REPORT
ON
THE KRONG BUK IRRIGATION PROJECT
IN
THE UPPER SREPOK BASIN

VIET NAM

DECEMBER 1964

THE OVERSEAS TECHNICAL COOPERATION AGENCY

TOKYO

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Preface

The Srepok is one of the major tributaries of the Mekong, and the Upper Srepok is an important water resource in Viet-Nam.

In response to the request of the Committee for Coordination of Investigations of the Lower Mekong Basin, the Government of Japan had conducted the hydrologic investigations of this river in the fiscal year 1961, and the studies on the irrigation scheme of the low-lying Darlac marshy land within the Upper Srepok basin in the fiscal year 1962.

According to the results of these investigations, it was disclosed that the development of the lower reaches of this river such as the Darlac marshy land should not be projected exclusively for the basin itself, but as a part of the comprehensive development project of the over-all Upper Srepok basin including flood control and irrigation schemes of the Krong Buk, Krong Pach, Krong Boung, Krong Kno and others.

In the light of these circumstances, the Government of Japan took steps to investigate the Krong Buk irrigation scheme as an essential part of the whole Upper Project in compliance with the urgent request of the said Mekong Committee and entrusted the investigation work to the Overseas Technical Cooperation Agency, the executive agency of the Government, in the fiscal year 1963.

The Agency organized a survey team upon conclusion of the Service Agreement with Nippon Koei Co., Ltd. and carried out a field works during the period from mid-November 1963 to mid-February 1964.

This report is compiled in accordance with the "Plan of Operation" signed by the Mekong Committee and the Government of Japan for the examination of the engineering and economic feasibility of the lower Krong Buk irrigation scheme, along with the provisional consideration of the comprehensive development plan of the whole Upper Krong Buk Basin.

On this opportunity, I wish to express my deep thanks to the authorities concerned of the Government of Viet-Nam and the Committee for Coordination of the Investigations of the Lower Mekong Basin for their generous collaboration in the course of this investigation works.

December, 1964

Shinichi Shibusawa

Director General,

The Overseas Technical Cooperation Agency

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Summary and Conclusion

As stated in the "Comprehensive Reconnaissance Report on the Major Tributaries of the Lower Mekong Basin", the Upper Srepok Basin has a great possibility of the development in terms of both power and irrigation. Moreover, the Government of Viet-Nam is now contemplating a large-scale development within this basin.

In view of necessity of the development of the Upper Srepok Basin, the preliminary design report on the irrigation scheme of the low-lying marshy area in the Darlac region was submitted in January 1964. According to this report, the final development scheme of the Darlac region should be completed jointly with the planning of the prospective upstream basin projects, because this region is situated in the lower reaches of the Upper Srepok, and has a close relation with the effect from the upstream projects.

Under such circumstances, the investigation of the Krong Buk which is located in the upstream of the low-lying Darlac region has been conducted through the contribution of the Government of Japan in the fiscal year 1963.

As the result of our investigation, the following matters have been made clear.

i) From the topographic features of the Krong Buk Basin, the basin can be widely divided into the highland area and the lowland area which is the main object of the investigation carried out in 1963.

ii) In order to irrigate about 10,000 hectares proposed in the original plan (mostly located in the lowland area), it is necessary to create f large-scale reservoir at the proposed lower site of the Krong Buk which is located just upstream of the point where the Krong Buk crosses the National Highway No.21 (Ban Me Thuot - Ninh Hoa). According to our study, a considerable amount of embankment materials will be required for creating such a large-scale reservoir from the topographic features of this dam site.

iii) Moreover, a part of the irrigable area of 10,000 hectares should be irrigated by pumping the water of the reservoir up above EL. 500 meters. For this purpose, an enormous expenditures will have to be invested in constructing the new pumping facility.

iv) From the reason mentioned above, an irrigable area commanded by the reservoir to be created at the lower site (the lower Krong Buk reservoir) is reasonably estimated at 3,500 hectares, taking into account the natural conditions of the basin and the limits of an economically justifiable investment.

In the light of these studies, the irrigation scheme for about 3,500 hectares of land (hereinafter referred to as "the lower Krong Buk irrigation scheme") extending on both banks of the Krong Buk is planned and the outline of this scheme is given below:

(1) Irrigation area	3,500 ha.
(2) Head works	
Reservoir:	
High water level	EL. 473.1 m
Total storage capacity	46 million m^3
Available storage capacity	33 million m^3
Dam:	
Crest elevation	EL. 476.7 m
Height	21.0 m
Type	Rolled earth-fill type
Earth volume	810,000 m^3
(3) Water conveying facilities	
Irrigation canal:	
Main canal	38.3 km
Laterals	57.5 km
(4) Reclamation area	3,460 ha.

The construction cost of this irrigation scheme is estimated at 3,875,000 US dollars which is equivalent to about 1,100 US dollars per hectare. This means a rather high initial investment.

On the other hand, the highland area for which the Government of Viet-Nam is now contemplating a large agricultural development by an adequate irrigation farming practice has an existing farmland of about 6,000 hectares with some rubber, tea and coffee plantations, and many hamlets have been established already in this area. In view of this situation, the development of the upper basin of the Krong Buk is considered significant and worthy of being realized.

According to our investigation, two suitable dam sites were found in the upstream reaches of the Krong Buk and in the Ea Jung which is a tributary of the Krong Buk. At these two sites, it will be possible to create two reservoirs by constructing an earth dam. One is the upper Krong Buk reservoir and the other is the Ea Jung reservoir.

By utilizing the upper Krong Buk reservoir, about 7,500 hectares of land including the existing farmland of about 6,000 hectares will be irrigated by gravity flow. On the other hand, the gravity irrigation of about 1,500 hectares of land extending on the right bank of the middle course of the Krong Buk will be realized by using the Ea Jung reservoir and an intake weir to be constructed at a point about 10 kilometers upstream from the Krong Buk dam site.

Consequently, the gravity irrigation of about 9,000 hectares of land in total will be contemplated in the highland area of the Krong Buk.

The construction cost of these irrigation schemes is provisionally estimated at 6,800,000 US dollars equivalent which equals to about 755 US dollars per hectare, although this estimation should be reviewed and revised in accordance with subsequent investigations and studies on these irrigation scheme.

Under such circumstances, it is desirable that the lower Krong Buk irrigation scheme is left for future development. The prompt development of the highland area of the Krong Buk Basin is required first. For this purpose, the detailed investigations, especially the agronomic researches in the irrigable area and the geological investigation on the proposed upper Krong Buk and Ea Jung dam sites should be carried out as early as possible for studying in detail the feasibility of the project.

Chapter I

GENERAL DESCRIPTION

1.1. Upper Srepok Basin

The Upper Srepok Basin, which has great possibility of the development of power or irrigation or of both, is situated in the plateau region of Central Viet-Nam.

The Srepok is one of the main tributaries of the Mekong. It rises in the Annam Cordillera, flowing through the highland of Viet-Nam and then passing through the Cambodia plain to drain into the Mekong near Stung Treng with two other large tributaries, the Se Krong and the Se San. It has a total length of about 390 kilometers and a total catchment area of about 31,000 square kilometers.

The Upper Srepok Basin consists of drainage areas of the Ea Krong, the Ea Krong Ana, the Krong Kno, the Krong Buk, the Krong Pach and so on. In view of topographic features, these whole areas can be widely divided into two, namely, the flat alluvial lowland and gently undulating upland. The lowland extending on both banks of each river is located at elevation ranging from EL. 410 to EL. 450 meters in general, while the upland ranges mainly from 450 to 580 meters in elevation.

The climate is tropical but characterized by two distinct seasons, i.e. the dry season and the rainy season. The annual precipitation averages 1,700 to 2,000 millimeters. The mean monthly temperature varies from 18°C to 26°C.

Basically the economy of this province is agricultural with rice as the most important crop. During the dry season covering the period of November through April, however, the agriculture becomes impossible for want of soil moisture. Only in the rainy season, rice is cultivated in the lowland which is affected frequently by the periodic flood. Other crops such as vegetables, fruits, corn, peanut, kenaf, etc., are grown in many of the small stream valleys. Besides, there are several rubber, tea and coffee plantations as a private commercial farming. Most of the upland is covered with grass and forest and is not cultivated. In recent years, the Government policy of encouraging settlement and ownership of the land cultivated has been taken up within the Project area for the agricultural development of this province. Under such circumstances, the present agricultural productivity in this area is very poor. Therefore, the adequate irrigation farming is required.

The principal city of the Upper Srepok Basin, Ban Me Thuot, is about 275 kilometers northeast of Saigon and 150 kilometers northwest of Nha Trang on the coast. It has good highway connections with each.

The government is making a determined effort to establish development centers in this area and places an emphasis upon intensification and diversification of production in the settlement areas for refugees from the north or overpopulated areas. This area is one of the designated resettlement areas.

Under these circumstance, the development of water resources in this area has been a long pending desire of Viet-Nam.

1.2. Prior investigation and report

In view of the above-mentioned necessity of the development of the Upper Srepok Basin, the hydrologic investigation of the Upper Srepok had been conducted by the contribution of the Government of Japan with its 1961-year bu get. Subsequently, in 1962 the Government of Japan had undertaken the investigation of the Upper Srepok-limited to the irrigation scheme of the low-lying marshy area in the Darlac region-with its 1962-year budget. The preliminary design report on the Darlac Irrigation Scheme had been submitted to the Committee for Coordination of the Investigations of the Lower Mekong Basin (hereinafter referred to as "the Mekong Committee") in January 1964. The outline of this report is as follows:

i) Since the low-lying marshy area of the Darlac region with an area of about 8,000 hectares is situated in the lower reaches of the Upper Srepok, it is inevitably required to consider it as a link in the chain of the comprehensive Upper Srepok Project covering the Krong Buk, the Krong Boung, the Krong Pach, and other rivers. Especially, as the drainage of the Darlac low-lying marshy area is affected by the flood control works for the upstream reaches, the final drainage plan shall be completed jointly with the planning of the upstream basin projects.

ii) In this area, however, about 500 hectares of land have been cultivated, and two hamlets have been established already. In order to stabilize these farmers' agricultural management as early as possible, it is imperative to perform the development works of this area so as to enable the farmers to maintain profitable irrigation farming during the dry season. For this purpose, it is possible to construct the irrigation system within the limits of an economically justifiable investment on the first development area of 1,000 hectares including about 500 hectares of existing farmland.

iii) As for the remained area of Darlac marshy land, its development is desirable to be considered as a part of the comprehensive development project all over the Upper Srepok Basin in future.

1.3. Krong Buk Basin

The Krong Buk is one of the tributaries of the Srepok. It rises in the mountain located in a center part of the Central Highland region in Viet-Nam and runs southward through the center of basin to drain into the Ea Krong Ana. It has a total length of about 70 kilometers and a total drainage area of about 740 square kilometers.

The Krong Buk area is situated upstream of the low-lying Darlac region, and it is being opened for new communities, and many hamlets have been established already. Since it is anticipated that the development of this area will make it possible to reduce the flood damage in the area just upstream of the Darlac region and also to facilitate the development of the downstream lowlands. Thereupon, the Krong Buk development project will have a beneficial effect on the development of the Darlac region in the future.

Chapter II

NATURAL CONDITIONS OF THE PROJECT AREA

2.1. Present conditions and need for agricultural development in the whole Upper Srepok area

Based on the results of our agronomic study on the rural conditions in the Upper Srepok area, the present agricultural conditions are summarized hereunder:

Until comparatively lately, most areas of the Upper Srepok basin were faintly used for the shifting agriculture by Moi tribes except some remarkable areas used for the plantation of rubber-, coffee- and tea-plants. Since 1957, the Government of Viet-Nam performed the inner colonial policy to establish new hamlets in the Central Highland Region with Ban Me Thuot as its center, and about 16,000 hectares of waste land were reclaimed by about 35,000 newly settled farmers by 1961. Thus, the total cultivated land in the Upper Srepok basin is estimated at about 30,000 hectares or about 3 per cent of the total Darlac Province.

The principal crop in this area is the rain-fed paddy, which is cultured in the lowland area extending on both banks of each river. Its yield is comparatively poor, averaging as low as 1.1 tons of paddy per hectare. This is because the rice is planted only once a year, depending entirely upon rainfall in the rainy season, without resorting to irrigation, manuring and other improved farming practices.

The culture of rubber plant is recently undertaken by new settlers to secure their cash income under the encouragement of the Government. Its cultivated area is estimated at about 5,000 hectares including the existing rubber plantation.

Besides, corn tobacco, beans, kenaf, peanut and other vegetables are also grown in this area, but their acreages and yields are generally small.

According to the Agricultural Statistics in 1961 published by the Government, the total annual yield of paddy in this province is about 26,000 tons (equal to 17,000 tons in cleaned rice) on a cultivated area of about 24,000 hectares, and other crop productions are as follows:

Crop	Planted area ha	Production ton	Yield per hectare ton/ha
Rubber	2,096	1,080	0.51
Coffee	3,600	2,100	0.58
Tobacco	230	200	0.87
Kapok	200	120	0.60
Peanut	1,300	1,720	1.30
Corn	150	240	1.60
Kenaf	1,500	1,500	1.0

It is considered that such low agricultural productivity of this area is largely due to three factors, i.e. (1) the lack of water for crops during the dry season, (2) the damage by inundation by the periodic flood occurring in the end of the rainy season in general and (3) the lack of farmers' experience in managerial skill. The total precipitation during the dry season is about 200 millimeters on an average, while the consumptive use of water for crop growth during the same season is estimated at approximately 800 millimeters. This means that one-crop culture is generally common in this area. Within the Project area, the lowland extending on both banks, especially the middle and lower reaches of Ea Krong Ana, is mostly inundated by frequent floods in every rainy season. In the present farming, almost no measures are being taken for improving the soil conditions and generally no careful considerations are given to the selection of an adequate crop variety and to the cultivation method.

Consequently, the livelihood of farmers is not so rich and scanty as a whole.

This area is suited for two or three crops a year in view of the favorable natural conditions of land and climatic conditions. Moreover, according to the results of the field experiments by Nippon Koei Co., Ltd. on upland irrigation culture of paddy on degraded lateritic soil at Pleiku city, an average yield of 3.5 tons of paddy per hectare was harvested by applying the so-called "upland irrigation farming method of paddy". Accordingly, it is obvious that the irrigation farming practice in this area is essential for the agricultural development of the Central Highland in Viet-Nam. Furthermore, the agricultural development by irrigation will pave the way to the comprehensive development of this area.

