 20 m to 100m

Distribution:

- NNE-SSW, WNW-ESE lineaments in Sengerema and Geita.
- NW-SE lineaments in Misungwi and Kwimba
- WNW-ESE lineaments in Bunda and Musoma
- NNW-SSE lineaments in Musoma, Serengeti and Tarime
- EW to WSW-ENE lineaments in Tarime

Estimated Yield: The only measure to estimate the yield is the inventory of surrounding wells. High values of more than 70 l/min can be achieved if it captures water bearing coarse grained fissure zone.

Parameters from Test Wells

Specific Capacity (m2/day): ranges from 0.224 to 3.226
Transmissivity (m2/day): ranges from 0.052 to 1.87

Remarks: Drilling target is narrow. It may not be possible to achieve 100% accuracy even if a resistivity sounding is conducted. Most of the lineaments in the valley are on a structural line of almost vertical, but some of them may vary their face angle. Although fissures or fractures exist, it is hard to predict the existence of water and its amount.

Water Quality: Characterized by high EC value and contains various ions. Most of the values of substances are not more than the allowable limit of the WHO, but some exceed the acceptable limit of Tanzania. Fluoride and NO_3^- concentrations are high in south Kwimba, Misungwi and Magu. This is also a trial and error process to get a safer aquifer.

As mentioned before, some Neocene deposits (alluvial, lacustrine, terrestrial, fluvatile and marine deposits) are concentrated with heavy metals as a placer. The minerals dissolved in the water are mainly due to the mineralization in the basement rocks experienced over the long term, not only as fissures in the basement but also as a placer.

In the southern to central area of Kwimba, a series of good yielding wells exist. The surface geology is Neocene deposit, but all the drill holes intrude into the granite under the Neocene deposit. No clear lineaments exist, but there may be some water bearing structure in the granite rock in the NW-SW direction from the topographical features.

Although the high potential area is revealed from the surveys and interpretation, the risk of drilling dry holes is high due to the nature of the aquifers in the area.

9.3.4 Examination of Groundwater Evaluation Map

The water availability map was made by the correlation between geology, yield of existing wells, lineaments and structures, and quality (EC value).

Potential for the development of the water source is mainly concentrated at the granite area, with high density of the lineament.

The grey area is considered as the target area of stratum aquifer in relation with fissure water. Light grey area in the map is considered as fissure water area. Therefore it is essential to examine the potential with the density or intensity of the lineaments. The yellowish area is defined as recent deposits which consist of loose material such as sand, clay and gravel.

Although the recent deposit is defined as low potential for high yield, there is possibility to intrude the basement rock area as actually found in the Kwimba District.

9.3.5 Potential Area for Groundwater Development

High potential area is marked as orange zone in the water availability map. The zone is defined as the area where;

- High density lineament area.
- Existence of medium – high yielding well
- Geological discontinuity such as fault and/or geological boundary

However, it is difficult to find out the exact point to capture the good aquifer and fissures from the past efforts and experiences made by the field survey. Therefore, additional investigation such as resistivity sounding is required for the further accuracy of the drilling site.

Additional difficulty is how to predict the high yielding area before drilling. It is confirmed that if the drilling site is close enough to the good yielding site, a better yield can be achieved.

As mentioned before, some Neocene deposits (alluvial, lacustrine, terrestrial, fluvatile and marine deposits) are concentrated with heavy metals as a placer. The minerals dissolved in the water are mainly due to mineralization in the basement rocks experienced over the long term, not only as fissures in the basement but also as a placer.

