REPUBLIC OF KENYA

LAKE BASIN DEVELOPMENT AUTHORITY

SONDU RIVER MULTIPURPOSE DEVELOPMENT PROJECT

VOLUME II

FEASIBILITY REPORT ON SONDU HYDROPOWER DEVELOPMENT PROJECT

DECEMBER [illegible]

JAPAN INTERNATIONAL COOPERATION AGENCY

NAIROBI OFFICE
P.O. BOX [illegible]
NAIROBI KENYA

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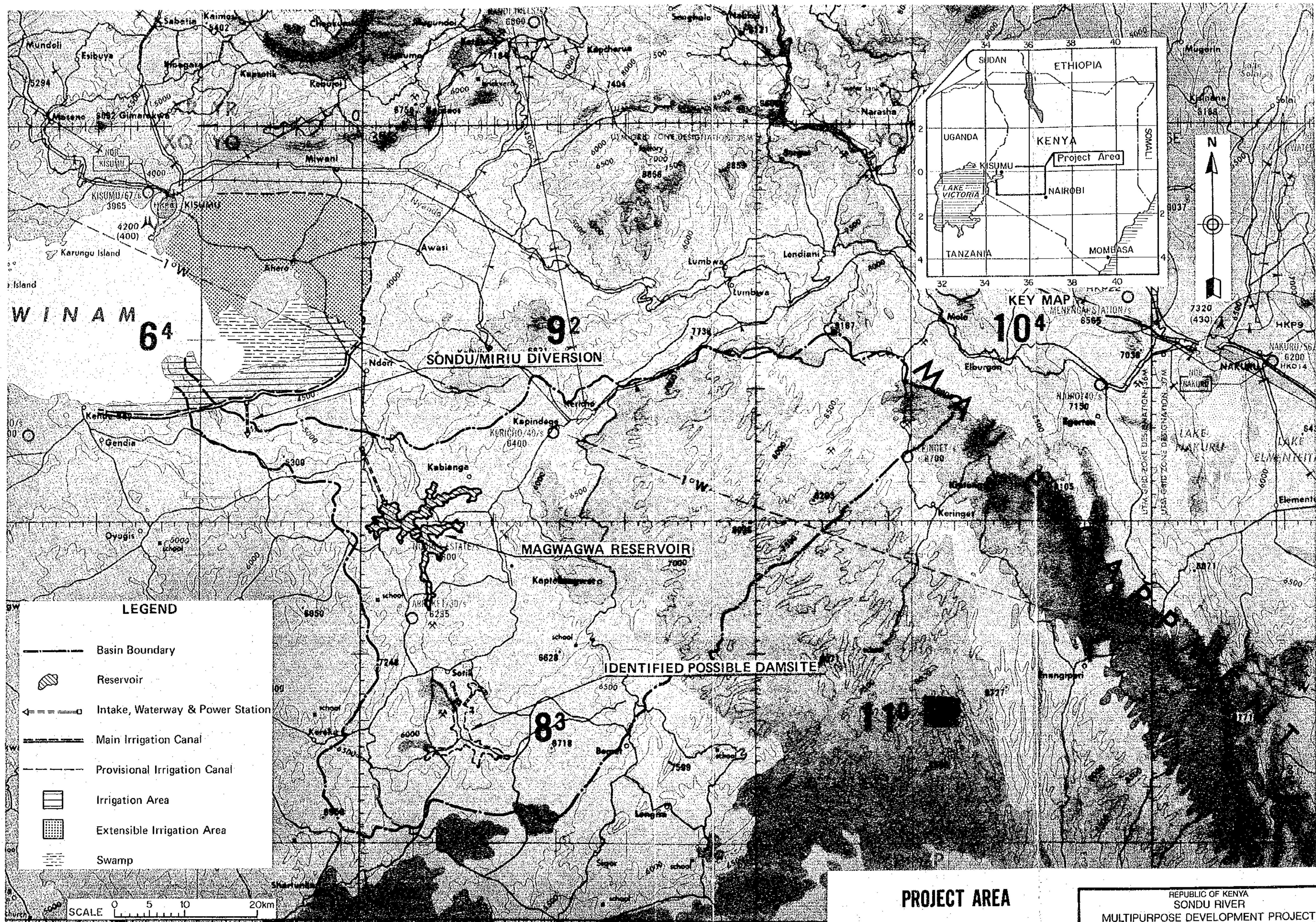

PROJECT AREA

REPUBLIC OF KENYA
SONDU RIVER
MULTIPURPOSE DEVELOPMENT PROJECT
JAPAN INTERNATIONAL COOPERATION AGENCY

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ABBREVIATIONS OF MEASUREMENT

Length

mm = millimetre
cm = centimetre
m = metre
km = kilometre

Area

cm^2 = square centimetre
m^2 = square metre
km^2 = square kilometre
ha = hectare

Volume

cm^3 = cubic centimetre
l = lit = litre
m^3 = cubic metre

Weight

kg = kilogram
ton = metric ton

Time

sec = second
min = minute
h = hour
yr = year

Electrical Measures

kW = kilowatt
MW = Megawatt
GW = Gigawatt
KV = Kilovolt

Other Measures

% = percent
o = degree
' = minute
^{o}C = degree in Celsius
10^3 = thousand
10^6 = million

Derived Measures

m^3/sec = cubic meter per second
KWh = kilowatt hour
MWh = Megawatt hour
GWh = Gigawatt hour
KVA = kilovolt ampere
cct = circuit

Money

KShs = Kenya Shilling
K£ = 20 Kenya Shillings
US$ = US dollar
US¢ = US cent
¥ = Japanese Yen

NOTATIONS

(1) Organization/Plan

EAP&L : East African Power and Lighting Co. Ltd.
GRDP : Gross Regional Domestic Product
IBRD : The International Bank for Reconstruction and Development
IMF : International Monetary Fund
JICA : Japan International Cooperation Agency
KPC : Kenya Power Co. Ltd.
KP&L : Kenya Power and Lighting Co. Ltd.
LBDA : Lake Basin Development Authority
LDC : Load Dispatching Centre
MERD : Ministry of Energy and Regional Development
MOWD : Ministry of Water Development
NPGS : National Power Grid System
PLC : Power Line Carrier
S/W : Scope of Works
TARDA : Tana and Athi Rivers Development Authority
TRDC : Tana River Development Co. Ltd.
UEB : Uganda Electricity Board
UNDP : United Nations Development Programme
WHO : World Health Organization

(2) Others

Alt. : Altitude above Mean Sea Level
C.I.F.: Cost, Insurance & Freight
D/D : Detailed Design
dia. : Diametre
El. : Elevation above Mean Sea Level
ERR : Economic Internal Rate of Return
F.O.B.: Free on Board
FRR : Financial Internal Rate of Return
FSL : Full Supply Level
GDP : Gross Domestic Product
GNP : Gross National Product
LRMC: Long-run Marginal Cost
MOL : Minimum Operation Level
O&M : Operation and Maintenance

Chapter 1. INTRODUCTION

1.1 Study Objectives

In response to the request of the Government of Republic of Kenya, the Government of Japan decided to extend technical cooperation in carrying out a feasibility study for the Sondu River Multipurpose Development Project, one of the most promising projects in the Western Kenya. This work has been executed by the Japan International Cooperation Agency (JICA), the official agency responsible for the implementation of technical cooperation programmes of the Japanese Government.

The main objective of this study is to conduct a feasibility study on this multi-objective project in accordance with the scope of work (S/W) concluded between representatives of the Lake Basin Development Authority (LBDA) of the Kenyan Government and JICA (October 1983). More specifically, the objectives consist of the following;

(1) to make a feasibility study of the Sondu River hydroelectric power development, and

(2) to make a pre-feasibility study of the irrigation development in the area delineated by S/W, by making use of water of the Sondu River.

The past studies envisage a few plans for multipurpose development of the Sondu River and Kano Plain. Those plans were, therefore, reviewed and included in this study.

Another implicit objective of the study is transfer of technology, which could be effected through field works in Kenya and the invitation of a few key Kenyan staff concerned in the study for training in Japan. In view of the technical cooperation policies of Japan, this in fact is an essential objective of the study.

