THE UNITED REPUBLIC OF TANZANIA

FEASIBILITY STUDY ON KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

FINAL REPORT

SUMMARY

OCTOBER, 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

THE UNITED REPUBLIC OF TANZANIA

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FINAL REPORT

SUMMARY

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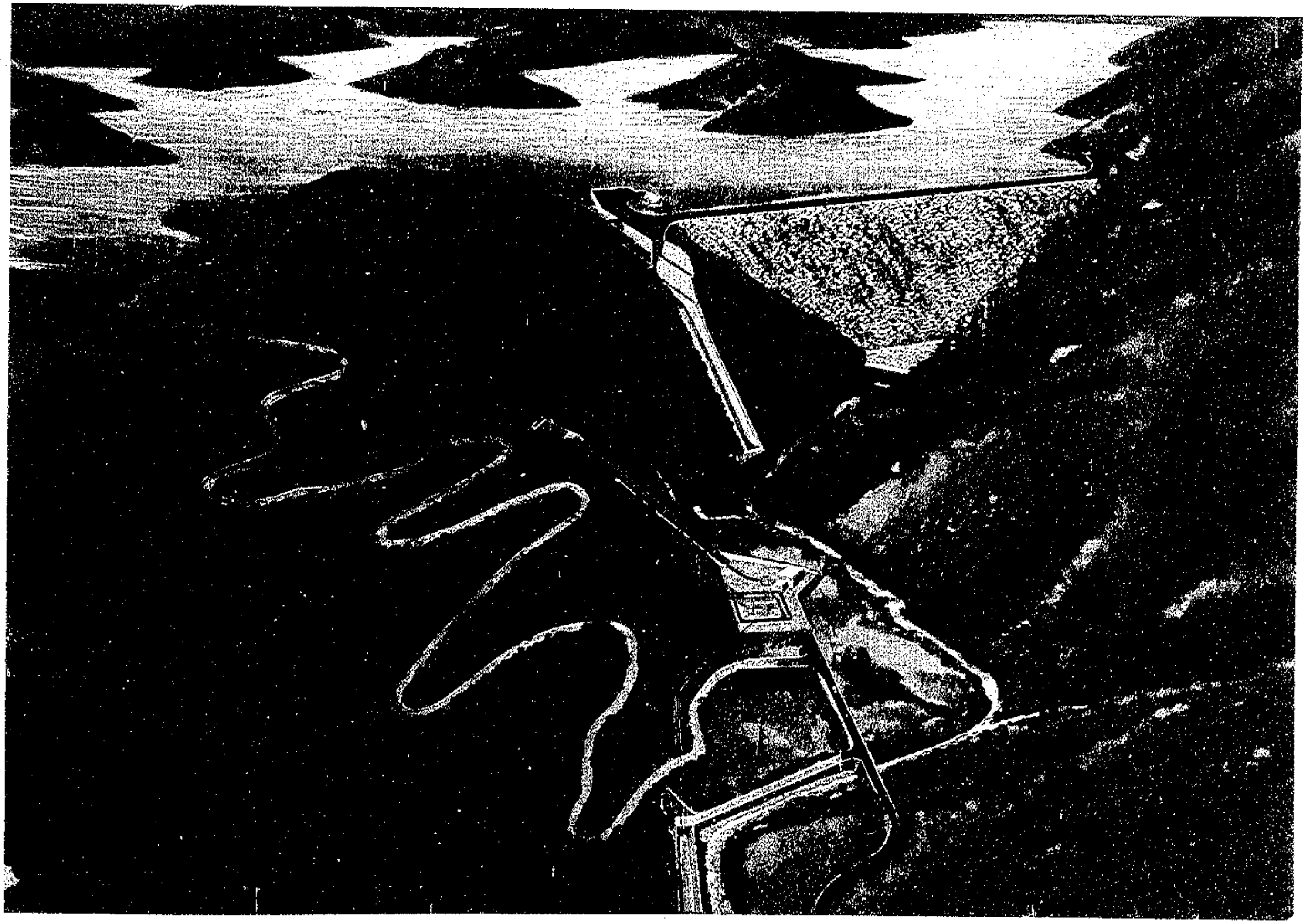
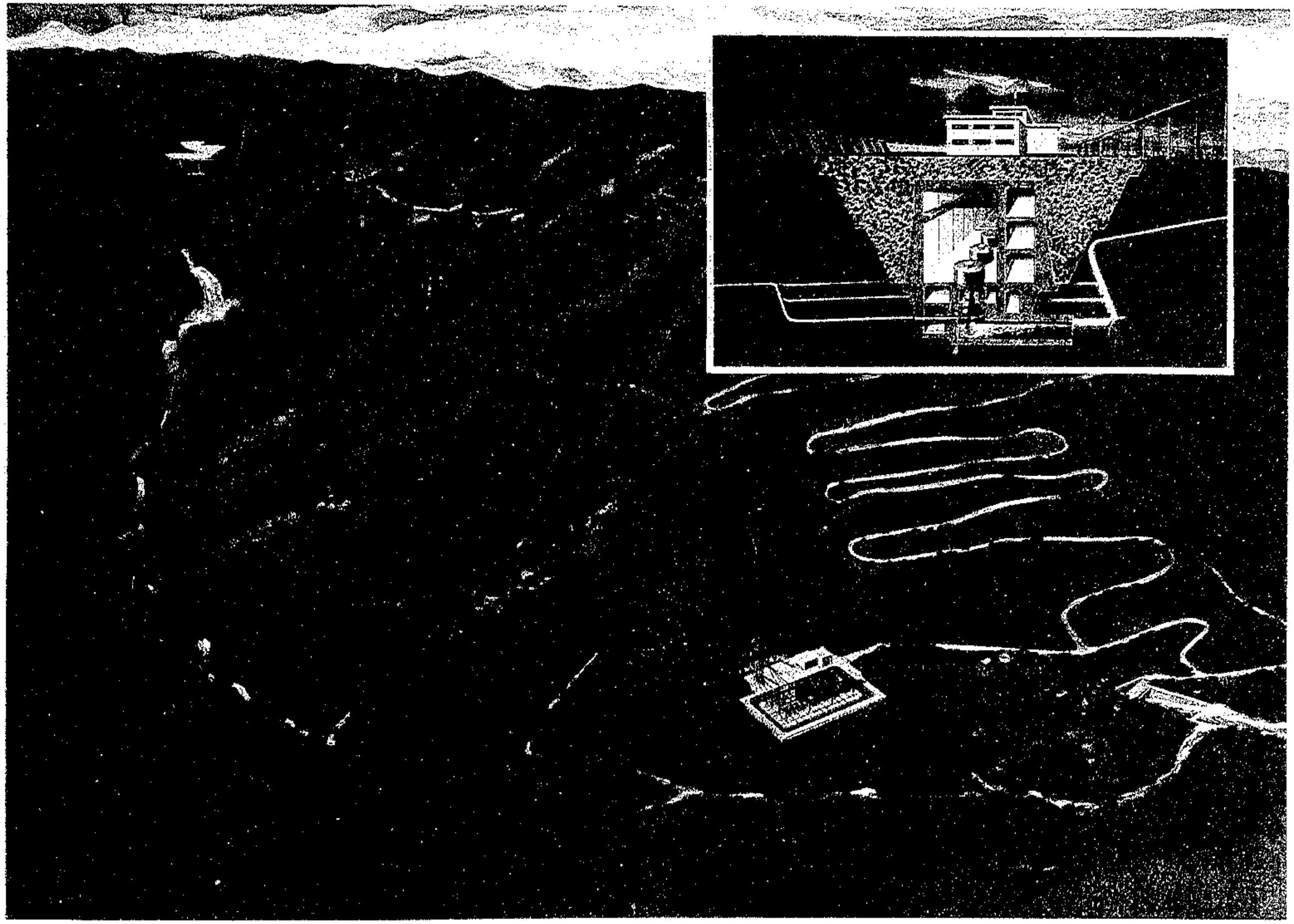


Upper Kihansi Project

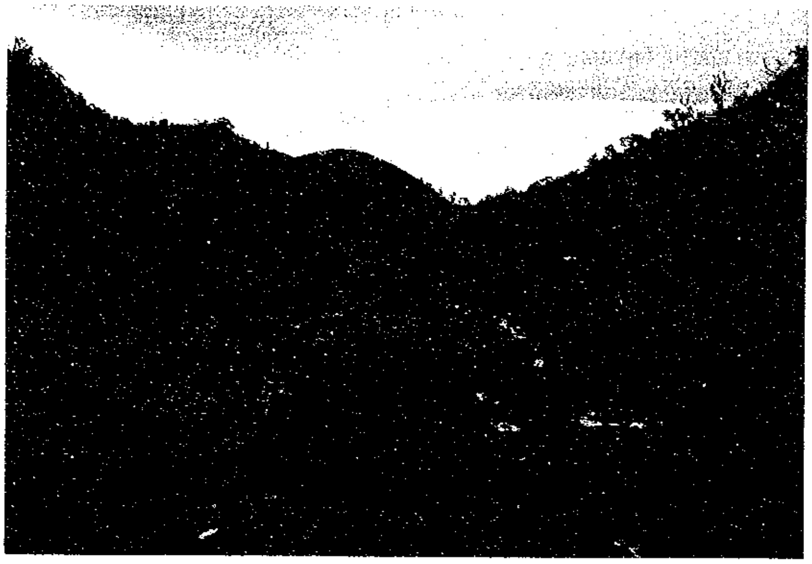


Lower Kihansi Project

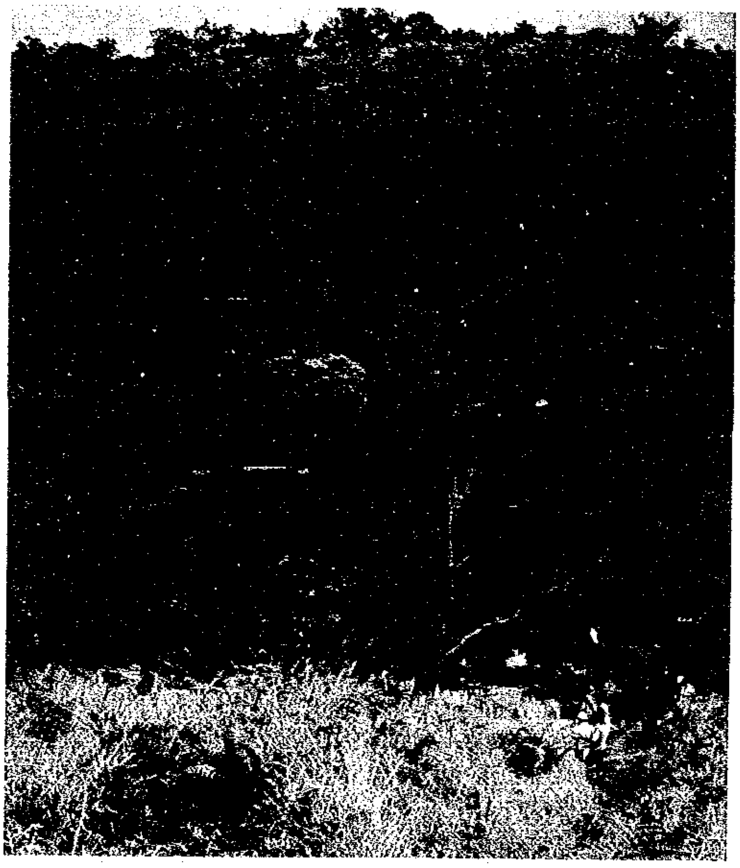
Upper Dam Site
View from the upstream left bank