2.2. Present conditions of the Krong Buk area

2.2.1. Present conditions of agriculture

The Krong Buk area which occupies a northeastern part of the Upper Srepok Basin is widely divided into two areas, i.e. highland and lowland areas, from the topographic features of the basin.

The highland area lies between two national highway No.14 and No.21 at an elevation ranging from 500 to 580 meters and has about 6,000 hectares of land cleared for cultivation including some rubber, tea and coffee plantations. Moreover, the Government is now energetically promoting the policy of establishing a large agricultural settlement in this area, and many hamlets have been already established. Furthermore, the Government envisages enthusiastically an adequate irrigation farming practice in this area for the successful development of agriculture in central highland area.

The lowland area which extends on both banks of the downstream reaches of the K ong Buk at an elevation of 440 to 500 meters is an area of about 5,000 hectares, with dense forests distributed over most of the area except a small farmland area situated around the village. According to the investigation, an existing farmland within the lowland area is estimated at approximately 40 hectares.

2.2.2. Soils

According to the results of our detailed reconnaissance soil survey over the Project area, the distributions and demarcation of the main soil groups in the area have been completed as illustrated in Plate No. 9. The principal natures and properties of the soil groups are interpreted hereunder.

The soils of the Project area can be broadly divided into two soil groups. One is the lowland soil group distributed in the low flat area of 440 to 450 meters, in elevation and is mainly composed of the recent alluvial soil transported and deposited by the Krong Buk and its tributaries. The other is the upland soil group distributed in the gently undulating area with an elevation of about 450 to 500 meters, and it is mainly composed of the basaltic residual latosol soils.

The former, the recent alluvial soil, has clay loam or silty clay loam texture with a weak acidity of 5.5 to 5.8 in PH, a relatively fair cation exchange capacity and base saturation degree, and its natural fertility is comparatively high. And this soil has also a medium water holding capacity and a low basic intake rate. Therefore, it is a favorable soil for agricultural development of this area.

However, the soil has been in the continuous overwet condition due to its topographical features unfavorable for draining during the rainy season. Especially in the late rainy season, from September to October, the land of this soil is periodically inundated with overflow of rivers and drains. This is why the land lies almost waste despite of its rather high natural fertility.

The basaltic residual latosol in upland area is the residual soil originated from the basalt. It has typical latosol profile where both of surface soil and subsoil have medium textures such as silty clay or silty clay loam, with relatively strong acidity of PH value of 4.5 or so, rather small cation exchange capacity and low base saturation degree, and with a small amount of plant nutrients. Generally speaking, the natural fertility of this soil is lower than that of the lowland soil aforementioned. The soil has been used for plantations of rubber, tea and coffee and for other perennial plants.

According to the results of the physico-chemical examinations and agronomic researches on the spots, it is confirmed that the contents of available plant nutrients in this soil are not always so rich. Though the soil is not so favored by chemical components, it is blessed with excellent physical nature due to its thick layer of 5 to 10 meters with uniform texture.

In view of these facts along with the experimental results on the farmland of similar soil groups, the upland soil of latosol is considered to be exactly within the bounds of possibility for profitable agricultural development provided an adequate amount of water would be supplied by the completed irrigation system.

Chapter III

PROVISIONAL DEVELOPMENT PLANS FOR THE ENTIRE UPPER SREPOK BASIN

The basin of the Upper Srepok and its tributaries has an area of about 7,800 square kilometers. It consists of several drainage areas of the Ea Krong Ana, Krong Buk, Krong Pach, Krong Bound and Krong Kno. These drainage areas have generally gently rolling topography with some spots of hilly land. In the Project area, the wide gentle slopes between the stream channels are under cultivation and some rubber, tea and coffee plantations are included among these cultures.

According to the reconnaissance of major tributaries of the Mekong which was undertaken by the Government of Japan, six projects for irrigation or power or for both are contemplated in the development plan of the Upper Srepok. Among them, the top priority is given to the irrigation project of the low-lying marshy land in the Darlac region. The field investigations of this project were undertaken by the Japanese team during Japan's fiscal year 1962, and the feasibility report on the Darlac Irrigation Project had been submitted to the Mekong Committee in January 1964.

Moreover, the Government of Japan has decided to undertake the investigations and preliminary design of the Krong Buk irrigation scheme and the studies of a general development plan for the Upper Srepok Basin with its 1963-year budget. Then, based on the results of the investigations that have been made so far, the prospective development plans now under consideration within the Upper Srepok Basin, except the Krong Buk project for which the preliminary design is shown in the subsequent chapter, are given below:

(1) Krong Pach irrigation scheme (irrigation area 9,000 ha.)

The Ea Krong Pach is situated upstream of the Ea Krong Ana; it is one of the rivers originating in the Annam Cordillera, flowing first westward and then turning southward to join the Ea Krong Ana.

There is a suitable dam site at a point about two kilometers east of B. Rok where the catchment area is estimated at about 490 square kilometers.

According to the geological investigations on the dam site, the rock-bed of sandstone lies beneath the silt deposits of about 10 meters in thickness. At this site, the reservoir with a total storage capacity of about 170 million cubic meters will be created by constructing the fill type dam of 18.5 meters in height. Out of about 170 million cubic meters of a total storage capacity, 72 million cubic meters of water may be used for the irrigation of about 9,000 hectares of flat land extending on both banks of the lower Krong Pach.

A ccording to the above plan, the construction cost may be estimated at about 6,300,000 US dollars equivalent that equals to 700 US dollars per hectare.

(2) Krong Boung irrigation scheme (irrigation area 6,000 ha.)

On the Ea Krong Boung which commands a basin area of about 790 square kilometers east of the Ea Krong Ana, there is a suitable site for dam construction at a point some 4 kilometers upstream from its confluence with the Ea Krong Ana. Here a dam could be constructed with the height of about 21 meters (Crest El. 450 m. H.W.L. El. 447.5 m.), by which a total storage capacity of 170 million cubic meters will be secured. This will enable regulation of flood, and water of about 10 cubic meters per second will be secured throughout the year. With this, about 6,000 hectares of lowland within the Ea Krong Ana flood regulating reservoir site could be irrigated, and the discharge of the Ea Krong Ana in the dry season will increase.

The construction cost will be estimated at about 4,000,000 US dollars.

(3) Darlac irrigation scheme (irrigation area 8,000 ha.)

As stated in the feasibility report of the Darlac Irrigation Project which had been submitted in January 1964, the irrigation of about 8,000 hectares of lowland in the Darlac region will be contemplated. We also reported that since this project area is situated in the lower reaches of the Upper Srepok and will be greatly improved by the flood control works for the upstream reaches, it is absolutely necessary to consider it as a link in the chain of the Comprehensive Upper Srepok Project. The development of the upper projects and the Krong Kno project will make it possible to regulate the flood discharge of the Ea Krong to about 800 cubic meters per second. Consequently, the lowland of about 6,000 hectares in the Darlac region may be saved from the damage of periodic flood in the rainy season. Then, the final design of irrigation and drainage system in the Darlac low-lying land will be required.

As stated in the feasibility report of the Darlac Irrigation Project, the irrigation of about 8,000 hectares of land including about 4,400 hectares of existing farm land will be realized successfully.

The outline of development plan in the Darlac region at the present stage is as follows:

<u>Irrigation facilities</u>:

Pump station	5 stations
Main irrigation canals	84 km.
Laterals	86 km.
Reclamation of land:	3,600 ha.

(4) Krong Kno irrigation scheme (irrigation area 2,000 ha.)

A reservoir with an available storage capacity of about 800 million cubic meters will be created in the upstream reaches of the Ea Krong Kno, which is one of the largest tributaries of the Upper Srepok. By means of this reservoir, the discharge of about 60 cubic meters per second needed for power generation of about 25,000 kilowatts and for irrigation of the downstream area of about 2,000 hectares will be secured throughout the year.

Chapter IV

HYDROLOGIC STUDIES

4.1. Period of record

There had been no hydrologic data available for the Upper Srepok before the hydrologic investigation of the Srepok was undertaken by the Government of Japan in 1961. By the contribution of the Government of Japan, two water gauging stations at Ban Bur and Kana were established on the river for collecting the hydrologic data for the Upper Srepok Project. In addition to the above-mentioned two gauging stations, two more stations were established near the proposed dam sites of the Krong Buk and the Krong Pach in 1963. Accordingly, water gauging has been undertaken at four stations.

The daily recording of water stage and the periodical measurement of stream discharge by current-meter have been carried out at these four stations. By these observations, the stream flow data of the Srepok and its tributaries, i.e. the Ea Krong Ana, the Krong Buk and the Krong Pach, have been obtained as shown in Table 4.1. The observations are still being continued by the local personnel for obtaining ample and more accurate flow data.

As for the meteorology in the Project area, only meteorological data of precipitation, temperature, evaporation and relative humidity at the Ban Me Thuot station were available since 1959, though there were some interruptions.

All these data are compiled in the Data Book.

4.2. River runoff and available discharge

We have had an available stream flow data covering a period of only six months at the Krong Buk gauging station, and they may not be satisfactory for the study of water resources development of this type, especially for the comprehensive flood control of this basin. Thereupon, an attempt was made to estimate the stream discharge at the Krong Buk gauging station from precipitation records available.

Runoff is a portion of the precipitation, so the runoff may have any relation with the precipitation. Then, we tried to find out such relation between the runoff and precipitation, using the stream flow data at an adjacent gauging site.

In this case, since only the flow data covering a period of two years at the Kana gauging site, which is located about 60 kilometers downstream from the Krong Buk site, were available, we were obliged to make a long term analysis of runoff by using the relation between runoff at the Kana station and precipitation at the Ban Me Thuot station. According to the investigation, the basin at the Kana site, which is much affected by the large retarding action in its upstream reaches, is very large as compared with the basin at the Krong Buk site. In the light of such circumstances, it may be considered that the runoff per unit basin area at the Kana site is smaller than that at the Krong Buk site, and this fact is shown in Table 4.1. Thereupon, the discharge at the Krong Buk site, which is estimated on the basis of the flow data at the Kana site, may safely be used as the design value for the irrigation purpose. Therefore, based upon the flow data at the Kana site, the provisional estimation of discharge was made, though the estimated discharge should be revised in future by using an ample flow data to be obtained by the subsequent observation.

As stated in detail in Appendix III, thereupon, the runoff precipitation relationships were established by correlation of actual monthly runoff observed at Kana gauging site with concurrent monthly precipitation at Ban Me Thnot which is located about 30 kilometers northwest of Kana station. By applying these relationships to the monthly precipitation data available, the monthly discharge at the Krong Buk gauging site for the period of 1959 through 1963 were estimated; from this data, the monthly discharges of the Upper Krong Buk dam site were computed using the ratio of the catchment area of two sites, as shown in Table 4.2. Similarly, the discharge of the lower Krong Buk and the Eu Jung dam sites were estimated as shown in Table 4.3 and 4.4, respectively.

According to these tables, the annual mean runoff at the Upper Krong Buk dam site is 2.67 cubic meters per second, say about 85 million cubic meters per year, and at the Lower Krong Buk dam site the annual mean runoff is 2.11 cubic meters per second which equals to about 67 million cubic meters. And the annual runoff at the Ea Jung dam site is about 25 million cubic meters, say about 0.79 cubic meters per second.

Of these total runoff, about 66 per cent flows during 6 months of the rainy season in May through October. In general, the river discharge increase gradually toward the end of the rainy season and it reaches at maximum in September or October, and after that it decreases little by little and the lowest flow occurs in April.

Table - 4.1 Monthly discharge at each gauging station (measured)

(discharge in m3/sec)

Year		Kana gauging station			Ban Bur gauging station			Krong Pach gauging station			Krong Buk gauging station		
		Mean discharge	Maximum discharge	Minimum discharge	Mean discharge	Maximum discharge	Minimum discharge	Mean discharge	Maximum discharge	Minimum discharge	Mean discharge	Maximum discharge	Minimum discharge
1961	O	85.6	139.0	30.5	487.4	822.0	266.0						
	N	59.4	72.5	43.0	195.3	296.0	160.0						
	D	31.8	45.5	25.0	120.0	160.0	90.0						
1962	J	25.5	36.5	20.0	64.2	103.0	41.5						
	F	18.1	21.5	15.0	50.1	61.0	38.0						
	M	12.9	16.5	10.5	45.0	57.0	41.5						
	A	9.8	11.5	8.5	42.3	50.0	39.0						
	M	13.0	24.5	8.0	62.0	100.0	41.0						
	J	14.4	35.5	9.5	83.6	123.0	63.0						
	J	37.8	91.0	12.0	211.6	416.0	59.0						
	A	88.7	158.0	41.0	259.3	403.0	57.0						
	S	94.8	185.0	35.0	94.0	227.0	38.0						
	O	(110.0)	(417.0)	(71.0)1/	336.5	1,040.0	121.0						
	N	286.4	400.0	133.0	627.1	1,000.0	305.0						
	D	172.9	395.0	51.0	283.3	482.0	114.0						
1963	J	34.98	54.0	24.5	88.5	111.0	73.0						
	F	19.93	24.0	16.0	60.8	73.0	51.0						
	M	13.06	15.0	12.0	44.2	49.0	41.0						
	A	11.13	12.0	10.0	35.6	40.0	31.0						
	M	10.95	15.0	10.0	36.7	61.7	28.7						
	J	11.63	16.9	10.0	48.4	98.1	31.0						
	J	33.58	39.2	29.2	59.4	78.3	43.8						
	A	71.97	104.0	34.1	158.0	260.2	61.7				4.26	9.30	1.76
	S	120.23	240.0	34.1	334.8	555.1	176.6				13.34	62.04	5.47
	O	214.73	355.9	39.3	466.7	764.2	271.9				18.75	74.99	3.13
	N	57.02	116.4	32.3	161.5	260.2	96.0				7.33	11.74	5.19
	D	(46.6)	(95.0)	(22.0)1/	84.6	118.6	58.7	11.68	27.53	5.58	4.59	7.42	3.13
1964	J	(38.0)	(48.0)	(15.0)1/	46.4	60.2	38.0	4.99	5.58	4.46	2.78	3.51	2.07
	F	15.58	19.8	12.7	38.9	42.7	35.6	4.42	5.15	9.09	1.90	2.07	1.76

1/ Estimated runoff

Table 4.2

Estimated mean monthly discharge at the Upper Krong Buk dam site (unit: m^3/s)

(Catchment area 149 km^2)

Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	(Next Year) Jan.	Feb.	Mar.	Mean
1959	0.82	0.88	1.02	1.57	3.63	4.64	7.69	3.91	1.56	1.09	0.83	0.49	2.34
1960	0.92	0.98	1.13	1.85	4.27	5.61	10.80	5.83	1.70	1.31	0.98	0.58	2.99
1961	1.20	1.21	1.39	2.00	4.62	6.07	9.26	4.70	1.88	1.41	1.06	0.63	2.95
1962	0.49	0.52	0.61	1.50	3.47	4.55	7.74	8.71	4.09	0.98	0.74	0.44	2.82
1963	0.42	0.53	0.52	1.66	3.78	4.96	7.39	3.75	1.50	0.90	0.62	0.38	2.20
Mean	0.77	0.82	0.93	1.72	3.95	5.17	8.58	5.38	2.15	1.14	0.85	0.50	2.67

Table 4.3

Estimated mean monthly discharge at the Lower Krong Buk dam site (unit: m^3/s)

(Remaining catchment area 118 km^2)

Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	(Next Year) Jan.	(Next Year) Feb.	(Next Year) Mar.	Mean
1959	0.65	0.70	0.81	1.24	2.88	3.67	6.09	3.09	1.24	0.87	0.65	0.39	1.86
1960	0.73	0.85	0.90	1.46	3.38	4.44	8.55	4.62	1.34	1.03	0.78	0.46	2.38
1961	0.88	0.95	1.10	1.58	3.66	4.81	7.33	3.72	1.49	1.12	0.84	0.50	2.33
1962	0.39	0.41	0.48	1.19	2.74	3.60	6.08	6.90	3.24	0.85	0.58	0.35	2.24
1963	0.34	0.36	0.42	1.29	2.99	3.92	5.85	2.97	1.19	0.71	0.48	0.30	1.74
Mean	0.60	0.65	0.74	1.35	3.13	4.09	6.78	4.26	1.70	0.92	0.67	0.40	2.11

Table 4.4

Estimated mean monthly discharge at the Ea Jung dam site (unit: m^3/S)

(Catchment area 44 Km^2)

Year	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. (Next Year)	Feb. (Next Year)	Mar. (Next Year)	Mean
1959	0.24	0.26	0.30	0.46	1.07	1.37	2.27	1.51	0.46	0.32	0.24	0.14	0.69
1960	0.27	0.29	0.33	0.55	1.26	1.66	3.19	1.72	0.50	0.39	0.29	0.17	0.89
1961	0.33	0.35	0.41	0.59	1.36	1.79	2.73	1.39	0.55	0.42	0.31	0.19	0.87
1962	0.14	0.15	0.18	0.44	1.02	1.34	2.29	2.57	1.21	0.29	0.22	0.13	0.83
1963	0.13	0.13	0.15	0.49	1.12	1.46	2.18	1.11	0.44	0.27	0.18	0.11	0.65
Mean	0.22	0.24	0.27	0.51	1.17	1.52	2.53	1.59	0.63	0.34	0.25	0.14	0.79

Chapter V

DEVELOPMENT PLAN

5.1. Development area

The initial development plan for the Krong Buk area shown in the Comprehensive Reconnaissance Report by the Japanese Mekong Team is to build the reservoir at the point where the National Highway No.21 crosses the Krong Buk to irrigate about 10,000 hectares of land extending over the downstream reaches on both banks (mostly on the right bank).

Based on this plan, we made thorough investigations on the possibility of irrigation of 10,000 hectares of land, from both engineering and economical viewpoints.

As the result, it has become clear that the agricultural development could be realized successfully by dividing the above area into two areas with separate water source for each, instead of only one in the Krong Buk basin. This has been made clear from economical and engineering points of view, as described in the following paragraph.

As aforementioned, a dense forests is distributed over most of the area except a small farmland with an area of about 40 hectares around the village in the lower Krong Buk area. Moreover, according to our study, a large-scale reservoir will have to be constructed at the lower Krong Buk dam site to secure the irrigation water needed for about 10,000 hectares of farmland from the topographic features of the dam site. Under such circumstances, it is difficult to expect the irrigation of about 10,000 hectares of land in the lower Krong Buk area mainly from the economical point of view. Then, the prospective irrigable land in this area is reasonably estimated at 3,500 hectares, taking into consideration the natural conditions of the basin and the economical investment for the successful development of agriculture.

On the other hand, in the upper Krong Buk area, there are about 6,000 hectares of land cleared for agricultural purpose with some rubber, tea and coffee plantations. Moreover, the following suitable dam sites have been found in the upstream reaches of the Krong Buk.

i) Upper Krong Buk dam site located about 7 kilometers northeast of B. Anur village.

ii) Ea Jung dam site located immediately above the point where the Ea Jung, a tributary of the Krong Buk, crosses the National Highway No.14 which is an important communication route in the central highland area running from Saigon to Kontum.

According to our studies, as mentioned in subsequent paragraph, it will be possible to create two reservoirs, i.e. the upper Krong Buk and the Ea Jung reservoirs by constructing an earth dam at these two sites, respectively; moreover, a concrete intake weir will be constructed at a point about 10 kilometers upstream from the lower Krong Buk dam site.

By utilizing the upper Krong Buk reservoir, about 7,500 hectares of land including the existing farmland of about 6,000 hectares will be irrigated by gravity flow. On the other hand, the gravity irrigation of about 1,500 hectares of land extending on the right bank of the middle course of the Krong Buk will be realized by using the Ea Jung reservoir and the intake weir.

Therefore, the prospective irrigable area in the Krong Buk Basin is estimated at 12,500 hectares, which is a total of 9,000 hectares in the upper Krong Buk area and 3,500 hectares in the lower Krong Buk area.

5.2. Prospective irrigation farming

In order to accomplish the successful development of agriculture of the Krong Buk area, two appropriate units of farm management, i.e. the paddy livestock farming unit and the upland livestock farming unit are proposed on the basis of our soil survey and agronomic researches.

Then, the standard acreage of a paddy livestock farming unit is determined at 2 hectares of which 1.8 hectares are used for cropping and 0.1 hectare for homestead, and remaining 0.1 hectare for grassland with forest. On the other hand, for an upland livestock farming unit, the standard acreage of 4.5 hectares including of 4.2 hectares for cropping, 0.15 hectare for homestead, and 0.15 hectare for grassland with forest around the premises are adopted.

As for the livestock raising, 2 milk cows, 2 swine and 11 poultry are riased for a paddy livestock farming unit, while 3 milk cows, 3 swine and 11 poultry are bred for an upland livestock farming unit.

The detailed description about these prospective farming units is given in Appendix V, Subsection 1.

In the lower Krong Buk area, the projected farmland of 3,500 hectares will be alloted to 1,360 farmers, which is a total of 20 existing farmers and 1,340 farmers to be moved into this area from the overpopulated area.

On the other hand, about 1,300 existing farmers within the upper Krong Buk area would be benefited by the irrigation farming.

5.3. Water requirements

Based on the proposed future cropping pattern shown in Fig.-5.1 and 5.2. of Appendix V the consumptive use of water for crop growth of each month in the proposed farm units of both lowland and upland are estimated as shown in Table 5.1.

As seen in this table, the maximum monthly consumptive use of water will occur in January in both lands, and these values are as follows:

Lowland	Upland
148 mm.	111 mm.

In order to determine an adequate water requirement for planning the irrigation scheme, water application losses and conveyance losses must be added to the consumptive use of water. Thus, the maximum water requirement is as shown below:

	Lowland	Upland
1. Max. consumptive use of water	148 mm.	111 mm.
2. Water application losses	77 mm.	83 mm.
3. Conveyance losses	77 mm.	71 mm.
4. Water requirements	302 mm.	265 mm.
	1.05 m^3/sec/1,000 ha	0.93 m^3/sec/1,000 ha

Based on the maximum water requirement and on the proposed irrigation scheme, the diversion water requirement is calculated as follows:

Upper Krong Buk area

	Lowland	Upland
Maximum water requirement	1.05 m^3/sec/1,000 ha	0.93 m^3/sec/1,000 ha
Irrigation area	-	9,000 ha
Diversion water requirement	-	8.37 m^3/sec

Lower Krong Buk area

	Lowland	Upland
Maximum water requirement	1.05 m^3/sec/1,000 ha	0.93 m^3/sec/1,000 ha
Irrigation area	2,100 ha	1,400 ha
Diversion water requirement	2.21 m^3/sec	1.30 m^3/sec

According to this table, the diversion water requirements for the upper Krong Buk area and the lower Krong Buk area are 8.37 and 3.51 cubic meters per second, respectively. These are equivalent to about 1.00 cubic meter per second per 1,000 hectares on an average.

Table – 5. 1 Calculation sheet of consumptive use of water

Farm unit : Lowland live stock farming unit

Crop	Length of Growing	K	Irrigation area	IRRIGATION PERIOD																																			
				Jan.			Feb.			Mar.			Apr.			May			Jun.			Jul.			Aug.			Sep.			Oct.			Nov.			Dec.		
Rice	120	1.00	0.5	0.725	0.795	0.840	0.840	0.795	0.700	0.575	0.425		0.130	0.280	0.440	0.600	0.725	0.795	0.840	0.840	0.795	0.700	0.575	0.425												0.130	0.280	0.440	0.600
Kenaf	150	0.75	0.2	0.254	0.252	0.245																										0.038	0.071	0.110	0.146	0.182	0.210	0.233	0.246
Tabacco	150	0.70	0.2	0.237	0.235	0.228																										0.035	0.066	0.102	0.136	0.169	0.196	0.217	0.230
Peanut	120	0.70	0.3	0.353	0.353	0.334	0.294	0.242	0.179																									0.055	0.118	0.185	0.252	0.305	0.334
Sweet potato	120	0.65	0.2	0.218	0.207	0.182	0.150	0.111																									0.034	0.073	0.114	0.156	0.189	0.207	0.218
Vegetables	90	0.55	0.1								0.016	0.038	0.060	0.076	0.087	0.092															0.016	0.038	0.060	0.076	0.087	0.092			
Soybeans	120	0.60	0.3									0.047	0.101	0.158	0.216	0.261	0.286	0.302	0.302	0.286	0.252	0.207	0.153																
Green beans	120	0.60	0.2									0.031	0.067	0.106	0.144	0.174	0.191	0.202	0.202	0.191	0.168	0.138	0.102																
Maize	120	0.70	0.3										0.055	0.118	0.185	0.252	0.305	0.334	0.353	0.353	0.334	0.294	0.242	0.179															
Paspalm	360	0.75	0.2	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
Fruits	360	0.55	0.1	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
Grassland with forest	360	0.55	0.1																																				
Home stead	360	0.60	0.1																																				
Total				1.992	2.047	2.034	1.489	1.353	1.084	0.780	0.646	0.321	0.618	0.943	1.277	1.584	1.712	1.838	1.902	1.875	1.754	1.544	1.277	0.809	0.205	0.205	0.205	0.205	0.205	0.205	0.221	0.316	0.436	0.621	0.806	1.119	1.332	1.607	1.833
f					1.125			0.727			0.324			0.527			0.951			1.024			0.672			0.114			0.114			0.180			0.471			0.882	
E					131.6			139.9			181.5			168.3			106.8			77.0			57.2			59.5			51.6			66.6			84.1			102.0	
U = E x f					148			102			59			89			102			79			38			7			6			12			40			90	

where K: Normal seasonal consumptive use coefficient.

E: Average monthly evaporation (mm)

f: Ratio of consumptive use to evaporation

U: Average monthly consumptive use of water per hectare

Farm unit: Upland livestock farming unit

Crop	Length of Growing	K	Irrigation area	IRRIGATION PERIOD																																			
				Jan.			Feb.			Mar.			Apr.			May			Jun.			Jul.			Aug.			Sep.			Oct.			Nov.			Dec.		
Rice	120	1.00	0.75	1.260	1.260	1.193	1.050	0.863	0.638							0.195	0.420	0.660	0.900	1.088	1.193	1.260	1.260	1.193	1.050	0.863	0.638							0.195	0.420	0.660	0.900	1.088	1.193
Kenaf	150	0.75	0.50																0.094	0.176	0.274	0.364	0.454	0.525	0.581	0.615	0.634	0.630	0.611										
Vegetable	90	0.55	0.10													0.016	0.038	0.060	0.076	0.087	0.092													0.016	0.038	0.060	0.076	0.087	0.092
Beans	120	0.65	0.65	0.710	0.710	0.672	0.592																											0.110	0.237	0.372	0.507	0.613	0.672
Peanut	120	0.70	0.40	0.445	0.392	0.322	0.238																									0.073	0.157	0.246	0.336	0.406	0.445	0.470	0.470
Maize	120	0.70	0.40	0.073	0.157	0.246	0.336	0.406	0.445	0.470	0.470	0.445	0.392	0.322	0.238																								
Tobacco	150	0.70	0.30																			0.053	0.099	0.153	0.204	0.254	0.294	0.326	0.344	0.355	0.353	0.342							
Green manure	150	0.60	0.10 0.30	0.073	0.684	0.093	0.098	0.101					0.045	0.085	0.131	0.175	0.218	0.252	0.279	0.295	0.304																		
Pasture	120	0.55	0.75																0.107	0.231	0.363	0.495	0.598	0.656	0.693	0.693	0.656	0.578	0.474	0.351									
Fruit	360	0.55	0.10	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
Sugar cone	360	1.00	0.10	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Rubber	360	0.50	1.50	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750
Total				3.466	4.108	3.431	3.219	2.275	1.988	1.375	1.375	1.350	1.342	1.312	1.274	1.291	1.581	1.877	2.361	2.782	3.131	3.077	3.316	3.432	3.433	3.330	3.127	2.439	2.334	1.611	1.258	1.320	1.062	1.472	1.936	2.403	2.833	3.163	3.332
f					0.846			0.608			0.333			0.321			0.386			0.673			0.799			0.804			0.519			0.296			0.472			0.758	
E					131.6			139.9			181.5			168.3			106.8			77.0			57.2			59.5			51.6			66.6			84.1			102.0	
U = E x f					111			85			60			54			41			52			46			48			27			20			40			77	

5.4. Irrigation headworks and method of water conveyance

5.4.1. Lower Krong Buk area

From the viewpoint of the topographic features, the lower Krong Buk project area can be divided into two area, i.e. 2,100 hectares of lowland (440 to 450 meters in elevation) extending on both banks of the Krong Buk and 1,400 hectares of upland (450 to 500 meters in elevation) being located in the northern part of the Project Area.

In order to irrigate an area of 3,500 hectares, it is necessary to raise the river water level of the Krong Buk up to an elevation of 473.1 meters by constructing an earth dam with a height of about 21 meters at the lower Krong Buk site.