1.2 Work Progress

The feasibility study of the Sondu River Multipurpose Development Project was initiated in January 1984, with a dispatch of an inception work team. The inception work, which lasted until mid-March, included the collection of basic data and information to be used in the works thereafter, background analysis of the project, and a preliminary study to identify prospective development schemes to be studied in more detail. During this period, the tendering for sub-contracting was also conducted for field investigation works in the main study, and the contract was awarded to H.P. Gauff KG Nairobi. The Inception Report was submitted to LBDA in March 1984, in which the programme and the schedule for the main study were proposed.

After further examination of the study programme and schedule by JICA, a field investigation team for the Feasibility Study was dispatched to Kenya in June 1984. The JICA team, performed the surveys and investigations on hydrology, geology, soil, construction materials, agriculture and irrigation, environmental aspect, socio-economy and regional development.

Through the field investigation, Kenyan counterparts participated in full and part time base and they engaged in the data collection, supervision of the field works.

Considerable parts of the field investigation works, including ground survey, test drilling, seismic exploration, test pitting and laboratory test, were undertaken by the local consulting engineers of Gauff through the contract with JICA. In the course of the field investigation, the JICA team prepared and submitted to LBDA two progress reports; one in August and another in November just before the completion of all the field works.

All the results of and data collected during the field investigation, including those compiled by Gauff, were brought back to Japan by the JICA team. Subsequently, the team started studies necessary for the formulation of the optimum development plan and the evaluation thereof, based on the collected data and information.

The scope of work for these studies in Japan was as follows:

(1) Analysis of the local geology and geological assessment of prospective dam sites

(2) Assessment of availability and quality of construction materials

(3) Hydrological analysis for assessing water available from alternative sources for irrigation in the Nyakach and the Kano plains

(4) Study of overall power generation schemes in Kenya and the Western region, including the analyses on existing power generation and transmission facilities, past electric power demand and its forecast, and plans for further development

(5) Hydropower potential analysis of the Sondu River

(6) Comparative study of alternative development schemes for hydropower and irrigation, and the formation of the optimal scheme

(7) Preliminary design of main structures for power generation and the irrigation main canal

(8) Quantity taking for construction works and preliminary estimate of project costs

(9) Preliminary assessment of economic and financial viability of the project

(10) Preparation of an Interim Report.

All the study results during this period were compiled into the Interim Report, which was transmitted to LBDA in advance of the dispatch of another JICA mission in March 1985. The JICA mission explained the contents of the Interim Report and discussed with the LBDA staff and others in related organizations on various aspects of the development schemes of the Sondu River Multipurpose Development Project. The staged development of the Sondu River, with the first stage development of a run-of-river power generation and trans-basin diversion of the Sondu River water for irrigation in the Nyakach plain, was basically accepted by the Kenyan side as recommended in the report.

Upon a strong request from LBDA, the JICA mission suggested that the study might be completed by the end of December 1985, instead of in June 1986 as originally agreed and specified in the S/W. This change of schedule was subsequently confirmed by the JICA Head Office.

Based on the discussions and the agreement with the Kenyan side as well as written comments received at a later date, the JICA team proceeded toward the completion of the study. The works carried out during the first home work period were re-examined, and the development schemes were further elaborated. In addition, the following were also carried out:

(1) Feasibility level design of hydropower-related structure and facilities, including layout and siting of the intake dam and power house, design of power generating equipment, metal works, transmission facilities and sub-stations, and other related drawings

(2) Pre-feasibility level design of the main structures related to irrigation such as turn-outs, syphones, aqueduct and others

(3) Construction planning for the construction schedule, transportation routes and construction machinery and equipment

(4) Overall appraisal of the project covering economic and financial analyses, regional development and environmental assessment

(5) Preparation of a Draft Final Report.

1.3 Organization of This Report

Following this Chapter 1 for introduction, the remaining part of this main report is organized in the following way. In Chapter 2, background of the Sondu River Multipurpose Development Project is described from a few different viewpoints: viz. national economic background, policy background and project background. These descriptions together would provide the motivation for promoting this important project.

Chapter 3 presents various macroscopic aspects of the Lake Basin area, where the Sondu project is located, to clarify the characteristics of the region and the position of the project for the development of the region. Chapter 4 is for more detailed descriptions of some important aspects of the project site, including the local topography, geology, meteorology and hydrology, availability of construction materials and environmental aspect.

Chapter 5 is devoted to power supply and demand. Existing power facilities and institutions are summarized, and expansion plans are described. On the demand side, power uses and demand forecasts in the recent past are reviewed, and comments are made on a most reasonable demand forecast.

The following three chapters are for planning, engineering design and cost estimate of the project. In Chapter 6, alternative development schemes on the Sondu River are formulated with respect to hydropower generation, and then compared on the basis of costs and benefits, taking account also of irrigation development in neighbouring basins. The optimal development scheme is selected among the alternatives.

Chapter 7 reports the results of engineering design for the optimal development scheme thus selected, covering all the main structures of the project including transmission lines and a substation. In Chapter 8, a construction plan for the project is presented together with the estimate of construction costs.

The project is evaluated in Chapter 9. Economic and financial viability of the project is assessed for the proposed first stage development. Moreover, attention is directed to other aspects, including the contributions to regional development and effects on environment. Finally in Chapter 10, recommendation is made on the next steps to be taken toward the implementation of the project.

Chapter 2. BACKGROUND

2.1 National Economic Scenes

The growth of Kenya's economy since its independence in 1963 may be illustrated by the data in Table 2.1, where real growth rates of the gross domestic product (GDP) are presented. In the first years of independence, the Kenya's economy made a steady growth and the annual growth rate averaged 5.8 percent during 1964 to 69. The economic growth accelerated in the early 1970's, but thereafter it slowed down significantly except the period of coffee boom (1977 to 78). This slow down is primarily due to a series of sharp increases in prices of crude oil, for which Kenya depends totally on imports. The annual growth rate in the 1970's was 5.1 percent on average.

The economy has been generally slow-moving in the early 1980's, partly reflecting international recession. Particularly in Kenya, the growth rate of GDP fell below the population growth in 1982, resulting in a decrease in the per capita GDP. In 1983, Kenya's economic performance started to show a sign of recovery, but the optimism was soon frustrated by the severe drought that hit the sub-Sahel region in Africa. The drought turned out to be the worst ever for Kenya, and as a result the real growth rate in 1984 fell to only 0.9 percent.

The outlook for the coming year is generally better than the performance in the past few years. The growth target of 4 percent per annum, to which the IMF standby arrangement (approved in February 1985) is geared, may be attained in 1985, and the official development programme aims to attain 6 percent per annum growth by the end of the decade.

As most other developing countries, agriculture is by far the most important sector of the Kenya's economy, accounting for about one-third of the GDP, both the traditional and the monetary economies combined (see Table 2.2). Dependence on this sector is in fact much heavier than appears from its share in the GDP, since over 80 percent of the country's population lives in rural areas, deriving their income primarily from agricultural activities.

The agricultural sector has been contributing to about fifty percent of the total export value in the past several years. In particular, two main cash crops -- viz. coffee and tea -- together account for some forty percent, although their shares vary considerably year by year as international market prices fluctuate (see Table 2.3). Another major export commodity is petroleum products, whose share in export had rapidly increased to attain 30 percent level by 1980, but thereafter it has been decreasing to reach below 20 percent. Still about two-thirds of the total export earnings is derived from these commodities. Such high dependence on a few products as foreign exchange earners makes the Kenya's economy vulnerable to natural conditions and changes in international markets.

Composition of imports, on the other hand, is characterized by a large share of fuels, which approaches forty percent of the total import value in recent years. These characteristics of economic structure together with the lack of fossil fuel resources are primarily responsible for the aggravating balance of payments (see Table 2.4). The trade balance improved slightly in 1983 but became worse in 1984 due to emergency food imports, despite the favourable price trends for tea and coffee.

2.2 Basic Development Policies

The long-term objectives of the nation have remained in substance unchanged since independence and continue to provide guidelines for the formulation of development policies and strategies. They include sustained economic growth and equitable development as well as other objectives related to basic human needs and socio-cultural ideas. Development policies and strategies, however, are necessarily geared to emerging difficulties in the national economy as outlined above and some specific aspects of development.