Cascade of Kihansi River Between Upper Dam and Powerhouse

Upper Powerhouse and Tailrace Sites
View from the site of the upper part of penstock

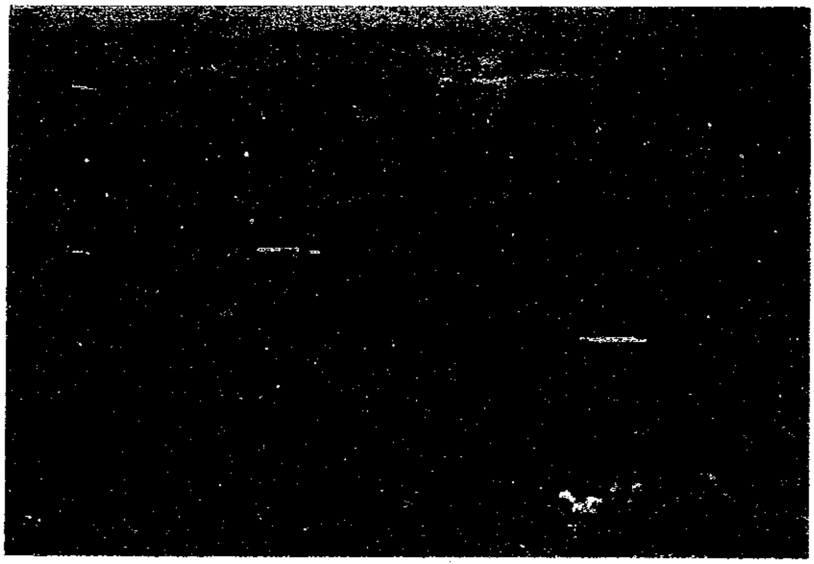


Lower Dam Site
View from the upstream left bank

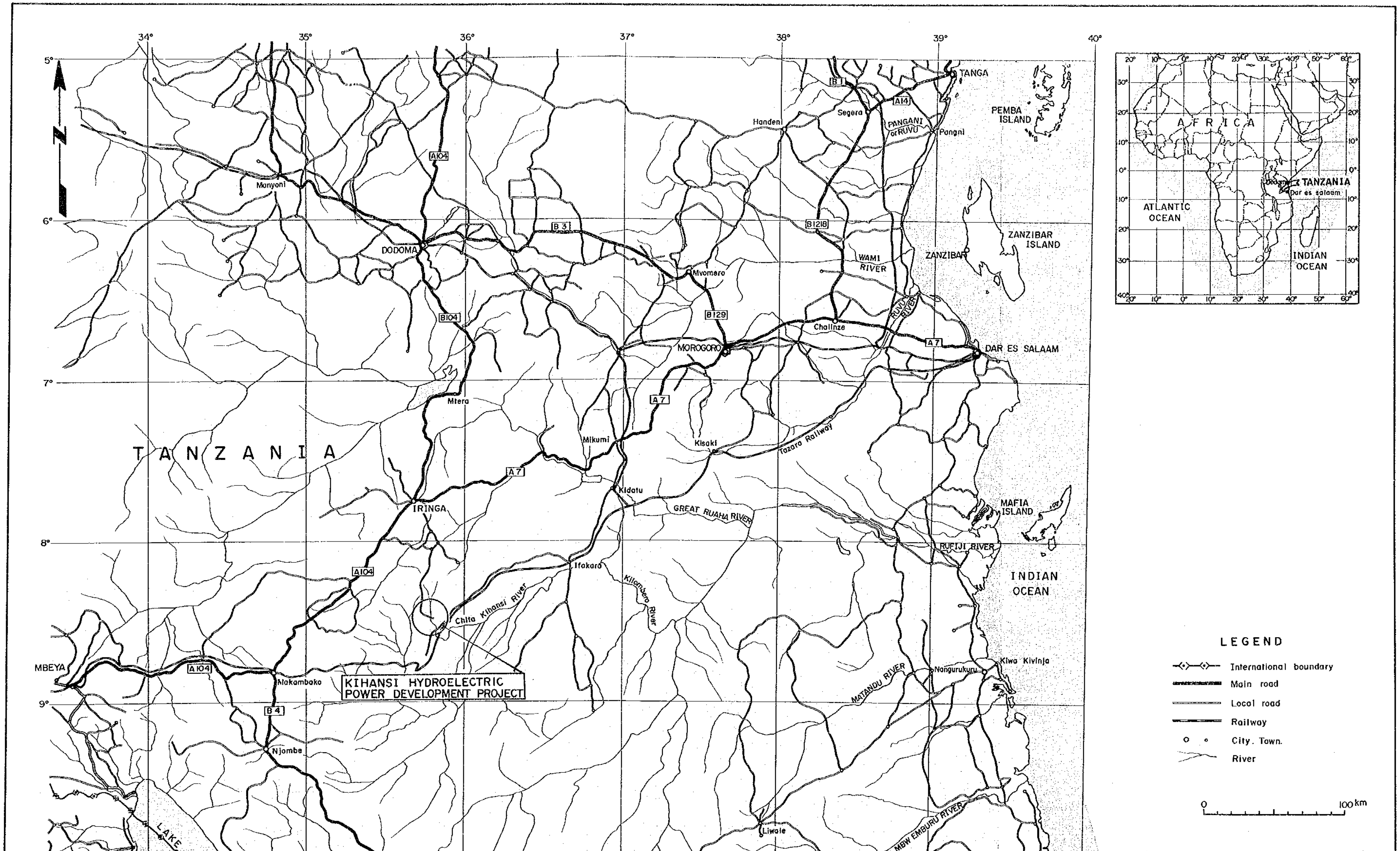


Lower Dam Axis
View from the high water level of left bank

Kihansi Fall
View from the downstream left bank



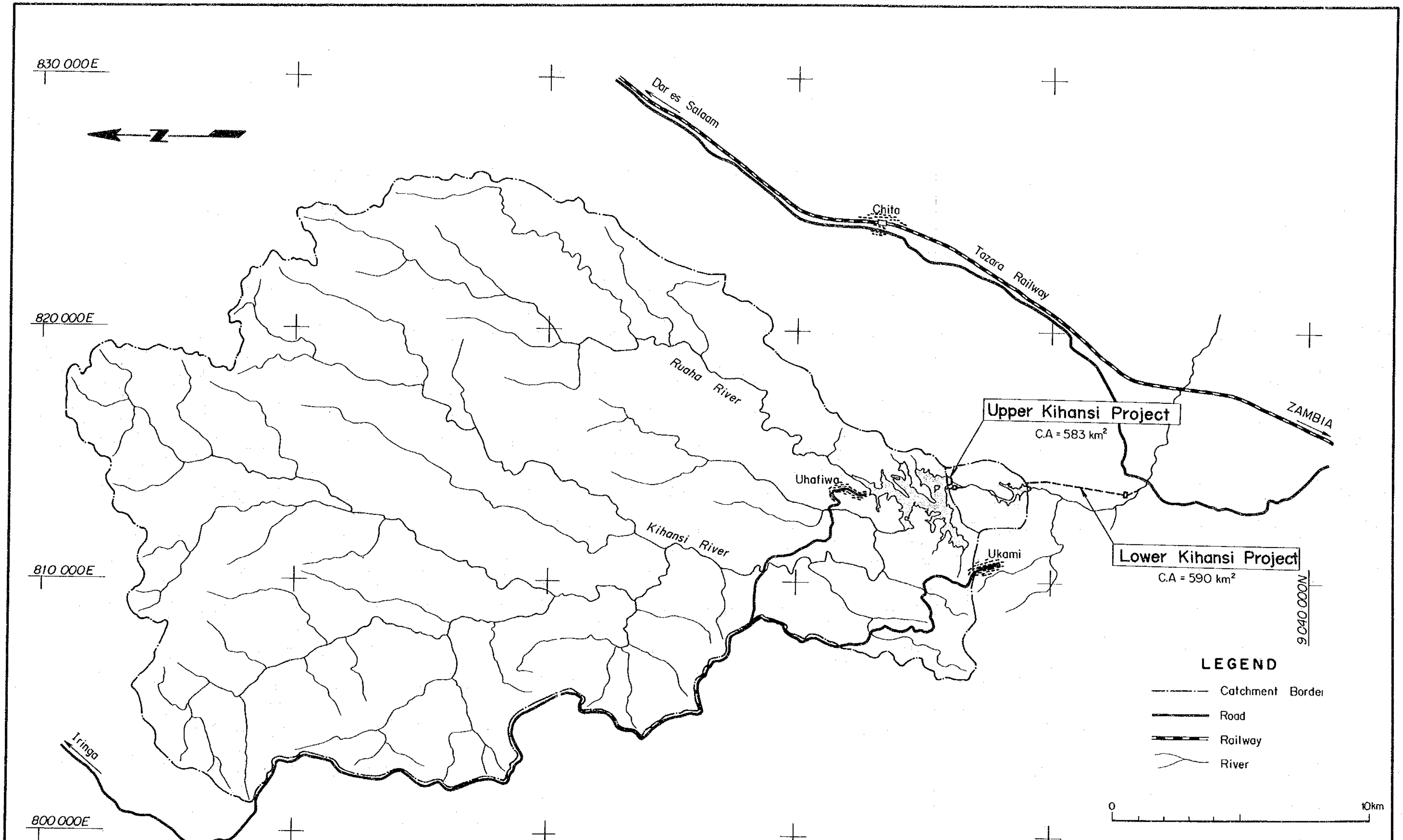
Lower Powerhouse and Tailrace Sites
View from the site of the upper part of penstock



KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

KEY AND LOCATION MAP

Fig. DATE;



KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

GENERAL PLAN OF KIHANSI RIVER

Fig.