The necessary irrigation water of 3.51 cubic meters per second supplied from the lower Krong Buk reservoir will be distributed into the irrigable area by means of three main canals; first, the water is conveyed through the I main canal to the upland of 500 hectares and the lowland of 1,500 hectares south-east of the reservoir; second, the water supplied through the II main canal irrigates 600 hectares of upland and 400 hectares of lowland extending on the left bank of the Krong Buk by gravity flow; third, the water for irrigating 300 hectares of upland and 200 hectares of lowland on the right bank is conducted through the III main canal.

1) Geology of dam site and selection of type of dam

.ccording to our investigations, there is a suitable dam site at the point where the Krong Buk crosses the Ban Me Thuot - Ninh Hoa highway at right angles near B. Krong Buk located at 50 kilometers east of Ban Me Thuot.

At the above proposed dam site, three exploratory holes were drilled for geological studies of the site as shown in Plate No.4. According to our test boring, a fresh basalt is found beneath the sand and gravel deposits of about 2 or 3 meters in thickness, and both abutments are covered with the reddish brown residual soils of basaltic origin. The depth of the layer is about 3 to 10 meters. Therefore, if a concrete gravity dam is adopted for this site, the above-mentioned residual soil layer should be removed completely for placing the dam foundation on the fresh basalt. Consequently, a considerable amount of excavation will be required. On the other hand, in case of a fill type dam, if a center core or cut-off wall should be constructed closely on the sound rock bed of basalt in order to minimize the percolation loss under the dam, and if the sufficient curtain grouting is done to the sand and gravel deposits, it will become possible to place the most part of dam body on such deposits.

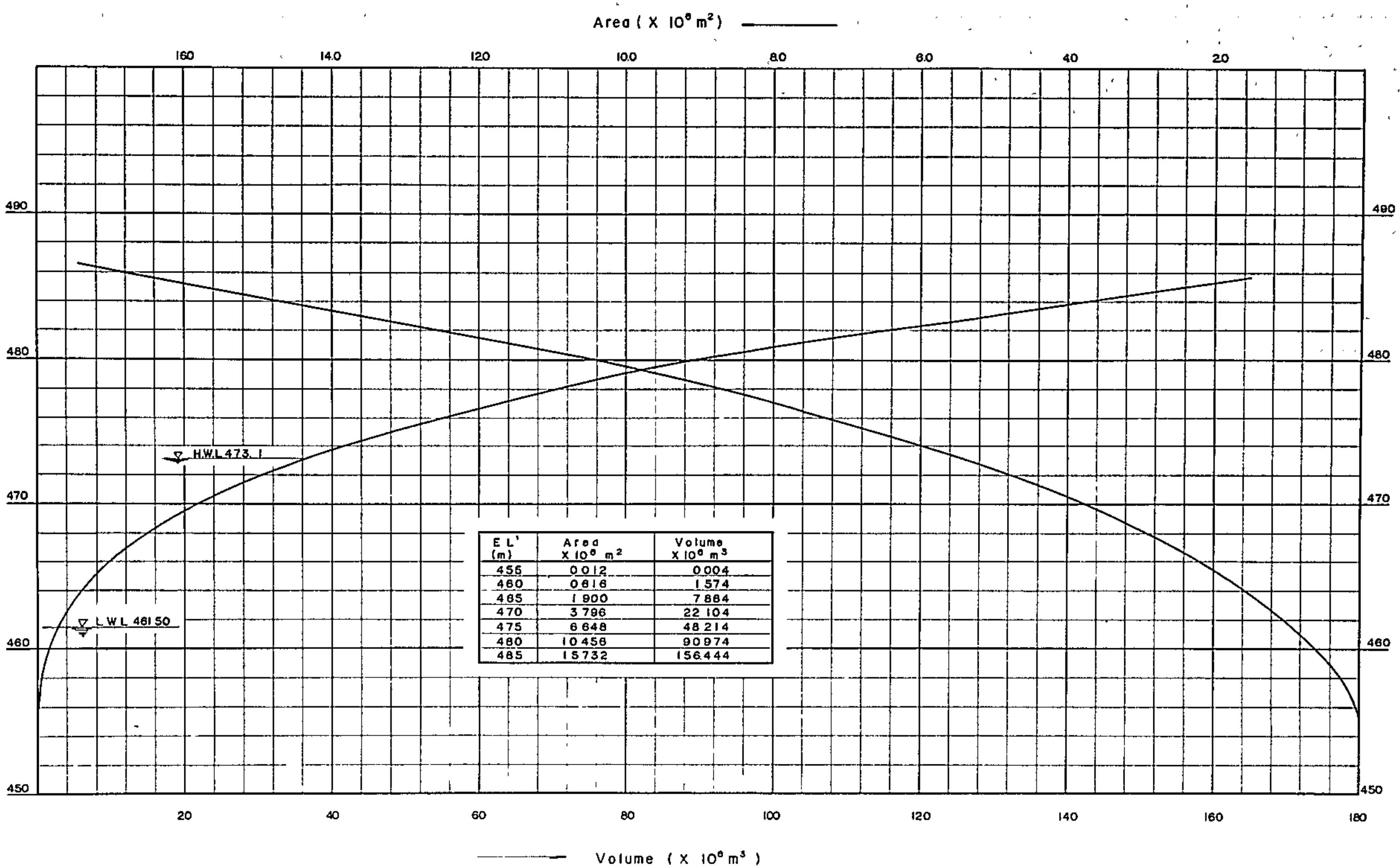
In view of the above-mentioned considerations, this site is suitable for a fill-type dam. For a fill-type dam, the rolled earth-fill type is adopted for the purpose of making the best use of the local materials. The required quantities of materials for dam body will be available in the areas on both banks. The materials to be obtained from this borrow pit consist of sandy clay or sandy loam. According to our laboratory test, these soils have hardly any undesirable characteristics for the materials of embankment. Taking into account these factors as well as construction cost, this dam is designed as homogeneous rolled earth-fill type.

2) Reservoir

We compiled the topographic maps of the Project area on a scale of 1:20,000 from aerial photos with ground control. From this map, the storage-area curve are drawn as shown in Fig. 5.1.

The reservoir with a high water level of 473.1 meters from sea level will spread over an area of 5.4 square kilometers impounding an effective storage of 33 million cubic meters with a drawdown of 11.6 meters for irrigation of 3,500 hectares of land in the dry season.

Fig - 5.1 LOWER KRONG BUK RESERVOIR



EL' (m)	Area X 10^6 m^2	Volume X 10^6 m^3
455	0.012	0.004
460	0.616	1.574
465	1.900	7.884
470	3.796	22.104
475	6.648	48.214
480	10.456	90.974
485	15.732	156.444

The storage capacity for 1.5 meters above the said high water level (EL. 474.6 m) will be about 10 million cubic meters and it is appropriated for flood control use.

Below 461.5 meters in elevation, the low water level of the reservoir, the storage capacity will be estimated at 3 million cubic meters which is considered as the dead storage.

3) <u>Dam and spillway</u>

Lower Krong Buk dam is of homogeneous rolled earth-fill type. The crest length will be 1,400 meters and the height of dam from the river bed to dam crest with an elevation of 476.7 meters will be 21 meters.

The plan, elevation, and section of the dam are shown on Plate No.3 and No.4.

The cross section of the dam consists of homogeneous rolled earth-fill in the main, center drain layer, offset drain layer, toe rockfill, and riprap on upstream surface.

The spillway will be constructed on the left bank of the river. The crest elevation of the spillway is determined at EL. 466.1 meters. The overflow portion is a gravity concrete structure of 8 meters in height.

Two tainter gates, net span of 11 meters and height of 7 meters, are to be installed at the overflow crest of the spillway for securing about 33 million cubic meters of water for irrigation of 3,500 hectares of land at an elevation of 473.1 meters.

4) <u>Outlet works</u>

Outlet works consist mainly of intake tower rising vertically 18 meters in height with its foundation in the reservoir and the intake conduit of reinforced concrete of about 590 meters in length. The maximum discharge through the conduit is estimated at 3.51 cubic meters per second. A Howell-Bunger valve will be installed at the end of the conduit.

5) Canal and lateral

In the Krong Buk area, three main canals with a total length of 38.3 kilometers will be required to supply the irrigation water for an area of 3,500 hectares.

The length and the commanding area of these canals are as follows:

1) I. Main canal	20.90 km	2,000 ha
2) II. Main canal	12.30 km	1,000 ha
3) III. Main canal	5.10 km	500 ha
Total	38.3 km	3,500 ha

These canals will be of earth canal type without artificial lining of bed or side, and their capacities have been determined on the basis of the diversion water requirement.

The number and the total length of laterals branching off each main canal are as follows:

I. Main canal	17 laterals	35.20 km
II. Main canal	15 laterals	13.80 km
III. Main canal	8 laterals	8.5 km
Total	40 laterals	57.5 km

All of these laterals will be of earth canal type.

6) Main structure

The main structures for the main canals and laterals are turnouts, drain culvert, cross drain, checks and spillways. The number of each main structure for main canals is as follows:

		Turnout	Cross drain	Drain culvert	Check	Spillway
Canals	I. Main canal	11	2	2	3	1
	II. Main canal	10	2	2	3	2
	III. Main canal	3	1	-	-	1
	Total	24	5	4	6	4

7) Principal features of main facilities

Principal features of the main irrigation facilities and summarized as follows:

Head works:

1. Reservoir

High water level	El. 473.1 m
Total storage capacity	46 million m^3
Effective storage capacity	33 million m^3
Drawdown	11.6 m

2. Dam

Crest elevation	El. 476.7 m
Height	21.0 m
Type	Homogeneous earth-fill type
Earth volume	810,000 m^3

Water conveying facilities:

1. No.1 area (irrigation area 2,000 ha.)

Canals

i) Main canal

Length	20.90 km
Discharge	2.04 m^3/sec.
Type	Earth canal
Related structures	19 nos.

ii) Laterals

Number of laterals	17 lines
Total length	35.20 km
Type	Earth canal

2. No.2 area (irrigation area 1,000 ha.)

Canals

i) Main canals

Length	12.30 km
Discharge	0.98 m^3/sec.
Type	Earth canal
Related structure	19 nos.

ii) Laterals

Number of laterals	15 lines

Total length	13.8 km
Type	Earth canal

3. No.3 area (irrigation area 500 ha.)

Canals

i) Main canals

Length	5.10 km
Discharge	0.49 m^3/sec.
Type	Earth canal
Related structure	5 nos.

ii) Laterals

Number of laterals	8 lines
Total length	8.5 km
Type	Earth canal

5.4.2. Upper Krong Buk area

As aforementioned, it is necessary to construct two reservoirs and one intake weir in order to irrigate an area of 9,000 hectares in the Upper Krong Buk area. As for the reservoirs, one is the upper Krong Buk reservoir to be created in the upstream reaches of the Krong Buk and the other is the Ea Jung reservoir, which will be constructed in the Ea Jung, a tributary of the Krong Buk.

However, the upper Krong Buk irrigation project was not the main object of the investigation carried out in 1963.

Therefore, only a few basic data for the perliminary design of this project are available. Under such circumstances, the provisional studies on the irrigation facilities such as reservoirs, intake weir and main irrigation canal were made, and the outline of these facilities is given below.

Head works:

1. Upper Krong Buk reservoir

High water level	El. 701.0 m
Total storage capacity	86.4 million m^3
Effective storage capacity	83.4 million m^3
Drawdown	15.0 m

Dam:	
Crest elevation	El. 705.5 m
Height	29.3 m
Type	Homogeneous rolled earth-fill type
Earth volume	950,000 m^3
2. Ea Jung reservoir	
High water level	El. 618.0 m
Total storage capacity	5.0 million m^3
Effective storage capacity	4.76 million m^3
Drawdown	11.0 m
Dam:	
Crest elevation	El. 620 m
Height	18.0 m
Type	Earth-fill type
Earth volume	400,000 m^3
3. Intake weir	
Crest elevation	El. 507 m
Crest length	30 m
Type	Concrete gravity type
Concrete volume	460 m^3

Water conveying facilities:

1. Upper area (irrigation area 7,500 ha.)

   Main canal 57 km

2. Ea Jung area (irrigation area 1,500 ha.)

   Main canal 40 km

5.5. Cost Estimates

The construction cost of the lower Krong Buk irrigation system is estimated at 3,875,000 US dollars of which 1,790,000 US dollars is required in foreign exchange and the remaining 2,085,000 US dolloars in local currency. Table 5.2 shows the breakdown of the estimated cost, all expressed in US dollars.

On the other hand, the construction cost of the upper Krong Buk irrigation system inclusive of the Ea Jung system is also estimated at 6,800,000 US dollars as shown in Table 5.3, although this estimation should be reviewed and revised in accordance with the subsequent studies on this development scheme for which the field investigations may be carried out in fiscal year 1964.

All estimates are exclusive of any import duties or other taxes on equipment, materials and supplies that might be payable in Viet-Nam, and of any taxes which might be levied in Viet-Nam on the engineer, the engineer's foreign employees, the contractors, contractors' equipment, or contractors' employees.

Table 5.2

Estimate of Construction Cost for the lower Krong Buk Irrigation Scheme (3,500 ha.)

Item	Cost in 1,000 U.S. Dollars			Remarks
	Foreign exchange	Local Currency	Total	
(A) Preparatory works	8.0	12.0	20.0	Including about 1,000 m^2 of office, Engineers' camp, etc.
(B) Reservoir	661.0	929.0	1,590.0	Including spillway
(C) Intake	117.0	100.0	217.0	Including intake gate and Howell-Bunger valve at the end of waterway
(D) Construction machineries	150.0	40.0	190.0	----
(E) Main canal				
(a) Earth works	265.2	142.5	407.7	Excavation and embankment
(b) Related structures	29.8	16.0	45.8	Turnouts, check gates, inverted siphons and so on
(F) Lateral				
(a) Earth works	46.0	50.0	96.0	----
(b) Related structures	12.0	30.0	42.0	----
(G) Reclamation of lands	122.5	332.5	455.0	Not including the construction of small distribution ditches
(H) General expenses and engineering service	233.5	272.0	505.5	About 15% of total cost
(I) Contingency and reserves	145.0	161.0	306.0	About 10% of total from (A) to (F)
Total	1,790.0	2,085	3,875	

Table 5.3

Estimate of Construction Cost for Upper Krong Buk Irrigation Scheme (9,000 ha.)

