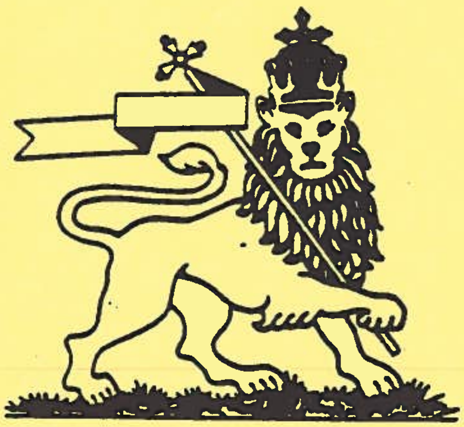
LAND AND WATER RESOURCES OF THE BLUE NILE BASIN



ETHIOPIA

APPENDIX I - PLANS AND ESTIMATES

Volume 1

Prepared for the Department of State
Agency for International Development

By the United States Department of the Interior
Bureau of Reclamation
1964

LAND AND WATER RESOURCES OF THE BLUE NILE BASIN

ETHIOPIA

APPENDIX I - PLANS AND ESTIMATES

Volume 1

United States
Department of the Interior

Bureau of Reclamation

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ABBREVIATIONS, CONVERSION FACTORS, AND ETHIOPIAN MONETARY AND CALENDAR EQUIVALENTS

Abbreviations:
- EELPA = Ethiopian Electric Light and Power Authority
- IEG = Imperial Ethiopian Government

Conversion Factors: Metric-English Systems
- 1 meter (m.) = 39.37 inches = 3.2808 feet
- 1 kilometer (km.) = 0.6214 mile = 3,280.8 feet
- 1 square meter (sq. m.) = 1.196 square yards = 10.764 square feet
- 1 hectare (ha.) = 10,000 square meters = 2.471 acres = 1/100 square kilometer
- 1 hectoliter = 0.1 cubic meter = 2.838 bushels; 26.417 gallons
- 1 square kilometer (sq. km.) = 0.3861 square mile = 100 hectares = 247.1 acres
- 1 cubic meter (cu. m. or m^3) = 1,000 liters = 1.308 cubic yards = 35.31 cubic feet
- 1 cubic meter = 0.000,810,7 acre-foot
- 1 acre-foot = 1,233 cubic meters
- 1 kilogram (kg.) = 2.204 pounds
- 1 kilogram per hectare (kg/ha) = 0.8926 pound per acre
- 1 metric ton = 2,204 pounds = weight of 1 cubic meter of water
- 1 kilogram per square centimeter (kg./sq. cm.) = 14.22 pounds per square inch = 32.8 feet of water
- 1 cubic meter per second ($m^3/s.$) = 35.31 cubic feet per second (c. f. s.)
- 1 English horsepower = 550 foot-pounds per second
- 1 metric horsepower = 75 kilogram-meters per second
- 1 metric horsepower = 0.9863 English horsepower = 735.45 watts
- 1 cubic meter of water per second under 1 meter head = 9.81 kilowatts at 100 percent efficiency
- 1 million cubic meters of water under 1 meter head = 2,730 kilowatt-hours at 100 percent efficiency

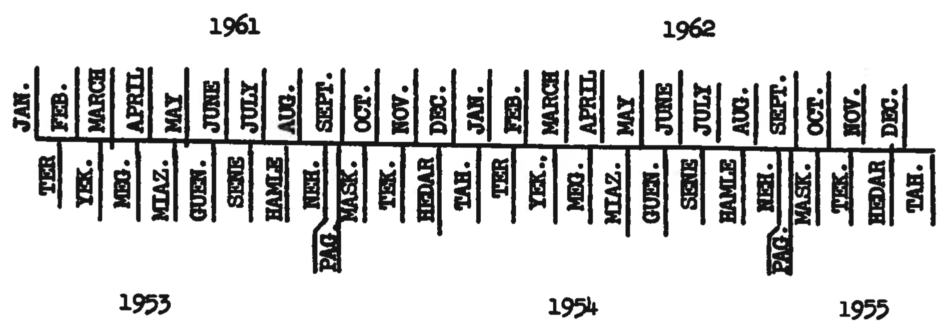
Temperature Conversion:

Centigrade: $C. = \frac{5}{9}(F^\circ - 32)$ Fahrenheit: $F. = \frac{9}{5}C^\circ + 32$

Ethiopian-United States Monetary Values: Rate of exchange used in this report
1 United States dollar (US$1.00) = 2.50 Ethiopian dollars (Eth$2.50)

Ethiopian Calendar (30-day months, except Pagume):
- Maskaram = Sept. 11 - Oct. 10
- Tekemt = Oct. 11 - Nov. 9
- Hedar = Nov. 10 - Dec. 9
- Tahessas = Dec. 10 - Jan. 8
- Ter = Jan. 9 - Feb. 7
- Yekatit = Feb. 8 - March 9
- Megabit = March 10 - April 8
- Miazia = April 9 - May 8
- Guenbot = May 9 - June 7
- Sene = June 8 - July 7
- Hamle = July 8 - Aug. 6
- Nehasse = Aug. 7 - Sept. 5
- Pagume = Sept. 6 - Sept. 10

UNITED STATES OR GREGORIAN CALENDAR



ETHIOPIAN CALENDAR

TRANSLITERATION

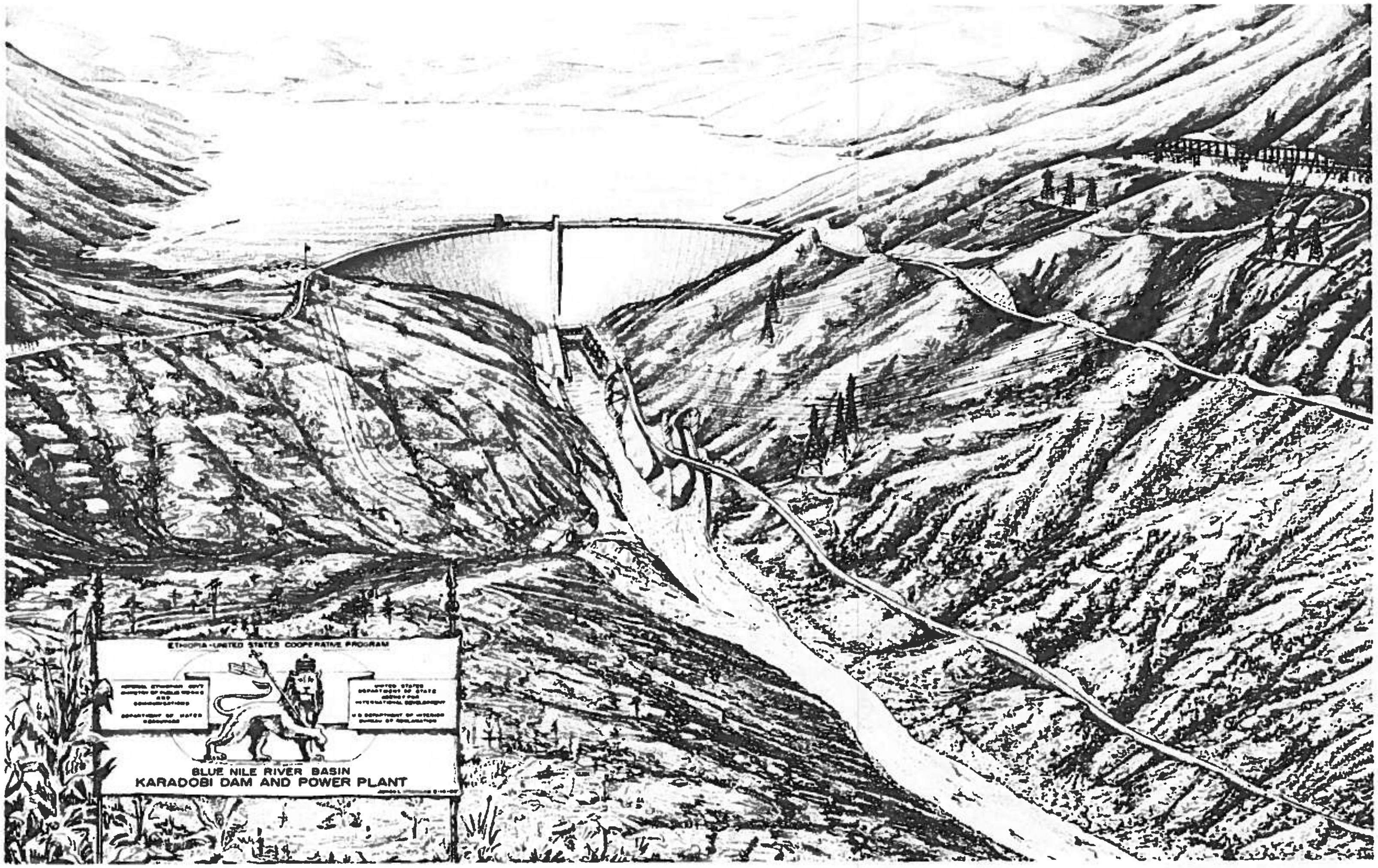
Certain inconsistencies in the spelling of names may be noted on maps and drawings and in the text. Because of the difficulty in transliterating Arabic, Amharic, Galla, and Italian into exact English equivalents, some variation of spellings and even in names occurs in the basic maps and drawings. It will be noted, however, that the phonetic pronunciation of names is similar regardless of spelling, except in the rare situation where an entirely different English name is used because of long established convention. An example of the latter is the name for the principal river, Blue Nile, which in Amharic is known as Abbay (Abbai). Addis Ababa is often referred to as Addis Abeba. Other examples are as follows:

Tvol	Tul
Lekkemt	Nekemti
Acachi	Akaki
Jima	Jimma, Gima
Langano	Langana
Shashamane	Shashamana
Shewa	Shoa
Welaka	Votaka

In western and northwestern Ethiopia, local usage of Arabic words for streams and mountains is usually retained. For example, "Jebel" denotes mountain and "Khor" identifies a watercourse. In addition, the English name or abbreviation sometimes precedes the Arabic term, as with "Mt. Jebel Kir."

Local usage sometimes requires different names along different lengths of the same river. For example, the Guder River is known as Tacur, Bello, and Guder.

Wherever possible, a consistent spelling has been used for identical places in this report.



Artist's Conception
KARADOBI DAM AND POWER PLANT

SECTION 1--INTRODUCTION

In this appendix to the Blue Nile River Basin report, information concerning all of the projects investigated is presented. Since a separate appendix has been prepared covering the hydroelectric power projects, only the plans and estimates as they pertain to hydroelectric power potentials, are included in this report. Irrigation projects are treated in greater detail.

In general, this includes a brief description of the drainage area or geographical subdivision of the Blue Nile River Basin, general geology and physiography, climate, project lands, and hydrology. A detailed description of the principal features includes a plan of development, site geology, construction materials and access, reconnaissance designs and construction cost estimates, and plan selection and alternatives. Operation, maintenance, and replacement cost estimates for irrigation facilities are included, the OM&R for power facilities being included in the power appendix.

Generally, the approach used in studying the potential irrigation projects was to utilize such topographic maps of the area as could be made available where field reconnaissance indicated a possible irrigation project could be developed. Land classification was performed, site geology conducted on the damsite tentatively selected, construction materials assessed, and hydrological studies performed. The final plan of development evolved from the correlation of all these investigative data.

The potential irrigation projects described herein will vary from project to project, dependent primarily upon the degree of engineering survey data available. On some of the project areas, rough topographic maps were made by means of field surveys and maps drawn from photogrammetric compilation. Layouts and designs were thus performed to a higher degree of accuracy than for those projects which did not receive this type of treatment. It must be emphasized, however, that availability of even this type of physical data is considered to be minimum for a reconnaissance-type study. Taken together with the meagerness of other physical data and such unknowns as subsurface conditons, the plans and estimates are considered to be of limited reconnaissance in character and dependent to a great extent upon the observation and judgment of technical personnel conducting the survey. These studies are not intended to serve as a basis for actual development, but rather as a guide in the selection of projects for further detailed studies prior to development. It is recognized that as a result of future, more detailed examination, some changes in the planned project features may occur. These changes, however, will not invalidate the data contained herein or detract from their value as a basic guiding instrument in the over-all development of the basin. The over-all plan of development for the Blue Nile River Basin, as evolved from reconnaissance studies for the development of irrigation and power projects, is presented in the Frontispiece.

GENERAL DESCRIPTION

Blue Nile Basin

Blue Nile (Abbay) River. The Blue Nile River, or Abbay River as it is locally identified in Ethiopia, originates in Lake Tana and is the principal river of the basin. Lake Tana has a drainage basin of about 15,000 square kilometers (5,800 square miles) and has a water surface area of 3,035 square kilometers (1,170 square miles). It is situated at an elevation of 1786 meters (5860 feet) above sea level.

The Blue Nile River emerges from the relatively narrow outlet at the southern portion of the lake and flows southeasterly over the hard volcanic rocks for a distance of about 30 kilometers (19 miles) and then plunges over the Tis Isat Falls, dropping some 45 meters (150 feet) into a deep, narrow gorge with vertical walls caused by the rapid erosion of the softer agglomerate and scoriaceous lava. The river remains entrenched in this deep canyon until it finally emerges near the Ethiopian-Sudanese border. The river makes a wide, irregular loop to the west, and some 900 kilometers (540 miles) from its source it enters Sudan at approximate elevation 487 meters (1600 feet). The Blue Nile River joins the White Nile near Khartoum, forming the main Nile River some 760 kilometers (470 miles) below the Ethiopian-Sudanese border. The general geology of the basin is indicated on Plate I (back pocket). Significant tributaries of the Blue Nile, entering from the north and starting from upstream, are the Birr, the Fettam, the Azena, the Beles, the Dindir, and the Rahad. Those entering from the east and south are the Beshilo, the Welaka, the Giamma, the Muger, the Guder, the Finchaa, the Diddessa, and the Dabus.

Areas of Potential Irrigation Projects. Physiographically, the Blue Nile River Basin may be classified into three distinct land bodies--the plateau and highlands, the plateau valleys, and the plains and eroded hill lands. The plateau and highlands are a vast area dominating the landscape on the eastern portion of the basin. Lying between 2135 and 2745 meters (7000 and 9000 feet) above sea level, they are intercepted by many isolated hills, deeply incised canyons, and mountain ranges rising to 4200 meters (13, 800 feet). In some scattered locations, the lands are topographically suited for irrigation and development. Being situated in most cases near the headwaters, the catchment basins are rather small to impound any appreciable amount of water required for any large scale development. However, there are many opportunities for small scale, direct diversions that would permit the farmer to supplement the rainfall for a few weeks after the end of the rainy season or, in some instances, to provide a full water supply to a few hectares.

The plateau valleys offer the greatest potential for irrigation development. Formed by the erosion of the plateau materials and lying generally from 335 to 920 meters (1000 to 3000 feet) below the level of the highlands, these valleys contain the greatest concentration of population because of a pleasant climate in contrast to the hot, oppressive, frequently malaria-infested climate of the plains or the cold, heavy rainfall season of the highlands. Because of their intermediate position relative to respective drainage basins, the topographic development, and the soil structures, the land areas in these valleys are suited to irrigation development to a variable extent--subject to water supply, upstream storage possibilities, and other factors. At the lower end of the valleys the streams usually fall sharply into the deeply eroded canyons which ultimately lead to the Blue Nile.

Along the western perimeter of the high plateau, the terrain drops off sharply to an elevation about 600 meters (2000 feet) below the general level of the plateau and then slopes gently, with decreasing gradient, toward the Ethiopian-Sudanese border. The international boundary crosses the eastern portion of an area commonly known as the Sudan Plain, which extends into Ethiopia. It is this area which is referred to in this report as the plains and eroded hill lands. It lies in the northwestern portion of the Blue Nile River Basin and is drained by the Blue Nile, the Dabus, the Dindir, and the Rahad Rivers and their tributaries. The headwaters of these streams are in the rough, broken areas below the plateau escarpment and, because of geologic conditions and the flatter gradient, have not formed upstream valleys of significant areal extent through the plains. The position of the middle reaches of these streams, flowing through more or less broken, hilly terrain just above the plains area, gives rise to favorable dam and storage reservoir sites. The vast plain on the lower reaches of these streams is topographically favorable for project development. The major area of potential development is in the Dindir-Rahad watersheds. A more limited area along the Dabus River is included in the plains and eroded hill lands area because of similar elevation, climate, and other characteristics.

The potential irrigation and power projects described in this volume are presented by geographic areas or sub-basins as shown on Figure I-1. Pertinent data for each project are contained in Table I-1 and separately in the following chapters.

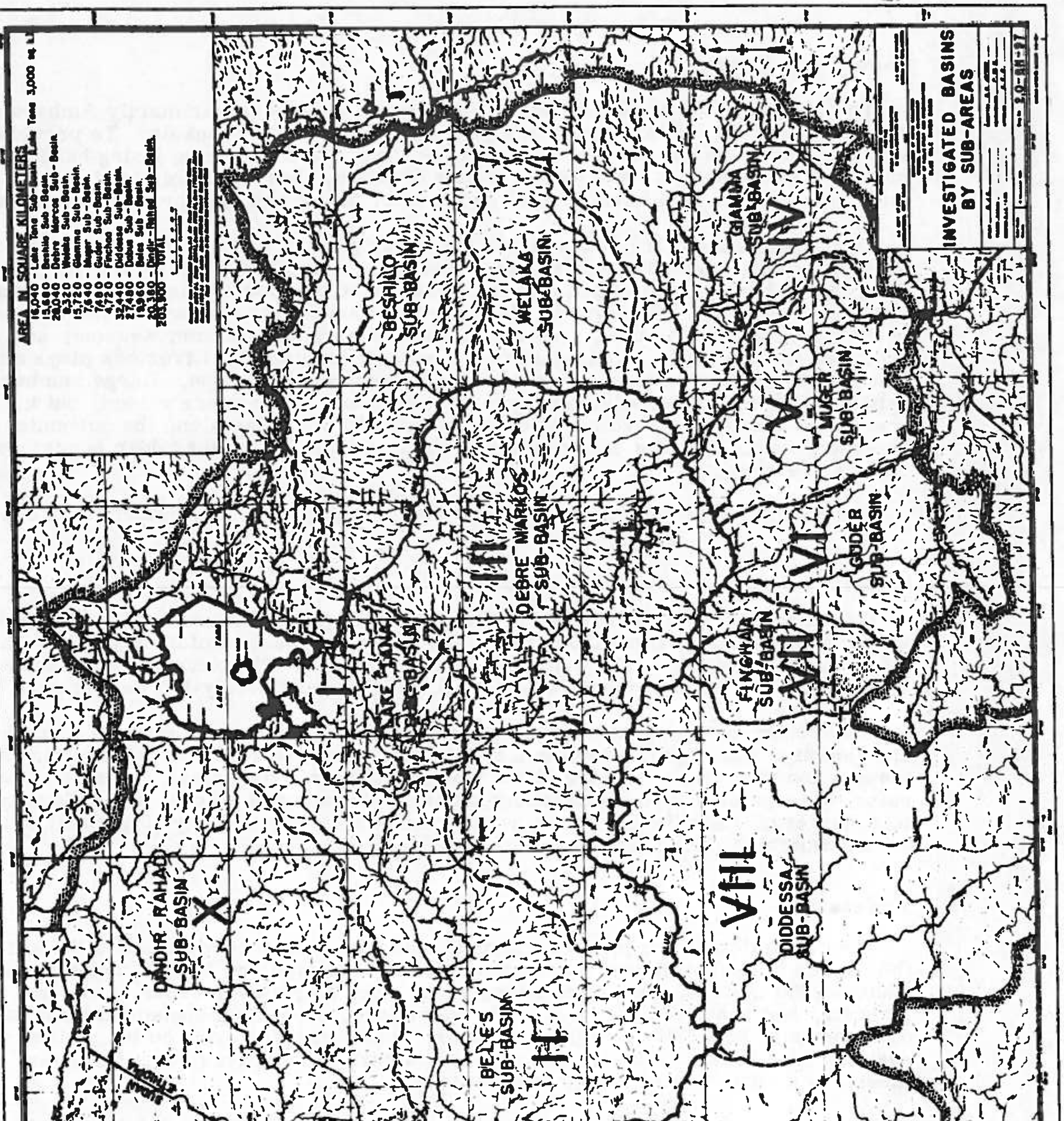


Figure I-1--Investigated Basins by Sub-areas

People and Crops

The people on the highlands and in the plateau valleys are primarily Amhara and Galla, while those in the lowland areas are primarily Nilotic and Shankala. To provide their subsistence, these people farm small tracts of from 4 to 8 hectares, using handtools and oxen much the same as they have for thousands of years. Not all of this land will be cultivated, for a typical farm will have several hectares of fallow and unimproved pastureland.

On the plateau and highlands and in the upper plateau valleys, the principal crops are grains, pulses, oilseeds, and spices. The more important of these are teff (a type of lovegrass), barley, and in some areas wheat or corn; noog or nigerseed and linseed; beans and peas; and hot peppers. In some local areas false banana forms the mainstay of the diet. In the lowlands, only small plots of sorghum, cotton, sesame, and corn are produced for a meager subsistence of the sparse population. Livestock plays an important part in the agricultural pattern on the plateau and highlands. Large numbers of cattle and sheep and smaller numbers of horses and donkeys are raised, but in the lower areas only small scattered herds of these animals are found along the perennial streams. However, herds of goats are common in the lowlands. Near the Sudan border some camels are seen.

The population of the Blue Nile River Basin in Ethiopia is estimated to be 4,870,000.

Climate

Differences in elevation result in differences in precipitation and temperature. Thus, at Metemma at 750 meters (2500 feet), the average annual rainfall is 100 centimeters (39 inches); at Gondar at 2100 meters (6900 feet), it is 127 centimeters (50 inches); and at Debre Tabor at 2550 meters (8500 feet), it is approximately 170 centimeters (67inches).

The maximum temperatures are from March to May, and the minima occur in December and January, although the variation is slight. There are two basic seasons in Ethiopia--the dry and the rainy--with the latter being divided into the "small" rains and the "big" rains. The small rains, which occur during February and March, are generally intermittent showers, while the big rains, which comprise approximately 80 percent of the total annual rainfall, extend from June through September.

Vegetation

The vegetation on the plateau and highlands varies in accordance with the altitude and the degree of encroachment into forested land. The highland forests, which range from 1400 to 2600 meters, vary from evergreens, such as juniper, cedar, and yew, to acacia, giant fig, and scattered palms at lower elevations, as well as euphorbia candelabra and other shrubs, generally along the streams. Small grasses grow on the plateau whereever the land is not cultivated and provide pasture for the livestock. However, the pastures, as a rule, are seriously overgrazed.

Elephant grass grows at the lower elevations and is of little value for grazing except in its early stages. It is used for the thatching of house roofs.

In the plateau valleys remnants of rain forests remain along the steeper slopes, generally on the windward side of the mountains or the escarpment. The valley floors are usually covered with tropical savanna woodland composed of fig, acacia, and other deciduous trees seldom exceeding 9 meters (30 feet) in height. They are generally open in growth, seldom exceeding one tree per 100 square meters. Coarse elephant grass from 3.6 to 5.0 meters (11.8 to 16.4 feet) in height occupies the space between the trees in a very dense growth. Along the perennial streams, which usually intersect these open forest areas, a dense growth of jungle occurs. Here the trees often exceed 38 meters (125 feet) in height and, with the lower-growing shrubs, provide a very dense cover. This is known as "riverine" forest and is very common to the plateau valleys and the plains and eroded hill lands along the streams.

Dense forests of highland tree bamboo occur at elevations from 2500 to 3500 meters. Bamboo does not require large amounts of moisture for healthy growth and in some cases exceeds 15 meters (49 feet) in height and 12 centimeters (5 inches) in diameter at the base. Once in about 7 years, the bamboo dies after blossoming and producing seed. It then sprouts again from the root or seed and develops a nearly impenetrable growth. It is not currently used commercially but is used locally in construction of houses and fences.

In the lowland areas, the open forest is very similar to that of the plateau valleys, except that the trees generally reach greater heights--up to 15 meters--and are generally less scattered. The riverine forest grows somewhat less dense and occurs along intermittent streams as well as along perennial ones. Trees with tropical characteristics, such as dum palm, baobab, mimosa, and camphor, occur at rather widely scattered intervals. Along the streams, clumps of bamboo and thickets of fan palms occur; and thorn trees and bush grow in the more arid areas. The bamboo occurring here is the lowland bamboo, a smaller grass than the highland bamboo.

During the dry season each year, itinerant local people and caravaneers burn off the elephant grass in both the plateau valleys and the plains and eroded hill lands. This is done for two reasons--to make travel safer through an area where the presence of snakes and large wild animals is common; and, in the plateau valleys, to provide better grazing on the early tender shoots of the elephant grass, which later becomes coarse and unpalatable to the animals.

GENERAL BASIC DESIGN DATA

Surveys

Geodetic. By a Special Service Agreement, signed March 5, 1957, the U.S. Department of Commerce agreed to furnish the International Cooperation Administration with technical assistance in geodesy in connection with the cooperative program between the United States and Ethiopia. The agreement provided that the surveys be connected to Sudanese triangulation and leveling in order that the 30th Meridian African datum and mean-sea-level elevations could be provided in the river basin. Connections to existing triangulation in western Eritrea and in central Ethiopia, southeast of Addis Ababa, were also required. The Coast and Geodetic Survey started operations in late 1957 and completed the work in 1961. Basic horizontal and vertical controls to first order, covering approximately 120,000 square miles, were performed on the west central part of Ethiopia, the area comprising the Blue Nile River Basin. Triangulation diagram is shown on Figure I-2 and the leveling diagram on Figure I-3.

General. Secondary surveys by Blue Nile Project personnel were necessary on all the projects studied, due to the relatively extreme distances established by geodetic controls. Difficulties in access to the sites, inexperienced personnel, and other problems dictated the type of surveys that could be made.

Horizontal Control. Horizontal controls were performed by tellurometer, by plane table, and by transit methods. The latter two were performed where sites were accessible to ground transportation and where a greater degree of accuracy was required. An arbitrary coordinate grid system of 2,500 meters was set up in some areas where tellurometer was used.

Vertical Control. For establishing vertical controls, T-3 transits, altimeters, and levels were employed, depending upon the area and accessibility to sites. Generally, topographic maps were prepared from tellurometer or altimeter data, usually on 20-meter contour intervals by photogrammetric process by the Aerial Surveys Project.

Available Photographs and Maps

Photographs. Aerial contact photographs of the entire Blue Nile Basin were made available early in 1958. Aerial photography was performed by the Mark Hurd Aerial Surveys, Inc., of Goleta, California, starting in November of 1957 and completing the work by the middle of the following January. Approximately 12,000 exposures were taken at an approximate scale of 1:50,000. Area covered included 7°30' to 13°00', North latitude and from 34°00' to 40°00' East longitude.

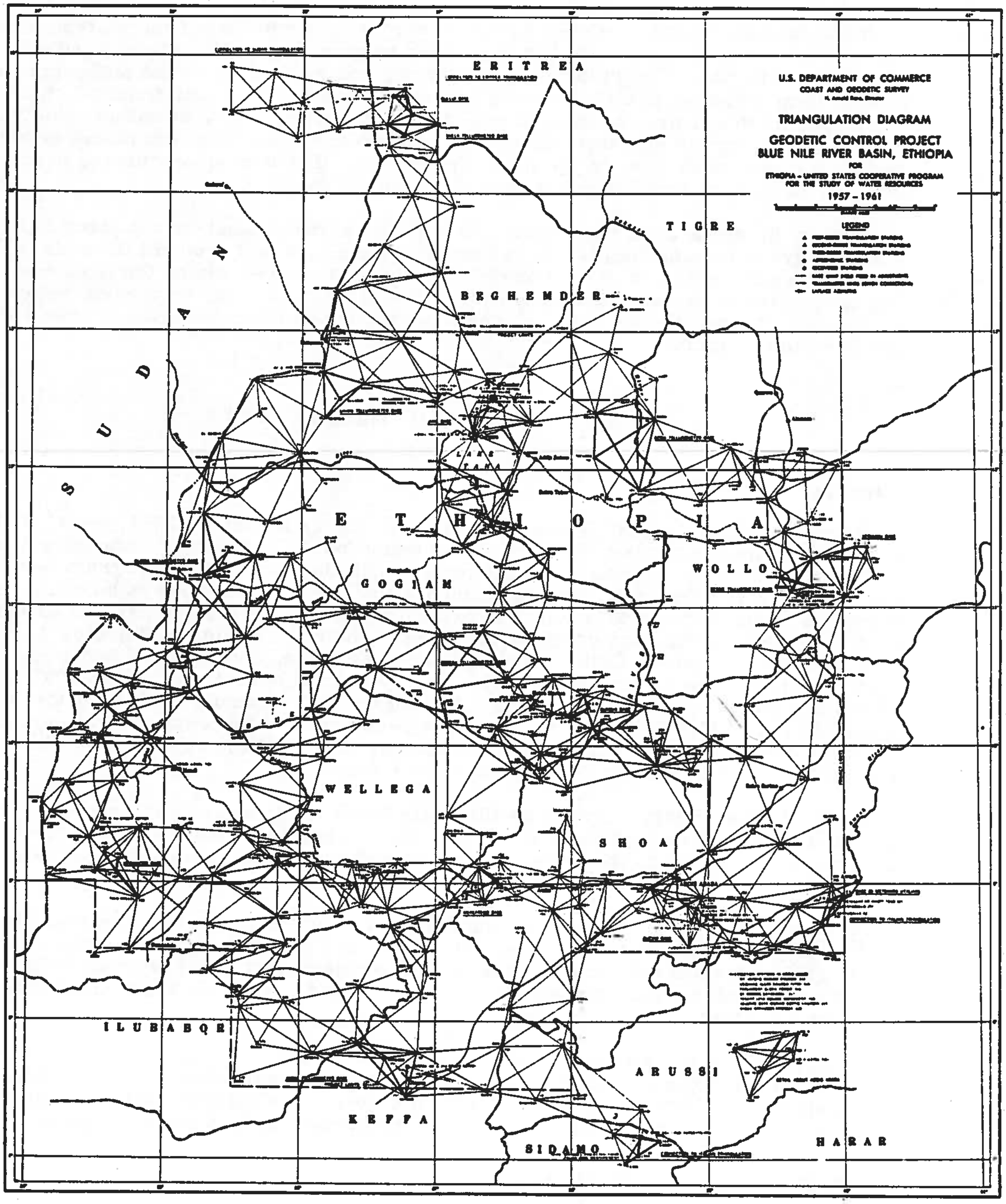


Figure I-2--Triangulation Diagram, Geodetic Control Project

Maps. At the start of the investigation, it was found that there were very few maps of any value in the study of the Blue Nile Basin. The Air Force preliminary base maps were found to be the most useful, although the scale of 1:500,000 lacked accuracy and detail for most project planning purposes. The following listed maps were found to have limited value.

USAF Preliminary Base Maps--Contour intervals 1,000 feet--Scale 1:500,000--Published 1947 to 1954 (referred to above).

USAF Jet Navigation Charts--Base 200--Contour intervals 2,000 feet--Scale 1:2,000,000--Published 1955.

World Aeronautical Charts--Several Bases--Contour intervals from 1,000 to 3,000 feet--Scale 1:1,000,000--Published 1951 to 1957.

US Army--Gulf of Aden, Africa, Asia--Contour intervals 500 meters--Scale 1:4,000,000--Published 1956.

British--Gulf of Aden--Scale 1:4,000,000--Published 1959.

Map of Ethiopia--Scale 1:3,500,000--Published in Great Britain.

GENERAL DESIGN CRITERIA

Introduction

In a reconnaissance study and for the purpose of this report, design drawings have been limited to brief reconnaissance layouts of major structures and switching diagrams on electrical facilities adequate for estimating purposes. For all other features, including powerplants, canals and structures, diversion dams, and tunnels, reconnaissance designs were not prepared. The criteria assumed in the design for estimating purposes were derived from Reclamation Instructions and other pertinent handbooks. Design criteria for some of the structures follow.

Dams

Storage. The reconnaissance designs of the various storage dams in general were limited to the selection of the type of dam that appeared to be best suited to the particular location. The final selection of the best type of dam for a particular site calls for a thorough consideration of the characteristics of each type, as related to the physical features of the site and adaptation to the purposes the dam is to serve, as well as economy, safety, and other limitations. The design of the spillway capacity has been based on the maximum probable flood; conservative design criteria were used on all earth dams in that the spillways were uncontrolled--not gated. Some further economy may also be realized in future detailed studies in regard to placement of the outlet works elevation. Sill elevation of the outlet works was located generally at the estimated 100-year sediment deposition level, thus increasing dead storage capacity. Hydrological operation studies were based on a 50-year period of analysis. For purposes of this study and with data available, it was determined that the structures as depicted in the drawings appear plausible and reflect engineering feasibility for construction.

Diversion. Diversion dams were estimated without actual drawings being prepared in most cases. Flood flows of 100-year probable frequency were generally used for spillway capacities. Foundations were assumed to be impervious unless specific data were otherwise indicated.

Power Canals

Inside slopes of 1:1 were adopted as design criteria on the assumption that the canals would be located generally in topography where the cross slopes would be steep. Being envisioned as masonry-lined, the coefficient of roughness "n" was adopted as being 0.020, and the ratio of base width to water depth as being 1:1.

Irrigation and Surface Drainage Canals

Designs for the canal sections were adopted as recommended in the Reclamation Instructions for unlined canals. For purposes of this study, it was determined that the proper relationships between bottom width, water depth, side slopes, freeboard, bank dimensions, and future operation and maintenance requirements as recommended in the Reclamation Instructions would suffice without undue consideration to get the most economical sections to fit the engineering requirements of the various irrigation projects. Water velocities were assumed between 0.671 to less than 1.0 meter per second. The coefficient of roughness "n" for Manning's formula was assumed at 0.0225, with inside slopes of 1.5:1. The canal slope used in the paper location of the irrigation projects was 0.0004 with the assumption that this would include canal and canal structure losses.

Canal and lateral capacities were determined from Figures I-4 and I-5 as determined from hydrologic studies based on the assumption that irrigation would be on a 10-day rotation system, 24-hour basis. Capacities as such may be larger in some cases than the actual requirements, as the water demand would vary from project to project, depending on many other factors, including the types of crops assumed and consumptive use.

The decision that application of water must be on a continuous 24-hour basis, in spite of the fact that the present practice (see Hydrology Appendix III, Irrigation Requirements) and experiences of the Wonji sugar plantation do not lend encouragement to this system of irrigation regimen, was based solely on economic justification. It is quite obvious that application of water during daylight operations only would require greater capacity of canals and the consequent increase in canal structures or a system of overnight storage reservoirs to meet the irrigation requirements. It would also lead to a considerable waste of water. Construction of additional storage reservoirs or increasing the size of the canal capacities would impose additional construction costs on the irrigation development. Most of the projects in the plateau valleys may be considered to have steep gradients from an irrigation point of view, requiring more checks and drops than would normally be expected and rather high dams for storage purposes.

It would be possible to design and construct a closed-pipe type of distribution system in most cases, making possible daylight-type operation; however, this type has a much higher initial construction cost per hectare to provide service and also requires much more skilled operation and maintenance personnel.

Canal structures, such as siphons, turnouts, checks, drops, farm bridges, cross drainages, and wasteways, were assumed to be constructed to Bureau of Reclamation standards, modified to reflect local conditions. Detail analysis should be made of the soil structures before construction, as the expansive type clays are prevalent throughout most of the project areas. Typical canal structures are shown on Figures I-6 through I-15.

Open, interceptor-type, drainage canals have been envisioned for carrying away irrigation waste and excess precipitation falling on the project lands. Design precepts anticipated for the irrigation canals would also be applicable here. No embankments would be required to be constructed.

ESTIMATES OF COSTS

Construction Costs

General: The estimates of construction cost in this report are based on prices prevailing in January of 1961 in Ethiopia and are adjusted to reflect anticipated cost after due consideration of the many factors involved.

The methodology used in arriving at the unit cost prices where applied was to compare bid contracts, especially those of Koka dam and reservoir and of the Imperial Highway Authority, with like items in Bureau of Reclamation contracts. It was found generally that work items requiring a large amount of hand labor, such as structural works, were

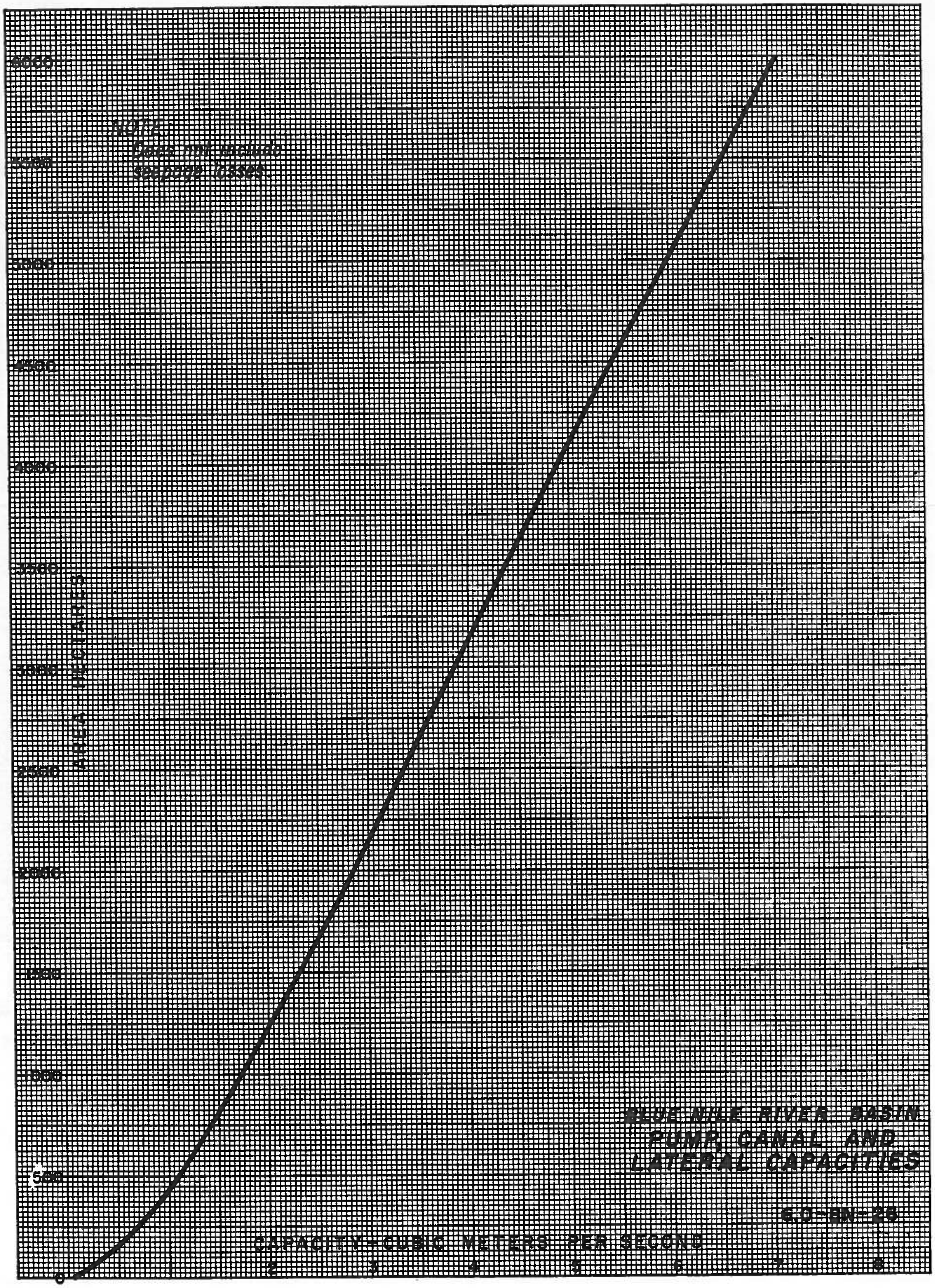
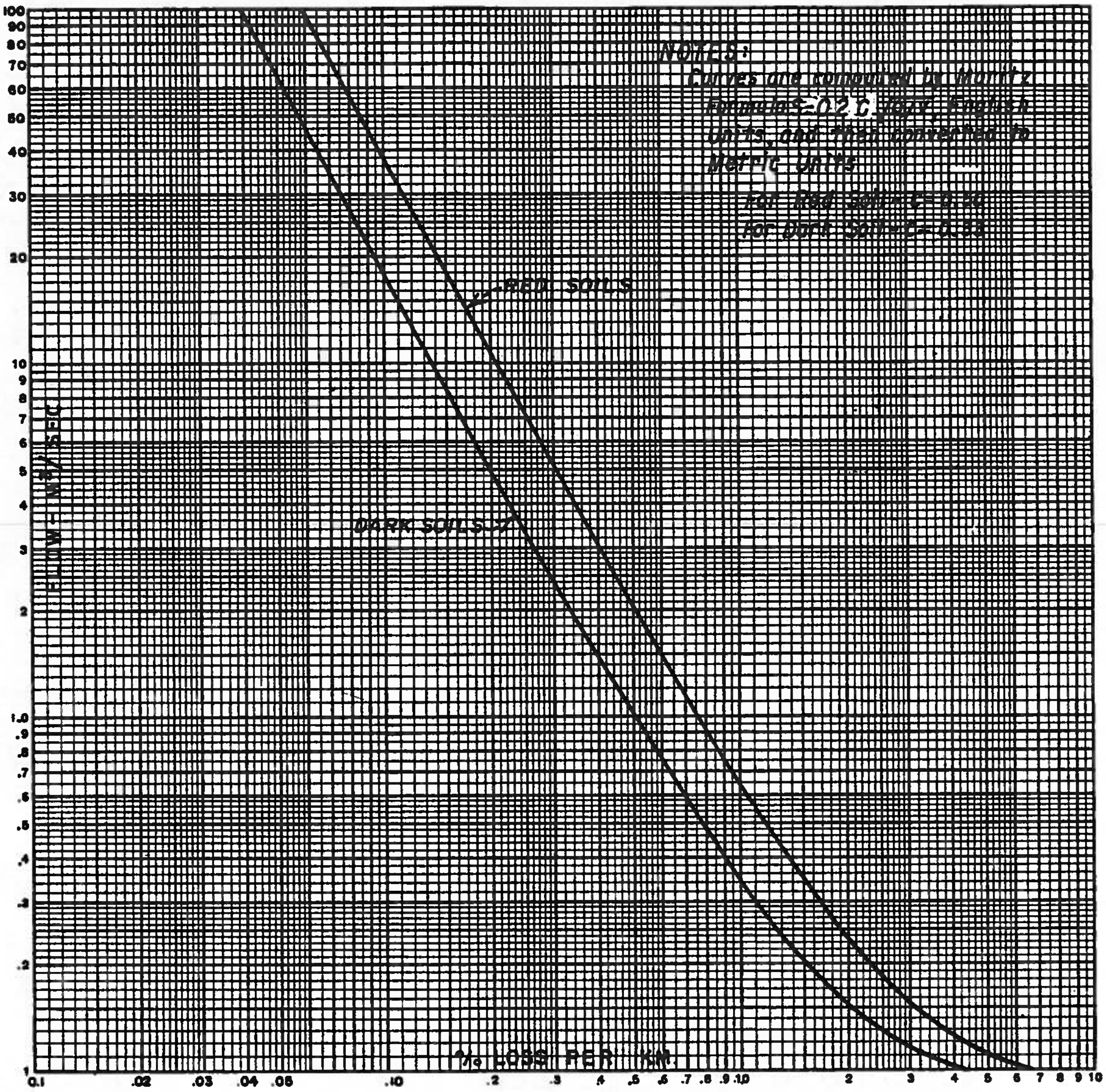


Figure I-4--Pump, Canal, and Lateral Capacities



BLUE NILE RIVER BASIN
CANAL SEEPAGE LOSSES

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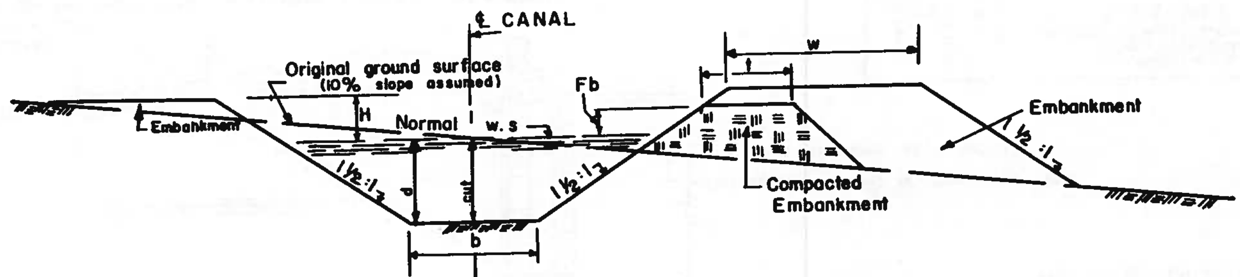
Figure I-5--Canal Seepage Losses



HYDRAULIC PROPERTIES

Capacity M3/S	Meters b	Meters d	Meters w	Meters H	Meters cut	AREA M^2	Vel. M/S	Hydraulic Radius	n	slope
1·0	1·525	0·61	1·31	0·46	0·61	1·49	0·671	0·400	0·0225	0·00077
20·60	6·71	2·44	3·72	1·00	2·18	25·25	0·816	1·63	0·0225	0·00018
40·40	9·75	3·20	4·73	1·13	2·71	46·50	0·869	2·19	0·0225	0·00013
57·50	12·20	3·66	5·31	1·22	2·94	64·6	0·890	2·55	0·0225	0·00012
78·00	13·72	4·27	6·04	1·28	3·42	85·8	0·909	2·95	0·0225	0·00010
100·50	15·25	4·88	6·86	1·37	3·83	110·00	0·914	3·35	0·0225	0·000084
123·50	18·30	5·18	7·32	1·49	3·98	135·00	0·915	3·65	0·0225	0·000075

COMPACTED EMBANKMENT

Meters

d	Fb	t
0·61 Max.	0.15 Min	0·92
1·22 Max.	H/3	1·22
1·83 Max.	H/3	1·83
Over 1·83	H/3	2·44

ETHIOPIA-UNITED STATES COOPERATIVE PROGRAM FOR THE STUDY OF WATER RESOURCES IN COLLABORATION WITH U.S. DEPT. OF ST. AGEN. FOR. INT. DEV. AND U.S. DEPT. OF INT., BUR. OF RECL.

DEPARTMENT OF WATER RESOURCES
IMPERIAL ETHIOPIAN GOVERNMENT
MINISTRY OF PUBLIC WORKS & COMMUNICATIONS

BLUE NILE RIVER BASIN

TYPICAL CANAL SECTIONS

DRAWN K. A. SUBMITTED A. P. B.
TRACED Gabre Christos RECOMMENDED P. W. K.
CHECKED K. A. – P. W. K. APPROVED C. E. B.

Addis Ababa Ethiopia Mar. 29, 1963 2·3- BN-5

Figure I-6--Typical Canal Sections

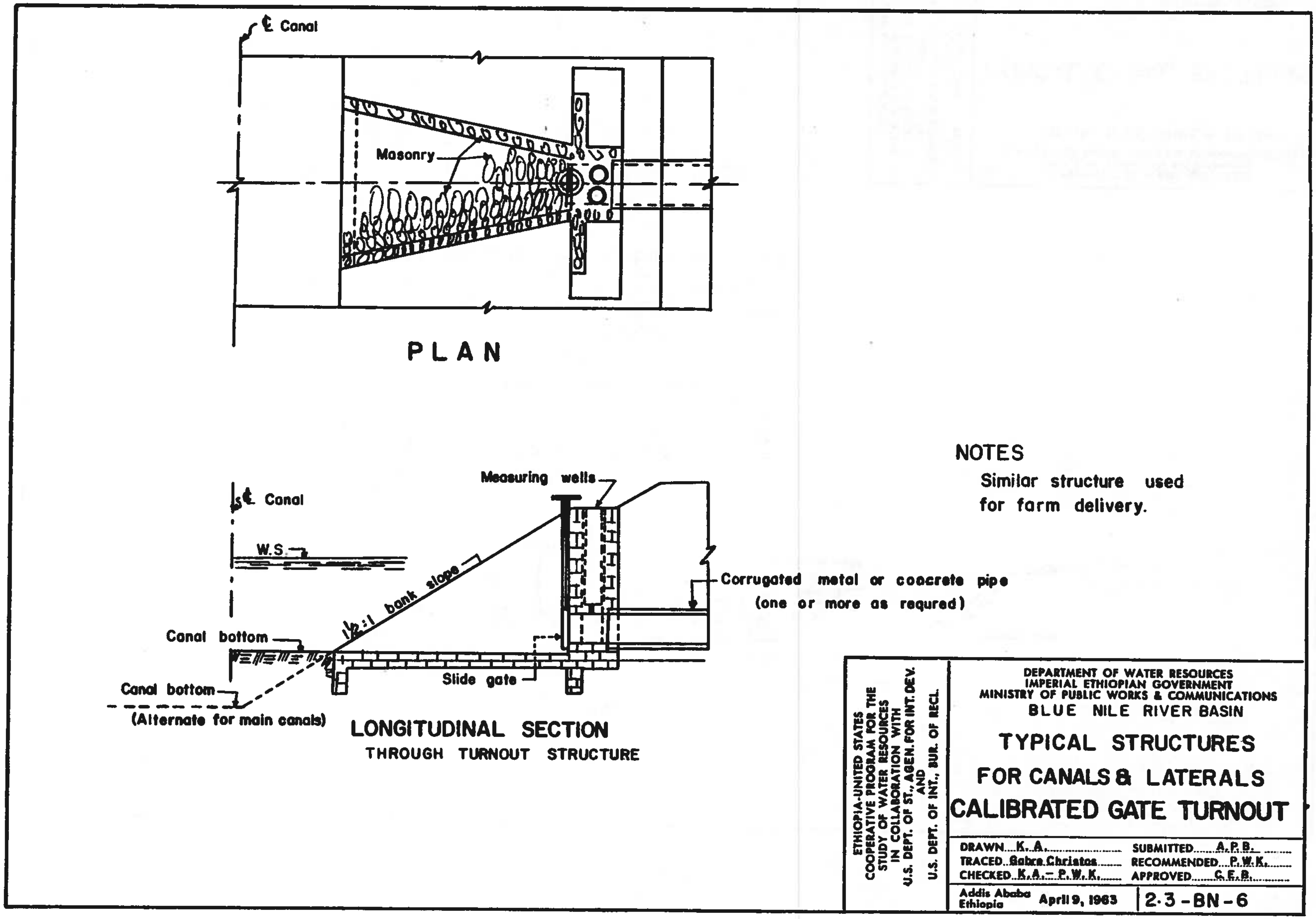


Figure I-7--Typical Structures for Canals and Laterals, Calibrated Gate Turnout

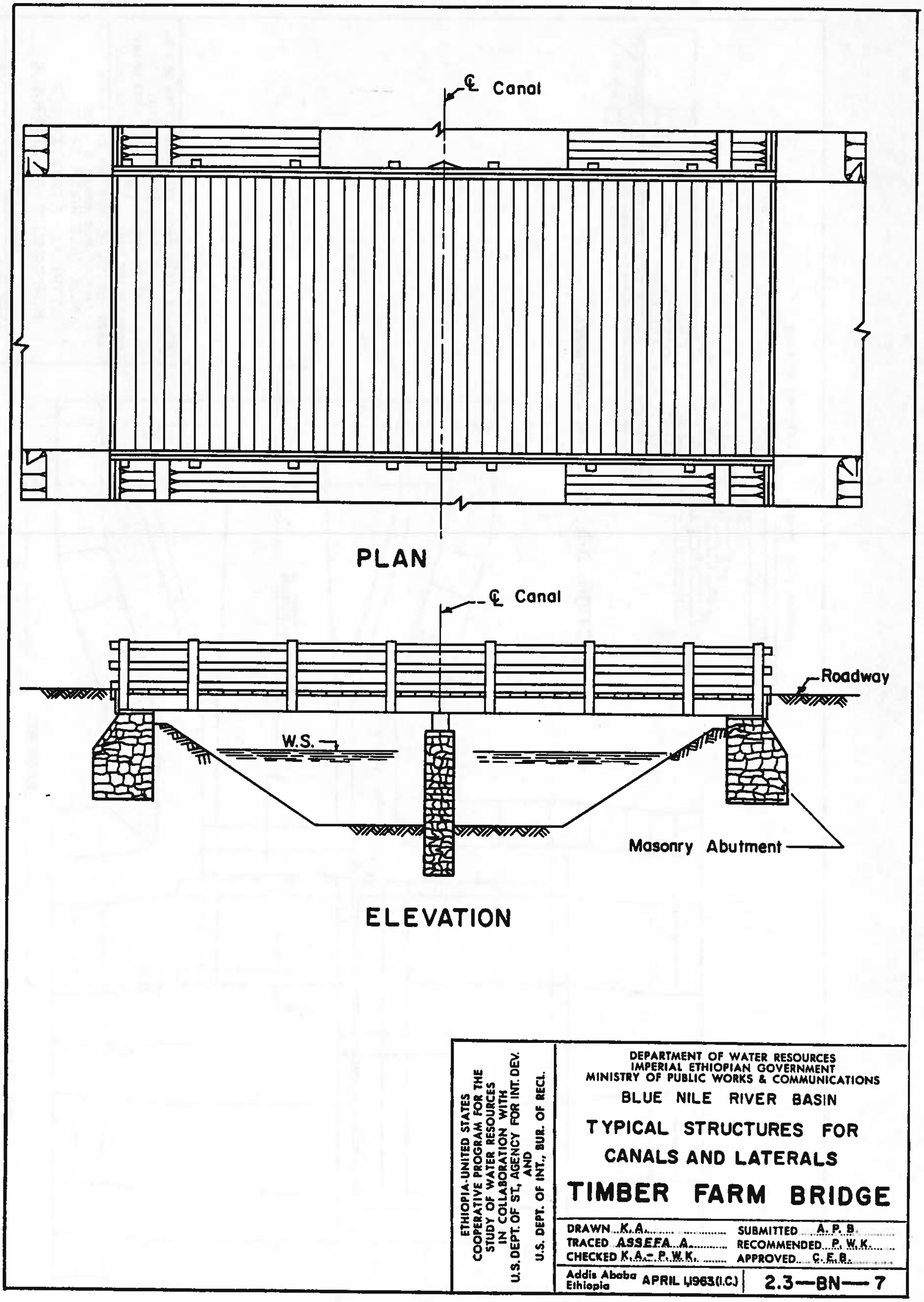


Figure I-8--Typical Structures for Canals and Laterals, Timber Farm Bridge

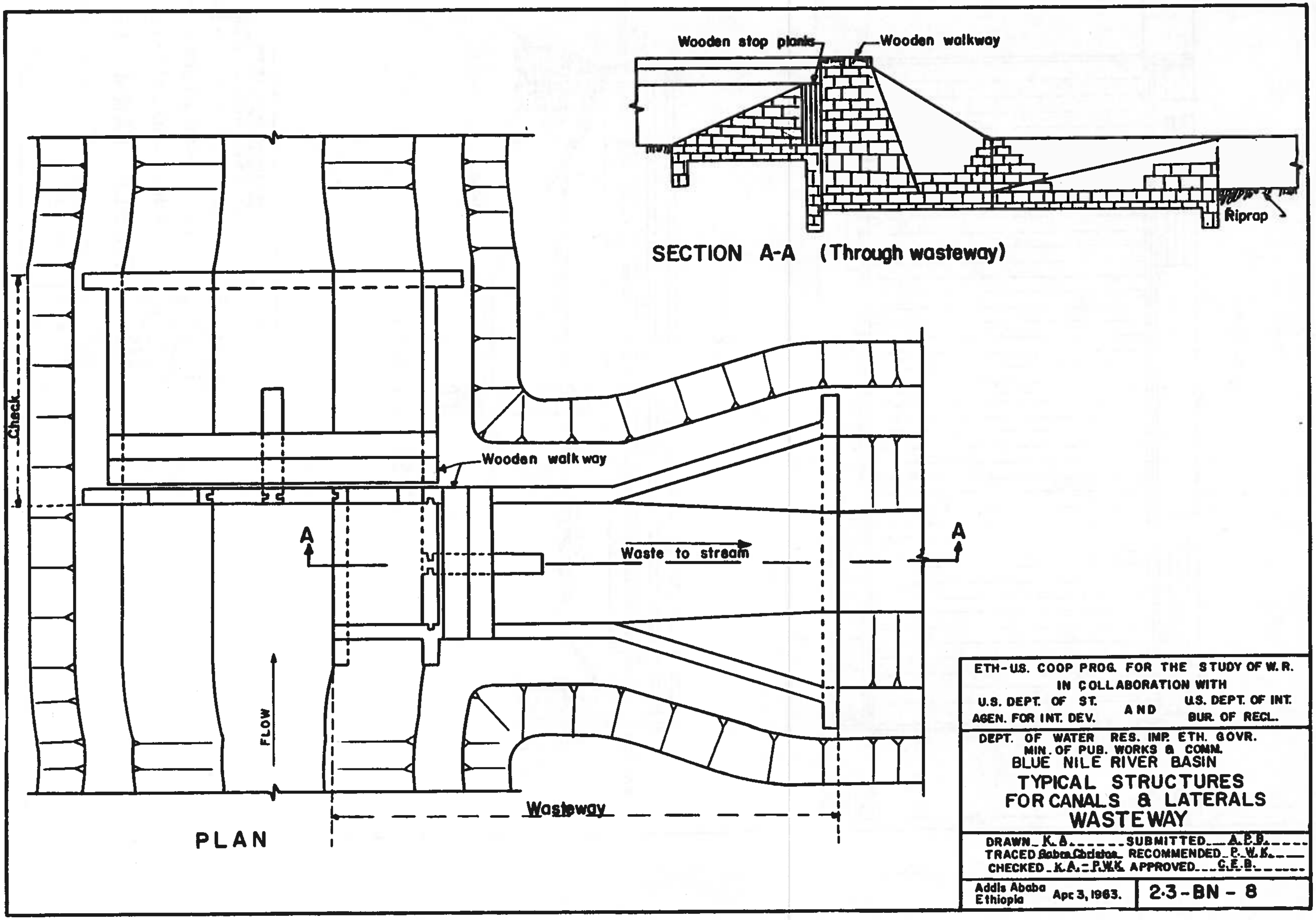


Figure I-9--Typical Structures for Canals and Laterals, Wasteway

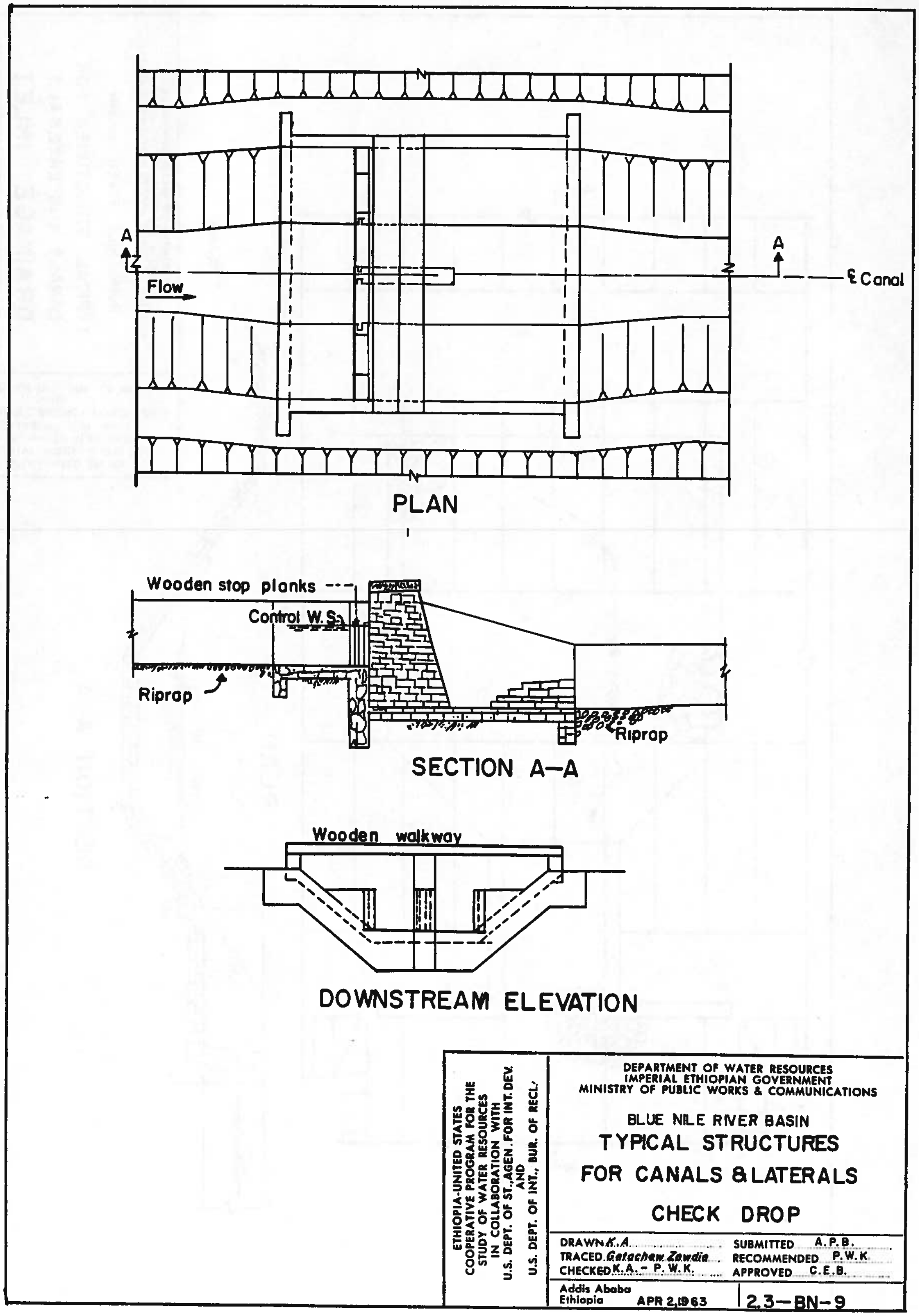


Figure I-10--Typical Structures for Canals and Laterals, Check Drop

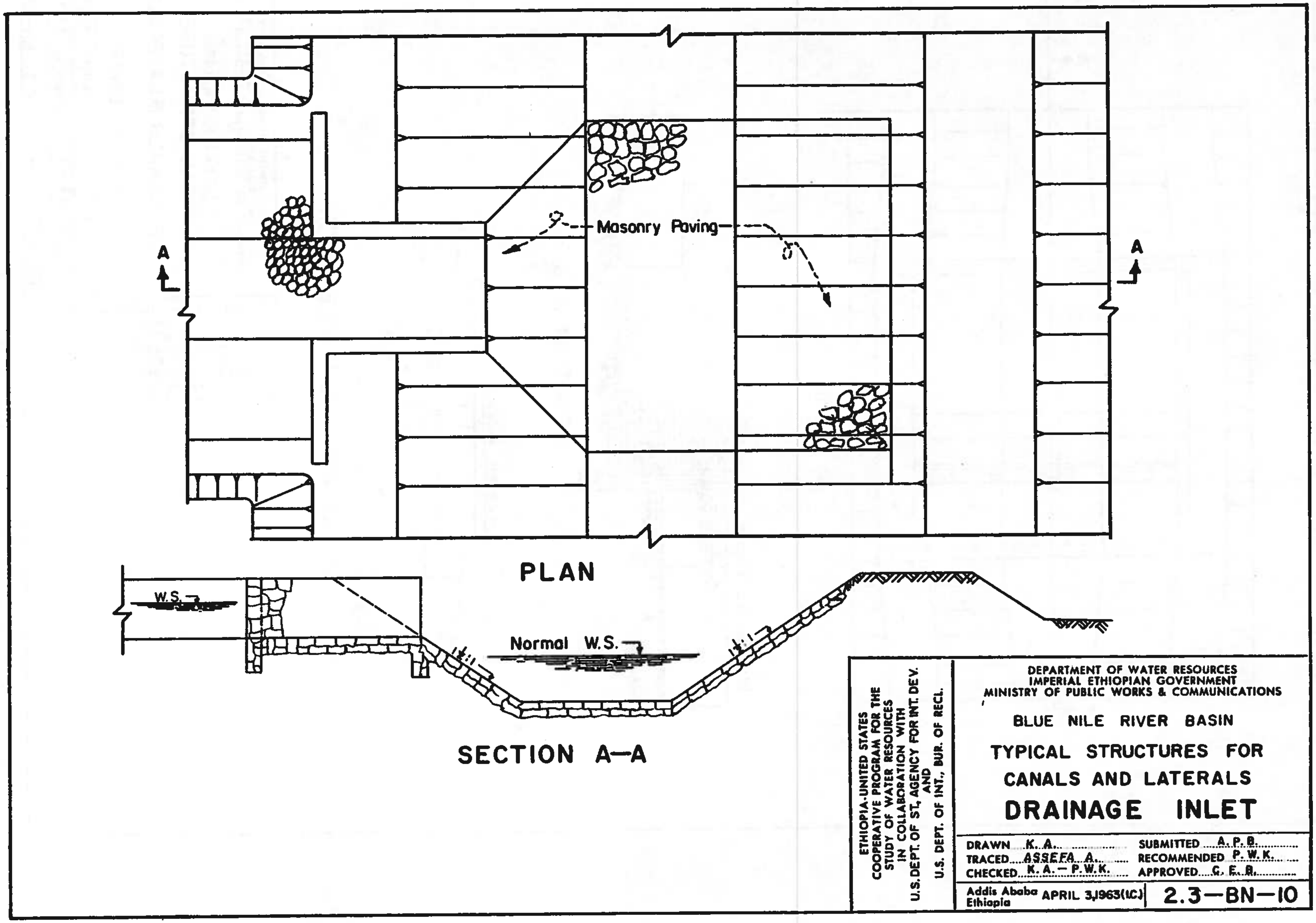
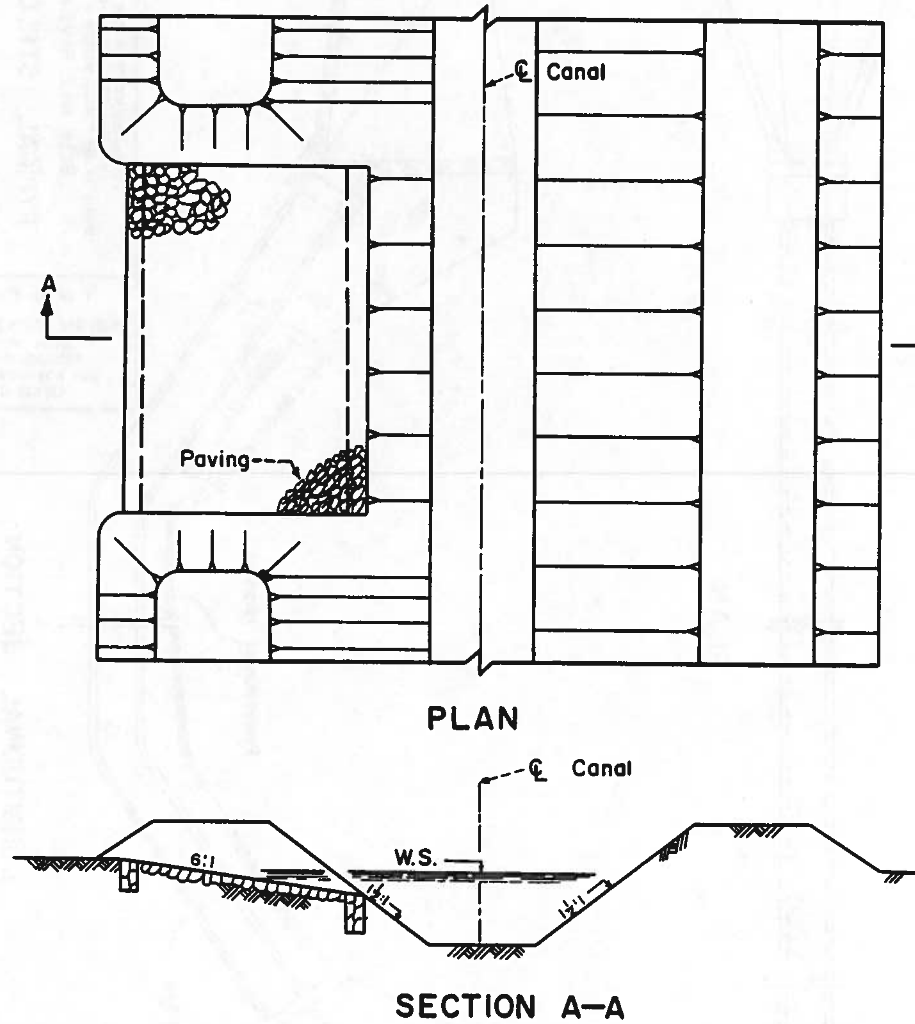


Figure I-11--Typical Structures for Canals and Laterals, Drainage Inlet



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DEPARTMENT OF WATER RESOURCES
IMPERIAL ETHIOPIAN GOVERNMENT
MINISTRY OF PUBLIC WORKS & COMMUNICATIONS
BLUE NILE RIVER BASIN

TYPICAL STRUCTURES FOR CANALS AND LATERALS

STOCK WATERING RAMP

DRAWN K.A.	SUBMITTED A.P.B.
TRACED ASSEFA A.	RECOMMENDED P.W.K.
CHECKED K.A.-P.W.K.	APPROVED C.E.B.
Addis Ababa Ethiopia MAR.29,1963(IC)	2.3—BN—11

Figure I-12--Typical Structures for Canals and Laterals, Stock Watering Ramp

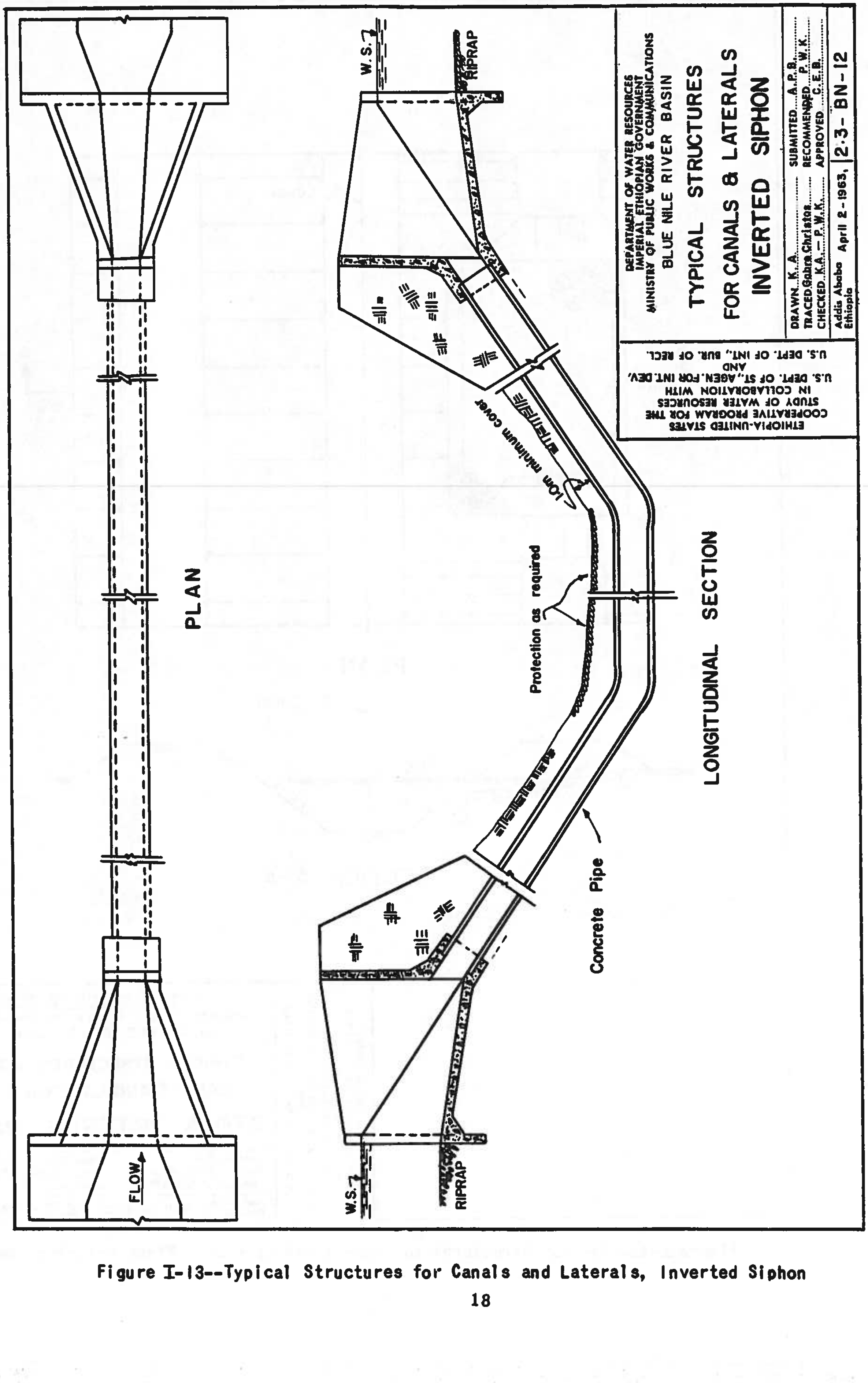


Figure I-13--Typical Structures for Canals and Laterals, Inverted Siphon

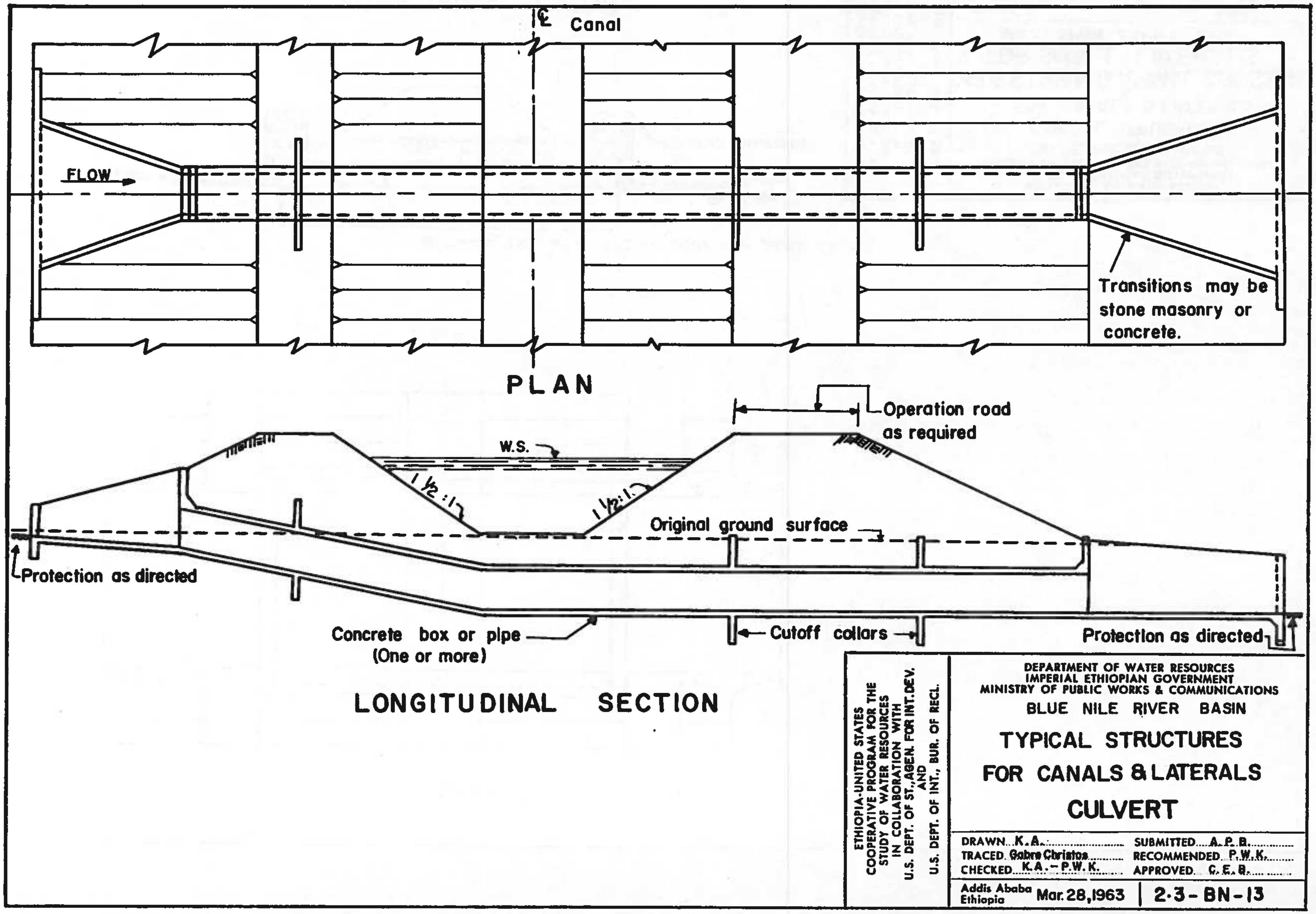


Figure I-14--Typical Structures for Canals and Laterals, Culvert

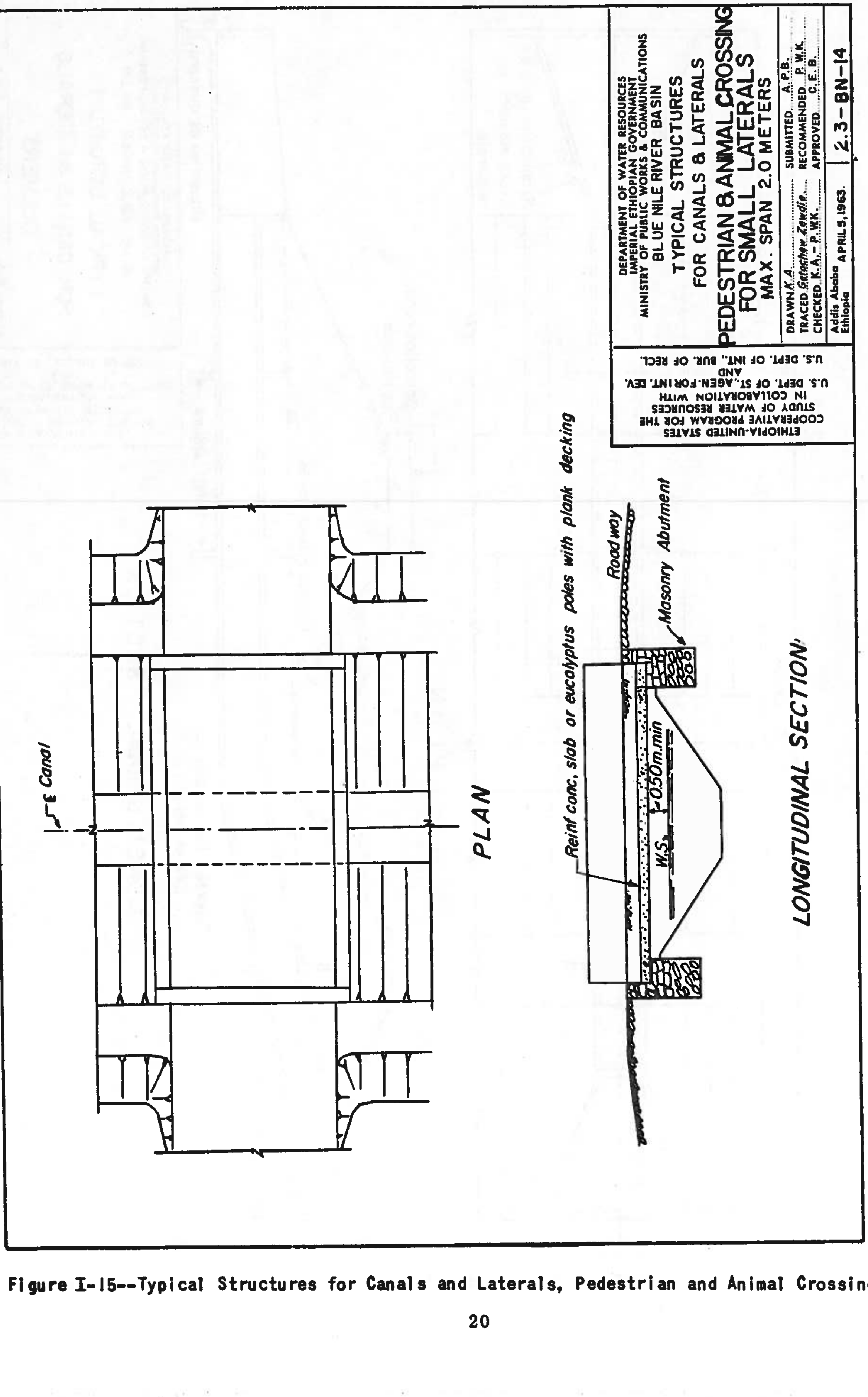


Figure I-15--Typical Structures for Canals and Laterals, Pedestrian and Animal Crossing cheaper to construct in Ethiopia and work items requiring employment of large equipment, such as earth excavation, were more costly than those in the United States. It was also found that electrical equipment, such as turbines and generators, could be installed with less cost than in the United States. It was generally concluded that in total costs, contracts in both countries approach unity, and, for the purpose of this report where unit costs items were not available, substitution of Bureau of Reclamation prices was considered to be a fair approximation of costs.

