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JUNE 1994

KOKUSAI KOGYO CO., LTD.

PACIFIC CONSULTANTS INTERNATIONAL

JAPAN INTERNATIONAL COOPERATION AGENCY

THE UNITED REPUBLIC OF TANZANIA
MINISTRY OF WATER , ENERGY AND MINERALS

STUDY
ON
WATER RESOURCES DEVELOPMENT
IN
THE RUVU RIVER BASIN

FINAL REPORT

VOLUME III
SUPPORTING REPORT

JUNE 1994

NIPPON KOEI CO., LTD.

PACIFIC CONSULTANTS INTERNATIONAL

SUPPORTING REPORT

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TOPOGRAPHIC SURVEY

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TOPOGRAPHIC SURVEY

1. Works Carried Out

During the Phase 1 Field Work, the following topographic survey works were carried out by the local survey firm under the supervision of the Study Team;

- Collection of basic topographic data including bench mark data and aero photographs of the Ruvu River basin
- River cross section survey along the Ruvu mainstream
- River cross section survey along the planned axis for each of Kidunda, Ngerengere, Mkombezi and Mgeta dams
- River cross section survey at the key stream gauging stations located in the Ruvu River basin

In addition to the above survey works conducted on a local contract basis, the Study Team installed a tide gauge at river mouth of the Ruvu in the Phase 1 Field Work in order to observe the tide level.

2. Collection of Basic Topographic Data

2.1 Topographic Data Collected

The following basic topographic data were collected from the Survey Department of Tanzania for use in the topographic survey;

- Coordinates of triangulation points in the Study Area
- Elevations of bench marks in the Study Area
- 1 to 50,000 scaled topographic maps covering the whole Ruvu River basin
- Aero photographs along the Ruvu mainstream and its major tributaries

2.2 Coordinates of Triangulation Points

Coordinates of the 5 triangulation points (TTP 185, TTP 284, TTP 285 and TTP 306) were obtained from the Survey Department, out of which TTP 284 was found to be destroyed at the commencement of the survey work. Taking into the availability of those triangulation points, TTP 285 was selected as the base triangulation point. The survey datum of TTP 285 is as follows;

- Coordinates N=9,267,442.24 (m)
  E=476600.26 (m)
- Height H=81.82 (m)

2.3 Elevation of Bench Marks

In Tanzania, the national bench marks are installed along the railway lines. Five (5) bench marks (IBM 53, IBM 56, IBM 63, IBM 65) were found in the Study Area and the IBM 53 with an elevation of 70.784 m was selected as the base bench mark through the check levelling in order to determine elevations of base points to be installed on the river cross sections along the Ruvu mainstream.

2.4 1 to 50,000 Scaled Topographic Maps

The existing topographic maps at a scale of 1 to 50,000 were produced between 1950's and 1980's. Contour lines of those produced in 1950's are shown in a unit of inch. It is considered that the most reliable maps are those produced after 1980's, which were mapped based on aero photographs taken in 1982.

The existing 1 to 50,000 scaled maps covering the entire Ruvu River basin are shown in Fig. A.1 together with their Index No. At present, the Survey Department is carrying out the mapping works for the whole Ruvu River basin with the aero photographs of 1982, but these were not wholly available during the Study period. The manuscripts of those new maps which were under production by the Survey Department were collected for the Index No. 185/3, 202/2, 202/4 and 203/1.

2.5 Aero Photographs

The aero photographs were newly produced during the Phase 1 Field Work entrusting the development works to the Survey Department in order to utilize them for the site reconnaissance as well as identification of the site conditions visually. Those photographs were produced for the area along the Ruvu mainstream and its major tributaries.

3. River Cross Section Survey

3.1 Ruvu Mainstream

The river cross section survey along the lower reach of the Ruvu was carried out for a river length of about 160 km from the river mouth mainly for the use in the river planning. The location of the river cross section survey is shown in Fig. A.2.

The field work was started from clearing work along the survey line indicated on the 1 to 50,000 scaled maps. After then, elevation was measured by levelling machine at an interval of 50 m and at points where ground elevation varies. The elevations of the river bed were gradually measured by inserting a staff to the river bed to read the depth from water level, and at the same time to measure the distance.

A base point made of concrete was installed on the survey line and elevations of those base points were determined by the levelling survey for routes connecting with the aforesaid national bench mark. In addition, coordinates of those base points were measured with GPS instruments. These data are tabulated in Table A.1.

3.2 Planned Dam Sites and Streamflow Gauging Station Sites

The river cross section survey along axis of promising four (4) dam sites, which were selected by the previous French Study, namely Kidunda, Ngerengere and Mgeta dam sites, were carried out for the use in estimate of the dam embankment volume.

In addition, the river cross sections at the following existing and new streamflow gauging station sites were performed so as to check the flood water levels by means of the uniform flow calculation;

- Mafsi
- Kidunda
- Kibungo
- 1H8
- Ihaia
- Kisaki
- Mgeta

The river cross section was taken at two different locations for each gauging station, namely upstream and downstream places thereof.

4. Installation of Tide Gauge and Observation of Tide Level

A tide gauge was installed by the Study Team at the Ruvu River mouth, about 10 km downstream of the Bagamoyo town area to investigate the tide water level which is used for non-uniform flow calculation to determine the flood water level along the Ruvu River. In the Phase 1 Field Work, the observation of tide water levels was gone on for about one month.

The levelling survey was done to relate the zero-point of the tide gauge with aforesaid base bench mark. The results of the tide water level observation are discussed in the Appendix-H of this Supporting Report.

APPENDIX-A

TABLES

Table A.1 ELEVATIONS OF BENCH MARKS NEWLY INSTALLED ALONG THE RUVU RIVER

No.	Elevation	Remarks
BM 1	47.801	IPC(IRONPIN IN CONCRETE)
BM 2	72.510	IPC
BM 3	72.765	IPC
BM 4	61.566	IPC
BM 5	64.220	IPC
BM 6	70.433	IPC
BM 7	48.011	IRONPIN IN ASPHALT
BM 8	65.199	IRONPIN IN TREE ROOT
BM 9	66.074	IPC
BM 10	44.077	IPC
BM 11	80.658	IRONPIN IN CONCRETE FOUNDATION
BM 12	61.888	IPC
TTP. 285	81.817	SQUARE PILLAR
BM 13	76.020	IPC
BM 14	71.446	IPC
BM 15	66.107	IPC
BM 16	66.591	IPC
BM 17	57.565	IPC
BM 18	35.579	IPC
BM 19	56.160	IPC
BM 20	32.893	IPC
BM 21	30.184	IPC
BM 22	27.020	IPC
BM 23	19.432	IPC
BM 24	10.554	IPC
BM 25	79.235	IPC
BM 26	59.687	IPC
BM 27	73.514	IPC
BM 28	32.981	IPC
BM 29	45.758	IPC
BM 30	35.360	IPC
BM 31	44.068	IPC
BM 32	48.653	IPC
BM 33	43.462	IPC
BM 34	47.533	IPC
BM 35	50.098	IPC
BM 36	48.228	IPC
BM 37	45.876	IPC
BM 38	45.074	IPC

Table A.2 ELEVATIONS AND COORDINATES OF BASE POINTS NEWLY INSTALLED ALONG THE RUVU RIVER

No. of Cross Section	Chainage (km)	No. of BM	Coordinates N (m)	Coordinates E (m)	Levelled Height (m)	Ruvu Water Level: Water Level (m)	Ruvu Water Level: Date of Observation	Lowest Height of River Bed (m)
0	0.00		(Indian Ocean/river mouth no Cross section measured)					
1	15.20	1L	9,289,329.73	481,329.98	1.89	-0.73	27/3/93	-7.70
2	23.80	2L	9,285,133.53	481,502.80	1.96	0.82	2/4//3	-2.59
2A	24.10	2AL	9,284,857.32	481,553.37	2.65	0.19	4/4/93	-1.81
2B	25.50	2BL	9,284,217.11	480,870.50	3.02	0.90	2/4/93	-4.90
2C	26.30	2CL	9,283,952.98	481,431.43	2.50	0.58	8/4/93	-2.85
3	31.90	CS3R	9,280,952.84	480,238.88	3.19	1.68	9/4/93	-4.32
4	42.50	4R	9,275,263.74	479,092.61	6.67	6.07	12/4/93	-0.83
5	51.20	CS5R	9,274,916.59	476,742.92	9.57	8.11	13/4/93	2.16
6	61.70	CS6R	9,266,987.86	473,438.09	12.87	8.67	18/7/93	4.82
7	70.30	CS7L	9,264,740.00	468,400.00	15.03	11.91	25/6/93	9.41
7A	79.70	7AR	9,260,750.00	466,228.00	20.26	14.07	29/6/93	10.51
7B	79.72	7BL	9,260,855.00	466,135.00	20.89	14.07	29/6/93	10.65
GS1H8	79.97		9,260,580.00	466,190.00	18.24	14.07	29/6/93	10.74
8	80.60	8R	9,260,200.00	465,940.00	17.84	14.18	30/6/93	11.14
9	94.20	9R	9,254,830.00	465,610.00	21.16	18.49	6/7/93	16.31
10	107.10	CS10R	9,249,960.00	463,040.00	25.30	22.62	6/7/93	20.52
10a	113.20	10AL	9,247,835.00	460,742.00	27.22	24.31	12/7/93	22.04
10b	113.30	10B	9,247,800.35	46,641.31	30.74	24.33	12/7/93	20.38
10c	113.35	10CL	9,247,742.00	460,679.00	27.12	24.33	12/7/93	20.23
11	115.60	11L	9,247,051.00	459,653.00	27.98	24.88	19/7/93	22.27
12	126.30	12L	9,242,434.00	457,558.00	31.38	27.83	14/7/93	26.12
13	134.70	13R	9,239,622.00	453,148.00	34.10	30.41	9/7/93	28.49
14	142.80	14L	9,235,400.00	450,558.00	36.36	33.28	3/7/93	31.47
15	151.80	15L	9,229,817.00	450,210.00	39.99	36.11	1/7/93	34.47
16	156.30	16L	9,226,709.00	450,776.00	45.07	37.63	25/6/93	35.90

Table A.3 ELEVATIONS AND COORDINATES OF BASE POINTS NEWLY INSTALLED AT PLANNED DAM SITES AND STREAM GAUGING STATIONS

(1) Dam Site

Name of Dam Site/ Bench mark	Coordinates N (m)	Coordinates E (m)	Elevation (m)	River Water level Water level (m)	River Water level Date of Observation
- Mgeta					
BM A (Cross Section A)	9181525.00	338755.00	197.15	196.97	12/6/93
BM B (Cross Section B)	9180320.00	338860.00	190.00	186.87	10/6/93
- Kidunda					
BM	9196275.00	413352.00	62.00	56.00	12/6/93
- Ngerengere					
BM NGG	9227045.97	422242.83	139.72		
BM NGL	9228967.00	422700.00	103.91	100.27	1/6/93
- Mkombezi					
MKO-A	9280051.44	443718.59	166.50		
MKO-L	9281470.00	445300.00	114.55	110.32	26/5/93

(2) Stream Gauging Station

No. of of Bench Mark	Coordinates N (m)	Coordinates E (m)	Elevation (m)	River Water level Water level (m)	River Water level Date of Observation
- GS MGETA (1HB2)	9222250.00	341945.00	1010.00		
Cross Sect. A				1005.76	3/6/93
Cross Sect. B				1005.24	3/6/93
- GU DUTUMI	9180990.00	364995.00	127.00		
Cross Sect. A				123.09	4/6/93
Cross Sect. B				123.04	4/6/93
- GS KIDUNDA	9197500.00	416550.00	60.00		
Cross Sect. A				54.27	18/6/93
Cross Sect. B				54.26	18/6/93
- GS MAFISI	9224 174	451987.00	45.00		
Cross Sect. A				37.41	23/6/93
Cross Sect. B				37.41	23/6/93
- GS 1H 5	9223780.00	368350.00	200.00		
Cross Sect. A				191.47	15/6/93
Cross Sect. B				191.19	15/6/93
- GS 1H8	9260580.00	466190.00	18.24		
Cross Sect. A				14.09	29/6/93
Cross Sect. B				14.08	29/6/93
- MB JICA/MAJI (GS 1HA	9224500.00	425250.00	93.71		
Cross Sect. A				89.55	1/6/93
Cross Sect. B				89.53	1/6/93

APPENDIX-A

FIGURES

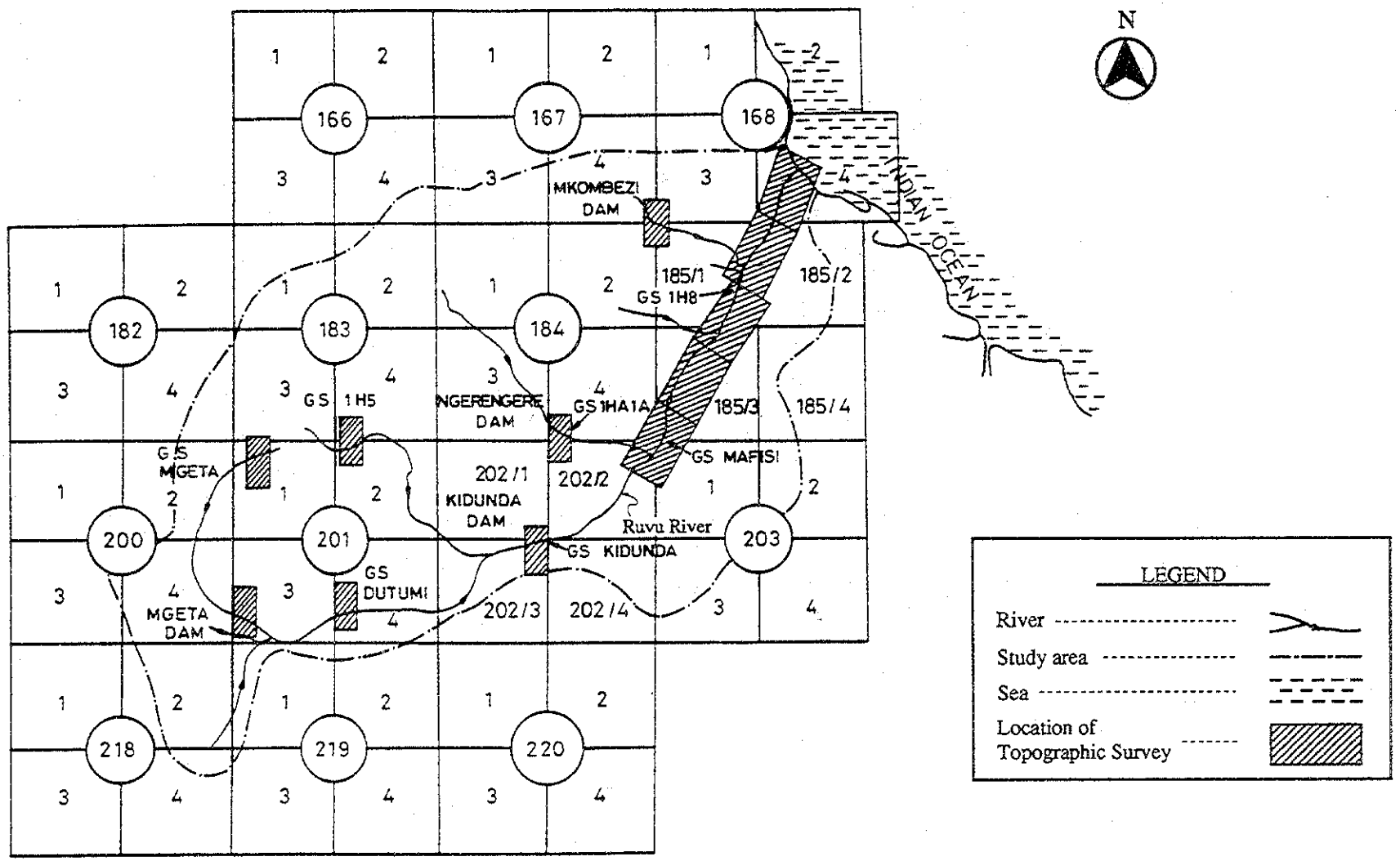

Fig. A.1 INDEX NO. OF EXISTING 1 TO 50,000 SCALED TOPOGRAPHIC MAPS

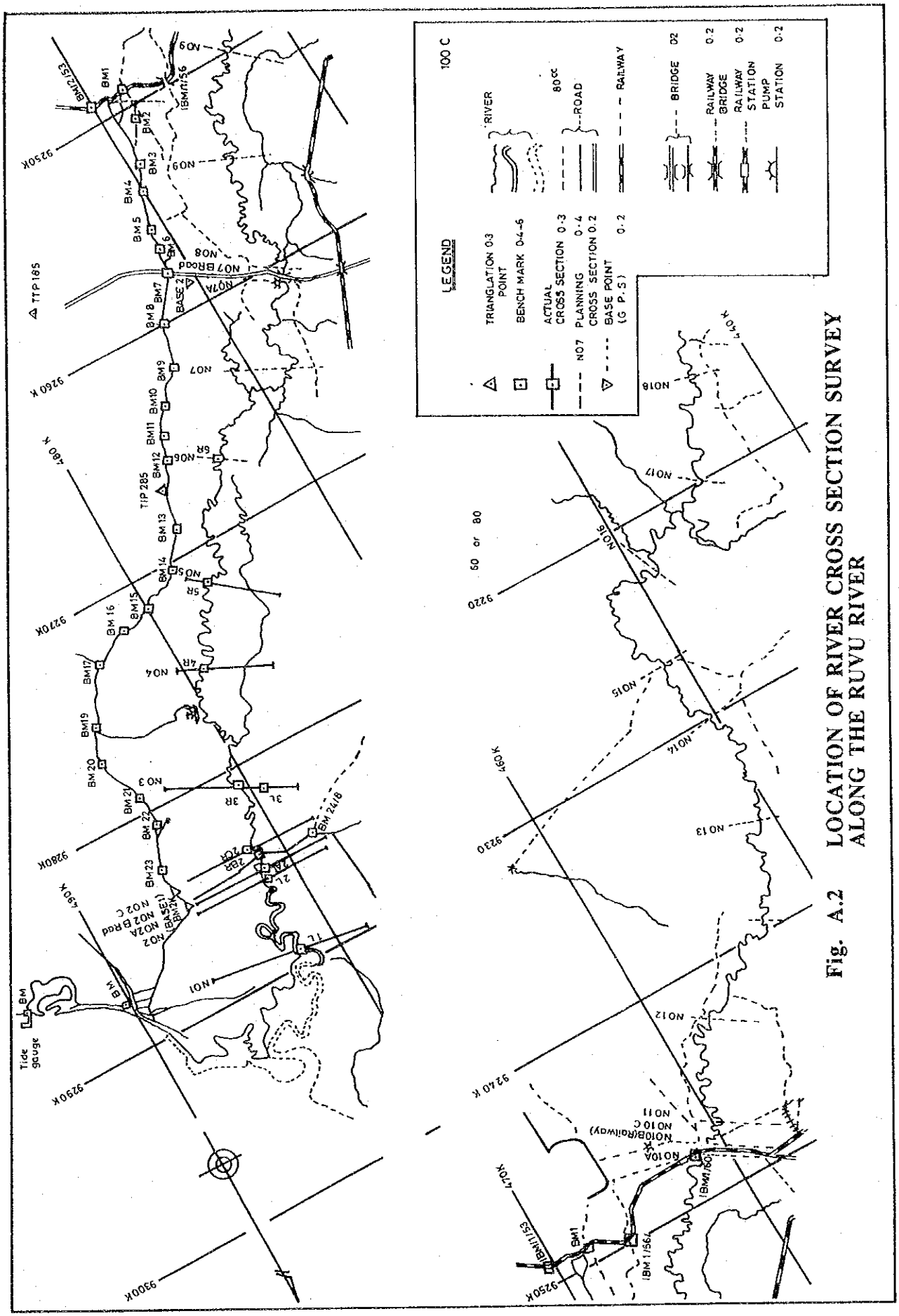

Fig. A.2 LOCATION OF RIVER CROSS SECTION SURVEY ALONG THE RUVU RIVER

APPENDIX-B

GEOLOGY AND HYDROGEOLOGY

APPENDIX - B

GEOLOGY AND HYDROGEOLOGY

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APPENDIX - B

GEOLOGY AND HYDROGEOLOGY

1. INTRODUCTION

During the Phase 1 and 2 Field Works, the Geologist of the Study Team carried out collected the data, information and reports of previous investigations and studies made by various agencies concerning the Study Area and conducted the field reconnaissance at the proposed dam sites. In this study, the geological investigation was focused on the field reconnaissance for the promising dam sites in the Ruvu River basin in order to assess the geological conditions and the likely issues.

2. DATA COLLECTION

2.1 Geological Maps

As shown in Fig. B.1, the whole area of Tanzania including the Study Area is covered by several geological maps prepared by the Geological Survey of Tanzania and other institutions. They are mainly as follows:

No.	Name of Geological Map	Scale
1	Geological Map of Tanganyika (1959)	1 : 2,000,000
2	Geological Map, Kent et al. (1971)	1 : 1,500,000
3	Hydrogeological Map of Tanzania, FAO/UNDP (1990)	1 : 1,500,000

More detailed regional geological maps of the Study Area were prepared by the study on the Coast/Dar Es Salaam Region Water Master Plan in 1979 and Morogoro Domestic Water Supply Plan in 1980.

Additionally, the following Quarter Degree Geological Maps, prepared by the Geological Survey of Tanganyika, cover the Study Area:

Sheet Number	Title Name	Surveyed by
167	Mbwewe	Solesbury(1963), Haidutov(1971)
168	Bagamoyo	Moor(1960)
183	Morogoro	Sampson and Wright(1961)
184	Kidugallo	Wright and Aitken(1960)
186	Dar Es Salaam	Batholomew(1963)
200	Doma	Mulgrew(1963)
201	Uluguru	Sampson and Spence(1959)

These quarter-degree geological maps were obtained from the office of Commissioner, Geology and Mines Division in Dodoma.