Item	Cost in 1,000 U.S. Dollars	Remarks
(A) Preparatory works	40	Including about 1,000 m^2 of office, Engineers' camp, etc.
(B) Reservoir	2,050	Including spillway
(C) Intake	520	Including intake gate and Howell-Bunger Valve at the end of waterway
(D) Construction machineries	320	――
(E) Main canal		
(a) Earth works	840	Excavation and embankment
(b) Related structures	640	Turnouts, check gates, inverted siphons and soon
(F) Lateral		
(a) Earth works	280	――
(b) Related structures	120	――
(G) Reclamation of lands	390	Not including the construction of small distribution ditches
(H) General expenses and engineering service	1,000	About 15% of total cost
(I) Contingency and reserves	600	About 10% of total from (A) to (F)
Total	6,800	

5.6. Benefit

5.6.1. Direct benefit of irrigation

As stated in the foregoing paragraph, the paddy livestock farming in lowland and the upland livestock farming in upland are adequate irrigation farming in the Krong Buk area.

In the lower Krong Buk area, it is estimated that the average annual gross income will be about 361 US dollars per hectare in lowland area and about 240 US dollars per hectare in upland area respectively on the basis of the pattern of land use, crop yields, livestock production, type and sizes of farm as stated in Appendix V. By the irrigation farming practice, double cropping of paddy rice will made possible and more than 3,900 tons of rice may be expected annually. Besides, corn, maize, fruits, vegetables, etc. could be produced in this area. And the total increase in agricultural products will amount to 900,000 US dollars equivalent.

On the other hand, since there is no reliable data on the present agricultural products in the upper Krong Buk area the total increase in agricultural products is roughly estimated at 2,300,000 US dollars equivalent, applying the result of our study on the farmers' income under irrigation farming in the lower Krong Buk area to this area.

5.6.2. Benefit of flood control

During the high water season, the flow of the Krong Buk stagnates and spreads over the lowland area extending on both banks of the river, inundating a large tract of land.

By the creation of the upper and lower Krong Buk reservoirs, the flood of about 22 million cubic meters in volume could be regulated, and by such flood control more than 2,000 hectares of lowland will be protected from the flood damage and would become suitable for cultivation. But, some tracts of land within the lowland area will not be protected from the damage caused by the synchronization of floods of the Krong Buk and the Krong Pach. In order to insure the complate effect of flood control, the comprehensive development plan in the Upper Srepok Basin will be required. Under the circumstances in which no detailed data are available for assessing the flood losses, at the present stage, it is difficult to evaluate the flood control benefits on a firm basis. However, some extent of benefits to be derived from flood control, such as increasing use of land for extension in arable land, public services, etc. will be expected, but these benefits cannot be expressed in terms of monetary value.

5.7. Project feasibility

The upper Krong Buk and the lower Krong Buk projects are of irrigation and flood control. Therefore, the economic feasibility of the projects should be justified on the basis of the economic justification on two factors, i.e. irrigation and flood control. However, as aforementioned, the flood control benefits and indirect benefits of irrigation cannot be expressed in terms of monetary value at this time. Therefore, these benefits were left out of consideration in studying the benefit-cost ratio for evaluating the project feasibility from the viewpoint of national economy.

In this study, the economic analysis will be made for a period of forty years after the completion of the Project. Interest on capital cost was assumed as 3 per cent per annum.

The upper Krong Buk irrigation scheme is justified by a benefit-cost ratio of 2.35 to 1.00, while the lower Krong Buk irrigation scheme is 1.95 to 1.00, as shown on the following table. Moreover, as stated in Subsection 4.6, the construction costs of the upper Krong Buk and the lower Krong Buk irrigation schemes are about 755 and 1,100 US dollars per hectare, respectively. Therefore, the upper Krong Buk irrigation scheme may be evaluated to be more economical as compared with the lower Krong Buk irrigation scheme.

Table 5.4

Trial computation on evaluating benefit-cost ratio

Item	Upper Krong Buk area	Lower Krong Buk area
(1) Annual benefit :		
Increased annual farm income	US$ 2,300,000	US$ 900,000
(2) Annual cost :		
Capital cost	US$ 6,800,000	US$ 3,875,000
Annual equivalent capital cost	US$ 6,800 x 0.0433 = US$ 294,000	US$ 3,875,000 x 0.043 = US$ 168,000
Annual operation, maintenance and repair cost	US$ 20.8 1/ /ha x 9,000 ha = US$ 187,000	US$ 25 2/ /ha x 2,100 ha + US$ 20.8 1/ /ha x 1,400 ha = US$ 82,000
Annual increase in farming expenses (Refer to Table 5.10 and 5.11 in Appendix V)	US$ (281 - 32) 3/ /4.5/ha x 9,000 ha = US$ 499,000	US$ (153 - 25) 3/ /2/ha x 2,100 ha + US$ (281 - 32) 3/ /4.5/ha x 1,400 ha = US$ 212,000
Total annual costs	US$ 294,000 + 187,000 + 499,000 = US$ 980,000	US$ 168,000 + 82,000 + 212,000 = US$ 462,000
(3) Benefit-cost ratio	US$ 2,300,000 / US$ 980,000 ≑ 2.35	US$ 900,000 / US$ 462,000 ≑ 1.95

1/, 2/ : Figures show the water rate to be levied from the farmers, as shown in Tables 5.10 and 5.11 in Appendix V.

3/ : Figures are itemized in the following table.

	Before irrigation		After irrigation	
	Paddy livestock	Upland livestock	Paddy livestock	Upland livestock
i) Depreciation of buildings	5	5	8	9
ii) Depreciation of farm	5	5	6	7
iii) Redemption of initial farm investment	-	-	4	6
iv) Self-supplied feed	5	5	35	78
v) Supplementary feed	5	5	10	15
vi) Supplementary seed	-	-	5	10
vii) Self-supplied manure	-	-	15	20
viii) Commercial fertilizer	-	5	40	100
ix) Agricultural chemicals	-	2	10	15
x) Others	5	5	20	22
Total	US$ 25/unit	US$ 32/unit	US$ 135/unit	US$ 281/unit

Chapter VI

FUTURE DEVELOPMENT

6.1 Irrigation

The highland of about 100,000 hectares around Ban Me Thuot consists mainly of comparatively flat land having rather high natural fertility. There is a great possibility of agricultural development in this area because of profitable conditions of topography and soil natures suitable for irrigation farming.

However, most of the area is covered with forests and grassland and left undeveloped except an existing farmland of about 6,000 hectares and some regions now in use for the plantations of rubber plant and coffee tree. Then, the preliminary studies have been made on the possibility of developing this area by irrigation in the comprehensive development of the Upper Srepok Projekt which is described in Appendix V. Besides, the following irrigation schemes are now being considerd as the future development plan.

1) A reservoir will be constructed at a point about 715 meters in elevation on the upstream side of the Krong Hnang 1/ and thereby will be reserved about 100 million cubic meters of available water. By utilizing this reservoir, the highland of about 8,500 hectares extending on the left bank of the Krong Buk could be irrigated by gravity flow.

2) Reservoirs will be constructed on the Ea Knir, the Tray Ho and the Ea Nang which are the branches of the Srepok and then the highland of about 3,500 hectares to the south of Ban Me Thuot could be irrigated with an available water of about 60 million cubic meters fed by these reservoirs.

The runoff in excess of the capacities of the Ea Jung and the Upper Krong Buk reservoirs will be supplied to the reservoir to be constructed on the Ea Uy, a tributary of the Ea Krong Buk, and the highland of about 5,000 hectares extending on the right bank of the Ea Krong Ana could thereby be irrigated by gravity flow.

1/ The Krong Hnang dose not belong to the Mekong system.

With these irrigation schemes in future, the total irrigable area will amount to about 17,000 hectares. Then, together with the irrigated area of about 35,500 hectares commanded by the Upper Krong Buk, the Ea Jung, the Krong Boung, the Upper Krong Pach and Darlac projects, the anticipated irrigable area around Ban Me Thuot will amount to 52,500 hectares.

Besides, the area extending on both banks downstream of the Ban Dray Falls is comparatively plane. Taking into consideration the future electric power scheme to be developed in this area, the irrigation scheme of this area can be contemplated as follows:-

1) By utilizing the tail water of the Dak Sor Power Project, downstream of the Ban Dray, the highland of about 35,000 hectares extending on both sides of the Drayling Power Station could be irrigated by gravity flow.

2) The irrigation of the alluvial lowland, about 5,000 hectares, extending on the left side of the Srepok to the west of Ban Don could be executed by gravity flow from the irrigation reservoir to be constructed on the Dak Ken, a tributary of the Srepok.

By these two irrigation schemes mentioned above, the anticipated irrigable area in future extending on both sides of the Srepok west of Ban Me Thuot will be about 40,000 hectares.

Therefore, when these future development plans are completed, the irrigable area within the Upper Srepok Basin will ultimately cover about 96,000 hectares in total.

6.2 Power generation

While the further detailed field investigations should be carried out, several hydroelectric power projects could be expected in the Krong Kno and in the downstream reaches of the Ban Dray Falls from the results of our rough studies on the topography and hydrology of the Srepok. These plans are outlined hereunder:

(1) Krong Kno project

The Krong Kno is one of the largest tributaries of the Srepok, and its drainage basin with an area of about 3,800 square kilometers is mostly covered with dense forest.

According to our investigation, there exists a suitable dam site at a point some 2 kilometers upstream of Ban Ton Srah.

Based on the discharge records at Ban Bur and Kana stations and on rainfall records in the past years, the mean monthly discharge during the dry season and the mean annual discharge at the proposed dam site located in the upstream reaches of the Krong Kno are estimated at about 13 and 43 cubic meters per second, resprctively.

At this site, by constructing the rock-fill dam of about 71 meters in height, a reservoir with a gross storage capacity of about 1.2 billion cubic meters will be created. With this reservoir, it will be possible to generate an electric power of approximately 20,000 kilowatts in firm. Moreover, the downstream low-lying area of about 2,000 hectares submerged during the rainy season may become available throughout the year by flood control of this reservoir.

Besides, the tail race water from the power station will be drained through a tunnel of about 1 kilometer in length to be constructed into the Dak Sor reservoir in the Dak Sor development plan mentioned in the following paragraph.

(2) Dak Sor development plan

In the Dak Sor, it will be possible to create a reservoir with a total storage capacity of about 650 million cubic meters by constructing an earth dam of about 54 meters in height at a point approximately 1 kilometer upstream from the confluence with the Ea Krong Ana.

With this reservoir, the power generation of about 23,000 kilowatts and irrigation of about 35,000 hectares of land extending on the left bank of the Srepok will be expected by utilizing the river water to be supplied from the Krong Kno basin.

(3) Ea Krong development plan

In the reaches of about 40 kilometers from the Ban Dray Falls to Ban Don, six power projects including the extension project of the existing Drayling power station will be contemplated from the topographical features of the Ea Krong river as follows:

a) The power generation of about 14,000 kilowatts will be realized by constructing the concrete gravity dam with a height of about 23 meters at a point some 4 kilometers downstream from the confluence with the Dak Sor ("D" dam site).

b) At a point about 5 kilometers upstream from the Drayling Falls ("C" dam site), it will be possible to construct the concrete gravity dam of about 12.5 meters in height, and about 7,600 kilowatts of power will be generated by utilizing this dam.

c) With completion of the extension project of the Drayling power station, the ultimate output of this station will be 10,000 kilowatts in firm.

d) There exist many of rapids in the reaches from the Drayling Falls to Ban Don. In this reaches, the power generation of about 8,400 kilowatts will be expected by creating the concrete gravity dam of about 20 meters in height. ("B" dam site)

e) A suitable dam site is found in the reaches from the Drayling Falls to Ban Don. ("A" dam site) Here, about 42 meters high concrete gravity dam could be constructed, and a firm output of about 18,000 kilowatts will be anticipated.

f) By constructing an earth dam at a point some 10 kilometers downstream of the "A" dam site, the power generation of about 21,000 kilowatts will be realized.

After the completion of these future power projects, a total annual energy output of about 865 mega watt-hours could be expected.

The outline of these power development plans is summarized in Table-6.1.

Table - 6.1 SUMMARY OF HYDROELECTRIC DEVELOPMENT IN UPPER SREPOK BASIN

SITE		KRONG KNO	DAK SOR	DAM "D"	DAM "C"	DRAY LING	DAM "B"	DAM "A"	BAN DON	TOTAL
I. Catchment area	(km^2)	2,965	Krong Kno 897	8,437	8,786	8,808	9,089	9,317	10,708	
II. Reservoir										
High water level	(m)	480	400	350	315	301.5	284.5	264	200	
Low water level	(m)	460	388						195	
Surface area	(km^2)	43.5	36.0						92	
Gross storage capacity	(m^3)	$1,170 \times 10^6$	655×10^6						$1,120 \times 10^6$	
Net storage capacity	(m^3)	510×10^6	350×10^6						480×10^6	
III. Dam										
Type		Rock fill	Earth	Concrete	Concrete	Concrete	Concrete	Concrete	Earth	
Height	(m)	71	54	23	12.5	2.5	19.5	42	28	
Crest Length	(m)	770	1,100	500	200	725	500	600	6,500	
Volume	(m^3)	3,750,000	4,900,000	70,000	20,000	11,000	100,000	290,000	6,500,000	
IV. Head										
Max. effective	(m)	59.0	49.0						24.0	
Min. effective	(m)	39.0	37.0	22.4	11.9	15.4	18.9	40.4	19.0	
Average effective	(m)	49.0	43.0	23.0	12.5	16.0	19.5	41.0	21.5	
V. Discharge										
Firm	(m3/s)	43	51	51	52	52.0	53	54	95	
Maximum	(m3/s)	66	78	78	80	80.0	81	82	140	
VI. Power generation										
Firm at min head	(KW)	17,000	18,000	9,600	5,300	6,800	8,400	18,000	16,000	
Firm at average head	(KW)	20,000	20,000						18,000	
Installed capacity	(KW)	20,000	23,000	14,000	7,600	10,000	12,300	26,000	21,000	133,600 KW
Annual energy output	(kwh)	149×10^6	157×10^6	84×10^6	46×10^6	59×10^6	73×10^6	157×10^6	140×10^6	865×10^6 KWH
Construction cost Dam and power plant	(US$)	36,600,000	27,400,000	6,500,000	3,700,000	4,500,000	5,300,000	6,900,000	33,300,000	
Construction cost per kwh	(US.Cent)	24.6	17.5	7.7	8.0	7.6	6.9	4.4	23.8	

Chapter VII

CONCLUSIONS AND RECOMMENDATIONS

1. As the result of our investigations and studies, an irrigable area to be commanded by the lower Krong Buk reservoir is reasonably estimated at 3,500 hectares, taking into consideration the natural conditions and the economical investment for the successful development of this basin, as stated in the preceding paragraph. According to this plan, however, rather high initial investment of about 1,100 US dollars per hectare will be required for establishing the irrigation system for 3,500 hectares of farmland, though this plan may be improved to some extent in future in connection with the upper Krong Buk irrigation scheme for which the investigation will be carried out in 1964.