All estimates of costs include allowances for engineering, supervision during construction, and general expense amounting to 15 to 25 percent of field costs, depending upon the type of feature to be constructed. All estimates also include an additional sum for contingencies amounting to 25 percent, reflecting the reconnaissance nature or rough approximation of the design data employed, except for certain electrical facilities where substantially all of the costs are manufactured equipment items. Costs derived from curves for various facilities and structures are indicated as lump sum amounts in the estimating sheet.

Storage Dams. Costs for dams and reservoirs were obtained by computing major items of work and applying unit costs. Miscellaneous and minor items of work were lumped together and usually indicated as a lump sum in the estimate. Costs for manufactured equipment, such as gates and valves, reflect Bureau of Reclamation prices.

Hydroelectric Powerplants. Curves on Figures I-16, I-17, and I-18, have been developed from data based largely on detailed "as-built" information obtained on Koka Dam and Powerplant, located about 80 kilometers southeast of Addis Ababa and placed in operation in 1960. Cost extensions above and below the Koka Dam capacity generally reflect cost trends in the United States adjusted for conditions prevailing in Ethiopia. The powerplant at Koka used European equipment, and the curves reflect these prices.

Transmission Lines. Estimates of construction cost for transmission lines of various voltages or capacities (Figures I-19, I-20, I-21, I-22, I-23, and I-24) were obtained from curves, using in part the cost data that were available on existing facilities in Ethiopia. Cost data as obtained from EELPA required modification and adjustment to a common cost basis as practiced by the Bureau of Reclamation and judgment exercised in compilation of the data for the curves.

Substations and Switchyards. Estimates of construction cost for these items (Figures I-25 and I-26) were developed on the assumption that the substations and switchyards would be of the outdoor type with controls and station service equipment located indoors. Curves developed for these items reflect the prices for European-type equipment, which are less than similar items in the United States.

Main Canal and Lateral Structures. Costs for canal earthwork were obtained by computing quantities with the aid of Figure I-27 and applying unit costs. Costs for rock excavation were assumed on a percentage basis for the entire length of canal and could vary widely from actual physical conditions.

For purposes of this study, it was determined to base estimates of canal structure costs on a percentage of total canal costs, based largely on Bureau of Reclamation experiences, which indicate a range of about 60 to 80 percent of structure costs to total canal costs. An average of 70 percent was used in determining canal structure costs in this study.

Diversion Dams. Costs for diversion dams were obtained by roughly estimating quantities from sketches and applying unit costs. Figure I-28 was utilized in the determination of the quantities. The lack of design data in most cases precluded a more refined estimate of costs. These estimates could vary widely from actual conditions, as stated; however, since this item would be a small amount in relation to the total project costs, the distortion in the over-all costs was considered not to be too significant.

Pumping Plants and Tunnels. Curves were employed in the determination of estimates of costs for these facilities (Figures I-29, I-30, I-31, and I-32). Data for the curves were compared with available local data and with those of Bureau of Reclamation design standards and practices and adjusted to local requirements and conditions. The estimates of costs for these facilities are accordingly indicated as lump sum.

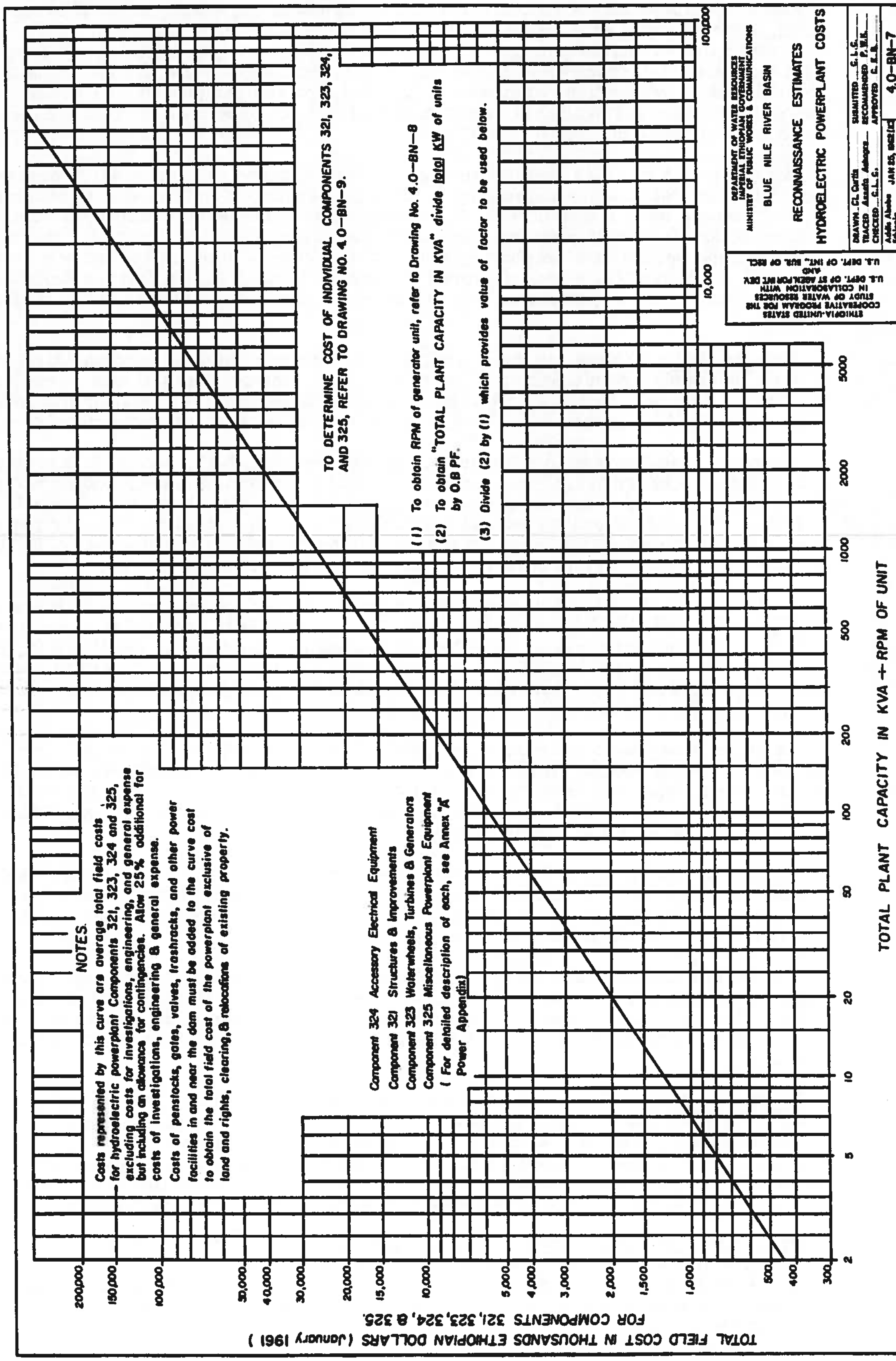


Figure I-16--Hydroelectric Powerplant Costs

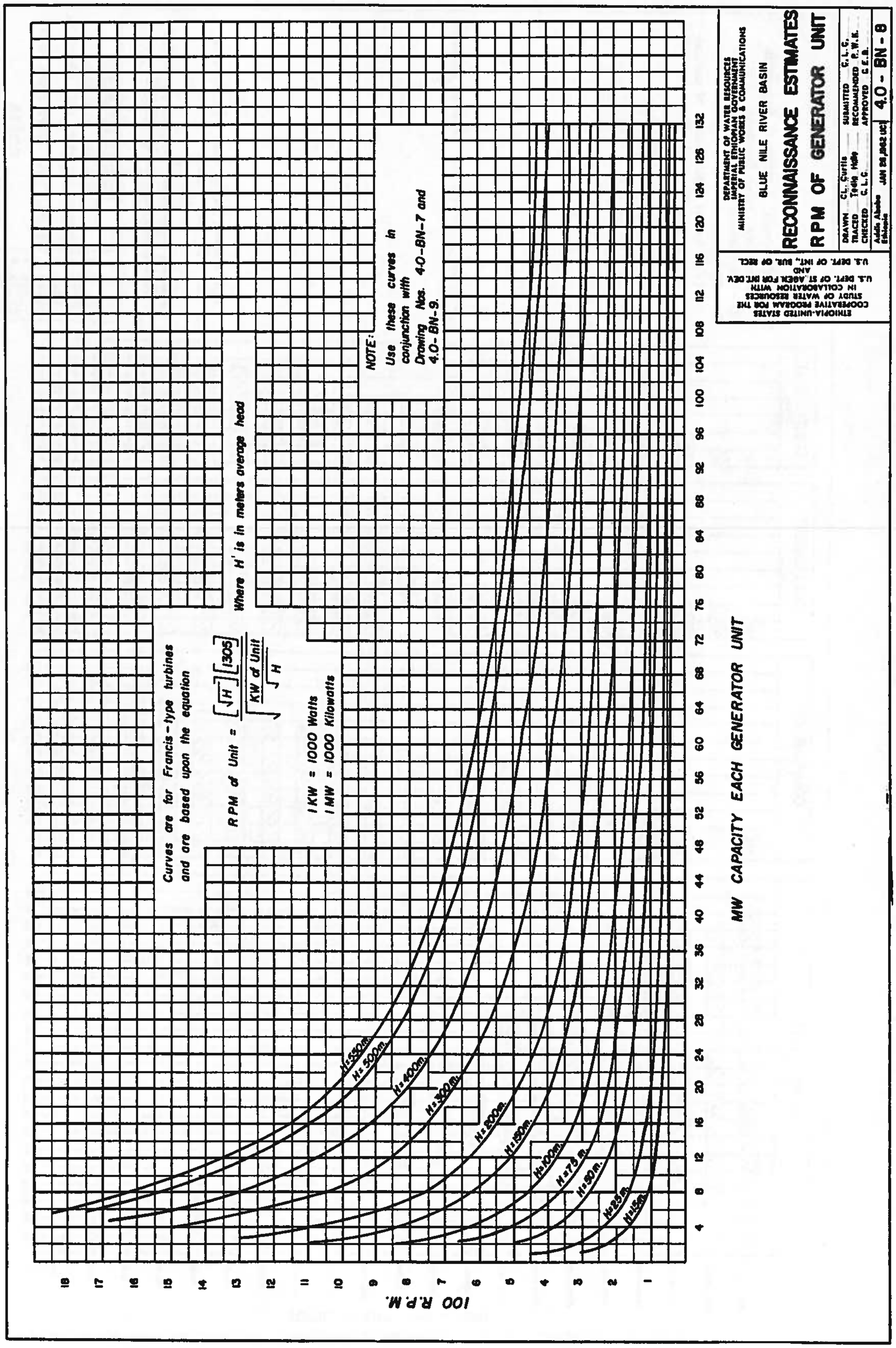


Figure I-17--R.P.M. of Generator Unit

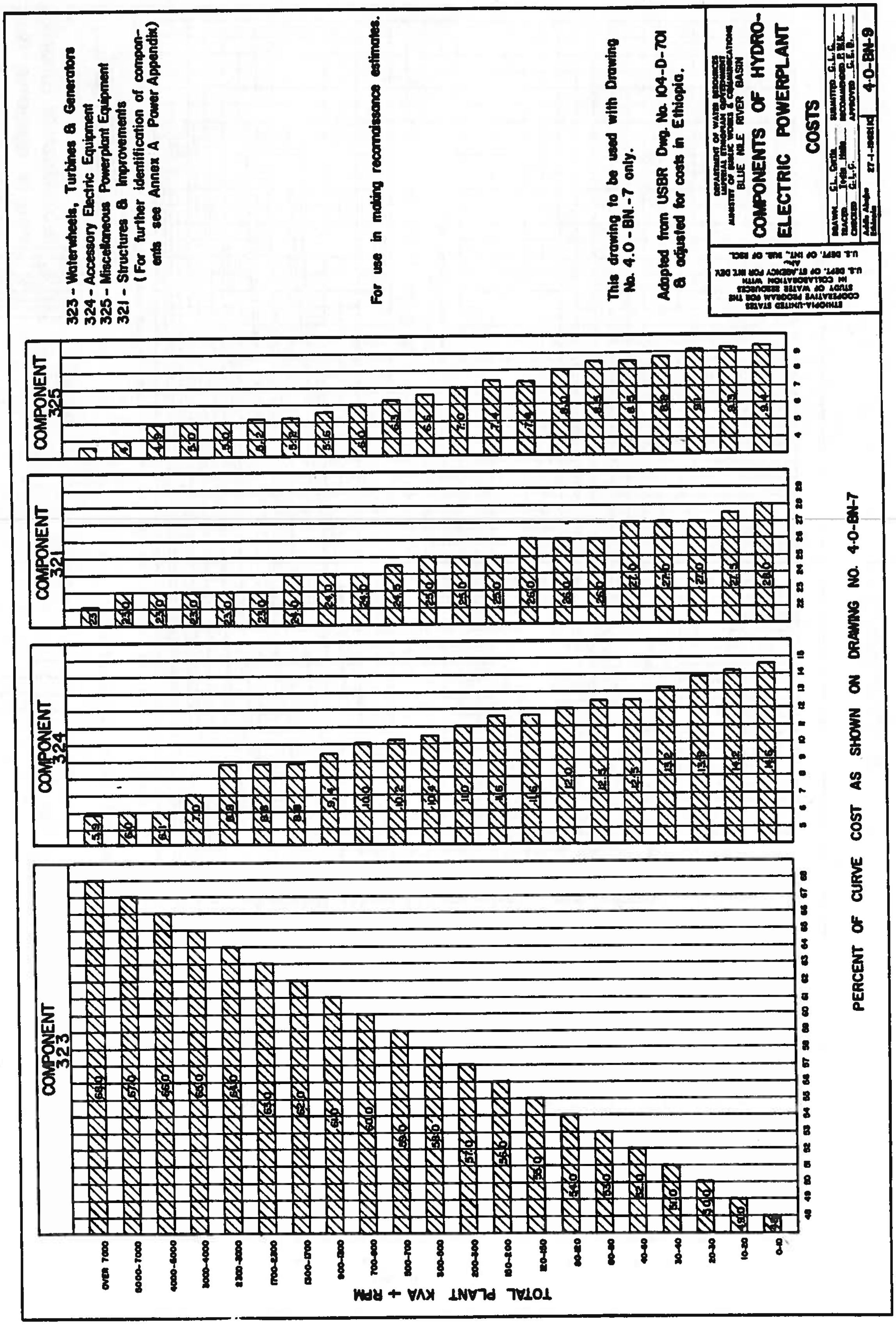


Figure I-18--Components of Hydroelectric Powerplant Costs

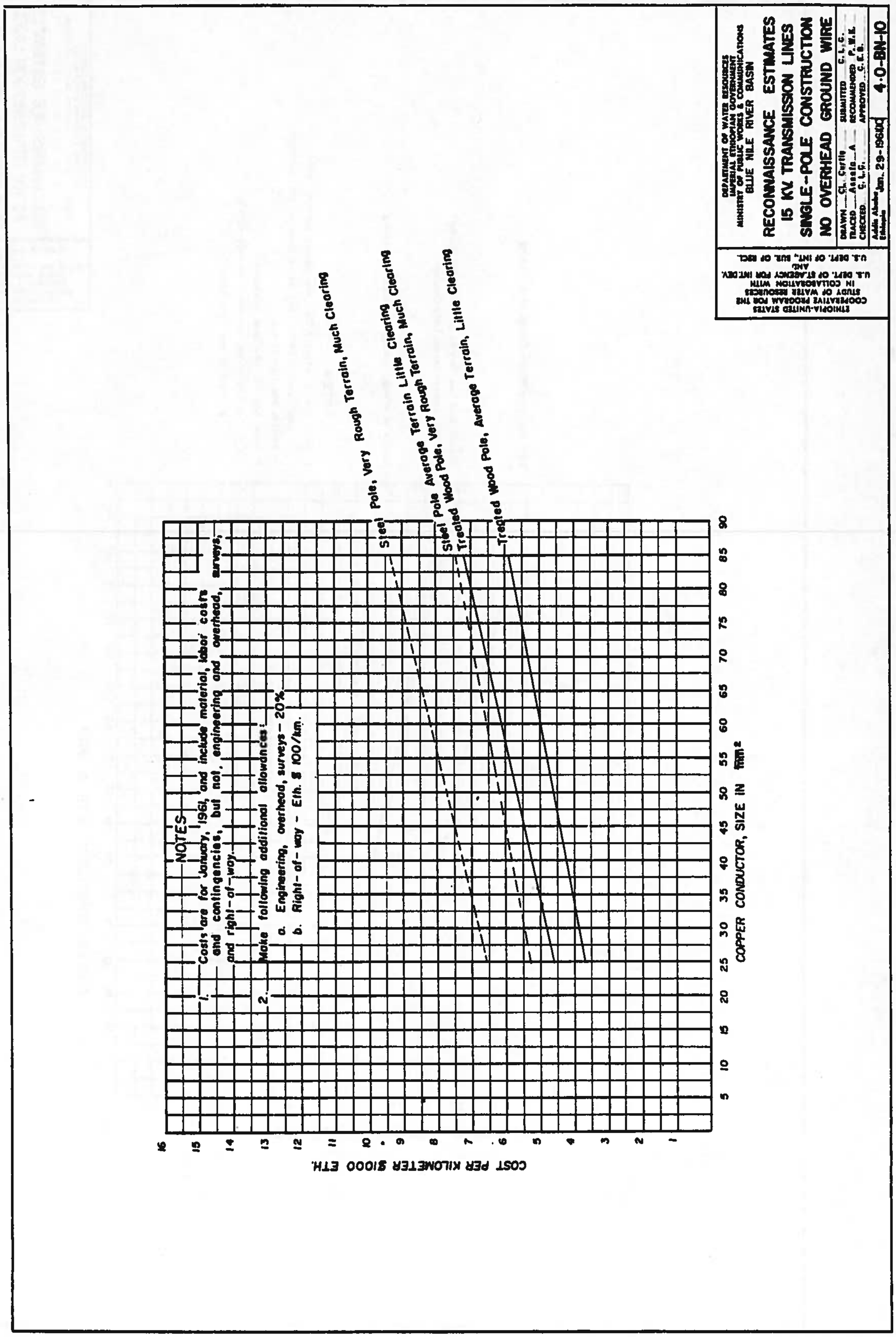


Figure I-19--15-Kv. Transmission Lines

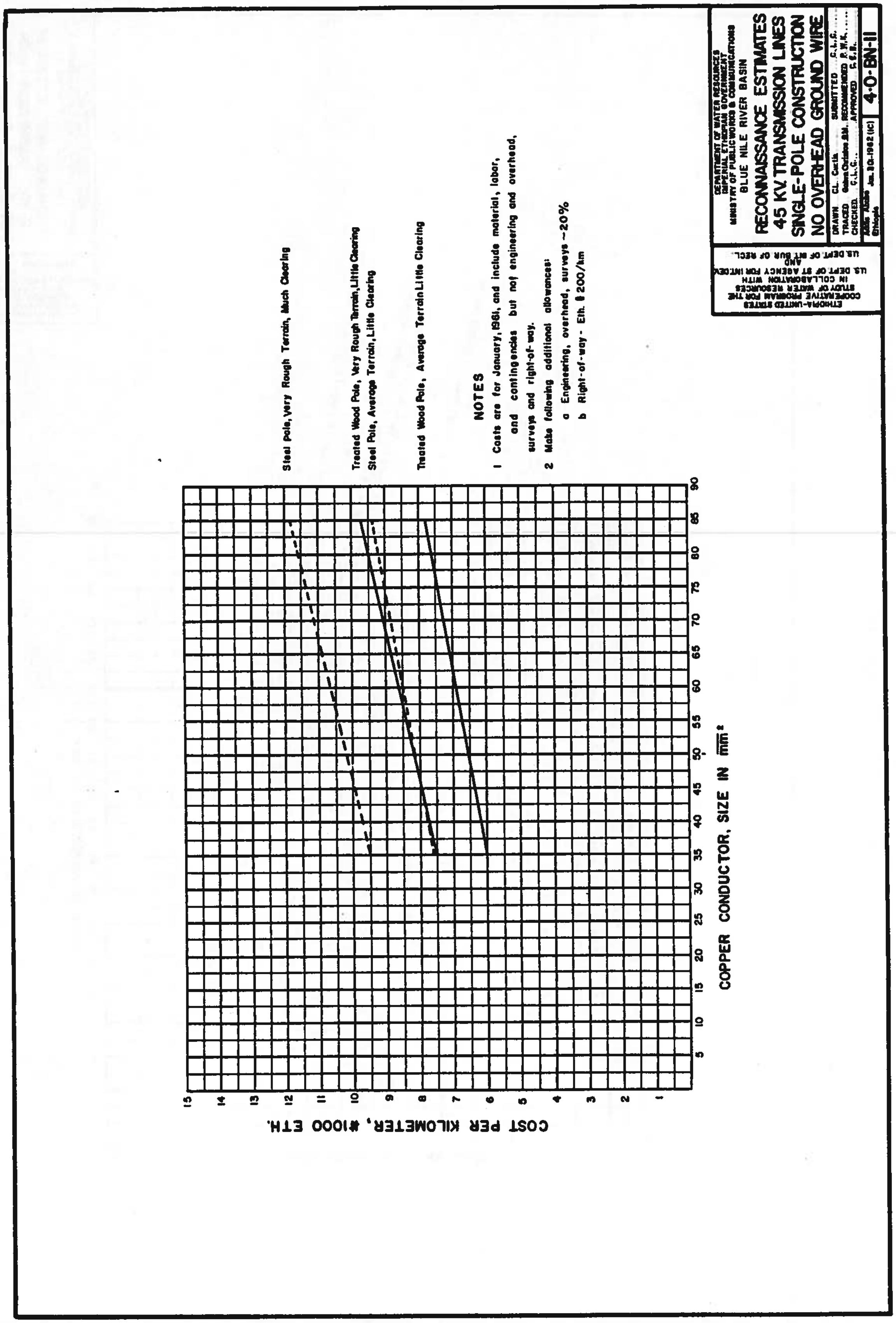


Figure I-20--45-Kv. Transmission Lines

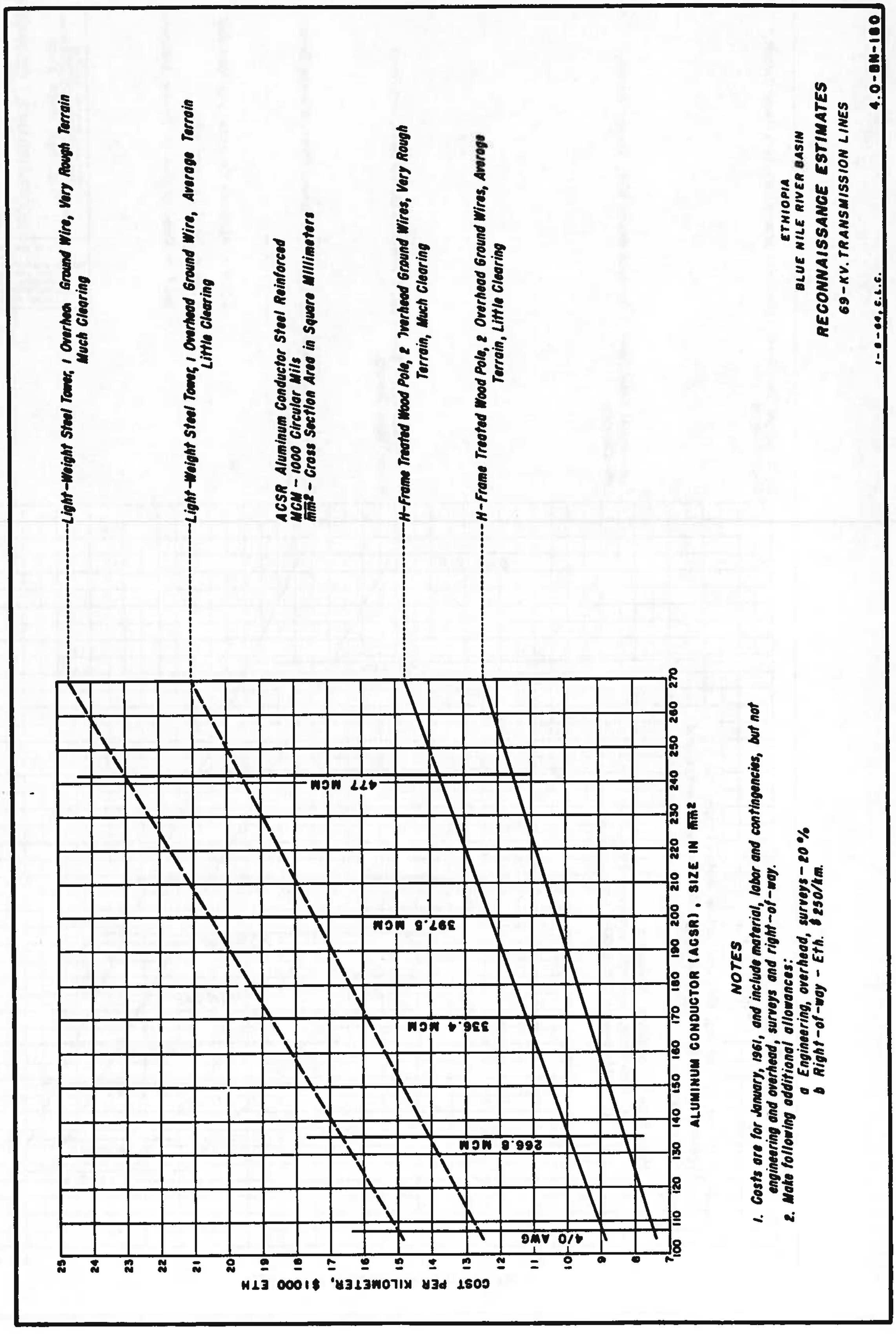


Figure I-21--69-Kv. Transmission Lines

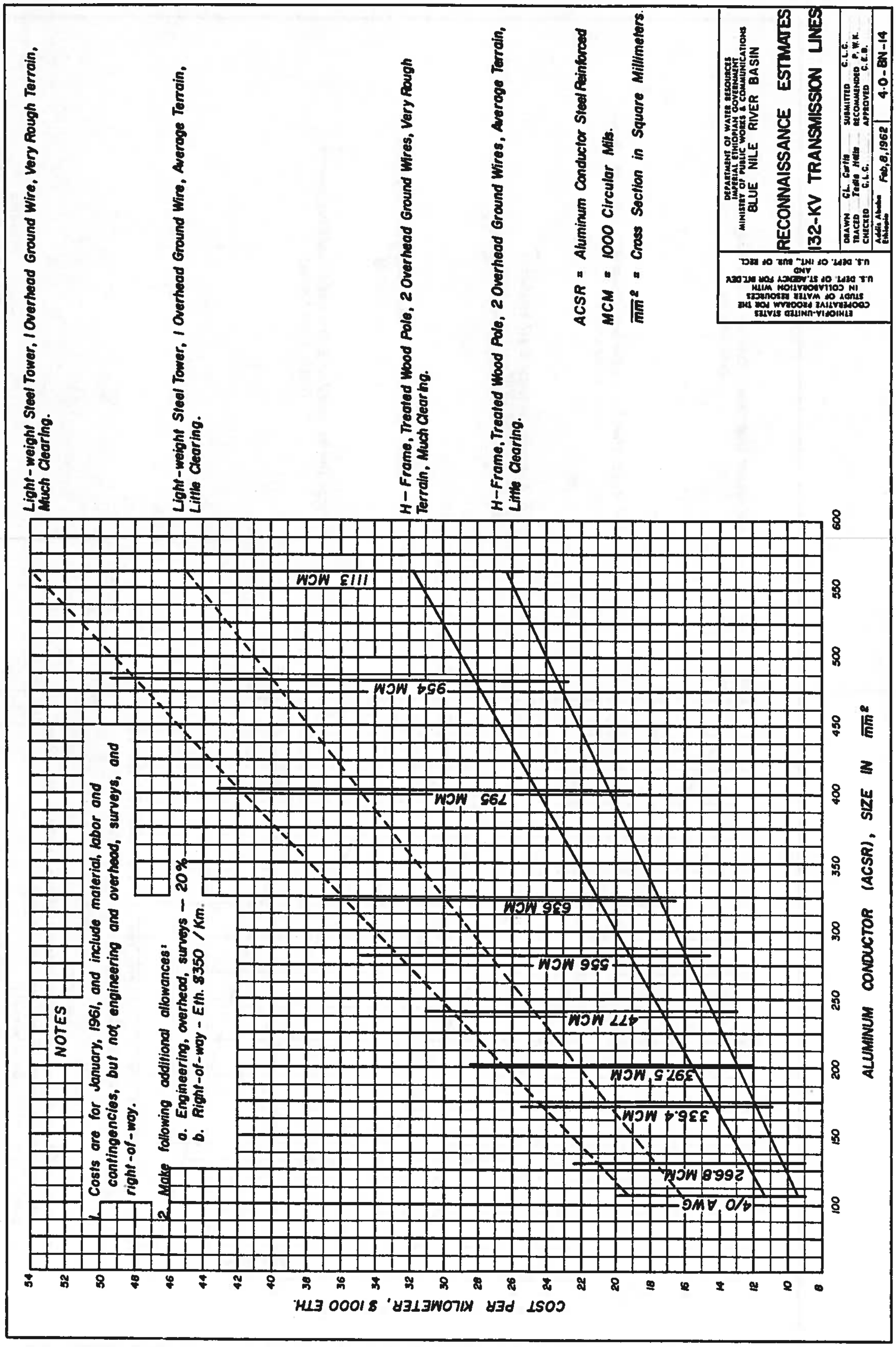


Figure I-22--132-Kv. Transmission Lines

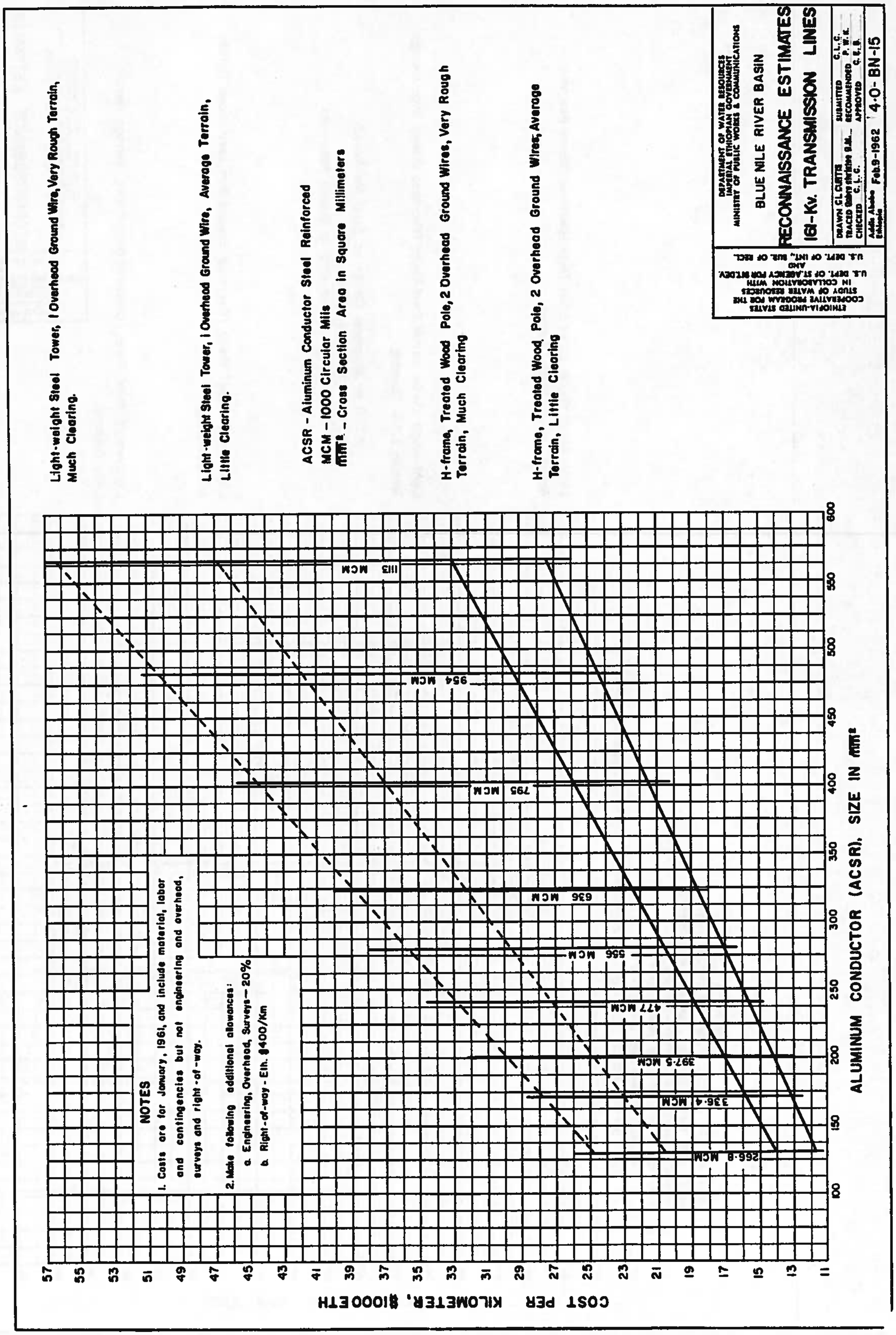


Figure I-23--161-Kv. Transmission Lines

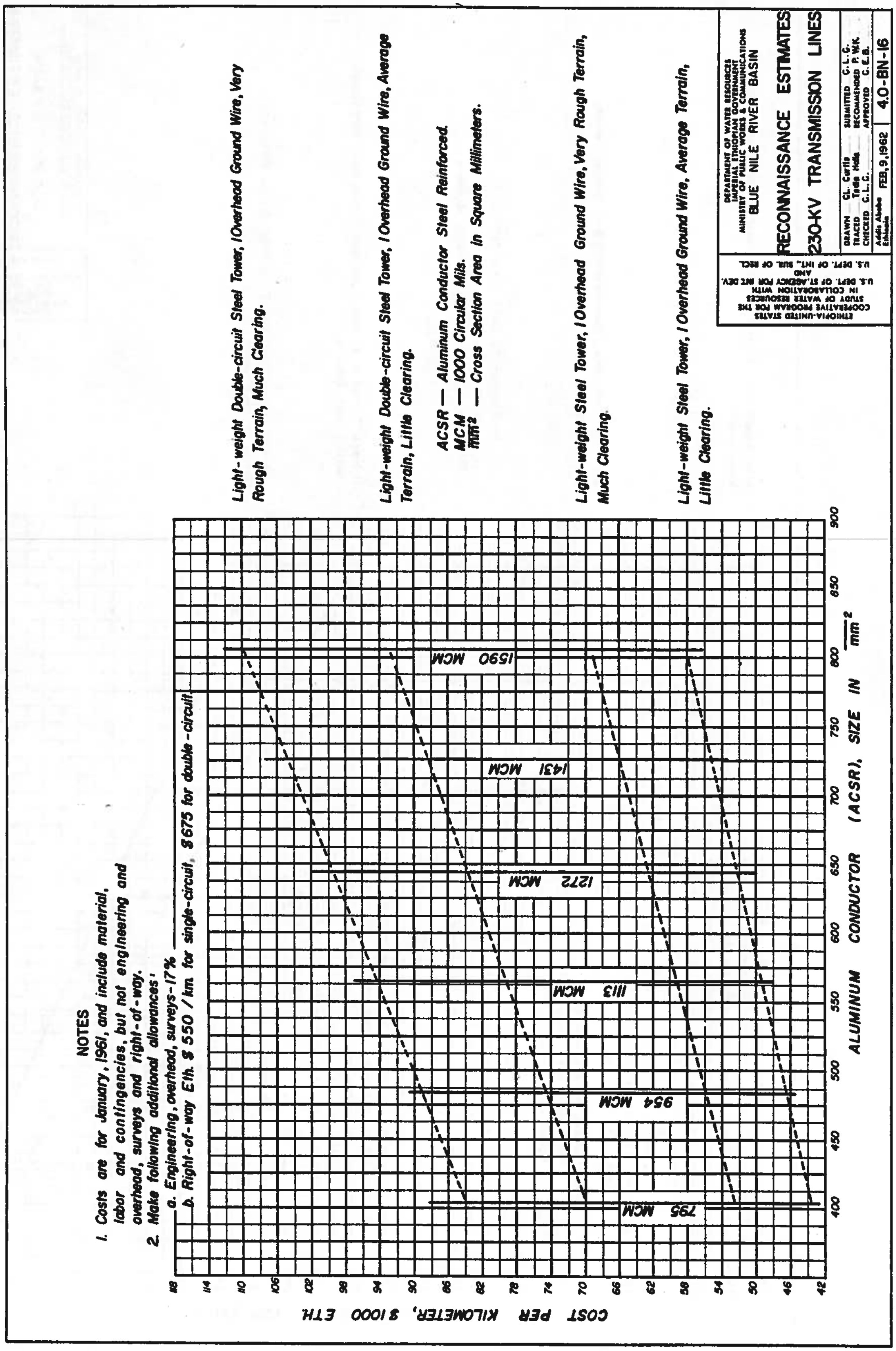


Figure I-24--230-Kv. Transmission Lines

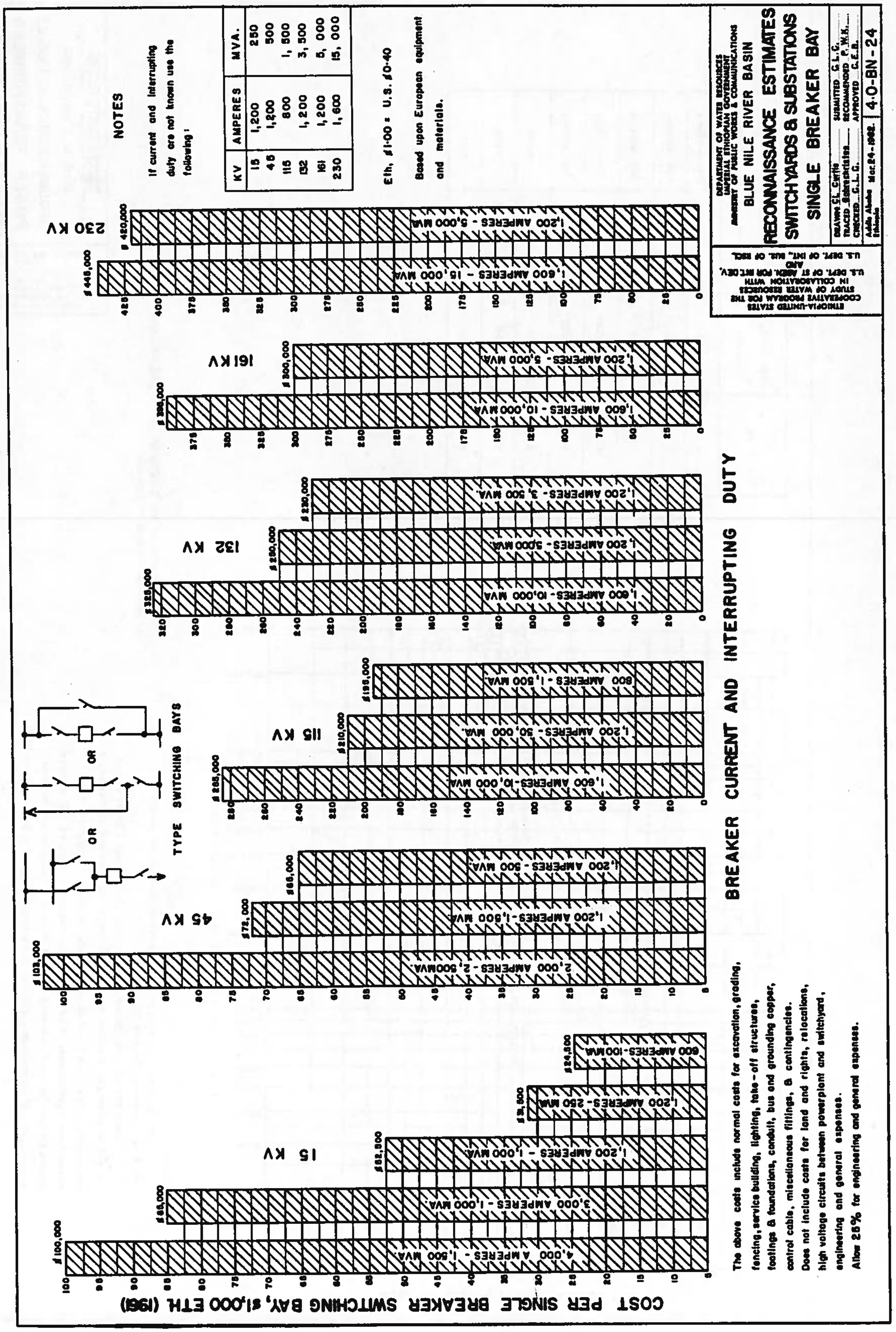
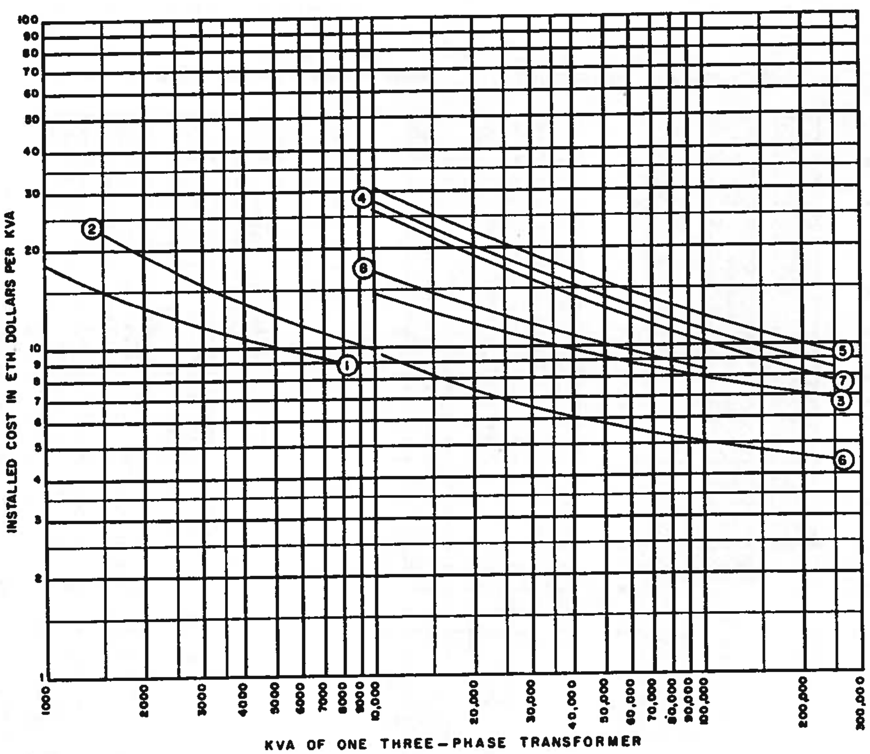


Figure I-25--Switchyards and Substations--Single Breaker Bay



Curve No.	High Voltage Kilovolts	Low Voltage Kilovolts	Transformer Type
1	15	2.4	Two-winding
2	45	15	Two-winding
3	115	15	Two-winding
4	230/196	15	Two-winding
5	230/196	45	Two-winding
6	115	15	Auto
7	230	115	Auto
8	132	45	Auto

NOTES

This drawing is to be used in conjunction with circuit breaker switching bay costs, Drawing No. 4.0-BN-24.

Costs are for self-cooled, 3 phase units and include 3 bushing type current transformers, lightning arresters, installation, labor and an allowance for contingencies. The costs do not include an amount for land and rights, relocations, foundations, and footings, bus take-off structures, high-voltage circuits between the power plant and switchyard, transfer tracks, untanking facilities, oil piping, etc., or allowance for engineering and general expenses. For the latter allow 25%.

Patterned after USBR Drawing No. 104-D-697, Adjusted to costs and practices in Ethiopia.

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DEPARTMENT OF WATER RESOURCES
IMPERIAL ETHIOPIAN GOVERNMENT
MINISTRY OF PUBLIC WORKS & COMMUNICATIONS

BLUE NILE RIVER BASIN

RECONNAISSANCE ESTIMATES

POWER TRANSFORMERS

INSTALLED COST PER KVA

DRAWN C.L. CURTIS — SUBMITTED C.L.C.
TRACED A NEGASH. M. — RECOMMENDED P.W.K.
CHECKED C.L.C. — APPROVED C.E.B.

Addis Ababa Ethiopia — 23 MAR. 1962 — 4.0-BN-25

Figure I-26--Power Transformers--Installed Cost per Kv.-a.

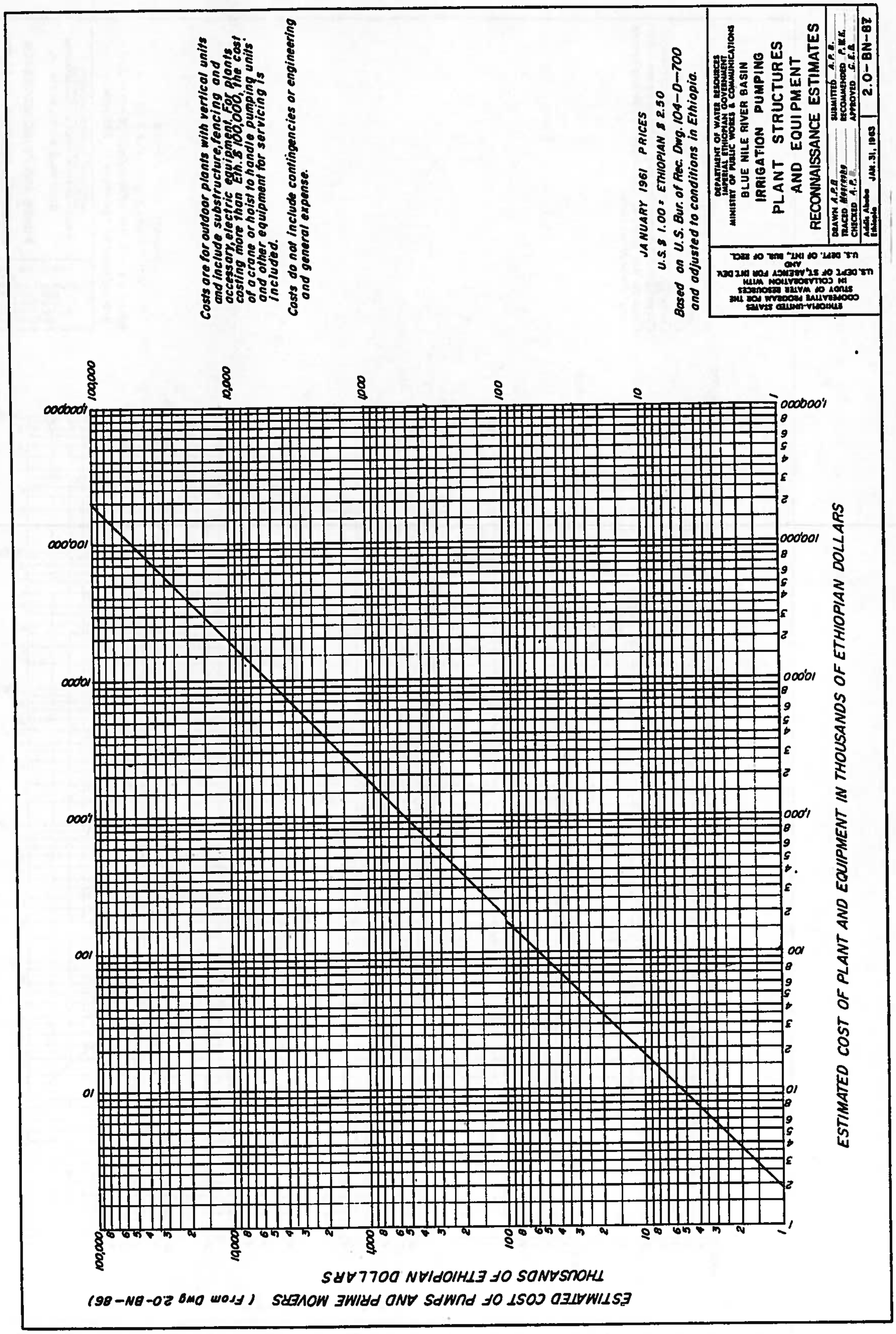


Figure I-29--Pumping Plant Structures and Equipment--Reconnaissance Estimates

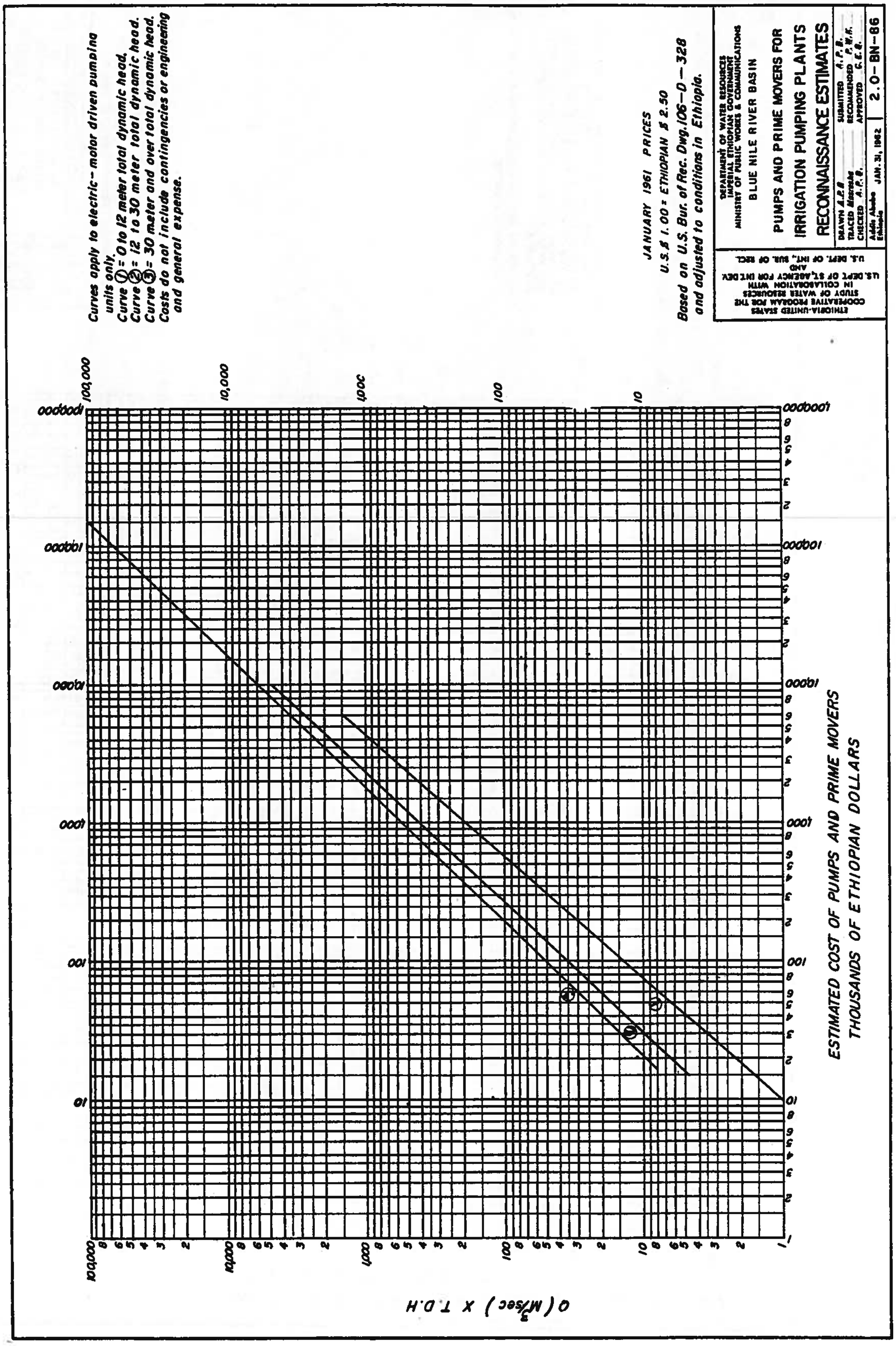
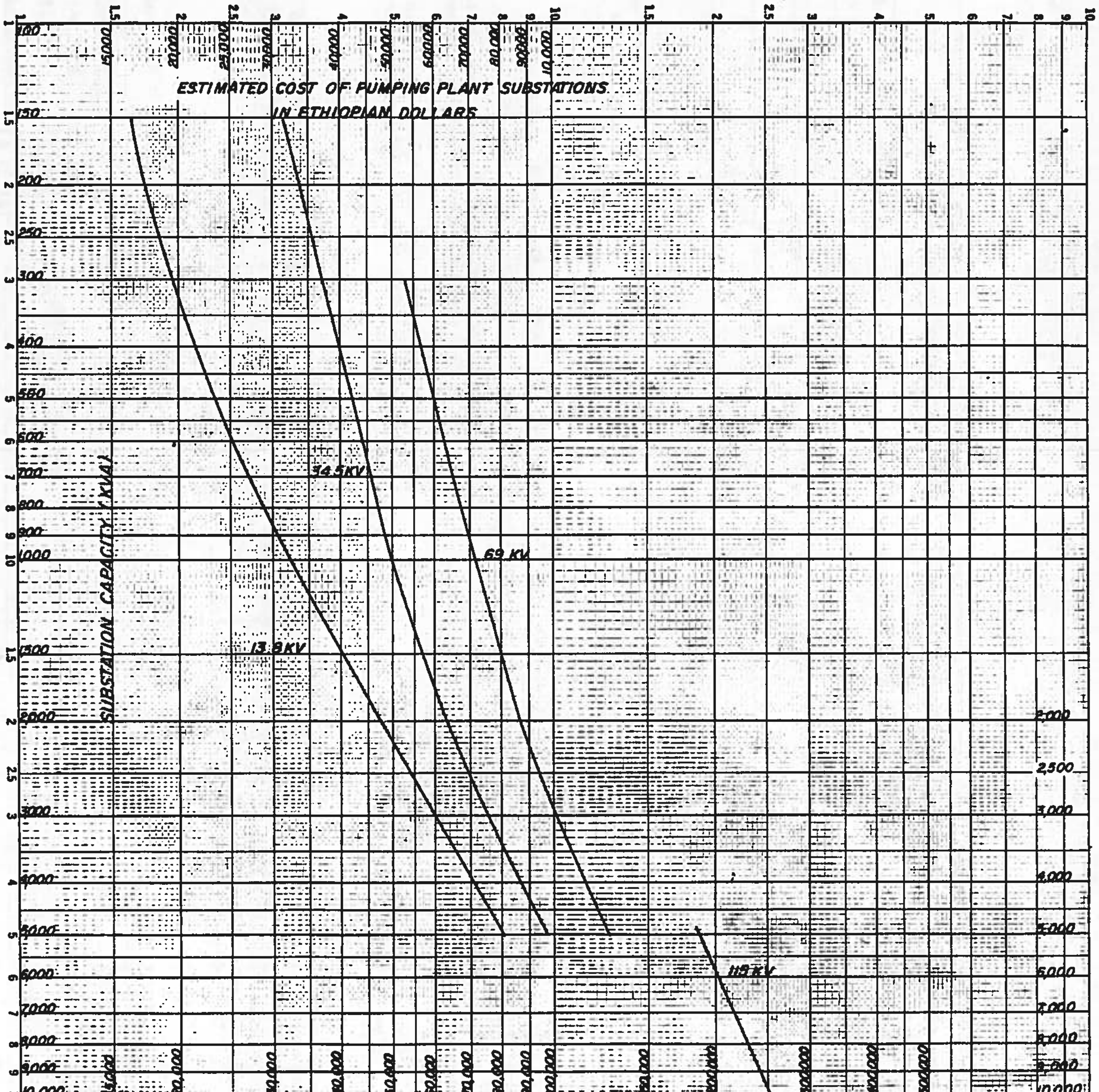


Figure I-30--Pumping Plant Pumps and Prime Movers--Reconnaissance Estimates

$$KW = \frac{9.812\ QH}{e} = 15.1\ QH$$

$$KVA = 1.25 \times KW$$

KW = Power requirement in Kilowatts
Q = Discharge in cubic meters per second
H = Totals dynamic head in meters
e = Assumed plant efficiency (0.65)
1.25 = Allowance for power factor of 0.80



ESTIMATED COST OF PUMPING PLANT SUBSTATIONS IN ETHIOPIAN DOLLARS

.These curves may be used for estimating the cost substations for small pumping plants when circuit breakers are not required in the substation.

The supply voltage in Kilovolts is indicated for each curve.

Costs obtained from these curves include normal leveling, fencing, wood pole structure, disconnecting switch, fuse, lightning arresters, step-down transformer for 220, 440 or 2,400 volts, but do not include access facilities, contingencies or engineering and general expense.

These curves are based on U.S.Bur. of Rec. Dwg. 104-D-699 and are adjusted to conditions in Ethiopia.

JANUARY 1961 PRICES
U.S. $1.00 = ETHIOPIAN $2.50

ETHIOPIA UNITED STATES COOPERATIVE PROGRAM FOR THE STUDY OF WATER RESOURCES IN COLLABORATION WITH U.S. DEPT OF ST. AGENCY FOR INT.DEV AND U.S. DEPT OF INT. BUR. OF RECL.

DEPARTMENT OF WATER RESOURCES
IMPERIAL ETHIOPIAN GOVERNMENT
MINISTRY OF PUBLIC WORKS & COMMUNICATIONS

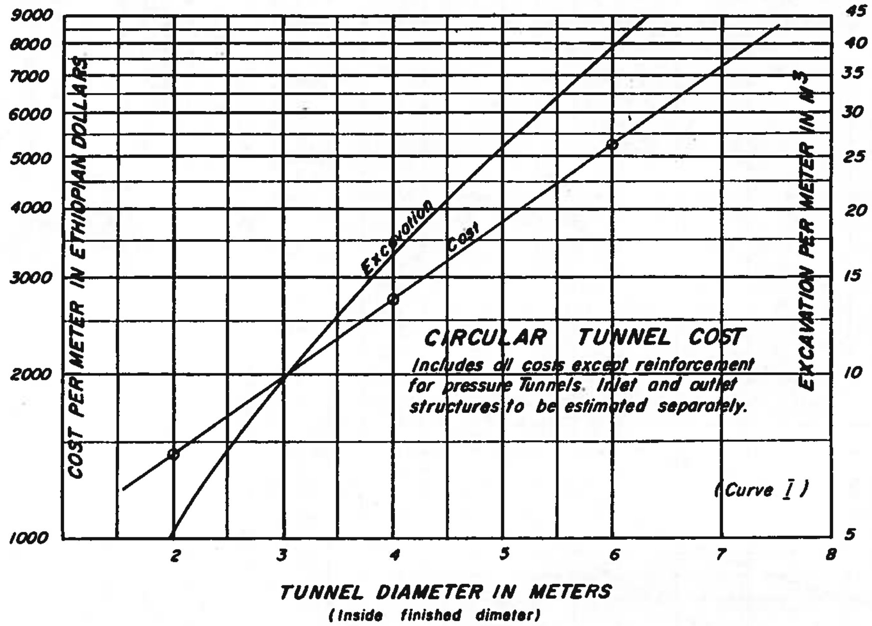
BLUE NILE RIVER BASIN

PUMPING PLANT SUBSTATIONS
RECONNAISSANCE ESTIMATES

DRAWN A.P.B. — SUBMITTED A.P.B.
TRACED Mesresha — RECOMMENDED P.W.K.
CHECKED A.P.B. — APPROVED C.E.A.

Addis Ababa Ethiopia — JAN 31, 1963 — 2.0-BN-88

Figure I-31--Pumping Plant Substations--Reconnaissance Estimates



APPROXMATE PERCENT OF COST (Curve I)

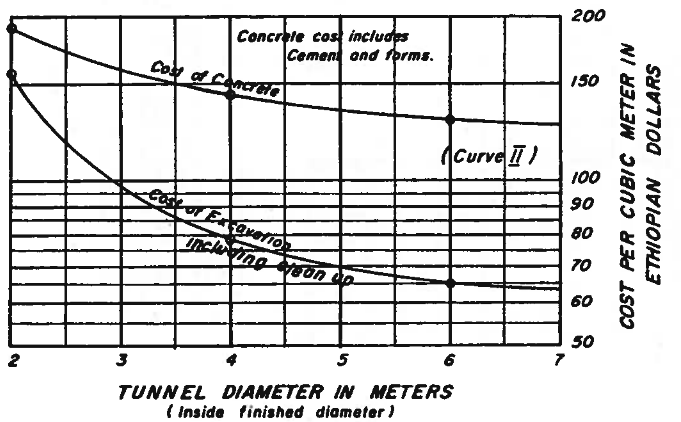
	2 M. Dia.	4 M. Dia.	6 M. Dia.
Exacvation	55 %	50%	49%
Concrete including cement & forms	24%	24%	25%
Supports & Logging (75% supported)	13%	17%	17%
Grouting, Drainage & Misc. work.	8 %	9 %	9%

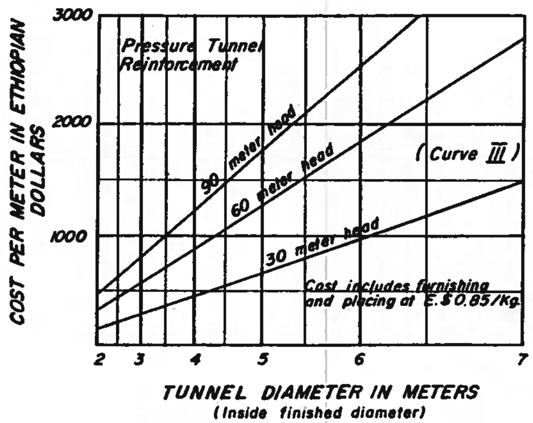
Estimated correction for length (Curve I)

Meters driven from one heading			Cost factor
0	to	800	1.1
800	to	4800	1.0
4800	to	6400	1.1
6400	to	8000	1.2
8000	to	9600	1.3

To the cost from the curves, add 25% contingencies to obtain field cost. Add 15% to field cost for engineering and general expense.

For pressure tunnels, the costs from Curves I & III must be added.
The thickness of concrete lining in curve I is 8.3 cm per meter of diameter.





January 1961 COSTS
Eth. $ 1.00 = U.S. $ 0.40

Ref. appendix "A" Recl. Instr. Series 150.

REVISED MAR. 19, 1962

ETHIOPIA-UNITED STATES COOPERATIVE PROGRAM FOR THE STUDY OF WATER RESOURCES IN COLLABORATION WITH U.S. DEPT. OF ST. AGENCY FOR INT. DEV. AND U.S. DEPT. OF INT., BUR. OF RECL.

DEPARTMENT OF WATER RESOURCES
IMPERIAL ETHIOPIAN GOVERNMENT
MINISTRY OF PUBLIC WORKS & COMMUNICATIONS

BLUE NILE RIVER BASIN

TUNNEL

RECONNAISSANCE ESTIMATES

DRAWN A.P.B. SUBMITTED A.P.B.
TRACED MASRESHA GH. RECOMMENDED P.W.K.
CHECKED G.L.B. APPROVED C.E.B.
Addis Ababa Ethiopia DEC. 28, 1961 (IC) 2-0-BN-28

Figure I-32--Tunnel--Reconnaissance Estimates

Distribution Systems and Drainage Canals. Estimates of construction costs for distribution systems and drainage canals for the various irrigation projects were obtained on a cost per hectare basis. More detailed studies performed on the Upper Birr Project, as a sample area, on these items indicated that the costs would be approximately Eth$330 per hectare for the distribution system and Eth$140 for the surface drainage requirements (see Table I-2). The sample area studied included variable topography ranging from level to fairly steep slopes and resulting in different shapes of potential farms; such topography influences to a great extent the costs of distribution systems and drains. As in canal structures, this method indicates an approximation of the magnitude of the costs, and the estimate of costs for each project for these items as stated could vary widely from the prototype adopted. Estimates of costs required for these structures, like those for the main canals, were assumed to be constructed in accordance with local methods, utilizing the abundance of stone and minimizing the use of concrete and reinforcement. Concrete pipe and Armco 101 slide gates were used in the estimates for the farm turnouts.

Service Facilities. Costs for this item were obtained from curves (Figure I-33) based on Bureau of Reclamation requirements and practices adjusted to local conditions. Cost generally associated with this item includes temporary as well as permanent structures and improvements. It includes construction roads and trails, housing facilities, schools, recreation facilities, garages, warehouses, shops, offices, and laboratories. It includes such equipment as office furniture, transportation, stores, shops, laboratory, tools, communication, miscellaneous, and other work equipment.

Development Costs

Clearing Costs. The development of land areas for irrigation of crops in the Blue Nile Basin requires clearing trees, brush, and vegetative debris from the potential project lands. The amount of clearing will vary from the removal of an occasional tree to the clearing of dense brush and tree cover so thick that it virtually forms a closed canopy. To estimate the cost for this item, studies were performed on limited data obtained from various plantations in Ethiopia together with the Gezira scheme in the Sudan. These costs, modified by informed judgment, are arrayed to show three levels of intensity of clearing, which in turn are applied to the areas under study in the Blue Nile Basin. The cost attributable to clearing operations cannot be considered as a precise figure because of many unmeasurable components.

Portions of certain projects require less clearing than others. This occurs when natural vegetation does not grow uniformly over a wide area or where man-made factors, such as fire or exploitation, have changed the natural vegetative pattern. The land use pattern in some areas causes a low total clearing requirement, although the clearing cost per tree may be high for the few large trees remaining.

Light Clearing. This category contemplates "tall grass, scattered-tree savanna" areas with scattered acacia and broad leafed species. The number of trees per hectare ranges up to 15 small trees with occasional larger specimens. The cost of clearing ranges from Eth$15.00 to Eth$80.00 per hectare. A median of Eth$58.00 per hectare is used for project estimating.

Medium Clearing. This category visualizes a closer tree growth with a higher proportion of trees of greater trunk diameter. Large acacia and broad-leaf species are involved. The number of trees varies from 15 to 150 per hectare, with occasional large trees. One large fig or baobab in an area of 25 square kilometers (about 10 square miles) would probably be representative of the plant composition. Bamboo forests, such as exist in the Beles River Basin, are also considered to fall in this category. The costs of clearing this type of growth range from Eth$81.00 to Eth$150.00 per hectare. A median of Eth$115.00 per hectare is used for project estimating purposes.

Heavy Clearing. This category includes limited areas of riverine growth adjacent to streams and areas of intense growth of acacia trees, which form a closed or nearly closed canopy at treetop level. Tree numbers exceed 150 per hectare. The costs for clearing this type of vegetation ranges from Eth$151.00 to Eth$310.00 per hectare. A median of Eth$230.00 per hectare is used for project estimating purposes.

TABLE I-2--RECONNAISSANCE ESTIMATE--BIRR SAMPLE AREA, IRRIGATION DISTRIBUTION AND DRAINAGE SYSTEMS

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project BIRR--SAMPLE AREA IRRIGATION DISTRIBUTION AND DRAINAGE SYSTEMS

Date of Estimate December 1962 — Currency in terms of Ethiopian Dollars

Prices as of January 1961 — (U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
					$	$	$
	DISTRIBUTION SYSTEM--15 main laterals off the Upper Birr Canal to serve 8,600 irrigable hectares. Initial lateral capacities, 4.5 to 0.2, average 1.15 cu meters/sec. Farm delivery to each 17 hectares.				2,854,917	3,425,900	4,282,000
	Waterways--Unlined laterals, 185 kms					Distribution System	
1	Excavation, common	155,025	m^3	1.40	217,035		
2	Excavation, from borrow	179,525	m^3	1.40	251,335	$2,854,917 / 8,600 ha = $331.96	
3	Shaping and consolidating canal banks	393,940	m^3	1.05	413,637		
	Subtotal--Waterways				882,007	Say $330 per ha	
	Structures						
	Checks, check-drops, drops, division boxes						
4	Excavation for structures	14,191	m^3	1.60	22,706		
5	Compacted backfill about structures	7,080	m^3	2.60	18,408		
6	Masonry	19,145	m^3	55.00	1,052,975		
7	Riprap	1,336	m^3	12.00	16,032		
8	Miscellaneous metalwork	12,921	kg	2.60	33,595		
9	Timber in gates and checks	124	m^3	318.00	39,432		
10	Staff gages	95	ea	10.00	950		
	Subtotal--Checks, etc.				1,184,098		
	Canal Crossings (111 farm bridges)						
11	Masonry in piers	1,819	m^3	55.00	100,045		
12	Timber for bridges	371	m^3	318.00	117,978		
	Subtotal--Canal Crossings				218,023		
	Road Crossings and River Siphon						
13	Excavation	2,958	m^3	1.40	4,141		
14	Compacted backfill	2,185	m^3	2.60	5,681		
15	Grouted rubble paving, transitions	147	m^3	15.00	2,205		
16	Concrete pipe, 1.50 meter diameter	352	lm	240.00	84,480		
17	Riprap	13	m^3	12.00	156		
	Subtotal--Road Crossings and Siphon				96,663		
	Farm Deliveries (509 required)						
18	Excavation for structures	735	m^3	1.60	1,176		
19	Compacted backfill about structures	735	m^3	2.60	1,911		
20	Masonry	1,378	m^3	55.00	75,790		
21	Concrete pipe (0.30 meter diameter)	509	lm	25.00	12,725		
22	Gates, circular slide (Armco 101)	7,700	kg	5.00	38,500		
23	Riprap	463	m^3	12.00	5,556		
	Subtotal--Farm Deliveries				135,658		
						Surface Drains	
	Wasteways						
24	Excavation for wasteways	140,270	m^3	1.40	196,378	$1,199,100 / 8,600 ha = $139.43	
25	Excavation for structures (drops)	13,517	m^3	1.60	21,627		
26	Masonry	2,029	m^3	55.00	111,595		
27	Riprap	739	m^3	12.00	8,868	Say $140 per ha	
	Subtotal--Wasteways				338,468		
	Subtotal--Distribution System				2,854,917		
	Contingencies (20±%)				570,983		
	Field Cost--Distribution System				3,425,900		
	Engineering and General Expense (25±%)						(856,100)
	DRAINS--31 kms of primary and 230 kms of secondary open lateral drains, for 8,600 irrigable hectares in the Birr sample area.				1,199,100	1,438,900	1,799,000
1	Excavation for drains, all classes	756,500	m^3	1.40	1,059,100		
	Structures--370 masonry drops						
2	Excavation for structures	13,230	m^3	1.60	21,168		
3	Masonry	2,000	m^3	55.00	110,000		
4	Riprap	736	m^3	12.00	8,832		
	Subtotal--Drains				1,199,100		
	Contingencies (20±%)				239,800		
	Field Cost--Drains				1,438,900		
	Engineering and General Expense (25±%)						(360,100)

Note: Additional embankment material, item 3 waterways, may be obtained from wasteway and drain excavation.

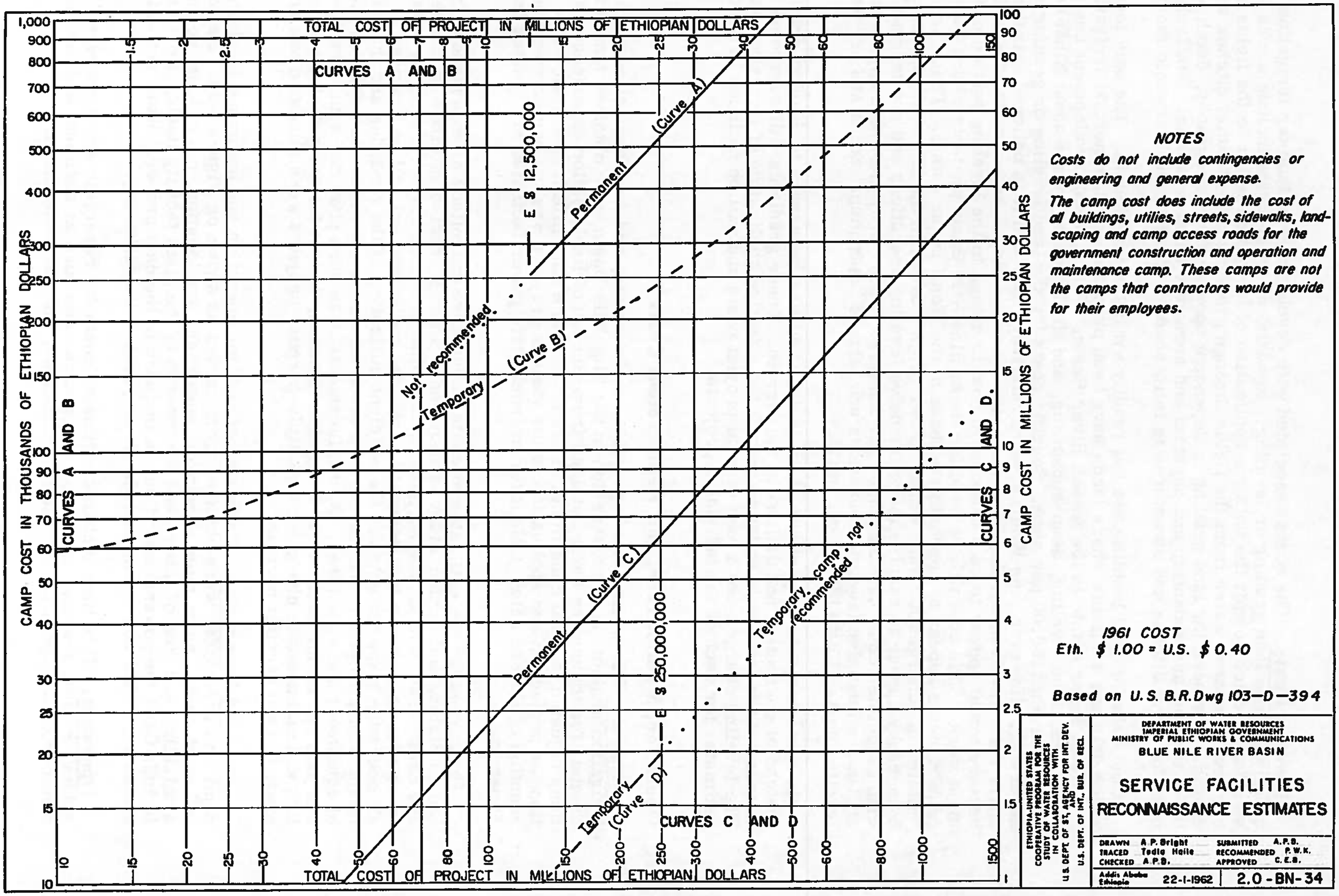


Figure I-33--Service Facilities--Reconnaissance Estimates

Leveling Costs. The costs associated with development of land for irrigation farming usually include land grading or leveling. In addition, these costs include works and structures which permit the uniform application of irrigation water to the fields and the removal of excess water from the fields through properly placed outlet ditches and field drains. The need for land grading is dependent upon surface topography, depth and quality of the soil and subsoils, and physical and economic considerations. Similarly, the need for farm ditches and structures is influenced by physical and economic factors.

Cost data for land leveling are not readily available in Ethiopia. The only location for which data are available where lands have been prepared for commercial irrigation is on the Wonji sugar estate in the Awash River Basin. There, total development costs, including drains, land leveling, deep-subsoiling, and final plowing, were about Eth$617.00 per hectare or Eth$150.00 per acre. Specific costs for the land leveling or grading were not separable. However, the Wonji area is relatively flat, and it is believed that the principal costs there involved development work other than leveling. An estimate of Eth$65.00 per hectare would appear to be a reasonable cost to assign to the leveling portion of the development work. This cost will be used for those Blue Nile Basin projects where land grading requirements appear to approximate those of the Wonji sugar estate. These are considered "minimum" charges for such work. Other project areas in the Blue Nile Basin with rougher topography appear to require more intensive leveling operations and are termed "moderate" with associated costs of Eth$125.00 per hectare. Those projects which appear to require still more intensive leveling operations are termed "maximum" areas and are assigned leveling costs of Eth$180.00 per hectare.

In some projects or portions of projects, it will be necessary to develop gradients instead of correcting undulations in the terrain. These gradients will overcome the flatness of the terrain in order to permit the effective application of irrigation water. The leveling charges are a part of total project costs and will be included in the final cost estimates for each of the individual projects.