2.2 Hydrogeological Investigation

(1) Data on seismic survey

Tanzanian Petroleum Development Corporation (TPDC) performed the Seismic investigation for the oil source covering the Ruvu basin. The results can be used not only for the investigation of oil but also to confirm the geological structure, thickness of weathering, position of possible aquifer. Some of them were collected from TPDC. The location of seismic survey lines by TPDC are shown in Fig. B.2.

(2) Data on borehole drilling

Many boreholes were drilled by the several agencies in the Study Area. Available data on boreholes are categorized into the following four groups:

a) Borehole File of MWEM (Ministry of Water, Energy and Minerals)
Borehole for ground water supply drilling, lithological records, results of pumping tests and water quality tests and data on structure of wells are available. Most of them are filed in the data base of MWEM.

b) Oil Company's Borehole Records
Tanzanian Petroleum Development Corporation(TPDC) made several investigation for oil, and their lithologic logs are useful for the geologic and hydrogeologic study on the Study Area.

c) CIDA's Borehole Records
Canadian International Development Agency(CIDA) drilled 118 boreholes for the study on Coast/Dar Es Salaam Region Water Master Plan in 1979. The details are described in their report.

d) Morogoro Water Supply Project's Borehole Records
Under the financial assistance of Ministry of Foreign Affairs of Kingdom of Netherlands (DGIS), DHV prepared the Morogoro Water Supply Plan in 1980. For the Study 15 deep boreholes and more than 500 hand-dug wells were dug and electric resistivity, calliper and natural gamma-ray were examined in the Morogoro Region. Their details are shown in their report.

These boreholes for ground water supply are given the standardized number by MWEM. Table B.1 shows borehole data which were drilled and tested between 1953 and 1988 in Tanzania. In the Study Area inclusive of the Dar Es Salaam, Coast and Morogoro Regions, a total of 543 boreholes were drilled for the period.

(3) Data on ground water assessment

The ground water assessment for the Study Area was made by the following reports:

No.	Name of Report Concerned with Ground Water Assessment in the Study Area
1.	CIDA, 1979, Coast/Dar Es Salaam Region Water Master Plan, Ministry of Water, Energy and Minerals, Tanzania
2.	DHV, 1980, Morogoro Water Supply Plan, Ministry of Water, Energy and Minerals, Tanzania
3.	IBRD/UNDP, 1990, Sub Saharan Africa Hydrogeological Assessment, SSDCC Countries, Country Report : Tanzania

2.3 Previous Studies

The geology and hydrogeology of the Study Area were assessed in the following previous studies:

No.	Title of Report (Remarks)
1.	FAO, 1961, An Outline Plan for the Development of the Ruvu Basin, Report No.1316, Rome (The report describes the geological conditions in the Ruvu basin by the existing data , then proposes 23 dam sites from the viewpoint of water resources development potential in the Ruvu River basin.)
2.	Sogreah, 1962,Report of the French Technical Mission for the Development of the Ruvu Basin, Ministry of Agriculture, Tanzania
3.	Sogreah, 1964, Selection of the Kidunda Dam Site, Ministry of Agriculture, Tanzania (The detailed geological study and investigations including drilling were made on the Kidunda dam site, and then two alternative dam axes were proposed.)
4.	CIDA, 1979, Coast/Dar Es Salaam Region Water Master Plan, Ministry of Water, Energy and Minerals, Tanzania (A total of 118 boreholes were drilled to make the assessment of ground water potential so that the report recommended the high ground water development potential at the bread flat apron of Quaternary deposits along the Ruvu River.)
5.	DHV, 1980, Morogoro Water Supply Plan, Ministry of Water, Energy and Minerals, Tanzania (The drilling of 15 boreholes and hand-dug wells more than 500 including the borehole tests were performed to confirm the hydrogeological condition of the Morogoro Region. As a result, the eastern foot of the Uluguru Mountains is assessed to have a high ground water development potential within the Ruvu River basin.)
6.	IBRD/UNDP, 1990, Sub Saharan Africa Hydrogeological Assessment, SSDCC, Countries, Country Report : Tanzania Countries, Country Report : Tanzania (The ground water development prospects throughout Tanzania were described based on the previous investigation and study.)

3. GEOMORPHOLOGY AND GEOLOGY OF THE STUDY AREA

3.1 Geomorphology

The Study Area spreads from the Uluguru Mountains with an altitude of more than 2,000 m in the west to the coastal plain with an altitude of less than 200 m in the east. The Study Area can be divided into the following four topographic categories:

- Uluguru Mountains
- Highland around Morogoro municipality
- Elevated rolling hills
- Alluvial lower plain along the Ruvu River

The Uluguru Mountains rise abruptly out of the coastal plain and form a compact unit which is physically and geologically distinct from the surrounding plains. The highland around Morogoro Municipality, with an altitude of approximately 500 m above sea level, is formed by the Ngerengere and Wami Rivers. These lands are scattered and are composed of intrusive rocks and Precambrian rocks. Elevated rolling hills with an altitude ranging from 50 m up to 300 m above sea level is spread between the Ruvu and Wami Rivers and between the Ruvu River and Indian Ocean. These hills consist of the Mesozoic and Neogene sediments that erode easily and forms gentle rolling hills. The Ruvu River forms the broad floodplain of 5 to 10 km wide. The floodplain consists of Quaternary deposits.

3.2 Geology

The geology of the Study Area can be categorized into the following five major divisions;

- Precambrian Rocks
- Karroo Rocks
- Jurassic Rocks
- Cretaceous Rocks
- Tertiary and Quaternary Rocks

Precambrian rocks mostly occur in the Uluguru Mountains and in the western part of the Ngerengere subbasin. These are mainly of meta-sedimentary rocks and can be divided into three major lithological groups; acid gneisses, granulite and crystalline limestone. They seem to have been thrust and uplifted by the upward movement of the basic gneisses, thus giving rise to serious fault zone in the rocks.

The Karroo rocks occupy southeastern area of the Uluguru Mountains. The rocks consist mainly of sandstone, and shales deposited in shallow fresh to blackish water. Their ages may vary from Permian to Triassic.

Jurassic rocks occur in the eastern margin of the Uluguru Mountains and elevated rolling hills between the Ruvu and Wami Rivers. They consist of course sandstone, mudstone, and oolitic limestone deposited under the marine environment.

Cretaceous rocks occupy the elevated rolling hills. They consist of clays, shales, calcareous sandstone, sandy limestone and mudstone.

Sediments of Tertiary and Quaternary ages occur in the sub-catchment area of the Ngerengere River near Morogoro Municipality, and in the elevated rolling hills and flood plains along the Ruvu River and extend up to Dar Es Salaam. The tertiary deposits consist of sandy clays, clayey sands with minor lenses of pure sand or clay, gravel and calcareous fragment. The Quaternary deposits were formed in the fluvial and alluvial fans with swampy environment. They consist of clay, silt, sand and rarely gravel.

3.3 Fracture Lineament by Aerial Photo Interpretation

(1) Major fractures

The regional geological map of East Africa is shown in Fig. B.3. The Study Area is located in the eastern part of the African Rift Valley, and simplified major faults along the Rift Valley in association with gravels and Tertiary to Recent Volcanics, stretching from the Red Sea to Mozambique. The Lake Victoria lies between the western and eastern branches. These major fractures strike in the North-South and NNE - SSW directions, which are the same as the directions of the Western Rift. The geological structure of rocks and fractures are shown in Fig. B.4. The main structure indicates the North - South and East - West directions.

(2) Fracture lineament by aerial photo interpretation

The results of the aerial photo interpretation for the downstream area of the Mgeta River basin are shown in Fig. B.6. The area is located at the southern edge of the Uluguru Mountains. Geologically, it is composed of granulite of Precambrian, Carbonatite formed along the fractures, sediment rocks of Karroo and Alluvial deposit developed along the rivers. The fracture lineament in the area is assessed as follows:

1) Major fractures can be clearly identified by the aerial photographs. They can be plotted mainly in the NNE - SSW or E - W direction. These lineament of fractures are classified as major faults in the existing geological maps. Especially, the fracture lineament running along the boarder between mountains on the right bank and alluvial plain of the Mgeta River are interpreted to be about 30 km long and 10 to 50 m in depth.

2) Other fracture lineaments of 1 to 10 km long extend mainly in three directions of N - S, NNW - SSE or ENE - WSW, and the fracture of rocks may be eveloped in the same direction. The lineament running in ENE - WSW direction is formed by the major fracture of E - W direction. The lineament of NNW - SSE direction is developed in parallel with the East African Rift System.

4. Geological Assessment of Each Dam Site

4.1 General

The FAO's study (1961) identified 23 dam sites in the Ruvu River basin. The geological condition of those dam sites are summarized in Table B.2 and Fig. B.7. The geological maps in the Figure were made based on Geological Map of the Coast and Dar Es Salaam Regions Water Master Plan (1979) at a scale of 1:500,000, Geological Map (1980) at a scale of 1:250,000 of the Morogoro Domestic Water Supply Plan, and other geological data and information which became available for the Study.

In the Phase 1 Study, the dam sites in the Study Area were carefully examined on the following geological conditions:

a. Existence of active faults in the Study Area
b. Bearing capacity of dam foundation
c. Permeability of dam foundation and reservoir area

(1) Active faults

According to the geological map, major active faults are running along the Mgeta River on the southern edge of the Uluguru Mountains. These faults penetrate between Precambrian rocks and Quaternary alluvial deposits. They are clearly interpreted as a lineament by the aerial photographs. Along with these faults, branch faults run and they form the fracture zone, as shown in Fig. B.6. It deems that five dam sites, namely Mgeta(No.1), M/LB/R1(No.4), Mngazi(No.5), Bwakira(No.6) and Dutumi(No.7), are located along or near the faults which seem to be active ones.

(2) Bearing capacity of dam foundation

Bearing capacity of alluvial clayey foundation is usually small. Of the 23 dam sites, it appears that four dam sites, namely RB/R2 (No.18), Band (No.20),Mbwawa (No.22) and Chombe (No.23), are covered by the comparatively thick alluvial layer.

(3) Permeability of dam foundation and reservoir

Limestone and calcareous rocks of Jurassic, marl or limestone of Cretaceous of the Study Area, have a high possibility to contain some druse which would cause a high permeability. Of the 23 dam sites, four (4) dam sites, namely Kidunda (No. 9), Mkulazi (No.10), LB/R1 (No.12) and Mbiki (No.13), deem to be located on the calcareous foundation judging from the geological maps.

4.2 Mgeta Dam Site

Because of the high water table in the Mgeta River, the proposed dam site was not accessible in the Phase 1 Field Work, but the Geologist could reconsider the dam site in the Phase 2 Work under the favorable weather condition. The river bed width at the proposed Mgeta dam site is about 700 m, from which both abutments rise at about 30 degrees with horizontal line. Especially, the steep mountain slope on the left abutment continues up to high elevation, while in the right abutment the moderate topography is seen.

At both abutments, the thickness of surface soil layers seems to be thin judging from the exposed weathered rocks. As a result of the site reconnaissance, it deems that the base rock of the Mgeta dam site is composed of carbonate and conglomerate.

The outcrops of carbonate have been found on the right bank side, just downstream of the dam site, and they seem to be very hard. Although the outcrop of the conglomearate could not be identified during the site reconnaissance, it deems that it distributes in and around the dam site since there exist a lot of debris thereof at foot of the steep slopes. These debris consist of gneiss of 2 to 10 cm in diameter, sandstone and limestone. The portion of limestone is porous,

but it is very hard. The river bed is covered by alluvial deposit of fine sand, containing gravel of 10 to 40 cm in diameter. The alluvial deposit seems to have a thickness of 5 to 15 m.

It was confirmed through the site reconnaissance that two lanes of cliffs run linearly in the downstream reach of the Mgeta River. These lineaments are summarized as follows:

No. of Lineament	Location : distance from the Mgeta dam site (m)	Direction of lineament	Height of cliff (m)	Direction of slope of cliff
1	about 700 m downstream	N50°E	about 5 m	Southeast
2	about 1,100 m downstream	N82°E	2 to 5 m	South

Judging from the vegetation as well as situation of erosion at these cliffs, it deems that they are not created in the recent age. These cliffs coincide with those identified on the aero-photogrphies in the Phase 1 Field Work and they seem not extend to the Mgeta dam site. There is a possibility that these are active fault, taking into account that they are formed in the alluvial deposits. However, further geologic investigation is required to clarify the non-existence of the active fault at the Mgeta dam site.

4.3 Ngerengere Dam Site

The dam site is located on the Jurassic coarse grain sandstone and siltstone alternation, siltstone or sandstone. They are solid and very hard in the fresh rock. The strata undulates inclining of 10 to 20 degrees. The strike of the foundation takes approximately north-west to south-east direction, and a depth of the weathered zone is estimated to range from 5 to 10 m. The weathered rocks are formed by the massive rocks with a diameter of 1 to 3 m. At the dam site, a careful investigation and study needs to be made on the depth of weathered rocks and permeability of sandstone in the next study.

4.4 Kidunda Dam Site

The proposed dam site was not accessible during the Phase 1 Field Work because of the flooding in the Ruvu River, but the site reconnaissance was done in the Phase 2 Field Work as well as the case in the aforesaid Mgeta dam site. According to the existing study reports and information, the dam site is located on the Jurassic limestone, calcareous sand stone, coarse to medium grained sand stone and sandy siltstone. Following the study by FAO (1960) and French Technical Mission (1962), the detailed investigation and study was carried out on the Kidunda dam sites. The results are summarized in a report titled "Selection of the Kidunda Dam Site" (1964). They studied four alternative dam sites, 1) lower downstream site, 2) upper downstream site, 3) intermediate site and 4) upstream site as shown in Figs. B.8 and B.9, and performed the geological investigations including core drilling. They are summarized as follows;

(1) Lower downstream site

The alternative site is located in the depression, where the Ruvu River flows down between Kidunda and Mwanga hills downstream of the confluence of the Mkulazi and Ruvu Rivers. The width of the bottom is about 380 m, and covered by the sandstone series at the bottom and

mainly sandstone in the both bank abutments, the limestone appears at the southern end of right bank abutment.

Three boreholes on the right bank and two ones on the left bank along the dam axis and one borehole at the downstream site on the right bank were drilled in the previous study. Based on the previous geological investigation, the dam site was assessed as follows:

- The wide open configuration of the site and substantial alluvium and weathered sandstone bed is suitable only for construction of earth or rock fill type dam.

- The weathered sandstone and sandy to clayey sand alluvium shows the permeability of 10^{-4} cm/sec and 10^{-3} cm/sec, respectively. Therefore deeper trenching or curtain grouting up to base rock is required to reduce the leakage in the foundation.

- Geographically, the alternative dam site has the largest catchment area among the alternative ones, including the Muklazi river basin.

For the lower downstream site, the site reconnaissance was performed by the Geologist of the Study Team along the dam axis from the river bed to an abutment of the left bank side. In addition to the above, the geological condition of the lower downstream site was assessed based on the site reconnaissance as follows:

The geology of the lower downstream site is composed mainly of the Jurassic limestone, sandstone, conglomerate and sandy limestone, which are covered by the alluvial clayey layer. It appears that the geology of the river bed differs from that of the abutment, that is, the river bed consists mainly of coarse sandy layer while the abutment of the hard limestone spreading over the so-called Kidunda hill. The strike and dip at the river bed show NE to N60°E, 15°SE, respectively. While, those at the left abutment are N40°W and 21°NE, respectively.

The foundation rocks which distribute at the river bed are assessed as follows:

i) Coarse sandstone
It contains quartz, feldspar and calcite, interbedded by limestone and conglomaerate layers. It seems that its fresh rock being sufficiently massive and hard has a compressive strength of 100 to 200 kg/cm^2. On the other hand, it is partially eroded along a strike of the rock layer and there seems to be a tendency that it is cracked along the layer.

ii) Conglomalite
The base rock thereof is of coarse sandstone, containing round gravels sparsely which are composed of meta-sedimentary rocks such as crystalline limestone and quartzite. It is estimated that the matrix composed of coarse grain sand, quartz and feldspar has a compressive strength of 50 kg/cm^2. As far as the outcrops show, a thickness of the layer would be about 1.5 m.

iii) Limestone

It is ineterbedded between the sandy layers with a thickness of 0.5 to 1.5 m. The weathered rocks which outcrop at the site are porous, having caves therein. There is a possibility that these caves develop up to the deep portion. These outcrops seem to have a compressive strength of 20 to 50 kg/cm^2 and to form the permeability zone after construction of the dam. However, it seems that the fresh rocks are as very hard as 500 to 1,000 kg/cm2 in the compressive strength.

According to the existing geologic map (DHV 1980), there is a fault between the sandy limestone zone at the lower downstream site and the sandy layer at the upstream intermediate site. However, the fault was not confirmed in the previous geological investigation.

(2) Upper downstream site

The alternative dam axis is located just upstream of the confluence with the Muklazi River, and the left bank hills of the Ruvu cross the stream, extending over the Mwanga hill on the right bank. The outcrops at the site consist of the same sandstone as the bottom rock series at the lower downstream site. The Ruvu dug itself a deep bed into the sandstone base rock, and the bottom is filled up with alluvium. No tectonic features such as faults or dipping banks which form outcrops were observed except banks in the Mkulazi River basin which might be a sign of slight dipping towards northeast.

Three additional bore holes were drilled on the left bank in addition to the previous twenty bore holes and a dozen wells in 1954. Based on these investigation results, the report assessed the site as follows:

- As same as the lower downstream site, the construction of concrete dam is unfavorable from the geological conditions of the site.

- The permeability of alluvium consisting of clay to sand shows the sufficient imperviousness in the foundation, but the sand is very fine, unconsolidated and saturated. Hence, there is possibility of occurrence of piping.

- The permeability of weathered sandstone shows high permeability up to the bottom, which requires deep excavation to avoid the leakage of foundation on the right bank abutment, but other slightly weathered section of the sandstone shows the sufficient imperviousness.

(3) Intermediate site

The site reconnaissance has been performed along the dam axis on the left bank side. The geology of the dam site is composed mainly of sandstone and mudstone of the Karroo system. The sandstone distributes over the right bank, while the mudstone on the left bank.

At the intermediate site, outcrops of the rocks are identified at river bed and mountain ridge on the left bank side of which the former forms a cliff with a height of 5 to 10 m. The sand stone

at the river bed consists of rock masses of 0.5 to 3 m in diameter due to weathering. The strike thereof is almost horizontal.

The outcrops at ridge of the left bank side consist of massive and hard sandstone of middle-grained sand and it seems to have a compressive strength of 50 to 300 kg/cm^2. The bedding of the sandstone is almost horizontal. Judging from these outcrops, the thickness of the surface soil and weathered layers would be very thin. As a whole, the Cm class rock seems to lie in a depth of about 5 m from the original ground surface and fresh rocks of the C_H or B class in a depth of 10 to 20 m therefrom.

Concerning the intermediate dam site, the geological investigation including core boring and the permeability test therein were carried out in 1962. As a result of the geological investigation, the following characteristics on the dam site are clarified;

- Sandstone distributes on the both river bank sides,
- There exist no alluvial deposits on the both river bank sides,
- The weathered rock layer is as thin as less than 5 m for most part of the dam axis, and
- The bedding of the rocks are almost horizontal.

The above results are mostly endorsed by the reconnaissance survey conducted by the Study Team. As aforesaid, the sandstone layer has a sufficient compressive strength so that even a 50 m high concrete gravity dam could be founded thereon. However, the intermediate dam site also has the following geologic issues, as far as the result of the previous geological investigation show:

- According to the permeability test done by Sogreah in boreholes in the sandstone layer, the Lugion values are obtained to be as high as 10 to 50. On the other hand, the permeability test was not done at every depth of the boreholes. Hence, there is a possibility that there exists the intermediate layers with high permeability.

- The previous investigation results show the existence of the clayey layers beneath the mudstone on the left bank side, but the extent and characteristics thereof are not made clear yet since only one bore hole was drilled therein at that time.

Nevertheless, the intermediate site of the Kidunda has the following advantages in comparison with the aforesaid lower downstream dam site;

a) The alluvial deposits along an axis of the intermediate dam site is nil or very less.

b) The sandstone which distributes at the site seems to have a sufficient compressive strength enough to support a 50 m high concrete gravity dam.

(4) Upstream site

The site is located on the Mgeta River before joining the Ruvu River. This site has the smallest catchment area among the alternative dam sites. A narrow ridge runs across this site and gradually extends to the plateaus on both sides.

Five bore holes along the axis, two bore holes downstream and upstream of the site were drilled so that the base rock is found to be of sandstone of Karroo. However, this sandstone dose not break through the weathered sand along the dam axix. The sand layer appears on the left bank with thickness of 30 m. The substratum consists of fine sandstone, silt and pelite. The coarse sandstone was identified on the right bank. The alternative dam site is assessed as follows:

- An earth or rock fill type dam is suitable for this site, but the concrete type dam may be considered on the firm foundation of the left bank side.

- The foundation shows rather high permeability which ranges between 10^{-4} and 10^{-5} cm/sec. It is expected that there exists layer with a higher permeability in the old alluvium site. Therefore, the leakage treatment is required to be carefully examined.

- The downstream rock of sandstone is erodable by rapid flow. Therefore, careful study on base rock erosion needs to be examined through the hydraulic model testing and/or for concrete lining of the base rock in terms of the design of spillway.

(5) Conclusion of the previous study

The aforesaid previous report concluded that the best dam site is the intermediate site for the following reasons:

- The site has less requirement of excavation for the foundation of the main dam and other structures as compared with other alternative dam sites,

- The lithological formation is more clear and simple as compared with other alternative dam sites

(6) Comments on the previous study

The investigations and assessment of dam sites, which are described in the previous study report, are summarized and commented below:

The dam sites are located on the alluvial deposit, weathered sandstone, and slightly weathered sandstone. The permeability tests on various layer were conducted and the results were obtained as follows;

- Alluvial deposit generally shows that the permeability ranges between 5.0×10^{-6} and 2.6×10^{-5} cm/sec (0.4 to 2.0 Lu). However, some parts show high permeability of 5.1×10^{-3} cm/sec (390 Lu).