Basic development policies are related to one another and naturally reflected in sectoral development strategies. Important basic policies, given the present status of Kenya's economy, are diversification of economy and equitable development, and strategies for energy and regional development are particularly related to these basic policies and the Sondu River multipurpose development project.

Diversification of economy means above all crop diversification, as the Kenya's economic development depends so much on agricultural sector. The crop diversification would not only reduce the dependence on a couple of cash crops as foreign exchange earners, but also expand and consolidate the bases for agro-related industries. These effects combined will in turn contribute to the enhancement of export performance in a longer run.

Another important aspect of this basic policy is diversification of energy sources. This of course would reduce the dependence on imported fuels and thus contribute to the improvement of trade balance. Accordingly, top priority has been given to hydropower and geothermal energy, two main indigenous energy resources that the country has.

In line with another basic policy of equitable development, the government is placing much emphasis on the development of less developed regions. Full realization of development potentials in those regions could again contribute to other objectives, including food self-sufficiency, diversification of the economy and enhancement of export performance. The rural electrification programme, also much stressed recently, is an important element of the regional development policy, as it will help to stimulate industrial and agricultural development as well as to promote general welfare in rural areas.

These policies are unmistakably reflected in the latest five-year development plan (1984-88), which sets the main theme of "mobilization of domestic resources for equitable development". Among the sub-themes of equitable development are provision of basic human needs, rural-urban balance and regional balance. Moreover, the plan stipulates the consolidation of regional development authorities with further transfer of responsibilities.

2.3 Project History

For decades, the Sondu River has been noted for high hydropower development potentials and also as water sources for irrigated agriculture in its own and neighbouring basins. During 1954 through 56, an incipient study was carried out for the Lake Victoria basin of Kenya by Sir Alexander Gibb and Partners (Africa) that resulted in a report entitled "Kenya Nile Basin Water Resources Survey".

This study dealt mainly with the development of the Kano Plain by making use of the water in the Nyando River, but also presented schemes to divert water from the Sondu River for supplementary irrigation purposes for the Kano Plain. This diversion, as the report pointed out, would offer the opportunity for hydropower generation.

A subsequent study in 1961 was more comprehensive in scope and integrated as far as the development of the Kano Plain and the Nyando River basin is concerned. However, only a brief mention was made of the diversion from the Sondu River. No other detailed study was conducted for the Sondu River, to say nothing of implementing any development scheme.

In 1979, the Lake Basin Development Authority (LBDA) was established by an Act of Parliament for planning and coordinating the implementation of development projects in the Lake Victoria catchment area. In the first few years since its inception, LBDA either concluded or initiated numerous studies on different aspects of the development of the Western

Kenya region under its jurisdiction. Many of them were concerned with specific projects for water resources development in major river basins in the region, but none dealt with the Sondu River except the National Master Water Plan study carried out by TAMS. The TAMS study presented two major schemes for hydropower development on the Sondu River -- one in the mid-stream with the Magwagwa reservoir and the other in the downstream reaches with the Sondu/Miriu reservoir.

Based on the past studies and recognizing the development potentials of the Sondu River, LBDA contemplated proceeding toward the multipurpose development of the Sondu River, including hydropower, flood control and irrigation. In response to the LBDA's request, a joint reconnaissance team of International Development Centre of Japan (IDCJ) and Nippon Koei (NK) visited the area in December 1980, to identify various aspects of the development of the Sondu River basin and its surroundings. The results of the study was compiled into a reconnaissance report, that was submitted to LBDA in February 1981.

The official request for technical assistance for feasibility study on the Sondu hydropower development project, formulated by the IDCJ/NK team as the top priority project in the basin, was submitted by the Kenyan Government to the Embassy of Japan in Nairobi. The request was subsequently transmitted to Tokyo.

Much information was exchanged between Kisumu/Nairobi and Tokyo concerning the Sondu project both on official and personal bases, for the purpose of clarifying project features, specific requests of LBDA and the scope of work (S/W) for the study to be undertaken. Finally the S/W was concluded in October 1983 between representatives of LBDA and the Japan International Cooperation Agency. The multipurpose nature of the development was once again emphasized in the S/W as reflected also in the project title: Sondu River Multipurpose Development Project.

Chapter 3. LAKE BASIN AREA

3.1 Location and Land

3.1.1 Administrative Divisions

The Lake Victoria Basin occupies some 47,709km^2 in the western part of Kenya, which accounts for about 8.4 percent of the total land area of Kenya of 569,137km^2. The area under the jurisdiction of LBDA consists of Nyanza and Western Provinces (seven districts) and areas beyond the administrative borders of these provinces, which include Kericho, Nandi, Trans-Nzoia and Uasin-Gishu districts and small parts of Narok, Nakuru, West Pokot and Elgeyo-Marakwet, all in Rift Valley Province.

The administrative divisions of LBDA area are shown in Figure 3.1, together with the sub-catchment areas of six major rivers. The areas of direct concern for the project consist of Kisumu, South Nyanza and Kisii districts in Nyanza Province, a major part of Kericho and small portions of Nandi and Nakuru districts of Rift Valley Province. These areas belong to the upper Yala, the Nyando and the Sondu basins and their flood plains.

3.1.2 Natural Conditions

The Lake Basin is situated between 34° and 36° of east longitude and 1°15' of north latitude and 1°55' of south latitude approximately. The equator passes through the centre of the region. The region borders on Uganda to the north west and Tanzania to the south.

On the north west corner of the region is Mount Elgon, 4,310 meters high and the second highest in Kenya, and in the east spreads the Kiptaber Forest. From the north east to the south east, Elgeyo Escarpment and Mau Forest and Esoit Oloololo Escarpment bound the region from the great Rift Valley.

The area is broadly divided into highlands above the Nandi and the Nyakach escarpments and the lowland around the shores of Lake Victoria. The elevation of the highlands ranges generally between 1,800 and 3,000 meters above the sea, and the lowlands are lying at around 1,150 meters (see Figure 3.1). The average water surface level of Lake Victoria is 1,134 meters.

The Sio and Nzoia rivers originate in the Mount Elgon, Kiptaber Forest and Aptagat Forest in the northern part of the region and drain into Lake Victoria flowing generally in the south western direction along the Ugandan border. The Yala River collects water from Kakamega Forest, Nandi Forest and Tinderet Forest and also drains to the Lake flowing from east to west direction. The Nyando River comes from Tinderet Forest and western Mau Forest and enters the Winam Gulf of the Lake flowing generally east to west. The Sondu River rises from the dense Mau Forest in the south eastern part of the region, and enters also the Winam Gulf. The Kuja River collects water from the south western part of the region and drains into the Lake near the Tanzanian border.

Some hydro-morphologic characteristics of these rivers may be illustrated by Figure 3.2. The figure compares the catchment area, annual discharge, sediment yield and organic pollution loads for the six major and a few other rivers in the Lake Basin.

The climate in the region is characterized by two rainy seasons. A long rain generally lasts from March to May and a short rain from November to December. Annual rainfalls much vary by locality as indicated below:

Station	River Basin	Annual Rainfall (mm)
Kitale	Nzoia	1,191
Eldoret	Nzoia	1,124
Kisumu	Nyando	1,306
Kericho	Sondu	2,081
Kisii	Kuja	1,957

The surface temperature in the region varies little throughout a year. It fluctuates between 20°C and 25°C in most areas except the mountainous zone, and average annual range of temperature change is about 2°C. Relative humidity varies from 50% to 70% through a year.

The highlands were developed in early times of colonialization and as a result deforested in some parts for cultivation and settlements, but are still covered with substantial forests. The lowlands are mostly flood plains of major rivers in the region and have more fertile soils, but contain some swampy areas. More details on these natural conditions are found in Chapter 4.

3.1.3 The Sondu River Basin

There exist six major rivers draining into Lake Victoria -- viz. Sio, Nzoia, Yala, Nyando, Sondu and Kuja. Of these, the Sondu River has been noted for high potentials for hydropower development and also as potential water sources for irrigated agriculture in its own and neighbouring basins.