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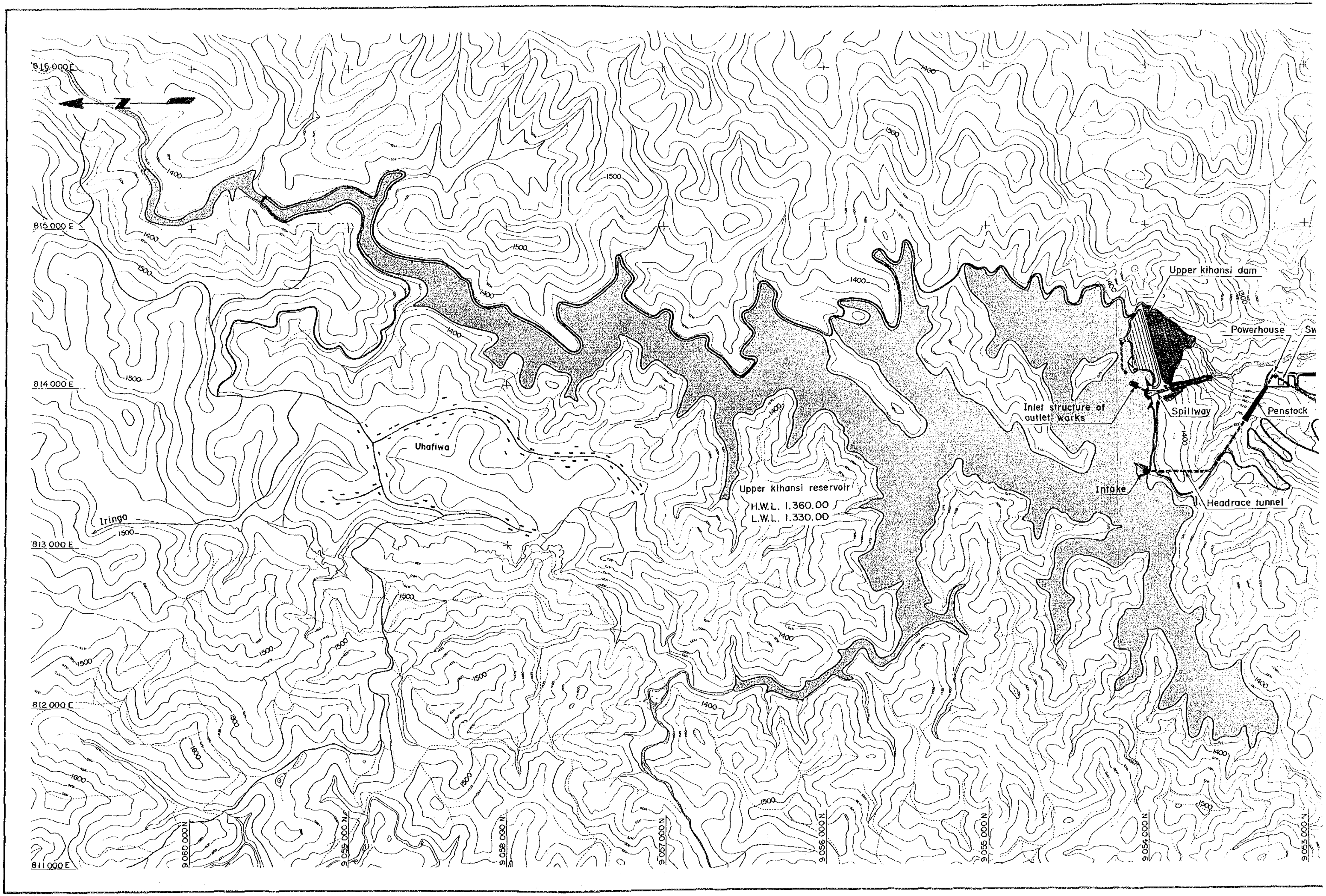

Upper kihansi dam
Powerhouse
Inlet structure of outlet works
Spillway
Penstock
Intake
Headrace tunnel
Upper kihansi reservoir
H.W.L. 1.360.00
L.W.L. 1.330.00
Uhafiwa
Iringa
816 000 E
815 000 E
814 000 E
813 000 E
812 000 E
811 000 E
9.060 000 N
9.059 000 N
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9.057 000 N
9.056 000 N
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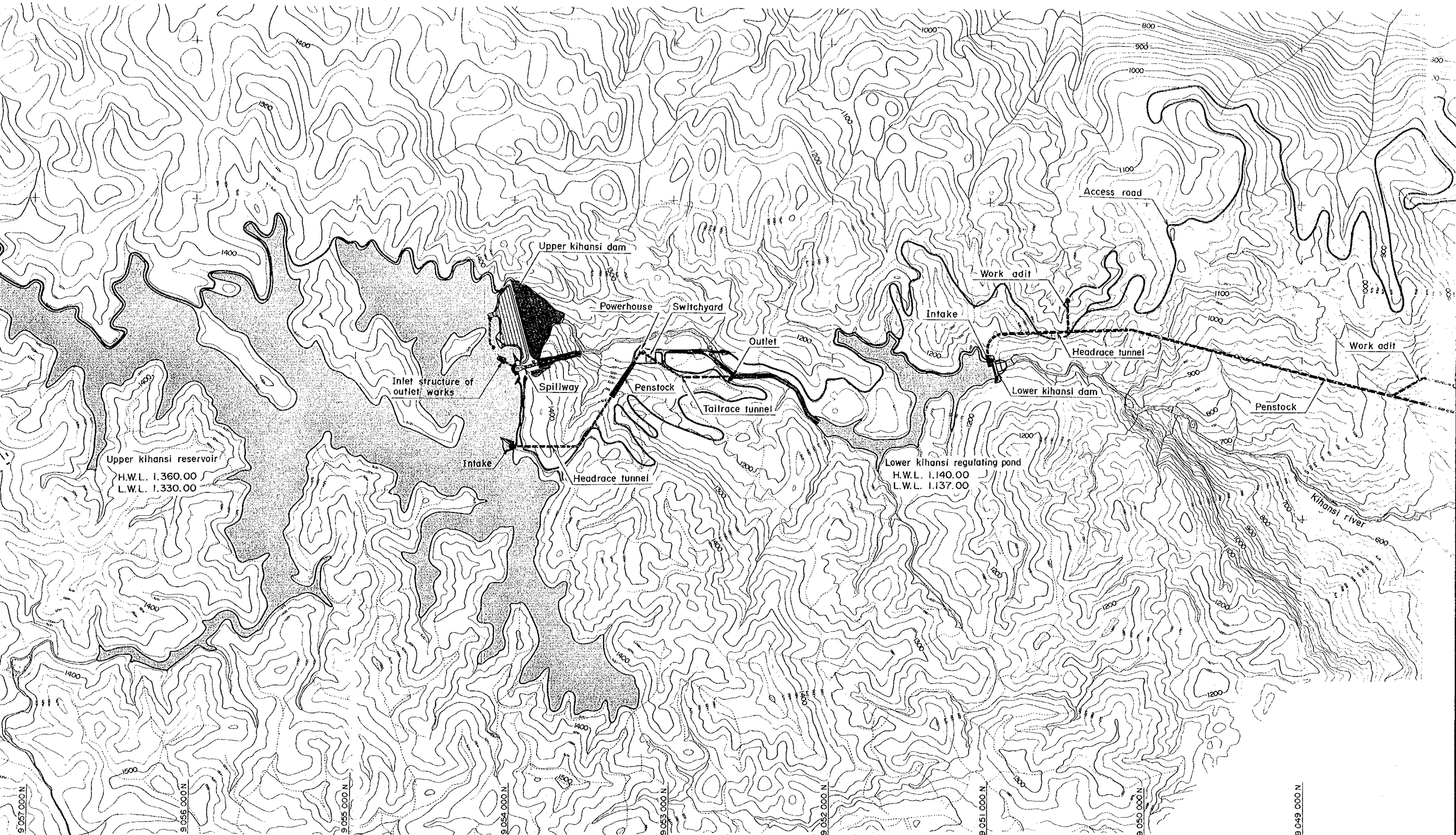
9.054 000 N
9.053 000 N