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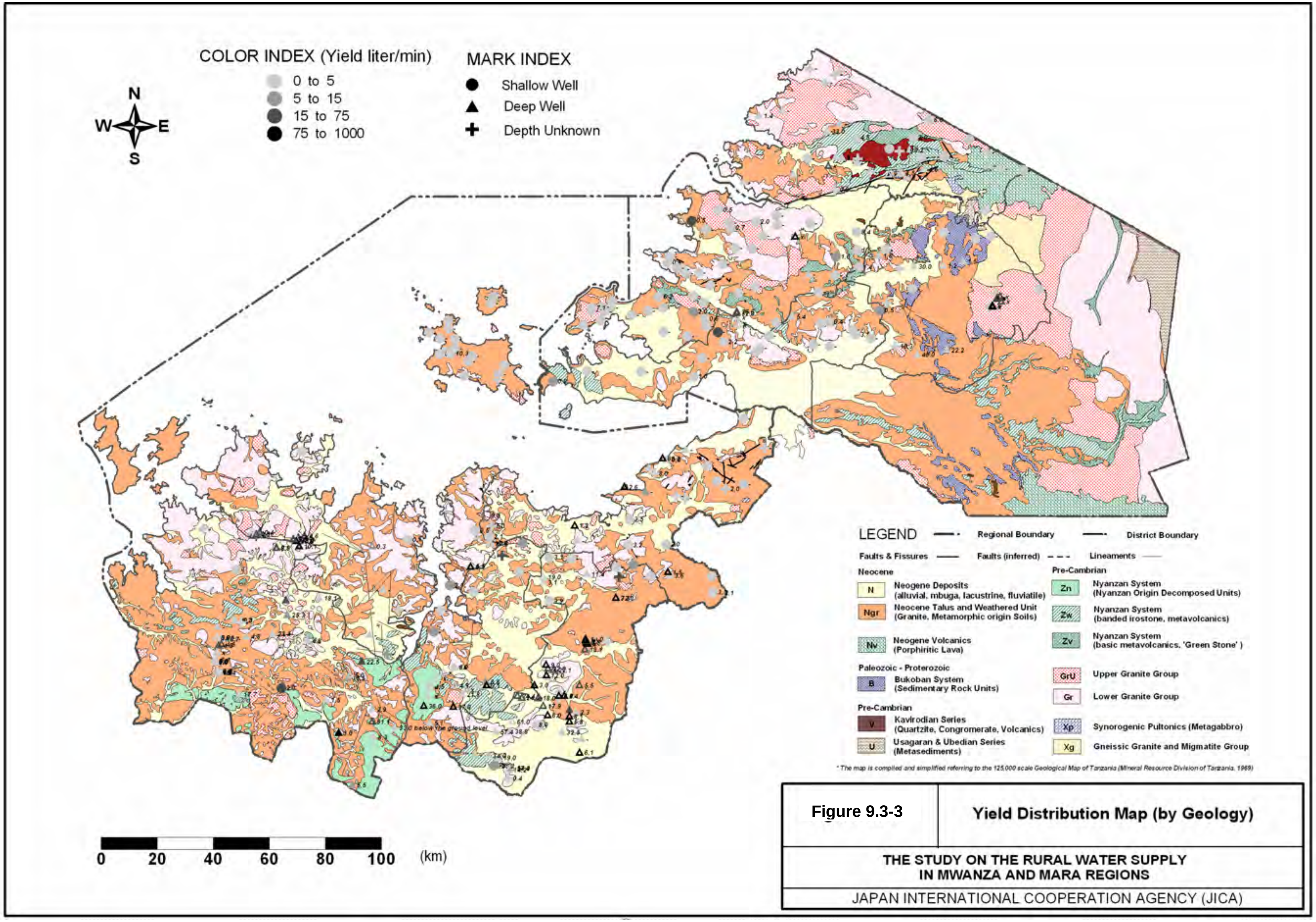