The Sondu (Miriu) River drains the total area of 3,470 km^2 and has two major sub-basins in the upstream. The south basin of about 1,510 km^2 is drained by the Kipsonoi River and the east basin of about 1,580 km^2 by Yurith River, respectively. Both rivers originate from the Mau Forest on the western slope of Mau Escarpment (El.2,500 - 2,800 m). The Kipsonoi flows first south-westwardly to near the Sotik settlement and then turns the course to the north to pass near the Magwagwa village, where it meets with the Yurith from the east. The Yurith River collects the flow from the Kimugu and the Itare rivers and then takes its course westward to join the Kipsonoi.

From the confluence of the Yurith and the Kipsonoi, the river changes its name to the Sondu (or the Miriu locally) and it heads to the north up to the Sondu village and then turns westward. Finally it drains into Winam Gulf of Lake Victoria cutting through the Nyakach Escarpment.

The longitudinal profile of the Sondu River is presented in Figure 3.3. As seen in this figure, the major course of the Sondu falls more than 100 m in altitude in such a short distance as less than 10 km in the lowermost reach. In the middle and lower reaches, the Sondu forms V-shaped valley along which narrow gorges are found in several places.

Eastern part of the basin is covered with gazetted forests in the upstream zone, consisting of South-Western Mau, Western Mau and Trans-Mara forests, and with well managed tea plantations in the lower reaches of the tributaries coming from the forests. The watershed is well conserved in this area.

The western part of the basin above the altitude of 1,800 m is used for crop cultivation and tea plantations. Along some parts of the river courses, marshy plants grow densely, and sparse forests are observed in very limited places. In these zones, the most crop cultivating lands are poorly conserved and susceptible to soil erosion. In the beak shaped lower reach, the valley slopes are covered with grasses and bush trees, interspersed with small patches of cultivated areas.

The upstream watershed of the Sondu basin receives rainfalls of more than 2,000 mm annually on an average. It is one of areas with ample rain in Kenya. However the part of the basin is less favoured with rainfalls with less than 1,500 mm annually. The vast Kano Plain, adjacent to the Sondu basin to the north, is endowed with much less rain of less than 1,000 mm annually.

The abundant rainfalls make the Sondu River the most promising water sources in the Lake Basin. Moreover, the Sondu River has several cascades after the confluence of the Yurith. This topography offers good potentials for hydropower generation, especially in the reaches of outfalls from the escarpment.

3.2 People and Population

3.2.1 People

There exist about forty different tribes and races in Kenya. The ethnic composition of Kenya may be seen from Table 3.1, which presents the population by tribe, race and nationality at the time of 1979 census.

The ethnic composition in Western Kenya is quite different from that in Kenya. Major tribes found in the region include Luhya, Luo, Kisii, Kalenjin, Masai, Iteso and Kuria. The Kalenjin is a collective name for the peoples who emerged from the incorporation and assimilation of Southern Cushitic-speaking people, who settled in highlands of Western Kenya, by later arrivals among whom were the Highland Nilotic-speakers. The Kalenjin in the region includes Kipsigis, Nandi and Sabaot. Also other tribes such as Tugen, Elgeyo, Marakwet and Pokot are marginally involved in the region.

General locations of inhabitation by these tribes are illustrated by Figure 3.4. As can be seen from the figure, the Luo command the largest territorial area in the project area.

The Luo people were orginally pastoralists, the remnant of which is still seen in their attitude toward cattle, that not only supports their economy in many ways but also serves a variety of social functions. With the riverine and lacustrine background, the Luo people were and many of them still are active fishermen. In these days, however, they are largely settled cultivators, growing not only more traditional grains such as sorghum and millet but increasingly more maize and cassava. This basic change in their lifestyle is said to be due to increasing population and limited movement imposed by the colonial government (see Chapter 1 of Volume VI for more details).

3.2.2 Population

The population of the LBDA area stands at some 7 million, which accounts for over 40% of the Kenya's total. Of this, about 10% live in the Sondu River basin. The rural population represents over 90% of the total.

The population, its density and growth rates of four districts in the Nyanza Province and also the Kericho district are compared in Table 3.2. As indicated by the table the population density is generally higher in the project area than most other parts of the country, and especially the Kisii district represents one of the highest density (395 per km^2 in 1979).

The inter-census growth rates of population, also shown in Table 3.2, tell that they are considerably lower in the project area than the average growth rate of Kenya or even Western Kenya. These characteristics may indicate that land resources are already becoming a limiting factor for further development of the area as long as the production activities there stay at subsistence level.

With already high population density and limited land resources, the population in the project area appears to be becoming stable. Rural to urban drift of people does not seem to be a major factor, except in the areas around the Kisumu municipality. Significant intra-region migration, however, has occurred in connection with major development project - e.g. The Chemelil Sugar Company in Kisumu district, tea plantations in Kericho, Sotik settlement scheme in Kisii and Awendo sugar development project in South Nyanza.

3.3 Economy

3.3.1 GRDP and Income

Reliable statistics on regional economies are most scarce in Kenya, despite the recent efforts by the Central Bureau of Statistics to compile them. There exist no reliable data on the gross regional domestic product (GRDP) of any region, but the shares of the GRDP in the Nyanza and the Western Provinces in the GDP of Kenya are significantly lower than their population shares.

Although the agricultural sector accounts for about one-third of the Kenya's GDP, the contribution of this sector to the economy of the Western Kenya region must be well over 50 percent. A recent study estimated that the agricultural activities in the Kano Plain area are responsible for some 65 percent of the total products[1/].

The same study on the Kano Plain estimated the per capita annual income for the area to be 640 Kenya Shillings. Current five-year development plans for the districts in the project area provide additional information on the per capita or the household incomes. The Siaya District Plan reports that the average income per capita from crops was estimated to be 617 Shillings in 1982. The Kisii District Plan estimated the average household income for the last five-year plan period to be about 6,000 Shillings per annum.

The JICA Study Team presented, at the time of its inception works, a typical farm budget of small holders in the project area. The average gross annual income of a typical small farm household was estimated to be 4,080 Kenya Shillings, consisting of 1,900 Shillings from crops, 1,080 Shillings from livestock and 1,000 Shillings off-farm income.

From the fragmented data and information presented above, the average per capita income in the project area at present seems to be between 1,200 and 1,500 Shillings per annum. This is still considerably lower than the average figure for the whole of Kenya, which is estimated to be 264 U.S. Dollars or about 3,500 Kenya Shillings in 1983[2/].

3.3.2 Agriculture and Other Primary Production Sectors

Cultivated areas and production of major crops are summarized in Table 3.3 for five districts in the project area. Food crops grown in the area include maize, sorghum, millet, rice, potatoes, cassava and beans, and dominant cash crops are coffee, tea, sugarcane, cotton and sisal. Except rice, that is planted almost exclusively in large scale pilot projects implemented by the National Irrigation Board, most food crops are grown by small scale farmers under rather primitive farm practices. Greater parts of cashcrops are cultivated in large scale under modern and intensive farming techniques, but small-scale farmers are becoming more important in cash crop production, too.

Small farm agriculture practised in the area under rain-fed conditions with little application of fertilizers and chemicals stays largely at subsistence level. According to the 1982 agricultural annual report of Nyanza Province, yields remain generally low; average figures are 2.5 ton/ha for maize, 1.1 ton/ha for sorghum, 0.9 ton/ha for sweet potatoes and 0.7 ton/ha for beans.

Activities in other primary production sectors, including livestock, fishery and forestry, are comparatively more important in Western Kenya than other regions. The importance of livestock and fishing activities is primarily attributable to cultural heritage of the dominant population in the area as mentioned before.

Some 98 percent of the fish production in the project area comes from the Kenya waters of Lake Victoria. The total catch of Lake Victoria fisheries has been rapidly increasing as shown in Table 3.4, but there is evidence that the lake fish has been over-exploited in the past few years and the sustainable maximum yield may be around 40,000 tons per year. Fishing activities in the area, however, are gaining momentum recently. In view of the high demand for fish among local inhabitants, a few programmes have been initiated by LBDA with the financial and technical cooperation of international aid organizations to increase inland fish production by rehabilitating existing fish ponds and establishing new fish farms.