- The weathered sandstone generally shows a permeability of 2.0×10^{-5} to 5.0×10^{-4} cm/sec (2 to 38 Lu). However, some parts show high permeability of 2.0×10^{-3} cm/sec (156 Lu). This higher permeability might be encountered in the surface layer.

- The slightly weathered sandstone generally shows a permeability ranging between 1 X 10^{-5} and 3 X 10^{-4} cm/sec (1.o to 36 Lu). However, some parts show high permeability of 3 X 10^{-3} cm/sec (156 Lu).

Most of the foundation of alternative dam sites show the low permeability, but it seems that the values of permeability for all the dam sites are not necessarily in an appropriate range for the following reasons;

a) Usually, the permeability becomes low by the depth from the surface, but according to the investigation results, high permeability was observed in the deeper layers and it dose not decrease in the deeper layer.

b) The permeability increases at the fracture zone or calcareous layer in the bore hole. It shows the high possibility of existence of porous layers.

c) The permeability tests in the bore holes were conducted not continuously through the core drilling. This would not clarify the actual permeability of all the layers.

d) No ground water table is shown, and it is rather difficult to determine the grouting depth on the both abutments of the dam.

The lower downstream site and upper downstream site are covered by the alluvial deposit, which is considered to be unconsolidated and of low bearing capacity with the maximum thickness of 20 m. This alluvial deposits needs to be carefully examined in view of the stability of dam.

According to the investigation results, less possibility of leakage of dam foundation which is usually caused by the porous limestone or calcareous rock, is considered, and the foundation mainly consists of sandstone. However, this sandstone intercalates several limestone layers which could be highly pervious as observed in the limestones at the other dam sites downstream. Hence, there is a possibility that limestone layer with a high permeability spreads in the upstream reservoir area. It is essential that more detailed investigation is to be carried out on the reservoir area in the next prefeasibility or feasibility study stage.

4.5 Rudete Dam Site

According to the existing geological data or information, the proposed dam site is located on the Pre-Cambrian meta-sedimentary rocks. On the left bank and under the river bed, hornblende-biotite granulite and gneiss develop. Silicified fault breccia or carbonatite formed in post-Jurassic ages covers the right bank of the dam site.

Judging from the topographic maps at a scale of 1 to 50,000, the proposed dam site is located at the bottleneck of the stream having wider valley upstream. It shows the topographically favorable dam site. The side slopes of valley are rather steep.

The foundation of right bank is expected to be a silicified fault breccia or carbonatite extending in the river flow direction. The fractures might exist along these layers. Ridges or elevated hills

are formed on the right bank. The carbonatites might be harder than granulite or gneiss in the area.

4.6 Mkombezi Dam Site

Topographically, the site is located on the gentle slope hill on the Cretaceous calcareous sandstone and sandy shale. The strike of these strata indicates north-northeast to south-southwest direction. The dip shows 20 to 30 degrees to east. The strike of strata is same as the direction of dam axis. The bedrock is generally so hard that sparks occur by hammer blowing. The depth of weathered layer is expected to range from 5 to 10 m.

4.7 Availability of Construction Materials for Kidunda and Mgeta Dams

The availability of embankment materials to be used for rockfill-type dam is assessed through the site reconnaissance for each of the Kidunda and Mgeta dams as follows;

(1) Kidunda dam

Rockfill material

As the rockfill material for the Kidunda dam, the sandy limestone lying on the left bank side of the lower downstream dam site is the most suitable judging from the qualitative and quantitative aspects. The sandstone distributing upstream of thereof is also usable as the rockfill material, but it may be difficult to quarry the rocks efficiently for the use in construction of the dam due to the thick weathered rock layers.

Earth and filter materials

The river deposits spread along the floodplain of the Ruvu River, but it appears that a content ratio of clay is somewhat high. Therefore, it might be difficult to sufficiently compact these soil materials during the dam construction as revealed in the Sogreah's report, in case they are used as the core material of rockfill dam. Although the availability of those river deposit material in the neighboring places will be investigated in detail through the laboratory test in the next study stage, those embankment materials would be required to be produced by mixing those river deposit materials with the crushed rocks.

(2) Mgeta dam

Rockfill material

The carbonate which forms the ridges of both bank at the Mgeta dam site is suitable for the use in the rockfill material in view of the sufficient strength and obtainable quantity.

Earth and filter materials

The alluvial deposits which consist of fine sand containing boulders of 10 to 40 cm in diameter are usable for the filter material, although they need to be sieved. Especially, the surface layer is suitable as the filter material since it contains lesser clay. Concerning the core materials, the borrow areas will be secured in the surrounding hills with thick coverage of surface soil.

4.8 Recommended Further Geological Investigation for Kidunda and Mgeta Dams

In the next prefeasibility or feasibility study stage, the following geological investigations and studies are recommended to be carried out:

a) Preparation of detailed geological map at a scale of 1 to 10,000 or 25,000

The detailed geological maps at a scale of 1 to 10,000 or 25,000 is required to be prepared covering the alternative dam sites and reservoir area referring to the existing geological maps, previous drilling and field investigations for the purpose of design of main structures as well as the treatment works of dam foundation for leakage.

b) Seismic survey along the selected dam axis

In order to obtain a picture of geological setting of the dam foundation, including depths of overburden, weathering, faults and fracture zones, the seismic survey by refraction method should be conducted along the selected dam axis.

c) Bore hole drilling and permeability tests

In order to clarify the permeability, ground water table, necessary depth of foundation treatment, degree of weathering and physical properties of foundation, core drilling needs to be additionally conducted along the selected dam axis. Using the results of core drilling, field permeability test and physical and dynamic property tests on sand, bearing capacity of the foundation layer should be examined.

d) Investigation of fill materials and borrow area

The dam embankment materials and location of their borrow area have an influence on the construction plan and cost. Therefore, in parallel with the investigation of dam site, the detailed investigation for construction materials and borrow area is recommended to be carried out in the next study stage.

Besides, the further geological investigation for the Kidunda and Mgeta Dams, which are selected as the priority dam projects, is specifically stated below:

(1) Further geological investigation required for the Kidunda Dam

As discussed above, the intermediate dam site seems to be superior to the lower downstream one from the geological viewpoint. But, further geological investigation in the next study stage should be performed placing a focus on the two alternative dam sites, namely the lower downstream site and intermediate site. In case the intermediate dam site is selected, the quarry site for rockfill material will be developed in the limestone area of the lower downstream dam site.

In the next study stage, it is recommended to carry out the following geological investigation concerning these two dam sites,

i) Site reconnaissance in and around the dam sites for preparing geologic maps at a scale of 1 to 20,000, in which distribution of alluvium deposits, debris, other lithology, outcrops of rocks will be shown.

ii) Seismic exploration for clarifying thickness of weathered rocks, location of fractured zones, ground water table at the dam sites : The seismic exploration line will be set adjacent to and along the proposed axis of the dams. The observation points will be set at a 10 m interval along the line.

iii) Core boring including the following:
- Core boring using rotary-type boring machine of 66 mm in diameter,
- Lugeon test in the drilled boreholes at an interval of 5 m depth,
- Laboratory test for the rock material obtained from core boring, including the unconfined compression test, specific gravity test, etc. for clarifying the strength and physical properties thereof.

(2) Further geological investigation required for the Mgeta Dam

Concerning the base rocks at the dam site, the carbonate is suitable for foundation of the high dam, while the conglomerate deems to be partially porous as far as debris depositing near the dam site show. On the other hand, none of existing geologic maps exhibit existence of the conglomerate in and around the Mgeta dam site. Therefore, the distribution of the conglomerate as well as their permeability needs to be clarified in the next study stage through site reconnaissance, core drilling, etc. as well as their permeability.

As aforesaid, there exist two cliffs in the downstream Mgeta flood plain of the dam site, which are 700 and 1,100 m distant from the Mgeta dam site. It is recommended that the further investigation for clarifying the non-existence of the active fault, and distribution/activity thereof, if any, should be carried out.

5. HYDROGEOLOGY

5.1 General

Based on the existing hydrogeological data and previous study results collected so far, the ground water development potential is assessed. The available data are as follows:

- Existing geological maps
- Bore hole data filed by MWEM
- CIDA, 1979, Coast/Dar Es Salaam Region Water Master Plan, MWEM
- DHV,1980, Morogoro Water Supply Plan, MWEM
- IBRD/UNDP, 1990, Sub Saharan Africa Hydrogeological Assessment SSDC Countries, Country Report; Tanzania

Location, yield, type of aquifer, and ground water quality of bore holes filed by MWEM are shown in Figs. B.11 to B.14, respectively.

5.2 Ground Water Resources

(1) Geology

The geology of the Study Area consists of Pre-Cambrian, Karroo, Jurassic, Cretaceous, Tertiary and Quaternary rocks. Hydrogeologically, they can be divided into the following four zones;

a) Zone A

This zone is located in western hill of the Ruvu River and the Uluguru Mountains. The area is mainly covered by the Pre-Cambrian rocks of the Uluguru Mountains System. The Pre-Cambrian rock consists of meta-sedimentary rocks such as crystalline limestone, acidic gneissose, granulite, etc., and meta-igneous rocks such as charnockitic rock. About 5 m thick sandy to stony loam and clay cover the Pre-Cambrian rock.

b) Zone B

Zone B consists of the Mesozoic (Sub-zone B-1), and Neogene (Sub-zone B-2) sediments. It is located between the Ruvu River and the Pre-Cambrian rock of Zone A. The Mesozoic sediment includes conglomerate of Karroo, calcareous sandstone or limestone of Jurassic and sediment deposit with sandstone/shale of Cretaceous. Neogene deposit consists of sandy clay, clayey sand, gravel and calcareous fragment.

c) Zone C

Zone C consists of the floodplain deposit of the Ruvu River. The deposit is of clay and fine sand, but partially contains the coarse grained sand. Their thickness deems to be more than 20 m in the downstream reaches of the Morogoro Road Bridge.

d) Zone D

Zone D spreads between the Ruvu River and Indian Ocean. It can be divided into the following four sub-zones from the geological and geographical viewpoints;

- D-1 : the Neogene highland
- D-2 : the Mesozoic rocks
- D-3 : the Neogene hill with depression filled by alluvial soil and minor Cretaceous outcrops
- D-4 : the wide flat "apron" of Quaternary deposit

These zones are shown in Fig. B.10.

(2) Aquifer properties

The MWEM's bore hole data are plotted based on their yield and lithology of aquifer as shown in Figs. B.12 to B.14.

1) Zone A

The aquifer along the Ngerengere River appears to lie in the unconsolidated sediment composed of alluvial deposits such as coarse sand. Their yields range from 10 to 50 m^3/hr. In some part of the mountainous area, on the other hand, the aquifer appears to exist in the fractured rocks and their yields show about 2 m^3/hr which are less than those in other areas.

2) Zone B

In the Subzone B-1, ground water is extracted mainly from the Jurassic limestone spreading between Kidunda and Kidugallo at yield of 10 to 50 m^3/hr. In Chalinze area, the ground water is extracted in the fractured calcareous sandstone at yield of 2 m^3/hr. In the Subzone B-2, the aquifer appears to be in weathered layers. they are mainly composed of silty or clayey soil. Therefore, the yield is very few.

3) Zone C

The deposits of recent alluvium close to the river channel are considered to be prospective aquifers. According to the result of borehole tests, the ground water yield were 1.18 m^3/hr at the lower Ruvu water treatment plant and 2 to 6 m^3/hr at shallow wells.

4) Zone D

The aquifer appears to be in the Neogene weathered layers. In the hilly area, the layers consist of silt and ground water yield is few. According to CIDA (1979), aquifer appears in the fracture zone and the yield was 2 to 6 m^3/hr in Pugu Railway Station area. In Dar Es Salaam area, the ground water yield was 2 to 10 m^3/hr.

(3) Water quality

The locations of bore holes with salty or poor water quality for drinking are plotted in Fig. B.14. The ground water extracted from the aquifer of weathered layer in Morogoro City and Ngerengere in Zone A and in the area between Kidgala and Chalinze in Zone B is getting worse in quality. In Zone C, bore holes drilled to the levels lower than sea level within distance of 10 km from the Indian Ocean extract saline water.

In Zone D, there is no bore holes having water quality problems as far as the MWEM's bore hole data are concerned. But according to CIDA (1979), it is reported that some bore hole with poor water quality is found within the Zone D. They might be bore holes drilled in saline soil or hot spring area. No influence of the sea water is conceivable in bore holes at the distance of more than 5 km from the sea.

5.3 Ground Water Development Potential

(1) Zone A

The Zone A is located in the Uluguru Mountains and its surrounding area, mainly covered by Pre-Cambrian rocks. Usually, the Pre-Cambrian rocks show low permeability. Therefore, the ground water development potential would be limited to the following areas:

- Alluvial deposit areas in the river valley
- Area with thick weathered layers
- Calcareous rock such as limestone area
- Fracture zone

DHV(1980) selected three high ground water potential areas i.e., Zone VI, VII and X in the Zone A as shown in Fig. B.15. They studied these areas in detail based on their geological investigation results as summarized below:

1) Hydrogeological sub-area VI

The sub-area is located between east of Morogoro Municipality and the north eastern foot hill of the Uluguru Mountains. Geologically, the area is covered by the east dipping calcareous and dolomitic marble intercalated with granulites and gneiss. The alluvial deposits in the valley and the metamorphic limestone are considered to be a water bearing formation.

The alluvial deposits show rather low permeability, but contain ground water of good quality. Because of high ground water table and its good quality, this aquifer is suitable for shallow wells. The metamorphic limestone is located near the fault and it may have many cracks. There are many Karrens and spring in the area. Therefore, it is considered that the ground water potential in this area is high.

2) Hydrogeological sub-area VII

The area is located in the Mgeta and Ruvu valleys in the south and east of the Uluguru Mountains. The sandstone, siltstone and shale of Karroo formation cover the area with northeast dipping. These rocks are covered by the quaternary deposit.

According to the pumping test of aquifer in the Karroo formation in the other area, the yield was estimated to be 1.0 to 1.4 m^3/hr. There seems to be a possibility of the similar yield in this area. The Quaternary deposits are composed of coarse sand to fine gravel. Therefore, if they are shallow, it would be possible to expand the shallow ground water development.

3) Hydrogeological sub-area X

The area is located in the catchment area of the Ngerengere River. The area is covered by Pre-Cambrian rocks and Jurassic rock separated by the fault. The area is hydrogeologically overlapped with Zone B.

According to the previous bore hole test results, the ground water yields were generally low (less than 1 m^3/hr) to very low (less than 0.4 m^3/hr). Ground water in most of the area is saline of which electric conductivity (EC) was very high, reaching 3,800 mS/m in the

maximum. But limestone in a narrow (2 to 3 km wide) and north-south orienting zone has fair prospect of exploiting medium to deep ground water.

The results of previous pumping tests in Kidugallo, which are located in the Jurassic limestone, are tabulated below:

Borehole Data in Jurassic Limestone

Borehole No.	Depth (m BGL)	Static Water Level (m.BGL)	Tested Yield (l/s)	Drawdown (m)	EC (mS/m)
2/34	146.31	0.00	2.4		130
23/53	121.92	16.76	1.3		190
2/56	122.23	53.74	2.2	59.44	106
46/71	201.78	36.27	1.2	59.44	150

According to these results, the yield of ground water is estimated to range between 3 and 10 m^3/hr and their EC is constant, ranging 120 and 190 mS/cm. The ground water is well brackish.

(2) Zone B

The ground water yield in this zone is very low and of low quality with salt, except for the previously mentioned Jurassic limestone area. Therefore, the area has less possibility of the ground water development.

(3) Zone C

Both bore holes and shallow wells have high yield of ground water in this zone. But the area along the lower reaches of the Ruvu River up to 10 km upstream of the river mouth contains salt water.

The ground water in the floodplain alluvium and recent river or relict stream channel has high development potential in this zone. Careful approach, however, is required for the possibility of salty ground water as indicated by the previous borehole data and investigation results.

(4) Zone D

The shallow well ground water development potential in the alluvium deposits within sub-zones D-1, D-2 and D-3 is high, though the further detailed investigation is required. There is less possibility to develop the ground water by deep bore holes in the Zone.

The alluvial deposits of the river valley in this zone have high ground water development potential, but in order to prevent the salt water intrusion, the bore hole depth should be limited to the sea level or its location should be more than 5 km distant from the coastal line.

(5) Recommended areas for ground water development

Based on the above discussion on each hydrogeological zones, it is possible to say that the following zones or sub-zones have rather high development potential of ground water;

1) Zone A, sub-area VI : The metamorphic limestone in the northeastern foot of the Uluguru Mountains

2) Zone A, sub-area VII : The Karroo formation and Quaternary deposits along the Mgeta and Ruvu River valleys at south and east of the Uluguru Mountains

3) Zone A, sub-area VIII : Jurassic limestone in the Ngerengere area

4) Zone C : The alluvium in the floodplain, present river channel and relict stream channel

5) Zone D, sub-zone D-4 : The broad flat "apron" of Quaternary deposit

The location of above mentioned high ground water development potential areas are shown in Fig. B.16. The yield of ground water in these area would be in a range of 16 to 50 m^3/hr (384 to 1,440 m^3/day) based on the previous borehole data as shown in Table B.4. But these figures were obtained by pumping test, and the actual yield of bore holes would be less than these figures.

Throughout the Study Area, salinity of ground water is usual. Therefore, in implementing the ground water development project, the investigation including electric resistivity test, resistivity log and pumping tests and water quality analysis needs to be carefully executed. It is recommended to carry out the electric resistivity survey for the investigation of aquifer in the rock.

6. SEISMOLOGY IN TANZANIA

The East African Rift system is associated with earthquakes. Tanzania is one of the East African countries which is traversed by this rift system. Earthquakes are also found to occur in Tanzania in areas distant from the rift system as shown in Fig. B.17. For designing structures, it is necessary to carry out the complete study of the seismicity in the region.

Location and period of operation of the seismograph stations in Tanzania are summarized below:

No.	Name of Station	Location	Period of Operation
1.	Dar Es Salaam	6.7 S 39.2 E	1906 - 1914
2.	Dodoma	6.2 S 35.7 E	1960 - 1961
3.	Stigle's Gorge Seismic Network	7.8 S 37.9 E	1978 - 1981
4.	Mbeya Panda Hill	8 58. 97 S 33 14 49	1991 - to date

It is reported that a total number of 2,767 earthquake events took place in and around Tanzania for the period from 1846 to 1988. The number of the earthquake events in Tanzania, which are reported in each decade for the period, are grouped in seven magnitude classes as follows:

Decade	Class of Magnitude of Earthquake							Total
	I	II	III	IV	V	VI	VII	
1846 - 1849	0	0	0	1	0	0	0	1
1850 - 1859	0	0	1	0	0	0	0	1
1860 - 1869	0	0	0	0	0	0	0	0
1870 - 1879	0	0	0	0	0	0	0	0
1880 - 1889	0	0	2	1	0	0	0	3
1890 - 1899	0	1	1	3	0	0	0	5
1900 - 1909	0	18	14	3	0	0	0	35
1910 - 1919	1	196	68	15	0	3	1	284
1920 - 1929	0	5	5	2	0	0	0	12
1930 - 1939	0	29	4	0	1	0	0	34
1940 - 1949	0	37	13	7	2	2	0	61
1950 - 1959	57	111	88	76	17	2	0	351
1960 - 1969	114	412	401	201	21	5	2	1156
1970 - 1979	4	113	274	93	6	1	0	491
1980 - 1988	13	122	115	37	7	2	1	333

Note: rating of class of earthquake by magnitude (M)

I = M < 3.9
II = 4.0 < M < 4.3
III = 4.4 < M < 4.7
IV = 4.8 < M < 5.1
V = 5.2 < M < 5.5
VI = 5.6 < M < 5.9
VII = 6.0 < M < 6.3

Fig. B.18 summarizes the seismicity in Tanzania and adjacent areas observed for the period from 1846 to 1988. The most intense seismic activity seems to be concentrated in the arc of the rift-faulting, stretching from the lake Nyasa to the North of lake Tanganyika, and in the north central area of Tanzania, the Eyasi - Manyara region.

The energy map of Tanzania is shown in Fig. B.9, which was prepared based on all the events with the magnitude of more than 5.2, which occured for the period from 1946 to 1988. As seen in Figs. B.18 and B.19, the spatial distribution of epicenters shows the two major zones of seismic activity namely the western and the Eastern Rifts in Tanzania. The epicenter and energy mapping reveal that the Ruvu River basin has energy of magnitude of less than 5.1. On the other hand, the further study for determining the earthquake coefficient is required to be carried out in the next feasibility study on the dam projects in order to properly design the dam and its appurtenant structures.