Operation, Maintenance, and Replacement Costs

General. The estimates of operation, maintenance, and replacement costs for the irrigation projects under discussion in the Blue Nile Basin were obtained from curves, the data for the curves being obtained from Bureau of Reclamation experiences and practices adjusted to local conditions. Lack of available data in Ethiopia in this type of operation for projection and application to the various projects was the primary reason for adoption of Bureau data. OM&R for hydroelectric power facilities are treated in the Power Appendix.

The curves for the estimates of costs indicate the magnitude as experienced in the United States, and further study is required if a more precise estimate is desired, with due consideration to all the variable factors that influence costs. Costs, as obtained from these curves, assume that adequate personnel and equipment will be provided to perform all operating requirements for the efficient utilization of the facilities and that proper maintenance programs will be carried out to minimize premature and costly replacements of equipment and structures. No replacements have been provided within the 50-year analysis period for exclusively irrigation features, except for the pumping plants. Operation and maintenance charges on multiple-purpose projects were allocated and charges made to each specific purpose.

Dams and Reservoirs. Estimates of cost for operation and maintenance charges for dams and reservoirs were obtained from curves as shown on Figure I-34. Factors that influence costs, aside from reservoir capacities, are location, operational requirements, availability and cost of labor, and the makeup of the plant facility itself. Costs do not include O&M for powerplants if one is included in the dam proper. Work activities associated with O&M costs may include all or parts of the following.

Operation. This item includes estimated costs for reservoir superintendent, guards, guides, marine service, collection of technical data such as sediment and test surveys, communication operators, utilities technicians, and gate attendants.

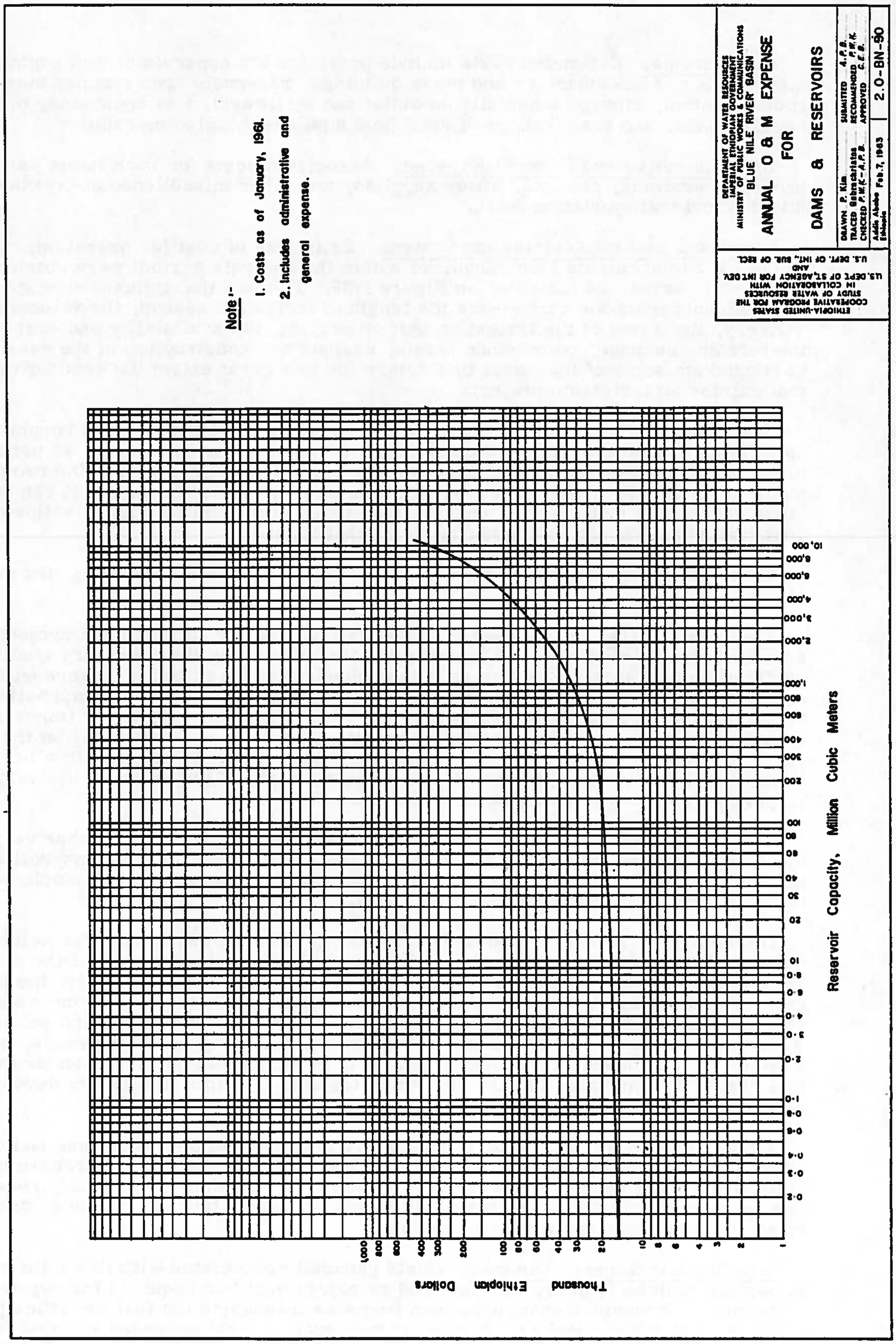


Figure I-34--Annual O&M Expense for Dams and Reservoirs

Maintenance. Estimated costs include provision for supervision and engineering, maintenance of headquarters and other buildings, reservoir area maintenance, weed and rodent control, riprap (especially on outlet and spillways), test apparatus, outlet works, access roads, and maintenance of electrical equipment including radio.

Administrative and General Expense. Associated costs for such items as centralized project operations, clerical, office supplies, and other miscellaneous expenses such as utilities and transportation fuels.

Canal and Lateral Distribution System. Estimates of cost for operation, and maintenance (no replacements being required within the analysis period) were obtained for this item from curves, as indicated on Figure I-35. Factors that influenced cost--not assumed or obtainable from the curve--are the length of irrigation season, the volume of water delivery, the shape of the irrigation unit or project, the availability and cost of labor, the terrain, seepage, conveyance length, designs and construction of the canal structures, to enumerate some of the items that determine to a great extent the cost for operating and maintaining an irrigation project.

The Bureau of Reclamation's experience in irrigation O&M costs is roughly apportioned as follows: 60 percent for personnel costs, 20 percent for equipment, 12 percent for supplies, and 8 percent for miscellaneous-expenses. The comparison of the two projects was made to convey the higher unit cost of the smaller project. Generally it can be said that labor costs were considerably cheaper than those in the United States, with equipment cost (including life and maintenance) somewhat higher.

Costs generally associated with an irrigation project by broad categories may be as follows.

Personnel Costs. A qualified manager is required for an irrigation project with an assistant usually employed for larger projects. Obtaining the necessary qualified managerial personnel may be costly, as it is probable that the initial managers will be foreign nationals who have acquired the necessary experience. It should be emphasized that formal education alone is not sufficient to qualify a man for this highly important and technical job; he should have years of irrigation experience, preferably on the same type of project that he eventually heads, and should have a proven capacity in all of the diverse fields that make up the operation of the project. Some of the larger projects may also employ a watermaster chargeable to this item.

Clerical and administrative personnel will be required with the number varying with the complexity and size of the projects. Collection of technical data, payroll and personnel cost accounting, water records, and ordering and issuing supplies would be some of the work activities associated with this cost.

Ditchtenders, laborers, and technicians would also be required. Receiving and filling water orders from the individual farmers would be the principal task of the ditchtenders. They would have the primary responsibility of regulating the turnouts for the proper releases of water. Maintenance personnel would maintain canal structures and facilities as required. Some of the representative duties would include debris and sediment removal, weed control, and maintenance and repair of canal linings, operating roads, bridges and wasteways, and headquarters buildings. It is expected that personnel under this category will readily be recruited locally with some training and time in which to develop the skills necessary for their duties.

Equipment Costs. Costs for this item are composed of operation (gas and oil) and depreciation of the equipment, but exclude labor costs. The initial purchase cost is provided under construction costs of service facilities. Equipment generally required for operation of an irrigation project would include pickups, trucks, tractors, draglines, and miscellaneous tools and work equipment.

Supplies and General Expense. Costs generally associated with this item would include materials such as lumber, cement, and reinforcement bar required for repairs to canal structures. It would also include such items as transportation fuel for office personnel, utilities, and office supplies. It may include such general expenses as legal fees, auditing fees, liability insurance, and insurance on buildings and equipment. It would also include depreciation on buildings not covered under other items.

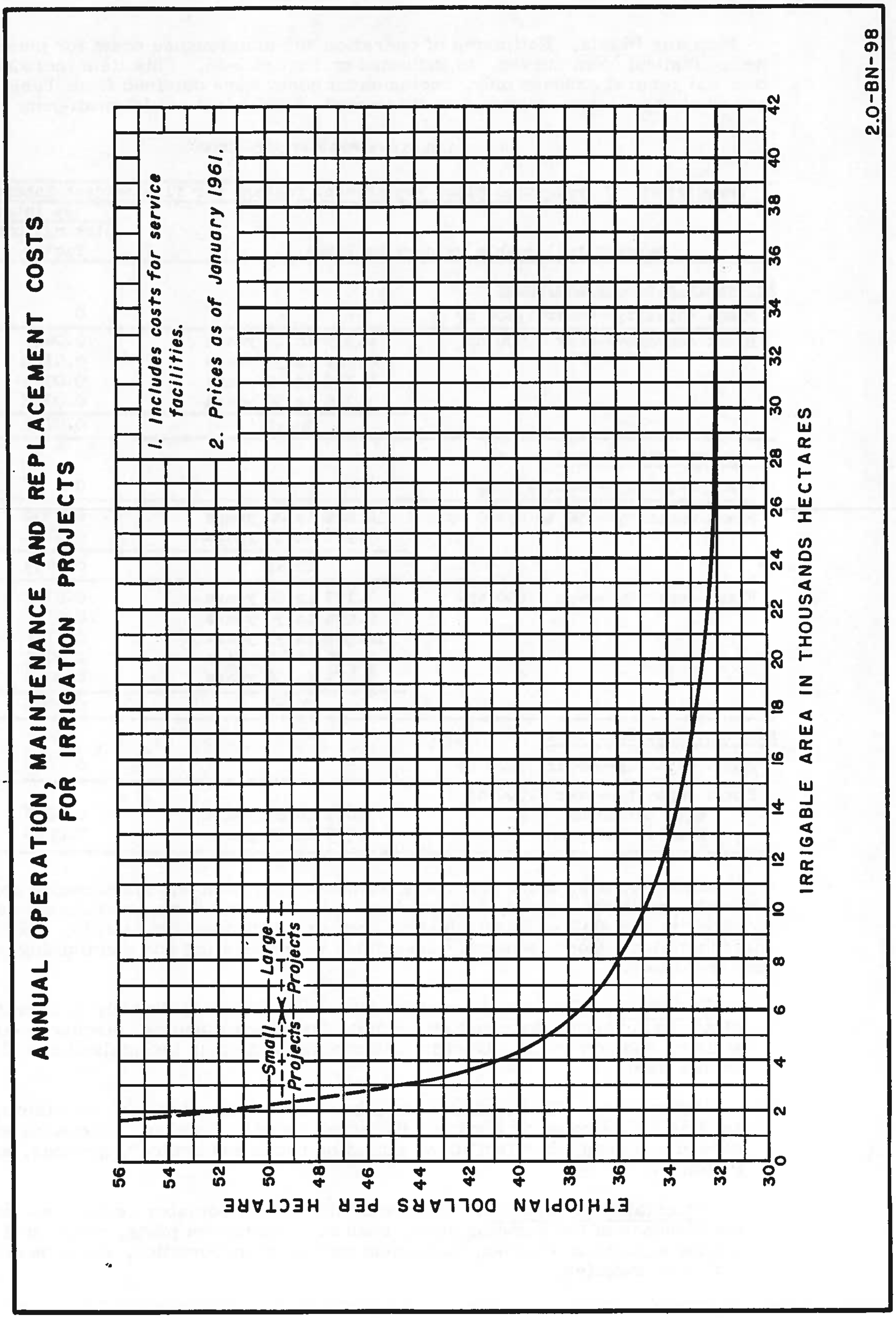


Figure I-35--Annual OM&R Costs for Irrigation Projects

Pumping Plants. Estimates of operation and maintenance costs for pumping plants were obtained from curves, as indicated on Figure I-36. This item includes administrative and general expense only, replacement costs were obtained from Table I-3, and power charges were estimated at three cents (Ethiopian) per kilowatt-hour.

TABLE I-3—PUMPING PLANT REPLACEMENT

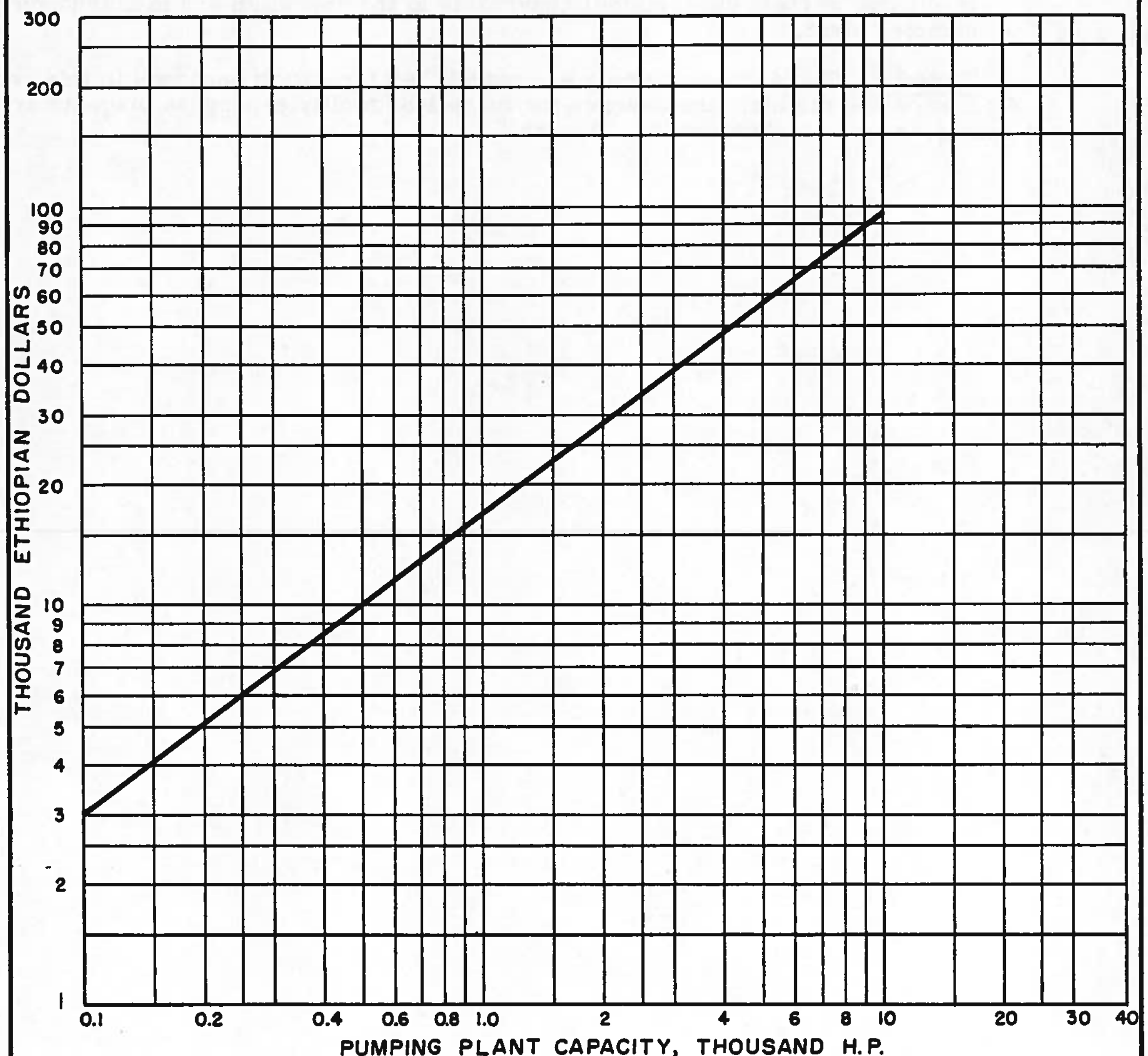
Computation of irrigation plant replacement factors for five percent interest rates		5% interest rate	
Percent replaceable by service lives		Sinking fund factor	Weighted factor
Accessory Electric Equipment			
Plant capacity--under 7,000 hp	-	0	0
Plant capacity--over 7,000 hp	0.53% in 15 years	0.0463	0.000246
	53.16% in 35 years	0.0111	0.005901
	0.73% in 40 years	0.0083	0.000061
	1.31% in 50 years	0.0048	0.000063
	Total	0.0705	0.006271
Pumps and Prime Movers			
Plant capacity--under 750 hp	-	0	0
Plant capacity--750 to 6,999 hp	10.62% in 20 years	0.0302	0.003207
	5.99% in 30 years	0.0151	0.000905
	Total	0.0453	0.004112
Plant capacity--over 7,000 hp	1.19% in 20 years	0.0302	0.000359
	0.69% in 30 years	0.0151	0.000104
	12.36% in 35 years	0.0111	0.001372
	3.93% in 40 years	0.0083	0.000326
	7.47% in 50 years	0.0048	0.000359
	Total	0.0695	0.002520
Miscellaneous Equipment			
Plant capacity--under 7,000 hp	-	0	0
Plant capacity--over 7,000 hp			
With telephone	7.66% in 25 years	0.0210	0.00161
Without telephone	4.33% in 25 years	0.0210	0.00091

Variable factors, those that could influence operation and maintenance costs and are not reflected in the curves, are location, climatic conditions, operational requirements, availability and skill of labor, designs and construction of the facility, and type of equipment installed. Costs generally associated with operating and maintaining pumping plants are as follows.

Operation. This would consider all labor costs used directly in operation of the plant, including intake canal or conduit, trashrack cleaning, discharge conduit, substation, and powerline. Guards, attendants, and other technicians are also included in this item.

Maintenance. This includes the labor costs associated with maintaining the plant, such as intake canal or conduit, discharge conduit, housing, substation equipment, powerlines, and other facilities, including roads and bridges, grounds, and other buildings.

Materials and Supplies. This would include all nonlabor costs associated with the maintenance of the pumping plant, such as replacement parts, paint, tool expense, testing equipment expense, equipment rental, transportation, and miscellaneous materials and supplies.



Notes:

1. *Curve excludes reservoir, dams and waterway expense.*
2. *Curve includes allowances for administrative and general expense.*
3. *Costs are for January, 1961*

BLUE NILE RIVER BASIN
RECONNAISSANCE ESTIMATES
ANNUAL O&M EXPENSES FOR PUMPING PLANTS
P.K. *3-12-64*

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Figure I-36--Annual O&M Expenses for Pumping Plants

Administration and General Expense. This item would include salaries, expenses, travel, and mileage costs of administrative employees and management personnel (exclusive of O&M supervision) chargeable to the operation and maintenance of the pumping plant.

Tunnels. There are no tunnels exclusively for irrigation purposes in this report. Operation and maintenance charges for tunnels on multiple-purpose projects are described and costs noted in Appendix V, "Power."

SECTION 2--LAKE TANA SUB-BASIN

Introduction

The Lake Tana Sub-basin is discussed in relation to four separate projects, each of which is described in detail in this section, which is limited to the northern and eastern portions of the basin on the perimeter of the lake. The utilization of Lake Tana for purposes of development of the adjacent Beles River Basin and the Gilgel Abbay Projects will be discussed elsewhere.

For obvious reasons, the general descriptions applicable to the basin will include Lake Tana and the Gilgel Abbay drainage area. Due to the interest shown, both in the past by international attention and currently by the Imperial Ethiopian Government in the exploitation of Lake Tana, the general description is given in greater detail than for the other areas in the Blue Nile Basin.

BASIN DESCRIPTION

The Lake Tana basin lies in northwestern Ethiopia and has a drainage area of approximately 15, 000 square kilometers (5, 800 square miles). Situated at an elevation of 1786 meters (5860 feet) above sea level, the lake is fed by four major tributaries--the Gilgel Abbay, the Megech, the Gumara, and the Ribb--all of which rise in the highlands surrounding the lake. Because of the restriction at its outlet and its large storage capacity, the lake rises slowly to reach its maximum stage near the end of the season of heavy rains and recedes slowly to its minimum discharge during the dry season.

The sub-basin is characterized by a large, flat to very gently sloping plain bordering the lake on the north and east and by an extensive area of gently rolling to hilly uplands on the south. Recent lava flows, hilly rocky land, low marshy areas, and mountainous terrain comprise a sizable portion of the landscape.

Studies of the areas on the northern and eastern sector of the basin indicate that it would be engineeringly feasible to construct and develop three storage dams on the Megech, Ribb, and Gumara Rivers for the agricultural production by gravity irrigation of 35, 000 hectares of land and the construction of three pumping plants around the perimeter of the lake for pumping would provide a water supply for the irrigation of 18, 000 hectares of land.

Water for the Megech Gravity Project would be supplied from the Megech Reservoir for irrigation of nearly 7, 000 hectares of land. The Ribb Dam and Reservoir would impound the rainy season flows to be released as required for irrigation of 15, 000 hectares of land. The Gumara Dam and Reservoir would provide enough storage for irrigation of 13, 000 hectares of land.

With Lake Tana as a forebay, the West and East Megech Pumping Plants would lift the water about 34 meters to irrigate nearly 13, 000 hectares of land. The Northeast Tana Pumping Project, also drawing water from the lake, would pump water onto the northeastern sector of the basin for irrigation of 5, 000 hectares.

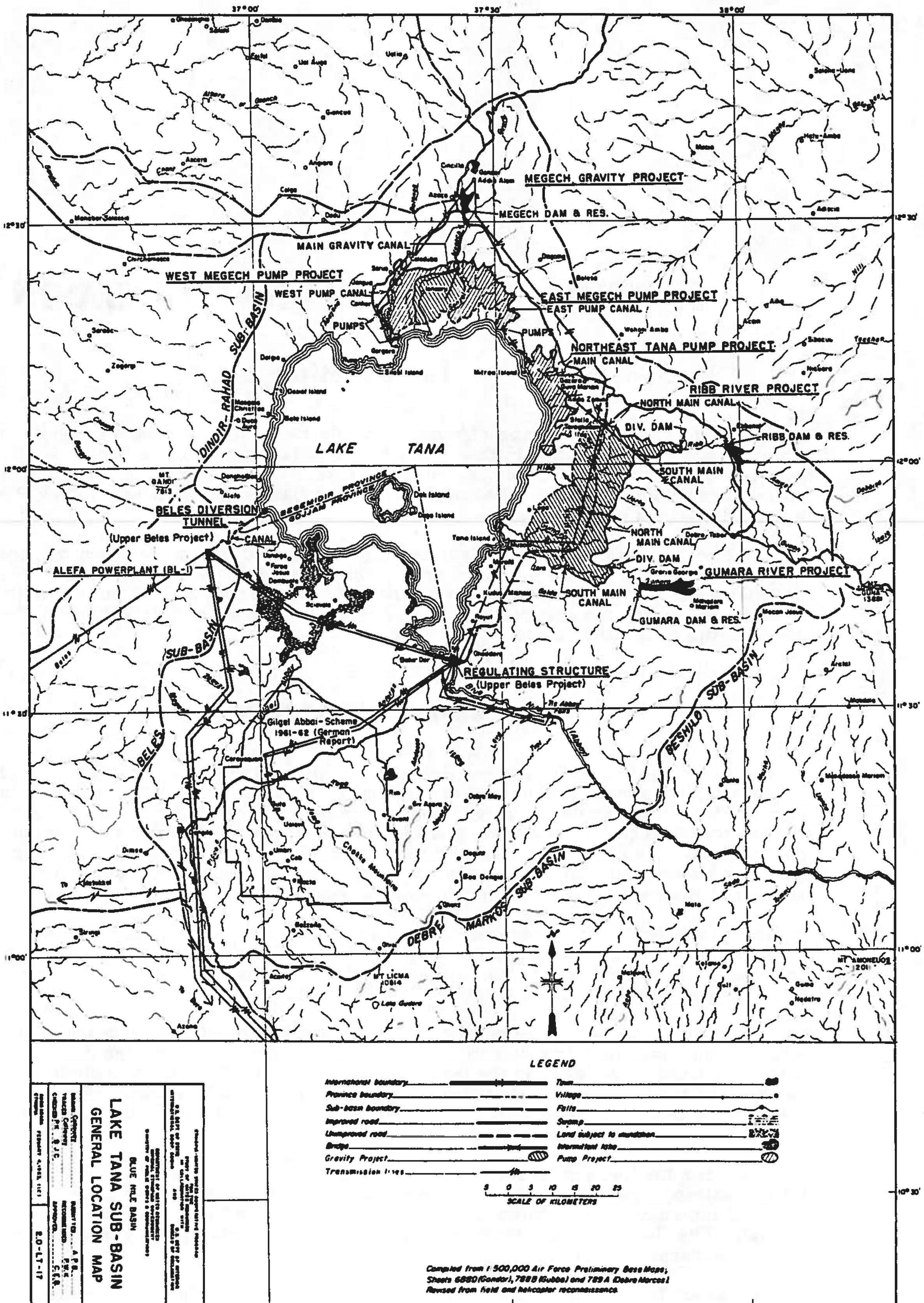


Figure I-37--Lake Tana Sub-basin--General Location Map

For convenience, the projects are grouped and treated in the two main methods of irrigation, that by gravity and pumping. A general location map, Figure I-37, shows the principal features proposed for development.

PRINCIPAL TOWNS AND CITIES

The principal centers of population and local trade in the sub-basin are Gondar, Azozo, and Gorgora in the north; Addis Zemin in the east; Bahir Dar in the south; and Dangila in the southwest. Of these towns, Bahir Dar, located at the southern end of the lake, has been selected by the IEG for development in their long range plan. In support of this, a considerable amount of construction has been done recently. The construction includes a domestic water supply system, a concrete bridge over the Blue Nile River at the outlet of the lake, a small hydroelectric powerplant at Tis Isat Falls for service to the town, a technical school for 1,000 students, and improvement of the highways leading to Addis Ababa and to Asmara. Numerous city plans have been prepared at various times by consulting firms, evidencing the importance attached to development of the city. The strategic location of Bahir Dar has been given as the reason for this attention. It is expected that Bahir Dar may serve both as the nucleus for economic exploitation and as the administrative center for the northwestern section of Ethiopia. Population in 1962 was estimated to be about 10,000. Gondar, to the north, one-time capital of the Empire, serves as the present outlet to Asmara and to the Red Sea ports for this portion of the basin.

ECONOMY OF THE AREA

Agriculture and the raising of cattle and sheep form the principal economy of the area. A variety of dryland crops is produced--mostly grains and berberi. Dryland cotton, coffee, and herbs are also grown on a limited scale. Exporting of hides and the cottage industries, including tanning of hides, pressing oil from seeds, beekeeping, and cloth weaving, are main sources of cash income.

Transportation

Transportation is provided by regularly scheduled boats of 65-ton capacity, which operate between Gorgora on the north side and Bahir Dar on the south side of the lake. All-weather highways to replace the present primitive trails around the lake and to provide outlets to other parts of the Empire are under active construction at the time of this writing.

GEOLOGY

Lake Tana lies in a large structural basin surrounded by volcanic mountains composed mostly of basaltic lava. The lakebeds northwest of Lake Tana are the only sedimentary rock formations in the vicinity of the lake and consist mostly of siliceous shales, sandstones, lignite beds, and cherty marl. The lakebeds have been faulted and tilted, indicating relatively recent movement along the rift. The rocks within the basin are all extrusive volcanic rocks representing three or more phases of volcanic activity.

The present lake was formed primarily by a younger volcanism which dammed off the previously eroded valley and drainage systems, impounding a broad, relatively shallow body of water. Some of the younger lava flows poured downstream in syrup-like flows. Although not exposed in the lake basin, it is believed that the volcanic rocks are underlain by essentially bedded sedimentary rock of the Mesozoic age, consisting of limestone sandstone, and shale. Underneath the sedimentary rock, the Precambrian "basement complex" consists of granitics, gneisses, schists, and variably altered metasediments and metavolcanics.

CLIMATE

Like most of the plateau area, the Lake Tana area has a temperate and equable climate in spite of its proximity to the equator. This is due to its elevated position. The yearly climate may be divided into two broad seasons--the rainy season and the dry season. The rainy season includes two general periods--the "little" rains, which occur during April and May and are insufficient for crop maturity, and the "big" rains, which last from mid-June to late September. Rainfall records from the Gondar weather station indicate an average annual rainfall of 127 centimeters (50 inches).

Uniformity of temperature throughout the year is also a climatic characteristic. Average annual daily temperature is recorded at 19.2° C (66.6° F), average annual maximum being 26° C (78.8° F). The coldest months are December and January, while the warmest months are March, April, and May. Frost damage to crops may occur during the former period.

Megech Gravity Project

GENERAL DESCRIPTION

Project Area

The Megech River area is situated in the northern portion of the sub-basin and has a catchment basin of about 700 square kilometers. The river flows generally in a southerly direction, emptying into Lake Tana. The main tributaries of the Megech River are the West Fork and the Angereb. The watershed is used primarily for pasture, but some dry-land farming is carried on. A few patches of trees are scattered over the upper part of the watershed, but this could not be considered a forested area. The project area is on the lake plain south of the Gondar-Debre Tabor road and begins at a point about 15 kilometers north of the lake where the Megech River breaks out of the steep canyon area into the lake plain.

Project Land

Soils in this area are generally well suited to irrigation. They are a mixture of deltaic and recent river alluvial deposits and are not homogeneous. A deep, all dark clay profile may be found in one spot, and nearby an entirely different texture may be found. Strata of medium and coarse texture may also be found in some profiles.

The land classification performed indicates that 6, 940 hectares are suitable for irrigation and could be provided a water supply from the project works.

Drainage control and improvement are needed, but it is believed that such controls can be accomplished with nominal investments.

HYDROLOGY

The Megech River is the only river on the north side of Lake Tana with a watershed area sufficiently large to supply surface water for a project larger than small farm diversions. The average annual runoff at the gaging station is estimated at 130 million cubic meters.

Annual farm delivery requirements were estimated to be 0.938 meter. Allowing 30 percent for canal losses, such as seepage and operational waste, the estimate for diversion requirements per hectare would then be 13, 400 cubic meters annually. The water supply as determined from reservoir operation studies indicates that a yield through storage of 93 million cubic meters annually would be available, based on a 6-year cyclical storage and taking shortages once in 10 years during the dry cycle. The available water supply being the limiting factor, the project area for irrigation is 6, 940 hectares.

PLAN OF DEVELOPMENT

The development plan includes a storage dam, a main canal and laterals, a distribution system, and drainage canals for irrigation of 6, 940 hectares of land.

The Megech Dam and Reservoir will impound the flows of the Megech River. Controlled releases would be made into the main canal from the outlet works. The main canal would extend in a southerly direction for 16 kilometers to the project area, where it would divide into three main laterals. Sublaterals would distribute the water to the individual farms for agricultural crop production.

PROJECT FEATURES

The features of the project plan are described in reconnaissance detail in the following paragraphs and are shown in general plan on Figure I-38. Area-capacity data for the reservoir were obtained from aerial photographs of 1:50, 000 scale compiled by stereoscopic (multiplex) projection on 20-meter contour intervals using altimeters to establish vertical controls (see Figure I-39). Layouts of the canals and distribution system were performed on uncontrolled photomosaics using altimeters to determine the rough approximation of the contour elevation.

Megech Dam and Reservoir

Megech Dam. The damsite is on the main stem of the Megech River, one-half kilometer downstream from its confluence with the Angereb River and 35 kilometers upstream from where it empties into Lake Tana. It would be an earth and rock fill dam with a structural height above streambed of 78 meters. Diversion during construction would be accomplished through a gap in the dam, the gap to be closed during the dry season following the completion of the outlet conduit. Plan, section, and profiles of the dam and appurtenant structures appear on Figure I-40.

Megech Dam Data

Type	earth-rock fill
Embankment volume (earth)	3, 500, 000 cu. m.
Embankment volume (pervious)	5, 000, 000 cu. m.
Top of dam	1, 952 m.
Freeboard	2 m.
Structural height	78 m.
Hydraulic height	76 m.
Length of crest	940 m.
Width of crest	10 m.

Spillway. The design of the spillway was based on the design inflow flood estimated to be at the peak flow of 1, 587 cubic meters per second and a 2. 25-day volume of 88. 5 million cubic meters. A side-channel uncontrolled spillway, located on the right abutment of the dam, with a crest length of 60 meters would pass 890 cubic meters per second at a surcharge head of 3. 9 meters, elevation 1950 meters. Superstorage to store part of the flood has been provided, amounting to 42. 5 million cubic meters. A stilling basin would be required at the end of the chute.

Spillway Data

Type	uncontrolled side channel
Crest elevation	1946. 13 m.
Inflow design flood	1, 587 cu. m.
Total flood volume, 2. 25-day period	88, 500, 000 cu. m.
Discharge at maximum water surface elevation	890 cu. m. per sec.

Outlet Works. An outlet works to release the necessary irrigation water would be located on the left abutment and would include an intake structure, a concrete conduit leading to a gate chamber about midway in the dam equipped with a slide gate, and a steel outlet pipe housed in a horseshoe conduit. A control structure at the discharge end of the outlet pipe, equipped with two slide gates to control the releases, and a stilling basin to dissipate the high-energy flows before discharging into the main canal are also included.

Outlet Works Data

Sill elevation	1875 m.
Capacity at maximum water surface elevation	18.4 cu. m. per sec.
Type of gates (2)	slide gates

Megech Reservoir. The reservoir basin is situated in the older volcanics, well blanketed with impermeable material. Seepage is not considered to be a serious factor. Sediment deposition at the end of 50 years of operation is not expected to affect storage capacity materially. Capacity of the storage reservoir has been predicated on a 6-year cycle, annual firm yield expected to be in the neighborhood of 93 million cubic meters and shortages are to be expected if the reservoir level drops below 80 percent of capacity. For area-capacity data, see Figure I-41, and for area-capacity curves, Figure I-42. Topography as compiled from stereoscopic projection appears on Figure I-39.

Site Geology. Overburden, consisting of basaltic and rhyolitic talus and silty and slightly sandy clay, may be as deep as 15 meters along the left abutment of the damsite, becoming shallower toward the top of the abutment. On the right abutment, weathered basaltic and rhyolitic rock with interbedded ash and tuff layers was observed. The harder rock layers form ledges along the slope in contrast to flatter areas where the tuff and ash occur. The sand and gravel portion of the overburden should be removed from a cutoff trench and replaced with impervious fill. The silty clay portion of the overburden may be impervious enough that it can be left in place, possibly with some compaction.

Construction Materials. Impervious fill material can be obtained from the slump area upstream from the axis on the left side of the river and in the reservoir basin. Sand, gravel, and cobbles can be obtained along the stream channel downstream from the damsite. Riprap can be quarried from the harder rhyolitic or basaltic deposits upstream from the damsite.

Access to Site. Construction of only 2.5 kilometers of access road would be required to reach the damsite. This would begin at the Megech River crossing of the Gondar-Debre Tabor road and follow the stream to the damsite.

Main Canal

From the discharge end of the outlet works, the main canal, with an initial capacity of 9.1 cubic meters per second, would extend in a southerly direction paralleling the Megech River for 16 kilometers to the project lands. The main canal would then be divided into three main laterals--one would continue in the direction of the main canal to serve the area on the upper half of the project; the second would head in a westerly direction toward the Megech River where it would be divided into two canals, one on either side of the river, to serve the lands sloping away from the river.

Canal excavation will not present unusual problems, with rock excavation only expected on the initial reaches before it breaks out into the valley. Bridges, culverts, wasteways, turnouts, drops, and checks would be some of the typical structures required along the main canal. Estimates of cost for these structures were obtained as a percentage of earthwork cost.

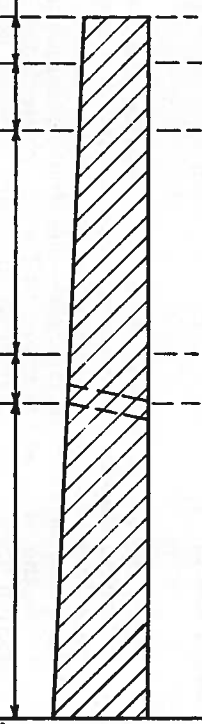
Canal Data

Type	unlined
Length	63 km.
Initial capacity	9.1 cu. m. per sec.
Initial water surface elevation	1870 m.

MEGECH (ME-2) DAM & RESERVOIR

AREA CAPACITY DATA

(with sediment distributed)

CONTROL POINTS				INITIAL AREA	CAPACITY (CUBIC METERS – 10^6)			
ITEM & ALLOCATION OF STORAGE CAPACITY		DIAGRAM OF DAM	ELEVATION (METERS)	(SQ. METERS – 10^6)	INITIAL		WITH 50-YR. SEDIMENT	
					INCREMENT	TOTAL	INCREMENT	TOTAL
TOP OF DAM			1952					
MAXIMUM W.S.	FREEBOARD		1950	11.6		267.8		
	FLOOD SURCHARGE				42.5			
NORMAL W.S.			1946.13	10.2		225.3		
	ACTIVE CAPACITY				225.1		Negligible change from initial.	
MINIMUM OPERATING W.S.			1876.1	0.2		0.2		
	INACTIVE CAPACITY				0.1			
LIP OF LOWEST OUTLET*			1875.0	0.1		0.1		
	DEAD STORAGE AND SILT				0.1			
STREAM BED			1874.0	0		0		

*100-YEAR SEDIMENT OF 6,400,000 M³ WILL TAKE 1875.0 METERS ELEVATION AT THE DAM.

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Figure I-41--Megech (ME-2) Dam and Reservoir--Area-Capacity Data

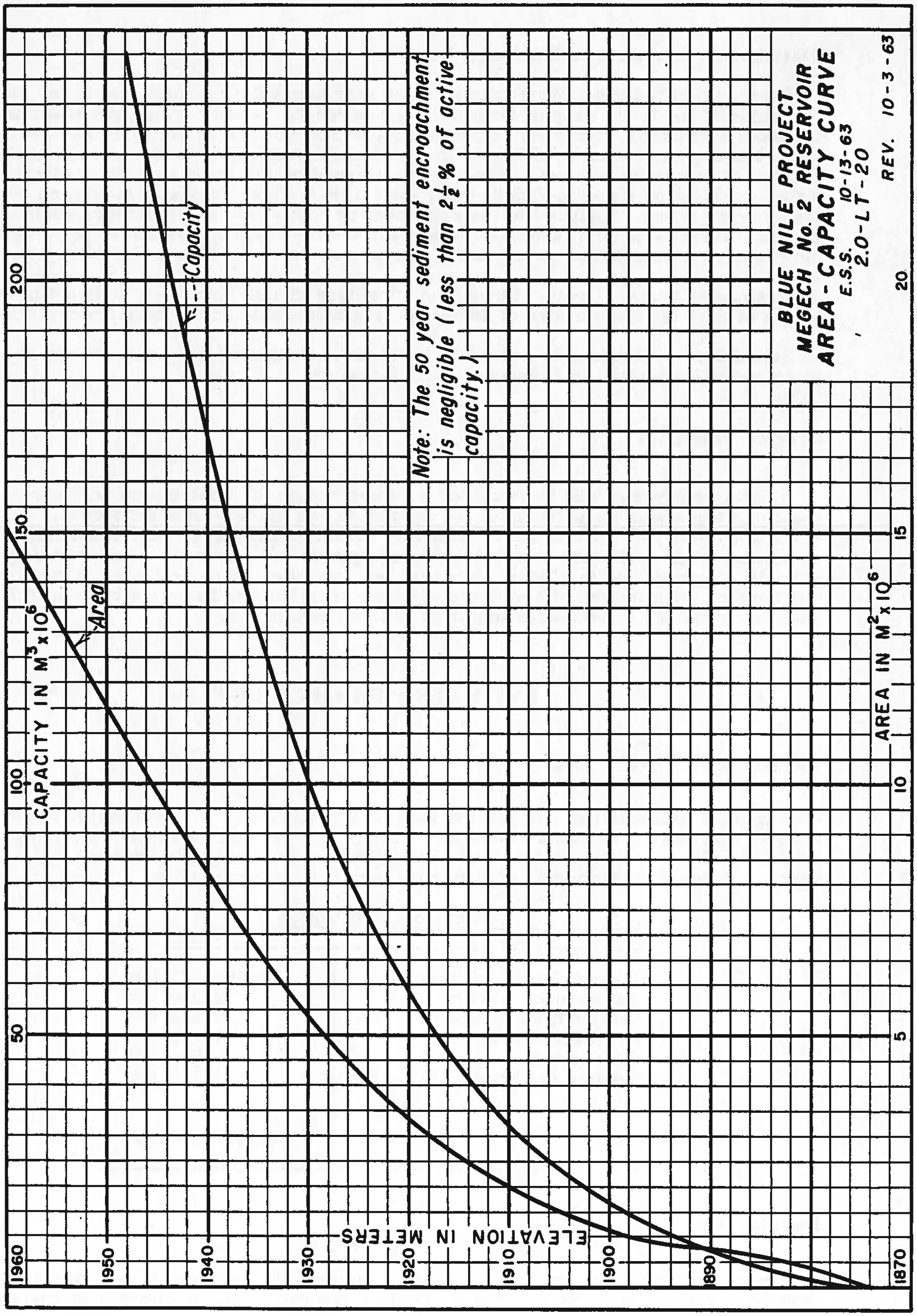


Figure I-42--Megech Reservoir--Area-Capacity Curves

Distribution System and Drainage Canals

Distribution System. Water distribution may present a problem due to the relatively flat slope of the land, ranging from 0.1 to 3 percent. Border irrigation would likely be the most successful method of irrigation. The distribution system for the 6,940 hectares of land is envisioned as an unlined canal with sufficient capacity to meet the peak demand during the irrigation season. It has been designed on the basis that the application of water would be on a continuous 24-hour operation during periods of maximum demand of the growing crops. Included in the estimates of cost would be structures such as drops, checks, wasteways, and turnouts. Costs for the distribution system were computed on a per-hectare basis, based on the sample area studied on the Upper Birr Project.

Drainage Canals. Open, interceptor, drainage canals have been included in the estimates of cost for the purpose of draining irrigation waste and excess precipitation.

Subsurface drainage may present a problem in irrigation development and should be given careful attention in subsequent detail studies.

Service Facilities

Temporary camps will be required for supervision of construction and more permanent buildings and shops required later for operation and maintenance personnel. Equipment associated with this item is office furniture, transportation, stores, laboratory, tools, communication, and other miscellaneous equipment. Permanent structures may include schools, recreational facilities, garages, warehouses, shops, offices, laboratories, and housing. Estimates of cost were obtained from curves based on Bureau of Reclamation practices and experiences modified to local conditions.

ESTIMATED PROJECT COST

Construction Cost

The total construction cost for the Megech Gravity Project is estimated to be Eth$76,082,000 on the basis of January 1961 prices, and as itemized with unit prices in Table I-4. The estimates of cost are reconnaissance in grade, and the following summary includes contingencies, engineering, and general expense.

Estimated Construction Cost

Feature	Cost
Megech Dam and Reservoir	Eth$66,979,000
Canals and laterals	2,360,000
Distribution system	3,253,000
Drainage canals	1,518,000
Access road	253,000
Service facilities	1,719,000
Total	Eth$76,082,000

Development Cost

Prior to agricultural crop production, clearing of the lands of trees, brush, and vegetative debris and land leveling or grading are required. Estimates of costs for these items on the potential project area are expected to be minimal as dry farming is practiced

TABLE I-4--MEGECH GRAVITY PROJECT--RECONNAISSANCE ESTIMATE

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project: MEGECH GRAVITY--Irrigation

Date of Estimate: January 1964

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U.S. $ 1.00 = Eth. $ 2.50)

ITEM NO.	ITEM	QUANTITY AMOUNT	UNIT	EQUIPMENT MATERIAL AND LABOR UNIT COST	EQUIPMENT MATERIAL AND LABOR COST	FIELD COST	TOTAL CONSTRUCTION COST
	MEGECH GRAVITY PROJECT--Irrigation					63,098,900	76,082,000
	MEGECH DAM--Earth and Rockfill; crest length, 940 meters; height of dam, 78 meters, Drawing No. 0A-23-94					55,816,300	66,979,000
1	Diversion and care of river	Lump sum		Lump sum	81,000		
2	Excavation, stripping borrow areas	350,000	m^3	1.15	402,500		
3	Excavation, all classes, dam foundation	520,000	m^3	1.95	1,014,000		
4	Excavation, rock, for grout cap	1,200	m^3	80.00	96,000		
5	Excavation, earthfill, in borrow areas and transportation to dam embankment	3,900,000	m^3	2.75	10,725,000		
6	Excavation, sand and gravel, in borrow areas and transportation to dam embankment	300,000	m^3	3.00	900,000		
7	Excavation, rock, in borrow areas and transportation to dam embankment	2,800,000	m^3	5.00	14,000,000		
8	Earthfill in dam embankment	3,500,000	m^3	0.65	2,275,000		
9	Sand, gravel, and rockfill in dam embankment	5,000,000	m^3	0.50	2,500,000		
10	Pressure grouting, all work and material	Lump sum		Lump sum	756,700		
	Subtotal--Embankment				32,750,200		
	Spillway--60-meter side channel with chute and basin. Maximum capacity, 890 m^3/sec.						
11	Excavation, all classes, open cut	616,000	m^3	3.25	2,002,000		
12	Concrete, crest structure	8,900	m^3	210.00	1,869,000		
13	Concrete, chute	9,000	m^3	180.00	1,620,000		
14	Concrete, stilling basin	7,100	m^3	160.00	1,136,000		
15	Reinforcement	2,223,000	kg	1.00	2,223,000		
16	Miscellaneous items	Lump sum		Lump sum	685,000		
	Subtotal--Spillway				9,535,000		
	Outlet Works--Trashracked intake, 1.83-meter diameter concrete conduit to gate chamber. Steel pipe, 1.22-meter diameter in 2.59-meter horseshoe tunnel.						
17	Excavation, all classes, open cut	285,000	m^3	3.25	926,250		
18	Concrete in intake structure	35	m^3	210.00	7,350		
19	Concrete in conduit	2,800	m^3	180.00	504,000		
20	Concrete in gate chamber	185	m^3	200.00	37,000		
21	Concrete in control house substructure	260	m^3	180.00	46,800		
22	Concrete in control house superstructure	15	m^3	210.00	3,150		
23	Concrete in stilling basin	440	m^3	160.00	70,400		
24	Reinforcement	382,000	kg	1.00	382,000		
25	Trashracks	Lump sum		Lump sum	4,500		
26	Steel outlet pipe	Lump sum		Lump sum	97,500		
27	Slide gates	Lump sum		Lump sum	162,500		
28	Electrical and minor mechanical items	Lump sum		Lump sum	21,300		
29	Miscellaneous items	Lump sum		Lump sum	105,000		
	Subtotal--Outlet Works				2,367,750		
	Subtotal--Items 1 through 29				44,652,950		
	Contingencies (25±%)				11,163,350		
	Field Cost--Megech Dam				55,816,300		
	Engineering and General Expense (20±%)				11,162,700		
	Total est. const. cost--Megech Dam				66,979,000		

Sheet 1 of 2

Table I-4--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project MEGECH GRAVITY--Irrigation

Date of Estimate January 1964

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	CANAL AND LATERALS--Unlined; length, 63.0						
	kilometers; capacities, 9.1 to 1.0 m^3/sec.					1,888,100	2,360,000
1	Canal excavation, common	418,400	m^3	0.95	397,480		
2	Canal excavation, rock	2,800	m^3	9.75	27,300		
3	Compacting embankment	104,700	m^3	0.98	102,606		
4	Concrete and masonry structures	Lump sum		Lump sum	822,700		
5	Gates, hoists, valves, and misc. metalwork	Lump sum		Lump sum	21,100		
6	Concrete pipe	Lump sum		Lump sum	50,700		
7	Miscellaneous work	Lump sum		Lump sum	88,600		
	Subtotal--Canal and Laterals				1,510,486		
	Contingencies (25±%)				377,614		
	Field Cost--Canal and Laterals				1,888,100		
	Engineering and General Expense (25±%)				471,900		
	Total est. const. cost--Canal and Laterals				2,360,000		
	IRRIGATION DISTRIBUTION SYSTEM--Unlined open						
	lateral system for 6,940 net hectares of new						
	service lands.					2,602,500	3,253,000
1	Laterals and structures	6,940	ha	300.00	2,082,000		
	Contingencies (25±%)				520,500		
	Field Cost--Distribution System				2,602,500		
	Engineering and General Expense (25±%)				650,500		
	Total est. const. cost--Distribution System				3,253,000		
	DRAINAGE SYSTEM--Open land drains for 6,940						
	net hectares of irrigated land.					1,214,500	1,518,000
1	Drains and drainage structures	6,940	ha	140.00	971,600		
	Contingencies (25±%)				242,900		
	Field Cost--Drainage System				1,214,500		
	Engineering and General Expense (25±%)				303,500		
	Total est. const. cost--Drainage System				1,518,000		
	ACCESS ROAD--From existing road, north to the						
	dam, and south to the project lands. Flat						
	to rolling terrain.					202,500	253,000
1	Road, two lane gravel	6.0	km	27,000.00	162,000		
	Contingencies (25±%)				40,500		
	Field Cost--Access Road				202,500		
	Engineering and General Expense (25±%)				50,500		
	Total est. const. cost--Access Road				253,000		
	SERVICE FACILITIES--Includes offices, shops,						
	equipment, housing, streets, and utilities.					1,375,000	1,719,000
1	Camp and equipment	Lump sum		Lump sum	1,100,000		
	Contingencies (25±%)				275,000		
	Field Cost--Camp and Equipment				1,375,000		
	Engineering and General Expense (25±%)				344,000		
	Total est. const. cost--Camp and Equipment				1,719,000		

Sheet 2 of 2

in the area with only a small scattering of trees and brush in the noncultivated areas. The topography is also well adapted to irrigation development. Estimates of cost for these two items are Eth$875, 000.

Operation, Maintenance, and Replacement Cost

The estimates of operation and maintenance cost for the various types of entities of work activities for the Megech Gravity Project have been obtained from curves, the data for the curves being based on Bureau of Reclamation practices and experiences adjusted to local conditions. The estimates assume that adequate personnel and equipment will be provided to perform all operating requirements for the efficient utilization of the facilities and that proper maintenance programs will be carried out to minimize premature and costly replacements of equipment and structures. No replacement is estimated to be required within the period of analysis.

Work division	Estimated annual cost
Megech Dam and Reservoir	Eth$ 20, 000
Conveyance system	253, 000

PLAN SELECTION AND ALTERNATIVES

Several stages of development and alternate plans were considered as a basis for selecting the project plan as presented in this report. As the dam is the most costly single item in the plan, various heights were studied in relation to cost per hectare served. The plan finally selected appears to have the most favorable ratio of cost of dam per hectare served.

Alternative plans studied were irrigation by direct diversion, but only about 400 hectares of the potential lands available could be served by direct diversion; and another plan which was considered and appeared to have real merit was by pumping from the lake, but the scheme was discarded because of the great distance from the lake.

Preliminary studies performed for possible hydroelectric power production indicated that it would not be economically feasible.

Ribb River Project

GENERAL DESCRIPTION

Project Area

The Ribb River is located on the east side of Lake Tana and has a drainage area of about 1, 790 square kilometers. It is one of the main streams on the east side flowing into the lake and, with its tributaries, forms a watershed on the west slope of the high mountainous area east of the town of Debre Tabor at an elevation of approximately 3050 meters. The river flows generally in a westerly direction and empties into Lake Tana.

The irrigation area under consideration for a potential irrigation project is situated south of the Addis Zemin-Debre Tabor road and begins at a point on the river about 33 kilometers east of the shore of Lake Tana where the Ribb River approaches the lake plain from the mountainous area. To the south, the project area is bordered by the low ridge between the Ribb and the Gumara drainage areas, except in the lower reaches where the two basins merge into the lake plains.

Project Lands

The predominant soils of the potential irrigation area are of the deltaic plain classification with minor areas of recent alluvial soils. The deltaic soils are dark gray plastic clays (grumusols) that exhibit wide, deep cracks when dry. The soils are uniformly fine textured and are poorly drained.

The land classification studies conducted indicate that 15, 270 hectares can be served by the project works.

Land Classes (ha.)

Class	Arable under canal	Irrigable
3	20, 400	15, 270

Drainage may be critical on these lands, unless closely controlled irrigation applications are practiced.

Subsurface drainage problems could be very serious. The water table during the rainy season rises close to the surface, and on this basis, the application of water for irrigation of the crops could have a very deleterious effect to the water table and, consequently, to the crops. Further investigations and detailed studies on this phase will be required before construction is recommended.

Hydrology

The Ribb River is one of the two rivers on the east side of Lake Tana with a watershed large enough to supply the water required for project-type irrigation. Estimated average annual runoff at the gaging station on the Ribb River is 539 million cubic meters from a drainage area of nearly 1, 800 square kilometers.

Annual farm delivery requirement was estimated to be 0.889 meter. Assuming 30 percent for canal losses--seepage, operational waste, and evaporation--the estimate for diversion requirements would amount to 12,700 cubic meters per hectare annually (4.17 feet). From the reservoir operation studies, it was found that a yield of nearly 194 million cubic meters (157,195 acre-feet) would be obtained with storage in average years.

PLAN OF DEVELOPMENT

The development plan includes a storage dam, a diversion dam, two main canals (one on each side of the river), a lateral distribution system, and drainage canals to provide full irrigation for 15,270 hectares of land. Storage would be provided by a reservoir on the main stem of the river where irrigation requirements for the project would be released into the river channel and picked up at a diversion dam for diversion into the two main canals for service to the project. The North Main Canal would extend in a westerly direction, and the South Main Canal would extend also in a westerly direction for the first 9 kilometers, where it would turn to the southwest and terminate near the ridge dividing the Ribb and the Gumara drainage basins.

PROJECT FEATURES

The general plan of a reconnaissance layout of the project features is shown on Figure I-43, and a description of these features is included in the following paragraphs. Topographic maps on the reservoir area were compiled from aerial photographs (Figure I-44) by stereoscopic (multiplex) projection on 20-meter contour intervals using altimeters for controls. Layout of the project features was made from photomosaics of a 1:50,000 scale. Engineering and other data were derived from these maps.

Ribb Dam and Reservoir

Ribb Dam. The Ribb River damsite is on the main stem approximately 1.5 kilometers upstream from the Addis Zemin-Debre Tabor road crossing and 44 kilometers east of Lake Tana. It would be an earth and rock fill dam with a structural height above streambed of 75 meters and a crest length of 1,154 meters. Diversion during construction would be accomplished through a gap in the dam, the gap to be closed during the dry season following the completion of the outlet conduit. Plan, section, and profiles of the dam and appurtenant structures appear on Figure I-45.

Ribb Dam Data

Type	earth-rock fill
Embankment volume (earth)	2,700,000 cu. m.
Embankment volume (pervious)	3,600,000 cu. m.
Top of dam elevation	1936 m.
Freeboard	2.2 m.
Structural height	75 m.
Hydraulic height	72.8 m.
Length of crest	1,154 m.
Width of crest	10 m.

Spillway. Based on the estimated peak inflow of 2,246 cubic meters per second, as indicated from design inflow studies, and a 2.5-day volume of 145 million cubic meters, a "U"-shaped or bathtub spillway was designed having a 200-meter crest length and the spillway at water surface elevation 1933.8 meters will discharge 1,906 cubic meters per second. Superstorage to store part of the flood at the aforementioned elevation will store 40.6 million cubic meters. A stilling basin at the end of the chute will be required to dissipate the high energies of the flows.

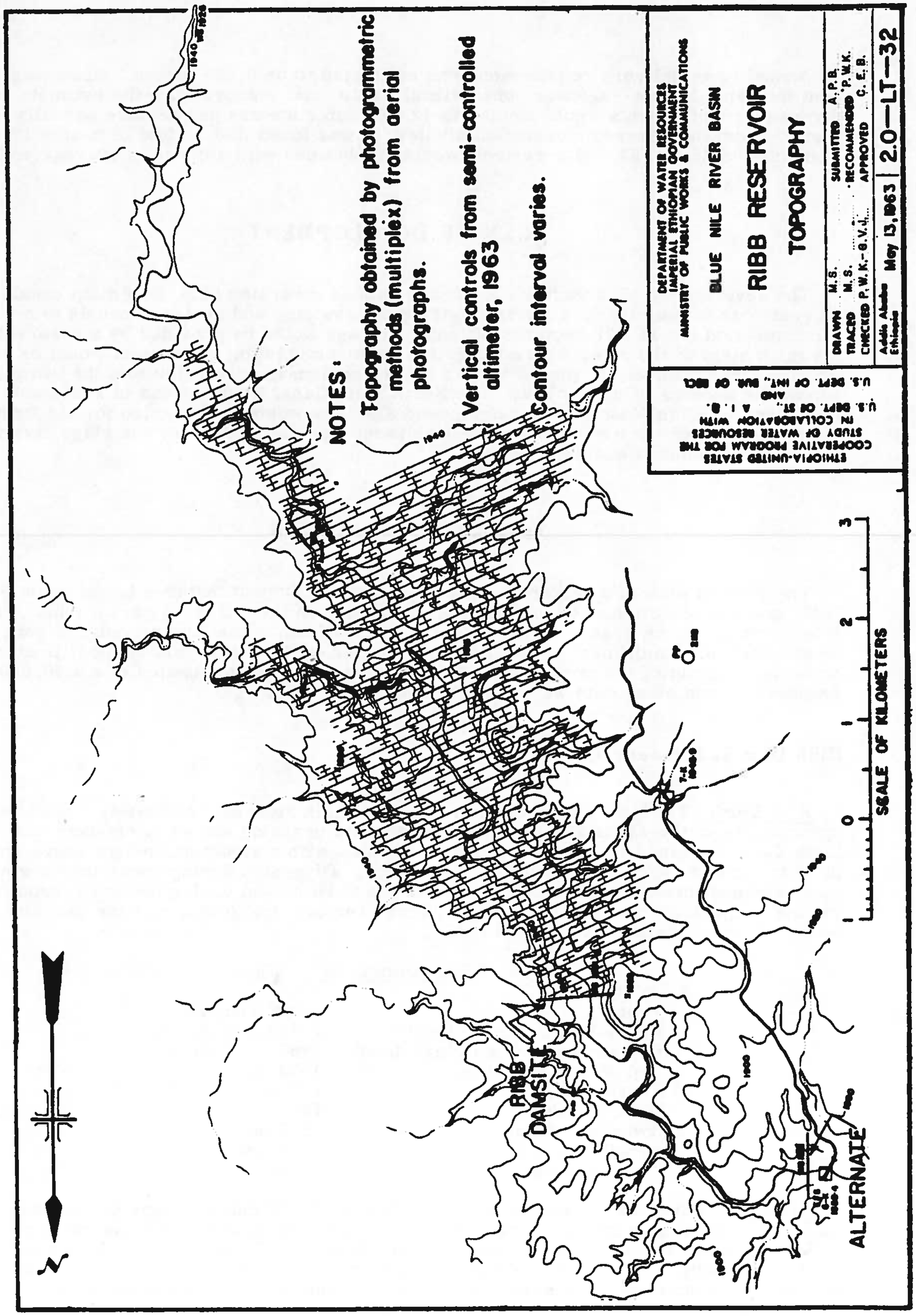


Figure I-44--Ribb Reservoir--Topography

Spillway Data

Type	"U"-shape uncontrolled
Crest elevation	1930.9 m.
Inflow design flood	2,246 cu. m. per sec.
Total flood volume, 2.5-day period	140,000,000 cu. m.
Discharge at maximum water surface elevation	1,906 cu. m. per sec.

Outlet Works. A conventional-type outlet works, consisting of an intake structure, conduit, gate chamber, steel outlet pipe, and a control house, is proposed for irrigation releases. The conduit would be a 1.83-meter-diameter concrete conduit with the steel outlet pipe having a 1.12-meter diameter. An emergency slide gate at the gate chamber and two slide gates at the control house would regulate the releases as required.

Outlet Works Data

Sill elevation	1869.3 m.
Capacity at minimum water surface elevation	5.7 cu. m. per sec.
Type of gates (2)	slide gates

Ribb Reservoir. The reservoir basin is situated in the older volcanics, overburden consisting of typical, reddish-brown, silty clay providing an impermeable blanket. Seepage in the storage basin should not be a serious problem. At normal water surface elevation, it is expected that about 13.3 square kilometers will be inundated and store about 313 million cubic meters initially. Sediment at the end of 50 years of operation is expected to displace about 10.6 million cubic meters of storage capacity. Area-capacity data appear on Figure I-46 and area-capacity curves on Figure I-47.

Site Geology. Visual examination at the selected damsite indicates that the foundations are composed of rocks variable in character and composition. In general, the rocks are of massive basaltic composition. Overburden was observed on the proposed dam axis and will have to be stripped before construction of the cutoff trench.

Construction Materials. Impervious fill material will be of the silty, plastic clay found in abundance within economical haul distance. Pervious materials of sand and gravel were observed near the site and downstream from the proposed location. Riprap can be obtained from the harder zones in the rhyolitic outcrops near the site.

Access to Site. Access to the damsite will not be difficult, as the Addis Zemin-Debre Tabor road is within 1.5 kilometers of the selected site. Access to the diversion damsite can be made by constructing a road approximately 12 kilometers long following the river downstream from the existing main road.

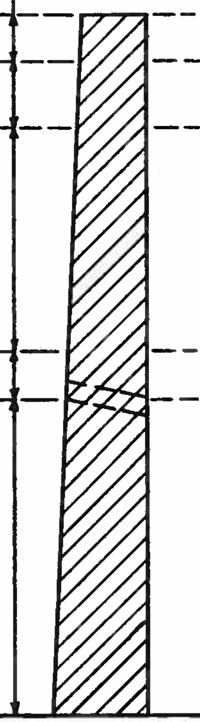
Diversion Dam

The river regulating structure and canal headworks would be located on the Ribb River about 12 kilometers downstream from the storage dam. It would be a masonry-concrete diversion dam designed to divert the releases from the storage dam into the main canals located on each side of the river by means of stoplogs. During the rainy season period, the stoplogs would be removed for passing the floodflows. The sill elevation would be located at approximately 1824 meters and the operating deck at elevation 1830.30 meters. The total weir length would be about 36 meters. Estimates of cost include canal headworks and wingwalls.

RIBB (Ri-2) DAM & RESERVOIR

AREA CAPACITY DATA

(with sediment distributed)

CONTROL POINTS				INITIAL AREA	CAPACITY (CUBIC METERS – 10^6)			
					INITIAL		WITH 50-YR. SEDIMENT	
ITEM & ALLOCATION OF STORAGE CAPACITY		DIAGRAM OF DAM	ELEVATION (METERS)	(SQ. METERS – 10^6)	INCREMENT	TOTAL	INCREMENT	TOTAL
TOP OF DAM			1936					
MAXIMUM W.S.	FREEBOARD		1933.8	14.74		353.2		342.6
	FLOOD SURCHARGE				40.6		40.6	
NORMAL W.S.			1930.9	13.27		312.6		302.0
	ACTIVE CAPACITY				309.6		300.5	
MINIMUM OPERATING W.S.			1873.3	0.62		3.0		1.5
	INACTIVE CAPACITY				1.8		1.2	
LIP OF LOWEST OUTLET*			1869.3	0.34		1.2		0.3
	DEAD STORAGE AND SILT				1.2		0.3	
STREAM BED			1861	0		0		0

*100-YEAR SEDIMENT OF 21,200,000 M^3 WILL TAKE 1869.3 METERS ELEVATION AT THE DAM.

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Figure I-46--Ribb (Ri-2) Dam and Reservoir--Area-Capacity Data

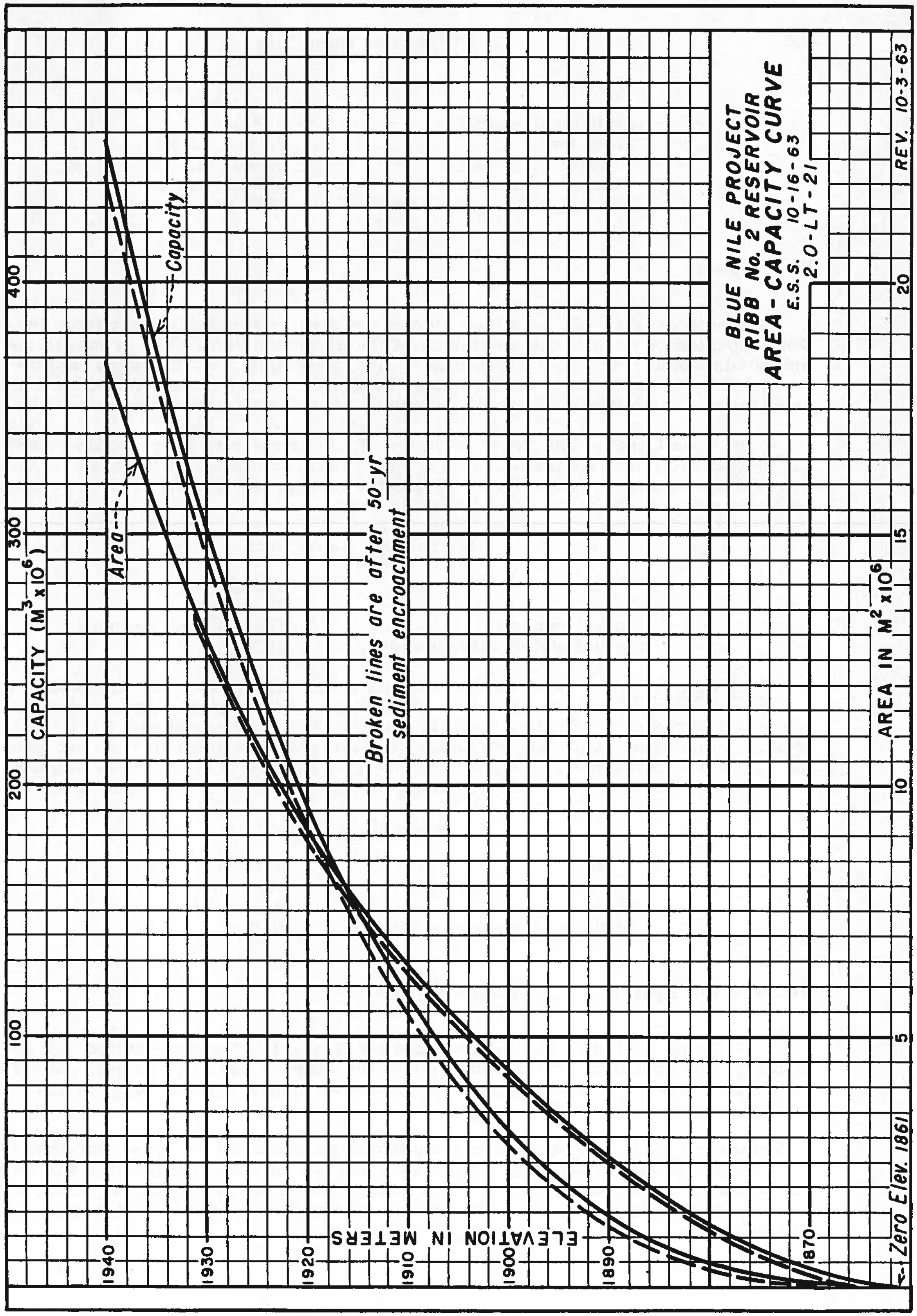


Figure I-47--Ribb Reservoir--Area-Capacity Curves

Diversion Dam Data

Type	masonry-concrete with stoplogs
Structural height	6.3 m.
Weir length	36 m.
Volume of concrete	37 cu. m.
Volume of masonry	570 cu. m.
Normal water surface elevation	1828 m.

Main Canals

Two main canals--one on either side of the river--would originate from the outlet works located on each of the abutments of the diversion dam. The proposed routes of the canals would traverse rolling hills to flat topography as it emerges into the lake plain. No difficulty is expected in constructing the canals; rock excavation may be encountered, especially in the initial reaches of the canal. Appropriate structures would be included.

North Main Canal. The North Main Canal, 35 kilometers long, would extend in a westerly direction to its terminus on the lake plain southwest of the town of Addis Zemin. It would have an initial capacity of 12.4 cubic meters per second, and is designed to serve approximately 8,500 hectares of irrigable land.

North Main Canal Data

Type	unlined
Length	35.2 km.
Initial capacity	12.4 cu. m. per sec.
Initial water surface elevation	1828 m.

South Main Canal. The South Main Canal would follow the river in a westerly direction for approximately 9 kilometers and then turn in a southwesterly direction to its terminus at the end of the ridge dividing the Ribb and Gumara drainage basins for a total distance of 37.4 kilometers. One large tributary crossing will be encountered, but otherwise, the usual structures will be required. The initial capacity of the canal would be 9.3 cubic meters per second and it would serve approximately 6,770 hectares of irrigable land.

South Main Canal

Type	unlined
Length	37.4 km.
Initial capacity	9.3 cu. m. per sec.
Initial water surface elevation	1828 m.

Distribution System and Drainage Canals

Distribution System. The laterals and sublaterals of the distribution will be similar in design and operating criteria to those of the Megech Gravity Project. Cost for the distribution system was assumed to be somewhat higher than for Megech due to more rolling topography.

Drainage Canals. A network of deep drainage canals on the lower portions of the project area to carry away the irrigation waste and excess precipitation will be required, due to the relatively flat gradient of the land. Subsurface drainage requirements will be similar to those for the Megech Project area, and further detailed investigations should be conducted.

Service Facilities

Service facilities will be required during construction of the project and for operation and maintenance after construction. Costs for this item are included in the estimates.

ESTIMATED PROJECT COST

Construction Cost

The total construction cost for the project is estimated to be Eth$78, 405, 000 on the basis of January 1961 prices and as itemized with unit prices in Table I-5. The estimates of cost are reconnaissance in grade, and the following summary includes contingencies, engineering, and general expense.

Estimated Construction Cost

Feature	Cost
Ribb Dam and Reservoir	Eth$57, 654, 000
Diversion Dam	320, 000
North Main Canal	3, 509, 000
South Main Canal	3, 420, 000
Distribution system	7, 635, 000
Drainage canals	3, 579, 000
Access roads	569, 000
Service facilities	1, 719, 000
Total	Eth$78, 405, 000

Development Cost

Some clearing of the scattered scrub trees and loose rocks will be needed, especially on the upland soils. It is expected to be minimal, however, for an estimated cost of Eth$900, 000. Land leveling costs are also expected to be minimal, as generally the relief of the land is smooth and uniformly sloping. An average cost per hectare of Eth$65 was assumed for this item, for a total cost of approximately Eth$1, 000, 000.

Operation, Maintenance, and Replacement Cost

Annual OM&R charges for the Ribb River Project are estimated as follows.

Work division	Estimated annual cost
Storage and diversion dams	Eth$ 25, 000
Conveyance system	512, 000

TABLE I.5--RIBB RIVER PROJECT--RECONNAISSANCE ESTIMATE

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN–ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project: RIBB RIVER--Irrigation

Date of Estimate: February 1964

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U. S. $ 1.00 = Eth. $ 2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	RIBB RIVER PROJECT--Irrigation					64,656,000	78,405,000
	RIBB DAM--Earth and rockfill; crest length, 1154 meters; height of dam, 75 meters. Drawing No. 0A-23-95					48,044,800	57,654,000
1	Diversion and care of river	Lump sum		Lump sum	96,000		
2	Excavation, stripping borrow areas	250,000	m^3	1.15	287,500		
3	Excavation, all classes, dam foundation	380,000	m^3	1.95	741,000		
4	Excavation, rock, for grout cap	1,500	m^3	80.00	120,000		
5	Excavation, earthfill, in borrow areas and transportation to dam embankment	2,900,000	m^3	2.75	7,975,000		
6	Excavation, sand and gravel, in borrow areas and transportation to dam embankment	500,000	m^3	3.00	1,500,000		
7	Excavation, rock, in borrow areas and transportation to dam embankment	1,700,000	m^3	5.00	8,500,000		
8	Earthfill in dam embankment	2,700,000	m^3	0.65	1,755,000		
9	Sand, gravel, and rockfill in dam embankment	3,600,000	m^3	0.50	1,800,000		
10	Pressure grouting, all work and material	Lump sum		Lump sum	893,000		
	Subtotal--Embankment				23,667,500		
	Spillway--200-meter, ungated, U-shaped crest, with chute and basin. Maximum capacity, 1,906 m^3/sec.						
11	Excavation, all classes, opencut	687,000	m^3	3.25	2,232,750		
12	Concrete, crest structure	13,600	m^3	210.00	2,856,000		
13	Concrete, chute	10,400	m^3	180.00	1,872,000		
14	Concrete, stilling basin	12,000	m^3	160.00	1,920,000		
15	Reinforcement	3,216,000	kg	1.00	3,216,000		
16	Miscellaneous minor items	Lump sum		Lump sum	986,400		
	Subtotal--Spillway				13,083,150		
	Outlet Works--Trashracked intake, 1.83-meter diameter concrete conduit to gate chamber. Steel pipe, 1.12-meter diameter in 2.44-meter horseshoe tunnel.						
17	Excavation, all classes, opencut	96,500	m^3	3.25	313,625		
18	Concrete, intake structure	90	m^3	210.00	18,900		
19	Concrete, conduit	2,740	m^3	180.00	493,200		
20	Concrete, gate chamber	185	m^3	200.00	37,000		
21	Concrete, control house substructure	260	m^3	180.00	46,800		
22	Concrete, control house superstructure	15	m^3	210.00	3,150		
23	Concrete, stilling basin	350	m^3	160.00	56,000		
24	Reinforcement	372,000	kg	1.00	372,000		
25	Trashracks	Lump sum		Lump sum	5,500		
26	Steel outlet pipe	Lump sum		Lump sum	85,000		
27	Slide gates	Lump sum		Lump sum	130,000		
28	Electrical and minor mechanical items	Lump sum		Lump sum	21,300		
29	Miscellaneous items	Lump sum		Lump sum	102,700		
	Subtotal--Outlet Works				1,685,175		
	Subtotal--Items 1 through 29				38,435,825		
	Contingencies (25±%)				9,608,975		
	Field Cost--Ribb Dam				48,044,800		
	Engineering and General Expense (20±%)				9,609,200		
	Total est. const. cost--Ribb Dam				57,654,000		

Sheet 1 of 3

Table I-5--Continued

RECONNAISSANCE ESTIMATE
BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project RIBB RIVER--Irrigation

Date of Estimate February 1964

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY AMOUNT	QUANTITY UNIT	EQUIPMENT MATERIAL AND LABOR UNIT COST	EQUIPMENT MATERIAL AND LABOR COST	FIELD COST	TOTAL CONSTRUCTION COST
	IRRIGATION DIVERSION DAM--Stone masonry piers with removable timber stop planks. Canal headworks, one each abutment. Crest length, 36 meters; checked water depth, 5 meters.					266,600	320,000
1	Diversion and care of river	Lump sum		Lump sum	10,000		
2	Excavation, common, channel and structures	8,850	m^3	2.00	17,700		
3	Concrete in foundations	300	m^3	180.00	54,000		
4	Concrete, work deck and headworks	37	m^3	210.00	7,770		
5	Stone masonry in piers and walls	570	m^3	70.00	39,900		
6	Grouted rock paving in aprons	1,100	m^2	15.00	16,500		
7	Reinforcement	15,330	kg	1.00	15,330		
8	Stop planks, timber	38	m^3	310.00	11,780		
9	Embedded metalwork, stop plank guides	1,400	kg	2.60	3,640		
10	Radial gates, canal headworks	4,900	kg	5.50	26,950		
11	Miscellaneous items	Lump sum		Lump sum	9,700		
	Subtotal				213,270		
	Contingencies (25±%)				53,330		
	Field Cost--Diversion Dam				266,600		
	Engineering and General Expense (20±%)				53,400		
	Total est. const. cost--Diversion Dam				320,000		
	MAIN CANALS AND LATERALS--Unlined; length, 115.3 kilometers; capacities, 12.4 to 1.3 m^3/sec.						
	North Main Canal and Laterals--Length, 58.0 kilometers; capacities 12.4 to 1.3 m^3/sec.					5,542,900	6,929,000
1	Excavation canal, common	510,960	m^3	0.90	459,864		
2	Excavation canal, rock	10,430	m^3	9.00	93,870		
3	Compacting embankment	131,100	m^3	0.92	120,612		
4	Structures, concrete and masonry	Lump sum		Lump sum	1,315,000		
5	Gates, hoists, valves, and misc. metalwork	Lump sum		Lump sum	33,700		
6	Concrete pipe	Lump sum		Lump sum	80,900		
7	Miscellaneous work	Lump sum		Lump sum	141,600		
	Subtotal				2,245,546		
	Contingencies (25±%)				561,354		
	Field Cost--North Main Canal				2,806,900		
	Engineering and General Expense (25±%)				702,100		
	Total est. const. cost--North Main Canal				3,509,000		
	South Main Canal and Laterals--Length, 57.3 kilometers; capacities, 9.3 to 2.2 m^3/sec.						
1	Excavation canal, common	444,950	m^3	0.95	422,703		
2	Excavation canal, rock	12,500	m^3	9.75	121,875		
3	Compacting embankment	115,000	m^3	0.98	112,700		
4	Structures, concrete and masonry	Lump sum		Lump sum	1,281,700		
5	Gates, hoists, valves, and misc. metalwork	Lump sum		Lump sum	32,900		
6	Concrete pipe	Lump sum		Lump sum	78,900		
7	Miscellaneous work	Lump sum		Lump sum	138,000		
	Subtotal				2,188,778		
	Contingencies (25±%)				547,222		
	Field Cost--South Main Canal				2,736,000		
	Engineering and General Expense (25±%)				684,000		
	Total est. const. cost--South Main Canal				3,420,000		

Table I-5--Continued

RECONNAISSANCE ESTIMATE
BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project RIBB RIVER--Irrigation

Date of Estimate February 1964

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	IRRIGATION DISTRIBUTION SYSTEM--Unlined open lateral system for 15,270 net hectares of new service lands.					6,108,000	7,635,000
1	Distribution system under North Main Canal	8,500	ha	320.00	2,720,000		(4,250,000)
2	Distribution system under South Main Canal	6,770	ha	320.00	2,166,400		(3,385,000)
	Subtotal				4,886,400		
	Contingencies (25±%)				1,221,600		
	Field Cost--Distribution System				6,108,000		
	Engineering and General Expense (25±%)				1,527,000		
	Total est. const. cost--Distribution System				7,635,000		
	LAND DRAINAGE SYSTEM--Open land drains for 15,270 net hectares of irrigated lands.					2,863,100	3,579,000
1	Drains under North Main Canal	8,500	ha	150.00	1,275,000		(1,992,000)
2	Drains under South Main Canal	6,770	ha	150.00	1,015,500		(1,587,000)
	Subtotal				2,290,500		
	Contingencies (25±%)				572,600		
	Field Cost--Drainage System				2,863,100		
	Engineering and General Expense (25±%)				715,900		
	Total est. const. cost--Drainage System				3,579,000		
	ACCESS ROADS--From existing Addis Zemin-Debra Tabor road to Ribb Dam and the diversion dam, flat to rolling terrain.					455,600	569,000
1	Road, flat to rolling terrain	13.5	km	27,000.00	364,500		
	Contingencies (25±%)				91,100		
	Field Cost--Access Road				455,600		
	Engineering and General Expense (25±%)				113,400		
	Total est. const. cost--Access Road				569,000		
	SERVICE FACILITIES--Includes office, shop, equipment, housing, streets, and utilities.					1,375,000	1,719,000
1	Camp and equipment	Lump sum		Lump sum	1,100,000		
	Contingencies (25±%)				275,000		
	Field Cost--Camp and Equipment				1,375,000		
	Engineering and General Expense (25±%)				344,000		
	Total est. const. cost--Camp and Equipment				1,719,000		

Sheet 3 of 3

PLAN SELECTION AND ALTERNATIVES

The selected plan of development appears to be the most economically feasible utilizing the only major stream available in the area. Alternative sites were considered but discarded as the site as selected appears to be the most economical in relation to storage capacity.