3.3.3 Other Sectors

Gold and associated minerals were extensively mined in Western Kenya in the 1930's by small-scale operators. It is reported that there exist promising mineral deposits of various types, both metalic and non-metalic within the LBDA area[3/]. Moreover, a preliminary exploration is going on in a few areas in the South Nyanza district, including the area around Oyugis just outside the Sondu River basin.

Existing agro-industries include coffee processing, flour mills, dairy factories, sugar factories, jaggeries, cotton mills, tea factories and recently inaugurated breweries. Most manufacturing establishments are of a small/cottage industry type. There exist only a few major factories -- viz. Kisumu Cotton Mills, six sugar factories, Panafrican Paper Mill at Webuye and Kenya Breweries in Kisumu. The six sugar factories employ over 20,000 people in total.

Tourism is another sector that is important for the development of the area due to the climatic conditions, the vicinity to Lake Victoria and a few other major tourism objects. The area is also located in a strategically important position, being central in the East African Community, which may be reformulated after opening-up of borders between Uganda and Tanzania in 1983.

3.4 Development Potentials

3.4.1 Constraints to Development

The highlands of Western Kenya are densely populated and extensively cultivated, resulting in deforestation and land erosion, while the lowlands have been susceptible to floods during rainy seasons, which do not preclude occasional shortage of water in dry seasons. Although the region is endowed with rich water resources, the lack of proper management of these resources and watersheds is a major constraint to the development.

The region is endowed also with large areas of fertile soils, and the climate is generally favourable for agriculture. At present, however, a major part of the region's agriculture stays at the subsistence level due to rather primitive farming techniques and the lack of appropriate infrastructure such as improved feeder roads and storage facilities as well as irrigation and drainage.

Establishment of more agro-related industries and expansion and consolidation of existing ones are hampered by insufficient supply of inputs. Other than agricultural products themselves, the most essential input of insufficient supply is electricity. Another essential input is fuel, and high transport costs of petroleum from Mombasa certainly constitute a major constraint to the industrial development in the region. With this respect, the substitution of energy sources for some industrial processes by electricity poses good prospects. A fundamental and long-term solution to this problem may be found in an improved transportation network with railways and navigation on Lake Victoria as well as roads, which would expand the supply and demand areas for the region.

3.4.2 Development Potentials and the Project

As indicated by preceding descriptions, the region has fairly good potentials for development in view of its resource endowments including soils, water, fish stocks and minerals as well as human resources and its geographic location itself. What is required is an initial breakthrough, and the Sondu project would serve just as such a trigger.

First the electricity generated by the project will add comparative advantages of the region for future industrial development as well as serve for domestic uses. Also the increase in agricultural production will expand the bases for establishing agro-related industries of various kinds. Moreover, improved power and water supply capacity with higher reliability will be essential for tourism development.

Secondly the project will provide opportunities to improve farming techniques. Expanded farm lands, with better irrigation and drainage and protection against floods will allow more intensive farming practices to take place, if combined with improved provision of infrastructure and extension services.

Another important effect of the project is foreseen on geographic distribution of population. If the lowlands in the region are developed so that they can sustain larger population and more economic activities, the people now living on highlands or hill slopes will be able to settle in the lowlands. This will in turn, prevent the encroachment of highlands and hill slopes by inappropriate farming practices such as shifting cultivations. Then a favourable effect is expected on the Sondu project being planned with improvement of its watersheds.

The Sondu multipurpose development project with its outputs of electricity and agricultural commodities would significantly contribute to the improvement of financial and project implementing capability of LBDA. This will in turn help the Authority to embark upon other major investment projects including those related to transportation infrastructure.

Chapter 4. PROJECT SITE CONDITION

4.1 Location and Topography

The Sondu River, one of six major rivers in the Lake Victoria basin, which has the catchment of 3,470 km^2 at the river mouth originates from the western slope of the Mau Escarpment and flows down westwards gathering major tributaries, the Yurith and Kipsonoi rivers. The Yurith River which passes Kericho areas with annual precipitation of more than 2,000 mm is characterized as the river with ample flow. Supported by this ample flow, the Sondu River has been marked as the river with high development potential since early 1900's. Annual average flow of 41.6 m^3/sec at the stream gauge near the proposed damsite, 1JG1, may endorse the attractiveness of development.

After the Yurith and Kipsonoi rivers merge, the Sondu River comes into the narrow gorge penetrating the Nyakach Escarpment and falls in cascade with scenery waterfalls called Odino falls to the flood plains at Nyakwere. Elevation falls from Sondu village (El.1,500 m) located 12 km downstream from the confluence of both rivers to the foot of escarpment (El.1,200 m), Nyakwere, are around 300 m for a distance of some 25 km. The Sondu River finally drains into Winam Gulf of Lake Victoria.

The proposed site of the Sondu/Miriu hydropower plan is located about 18 km downstream from Sondu village accessible from Kisumu within one hour using the all paved Kisumu-Kisii highway (Route A1). Topography at this site has such a favour that a large impounding reservoir can be created by building an 80-100 m scale dam and that trans-basin of the Sondu River flow to the Nyakach Plain can be made possible with a 4 km long waterway heading Thurdibuoro village from the reservoir.

This trans-basin plan not only creates high head difference of 145 m (river bed elevation at the damsite, 1,350 m minus tailwater level, 1,205 m), but also makes possible to utilize water released from the tailrace of power plant to irrigation supply in the Nyakach and Kano plains. Thus, the proposed site of the Sondu/Miriu hydropower plan can be said to retain great advantages in the sense to utilize limited resources in full extent.

4.2 Geology

4.2.1 Regional Geology

Figure 4.1 shows a geological plan of the project area.

The region consists mainly of granodiorite which is intrusive rock of post-Cambrian period, with minor occurrence of diorite, hornblende gneiss and dolerite. The region is divided by a prominent escarpment, Kendu fault, running in almost east-west direction. North of this escarpment occur hillwash deposits with a depth of 10 to 20 m underlain by heavily weathered granodiorite. The proposed location of power station is selected at gently sloped area just at the foot of this escarpment.

On the plateau south of this escarpment are situated the potential sites for storage or intake dams along the Sondu River valley at some 1,300 m to 1,500 m in elevation. Over the most parts of the Valley, the outcrops of granodiorite are found with gneiss at places. The left side bank is of relatively coarse grained texture and affected by weathering at the upper part of the abutment, while the right side bank consists of hard and fine texture rock.

4.2.2 Seismicity

The seismicity of the area was reviewed to assess the earthquake coefficient to be used for the dam design, based on the following data and reports:

- Earthquake records in the western Kenya (data collected through International Seismological Centre)

- A catalogue of felt earthquake in Kenya by I.S. Loupekine, 1971
- Preliminary report on the Homa bay earthquake by I.S. Loupekine, 1968
- Engineering report on Kiambere Project.

Most records show that the area is situated in a low risk zone, despite the fact that the Eastern or Gregory Rift Valley runs north-south 100 to 200 km away from the proposed damsites. The computation of the ground acceleration indicates 50 to 60 gals for the prominent events, which correspond to seismic coefficient of $K \doteqdot 0.05$ and 80 gals for the maximum probable earthquake with a return period of 100 years, which correspond to seismic coefficient of $K \doteqdot 0.08$.

The seismic coefficient of $K = 0.05$ could be adopted in such a low risk zone. However, it is prudent for the feasibility design to adopt $K = 0.10$ as a coefficient of earthquake of maximum probable earthquake to occur once in 100 years.

4.2.3 Engineering Geological Assessment of Potential Project Sites

In addition to general geological survey of the project area, more detailed geological investigations were made for the potential project sites along the lower reaches of the Sondu River. The results are contained in Appendix I, Volume IV. Engineering geological assessment indicates that local geology of the potential project sites, as partly reported in the Interim Report, is suitable for constructing major structures of the Sondu/Miriu project.

4.3 Hydrology and Meteorology

4.3.1 General Features

The climate of the Sondu River basin located at highlands of El. 1,600 m to El.2,700 m is, in general, gentle with small variation of average air temperature of 19°C to 25°C throughout a year, whilst daily temperature varies much larger, ranging from 15°C to 30°C. This basin receives relatively abundant annual rainfall of 1,500 mm to 1,600 mm varying 2,000 mm in highland to 1,200 mm in lowland. Rainfall is eminent in the period of March to June, but there is no remarkable dry month. It is however pointed out that over-year variation of annual rainfall is considerably large.