APPENDIX-B

TABLES

Table B.1 LIST OF BOREHOLE FOR GROUND WATER SUPPLY

Drilling Progress

Region	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Arusha	9	9	9	2	-	10	3	-	1	-	-	-	1	-	4	18	17	11	3	3	17	5	12	18	9	17	25	24	7	11	11	8	12	15	22	7	320
Dodoma	27	19	7	6	7	1	7	10	11	4	1	10	12	9	17	17	26	23	70	86	85	67	53	11	12	19	3	5	11	23	4	4	2	5	6	8	688
Singida	1	9	-	8	6	6	7	8	5	6	4	3	7	4	3	15	14	13	13	16	58	53	16	30	42	24	15	18	22	8	2	5	15	1	3	26	486
Kilimanjaro	1	1	-	-	1	2	-	-	4	-	2	4	8	-	1	5	6	14	6	3	13	7	7	2	9	3	3	7	3	8	5	6	2	8	4	6	151
Mwanza	-	2	5	5	1	-	-	-	-	1	1	1	3	-	6	4	1	3	3	16	-	13	34	57	7	4	4	4	3	1	-	3	7	5	6	39	239
Shinyanga	4	-	2	2	-	2	1	5	-	9	1	3	-	-	1	-	2	4	2	1	7	17	3	3	8	3	7	4	7	4	3	1	1	2	2	2	113
Mara	-	-	4	-	-	1	-	-	-	-	-	-	-	-	3	1	4	4	6	21	4	8	13	7	14	2	5	1	4	2	1	3	-	5	2	1	116
Bukoba	-	-	5	1	3	-	-	3	5	3	4	-	-	1	-	-	9	14	11	-	14	10	13	24	6	9	-	-	-	-	-	-	3	6	9	7	160
Kigoma	-	-	-	1	-	-	-	1	-	-	-	-	-	2	-	-	-	-	1	11	4	4	5	13	12	-	1	-	20	-	-	-	-	-	-	-	75
Ruvuma	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23	-	1	4	2	14	-	10	54
Rukwa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	77	28	40	80	163	13	85	-	486
Mbeya	-	-	2	-	1	3	1	-	-	-	-	-	-	2	-	-	1	-	3	10	-	-	-	-	7	6	2	14	21	1	2	4	-	-	1	2	83
Iringa	-	-	2	-	2	1	-	-	-	-	-	-	-	-	-	3	1	-	-	10	2	3	2	27	14	1	2	2	23	1	-	1	1	-	36	1	135
Tanga	-	4	3	5	13	1	-	3	3	2	3	3	-	3	3	6	6	10	5	20	23	24	13	15	4	5	10	7	1	-	-	-	-	2	-	-	197
Tobora	-	4	13	5	1	3	-	3	-	-	-	-	-	2	8	6	2	4	1	5	20	8	15	8	10	39	21	5	5	1	-	-	-	-	-	2	191
Dar es Salaam	-	-	2	1	-	-	8	-	1	-	-	-	-	-	-	1	-	-	-	-	-	31	11	8	5	3	2	2	2	2	6	2	-	3	4	7	101
Coast	-	-	-	1	-	-	-	1	7	-	1	-	-	1	-	9	2	11	4	24	18	7	12	7	59	22	14	21	11	8	2	1	2	3	1	2	251
Miwara	-	-	-	-	-	-	-	-	-	-	-	9	2	-	4	4	6	5	3	11	3	10	37	14	6	5	5	5	16	1	9	1	9	6	2	2	175
Lindi	-	-	-	-	-	-	-	-	-	-	-	1	3	2	-	-	-	-	-	1	5	21	28	12	5	13	9	18	14	3	8	-	2	-	-	3	148
Morogoro	3	4	3	8	8	-	6	6	2	10	3	3	3	1	2	4	8	4	9	5	-	5	7	1	9	12	22	11	4	4	2	7	1	2	5	5	189
Total	45	52	57	45	43	30	33	40	39	35	20	37	39	27	52	93	105	120	140	243	273	293	281	257	238	187	150	148	274	106	96	130	222	90	188	130	

Source : Sub Saharan Africa Hydrological Assessment, SADCC Countries

Table B.2 GEOLOGIC CONDITION OF EACH DAM SITE

No.	Name of Damsite	Location	Dam Height (m)	Geological Feature		Remarks
				Formation	Lithology	
1	Mgeta	Nr. Kisaki	21.3*	Post-Triassic	Sillicified fault breccias; carbonatites	Proximity to major fault (about 0.5 km)
2	Rudete	"	–	Precambrian	Hornblend-biotite granulate and gneiss	
				Post-Triassic	Sillicified fault breccias carbonatites	
3	Msoro	"	–	Quaternary	River alluvium Clays, loams, sands, gravels	
4 5 6 7	M/LB/R1 Mngazi Bwakira Dutumi	"	–	Precambrian	Banded pyroxene granulate. Biotite Granulate	Proximity tomajor fault (0.5 to 2 km)
8	Ngere ngere	Nr. Kissio	16.8	Jurassic	Siltstones and fine grained sandstones; lower part is calcareous	
9	Ruvu-Mgeta	Nr. Kidunda	21.3	Jurassic	Oolitic and pisolitic limestones. Calcareous sandstones	*The alluvium deposits is rather thick some 15 meter deep across the river. limestones is generally permeable.
10	Mkulazi	Nr. Kidunda	15.8	Jurassic	Oolitic and pisolitic limestones calcareous sandstones: Siltstones and finegrained sandstones.	
11	LB/R1	Nr. Rusako	9.1	Tertiary	Sandy clays and clayey sands. Gravels, calcareous fragments.	•Poor solidity •Soft rocks
12	MSUS	South Chalimze	15.2	Cretaceous Tertiary	Marls and their limestones Sandstones and gravels	
13	Mbiki (major)	Major Tribs	15.2	Jurassic Cretaceous	Calcareous Sandstones Marls and their limestones	
14	Mbiki (minor)	North Trib	14.0	Tertiary	Sands and Gravels	Poor solidity
15	Mkombezi	Nr. Tarawanda	18.3	Cretaceous	Cray shale interbedded sandstone	
16	Usigwe	Nr. Simbo	16.8	Tertiary	Course grain sandstones with quarter	The center of the river is dominated by alluvium deposit.
17	RB/R1	Nr. Maneromango	13.7		Clays, shales, Calcareous sandstone sandy limestone	The center of the river is dominated by alluvium deposits
18	RB/R2	"	9.8	Cretaceous	Clays, shales Calcareous sandstones sandy limestones	"
19	RB/R3	Nr. Mafisi	7.6	Cretaceous	Claps, shales Calcareous sandsstones sandy limestones	
20	Banda		11.9	Tertiary (N3)	Sandy clays, clayey sands with minor lenses of pure sand or clay	
21	Mlandisi		16.8	Tertiary (N3)	"	The center of the river is dominated by alluvium deposits.
22	Mbwawa		27.4	Tertiary (N3)	"	"
23	Chombe		15.2	Tertiary (N3)	"	"

Table B.3 GROUND WATER USE IN THE STUDY AREA

		The Number of Wells		Yield(m3/hr)※3			
		total	Wells of yield clear	total	maximum	minimum	average
The Total Number of Wells except next line number※1	All wells	100	67	662.1	59.0	0.04	9.3
	except poor quality	80	51	427.1	30.4	0.04	8.4
Wells drilled before 1978 in Kisarawe and Bagamoyo※2	All wells	121	11	83.3	54.6	0.40	7.6
	except poor quality	114	9	75.1	54.6	0.40	8.3
All Wells	All wells	221	78	705.4	59.0	0.04	9.0
	except poor quality	194	60	502.2	54.6	0.04	8.4

Note:※1 From Data Base of MWEM office

※2 Geological Map of Coast Region MWEM(1988)

※3Yield is considered the data when the pomptest was carried out

Table B.4 GROUND WATER YIELD IN THE STUDY AREA

Aqufer	Unconsolidated sediments	Weathered layers	Fractured rocks	Other rocks	Unknown
The number of total wells	37	7	6	11	39
Wells of yield clear(m3/hr)	19	6	6	8	28
Total yield (m3/hr)	180.8	67.5	26.3	93.8	253.7
Average yield per a well(m3/hr)	9.5	11.3	4.4	11.7	9.1
Maximum yield (m3/hr)	26.1	30.4	16.4	41.3	59.0
Minimum yield (m3/hr)	0.1	1.3	0.1	0.7	0.04

APPENDIX-B

FIGURES

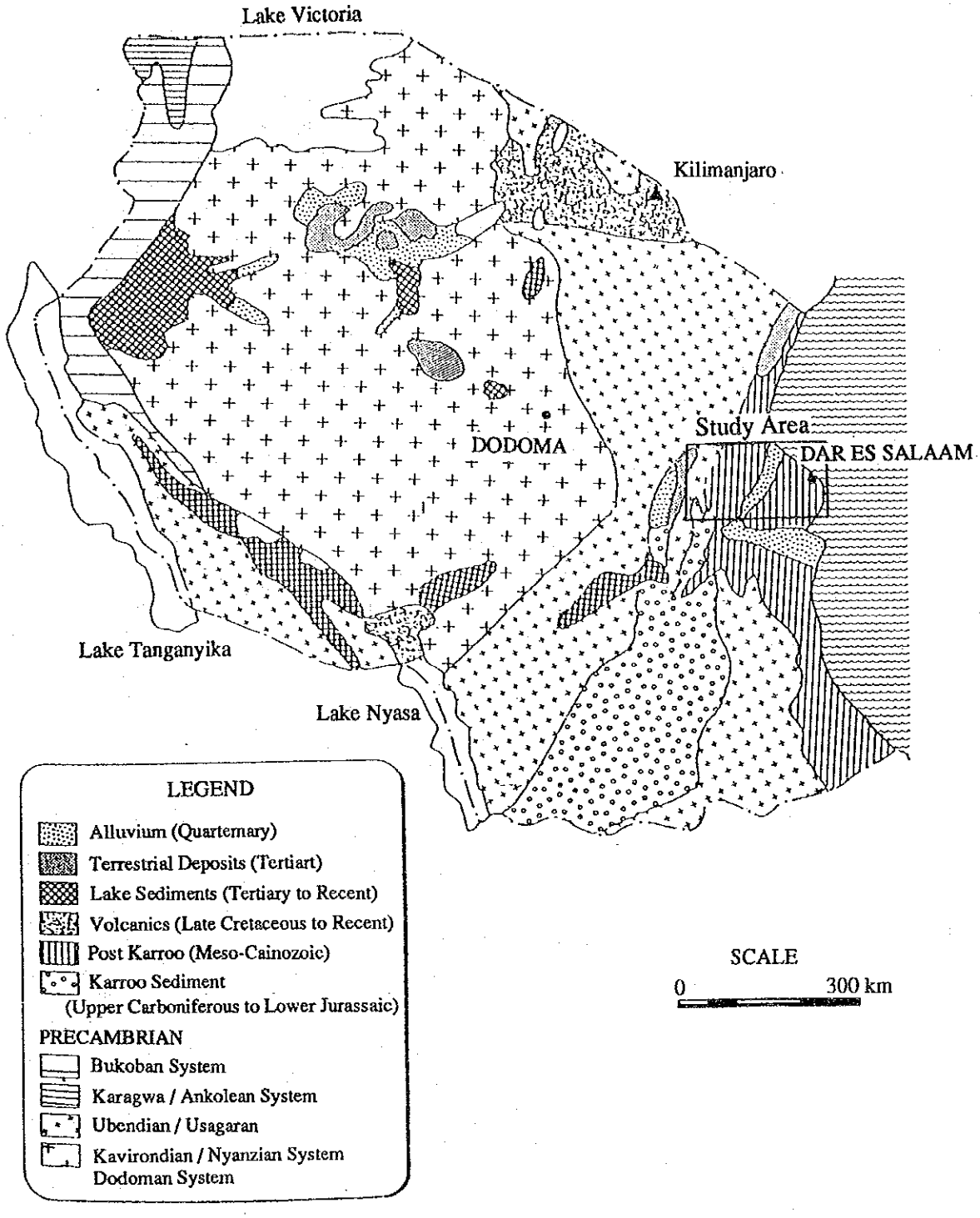


Fig. B.1 SUMMARY OF GEOLOGY IN TANZANIA

(SOURCE : Sub Saharan Africa Iecesba 1990)

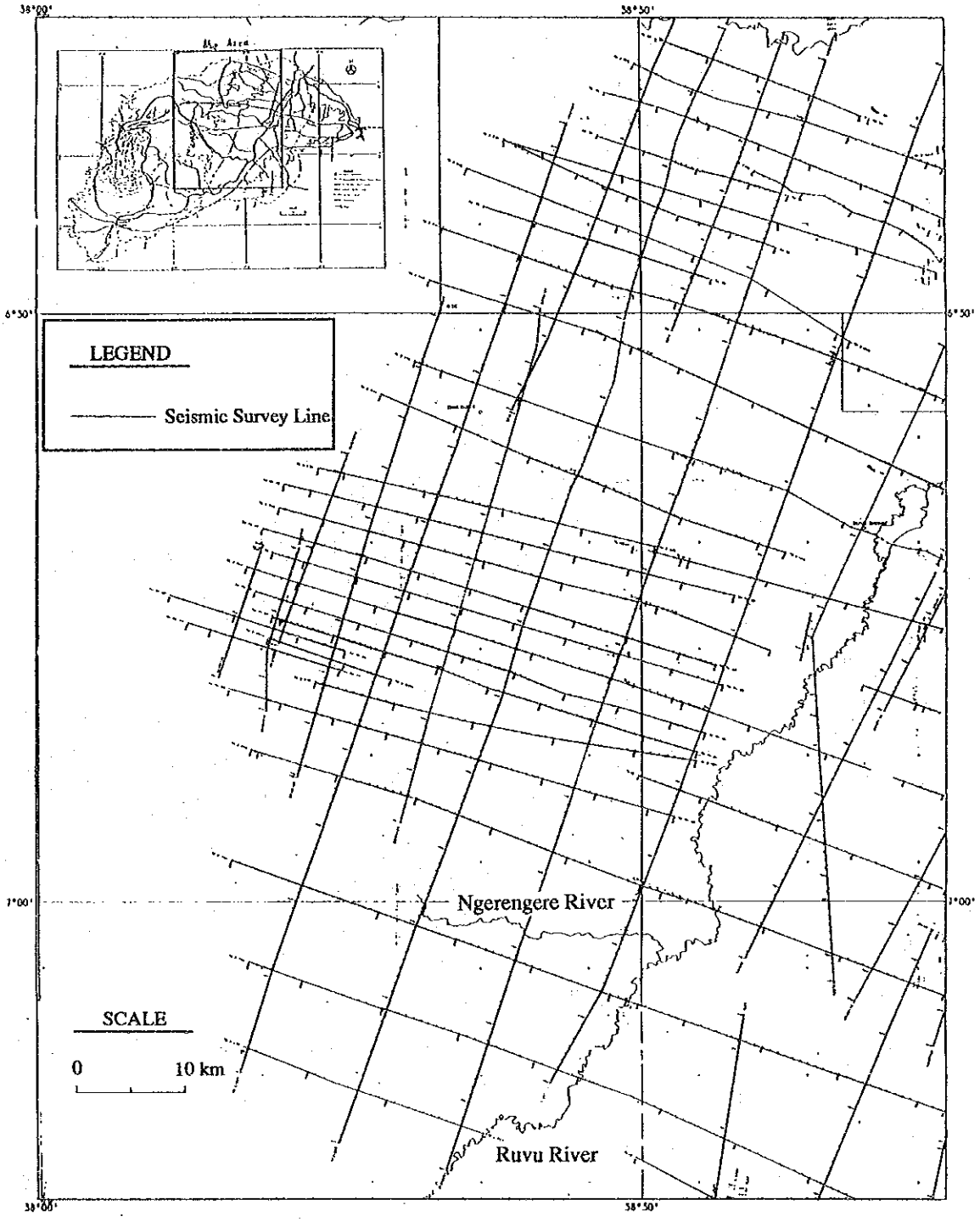
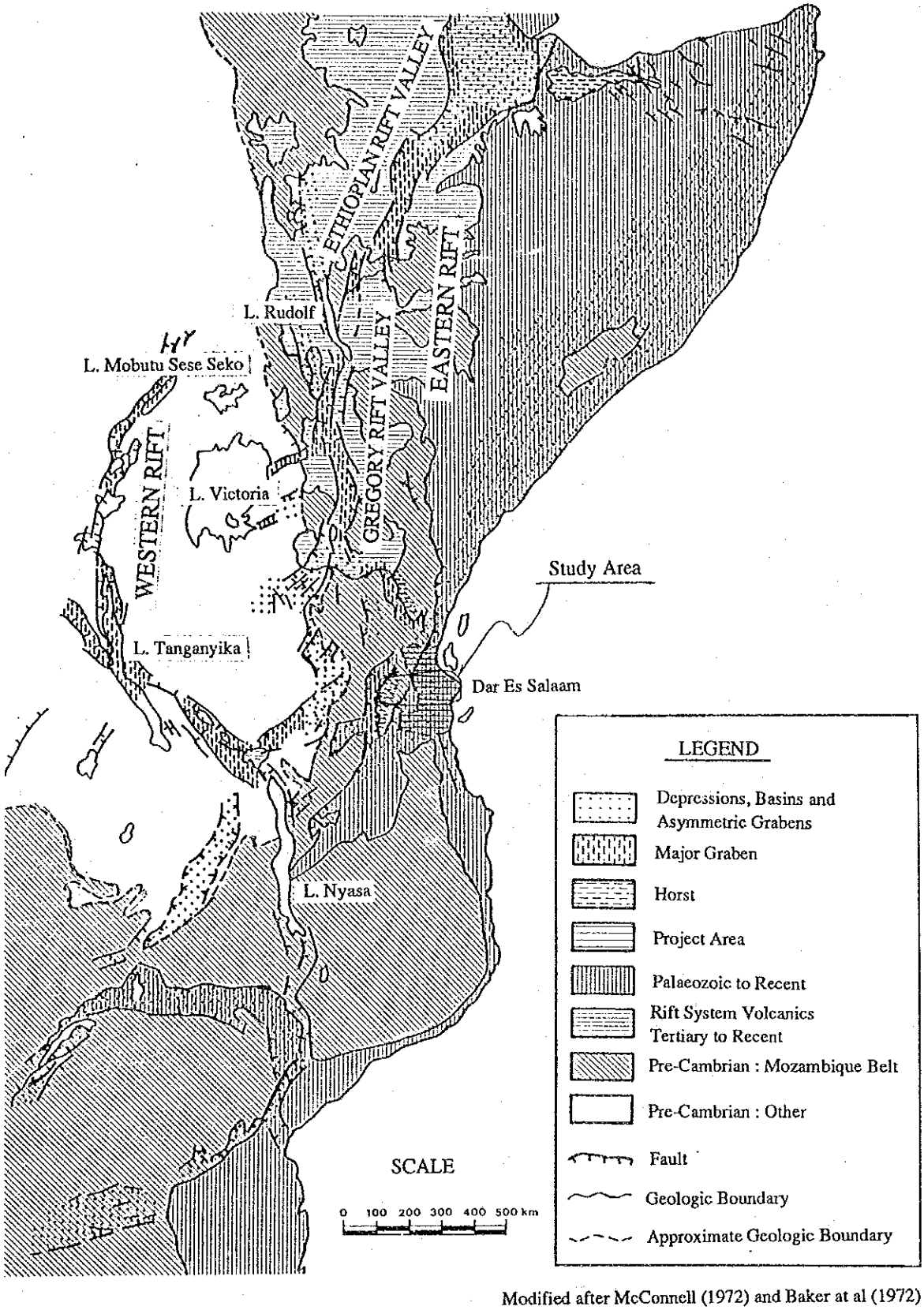


Fig. B.2 LOCATION MAP OF THE SEISMIC SURVEY BY TPDC



Modified after McConnell (1972) and Baker at al (1972)