Upper kihansi dam
Powerhouse
Switchyard
Outlet
Intake
Work adit
Access road
Headrace tunnel
Work adit
Inlet structure of outlet works
Spillway
Penstock
Tailrace tunnel
Lower kihansi dam
Penstock
Upper kihansi reservoir
H.W.L. 1.360.00
L.W.L. 1.330.00
Intake
Headrace tunnel
Lower kihansi regulating pond
H.W.L. 1.140.00
L.W.L. 1.137.00
Kihansi river
9.057.000 N
9.056.000 N
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9.054.000 N
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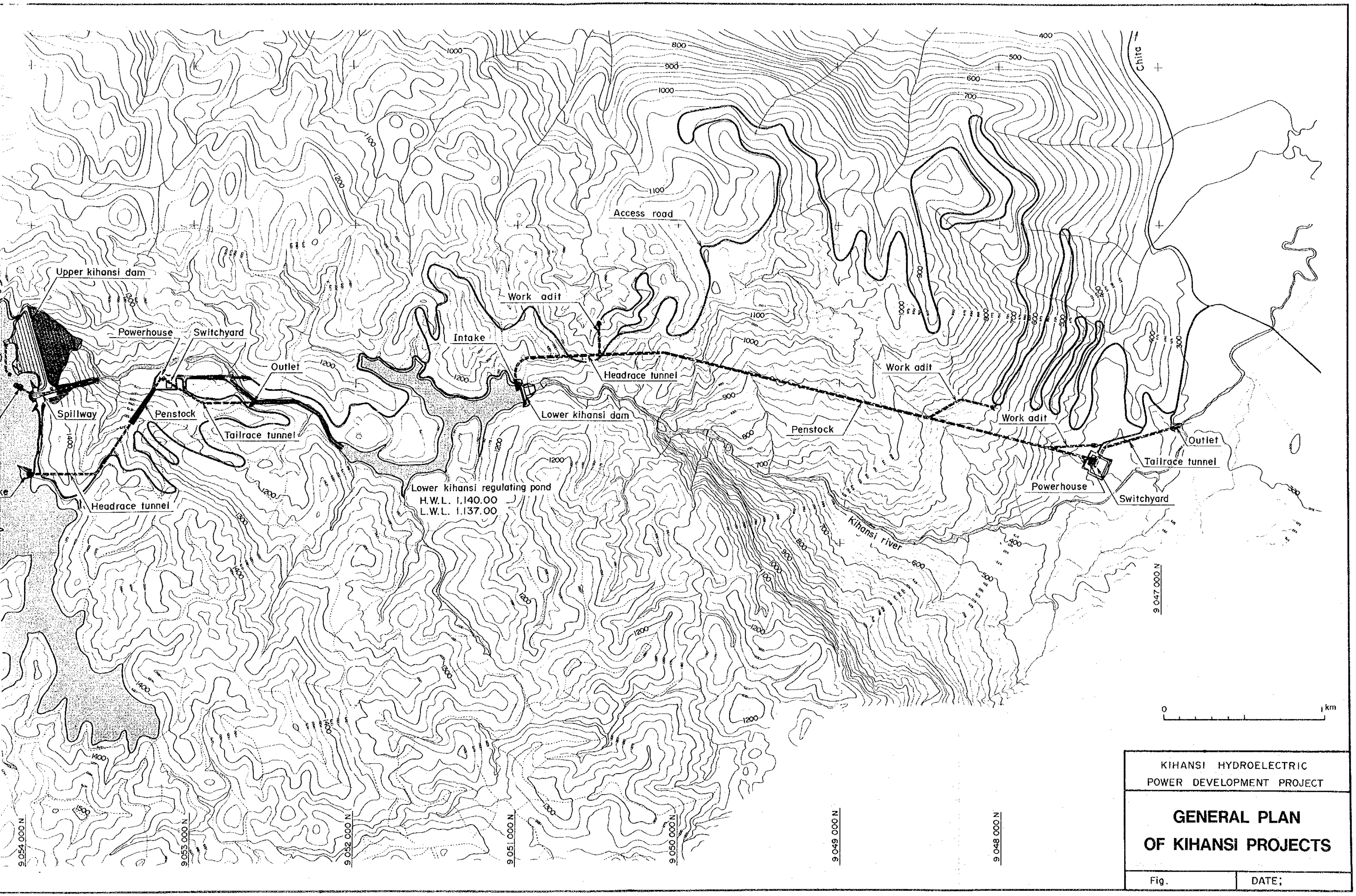


KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

GENERAL PLAN OF KIHANSI PROJECTS

Fig. | DATE;

CONTENTS

Chapter 1 INTRODUCTION

1.1 Antecedents

Tanzania suspended the 4th 5-Year Economic Development Plan (1981 - 1985) and is restructuring its economy by formulating National Economic Saving Program (NESP) and Structural Adjustment Program in 1986 as well as Economic Recover Program (ERP) in 1986.

According to a long term power demand forecast prepared by Tanzania Electric Supply Company Limited (TANESCO), the demand of electricity will increase by some 5% from 1992, when a symptom of economic recovery by ERR executed from 1987 will appear.

Tanzania is endowed with energy resources for power generation such as coal, natural gas, hydroelectric potentials. Among these resources, TANESCO basically puts emphasis on development of hydroelectric energy. In order to meet demand of electricity in mid 1990's, hydroelectric power development on Kihansi River is recommended as a most appropriate project in "Master Plan" prepared by Norconsult (Norway) and "Power Development Plan 1985 - 2010" prepared by ACRES (Canada).

Kihansi hydroelectric power development scheme is located on the middle part of Kihansi River, a tributary of Rufiji River, approximately 450 km south-west of Dar Es Salaam.

The project consists of Upper Kihansi scheme (with a reservoir which can regulate totally the annual inflow), Lower Kihansi scheme (with a regulating reservoir downstream Upper Kihansi), and Transmission Line scheme (interconnecting Lower Kihansi - Upper Kihansi - Iringa

Substation). Total installed capacity of the project will be 200 MW.

In October 1987, Government of Tanzania requested Japan to implement feasibility study on Kihansi Hydroelectric Power Development Project, contemplating the completion of Lower Kihansi Project by 1995 and Upper Kihansi Project by 1997, so as to meet the increasing electric power demand of the country.

And that Tanzania requested again the immediate implementation of the Project during discussion with JICA mission for Project Selection Confirmation dispatched in November 1987.

Responding to this request, JICA dispatched Scope of Work mission in October 1988 to carry out field investigation and discussion with TANESCO and confirmed that feasibility study should be implemented. Thus Scope of Work was concluded between TANESCO and JICA on October 20, 1988.

1.2 Purpose and Scope of Work

Kihansi Hydroelectric Power Project is recommended as a project which should be implemented immediately in the Master Plan Study and Power Development Plan conducted by Norway and Canada respectively. Main purpose of the study is to prepare feasibility report by examining feasibility of the Project from technical, economical and environmental points of view, based on evaluating existing data and field reconnaissance. Another purpose is to transfer technology the counterpart engineers through implementation of the study.

JICA commenced its work in February 1989 based on 'the Scope of Work'.

JICA has sent the Study Team to the Republic of Tanzania and submitted reports as follows:

First Field Reconnaissance	:	February 15 - March 31, 1989
Inception Report	:	March 1989
Second Field Reconneissance	:	June 1 - June 30, 1989
First Progress Report	:	June 1989
Third Field Reconneissance (Geology)	:	August 1 - November 30, 1989
" (Environment)	:	August 1 - September 29, 1989
Second Progress Report	:	October 1989
Reporting of Progress	:	December 1 - December 15, 1989
Third Progress Report	:	December 1989
Explanation on Interim Report	:	February 19 - March 5, 1990
Interim Report	:	February 1990
Explanation on Final Draft Report	:	September 2 - September 16, 1990
Final Draft Report	:	September 1990

During the above mentioned period, the following field study, investigation works and laboratory test were carried out by the JICA Study Team and TANESCO:

(1) Topography

Establishment of aerophotographic marks and benchmarks		19	points
Levelling		60	km
Aero photography	1 : 30,000	110	km^2
"	1 : 7,000	22	km^2
Mapping	1 : 5,000	16.5	km^2
"	1 : 1,000	1.5	km^2

(2) Geological Investigation Work

Drilling (including permeability test)	8 holes	230 m
" (material test)	2 holes	40 m
Seismic Prospecting	2 lines	105 m
Test Pitting	4 pits	6.8 m
Laboratory Test		27 samples

(3) Other studies

Installation of runoff gauging station	one (1) set
Runoff measurement	weekly (1 year) monthly (continuing)
Water quality	anytime (continuing)

1.3 Features of the Project

The Kihansi Hydroelectric Power Development Project consists of an Upper Kihansi Project located at the midstream stretch of the Kihansi River in the Rufiji River System, a project at a site for dam-type power generation with a reservoir capable of complete regulation of the annual inflow of a catchment area of 583 km^2, a Lower Kihansi Project downstream for waterway-type power generation with a regulating reservoir, and a power transmission line project to Iringa Substation. This Kihansi River rises from a hill area south of Iringa and the river channel meanders gently down to the Upper Kihansi Project site, but downstream of the dam, the river gradient abruptly changes to that of a swift stream, and in spite of the fact that the outlet point of Lower Kihansi Power Station is reached with a horizontal distance of 5 km, the river channel is so steep that the head is as much as 1,000 m.

Although annual rainfall ranges widely between 1,000 mm and 1,800 mm, this is a high-rain area with distinct rainy and dry seasons. However, the flow-duration curve of the project site indicates an extremely even shape and effects of the dry season are not prominent. In other words, contrasted to an annual average discharge of 15.9 m^3/s, the firm discharge (95%) is 11.8 m^3/s.

Consequently, the runoff regulation to be done in the Upper Project is for complete regulation with a small reservoir capacity of 75 x 10^6 m^3, and all of the runoff can be made effective.

Meanwhile, there are approximately 3,400 people living along ridges of hill areas in the vicinity of the project site engaged in subsistence farming based on slash-and-burn agriculture.

The slash-and-burn farmland to be submerged in the reservoir area as a result of this Project is a few and no resident exists, while there is nothing else at all, such as roads, public buildings, etc., requiring compansation.

The basement rocks comprising the geology of the river basin are Precambrian gneisses, and these are widely distributed. The geological structure has dykes running predominantly in the northeast-southwest direction, but prominent faults are not seen. However, at parts of high elevation, rain forest soils and laterite soils overlie the basement rocks, and these go down to depths of as much as 30 m in places.

The development program based on these conditions, considered from a physical development schedule, is for start-up of the Lower Kihansi Project to be in 1996, and that of the Upper Kihansi Project in 1999.

These timings can even be said to be almost too late considered on the basis of the power demand forecast, and it is desirable for the Kihansi Hydroelectric Power Development Project to start operation at an early stage as much as possible. It may be expected that the development of the Kihansi power generation project will contribute greatly to economic development in the project area.

Chapter 2 RESULTS OF EXAMINATION OF BASIC DATA

2.1 Hydrology and Meteorology

(1) Dam Site Runoff

The catchment areas of the Upper Kihansi and Lower Kihansi damsites are 583 km^2 and 590 km^2, respectively.

There are the three runoff gauging stations of 1KB28, NC3, and NC1 in the Kihansi Basin. Of these, water level observations have been continued at 1KB28 (catchment area, 618 km^2) since 1975, and the runoff at the dam site after 1975 was calculated mainly through catchment area conversions from measured data of 1KB28. Regarding 1974 and before, data were prepared by the methods described below.

1) 1957-1974

At the Mpanga River adjacent on the west of the Kihansi, there have been water level observations made at 1KB8 Gauging Station since 1957, and as the correlation with 1KB28 is good, the runoff of the 1KB28 site was calculated from the 1KB8 runoff by a regression equation.

2) 1927-1956

It has been confirmed through various meteorological data and literature that the general area of East Africa before 1955, compared with after that year, had tended to be droughty. To be able to set appropriate reservoir scales and reservoir operation rules, pre-1955 data observed at Ifakara since 1927 were converted to runoff by the tank model method.

The monthly runoff data for the Upper Kihansi and Lower Kihansi dam sites are given in Tables 1 and 2.

(2) Design Flood Discharge

Since runoff data sufficient for calculating statistic probability values were not available on the Kihansi and neighboring river basins, and in view of the importance of the Kihansi Project for the Tanzanian economy and society, and of the fact that Upper Kihansi Dam is to be a large scale dam of a height about 100 m, PMF techniques were adopted for calculating the design flood discharge, and 400 m^3/s was adopted for both Upper Kihansi Dam and Lower Kihansi Dam. Further, the flood discharge needed for care of river flow during construction was calculated by probability techniques and, for Upper Kihansi Dam, which is to be a rockfill type, the 20-year return period value of 90 m^3/sec was adopted, while for Lower Kihansi Dam, which is to be of concrete gravity type, the 5-year return period value of 80 m^3/sec was adopted.