Pumping possibilities from the lake were considered; however, from the data available, it appears that the distance and lift required would be uneconomical.

Possible hydroelectric power production was considered in conjunction with irrigation requirements. Brief studies conducted did not indicate that power production was feasible.

Gumara River Project

GENERAL DESCRIPTION

Project Area

The Gumara River area is east of Lake Tana and has a drainage area of 1,500 square kilometers. The river rises in the high mountainous area south and east of the town of Debre Tabor at an approximate elevation of 3000 meters. It flows generally in a westerly direction and empties into Lake Tana about 35 kilometers north of the town of Bahir Dar. The main tributaries of the Gumara River are the North Fork, the South Fork, and the Little Gumara. The project land area extends from the toes of the mountains to near the lake and blends into the Ribb River area to the north, the average elevation of the project lands being about 1840 meters. A ridge extending to the lake is the southern boundary of the area. The Bahir Dar-Debre Tabor highway extends through the area.

Project Lands

Like other lake plain soils of the Ribb River Project, those in the project area were developed on deltaic deposits overlying deeper lacustrine deposits. Alluvium and red latosol soils, better suited to irrigation, are also found in the project lands, comprising about 25 percent of the project lands. They are considered to be more desirable for irrigation purposes than the grumusols.

The irrigable lands under the canal that could be served by gravity irrigation were estimated at 12,920 hectares. The irrigable area, after allowing for canals, roads, buildings, and taking into consideration the factor of being a reconnaissance study, was determined to be composed of the following land classes.

Land Classes (ha.)

Class	Arable under canal	Irrigable
1	2,100	1,570
2	2,090	1,570
3	13,029	9,780
Total	17,219	12,920

Critical drainage problems on the lake plains resulted in the elimination of those lands bordering the lake. The western boundary of the project land extends away from the lake a few kilometers in order to avoid, as much as possible, the seasonally inundated plain. Internal drainage characteristics are such that tile drainage would probably not be feasible. The more highly elevated lands of the project area should not present anÿ undue problem in surface drainage in carrying away any irrigation waste and excess precipitation.

Hydrology

Hydrologic studies conducted indicate that there is an abundant water supply to irrigate the 12,920 hectares of land.

PLAN OF DEVELOPMENT

The plan includes a storage dam, a diversion dam, two main canals (one on each side of the river), a lateral distribution system, and drainage canals to provide full irrigation service for 12,920 hectares of land. Storage would be provided by a reservoir on the Gumara River. The diversion dam would turn water into the two main canals for service to the project. The North Main Canal would extend in a generally northerly direction to its terminus at the end of the ridge between the Ribb and Gumara drainage basins. The South Main Canal would extend in a westerly and then northwesterly direction following the edge of the steeper ground south of the river. Laterals and feeders would branch off the main canals to the land.

PROJECT FEATURES

The general plan of a reconnaissance layout of the project features is shown on Figure I-48, and a description of these features follows. Surveys of the reservoir area for determination of area-capacity were performed by taking cross sections of the river valley at various points and at the damsite. Layouts of the canals were prepared from uncontrolled photomosaics of 1:50,000 scale.

Gumara Dam and Reservoir

Gumara Dam. The damsite is on the main stem of the Gumara River, approximately 35 kilometers east of Lake Tana and 18 kilometers upstream from the Addis Zemin-Bahir Dar road. It would be an earth and rock fill dam with a structural height above streambed of 71 meters and with a crest length of 683 meters. Diversion during construction would be accomplished through a gap in the dam, the gap to be closed during the dry season following the completion of the outlet conduit. A dike on the north side of the proposed reservoir will be required. Plan, section, and profiles of the dam and appurtenant works appear on Figure I-49.

Gumara Dam Data

Type	earth and rock fill
Embankment volume (earth)	2,600,000 cu. m.
Embankment volume (pervious)	3,100,000 cu. m.
Top of dam	1960 m.
Freeboard	1.7 m.
Structural height	71 m.
Hydraulic height	69.3 m.
Length of crest	683 m.
Width of crest	10 m.

Dike

Type	earth and rock fill
Embankment volume (earth)	1,300,000 cu. m.
Embankment volume (pervious)	1,300,000 cu. m.
Structural height	$38^{\pm}$ m.
Crest length	$690^{\pm}$ m.

Spillway. The design of the spillway was based on the inflow design flood, with a peak at 1,490 cubic meters per second, and a 2.25-day volume of 84 million cubic meters. It would be a side channel, uncontrolled type, located on the right abutment of the dam. With a crest length of 50 meters, it is designed to pass a maximum flow of 926 cubic meters per second at elevation 1958.3 meters. At this elevation it would have a surcharge head of 4 meters and superstorage of nearly 37 million cubic meters. A stilling basin at the end of the chute would be required.

Spillway Data

Type	side channel uncontrolled
Crest elevation	1954.3 m.
Inflow design flood, 2.25-day period	84,000,000 cu. m.
Discharge at maximum water surface elevation	926 cu. m. per sec.

Outlet Works. An outlet works on the left abutment of the dam that would release water as required into the river channel and divert it into the main canals for irrigation, is planned. It would include an intake structure, an upstream conduit, a gate chamber equipped with slide gate for emergency control, a steel outlet pipe inside a horseshoe conduit, a control house with two slide gates, and a stilling basin.

Outlet Works Data

Sill elevation	1895.2 m.
Discharge at minimum optimum water surface elevation	3.9 cu. m. per sec.
Type of gates (2)	slide gates
Size of pipe (diameter)	1.22 m.

Gumara Reservoir. The reservoir basin probably is underlain by younger volcanic flows, which are quite permeable. The thickness of these flows may not be great and, since the basin is covered with impermeable overburden, seepage may not be a problem. Storage is estimated to be about 236.7 million cubic meters and will inundate an area of 8.7 square kilometers. No shortages are expected, as a firm yield of 163,200,000 cubic meters annually is estimated. For area-capacity data and curves, see Figures I-50 and I-51.

Site Geology. The selected damsite is believed to be geologically feasible to provide storage for the proposed project, but the foundation materials should be thoroughly explored during preconstruction studies to determine the thickness and permeability of foundation materials and the corrective measures required to prevent excessive leakage. In excavating for the cutoff trench, it may be advisable to remove the scoriaceous basaltic lava to the sounder older volcanics to assure sealing off the reservoir at the damsite.

Construction Materials. Impervious embankment materials are available from the valley floor downstream from the dam axis. Pervious fill and sand and gravel can be obtained from the gravel lenses in the stream channel downstream from the damsite. Riprap and pervious rockfill can be obtained at the site from the rhyolitic or basaltic lava near the site.

Access to Site. A 24-kilometer road from the Addis Zemin-Bahir Dar highway would have to be constructed, mostly through flat to gently rolling terrain.

Diversion Dam

The diversion dam would be about 8 kilometers downstream on the Gumara River from the main storage dam. The masonry-concrete regulating structure will divert the irrigation releases from the storage dam by means of canal headworks located on each abutment. The weir length would be about 44 meters with 10 piers for insertion of the stoplogs. The logs would be removed during the rainy season for bypassing the high floodflows. The sill is assumed to be at elevation 1872.4 meters, with the top of the dam at elevation 1877 meters. Estimates of cost include channel improvements and wingwalls.

GUMARA (GM-6) DAM & RESERVOIR

AREA CAPACITY DATA
(with sediment distributed)

CONTROL POINTS				INITIAL AREA (SQ. METERS - 10^6)	CAPACITY (CUBIC METERS - 10^6)			
ITEM & ALLOCATION OF STORAGE CAPACITY		DIAGRAM OF DAM	ELEVATION (METERS)		INITIAL		WITH 50-YR. SEDIMENT	
					INCREMENT	TOTAL	INCREMENT	TOTAL
TOP OF DAM			1960.0					
MAXIMUM W.S.	FREEBOARD		1958.3	9.172		273.66		264.26
	FLOOD SURCHARGE				36.96		36.96	
NORMAL W.S.			1954.3	8.694		236.70		227.30
	ACTIVE CAPACITY				235.08		226.83	
MINIMUM OPERATING W.S.			1897.92	0.405		1.62		0.47
	INACTIVE CAPACITY				0.91		0.37	
LIP OF LOWEST OUTLET*			1895.2	0.252		0.71		0.10
	DEAD STORAGE AND SILT				0.71		0.10	
STREAM BED			1890.0	0		0		0

*100-YEAR SEDIMENT OF 18.8 $(10)^6$ M^3 WILL TAKE 1895.2 METERS ELEVATION AT THE DAM.

2.2-BN-5

Figure I-50--Gumara (GM-6) Dam and Reservoir--Area-Capacity Data

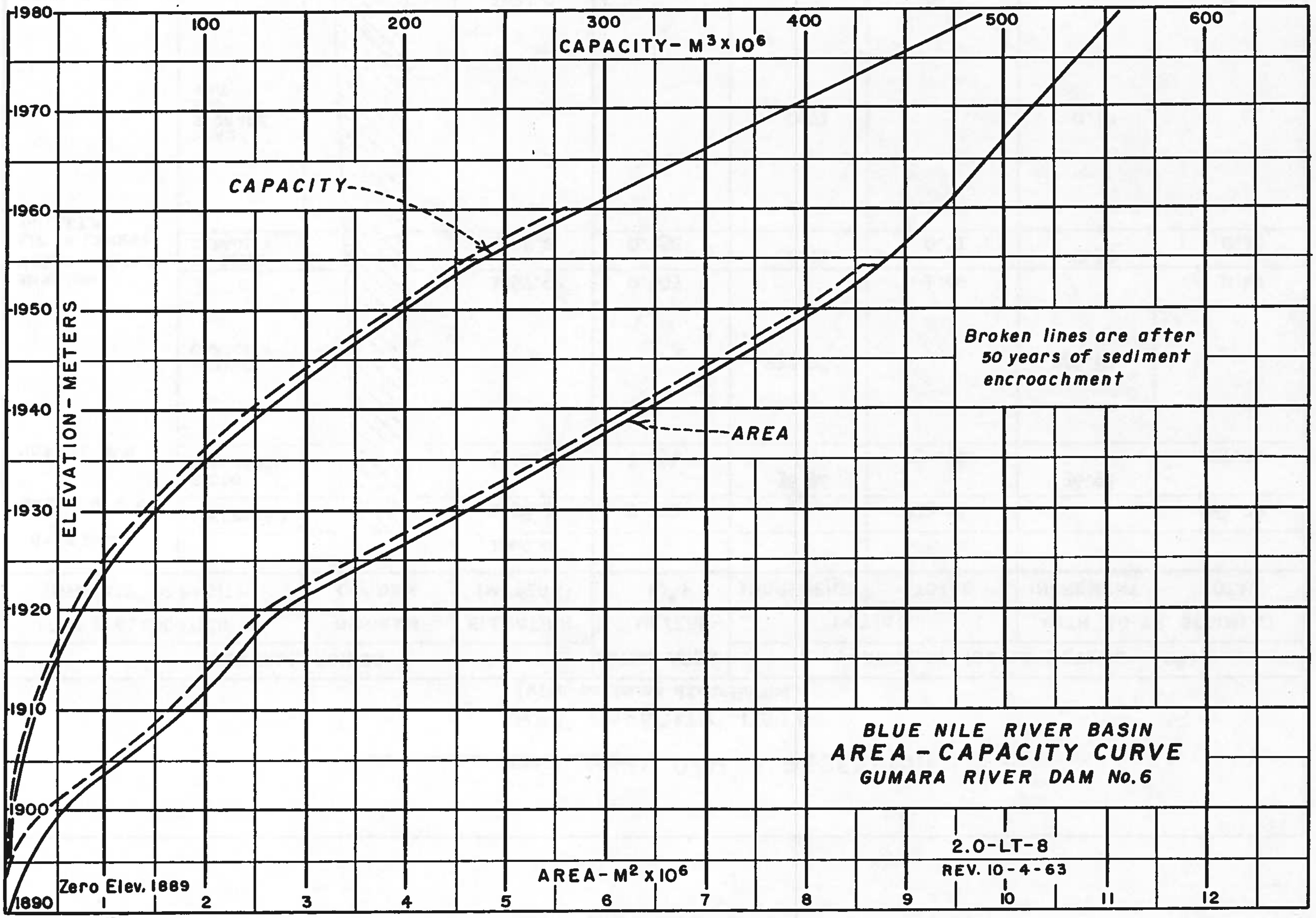


Figure I-51--Gumara Dam--Area-Capacity Curve

Diversion Dam Data

Type	masonry-concrete with stoplogs
Structural height	4.6 m.
Weir length	44 m.
Volume of concrete	435 cu. m.
Volume of masonry	400 cu. m.
Normal water surface elevation	1876 m.

Main Canals

In common with other irrigation projects in the Blue Nile Basin, a main canal on each side of the river to service the project lands will be required. Being adjacent to the Ribb River Project, the topography and subsurface soil conditions will be similar. It will traverse flat to rolling terrain, with some rock excavation expected to be encountered where the overburden is thin. Typical structures such as bridges, culverts, wasteways, turnouts, siphons, checks, and drops would have to be provided as required.

North Main Canal. The canal would extend in a northerly direction from the diversion dam headworks for a distance of approximately 59.5 kilometers. It would have an initial capacity of 10.6 cubic meters per second, designed to serve by gravity 9,100 hectares of land.

North Main Canal Data

Type	unlined
Length	59.5 km.
Initial capacity	10.6 cu. m. per sec.
Initial water surface elevation	1875 m.

South Main Canal. The canal would extend in a westerly direction from the diversion dam headworks for a distance of 32.5 kilometers, and thence northwesterly for 8 kilometers to its terminus about 4 kilometers east of the lake shore. It would have an initial capacity of 4.65 cubic meters per second designed to serve 3,820 hectares of land.

South Main Canal Data

Type	unlined
Length	32.5 km.
Initial capacity	4.65 cu. m. per sec.
Initial water surface elevation	1875 m.

Distribution System and Drainage Canals

Distribution System. The general terrain and conditions being similar to those of the Ribb Project, the same cost per hectare was used to arrive at cost for this item.

Drainage Canals. Surface and subsurface conditions are similar to those described for the Ribb Project.

Service Facilities

Service Facilities. Service facilities will be required for the reasons stated for the Megech Gravity Project; cost also being obtained from curves.

ESTIMATED PROJECT COST

Construction Cost

The total construction cost for the Gumara River Project is estimated to be Eth$79, 633, 000 on the basis of January 1961 prices and as itemized with unit prices in Table I-6. The estimates of cost are reconnaissance in grade, and the following summary includes contingencies, engineering, and general expense.

Estimated Construction Cost

Feature	Cost
Gumara Dam and Reservoir	Eth$64, 450, 000
Diversion Dam	315, 000
North Main Canal	1, 862, 000
South Main Canal	1, 444, 000
Distribution system	6, 056, 000
Drainage canals	3, 028, 000
Access roads	759, 000
Service facilities	1, 719, 000
Total	Eth$79, 633, 000

Development Cost

The development cost which includes clearing and land leveling is estimated to be Eth$1, 600, 000 for the potential irrigation project.

Operation, Maintenance, and Replacement Cost

Operation and annual cost for the project is estimated as follows by major divisions of work activities. No replacements are required within the period of analysis.

Work division	Estimated annual cost
Storage and diversion dams	Eth$ 20, 000
Conveyance system	440, 000

PLAN SELECTION AND ALTERNATIVES

Plan selection was generally controlled by the selection of a damsite. Two other damsites were investigated, one on the South Fork and the other on the North Fork. The site as selected appeared the most feasible by comparison of reservoir capacity to cost of dam.

Possible hydroelectric power production was considered, inasmuch as hydrologic studies indicated the yield was in excess of irrigation requirements. Brief studies conducted indicate that about 4, 500 kilowatts could be produced if a high dam (100 meters) were to be constructed. It showed, however, that the extra height required for production of this power would be uneconomical. A smaller plant of about 500 kilowatts for local use might prove feasible at the time the irrigation dam is constructed. (See Appendix V, "Power" for further details.)

TABLE 6--GUMARA RIVER PROJECT--RECONNAISSANCE ESTIMATE

RECONNAISSANCE ESTIMATE
BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project GUMARA RIVER--Irrigation

Date of Estimate February 1964

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U S $100 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY AMOUNT	UNIT	EQUIPMENT MATERIAL AND LABOR UNIT COST	EQUIPMENT MATERIAL AND LABOR COST	FIELD COST	TOTAL CONSTRUCTION COST
	GUMARA RIVER PROJECT--Irrigation					65,866,200	79,633,000
	GUMARA DAM--Earth and rockfill; crest length, 683 meters; height of dam, 71 meters. Crest length of dike, 690 meters; height of dike, 40 meters. Drawing No. 04-23-93					53,708,700	64,450,000
	Dam						
1	Diversion and care of river	Lump sum		Lump sum	60,000		
2	Excavation, stripping borrow pits	220,000	m^3	1.15	253,000		
3	Excavation, all classes, dam foundation	640,000	m^3	1.95	1,248,000		
4	Excavation, rock, for grout cap	880	m^3	80.00	70,400		
5	Excavation, earthfill, in borrow areas and transportation to dam embankment.	2,700,000	m^3	2.75	7,425,000		
6	Excavation, sand and gravel, in borrow areas and transportation to dam embankment	200,000	m^3	3.00	600,000		
7	Excavation, rock, in borrow areas and transportation to dam embankment	1,400,000	m^3	5.00	7,000,000		
8	Earthfill in dam embankment	2,600,000	m^3	0.65	1,690,000		
9	Sand, gravel, and rockfill in dam embankment	3,100,000	m^3	0.50	1,550,000		
10	Foundation grouting, all work and material	Lump sum	m^3	Lump sum	532,400		
	Subtotal--Dam				20,428,800		
	Dike						
11	Excavation, stripping borrow pits	110,000	m^3	1.15	126,500		
12	Excavation, all classes, dike foundation	380,000	m^3	1.95	741,000		
13	Excavation, rock for grout cap	920	m^3	80.00	73,600		
14	Excavation, earthfill, in borrow areas and transportation to dike embankment	1,500,000	m^3	2.75	4,125,000		
15	Excavation, sand and gravel in borrow areas and transportation to dike embankment	90,000	m^3	3.00	270,000		
16	Excavation, rock, in borrow areas and transportation to dike embankment	700,000	m^3	5.00	3,500,000		
17	Earthfill in dike embankment	1,300,000	m^3	0.65	845,000		
18	Sand, gravel, and rockfill in dike embankment	1,300,000	m^3	0.50	650,000		
19	Foundation grouting, all work and material	Lump sum		Lump sum	488,500		
	Subtotal--Dike				10,819,600		
	Spillway--60-meter side channel with chute and stilling basin.						
20	Excavation, all classes, opencut	602,000	m^3	3.25	1,956,500		
21	Concrete in spillway crest structure	8,000	m^3	210.00	1,680,000		
22	Concrete in chute	7,200	m^3	200.00	1,440,000		
23	Concrete in stilling basin	8,200	m^3	160.00	1,312,000		
24	Reinforcement	2,105,000	kg	1.00	2,105,000		
25	Miscellaneous items	Lump sum		Lump sum	653,700		
	Subtotal--Spillway				9,147,200		
	Outlet Works--Trashracked box intake, pressure upstream conduit, steel pipe in downstream tunnel.						
26	Excavation, all classes, opencut	395,000	m^3	3.25	1,283,750		
27	Concrete, intake structure and control house	50	m^3	210.00	10,500		
28	Concrete in control house substructure	260	m^3	180.00	46,800		
29	Concrete in conduits and stilling basin	2,850	m^3	180.00	513,000		
30	Concrete in gate chamber	185	m^3	200.00	37,000		
31	Reinforcement	341,000	kg	1.00	341,000		
32	Trashracks	Lump sum		Lump sum	4,500		
33	Steel outlet pipe	Lump sum		Lump sum	70,000		
34	Slide gates	Lump sum		Lump sum	150,000		
35	Minor electrical and mechanical items	Lump sum		Lump sum	20,000		
36	Miscellaneous items	Lump sum		Lump sum	94,800		
	Subtotal--Outlet Works				2,571,350		
	Subtotal--Items 1 through 36				42,966,950		
	Contingencies (25%)				10,741,750		
	Field Cost--Gumara Dam				53,708,700		
	Engineering and General Expense (20%)				10,741,300		
	Total est. const. cost--Gumara Dam				64,450,000		

Sheet 1 of 3

Table I-6--Continued

RECONNAISSANCE-ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project GUMARA RIVER--Irrigation

Date of Estimate February 1964

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	IRRIGATION DIVERSION DAM--Stone masonry piers with removable timber stop planks between. Crest length, 50 meters; checked water depth, 3.6 meters; canal headworks, one each abutment.					262,600	315,000
1	Diversion and care of river	Lump sum		Lump sum	10,000		
2	Excavation channel and structures, common	6,900	m^3	2.00	13,800		
3	Concrete in foundations	390	m^3	180.00	70,200		
4	Concrete, work deck and headworks	45	m^3	210.00	9,450		
5	Stone masonry in piers and walls	400	m^3	70.00	28,000		
6	Grouted rock paving in aprons	1,300	m^2	15.00	19,500		
7	Reinforcement	19,650	kg	1.00	19,650		
8	Stop planks (timber)	26	m^3	310.00	8,060		
9	Embedded metalwork (for stop planks)	1,230	kg	2.60	3,198		
10	Radial gates, canal headworks	3,400	kg	5.50	18,700		
11	Miscellaneous items	Lump sum		Lump sum	9,500		
	Subtotal				210,058		
	Contingencies (25±%)				52,542		
	Field Cost--Diversion Dam				262,600		
	Engineering and General Expense (20±%)				52,400		
	Total est. const. cost--Diversion Dam				315,000		
	MAIN CANALS AND LATERALS--Unlined					2,644,900	3,306,000
	North Main Canal and Laterals--Unlined; length, 59.5 kms; capacities 10.6 to 1.1 m^3/sec.						
1	Canal excavation, common	322,500	m^3	0.90	290,250		
2	Canal excavation, rock	1,600	m^3	9.00	14,400		
3	Compacting embankment	121,100	m^3	0.92	111,412		
4	Structures, concrete and masonry	Lump sum		Lump sum	649,100		
5	Gates, hoists, valves, and misc. metalwork	Lump sum		Lump sum	16,600		
6	Concrete pipe	Lump sum		Lump sum	39,900		
7	Miscellaneous work	Lump sum		Lump sum	70,000		
	Subtotal				1,191,662		
	Contingencies (25±%)				297,938		
	Field Cost--North Main Canal				1,489,600		
	Engineering and General Expense (25±%)				372,400		
	Total est. const. cost--North Main Canal				1,862,000		
	South Main Canal and Laterals--Unlined; length, 32.5 kms; capacities 4.65 to 1.9 m^3/sec.						
8	Canal excavation, common	198,900	m^3	0.95	188,955		
9	Canal excavation, rock	8,300	m^3	9.75	80,925		
10	Compacting embankment	53,900	m^3	0.98	52,822		
11	Structures, concrete and masonry	Lump sum		Lump sum	503,400		
12	Gates, hoists, valves, and misc. metalwork	Lump sum		Lump sum	12,900		
13	Concrete pipe	Lump sum		Lump sum	31,000		
14	Miscellaneous work	Lump sum		Lump sum	54,200		
	Subtotal				924,202		
	Contingencies (25±%)				231,098		
	Field Cost--South Main Canal				1,155,300		
	Engineering and General Expense (25±%)				288,700		
	Total est. const. cost--South Main Canal				1,444,000		

Table I-6--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project GUMARA RIVER--Irrigation

Date of Estimate February 1964 — Currency in terms of Ethiopian Dollars

Prices as of January 1961 — (U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	IRRIGATION DISTRIBUTION SYSTEM--Unlined open lateral system for 12,920 net hectares of new service lands.					4,845,000	6,056,000
1	System under the North Main Canal	9,100	ha	300.00	2,730,000		(4,265,600)
2	System under the South Main Canal	3,820	ha	300.00	1,146,000		(1,790,400)
	Subtotal				3,876,000		
	Contingencies (25±%)				969,000		
	Field Cost--Distribution System				4,845,000		
	Engineering and General Expense (25±%)				1,211,000		
	Total est. const. cost--Distribution System				6,056,000		
	LAND DRAINAGE SYSTEM--Open land drains for 12,920 net hectares of irrigated lands.					2,422,500	3,028,000
1	Drains under the North Main Canal	9,100	ha	150.00	1,365,000		(2,132,700)
2	Drains under the South Main Canal	3,820	ha	150.00	573,000		(895,300)
	Subtotal				1,938,000		
	Contingencies (25±%)				484,500		
	Field Cost--Drainage System				2,422,500		
	Engineering and General Expense (25±%)				605,500		
	Total est. const. cost--Drainage System				3,028,000		
	ACCESS ROAD--From the existing Bahir Dar to Addis Zemin highway to Gumara Dam. Two-lane gravel road.					607,500	759,000
1	Access road, flat terrain	18	km	27,000.00	486,000		
	Contingencies (25±%)				121,500		
	Field Cost--Access Road				607,500		
	Engineering and General Expense (25±%)				151,500		
	Total est. const. cost--Access Road				759,000		
	SERVICE FACILITIES--Includes office, shops, equipment, housing, streets, and utilities.					1,375,000	1,719,000
1	Camp and equipment	Lump sum		Lump sum	1,100,000		
	Contingencies (25±%)				275,000		
	Field Cost--Service Facilities				1,375,000		
	Engineering and General Expense (25±%)				344,000		
	Total est. const. cost--Service Facilities				1,719,000		

Sheet 3 of 3

Megech River Area--Pumping Projects

INTRODUCTION

Of the approximately 45,000 hectares determined to be suitable for irrigation development in the Megech River area, less than 20 percent of the potential arable lands could be served by the Megech Gravity Project. A scheme involving two pumping projects to irrigate lands not served by the gravity project is proposed. The West Megech Pumping Project and the East Megech Pumping Project are adjacent to the boundaries of the Megech Gravity Project and, as the names imply, east and west of the Megech River. The areas have similar characteristics, being in close proximity to each other. The following general descriptions would be applicable to both projects.

GENERAL DESCRIPTION

The proposed project lands are situated on the broad alluvial plain. The topography is relatively flat to rolling and, unlike many areas in the Blue Nile Basin, there are no significant tributaries which contribute to the main Megech River. The elevation of the areas ranges from 1786 meters above sea level (the surface elevation of Lake Tana) to about 1820 meters at the upper extremity.

Project Lands

Nearly every soil type occurring in the Blue Nile Basin may be found in the areas proposed for development. The soils are not of the best quality land for irrigation. Hardpans or indurated horizons occur throughout the project lands, generally due to iron and silica cementation. Such soils are intermingled with typical dark-clay grumusols on flatter terrain, and with the red earth or latosols on upland, well-drained positions.

The lands were determined to be in Class 3 category. The arable lands within the potential projects were estimated to be about 17,285 hectares, of which 12,970 hectares were determined to be irrigable.

Hydrology

From the data available, Lake Tana appears to be the only possible source of surface water supply for the two pumping projects. Annual farm delivery requirements would be about the same as on the Megech Gravity Project, namely 0.958 meter. Allowing a liberal allowance of 30 percent for canal losses, the estimate for diversion requirements would be 13,400 cubic meters per hectare for a total water requirement to be pumped from Lake Tana of 173,800,000 cubic meters annually.

West Megech Pumping Project

PLAN OF DEVELOPMENT

The development plan for the West Megech Pumping Project includes the construction of two pumping plants, two main canals, a lateral distribution system, and drainage canals for irrigation of 7,080 hectares of new service lands.

The main plant would pump the irrigation water from Lake Tana, discharging into the lower main canal. The lower main canal would extend on a northerly direction, and about 20 kilometers from the main plant, a relift pumping plant would relift the water to the upper main canal, using the main canal as a forebay. The upper main canal would continue to extend in a northwesterly direction, making a loop towards the east, with its terminus at the Megech River.

PROJECT FEATURES

The features of the project plan are described in reconnaisance detail in the following paragraphs and shown in general plan on Figure I-52. Basic general data were very limited, the layout of the project plan having been evolved from uncontrolled planimetric maps of 1:50,000 scale, employing altimeters for determination of elevations for the areas.

Main Pumping Plant

The plant would be located on the lake shore about 2 kilometers north of the village of Gorgora. A small amount of excavation and dredging would be necessary to create an intake channel. The pump intake would be placed below the 1783-meter, minimum lake operational level. Normal water surface elevation is established at 1786 meters. A total static lift of 14 meters--to elevation 1800, the beginning of the lower main canal--will be required. A concrete pipe 2.0 meters in diameter and 300 meters long would be required, having a design capacity of 9.24 cubic meters per second (326 c.f.s.). Assuming a total efficiency of 65 percent for the pumps and motors, the total motor nameplate rating required would be 3,175 horsepower. For operational efficiency, various capacity pumps would be employed. Rough reconnaissance estimates were made for the pumps and prime mover.

<u>Pumping Plant Data</u>

Type of forebay	lake
Forebay elevation (invert)	1783 m.
Total dynamic head	17 m.
Static head	14 m.
Size of discharge pipe (diameter)	2 m.
Capacity of pumps	9.24 cu. m. per sec.
Motor rating	3,175 hp.

Relift Pumping Plant

This pumping plant would be located at the end of the lower main canal. The discharge line would be 1.5-meter-diameter concrete pipe with a designed capacity of 4.66 cubic meters per second (165 c.f.s.) and would be 350 meters long. The required static lift to the 1820-meter contour elevation would be 25 meters. A number of pumps and motors would be required for operating efficiency, with a total nameplate motor rating of 2, 450 horsepower.

Relift Pumping Plant Data

Type of forebay	canal
Forebay elevation (invert)	1795 m.
Total dynamic head	27 m.
Total static head	25 m.
Size of discharge pipe (diameter)	1.5 m.
Capacity of pumps	4.66 m.
Motor ratings	2,450 hp.

Lower Main Canal

The canal would begin at the end of the discharge line of the main pumping plant and would follow approximately along the 1800-meter contour for approximately 26 kilometers to convey water for irrigation of 3, 650 hectares of land. Its first 20.6 kilometers would proceed in a northerly direction along the west edge of the project. This reach would carry the water from the lower pumping plant to the upper pumping plant and would have a capacity of 9.24 cubic meters per second. Just beyond the intake pipe of the relift pumping plant, the canal would be gated and the capacity reduced to 4.02 cubic meters per second for the next reach of canal. The canal would then continue eastward at this capacity to its terminus at a wasteway into a stream. Two main laterals would leave the canal near its end for a combined total distance of about 21.5 kilometers.

Lower Main Canal Data

Type	unlined
Length	47.5 km.
Initial capacity	9.24 cu. m. per sec.
Initial water surface elevation	1800 m.

Upper Main Canal

This canal would begin at the end of the discharge line of the relift pumping plant. It would continue northward for about 5 kilometers and then proceed in an easterly direction. Its capacity would be 4.66 cubic meters per second for its entire length of 17 kilometers to convey water for 3, 430 hectares of irrigable land. Near its end two main laterals would be required to reach the individual farm units.

Upper Main Canal Data

Type	unlined
Length	31.5 km.
Initial capacity	4.66 cu. m. per sec.
Initial water surface elevation	1820 m.

Distribution System and Drainage Canals

The design of the distribution system and drainage canals would be similar in scope to that of the Megech Gravity Project, having the same general topography and natural drainage channels. Subsurface drainage requirements would also be similar to those of the Megech Gravity Project.

Service Facilities

Temporary and permanent facilities will be required for supervision of construction and for housing and administration of operation and maintenance personnel. Costs for this item have been obtained from curves.

ESTIMATED PROJECT COST

Construction Cost

The total construction cost for the West Megech Pumping Project is estimated to be Eth$12, 617, 000 on the basis of January 1961 prices and as itemized with unit prices on Table I-7. The estimates of cost are reconnaissance in grade, and the following summary includes contingencies, engineering, and general expense.

Estimated Construction Cost

Feature	Cost
Main Pumping Plant	Eth$ 1, 976, 000
Relift Pumping Plant	1, 689,000
Transmission lines and substations	877, 000
Lower Main Canal	2, 115, 000
Upper Main Canal	859, 000
Distribution system	3, 319, 000
Drainage canals	1, 438, 000
Access roads	156, 000
Service facilities	188, 000
Total	Eth$12, 617, 000

Development Cost

Clearing and land leveling costs are expected to cost about the same as the Megech Gravity Project as the conditions are similar. Cost for these two items is estimated to be about Eth$870, 000.

Operation, Maintenance, and Replacement Cost

Annual OM&R charges are estimated to be as follows. Power has been assumed to cost 3 cents per kilowatt-hour for an estimated annual consumption of 10, 170, 000 kilowatt-hours for both pumping plants.

Feature	Operation and maintenance	Special items and replacement	Power cost
Pumping plants	Eth$ 70, 000	Eth$14, 000	Eth$305, 000
Electrical facilities of pumping plant	23, 000	3, 000	--
Conveyance system	260, 000	--	--

TABLE T-7--WEST MEGECH PUMPING PROJECT--RECONNAISSANCE ESTIMATE

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project WEST MEGECH PUMPING--Irrigation

Date of Estimate January 1964

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	WEST MEGECH PUMPING PROJECT--Irrigation					10,107,400	12,617,000
	MAIN PUMPING PLANT--Capacity, 9.24 m^3/sec; total dynamic head, 17 meters.					1,580,900	1,976,000
1	Cofferdam in lake and unwatering site	Lump sum		Lump sum	20,000		
2	Excavation for intake channel, common	1,200	m^3	1.95	2,340		
3	Excavation for intake channel, rock	780	m^3	6.50	5,070		
4	Excavation and backfill for discharge pipe	1,330	m^3	4.00	5,320		
5	Pumping plant structure, outdoor plant	Lump sum		Lump sum	730,000		
6	Pumps and prime movers	Lump sum		Lump sum	400,000		
7	Concrete discharge pipe, 2.0-meter diameter	300	lm	340.00	102,000		
	Subtotal				1,264,730		
	Contingencies (25±%)				316,170		
	Field Cost--Main Pumping Plant				1,580,900		
	Engineering and General Expense (25±%)				395,100		
	Total est. const. cost--Main Pumping Plant				1,976,000		
	RELIFT PUMPING PLANT--Capacity, 4.66 m^3/sec; total dynamic head, 27 meters.					1,351,400	1,689,000
1	Excavation and backfill for discharge pipe	900	m^3	4.00	3,600		
2	Concrete discharge pipe, 1.5-meter diameter	350	lm	250.00	87,500		
3	Pumping plant structure, outdoor plant	Lump sum		Lump sum	640,000		
4	Pumps and prime movers	Lump sum		Lump sum	350,000		
	Subtotal				1,081,100		
	Contingencies (25±%)				270,300		
	Field Cost--Relift Pumping Plant				1,351,400		
	Engineering and General Expense (25±%)				337,600		
	Total est. const. cost--Relift Pumping Plant				1,689,000		
	TRANSMISSION LINES AND SUBSTATIONS--Required to supply power to pumping plants.					715,400	877,000
	Transmission Line--Gondar to West Megech relift pumping plant. Steel poles, 45 kv with 1 AWG copper conductor.						
1	Average terrain (Field Cost)	23	km	9,800.00	225,400		
	Engineering and General Expense (20±%)				44,600		
	Total est. const. cost--Transmission Line				270,000		
	Transmission Line--West Megech relift to West Megech main pumping plant. Steel pole, 15 kv with 3/0 AWG copper conductors.						
2	Average terrain (Field Cost)	18	km	7,500.00	135,000		
	Engineering and General Expense (20±%)				27,000		
	Total est. const. cost--Transmission Line				162,000		
	Gondar Substation--Stage 02 only, as shown on Drawing No. 4.0-BN-194.						
3	Bay X1, 15 kv	Lump sum		Lump sum	29,000		
4	Bay Z1, 45 kv	Lump sum		Lump sum	65,000		
5	Transformer, KX1A	Lump sum		Lump sum	72,000		
	Field Cost--Gondar Substation				166,000		
	Engineering and General Expense (25±%)				42,000		
	Total est. const. cost--Gondar Substation				208,000		
	Substation--Relift pumping plant						
6	Transformer	Lump sum		Lump sum	40,000		
7	Fuse disconnect switch	Lump sum		Lump sum	6,000		
8	Disconnect switch	Lump sum		Lump sum	10,000		
9	Motor protection	Lump sum		Lump sum	20,000		
10	Station service, communication and misc.	Lump sum		Lump sum	14,000		
	Field Cost--Substation, Relift Pumps				90,000		
	Engineering and General Expense (25±%)				23,000		
	Total est. const. cost--Substation, Relift Pumps				113,000		

Sheet 1 of 3

Table I-7--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project: WEST MEGECH PUMPING--Irrigation

Date of Estimate: January 1964

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U S $ 1.00 = Eth. $ 2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	Substation--Main Pumping Plant						
11	Transformer	Lump sum		Lump sum	50,000		
12	Fuse disconnect switch	Lump sum		Lump sum	6,000		
13	Disconnect switch	Lump sum		Lump sum	3,000		
14	Motor protection	Lump sum		Lump sum	24,000		
15	Station service, communication and misc.	Lump sum		Lump sum	16,000		
	Field Cost--Substation, Main Pumps				99,000		
	Engineering and General Expense (25±%)				25,000		
	Total est. const. cost--Substation, Main Pumps				124,000		
	LOWER MAIN CANAL AND LATERALS--Unlined; length, 47.5 kms; capacities 9.24 to 1.16 m³/sec.					1,692,100	2,115,000
1	Canal excavation, common	385,200	m³	0.90	346,680		
2	Compacting embankment	97,200	m³	0.93	90,396		
3	Concrete and masonry structures	Lump sum		Lump sum	767,100		
4	Gates, hoists, valves, and misc. metalwork	Lump sum		Lump sum	19,700		
5	Concrete pipe	Lump sum		Lump sum	47,200		
6	Miscellaneous work	Lump sum		Lump sum	82,600		
	Subtotal				1,353,676		
	Contingencies (25±%)				338,424		
	Field Cost--Lower Main Canal				1,692,100		
	Engineering and General Expense (25±%)				422,900		
	Total est. const. cost--Lower Main Canal				2,115,000		
	UPPER MAIN CANAL AND LATERALS--Unlined; length, 31.5 kms; capacities 4.66 to 1.19 m³/sec.					687,100	859,000
1	Canal excavation, common	184,900	m³	0.95	175,655		
2	Compacting embankment	1,900	m³	0.98	1,862		
3	Concrete and masonry structures	Lump sum		Lump sum	311,500		
4	Gates, hoists, valves, and misc. metalwork	Lump sum		Lump sum	8,000		
5	Concrete pipe	Lump sum		Lump sum	19,200		
6	Miscellaneous work	Lump sum		Lump sum	33,500		
	Subtotal				549,717		
	Contingencies (25±%)				137,383		
	Field Cost--Upper Main Canal				687,100		
	Engineering and General Expense (25±%)				171,900		
	Total est. const. cost--Upper Main Canal				859,000		
	IRRIGATION DISTRIBUTION SYSTEM--Unlined open laterals and structures for 7,080 net hectares of new service lands.					2,655,000	3,319,000
1	Served from lower main canal	3,650	ha	300.00	1,095,000		(1,711,000)
2	Served from upper main canal	3,430	ha	300.00	1,029,000		(1,608,000)
	Subtotal				2,124,000		
	Contingencies (25±%)				531,000		
	Field Cost--Distribution System				2,655,000		
	Engineering and General Expense (25±%)				664,000		
	Total est. const. cost--Distribution System				3,319,000		

Table I-7--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project: WEST MEGECH PUMPING--Irrigation

Date of Estimate: January 1964

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	DRAINAGE SYSTEM--Open land drains and						
	structures for 7,080 net hectares of					1,150,500	1,438,000
	irrigated lands.						(741,400)
1	Below the lower main canal	3,650	ha	130.00	474,500		(696,600)
2	Below the upper main canal	3,430	ha	130.00	445,900		
	Subtotal				920,400		
	Contingencies (25±%)				230,100		
	Field Cost--Drainage System				1,150,500		
	Engineering and General Expense (25±%)				287,500		
	Total est. const. cost--Drainage System				1,438,000		
	ACCESS ROADS--From existing Gorgora road to						
	pumping plants. Flat terrain, one-lane					125,000	156,000
	gravel.						
1	Access roads	5	km	20,000.00	100,000		
	Contingencies (25±%)				25,000		
	Field Cost--Access Roads				125,000		
	Engineering and General Expense (25±%)				31,000		
	Total est. const. cost--Access Roads				156,000		
	SERVICE FACILITIES--Includes office, shop,					150,000	188,000
	equipment, housing, streets, and utilities.						
1	Camp and equipment	Lump sum		Lump sum	120,000		
	Contingencies (25±%)				30,000		
	Field Cost--Service Facilities				150,000		
	Engineering and General Expense (25±%)				38,000		
	Total est. const. cost--Service Facilities				188,000		

East Megech Pumping Project

PLAN OF DEVELOPMENT

The plan of development for the East Megech Pumping Project would include a pumping plant, a main canal, a distribution system, and drainage canals for the irrigation of 5,890 hectares of land.

As in the case for West Megech Pumping Project, the lake would serve as a forebay. The pumping plant would pump the water into a main canal which would extend on a northerly direction with its terminus at the Megech River. The main canal would serve the lands between it and the eastern boundary of the Megech Gravity Project.

PROJECT FEATURES

The features of the project plan are described in reconnaissance detail in the following paragraphs and shown in general plan on Figure I-52. Data available were the same as the West Megech Pumping Project.

Pumping Plant

The plant would be located on the shore of Lake Tana about 16 kilometers east of the mouth of the Megech River. The pump intake would be placed below the minimum water surface, at 1783-meter elevation, to insure an adequate water supply at all times. A concrete pipe with a 1.8-meter diameter, of 7.54-cubic-meters-per-second capacity (266 c.f.s.), and 400 meters long would be required.

The static lift would be 37 meters. Assuming a total efficiency of 65 percent for the pumps and motors, the total motor nameplate rating required would be 6,850 horsepower. Cost of the pumping plant and prime movers has been obtained from curves.

Pumping Plant Data

Type of forebay	lake
Forebay elevation (minimum water surface)	1783 m.
Total dynamic head	45 m.
Static head	37 m.
Size of discharge pipe (diameter)	1.8 m.
Capacity of pumps	7.54 cu. m. per sec.
Motor rating	6,850 hp.

Main Canal

The discharge line of the pumping plant would end at the top of a high knoll. It would be necessary to siphon the water a distance of 650 meters to a point where the canal can begin. The canal would follow approximately along the 1820-meter contour for a distance of about 45 kilometers, having an initial capacity of 7.54 cubic meters per second. Besides many small laterals and turnouts, three fairly large capacity laterals will be required to convey the water to distribute the water to the irrigable lands.

Canal Data

Type	unlined
Length	45 km.
Initial capacity	7.54 cu. m. per sec.
Initial elevation	1820 m.

Distribution System and Drainage Canals

Similar requirements to the West Megech Pumping Plant.

Service Facilities

Similar requirements to the West Megech Pumping Plant.

ESTIMATED PROJECT COST

Construction Cost

Construction of East Megech Pumping Project is estimated to cost Eth$11, 488, 000 on the basis of January 1961 prices and as itemized with unit prices on Table I-8. The estimates of cost are reconnaissance in grade, and the following summary includes contingencies, engineering, and general expense.

Estimated Construction Cost

Feature	Cost
Pumping plant	Eth$ 3, 587, 000
Transmission line and substation	351, 000
Canals and laterals	3, 014, 000
Distribution system	2, 761, 000
Drainage canals	1, 197, 000
Access roads	406, 000
Service facilities	172, 000
Total	Eth$11, 488, 000

Development Cost

Clearing and land leveling costs are expected to be about the same as for the Megech Gravity Project as the conditions are similar. Total estimated cost for these two items, Eth$725, 000.

TABLE I-8--EAST MEGECH PUMPING PROJECT--RECONNAISSANCE ESTIMATE

RECONNAISSANCE ESTIMATE
BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project: EAST MEGECH PUMPING--Irrigation

Date of Estimate: January 1964

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U.S. $ 1.00 = Eth. $ 2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	EAST MEGECH PUMPING PROJECT--Irrigation					9,194,100	11,488,000
	PUMPING PLANT--Capacity, 7.54 m^3/sec; total dynamic head, 45 meters.					2,869,900	3,587,000
1	Cofferdam and unwatering site	Lump sum		Lump sum	16,000		
2	Excavation for intake channel, common	960	m^3	1.95	1,872		
3	Excavation for intake channel, rock	620	m^3	6.50	4,030		
4	Excavation and backfill for discharge pipe	13,500	m^3	4.00	54,000		
5	Pumping plant structure, outdoor type	Lump sum		Lump sum	1,150,000		
6	Pumps and prime movers	Lump sum		Lump sum	620,000		
7	Concrete discharge pipe, 1.8-meter diameter	1,500	lm	300.00	450,000		
	Subtotal				2,295,902		
	Contingencies (25±%)				573,998		
	Field Cost--Pumping Plant				2,869,900		
	Engineering and General Expense (25±%)				717,100		
	Total est. const. cost--Pumping Plant				3,587,000		
	TRANSMISSION LINE AND SUBSTATION--Required for pumping plant.					284,800	351,000
	Transmission Line--Northeast Tana Pumping Plant to East Megech Pumping Plant. 45 kv, steel pole with No. 2 AWG conductors.						
1	Average terrain (Field Cost)	13	km	7,600.00	98,800		
	Engineering and General Expense (20±%)				19,200		
	Total est. const. cost--Transmission Line				118,000		
	Substation						
2	Transformer	Lump sum		Lump sum	120,000		
3	Fuse disconnect switch	Lump sum		Lump sum	7,500		
4	Disconnect switch	Lump sum		Lump sum	13,000		
5	Motor protection	Lump sum		Lump sum	30,000		
6	Station service, communication, etc.	Lump sum		Lump sum	15,500		
	Field Cost--Substation				186,000		
	Engineering and General Expense (25±%)				47,000		
	Total est. const. cost--Substation				233,000		
	CANAL AND MAIN LATERALS--Unlined; length, 45 kilometers; capacities, 7.54 to 1.23 m^3/sec.					2,411,000	3,014,000
1	Canal excavation, common	518,400	m^3	0.95	492,480		
2	Compacting embankment	133,000	m^3	0.98	130,340		
3	Concrete and masonry structures	Lump sum		Lump sum	1,093,000		
4	Gates, hoists, valves, and misc. metalwork	Lump sum		Lump sum	28,000		
5	Concrete pipe	Lump sum		Lump sum	67,300		
6	Miscellaneous work	Lump sum		Lump sum	117,700		
	Subtotal				1,928,820		
	Contingencies (25±%)				482,180		
	Field Cost--Canal and Main Laterals				2,411,000		
	Engineering and General Expense (25±%)				603,000		
	Total est. const. cost--Canal and Main Laterals				3,014,000		

Sheet 1 of 2

Table I-8--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN–ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project: EAST MEGECH PUMPING--Irrigation

Date of Estimate: January 1964

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	IRRIGATION DISTRIBUTION SYSTEM--Unlined open						
	lateral system for 5,890 net hectares of						
	new project lands.					2,208,800	2,761,000
1	Laterals and structures	5,890	ha	300.00	1,767,000		
	Contingencies (25±%)				441,800		
	Field Cost--Distribution System				2,208,800		
	Engineering and General Expense (25±%)				552,200		
	Total est. const. cost--Distribution System				2,761,000		
	LAND DRAINAGE SYSTEM--Open land drains for						
	5,890 net hectares of irrigated lands.					957,100	1,197,000
1	Drains and drainage structures	5,890	ha	130.00	765,700		†
	Contingencies (25±%)				191,400		
	Field Cost--Drainage System				957,100		
	Engineering and General Expense (25±%)				239,900		
	Total est. const. cost--Drainage System				1,197,000		
	ACCESS ROAD--From existing Addis Zemin to						
	Azozo road to pumping plant. One-lane						
	gravel.					325,000	406,000
1	Access road, flat terrain	13	km	20000.00	260,000		
	Contingencies (25±%)				65,000		
	Field Cost--Access Road				325,000		
	Engineering and General Expense (25±%)				81,000		
	Total est. const. cost--Access Road				406,000		
	SERVICE FACILITIES--Includes offices, shop,						
	equipment, housing, streets, and utilities					137,500	172,000
1	Camp and equipment	Lump sum		Lump sum	110,000		
	Contingencies (25±%)				27,500		
	Field Cost--Service Facilities				137,500		
	Engineering and General Expense (25±%)				34,500		
	Total est. const. cost--Service Facilities				172,000		

Sheet 2 of 2

Operation, Maintenance, and Replacement Cost

Annual OM&R and power costs are estimated as follows:

Feature	Operation and maintenace	Special items and replacements	Power cost
Pumping plant	Eth$ 73,000	Eth$8,000	Eth$386,000
Electrical facilities to pumping plant	14,500	1,500	--
Conveyance system	224,000	--	--

PLAN SELECTION AND ALTERNATIVES

Since there were no alternative sources of water supply except from Lake Tana, studies were limited to various plans that could be devised for pumping water onto the Megech lands. One of these plans was discussed as an alternative plan in the report on the Megech Gravity Project. The most economical method would probably be several pump lifts whereby large quantities of water would not be lifted higher than the level where it would be used. Presently available data are not sufficient to allow further refinement. The plans described herein take advantage of sites along the lake shore where short discharge lines from the pump plants would be possible, and where the maximum quantity of land can be irrigated. On the East Megech Pumping Project, all of the water would be pumped to the highest level and then delivered to the land by gravity distribution. On the West Megech Pumping Project, the same general procedure was adopted except that two pump lifts appear practical in this case, and this serves as a good example for a multiple-lift pumping project.

Although the land area of the Megech Gravity Project has not been included in the pumping project plans, it could easily be served by the East Megech Pumping Project, eliminating the need for the storage dam and reservoir, however, it would be necessary to enlarge the East Megech Canal and its pumping plant. Otherwise, all canals and laterals of both projects would remain the same.

Northeast Tana Pumping Project

GENERAL DESCRIPTION

The land areas considered are located on the lake plain on the northeast shore of Lake Tana, extending from Mitraa Island southward to the edge of the Ribb River valley. The area is about 14 kilometers in length and from 2 to 6 kilometers in width. The broad, flat-sloped area is cut by a few small streams and is interrupted by a few hills and knolls which are an extension of the hilly area occurring just north of the village of Addis Zemin. The main road from Gondar to Addis Zemin passes very near the northeastern limit of the project. See Figure I-53 for general topography of the area.

Project Lands

The soils of the proposed project, while very similar to the Ribb River Project, are generally of more recent origin and are somewhat more stratified. Seasonal flooding occurs occasionally in this area, and deposits sediment over the land. However, because of the fine texture of the soils on the adjacent uplands (mostly dark clays), the recent sediment deposits are difficult to distinguish from previous deposition. The lands were determined to be in the Class 3 category. Of the 6, 430 hectares of arable land below the canal, 5, 000 hectares were determined to be irrigable for the production of crops.

Hydrology

Lake Tana is the only source of water supply for the proposed project. Annual farm delivery requirements were determined to be 0. 958 meter, the diversion requirements, adding 30 percent for seepage and operational loss before reaching the farmer, would be 13, 400 cubic meters per hectare for a total water requirement for the project area of 67, 000, 000 cubic meters for the 5, 000 hectares of land.

PLAN OF DEVELOPMENT

The plan of development for the Northeast Tana Pumping Project includes a pumping plant, a main canal, a lateral distribution system, and drainage canals for irrigation of 5, 000 hectares of new service land. Water would be pumped from Lake Tana by means of a pumping plant and then conveyed to the land by a main canal as shown.

PROJECT FEATURES

The features of the project plan are described in reconnaissance detail in the following paragraphs and shown in a general plan on Figure I-54. Topographic maps were compiled by stereoscopic projection (multiplex) on 20-meter contour intervals from aerial photographs. Altimeters were used for vertical controls. Engineering data and layouts of the project were based on these maps.

Pumping Plant

The plant would be located on the shore of Lake Tana at a point about 1 kilometer from Mitraa Island. It would have a concrete discharge pipe about 70 meters long of concrete, 1.67 meters in diameter, with a design capacity of 6.44 cubic meters per second (227 c.f.s.). The static head would be 34 meters, discharging into the main canal at elevation 1820 meters. The total motor nameplate rating required would be 4,500 horsepower.

Pumping Plant Data

Type of forebay	lake
Forebay elevation (invert)	1783 m.
Total dynamic head	34.5 m.
Static head	34 m.
Size of discharge pipe (diameter)	1.67 m.
Capacity of pumps	6.44 cu. m. per sec.
Motor rating	4,500 hp.

Main Canal

The main canal would originate at the discharge pipe from the pumping plant and follow approximately along the 1820-meter contour for approximately 67 kilometers. Its initial capacity would be 6.44 cubic meters per second. It would extend on a northerly direction for about 10 kilometers and then turn sharply on a southerly direction to its terminus.

Canal Data

Type	unlined
Length	67 km.
Initial capacity	6.44 cu. m. per sec.
Initial water surface elevation	1820 m.

Distribution System and Drainage Canals

Construction of the distribution system and drainage canals should not present any major problems, as the relief of the land is smooth and uniformly sloping, well adapted to the use of modern mechanized equipment.

Service Facilities

Housing for operation and maintenance personnel will be required for the pumping plant and for the irrigation facilities.

ESTIMATED PROJECT COST

Construction Cost

The total construction cost for the Northeast Tana Pumping Project is estimated to be Eth$9,634,000 on the basis of January 1961 prices and as itemized with unit prices on Table I-9. The estimates of cost are reconnaissance in grade and the following summary includes contingencies, engineering, and general expense.

TABLE I-9--NORTHEAST TANA PUMPING PROJECT--RECONNAISSANCE ESTIMATE

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project NORTHEAST TANA PUMPING--Irrigation

Date of Estimate February 1964

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U S $1.00 = Eth $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	NORTHEAST TANA PUMPING PROJECT--Irrigation					7,713,000	9,634,000
	PUMPING PLANT--Capacity, 6.44 m^3/sec.; total dynamic head, 34.5 meters.					1,451,900	1,815,000
1	Cofferdam and unwatering site	Lump sum		Lump sum	15,000		
2	Channel excavation, common	820	m^3	1.95	1,599		
3	Channel excavation, rock	530	m^3	6.50	3,445		
4	Excavation and backfill for discharge pipe	560	m^3	4.00	2,240		
5	Pumping plant structure, outdoor type	Lump sum		Lump sum	720,000		
6	Pumps and prime movers	Lump sum		Lump sum	400,000		
7	Concrete discharge pipe, 1.67 meter diameter	70	lm	275.00	19,250		
	Subtotal				1,161,534		
	Contingencies (25±%)				290,366		
	Field Cost--Pumping Plant				1,451,900		
	Engineering and General Expense (25±%)				363,100		
	Total est. const. cost--Pumping Plant				1,815,000		
	TRANSMISSION LINE AND SUBSTATIONS--Required for irrigation pumping.					401,000	493,000
	Transmission line--45-kv, from Stella Substation to Northeast Tana Pumping Plant. Steel pole with 2 AWG conductors.						
1	Average terrain (Field Cost)	20	km	7,600.00	152,000		
	Engineering and General Expense (20+%)				30,000		
	Total est. const. cost--Transmission Line				182,000		
	Substation--At pumping plant						
2	Transformer	Lump sum		Lump sum	65,000		
3	Fuse disconnect	Lump sum		Lump sum	12,000		
4	Disconnect switch	Lump sum		Lump sum	7,000		
5	Motor protection	Lump sum		Lump sum	24,000		
6	Station service and communication	Lump sum		Lump sum	16,000		
	Field Cost--Substation				124,000		
	Engineering and General Expense (25±%)				31,000		
	Total est. const. cost--Substation				155,000		
	Stella Substation--Stage 02 only. Drawing No. 4.0-BN-193						
7	Bay Z1, 45 kv	Lump sum		Lump sum	60,000		
8	Bay Z3, 45 kv	Lump sum		Lump sum	65,000		
	Field Cost--Stella Substation				125,000		
	Engineering and General Expense (25+%)				31,000		
	Total est. const. cost--Stella Substation				156,000		
	MAIN CANAL--Unlined; length, 67.0 kilometers; capacity 6.44 to 1.98 m^3/sec.					2,828,800	3,536,000
1	Canal excavation, common	483,600	m^3	0.95	459,420		
2	Canal excavation, rock	14,900	m^3	9.75	145,275		
3	Compacting embankment	128,600	m^3	0.98	126,028		
4	Structures, concrete and masonry	Lump sum		Lump sum	1,282,400		
5	Gates, hoists, valves, and misc. metalwork	Lump sum		Lump sum	32,900		
6	Concrete pipe	Lump sum		Lump sum	78,900		
7	Miscellaneous work	Lump sum		Lump sum	138,100		
	Subtotal				2,263,023		
	Contingencies (25±%)				565,777		
	Field Cost--Main Canal				2,828,800		
	Engineering and General Expense (25±%)				707,200		
	Total est. const. cost--Main Canal				3,536,000		

Sheet 1 of 2

Table I-9--Continued

RECONNAISSANCE ESTIMATE
BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project NORTHEAST TANA PUMPING--Irrigation

Date of Estimate February 1964

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U S $1.00 = Eth. $2.50)

ITEM NO	ITEM	QUANTITY AMOUNT	UNIT	EQUIPMENT MATERIAL AND LABOR UNIT COST	EQUIPMENT MATERIAL AND LABOR COST	FIELD COST	TOTAL CONSTRUCTION COST
	IRRIGATION DISTRIBUTION SYSTEM--Unlined open lateral system for 5,000 net hectares of new project lands.					1,875,000	2,344,000
1	Laterals and structures	5,000	ha	300.00	1,500,000		
	Contingencies (25±%)				375,000		
	Field Cost--Distribution System				1,875,000		
	Engineering and General Expense (25±%)				469,000		
	Total est. const. cost--Distribution System				2,344,000		
	LAND DRAINAGE SYSTEM--Open land drains for 5,000 net hectares of irrigated lands.					812,500	1,016,000
1	Drain and structures	5,000	ha	130.00	650,000		
	Contingencies (25±%)				162,500		
	Field Cost--Drainage System				812,500		
	Engineering and General Expense (25±%)				203,500		
	Total est. const. cost--Drainage System				1,016,000		
	ACCESS ROAD--From existing Addis Zemin to Azozo road to pumping plant. One-lane gravel.					212,500	266,000
1	Access road, mostly flat terrain	8.5	km	20,000.00	170,000		
	Contingencies (25±%)				42,500		
	Field Cost--Access Road				212,500		
	Engineering and General Expense (25±%)				53,500		
	Total est. const. cost--Access Road				266,000		
	SERVICE FACILITIES--Includes office, shop equipment, housing, streets, and utilities.					131,300	164,000
1	Camp and equipment	Lump sum		Lump sum	105,000		
	Contingencies (25±%)				26,300		
	Field Cost--Camp and Equipment				131,300		
	Engineering and General Expense (25±%)				32,700		
	Total est. const. cost--Camp and Equipment				164,000		

Sheet 2 of 2

Feature	Cost
Pumping plant	Eth$1, 815, 000
Transmission lines and substations	493, 000
Main Canal	3, 536, 000
Distribution system	2, 344, 000
Drainage canals	1, 016, 000
Access roads	266, 000
Service facilities	164, 000
Total	Eth$9, 634, 000

Estimated Construction Cost

Development Cost

Clearing and land leveling are expected to be minimal as the topography is generally uniform with gentle slopes. Cost for these two items is estimated to be roughly Eth$500, 000.

Operation, Maintenance, and Replacement Cost

Annual OM&R and power costs are estimated as follows. Annual energy requirement, based on the irrigation season, should be about 8, 642, 000 kilowatt-hours.

Feature	Operation and maintenance	Special items and replacement	Power cost
Pumping plant	Eth$ 55, 000	Eth$7, 000	Eth$260, 000
Electrical facilities to pumping plants	13, 000	2, 000	--
Conveyance system	195, 000	--	--

PLAN SELECTION AND ALTERNATIVES

Pumping water from Lake Tana appears to be the only feasible method of providing water for irrigation of the land included in this project. There is no site nearby where water could be stored for gravity irrigation, nor is there sufficient drainage area to provide the water required. It might be possible to provide water for this area from storage in the Ribb River Valley; however, the development plan for the Ribb Project would make better use of the available water and storage in other areas.

The plan of development presented herein assumes the construction of only one pumping plant for the entire project which is located so as to provide the shortest possible pump discharge line and to serve the maximum possible amount of land. This scheme would probably present the lowest per-hectare cost for construction. However, if the cost of operation of the project is considered, the overall cost of the project would probably be reduced if several smaller pump lifts are used, each lifting water only to the level where it would be used.

SECTION 3--BELES SUB-BASIN

Introduction

Reconnaissance studies performed on the Beles River drainage basin indicated a limited power potential and a fairly large block of land that was suitable for irrigation development but lacked sufficient water for economic exploitation. The plan of development for the basin conceives the importation of water from Lake Tana by regulating the lake. The development of the basin includes two projects--the Upper Beles Multipurpose Project and the Middle Beles Power Project (Figure I-55)--for the multiple objectives of utilizing the land and water resources for irrigation and hydroelectric power production.

GENERAL DESCRIPTION

Area Description

The Beles Sub-basin is located on the west central portion of the Blue Nile Basin and has an area of about 20,000 square kilometers. Situated at about an average elevation of 1150 meters above sea level, the basin is bounded on the east by a precipitous escarpment and on the west by rolling to hilly terrain that divides it from the Dindir drainage basin. The main stem of the Beles River originates on the face of the escarpment across the divide to the west of the southwestern portion of Lake Tana. It runs in a southwesterly direction to a point where it leaves the project area, then swings westward to its confluence with the Blue Nile River near the Sudan border.

The area under consideration for the potential irrigation development extends along both sides of the Beles River, starting about 35 kilometers from its headwaters and reaching downstream to the old village of Mambuk, a distance of approximately 75 kilometers. At its widest point, the area is about 30 kilometers wide.

Geology and Physiography

Metamorphic and granitic rocks are exposed along the incised river channels. However, residues of basaltic rock frequently appear in the lower part of some soil profiles, so it appears that weathering of basalt has had more influence on soil development than the metamorphic rocks. Local alluviums occur throughout the area but more extensively in the northeastern portion. In this area there are many recent alluvial depositions of colluvium and outwash fans. Much of the northwestern area appears to be ancient alluvial fan depositions, which have weathered considerably in place. The southern half, except for land near the escarpment, appears to be residual soils weathered from ancient basalt.

The physiography also varies from north to south. The southern half is generally characterized by a well defined, well incised, dendritic drainage pattern with many narrow ridges. The northern half, and particularly the northwestern portion, has a broad, smooth, gently rolling plain with much broader ridge tops and less distinct natural drainageways.

Climate

There are no climate stations in the project area but at the project elevation of 1150 meters, the climate is warm and subtropical. Records from nearby stations indicate

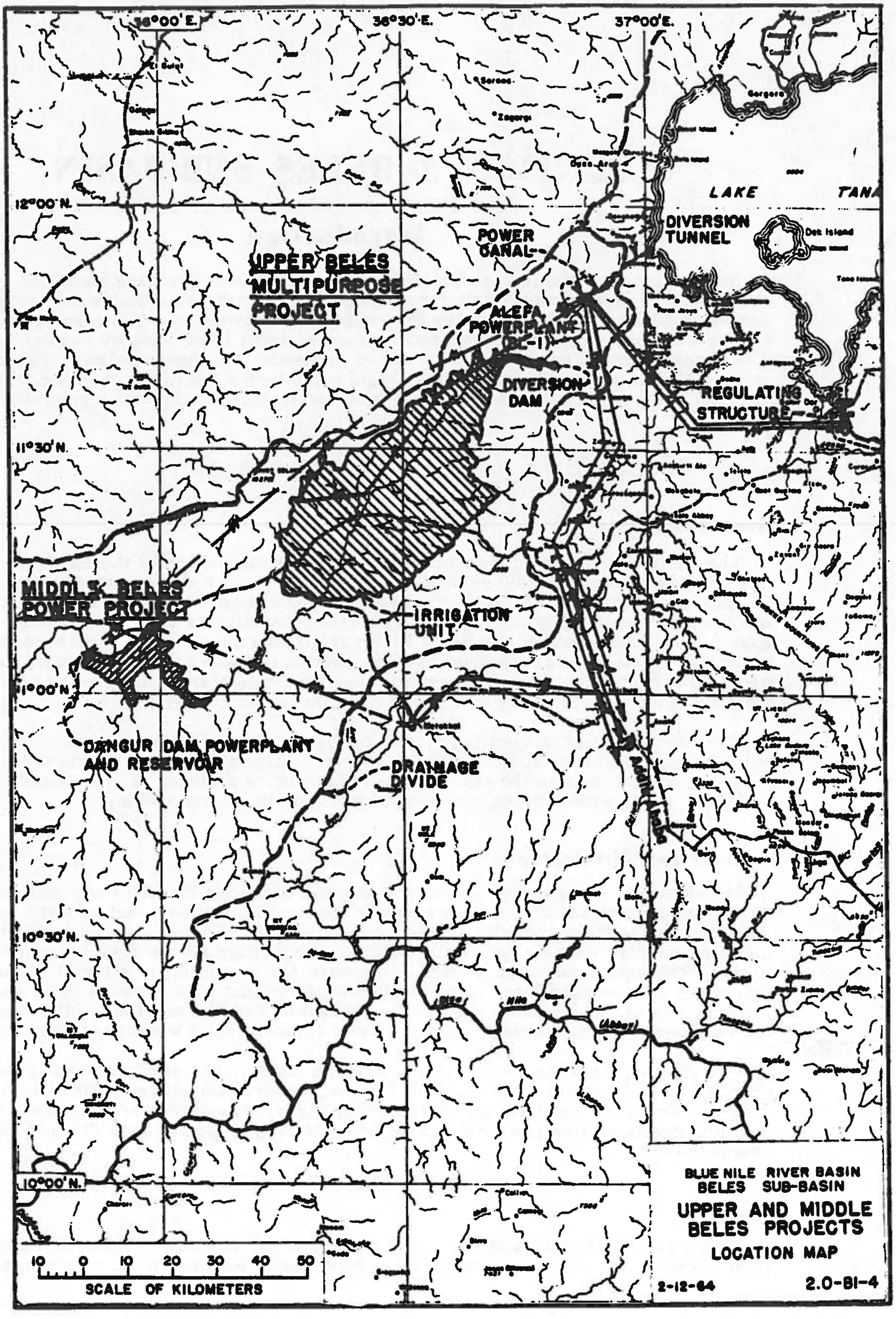


Figure I-55--Upper and Middle Beles Projects--Location Map that an average annual temperature of near 25° C might be anticipated, with fluctuations in the range of 8° to 35° C. Precipitation is estimated to total 100 centimeters per year. Accurate climatic data are needed for any advanced planning. Several years of record are needed to indicate the fluctuations in temperature and precipitation that may be anticipated.

Projects Land

Grumusols or black clay soils predominate in the Beles River Basin and particularly in the northwestern area where topographic conditions are best suited for irrigation. They exhibit marked contraction and cracking when dry. They are quite plastic and nearly impermeable when wet. Tillage is very difficult because of the tough clay soils. Irrigation is secured through the cracks.

Reddish brown lateritic soils occur most frequently in the southern half and comprise about 40 percent of the total project area. The latosols are permeable and very well adapted to irrigation.

The following table summarizes the results of the land classification conducted in the area.

Land Classes (ha.)

Area	Class 1	Class 2	Class 3	Total
Total arable	5,700	35,000	67,200	107,900
Arable under canal	4,900	30,100	62,200	97,200
Irrigable	3,200	19,600	40,400	63,200

Drainage conditions are expected to be variable, depending largely upon topographic conditions. The northwestern area, which has the smoothest topography, can be expected to have the most drainage problems, due to the fact that the natural drainageways are mostly shallow and widely spaced. Possibly subsurface drainage systems may be required. The northeastern area has flood-plain type of natural drainageways at present, with intermittent, narrow, moderately deep, eroded channels. Internal drainage characteristics of the soils here are generally considerably better than in the northwestern sector. This approximate half of the project area has a well developed drainage system, and additional drainage construction is expected to be minimal.

Hydrology

Because of the irrigation project area being on the upper part of the drainage basin, the Beles River would provide only an insignificant amount of water compared to the requirements for the irrigable land. Water from Lake Tana, conveyed by means of a diversion tunnel, is therefore planned for irrigation of the potential project area and for power production. It is planned to utilize a portion of the water discharged from the Alefa Powerplant only for irrigation, the balance being bypassed to the Dangur Reservoir farther downstream.

Studies conducted to determine the consumptive use of water by crops resulted in an estimated farm delivery requirement of 1.022 meters. Allowing 35 percent for losses--15 percent for seepage and 20 percent for operational waste--the estimates for diversion requirements per hectare would then be 1.57 meters (5.15 feet) annually.

Upper Beles Multipurpose Project

PLAN OF DEVELOPMENT

The development plan for the upper Beles River area envisages the construction of a regulating structure at the outlet of Lake Tana; a diversion tunnel from the southwestern part of Lake Tana to the Beles drainage basin; a power canal leading into a shaft and tunnel; penstocks and a powerplant; an irrigation diversion dam, main canals, and two pumping plants; and a distribution system and drainage canals for irrigation of 63,200 hectares of land and 1,197 million kilowatt-hours of electric generation per year.

A low, masonry-concrete, gravity dam at the outlet of Lake Tana at the southern end of the lake would convert the lake into an artificial reservoir by controlling its level at or near the maximum elevations now recorded. The stored water would then be diverted by means of a 5.3-meter-diameter concrete tunnel, some 6.7 kilometers in length, to the water-deficient Beles Basin. A power canal of 110 cubic meters per second capacity would then convey the water, following the 1760-meter contour, to discharge into a 245-meter drop shaft and tunnel; four steel penstocks, each of 2.7-meter diameter, would be installed, discharging into the turbines of the Alefa Powerplant with four 50,000-kw capacity generators. The transmission lines would carry the generated power to the load centers of Addis Ababa, Gondar, Bahir Dar, and as far west as Metekkel.

Discharging directly into the Beles River channel, a portion of the water required for irrigation would be diverted by the Beles Irrigation Diversion Dam, some 25 kilometers downstream from the powerplant. Two canals, the North Main Canal and the South Main Canal, would originate at the two outlet works on the abutments of the diversion dam. Starting at the 1300-meter contour, the South Main Canal would extend in a southerly direction for 144 kilometers with an initial capacity of 38.8 cubic meters per second. The North Main Canal would also start at the 1300-meter contour and would extend in a southerly direction for 143 kilometers. The design capacity for this canal would be 36.1 cubic meters per second. Two pumping plants are included in the development plan to serve an additional 7,600 hectares of land. Pumping Plant No. 1 would be located at Kilometer 87.5, and Pumping Plant No. 2 at Kilometer 105.

A distribution system to convey the water to the farmers' turnouts and drainage canals to carry away the irrigation waste would be included in the facilities of the Beles Irrigation Unit of the multipurpose project.

Lake Tana Unit

The features of the Lake Tana Unit of the Upper Beles Multipurpose Project are described in reconnaissance detail in the following paragraphs and are shown in general plan on Figure I-56. The topographic map of the river channel prepared by the J. G. White Engineering Corporation and published in 1930 was used, after being spot checked and adjusted to the U.S. Coast and Geodetic Survey datum.

LAKE TANA DAM

The selected site for the low dam is located on the Chara Chara cataracts a few hundred meters downstream from the lake outlet and some distance upstream from the recently completed concrete bridge. It would be a masonry-concrete structure abutting compacted earthfill dikes. The function of the dam would be to convert Lake Tana into an artificial reservoir to store the rainy season flows for irrigation and hydroelectric power production. It would be a gated structure for practically the entire width of the channel, being 9 meters high above streambed with a total length of 150 meters. Diversion during construction would be accomplished in two stages. Plan, elevations, and section of the structure appear on Figure I-57.

Dam Data

Type	masonry-concrete gravity
Volume of masonry	7,010 cu.m.
Volume of concrete	2,860 cu.m.
Structural height	9 m.
Hydraulic height	4.57 m.
Length of crest	150 m.
Sill elevation	1783 m.

Spillway. The design for passing the flood flows was based on the following criteria. The July-through-September inflow for 1959 (the largest quantity of record) was used as the basis and a 15-day rain-produced flood was added to this base to obtain the design inflow flood hydrograph. This 3-month flood with a peak flow of 5,150 cubic meters per second and a volume of 10,040 million cubic meters was routed with the following assumptions.

1. The Beles Diversion Tunnel would be discharging at required rates for power production.
2. The lake would be at elevation 1785.34 on June 30.
3. Gate openings would be assumed sufficiently large to pass the design inflow flood when lake level was at normal water surface elevation of 1787.25 and not to exceed elevation 1787.57 meters.

In routing the flood, a spillway designed to pass 835 cubic meters per second at maximum water surface elevation of 1787.57 meters was required. With the sill elevation of the gated structure at elevation 1783 meters, it was found that 20 radial gates, each 6.5 meters long and 4.25 meters high and supported by 1.25-meter-thick piers would accomplish the desired results, Each gate is estimated to weigh approximately 9,000 kilograms. Releases for downstream requirements (Minimum of 3 cubic meters per second) would be accomplished by manipulation of the gates.

Dikes and River Channel Improvements. Dikes and channel improvements will be necessary to contain the floods within the existing channel and to smooth out the approach flows to the regulating structure. The channel improvements would extend from the lake at the south end of Debre Mariam Island through the Chara Chara cataracts to the foot of Fukur Ishal Island. This channel would have a base width of 150 meters and 1.5:1 side slopes. The bottom of the channel would be at elevation 1783 meters for its entire length.

Abutting the concrete-masonry control structure would be compacted earthfill dikes totaling some 750 meters in length. The West Dike would make a sharp bend downstream to close off the low sections through the reef for some 500 meters in length; the East Dike would also bend somewhat downstream for some 250 meters.

More than 300,000 cubic meters of rock excavation to improve the channel hydraulically are estimated. Potholes in the river channel would be filled and rock obstructions removed. Included in the plan of development would be an access road on top of the West Dike for servicing and operating the gated structure.

Lake Tana Reservoir

Conversion of Lake Tana into an artificial reservoir would be accomplished by construction of the low dam at the outlet channel. Placing the sill elevation of the control structure at 1783 meters, the reservoir will have an active capacity of 10,604 million cubic meters. The historical record low water surface elevation is 1785.34. Sediment at even the 100-year period is not expected to encroach on the active storage capacity. The stored water will be used for multiple-purpose development of the Beles drainage basin. For area-capacity data, see Figure I-58.

Site Geology

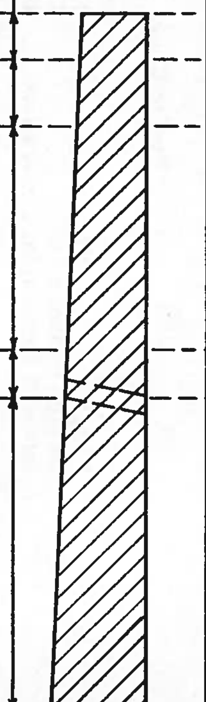
The selected site will be on a foundation of hard basalt, which is generally exposed in the wide, shallow river channel. The rock is fractured, but, with excavation to remove the fractures and mud seams, it is believed that the foundation will be satisfactory for the proposed dam. A grout curtain will be required to consolidate the foundation rock and reduce possible seepage under the dam.

Construction Materials

Impervious embankment materials of residual soils are available on the slopes and ridges near the damsite. Basaltic rock for pervious embankment, riprap, masonry stone, or crushed aggregate can be quarried near the damsite.

NOTE: 50- and 100-year sediment deposition is not expected to encroach on active capacity; 100-year sediment, 248 million cubic meters.

LAKE TANA DAM & RESERVOIR
AREA CAPACITY DATA

CONTROL POINTS				INITIAL AREA	CAPACITY (CUBIC METERS – 10^6)			
ITEM & ALLOCATION OF STORAGE CAPACITY		DIAGRAM OF DAM	ELEVATION (METERS)	(SQ. METERS – 10^6)	INITIAL		WITH 50-YR. SEDIMENT	
					INCREMENT	TOTAL	INCREMENT	TOTAL
TOP OF DAM			1792.0					
	FREEBOARD							
MAXIMUM W.S.			1787.57	3,216		14,010*		
	FLOOD SURCHARGE				1,023			
NORMAL W.S.			1787.25	3,185		12,987*		
	ACTIVE CAPACITY				10,604		50-year sediment deposition will be negligible.	
MINIMUM OPERATING W.S.			1783.89	2,989		2,383*		
	INACTIVE CAPACITY				2,383			
SILL ELEVATION			1783.00	2,957		0*		
	DEAD STORAGE AND SILT				17,000±			
LAKE BOTTOM			1773±	0		0		

* Capacities given are above outlet sill elevation.

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Figure I-58--Lake Tana Dam and Reservoir--Area-Capacity Data

Lake Tana-Beles Diversion Tunnel and Alefa Powerplant

The features of this unit of the project are described in reconnaissance detail in the following paragraphs and appear in general plan in Figure I-59. Topography of the area was compiled from stereoscopic (multiplex) projection from aerial photographs (1:50,000 scale), using second order triangulation for vertical and tellurometer for horizontal controls. Engineering data were based on 20-meter contour interval maps.

CONVEYANCE SYSTEM

Diversion Tunnel

The site for the inlet portal of the diversion tunnel would be located on the southwestern shore of the lake on a small bay near the village of Alefa. The tunnel would be concrete lined, with a finished diameter of 5.3 meters. It would be a free-flow tunnel, in that at maximum capacity of 110 cubic meters per second it would be flowing at about 80 percent of its area. It would be about 6,700 meters in length. Other appurtenant structures include inlet and outlet works, with cost for care and dewatering during construction being included in the estimates.