Fig. B.3 REGIONAL SETTING AND EAST AFRICA RIFT SYSTEM

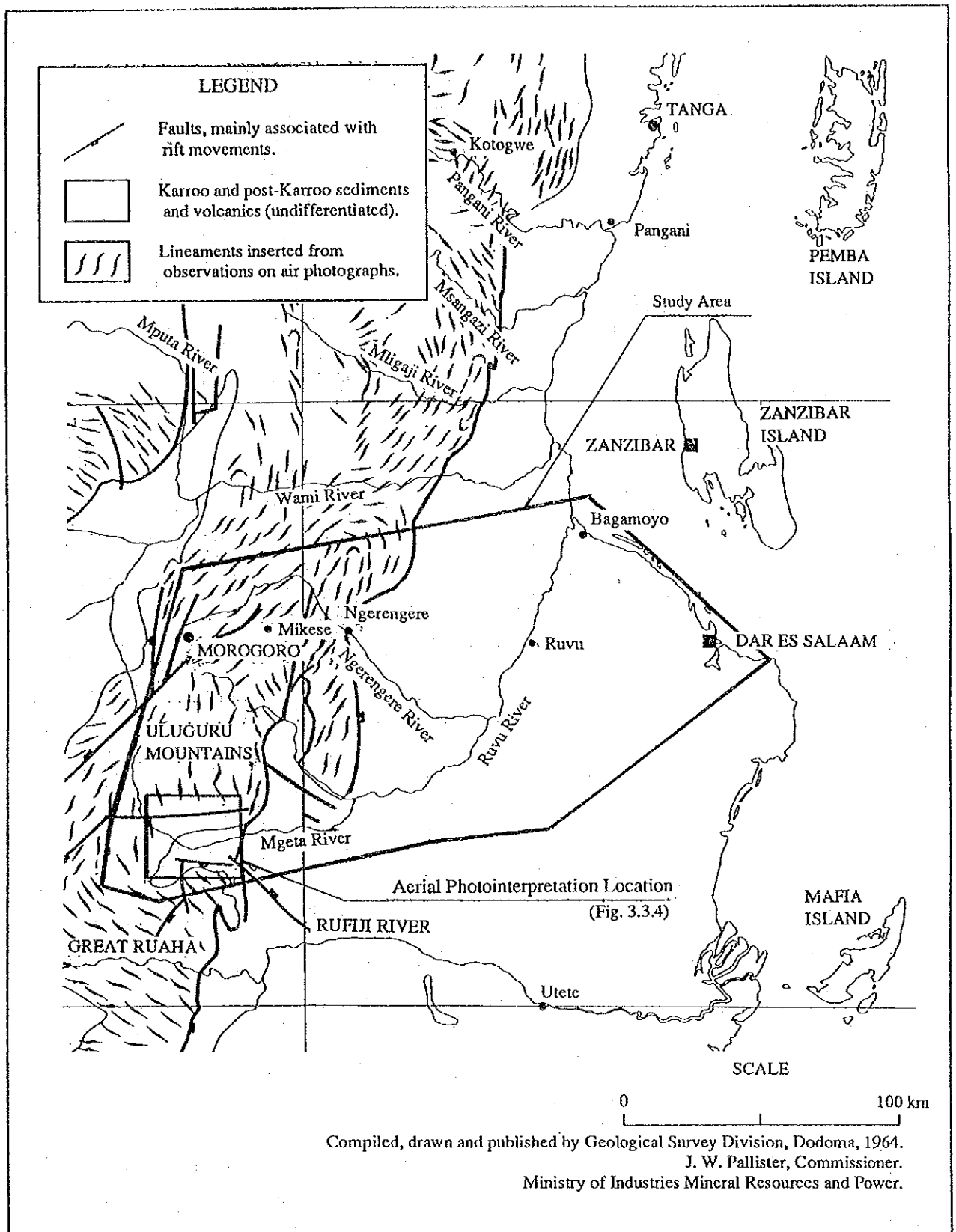


Fig. B.4 GEOLOGICAL STRUCTURE AROUND THE STUDY AREA

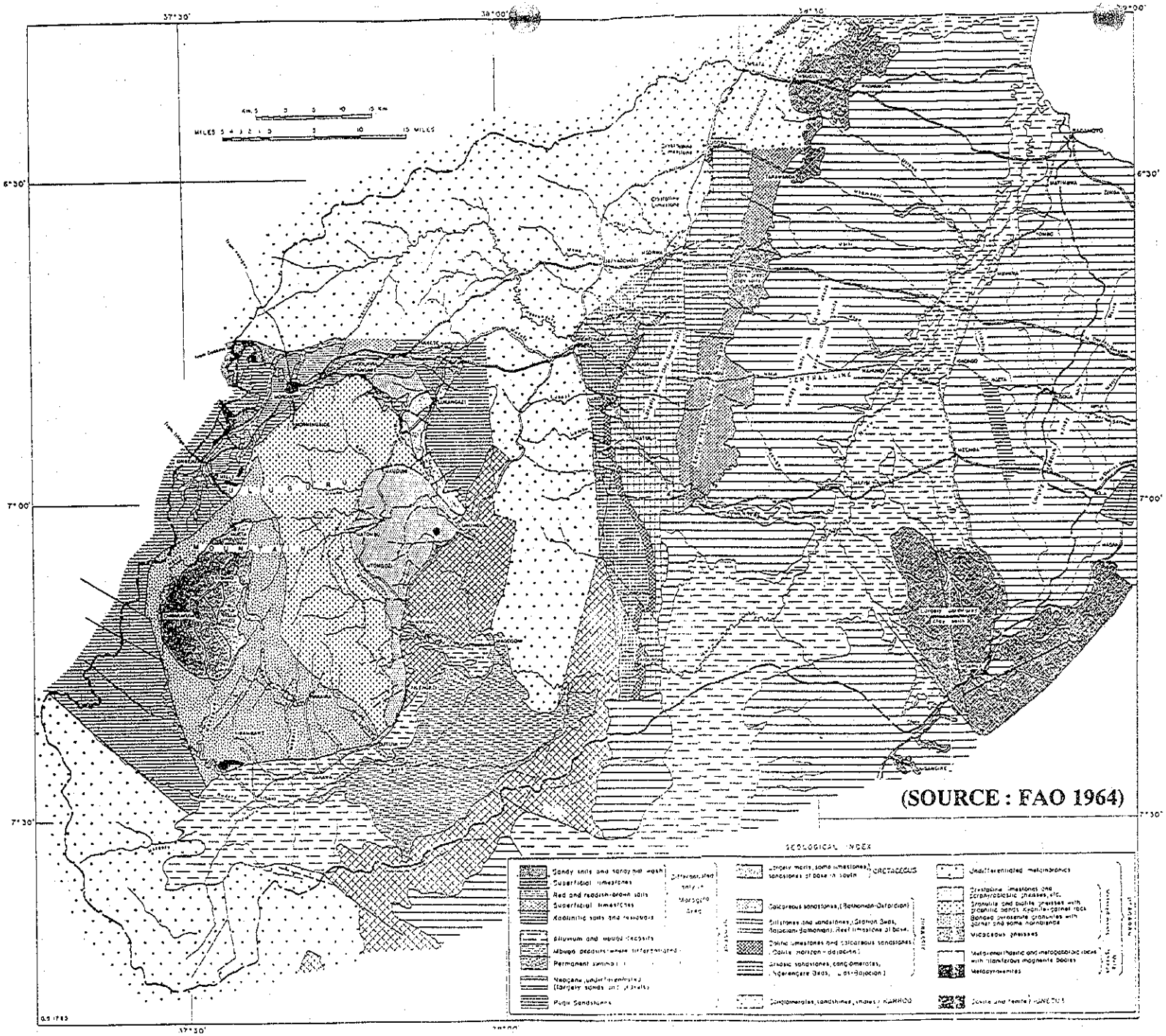


Fig. B.5 GEOLOGICAL MAP OF THE RUVU RIVER BASIN

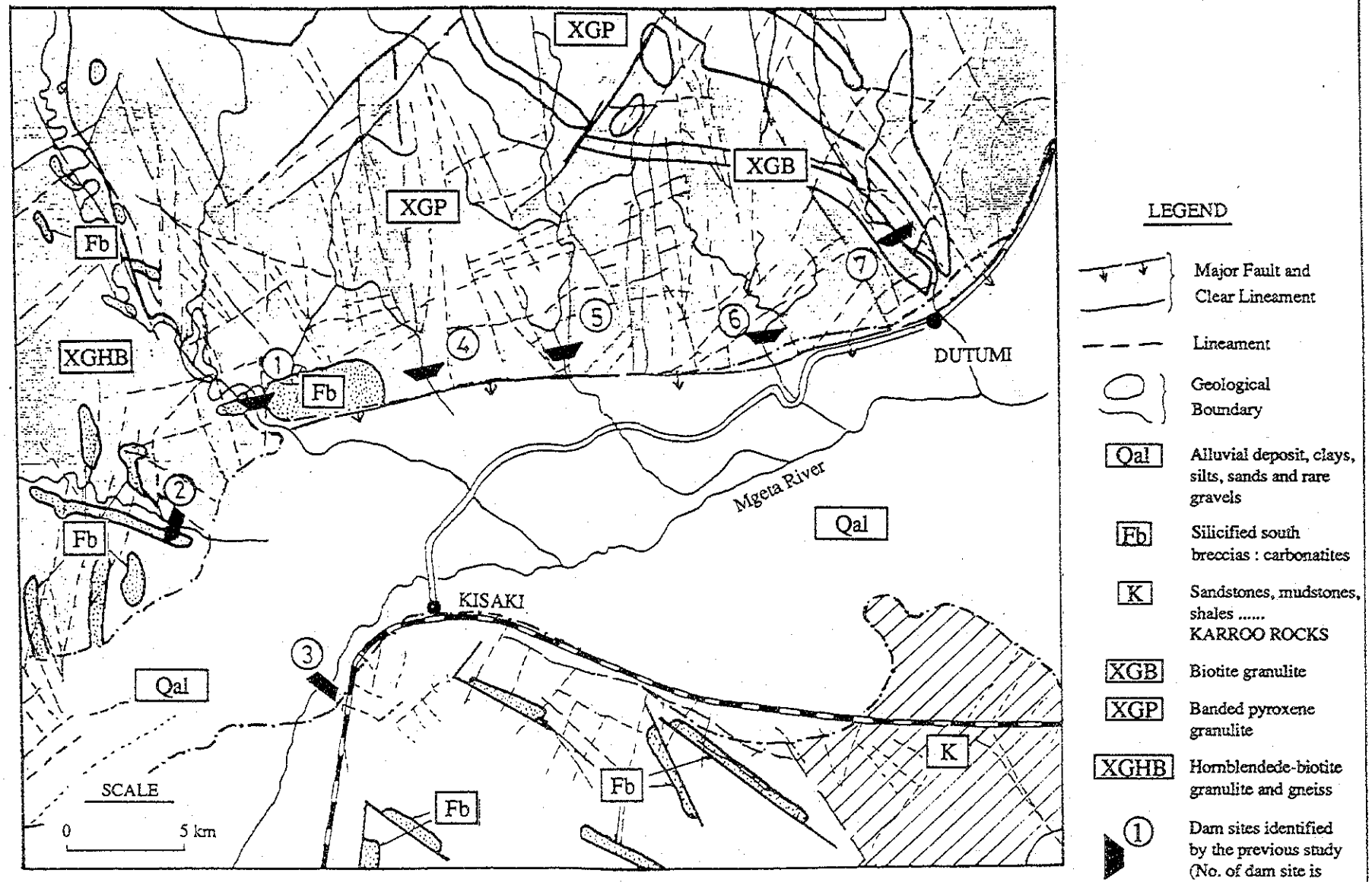


Fig. B.6 AIR PHOTO LINEAMENT IN THE LOWER REACH OF THE MGETA RIVER

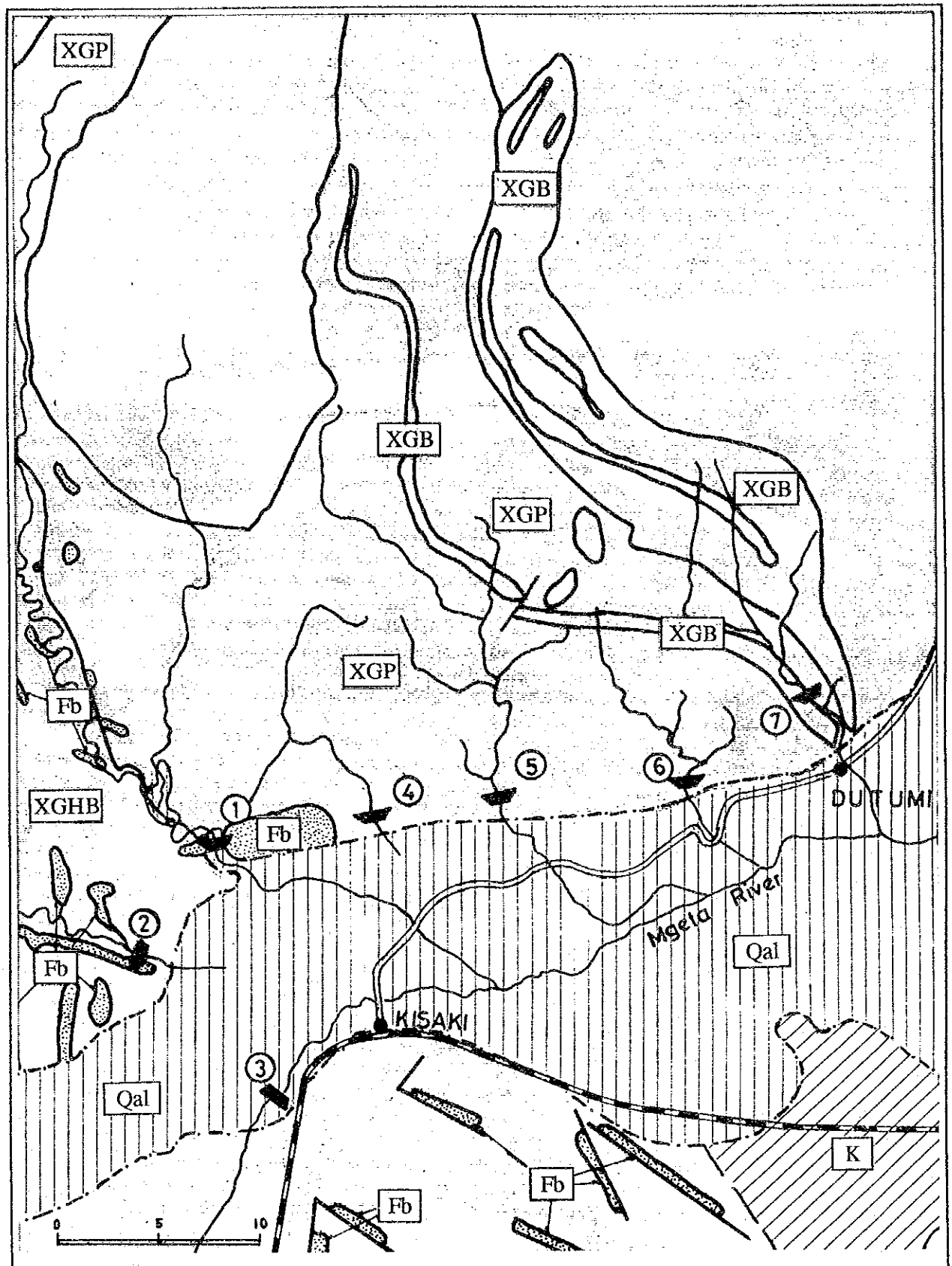


Fig. B.7 GEOLOGICAL MAP OF DAM SITES IDENTIFIED BY THE PREVIOUS STUDY (1/6)
(Legend is attached in Fig. B.7 (6/6))

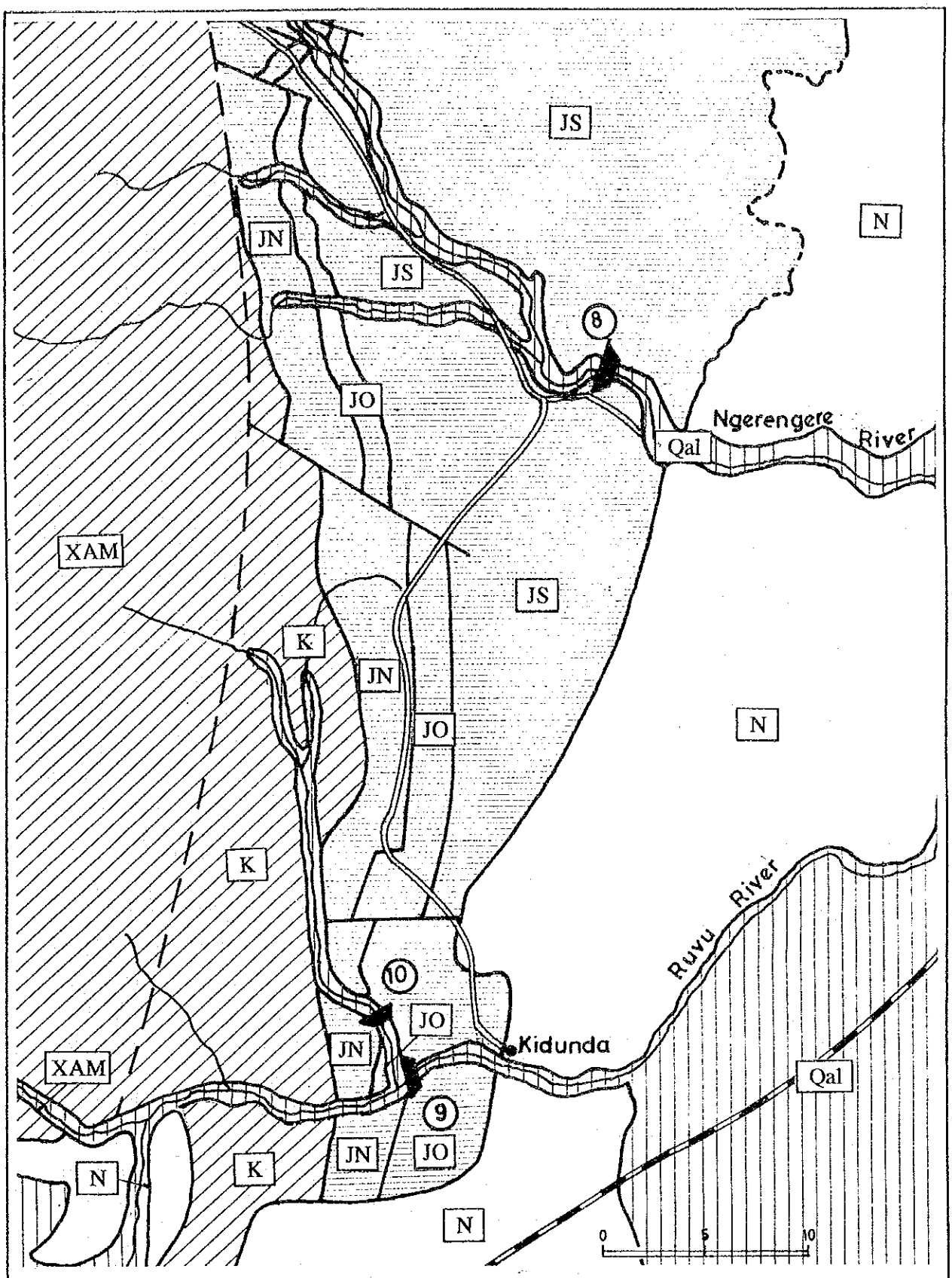


Fig. B.7 GEOLOGICAL MAP OF DAM SITES IDENTIFIED BY THE PREVIOUS STUDY (2/6)
(Legend is attached in Fig. B.7 (6/6))

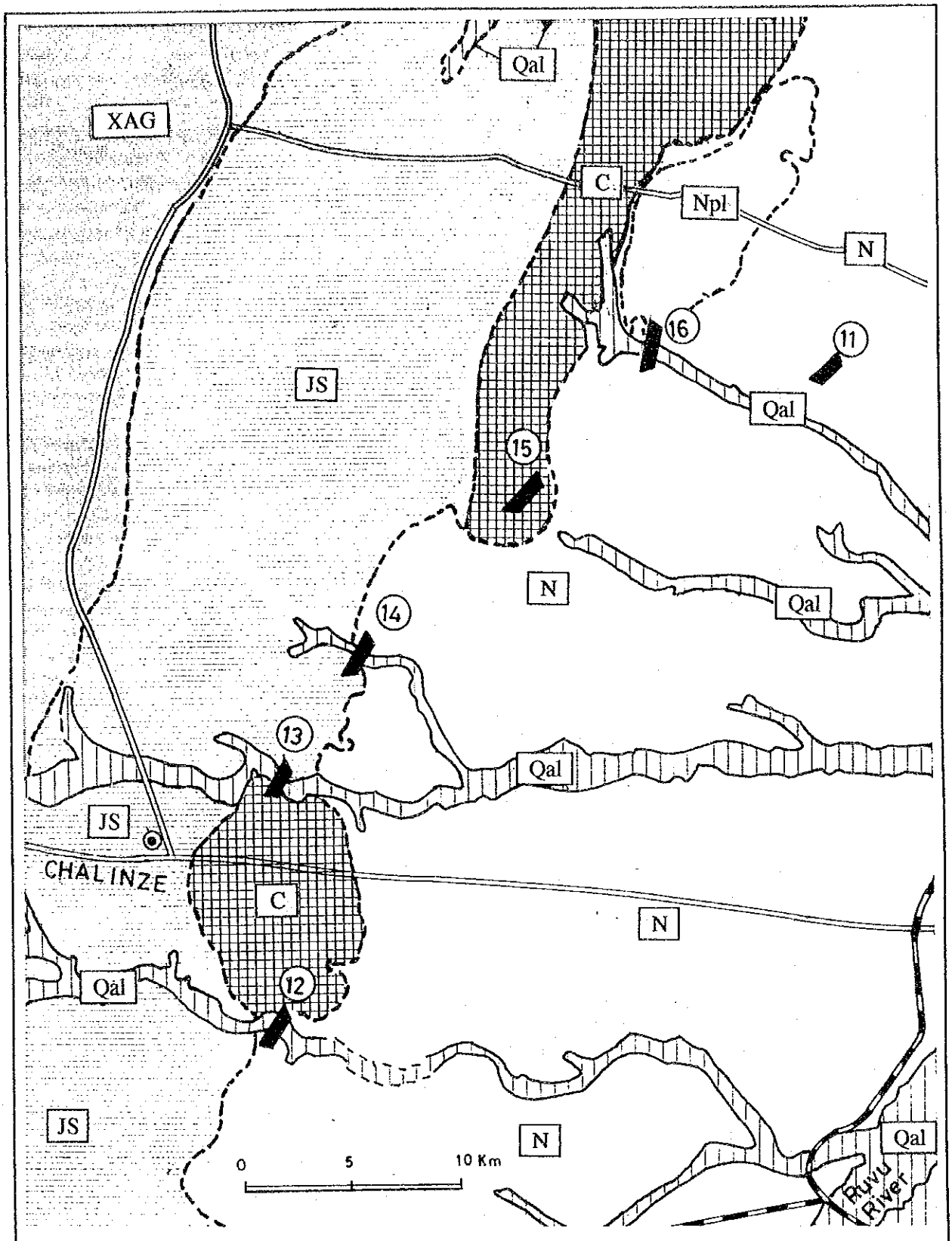


Fig. B.7 GEOLOGICAL MAP OF DAM SITES IDENTIFIED BY THE PREVIOUS STUDY (3/6)
(Legend is attached in Fig. B.7 (6/6))