Figure 9.3-3 **Yield Distribution Map (by Geology)**

THE STUDY ON THE RURAL WATER SUPPLY IN MWANZA AND MARA REGIONS

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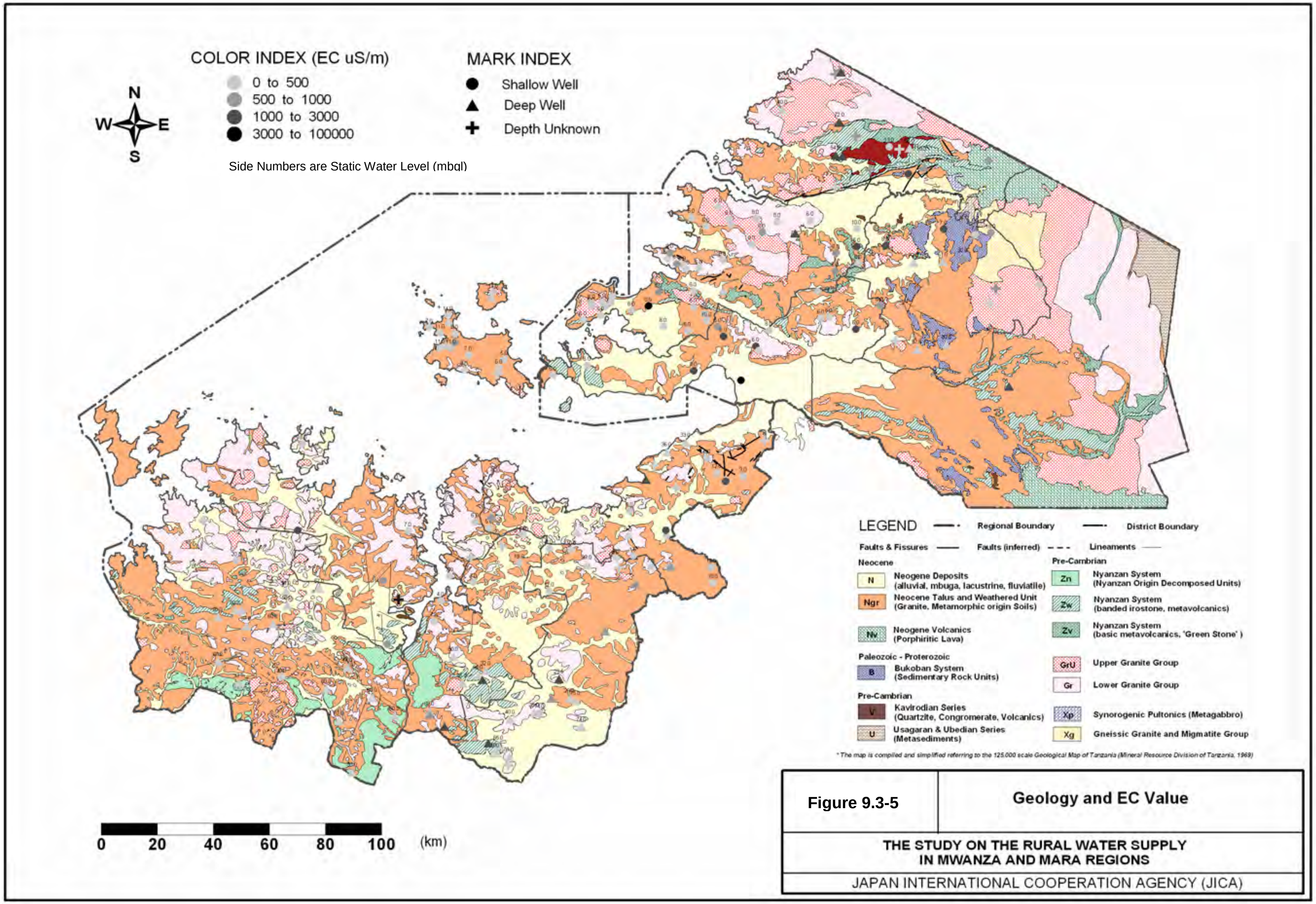