2. The Government of Viet-Nam is now making a determined effort to establish a development center in the upper Krong Buk in which about 6,000 hectares of farmland with some rubber, tea and coffee plantations is being opened for cultivation, so that the Government envisages enthusiastically a large agricultural development by an adequate irrigation farming practice in this area.

According to our provisional studies on the upper Krong Buk irrigation scheme, the gravity irrigation of about 9,000 hectares of land will be realized by creating the upper Krong Buk and the Ea Jung reservoirs in the upstream reaches of the Krong Buk, and the unit construction cost of irrigation system is estimated at about 755 US dollars per hectare.

3. Under such circumstances, it is desirable that the lower Krong Buk irrigation scheme, which is the main object of our investigations carried out in 1963, is left for future development.

The prompt development of the upper Krong Buk area is requires first.

4. The detailed investigations especially the agronomic researches in the upper Krong Buk project area and the geological investigation on the proposed dam sites should be carried out as early as possible for studying the feasibility of the project in detail.

5. For studying the reasonable flood control scheme, usually it is necessary to collect ample and accurate hydrological data, especially flood runoff records in the past.

Especially, for the economic and effective flood control the study of the basin having a complex runoff system like the Upper Srepok Basin, and an accurate hydrological analysis on the relation between the rainfall and runoff at the flood time should be made on the basis of abundant available records to be obtained by subsequent investigations.

6. Rubber plant which is one of the crops being promoted strongly by the Government at present has been usually grown without availing any irrigation water except during its seedling and replantation periods at the early stage of its growth, as it has strong drought resistance due to its remarkably deep root zone.

But it is presumable that the growth of this plant will be vigorous on land where by practice of irrigation in the dry season the soil moisture content is regulated at optimum level throughout the growing period of the plants.

However, the fact that no sufficient data is available for evaluating the effect of irrigation on the growth of rubber plant especially on its productivity of latex precludes the study of the feasibility of the project.

Therefore, it is necessary to perform the field experiment on the effect of irrigation on the growth of rubber plant within the Project area.

APPENDIXES

APPENDIXES

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APPENDIX I

INVESTIGATION

APPENDIX I

INVESTIGATION

Section 1 General

In accordance with the "Plan of Operation" for the investigation of the irrigation scheme of the Krong Buk area in the Upper Srepok Basin to be undertaken by the Government of Japan in cooperation with the Government of Viet-Nam and the Committee for Coordination of Investigations of the Lower Mekong Basin, the field works were carried out for a three-month period from mid-November 1963 to mid-February 1964 in the Upper Srepok Basin covering the Ea Krong Buk, the Ea Krong Pach, the Ea Krong Boung and other rivèrs. The survey team, which consists of two civil engineers, one geologist, one irrigation engineer and one pedologist, executed the topographic survey, soil and water studies, agricultural researches, hydrologic and geological investigations as described in the following:

Description	Works performed
(1) Topographic survey of the proposed dam site mainly for the Krong Buk and profile leveling along the rivers.	Topographic survey of the proposed dam sites were accomplished at the Krong Buk with an area of about 2.75 square kilometers and at other sites, such as Ea Krong Pach, Ea Krong Boung, Ea Hlang, Ea Jung, Upper Krong Buk, Ea Krong Ana, Lower Krong Pach and Ea Kmat with an area of about 4.96 square kilometers in all. Profile leveling were done for about 65 kilometers from Ngo Dien to Quang Cu along the Ea Krong Ana and for 64 kilometers along the Krong Buk.

(2)	Geological boring along the proposed dam axis mainly for the Krong Buk and investigations for the dam embankment	Test boring of 45 meters in total depth was performed at five spots, and test pitting of 32 meters in total depth for investigating the dam embankment materials was executed at eight holes where it was necessary.
(3)	Agricultural investigations	Detailed reconnaissance soil survey and agronomic investigations were done over the whole irrigable land within the Krong Buk Project area.
(4)	Hydrological investigations, collection of meteorological and hydrological data, observation of river stages and measurement of stream discharge during the survey period.	The water gauging stations were set up at the Krong Buk and the Krong Pach, respectively. Hydrological and meterological observations are still being continued by the local personnel.
(5)	Spot leveling for mapping from aerial photo.	Ground control survey, including spot leveling, was extended to about 500 square kilometers in total.

Section 2 Survey

2.1. Basic leveling

Basic leveling was done by two engineers for two months from November to December 1963.

The existing bench-marks along the National Highway No.21 were utilized as the datum points for basic leveling, which was extended over about 25 kilometers from the Krong Buk to the Krong Pach along the National Highway No.21, and another basic leveling was carried out for about 8 kilometers from the Thang Tien community to the B. Knir community.

The off-set levelings were extended over 55 kilometers along the Ea Krong Pach and the Ea Krong Ana through B. Hang Alâ, Phuoc Trach, Le Giao and Khue Dien.

All the bench-marks set on these lines were made of concrete so as to be durable. The details of the bench-marks are shown in the Attached Data Books.

In leveling, the precise Japanese tilting levels were used. The maximum length of sight was kept at 100 meters by stadia, and the difference in length between the foresight distance and the backsight distance was kept within twenty meters in the interval of temporary bench-marks.

On the main route, double-run leveling was undertaken on all temporary bench-marks in order to check the discrepancies. The allowable error was 10 millimeters times the square root of the lengths of the running distances in kilometers, and whenever these discrepancies were noted, third-run leveling was undertaken.

2.2. Ground control surveys

Ground control, including spot leveling for mapping from aerial photo, was done by four engineers for three months from mid-November 1963 to mid-February 1964.

By utilizing the aerial photographs of U.S. Army Map Service, aerial triangulation was carried out in the whole proposed project area of about 500 square kilometers by using Tellurometer and Wild surveying instruments. The results of the aerial triangulation are shown in the Attached Data Books.

By using the results of the basic and off-set levelings, spot leveling was executed, extending over 225 kilometers in total length for aerial mapping of the Project area.

2.3. Topographic surveys

The field works was started by four engineers at the beginning of mid-November 1963, and finished by the end of January 1964.

The detailed topographic survey was carried out on the proposed Krong Buk dam site, and other topographic surveys by stadia were executed at the following dam sites. These topographic surveys were extended over 7.7 square kilometers in area.

The topographic maps were drawn on a scale of 1 to 1,000 with contour intervals of 1 meter.

Dam sits			Survey area km^2
Krong Buk	dam site		2.75
Krong Boung	"		1.21
Krong Pach	"		0.58
Upper Krong Buk	"		0.28
			0.93
Ea Jung	"		0.65
Ea Hlang	"		0.36
Krong Ana	"		0.29
Lower Krong Pach	"		0.31
Ea Kmat	"		0.35
		Total	7.71 km^2

2.4. Profile leveling along the rivers

By utilizing the existing bench-marks and the temporary bench-marks which were set up by our survey team, two profile levelings along the rivers were done by two engineers. One was extended over 65 kilometers along the Ea Krong Ana and the Ea Krong Pach, and the other was about 64 kilometers from the confluence with the Ea Krong Ana to the proposed dam site along the Krong Buk.

Section 3 Aerial mapping

By the use of the ground control survey results and the aerial photograph on a scale of 1 to 40,000 of U.S. Army Map Service, the topographic maps of the Project area on a scale of 1 to 20,000 with contour intervals of 1 meter for plain area and of 5 to 10 meters for steep sloping area were prepared in Tokyo. The area and extent of the aerial mapping are as follows:

Area	Scale	Contour interval	Extent
			Km^2
Krong Kno reservoir area	1/50,000	5 meter intervals	150
Krong Boung reservoir area	1/50,000	5 meter interval	155.6
Irrigable land of the Krong Buk area	1/20,000	1 meter interval	707
		Total	1,012.6 Km^2

Section 4 Geological investigations

The test borings were carried out at the following dam sites by using the high-speed rotary boring machines.

(1) Krong Buk dam site: At the Krong Buk dam site located about 42 kilometers east of Ban Me Thuot, along the National Highway No.21, three core borings with a total depth of 16 meters were drilled, and the test pittings for investigating the dam embankment materials were conducted at four spots on the right bank of the dam site.

(2) Krong Pach dam site: The core borings with a total depth of 29 meters were carried out at the proposed dam site which was located near Quan Cu community, and four test pitting holes were excavated near the dam site.

In core borings, sampling of core was done by using the metal crown of 73 millimeters in diameter and the bit of 46 millimeters in diameter.

Section 5 Meteorological and hydrological investigations

In addition to two gauging stations already established in Kana and Ban Bur by the contribution of Japanese Government in 1961, two more gauging stations were established near the proposed dam sites of the Krong Buk and the Krong Pach. The observation of river water stage were conducted daily at these four stations, and the measurement of stream discharge by current-meter was carried out periodically at each station during the survey period. The observation of river water stage is being continued by the local personnel.

The meteorological data such as rainfall, temperature, relative humidity and evaporation were collected from the Service Meteorologique in Saigon.

Section 6 Agricultural investigations

The detailed reconnaissance soil survey was carried out over the whole irrigable land in the Project Area. In the course of field works, several principal soil characteristics such as specific gravity, moisture contents, field capacity, etc., were disclosed to determine the design criteria of irrigation system in the Project area.

The current states of crop production and farm management were also investigated during the soil survey period. Based upon these data, the detailed reconnaissance soil map and land capability map giving a broad outline of type and fertility of soils were prepared.

The most adapted farming unit was also illustrated for deciding the type and pattern of crops suitable to the natural and economical conditions of the Project Area. They are shown in Appendix of this report.

APPENDIX II

METEOROLOGY

APPENDIX II

METEOROLOGY

Section 1. General

The Annan Cordillera lying east of the Srepok basin runs approximately from north to south and forms a barrier against the north-eastern monsoon, which brings about a large quantity of rainfall in front of the Cordillera, and only a small quantity at the back of the Cordillera. In case of the southwestern monsoon, the reverse phenomenon takes place.

Section 2. Precipitation

The monthly rainfall record at Ban Me Thuot, situated about 30 kilometers from the Project site, is shown below:

Table-2.1. Mean monthly precipitation (unit:mm)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1.7	2.4	25.9	104.1	213.0	234.3	268.5	277.9	298.2	207.0	78.8	16.5	1,728.3

(Source: Engineers in charge of hydrologic investigation on the Upper Srepok, the Government of Japan.)

The highest record of monthly average precipitation is 450 millimeters in September 1960.

The mean precipitation in the four months of the dry season (December to March next year) is 42.8 millimeters in total, or 10.7 millimeters per month; consequently water is not sufficient for cropping, unless supplied from other sources.

Section 3. Evaporation

According to the observation records, evaporation in each month is as shown in the following table.

Table - 2.2. Mean monthly evaporation (Unit; mm/day)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
2.80	5.00	5.86	5.61	3.44	2.61	2.17	1.92	1.72	2.15	2.80	3.20	3.27

The annual mean evaporation is about 1,190 millimeters, which is equivalent to about 3.27 millimeters per day. The evaporation is considerable during the dry season from November to April and is 4.21 millimeters per day, and 2.34 millimeters per day in the rainy season from May to October.

Reservoir evaporation: In calculating the reservoir evaporation from the pan records, the appropriate conversion coefficient will be required. In general, about 65 to 85 percent of values observed in the pan would be the amount of the reservoir evaporation. Furthermore, the reservoir surface area by which is affected the reservoir evaporation varies with storage capacity, and about 30 to 50 percent of the full water surface area would be mean water surface area during storage. Therefore, the amount of the reservoir evaporation Q during storage can be expressed by the following equation.

$$Q = C_1 \cdot C_2 \cdot A \cdot E$$

where E : Annual evaporation in the pan at Ban Me Thuot 1,190 mm

C_1 : Conversion coefficient for E = 70%

A : Full water surface area of the reservoir in m^2

C_2: Conversion coefficient for A = 40%

By substituting these values into the above equation:

$$Q = 0.7 \times 0.4 \times 1.19 \times A = 0.333 \cdot A$$

Therefore, the total amount of the reservoir evaporation during storage can be calculated by using the above equation.

Section 4. Temperature

The annual mean temperature is 24.23°C and the highest mean monthly temperature is 26.5°C in April, while the lowest is 21.3°C in January.

The maximum daily temperature is 39.4°C (April, 1937)

The minimum daily temperature is 7.4°C (December 1955)

Table-2.3. Mean monthly temperature (Unit: degree in Centigrade)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
21.30	23.33	25.81	26.54	26.11	25.27	24.87	24.80	24.52	23.73	22.93	21.57	24.23

(Source: Meteorological Bureau's data 1937-'39, 1955-'63)

Section 5. Mean monthly relative humidity

The mean monthly relative humidity in Ban Me Thuot is as shown in the following table.