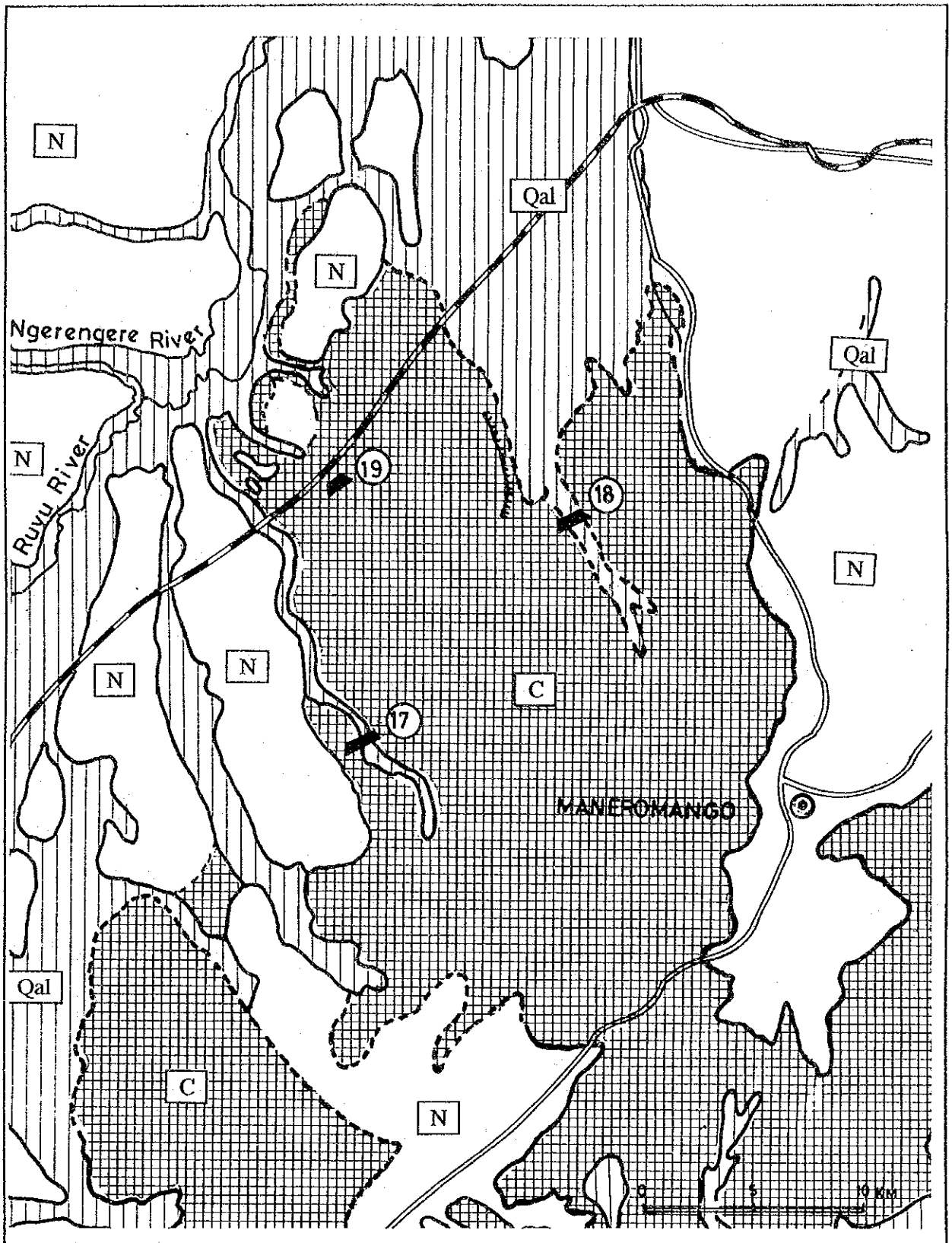


Fig. B.7 GEOLOGICAL MAP OF DAM SITES IDENTIFIED BY THE PREVIOUS STUDY (4/6)
(Legend is attached in Fig. B.7 (6/6))

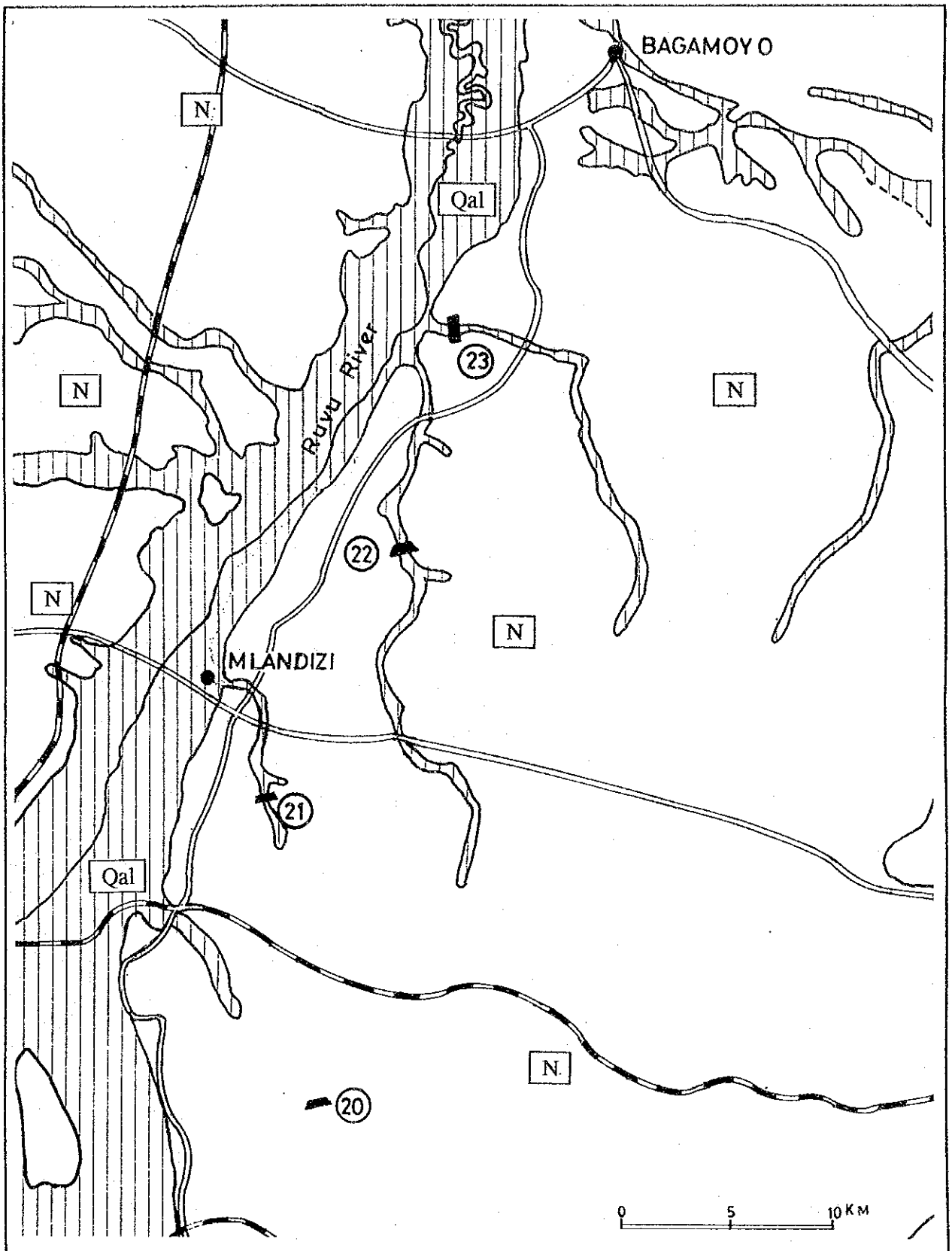


Fig. B.7 GEOLOGICAL MAP OF DAM SITES IDENTIFIED BY THE PREVIOUS STUDY (5/6)
(Legend is attached in Fig. B.7 (6/6))

LEGEND for Fig. 3.7

QUATERNARY	Qal	Alluvial deposit, clays, silts, sands and rare gravels
TERTIARY	N	Interbedded clays and clayey sand with minor lenses of pure sand and clay
	Npl	Mauve red sand over massive white gritty sands and a basal-cemented conglomerate, all bound in some clay
CRETACEOUS	C	Clays, shales, calcareous sandstones sandy limestones, mudstones
JURASSIC	JS	Calcareous siltstones and sandstone, occasional thin limestone and reddish marls bone in upper part, also occasional thin conglomerate sands
	JO	Oolitic and pisolitic limestones,calcareous sandstones, sandy siltstones, upper part in calcareous
	JN	Course-medium grained sandstones, conglomerate in part
POST-TRIASSIC	Fb	Silicified south breccias : carbonatites
CARBONIFEROUS -TRAIASSIC	K	Sandstones, mudstones, shales ..... KARROO ROCKS
	XAM	Muscovite-biotite
PRECAMBRIAN	XGB	Biotite granulite
	XGP	Banded pyroxene granulite
	XGHB	Hornblendede-biotite granulite and gneiss
	XAG	Biotite garnet kyanite/sillimanite gneiss

Dam Sites identified by previous study
No. of dam sites is referred in Table I.1 in the Appendix-I

Fig. B.7 GEOLOGICAL MAP OF DAM SITES IDENTIFIED BY THE PREVIOUS STUDY (6/6)

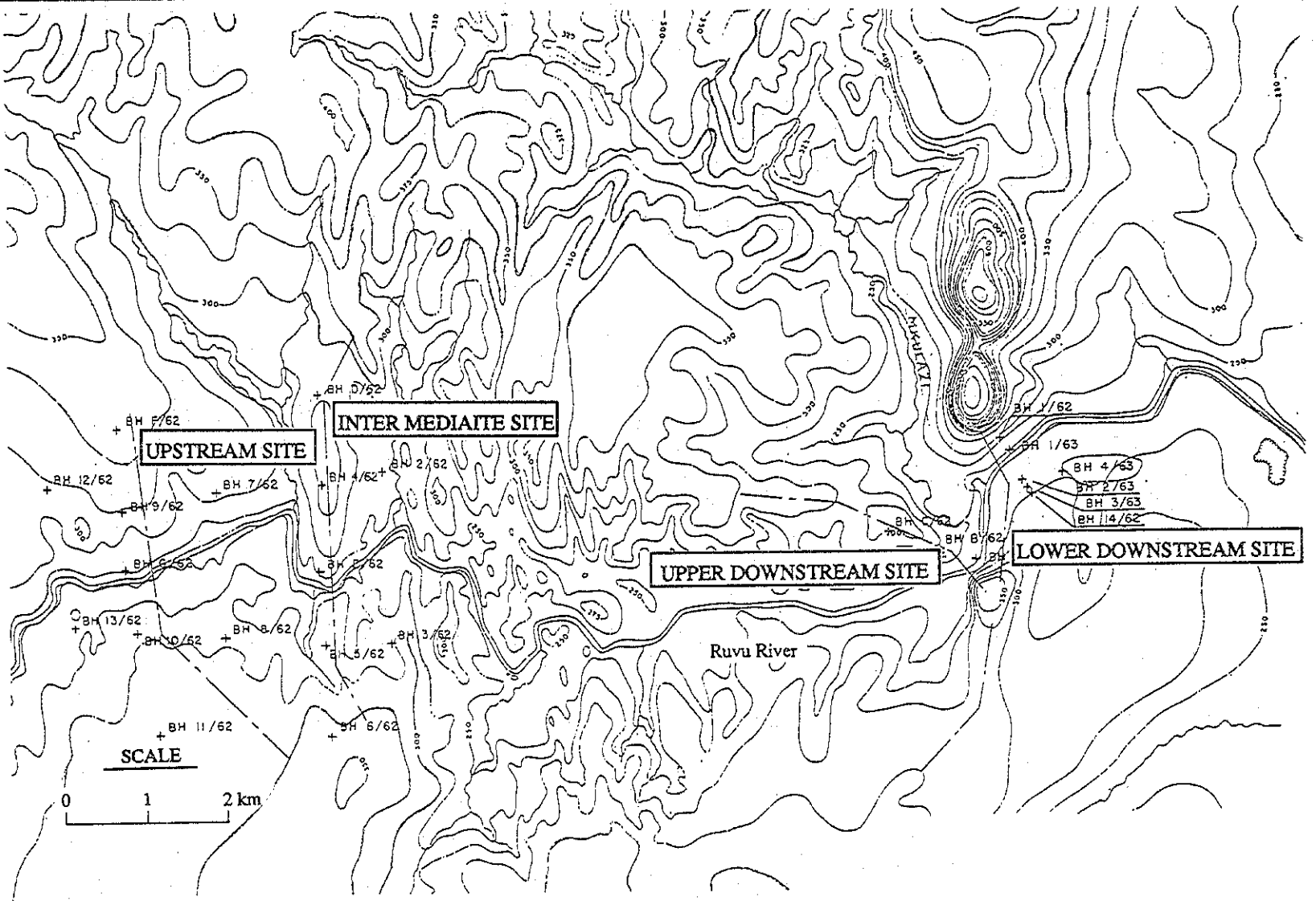


Fig. B.8 LOCATION OF THE BOREHOLES AND PROPOSED DAM AXIS

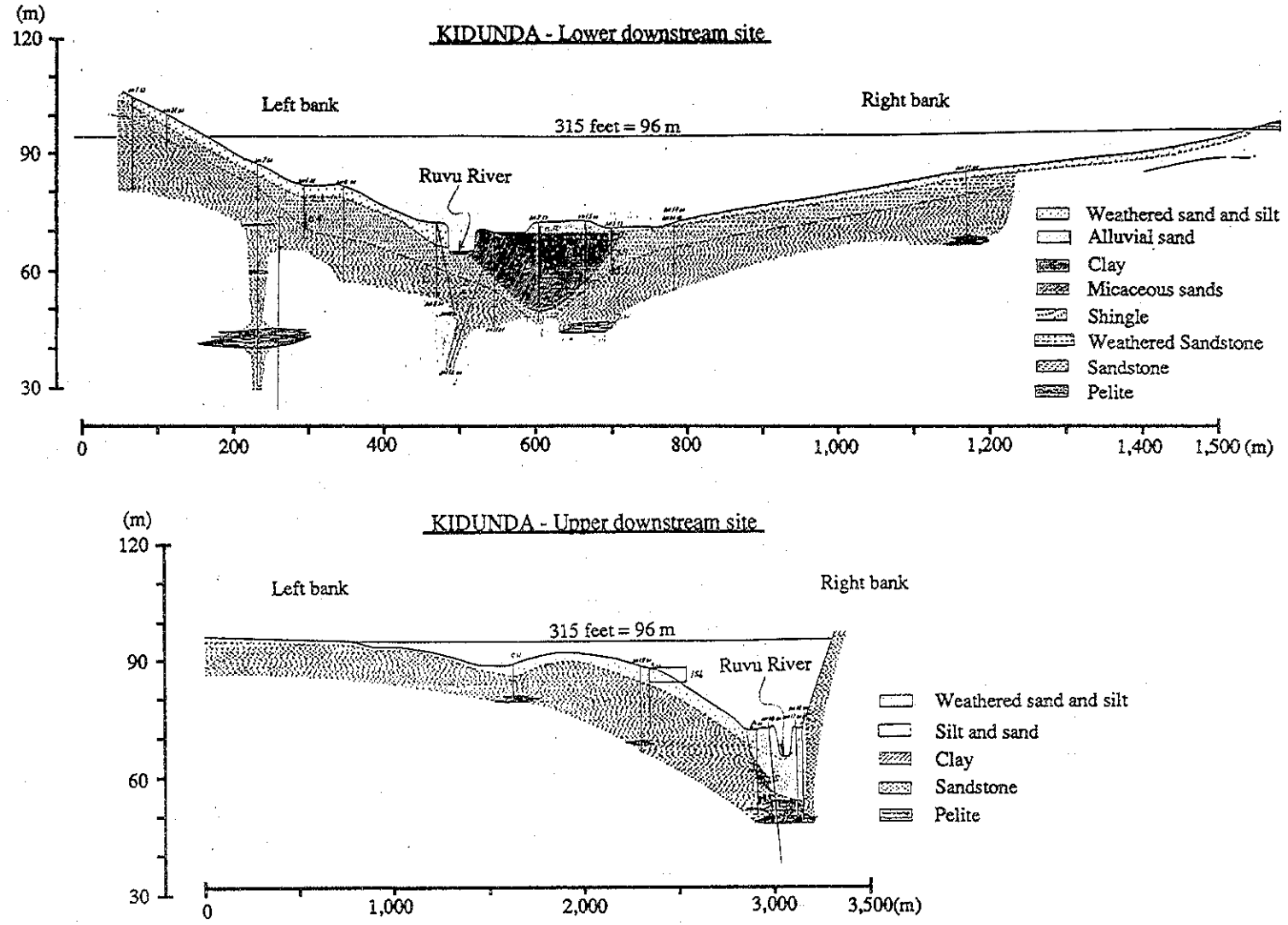


Fig. B.9 GEOLOGICAL PROFILE AT ALTERNATIVE SITES OF KIDUNDA DAM (1/3)

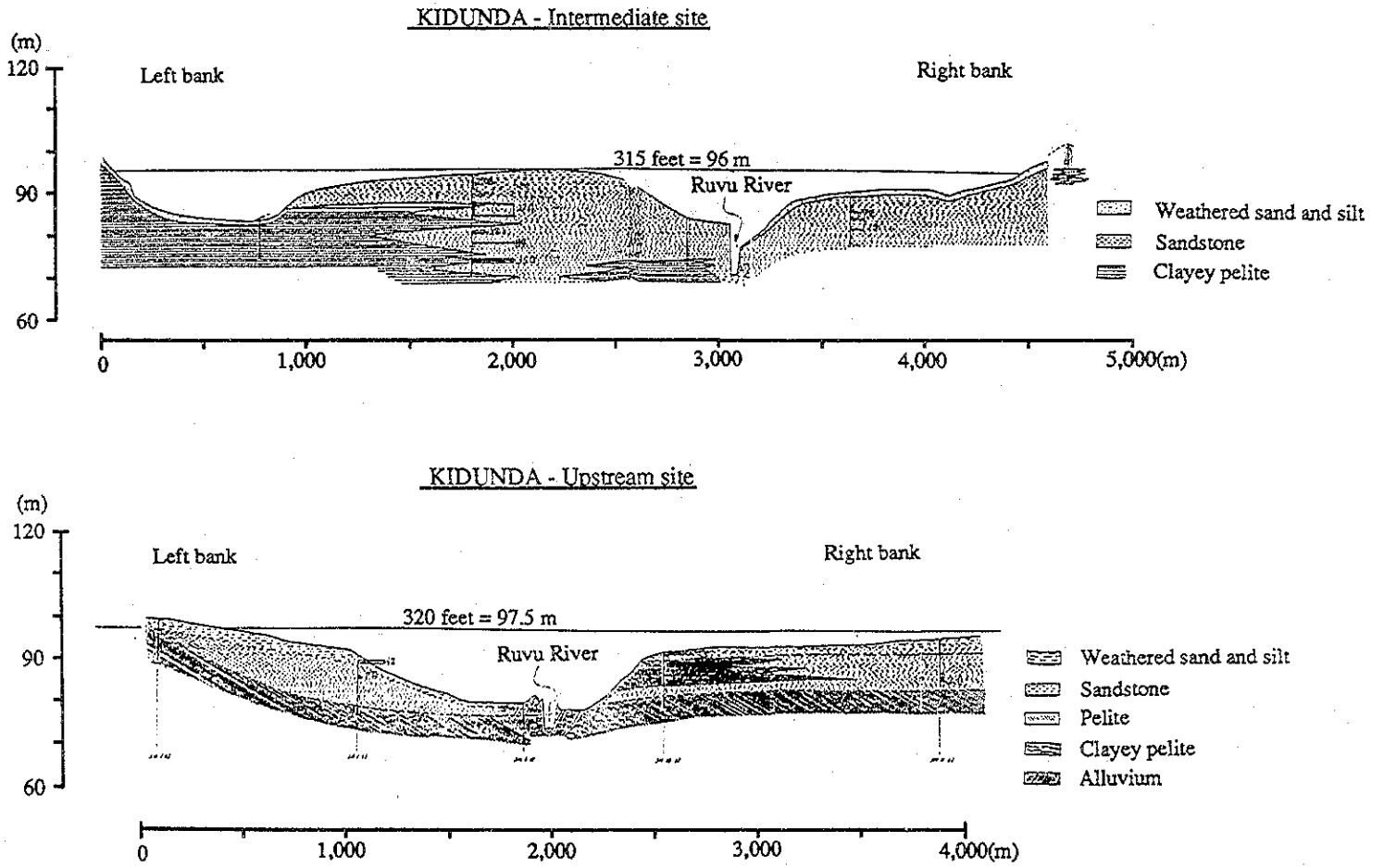


Fig. B.9 GEOLOGICAL PROFILE AT ALTERNATIVE SITES OF KIDUNDA DAM (2/3)

KIDUNDA - OVERALL GEOLOGICAL STRUCTURE

Large-scale variation of the Karoo sandstone facies - General dip of the formation - Respective position of Jurassic limestone and Karoo sandstone

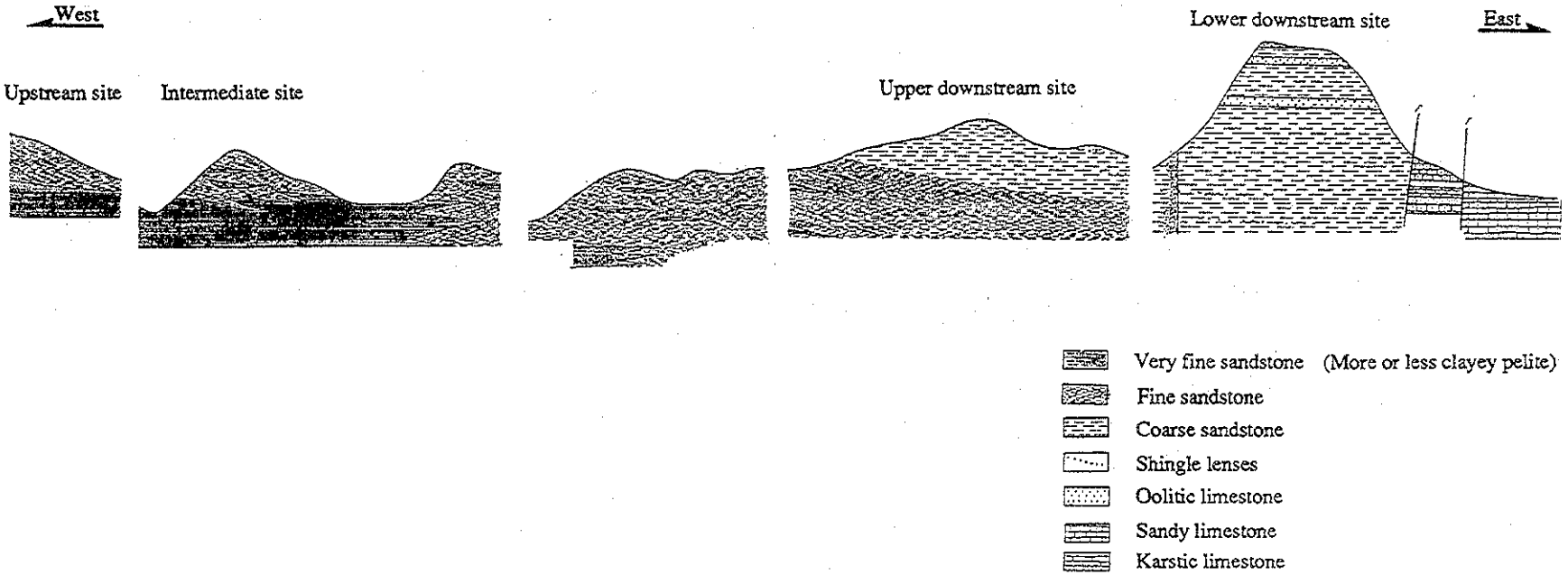


Fig. B.9 GEOLOGICAL PROFILE AT ALTERNATIVE SITES OF KIDUNDA DAM (3/3)