Tunnel Data

Type	free-flow
Volume of concrete	54,000 cu.m.
Length	6,700 m.
Diameter	5.3 m.
Design capacity	110 cu.m. per sec.

Power Canal

The canal would originate at the discharge end of the stilling basin. It would be about 12 kilometers in length and would be masonry lined. Capacity of the canal would be 110 cubic meters per second. Cost for this canal would include headworks and terminal structures as well as cross drainage structures.

Power Canal Data

Type	masonry-lined
Length	12 km.
Design capacity	110 cu.m. per sec.
Initial water surface elevation	1760 m.

Pressure-penstock Tunnel and Shaft

From the forebay of the power canal, the water would be discharged into a vertical shaft. The shaft would extend from approximate elevation 1745 meters to elevation 1500 meters, a drop of 245 meters. The tunnel would then be continued on the horizontal at elevation 1500 meters for a distance of 1,850 meters. It would then be divided into two 6.65-meter-diameter tunnels, each tunnel to house two 2.7-meter-diameter welded steel penstocks. The four penstocks in the two tunnels would each be 1,200 meters long and would terminate at the powerplant.

Penstock and Tunnel Data

Data	Unit	Shaft	Pressure tunnel	Two penstock tunnels (ea)	Four penstocks (ea)
Length	m.	245	1,850	1,200	1,200
Diameter	m.	6	6	6.65	2.7
Capacity	cu.m/per sec.	110	110	55	27.5

Site Geology

The diversion tunnel will traverse volcanic lava rocks. These rocks have been broken by a series of northeast-southwest trending faults, which generally parallel the western side of the lake. The outlet of the tunnel is generally beyond the fault zone and in more or less massive, horizontally bedded basalt.

An underground powerplant was not considered feasible at the base of the shaft due to the fact that the rocks were too jointed and fractured. The geologic conditions believed to exist in the area dictated the use of reinforced concrete-lined tunnels. Unusual problems during tunnel excavation are not anticipated. (See Appendix II, "Geology," for further details.)

POWER SYSTEM

Alefa Powerplant

The powerplant would be located near the headwaters of the Beles drainage basin, adjacent to the Beles River, with the tailrace of the powerplant being the river channel. It would be equipped with four, Francis-type turbines of 70,550 horsepower. Four generators of 50 mw. each would be installed, providing a total plant capacity of 250 mv.-a. at 0.8 power factor.

Powerplant Data

Design head	239 m.
Number of generators	4
Rating of each generator	50,000 kw.
Total plant capacity	250,000 kv.-a.
Turbine ratings (English)	70,550 hp.
Synchronous speed	375 r.p.m.
Type of turbines	Francis

Switchyard

The switchyard for the Alefa Powerplant would be located near the powerplant and would include eight bays with single and double breakers with 132-kv. lines. Included in the estimates of construction costs would be transformers and circuit breakers. For powerplant and switchyard electrical facilities, see Figure I-60.

Transmission Lines

To transport the energy generated, transmission lines totaling some 946 kilometers are envisioned. Construction costs include conductors and, in addition, overhead ground wire for voltages over 45 kv.

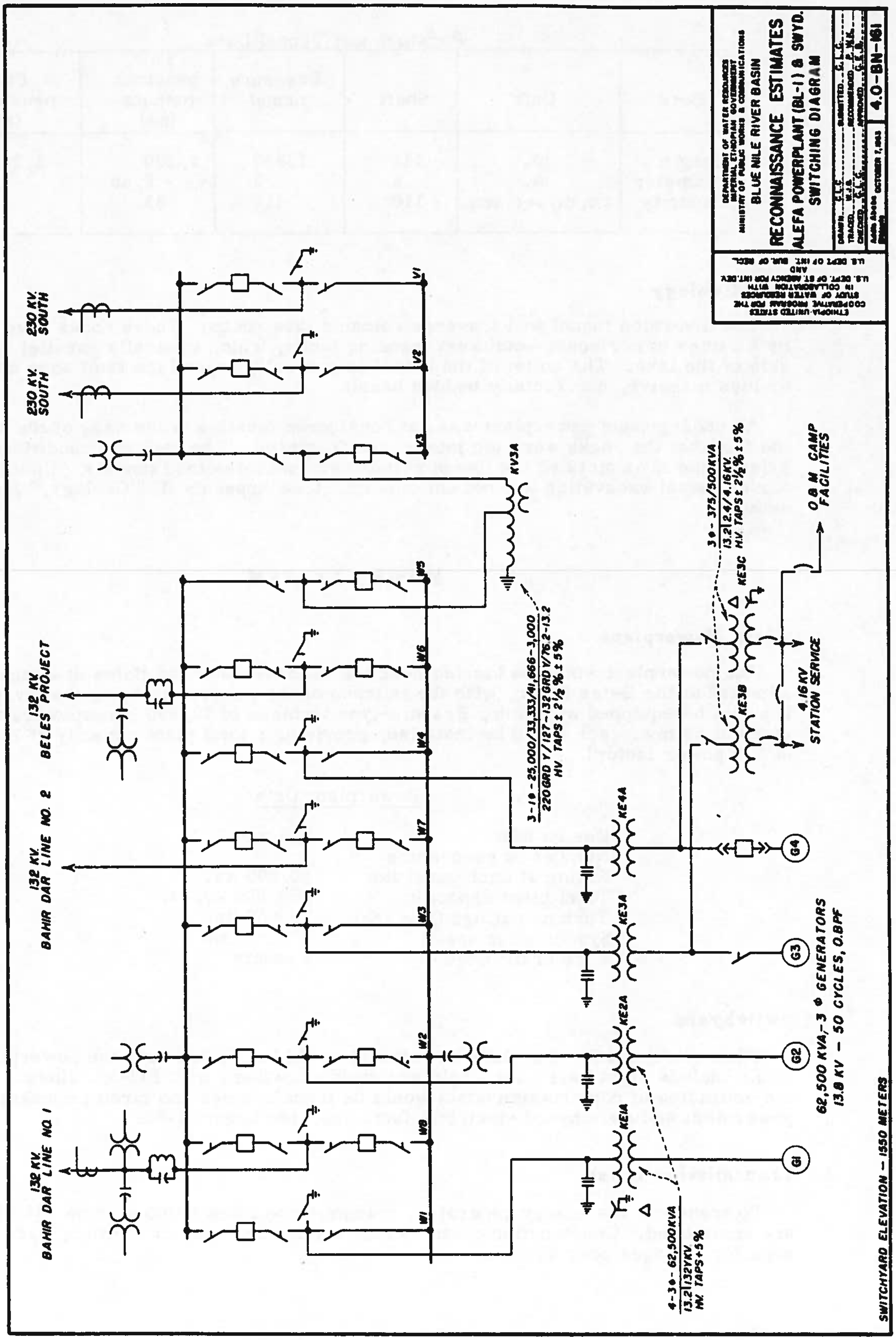


Figure I-60--Alefa Powerplant (BL-1) and Switchyard--Switching Diagram

Transmission Lines Data

Facilities		Length	Voltage	Structure	Circuit
From	To	(km.)	(kv.)	(type)	(No.)
Alefa Powerplant	Bahir Dar	65	132	Steel tower	double
Alefa Powerplant	E. Addis Ababa	450	230	Steel tower	double
Bure	Jiga	37	45	Steel pole	single
Bure	Injibira	70	45	Steel pole	single
Injibira	Metekkel	50	45	Steel pole	single
Bahir Dar	Gondar (via Stella)	146	132	Steel tower	single
Stella	Debre Tabor	40	45	Steel pole	single
Alefa Powerplant	Pump No. 2	80	132	Steel tower	single
Pump No. 2	Pump No. 1	8	15	Steel pole	single

Substations

Various substations at the terminals of the transmission lines will be required to step down the voltages at the different load centers. The substations would be of the outdoor type with controls and service equipment located indoors. It will be noted that some of the substations will be in various stages of development as the power is put on the line. Included in the estimates of cost are bays of various capacities, transformers, switching facilities, and station service equipment. Schematic diagram of the 11 substations (excluding pumping plants) appears in the following indicated drawings.

Substations

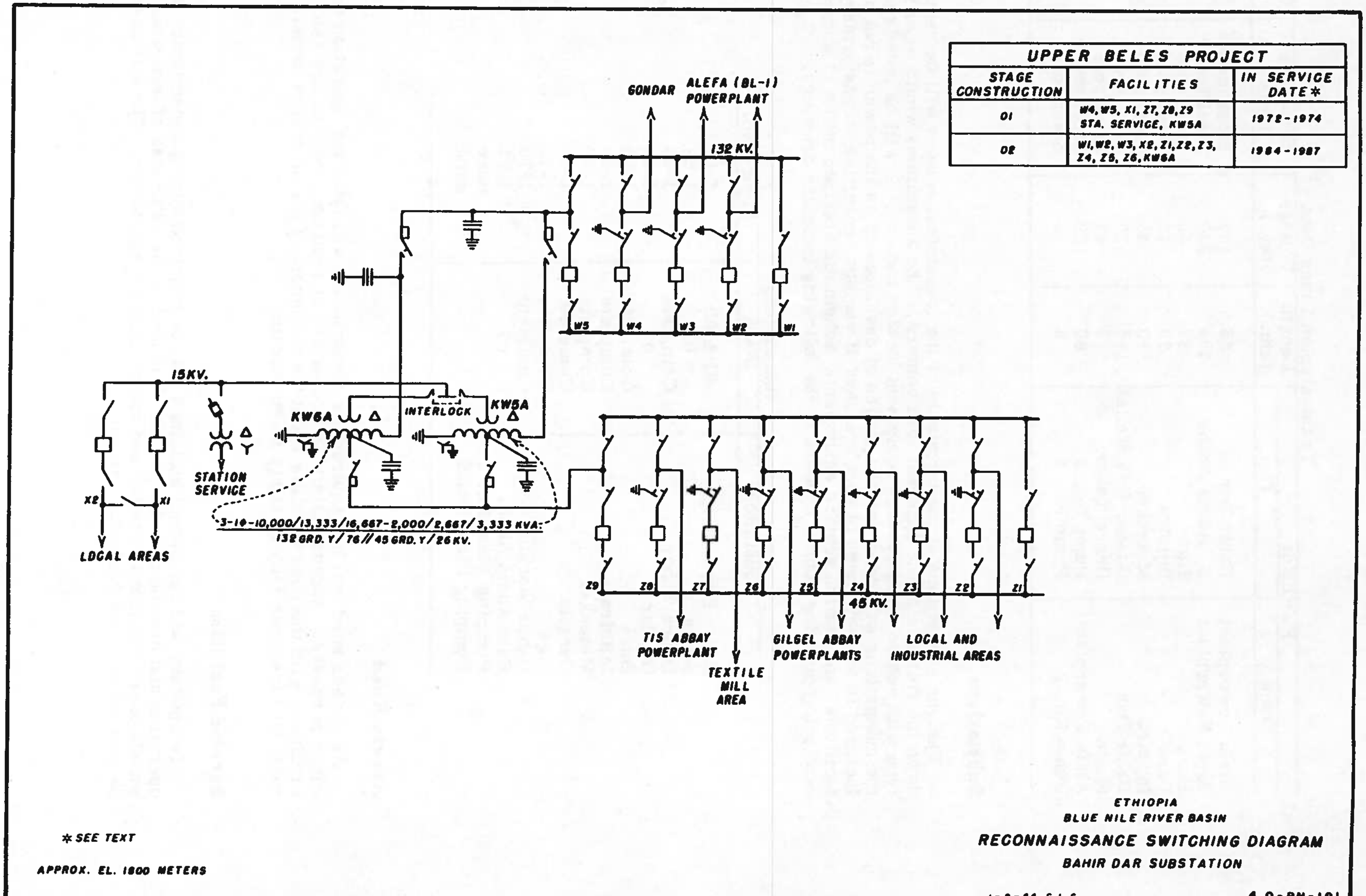
Substation	Stage	Figure No.
Bahir Dar	01 & 02	I-61
Stella	01	I-62
Debre Tabor	Complete	I-63
Gondar	01	I-64
Bure	Complete	I-65
Injibira	Complete	I-66
Metekkel	Complete	I-67
Dangila	Complete	I-68
Jiga	Complete	I-69
Debre Markos	Complete	I-70
East Addis Ababa	03	I-71
Pumping Plant No. 1		none
Pumping Plant No. 2		none

Access Road

An access road will be required for construction and later for operation and maintenance purposes. Approximately 28 kilometers of road construction are estimated to be required, with the road to follow about the alignment of the diversion tunnel. The proposed route will traverse hilly to fairly steep terrain.

Service Facilities

Temporary and permanent buildings will be required during construction and later for operation and maintenance personnel. Included in the estimates of cost would be shops, warehouses, and transportation and communication equipment. The site is expected to be located near the Alefa Powerplant.



UPPER BELES PROJECT		
STAGE CONSTRUCTION	FACILITIES	IN SERVICE DATE*
01	W4, W5, X1, Z7, Z8, Z9 STA. SERVICE, KW5A	1972-1974
02	W1, W2, W3, X2, Z1, Z2, Z3, Z4, Z5, Z6, KW6A	1984-1987

Figure I-61--Bahir Dar Substation--Switching Diagram

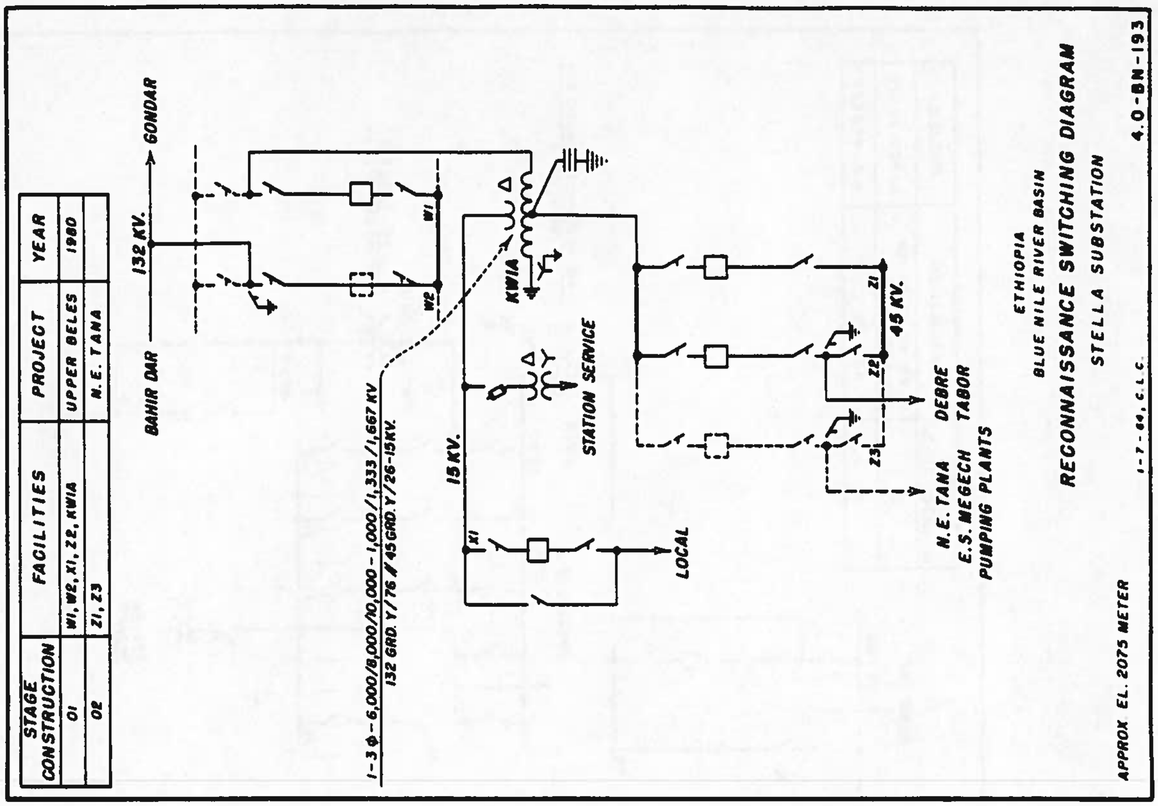


Figure I-62--Stella Substation--Switching Diagram

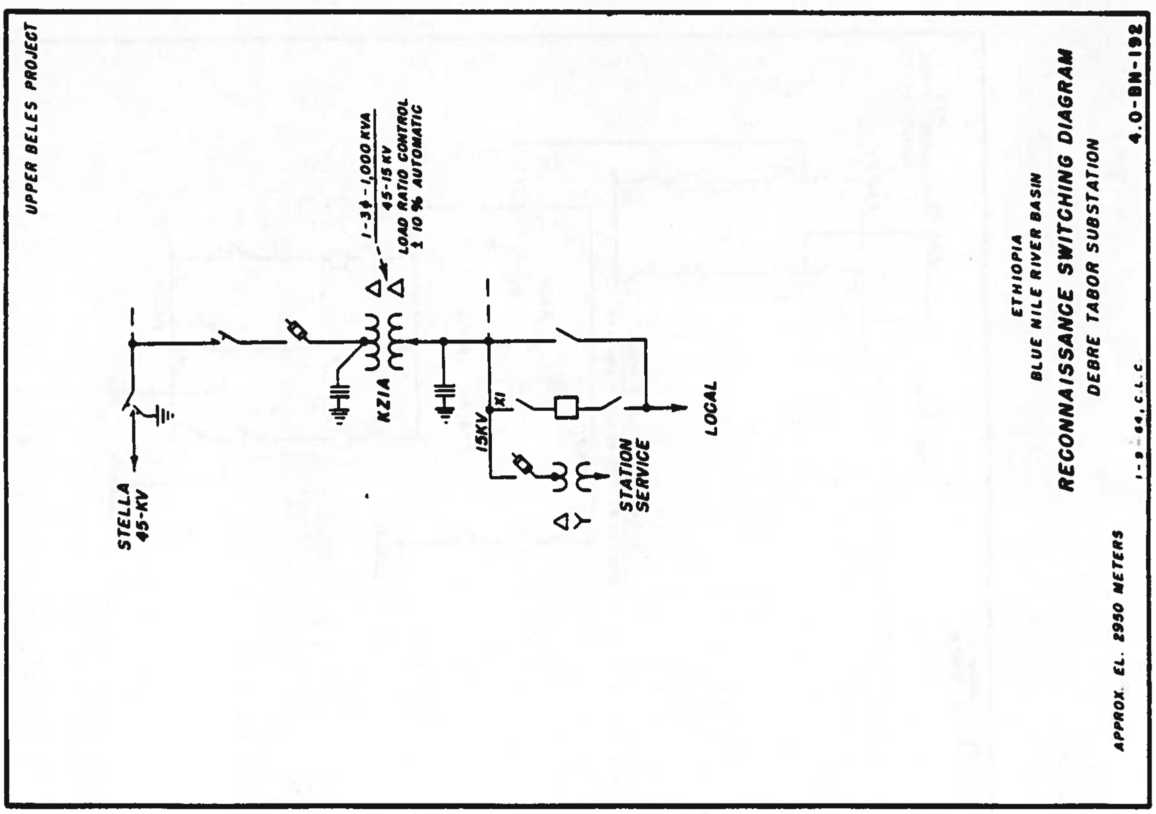


Figure I-63--Debre Tabor Substation--Switching Diagram

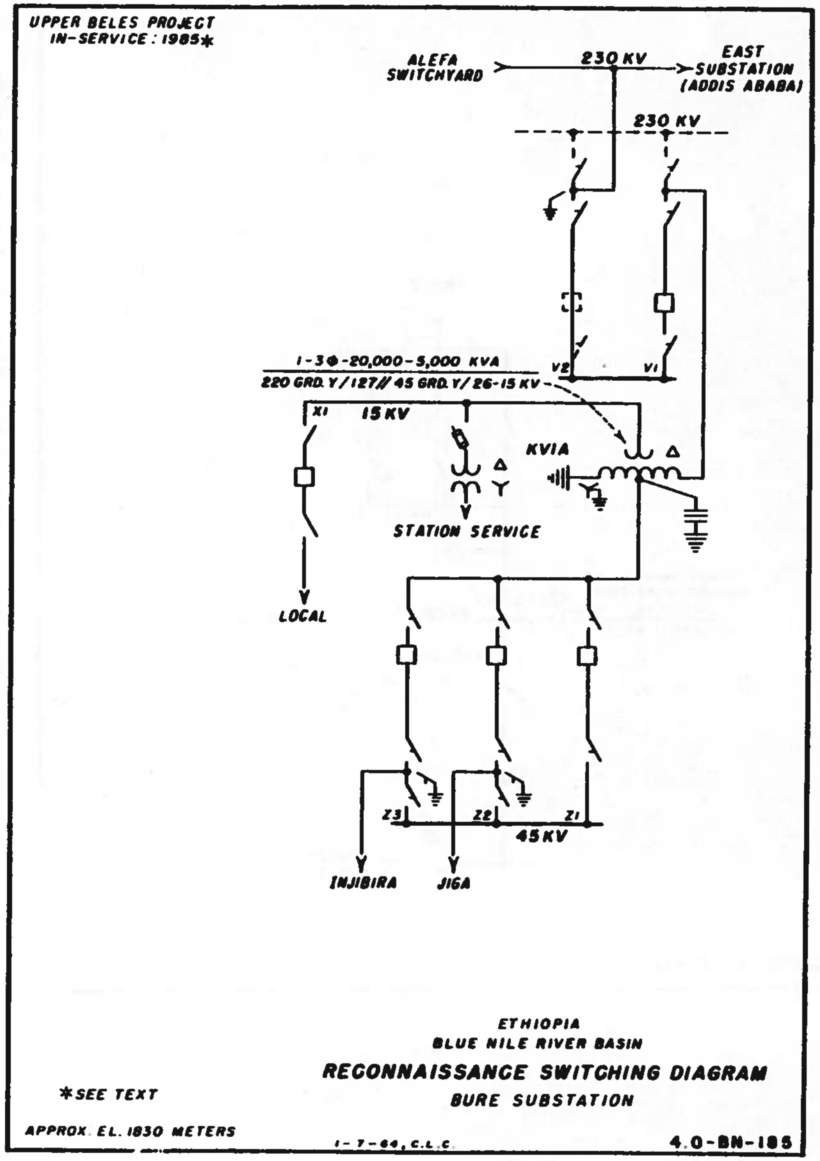


Figure I-65--Bure Substation--Switching Diagram

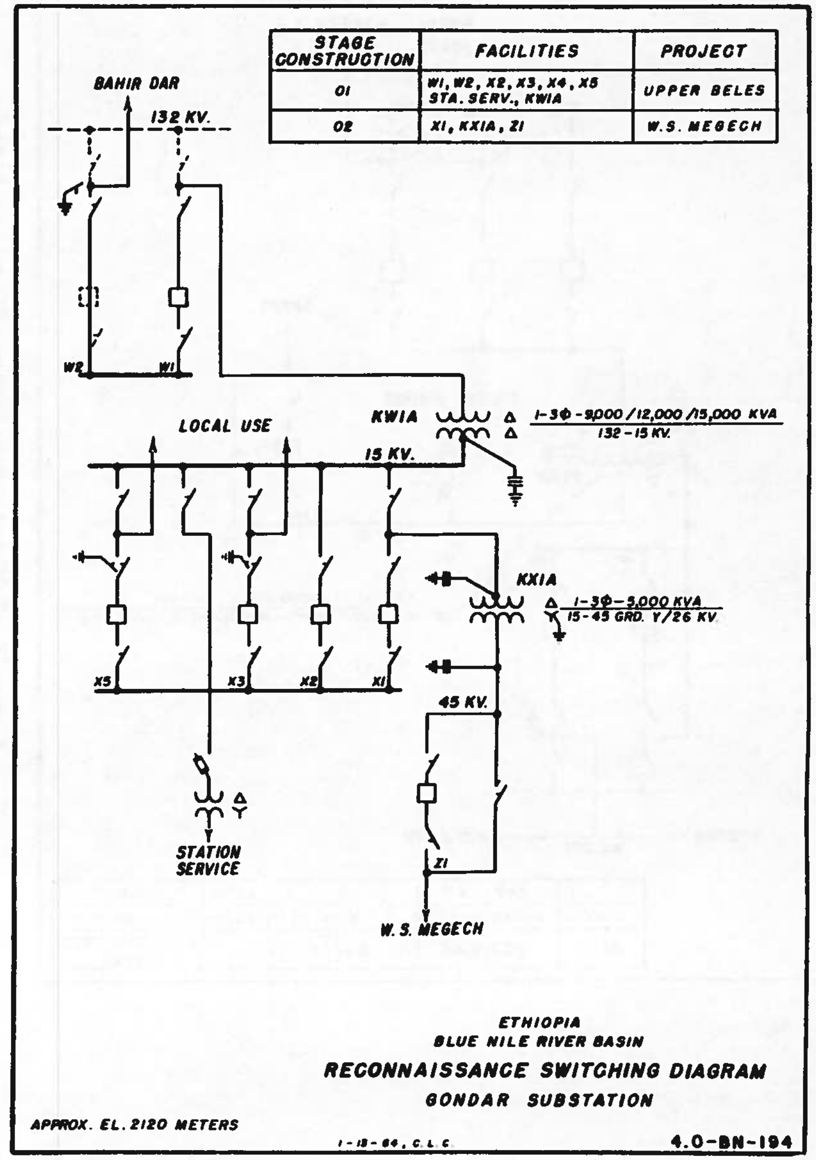


Figure I-64--Gondar Substation--Switching Diagram

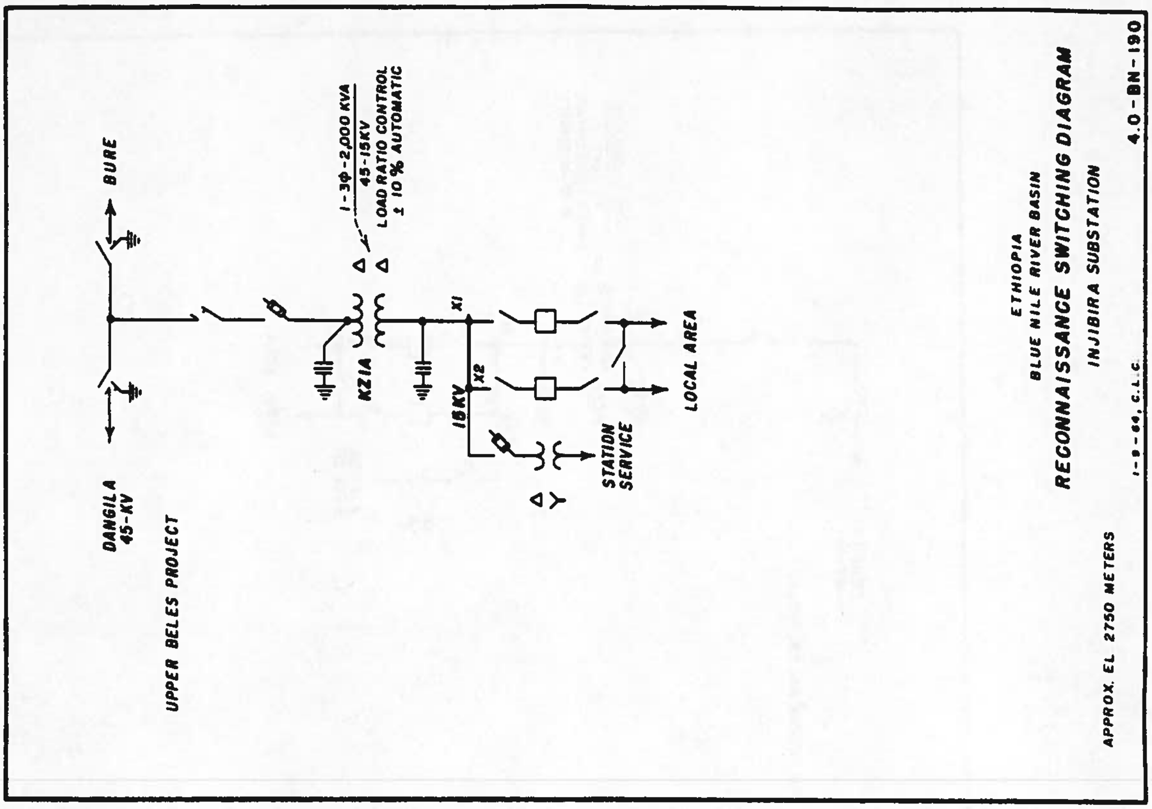


Figure I-66--Injibira Substation--Switching Diagram

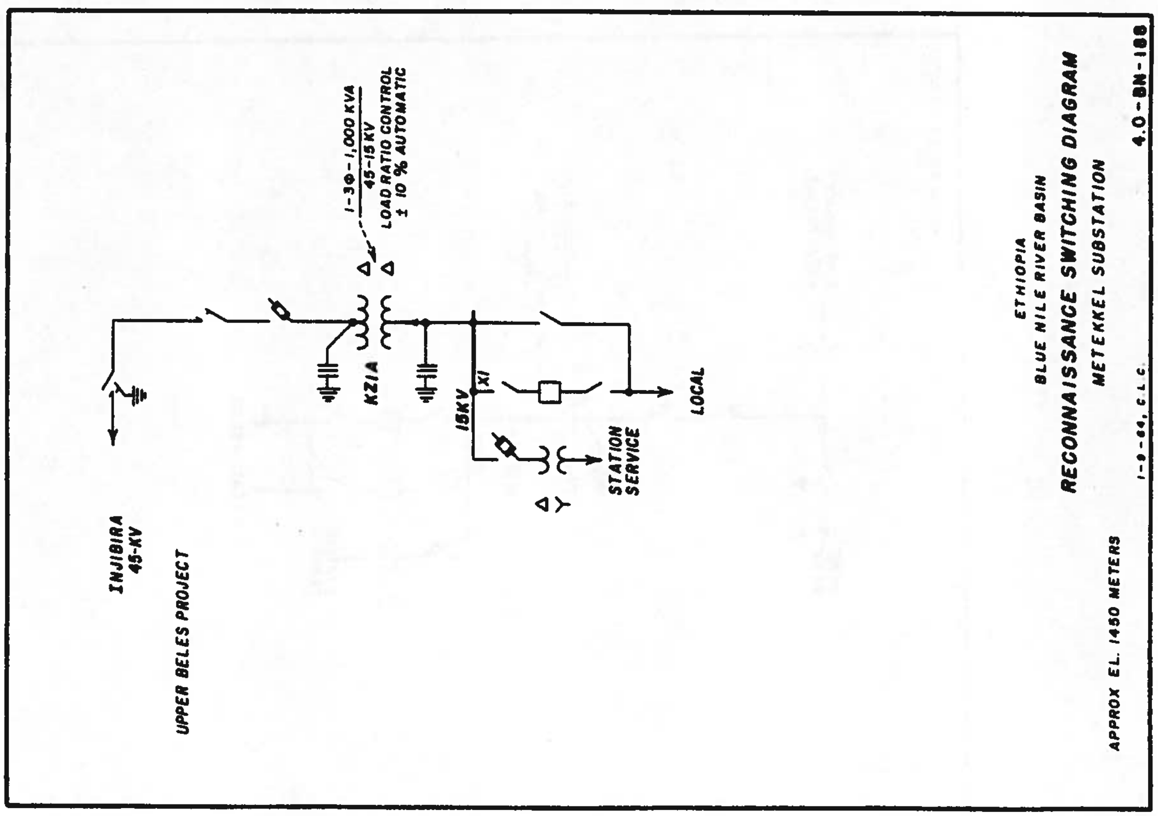


Figure I-67--Metekkel Substation--Switching Diagram

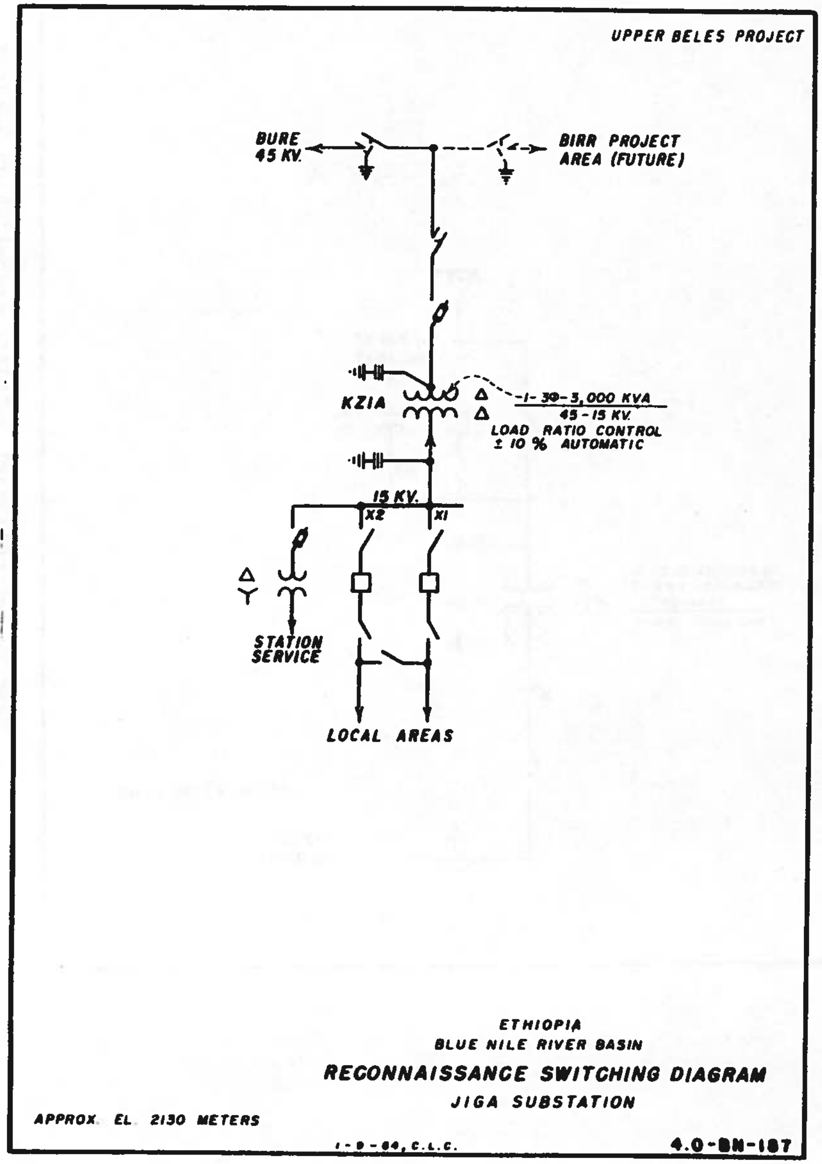


Figure I-69--Jiga Substation--Switching Diagram

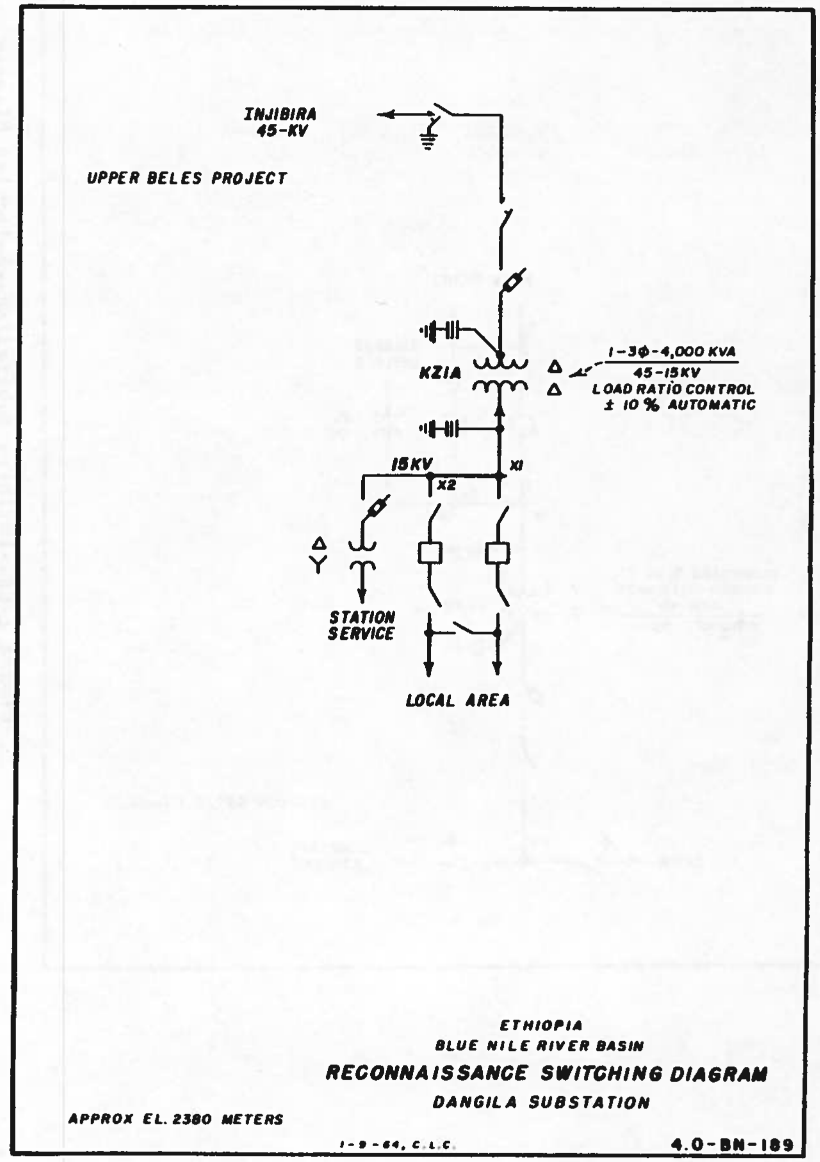


Figure I-68--Dangila Substation--Switching Diagram

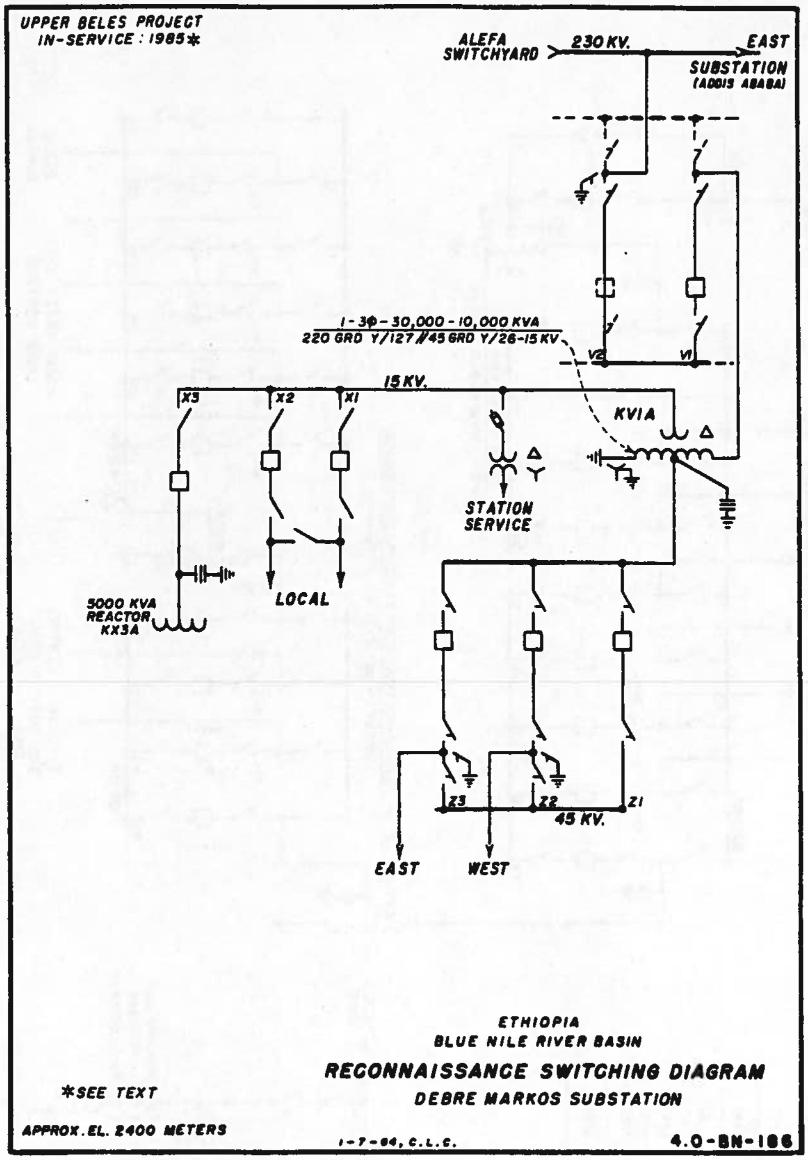
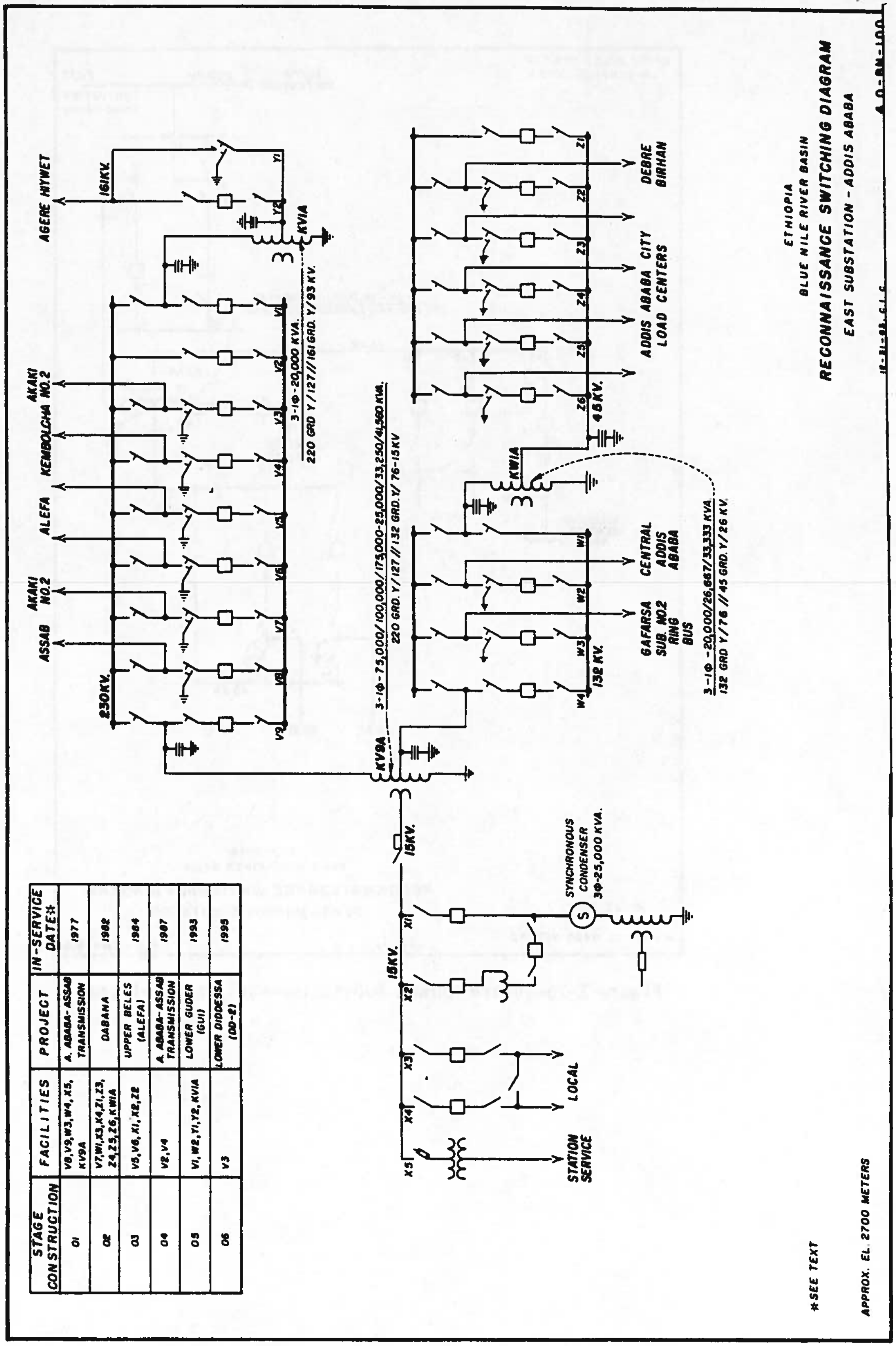


Figure I-70--Debre Markos Substation--Switching Diagram



STAGE CONSTRUCTION	FACILITIES	PROJECT	IN-SERVICE DATE*
01	V8,V9,W3,W4,X5, KV9A	A. ABABA-ASSAB TRANSMISSION	1977
02	V7,W1,X3,X4,Z1,Z3, Z4,Z5,Z6,KW1A	DABANA	1982
03	V5,V6,X1,X2,Z2	UPPER BELES (ALEFA)	1984
04	V2,V4	A. ABABA-ASSAB TRANSMISSION	1987
05	V1,W2,Y1,Y2,KV1A	LOWER GUDER (GUI)	1993
06	V3	LOWER DIDDESSA (DD-2)	1995

Figure I-71--East Substation, Addis Ababa--Switching Diagram

Irrigation Unit

The general plan of the reconnaissance layout of the irrigation features of the project appears on Figures I-72 and I-73 with descriptions of the principal features in the following paragraphs. Topography of the project area was compiled by stereoscopic (multiplex) projection from aerial photographs on 1:50,000 scale at 20-meter contour intervals. Controls for multiplex compilation consisted of (1) horizontal distances measured with tellurometer, third order, and (2) vertical measurements by altimeters.

Beles Diversion Dam

The irrigation diversion dam would be about 25 kilometers downstream from the powerplant on the Beles River in a narrow canyon. It would be a concrete-gravity, ogee type of dam, 16 meters high above streambed, and would have a crest length of 25 meters. Two 5.2-meter-diameter short tunnels, one on either side of the river at elevation 1295 meters, are planned, leading into a division structure installed with two slide gates with one opening to the river channel. It is planned during periods of high flood flows, estimated to be in the magnitude of 960 cubic meters per second in a flood of once in 100 years, to utilize the bypass due to the limited crest length. It would also serve for sluicing. The other opening in the division structure would lead into the main canals.

Irrigation Diversion Dam Data

Type	concrete-ogee
Volume of masonry-concrete	4,908 cu.m.
Structural height	16 m.
Spillway crest length	25 m.
Discharge capacity	960 cu.m. per sec.

Pumping Plants

The two pumping plants included in the plan of development would be located off the North Main Canal to serve lands situated above the canals that cannot be reached by gravity.

Pumping Plant No. 1. The pumping plant would be located on the western part of the project area on the North Main Canal about 87.5 kilometers from the headworks of the main canal. The plant would provide irrigation water for 3,000 hectares of irrigable land. Power would be supplied from the Alefa Powerplant. A short intake channel for forebay purposes will be required from the North Main Canal.

Pump Data--Plant No. 1

Forebay, water surface elevation	1137 m.
Total dynamic head	91 m.
Maximum lift	83 m.
Size of discharge pipe (diameter)	1.3 m.
Length of discharge pipe	1,000 m.
Capacity of pumps	3.86 cu. m. per sec.
Motor rating	6,500 h.p.

Pumping Plant No. 2. This pumping plant would be located off the North Main Canal, 17.5 kilometers below the first pumping plant and about 105 kilometers from the diversion dam outlet works. The plant would provide irrigation water for 4,600 hectares of irrigable land. Power would be supplied from the Alefa Powerplant. A short intake channel from the North Main Canal will be required for forebay purposes.

Pump Data--Plant No. 2

Forebay, water surface elevation	1128 m.
Total dynamic head	87 m.
Maximum lift	84 m.
Size of discharge pipe (diameter)	1.5 m.
Length of discharge pipe	300 m.
Capacity of pumps	5.5 cu. m. per sec.
Motor rating	9,225 h.p.

Canal System

Two gravity main canals and two pump canals have been included in the development plan for irrigating the project lands. The topography of the valley is typified by large areas of gently sloping land transected by more or less entrenched stream channels, generally widely spaced. Only in the southern portion of the area are there undulating to gently rolling ridges.

Canal excavation should not present any major problems, but rock may be encountered in some isolated reaches, especially near stream crossings. Canal structures, such as checks, drops, wasteways, turnouts, culverts, bridges, and siphons, would be provided as necessary. Canal earthwork costs were obtained by computing the quantities and applying unit prices; cost of canal structures was based on a percentage of earthwork costs.

Water will be released through the outlet works located on either end of the Beles Diversion Dam to the North and South Main Canals.

North Main Canal. The main canal would originate at the discharge end of the outlet works on the right abutment of the diversion dam at approximate elevation 1300 meters, and would have an initial capacity of 36.1 cubic meters per second. It would extend in a southwesterly direction for 143 kilometers. At Kilometer 59, the canal would start to drop so that at Kilometer 70, the canal would be at elevation 1140 meters. At the terminus, the elevation would be 1110± meters. The North Main Canal would irrigate 23,000 hectares by gravity.

North Main Canal Data

Type	unlined
Length	143 km.
Initial capacity	36.1 cu. m. per sec.
Initial water surface elevation	1300 m.

Pump Canal No. 1. This canal would originate at the discharge pipe outlet from Pumping Plant No. 1 at approximate elevation 1220 meters and would extend in a westerly direction, following a ridge for a short distance, where it would fork to the north and the south. Total length of the canal has been estimated to be 30 kilometers and it would serve 3,000 hectares of land.

Pump Canal No. 1 Data

Type	unlined
Length	30 km.
Initial capacity	3.86 cu. m. per sec.
Initial water surface elevation	1220 m.

Pump Canal No. 2. This canal would originate at the discharge pipe outlet from Pumping Plant No. 2 at approximate elevation 1212 meters and would extend in a southwesterly direction roughly paralleling the main canal for a distance of about 27 kilometers. The canal would convey water for irrigation of about 4,600 hectares of land.

Pump Canal No. 2 Data

Type	unlined
Length	27 km.
Initial capacity	5.5 cu. m. per sec.
Initial water surface elevation	1212 m.

South Main Canal. The south main canal would originate at the discharge end of the outlet works located on the left abutment of the diversion dam at approximate elevation 1300 meters with an initial capacity of 38.8 cubic meters per second. It would extend in a southerly direction, making a loop and terminating near the southwestern portion of the project area, a total distance of 144 kilometers. The canal has been designed to serve 32,600 hectares of irrigable land.

South Main Canal Data

Type	unlined
Length	144 km.
Initial capacity	38.8 cu. m. per sec.
Initial water surface elevation	1300 m.

Distribution System and Drainage Canals

Distribution System. Construction of a distribution system to spread the water over the project lands will vary according to topography. In the northwestern sector, slopes average about 1.0 to 1.5 percent down the ridges and about 2.0 percent toward the side drainages. Ridges are very broad and long, and construction of a distribution system should not be unduly expensive. The rough alluvial fan area in the northeastern part of the project is subject to considerable flooding and contains numerous isolated high areas which cannot be reached by gravity. The approximate southern half of the project is characterized by an undulating to severely undulating topography. Ridges are the choicest topography for irrigation in this area, but these are usually narrow (50 to 150 meters) and have a slope of 2.0 to 3.0 percent parallel to the ridge. Slopes are steep into the side drainages with 3.0 to 11 percent or greater. Numerous drop structures to stabilize against excessive erosion and numerous flumes and siphons to cross the many drainageways are expected to be required.

Drainage Canals. Drainage conditions associated with the three types of topography are found in the project area. The northwestern area, which has the smoothest topography, can be expected to have the most drainage problems. This is due to the fact that natural drainageways are mostly shallow and widely spaced, and soils are slowly permeable and have poor internal drainage characteristics. An improved surface drainage system is envisioned for this area. The northeastern area has a flood plain type of natural drainageways with intermittent, narrow, moderately deep, eroded drainageways. Flood hazards may be the greatest problem here. The approximate southern half of the project has a well developed drainage system, and the need for further construction is expected to be minimal. Surface drainage canals for the evacuation of irrigation waste and excess precipitation have been provided in the estimates of cost.

Subsurface drainage requirements cannot be estimated at this time due to lack of sufficient data. Further studies are recommended, especially on the upper half of the project lands prior to development as a means of estimating the water table behavior which may be anticipated with irrigation.

Access Road

An access road to the project lands will be required. If the proposed road would take off from the present Dangila-Guba road, it would traverse flat to hilly terrain and would be approximately 50 kilometers long.

Service Facilities

Temporary and permanent camp will be required for this unit of the project in addition to the one provided at the Alefa Powerplant, on the assumption that the distance would be too great for efficient operation of the irrigation unit from the powerplant facilities.

ESTIMATED PROJECT COST

Construction Cost

The total construction cost for the project on the basis of January 1961 prices is estimated to be Eth$346,717,000 as itemized in Table I-10 with quantities and unit prices. Items indicated as lump sums were generally obtained from curves. The following table summarizes the estimated construction cost for the three units and includes contingencies, engineering, and general expense.

Estimated Construction Cost--Upper Beles Multipurpose Project

Feature	Total construct-tion cost	Facilities		
		Joint-use (Eth$1,000)	Irrigation (Eth$1,000)	Power (Eth$1,000)
Lake Tana Dam and Reservoir	6,564	6,564		
Diversion Tunnel	43,136	43,136		
Power Canal	13,409			13,409
Tunnel and Penstocks	74,852			74,852
Alefa Powerplant	17,863			17,863
Switchyard	9,725			9,725
Transmission Lines	48,733			48,733
Substations	11,940			11,940
Access Road	1,094			1,094
Service Facilities--No. 1	1,719			1,719
Beles Diversion Dam	5,956		5,956	
Pumping Plant No. 1	3,327		3,327	
Pumping Plant No. 2	3,980		3,980	
Transmission Lines and Substations	2,348		2,348	
North Main Canal	22,841		22,841	
Pump Canals	2,684		2,684	
South Main Canal	25,133		25,133	
Distribution System	32,588		32,588	
Drainage System	13,825		13,825	
Access Road	2,344		2,344	
Service Facilities--No. 2	2,656		2,656	
Total	346,717	49,700	117,682	179,335

Development Cost

Clearing the lands prior to irrigation development will vary in the project area. The northwestern portion has a mixture of open grass savanna and dense groves of bamboo. There are also occasional thickets or clumps of bamboo in with the grassland. In the southern half of the project, the principal natural vegetation is woodland savanna composed of various species of acacia, fig, and associated small trees. This open forest is interspersed with a dense growth of tall grass. An average cost of Eth$115 per hectare is estimated for clearing requirements for a total of Eth$7,250,000. Land leveling costs are expected to be moderate to expensive due to the undulating nature of the topography. Due to the variable topography, leveling costs are expected to range from about Eth$65 to Eth$180 per hectare. For the purpose of this study, an average of about Eth$125 per hectare was applied to the 63,200 hectares determined to be suitable for irrigation for a total estimated cost of Eth$7,900,000.

TABLE I-10--UPPER BELES PROJECT--RECONNAISSANCE ESTIMATE

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project UPPER BELES--Multiple-purpose

Date of Estimate January 1964

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. \$1.00 = Eth. \$2.50)

ITEM NO	ITEM	QUANTITY AMOUNT	UNIT	EQUIPMENT MATERIAL AND LABOR UNIT COST	EQUIPMENT MATERIAL AND LABOR COST	FIELD COST	TOTAL CONSTRUCTION COST
	UPPER BELES PROJECT--Multiple-purpose					288,181,800	346,717,000
	LAKE TANA UNIT Sheet 1						
	POWER UNIT Sheets 2-7						
	IRRIGATION UNIT Sheets 8-11						
	Joint-use features						(49,700,000)
	Power features						(179,335,000)
	Irrigation features						(117,682,000)
	I LAKE TANA UNIT--Gated masonry and concrete control structure on the Blue Nile River at the outlet of Lake Tana. Drawing No. 2.0-IP-16					5,251,100	6,564,000
	Channel Improvements and Dikes						
1	Care of river during construction	Lump sum		Lump sum	150,000		
2	Excavation for channel, rock	305,680	m^3	6.50	1,986,920		
3	Excavation for roads and dikes	1,580	m^3	1.95	3,081		
4	Placing rockfill in dikes, including haul	38,350	m^3	0.65	24,928		
5	Earthfill in dikes, including excavation from borrow, haul and placing	25,050	m^3	3.40	85,170		
6	Hauling and placing riprap on dikes	15,840	m^3	11.00	174,240		
7	Crushed rock for road surfacing	2,700	m^3	15.00	40,500		
	Subtotal--Channel and Dikes				2,464,839		
	Control Structure						
8	Excavation for structures, rock	13,150	m^3	10.00	131,150		
9	Compacted backfill about structures	1,500	m^3	3.30	4,950		
10	Masonry in structures	7,010	m^3	70.00	490,700		
11	Concrete in hoist deck	100	m^3	210.00	21,000		
12	Concrete in apron	2,760	m^3	150.00	414,000		
13	Reinforcement	90,200	kg	1.00	90,200		
14	Radial gates, complete, twenty 6.5 m x 4.25 m	182,000	kg	2.50	455,000		
15	Miscellaneous metalwork	33,000	kg	3.00	99,000		
16	Foundation grouting, all work and material	Lump sum		Lump sum	30,000		
	Subtotal--Control Structure				1,736,000		
	Subtotal--Items 1 through 16				4,200,839		
	Contingencies (25±%)				1,050,261		
	Field Cost--Lake Tana Unit				5,251,100		
	Engineering and General Expense (25±%)				1,312,900		
	Total est. const. cost--Lake Tana Unit				6,564,000		

Table I-10--Continued

RECONNAISSANCE ESTIMATE
BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project UPPER BELES--Multiple-purpose

Date of Estimate January 1964

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	POWER UNIT.--Includes the following features: Diversion from Lake Tana and power conveyances; Alefa Powerplant; and power transmission plant.					188,925,000	222,471,000
	WATERWAYS--From Lake Tana to Alefa Powerplant. Drawing No. 4.0-BN-115					113,450,000	131,760,000
	Intake Structure--Intake channel; trash-racked concrete intake structure; and gated control works.						
1	Cofferdam, in Lake Tana	Lump sum		Lump sum	75,000		
2	Excavation for intake channel, common	68,000	m^3	1.95	132,600		
3	Excavation for intake channel, rock	103,000	m^3	6.50	669,500		
4	Concrete in intake structure	1,080	m^3	210.00	226,800		
5	Reinforcement	38,880	kg	1.00	38,880		
6	Trashracks	87,430	kg	2.60	227,318		
7	Radial gate and hoist, 5.3 x 5.3 meters	9,550	kg	5.50	52,525		
	Subtotal				1,422,623		
	Contingencies (25±%)				355,677		
	Field Cost--Intake Structure				1,778,300		
	Engineering and General Expense (25±%)				444,700		
	Total est. const. cost--Intake Structure				2,223,000		
	Diversion Tunnel--Free flow; concrete lined; diameter, 5.3 meters; length, 6700 meters; capacity, 110 m^3/sec.						
8	Excavation for tunnel	204,000	m^3	68.00	13,872,000		
9	Concrete in tunnel lining	54,000	m^3	132.00	7,128,000		
10	Supports and lagging	Lump sum		Lump sum	4,810,000		
11	Grouting, drainage, and misc. work	Lump sum		Lump sum	2,548,000		
	Subtotal				28,358,000		
	Contingencies (25±%)				7,089,500		
	Field Cost--Diversion Tunnel				35,447,500		
	Engineering and General Expense (15±%)				5,317,500		
	Total est. const. cost--Diversion Tunnel				40,765,000		
	Stilling Basin--Stone masonry structure at outlet of diversion tunnel.						
12	Excavation, common	2,070	m^3	1.95	4,037		
13	Excavation, rock	1,380	m^3	8.00	11,040		
14	Compacted backfill	470	m^3	2.05	964		
15	Masonry in walls and floors	1,123	m^3	70.00	78,610		
	Subtotal				94,651		
	Contingencies (25±%)				23,649		
	Field Cost--Stilling Basin				118,300		
	Engineering and General Expense (25±%)				29,700		
	Total est. const. cost--Stilling Basin				148,000		
	Power Canal--Grouted rubble stone lining; length, 12.0 kms; capacity, 110.0 m^3/sec.						
16	Canal excavation, common	626,400	m^3	0.82	513,648		
17	Canal excavation, rock	417,600	m^3	8.00	3,340,800		
18	Compacting embankment	264,000	m^3	0.98	258,720		
19	Lining, grouted rubble stone paving	228,000	m^2	15.00	3,420,000		
20	Structures for cross drainage	Lump sum		Lump sum	753,000		
21	Gated canal headworks	Lump sum		Lump sum	80,000		
	Subtotal				8,366,168		
	Contingencies (25±%)				2,091,532		
	Field Cost--Power Canal				10,457,700		
	Engineering and General Expense (25±%)				2,614,300		
	Total est. const. cost--Power Canal				13,072,000		

Sheet 2 of 11

Table I-10--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project UPPER BELES--Multiple-purpose

Date of Estimate January 1964

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	WATERWAYS (Continued)						
	Forebay--Located at top of vertical shaft and terminus of power canal. Capacity, 6,300 m³; grouted stone masonry-lined basin with control weir and wasteway.						
22	Excavation, common	1,300	m^3	1.95	2,535		
23	Excavation, rock	5,170	m^3	8.00	41,360		
24	Compacting embankment	4,350	m^3	0.98	4,263		
25	Grouted stone lining	7,120	m^2	15.00	106,800		
26	Stone masonry	700	m^3	70.00	49,000		
27	Gate, 1 meter square slide gate--drain	310	kg	5.50	1,705		
28	Chain link fence, 2 meters high	250	lm	39.20	9,800		
	Subtotal				215,463		
	Contingencies (25±%)				53,837		
	Field Cost--Forebay				269,300		
	Engineering and General Expense (25±%)				67,700		
	Total est. const. cost--Forebay				337,000		
	Pressure Tunnel and Shaft--Diameter, 6.0 meters; concrete lined; vertical shaft, 245 meters deep; horizontal tunnel, 1,850 meters long.						
29	Excavation for tunnel	55,650	m^3	65.00	3,617,250		
30	Concrete in tunnel lining	21,441	m^3	130.00	2,787,330		
31	Supports and lagging	Lump sum		Lump sum	1,473,000		
32	Grouting, drainage, and misc. work	Lump sum		Lump sum	768,550		
	Subtotal				8,646,130		
	Contingencies (25±%)				2,161,570		
	Field Cost--Pressure Tunnel				10,807,700		
	Engineering and General Expense (15±%)				1,621,300		
	Total est. const. cost--Pressure Tunnel				12,429,000		
	Penstock Tunnels--Four 2.7-meter diameter penstocks, two each in two 6.65-meter equivalent diameter concrete-lined tunnels. Length, 1,200 meters.						
33	Excavation for tunnels	113,200	m^3	64.00	7,244,800		
34	Concrete in tunnel lining	29,900	m^3	125.00	3,737,500		
35	Supports and lagging	Lump sum		Lump sum	2,525,900		
36	Grouting, drainage, and misc. work	Lump sum		Lump sum	1,317,900		
37	Steel penstocks	9,532,800	kg	3.00	28,598,400		
	Subtotal				43,424,500		
	Contingencies (25±%)				10,856,100		
	Field Cost--Penstock Tunnels				54,280,600		
	Engineering and General Expense (15±%)				8,142,400		
	Total est. const. cost--Penstock Tunnel				62,423,000		
	Tailrace--Improvements to existing river channel below powerplant.						
38	Excavation, all classes, open cut	50,000	m^3	3.25	162,500		
39	Stone masonry retaining walls	1,000	m^3	70.00	70,000		
	Subtotal				232,500		
	Contingencies (25±%)				58,100		
	Field Cost--Tailrace				290,600		
	Engineering and General Expense (25±%)				72,400		
	Total est. const. cost--Tailrace				363,000		

Sheet 3 of 11

Table I-10--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA.ETHIOPIA

Project: UPPER BELES--Multiple-purpose

Date of Estimate: January 1964

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY AMOUNT	UNIT	EQUIPMENT MATERIAL AND LABOR UNIT COST	EQUIPMENT MATERIAL AND LABOR COST	FIELD COST	TOTAL CONSTRUCTION COST
	ALEFA POWERPLANT--Hydro, located on the Beles River					14,000,000	17,500,000
	Structures and Improvements						
1	Masonry and reinforced concrete powerhouse structure	Lump sum		Lump sum	3,430,000		
	Turbines and Generators--Four units, 62,500 kva each. Generators, 13.8 kv, 0.8 power factor, 50 cycle. Francis turbines, 70,550 hp at 375 rpm and 230 meters of head. Penstock valves and appurtenances.						
2	Turbines, generators	Lump sum		Lump sum	8,260,000		
	Accessory Electrical Equipment						
3	All equipment required for control and protection of generators and station-service power	Lump sum		Lump sum	1,428,000		
	Miscellaneous Powerplant Equipment						
4	All equipment required for general station use	Lump sum		Lump sum	882,000		
	Field Cost--Powerplant				14,000,000		
	Engineering and General Expense (25%)				3,500,000		
	Total est. const. cost--Powerplant				17,500,000		
	TRANSMISSION LINES; SWITCHYARD AND SUBSTATIONS					58,825,000	70,398,000
	Alefa Switchyard						
1	Single breaker, 132-kv line bays: W1, W3, W4, and W5	Lump sum		Lump sum	1,000,000		
2	Double breaker, 132-kv line bays: W2, W6, W7, and W8	Lump sum		Lump sum	1,332,000		
3	Single breaker, 230-kv line bay: V3	Lump sum		Lump sum	445,000		
4	Double breaker, 230-kv line bay: V1 and V2	Lump sum		Lump sum	1,186,000		
5	Autotransformer (KV3A) installation	Lump sum		Lump sum	900,000		
6	Transformers: KK1A, KK2A, KK3A, KK4A	4	ea.	625,000	2,500,000		
7	Powerhouse circuits: 132 kv, steel tower with one overhead ground wire and 266.8 MCM ACSR conductors per circuit, each 0.2 km long	0.8	km	21,000	16,800		
8	Miscellaneous equipment, communication, etc.	Lump sum		Lump sum	400,000		
	Field Cost--Alefa Switchyard				7,779,800		
	Engineering and General Expense (25%)				1,945,200		
	Total est. const. cost--Alefa Switchyard				9,725,000		
	Transmission Line--Alefa Switchyard to Bahir Dar. Double-circuit steel towers with one overhead steel ground wire and 636 MCM ACSR conductors, 132 kv.						
9	Rough terrain	20	km	35,500	710,000		
10	Average terrain	45	km	30,000	1,350,000		
	Field Cost--Transmission Line				2,060,000		
	Engineering and General Expense (20%)				412,000		
	Total est. const. cost--Transmission Line				2,472,000		
	Transmission Line--230 kv, Alefa Switchyard to East Substation (Addis Ababa). Double-circuit steel towers with one overhead ground wire and 954 MCM ACSR conductors						
11	Rough terrain	110	km	89,000	9,790,000		
12	Average terrain	340	km	75,000	25,500,000		
	Field Cost--Transmission Line				35,290,000		
	Engineering and General Expense (17%)				5,999,000		
	Total est. const. cost--Transmission Line				41,289,000		

Table I-10--Continued

RECONNAISSANCE ESTIMATE
BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project UPPER BELES--Multiple-purpose

Date of Estimate January 1964

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. $ 1.00 = Eth. $ 2.50)

ITEM NO	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	TRANSMISSION LINES, SWITCHYARD AND SUBSTATIONS (Continued)						
	Transmission Line--45 kv. Bure to Jiga. Steel pole with No. 2 AWG copper conductors.						
13	Average terrain. Field Cost	37	km	7,600	281,200		
	Engineering and General Expense (20±%)				55,800		
	Total est. const. cost--Transmission Line				337,000		
	Transmission Line--45 kv. Bure to Dajibira to Dangila. Steel pole with 2/0 AWG copper conductors.						
14	Average terrain. Field Cost	70	km	8,600	602,000		
	Engineering and General Expense (20±%)				120,000		
	Total est. const. cost--Transmission Line				722,000		
	Transmission Line--45 kv. Dajibira to Metekkel. Steel pole with 2/0 AWG copper conductors.						
15	Rough terrain. Field Cost	50	km	10,900	545,000		
	Engineering and General Expense (20±%)				109,000		
	Total est. const. cost--Transmission Line				654,000		
	Transmission Line--132 kv. Bahir Dar to Stella to Gondar. Steel tower with one overhead ground wire and 4/0 AWG ACSR conductors.						
16	Average terrain. Field Cost	146	km	16,000	2,336,000		
	Engineering and General Expense (20±%)				467,000		
	Total est. const. cost--Transmission Line				2,803,000		
	Transmission Line--45 kv. Stella to Debra Tabor. Steel pole with No. 2 AWG copper conductors.						
17	Rough terrain. Field Cost	40	km	9,500	380,000		
	Engineering and General Expense (20±%)				76,000		
	Total est. const. cost--Transmission Line				456,000		
	Bahir Dar Substation--Stages 01 and 02. Drawing No. 4.0-BN-191						
18	Bays (132 kv) W1, W2, W3, W4, and W5	Lump sum		Lump sum	1,115,000		
19	Bays (45 kv) Z1, Z2, Z3, Z4, Z5, Z6, Z7, Z8, and Z9	Lump sum		Lump sum	577,000		
20	Bays (15 kv) X1 and X2, station service	Lump sum		Lump sum	78,000		
21	Autotransformers, KW5A and KW6A	Lump sum		Lump sum	1,540,000		
22	Miscellaneous items, including communication facilities	Lump sum		Lump sum	50,000		
	Field Cost--Bahir Dar Substation				3,360,000		
	Engineering and General Expense (25±%)				840,000		
	Total est. const. cost--Bahir Dar Substation				4,200,000		
	Stella Substation--Stage 01. Drawing No. 4.0-BN-193						
23	Bays (132 kv) W1 and W2	Lump sum		Lump sum	275,000		
24	Bays (15 kv) X1 and station service	Lump sum		Lump sum	39,000		
25	Bay (45 kv) Z2	Lump sum		Lump sum	65,000		
26	Autotransformer KW1A	Lump sum		Lump sum	187,000		
27	Communication and misc. items	Lump sum		Lump sum	15,000		
	Field Cost--Stella Substation				581,000		
	Engineering and General Expense (25±%)				145,000		
	Total est. const. cost--Stella Substation				726,000		

Sheet 5 of 11

Table I-10--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project: UPPER BELES--Multiple-purpose

Date of Estimate: January 1964

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY: AMOUNT	QUANTITY: UNIT	EQUIPMENT MATERIAL AND LABOR: UNIT COST	EQUIPMENT MATERIAL AND LABOR: COST	FIELD COST	TOTAL CONSTRUCTION COST
	TRANSMISSION LINES, SWITCHYARD, AND SUBSTATIONS (Continued)						
	Debre Tabor Substation--Drawing No. 4.0-EE-199						
28	Line switch installation	Lump sum		Lump sum	9,000		
29	Transformer KZ1A	Lump sum		Lump sum	34,000		
30	Bay (15 kv) X1	Lump sum		Lump sum	31,500		
31	Station service	Lump sum		Lump sum	3,000		
32	Communication and misc. items	Lump sum		Lump sum	6,500		
	Field Cost--Debre Tabor Substation				84,000		
	Engineering and General Expense (25±%)				21,000		
	Total est. const. cost--Debre Tabor Substation				105,000		
	Gondar Substation--Stage 01. Drawing No. 4.0-EE-194						
33	Bays (138 kv) W1 and W2	Lump sum		Lump sum	275,000		
34	Bays (15 kv) X2, X3, X5, and station service	Lump sum		Lump sum	98,000		
35	Transformer KW1A	Lump sum		Lump sum	250,000		
36	Communication and misc. items	Lump sum		Lump sum	35,000		
	Field Cost--Gondar Substation				658,000		
	Engineering and General Expense (25±%)				165,000		
	Total est. const. cost--Gondar Substation				823,000		
	Bure Substation--Drawing No. 4.0-EE-185						
37	Bays (230 kv) V1 and V2	Lump sum		Lump sum	505,000		
38	Bays (45 kv) Z1, Z2, and Z3	Lump sum		Lump sum	190,000		
39	Bays (15 kv) X1 and station service	Lump sum		Lump sum	41,000		
40	Autotransformer KY1A	Lump sum		Lump sum	340,000		
	Field Cost--Bure Substation				1,076,000		
	Engineering and General Expense (25±%)				269,000		
	Total est. const. cost--Bure Substation				1,345,000		
	Injibira Substation--Drawing No. 4.0-EE-190						
41	Special line switch installations, tap structure, 45 kv	Lump sum		Lump sum	18,000		
42	Transformer KZ1A	Lump sum		Lump sum	50,000		
43	Bays (15 kv) X1, X2, and station service	Lump sum		Lump sum	66,000		
44	Communication and misc. items	Lump sum		Lump sum	6,000		
	Field Cost--Injibira Substation				140,000		
	Engineering and General Expense (25±%)				35,000		
	Total est. const. cost--Injibira Substation				175,000		
	Metekel Substation--Drawing No. 4.0-EE-188						
45	Line switch installation	Lump sum		Lump sum	9,000		
46	Transformer KZ1A	Lump sum		Lump sum	34,000		
47	Bay (15 kv) X1 and station service	Lump sum		Lump sum	34,500		
48	Communication and misc. items	Lump sum		Lump sum	6,500		
	Field Cost--Metekel Substation				84,000		
	Engineering and General Expense (25±%)				21,000		
	Total est. const. cost--Metekel Substation				105,000		
	Dangila Substation--Drawing No. 4.0-EE-189						
49	Special line switch installation	Lump sum		Lump sum	9,000		
50	Transformer KZ1A	Lump sum		Lump sum	72,000		
51	Bays (15 kv) X1, X2, and station service	Lump sum		Lump sum	67,000		
52	Communication and misc. items	Lump sum		Lump sum	8,000		
	Field Cost--Dangila Substation				156,000		
	Engineering and General Expense (25±%)				39,000		
	Total est. const. cost--Dangila Substation				195,000		

Table I-10--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project UPPER BELES--Multiple-purpose

Date of Estimate January 1964 | Currency in terms of Ethiopian Dollars

Prices as of January 1961 | (U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	TRANSMISSION LINES, SWITCHYARD, AND SUBSTATIONS (Continued)						
	Jiga Substation--Drawing No. 4.0-[illegible]-187						
53	Line switch installation	Lump sum		Lump sum	9,000		
54	Transformer KZ1A	Lump sum		Lump sum	63,000		
55	Bays (15 kv) X1, X2, and station service	Lump sum		Lump sum	67,000		
56	Communication and misc. items	Lump sum		Lump sum	7,000		
	Field Cost--Jiga Substation				146,000		
	Engineering and General Expense (25±%)				37,000		
	Total est. const. cost--Jiga Substation				183,000		
	Debre Markos Substation--Drawing No. 4.0-[illegible]-186						
57	Bays (230 kv) Y1 and Y2	Lump sum		Lump sum	505,000		
58	Bays (45 kv) Z1, Z2, and Z3	Lump sum		Lump sum	190,000		
59	Bays (15 kv) X1, X2, and station service	Lump sum		Lump sum	73,000		
60	Autotransformer KY1A	Lump sum		Lump sum	480,000		
61	Reactor equipment Y3	Lump sum		Lump sum	75,000		
	Field Cost--Debre Markos Substation				1,323,000		
	Engineering and General Expense (25±%)				331,000		
	Total est. const. cost--Debre Markos Substation				1,654,000		
	East (Addis Ababa) Substation--Stage 03 only. Drawing No. 4.0-[illegible]-100						
62	Bays (230 kv) Y5 and Y6	Lump sum		Lump sum	890,000		
63	Bay (45 kv) Z2	Lump sum		Lump sum	65,000		
64	Bays (15 kv) X1 (Syn. cond.) and X2	Lump sum		Lump sum	988,000		
	Field Cost--East Substation				1,943,000		
	Engineering and General Expense (25±%)				486,000		
	Total est. const. cost--East Substation				2,429,000		
	ACCESS ROAD--From existing road near tunnel inlet on Lake Tana, following closely tunnel and power canal alignment, to Alefa Powerplant					875,000	1,094,000
1	Gravel road, mostly one lane	28	km	25,000	700,000		
	Contingencies (25±%)				175,000		
	Field Cost--Access Road				875,000		
	Engineering and General Expense (25±%)				219,000		
	Total est. const. cost--Access Road				1,094,000		
	SERVICE FACILITIES--Includes offices, shops and equipment, housing, streets, and utilities					1,375,000	1,719,000
1	Camps and equipment	Lump sum		Lump sum	1,100,000		
	Contingencies (25±%)				275,000		
	Field Cost--Service Facilities				1,375,000		
	Engineering and General Expense (25±%)				344,000		
	Total est. const. cost--Service Facilities				1,719,000		

Sheet 7 of 11

Table I-10--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN—ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project Upper Beles--Multiple-purpose

Date of Estimate January 1964

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. $ 1.00 = Eth. $ 2.50)

ITEM NO.	ITEM	QUANTITY AMOUNT	UNIT	EQUIPMENT MATERIAL AND LABOR. UNIT COST	EQUIPMENT MATERIAL AND LABOR. COST	FIELD COST	TOTAL CONSTRUCTION COST
	IRRIGATION UNIT--Includes the following features: Irrigation diversion dam on the Beles River, irrigation canals, canal side pumping plants, and irrigation distribution and land drainage systems.					94,405,700	117,680,000
	BELES DIVERSION DAM AND CANAL HEADWORKS--Stone masonry uncontrolled ogee; height of dam, 16 meters; crest length, 25 meters.					4,963,600	5,956,000
1	Diversion and care of river	Lump sum		Lump sum	20,000		
2	Excavation in channel, rock	19,000	m^3	6.50	123,500		
3	Excavation for weir, rock	1,860	m^3	8.00	14,880		
4	Stone masonry in weir	4,710	m^3	70.00	329,700		
5	Concrete, weir crest and bucket	198	m^3	180.00	35,640		
6	Minor items	Lump sum		Lump sum	26,200		
	Subtotal--Weir				549,920		
	Canal Headworks--Two 5.8-meter diameter concrete-lined tunnels, one each bank.						
7	Excavation in tunnels and shafts	17,340	m^3	82.00	1,421,880		
8	Concrete lining, tunnels and shafts	3,460	m^3	161.00	557,060		
9	Reinforcement	121,100	kg	1.00	121,100		
10	Tunnel supports and lagging	Lump sum		Lump sum	483,400		
11	Trashracks and bulkheads	Lump sum		Lump sum	25,000		
12	Fixed-wheel gates, hoists, and controls, four required	139,563	kg	4.12	575,000		
13	Diesel generator for fixed-wheel gates, including wiring and equipment	Lump sum		Lump sum	10,000		
14	Bridge	150	m^2	97.00	14,550		
15	Miscellaneous items	Lump sum		Lump sum	213,000		
	Subtotal--Headworks				3,420,990		
	Subtotal--Items 1 through 15				3,970,910		
	Contingencies (25%)				992,690		
	Field Cost--Dam and Headworks				4,963,600		
	Engineering and General Expense (20%)				992,400		
	Total est. const. cost--Dam and Headworks				5,956,000		
	PUMPING PLANT NO. 1--Maximum capacity, 3.86 m^3/sec; total dynamic head, 91 meters					2,661,500	3,327,000
1	Plant structure and equipment	Lump sum		Lump sum	1,200,000		
2	Pumps and prime movers	Lump sum		Lump sum	660,000		
3	Excavation and backfill for discharge pipe	2,300	m^3	4.00	9,200		
4	Pipe, 1.3-meter diameter concrete	1,000	lm	260.00	260,000		
	Subtotal				2,129,200		
	Contingencies (25%)				532,300		
	Field Cost--Pumping Plant No. 1				2,661,500		
	Engineering and General Expense (25%)				665,500		
	Total est. const. cost--Pumping Plant No. 1				3,327,000		
	PUMPING PLANT NO. 2--Maximum capacity, 5.5 m^3/sec; total dynamic head, 87 meters					3,184,200	3,980,000
1	Plant structure and equipment	Lump sum		Lump sum	1,600,000		
2	Pumps and prime movers	Lump sum		Lump sum	850,000		
3	Excavation and backfill for discharge pipe	1,100	m^3	4.00	4,400		
4	Pipe, 1.5-meter diameter concrete	300	lm	310.00	93,000		
	Subtotal				2,547,400		
	Contingencies (25%)				636,800		
	Field Cost--Pumping Plant No. 2				3,184,200		
	Engineering and General Expense (25%)				795,800		
	Total est. const. cost--Pumping Plant No. 2				3,980,000		

Sheet 8 of 11

Table I-10--Continued

RECONNAISSANCE ESTIMATE
BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project UPPER BELES--Multiple-purpose

Date of Estimate January 1964

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth $2.50)

ITEM NO.	ITEM	QUANTITY AMOUNT	UNIT	EQUIPMENT MATERIAL AND LABOR UNIT COST	EQUIPMENT MATERIAL AND LABOR COST	FIELD COST	TOTAL CONSTRUCTION COST
	TRANSMISSION LINES AND SUBSTATIONS--Required for irrigation pumping					1,940,100	2,348,000
	Transmission Line--132 kv, Alefa Switchyard to Pumping Plant No. 2 Substation. Single-circuit steel towers with one over-head ground wire and 4/0 AWG ACSR conductors.						
1	Rough Terrain	55	km	19,500.00	1,072,500		
2	Average terrain	25	km	16,000.00	400,000		
	Field Cost--Transmission Line				1,472,500		
	Engineering and General Expense (20%)				294,500		
	Total est. const. cost--Transmission Line				1,767,000		
	Transmission Line--15 kv. Pumping Plant No. 2 to Pumping Plant No. 1. Steel poles, 477 MCM ACSR conductors.						
3	Average terrain, Field Cost	8	km	8,700.00	69,600		
	Engineering and General Expense (20%)				13,400		
	Total est. const. cost--Transmission Line				83,000		
	Substation--Pumping Plant No. 2						
4	Transformer KXIA	Lump sum		Lump sum	170,000		
5	Fuse KXIA	Lump sum		Lump sum	25,000		
6	Switch YXIA	Lump sum		Lump sum	10,000		
7	Fusing, motors	Lump sum		Lump sum	50,000		
8	Station service and communication	Lump sum		Lump sum	20,000		
	Field Cost--Substation No. 2				275,000		
	Engineering and General Expense (25%)				69,000		
	Total est. const. cost--Substation No. 2				344,000		
	Substation--Pumping Plant No. 1						
9	Transformer KXIA	Lump sum		Lump sum	70,000		
10	Fuse KXIA	Lump sum		Lump sum	6,000		
11	Switch YXIA	Lump sum		Lump sum	3,000		
12	Fusing, motors	Lump sum		Lump sum	24,000		
13	Station service and communication	Lump sum		Lump sum	20,000		
	Field Cost--Substation No. 1				123,000		
	Engineering and General Expense (25%)				31,000		
	Total est. const. cost--Substation No. 1				154,000		
	IRRIGATION CANALS--Unlined					40,526,300	50,658,000
	North Main Canal and Laterals--Canal length, 143 kms; capacity, 36.07 to 5.35 m^3/sec. Main gravity laterals length, 27 kms; capacities, 5.5 to 3.3 m^3/sec.						
1	Canal excavation, common	3,258,700	m^3	0.70	2,281,090		
2	Canal excavation, rock	171,500	m^3	6.50	1,114,750		
3	Compacting embankment	942,620	m^3	0.75	706,965		
4	Masonry and concrete structures	Lump sum		Lump sum	8,800,500		
5	Gates, hoists, valves, and misc. metalwork	Lump sum		Lump sum	225,600		
6	Concrete pipe	Lump sum		Lump sum	541,600		
7	Miscellaneous work	Lump sum		Lump sum	947,700		
	Subtotal				14,618,205		
	Contingencies (25%)				3,654,595		
	Field Cost--North Main Canal				18,272,800		
	Engineering and General Expense (25%)				4,568,200		
	Total est. const. cost--North Main Canal				22,841,000		

Table I-10--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project: UPPER BELES--Multiple-purpose

Date of Estimate: January 1964

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U S $ 1.00 = Eth. $ 2.50)

ITEM NO	ITEM	QUANTITY: AMOUNT	QUANTITY: UNIT	EQUIPMENT MATERIAL AND LABOR: UNIT COST	EQUIPMENT MATERIAL AND LABOR: COST	FIELD COST	TOTAL CONSTRUCTION COST
	IRRIGATION CANALS (Continued)						
	Pump Canal No. 1--Length, 30 kms; capacity, 3.86 to 1.21 m^3/sec.						
8	Canal excavation, common	136,860	m^3	0.95	130,017		
9	Canal excavation, rock	2,800	m^3	9.75	27,300		
10	Compacting embankment	31,580	m^3	0.98	30,948		
11	Masonry and concrete structures	Lump sum		Lump sum	403,800		
12	Gates, hoists, valves, and misc. metalwork	Lump sum		Lump sum	10,400		
13	Concrete pipe	Lump sum		Lump sum	24,800		
14	Miscellaneous work	Lump sum		Lump sum	43,500		
	Subtotal				670,765		
	Contingencies (25±%)				167,635		
	Field Cost--Pump Canal No. 1				838,400		
	Engineering and General Expense (25±%)				209,600		
	Total est. const. cost--Pump Canal No. 1				1,048,000		
	Pump Canal No. 2--Length, 27 kms; capacity, 5.5 to 3.3 m^3/sec.						
15	Canal excavation, common	209,800	m^3	0.95	199,310		
16	Canal excavation, rock	4,300	m^3	9.75	41,925		
17	Compacting embankment	53,700	m^3	0.98	52,626		
18	Masonry and concrete structures	Lump sum		Lump sum	630,300		
19	Gates, hoists, valves, and misc. metalwork	Lump sum		Lump sum	16,200		
20	Concrete pipe	Lump sum		Lump sum	38,800		
21	Miscellaneous work	Lump sum		Lump sum	67,900		
	Subtotal				1,047,061		
	Contingencies (25±%)				261,739		
	Field Cost--Pump Canal No. 2				1,308,800		
	Engineering and General Expense (25±%)				327,200		
	Total est. const. cost--Pump Canal No. 2				1,636,000		
	South Main Canal--Length, 144 kms; capacity, 38.81 to 3.05 m^3/sec. Main gravity laterals length, 25 kms; capacities, 8.17 to 2.48 m^3/sec.						
22	Canal excavation, common	3,564,900	m^3	0.70	2,495,430		
23	Canal excavation, rock	187,600	m^3	6.50	1,219,400		
24	Compacting embankment	1,066,200	m^3	0.75	799,650		
25	Masonry and concrete structures	Lump sum		Lump sum	9,683,600		
26	Gates, hoists, valves, and misc. metalwork	Lump sum		Lump sum	248,300		
27	Concrete pipe	Lump sum		Lump sum	595,900		
28	Miscellaneous work	Lump sum		Lump sum	1,042,800		
	Subtotal				16,085,080		
	Contingencies (25±%)				4,021,220		
	Field Cost--South Main Canal				20,106,300		
	Engineering and General Expense (25±%)				5,026,700		
	Total est. const. cost--South Main Canal				25,133,000		
	IRRIGATION DISTRIBUTION SYSTEM--Open lateral, unlined system for 63,200 net hectares on both sides of the Beles River, including lands served by pumping.					26,070,000	32,588,000
1	System under the North Main Canal	23,000	ha	330.00	7,590,000		(11,859,000)
2	System under Pump Canal No. 1	3,000	ha	330.00	990,000		(1,547,000)
3	System under Pump Canal No. 2	4,600	ha	330.00	1,518,000		(2,372,000)
4	System under the South Main Canal	32,600	ha	330.00	10,758,000		(16,810,000)
	Subtotal				20,856,000		
	Contingencies (25±%)				5,214,000		
	Field Cost--Distribution System				26,070,000		
	Engineering and General Expense (25±%)				6,518,000		
	Total est. const. cost--Distribution System				32,588,000		

Sheet 10 of 11

Table I-10--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project: UPPER NILES--Multiple-purpose

Date of Estimate: January 1964

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	DRAINAGE SYSTEM--Open land drains for						
	63,200 net hectares of irrigated land.					11,060,000	13,825,000
1	Drains under the North Main Canal	23,000	ha	140	3,220,000		(5,032,000)
2	Drains under Pump Canal No. 1	3,000	ha	140	420,000		(656,000)
3	Drains under Pump Canal No. 2	4,600	ha	140	644,000		(1,006,000)
4	Drains under South Main Canal	32,600	ha	140	4,564,000		(7,131,000)
	Subtotal				8,848,000		
	Contingencies (25±%)				2,212,000		
	Field Cost--Drainage System				11,060,000		
	Engineering and General Expense (25±%)				2,765,000		
	Total est. const. cost--Drainage System				13,825,000		
	ACCESS ROAD--From existing Dangila-Guba road						
	to Irrigation Diversion Dam.					1,875,000	2,344,000
1	Road, two-lane gravel, flat to hilly terrain	50	km	30,000	1,500,000		
	Contingencies (25±%)				375,000		
	Field Cost--Access Road				1,875,000		
	Engineering and General Expense (25±%)				469,000		
	Total est. const. cost--Access Road				2,344,000		
	SERVICE FACILITIES--Includes offices, shops						
	and equipment, housing, streets, and						
	utilities.					2,125,000	2,656,000
1	Camp and equipment	Lump sum		Lump sum	1,700,000		
	Contingencies (25±%)				425,000		
	Field Cost--Camp				2,125,000		
	Engineering and General Expense (25±%)				531,000		
	Total est. const. cost--Camp				2,656,000		

Operation, Maintenance, and Replacement Cost

The operation, maintenance, and replacement costs for the multi-purpose project are indicated below for the irrigation and joint-use features only. The OM&R for the power features is treated separately in Appendix V, "Power." The estimates of cost were obtained from curves, the data for the curves being based on Bureau of Reclamation practices and experiences, modified to local conditions especially in regard to the labor costs prevailing in Ethiopia. Power cost for pumping were assumed to be Eth$0.03 per kilowatt-hour.