The Sondu River is generally characterized as the river with ample flow replenished by abundant rainfall of the basin. Seasonal distribution of discharge is similar to that of rainfall, but seasonal fluctuation of flow is smaller than that of rainfall due to retention and retardation effects of swamps, channels, dense forests and tea plantations in the upper reaches. Floods have characteristics that a dull peak discharge prolongs for a long time strongly influenced with these retention and retardation effects.

4.3.2 Meteorology

Rainfall data were collected in and around the Sondu River basin at the Hydrology Section of the Ministry of Water Development (MOWD). Monthly rainfall data were gathered from 157 stations, whilst four stations out of the above 157 stations for daily rainfall.

Based on the data of 157 stations, an isohyetal map of annual rainfall was prepared in and around the Sondu River basin as presented in Figure 4.2. Annual rainfall ranges from 2,000 mm in Kericho area to 1,200 mm at the river south with an average value of 1,480 mm. This figure may disclose that the Yurith River of which catchment is covered with the 1,800 mm/yr isoline contributes to substantial flow of the Sondu.

Figure 4.2, furthermore, depicts average monthly rainfall of eight rain gauges selected in and around the Sondu River basin. A peak of more than 200 mm/month appears in the period of March to May.

Using daily rainfall data collected from four stations, a frequency analysis was carried out to estimate probability of 1-day, 3-day, 5-day, 7-day and 15-day basin rainfall. The probable rainfall estimated are shown in Table 4.1 and will be used to predict flood discharge using the relationship between rainfall and runoff.

Daily evaporation data were, on the other hand, collected at two meteorological stations, Sotik Water Supply (9035297) and Ahero Experimental Station (9034086) for estimating the evaporation rate from the reservoir surface. In addition, evaporation data at the Kisumu Airport and Kericho Timilil T.R.I. summarized in East African Meteorological Report, Meteorological Development Nairobi were referred for evaluating the reliability of data collected at the Sotik Water Supply and Ahero Experimental Station. The evaporation rate at the proposed reservoir sites, the Sondu/Miriu and Magwagwa, which will be discussed in the subsequent Chapter 6, was consequently estimated as follows:

Unit : mm/day

J	F	M	A	M	J	J	A	S	O	N	D
4.0	4.2	3.8	3.4	3.2	3.2	3.0	3.2	3.5	3.6	3.4	3.5

4.3.3 Hydrology

Low Flow: Stage records were collected from 13 stations operated by the Hydrology Section of MOWD; nine in the Sondu River and four in the Nyando River. The locations of those stream gauges are shown in Figure 4.3.

The stream gauge of 1JG1 near Sondu village acts as a key station for the determination of development scale of the Sondu Multipurpose Development Project, since 1JG1 is not only located near the project site, but also keeps the longest records in the basin. High attention was therefore paid to the runoff prediction at 1JG1.

The reliability of the rating curve developed at 1JG1 by the MOWD was at first tested with the double mass curve and correlation method. Then, the interpolation of missing data was made, because the simulation study to determine the development scale of the project requires continuous runoff data for the simulation period.

Continuous runoff data on daily basis were obtained at 1JG1 for the period of 1946 to 1983, and then monthly mean discharge was computed as shown in Table 4.2. A value of 41.6 m^3/sec was obtained as an average of monthly mean discharge. Besides, Table 4.3 shows monthly mean discharge computed at 1GD1, 1GD3 and 1GD4 using the rating curve revised by Lotti[1/].

High flow: Flood hydrographs were prepared for the design of spillway, intake weir and diversion facilities. Prediction of flood hydrographs is based on the synthetic method using the relationship between rainfall and runoff. Furthermore, reliability of synthesized hydrographs was evaluated with probable instantaneous peak discharge estimated with annual peak discharge collected by reading the stage recording charts at 1JG1.

A non-linear mathematical model derived by Chow and Kulandaiswamy[4/] was applied as the model to synthesize flood hydrographs, considering the high non-linearity of the Sondu River basin; flood hydrographs measured at 1JG1 have characteristics that flood peak discharge is rather small in terms of specific discharge and that a dull peak prolongs for a long duration.

The synthesized hydrographs for each recurrence interval are shown in Figure 4.4, adding the base flow of 20 m^3/sec, the average value of March flow, by assuming that the floods frequently occurred on April and May start on March.

Discharge measurements and new stream gauges: Reliability of discharge data much relies on whether or not a reliable rating curve is developed. Intensive discharge measurements are therefore carried out for the confirmation and extension of the rating curves under cooperative work of LBDA, MOWD and JICA.

Besides intensive discharge measurements, two new automatic stream gauges were established to reinforce the programme of runoff observation in the Sondu River basin. The locations of two gauges named 1JG4 and 1JF8 are near the gauges 1JG3 and 1JF1 as shown in Figure 4.3; the former is currently under operation with staff gauges.

Sedimentation: Sediment loads into the reservoir were estimated by developing a rating curve of sediment yield based on the measurement records at 1JG1, 1JF1 and 1JG2 on late 1940's and 1950's.

Annual sediment yield estimated for the proposed reservoir sites was as follows:

$5,750 \times 10^3$ m^3 for the Sondu/Miriu
$4,940 \times 10^3$ m^3 for the Magwagwa.

In terms of the denudation rate, it corresponds to the order of 0.2 mm/km^2.

Development of the watershed of the Sondu River was briefly examined with the interpretation of Landsat images in late 1970's to supplement the validity of the rating curve developed based on the measurement records of suspended load on late 1940's and 1950's. As a result, there was little indication that such devastation as to cause sediment yield increases as time goes by, i.e. 1950's to date. The rating curve of the sediment yield so developed may be concluded to be valid. However, it should be stressed that there is an urgent need to identify the measurement of sediment yield especially during floods.

4.3.4 Water Demands and Mandatory Release

Surface water of the Sondu River is at present abstracted for domestic, public, irrigation, industrial, power (flour mills) and other uses with the net consumption of 0.07 m^3/sec in normal flow and 0.89 m^3/sec in flood flow.

Referring to the Lotti's information[5/], water demand in the Sondu River will increase five times over a 30-year period of 1978 to 2008. Applying this estimate, net consumption in the normal flow will reach an order of 0.3 to 0.4 m^3/sec (0.07 x 5 = 0.35 m^3/sec) at early 2000's.

On the other hand, a large scale transbasin scheme is contemplated in the Nyando; the Greater Nakuru Water Supply Project. An amount of 0.3 m^3/sec will be deducted from the substantial flow of the Nyando by the year 2005 when the project is expected to reach the full development scale. In building a simulation model to determine the development scale of the Sondu Multipurpose Project, these water demands should, in advance, be taken into account to stand all the contemplated projects soundly.

According to information of MOWD, permit holders of water abstraction in the downstream reaches from the confluence of the Yurith and Kipsonoi rivers are seven, totalling 1,058.93 m^3/day (0.012 m^3/sec) in gross abstraction. Meanwhile, water abstraction is limited to a negligible order in the downstream reaches from the Nyakwere village. Thus, even if water abstraction increases in future, the mandatory release from the reservoir to the lower reaches may be determined in terms of river conservation including the preservation of the Odino Falls as tourism. Further discussions on hydrology and meteorology are given in Appendix III of Volume IV.

4.4 Construction Material

4.4.1 General

The objective of the construction materials investigation at this time has been to assess the availability of suitable natural materials in the project area for the major requirements of the project and to make initial assessment of their properties. The field survey of construction materials was carried out from June to November 1984, in close association with the geological survey. The prospective explored sources of earthfill, rock and sands are shown in Figure 4.5.

The construction material survey started on June 27, 1984 with test pitting works in the proposed borrow area. From each test pit, the soils to be used for the impervious earthfill were sampled for laboratory testing. Concerning quarried rock to be used for the rockfill as well as for the concrete aggregate, the rock samples were taken from the bored cores for laboratory testing. In addition to those samples, sands occurring at and around the power station site were also taken for laboratory testing. All the samples were hauled to the Gauff's laboratory in Nairobi.