(3) Sedimentation

For estimates of sedimentation, suspended load measurement data of the Kihansi River and data of neighboring rivers were used, with bed load and reservoir trapping effects taken into account, and the values for the project sites 50 years after construction of the dams were adopted. The results are as follows:

Upper Kihansi Dam	
sedimentation volume	750 x $10^3 m^3$
sedimentation level	1,300.00 m
Lower Kihansi Dam	
sedimentation volume	125 x $10^3 m^3$
sedimentation level	1,125.00 m

Table 1 Monthly Discharge at Upper Dam

(Unit: m^3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	average
1927	16.14	10.01	12.36	15.47	11.83	10.69	9.77	9.08	8.60	8.16	7.75	10.85	10.91
1928	8.76	9.26	18.57	18.57	14.47	11.34	10.31	9.39	9.06	8.90	9.04	11.73	11.62
1929	9.12	8.23	12.52	26.73	11.64	10.25	9.22	8.45	7.92	7.44	7.09	7.53	10.50
1930	11.51	8.91	24.37	27.48	14.36	12.47	10.91	9.70	8.88	8.26	7.68	7.10	12.65
1931	9.87	14.28	29.32	38.93	22.53	16.35	14.08	12.27	10.88	9.74	8.88	9.74	16.40
1932	14.76	20.78	27.10	41.42	19.01	15.74	13.70	12.12	10.79	9.74	9.32	9.22	16.93
1933	16.94	18.68	22.01	26.43	16.59	13.97	12.26	10.99	9.94	9.08	8.42	7.85	14.40
1934	18.38	12.65	13.09	19.51	17.07	16.19	13.34	12.00	10.90	9.86	8.92	11.74	13.64
1935	14.14	15.05	22.40	14.06	12.84	11.45	10.38	9.44	8.78	9.08	9.05	23.99	13.41
1936	21.57	15.97	13.53	51.74	30.34	18.24	16.02	13.87	12.23	10.91	9.79	10.66	18.71
1937	13.13	10.83	27.54	25.07	21.29	15.01	13.15	11.66	10.86	10.08	9.26	8.56	14.74
1938	7.90	8.33	8.01	15.85	10.24	9.26	8.50	7.99	7.59	8.31	8.08	7.68	8.97
1939	13.01	8.61	12.54	42.20	18.40	13.85	12.10	10.74	9.83	8.95	8.44	8.20	13.90
1940	19.75	14.58	14.07	28.75	15.24	12.68	11.15	10.08	9.20	9.22	8.33	10.24	13.59
1941	10.35	19.64	19.36	14.74	19.16	12.43	11.01	9.84	8.95	8.41	11.40	10.96	12.98
1942	18.63	11.28	25.23	34.27	20.88	15.73	13.62	11.93	10.60	9.52	8.78	12.09	16.07
1943	8.75	11.42	13.36	15.25	22.79	11.58	10.22	9.14	8.45	7.91	7.37	6.92	11.10
1944	8.86	7.28	9.70	31.27	17.13	12.41	10.91	9.71	8.75	8.06	9.27	14.06	12.27
1945	16.48	13.05	14.40	25.80	23.99	14.12	12.43	10.94	9.76	8.80	8.09	10.40	14.03
1946	8.17	7.34	9.37	35.41	14.57	11.84	10.40	9.26	8.40	7.84	7.85	7.52	11.48
1947	16.06	14.23	19.55	22.17	19.16	14.84	12.65	11.12	9.91	9.01	8.20	22.05	14.93
1948	20.44	15.13	23.41	16.37	15.51	12.61	11.14	10.05	9.09	8.40	11.03	8.06	13.44
1949	9.98	20.44	12.00	19.96	12.91	11.00	9.79	8.83	8.12	7.59	7.08	6.67	11.12
1950	6.60	8.65	22.70	19.41	19.85	12.82	11.24	9.98	9.43	8.56	7.94	7.44	12.08
1951	7.79	11.07	10.72	21.99	13.96	10.67	9.78	8.70	8.02	7.45	15.73	10.50	11.34
1952	15.68	18.56	19.48	29.01	35.73	16.48	14.11	12.21	10.74	9.58	12.72	9.02	16.92
1953	8.22	7.36	11.66	12.85	16.08	10.30	9.24	8.36	7.75	7.30	6.85	9.16	9.61
1954	12.71	9.27	9.74	12.44	11.41	9.00	8.08	7.47	7.03	6.75	6.41	6.31	8.89
1955	7.25	16.74	14.68	39.33	22.35	16.59	13.97	12.13	10.64	9.42	9.28	8.27	15.00
1956	19.28	17.14	15.45	38.87	18.65	14.85	12.88	11.27	10.01	9.00	8.19	8.35	15.29
1957	18.99	18.40	16.62	35.81	28.36	15.03	13.29	12.47	11.58	10.82	10.26	11.61	16.91
1958	13.29	14.84	26.00	38.24	23.63	14.13	12.66	12.05	11.42	10.87	10.12	15.14	16.87
1959	13.74	15.08	20.84	21.30	15.04	12.21	11.62	11.13	10.48	10.20	10.08	11.67	13.60
1960	10.50	15.00	29.31	51.44	23.52	15.07	11.22	9.70	8.61	8.69	9.52	9.83	16.83
1961	11.74	14.65	15.39	19.57	20.78	9.80	10.30	11.08	8.85	8.66	11.14	15.87	13.15
1962	35.70	33.59	38.65	40.17	27.88	18.74	16.67	14.92	11.80	12.50	11.14	12.95	22.83
1963	25.92	29.47	38.88	51.25	27.13	17.54	17.32	14.99	13.52	12.32	18.00	10.37	22.98
1964	17.66	22.44	36.50	49.89	28.85	22.15	19.10	17.42	15.13	13.39	12.44	13.99	22.39
1965	16.57	19.05	26.53	40.75	20.33	14.75	13.59	12.91	11.85	11.41	10.96	12.92	17.60
1966	16.20	17.04	30.23	43.55	22.34	16.41	13.61	13.24	12.16	7.91	7.75	8.39	17.38
1967	15.07	16.92	19.94	27.36	27.57	17.85	14.50	13.36	11.98	11.22	13.02	30.77	18.31
1968	25.68	28.91	50.08	57.83	36.72	29.10	23.42	19.71	17.33	14.89	14.91	18.74	28.08
1969	20.40	19.00	22.90	32.52	23.92	15.04	13.49	13.41	11.74	10.58	10.93	11.65	17.11
1970	20.16	30.90	29.23	26.14	16.52	13.36	12.77	11.84	10.98	9.86	8.97	17.11	17.24
1971	14.63	19.22	20.63	37.27	20.04	13.55	14.08	12.36	11.61	14.14	10.91	12.00	16.66
1972	16.88	16.35	32.64	44.81	30.04	18.43	15.77	13.37	14.09	12.65	12.25	21.90	20.77
1973	30.79	22.30	29.02	42.75	32.16	18.49	16.22	14.16	13.39	12.49	12.26	14.26	21.52
1974	19.13	26.83	17.36	43.39	39.41	20.21	16.43	13.56	13.41	12.28	11.73	9.18	20.17
1975	14.91	12.04	13.70	27.40	25.26	17.34	13.95	12.64	12.27	10.54	9.47	10.98	15.05
1976	13.72	15.11	19.90	28.36	25.53	20.58	15.75	13.80	12.12	11.00	9.66	9.27	16.23
1977	12.95	10.13	13.81	24.78	21.39	14.74	12.64	11.32	10.11	9.40	10.54	14.77	13.90
1978	14.79	13.50	17.99	27.36	23.31	15.94	12.94	11.28	10.16	9.13	11.05	13.96	15.12
1979	19.61	18.74	27.25	39.29	39.83	30.50	22.38	17.28	14.61	12.50	12.45	15.27	22.49
1980	16.12	16.24	15.43	20.41	22.59	14.70	12.96	11.66	10.47	9.65	9.36	11.08	14.22
1981	11.49	12.29	15.21	20.22	17.88	12.75	11.08	10.29	9.21	9.33	8.08	10.16	12.33
1982	8.79	10.55	11.92	19.29	23.91	13.73	11.86	10.41	9.55	10.13	10.97	15.50	13.07
1983	23.88	15.80	19.25	31.77	31.43	22.87	17.79	14.05	12.23	10.91	10.00	10.41	18.38
1984	12.03	12.46	18.89	28.51	28.42	20.44	16.18	13.36	12.08	11.18	10.61	17.58	16.82
1985	23.46	17.74	22.47	38.96	29.84	21.30	17.66	14.46	12.86	11.33	13.25	19.95	20.28
1986	23.97	25.86	25.44	41.57	37.92	28.40	21.97	18.31	14.60	12.71	15.20	21.96	23.97
1987	23.19	21.11	23.19	22.62	23.37	17.91	15.18	13.14	11.40	10.91	11.06	13.88	17.23
Ave.	15.61	15.84	20.55	30.43	22.21	15.54	13.36	11.84	10.70	9.92	10.07	12.23	15.68