Annual Cost--Irrigation and Joint-use Features

Feature	O&M (Eth$)	Replacements (Eth$)	Power cost (Eth$)
Diversion Tunnel	10,000	-	-
Lake Tana Dam and Reservoir	100,000	-	-
Conveyance System	2,022,000	-	-
Pumping Plants (2)	160,000	10,000	1,042,000
Electrical Facilities to Pumping Plants	49,000	4,000	-

PLAN SELECTION AND ALTERNATIVES

Lake Tana Unit

The most desirable location for the control structure appeared to be in the vicinity of the present bridge across the Blue Nile River. This location was abandoned when it was discovered that the bridge would seriously interfere with the control structure discharge unless the bridge pier foundations were extensively revised. In addition, the riverbed at the bridge is about 2 meters (6.5 feet) below the bottom of the control gates. This would increase the cost of the structure by increasing the quantity of masonry, as well as increasing the cost of the cofferdams and their unwatering.

Fukur Ishal Island was considered as a possible location for the control structure. This location would have the advantage of a shorter access road and the possibility that the cost of cofferdams and unwatering would be decreased. The location was rejected, however, because it was believed that the cost of the increased length and height of the required dikes would more than offset other savings.

A "folded" uncontrolled weir at Chara Chara cataract was investigated. This solution was rejected because of the excessive amount of excavation and masonry which would have been required.

The Chara Chara cataract was finally selected as the site for the control structure, having among others the hydrologic advantage of being narrow at that point. In addition, it is believed that the construction and unwatering of cofferdams will not be serious problems.

The actual amount of channel improvement may be overestimated. This can be determined only after detailed flow measurements have been made of both the Mesera channel and the Debre Mariam lagoon.

A structure similar to the one selected but with fewer flood release gates (15 instead of 20) would be adequate if reservoir yield were held constant throughout the year. Under this operation, a constant release of 110 cubic meters per second would be necessary when the lake level reached elevation 1785.25 with full gate openings required when the water level reached elevation 1787.25 to pass the flood flows. The savings in construction cost with the smaller number of gates is estimated to be about Eth$1,700,000.

More detailed investigations might show that some savings may be made by raising the maximum allowable lake flood level. Preliminary surveys conducted did not reveal extensive damage if the lake level would slightly exceed the historical flood level as previous investigations indicated.

Lake Tana-Beles Diversion Tunnel

Alternate locations for the diversion tunnel were considered and appear to have merit if considered exclusively for single-purpose development. A diversion tunnel to the Rahad drainage area would be engineeringly feasible and for power production appears to be economically attractive due to the high heads it would make available. For irrigation development only, a shorter tunnel would be possible to the Beles drainage basin.

From preliminary studies, the selected plan of development for utilizing the waters of Lake Tana by diversion appears to combine the two desirable economic goals--those of irrigation and hydroelectric power production. The selected location of the diversion tunnel would not develop quite as much hydro-power as the Rahad site but would make it feasible to irrigate 63,200 hectares of land.

Irrigation Unit

The upper Beles area appears to be one of the more attractive locations for irrigation development with regulation of Lake Tana. Requiring only a small diversion dam at the upper part of the project area, two main canals emanating on each side of the river would irrigate most of the lands determined to be arable by the most economical, gravity method.

Two small pumping plants have been included in the plan to encompass an additional 7,600 hectares of land situated above the gravity canal and this could well be considered as a second stage of development.

One of the alternative plans considered was to install a small hydroelectric powerplant on the South Main Canal at the 1300-meter contour elevation and dropping it to the 1220-meter contour, where the map indicated the narrowest point for use of the two pumping plants. The abundance of power production at the Alefa Powerplant was considered to be the more economical place to supply the power required for the two pumping plants. This plan also would have entailed construction of additional canal reach to swing it back to the project lands.

Other alternative studies conducted included storage facilities on the Beles River for the project area. Inasmuch as present hydrologic studies indicate that direct diversion from Lake Tana would suffice for meeting the water demand for the proposed project lands, water could be re-regulated by construction of a storage reservoir if future requirements indicate the necessity of a larger water requirement. The potential damsite would be a few kilometers upstream from the location of the diversion dam designated in one of the maps as BL-7. Although studies were not performed in estimating the cost of construction for this dam, it appears to have a fair amount of reservoir capacity for the height required to impound the water.

Further investigations may disclose the desirability of exporting water to the Dindir River drainage area. Preliminary studies indicate that it would appear feasible to construct a canal through a saddle now separating the two drainage areas, and it is suspected that there may be additional arable lands to the west of the project lands that would be susceptible for production of irrigated crops.

Middle Beles Power Project

PLAN OF DEVELOPMENT

The plan of development for the Middle Beles Power Project includes construction of a dam and reservoir, a powerplant, a substation, and transmission lines for an estimated annual generation of 741,700,000 kilowatt-hours.

PROJECT FEATURES

The features of the project plan are described in reconnaissance detail in the following paragraphs. Engineering data were obtained from topographic maps compiled from aerial photographs by stereoscopic (multiplex) projection. Altimeters were used for determination of vertical distances and plotted at 20-meter contour elevations.

Dangur Dam and Reservoir

Dangur Dam. The site is about 185 kilometers from the headwaters of the Beles River and approximately 60 airline kilometers west of the town of Metekkel and would control a drainage area of slightly more than 9,000 square kilometers. The structure would be a double curvature, variable center, thin concrete arch dam, 133.5 meters high and 405 meters long at the crest. For by-passing and controlling the river during construction, two 10-meter-diameter concrete-lined tunnels having an average length of 610 meters would be constructed, one on each bank of the river. The tunnels would be plugged after serving their purpose, in line with the high pressure grout curtain. The tunnels are designed to pass the 25-year flood frequency estimated to be in the magnitude of 3,400 cubic meters per second. The general plan and discharge curves are shown on Figure I-74, with the section and elevations of the appurtenant structures on Figure I-75.

Dam Data

Type	Concrete thin arch
Mass concrete (volume)	961,500 cu. m.
Top of dam elevation	848.5 m.
Structural height	133.5 m.
Hydraulic height	133.5 m.
Base width at plane of centers	24 m.
Crest length	602 m.
Top width	8 m.

Spillways. Spillway requirements were based on inflow design flood studies which indicated a peak inflow flood of 8,030 cubic meters per second and a 6-day volume of 1,310 million cubic meters. The service spillway was located on a convenient saddle near the left abutment of the dam. In routing the flood, it was assumed that the reservoir would be at normal water surface elevation 845 meters at the beginning of the flood. The control structure would be equipped with two radial-type gates with the discharge channel being open. At maximum water surface elevation of 848.5 meters, the service spillway will discharge 3,850 cubic meters per second. In addition, the river outlet works will discharge 198 cubic meters per second with the powerplant discharging an additional 174 cubic meters per second for passing a combined total flood of 4,222 cubic meters per second. The crest elevation of the spillway would be located at elevation 824.5 meters. No terminal structure was provided, as the discharges are not expected to be detrimental to the dam proper.

Spillway Data

Type	Gated open channel
Crest elevation	824.5 m.
Maximum capacity	3,850 cu. m. per sec.
Inflow design flood--	
6-day period	1,310,000,000 cu. m.
Type of gates (2)	radial

Power and River Outlet Works. Four power penstocks are planned to lead to the four turbines of the powerplant. The intake structures would be equipped with trashracks and controlled by a fixed-wheel gate. In addition to these outlet works, two river outlet pipes located to the right of the power outlets are planned for greater operational efficiency. They would consist of a common trashrack structure and two parallel outlet pipes, each equipped with a hollow-jet valve for controlling releases into the stilling basin. Capacity of each outlet would be 38.10 cubic meters per second. See Figures I-74 and I-75 for location and details of outlet works.

Dangur Reservoir. The reservoir basin is considered to be excellent for storage purposes, as it is mantled with impervious clay material. No serious leakage problems are expected to arise. Clearing will have to be performed as there are patches of bamboo growth and other small trees in the area. Initial active capacity of the reservoir to elevation 845 meters, without sediment, would be 3,408 million cubic meters with inactive and dead storage of 566 million cubic meters. Additional reservoir storage data are presented on Figure I-76.

Site Geology. The selected site is on Precambrian metamorphic rock considered to be suitable for the structure planned. Visual examination of the site did not reveal any appreciable overburden, attesting to the headward erosion condition of the area.

Construction Materials. A cursory examination of the immediate vicinity did not reveal any natural deposits of aggregate materials for making concrete. Further detailed examination of the area should be performed prior to selection of type of dam desired from the standpoint of available construction materials. Concrete aggregates can be crushed from quarried rock available in abundant quantities.

Access to Site. Construction of an access road to the potential damsite will be required. About 8 kilometers of road through flat, rolling topography are estimated to be required.

Dangur Powerplant

The power generating facilities are housed at the downstream toe of the dam. The Francis-type turbines are designed to operate on heads varying from 53.25 to 87 meters. The plant includes four 42,000-kilowatt generators for a total of 168,000 kilowatts of installed capacity.

Powerplant Data

Minimum head	54.25 m.
Design head	87 m.
Number of generators	4
Rating of each generator	42,000 kw.
Total plant capacity	168,000 kw.
Turbine rating (English)	59,263 hp.
Synchronous speed	176.5 r.p.m.
Type of turbine	Francis

Switchyards, Transmission Lines, and Substations

Construction costs for these items, especially the transmission lines, are rough estimates, inasmuch as power marketing load studies were not performed beyond the year 2000 for utilization of the energy generated. Thus the length of transmission lines required to load centers reflects only a rough estimate of cost.

DANGUR (BL-3) DAM & RESERVOIR

AREA CAPACITY DATA
(with sediment distributed)

CONTROL POINTS				INITIAL AREA	CAPACITY (CUBIC METERS - 10^6)			
ITEM & ALLOCATION OF STORAGE CAPACITY		DIAGRAM OF DAM	ELEVATION (METERS)	(SQ. METERS - 10^6)	INITIAL		WITH 50-YR. SEDIMENT	
					INCREMENT	TOTAL	INCREMENT	TOTAL
TOP OF DAM and MAXIMUM W.S.			848.5	111.7		4,354		3,907
					380		371	
NORMAL W.S.	FLOOD SURCHARGE		845.0	105.3		3,974		3,536
	ACTIVE CAPACITY				3,408		3,156	
MINIMUM OPERATING W.S.			791.25	31.1		566		380
	INACTIVE CAPACITY				460		353	
LIP OF LOWEST OUTLET*			768.66	10.5		106		27
	DEAD STORAGE AND SILT				106		27	
STREAM BED			730±	0		0		0

*100-YEAR SEDIMENT OF 898 x 10^6 M^3 WILL TAKE 767.7 METERS ELEVATION AT THE DAM.

2.2-BN-24

Figure I-76--Dangur (BL-3) Dam and Reservoir--Area-Capacity Data

Service Facilities

Cost for this item was obtained from curves.

ESTIMATED CONSTRUCTION COST

The estimates of construction cost for this project, based on January 1961 prices, total Eth$213,737,000. The estimates were based on limited reconnaissance design. Table I-11 shows quantities and unit prices applied on the major structure. A summary from this table is indicated below.

Feature	Cost
Dangur Dam and Reservoir	Eth$149,963,000
Powerplant	33,750,000
Transmission Lines, Switchyard, and Substation	26,090,000
Access Road	250,000
Service Facilities	3,684,000
Total Construction Cost	Eth$213,737,000

TABLE I-11--MIDDLE BELES PROJECT--RECONNAISSANCE ESTIMATE

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project: MIDDLE BELES--Power

Date of Estimate: March 1964

Prices as of: January 1961

Currency in terms of Ethiopian Dollars (U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	DANGUR DAM PROJECT--POWER					171,352,500	213,737,000
	DANGUR DAM--Concrete arch; crest length, 602 meters; height of dam, 133.5 meters. Spillway; side channel trapezoidal chute with bottom width 16.15 meters, depth 12.80 meters. Entrance controlled by two 12.19 x 16.00 radial gates. Outlet works; two 2.13-meter-diameter pipes. Penstocks; four 4.27-meter-diameter pipes. Drawings No. 0A-23-111 and 112					119,970,500	149,963,000
1	Diversion and care of river during construction and unwatering foundations	Lump sum		Lump sum	2,790,000		
2	Excavation for dam and gravity walls, mostly rock	246,700	m^3	12.00	2,960,400		
3	Excavation in open cut for spillway inlet and chute, mostly rock	222,500	m^3	6.50	1,446,250		
4	Drilling grout holes	9,600	m	27.50	264,000		
5	Drilling drainage holes	2,500	m	37.50	93,750		
6	Metal pipe and fittings for foundation grouting and drainage	21,000	kg	3.75	78,750		
7	Metal tubing and fittings for contraction joint grouting	49,400	kg	5.00	247,000		
8	Pressure grouting foundations	800	m^3	250.00	200,000		
9	Pressure grouting contraction joints and cooling systems	300	m^3	315.00	94,500		
10	Cement	120,000	m^3	138.00	16,560,000		
11	Reinforcement	1,900,000	kg	0.90	1,710,000		
12	Metal pipe or tubing and fittings for concrete cooling systems	310,000	m	2.50	775,000		
13	Metal sealing strips	14,600	m	20.00	292,000		
14	Cooling concrete	961,500	m^3	1.00	961,500		
15	Concrete in dam	961,500	m^3	35.00	33,652,500		
16	Concrete in sidewalks and parapets for dam and gravity walls	2,000	m^3	210.00	420,000		
17	Concrete in elevator tower	370	m^3	250.00	92,500		
18	Concrete in trashracks and gate hoist structure	4,400	m^3	210.00	924,000		
19	Concrete in spillway intake structure	11,200	m^3	140.00	1,568,000		
20	Concrete in spillway chute	20,200	m^3	160.00	3,232,000		
21	Concrete in spillway hoist bridges	180	m^3	220.00	39,600		
22	Concrete in outlet stilling basin	4,300	m^3	180.00	774,000		
23	Concrete in gravity walls	16,100	m^3	65.00	1,046,500		
24	Trashrack sections	277,000	kg	1.25	346,250		
25	Four fixed-wheel gates (3.53 m. x 6.75 m.)	235,870	kg	3.50	825,545		
26	Four fixed-wheel gate frames and guides	96,620	kg	3.25	314,015		
27	Four fixed-wheel gate hoists	154,290	kg	5.65	871,400		
28	Four fixed-wheel gate controls	8,165	kg	12.00	97,980		
29	Four sets stoplog guides for penstocks	130,200	kg	3.25	423,150		
30	Set of stoplogs for penstocks	125,200	kg	1.25	156,500		
31	Lifting frame for stoplogs for penstocks	1,225	kg	1.25	1,531		
32	Four penstocks (4.27-meter diameter)	1,088,600	kg	2.40	2,612,640		
33	Bulkhead gate for river outlets	9,100	kg	3.00	27,300		
34	Two sets bulkhead gate frames and guides	25,400	kg	4.70	119,380		
35	Two steel outlet pipes (2.13-meter diameter)	90,700	kg	2.40	217,680		
36	Two ring-follower gates (2.13-meter diameter)	106,600	kg	3.90	415,740		
37	Two hollow-jet valves (2.13-meter diameter)	79,400	kg	4.40	349,360		
38	Control system for ring-follower gates and hollow-jet valves	4,000	kg	12.00	48,000		
39	Gantry crane (100 metric tons)	90,700	kg	3.25	294,775		
40	Elevator	Lump sum		Lump sum	95,000		
41	Lifting frame for river outlet bulkhead gate	1,360	kg	1.25	1,700		
42	Four radial gates (12.19 m. x 16.00 m.) and embedded metalwork	720,000	kg	2.50	1,800,000		
43	Four radial gate hoists	164,000	kg	4.75	779,000		
44	Miscellaneous metalwork, piping, stairways, and crane rails	350,000	kg	3.00	1,050,000		
	Subtotal--Dam, Spillway and Outlet Works				81,059,196		

Sheet 1 of 3

Table I-11--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN–ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project: MIDDLE BELES--Power

Date of Estimate: March 1964

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	Diversion Works--Upstream cofferdam earthfill, 47 meters high; downstream cofferdam earthfill, 16 meters high; two diversion tunnels, 10.67-meter diameter. Drawings No. OA-21-111 and 112.						
45	Excavation in open cut for diversion tunnel portals, mostly rock	100,000	m^3	6.50	650,000		
46	Excavation, all classes, in tunnels	116,100	m^3	63.00	7,314,300		
47	Concrete in diversion tunnel closure structures	2,860	m^3	163.00	466,180		
48	Concrete in tunnel lining	17,900	m^3	120.00	2,148,000		
49	Concrete in tunnel plugs	7,500	m^3	100.00	750,000		
50	Cement	5,100	m^3	138.00	703,800		
51	Reinforcement	231,700	kg	0.90	208,530		
52	Permanent structural steel tunnel supports	313,700	kg	1.50	470,550		
53	Fill in cofferdams	727,500	m^3	2.50	1,818,750		
54	Removing downstream cofferdam	30,700	m^3	2.15	66,005		
55	Stoplog guides	25,850	kg	2.60	67,210		
56	Stoplogs (steel)	195,100	kg	1.25	243,875		
	Subtotal--Diversion Works				14,907,200		
	Subtotal--Items 1 through 56				95,976,396		
	Contingencies (25±%)				23,994,104		
	Field Cost--Dangur Dam				119,970,500		
	Engineering and General Expense (25±%)				29,992,500		
	Total est. const. cost--Dangur Dam				149,963,000		
	DANGUR POWERPLANT--Hydro, located at the base of the dam.					27,000,000	33,750,000
1	Structures and improvements--Masonry and reinforced concrete	Lump sum		Lump sum	6,480,000		
2	Turbines and generators--Four units; turbines, 59,263 English hp at 176.5 rpm; Francis type; generators, 42,000 kw, 11.8 kv, 0.8 pf, 50 cycles	Lump sum		Lump sum	16,470,000		
3	Accessory electrical equipment--All equipment required for control and protection of generators and station service power	Lump sum		Lump sum	2,538,000		
4	Miscellaneous powerplant equipment--Required for general station use	Lump sum		Lump sum	1,512,000		
	Field Cost--Powerplant				27,000,000		
	Engineering and General Expense (25±%)				6,750,000		
	Total est. const. cost--Powerplant				33,750,000		
	TRANSMISSION LINES, SWITCHYARD AND SUBSTATIONS					21,235,000	26,090,000
	Dangur Switchyard--Located on east abutment above the canyon.						
1	Total switchyard items including transformation and powerhouse-switchyard circuits. Field Cost	Lump sum		Lump sum	6,720,000		
	Engineering and General Expense (25±%)				1,680,000		
	Total est. const. cost--Switchyard				8,400,000		
2	Transmission lines, to load centers. Field Cost	Lump sum		Lump sum	9,075,000		
	Engineering and General Expense (20±%)				1,815,000		
	Total est. const. cost--Transmission Lines				10,890,000		
3	Substation, receiving and terminal facilities. Field Cost	Lump sum		Lump sum	5,440,000		
	Engineering and General Expense (25±%)				1,360,000		
	Total est. const. cost--Substation				6,800,000		

Sheet 2 of 3

Table I-11--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN—ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project: MIDDLE BELES--Power

Date of Estimate: March 1964

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	ACCESS ROAD					200,000	250,000
1	One lane gravel; from existing road Dangila						
	to Guba, 8 kilometers south to dam	8	km	20,000.00	160,000		
	Contingencies (25±%)				40,000		
	Field Cost--Access Road				200,000		
	Engineering and General Expense (25±%)				50,000		
	Total est. const. cost--Access Road				250,000		
	SERVICE FACILITIES--Includes offices, shops						
	and equipment, housing, streets, and						
	utilities.					2,947,000	1,684,000
1	Camps and equipment	Lump sum		Lump sum	2,357,600		
	Contingencies (25±%)				589,400		
	Field Cost--Service Facilities				2,947,000		
	Engineering and General Expense (25±%)				737,000		
	Total est. const. cost--Service Facilities				3,684,000		

Sheet 3 of 3

SECTION 4--DEBRE MARKOS SUB-BASIN

General Description

Basin Description

The Debre Markos plateau is in the central portion of the Blue Nile Basin, bounded on the northeast, east, and south by the great loop of the Blue Nile River and on the west by rolling hills and escarpment where it meets the Sudan plain. The plateau is dominated on its eastern half by the Mangestu Mountains, rising some 4100 meters (13,400 feet) above sea level, and on the northwest by the Chokke Mountains, headwaters of many of the streams. The area is drained by many small to large streams, the principal ones being the Abeye, Tumni, Cheye, Sena, Chemoga, Birr, Debohila, Fettam, Azena, and Dura Rivers. Some of the smaller tributaries of these streams drain a substantial portion of the area before joining the Blue Nile River. The area is characterized by innumerable draws and ravines, showing the effects of erosion, by rolling hills to mountainous terrain, and by wide grassy valleys. Because of their pleasant climate, the plateau valleys are relatively heavily populated in contrast to the sparsely settled lower plains.

The plan envisions a stage development of the area into two main projects--the Upper Birr Project and the Debohila Project. A third, the Lower Birr Project, is also proposed but is dependent upon prior construction of the Upper Birr Project so that its return flow may be used to firm up the water supply of the Lower Birr Project. A small unit of the Upper Birr Project--the Jiga Spring Pilot Project, which would have its own separate water supply from springs--is also proposed as a demonstrational or pilot project discussed in Section 14, Special Reports. The topography of the area is indicated in Figures I-77, I-78, and I-79, with the location of the projects shown on Figure I-80.

Projects Area Description

The Birr River area is one of the valleys in the plateau situated at an average of about 1820 meters (5300 feet) above sea level. The Birr River with its many tributaries drains an area of about 5,400 square kilometers (2,000 square miles) in southeastern Gojjam Province about 415 kilometers (255 miles) northwest of Addis Ababa. The area lies on a bench within the drainage area of the Birr River and its tributaries. Most of the tributaries rise along the southern slopes of the Chokke Mountains and flow southward, cutting gullies and ravines through the project area before joining the Birr River. The river flows generally to the south, eventually emptying into the Blue Nile River. The main stream originates well to the north of its tributaries and skirts the project on the eastern and southern sides. It traverses deep, flat, "U"-shaped valleys through the mountains in its upper reaches and has cut a deep canyon along the southern edge of the project area.

Geology and Physiography

The Birr River area is part of the volcanic plateau which is typical of a large part of the Blue Nile River Basin. Geologically, the area is characterized by a thick capping of Tertiary and late Cretaceous volcanic rocks, with more recent lava flows in evidence in some sectors. The volcanic strata are underlain by sedimentary sandstones and shales of the Triassic age. The underlying basement complex includes Precambrian granites, gneisses, and schists. The volcanic understrata, which served as parent material for the majority of the soils, consist predominately of basaltic lavas with minor amounts of rhyolitic lava, tuff, and ash.

Physiographically, the area consists of a gently sloping upland, dissected to a limited extent by small streams and drainageways. Low-lying, flat poorly drained land and rolling to hilly terrain comprise a sizable portion of the area.

Climate

There is no climatic station in the project area. However, from the records at Dangila, which corresponds closely to the same elevation, the average annual rainfall is approximately 145 centimeters (57 inches). The majority of the precipitation falls during July and August, the period of the "big" rains. Average annual temperature is estimated at 18° C (65° F). The coldest months are December and January, while the warmest are March, April, and May.

Project Land

The soils of the Birr area may be grouped into two broad categories, based on physiographic position: upland, red, latosolic soils; and lower-lying, dark clays (grumusols). Upland soils are the most extensive group and comprise the best quality arable lands. They have developed in places from underlying volcanic materials, principally basaltic lava, tuff, and ash. The latosolic soils are easily tilled, are permeable, and have moderate water-holding capacities. These soils are well suited for irrigation agriculture. The dark gray grumusols have slow rates of permeability, high water-holding capacity, and moderate amounts of organic matter and total nitrogen. These soils appear to be only moderately well suited for irrigation agriculture because of the heavy texture and moderate to poor drainage features.

The following table summarizes the land classification for this area.

Land Classes

Class	Areas in hectares					
	Total arable	Arable under canal	Irrigable land by projects			
			Upper Birr	Debo-hila	Lower Birr	Jiga Spring
1	22,767	22,465	13,150	3,240	300	224
2	8,577	3,520	1,700	960	-	-
3	36,240	20,980	9,500	-	6,300	-
Presently irrigated	2,188	-	-	-	-	-
Total	69,772	46,965	24,350	4,200	6,600	224

Much of the flatter areas and lands with dark clay soils are poorly drained and will require surface and subsurface drainage. Natural drainage channels are too widely spaced for effective ground-water control. In addition to the anticipated drainage problems in the Lower Birr Project area, the lack of a well developed natural drainage pattern in the eastern half of the Debohila Project will require considerable construction of drainageways to alleviate ground-water problems that may be anticipated.

Hydrology

Investigations revealed that the Birr River area had some 11 streams, which, if all the flow could be stored, would produce enough water to irrigate most of the land. However, it was found that the area lacked good storage sites to impound all of the water, and shortages on the irrigation projects will occur if water years similar to the 1912-17 cycle occur. The plan selected involves tapping the Selale, Adefita, and Ghussa streams

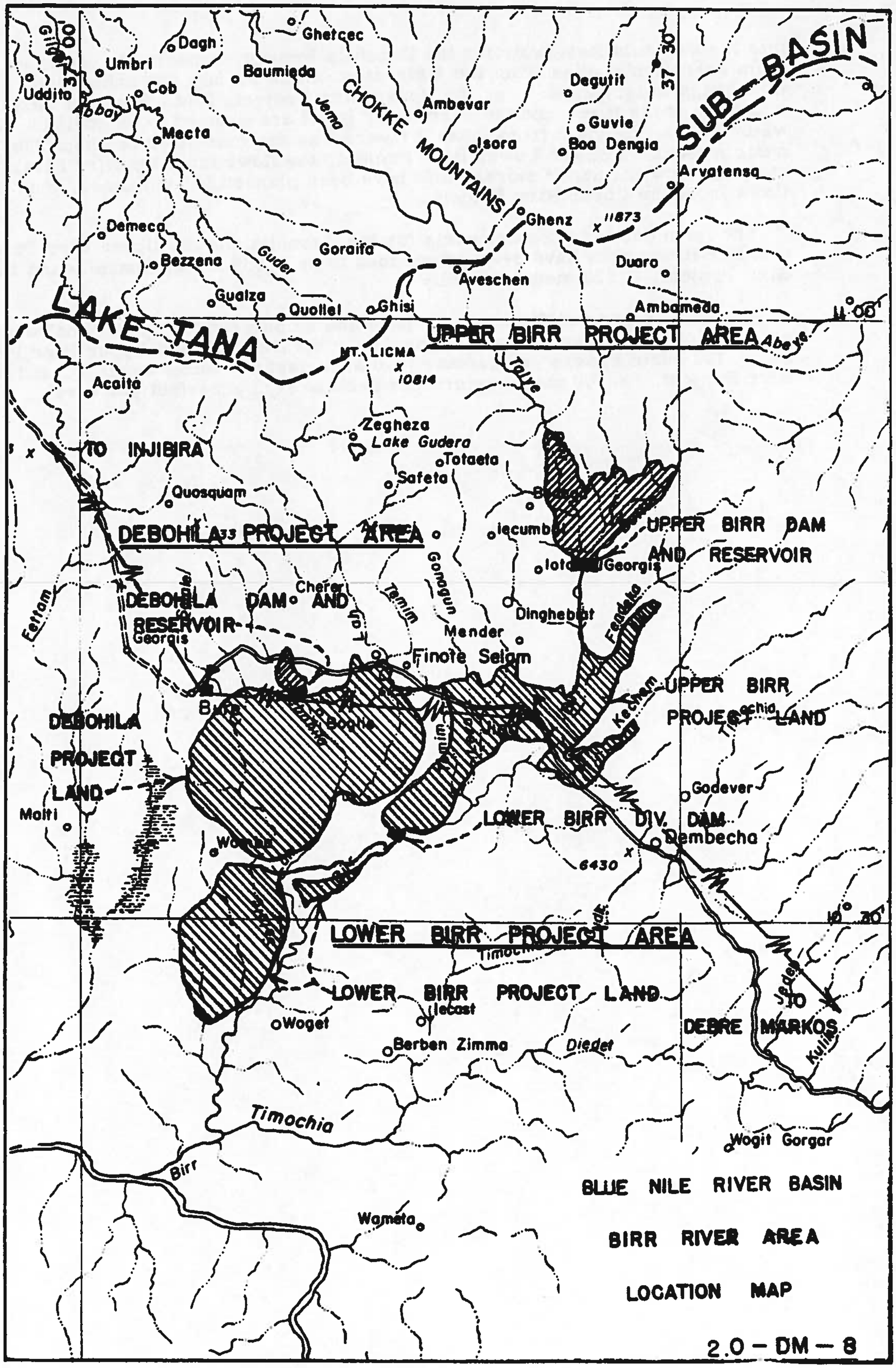


Figure I-80--Birr River Area--Location Map into the Debohila Reservoir for the Debohila Project, expected to yield, as determined from operation studies from the 4 streams, some 55,500,000 cubic meters annually in average water years. For the Upper Birr Project, flows from the Talya River, a tributary of the Birr, and the Birr River itself are planned to be utilized. In normal water years, the yield from these 2 rivers was determined to be about 298,770,000 cubic meters. For the Lower Birr Project, the flows from the Birr River and its tributaries below the upper storage site have been planned to be utilized, plus the return flows from the Upper Birr Project.

The farm delivery requirements for the Debohila and the Upper Birr Projects lands in the Birr River area have been determined to be 0.859 meter annually and for the Lower Birr Project, 0.929 meter annually.

Allowing 10 percent for canal seepage and 20 percent for operational waste and evaporation, the diversion requirements for the Debohila and Upper Birr Projects would be 12,300 cubic meters per hectare (4.0 acre-feet per acre) annually, and for the Lower Birr Project, 13,300 cubic meters per hectare (4.3 acre-feet per acre).

Upper Birr Project

PLAN OF DEVELOPMENT

The plan of development for the Upper Birr Project includes a storage dam, two main canals, a lateral distribution system, and drainage canals for irrigation of 24,350 hectares of land.

Storage would be provided by the potential Upper Birr Dam and Reservoir. Water would be released into the Upper Birr Main Canal from the outlet works on the right (west) abutment of the dam. The canal would extend in a southerly direction for about 12 kilometers, then turn westward to its terminus near the Selale River for a total distance of 87 kilometers. About 8 kilometers downstream on the Upper Birr Main Canal, the Fendeka-Kechem Main Canal would extend in a southeasterly direction, crossing the Birr River by means of a siphon and terminating on the Kechem River after traversing a distance of some 57 kilometers.

PROJECT FEATURES

The features of the project plan are described in reconnaissance detail in the following paragraphs and are shown in general plan in Figure I-81. Topographic maps were compiled from stereoscopic (multiplex) projection on 20-meter contour intervals with occasional 10-meter contours interposed. Horizontal distances were measured with tellurometer, third order, with vertical distances being computed by trigonometric leveling, using in both cases first order triangulation stations for the basis of survey. Locations of structures and other engineering data were derived from these maps.

Upper Birr Dam and Reservoir

Upper Birr Dam. The selected site is on the Birr River about 1 kilometer downstream from its confluence with the Talya River. It would be a single-purpose dam and reservoir for irrigation, providing a total of 537,400,000 cubic meters of initial storage. It would be an earth and rock fill dam with a structural height of 48 meters and a crest length of 3,700 meters. Diversion during construction would be accomplished through a gap in the dam, the gap to be closed during the dry season following the completion of the outlet conduit. See Figure I-82 for plan, section, and profile of the dam and appurtenant structures.

Dam Data

Type	earth-rockfill
Embankment volume (earth)	9,900,000 cu. m.
Embankment volume (rock)	2,900,000 cu. m.
Top of dam, elevation	1928 m.
Freeboard	1.64 m.
Structural height	48.00 m.
Hydraulic height	46.36 m.
Length of crest	3,700 m.
Width of crest	10 m.

Spillway. The peak design inflow flood being estimated at 2,059 cubic meters per second with a 2-1/2-day volume of 129 million cubic meters, a side channel ungated spillway having a 90-meter crest length would pass 822 cubic meters per second at a surcharge head of 2.8 meters. It was assumed that the reservoir water level would be at normal water surface elevation of 1923.56 meters at the start of the flood. Superstorage capacity of 82.3 million cubic meters would be provided for the floodflows. The spillway is located on the right abutment of the dam with a stilling basin provided at the discharge end.

Spillway Data

Type	uncontrolled side channel
Spillway crest elevation	1923.56 m.
Inflow design flood	2,059 cu. m. per sec.
Total flood volume--2-1/2-day period	122,000,000 cu. m.
Discharge at maximum w. s. elevation	822 cu. m. per sec.

Outlet Works. To release the water needed for irrigation, an outlet works discharging into the main canal has been provided on the right abutment of the dam and crossing the spillway chute. With the sill elevation of the intake structure at 1884 meters, the water would be conveyed through a concrete conduit to the gate chamber, about midway in the dam with a high pressure gate installed for emergency purposes. A horseshoe conduit would then be constructed to house the steel outlet pipe, and a control structure equipped with a high pressure gate and a stilling basin to dissipate the high energy flows before entering the main canal would complete the outlet works.

Outlet Works Data

Sill elevation	1884 m.
Capacity at minimum operating w. s. elevation	8.37 cu. m. per sec.
Type of gates	high pressure

Upper Birr Reservoir. The reservoir basin is in older plateau volcanics, well blanketed with impermeable material, and seepage should not be a serious factor. It is believed to be underlain by older volcanic rock. At normal water surface elevation of 1923.56 meters, the active storage capacity at the end of 50 years would be 519.4 million cubic meters, 18 million cubic meters of sediment being expected by that time. For reservoir data, see Figure I-83; area-capacity curve is shown on Figure I-84.

Site Geology. At the selected damsite, bedrock crops out at several places along the axis, and overburden along the steeper slopes is probably quite shallow. The foundations will be entirely underlain by the older volcanics, consisting of basaltic flows with some softer, interbedded ash and tuff. The basalt is vertically jointed and blocky and weathers readily on exposed surfaces, but within a depth of about 2 meters it probably becomes quite sound. It is thought to be susceptible to satisfactory grouting, and a grout curtain the entire length of the axis will be necessary if the material is not found satisfactorily cemented. Overburden along the valley walls is the typical, reddish-brown, silty, plastic clay with occasional basaltic boulders noted at the surface. Along the valley bottoms, the overburden is usually the dark gray to black, heavy, expansive, plastic clay.

Construction Materials. Several kilometers downstream from the site, small isolated gravel bars were noted that may be a suitable source of pervious materials and aggregate. However, it is anticipated that the major source of pervious material will be weathered basalt from selected quarry sites near the damsite. Riprap is available at the damsite from the basaltic flows. Impervious fill material can be found almost anywhere in the vicinity of the proposed site.

Access to Site. Access to the proposed damsite would have to be provided. The terrain from the town of Jiga to the site is gently rolling and would not require excessive costs for road construction. The length of the road is estimated to be approximately 15 kilometers.

Main Canals

The main canals would be designed with as flat a slope as practicable in order to irrigate as much of the project area as possible by gravity. In general, the proposed alinement of the canal would traverse relatively smooth, evenly sloped land, although numerous rivers, draws, and ravines would be encountered and suitable structures would have to be provided to protect the canal from high flows during the rainy season. Flat cross slopes would be found throughout most of the length, but in a few reaches the cross slope would be quite steep.

UPPER BIRR (B-5) DAM & RESERVOIR

AREA CAPACITY DATA
(with sediment distributed)

CONTROL POINTS: ITEM & ALLOCATION OF STORAGE CAPACITY		DIAGRAM OF DAM	ELEVATION (METERS)	INITIAL AREA (SQ. METERS - 10^6)	CAPACITY (CUBIC METERS - 10^6): INITIAL INCREMENT	INITIAL TOTAL	WITH 50-YR. SEDIMENT INCREMENT	WITH 50-YR. SEDIMENT TOTAL
TOP OF DAM			1928.0					
	FREEBOARD							
MAXIMUM W.S.			1926.36	29.3		619.7		601.7
	FLOOD SURCHARGE				82.3		82.3	
NORMAL W.S.			1923.56	26.8		537.4		519.4
	ACTIVE CAPACITY				533.8		517.25	
MINIMUM OPERATING W.S.			1884.6	0.9		3.6		2.15
	INACTIVE CAPACITY				1.1		0.35	
LIP OF LOWEST OUTLET*			1884.0	0.7		2.5		1.8
	DEAD STORAGE AND SILT				2.5		1.8	
STREAM BED			1880.0	0		0		0

*100-YEAR SEDIMENT OF 36,000,000 M^3 WILL TAKE 1883.8 METERS ELEVATION AT THE DAM.

2.2-BN-8

Figure I-83--Upper Birr (B-5) Dam--Area-Capacity Data

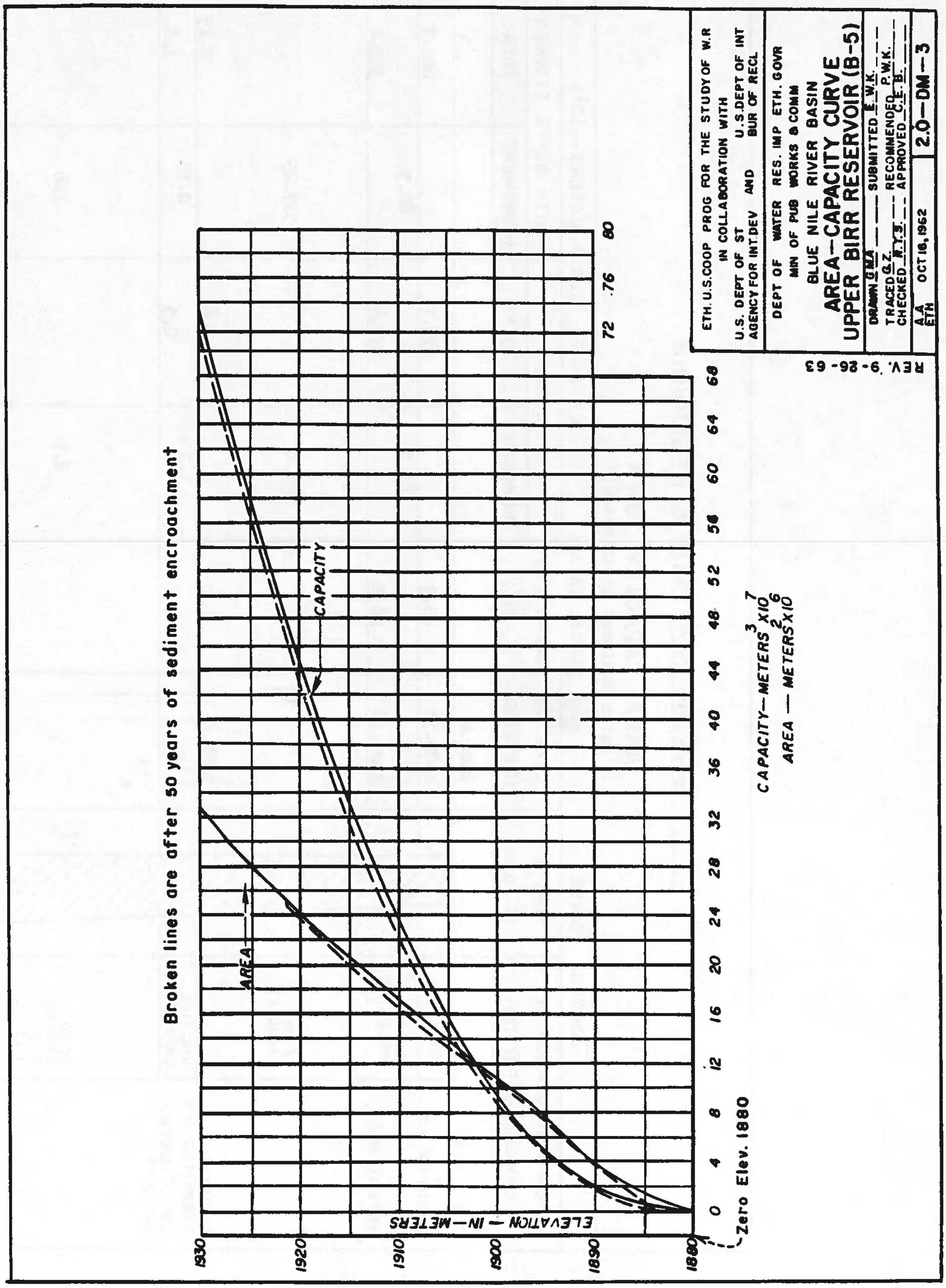


Figure I-84--Upper Birr (B-5) Reservoir--Area-Capacity Curves

Geologically, the canal routes are underlain with basaltic flows, although it is expected to be quite weathered and broken. Overburden in some cases would extend to 15 meters (49 feet), and on some of the steeper slopes, weathered basalt is expected to be encountered. In some reaches, particularly between the Temim and the Lah Rivers and in the Leza and upper Birr valleys, the underlying basalt is quite spongy and pervious. Most of the proposed canal alinement traverses presently cultivated land, but scrub trees and brush will be found along the rivers, in some of the ravines, and on some of the steeper sloped hillsides.

Canal excavation will not present any major problems, but some rock excavation will be required in several reaches. The soils along most of the length of the canal are satisfactory for canal construction, but black cotton soils occur along the first reach of the canal and along the last reach. This is a clay soil which is highly expansive when saturated and probably will require corrective action to counteract this condition.

Compacted earth embankments will be required, particularly along the lower slope when cross slopes are steep. Compacted earth lining will also be necessary in some reaches, especially when the underlying basalt is pervious.

Bridges, culverts, wasteways, turnouts, and measuring devices would be provided as needed along the canal. Major turnout structures would be required to convey the water into the main laterals at appropriate places along the canal for delivery of water to the farmers.

The estimated costs for the main canal were obtained by computing the earthwork quantities and applying unit prices; canal structure costs were obtained as a percentage of canal earthwork costs.

Upper Birr Main Canal. The Upper Birr Main Canal would start at the outlet works located on the right (west) abutment of the dam and extend in a southerly direction for about 87 kilometers, terminating near the Selale River. It would have an initial capacity of 34 cubic meters per second, and serve approximately 20,600 hectares of irrigable land.

Canal Data

Type	unlined
Length	86.9 km.
Initial capacity	34 cu. m. per sec.
Initial w. s. elevation	1880 m.

Fendeka-Kechem Main Canal. This main canal would originate, at the bifurcation works located about 8 kilometers downstream from the outlet works. It would start in a southeasterly direction, immediately crossing the Birr River by means of a siphon. It would extend initially in a northeasterly direction, making many turns before terminating near the Kechem River, traversing a distance of some 57 kilometers. It would serve approximately 3,750 irrigable hectares.

Canal Data

Type	unlined
Length	57 km.
Initial capacity	5.7 cu.m. per sec.

Distribution System and Drainage Canals

Distribution System. The distribution system would consist of a number of main laterals and many small sublaterals, which would carry the water from the main canal to the boundary of each farm unit. The main laterals would generally follow the high ridges in order that the sublaterals emanating from them could follow along contours to distribute water to the farmers. Slopes vary greatly in the project area. An estimated 20 percent has slopes of 1 percent or less; an additional 20 percent has slopes of from 1 to 3 percent; and the remaining 60 percent has steeper slopes, ranging as high as 12 percent. Locations of the sublaterals would require further investigations based on detailed topography of the area. It is estimated that about 20 sublaterals would be required.

The capacity of the canals for the distribution system was based on the assumption that the application of water would be on a continuous 24-hour operation when required on a rotation system of a lateral service area. Structures such as drops, checks, culverts, farm crossings, and turnouts were sketched and quantities computed on the sample area. The field cost thus obtained on a hectare has been used throughout the irrigation projects under discussion with appropriate adjustments for determination of distribution system cost. The total cost per hectare was found to be Eth$515.

Drainage Canals. Open, interceptor drainage canals have been provided to carry off the irrigation waste and excess precipitation. The erosion aspects of the soils, especially those of the latosol soils, and the steep slopes of the land indicate that without proper drainage, numerous deep, vertically walled drainageways would develop and wash away the soil resources. The natural drainage channel was used for outlet purposes where practicable. Included in the estimated construction cost on this sample area were drop structures in the canals. Surface drainage canals costs were found to be nearly Eth$220 per hectare.

Subsurface drainage costs were not determined due to lack of sufficient data generally and specifically for this project area. A detrimental water table under irrigation may or may not develop. The natural drainage channels are too widely spaced for effective ground water control.

Service Facilities

Service facilities will be required both for supervision during construction and later for operation and maintenance purposes. Cost for this item has been obtained from curves.

ESTIMATED PROJECT COSTS

Construction Cost

The total construction cost for the project is estimated at Eth$140,718,000 on the basis of January 1961 prices as itemized with unit prices in Table I-12. The following summary estimates have been based on limited reconnaissance designs and include allowance for contingencies, engineering, and general expense.

Estimated Construction Costs

Feature	Estimated cost
Upper Birr Dam and Reservoir	Eth$103,753,000
Upper Birr Main Canal	13,016,000
Fendeka-Kechem Canal	2,238,000
Distribution System	12,556,000
Drainage Canals	5,327,000
Service Facilities	3,125,000
Access Roads	703,000
Total Construction Costs	Eth$140,718,000

Development Cost

Clearing the lands of trees and brush will be required before irrigation for crop production. On an average, clearing costs are estimated to be about Eth$58 per hectare for a total of Eth$1,412,000 for 24,350 hectares. Land leveling costs are expected to be moderate to high, due to the steepness of the slopes. Cost per hectare for this item should approximate Eth$125 for a total estimated cost of Eth$3,044,000.

TABLE I.12--UPPER BIRR PROJECT--RECONNAISSANCE ESTIMATE

RECONNAISSANCE ESTIMATE
BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project UPPER BIRR--Irrigation

Date of Estimate December 1963

Prices as of January 1963

Currency in terms of Ethiopian Dollars

(U S $1.00 = Eth. $2.50)

ITEM NO	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	UPPER BIRR PROJECT					116,032,500	140,718,000
	UPPER BIRR DAM--Earth and rockfill; crest length, 3700 meters; height of dam, 48 meters. Drawing No. OA-23-90					86,460,500	103,753,000
1	Diversion and care of river	Lump sum		Lump sum	85,000		
2	Excavation, stripping borrow pits	640,000	m^3	1.15	736,000		
3	Excavation, all classes, dam foundation	1,200,000	m^3	1.95	2,340,000		
4	Excavation, rock, for grout cap	4,000	m^3	80.00	320,000		
5	Excavation, common in borrow areas and transportation to dam embankment	11,400,000	m^3	2.75	31,350,000		
6	Excavation, rock in borrow areas and transportation to dam embankment	1,500,000	m^3	5.00	7,500,000		
7	Riprap on upstream slope of embankment	360,000	m^3	11.00	3,960,000		
8	Bedding for riprap on dam embankment	180,000	m^3	15.00	2,700,000		
9	Earthfill in dam embankment	9,900,000	m^3	0.65	6,435,000		
10	Rockfill in dam embankment	2,900,000	m^3	0.50	1,450,000		
11	Pressure grouting, all work and material	Lump sum		Lump sum	2,099,000		
12	Furnishing and constructing 30 cm concrete pipe toe drains with open joints	1,500	lm	21.00	31,500		
13	Furnishing and constructing 46 cm concrete pipe toe drains with open joints	1,500	lm	57.00	85,500		
	Subtotal--Dam				59,092,000		
	Spillway--90 meter, uncontrolled side channel with chute and stilling basin						
14	Excavation, all classes, opencut	733,000	m^3	3.25	2,382,250		
15	Concrete in crest structure	8,500	m^3	160.00	1,360,000		
16	Concrete in chute	5,200	m^3	200.00	1,040,000		
17	Concrete in stilling basin	6,800	m^3	180.00	1,224,000		
18	Reinforcement	2,100,000	kg	1.00	2,100,000		
19	Minor items	Lump sum		Lump sum	572,400		
	Subtotal--Spillway				8,678,650		
	Outlet Works--Trashracked intake, 2.4 meter diameter conc. conduit to gate chamber, 1.7 meter dia steel pipe in 3.0 meter diameter tunnel						
20	Excavation, all classes, opencut	80,000	m^3	3.25	260,000		
21	Concrete in intake structure	100	m^3	210.00	21,000		
22	Concrete in conduit	2,100	m^3	180.00	378,000		
23	Concrete in gate chamber	100	m^3	200.00	20,000		
24	Concrete, control house substructure	260	m^3	180.00	46,800		
25	Concrete, control house superstructure	15	m^3	210.00	3,150		
26	Concrete in stilling basin	130	m^3	180.00	23,400		
27	Reinforcement	256,000	kg	1.00	256,000		
28	Minor items	Lump sum		Lump sum	74,800		
29	Trashracks	Lump sum		Lump sum	10,000		
30	High pressure gates, hoists and equipment	Lump sum		Lump sum	200,000		
31	Steel outlet pipe, 1.7 meter diameter	Lump sum		Lump sum	85,000		
32	Ventilation system	Lump sum		Lump sum	6,000		
33	Reservoir level gage and piping	Lump sum		Lump sum	6,000		
34	Miscellaneous metalwork	Lump sum		Lump sum	1,300		
35	Electrical apparatus and conductors	Lump sum		Lump sum	6,300		
	Subtotal--Outlet Works				1,397,750		
	Subtotal--Items 1 through 35				69,168,400		
	Contingencies (25%)				17,292,100		
	Field Cost--Upper Birr Dam				86,460,500		
	Engineering and General Expense (20%)				17,292,500		
	Total est. const. cost--Upper Birr Dam				103,753,000		

Sheet 1 of 3

Table I-12--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project UPPER BIRR--Irrigation

Date of Estimate December 1963

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U S $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	CANALS AND MAIN LATERALS--Unlined					12,203,800	15,254,000
	Upper Birr Canal--Length, 86.9 kms; capacity 34.0 to 2.0 m³/sec.						
1	Canal excavation, common	1,661,100	m^3	0.90	1,494,990		
2	Canal excavation, rock	25,700	m^3	9.00	231,300		
3	Compacting embankment	475,200	m^3	0.92	437,184		
4	Earth lining (special, 3 kms only)	32,000	m^3	2.20	70,400		
5	Structures, masonry and concrete	Lump sum		Lump sum	3,920,000		
6	Gates, hoists, valves and misc. metalwork	Lump sum		Lump sum	100,500		
7	Concrete pipe	Lump sum		Lump sum	241,300		
8	Miscellaneous work	Lump sum		Lump sum	422,200		
	Subtotal				6,917,874		
	Contingencies (25±%)				1,729,626		
	Field Cost--Upper Birr Canal				8,647,500		
	Engineering and General Expense (25±%)				2,161,500		
	Total est. const. costs--Upper Birr Canal				10,809,000		
	Main Laterals--Laterals off the Upper Birr Canal; length, 89.4 kms; capacities, 5.0 to 1.0 m³/sec.						
9	Canal excavation, common	325,080	m^3	0.95	308,826		
10	Canal excavation, rock	6,630	m^3	9.75	64,643		
11	Compacting embankment	84,360	m^3	0.98	82,673		
12	Structures, masonry and concrete	Lump sum		Lump sum	800,500		
13	Gates, hoists, valves and misc. metalwork	Lump sum		Lump sum	20,500		
14	Concrete pipe	Lump sum		Lump sum	49,200		
15	Miscellaneous work	Lump sum		Lump sum	86,200		
	Subtotal				1,412,542		
	Contingencies (25±%)				353,158		
	Field Cost--Main Laterals				1,765,700		
	Engineering and General Expense (25±%)				441,300		
	Total est. const. cost--Main Laterals				2,207,000		
	Fandaka-Kechem Canal--length, 60.7 kms; capacity, 5.0 to 1.1 m³/sec.						
16	Canal excavation, common	331,950	m^3	0.95	315,353		
17	Canal excavation, rock	6,770	m^3	9.75	66,008		
18	Compacting embankment	82,880	m^3	0.98	81,222		
19	Structures, masonry and concrete	Lump sum		Lump sum	811,800		
20	Gates, hoists, valves and misc. metalwork	Lump sum		Lump sum	20,800		
21	Concrete pipe	Lump sum		Lump sum	49,900		
22	Miscellaneous work	Lump sum		Lump sum	87,400		
	Subtotal				1,432,883		
	Contingencies (25±%)				358,117		
	Field cost--Fandaka-Kechem Canal				1,790,600		
	Engineering and General Expense (25±%)				447,400		
	Total est. const. cost--Fandaka-Kechem Canal				2,238,000		
	IRRIGATION DISTRIBUTION SYSTEM--Unlined open lateral system for 24,350 net hectares under the Upper Birr and Fandaka-Kechem canals.					10,044,400	12,556,000
1	Laterals and structures	24,350	ha	330.00	8,035,500		
	Contingencies (25±%)				2,008,900		
	Field Cost--Distribution System				10,044,400		
	Engineering and General Expense (25±%)				2,511,600		
	Total est. const. cost--Distribution System				12,556,000		

Sheet 2 of 3

Table I-12--Continued

RECONNAISSANCE ESTIMATE
BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project UPPER BIRR--Irrigation

Date of Estimate December 1963

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U S $1.00 = Eth $2.50)

ITEM NO	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	LAND DRAINAGE--Open land drains and structures to drain 24,350 net hectares of irrigated land					4,261,300	5,327,000
1	Drains and drainage structures	24,350	ha	140.00	3,409,000		
	Contingencies (25±%)				852,300		
	Field Cost--Land Drainage				4,261,300		
	Engineering and General Expense (25±%)				1,065,700		
	Total est. const. cost--Land Drainage				5,327,000		
	ACCESS ROAD--From existing Highway No. 3 to Upper Birr Dam. Flat to gently rolling terrain					562,500	703,000
1	Road, two lane gravel	15	km	30,000.00	450,000		
	Contingencies (25±%)				112,500		
	Field Cost--Access Road				562,500		
	Engineering and General Expense (25±%)				140,500		
	Total est. const. cost--Access Road				703,000		
	CAMP--Office, shops, housing, streets and utilities					2,500,000	3,125,000
1	Camp	Lump sum		Lump sum	2,000,000		
	Contingencies (25±%)				500,000		
	Field Cost--Camp				2,500,000		
	Engineering and General Expense (25±%)				625,000		
	Total est. const. cost--Camp				3,125,000		

Operation, Maintenance, and Replacement Cost

Estimates of operation, maintenance, and replacement costs for the dam and reservoir, obtained from a curve, are approximately Eth$25, 000 annually: Annual OM&R costs for the canals and distribution system, including the headquarters facilities and roads, are estimated to be about Eth$785, 000.

DEBOHILA PROJECT

PLAN OF DEVELOPMENT

The Debohila Project development plan includes a storage dam, three diversion dams, a feeder canal, a lateral distribution system, and drainage canals for irrigation of 4,200 hectares of land. The potential Debohila Dam and Reservoir would provide storage for the project. The three diversion dams and the feeder canal would divert the flows from the Selale, Adefita, and Ghussa Rivers into the Debohila Reservoir. The West Debohila and East Debohila Canals, each about 17 kilometers in length, would convey the water by gravity to the distribution system and thence to the farmers' headgates.

PROJECT FEATURES

The features of the project plan are described in reconnaissance detail in the following paragraphs, the general plan being shown in the same drawing as the Upper Birr Project (Figure I-81). Engineering data and layout of the general plan were based on the topographic maps compiled in the same manner as for the Upper Birr Project.

Debohila Dam and Reservoir

Debohila Dam. The proposed site of the Debohila Dam is about one-half kilometer south of the main road between the towns of Finote Selam and Bure. It would be a single-purpose dam for irrigation, constructed with impervious earth core and pervious and semipervious fill materials. Diversion during construction would be accomplished through a gap in the dam, the gap to be closed during the dry season following the completion of the outlet conduit. See Figure I-85 for plan, sections, and profile of the dam.

Dam Data

Type	earth-rockfill
Embankment volume (earth)	1,800,000 cu. m.
Embankment volume (rock)	2,000,000 cu. m.
Top of dam	2024.5 m.
Freeboard	2.2 m.
Structural height	59.5 m.
Hydraulic height	57.3 m.
Length of crest	1,800 m.
Width of crest	10 m.

Spillway. The spillway design was based on the inflow design flood studies. With the peak inflow being estimated at 428 cubic meters per second and with a 5-day volume of 815 million cubic meters, an uncontrolled side channel with a 61-meter crest length would discharge 308 cubic meters per second at maximum water surface elevation of 2022.3 meters. Superstorage would be 6,210,000 cubic meters. The spillway would be located on the right abutment, requiring a long chute and stilling basin.

Spillway Data

Type	side channel
Crest elevation	2020.4 m.
Inflow design flood	428 cu. m. per sec.
Total flood volume, 5-day period	815,000,000 cu. m.
Discharge at maximum w. s. elevation	308 cu. m. per sec.

Outlet Works. The outlet works would be located on the left abutment of the dam and would discharge into the feeder canal. The sill elevation of the intake structure would be at 1980 meters and would discharge under pressure into the upstream conduit. A gate chamber located approximately at the center of the dam with an emergency gate valve would discharge into the outlet pipe inside the downstream conduit. A hollow-jet valve would control the water releases into a stilling basin before they enter the main canal.

Outlet Works Data

Sill elevation	1980 m.
Capacity at minimum operating w. s. elevation	1.55 cu. m. per sec.
Type of gate valve	wedge
Size of outlet (hollow jet)	0.76 m.

Debohila Reservoir. Geologically, the reservoir area is similar to that of the Upper Birr Reservoir site, being well blanketed with impermeable material with seepage expected to be at a minimum. Initial storage capacity at normal water surface elevation of 2020.4 meters would be 50,140,000 cubic meters covering an area of a little over 3 square kilometers. See Figure I-86 for reservoir data and Figure I-87 for area-capacity curves.

Site Geology. Although rock is not exposed along the selected dam axis, bedrock is believed to be massive, fairly hard basalt with possibly some softer interflow zones of ash and tuff. With a cutoff trench and grouting, no serious seepage problem should be encountered. Overburden at the site is the typical, red, silty, plastic clay. The depth of this material may approach 12 meters in some places along the axis of the dam and average as much as 8 meters.

Construction Materials. Unlimited quantities of impervious material, consisting of the red clay, are available near the site. Semipervious materials, such as sand or gravel, are not available within economical haul distance. Basaltic rock is plentiful for riprap and other purposes near the immediate vicinity.

Access to Site. Since the existing road passes so close to the potential damsite, adequate access is assured, and no further construction for this purpose is necessary. The main road would be relocated to utilize the top of dam.

Feeder Canal and Diversion Dams

For the purpose of providing sufficient water supply for the Debohila Project, the Debohila Feeder Canal and the three diversion dams located on the Selale, Adefita, and Ghussa Rivers are necessary. The diversion dams would all be stone masonry, ogee-type structures with suitable provision for sluicing. The feeder canal would follow approximately along the 2030-meter contour or above in order to pass through the saddle on the west side of the Debohila Reservoir, and the diversion dams would be located accordingly. The feeder canal would begin at the control gate structure of the Selale with a capacity of 2.0 cubic meters per second (70 cubic feet per second) and would proceed for about 4 kilometers (2.5 miles) to the Adefita River. The flow would be delivered into the Adefita River and then picked up by the canal at the control gate of the Adefita Diversion Dam with a capacity of 3.0 cubic meters per second (105.0 cubic feet per second). It would continue with this capacity for about 2.5 kilometers (1.5 miles) and would be delivered into the Ghussa River. It would then be diverted into the canal by the Ghussa Diversion Dam. The canal would then proceed for an additional 2.5 kilometers to the Debohila Reservoir with a capacity of 5.0 cubic meters per second (175 cubic feet per second). A terminal structure is included in the estimates of cost.

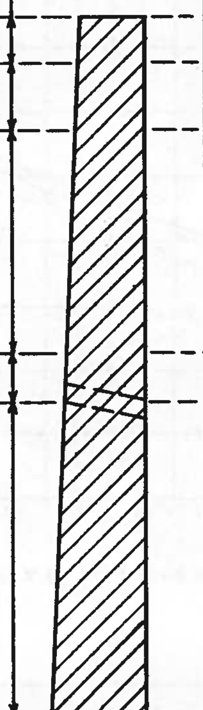
Feeder Canal Data

Type	unlined
Length	9.0 km.
Initial capacity	2.0 cu. m. per sec.
Discharge capacity	5.0 cu. m. per sec.
Initial w. s. elevation	2030 m.

DEBOHILA (DE-3) DAM & RESERVOIR

AREA CAPACITY DATA

(with sediment distributed)

CONTROL POINTS				INITIAL AREA (SQ. METERS - 10^6)	CAPACITY (CUBIC METERS - 10^6)			
ITEM & ALLOCATION OF STORAGE CAPACITY		DIAGRAM OF DAM	ELEVATION (METERS)		INITIAL		WITH 50-YR. SEDIMENT	
					INCREMENT	TOTAL	INCREMENT	TOTAL
TOP OF DAM			2024.5	3.810				
	FREEBOARD							
MAXIMUM W.S.			2022.3	3.436		56.350		55.250
	FLOOD SURCHARGE				6.210		6.210	
NORMAL W.S.			2020.40	3.157		50.140		49.040
	ACTIVE CAPACITY				48.496		47.790	
MINIMUM OPERATING W.S.			1984.41	0.286		1.644		1.250
	INACTIVE CAPACITY				0.924		0.810	
LIP OF LOWEST OUTLET*			1980.0	0.120		0.720		0.440
	DEAD STORAGE AND SILT				0.720		0.440	
STREAM BED			1965.0	0.004		0		0

*100-YEAR SEDIMENT OF 2.2 $(10)^6$ x M^3 WILL TAKE 1975.6 METERS ELEVATION AT THE DAM.

2.2-BN-9

Figure I-86--Debohila (DE-3) Dam and Reservoir--Area-Capacity Data

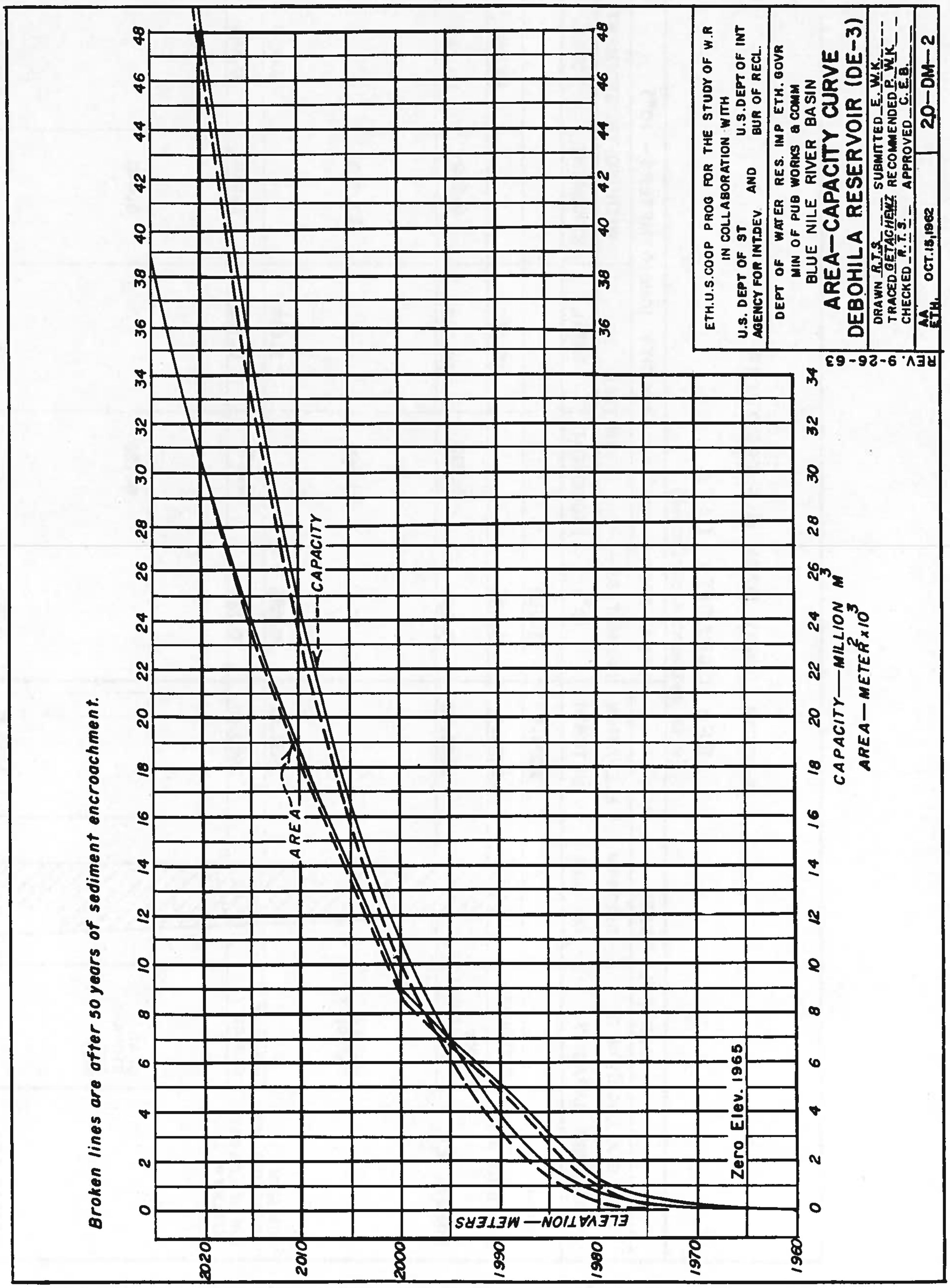


Figure I-87--Debohila (DE-3) Reservoir--Area-Capacity Curve

Diversion Dams Data

Item	Unit	Selale	Adefita	Ghussa
Type	-	masonry	ogee	overflow
Volume of masonry	cu. m.	2,846	1,098	5,498
Spillway crest length	m.	25	15	20
Crest length	m.	104	71	234
Structural height	m.	4	3.7	6.6

Debohila Main Canals

Two main canals would be required for the Debohila Project--the West Debohila Canal and the East Debohila Canal. They would flow in their respective directions approximately along the 1980-meter contour. The East Debohila Canal would begin at the end of the outlet works of the Debohila Dam, and it would be necessary for the West Debohila Canal to be siphoned across the Debohila River. The West Debohila Canal would be about 16.5 kilometers in length, and the East Debohila Canal, 17.0 kilometers. The initial capacity of the east canal would be 7.5 cubic meters per second, which would be reduced to 4.0 cubic meters per second where the west canal branches off, and further reduced to 1.6 cubic meters per second at the Ghussa River crossing. The initial capacity of the West Debohila Canal would be 3.5 cubic meters per second, which would be reduced to 1.4 cubic meters per second at the Arera River crossing.

The canals would be similar in design to the Upper Birr Canal with as flat a slope as practicable. They would cross terrain similar to that crossed by the Upper Birr Main Canal, except that no black cotton soils (latosols) would be encountered.

East Debohila Canal Data

Type	unlined
Length	17 km.
Initial capacity	7.5 cu. m. per sec.
Initial w. s. elevation	1980 m.

West Debohila Canal Data

Type	unlined
Length	16.5 km.
Initial capacity	3.5 cu. m. per sec.

Distribution System and Drainage Canals

Distribution System. The distribution system would be similar in design and operating criteria to the Upper Birr Project. The proposed locations of the larger laterals and sublaterals are shown on the general plan drawing. The entire cost of the distribution system for this project has been estimated, using the same cost per hectare as for the Upper Birr Project on the assumption that it closely approximates the topography and shape of the potential farm units.

Drainage Canals. Costs for surface drainage requirements have been estimated on the same unit cost per hectare as used on the Upper Birr Project. As in the treatment of the Upper Birr Project, no attempt has been made in this study to estimate the cost of subsurface drainage that may be required if determined by future investigations. The eastern half of the project area may be especially susceptible to ground-water problems.