Table-2.4. Mean monthly relative humidity (Unit: %)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
79.4	74.7	73.2	74.4	82.2	85.7	87.0	87.6	88.7	86.9	85.9	82.5	82.4

(Source: Meteorological Bureau's data 1937-'44, 1954-'57)

Fig. 2.1 Monthly mean precipitation

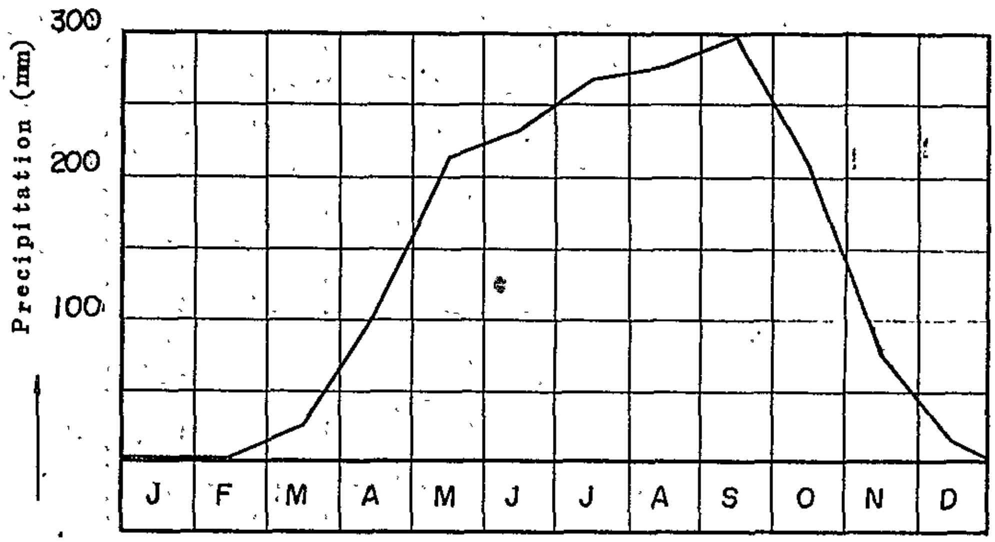


Fig. 2.2 Monthly mean evaporation

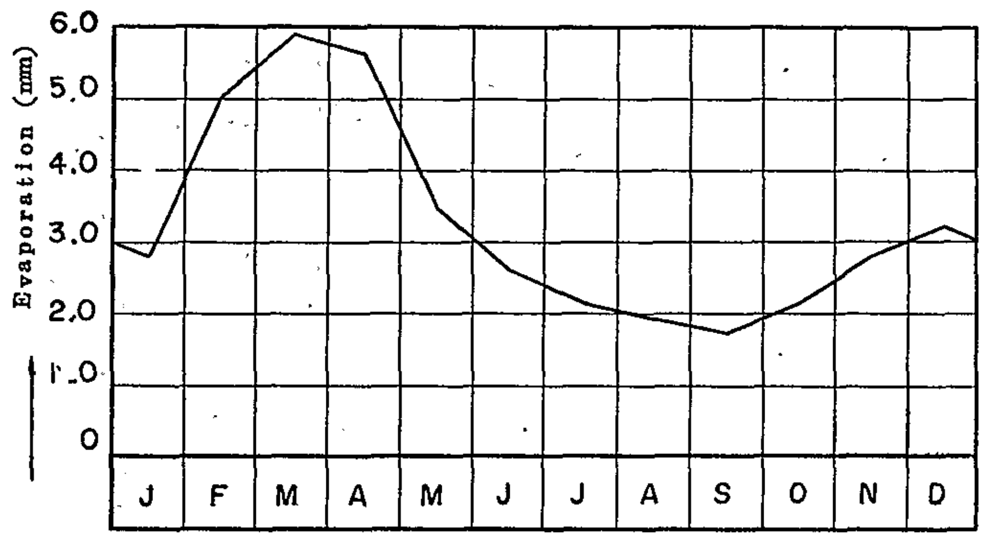


Fig. 2.3 Mean temperature by month

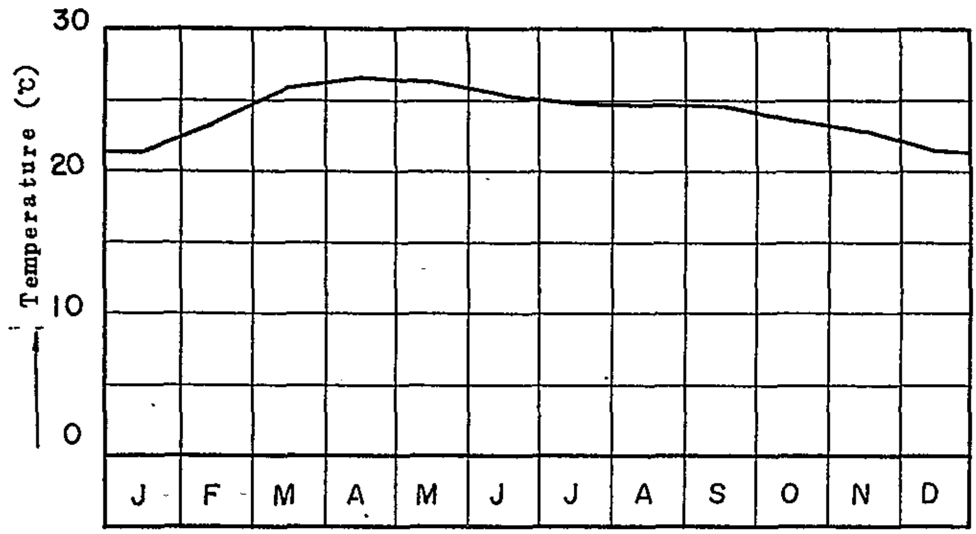
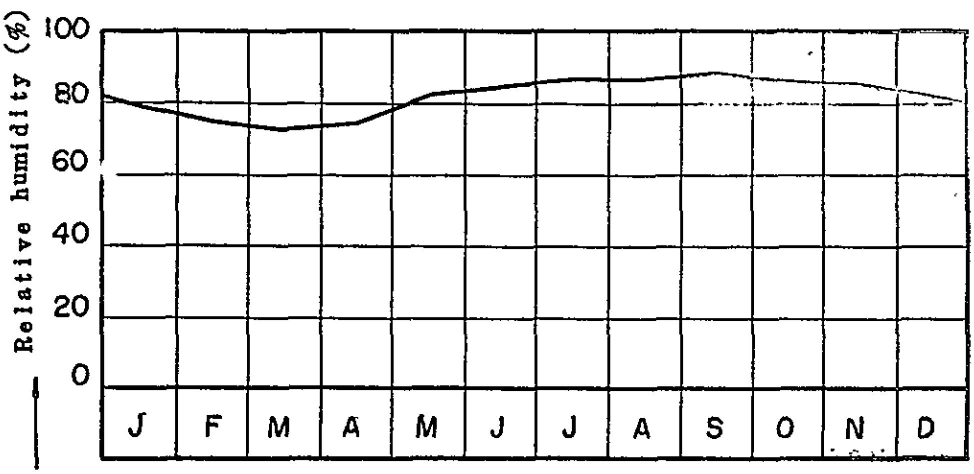


Fig. 2.4 Monthly mean relative humidity



APPENDIX III

H Y D R O L O G Y

APPENDIX III

HYDROLOGY

Section 1. Available data

1) Precipitation

Precipitation is the important factor for determining the river discharge. There is one meteorological station at Ban Me Thuot. Precipitation records at Ban Me Thuot covering 9 years from 1955 up to now are available for the project planning and listed below.

Table-3.1 Annual precipitation (m.m.)

Year	Annual precipitation	Year	Annual precipitation
1955	1,695	1960	1,960
1956	1,541	1961	1,960
1957	1,881	1962	1,807
1958	1,603	1963	2,016
1959	1,617		

2) Discharge record

The daily recording of water stage and periodical measurement of stream discharge have been carried out at the following four gauging stations established by the contribution of the Government of Japan.

Station	Discharge records available
Kana	Oct. 1961 - Feb. 1964
Ban Bur	Oct. 1961 - Feb. 1964
Krong Buk (Lower Krong Buk dam site)	Sept. 1963 - Feb. 1964
Krong Pach	Dec. 1963 - Feb. 1964

These discharge records are derived from the water stage data which were read daily during the observation period. The average monthly discharge and daily records at each station are given in Table-3.2 and in the Attached Date Books respectively.

Table - 3.2 Monthly discharge at each gauging station (measured)

(discharge in m3/sec)

Year		Kana gauging station			Ban Bur gauging station			Krong Pach gauging station			Krong Buk gauging station		
		Mean discharge	Maximum discharge	Minimum discharge	Mean discharge	Maximum discharge	Minimum discharge	Mean discharge	Maximum discharge	Minimum discharge	Mean discharge	Maximum discharge	Minimum discharge
1961	O	85.6	139.0	30.5	487.4	822.0	266.0						
	N	59.4	72.5	43.0	199.3	296.0	160.0						
	D	31.8	45.5	25.0	120.0	160.0	90.0						
1962	J	25.5	36.5	20.0	64.2	103.0	41.5						
	F	18.1	21.5	15.0	50.1	61.0	38.0						
	M	12.9	16.5	10.5	45.0	57.0	41.5						
	A	9.8	11.5	8.5	42.3	50.0	39.0						
	M	13.0	24.5	8.0	62.0	100.0	41.0						
	J	14.4	35.5	9.5	83.6	123.0	63.0						
	J	37.8	91.0	12.0	211.6	416.0	59.0						
	A	88.7	158.0	41.0	259.3	403.0	57.0						
	S	94.8	185.0	35.0	94.0	227.0	38.0						
	O				336.5	1,040.0	121.0						
	N	286.4	400.0	133.0	627.1	1,000.0	305.0						
	D	172.9	395.0	51.0	283.3	482.0	114.0						
1963	J	34.98	54.0	24.5	88.5	111.0	73.0						
	F	19.93	24.0	16.0	60.8	73.0	51.0						
	M	13.06	15.0	12.0	44.2	49.0	41.0						
	A	11.13	12.0	10.0	35.6	40.0	31.0						
	M	10.95	15.0	10.0	36.7	61.7	28.7						
	J	11.63	16.9	10.0	48.4	98.1	31.0						
	J	33.58	39.2	29.2	59.4	78.3	43.8						
	A	71.97	104.0	34.1	158.0	260.2	61.7				4.26	9.30	1.76
	S	120.23	240.0	34.1	334.8	555.1	176.6				13.34	62.04	5.47
	O	214.73	355.9	39.3	466.7	764.2	271.9				18.75	74.99	3.13
	N	57.02	116.4	32.3	161.5	260.2	96.0				7.33	11.74	5.19
	D				84.6	118.6	58.7	11.68	27.53	5.58	4.59	7.42	3.13
1964	J				46.4	60.2	38.0	4.99	5.58	4.46	2.78	3.51	2.07
	F	15.58	19.8	12.7	38.9	42.7	35.6	4.42	5.15	9.09	1.90	2.07	1.76

Section 2. Characteristics of the Krong Buk drainage area

The Ea Krong Buk with rather steep slope of 1:400 runs southward through the central part of the plain lying east of Ban Me Thuot.

The catchment area above the proposed lower Krong Buk dam site is about 460 square kilometers.

The characteristics of the area are determined under four categories:

1. The area has an undulating topography with rather steep slopes of 4 to 10 per cent.

2. Part of the area is grassland, but most of it is forest.

3. According to our soil survey, the soil of this area is the lateritic soil of basaltic origin which is of rather low infiltration capacity.

4. The conditions of surface storage, are suited for quick flow of water, because the surface depressions are few and shallow, drainage ways are steep and small, and there are no ponds, nor marshes.

Section 3. Hydrologic year

According to the hydrograph observed, the stream flow continues to increase during the rainy season, and the peak of stream flow occurs generally in September or October, and after that it decreases gradually till the end of the dry season. Such characteristics of hydrograph also appear at each gauging station. Therefore, we have determined that the hydrologic year should be from April to March next year.

Section 4. Available discharge

The discharge records at the Lower Krong Buk dam site are available for only six months. The Kana gauging station which is located in the middle of the course of the Ea Krong Ana has the runoff records covering a period of two years. Even at the Kana gauging station, as records are available only for two years, in order to estimate the discharge in the past years, we tried to find out the relation between the runoff and the precipitation.

1) Runoff

In order to find out the relation between the runoff and the precipitation, first, we tried to modify the actual discharge as follows: (The unit of runoff is millimeter)
According to the analysis of the above-mentioned discharge records, it is considered that the river discharges recorded in November and December 1962 increase to some extent under the influence of flood.

The extent of such increase may be about 70 per cent of the runoff at the flood time in November and 30 per cent in December.
On the other hand, by the Cook's method,/1 the runoff at the flood time is estimated at 70 per cent of the daily rainfall by storm which was observed at 170 millimeters. Therefore, the increases in runoff affected by storm are calculated as follows:

170 mm x 0.7 x 0.7 = 83.63 mm in November

170 mm x 0.7 x 0.3 = 35.56 mm in December

In Table-3.3, it may be said that the figures with the mark * show the normal river discharges in 1962 not affected by flood. These figures are obtained by deducting the above-mentioned increases of runoff from the actual river discharge recorded in November and December, respectively and are used for the calculation of the river discharge in the past years.

Table-3.3 Runoff at Kana station in m.m.

Year	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1962	7.90	10.84	11.62	31.52	74.84	77.84	110.00	*82.13 (165.76)	*78.09 (113.65)	29.17	15.01	10.90
1963	8.98	9.09	9.36	28.02	60.04	92.32	148.79	41.87	46.63			

/1 : This method is indicated in "Soil and Water Conservation Engineering" by Richard K. Frevert, Glenn O. Schwab, Talcott W. Edminster, Kenneth K. Barnes: (1955).

2) Relation between runoff and precipitation

Runoff is a portion of the precipitation, so the runoff may have any relation with the precipitation. Then we tried to find any relation between runoff and precipitation by the following procedures. First, a hydrologic year is divided into four periods, i.e. i) April to June, ii) July to September, iii) October to December and iv) January to March. Second, the discharge of each of the said four period at Kana gauging station is affected by the precipitation in each period shown below on assumption that the lag-time of runoff due to the high natural retention action of the Krong Ana basin is ten days.

i) Mar. 21 to June 20   ii) June 21 to Sept. 20
iii) Sep. 21 to Dec. 20   iv) Dec. 21 to Mar. 20

Then, by using the estimated discharge aforementioned, the ratios of the runoff in a trimester to a total precipitation for the period up to the trimester are calculated as shown in the following table on the basis of the above-mentioned assumption.

Table-3.4 Ratio of the runoff to the accumulated precipitation

Year	Item	(i) Apr. - June	(ii) July - Sept.	(iii) Oct. - Dec.	(iv) Jan. - Mar.
	Runoff in m.m.	30.36	184.20	270.22	55.08
1962	A.P. *	318.0	1,134.8	1,422.2	1,433.7
	Ratio	0.095	0.162	0.190	0.038
	Runoff in m.m.	27.43	180.38	245.64	
1963	A.P. *	251.3	1,201.3	1,621.5	
	Ratio	0.109	0.151	0.147	

* : Accumulated precipitation.

In this table, there are not so much differences among the ratios of the trimester in each year. Then, we used, though it is an arbitrary decision to do so, the following ratios of runoff to the accumulated precipitation in order to estimate a runoff in a trimester in the past years.

Trimester	(i)	(ii)	(iii)	(iv)
Ratio	0.102	0.156	0.168	0.030

3) Estimation of the mean monthly discharge in the past years

By using the ratios described in the preceding paragraph, the runoff at the Krong Buk gauging station in a trimester at a given year can be estimeted from the precipitation records. In order to calculate the mean monthly discharge from the estimated runoff in a trimester, an adequate distribution ratio of the mean monthly discharge to total runoff by trimester has been derived from the stream discharge records observed at Kana gauging station as shown in Table-3. 5.

Table-3.5 Distribution ratio for each month /1

Trimester	(i)			(ii)			(iii)			(iv)		
Month	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Ratio	0.30	0.33	0.37	0.16	0.37	0.47	0.59	0.29	0.12	0.47	0.32	0.21

Therefore, the monthly discharge at the Krong Buk gauging site can be estimated by using the above ratios of the runoff to the precipitation; from this data, the monthly discharge at the lower Krong Buk dam site is computed using the ratio of the catchment area of the gauging station and the lower Krong Buk dam site. Simiraly, the discharges of the upper Krong Buk and the Ea Jung dam sites are estimated as shown in Tables 3.7 and 3.8.