Table 2 Monthly Discharge at Lower Dam

(Unit: m^3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	average
1927	16.33	10.13	12.51	15.66	11.97	10.82	9.89	9.18	8.71	8.26	7.84	10.98	11.04
1928	8.87	9.38	18.80	18.80	14.64	11.48	10.43	9.50	9.17	9.00	9.15	11.87	11.76
1929	9.23	8.32	12.67	27.05	11.78	10.38	9.33	8.55	8.02	7.53	7.18	7.62	10.63
1930	11.65	9.02	24.66	27.81	14.53	12.62	11.04	9.81	8.98	8.36	7.77	7.19	12.80
1931	9.99	14.45	29.67	39.40	22.80	16.54	14.25	12.42	11.01	9.86	8.98	9.86	16.59
1932	14.94	21.03	27.43	41.92	19.24	15.92	13.86	12.27	10.92	9.85	9.43	9.33	17.14
1933	17.15	18.90	22.27	26.75	16.79	14.14	12.41	11.12	10.06	9.19	8.53	7.94	14.57
1934	18.60	12.80	13.25	19.74	17.27	16.38	13.50	12.14	11.03	9.98	9.03	11.88	13.80
1935	14.31	15.23	22.66	14.22	12.99	11.59	10.50	9.56	8.89	9.18	9.16	24.28	13.57
1936	21.83	16.16	13.69	52.36	30.70	18.46	16.21	14.03	12.37	11.04	9.91	10.79	18.93
1937	13.29	10.96	27.87	25.38	21.55	15.19	13.31	11.80	10.99	10.21	9.38	8.66	14.91
1938	7.99	8.43	8.11	16.04	10.37	9.38	8.60	8.09	7.69	8.41	8.17	7.77	9.08
1939	13.17	8.72	12.69	42.70	18.62	14.01	12.25	10.87	9.95	9.06	8.54	8.30	14.06
1940	19.99	14.76	14.23	29.10	15.42	12.83	11.28	10.21	9.31	9.33	8.43	10.37	13.76
1941	10.47	19.88	19.59	14.92	19.39	12.58	11.14	9.96	9.06	8.52	11.53	11.09	13.14
1942	18.86	11.42	25.53	34.68	21.13	15.91	13.79	12.08	10.73	9.63	8.89	12.24	16.27
1943	8.85	11.56	13.52	15.44	23.07	11.71	10.34	9.25	8.55	8.00	7.46	7.01	11.24
1944	8.96	7.37	9.81	31.65	17.34	12.56	11.05	9.82	8.86	8.15	9.38	14.22	12.42
1945	16.68	13.20	14.57	26.11	24.28	14.29	12.58	11.07	9.88	8.91	8.19	10.52	14.20
1946	8.27	7.43	9.48	35.84	14.74	11.98	10.52	9.38	8.50	7.93	7.94	7.61	11.62
1947	16.25	14.40	19.78	22.44	19.39	15.02	12.80	11.26	10.02	9.12	8.30	22.31	15.11
1948	20.69	15.31	23.70	16.56	15.70	12.76	11.27	10.17	9.20	8.50	11.16	8.15	13.60
1949	10.10	20.69	12.14	20.20	13.06	11.13	9.91	8.94	8.22	7.69	7.17	6.75	11.26
1950	6.68	8.75	22.97	19.64	20.09	12.97	11.37	10.10	9.55	8.66	8.04	7.53	12.22
1951	7.89	11.20	10.85	22.25	14.13	10.80	9.90	8.80	8.11	7.54	15.91	10.63	11.48
1952	15.87	18.78	19.71	29.36	36.15	16.68	14.28	12.35	10.86	9.69	12.87	9.13	17.13
1953	8.32	7.45	11.80	13.00	16.28	10.43	9.35	8.46	7.84	7.39	6.93	9.27	9.73
1954	12.86	9.38	9.85	12.59	11.55	9.11	8.18	7.56	7.11	6.83	6.48	6.39	8.99
1955	7.33	16.94	14.86	39.80	22.62	16.79	14.14	12.28	10.77	9.54	9.39	8.37	15.18
1956	19.51	17.35	15.64	39.33	18.87	15.03	13.03	11.41	10.13	9.11	8.29	8.45	15.48
1957	19.22	18.62	16.82	36.24	28.70	15.21	13.45	12.62	11.71	10.95	10.39	11.75	17.12
1958	13.45	15.02	26.31	38.70	23.92	14.30	12.81	12.19	11.56	11.00	10.24	15.32	17.07
1959	13.91	15.27	21.09	21.56	15.22	12.35	11.76	11.27	10.61	10.32	10.21	11.81	13.77
1960	10.63	15.18	29.66	52.06	23.80	15.25	11.35	9.81	8.72	8.79	9.63	9.95	17.03
1961	11.88	14.83	15.57	19.80	21.03	9.92	10.43	11.22	8.96	8.76	11.27	16.06	13.31
1962	36.13	34.00	39.11	40.65	28.21	18.96	16.87	15.10	11.94	12.65	11.27	13.11	23.10
1963	26.23	29.82	39.34	51.87	27.46	17.75	17.53	15.17	13.68	12.47	18.22	10.49	23.26
1964	17.87	22.71	36.94	50.48	29.19	22.42	19.33	17.63	15.31	13.55	12.59	14.16	22.65
1965	16.77	19.28	26.85	41.24	20.57	14.93	13.76	13.06	11.99	11.55	11.09	13.08	17.81
1966	16.39	17.24	30.60	44.07	22.61	16.61	13.78	13.39	12.31	8.00	7.84	8.49	17.59
1967	15.26	17.13	20.18	27.69	27.90	18.06	14.67	13.52	12.12	11.35	13.17	31.14	18.53
1968	25.99	29.26	50.68	58.52	37.16	29.45	23.71	19.94	17.54	15.07	15.09	18.97	28.42
1969	20.64	19.23	23.18	32.91	24.21	15.22	13.65	13.58	11.88	10.70	11.06	11.79	17.32
1970	20.40	31.28	29.59	26.45	16.72	13.52	12.93	11.98	11.11	9.98	9.08	17.32	17.44
1971	14.81	19.45	20.88	37.72	20.28	13.71	14.24	12.51	11.75	14.31	11.05	12.14	16.86
1972	17.08	16.54	33.03	45.35	30.40	18.65	15.96	13.53	14.26	12.80	12.40	22.16	21.02
1973	31.16	22.57	29.37	43.27	32.55	18.71	16.41	14.33	13.55	12.64	12.41	14.43	21.78
1974	19.36	27.15	17.57	43.91	39.89	20.45	16.63	13.72	13.57	12.43	11.87	9.29	20.41
1975	15.09	12.18	13.86	27.72	25.57	17.55	14.12	12.79	12.42	10.66	9.59	11.11	15.23
1976	13.88	15.29	20.13	28.70	25.83	20.83	15.94	13.97	12.27	11.13	9.78	9.38	16.42
1977	13.11	10.25	13.98	25.08	21.64	14.92	12.79	11.46	10.23	9.51	10.66	14.95	14.06
1978	14.97	13.66	18.21	27.69	23.59	16.13	13.10	11.42	10.28	9.24	11.18	14.13	15.30
1979	19.85	18.97	27.58	39.76	40.31	30.87	22.65	17.49	14.79	12.65	12.60	15.46	22.76
1980	16.32	16.44	15.62	20.66	22.86	14.87	13.12	11.80	10.60	9.77	9.47	11.21	14.39
1981	11.63	12.44	15.39	20.46	18.09	12.91	11.21	10.42	9.32	9.44	8.17	10.28	12.48
1982	8.90	10.67	12.07	19.52	24.20	13.89	12.00	10.53	9.66	10.25	11.10	15.69	13.22
1983	24.16	15.99	19.49	32.15	31.81	23.14	18.01	14.22	12.37	11.05	10.12	10.53	18.60
1984	12.17	12.61	19.11	28.85	28.76	20.69	16.37	13.52	12.22	11.31	10.74	17.80	17.02
1985	23.74	17.96	22.74	39.43	30.20	21.56	17.87	14.64	13.01	11.47	13.41	20.19	20.53
1986	24.26	26.17	25.75	42.07	38.38	28.74	22.23	18.53	14.78	12.86	15.38	22.23	24.26
1987	23.47	21.37	23.47	22.89	23.65	18.12	15.36	13.30	11.53	11.05	11.19	14.04	17.43
Ave.	15.80	16.03	20.79	30.79	22.48	15.72	13.52	11.99	10.83	10.04	10.19	12.38	15.87

2.2 Geology, Construction Materials and Seismicity

(1) Geology

The Upper Kihansi and Lower Kihansi project sites, as shown in Figs. 1 and 2, are composed of gneisses of Precambrian era, and Quaternary slope wash and alluvium which cover these gneisses at parts.

The "gneisses" mentioned here is a general term for biotite gneiss, quartz gneiss, amphibolite, and lamprophyre, and of these, biotite gneiss is distributed the most widely.

Slope wash and alluvium are mainly distributed downstream of the Lower Kihansi dam site, and are seen at the foots of cliffs and in the Kihansi River.

As for geologic structure, there is a foliation of gneisses striking in the NNE-SSW direction and dipping 20° to 70° to the west intersecting slightly diagonally the Kihansi River which flows approximately north-south. According to aerial photo interpretations, predominant lineament patterns are seen in the N-S, NE-SW, and WNW-ESE directions. There are few faults confirmed through outcropping at the ground surface, and faults have not been confirmed at the ground surface at even the Uzungwa Scarp thought to be a fault scarp.

Although not shown in Figs. 1 and 2, a comparatively thick weathered layer covers the area upstream from the vicinity of the Lower Kihansi dam site. According to boring investigations made at the Upper Kihansi dam site, there are places where a weathered layer 30 m or more in thickness has been confirmed. Since outcrops of bedrock are seen comparatively frequently at the river bed of this area as a whole, it may be said there is a trend for the

weathered layer to be thick at the gently-sloped ridges and thin in the vicinity of the river bed.

To summarize the engineering geological evaluations of the principal civil structure sites planned, the following may be said:

i) Upper Kihansi Project Site

- A soft, weathered layer of thickness approximately 20 m is distributed at the dam site, mainly at ridges. On the other hand, bedrock existing at deep parts and at the river bed is generally hard although deteriorated portions may be partially observed, and this is thought to possess ample suitability as the foundation rock for a rockfill dam of height approximately 100 m.

- It is thought that for the dam axis, the geological conditions are better with less weathering to shift approximately 80 m downstream rather than the line connecting the sites of boring (KU-1 and KU-3) performed at the slopes of both banks. Consequently, the dam axis should be selected at this line.

- Of the waterway route, the ground surface of the section including the projected intake and the headrace tunnel is expected to have a distribution of a slightly thick weathered layer. However, if the tunnel elevation is as projected, the tunnel is to pass through comparatively fresh bedrock.

- It can be expected that sound bedrock is to be exposed as the foundation for the projected Upper Powerhouse.

ii) Lower Kihansi Project Site

- The line connecting the boreholes at the both banks is thought to be most suitable for the Lower dam axis from the facts that it avoids waterfalls, the river width is narrowed by a ridge protruding out at the left bank, and surface deposits are small in quantity. The thicknesses of weathered layers here are estimated to be 5 to 7 m.

- For the headrace and the penstock, it is considered that a tunnel proposal is to be more advantageous than a surface proposal in view of the facts that there are many places of steeply-sloped topography and numerous scars can be seen.

- From the points of view of topography and geology, the location of the Lower Kihansi Powerhouse should be selected inside the gentle slope shown in Fig. 2. However, since it is possible the lineament pattern in the N76°W direction shown in Fig. 2 is that of a fault, it is desirable to avoid this.