Service Facilities

The estimated cost of this item has been obtained from curves, required for the same reason given for the Upper Birr Project.

ESTIMATED PROJECT COSTS

Construction Cost

The total construction cost for the project is estimated to be Eth$43, 531, 000 on the basis of January 1961 prices, as itemized with unit prices in Table I-13. The following summary of estimates has been based on limited reconnaissance designs and includes allowance for contingencies, engineering, and general expense.

Estimated Construction Costs

Feature	Cost
Dam and reservoir	Eth$36, 586, 000
Feeder canal and diversion dams	1, 455, 000
Main canals	1, 499, 000
Distribution system	2, 166, 000
Drainage canals	919, 000
Service facilities	906, 000
Total construction cost	Eth$43, 531, 000

Development Cost

Estimates of costs for clearing the lands and land leveling preparatory to crop production by irrigation are assumed to closely approximate the conditions of the Upper Birr Project requirements. Thus, the cost for development of 4, 200 hectares for irrigation purposes is estimated to be Eth$245, 000 for clearing and Eth$525, 000 for land leveling.

Operation, Maintenance, and Replacement Cost

The estimated operation, maintenance, and replacement cost for the Debohila Dam and Reservoir, although considerably less than that for the Upper Birr Dam and Reservoir, would require nearly as many personnel due to the three diversion dams and the feeder canal. Accordingly, the estimated cost for this item is approximated at Eth$23, 000 annually.

The OM&R charges for the conveyance systems are estimated to be approximately Eth$175, 000 annually.

TABLE I-13--DEBOHILA PROJECT--RECONNAISSANCE ESTIMATE

RECONNAISSANCE ESTIMATE
BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project DEBOHILA--Irrigation

Date of Estimate December 1963

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	DEBOHILA PROJECT					36,086,100	43,531,000
	DEBOHILA DAM--Earth and rockfill; crest length, 1,800 meters; height of dam, 59.5 meters. Drawing No. 0A-23-92					30,488,000	36,586,000
1	Diversion and care of river	Lump sum		Lump sum	16,000		
2	Excavation, stripping borrow pits	130,000	m^3	1.15	149,500		
3	Excavation, all classes, dam foundation	750,000	m^3	1.95	1,462,500		
4	Excavation, rock, for grout cap	2,400	m^3	80.00	192,000		
5	Excavation, common, in borrow areas and transportation to dam embankment	1,500,000	m^3	2.75	4,125,000		
6	Excavation, rock, in borrow areas and transportation to dam embankment	1,200,000	m^3	5.00	6,000,000		
7	Earthfill in dam embankment	1,800,000		0.65	1,170,000		
8	Rockfill in dam embankment	2,000,000	m^3	0.50	1,000,000		
9	Pressure grouting, all work and material	Lump sum		Lump sum	1,459,000		
	Subtotal--Dam				15,574,000		
	Spillway--Side channel, 61 meter crest, with chute and basin.						
10	Excavation, all classes, open cut	714,000	m^3	3.25	2,320,500		
11	Concrete, mass, in crest structure	5,900	m^3	150.00	885,000		
12	Concrete, crest structure walls and floor, and bridge deck	2,070	m^3	210.00	434,700		
13	Concrete in chute	7,060	m^3	200.00	1,412,000		
14	Concrete in stilling basin	3,500	m^3	180.00	630,000		
15	Reinforcement	1,575,000	kg	1.00	1,575,000		
16	Structural steel for bridge	11,600	kg	1.65	19,140		
17	Miscellaneous minor items	Lump sum		Lump sum	725,700		
	Subtotal--Spillway				8,002,040		
	Outlet Works--Trashracked box intake, pressure upstream conduit, steel pipe in downstream tunnel. Design capacity 7.5 m^3/sec. (Min. capacity, 0.75 m^3/sec. at elevation 1975.81)						
18	Excavation, all classes, open cut	75,000	m^3	3.25	243,750		
19	Concrete, intake structure	35	m^3	210.00	7,350		
20	Concrete in conduit	1,230	m^3	180.00	221,400		
21	Concrete in gate chamber	135	m^3	200.00	27,000		
22	Concrete, control house substructure	65	m^3	180.00	11,700		
23	Concrete, control house superstructure	10	m^3	210.00	2,100		
24	Concrete in stilling basin	85	m^3	180.00	15,300		
25	Reinforcement	160,000	kg	1.00	160,000		
26	Trashracks	Lump sum		Lump sum	4,500		
27	Steel outlet pipe	Lump sum		Lump sum	17,500		
28	Wedge gate valve	Lump sum		Lump sum	12,500		
29	Hollow jet valve	Lump sum		Lump sum	10,000		
30	Minor mechanical and electrical items	Lump sum		Lump sum	12,500		
31	Miscellaneous minor items	Lump sum		Lump sum	68,800		
	Subtotal--Outlet Works				814,400		
	Subtotal--Items 1 through 31				24,390,440		
	Contingencies (25±%)				6,097,560		
	Field Cost--Debohila Dam				30,488,000		
	Engineering and General Expense (20±%)				6,098,000		
	Total est. const. cost--Debohila Dam				36,586,000		

Sheet 1 of 3

Table I-13--Continued

RECONNAISSANCE ESTIMATE
BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project: Dabohila--Irrigation

Date of Estimate: December 1963

Prices as of: January 1961

Currency in terms of Ethiopian Dollars (U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY: AMOUNT	QUANTITY: UNIT	EQUIPMENT MATERIAL AND LABOR: UNIT COST	EQUIPMENT MATERIAL AND LABOR: COST	FIELD COST	TOTAL CONSTRUCTION COST
	DIVERSION DAMS--Three required to capture the flows of the Selale, Adefita and Ghussa Rivers for diversion and storage in the Dabohila Reservoir. Including feeder canals.					1,206,600	1,455,000
	Selale Diversion Dam--Stone masonry dam with 25 meter ogee spillway; crest length, 104 meters; max. height, 4 meters.						
1	Diversion and care of river	Lump sum		Lump sum	11,000		
2	Excavation, common for weir and structures	1,660	m^3	1.95	3,237		
3	Excavation, rock for weir and structures	420	m^3	8.00	3,360		
4	Masonry in weir and abutments	2,846	m^3	70.00	199,220		
5	Concrete in headworks and sluiceways	50	m^3	210.00	10,500		
6	Grouting foundations	104	lm	83.00	8,632		
7	Gates, gate hoists, handrails, etc.	Lump sum		Lump sum	11,300		
	Subtotal				247,249		
	Contingencies (25±%)				61,851		
	Field Cost--Selale Diversion Dam				309,100		
	Engineering and General Expense (20±%)				61,900		
	Total est. const. cost--Selale Diversion Dam				371,000		
	Adefita Diversion Dam--Stone masonry dam with 15 meter ogee spillway; crest length, 71 meters; maximum height 3.7 meters.						
1	Diversion and care of river	Lump sum		Lump sum	4,900		
2	Excavation, common for weir and structures	1,140	m^3	1.95	2,223		
3	Excavation, rock for weir and structures	280	m^3	8.00	2,240		
4	Masonry in weir and abutments	1,098	m^3	70.00	76,860		
5	Concrete in headworks and sluiceways	56	m^3	210.00	11,760		
6	Grouting foundations	71	lm	83.00	5,893		
7	Gates, gate hoists, handrails, etc.	Lump sum		Lump sum	5,000		
	Subtotal				108,876		
	Contingencies (25±%)				27,224		
	Field Cost--Adefita Diversion Dam				136,100		
	Engineering and General Expense (20±%)				26,900		
	Total est. const. cost--Adefita Diversion Dam				163,000		
	Ghussa Diversion Dam--Stone masonry dam with 20 meter ogee spillway; crest length, 234 meters; maximum height, 6.6 meters.						
1	Diversion and care of river	Lump sum		Lump sum	21,000		
2	Excavation, common for weir and structures	3,740	m^3	1.95	7,293		
3	Excavation, rock for weir and structures	940	m^3	8.00	7,520		
4	Masonry in weir and abutments	5,498	m^3	70.00	384,860		
5	Concrete in headworks and sluiceway	90	m^3	210.00	18,900		
6	Grouting foundations	234	lm	83.00	19,422		
7	Gates, gate hoists, handrails, etc.	Lump sum		Lump sum	21,900		
	Subtotal				480,895		
	Contingencies (25±%)				120,205		
	Field Cost--Ghussa Diversion Dam				601,100		
	Engineering and General Expense (20±%)				119,900		
	Total est. const. cost--Ghussa Diversion Dam				721,000		
	Dabohila Feeder Canals--To divert water to the Dabohila Res. 9 kms, 2 to 5 m^3/sec.						
1	Canal excavation, common	50,200	m^3	0.82	41,164		
2	Canal excavation, rock	2,100	m^3	8.00	16,800		
3	Compacting embankment	11,800	m^3	0.98	11,564		
4	Cross drainage	Lump sum		Lump sum	6,400		
5	Pedestrian crossings	5	ea.	1,100.00	5,500		
	Three terminal structures:						
6	Structural excavation and backfill	220	m^3	4.00	880		
7	Masonry	52	m^3	70.00	3,640		
8	Radial gates and hoists, installed	2,010	kgs	5.50	11,055		
9	Excavation for chute into Dabohila Reservoir	1,500	m^3	0.82	1,230		
10	Rubble paving for chute into Dabohila Res.	2,000	m^2	15.00	30,000		
	Subtotal				128,233		
	Contingencies (25±%)				32,067		
	Field Cost--Dabohila Feeder Canal				160,300		
	Engineering and General Expense (25±%)				39,700		
	Total est. const. cost--Dabohila Feeder Canal				200,000		

Sheet 2 of 3

Table I-13--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project DEBOHILA--Irrigation

Date of Estimate December 1963

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	IRRIGATION CANALS--Unlined					1,199,000	1,499,000
	West Debohila Canal; length, 16.5 kms; capacity, 3.5 to 1.6 cu. meters/sec.						
1	Canal excavation, common	97,910	m^3	0.95	93,015		
2	Canal excavation, rock	4,100	m^3	9.75	39,975		
3	Compacting embankment	24,520	m^3	0.98	24,030		
4	Structures, concrete and masonry	Lump sum		Lump sum	306,189		
5	Gates, hoists, valves, and misc. metalwork	Lump sum		Lump sum	7,850		
6	Concrete pipe	Lump sum		Lump sum	18,800		
7	Other miscellaneous work	Lump sum		Lump sum	33,000		
	Subtotal				522,859		
	Contingencies (25±%)				130,741		
	Field Cost--West Debohila Canal				653,600		
	Engineering and General Expense (25±%)				163,400		
	Total est. const. cost--West Debohila Canal				817,000		
	East Debohila Canal; length, 17.0 kms; capacity, 7.5 to 1.4 cu. meters/sec.						
1	Canal excavation, common	81,650	m^3	0.95	77,568		
2	Canal excavation, rock	3,400	m^3	9.75	33,150		
3	Compacting embankment	20,730	m^3	0.98	20,315		
4	Structures, concrete and masonry	Lump sum		Lump sum	255,514		
5	Gates, hoists, valves, and misc. metalwork	Lump sum		Lump sum	6,550		
6	Concrete pipe	Lump sum		Lump sum	15,700		
7	Other miscellaneous work	Lump sum		Lump sum	27,500		
	Subtotal				436,297		
	Contingencies (25±%)				109,103		
	Field Cost--East Debohila Canal				545,400		
	Engineering and General Expense (25±%)				136,600		
	Total est. const. cost--East Debohila Canal				682,000		
	IRRIGATION DISTRIBUTION SYSTEM--Unlined open lateral system for 4,200 net hectares under both the West and East Debohila Canals.					1,732,500	2,166,000
1	Laterals and structures	4,200	ha	330.00	1,386,000		
	Contingencies (25±%)				346,500		
	Field Cost--Distribution System				1,732,500		
	Engineering and General Expense (25±%)				433,500		
	Total est. const. cost--Drainage System				2,166,000		
	DRAINAGE SYSTEM--Open land drains for 4,200 net hectares of irrigated land.					735,000	919,000
1	Drains and drainage structures	4,200	ha	140.00	588,000		
	Contingencies (25±%)				147,000		
	Field Cost--Drainage System				735,000		
	Engineering and General Expense (25±%)				184,000		
	Total est. const. cost--Drainage System				919,000		
	CAMP--Includes office, shops, housing, and utilities.					725,000	906,000
1	Camp	Lump sum		Lump sum	580,000		
	Contingencies (25±%)				145,000		
	Field Cost--Camp				725,000		
	Engineering and General Expense (25±%)				181,000		
	Total est. const. cost--Camp				906,000		

Sheet 3 of 3

LOWER BIRR PROJECT

PLAN OF DEVELOPMENT

The Lower Birr Project would have a diversion dam on the Birr River and a main canal with lateral distribution system and drainage canals to provide water for irrigation of 6,600 hectares (16,300 acres) of new service lands. No storage would be required. Return flows from the Upper Birr Project plus flows from tributaries joining the river below the Upper Birr Dam would provide sufficient water supply to be diverted for the irrigation of the project. The main canal would be about 29 kilometers (18 miles) in length.

PROJECT FEATURES

The features of the project plan are described in reconnaissance detail in the following paragraphs and are shown in general plan on Figure I-88. There were no horizontal or vertical control surveys performed in this area, the contours indicated being bridged by photogrammetric (multiplex) methods from controls established in the Upper Birr Project area. The topographic map of the lower diversion dam was derived by stereoscopic means from 1:50,000 aerial photographs.

Lower Birr Diversion Dam

The diversion dam would be located on the Birr River about 11 kilometers directly south of the village of Finote Selam. At the selected site, the canyon is very deep and steep, probably requiring a cableway for construction purposes. The structure itself is envisioned to be a concrete masonry, ogee-type dam; and no particular problem should be encountered in passing a 100-year frequency flood of 790 cubic meters per second (28,000 cubic feet per second). Suitable provision should be made for flushing of the sediment load. Outlet headworks to the conveyance system would be designed for a capacity of 8.6 cubic meters per second and would be located on the right abutment of the dam. Crest length of the dam is estimated at 90 meters with a height of about 5 meters.

Diversion Dam Data

Type	masonry ogee overflow
Volume of masonry	2,980 cu.m.
Spillway crest length	80 m.
Dam length	90 m.
Structural height	5 m.
Headworks w. s. elevation	1600 m.

Site Geology. At the proposed site, the river has carved a steep, nearly vertically sided canyon several hundred feet deep through a thin veneer of younger volcanics into the older basaltic flows. Bedrock is basalt with interbedded interflow zones, ash, and tuff layers. Very little overburden, except a few boulders, has been allowed to accumulate due to the steep gradient in a narrow confined channel. Overlying the older basaltic flows, which are suitable for a dam foundation, are the very porous younger volcanic flows. The actual thickness is unknown, but where the slope flattens out near the top of canyon, the younger flows were observed.

Construction Materials. Impervious material available consists of a thin layer of the typical, reddish-brown or black, plastic clay along the canyon rim. Semipervious and pervious materials are not available in the area. Gravel and sand for concrete aggregate are not available in sufficient quantity in the area. This material would probably have to be processed from the harder (older) basaltic flows at the site.

Access to Site. Access could be provided by construction of a road about 11 kilometers (7 miles) in length, extending from the existing road near Finote Selam. Construction of this road would be relatively easy. Cableways of a light nature might be needed to get materials and personnel down to the bottom of the canyon.

Conveyance System

In order to get out of the Birr River canyon, the first 2.5 kilometers of the conveyance system will require low-head concrete pipe conduit. The pipe (precast or monolithic), 2.3 meters in diameter, would be placed by cut and cover method and would require some large stone protection against falling rocks and flooding by the stream.

The main canal would then extend from the end of the pipeline in the Birr River canyon for a distance of about 29 kilometers, proceeding along the northern edge of the Lower Birr area. The canal would have an initial capacity of 8.6 cubic meters per second, which would reduce slightly at each lateral turnout.

Distribution System and Drainage Canals

Distribution System. The distribution system would be similar in design and operating criteria to that of the Upper Birr Project. The proposed locations of the main laterals are shown on the general plan drawings. It can be seen on the drawings that the area is crossed by a number of streams flowing southward, all eventually entering the Birr River. The main canal traverses the northern edge of the project, and the main laterals follow the ridges in order to serve the lands in each narrow strip between the streams. There would be about seven main laterals having initial capacities between 1.0 and 2.6 cubic meters per second and lengths of from 4.0 to 14.0 kilometers.

Drainage Canals. Due to the flat area and poor drainage characteristics of the dark gray soils, much of the project area will require a network of surface drainage channels to carry away irrigation waste and excess precipitation. Estimates of cost for this item have been included in the total project costs.

It is quite possible that subsurface drainage channels may be required under irrigated agriculture at some future time. Lying below the Debohila and Upper Birr Projects, irrigation wastes from these two projects could very well contribute to the raising of the ground-water table to a level that would be injurious to the raising of crops. Futher detailed investigations will be required to determine the extent and feasibility of construction of subsurface drains.

Service Facilities

The reasons given for the Upper Birr Project would also apply for requirement of this item; cost has been obtained from curves.

ESTIMATED PROJECT COSTS

Construction Cost

The total construction cost for the Lower Birr Project is estimated to be Eth$12,300,000 on the basis of January 1961 prices, as itemized with unit prices in Table I-14. The following summary estimates have been based on limited reconnaissance designs and include allowances for contingencies, engineering, and general expense.

TABLE I-14--LOWER BIRR PROJECT--RECONNAISSANCE ESTIMATE

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project LOWER BIRR--Irrigation

Date of Estimate April 1963 — Currency in terms of Ethiopian Dollars

Prices as of January 1961 — (U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	LOWER BIRR PROJECT--Irrigation					9,853,000	12,300,000
	DIVERSION DAM--Stone masonry dam with 80 meter ogee spillway; crest length, 90 meters; maximum height, 5.0 meters.					330,900	397,000
1	Diversion and care of river	Lump sum		Lump sum	10,000		
2	Excavation, common for weir and structures	320	m^3	2.00	640		
3	Excavation, rock for weir and structures	480	m^3	8.00	3,840		
4	Masonry in weir and abutments	2,980	m^3	70.00	208,600		
5	Concrete in headworks and sluiceway	105	m^3	210.00	22,050		
6	Grouting foundations	90	lm	83.00	7,470		
7	Gates, hoists, handrails, etc.	Lump sum		Lump sum	12,130		
	Subtotal				264,730		
	Contingencies (25±%)				66,170		
	Field Cost--Diversion Dam				330,900		
	Engineering and General Expense (20±%)				66,100		
	Total est. const. cost--Diversion Dam				397,000		
	MAIN CONVEYANCE--Pipeline and canals over 1.0 cubic meters per second, from Diversion Dam to service area.					5,123,300	6,404,000
	Concrete Pipe--Starting at Diversion Dam and extending 2.5 kms down the Birr River Canyon.						
1	Excavation for pipe trench, common	3,640	m^3	2.00	7,280		
2	Excavation for pipe trench, rock	5,470	m^3	8.00	43,760		
3	Selected backfill and cover for pipe	25,450	m^3	2.50	63,625		
4	Concrete pipe, 2.30 meters diameter	2,500	lm	410.00	1,025,000		
5	Stone protection for pipe	2,000	m^3	15.00	30,000		
6	Bends and pipe fittings	Lump sum		Lump sum	58,500		
	Subtotal--Concrete pipe				1,228,165		
	Main Canal--Length, 29.0 kms; capacity, 8.6 to 2.7 cubic meters per second.						
7	Canal excavation, common	282,850	m^3	0.95	268,708		
8	Canal excavation, rock	17,420	m^3	9.75	169,845		
9	Compacting embankment	73,870	m^3	0.98	72,393		
10	Structures, concrete and masonry	Lump sum		Lump sum	1,096,000		
11	Gates, hoists, valves and misc. metalwork	Lump sum		Lump sum	28,100		
12	Concrete pipe	Lump sum		Lump sum	67,400		
13	Other miscellaneous work	Lump sum		Lump sum	118,000		
	Subtotal--Main Canal				1,820,446		
	Main Laterals--Length, 64.8 kms; capacity, 2.1 to 1.1 cubic meters per second.						
14	Canal excavation, common	217,370	m^3	0.95	206,502		
15	Canal excavation, rock	4,440	m^3	9.75	43,290		
16	Compacting embankment	45,820	m^3	0.98	44,904		
17	Structures, concrete and masonry	Lump sum		Lump sum	632,100		
18	Gates, hoists, valves and misc. metalwork	Lump sum		Lump sum	16,200		
19	Concrete pipe	Lump sum		Lump sum	38,900		
20	Other miscellaneous work	Lump sum		Lump sum	68,100		
	Subtotal--Main Laterals				1,049,996		
	Subtotal--Main Conveyance (Items 1-20)				4,098,607		
	Contingencies (25±%)				1,024,693		
	Field Cost--Main Conveyance				5,123,300		
	Engineering and General Expense (25±%)				1,280,700		
	Total est. const. cost--Main Conveyance				6,404,000		

Table I-14--Continued

LOWER BIRR--Irrigation

April 1963

January 1961

Item	Description	Quantity	Unit	Unit price	Amount	Field cost	Total cost
	IRRIGATION DISTRIBUTION SYSTEM--Unlined open lateral system for 6,600 net hectares of new service lands.					2,722,500	3,403,000
1	Laterals and structures.	6,600	ha	330.00	2,178,000		
	Contingencies (25±%)				544,500		
	Field Cost--Distribution System				2,722,500		
	Engineering and General Expense (25±%)				680,500		
	Total est. const. cost--Distribution System				3,403,000		
	DRAINAGE SYSTEM--Open land drains for 6,600 net hectares of irrigated land.					1,155,000	1,444,000
1	Drains and drainage structures	6,600	ha	140.00	924,000		
	Contingencies (25±%)				231,000		
	Field Cost--Drainage System				1,155,000		
	Engineering and General Expense (25±%)				289,000		
	Total est. const. cost--Drainage System				1,444,000		
	SERVICE FACILITIES--Construction of access road into the service area. Construction, operations and maintenance camp.					521,300	652,000
1	Access road	11	km	27,000.00	297,000		
2	Camp and facilities	Lump sum		L.S.	120,000		
	Subtotal				417,000		
	Contingencies (25±%)				104,300		
	Field Cost--Service Facilities				521,300		
	Engineering and General Expense (25±%)				130,700		
	Total est. const. cost--Service Facilities.				652,000		

Estimated Construction Costs

Feature	Cost
Diversion Dam	Eth$ 397,000
Conveyance system	6,404,000
Distribution system	3,403,000
Drainage system	1,444,000
Service facilities	652,000
Total construction cost	Eth$12,300,000

Development Cost

Clearing the lands for irrigated agriculture is expected to be at a minimum cost, as the area is sparsely covered with trees and brush. The cost for clearing 6,600 hectares of land is estimated to be about Eth$383,000.

Generally speaking, the Lower Birr Project area has the smoothest topography in the Birr River area and would be the easiest and least costly to develop for irrigation. The sum of Eth$400,000 is estimated for this item.

Operation, Maintenance, and Replacement Cost

Estimates of operation, maintenance, and replacement charges would be negligible for the diversion dam, which in actual practice should be operated and maintained by the ditchriders of the canal system. For this reason, no specific estimates of cost have been provided, this item being included in the distribution and main canals operation. The OM&R for the Lower Birr Project on the conveyance facilities has been estimated from the curve at about Eth$250,000 annually.

PLAN SELECTION AND ALTERNATIVES

Rough studies were made of 16 surveyed damsites and several unsurveyed potential sites before selection of a plan for the Birr River area. The potential damsites were compared as to reservoir storage capacity, height of dam, crest length of dam, rough comparative cost of dam, water available for storage, geologic conditions, and suitability of the storage site for irrigation or hydroelectric power. No excellent damsites were found in the Birr area. It was found that most of the valleys are quite broad, requiring long dams, and that most have rather steep slopes, requiring high dams to obtain the amount of storage necessary. These conditions would cause the construction of dams in these valleys to be very expensive. Some potential sites were found to be deficient in geologic foundation for the dam or to have probable excessive leakage from the reservoir.

From the data available, the selected sites appear to be reasonably free from geologic deficiencies, to be the most economical sites having the ability to store the required capacity, and to be situated where the water can be used to the best advantage. These sites, however, should have further investigation before any definite plans for construction are formulated. It is possible that a damsite on the Talya River or on the Birr River about 5 kilometers (3.1 miles) upstream from the chosen site, or a combination of the two sites, might be more feasible. These two sites are both sound geologically. Surveys were made but did not extend high enough to determine availability of the required storage capacity. They are well located hydrologically to make use of the three river valleys for storage and to leave enough drainage area above the reservoir for catchment of rainwater. The Birr River Valley in this area has a flat slope, and use of the higher reservoirs would not materially increase the elevation of the canal and thus would not increase the amount of land which could be irrigated. Canal construction from the higher reservoirs would be more difficult and more costly.

The lack of good, well situated reservoirs in the Birr area was the primary factor which dictated the choice of the proposed plan. The river valley was the only place where a potential reservoir could be found which would have sufficient capacity and water supply to irrigate a majority of the project lands. Another difficulty was that none of the potential reservoirs found was high enough to irrigate all of the available land.

The Upper Birr Canal would follow approximately along the 1880 meter contour, leaving a considerable amount of good land above this contour to be irrigated by other means if possible. A good reservoir was found on the Debohila River which, with diversions from the Selale, Adefita, and Ghussa Rivers, could supply enough water for a portion of this highland. The Leza River Valley was investigated, but it was found that potential reservoirs in this valley would be subject to excessive leakage. The Lah River was found to have a good water supply but also has poor geologic conditions. A large flow of younger pervious volcanics extends down the valley between the Lah and the Temim Rivers, and most of the water runs underground. There is a possibility that enough of this flow re-enters the Lah to justify diversion from the river about 4.0 kilometers (2.5 miles) upstream from Finote Selam. Water thus stored in a high, potential reservoir in the Arera River drainage could then be distributed to the highlands. This possible plan would require a great amount of further investigation and has been deferred from this reconnaissance report.

All streams in this higher area were studied for the possibility of direct diversion, but it was found that only very small plots of land could be irrigated by this means because the streamflows are at their lowest at the time when the irrigation water demand is the highest. Pumping possibilities were also considered but were not found feasible due to the lack of good, well situated reservoirs necessary for this operation.

Sound reservoirs were found in the Fendeka and Kechem Valleys, but they proved to be very expensive and are not well located for irrigation of any land outside of these valleys. It was determined that it would be more economical to irrigate these valleys from the Upper Birr Reservoir.

The Upper Birr Reservoir does not have enough storage capacity or water supply to irrigate the lands in the Lower Birr Project. It was found, however, that return flows from the Upper Birr Project would provide sufficient flow, at the proper time, in the Birr River at the site of the Lower Birr Diversion Dam to allow direct diversion from the river for irrigation of the Lower Birr Project lands. It is believed that return flows into the Selale and Lah Rivers would also provide an adequate supply for diversion. It is possible that direct diversion from the Selale and Lah Rivers might be more economica than direct diversion from the Birr River, but no investigations of this possibility have been performed in this study.

Possible hydroelectric power developments were considered in conjunction with irrigation requirements. None of the power developments appeared to be justified economically. A high dam at the site of the Lower Birr Diversion Dam was considered and appeared to be the most promising for power generation until it was found that the reser voir could not be raised above elevation 1700 meters without excessive leakage through pervious younger volcanics which lie above that elevation. Effects of flood and erosion benefits were not appraised.

SECTION 5--GIAMMA SUB-BASIN

General Description

The Giamma Sub-basin is in the southeastern sector of the Blue Nile River Basin, draining an area of approximately 15,700 square kilometers. Elevation ranges from more than 3000 meters on the extreme southeastern portion at the divide separating it from the Awash River Valley to about 1000 meters in the northwest where the Giamma River joins the Blue Nile. The area is characterized by mountain ranges and high plateaus, progressively deepening steep canyons, and badly eroded lands as it drains into the Blue Nile River.

Irrigation development was considered to be unfavorable due to the physical characteristics of the area. Areas of possible irrigation on gentle slopes are located on the high plateau where the temperatures would be too cool for the raising of agricultural crops. Another unfavorable factor is that such areas lie close to the headwaters and would have limited storage of water. There were no areas for project-type development on the lower portion of the basin, which consists of badly eroded, broken lands.

Hydroelectric power production was considered to be the only feasible exploitation of the water resources, after preliminary studies indicated sufficient water supply with regulation.

Plan of Development

The development plan for the Giamma River would be for the development of hydroelectric power. It includes the construction of a dam and reservoir with appurtenant structures, a powerplant, a switchyard, and transmission lines. Annual generation of firm energy is estimated to be nearly 271 million kilowatt-hours.

PROJECT FEATURES

The features of the potential power project are described in reconnaissance detail in the following paragraphs and depicted in general plan on Figure I-89. Reservoir topography (Figure I-90) was developed from aerial photographs at 1:50,000 scale, using tellurometer for horizontal and second order triangulation for vertical controls. Contour elevations were plotted at 20-meter intervals.

Giamma Dam and Reservoir

Giamma Dam. The potential damsite, on the Giamma River and located where the structure would control a drainage area of 6,140 square kilometers, is about 82.5 kilometers upstream from the confluence of the Giamma and Blue Nile Rivers. It would be an earth and rock fill dam, having a structural height above streambed of 139 meters and a crest length of 884 meters. Diversion during construction would be accomplished by construction of two 10-meter-diameter concrete tunnels with capacity to pass a 25-year flood frequency estimated to peak at 2,800 cubic meters per second. Plan, profile, and section of the dam and appurtenant structures appear on Figure I-91.

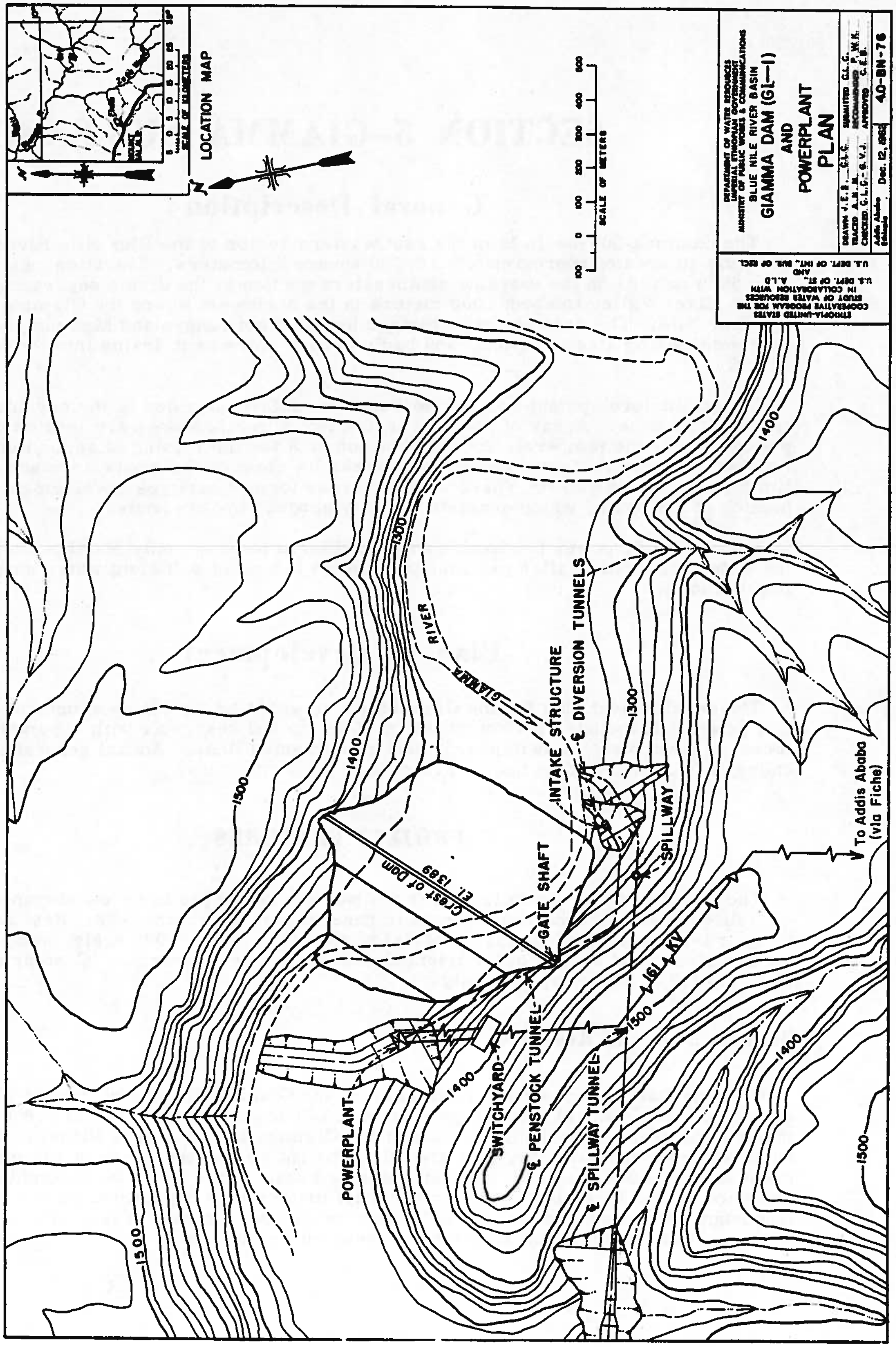


Figure I-89--Giamma Dam (GI-I) and Powerplant--Plan

Dam Data

Type	earth-rock fill
Embankment volume (earth)	11,400,000 cu.m.
Embankment volume (pervious)	16,200,000 cu.m.
Top of dam elevation	1389 m.
Freeboard	3.19 m.
Structural height	139 m.
Hydraulic height	135.81 m.
Length of crest	884 m.
Width of crest	10 m.

Spillway. Inflow design flood studies predicated on maximum probable flood, which indicated a peak inflow of 6,690 cubic meters per second and a 5-day volume of 885 million cubic meters, were used to determine spillway designs. In routing the flood, it was assumed that the reservoir would be at normal water surface elevation 1376.61 at the beginning of the flood. The spillway would discharge 839 cubic meters per second at maximum water surface elevation 1385.81. A superstorage capacity of 728 million cubic meters would be provided in the reservoir. The spillway would utilize one of the 10-meter-diameter diversion tunnels located on the left abutment of the dam and would consist of a morning-glory-type structure having a 26.8-meter-diameter crest. Excavation would be required for the stilling basin and channel to the river.

Spillway Data

Type	uncontrolled morning glory
Crest elevation	1376.61 m.
Peak inflow	6,820 cu.m. per. sec.
Total flood volume, 5-day period	885,000,000 cu.m.
Discharge at max. w.s. elevation	839 cu.m. per. sec.

Outlet Works. The outlet works would consist of an intake structure, a conduit, a gate chamber equipped with fixed-wheel gate, a 3.6-meter-diameter steel penstock, and butterfly valves. Utilizing one of the diversion tunnels, the intake structure would be constructed to intercept the tunnel for releases into the powerplant. The penstock would fork into two 2.54-meter-diameter pipes before being connected to the powerplant's turbines. Sill elevation of the intake structure has been located above the estimated 100-year sediment deposition level.

Giamma Reservoir. The reservoir basin lies within Jurassic and Cretaceous sedimentary rocks. Leakage from the potential reservoir is not anticipated, as the formation materials are relatively tight and are dipping downstream. The reservoir at normal water surface elevation 1376.61 would have an active initial capacity of 2,709 million cubic meters with 460 million cubic meters of inactive and dead storage. For area-capacity data and curves, see Figures I-92 and I-93.

Site Geology. The damsite is in a massive Jurassic limestone and soft, marly limestone, containing thinly bedded chert. The unstable conditions due to the marl and cherty limestones precluded the employment of a concrete dam, even if found desirable. Cut-off excavation depths are estimated to be about 30 meters in the stream channel section, which is expected to contain alluvium deposits of sand, gravel, and talus. Reference is made to the geologic appendix for greater details.

Construction Materials. From visual examination of the area, sand and gravel deposits were noted upstream from the proposed damsite, which are believed to be adequate for construction purposes. Impervious material for the core is available in unlimited quantities near the site.

Access to Site. An access road to the proposed construction site will have to be provided. For estimating purposes, it was assumed that a road from the town of Fiche would be approximately 28 kilometers in length, constructed through rolling and hilly terrain.

GIAMMA (GI-1) DAM & RESERVOIR

AREA CAPACITY DATA

(with sediment distributed)

CONTROL POINTS: ITEM	ALLOCATION OF STORAGE CAPACITY	DIAGRAM OF DAM	ELEVATION (METERS)	INITIAL AREA (SQ. METERS - 10^6)	CAPACITY (CUBIC METERS - 10^6): INITIAL INCREMENT	INITIAL TOTAL	WITH 50-YR. SEDIMENT INCREMENT	WITH 50-YR. SEDIMENT TOTAL
TOP OF DAM			1389					
	FREEBOARD							
MAXIMUM W.S.			1385.81	84.5		3897		3378
	FLOOD SURCHARGE				728		728	
NORMAL W.S.			1376.61	74.3		3169		2650
	ACTIVE CAPACITY				2709		2437	
MINIMUM OPERATING W.S.			1317.0	19.7		460		213
	INACTIVE CAPACITY				211		137	
LIP OF LOWEST OUTLET*			1304.0	12.7		249		76
	DEAD STORAGE AND SILT				249		76	
STREAM BED			1250.0	0		0		0

*100-YEAR SEDIMENT OF 1,042 x 10^6 M^3 WILL TAKE 1303.7 METERS ELEVATION AT THE DAM.

2.2-BN-12

Figure I-92--Giamma (GI-1) Dam and Reservoir--Area-Capacity Data

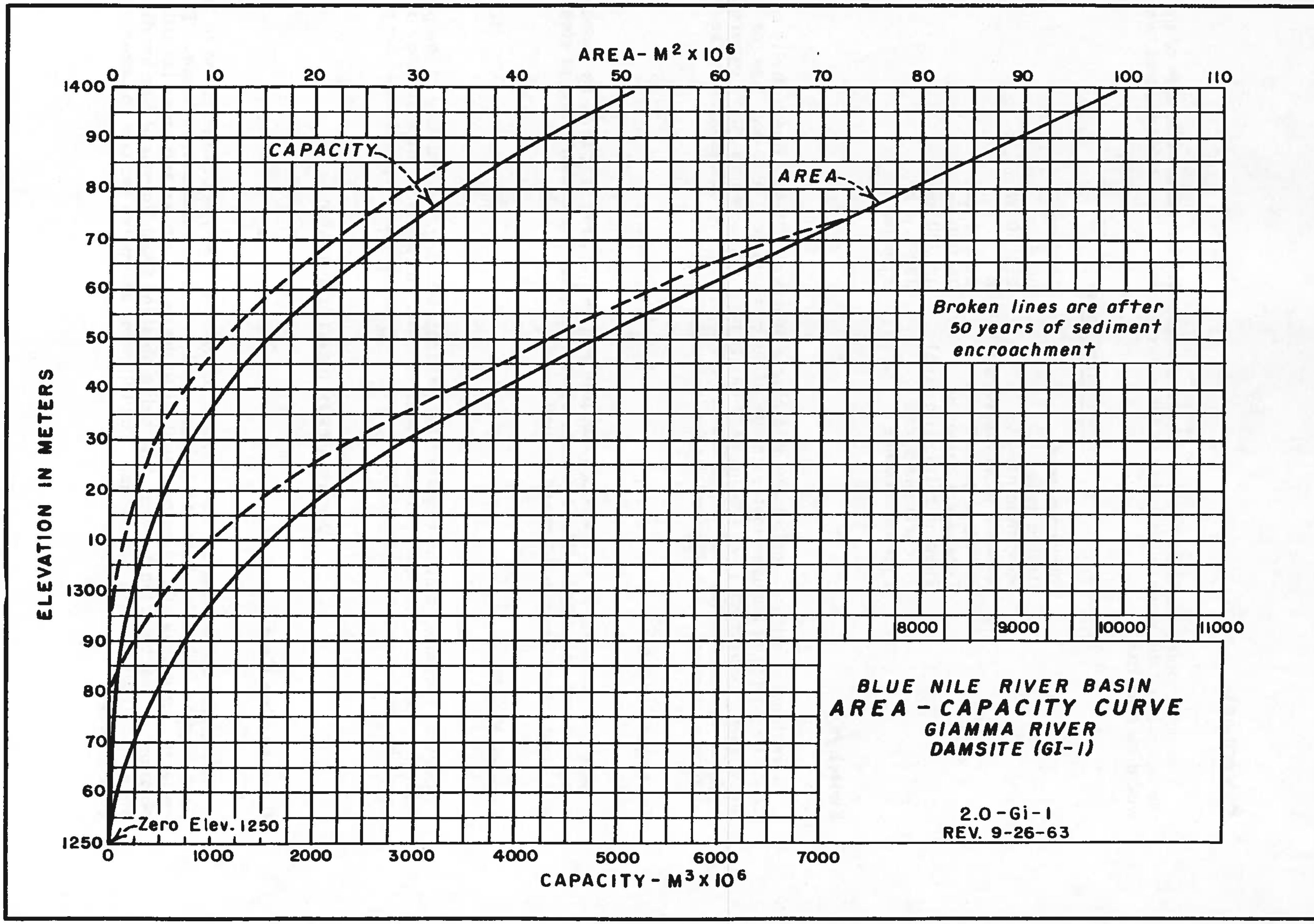


Figure I-93--Giamma (GI-1) Reservoir--Area-Capacity Curves

Powerplant

The powerplant would be located on the downstream toe on the left side of the dam, with the tailrace of the powerplant being in the river channel. Two turbines and two generators would be installed.

Powerplant Data

Minimum head	58.75 m.
Design head	90.4 m.
Maximum head	118.50 m.
Number of generators	2
Rating of generators	30,000 kw.
Total plant capacity	75,000 kv.-a.
Turbine rating (English)	42,330 hp.
Synchronous speed	230 r.p.m.
Type of turbines	Francis

Switchyard

A switchyard with a single bay and a single breaker, 161-kv. line initially is planned, located a couple of hundred meters south of the powerplant. A 45-kv. line for rural and other small commercial uses could very easily be constructed as future expansion warranted. Included in the cost estimates are transformer and communication and miscellaneous equipment. See Figure I-94 for switching diagram.

Transmission Line

About 25 kilometers of transmission line will be required if it is to be connected to the basic network facilities. The estimate of cost includes the construction of steel towers with conductors and one overhead ground wire.

Service Facilities

Service facilities will be required for personnel during construction of the project and later for operation and maintenance requirements. Included in the estimates of cost would be shops, warehouses, and equipment necessary for efficient operation of the project.

ESTIMATED PROJECT COST

Construction Cost

The construction cost for the Giamma River Power Project is estimated to be Eth$269,040,000 on the basis of January 1961 prices as summarized below. Table I-15 reflects unit prices and quantities applied to the dam. Power and other facilities were obtained primarily from curves, data being obtained from Bureau of Reclamation experiences modified to local conditions. The following estimates include engineering and general expense.

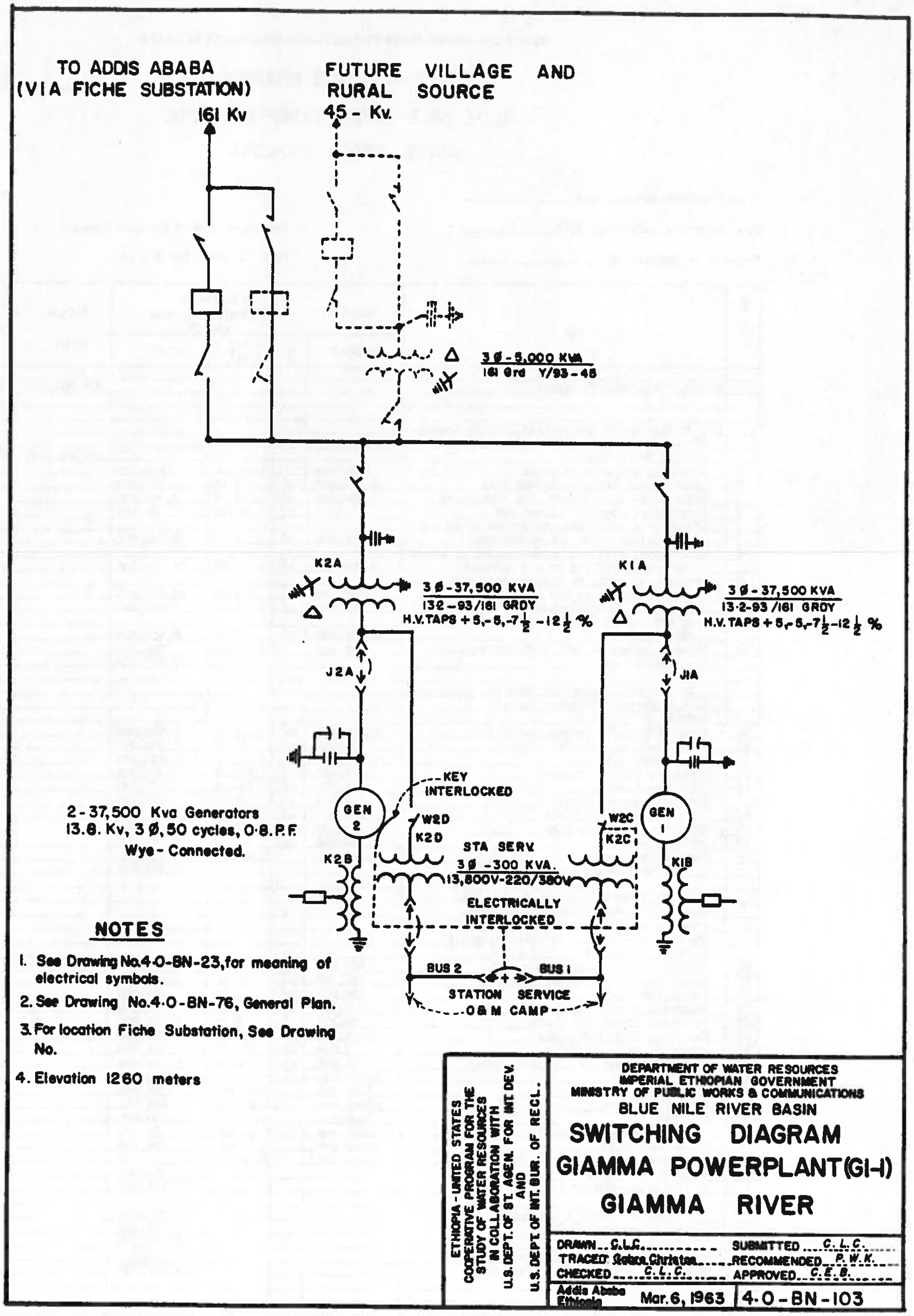


Figure I-94--Giamma Powerplant (GI-I)--Switching Diagram

TABLE I-15--GIAMMA RIVER PROJECT--RECONNAISSANCE ESTIMATE

RECONNAISSANCE ESTIMATE
BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project GIAMMA RIVER--Power

Date of Estimate February 1964

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	GIAMMA RIVER PROJECT--Power					223,389,900	269,040,000
	GIAMMA DAM--Earth and rockfill; crest length, 884 meters; height of dam, 139 meters. Drawing No. OA-23-97					202,981,400	243,578,000
1	Diversion and care of river	Lump sum		Lump sum	460,000		
2	Excavation, stripping borrow pits	1,200,000	m^3	1.15	1,380,000		
3	Excavation, all classes, dam foundation	1,900,000	m^3	1.95	3,705,000		
4	Excavation, rock, for grout cap	1,200	m^3	80.00	96,000		
5	Excavation, earthfill, in borrow areas and transportation to dam embankment	14,200,000	m^3	2.75	39,050,000		
6	Excavation, sand and gravel in borrow areas and transportation to dam embankment	5,000,000	m^3	3.00	15,000,000		
7	Excavation, rock, in borrow areas and transportation to dam embankment	5,600,000	m^3	5.00	28,000,000		
8	Earthfill in dam embankment	11,400,000	m^3	0.65	7,410,000		
9	Sand and gravel and rockfill in dam embankment	16,200,000	m^3	0.50	8,100,000		
10	Pressure grouting, all work and material	Lump sum		Lump sum	724,000		
	Subtotal--Dam				103,925,000		
	Spillway--A 26.8-meter diameter glory hole with a 10-meter diameter tunnel. Drawing No. OA-23-97						
11	Excavation, all classes, opencut	1,133,231	m^3	3.25	3,683,000		
12	Excavation, all classes, tunnel	130,000	m^3	64.00	8,320,000		
13	Tunnel supports	927,000	kg	1.40	1,298,000		
14	Concrete, crest structure	4,400	m^3	210.00	924,000		
15	Concrete, tunnel	30,700	m^3	126.00	3,868,200		
16	Concrete, tunnel chute	4,650	m^3	138.60	644,490		
17	Concrete, stilling basin	5,400	m^3	160.00	864,000		
18	Concrete, diversion plug	3,150	m^3	150.00	472,500		
19	Reinforcement	3,160,000	kg	1.00	3,160,000		
20	Miscellaneous items	Lump sum		Lump sum	586,500		
	Subtotal--Spillway				23,820,690		
	Outlet Works--Trashracked drop inlet structure, 4-meter diameter concrete pressure conduit, gate shaft, and 3.6-meter diameter penstock in 10-meter diameter tunnel. Drawing No. OA-23-97						
21	Excavation, all classes, opencut	1,760,000	m^3	3.25	5,720,000		
22	Excavation, all classes, tunnel	102,300	m^3	64.00	6,547,200		
23	Tunnel supports	705,000	kg	1.40	987,000		
24	Concrete, intake structure	8,700	m^3	210.00	1,827,000		
25	Concrete, tunnel and shaft	25,200	m^3	126.00	3,175,200		
26	Concrete, diversion walls	4,640	m^3	160.00	742,400		
27	Concrete, tailrace walls	3,260	m^3	160.00	521,600		
28	Concrete, diversion plug and anchor	15,600	m^3	150.00	2,340,000		
29	Reinforcement	3,393,000	kg	1.00	3,393,000		
30	Trashracks	Lump sum		Lump sum	325,000		
31	Butterfly valves	Lump sum		Lump sum	625,000		
32	Penstock	Lump sum		Lump sum	7,050,000		
33	Intake structure bulkhead	Lump sum		Lump sum	25,000		
34	Fixed-wheel gate	Lump sum		Lump sum	750,000		
35	Electrical and minor mechanical items	Lump sum		Lump sum	25,000		
36	Miscellaneous items				586,000		
	Subtotal--Outlet Works				34,639,400		
	Subtotal--Items 1 through 36				162,385,090		
	Contingencies (25%)				40,596,310		
	Field Cost--Giamma Dam				202,981,400		
	Engineering and General Expense 20%)				40,596,600		
	Total est. const. cost--Giamma Dam				243,578,000		

Sheet 1 of 2

Table I-15--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project: GIAMMA RIVER--Power

Date of Estimate: February 1964

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	POWERPLANT--Hydro, located on left abutment near base of dam.					12,000,000	15,000,000
1	Structures and improvements--Masonry and reinforced concrete	Lump sum		Lump sum	3,000,000		
2	Turbines and generators--Two units: turbines, 42,330 English hp at 230 rpm Francis type; generators, 37,500-kva, 13.8-kv, 0.8 pf, 50 cycles	Lump sum		Lump sum	6,840,000		
3	Accessory electrical equipment--All equipment required for control and protection of generators and station-service power	Lump sum		Lump sum	1,320,000		
4	Miscellaneous powerplant equipment--Required for general station use	Lump sum		Lump sum	840,000		
	Field Cost--Powerplant				12,000,000		
	Engineering and General Expense (25±%)				3,000,000		
	Total est. const. cost--Powerplant				15,000,000		
	SWITCHYARD, TRANSMISSION LINE, AND TERMINAL FACILITIES					5,462,000	6,790,000
	Giamma Switchyard--Located 225 meters south of powerplant. Drawings No. 0A-23-97 and 4.0-BN-103.						
1	Single breaker line bay, 161-kv, 1,200-ampere complete	Lump sum		Lump sum	300,000		
2	Switchyard circuits: two units each 0.3-km long; steel towers with overhead ground wire; 161-kv; 266.8 MCM ACSR	Lump sum		Lump sum	12,000		
3	Two transformers, 3-phase, 37,500-kva, 13.2-93/161-kv. Installation complete	Lump sum		Lump sum	1,300,000		
4	Communication and miscellaneous items	Lump sum		Lump sum	100,000		
	Field Cost--Giamma Switchyard				1,712,000		
	Engineering and General Expense (25±%)				428,000		
	Total est. const. cost--Giamma Switchyard				2,140,000		
	Transmission Line--Switchyard to basic network, 161-kv, single-circuit steel towers with overhead ground wire and 397.5 MCM ACSR conductors						
5	Rough terrain (Field Cost)	25	km	30,000.00	750,000		
	Engineering and General Expense (20±%)				150,000		
	Total est. const. cost--Transmission Line				900,000		
	Terminal Facilities						
6	Receiving-end (Field Cost)	Lump sum		Lump sum	3,000,000		
	Engineering and General Expense (25±%)				750,000		
	Total est. const. cost--Terminal Facilities				3,750,000		
	ACCESS ROAD--From Fiche to Giamma damsite, single-lane gravel.					875,000	1,094,000
1	Access road, flat to hilly terrain	28	km	25,000.00	700,000		
	Contingencies (25±%)				175,000		
	Field Cost--Access Road				875,000		
	Engineering and General Expense (25±%)				219,000		
	Total est. const. cost--Access Road				1,094,000		
	SERVICE FACILITIES--Includes office, shops, equipment, housing, streets, and utilities.					2,062,500	2,578,000
1	Camp and equipment	Lump sum		Lump sum	1,650,000		
	Contingencies (25±%)				412,500		
	Field Cost--Service Facilities				2,062,500		
	Engineering and General Expense (25±%)				515,500		
	Total est. const. cost--Service Facilities				2,578,000		

Sheet 2 of 2

Estimated Construction Cost	
Feature	Estimated cost
Giamma Dam and Reservoir	Eth$243,578,000
Powerplant	15,000,000
Switchyard and transmission lines	6,790,000
Access road	1,094,000
Service facilities	2,578,000
Total	Eth$269,040,000

PLAN SELECTION AND ALTERNATIVES

No alternative sites were examined except for cursory examination of the area, which revealed that the selected site appeared to be the most promising in consideration of all aspects of the problem. It did not appear that large scale irrigation projects could be developed in conjunction with hydroelectric power production.

The problem here was the costly relationship of the capacity of the reservoir to the flood flows. The high flood flows during the rainy season in a relatively small basin necessitated costly diversion and spillway facilities in proportion to the usable storage capacity, thus adversely affecting cost-per-kilowatt ratio. For this economic reason, the power project is not included in the initial phase of development of the Blue Nile River Basin.

SECTION 6--MUGER SUB-BASIN

General Description

The Muger Sub-basin is located in the southeastern part of the Blue Nile Basin contiguous to the capital city of Addis Ababa, just over the Entotto Mountains which form the southern boundary. The main stream of the basin is the Muger River, which drains an area of approximately 7,600 square kilometers, flowing from southeast to northwest until it joins the Blue Nile. The area is bounded on the east by a range of high hills and on the west by rolling, hilly terrain. On the approximate lower northern half of the basin, the area is characterized by rolling eroded breaks leading to the precipitous canyon escarpment over which the Muger River falls approximately 400 meters. The small valley is situated at about 2500 meters elevation, the area below the escarpment being less than 1000 meters above sea level. Evaluation of the physical factors involved led to limitation to hydroelectric power development as explained in the latter part of the chapter. From preliminary hydrologic studies it was concluded that runoff with regulation would provide sufficient supply for this purpose.

Plan of Development

The economic development of the Muger River area as it is envisioned at present from preliminary studies would be limited to hydroelectric power. Its major structures and facilities would include a storage dam, a power canal, a diversion dam, and two powerplants. Switchyards and transmission lines would convey the power, estimated to be 121.6 million kilowatt-hours annually.

Chancho Dam, the first upstream feature of the project, would be located on the Muger River about 3 kilometers due west of the village of Chancho and about 35 kilometers north of the capital city of Addis Ababa. It would impound the water in the Chancho Reservoir with controlled releases into a power canal. This canal would carry the water into the turbines of Chancho Powerplant, with the tailrace of the powerplant located in the river channel. The water from the discharges from this powerplant would again be diverted by a diversion dam, about 12 kilometers downstream, into the penstock and thence into the Falls Powerplant located at the bottom slope of Muger Falls, utilizing the natural drop of the falls of approximately 220 meters. General plan and topography of the proposed power project appear on Figure I-95.

PROJECT FEATURES

Chancho Dam and Reservoir

Chancho Dam. The storage structure, controlling a drainage area of about 500 square kilometers, would be a rock and earthfill dam with a height of 47 meters above streambed and a crest length of 504 meters. Diversion during construction would be accomplished

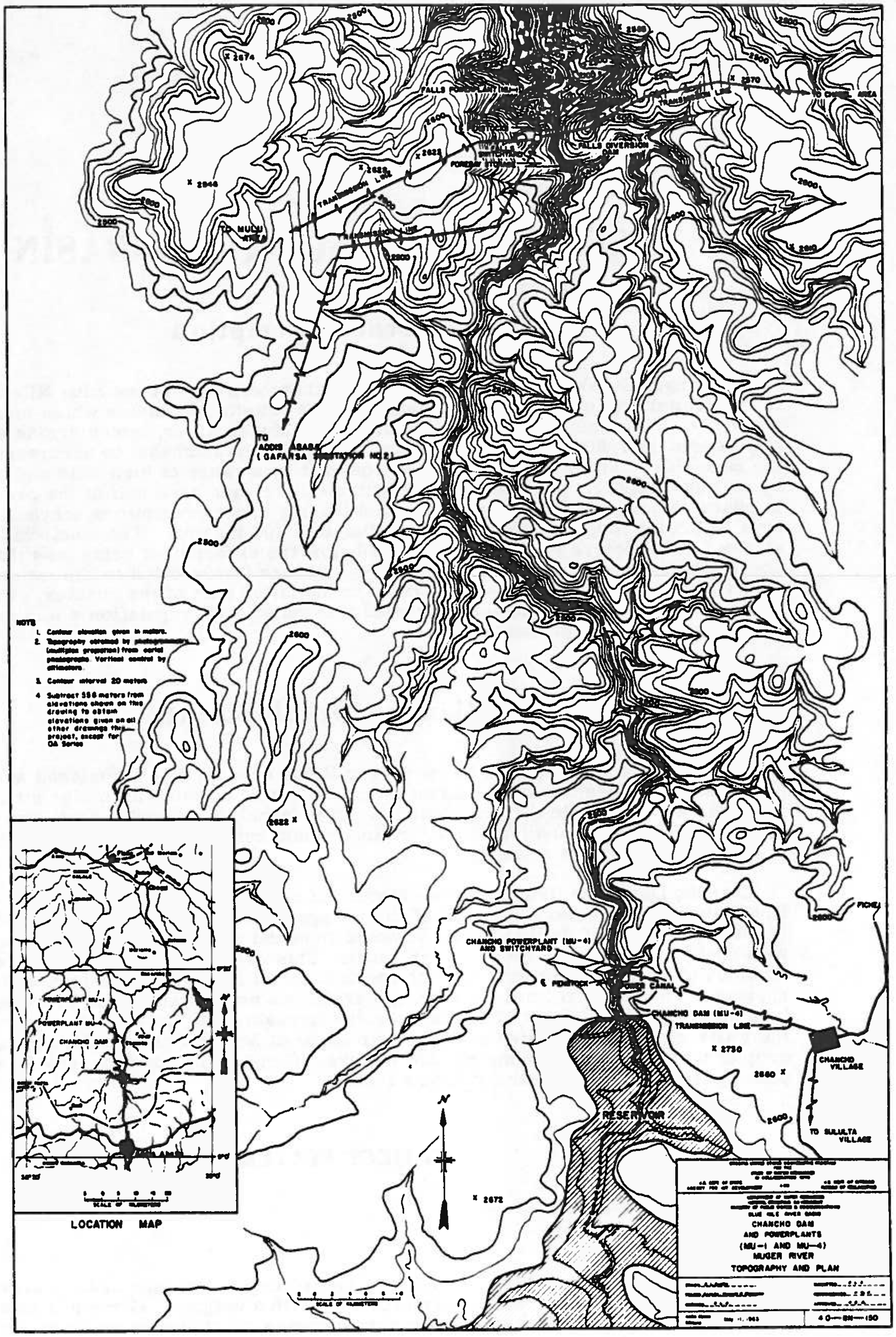


Figure I-95--Chancho Dam and Power Plants (MU-I and MU-4)--Topography and Plan by a gap in the dam, the gap to be closed after completion of the outlet works. Plan, profile, and maximum section of the dam appear on Figure I-96. Profiles of the outlet works and spillway are also included in the drawing.

Dam Data

Type	earth-rock fill
Embankment volume (earth)	250,000 cu. m.
Embankment volume (pervious)	280,000 cu. m.
Top of dam	2571 m.
Freeboard	2.48 m.
Structural height	47 m.
Hydraulic height	44.52 m.
Length of crest	504 m.
Width of crest	10 m.

Spillway. Design of the spillway was based on inflow design flood studies on the maximum probable flood, which indicated a peak inflow of 1,805 cubic meters per second and a 2.5-day volume of 105 million cubic meters. In routing the flood, it was assumed that the reservoir would be at normal water surface elevation 2566.35 at the beginning of the flood. The spillway would discharge 556 cubic meters per second at maximum water surface elevation 2568.52 meters; a superstorage capacity of 102.45 million cubic meters would be provided in the reservoir. The spillway would be located on the left abutment of the dam and would consist of an uncontrolled, side-channel ogee weir with a crest length of 90 meters, a concrete-lined channel with a stilling basin. A channel would be excavated from the stilling basin to the river.

Spillway Data

Type	uncontrolled side channel
Crest elevation	2566.35 m.
Peak inflow flood	1,805 cu. m. per sec.
Total flood volume-- 2.5-day period	105,000,000 cu. m.
Discharge at max. w. s. elevation	556 cu. m. per sec.

Outlet Works. The outlet works would be located on the right abutment of the dam and would consist of an intake structure with the sill elevation at 2551 meters, above the estimated 100-year sediment deposition level. It would discharge into a 1.83-meter-diameter concrete pressure conduit to the gate chamber, about midway in the dam. The chamber would house the emergency slide gate. A 2.75-meter-diameter horseshoe conduit, housing a 1.37-meter-diameter steel pipe, would lead from the chamber and terminate at the control house located at the toe of the dam. Two slide gates for greater operating and maintenance efficiency would be provided at the forked outlet pipe. The controlled releases from the reservoir would be made into the stilling basin.

Outlet Works Data

Sill elevation of intake structure	2551 m.
Capacity at minimum w. s. elevation	4.12 cu. m. per sec.
Type of gate (control house)	slide gates
Size of outlet pipe (diameter)	1.37 m.

Chancho Reservoir. The reservoir basin is entirely mantled with dark gray plastic clays, and no serious leakage problem is anticipated. The reservoir area is devoid of trees and would require very little clearing. The storage would be utilized exclusively for the production of electric power, however, there would be some sediment and inactive storage due to the requirements for releases into the power canal. Storage capacity was limited to the estimated available water supply. It would be a cyclical storage reservoir, in that filling and drawdown criteria were based on a 6-year dry cycle, 1911 through 1917. The dam would impound water in the Chancho Reservoir, which would have an initial storage capacity of 270 million cubic meters of active and 30.3 million cubic meters of inactive and dead storage. It would inundate approximately 42 square kilometers of land. For reservoir data and area-capacity curves, see Figures I-97 and I-98.

Site Geology. The proposed site is located on basaltic rock. The basalt, although moderately weathered at the surface, is quite hard, dense, black, and only slightly scoriaceous. It is vertically jointed with joint spaces ranging upward from 6 to 10 centimeters. With minor amounts of stripping of weathered material from the rock surfaces, good foundation rock can be exposed. The rock, which is well jointed, can be successfully grouted, and the probable need for a grout curtain across the entire length of the axis is recognized. See Appendix II, "Geology."

Construction Materials. Impervious fill material is readily available from the silty clay overburden in the area of the damsite and in the reservoir. Concrete aggregate, pervious material, and rockfill materials will have to be processed from the basaltic rock at the site.

Chancho Powerplant

The powerplant would be located at the discharge end of the power canal and about 750 meters downstream from Chancho Dam. It would have two turbine-driven generators, each generator having an installed capacity of about 1,000 kw. It would be served by a single 0.80-meter-diameter penstock forking before being discharged into the two turbines.

Powerplant Data

Design head	60 m.
Number of generators	2
Rating of each generator	1,000 kw.
Total plant capacity	2,500 kv.-a.
Turbine rating, each (English)	1,415 hp.
Synchronous speed	750 r.p.m.
Type of turbines	Francis

Falls Powerplant

The Falls Powerplant would be located on the bottom slopes of the Muger Falls on the left side, about 600 meters downstream from the diversion dam. It would be served by a 1.20-meter-diameter-steel penstock, 595 meters in length, dividing into two smaller penstocks just before discharging into the turbines. It would have two turbine-driven generators, each generator having an installed capacity of 12,000 kw.

Powerplant Data

Design head	362 m.
Number of generators	2
Rating of each generator	12,000 kw.
Total plant capacity	30,000 kv.-a.
Turbine rating, each (English)	16,933 hp.
Synchronous speed	374 r.p.m.
Type of turbines	impulse

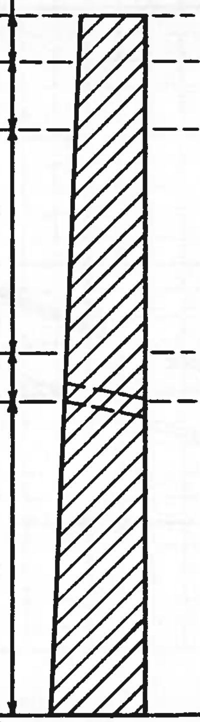
Falls Diversion Dam

The diversion dam would be about 12 kilometers from Chancho Dam on the Muger River and adjacent to the Muger Falls. It would be a masonry-concrete overflow structure, 106 meters long. Height of dam above streambed would be about 19 meters, with the crest length of the ogee-type spillway being about 81 meters. The outlet works of the dam would be located on the left abutment for controlled releases into the penstock with a design capacity of 5.3 cubic meters per second.

CHANCHO (MU-4) DAM & RESERVOIR

AREA CAPACITY DATA

(with sediment distributed)

CONTROL POINTS: ITEM & ALLOCATION OF STORAGE CAPACITY		DIAGRAM OF DAM	ELEVATION (METERS)	INITIAL AREA (SQ. METERS – 10^6)	CAPACITY (CUBIC METERS – 10^6): INITIAL – INCREMENT	INITIAL – TOTAL	WITH 50-YR. SEDIMENT – INCREMENT	WITH 50-YR. SEDIMENT – TOTAL
TOP OF DAM			2571.00					
MAXIMUM W.S.	FREEBOARD		2568.52	52.2		403.1		394.2
NORMAL W.S.	FLOOD SURCHARGE		2566.35	41.8	102.45	300.65	102.45	291.75
	ACTIVE CAPACITY				270.35		265.45	
MINIMUM OPERATING W.S.			2552.8	6.0		30.3		26.3
LIP OF LOWEST OUTLET*	INACTIVE CAPACITY		2551.0	4.3	9.4	20.9	8.8	17.5
	DEAD STORAGE AND SILT				20.9		17.5	
STREAM BED			2524.0	0		0		0

*100-YEAR SEDIMENT OF 17,800,000 M^3 WILL TAKE 2538.5 METERS ELEVATION AT THE DAM.

2.2-BN-13

Figure I-97--Chancho (MU-4) Dam and Reservoir--Area-Capacity Data

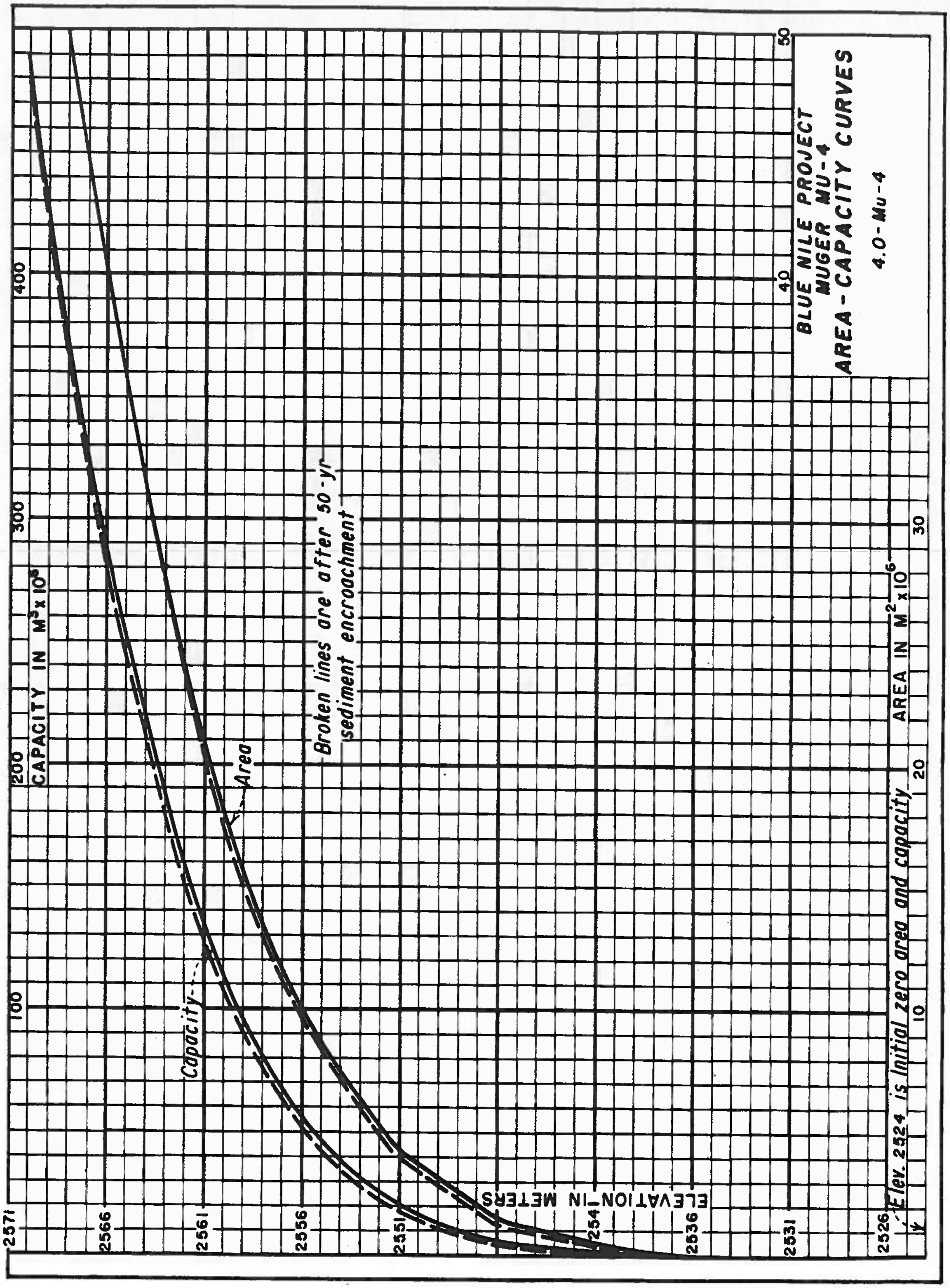


Figure I-98--Chancho (MU-4) Reservoir--Area-Capacity Curves

Diversion Dam Data

Type	masonry-ogee
Structural height	19 m.
Length of crest	106 m.
Length of spillway section	81 m.

Power Canal

The masonry-lined canal would originate at the discharge end of the stilling basin of the outlet works of Chancho Dam. It would extend for 550 meters and would have a capacity of 4.25 cubic meters per second. Included in the estimates of cost would be terminal outlet structures for controlled releases into the penstock of the Chancho Powerplant. Initial water surface elevation would be at 2550 meters.

Transmission Facilities

Switchyard for the Chancho Powerplant would be located on the roof of the powerplant and that for the Falls Powerplant would be about 150 meters west of the Falls Diversion Dam. Costs for the transmission lines and terminal substations have been obtained from curves; these facilities are not required in the initial phase of development.

Access Roads

Access to the Chancho Dam and other features of the power project is not expected to be unduly costly, as the primary road passes through the village of Chancho about 3 kilometers east of the site.

Service Facilities

Estimates of construction cost include the required service facilities for the power project. Cost for this item was obtained from curves.

ESTIMATED PROJECT COST

Construction Cost

The estimates of construction cost for the project total Eth$31,088,000, based on January 1961 prices. The estimates have been based on limited reconnaissance designs, quantities being computed and unit prices applied on the Chancho Dam and appurtenant structures and other civil works as indicated in Table I-16. Power facilities costs were obtained from curves as indicated on a lump-sum basis. The following summary of costs includes allowances for contingencies, engineering, and general expense.