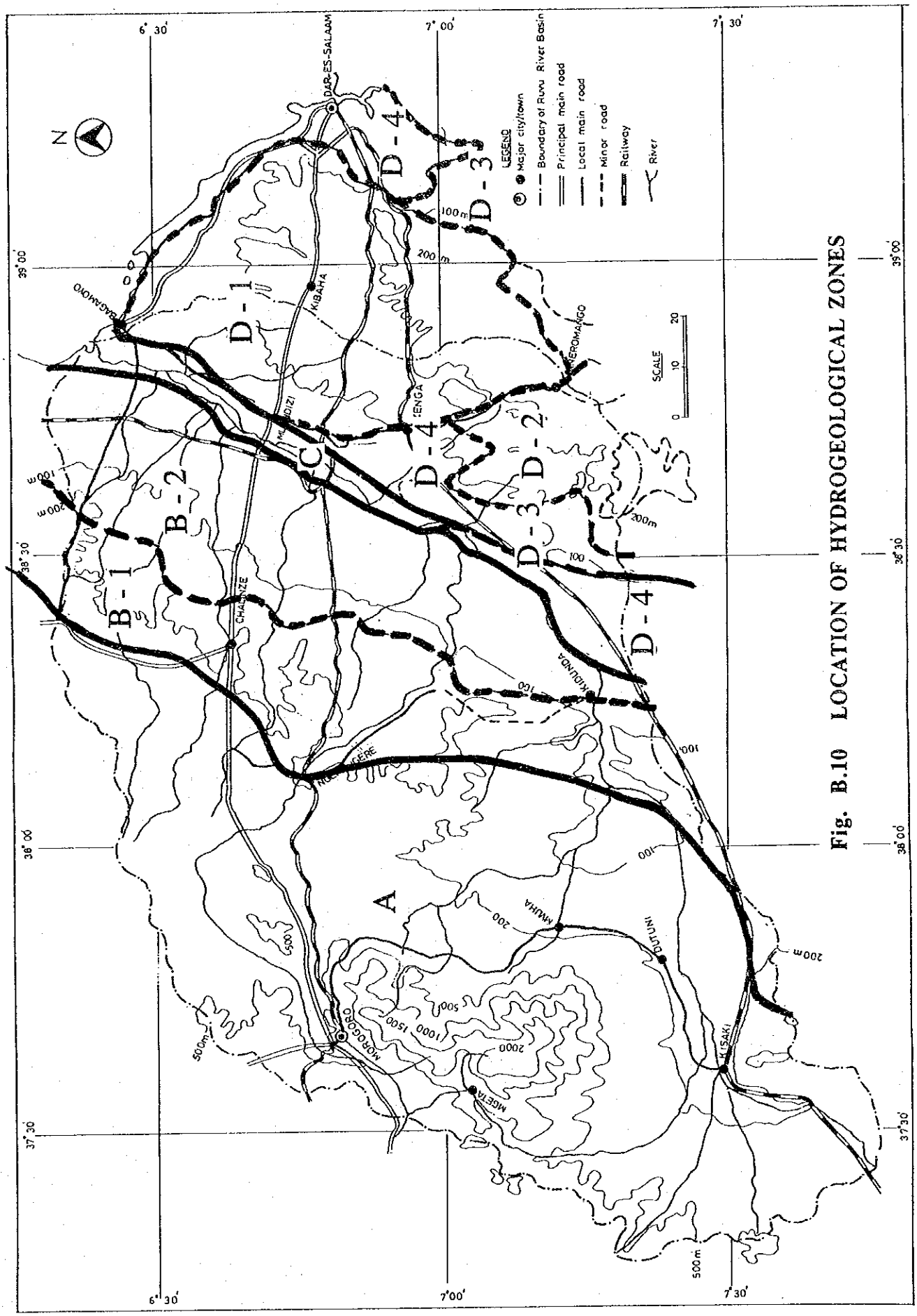


Fig. B.10 LOCATION OF HYDROGEOLOGICAL ZONES

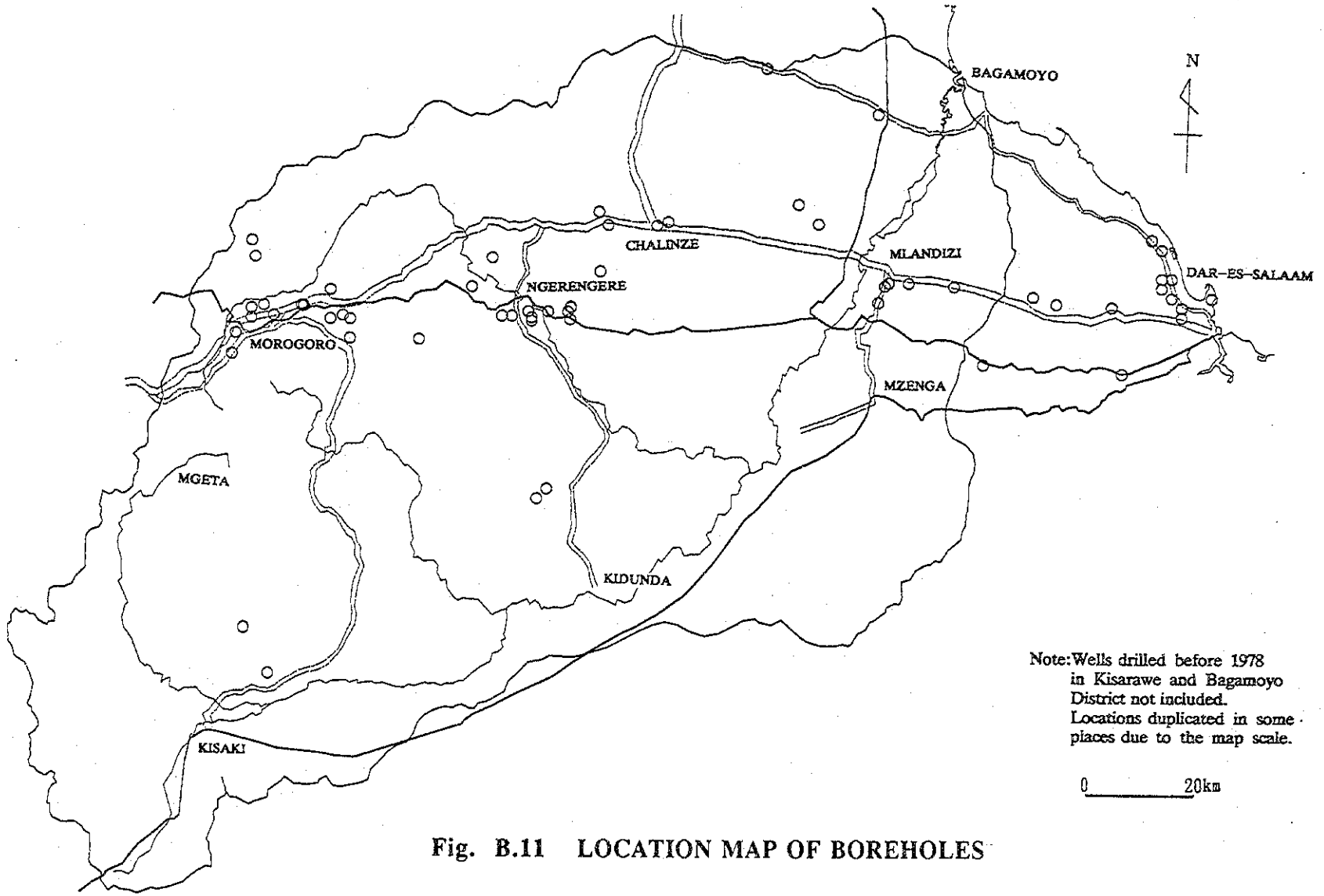


Fig. B.11 LOCATION MAP OF BOREHOLES

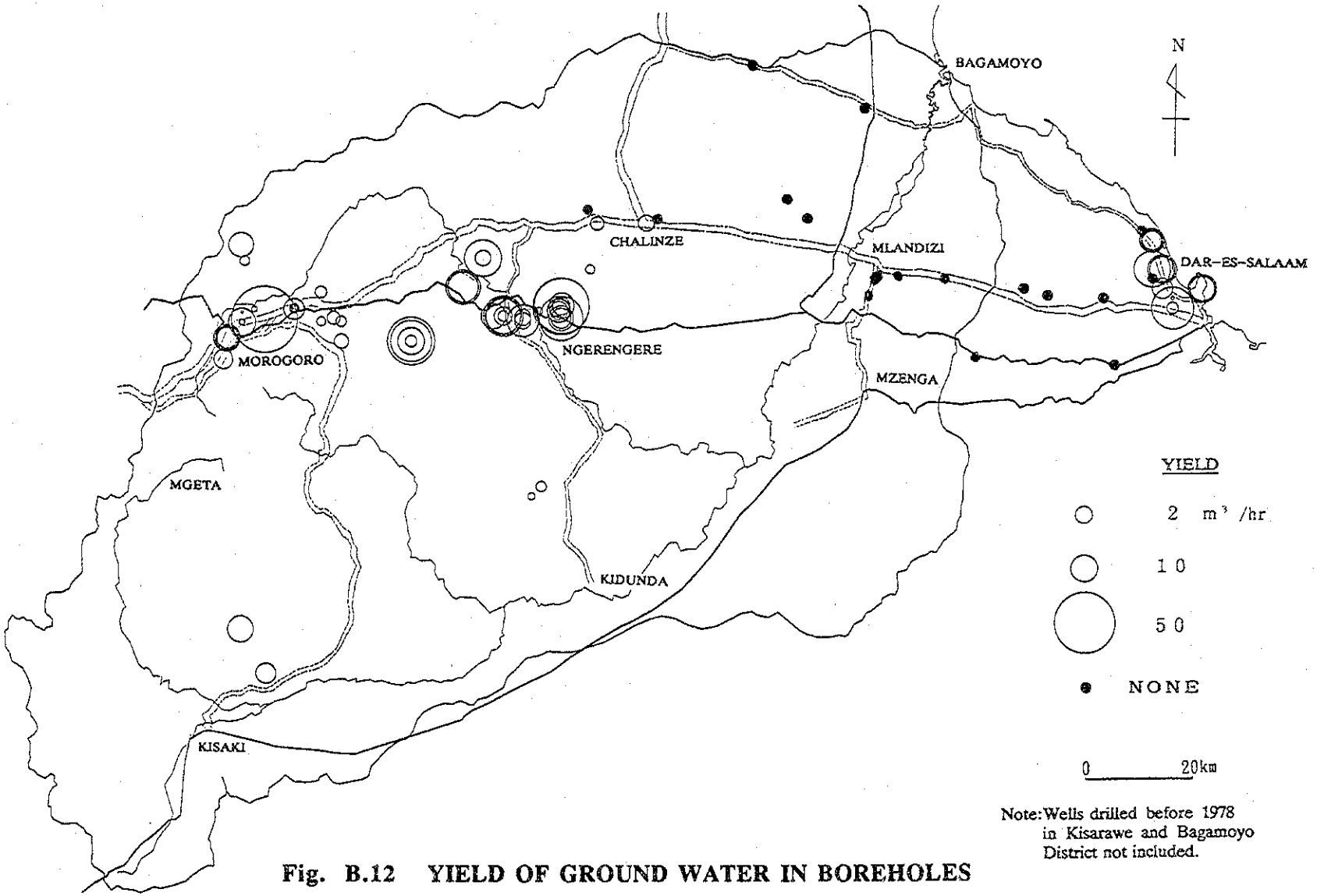


Fig. B.12 YIELD OF GROUND WATER IN BOREHOLES

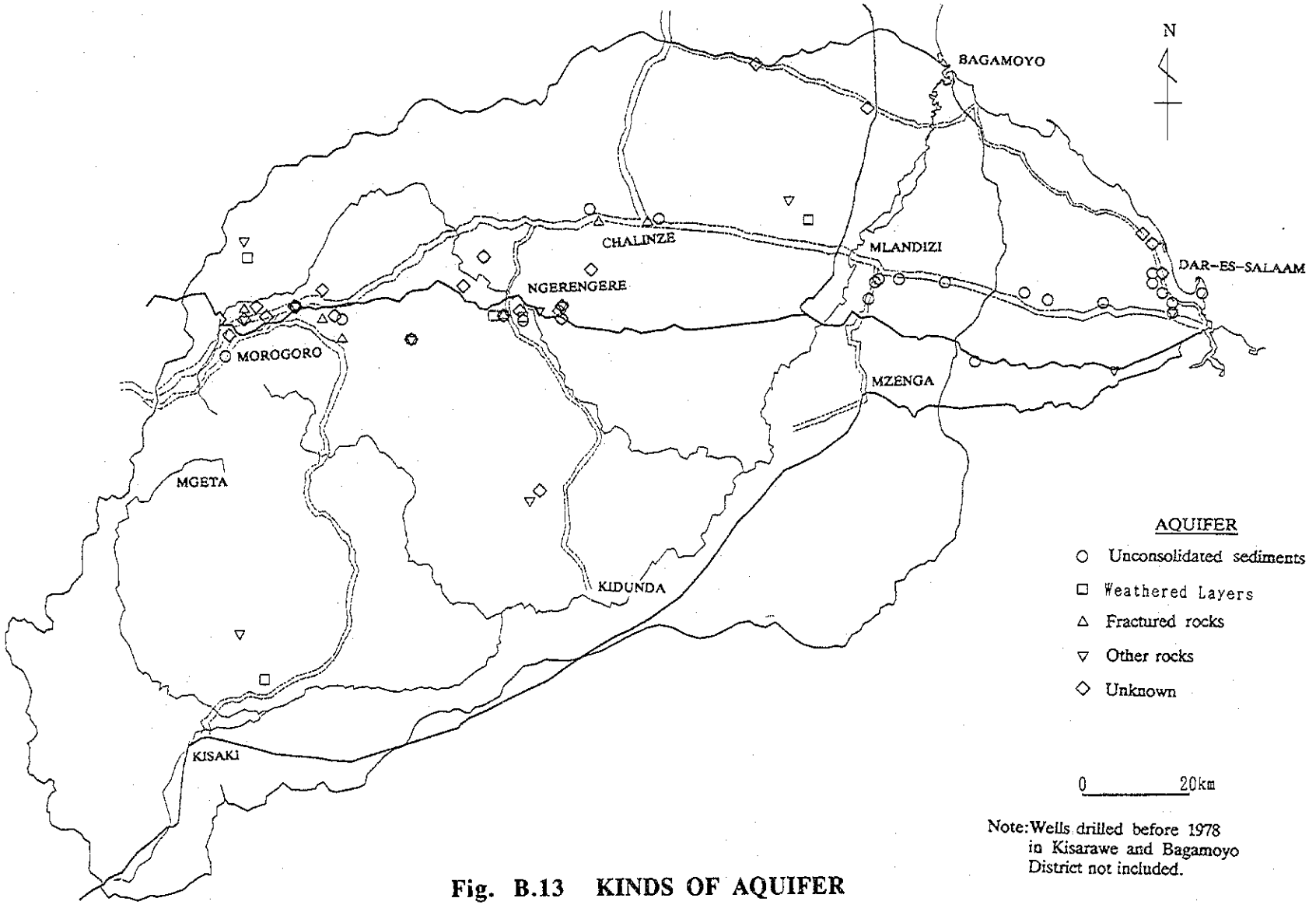


Fig. B.13 KINDS OF AQUIFER

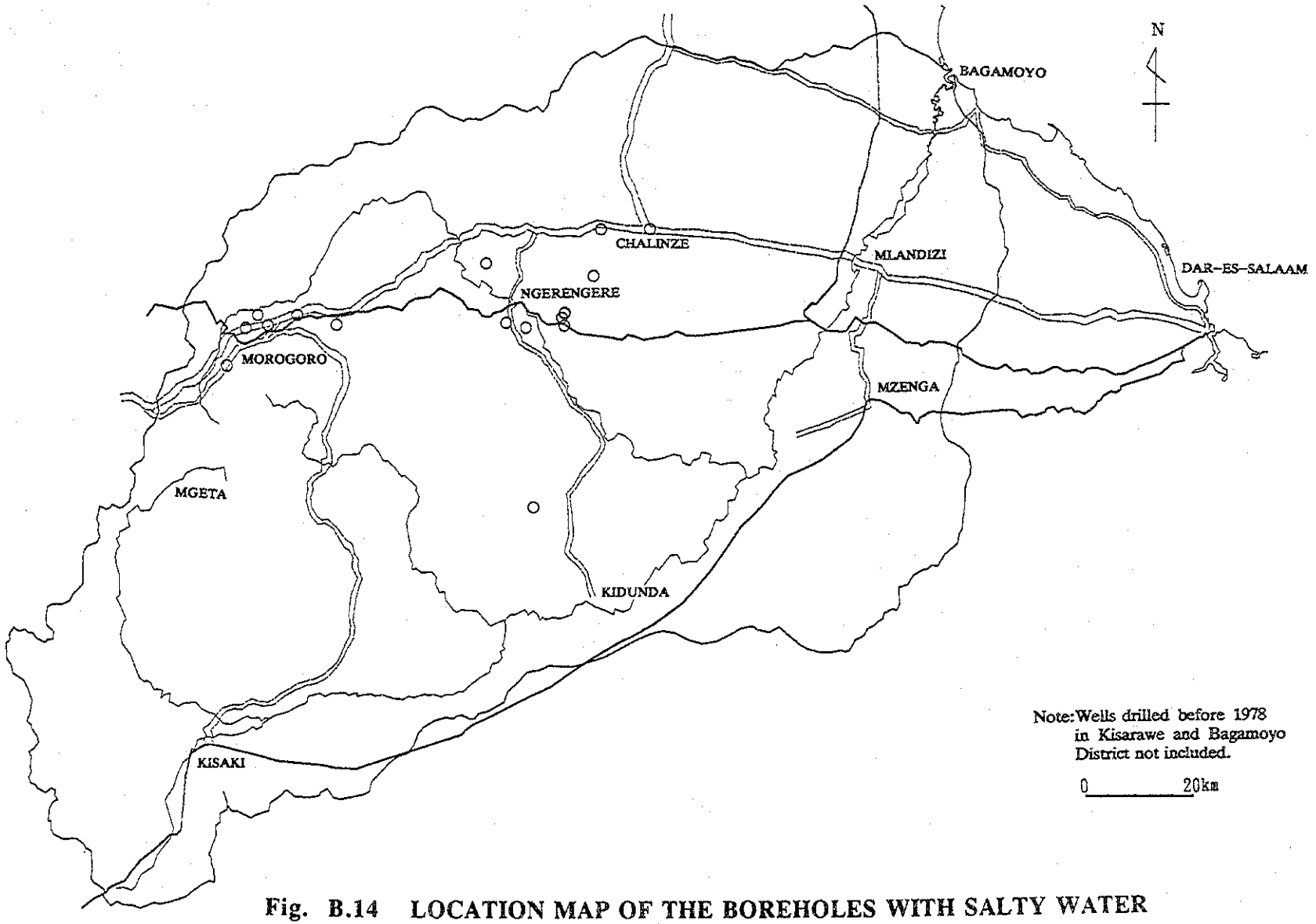
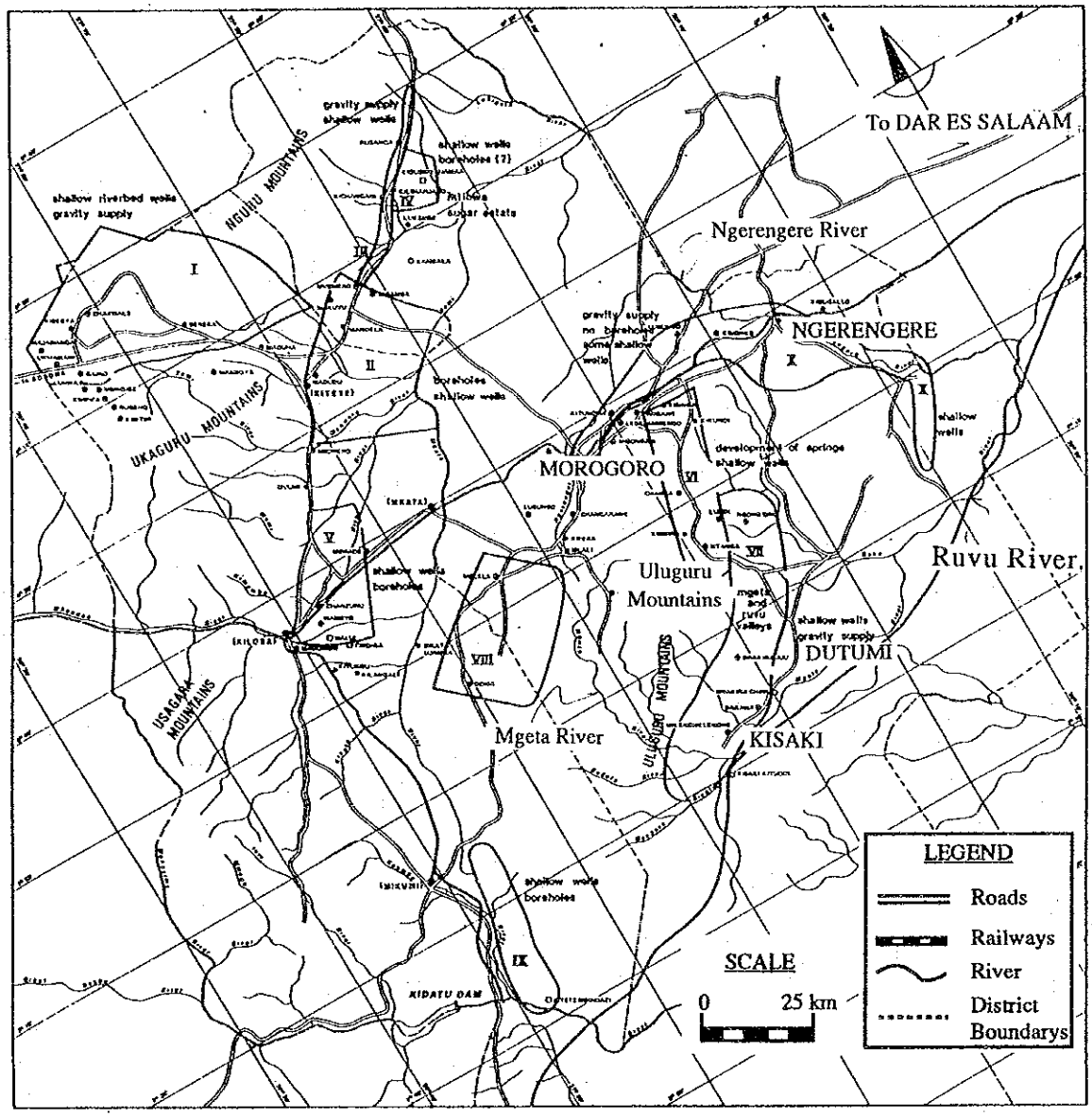