4.4.2 Impervious Material

Impervious earth for the dam embankment will be obtained from the weathered layer of granodiorite formation in the proposed borrow area. The material of this source, which had been considered to be lateritic red soils at the inception stage, was found out after test pitting to be "heavily weathered granodiorite" which was overlaid by the lateritic red soils with a thickness of 1 to 2 m.

Exploratory excavation in the borrow area on the range (500 m x 2,000 m) indicated that the area contained ample quantity of the earthfill material, probably not less than 1,000,000 m^3.

The heavily weathered granodiorite is classified as silty-sand (SM). Through such handling process as excavation, stockpiling, loading and unloading, it will probably lose moisture content and tend to be a semi-impervious soil of low or moderate plasticity. The weathered granodiorite showed rather high permeability; that is, 1 to 3 x 10^{-4} cm/sec in the laboratory test as shown in Figure 4.6. In spite of this fact, the engineer is of such an opinion that the permeability of this material could be reduced to the allowable limit of $K = 5 \times 10^{-5}$ cm/sec, if the materials are well broken down and compacted with addition of water to bring the moisture content to slightly higher than optimum; that is, 3 to 4 percent above optimum, in the embankment work. To clarify and confirm these compaction-permeability characteristics will be carefully examined at the next investigation stage.

The compaction characteristics for the representative weathered granodiorite and lateritized red soil are shown in Figure 4.7 and Figure 4.8.

4.4.3 Quarried Rock, Filter and Concrete Aggregate

Two potential sources of quarried rock, viz. the proposed quarry site and the excavated rock in the dam foundation and tunnel, were investigated. The quarry site appears to have abundant reserves. Materials sampled from the both sites showed the well performance in such tests as water absorption, Los Angeles abrasion, sulphate soundness and unconfined compressive strength as shown in Table 4.4.

These quarried rocks are durable and strong. Uniaxial compressive strengths are almost over 1,000 kg/cm^2 not only in dry condition but also in wet condition. Furthermore, the loss by the sodium sulphate soundness test was rather low. Therefore, both are considered to be suitable for rockfill as well as for filter and concrete aggregates after being crushed and classified.

The weathered quarried rocks will be usable exclusively for the random zone of the rockfill dam.

4.4.4 Gravel-sands

No significant reserves of gravel-sands occur within the project area as alluvial deposits in the bed and banks of the Sondu River. The surface exploration along the river has revealed that deposits of river sand are found in quite limited localities and scarce in quantity. Furthermore, based on the brief reconnaissance in the project area and the geological interpretations in the area concerned, any idea of designating the borrow site along the river had to be abandoned for obtaining sand and gravel materials to be used for filter and concrete aggregates. Therefore, no exploratory excavation was carried out at this stage, except sampling river sands which occur in places along the small streams and the gullies formed on the hill wash on the north of the escarpment. These sands are now seen to be used for the concrete works such as bridge construction around there.

According to the basic engineering properties such as specific gravity and gradation, the sands are considered to be suitable for fine aggregates. The gradation curves are shown in Figure 4.9.

4.5 Environmental Aspect

4.5.1 General

Environmental impact associated with implementing major investment projects is a matter of increasing concern in Kenya. With this view, an environmental study was carried out at this time as a part of the feasibility study on the Sondu River multipurpose development project.

The objectives of the environmental study were first to clarify the existing conditions of the environment in and around the project site, particularly in the Sondu River basin, and secondly to assess possible environmental impact of the Sondu project. The environmental impact assessment as reported in Chapter 9 is only at a preliminary level, as the project is still at relatively early planning stage.

4.5.2 Existing Environmental Conditions

Existing environmental conditions in the Sondu River basin were studied in many aspects, based on the existing data and reports, hearings from government officials, experts and others and limited field surveys and investigation. Aspects covered by the study are population, land use, economic activities, archeology, public health, climate, soils, water quality, vegetation, wildlife, fish and fisheries and nature conservation.

Study results are contained in Chapter 3 of Volume VI: Supporting Study Report for Socio-Economy and Environment. Main features of the environment are summarized in the following.

Land use and vegetation

The present land use pattern in the Sondu River basin is summarized as follows:

	Land use	Area in ha	(Share in %)
I.	Agriculture	164,792	(46)
	Active cultivation	87,531	
	Cash crops	32,078	
	Staple crops	31,370	
	Vegetables/fruits	2,180	
	Other/unidentified	3,823	
	Field borders	2,057	
	Fallow fields	13,789	
	Managed pasture	61,415	
II.	Infrastructure	21,378	(6)
III.	Natural vegetation	171,358	(48)
	Total	359,895.	(100)

In the Sondu River basin, natural vegetation and agricultural land take most part of the land. More detailed land use data by sub-basin are contained in Volume VI.

Public health

Most of the diseases afflicting many Kenyans today are either communicable or due to poor nutrition. The most prevalent disease in Kisumu and South Nyanza districts is malaria that accounts for 32.9 percent in Kisumu district and 34.8 percent in South Nyanza district of the total new cases of infections. Acute respiratory infections and diarrhea also have high infection rates.

The probable endemic diseases in the study area which may be affected by the hydro-electric and irrigation development are (1) malaria and (2) schistosomiasis (S.haematobium and S.mamsoni). These are described below.

(1) Malaria

Plasmodium falciparum - causing falciparum malaria especially in the humid tropics where transmission is possible all year round. This is the most serious form, and may be fatal.

Plasmodium vivax - causing vivax malaria especially where, due to a pronounced dry or cool season, transmission is seasonal.

Plasmodium malariac - causing quartan malaria, in which there are usually bouts of fever every three days. It has a patchy distribution in the tropics and subtropics.

Plasmodium ovale - causing ovale malaria, uncommon and found mainly in West Africa.

By far the most common and serious malaria infections are caused by P. falciparum and P. vivax.

The area along Lake Victoria has the highest incidence of malaria in Kenya (see volume VI for details). Out-patient morbidity of malaria per 100,000 of population is much higher in Nyanza Province than in surrounding Western and Rift Valley Provinces, and especially high in Kisumu district. According to annual reports, the number of deathes by malaria in Nyanza Provice was 100 in 1981, 71 in 1982 and 141 in 1983.

(2) Schistosomiasis

Schistosomiasis, also known as bilharzia, is an important disease whose vector is not an arthropod, but an aquatic snail. Schistosomiasis in man is mainly caused by one of four species of trematode worms:

Schistosoma japonicum - found in East Asia and the Philippines and infecting domestic and wild animals as well as man.

Schistosoma mansoni - found in Africa, the Middle East, South America, and the Caribbean and infecting man and some animals.

Schistosoma haematobium - found in Africa and the Middle East and rarely infecting animals.

Schistosoma intercalatum - found in Cameroon, Congo, Gabon, and Zaire.

Of these kinds, S. mansoni and S. haematobium are distributed in the study area.

The percentage which schistosomiasis occupies in the out-patient morbidity is 0.2% in Kisumu district and 0.4% in South Nyanza district. These percentages are small in number, but compared to Western and Rift valley Province, they are comparatively large. According to annual reports, no people died of schistosomiasis both in 1982 and in 1983.

Water quality

Water quality data on the Nzoia and the Nyando rivers are available up to 1957 from Monitoring Programme of the Water Quality and Pollution Control Section in the Ministry of Water Development. As there were no such data for the Sondu River, water samples were taken at selected points of the river and analyzed at this time. Results are contained in Volume VI.

The Sondu River shows red brown colour with high turbidity. Concentration of dissolved oxygen is found at almost saturation level. Concentration of nitrate-N is comparatively high. The analysis of chemical property indicates water quality in Sondu River is suited for irrigation.

Fauna and flora

(1) Vegetation

Natural vegetation covers about 48 percent of the Sondu basin as already mentioned. It is further broken down into the following:

Vegetation type	Area in ha	Share in %
Tree cover	77,349	21.5
Bush cover	31,087	8.6
Herbaceous cover	62,922	17.5
Total	171,358	47.6

More details by sub-basin are included in Chapter 3, Volume VI.