TABLE I-16--MUGER RIVER PROJECT--RECONNAISSANCE ESTIMATE

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project: Muger River--Power

Date of Estimate: February 1964

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD	TOTAL CONSTRUCTION
		AMOUNT	UNIT	UNIT COST	COST	COST	COST
	MUGER RIVER PROJECT--Power					25,425,300	31,088,000
	CHANCHO DIVISION--MU-4					16,430,400	19,988,000
	CHANCHO DAM--Earth and rockfill; crest length,						
	504 meters; height of dam, 47 meters.						
	Drawing No. 0A-23-06					12,199,300	14,639,000
1	Diversion and care of river	Lump sum		Lump sum	75,000		
2	Excavation, stripping, borrow pits	21,000	m³	1.25	26,250		
3	Excavation, all classes, dam foundation	93,000	m³	2.15	199,950		
4	Excavation, rock, for grout cap	570	m³	80.00	45,600		
5	Excavation, common, in borrow areas and						
	transportation to dam embankment	260,000	m³	3.00	780,000		
6	Excavation, rock, in borrow areas and						
	transportation to dam embankment	150,000	m³	5.50	825,000		
7	Earthfill in dam embankment	250,000	m³	0.70	175,000		
8	Sand, gravel, and rockfill in dam						
	embankment	280,000	m³	0.55	154,000		
9	Pressure grouting, all work and material	Lump sum		Lump sum	299,400		
	Subtotal--Dam				2,580,200		
	Spillway--Uncontrolled, 90-meter side						
	channel. Drawing No. 0A-23-06						
10	Excavation, all classes, cement	410,000	m³	3.25	1,332,500		
11	Concrete, crest structure	8,850	m³	210.00	1,858,500		
12	Concrete, chute	3,980	m³	180.00	716,400		
13	Concrete, stilling basin	3,540	m³	160.00	566,400		
14	Reinforcement	1,394,000	kg	1.00	1,394,000		
15	Miscellaneous items	Lump sum		Lump sum	453,500		
	Subtotal--Spillway				6,321,300		
	Outlet Works--Trashracked 1.83-meter						
	diameter pressure conduit, horizontal gate						
	chamber, 1.37-meter diameter outlet pipe.						
	Drawing No. 0A-23-06						
16	Excavation, all classes, cement	37,000	m³	3.25	120,250		
17	Concrete, intake structure	35	m³	210.00	7,350		
18	Concrete, conduit	1,025	m³	180.00	184,500		
19	Concrete, gate chamber	185	m³	180.00	33,300		
20	Concrete, control house substructure	260	m³	170.00	44,200		
21	Concrete, control house superstructure	15	m³	210.00	3,150		
22	Concrete, stilling basin	185	m³	160.00	29,600		
23	Reinforcement	169,000	kg	1.00	169,000		
24	Trashracks	Lump sum		Lump sum	4,500		
25	Steel outlet pipe	Lump sum		Lump sum	40,000		
26	Slide gates	Lump sum		Lump sum	162,500		
27	Miscellaneous items	Lump sum		Lump sum	47,100		
28	Electrical and minor mechanical items	Lump sum		Lump sum	12,500		
	Subtotal--Outlet Works				857,950		
	Subtotal--Items 1 through 28				9,759,450		
	Contingencies (25%)				2,439,850		
	Field Cost--Chancho Dam				12,199,300		
	Engineering and General Expenses (20%)				2,439,700		
	Total est. const. cost--Chancho Dam				14,639,000		
	[illegible]--Power Canal from Chancho Dam to						
	Chancho Powerplant: length, 550 meters;						
	capacity, 4.25 m³/sec; grouted rubble stone						
	lining. Drawing No. 4.0-[illegible]-157					401,600	502,000
1	Canal excavation, common	6,400	m³	1.95	12,480		
2	Canal excavation, rock	2,135	m³	8.00	17,080		
3	Compacting embankment	7,150	m³	0.98	7,007		
4	Lining, grouted rubble stone paving	2,400	m²	15.00	36,000		
5	Structures for cross drainage	Lump sum		Lump sum	24,300		
	Subtotal--Power Canal				96,867		
	Contingencies (25%)				24,233		
	Field Cost--Power Canal				121,100		
	Engineering and General Expenses (25%)				30,000		
	Total est. const. cost--Power Canal				151,000		

Sheet 1 of 4

Table I-16--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project MUGER RIVER--Power

Date of Estimate February 1964 — Currency in terms of Ethiopian Dollars

Prices as of January 1961 — (U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	WATERWAYS (Continued)						
	Forebay--Grouted rubble stone lining; bottom, 25 meters by 60 meters; water depth, 9 meters; overflow weir to wasteway.						
6	Excavation, common	14,390	m^3	1.95	28,060		
7	Excavation, rock	4,800	m^3	8.00	38,400		
8	Compacting embankment	18,495	m^3	0.98	18,125		
9	Lining, grouted rubble stone paving	4,882	m^2	15.00	73,230		
10	Concrete, overflow weir	4	m^3	210.00	840		
11	Reinforcement	108	kg	1.00	108		
	Subtotal--Forebay				158,763		
	Contingencies (25±%)				39,737		
	Field Cost--Forebay				198,500		
	Engineering and General Expense (25±%)				49,500		
	Total est. const. cost--Forebay				248,000		
	Wasteway--Grouted rubble stone lining; length, 120 meters; trapezoidal section, 1-meter bottom width.						
12	Canal excavation, common	1,145	m^3	1.95	2,233		
13	Canal excavation, rock	380	m^3	8.00	3,040		
14	Compacting embankment	1,240	m^3	0.98	1,215		
15	Lining, grouted rubble stone paving	550	m^2	15.00	8,250		
	Subtotal--Wasteway				14,738		
	Contingencies (25±%)				3,662		
	Field Cost--Wasteway				18,400		
	Engineering and General Expense (25±%)				4,600		
	Total est. const. cost--Wasteway				23,000		
	Penstock--Steel, 0.80-meter-inside-diameter; length, 153 meters.						
16	Excavation, common, headworks	15	m^3	1.95	29		
17	Excavation, rock, headworks	5	m^3	8.00	40		
18	Concrete, headworks structure	6	m^3	210.00	1,260		
19	Trashrack, steel	55	kg	2.60	143		
20	Steel slide gate and hoist	3,630	kg	5.50	19,965		
21	Reinforcement	280	kg	1.00	280		
22	Steel penstock	8,680	kg	2.80	24,304		
23	Anchors and supports (20% of Item 22)	Lump sum		Lump sum	4,861		
	Subtotal--Penstock				50,882		
	Contingencies (25±%)				12,718		
	Field Cost--Penstock				63,600		
	Engineering and General Expense (25±%)				16,400		
	Total est. const. cost--Penstock				80,000		
	CHANCHO POWERPLANT--MU-4, located about 750 meters below the dam. Two units, 1,000 kw each.					2,900,000	3,625,000
1	Structures and improvements--Masonry and reinforced concrete	Lump sum		Lump sum	783,000		
2	Turbines and generators--Two units; turbines, 1,415 English hp at 750 rpm; generators, 1,000 kw, 0.8 power factor, 1,250 kva, 50 cycles	Lump sum		Lump sum	1,479,000		
3	Accessory electrical equipment--All equipment required for control and protection of generators and station-service power	Lump sum		Lump sum	382,800		
4	Miscellaneous powerplant equipment--Required for general station use	Lump sum		Lump sum	255,200		
	Field Cost--Powerplant				2,900,000		
	Engineering and General Expense (25±%)				725,000		
	Total est. const. cost--Powerplant				3,625,000		

Sheet 2 of 4

Table I-16--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project MUGER RIVER--Power

Date of Estimate February 1964 — Currency in terms of Ethiopian Dollars

Prices as of January 1961 — (U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY: AMOUNT	QUANTITY: UNIT	EQUIPMENT MATERIAL AND LABOR: UNIT COST	EQUIPMENT MATERIAL AND LABOR: COST	FIELD COST	TOTAL CONSTRUCTION COST
	TRANSMISSION LINES, SWITCHYARD, AND SUBSTATION					192,000	240,000
	Chancho Switchyard--Located on the roof of the powerplant.						
1	Line bay, one each, 15-kv with circuit breaker and bypass switch	Lump sum		Lump sum	31,500		
2	Transformers, two each, 1,500-kva, 6-15-kv delta-delta	Lump sum		Lump sum	60,000		
3	Communication and miscellaneous items	Lump sum		Lump sum	10,500		
	Field Cost--Switchyard				102,000		
	Engineering and General Expense (25%)				26,000		
	Total est. const. cost				128,000		
4	Chancho Transmission Line (Field Cost)	Lump sum		Lump sum	10,000		
	Engineering and General Expense (20%)				2,000		
	Total est. const. cost				12,000		
5	Terminal substation, receiving-end (Field Cost)	Lump sum		Lump sum	80,000		
	Engineering and General Expense (25%)				20,000		
	Total est. const. cost				100,000		
	ACCESS ROAD--From existing road about 1 kilometer south of Chancho to Chancho Dam and Powerplant					112,500	141,000
1	Gravel road, mostly one lane	3	km	30,000.00	90,000		
	Contingencies (25%)				22,500		
	Field Cost--Access Road				112,500		
	Engineering and General Expense (25%)				28,500		
	Total est. const. cost--Access Road				141,000		
	SERVICE FACILITIES--Includes offices, shops and equipment, housing, streets, and utilities					625,000	781,000
1	Camp and equipment	Lump sum		Lump sum	500,000		
	Contingencies (25%)				125,000		
	Field Cost--Service Facilities				625,000		
	Engineering and General Expense (25%)				156,000		
	Total est. const. cost--Service Facilities				781,000		
	(Note: These service facilities are also to be used by the Falls Division.)						
	FALLS DIVISION--MU-1					8,994,900	11,160,000
	FALLS DIVERSION DAM--Stone masonry; crest length, 106 meters; height of dam, 19 meters; 81-meter crest ogee spillway					842,400	1,011,000
1	Diversion and care of river	Lump sum		Lump sum	20,000		
2	Excavation, all classes, dam foundation and spillway retaining walls	580	m^3	2.50	1,450		
3	Excavation, rock, for grout cap and headworks	110	m^3	80.00	8,800		
4	Masonry in dam and retaining walls	7,810	m^3	70.00	546,700		
5	Pressure grouting, all work and material	Lump sum		Lump sum	40,300		
6	Concrete in outlet works	52	m^3	210.00	10,920		
7	Reinforcement	2,590	kg	1.00	2,590		
8	Two slide gates for sluiceway and penstock headworks, including hoists	2,270	kg	5.50	12,485		
9	Miscellaneous items	Lump sum		Lump sum	30,650		
	Subtotal--Dam				673,895		
	Contingencies (25%)				168,505		
	Field Cost--Falls Diversion Dam				842,400		
	Engineering and General Expense (20%)				168,600		
	Total est. const. cost--Dam				1,011,000		

Sheet 3 of 4

Table I-16--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project MUGER RIVER--Power

Date of Estimate February 1964 — Currency in terms of Ethiopian Dollars

Prices as of January 1961 — (U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	WATERWAYS--Steel penstock, 1.20-meter-inside diameter; length, 595 meters, from diversion dam to powerplant.					856,300	1,070,000
1	Steel penstock	194,100	kg	2.80	543,480		
2	Anchors and supports	Lump sum		Lump sum	109,000		
3	Miscellaneous items	Lump sum		Lump sum	32,600		
	Subtotal--Penstock				685,080		
	Contingencies (25%)				171,220		
	Field Cost--Penstock				856,300		
	Engineering and General Expense (25%)				213,700		
	Total est. const. cost--Penstock				1,070,000		
	FALLS POWERPLANT--MU-1, located on left side of the river about 600 meters downstream from Falls Dam. Two units, 12,000-kw each.					4,500,000	5,625,000
1	Structures and improvements--Masonry and reinforced concrete	Lump sum		Lump sum	1,170,000		
2	Turbines and generators--Two units: turbines, impulse, single-runner, single-jet, 16,933-English hp at 374 rpm; generators, 12,000-kv, 0.8 power factor, 50-cycle, 15,000-kva	Lump sum		Lump sum	2,430,000		
3	Accessory electrical equipment--All equipment required for control and protection of generators and station-service power	Lump sum		Lump sum	540,000		
4	Miscellaneous powerplant equipment--Required for general station use	Lump sum		Lump sum	360,000		
	Field Cost--Powerplant				4,500,000		
	Engineering and General Expense (25%)				1,125,000		
	Total est. const. cost--Powerplant				5,625,000		
	TRANSMISSION LINES, SWITCHYARD, AND SUBSTATION					2,356,200	2,904,000
	Falls Switchyard--Located about 150 meters west of Falls Diversion Dam						
1	Complete switchyard (Field Cost)	Lump sum		Lump sum	570,400		
	Engineering and General Expense (25%)				142,600		
	Total est. const. cost				713,000		
2	Transmission Lines (Field Cost)	Lump sum		Lump sum	812,500		
	Engineering and General Expense (20%)				162,500		
	Total est. const. cost				975,000		
3	Powerplant circuits to switchyard (Field Cost)	Lump sum		Lump sum	13,300		
	Engineering and General Expense (20%)				2,700		
	Total est. const. cost				16,000		
4	Terminal substation, receiving-end (Field Cost)	Lump sum		Lump sum	960,000		
	Engineering and General Expense (25%)				240,000		
	Total est. const. cost				1,200,000		
	ACCESS ROAD--From existing road about 6 kilometers north of Chancho to Falls Dam and Powerplant					440,000	550,000
1	Gravel road, mostly one-lane	11	km	32,000.00	352,000		
	Contingencies (25%)				88,000		
	Field Cost--Access Road				440,000		
	Engineering and General Expense (25%)				110,000		
	Total est. const. cost--Access Road				550,000		

Sheet 4 of 4

Estimated Construction Cost

Feature	Estimated cost
Chancho Division	
Chancho Dam and Reservoir	Eth$14,639,000
Waterways	502,000
Chancho Powerplant	3,625,000
Transmission lines, switchyard, and substation	240,000
Access road	141,000
Service facilities	781,000
Falls Division	
Falls Diversion Dam	1,011,000
Waterways (penstock)	1,070,000
Falls Powerplant	5,625,000
Transmission lines, switchyard, and substation	2,904,000
Access road	550,000
Total Construction Cost	Eth$31,088,000

PLAN SELECTION AND ALTERNATIVES

This small valley is situated near the city of Addis Ababa, separated from it by the Entotto Mountains. The nearness to the largest city in Ethiopia made it attractive at first glance to attempt to exploit the land and water resources in the valley. Land classification conducted in the area revealed that about 8,700 hectares in scattered patches were arable. Reconnoitering of the area, however, revealed that there were no suitable storage sites and runoff was inadequate for gravity irrigation. Impoundment of the Muger River would require pumping to the higher elevated arable lands, and this was determined to be uneconomical for development, especially in view of the scattered nature of the lands.

Irrigation development therefore was abandoned in favor of hydroelectric generation, especially in view of the fact that the Muger Falls offered a natural head, enhancing the reasons for full development for power. The potential reservoir would inundate some of the lands that were determined to be suitable for irrigation. No studies were performed as to alternative sites for Chancho Dam, except that cursory visual examination indicated the selected site appeared to be the most favorable from topographic conditions.

The proximity of the reservoir to Addis Ababa (approximately 35 kilometers) suggests that it could become a potential source of municipal water supply.

SECTION 7--GUDER SUB-BASIN

GENERAL DESCRIPTION

Basin Description

The Guder River Sub-basin is in Shewa Province in the southeastern part of the Blue Nile River Basin and has a drainage area of about 7,500 square kilometers (2,900 square miles). The principal river of this basin is the Guder River, which rises in the mountain ranges south of the towns of Ambo and Guder at an elevation above 3000 meters (10,000 feet). The river flows in a northerly direction and empties into the Blue Nile River at elevation 1000 meters (3200 feet). Two single-purpose projects are planned for development in the sub-basin, an irrigation project in the upper portion and a hydroelectric power project in the lower part of the sub-basin. See Figure I-99 for location of the projects. The following descriptions pertain to the irrigation or upper part of the sub-basin.

Project Area Description

The Upper Guder Project area is contiguous to the town of Guder and mostly south of the main Addis Ababa-Lekkemt road. To the west, the area is surrounded by rolling hills to mountainous terrain; to the north, by deep gullies and ravines; and to the east toward the town of Ambo, by rolling hills and plains. The western boundary is formed by the Guder River and the eastern boundary by the Large Boggi stream. The eastern extremity of the project area is approximately 140 kilometers (85 miles) from Addis Ababa.

Geology and Physiography

Geologically, the project area is characterized by extrusive volcanics, largely basalt and trachyte, with lesser amounts of tuff and cinders. It is from these materials that the greater part of the soils formed. Small, localized remnants of Triassic sandstone, limestone, and travertine are also found.

Physiographically, the lower area is characterized by long, relatively smooth, gently sloping to steep, fan-like slopes which extend from the adjoining hilly to mountainous lands. Elevations range from 2170 meters (7500 feet) at the top or below the escarpment to approximately 2130 meters (7000 feet) at the toe or northern boundary. Low, marshy areas and hilly, rocky land and mountainous terrain comprise a sizable portion of the landscape.

Climate

The project area, like most of the central highlands, has a temperate and equable climate. Climatic data from the Ambo Agricultural School for the period 1951 to 1957 indicate that an average rainfall of 108 centimeters (42 inches) is normal for this area. The greater part of this falls during the months of the big rains, mid-June to late September. Temperature data recorded for the above period revealed an average daily maximum of 25 degrees C (77 degrees F) with an average daily minimum of 11 degrees C (52 degrees F).

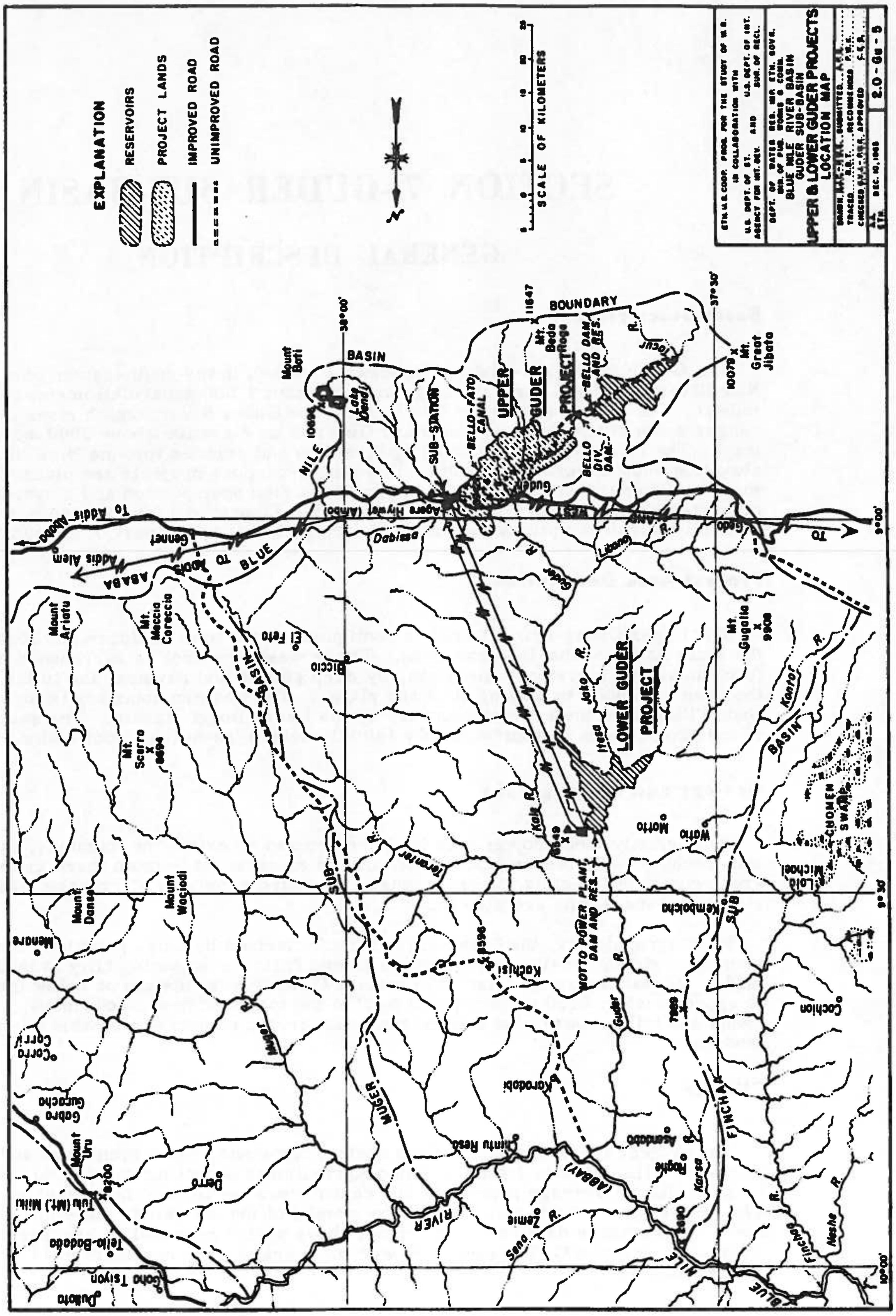


Figure I-99--Upper and Lower Guder Projects--Location Map

Project Lands

Three major soil types are found in the project area--grumusols, latosols, and an intermediate brown soil, with the grumusols predominating. The grumusols are black tropical soils which have a clay or silty clay texture and crack deeply on drying. Care must be taken in disposal of surface wastes to prevent excessive gully type erosion. Because of the greater difficulty in farming and an anticipated average lower production, this type of soil is considered to be in Class 3 or a marginal type for irrigation. (For details, see Appendix IV, "Land Classification."

The following table summarizes the semidetailed land classification performed in the area.

Land Class Areas (in hectares)

Land type	Class 1	Class 2	Class 3	Total
Arable below canal	260	1,240	3,950	5,450
Irrigable	240	1,160	3,700	5,100

Natural, deeply incised drainageways, 5 to 20 or more meters in depth, occur in all parts of the project area on an average of about 1 kilometer apart. These natural channels could be utilized for evacuation of excess precipitation and irrigation waste. Checks or drop structures may be required to control excessive erosion of these natural drainageways.

Hydrology

The Bello (Guder) River would be the source of water supply for the project. Other possible sources of supplemental water supply for the project lands would include the Fato, Melke, and Indris streams. A survey of the area revealed that there were no storage sites available on the latter two streams. Hydrologic studies conducted indicated that the Bello River would have a larger and more dependable yield than the Fato. Utilizing the Fato meant that shortages for irrigation requirements would occur.

Farmgate water requirements for irrigation of crops were determined to be as follows:

Average Monthly Water (in millimeters)

Month	Requirement
October	110.1
November	127.8
December	93.0
January	122.7
February	95.4
March	39.2
April	50.4
May	60.5
Total	699.1

Adding 30 percent for canal losses, such as seepage and operational waste for diversion requirements, the estimated water requirements per hectare would be 10,000 cubic meters annually or a total requirement for 5,100 hectares of 51,000,000 cubic meters (41,000 acre-feet).

UPPER GUDER PROJECT

PLAN OF DEVELOPMENT

The plan for the potential irrigation project includes a storage dam, a diversion dam, a main canal, a lateral distribution system, and drainage canals for a sustained irrigation of 5,100 hectares (12,600 acres) of new service lands.

Storage would be provided by the potential Bello Reservoir on the Bello River. As needed for irrigation, water would be released through the outlet works and diverted into the main canal by the Bello Diversion Dam. The canal would extend for 36.5 kilometers (22.7 miles) in a northeasterly direction to its terminus at Large Boggi Creek. The yield from the Bello River is more than adequate to supply fully all the water requirements of the project area. Feeder canals and laterals would convey the water to the project lands for irrigation.

PROJECT FEATURES

The features of the project plan are described in reconnaissance detail in the following paragraphs and are shown in general plan on Figure I-100. Topographic map of the dam-site area on 5-meter contour intervals was obtained by plane table surveys. (See Figure I-101.) Area-capacity data for the reservoir were obtained from stereoscopic (multiplex) projection on 20-meter contour intervals. Engineering surveys to locate the main canal were performed, using a constant slope of 0.00035 and mapped at a scale of 1:20,000. Laterals and sublaterals of the distribution system were located using uncontrolled photo mosaics of 1:25,000 scale.

Bello Dam and Reservoir

Bello Dam. The selected site is on the Bello River about 19 kilometers (11 miles) upstream from its confluence with the Indris River adjacent to the town of Guder. It will be a single-purpose dam and reservoir for irrigation, providing a total of 70,640,000 cubic meters of initial storage. It will be a homogenous earthfill dam with a structural height of 41 meters and a crest length of 188 meters. Diversion during construction would be accomplished by a 4-meter-diameter concrete tunnel. Plan, profile, and section of the dam are shown on Figure I-102.

Bello Dam Data

Type	earthfill
Embankment volume	380,000 cu.m.
Elevation of crest	2432 m.
Freeboard	2 m.
Structural height	41 m.
Hydraulic height	39 m.
Length of crest	188 m.
Width of crést	10 m.

Spillway. Spillway design capacity was based on the inflow design flood studies, with the peak inflow being estimated to be 1,085 cubic meters per second and a 2-day volume of 57 million cubic meters. It was assumed that the reservoir water level would be at normal water surface elevation of 2428 meters at the start of the flood. A morning-glory type of spillway having a 26.8-meter diameter would pass 518 cubic meters per second at maximum water surface elevation of 2430 meters. Superstorage capacity for the flood would be 33,860,000 cubic meters. The spillway would be located on the right abutment, intercepting the diversion tunnel near the upstream toe of the dam.

Spillway Data

Type	morning glory
Spillway crest elevation	2428 m.
Inflow design flood	1,085 cu.m. per sec.
Total flood volume, 2-day period	57,000,000 cu.m.
Discharge at m.w.s. elevation	518 cu.m. per sec.

Outlet Works. The outlet works required to release water for irrigation would be located on the right side of the river paralleling the diversion tunnel. The tunnel would be a concrete conduit having an initial diameter of 1.8 meters to the gate chamber and then enlarging to a 2-meter-diameter horseshoe to house the 0.51-meter-diameter steel outlet pipe. Other structures required would include an intake structure, a control house with a 2-meter-diameter access shaft tunnel, and a 0.46-meter-diameter hollow-jet valve.

Outlet Works Data

Sill elevation	2420 m.
Capacity at minimum w.s. elevation	3.65 cu.m. per sec.
Type of gate	high pressure
Size of outlet (hollow-jet)	0.46-m. valve

Bello Reservoir. Geologic conditions of the potential reservoir area are similar to those discussed under "Site Geology" below, with the possible exception that tuff beds may become more numerous farther downstream and may lie in thicker layers than at the damsite. In general, it is believed that the cover of impermeable clays over most of the reservoir area will provide an adequate blanket, and no great seepage problems should arise. See Figure I-103 for area-capacity data and Figure I-104 for area-capacity curves.

Site Geology. At the site selected for the dam, the younger volcanic flows are primarily hard basalt. The upper surface of the basalt will be somewhat weathered and broken, but, with excavation of a minimum of 3 meters of this weathered zone in a cutoff trench, hard unweathered material will be found. However, within the foundation of the dam there may be thin layers of tuff or volcanic ash. It is believed that, with an adequate provision for a cutoff trench and with a grout curtain in the basaltic rock, no serious foundation problem should arise. No foundation exploration was performed, so this information is subject to change with more detailed examination of the site.

Construction Materials. Impervious fill material can be found almost anywhere in the vicinity of the proposed site. The material is all plastic, slightly sandy, silty clay. There are no deposits of semipervious or pervious materials anywhere near the vicinity of the damsite. Some exposures of the weathered and broken basalt appear to be suitable sources of these materials and, if extensive zones of extremely weathered or broken rock can be found, may also be possible sources of impervious fill material. Riprap can be quarried just downstream from the site from the hard basaltic flows cropping out there. In the reservoir basin it is believed that the cover of impermeable clays over most of the reservoir bottom will provide an adequate blanket.

Access to Site. Access to the proposed damsite will have to be provided. The terrain from the town of Guder to the site is rolling, and, if the present footpaths are utilized as the future road, only the crossing at the confluence of the Fato and Melke streams would present a moderate cost. Distance to the site from the main Addis Ababa-Lekkemt road would be approximately 22 kilometers (13.6 miles).

Bello Diversion Dam

A concrete-masonry, ogee-type structure is planned with suitable provisions for sluicing. The site chosen for the structure would be about 3.5 kilometers (2.2 miles) downstream from the storage dam, and no serious problem is expected to be encountered in constructing the structure. Outlet works to the main canal would be located on the right abutment of the diversion dam. The weir section would be 53 meters (174 feet) long and 3 meters (10 feet) high, designed with enough capacity to discharge flood frequencies of once in a hundred years. Plan and section are shown in Figure I-105.

BELLO (GU-4) DAM & RESERVOIR

AREA CAPACITY DATA

(with sediment distributed)

CONTROL POINTS				INITIAL AREA	CAPACITY (CUBIC METERS - 10^6)			
ITEM & ALLOCATION OF STORAGE CAPACITY		DIAGRAM OF DAM	ELEVATION (METERS)	(SQ. METERS - 10^6)	INITIAL		WITH 50-YR. SEDIMENT	
					INCREMENT	TOTAL	INCREMENT	TOTAL
TOP OF DAM			2432					
	FREEBOARD							
MAXIMUM W.S.			2430	18.50		104.50		93.26
	FLOOD SURCHARGE				33.86		33.86	
NORMAL W.S.			2428	15.36		70.64		59.40
	ACTIVE CAPACITY				47.69		47.46	
MINIMUM OPERATING W.S.			2421.89	3.01		22.95		11.94
	INACTIVE CAPACITY				4.87		4.54	
LIP OF LOWEST OUTLET*			2420	2.12		18.08		7.40
	DEAD STORAGE AND SILT				18.08		7.40 D.S. (10.68 silt)	
STREAM BED			2391	0		0		0

*100-YEAR SEDIMENT OF 22.4 $(10)^6$ M^3 WILL TAKE 2419.4 METERS ELEVATION AT THE DAM.

2.2-BN-6

Figure I-103--Bello (GU-4) Dam and Reservoir--Area-Capacity Data

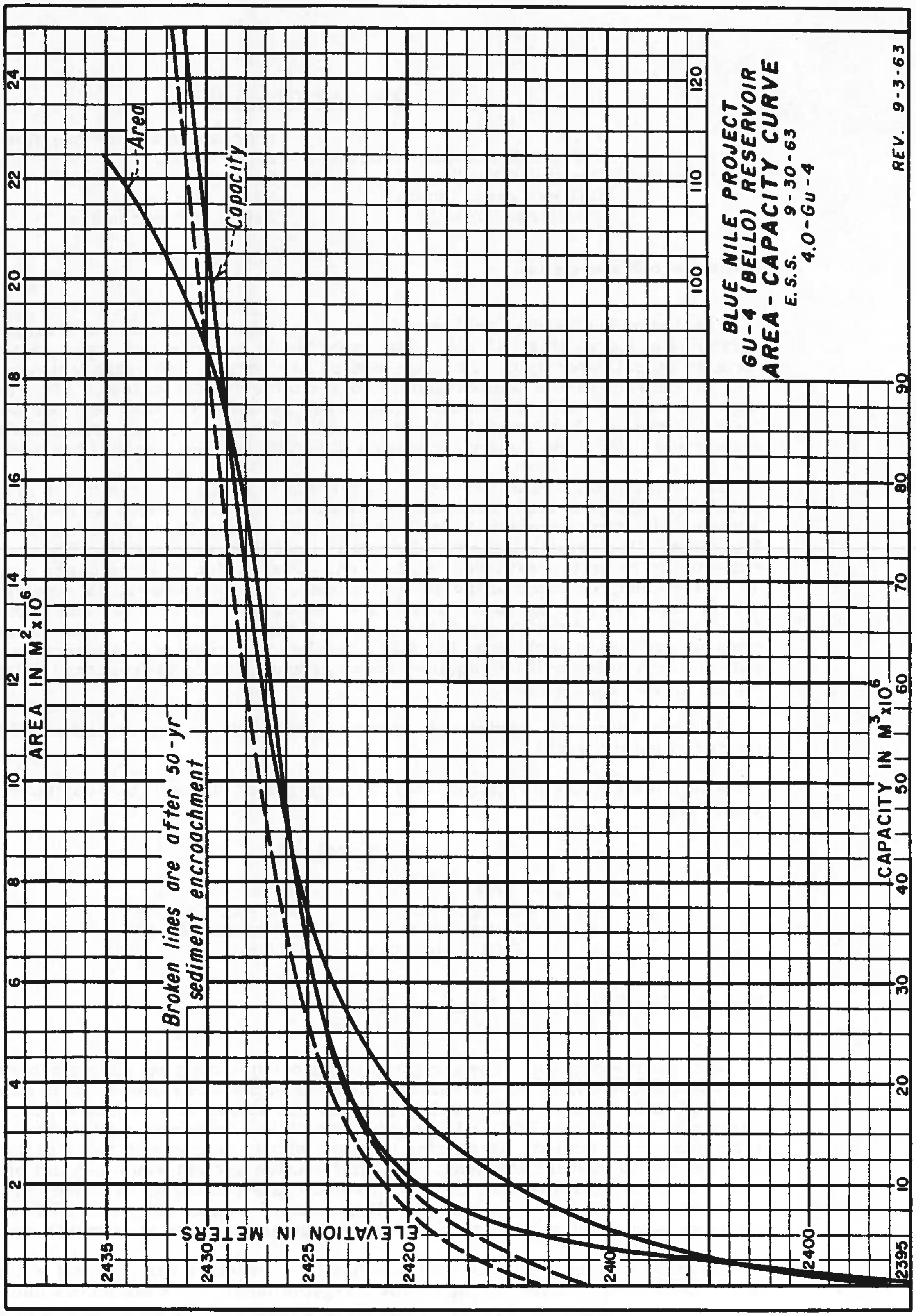


Figure I-104--Bello (GU-4) Reservoir--Area-Capacity Curves

Diversion Dam Data

Type	concrete-masonry overflow
Volume of masonry concrete	2,095 cu.m.
Structural height	6.5 m.
Spillway crest length	53 m.
Discharge capacity	340 cu.m. per sec.

Bello-Fato Main Canal

The Bello-Fato Main Canal would extend northeasterly from the diversion dam to its terminus at Large Boggi Creek. The canal would be entirely in open section and would have an initial capacity of 6.8 cubic meters per second (240 cubic feet per second) all the way to the Fato River, approximately 15.8 kilometers (10 miles). After the crossing, the capacity would drop to 6.08 cubic meters per second (215 cubic feet per second) to the Indris Creek; 4.25 cubic meters per second (150 cubic feet per second) to an unnamed creek; and 0.56 cubic meter per second (20 cubic feet per second) to its terminus.

The main canal would traverse hilly terrain to reach as much of the project area as possible. The proposed alinement of the canal is characterized by many draws and ravines, and suitable structures will have to be provided to take care of the high flows during the big rains. Geologically, the canal route is underlain with basaltic flows, although it is expected to be quite weathered and broken. Overburden in some cases would extend to 15 meters and, on some of the steeper slopes, weathered basalt is expected to be encountered, especially on the initial reaches of the canal. Scrub trees and sagebrush are found over most of the length of the proposed canal alinement. Canal excavation will not present any major problems, but many reaches will require some rock excavation. Compacted earth lining will be required above ground surface to freeboard height, especially on the lower cross slopes.

Bridges, culverts, wasteways, turnouts, siphons, or overchutes would be provided as needed along the canal.

Water for gravity irrigation of 5,100 hectares of land will be supplied from the Bello Reservoir.

Canal Data

Type	unlined
Length	36.5 km.
Initial capacity	6.8 cu.m. per sec.
Initial elevation	2710 m.

Distribution System and Drainage Canals

Distribution System. The irrigable lands occur mostly on ridges between drainageways and occasionally follow natural channels in the streambeds. It is estimated that about 80 to 85 percent of the irrigable lands has slopes of less than 2 percent and the remainder has slopes of 5 to 12 percent, which is considered maximum for suitable irrigation development. Depending upon the slope, checks and drops in the laterals will be required to prevent scouring. The distribution system would consist of a number of main laterals following the ridges with sublaterals emanating to convey the water to the farmers. The distribution system will be unlined canals with sufficient capacity to meet the peak demand of any lateral service area during the period of maximum demand.

Drainage Canals. Surface drainage has been provided for removal of irrigation waste and excess precipitation falling on the irrigable lands. The numerous natural drainageways would be utilized wherever possible and improved by construction of structures where necessary.

Practically all of the project area is underlain by basalt or trachyte. Although no water table problems were observed in the course of the investigation, it is possible that some water table problems may develop with irrigation. Further studies will be required to determine the requirements and feasibility of subsurface drainage.

Service Facilities

Camps and buildings will be required by Government personnel to supervise the contract and later for operation and maintenance purposes. The estimates of cost for this item were obtained from curves, the data for the curves being based on Bureau of Reclamation experience and practices modified to local conditions.

ESTIMATED PROJECT COSTS

Construction Cost

The total construction cost for the Upper Guder Irrigation Project is estimated at Eth$13, 962, 000 on the basis of January 1961 prices. The estimate includes allowances for contingencies, engineering, and general expense. The estimates have been based on limited reconnaissance data. Table I-17 shows unit prices and quantities for the various facilities and is summarized as follows.

Estimated Construction Costs

Feature	Estimated cost
Bello Dam and Reservoir	Eth$ 7, 590, 000
Bello Diversion Dam	486, 000
Bello-Fato Main Canal	1, 172, 000
Distribution system	2, 630, 000
Drainage canals	956, 000
Access roads	928, 000
Service facilities	200, 000
Total	Eth$13, 962, 000

Development Cost

A large portion of the land area has been dry farmed at one time or another with only a scattering of trees and brush remaining. Clearing costs are expected to be minimal, estimated for the 5, 100 hectares to be about Eth$296, 000.

Leveling costs are expected to be low, because the land is fairly smooth and has sufficient slope to obviate the necessity of highly precise leveling. Estimated cost for leveling for the project lands is Eth$332, 000.

Operation, Maintenance and Replacement Cost

Annual charges for operation, maintenance, and replacement costs obtained from curves for the conveyance system was estimated to be Eth$200, 000 and for the storage and diversion dams, Eth$19, 000.

TABLE I 17--UPPER GUDER PROJECT--RECONNAISSANCE ESTIMATE

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN–ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project: UPPER GUDER--Irrigation

Date of Estimate: November 1963

Prices as of: January 1961

Currency in terms of Ethiopian Dollars (U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	UPPER GUDER PROJECT--Irrigation					11,438,900	13,962,000
	BELLO DAM--Earthfill; crest length, 188 meters; height of dam, 41 meters. Dwg. 04-23-89					6,325,200	7,590,000
1	Diversion and care of river	Lump Sum		Lump Sum	41,000		
2	Excavation, stripping borrow pits	21,000	m^3	1.15	24,150		
3	Excavation, common, dam foundation	53,000	m^3	1.95	103,350		
4	Excavation rock, for grout cap	270	m^3	80.00	21,600		
5	Excavation, common, in borrow areas and transportation to dam embankment	430,000	m^3	2.75	1,182,500		
6	Furnishing and placing sand and gravel in downstream filter blanket	17,000	m^3	15.00	255,000		
7	Earthfill in dam embankment	380,000	m^3	0.65	247,000		
8	Riprap on upstream slope of embankment	5,900	m^3	11.00	64,900		
9	Bedding for riprap on dam embankment	3,000	m^3	15.00	45,000		
10	Pressure grouting, all work and material	Lump Sum		Lump Sum	396,600		
11	Furnishing and constructing 20 cm concrete pipe toe drains with open joints	180	lm	21.00	3,780		
12	Furnishing and constructing 30 cm concrete pipe toe drains with open joints	120	lm	37.00	4,440		
	Subtotal--Dam				2,389,320		
	Spillway--26.8 meter diameter glory hole and 5.3 meter diameter tunnel						
13	Excavation, all classes, open cut	18,300	m^3	3.25	59,475		
14	Excavation, tunnel and shaft	10,300	m^3	67.00	690,100		
15	Tunnel supports	75,000	kg	1.40	105,000		
16	Concrete, inlet structure	2,000	m^3	210.00	420,000		
17	Concrete, tunnel and shaft lining	3,500	m^3	132.00	462,000		
18	Concrete, flip bucket	100	m^3	180.00	18,000		
19	Concrete, diversion plug	245	m^3	150.00	36,750		
20	Reinforcement	370,000	kg	1.00	370,000		
21	Minor items	Lump Sum		Lump Sum	63,000		
	Subtotal--Spillway				2,224,325		
	Outlet Works--Drop inlet, 0.46 meter diameter steel pipe in 2.0 meter diameter horseshoe tunnel						
22	Excavation, all classes, open cut	1,200	m^3	3.25	3,900		
23	Excavation, tunnel and shaft	1,000	m^3	160.00	160,000		
24	Tunnel supports	33,000	kg	1.40	46,200		
25	Concrete, intake structure	65	m^3	210.00	13,650		
26	Concrete, tunnel and shaft lining	500	m^3	180.00	90,000		
27	Concrete, outlet channel lining	25	m^3	150.00	3,750		
28	Concrete, control house	10	m^3	210.00	2,100		
29	Reinforcement	40,000	kg	1.00	40,000		
30	Trashracks	Lump Sum		Lump Sum	10,000		
31	H.P. gate and hoist, 0.70 X 0.70 meter	Lump Sum		Lump Sum	26,200		
32	Outlet pipe, 0.51 meter diameter, steel	Lump Sum		Lump Sum	13,750		
33	Hollow-jet valve, 0.46 meter diameter	Lump Sum		Lump Sum	8,750		
34	Ventilation system	Lump Sum		Lump Sum	5,000		
35	Reservoir level gage and piping	Lump Sum		Lump Sum	5,000		
36	Miscellaneous metal work	Lump Sum		Lump Sum	1,250		
37	Electrical apparatus and conductors	Lump Sum		Lump Sum	6,250		
38	Minor items	Lump Sum		Lump Sum	10,700		
	Subtotal--Outlet Works				446,500		
	Subtotal--Items 1 through 38				5,060,145		
	Contingencies (25±%)				1,265,055		
	Field Cost--Bello Dam				6,325,200		
	Engineering and General Expense (20±%)				1,264,800		
	Total est. const. cost--Bello Dam				7,590,000		

Sheet 1 of 4

Table I-17--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project: UPPER GUDER--Irrigation

Date of Estimate: November 1963

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U S $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	BELLO DIVERSION DAM--Ungated overflow weir; crest length, 53 meters; maximum height, 3 meters, Dwg. 2.3-On-7					404,800	486,000
1	Diversion and care of river	Lump Sum		Lump Sum	20,000		
2	Excavation for weir and structures, common	910	m^3	1.95	1,775		
3	Excavation for weir and structures, rock	8,170	m^3	8.00	65,360		
4	Masonry in weir	1,325	m^3	70.00	92,750		
5	Masonry in abutments	275	m^3	80.00	22,000		
6	Concrete in sluiceway	75	m^3	210.00	15,750		
7	Concrete in headworks	420	m^3	210.00	88,200		
8	Gates, hoists, handrails and misc. metalwork	Lump Sum		Lump Sum	18,000		
	Subtotal				323,835		
	Contingencies (25±%)				80,965		
	Field Cost--Diversion Dam				404,800		
	Engineering and General Expense (20±%)				81,200		
	Total est. const. cost--Bello Diversion Dam				486,000		
	BELLO-FATO IRRIGATION CANAL--Unlined; length, 36.5 kms; capacity, 6.8 to 0.56 m^3/sec.					937,600	1,172,000
	Waterways					(470,700)	
1	Canal excavation, common	291,700	m^3	0.82	239,194		
2	Canal excavation, rock	7,900	m^3	8.00	63,200		
3	Compacting embankment	75,640	m^3	0.98	74,127		
	Subtotal--Waterways				376,521		
	Contingencies (25±%)				94,179		
	Field Cost--Waterways				470,700		
	Structures					(466,900)	
	Modified Parshall Flume--6.8 m^3/sec.						
1	Excavation and backfill about structure	309	m^3	4.00	1,236		
2	Concrete in structure	46.9	m^3	210.00	9,849		
3	Reinforcement	2,629	kgs	1.00	2,629		
4	Dry rock paving	146	m^2	15.00	2,190		
5	Timber	0.0[illegible]	m^3	318.00	30		
6	Miscellaneous metalwork	36	kgs	2.60	94		
	Subtotal--Parshall Flume				16,028		
	Checks--6 required						
1	Excavation and backfill about structures	270	m^3	4.00	1,080		
2	Concrete in structures	76.9	m^3	210.00	16,149		
3	Reinforcement	3,750	kgs	1.00	3,750		
4	Timber	3.0	m^3	318.00	954		
5	Miscellaneous metalwork	958	kgs	2.60	2,491		
	Subtotal--6 checks				24,424		
	Check, Wasteway and Siphon--6.08 m^3/sec. Siphon 100 meters long and 1.83 meters in diameter						
1	Excavation and backfill about structures	2,588	m^3	4.00	10,352		
2	Excavation, rock in stream bed	328	m^3	8.00	2,624		
3	Concrete in structures	47	m^3	210.00	9,870		
4	Concrete in siphon barrel	156	m^3	210.00	32,760		
5	Reinforcement	11,302	kgs	1.00	11,302		
6	Gates, radial	3,073	kgs	5.50	16,902		
7	Miscellaneous metalwork	675	kgs	2.60	1,755		
8	Blowoff structure	Lump Sum		Lump Sum	3,000		
9	Riprap	218	m^3	11.00	2,398		
	Subtotal--Check, Wasteway and Siphon				90,963		
	Culverts--10 single barrel and 4 double barrels. One meter diameter						
1	Excavation and backfill	3,782	m^3	4.00	15,128		
2	Concrete in transitions	183.9	m^3	210.00	38,619		
3	Reinforcement	7,200	kgs	1.00	7,200		
4	Concrete pipe	325	lm	150.00	48,750		
	Subtotal--Culverts				109,697		

Sheet 2 of 4

Table I-17--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project UPPER GUDER--Irrigation

Date of Estimate November 1963

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U S $1.00 = Eth $2.50)

ITEM NO	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	BELLO-FATO IRRIGATION CANAL (Continued)						
	Structures (Continued)						
	Drainage Inlets--4 required						
1	Excavation and backfill	26.3	m^3	4.00	105		
2	Concrete in headwalls	5.2	m^3	210.00	1,092		
3	Reinforcement	173	kgs	1.00	173		
4	Corrugated metal pipe, 0.60 meter diameter	20	lm	87.00	1,740		
5	Riprap	32	m^3	11.00	352		
	Subtotal--Drainage Inlets				3,462		
	Concrete Flume--18.3 meters long across the Indiris River. Capacity, 4.25 m^3/sec.						
1	Excavation	90	m^3	4.00	360		
2	Concrete in footings	6	m^3	150.00	900		
3	Concrete in structures	72	m^3	210.00	15,120		
4	Reinforcement	4,290	kgs	1.00	4,290		
	Subtotal--Concrete Flume				20,670		
	Steel Pipe Flume--Length, 10 meters; capacity, 0.56 m^3/sec; 3 required.						
1	Excavation	7.5	m^3	4.00	30		
2	Steel pipe, 0.60 meter diameter	1,732	kgs	2.60	4,503		
3	Steel in piers	220.4	kgs	2.60	573		
4	Concrete in footings	3.6	m^3	150.00	540		
	Subtotal--Three Steel Flumes				5,646		
	Lateral Turnouts--Constant head orifice; 13 required						
1	Capacity, 0.29 m^3/sec.	1	ea	3,100.00	3,100		
2	Capacity, 0.40 m^3/sec.	1	ea	4,700.00	4,700		
3	Capacity, 0.45 m^3/sec.	1	ea	5,000.00	5,000		
4	Capacity, 0.51 m^3/sec.	3	ea	5,400.00	16,200		
5	Capacity, 0.54 m^3/sec.	2	ea	5,500.00	11,000		
6	Capacity, 1.10 m^3/sec.	2	ea	7,600.00	15,200		
7	Capacity, 1.25 m^3/sec.	1	ea	7,900.00	7,900		
8	Capacity, 1.36 m^3/sec.	1	ea	8,200.00	8,200		
9	Capacity, 2.55 m^3/sec.	1	ea	9,400.00	9,400		
	Subtotal--Lateral Turnouts				80,700		
	Farm Bridges--Timber, 4.9 meters wide, for light use; 7 required						
1	Bridges	215	m^2	97.00	20,855		
	Subtotal--Bridges				20,855		
	Check and Terminal Structure--One required						
1	Excavation	6.0	m^3	4.00	24		
2	Concrete	3.9	m^3	210.00	819		
3	Reinforcement	109	kgs	1.00	109		
4	Miscellaneous metalwork	13.2	kgs	2.60	34		
5	Timber	0.2	m^3	318.00	64		
	Subtotal--Check and Terminal Structure				1,050		
	Subtotal--Structures				373,495		
	Contingencies (25±%)				93,405		
	Field Cost--Structures				466,900		
	Field Cost--Bello-Fato Canal				937,600		
	Engineering and General Expense (25±%)				234,400		
	Total est. const. cost--Bello-Fato Canal				1,172,000		

Table I-17--Continued

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project UPPER GUDER--Irrigation

Date of Estimate November 1963

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD COST	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST		
	DISTRIBUTION SYSTEM--Unlined, open laterals including structures					2,103,800	2,630,000
1	Upper Guder project lands, net hectares	5,100	ha	330.00	1,683,000		
	Contingencies (25±%)				420,800		
	Field Cost--Distribution System				2,103,800		
	Engineering and General Expense (25±%)				526,200		
	Total est. const. cost--Distribution System				2,630,000		
	DRAINAGE SYSTEM--Open ditch collector drain and structures					765,000	956,000
1	Upper Guder project lands, net hectares	5,100	ha	120.00	612,000		
	Contingencies (25±%)				153,000		
	Field Cost--Drainage System				765,000		
	Engineering and General Expense (25±%)				191,000		
	Total est. const. cost--Drainage System				956,000		
	ACCESS ROAD--Two lane, gravel					742,500	928,000
1	Access road, flat terrain	22	km	27,000.00	594,000		
	Contingencies (25±%)				148,500		
	Field Cost--Access Road				742,500		
	Engineering and General Expense (25±%)				185,500		
	Total est. const. cost--Access Road				928,000		
	CAMP					160,000	200,000
1	Offices, shops, housing, and streets	Lump Sum		Lump Sum	128,000		
	Contingencies (25±%)				32,000		
	Field Cost--Camp				160,000		
	Engineering and General Expense (25±%)				40,000		
	Total est. const. cost--Camp				200,000		

PLAN SELECTION AND ALTERNATIVES

Several stages of development and alternative plans which appear to have merit were considered as a basis for selecting the project plan presented in this report. Brief preliminary plans were studied to determine the feasibility of a demonstrational or pilot project in the area. Direct diversion could be accomplished on some of the larger streams and a small plot could be developed.

Studies on alternative plans were limited to the major storage potentialities of the Fato drainage basin. Rough cost estimates performed indicated that they would approximate the costs of the Bello Dam without its attendant benefits of firm yield. Operation studies indicated that they would be deficient in storage capacities for full development of the project lands.

Pumping possibilities to the upper valley from the Bello Reservoir were not studied. The Jibat damsite was abandoned for storage on the premise that engineering surveys indicated pumping would be required and the added cost of constructing a dam would prove too costly to develop the area for irrigation purposes.

Brief studies conducted on possible hydroelectric power production indicated that it would not be economically feasible to develop if the reservoir were to be used in conjunction with irrigation. The added height of dam required to capture the additional water supply for hydroelectric production indicates that at best only a powerplant capable of delivering 2,000 kw. of firm power could be developed.

It was concluded that such a small powerplant could not economically absorb the cost of added reservoir capacity necessary to yield water at a constant rate even during the nonirrigation months. The cheapest alternative source at this location would be a diesel plant, which could be installed for about Eth$500 per kilowatt.

Under the irrigation plan studied, all the water for the project lands would be obtained from the Bello River. As indicated by the hydrologic studies (see Appendix III, "Hydrology"), surface runoff at the damsite is estimated at 219,000,000 cubic meters (176,000 acre-feet) annually. There is storage capacity to impound this water, and, if further investigations reveal that additional lands could be incorporated into the plan, the height of the dam could be extended. Another possibility is to tap some of the larger streams, especially the Indris and the Fato, into the canal enroute. This cannot be considered for a firm supply, however, as preliminary hydrologic studies indicate that at the time of maximum demand the streams would yield little or no flow.

LOWER GUDER POWER PROJECT

PLAN OF DEVELOPMENT

The plan of development for the Lower Guder Power Project includes construction of a dam and reservoir, a powerplant, a substation, and transmission lines for an estimated annual generation of nearly 225 million kilowatt-hours.

PROJECT FEATURES

The features of the project plan are described in reconnaissance detail in the following paragraphs and are shown in general plan on Figure I-106. Topographic maps were compiled from aerial photographs by stereoscopic (multiplex) projections. Altimeters were used for determination of vertical distances plotted on 20-meter contour intervals.

Motto Dam and Reservoir

Motto Dam. The selected site is located in Shewa Province about 60 kilometers north of the town of Guder on the Guder River. It would be an earth and rock fill dam with a crest length of 400 meters and a height of 121 meters above streambed. A dike on a low saddle on the west side of the river will be required. It would be approximately 660 meters long and 26 meters high. Diversion of the river during construction would be accomplished by two 10-meter-diameter tunnels located on the left abutment of the dam. Plan, section, and profiles of the dam appear on Figure I-107.

Dam Data

Type	earth-rock fill
Embankment volume (earth)	2,600,000 cu. m.
Embankment volume (rock)	4,000,000 cu. m.
Top of dam elevation	1376 m.
Freeboard	2.26 m.
Structural height	121 m.
Hydraulic height	118.74 m.
Length of crest	400 m.
Width of crest	10 m.

Spillway. Based on inflow design flood studies which indicate a peak inflow of 5,600 cubic meters per second and a 4-day volume of 590 million cubic meters, a morning-glory type of spillway was designed. The spillway would have a 30-meter-diameter crest and would discharge into one of the two tunnels constructed for diversion of the river. At maximum water surface elevation of 1373.74 meters, the maximum discharge would be 1,386 cubic meters per second. Superstorage capacity for the flood would be 443,000,000 cubic meters. The spillway would be located on the left abutment.

Spillway Data

Type	morning glory
Spillway crest elevation	1368.11 m.
Inflow design flood	5,600 cu. m. per sec.
Total flood volume, 4-day period	590,000,000 cu. m.
Discharge at m.w.s. elev.	1386 cu. m. per sec.

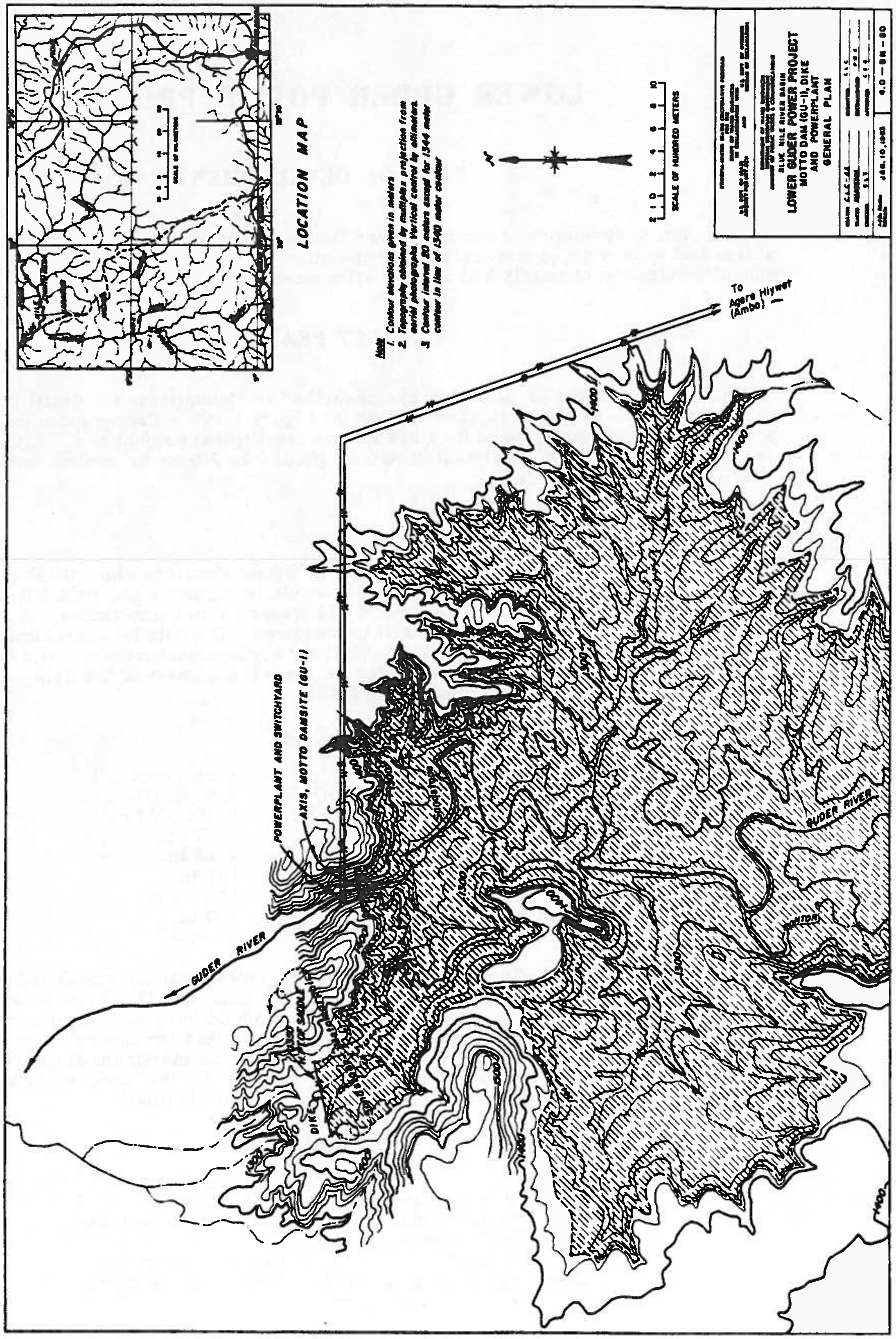


Figure I-106--Motto Dam (GU-1), Dike, and Powerplant--General Plan

Outlet Works. The reservoir outlet would be a conduit through the left side of the dam. The outlet works would consist of an intake structure with a fixed-wheel gate and a 4.5-meter-diameter welded-steel penstock in one of the two horseshoe conduits, constructed beforehand. The penstock would divide before reaching the turbines, each branch being equipped with a butterfly valve.

Outlet Works Data

Sill elevation	1313 m.
Maximum capacity (each)	60 cu. m. per sec.
Type of gate	fixed wheel
Size of outlet (diameter)	4.5 m.

Reservoir. The reservoir area is in sandstone except for the small area in Precambrian rock near the damsite. It is believed that the cover of impermeable clays over most of the reservoir area will provide an adequate blanket, and no serious seepage problem is anticipated. At normal water surface elevation of 1368.11 meters, the initial storage capacity is estimated at 2,557 million cubic meters, covering an area of 7.45 square kilometers. See Figure I-108 for area-capacity data and Figure I-109 for area-capacity curves.

Site Geology. The damsite is located in a narrow, V-shaped gorge in banded quartz diorite gneiss of Precambrian age. The rock is variably jointed and, with a smooth, hard, rock foundation, could be exposed. Foundation excavation to obtain fresh rock and a smooth surface may range from 3 to 10 meters.

Construction Materials. There is an abundance of impervious material within economical haul distance of the damsite. Pervious or semipervious material will have to be quarried from the Precambrian rock. Deposits of natural aggregate are too small in quantity to be considered as a source of construction materials.

Access to Site. An access road will have to be constructed through rolling and hilly terrain. Distance from Ambo or Guder to the construction site would be approximately 60 kilometers.

Powerplant

The hydroelectric plant would be located adjacent to the dam at the toe of the downstream slope. It would contain two turbine-driven generators, each supplied by a steel penstock from the outlet works.

Powerplant Data

Design head, net	86.1 m.
Maximum head, net	107.6 m.
Minimum head, net	64.2 m.
Number of generators	2
Installed capacity (each)	25,000 kw.
Type of turbine	Francis
Synchronous speed	230 r.p.m.

Switchyard

Two bays, each consisting of a single-breaker, 132-kv. line, would be required. It is envisioned that the switchyard would be located on the roof of the powerplant. See Figure I-110.

Transmission Lines

About 175 kilometers of transmission lines are planned to conduct the energy generated; 60 kilometers will be to the Agere Hiywet (Ambo) Substation, 110 kilometers of 161-kv. line to the East Addis Ababa Substation, and 5 kilometers from the East Addis Ababa Substation to the Central Addis Ababa Substation.

MOTTO (GU-1) DAM & RESERVOIR

AREA CAPACITY DATA

(with sediment distributed)

CONTROL POINTS				INITIAL AREA (SQ. METERS - 10^6)	CAPACITY (CUBIC METERS - 10^6)			
ITEM & ALLOCATION OF STORAGE CAPACITY		DIAGRAM OF DAM	ELEVATION (METERS)		INITIAL		WITH 50-YR. SEDIMENT	
					INCREMENT	TOTAL	INCREMENT	TOTAL
TOP OF DAM			1376.00					
	FREEBOARD							
MAXIMUM W.S.			1373.74	83.1		3000.0		2467.0
	FLOOD SURCHARGE				443.0		443.0	
NORMAL W.S.			1368.11	74.5		2557.0		2024.0
	ACTIVE CAPACITY				2023.1		1786.6	
MINIMUM OPERATING W.S.			1324.73	23.9		533.9		237.4
	INACTIVE CAPACITY				172.5		120.1	
LIP OF LOWEST OUTLET*			1317.00	18.3		361.4		117.3
	DEAD STORAGE AND SILT				361.4		117.3	
STREAM BED			1255.00	0		0		0

*100-YEAR SEDIMENT OF 1.074 x $(10)^6$ M^3 WILL TAKE 1317.1 METERS ELEVATION AT THE DAM.

2.2-BN-11

Figure I-108--Motto (GU-1) Dam and Reservoir--Area-Capacity Data

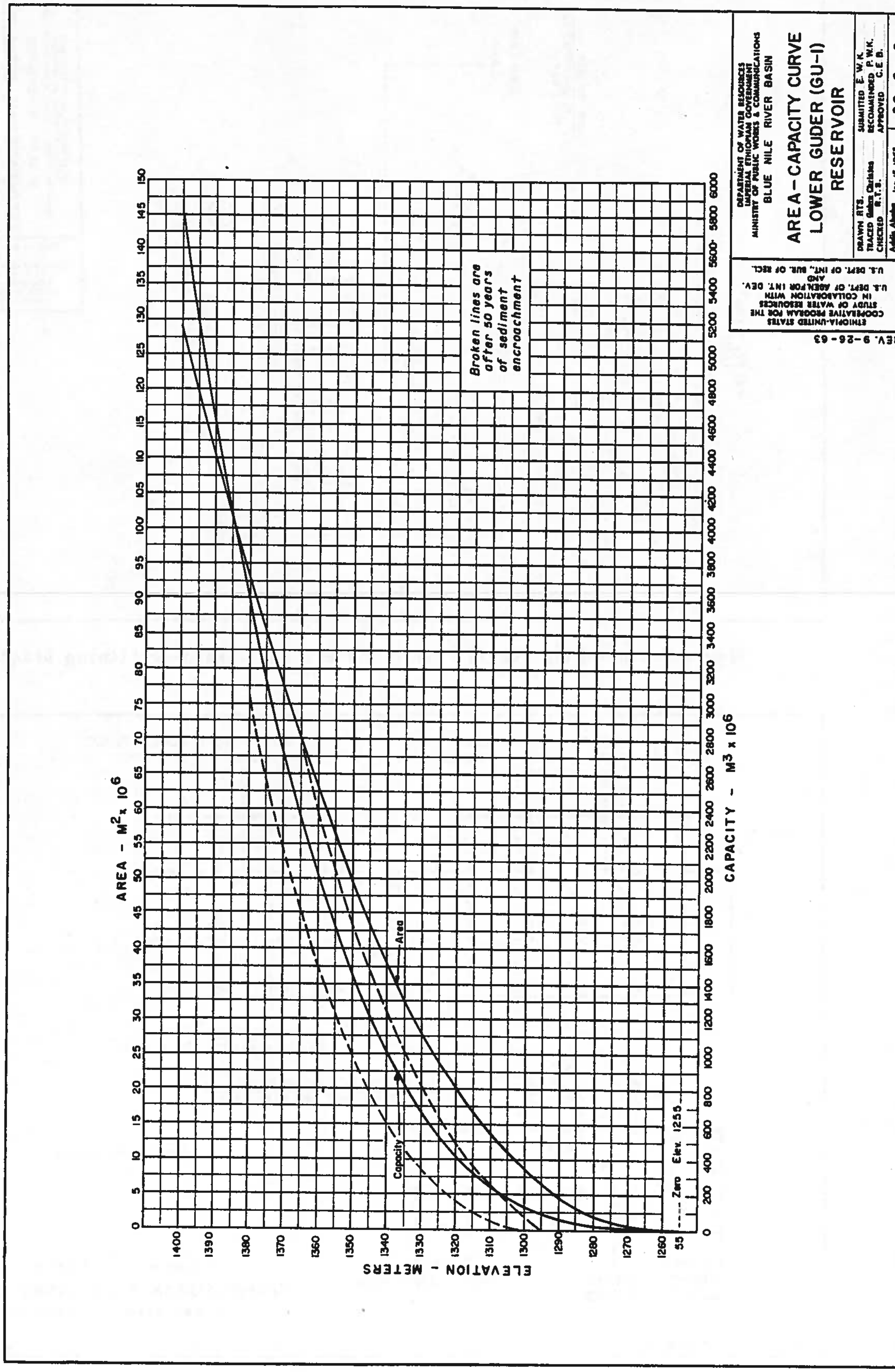


Figure I-109--Motto (GU-I) Reservoir--Area-Capacity Curves

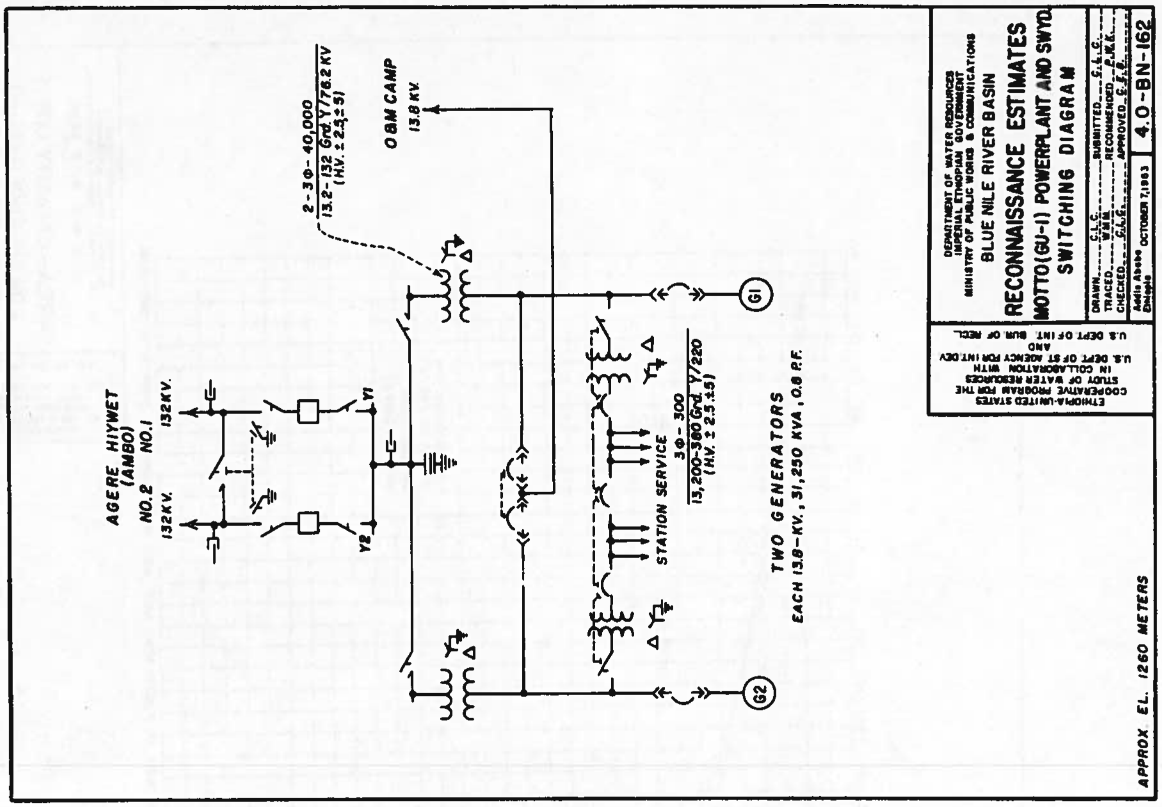


Figure I-110--Motto (GU-1) Powerplant and Switchyard--Switching Diagram

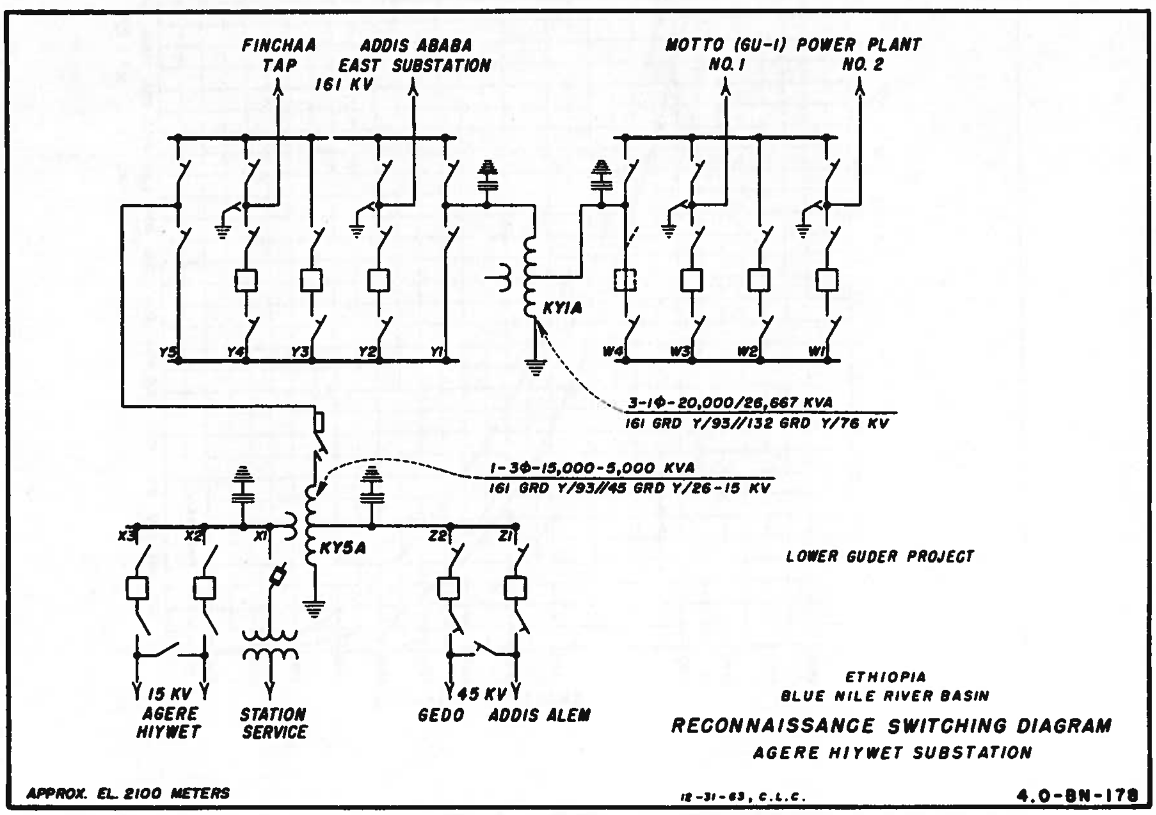


Figure I-111--Agere Hiywet Substation--Switching Diagram

Substations

One substation and part of another will be required, one at Agere Hiywet (Ambo), Figure I-111, and the other (Stage 05) on the east side of the city of Addis Ababa (Figure I-71). The substations will be of the outdoor type with controls and service equipment located indoors.

Service Facilities

Service facilities will be required to operate and maintain the facilities. Costs contained in this item include office and shop buildings, housing facilities for operating personnel, and equipment.

ESTIMATED CONSTRUCTION COST

The construction costs for the Lower Guder Power Project are estimated at Eth$126,848,000 on the basis of January 1961 prices as summarized below. As indicated in Table I-18, quantities and unit cost prices were applied to the dam and appurtenant structures. Costs for other features were obtained from curves, as indicated in lump-sum estimates. The estimate includes allowances for contingencies, engineering, and general expense.

Lower Guder Project

Feature	Estimated cost
Motto Dam and Reservoir	Eth$ 95,501,000
Powerplant	14,106,000
Switchyard	1,781,000
Transmission lines	5,681,000
Substations	5,997,000
Access road	2,813,000
Service facilities	969,000
Total	Eth$126,848,000

PLAN SELECTION AND ALTERNATIVES

Brief studies conducted were limited to an alternate damsite. A few kilometers downstream from the selected site, where the Teranter and Kale Rivers join the Guder River, a possible site (GU-2) was considered to take advantage of the greater water supply. Preliminary studies indicated that it would be much more costly to develop and that the cost per kilowatt would be higher to produce. The site would not appreciably add to the storage capacity and, being about 74 meters lower than the selected site, would require a higher dam and a long dike to store the equivalent amount of water.

TABLE I-18--LOWER GUDER PROJECT--RECONNAISSANCE ESTIMATE

RECONNAISSANCE ESTIMATE

BLUE NILE RIVER BASIN-ETHIOPIA

ADDIS ABABA, ETHIOPIA

Project LOWER GUDER--Power

Date of Estimate December 1963

Prices as of January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD	TOTAL CONSTRUCTION
		AMOUNT	UNIT	UNIT COST	COST	COST	COST
	LOWER GUDER PROJECT					104,850,600	126,848,000
	MOTTO DAM--Earth and rockfill: crest length, 400 meters: height of dam, 121 meters. Crest length of dike, 660 meters: height of dike, 26 meters. Drawing No. OA-23-88					79,984,200	95,501,000
1	Diversion and care of river	Lump sum		Lump sum	354,000		
2	Excavation, stripping borrow areas	270,000	m^3	1.15	310,500		
3	Excavation, all classes, dam foundation	430,000	m^3	1.95	838,500		
4	Excavation, rock, for grout cap	1,500	m^3	80.00	120,000		
5	Excavation, common, in borrow areas and transportation to dam embankment	3,000,000	m^3	2.75	8,250,000		
6	Excavation, rock, in borrow areas and transportation to dam embankment	2,500,000	m^3	5.00	12,500,000		
7	Earthfill in dam embankment	2,600,000	m^3	0.65	1,690,000		
8	Rockfill in dam embankment	4,000,000	m^3	0.50	2,000,000		
9	Pressure grouting, all work and material	Lump sum		Lump sum	891,000		
	Subtotal--Dam and dike				26,954,000		
	Spillway--30-meter diameter glory hole and 10-meter diameter tunnel.						
10	Excavation, all classes, open cut	94,000	m^3	3.25	305,500		
11	Excavation, all classes, tunnel	107,000	m^3	67.00	7,169,000		
12	Tunnel supports	645,000	kg	1.40	903,000		
13	Concrete, crest structure and transition	5,500	m^3	210.00	1,155,000		
14	Concrete, tunnel and shaft lining	24,600	m^3	125.00	3,075,000		
15	Concrete, flip bucket	1,900	m^3	180.00	342,000		
16	Concrete, diversion plug	2,400	m^3	150.00	360,000		
17	Reinforcement	2,100,000	kg	1.00	2,100,000		
18	Minor items	Lump sum		Lump sum	462,300		
	Subtotal--Spillway				15,871,800		
	Outlet Works--Upstream fixed-wheel gate, 4.5-meter diameter steel penstock in 6- and 10-meter diameter tunnels.						
19	Excavation, all classes, open cut	257,000	m^3	3.25	835,250		
20	Excavation, all classes, tunnel	80,000	m^3	67.00	5,360,000		
21	Tunnel supports	532,000	kg	1.40	744,800		
22	Concrete, intake structure	3,330	m^3	210.00	699,300		
23	Concrete, tunnels and shaft	21,400	m^3	125.00	2,675,000		
24	Concrete, anchor block	17,600	m^3	130.00	2,288,000		
25	Concrete, diversion plugs	4,100	m^3	150.00	615,000		
26	Concrete, bridge deck	120	m^3	210.00	25,200		
27	Concrete, bridge piers	300	m^3	180.00	54,000		
28	Reinforcement	2,200,000	kg	1.00	2,200,000		
29	Trashracks	Lump sum		Lump sum	235,000		
30	Steel penstocks	Lump sum		Lump sum	3,370,000		
31	Fixed-wheel-gate, complete	Lump sum		Lump sum	587,500		
32	Ventilation system	Lump sum		Lump sum	57,500		
33	Butterfly valves, complete	Lump sum		Lump sum	400,000		
34	Stoplog seats and guides	Lump sum		Lump sum	30,000		
35	Gate hoist enclosure	Lump sum		Lump sum	50,000		
36	Structural steel for bridge	Lump sum		Lump sum	150,000		
37	Minor items	Lump sum		Lump sum	465,000		
	Subtotal--Outlet work				20,841,550		
	Subtotal--Items 1 through 37				63,667,350		
	Contingencies (25±%)				15,916,850		
	Field Cost--Motto Dam				79,584,200		
	Engineering and General Expense (20±%)				15,916,800		
	Total est. const. cost--Motto Dam				95,501,000		

Sheet 1 of 3

Table I-18--Continued

RECONNAISSANCE ESTIMATE
BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project: LOWER GUDER--Power

Date of Estimate: December 1963

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U.S. $1.00 = Eth. $2.50)

ITEM NO.	ITEM	QUANTITY: AMOUNT	QUANTITY: UNIT	EQUIPMENT MATERIAL AND LABOR: UNIT COST	EQUIPMENT MATERIAL AND LABOR: COST	FIELD COST	TOTAL CONSTRUCTION COST
	POWERPLANT--Hydro, located at toe of dam.					11,284,400	14,106,000
	Structures and Improvements.						
1	Powerhouse structure, masonry and reinforced concrete	Lump sum		Lump sum	2,200,000		
	Waterways.						
2	Excavation for tailrace, open cut	70,000	m^3	3.25	227,500		
	Turbines and Generators.						
3	Two units, 31,250 kva each, 13.2 kv, 0.8 pf, 50-cycle generators. Francis turbines, 35,275 hp, 230 rpm, 86-meter head.	Lump sum		Lump sum	5,016,000		
	Accessory Electrical Equipment.						
4	Equipment required for control and protection of generators and station service power.	Lump sum		Lump sum	968,000		
	Miscellaneous Powerplant Equipment.						
5	Equipment required for general station use	Lump sum		Lump sum	616,000		
	Subtotal--Items 1 through 5				9,027,500		
	Contingencies (25±%)				2,256,900		
	Field Cost--Powerplant				11,284,400		
	Engineering and General Expense (25±%)				2,821,600		
	Total est. const. cost--Powerplant				14,106,000		
	TRANSMISSION LINES, SWITCHYARD, AND SUBSTATIONS					10,957,000	13,459,000
	Motto Switchyard--Single breaker 132-kv line bays, located on powerhouse roof.						
1	Bay Y1 and transformer	Lump sum		Lump sum	650,000		
2	Bay Y2 and transformer	Lump sum		Lump sum	650,000		
3	Miscellaneous items	Lump sum		Lump sum	125,000		
	Field Cost--Switchyard				1,425,000		
	Engineering and General Expense (25±%)				356,000		
	Total est. const. cost--Switchyard				1,781,000		
	Transmission Line--Motto Powerplant to Agere Hiywet Substation, 132-kv, double-circuit steel towers with one overhead ground wire and six 266.8 MCM ACSR conductors.						
4	Rough Terrain	20	km	35,700.00	714,000		
5	Average terrain	40	km	29,750.00	1,190,000		
	Transmission Line--Agere Hiywet Substation to East Addis Ababa Substation, 161-kv, single-circuit steel towers with one overhead ground wire and three 397.5 MCM ACSR conductors.						
6	Average terrain	110	km	25,000.00	2,750,000		
	Transmission Line--East Addis Ababa Substation to Central Addis Ababa Substation, 132-kv, single-circuit steel towers with one overhead ground wire and three 4/0 AWG ACSR conductors.						
7	Average terrain	5	km	16,000.00	80,000		
	Field Cost--Transmission Lines				4,734,000		
	Engineering and General Expense (20±%)				947,000		
	Total est. const. cost--Transmission Lines				5,681,000		

Sheet 2 of 3

Table I-18--Continued

RECONNAISSANCE ESTIMATE
BLUE NILE RIVER BASIN-ETHIOPIA
ADDIS ABABA, ETHIOPIA

Project: LOWER GUDER--Power

Date of Estimate: December 1963

Prices as of: January 1961

Currency in terms of Ethiopian Dollars

(U S $1.00 = Eth. $ 2.50)

ITEM NO.	ITEM	QUANTITY		EQUIPMENT MATERIAL AND LABOR		FIELD	TOTAL CONSTRUCTION COST
		AMOUNT	UNIT	UNIT COST	COST	COST	
	TRANSMISSION LINES, SWITCHYARD AND SUBSTATIONS (Continued)						
	Agere Hiywet Substation--Complete as shown on Drawing No. 4.0-BN-178.						
8	Bay Y1, 161 kv	Lump sum		Lump sum	75,000		
9	Bay Y2, 161 kv	Lump sum		Lump sum	300,000		
10	Bay Y3, 161 kv	Lump sum		Lump sum	285,000		
11	Bay Y4, 161 kv	Lump sum		Lump sum	300,000		
12	Bay Y5, 161 kv	Lump sum		Lump sum	75,000		
13	Bay W1, 132 kv	Lump sum		Lump sum	230,000		
14	Bay W2, 132 kv	Lump sum		Lump sum	215,000		
15	Bay W3, 132 kv	Lump sum		Lump sum	230,000		
16	Bay W4, 132 kv	Lump sum		Lump sum	60,000		
17	Bay Z1, 45 kv	Lump sum		Lump sum	65,000		
18	Bay Z2, 45 kv	Lump sum		Lump sum	65,000		
19	Bay X1, 15 kv	Lump sum		Lump sum	10,000		
20	Bay X2, 15 kv	Lump sum		Lump sum	31,500		
21	Bay X3, 15 kv	Lump sum		Lump sum	31,500		
22	Autotransformer KY1A	Lump sum		Lump sum	960,000		
23	Autotransformer KY5A	Lump sum		Lump sum	120,000		
24	Communication facilities	Lump sum		Lump sum	10,000		
	Field Cost--Agere Hiywet Substation				3,063,000		
	Engineering and General Expense (25±%)				765,000		
	Total est. const. cost--Agere Hiywet Substation				3,828,000		
	East Addis Ababa Substation--Stage 05 only as shown on Drawing No. 4.0-BN-100.						
25	Bay V1, 230 kv	Lump sum		Lump sum	425,000		
26	Bay Y1, 161 kv	Lump sum		Lump sum	85,000		
27	Bay Y2, 161 kv	Lump sum		Lump sum	275,000		
28	Bay W2, 132 kv	Lump sum		Lump sum	230,000		
29	Autotransformer KV1A	Lump sum		Lump sum	720,000		
	Field Cost--East Addis Ababa Substation				1,735,000		
	Engineering and General Expense (25±%)				434,000		
	Total est. const. cost--East Addis Ababa Substation				2,169,000		
	ACCESS ROAD--From Agere Hiywet (Ambo) to Motto Dam. Flat to hilly terrain.					2,250,000	2,813,000
1	Road, two-lane gravel	60	km	30,000.00	1,800,000		
	Contingencies (25±%)				450,000		
	Field Cost--Access Road				2,250,000		
	Engineering and General Expense (25±%)				563,000		
	Total est. const. cost--Access Road				2,813,000		
	SERVICE FACILITIES--Includes offices, shops, housing, equipment, streets, and utilities.					775,000	969,000
1	Camp and equipment	Lump sum		Lump sum	620,000		
	Contingencies (25±%)				155,000		
	Field Cost--Camp				775,000		
	Engineering and General Expense (25±%)				194,000		
	Total est. const. Cost--Camp				969,000		

Sheet 3 of 3