Figure 9.3-5 Geology and EC Value

THE STUDY ON THE RURAL WATER SUPPLY
IN MWANZA AND MARA REGIONS

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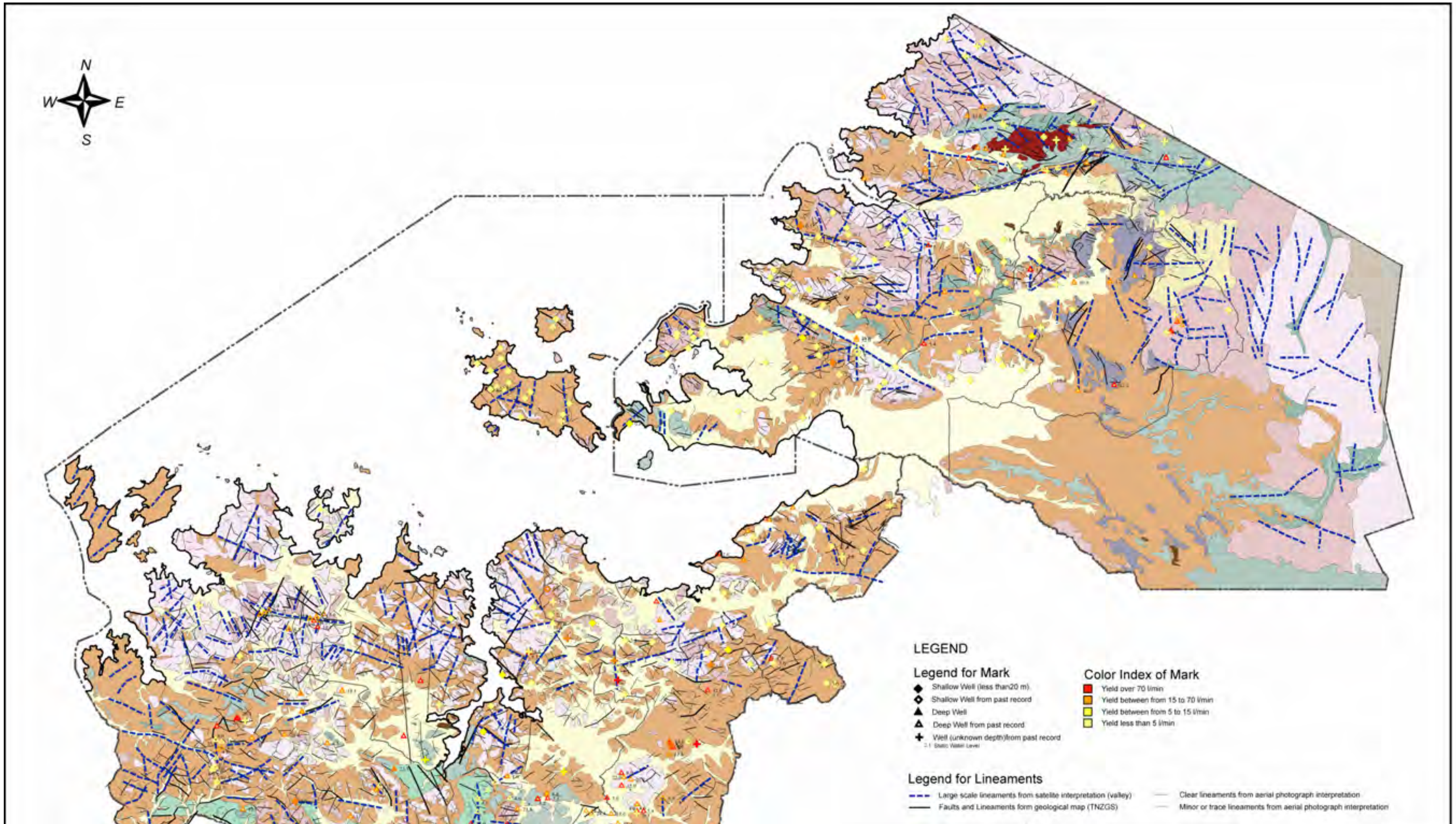