Fig. B.14 LOCATION MAP OF THE BOREHOLES WITH SALTY WATER



Note:This location map is edited by DHV(1980)

Fig. B.15 WATER POTENTIAL OF HYDROGEOLOGICAL SUB-AREAS

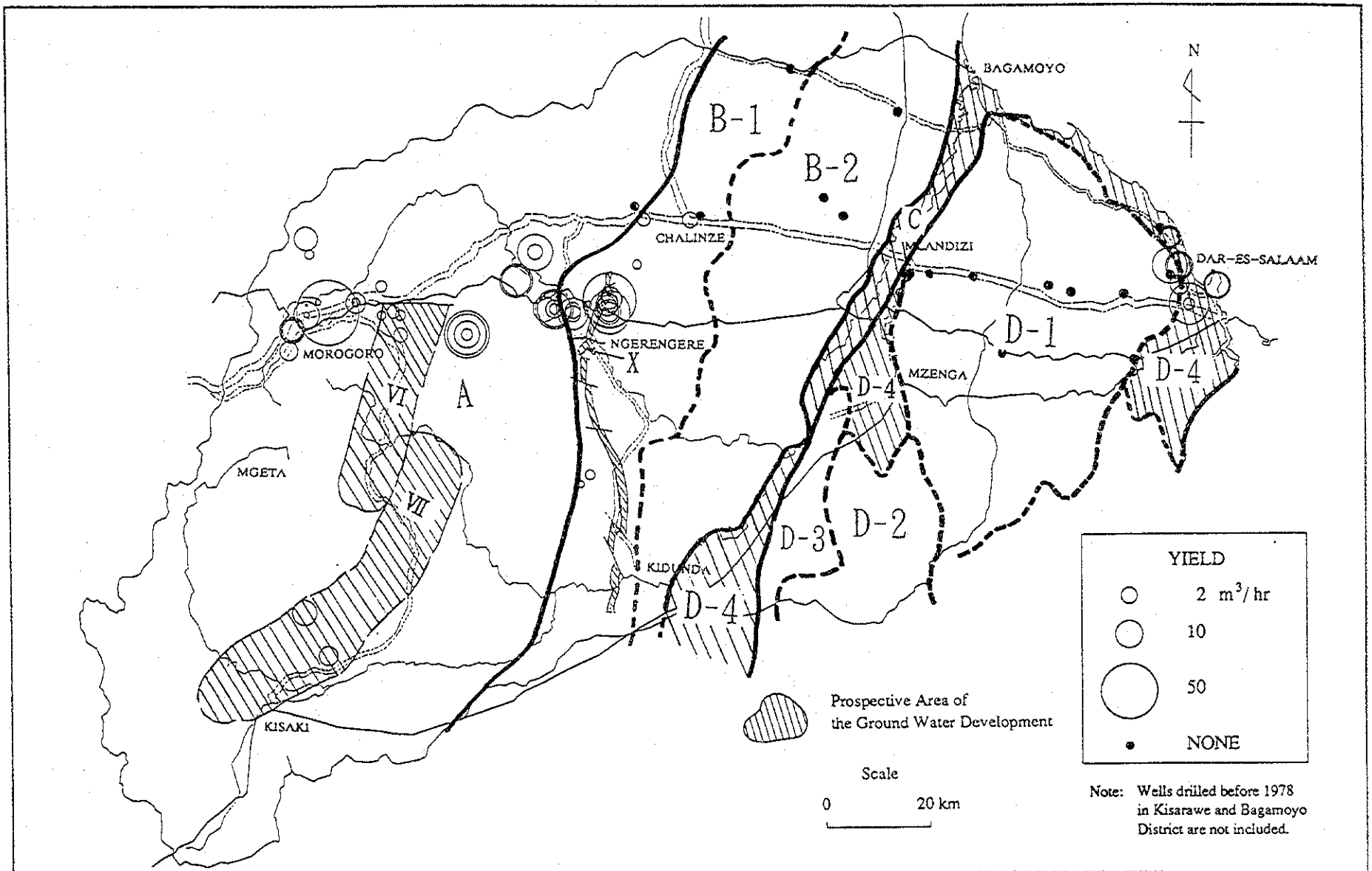


Fig. B.16 LOCATION OF PROSPECTIVE AREA FOR GROUND WATER DEVELOPMENT

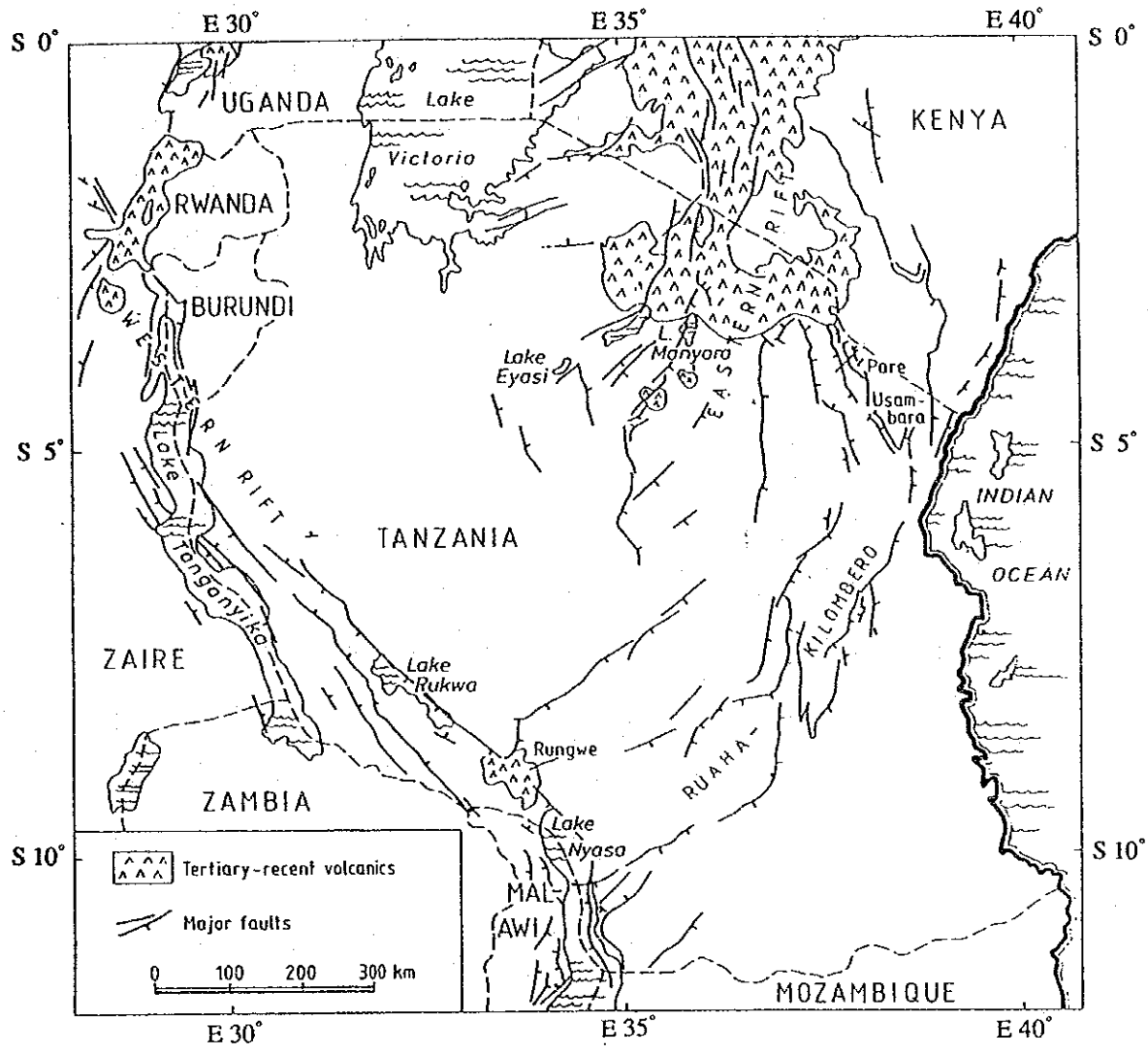


Fig. B.17 EAST AFRICAN RIFT SYSTEM OF TANZANIA

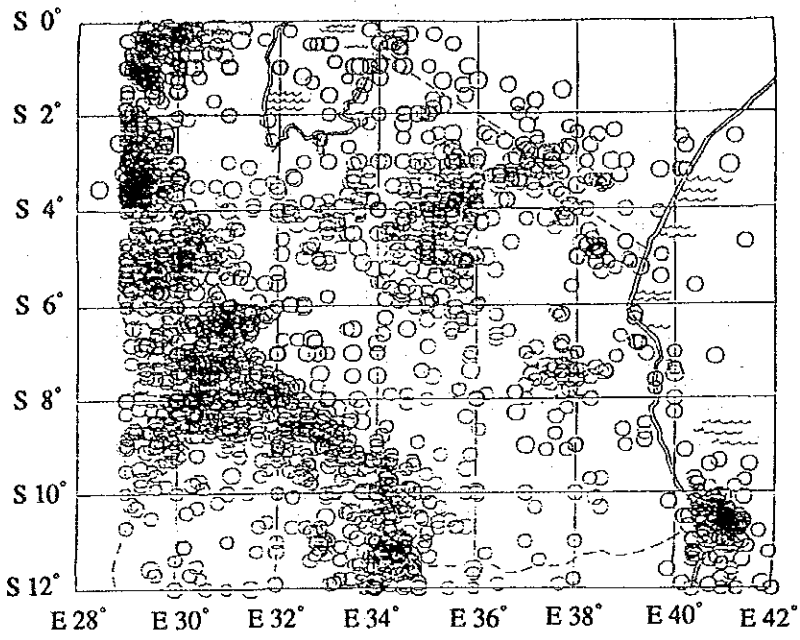


Fig. B.18 SPATIAL DISTRIBUTION OF EARTHQUAKE EPICENTERS

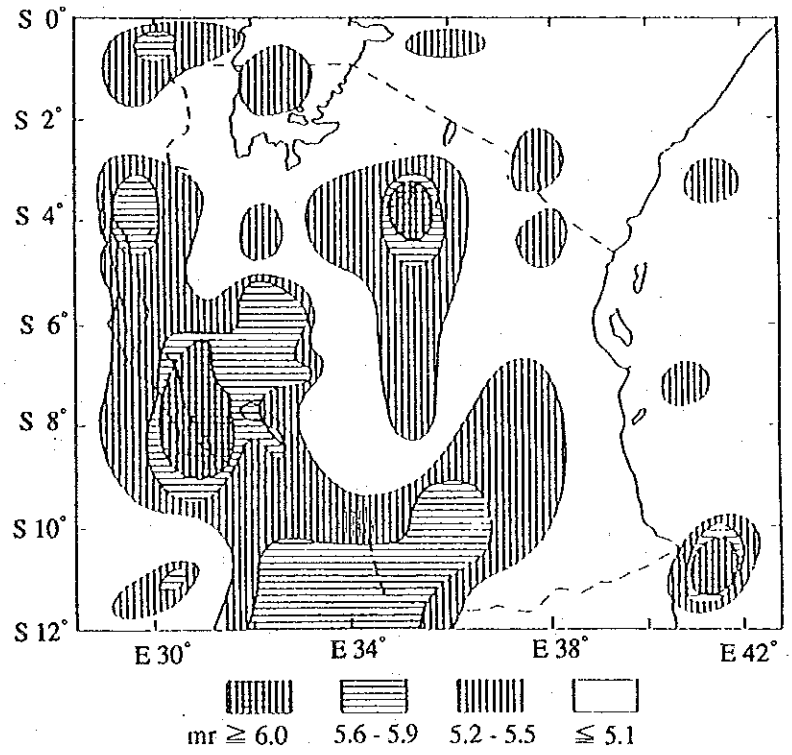


Fig. B.19 ENERGY MAP OF TANZANIA

APPENDIX-C

HYDROLOGY

APPENDIX - C

HYDROLOGY

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HYDROLOGY

1 INTRODUCTION

1.1 Objective of the Hydrological Study

The main objective of the hydrological study is to clarify the hydrological condition in the Ruvu River basin for the Study on Water Resources Development therein (hereinafter refer to as "the Study").

In the Phase 1 Field Work, the existing meteo-hydrological data and information were collected. The field investigation was also carried out. In the Phase 1 Home Office Work, preliminary low and high flow analyses on the basin were carried out based on the meteo-hydrological data collected.

The results of the preliminary analyses were checked in the Phase 2 Field Work and a more detailed analyses were made. All the results of the analyses were checked and incorporated in the Final Report including the Data Book were prepared in the Phase 2 Home Office Work.

1.2 Summary of Field Work

The works carried out during the Phase 1 and 2 Field Works are summarized below:

- Data collection	Monthly rainfall	(66 Stations)
	Daily rainfall	(19 Stations)
	Meteorological data	(4 Stations)
	Hydrological data	(11 Stations)
- Installation of automatic water level recorder		(5 Stations)
- Discharge measurement		(6 Stations)
- Data analysis and Preparation of Simple Database		
- Other field investigation		

1.3 Summary of Home Office Work

(1) Summary of Meteorology

The climate of the Study Area can be classified as the tropical savanna type. While rainfall occurs throughout the year in the Study Area, it is extremely variable and undependable. The mean monthly rainfall is higher during the period of November to May than that of June to October and these periods are generally referred to as the wet season and dry season, respectively. In the north-eastern part of the Study Area, the mean monthly rainfall during March to May is higher than that of November to December.

Annual rainfall at low land and hilly districts varies from 800 to 1,000 mm and at the Uluguru Mountains' foot it varies widely from 1,000 to 2,000 mm. An annual rainfall of more than 2,000 mm occurs in the high mountainous area.

The meteorological parameters of the Study Area are summarized below:

Annual rainfall	1,080 mm
Mean temperature	26°C
Average maximum temperature	30°C
Average minimum temperature	20°C
Relative humidity	62%
Wind velocity	1.4 m/s
Sunshine	7 hrs/day
Potential evaporation	1,800 mm

(2) Summary of Hydrology

There are 66 rainfall gauging stations available for the Study in and around the Ruvu River basin. Considering the location and the data availability of those stations, 19 stations were selected for the Study. Using monthly rainfall data of the 19 stations selected and the Thiessen Polygon method, the total average rainfall in the Ruvu River basin was estimated as shown below;

Mean Rainfall in the Ruvu River Basin (mm)

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Rainfall	112	96	171	232	119	28	16	18	29	58	97	109	1,081

From the results of the hydrological analysis, an annual runoff depth of 125 mm was estimated for the Ruvu River basin. Therefore an amount of more or less 12 % of rainfall is expected to result in surface runoff.

2. FIELD WORK

2.1 Data Collection

(1) Rainfall data

The rainfall data related to the Study Area are available at 66 rainfall gauging stations in and around the Ruvu River basin, which are shown in Table C.1 and Fig. C.1. The monthly rainfall data at these stations were collected from the Directorate of Meteorology (hereinafter referred to as "DOM"). Considering the data availability and the location, 19 stations were selected for the hydrological analysis. The daily rainfall data of these 19 stations were collected.

(2) Meteorological data

Meteorological data are available at the following 4 meteorological stations in and around the Ruvu River basin as listed in Table C.2. The daily meteorological parameters were collected for all stations except Mikula.

- Morogoro Meteorological Station (DOM 9637076)
- Kibaha Farmers (DOM 9638027)
- Mikula (monthly data only are available, MWEM)
- Experimental Farm, Bagamoyo Irrigation Development Project (JICA)

(3) Hydrological data

a. River water level

There are more than 20 stream gauging stations in the Ruvu River basin. Considering their location and scale of the catchment area, 11 gauging stations with a catchment area of more than 100 km2 were selected for the Study as shown in Table C.3 and Fig. C.1. The mean daily water level was observed at these 11 stream gauging stations.

b. Discharge measurement and river section data

The discharge measurement and river section data at the aforementioned 11 stream gauging stations were collected for calibration of the stage-discharge rating (H-Q) curve.

Totally 10 culverts are installed on the right bank of the Ruvu Bridge (1H8). When water level is high, some amount of discharge flowing through the culverts could be observed. There are a few discharge data at the culverts, which were measured for the period from 1960 to 1964. Besides, the Study Team found the report on the culvert discharge written by C.H.L. Moller in 1968. These data and report were collected during the field works. The section and elevation of these culverts were checked in the Phase 1 Field Work.

c. Discharge data

The following publications which compile a series of discharge data were collected from the MWEM office.

- Hydrological Year-Book 1965-1970
- Hydrological Year-Book 1971-1980

The Year-Books mentioned above cover the whole stream gauging stations in Tanzania, including the mean daily discharge data at the 5 stations located in the Study Area (1H5, 1H8, 1H10, 1HA8 and 1HB2).

d. Sediment data

Suspended sediment data were collected at the following sites :

Site	Observation Period	Catchment Area
1H8 Morogoro Road Bridge	from 1958 to 1986	15,190 km^2
1H10 Mikula	from 1970 to 1977	5,870 km^2
Kikundi River(DHV)	from 1978 to 1979	4.4 km^2

2.2 Field Investigation

The field investigation was carried out to confirm the stream condition. In the Phase I Field Work (rainy season), the maximum high water level at the Ruvu Bridge (1H8) was observed to be more than 8 m at the end of April and approximately 850 m^3/sec of flood discharge was estimated to flow down. This river discharge was one of the major floods in the latest 30 years.

Most of retarding areas with an altitude of 80 to 120 m in altitude were inundated by the flood water for 2 or 3 weeks. From the hearing survey it is observed that the flood occurs almost in in April and May every year and brings about a big problem for the local transportation in these areas.

In the Phase II Field Work (dry season), the minimum low water level at 1H8 was observed at 1.20 m at the end of October and approximately 9.5 m^3/sec of river discharge was estimated. This river discharge was about less than the mean minimum river discharge of October by 1m^3/sec.

There was no river flow in most of the tributaries which flow into the Ruvu River except the Mgeta River, Ngerengere River and the tributaries which originate from the Uluguru Mountains. Especially, the tributaries in the lower Ruvu were completely dry, even in the Mbiki and Mkombezi Rivers with a catchment area of more than 800 km^2. According to the hearing survey, there is no river flow in these tributaries for the period from July to October.

There are two routes of the Ruvu River in the lower part of the Ruvu Bridge as shown in Fig. C.1. In the rainy season, the river flow is diverted approximately 7 km downstream of the bridge. These rivers join approximately 2 km downstream of the existing NUWA's Lower Ruvu intake weir. According to the field investigation, the Ruvu River mostly takes the right side route and in the dry season, the river flow is not diverted and all the river discharge from upper stream flows down to the right side river route. It was roughly estimated that the river flow will start to divert when the river discharge is around 150 m^3/sec.

2.3 Discharge Measurement

Discharge measurement was carried out by the Study Team during the Phase 1 and 2 Field Works. The locations of the measurement are shown in Fig. C.1 and the results are shown in Table C.5.

2.4 Installation of Automatic Water Level Recorder

Automatic water level recorders were installed at 6 places on the Ruvu mainstream and its tributaries to clarify the runoff characteristics of the Ruvu River basin. The new installation

sites were determined considering the location of existing gauges and their present operational conditions, stabilization of river channel, accessibility to the site for operation and maintenance, etc.

As a result of the site investigation and mutual discussion between MWEM and the Study Team, the automatic water level recorders were installed at the following 6 stations and their locations are shown in Table C.4 and Fig. C.1

- 1H8 Ruvu Bridge (reinstalled by MWEM)
- Mafisi Mafisi (newly installed by the Study Team)
- 1H3 Kidunda (newly installed by the Study Team)
- 1H5 Kibungo (reinstalled by the Study Team)
- 1HA1A Utari Bridge (newly installed by the Study Team)
- Dutumi Dutumi (newly installed by the Study Team)

2.5 Establishment of Simple Data Base

All the meteorological and hydrological data collected during the Phase I and II Field Works, and the results of the hydrological analysis were installed in the computer procured by JICA. A simple data base system was established using the software "Lotus 123".

The simple database developed is summarized as below:

Data	Directory
Monthly Rainfall Data (66 Stations)	C:\RAINM1
Daily Rainfall Data (19 Stations)	C:\RAIND
Other Meteorological Data (4 Stations)	C:\METEO1
Hydrological Data	
Water Level Data	C:\WATERL
Discharge Measurement Data and Rating Curve	C:\HQ
River Discharge	C:\DISCHARG
Sediment Data and Analysis	C:\SEDIMENT
Low Flow Analysis	C:\TANK1
High Flow Analysis	C:\STFUNK1

3. AVAILABILITY OF METEO-HYDROLOGICAL DATA

3.1 Meteorological Data

The meteorological stations in and around the Study Area, which include rainfall stations, are operated by DOM, MWEM and agricultural institutions. All are registered by DOM from which all rainfall data are obtainable in daily and monthly form.