(2) Construction Materials

With regard to borrow materials, it is considered most suitable for the residual soil and weathered rock widely distributed at the ground surface in the vicinity of the Upper Kihansi dam site to be used mixed with coarse material.

With regard to concrete aggregates, there are no sediments to be seen in this area which are available in large quantities. As a result of testing, the gneisses widely distributed as basement rock in this area can be used as concrete aggregates from the standpoints of specific gravity, absorption, alkali-aggregate reaction, and

further, strength. Consequently, it is thought the best method for this Project is to select a quarry at the optimum location and obtain concrete aggregates in the form of crushed stone.

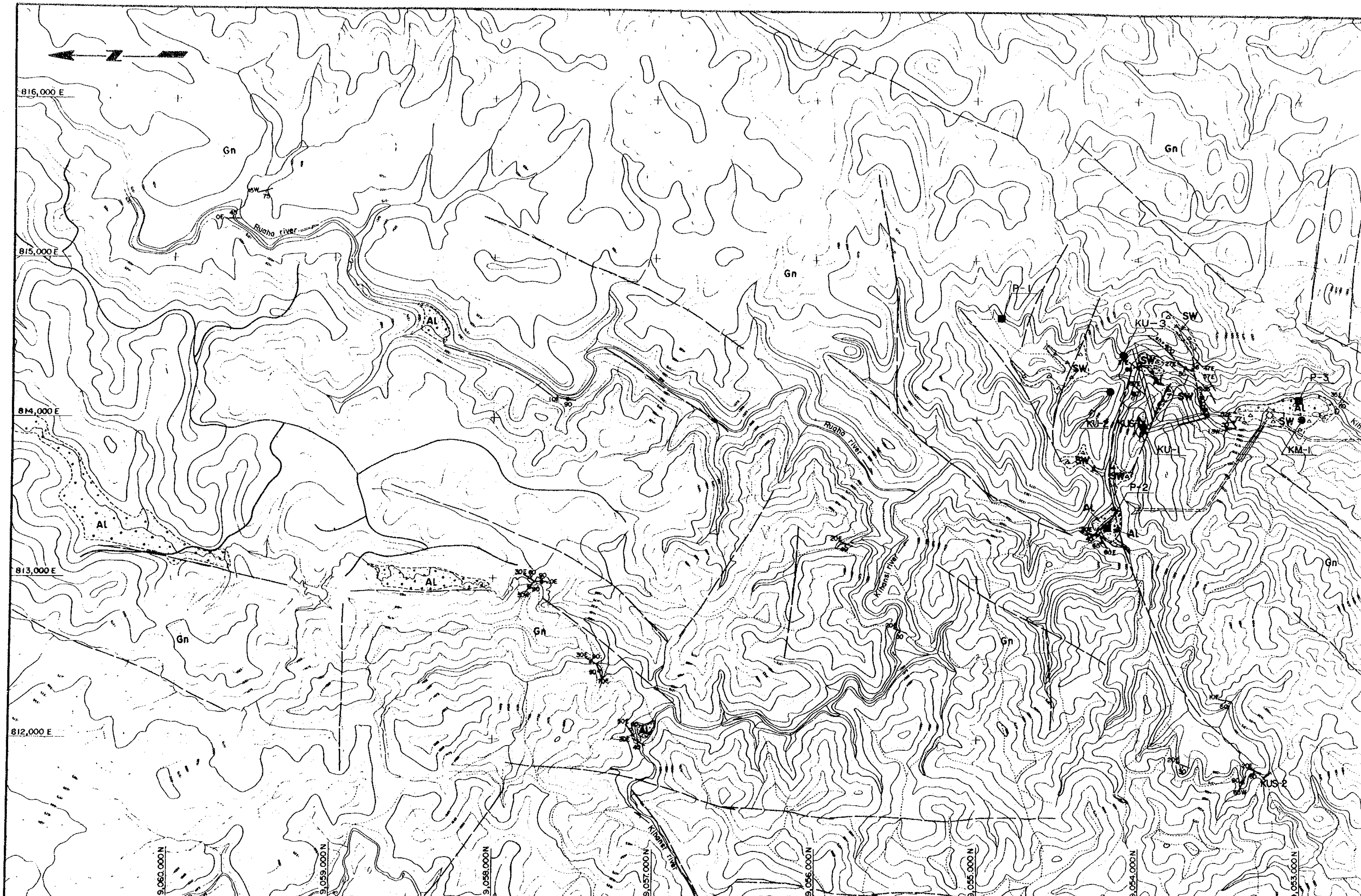
Furthermore, it is necessary hereafter to ascertain at the quarry site the quantity and properties of the weathered layer that can be furnished as borrow material, and to investigate the distribution of fresh rock that can be considered for blending with borrow material and that can be used as concrete aggregates. Particularly, with regard to fresh rock, confirmation of rock type is an important point in investigations since in the case of gneiss containing large amounts of biotite "abrasion loss" is presupposed to be high, and it is conceivable that securing the necessary quantity of coarse aggregate may be difficult.

(3) Seismicity

As a result of investigations, 349 earthquakes were found to have occurred during the 78 years from 1910 to 1987 within a radius of 500 km from the dam site. The magnitudes had all been under 7, with hypocenters concentrated along the Western Rift Valley passing the vicinity of Mubeya.

As a result of statistical analyses based on these earthquake data, approximately 13 gal was obtained as the design earthquake intensity of this project site in terms of 10,000-year return period.

Based on a comprehensive judgment of such statistical analysis results and existing data concerning earthquakes, the design horizontal seismic coefficient of the project site was set as 0.10.



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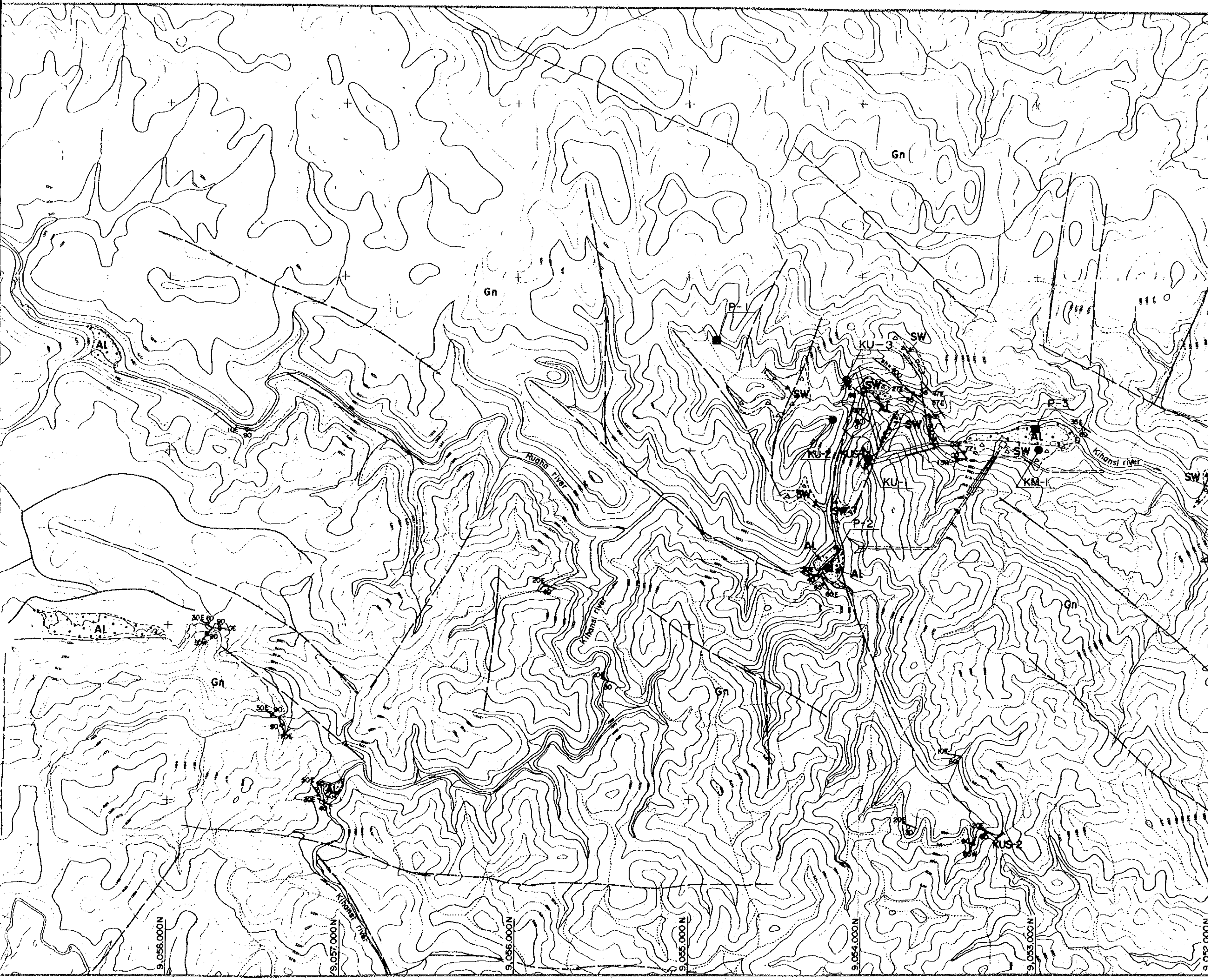
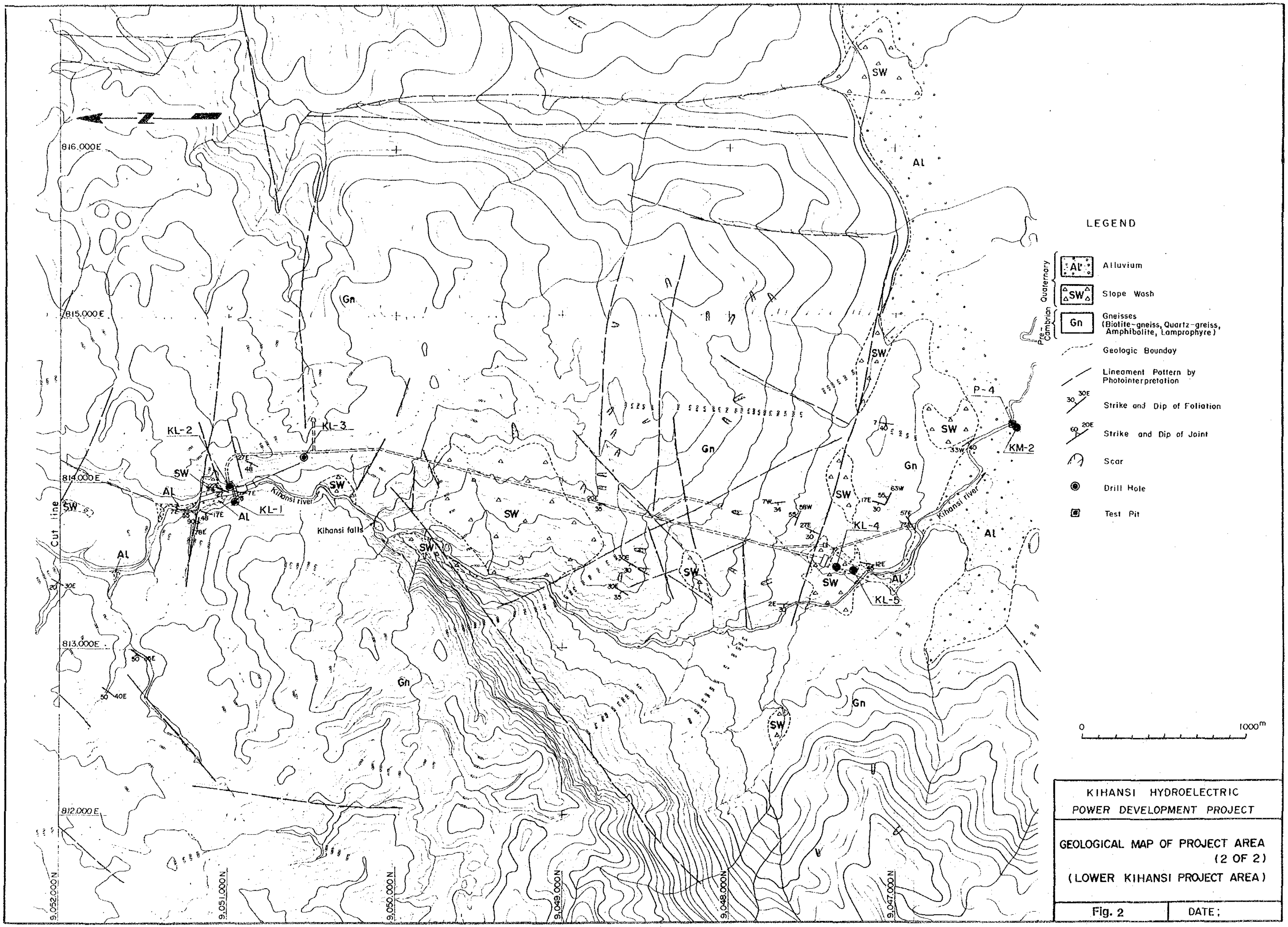


KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

GEOLOGICAL MAP OF PROJECT AREA (1 OF 2) (UPPER KIHANSI PROJECT AREA)

Fig. 1	DATE;



KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

GEOLOGICAL MAP OF PROJECT AREA (2 OF 2) (LOWER KIHANSI PROJECT AREA)

Fig. 2

DATE;

2.3 Electric Power Demand and Supply

The electric power systems of the Republic of Tanzania consists of the interconnected power system that links major cities of the country and isolated power systems which supply small settlements which are far isolated from the main interconnected power system. The interconnected power system has been expanded gradually, and most major cities of the country is today interconnected after the interconnection has been extended to the region of Victoria Lake of the northwest in 1988.

As of January, 1989, the total generating capacity connected to the interconnected system is 418 MW, with approximately 79% (329 MW) of the facilities consisting of hydroelectric power stations.

All thermal power generation facilities are small capacity of diesel and gas turbine plants. As all petroleum fuel is imported, the basic policy of TANESCO is to supply as much energy as possible from the hydroelectric power stations, and to use the thermal power stations as reserve capacities.

As the interconnected power system has been expanded by new transmission lines, the total demand of interconnected system is steadily increasing. The total energy consumption in 1988 was 1,123 GWh, and the maximum peak generation was 219 MW.

Power demand in Tanzania, reflecting stagnation of the economy, had shown an annual growth rate of 5.9 percent up to 1985, but as a result of the economy turning around favorably with an economy recovery programme receiving aid from the World Bank, the growth rate rose sharply to 10.3 percent in 1986 - 1988. Hereafter, from 1990 to 2005, it is estimated that the growth rate in power demand will be

an annual 6.2 percent. The projection of energy generation and peak power generation for the period between 1991 and 2005 are presented in the table below.

	Energy Generation (GWh)	Peak Power (MW)
1991	1707	304
1992	1813	323
1993	1925	343
1994	2045	365
1995	2171	387
1996	2306	411
1997	2449	437
1998	2601	464
1999	2762	493
2000	2933	523
2001	3115	556
2002	3309	590
2003	3514	627
2004	3731	666
2005	3963	707

TANESCO plans to meet this demand growth totally by supply from hydroelectric power generation facilities, except for a thermal power plant (20 MW) which is to be constructed in 1992 as a supplemental measure. The hydroelectric power development program based on the plans of TANESCO and this case study are as presented below.

Year of Commissioning	Project	Installed Capacity (MW)
1995	Pangani Falls Redevelopment	60.0
1996	Lower Kihansi	153.0
1999	Upper Kihansi	47.0
2002	Masigira	80.0
2005	Rumakali	204.0
2009	Ruhudji Stage 1	250.0
2012	Mpanga	160.0

When the balance of supply and demand is examined from the demand projection obtained above and this development program, it is found that the pace of development is a little slow. That is, energy supply shortage is to be faced in case of a dry year in 1996, and shortage in both energy supply and reserve power capacity is also anticipated in dry years after 2000 and before 2005 when Rumakali is commissioned.

2.4 Power System Analysis

As large supply sources of Kidutu and Mtera Hydroelectric Power Stations are situated in the central region of Tanzania, the demands are concentrated at Dar Es Salaam and on the substations along the 132 kV transmission system that extends from Dar Es Salaam to the north. Therefore, heavy power flows from Kidutu and Mtera Power Stations to Dar Es Salaam and then northward to Arusha which is located at the northern end of the power system.

Due to this power flow, the voltage of the interconnected system tends to be reduced in the eastern areas and tends to be raised in the western areas where load is relatively light. As this trend is to persist in future, it is required to install appropriate reactive power suppliers corresponding to the increase of load of the power system.

TANESCO plans to construct a new, single circuit 220 kV transmission line from Singida Substation which is in the western part of the interconnected system to Njiro Substation at Arusha. TANESCO also plans to construct a single circuit 220 kV transmission line from Kidatu Power Station to Ubungo Substation at outskirts of Dar Es Salaam, and construct a new substation along the 220 kV system of Dar Es Salaam.

Although such reinforcement of power system is to make it possible to deal with the demand increase in the interconnected power system, the effect of line failure, such as those caused by thunder strokes, is to be serious because most of transmission lines are of single circuit design. In particular, it is desirable to have the 220 kV transmission lines from Mtera Power Station through Iringa Substation to Kidatu Substation made to double circuits in order to improve the reliability of the interconnected power system.

It is planned that the transmission line from Upper Kihansi and Lower Kihansi Power Stations is to be directly connected to Iringa Substation which is the key substation in the interconnected power system. The length of transmission is 113 km (105 km from Upper Kihansi). The voltage is selected at 220 kV and the number of circuits to be two, by due consideration on the transmission capacity and reliability.

2.5 Environment and Compensation

There are almost no residents and facilities to be affected by the construction of the power stations since Kihansi and Ruaha Rivers have no irrigation facilities. Part of the forest reserve with an area of 2.3 km^2 is to be submerged by the planned impoundment of the upper reservoir, covering only less than 1% of the total area of the forest reserve with an area of 300 km^2.

Aquatic animals such as fishes, etc., are scarcely seen in Kihansi and Ruaha Rivers since the water quality of both steep rivers with exposed rocks at the riverbed shows relatively strong acidity and sterility due to surface soil and burned/cultivated fields. The inhabitation of large-sized animals has not been confirmed since the planned power station site area is widely cleared away as burned/cultivated fields and their unused fields.

According to the on-site survey of the environment, there are two villages with a population of 3,400 and 540 houses. The planned power station site consists of these residents' burned/cultivated fields and their unused fields, and a great deal of nature there has been already changed. Residents live on a hill far away from the power stations except huts for agricultural work, and they scarcely have to move their houses.

It is possible to lawfully acquire land required for the establishment of the power stations under the provisions of the Land Act of the Republic of Tanzania. Since the compensation system for acquired land has been established and the amount of compensation money is small, this does not become a controversial issue at all.

The power stations are expected to largely contribute to the development of this region since public facilities such

as roads, etc., are to be established following the construction and operation of the power stations. The upper reservoir will provide waterfowls with new habitats, and residents with the possibility of the cultivation of fishes such as introduced species and of water-borne traffic respectively. However, the occurrence of harmful plants and vermin should be carefully controlled.

As mentioned above, the power stations are expected to affect the natural and social environment scarcely as a whole while this power station project aims at the stable supply of power, largely contributing to the development of regional societies.

As a part of the maintenance of the power stations, the effects of the power stations should be environmentally monitored for grasping changes in the environment.

Chapter 3 OUTLINE OF THE DEVELOPMENT SCHEME

The total of maximum outputs of the Upper Kihansi Project and Lower Kihansi Project of the Kihansi Hydroelectric Power Development Project is 200 MW. The annual firm energy from this hydroelectric power generation is calculated as 886.7 GWh.

When this is compared with coal-fired power generation, it corresponds to an annual coal consumption of approximately 680,000 tons. The principal specifications are as described below.

(1) The Upper Kihansi Project

This Project is located at the upstream of the Kihansi River, one of the tributary of the Rufiji River.

A rockfill dam with height 95 m and dam volume 5.35×10^6 m^3 is constructed to provide gross reservoir storage capacity of 94.9×10^6 m^3 with the effective of 75.1×10^6 m^3 at about 3 km downstream from the confluence of the tributary Ruaha River and average annual inflow of 494×10^6 m^3 is regulated in this reservoir.

The maximum available discharge of 25.7 m^3/s introduced to the intake at 500 m upstream of the right bank of the dam is conducted to the powerhouse situated at the right bank through the headrace tunnel and the open type penstock with total length of 1,163 m and generated maximum output of 47 MW with annual electric firm energy of 335.7 GWh with effective head of 214.5 m. The generated water is to be discharged to a regulating reservoir of the Lower Kihansi Project through a tailrace tunnel and open channel with length of 1,140 m.