Figure 9.3-6	**Lineaments and Structure with Yield**

THE STUDY ON THE RURAL WATER SUPPLY IN MWANZA AND MARA REGIONS

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

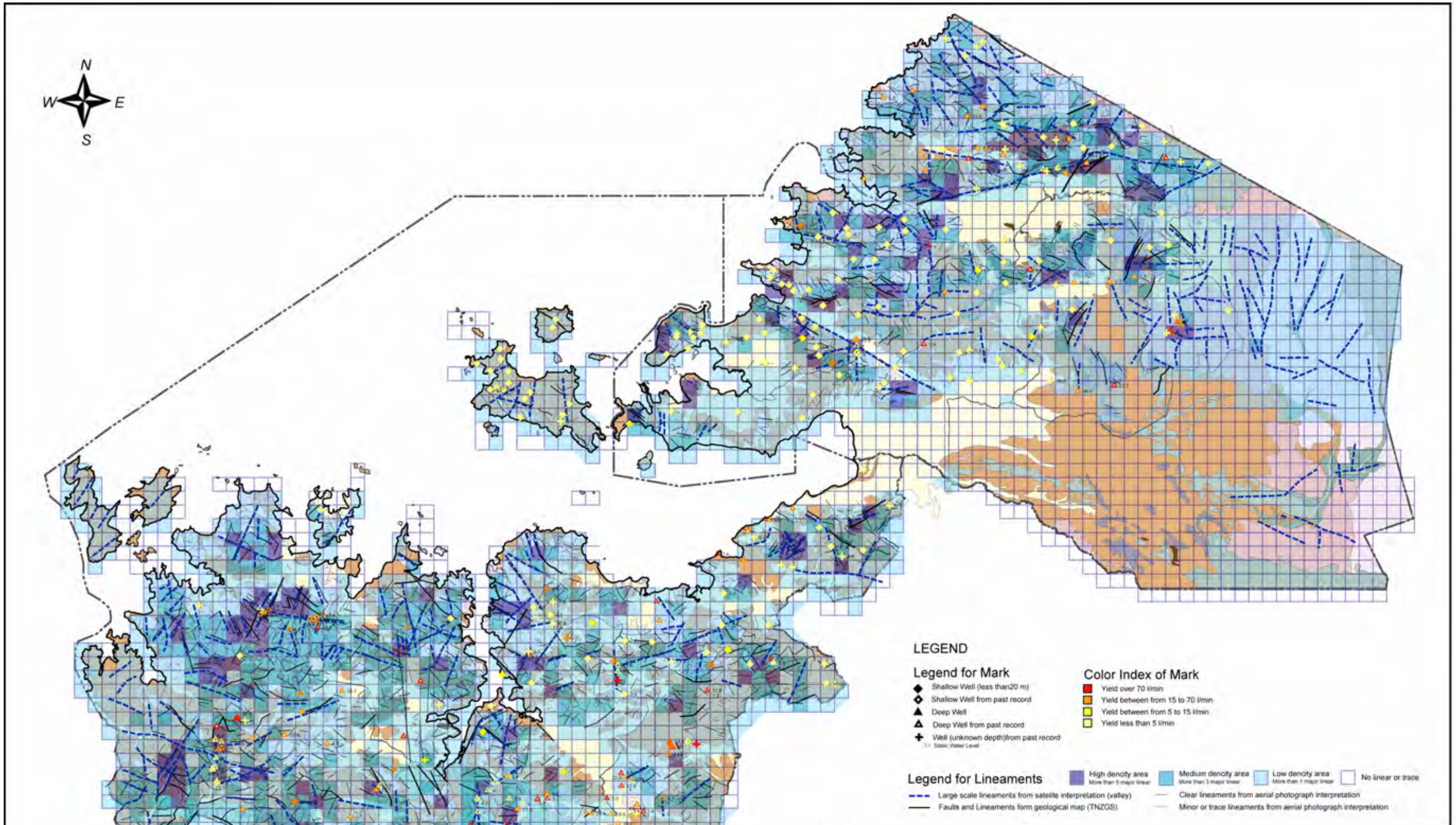

Figure 9.3-7 **Lineament Density Map**

THE STUDY ON THE RURAL WATER SUPPLY IN MWANZA AND MARA REGIONS

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