(2) Wildlife

There exist no data available on wildlife of the Sondu basin. Hearings from the local people around dam site indicate the principal widelives include the following:

Mammals

ENGLISH	LUO
Bushbuck	Ngao
Antelope	Mwanda
Monkey	Onger
Rabbit	Apuoyo
Sacred Baboon	
Squirrel	
Rat	

Reptiles

Lizard	Ogwe
Monitor	N'gech
Crocodile	Nyan'g
Cobra	Rai
Python	Ngielo
Blackmamba	Rachier
Brownmamba	Olueru.

(3) Fishes and Fisheries

Lake Victoria has representatives of five orders, thirteen families, twenty-eight genera, and over 200 species. The followings indicate representatives of the most important groups giving the scientific names. All the species of fish present in Lake Victoria are edible.

The Lake has a Nilotic fish fauna with a degree of endemism. During 1951/54 four non-endemic Tilapia species were introduced in Lake Victoria. Tilapia niloticus and Tilapia leucosticus were from Lake Edward in Uganda. Tilapia zillii a native of Lake Albert in Uganda was also introduced during the same period. Tilapia rendalli a fish found in Lake Malawi and other southern African waters and a close relative of Tilapia zillii also escaped into Lake Victoria from fish ponds near Kisumu.

For Lake Victoria, another development of considerable significance occured during the period 1962/63 when the predator fish Lates niloticus, the Nile perch was introduced in Lake Victoria from both Lake Albert, Uganda and Lake Turkana, Kenya. Nile perch is the largest of all African freshwater fish. Heaviest recorded weight is 160kg but fish of 50kg is common.

Two indigenous species of Tilapia namely Tilapia esculentus and Tilapia variabilis previously the mainstay of the fishing industry and the fishes of greatest commercial importance, have virtually disappeared from the Winam Gulf. Numerous other fish species also have declined drastically, especially Haplochromis, Labeo, Barbus, Mormyrus, Schilbe, Synodontis, Bagrus, Clarias, Alestes and Protopterus.

The riverine fishery is based on the species of fish that travel upstream to spawn during the rainy season especially when the rivers are in flood. During the rains, the rivers bring a flush of rich nutrient materials into the lake leading to more food resources in the sublittoral zone.

Some of the fishes in the Winam Gulf especially Barbus, Labeo, Alestes, Clarias and Schilbe migrate upstreams when the rivers are in flood, breed in them and return with the young fish to the lake as the water level of the rivers drops.

Chapter 5. POWER SUPPLY AND DEMAND

5.1 Organization of Power Sector

The electricity supply in Kenya at present is managed by four organizations:

(1) The Kenya Power and Lighting Co. Ltd. (KP&L),
(2) The Kenya Power Co. Ltd. (KPC),
(3) Tana River Development Co. Ltd. (TRDC), and
(4) Tana and Athi Rivers Development Authority (TARDA).

KP&L was incorporated in 1922 with its original name of the East African Power and Lighting Co. Ltd (EAP&L), as a sole distributor of electricity in Kenya. Both KPC and TRDC were established by EAP&L, the Kenyan Government and Commonwealth Corporation, the former in 1955 principally to finance the interconnection with Uganda and sell the imported power to EAP&L, and the latter in 1964 to develop the hydropower potentials of the Tana River. Since 1979, the Kenyan Government has been the majority shareholder of KP&L for policy reasons. The Government had also acquired the total equity of KPC and TRDC in 1971.

KP&L, primarily concerned with commercial distribution of electricity throughout Kenya, also generates the entire power requirements of the coast system covering Mombasa, Malindi and Kwale, provides the necessary thermal back-up for the main grid system, and operates generating stations not connected to the grid. Moreover, the company manages and staffs KPC, coordinates all sources of power, and takes charge of the Olkaria geothermal power project.

TARDA owns the Masinga hydropower station, which was completed at the end of 1980 as the first hydropower project since TARDA was established in 1974 (as Tana River Development Authority or TRDA), and is now implementing the Kiambere hydropower project. Agreements between KP&L and TARDA on the management and operation of these facilities may be indicative of how the Sondu project would be managed and operated after its completion.

The Masinga power station, owned by TARDA, is presently managed and staffed by KP&L, which through TRDC purchases the electricity on the basis of an agreed price per unit of electricity received. These revenues received by TARDA cover its debt service related to the financing of Masinga dam and power station. Operating expenses and administration costs including insurance are borne by KP&L.

For the Kiambere power station, however, an alternative arrangement for operation has been sought by KP&L and TARDA. This arrangement would include the leasing of all the power-related facilities of Kiambere by KP&L, which would pay the proper amount of rent to cover TARDA's overhead expenses as well as debt service related to Kiambere's power-related fixed assets.

5.2 Existing Power Supply System

5.2.1 General

The national power grid system (NPGS) has 9 major power stations (except Owen falls power station in Uganda) and 20 major substations linked with each other through 220 KV and 132 KV trunk lines, as summarized in the following (See also Table 5.1):

(1) Generating plants	Total installed capacity
(a) 6-hydro-electric plants	342.3 MW
(b) 2-oil-fired steam and gas turbine plant	128.1 MW
(c) 1-geothermal plant	30.0 MW
Total	500.4 MW
(2) Transmission and sub-transmission lines	5,446 km-cct
(3) Distribution lines (11kV)	6,306 km-cct
(4) Substation transformer capacity	2,108 MVA
(5) Distribution transformer capacity	931 MVA.

Moreover, a firm power of 30MW has been supplied since 1955 from Owen Falls hydropower station of the Uganda Electricity Board (UEB) by a double circuit 132 KV transmission line. The supply will continue up to the year 2005 under terms of contract with Uganda.

The load dispatching center (LDC) for the NPGS has been provided in Juja Road substation at Nairobi with a semi-automatic mosaic tile board incorporating switches and lamps, but operations are usually carried out by instruction through power line carrier (PLC) facilities to the substations. The LDC is planned to be improved by 1986 since microprocessor based equipment is provided at Lessos and Kamburu for data transmission thereto.

5.2.2 Existing Power Plants

The total installed capacity of all the power plants in Kenya is 526.7 MW as detailed in Table 5.2, excluding import of hydro power from Uganda. The composition is 66.2% of hydro plants, 28.1% of fossile fuel fired generation plants and 5.7% of geothermal plants.

All hydropower plants (342.3 MW) except some small ones are concentrated on the Tana River. Oil-fired steam plants (98 MW) are located at Mombasa which is the only power station of this kind in Kenya. In the Western area, only Gogo Falls power station (2x1.0MW) was developed for mines and now connected to the NPGS at 33 KV line.

Some old thermal plants (2x5 MW) are planned to be retired according as a new plant is completed, probably in 1988 upon completion of Kiambere hydroelectric project. A diesel power plant (20 MW) connected to the NPGS will also be retired at the same time due to age.

Geothermal power plant (2 x 15 MW) at Olkaria which is located about 50 km westward from Nairobi was recently developed and started its services in 1981 as base load plant. The third unit (15 MW) was commissioned in 1985.

The electricity supply (30 MW) from Uganda, started in 1955, is expected to continue at least up to 2005. KP&L, however, does not consider it to be firm power from 1988 onward for its development plan.

In addition, some industries own captive power to generate electricity for sugar factories, tea processors, breweries and others. However, as these plants do not operate in parallel with the NPGS during the system outages, KP&L has no contract of purchasing power from them.

5.2.3 Existing Transmission Lines and Substations

As given in Table 5.1, the total circuit length of the existing transmission and sub-transmission lines is about 5,400 km as of 1983, of which the increment in 1983 was about 900 km (17%). The principal transmission line routes are given in Figure 5.1. Recently a 220 kV transmission line between Kamburu power station and Rabai substation at Mombasa was completed. Total length of the existing 11 kV distribution lines is about 6,300 km as of 1983 and expanded by 280 km (4%) in 1983, as shown in the same Table.

The major substations are located along a 132 kV transmission lines from Nairobi to Lessos-Musaga northwestward and to Mombasa southeastward as shown in Figure 5.1.

The transformers in services are summarized below:

(1) Generating substations	35 nos.	854 MVA
(2) Distribution substations	158 nos.	1,253.5 MVA
(3) Distribution transformers	6,330 nos.	931 MVA
Total	6,523 nos.	3,038.5 MVA.