Table - 3.6 Estimated mean monthly discharge at the Lower Krong Buk dam site

(catchment area 118 km^2)

Year		Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1959	A.P. 1/m.m.	83.7	352.9	542.1	807.7	1,105.8	1,309.6	1,492.7	1,587.0	1,613.8	1,614.9	1,615.4	1,619.6
	R.F. 2/m3/sec	0.65	0.70	0.81	1.24	2.88	3.67	6.09	3.09	1.24	0.87	0.65	0.39
1960	ditto	5.91	370.5	605.2	910.1	1,089.4	1,539.3	1,627.7	1,748.5	1,752.8	1,754.4	1,754.4	1,823.5
		0.73	0.85	0.90	1.46	3.38	4.44	8.55	4.62	1.34	1.03	0.78	0.46
1961	ditto	156.3	422.7	743.7	1,109.7	1,406.8	1,656.3	1,899.8	1,938.3	1,944.1	1,944.4	1,947.0	1,950.0
		0.88	0.95	1.10	1.58	3.66	4.81	7.33	3.72	1.49	1.12	0.84	0.50
1962	ditto	44.8	203.7	322.6	742.5	1,006.3	1,241.5	1,325.7	1,444.5	1,445.5	1,444.5	1,449.0	1,449.0
		0.39	0.41	0.48	1.19	2.74	3.60	6.08	3.09 3/ (6.90)4/	1.24 3/ (3.24)4/	0.85	0.85	0.30
1963	ditto	17.4	134.1	280.4	512.6	896.7	1,352.8	1,527.4	1,549.1	1,549.1	-	-	-
		0.34	0.36	0.42	1.29	2.99	3.92	5.85	2.97	1.19	0.71	0.48	0.30
	Total	2.99	3.27	3.71	6.76	15.65	20.44	33.90	21.30	8.50	4.58	3.33	2.00
	Mean	0.60	0.65	0.74	1.35	3.13	4.09	6.78	4.26	1.70	0.92	0.67	0.40

1/ A.P.: Accumulated precipitation
2/ R.F.: Run-off
3/ The normal discharge not affected by flood
4/ The actual discharge recorded

Table - 3.7 Estimated mean monthly discharge at the Upper Krong Buk dam site

(Catchment area 149 km^2)

Year		Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1959	A.P. 1/ m.m.	83.7	352.9	542.1	807.7	1,105.8	1,309.6	1,492.7	1,587.0	1,613.8	1,614.9	1,615.4	1,619.6
	R.F. 2/ m^3/sec	0.82	0.88	1.02	1.57	3.63	4.64	7.69	3.91	1.56	1.09	0.83	0.49
1960	ditto	5.91	370.5	605.2	910.1	1,089.4	1,539.3	1,627.7	1,748.5	1,752.8	1,754.4	1,754.4	1,823.5
		0.92	0.98	1.13	1.85	4.27	5.61	10.80	5.83	1.70	1.31	0.98	0.58
1961	ditto	156.3	422.7	743.7	1,109.7	1,406.8	1,656.3	1,899.8	1,938.3	1,944.1	1,944.4	1,947.0	1,950.0
		1.20	1.21	1.39	2.00	4.62	6.07	9.26	4.70	1.88	1.41	1.06	0.63
1962	ditto	44.8	203.7	322.6	742.5	1,006.3	1,241.5	1,325.7	1,444.5	1,444.5	1,444.5	1,449.0	1,449.0
		0.49	0.52	0.61	1.50	3.47	4.55	7.74	3.90 3/ (8.71) 4/	1.56 3/ (4.09) 4/	0.98	0.74	0.44
1963	ditto	17.4	134.1	280.4	512.6	896.7	1,352.8	1,527.4	1,549.1	1,549.1	-	-	-
		0.42	0.53	0.52	1.66	3.78	4.96	7.39	3.75	1.50	0.90	0.62	0.38
	Total	3.85	4.12	4.67	8.58	19.77	25.83	42.88	26.90	10.73	5.69	4.23	2.52
	Mean	0.77	0.82	0.93	1.72	3.95	5.17	8.58	5.38	2.15	1.14	0.85	0.50

1/ A.P.: Accumulated precipitation
2/ R.F.: Run-off
3/ The normal discharge not affected by flood
4/ The actual discharge recorded

Table - 3.8 Estimated mean monthly discharge at the Ea Jung dam site

(Catchment area 44 km^2)

Year		Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1959	A.P. 1/ m.m.	83.7	352.9	542.1	807.7	1,105.8	1,309.6	1,492.7	1,587.0	1,613.8	1,614.9	1,615.4	1,619.6
	R.F. 2/ m3/sec	0.24	0.26	0.30	0.46	1.07	1.37	2.27	1.15	0.46	0.32	0.24	0.14
1960	ditto	5.91	370.5	605.2	910.1	1,089.4	1,539.3	1,627.7	1,748.5	1,752.8	1,754.4	1,754.4	1,823.5
		0.27	0.29	0.33	0.55	1.26	1.66	3.19	1.72	0.50	0.39	0.29	0.17
1961	ditto	156.3	422.7	743.7	1,109.7	1,406.8	1,656.3	1,899.8	1,938.3	1,944.1	1,944.4	1,947.0	1,950.0
		0.33	0.35	0.41	0.59	1.36	1.79	2.73	1.39	0.55	0.42	0.31	0.19
1962	ditto	44.8	203.7	322.6	742.5	1,006.3	1,241.5	1,325.7	1,444.5	1,444.5	1,444.5	1,449.0	1,449.0
		0.14	0.15	0.18	0.44	1.02	1.34	2.29	1.15 3/ (2.57)4/	0.37 3/ (1.21)4/	0.29	0.22	0.13
1963	ditto	17.4	134.1	280.4	512.6	896.7	1,352.8	1,527.4	1,549.1	1,549.1	-	-	-
		0.13	0.13	0.15	0.49	1.12	1.46	2.18	1.11	0.44	0.27	0.18	0.11
	Total	1.11	1.18	1.37	2.53	5.83	7.62	12.66	7.94	3.16	1.69	1.24	0.74
	Mean	0.22	0.24	0.27	0.51	1.17	1.52	2.53	1.59	0.63	0.34	0.25	0.14

1/ A.P. : Accumulated precipitation
2/ R.F. : Run-off
3/ The normal discharge not affected by flood
4/ The actual discharge recorded

APPENDIX IV

GEOLOGY

APPENDIX IV

GEOLOGY

Section 1. General

During November 15, 1963 to November 30, 1963 and also during February 1, 1964 to February 12, 1964, the geological reconnaissance was conducted by our consulting geologist in the basin of the Ea Krong Ana. And the test borings were carried out at the following dam sites for 3 months from mid-November 1963 to mid-February 1964.

i) Lower Krong Buk site, 3 holes, total depth: 16m
ii) Upper Krong Pach site, 2 holes, total depth: 29m

Section 2. Geology of the basin

The basin of the Ea Krong Ana located at an elevation of 750 to 430 meters from sea level occupies approximately a southern part of the Central Highland in Viet-Nam, and most part of the basin belongs to the highland area with a gentle slope on which there exist several hilly spots with a height of 50 to 100 meters.

Basal formations of the highland is of paleozoic. The paleozoic formation had been intruded by granitic rocks probably in the tertiary period; subsequently it was extruded by volcanic rocks in the late tertiary or early quaternary period. The hilly spots dotted within the highland consist of the paleozoic rocks.

The volcanic rocks are mainly composed of basalt. In many of the rivers within the basin, there exist numerous small falls and rapids caused by the basaltic lava interrupting the flow of the river. These volcanic activities developed the typical topography of rolling plain. The basaltic lava erupted over the area by volcanic activities is decomposed under the tropical monsoon climate; in consequence, it forms the thick residuals of brick red and clayey soils which are called "terre rouge". It is generally told that the terre rouge is a good soil for plantation farming especially for rubber plantation. But, analysis of its chemical compositions does not always show special fertility.

The mountain ranges with an elevation of 1,000 to 2,000 meters from sea level mainly consist of granitic rocks in the tertiary period, and they have a steep slope topography. The rivers with their origins in the mountain ranges have a steep slope, and the river water is relatively clear and not so muddy even in the flood season.

Section 3. Geology in the dam sites

(1) Lower Krong Buk dam site: The Krong Buk is one of the main tributaries of the Ea Krong Ana. The Krong Buk joins the Ea Drang about 750 meters upstream from the point where the Krong Buk crosses the National Highway No.21. From the topographic viewpoint, two dam sites are found in upstream and downstream reaches from the confluence.

Then, the investigation on these two sites were made in order to select the suitable site from the topographical, geological and economical viewpoints.

Basal foundations of both sites are composed of basalt. According to our boring test, the sound bed-rock of basalt lies beneath alluvial deposits of about 3 meters in thickness at the upper site (about 250 meters upstream from the confluence), while the fresh basalt crops out at a part of the river bed of the lower site (about 500 meters downstream from the confluence).

In view of the topographical features of the upper site, it is possible to construct a dam of more than 20 meters in height and with a crest length of about 1,400 meters, crossing two rivers of the Krong Buk and Ea Drang. Such being the case, if the concrete gravity type is undertaken, considerable excavation will be required for constructing a dam foundation on the fresh bed-rock after removing alluvial deposits completely. This requires large investment for treatment of the dam foundation.

On the other hand, the proposed lower site has the favorable topography for creating the dam with a crest length of about 600 meters, but it is impossible to bank the dam up to more than 15 meters in height above the river bed because of a low elevation of both abutments.

In the proposed development plan for the Krong Buk area, the reservoir with a usable storage capacity of about 50 million cubic meters will be required for irrigation and flood control purposes. For these purposes, it is necessary to construct a dam of about 21 meters in height. From the topographic features of the dam sites, therefore, the upper site was selected as suitable site, and a fill type will be selected as a type of dam, taking into consideration such factors as construction cost, foundation treatment and embankment materials.

(2) Upper Krong Buk dam site: According to our investigations, there is a suitable dam site (catchment area; about 149 Km^2) located about 7 kilometers northeast of B.Anur village.

From the result of our geological reconnaissance, it may be considered that residual soils of about 2 meters in thickness lie on the basal foundation of basalt.

At this site, it is possible from the geological and topographical viewpoints, to construct a fill type dam with a height of 29 meters and a crest length of about 665 meters.

As for the embankment materials, the residual soils and basalt to be obtained near the dam site may be available.

(3) Ea Jung dam site: Ea Jung dam site is located immediately above the point where the Ea Jung crosses the National Highway No.14 running from Saigon to Kontum which is an important communication route in the central highland area. According to our geological reconnissance, this site is composed of basalt with covering of alluvial deposits of 2 to 3 meters in thickness. Mainly from the viewpoint of its situation it will be possible

to construct a concrete gravity type dam, though the further detailed geological investigations should be carried out. Therefore, the combined type of dam will be adopted to make the best use of embankment materials to be economically obtained near the dam site.

(4) Krong Boung dam site: The Krong Boung which commands a basin area of about 790 square kilometers is one of the tributaries of the Ea Krong Ana. On the Krong Boung, there is a suitable dam site for dam construction at a point some 4 kilometers upstream from its confluence with the Ea Krong Ana.

Since the cropouts of argillite are found on the existing road situated on both abutments of the river, it may be considered that a sound bed-rock lies at a depth of several meters under the river bed. Therefore, the dam site may be suitable for any type of dam from the geological and topographical points of view.

(5) Lower Krong Pach dam site: On the Ea Krong Pach which is situated upstream of the Ea Krong Ana, there is a suitable dam site at point about 2 kilometers upstream from the confluence with the Krong Boung.

In the upstream reaches from the site, the low-lying marshy land extending over about 15 kilometers in length and about 2 kilometers in width exists on both banks of the river.

Both abutments of the site with an elevation of 600 to 640 meters consist of the Tertiary composed mainly of quartzite, and basal foundation of basalt covered with alluvial deposits of silt or clay is found in the lowland area. Around the site, there exists the cropouts of basalt along the shore line at the low water level in the dry season.

As this dam site may be suitable for any type of dam from the geological point of view, the dam with a considerable length of crest and with an adequate storage capacity for flood control use may be constructed in view of the topographic features. From the viewpoint of such topography of the site and economical use of local materials for embankment, a fill type dam is recommendable.

(6) Upper Krong Pach dam site: According to our investigations, there exists a suitable dam site at a point about 20 kilometers upstream from the lower Krong Pach dam site. From the results of test boring on the proposed dam site, it became clear that the bed-rock of sandstone lies beneath the silt deposits of about 11 to 13 meters in thickness. Under such circumstances it is desirable to construct a fill type dam at this site mainly from the economical viewpoint.

APPENDIX V

AGRICULTURAL STUDIES

Section 1. Farming method

For the successful development of agriculture in the Upper Srepok Basin, the combined management of paddy or upland culture and dairy farming is recommended by introducing stock-raising into the farm unit in view of the natural and economical conditions in this basin, and the farming units of sustainable management are framed on the basis of the soil survey and agricultural researches.

The standard acreage of farming units are determined at 2 hectares for paddy livestock farming in lowland area and at 4.5 hectares for upland livestock farming in upland area.

Such small scale farm units will be most adaptable for Asian farmers who have long experience in a small scale farming on narrow land.

The essentials of the proposed farming units are outlined hereunder:

(1) Paddy livestock farming unit.

Land use: Out of 2 hectares in total, 1.8 hectares are used for cropping and 0.1 hectare for homestead, and remaining 0.1 hectare for grassland with forest.

Adapted crops and cropping pattern: As for the adapted crops in the Project area, most of plants usually cultivated in other tropical monsoon climatic region can be generally grown up and the adapted rotative cropping pattern should be framed up in consideration of efficient utilization of farmland, growing period, protection against harm insects and diseases as well as effective use of family labours for profitable farming.

Paddy rice is grown up as the most principal crop, and vegetables such as chinese cabbage, onion, red pepper, and tomato are also cultivated for domestic demand and for sale. Pasture grasses are planted for domestic animals, and kenaf,tobacco, ramie, peanut, green bean are cultured mainly for sale.

The cropping pattern for a farming unit is graphically shown in Fig.-5.1.

Livestock: The most fundamental object of livestock raising in this farming unit is the production of stable manure necessary for the maintenance and increase of the productivity of farmland as well as the production of animal products for the increase of farming profit. For this purpose, 2 milk cows, 2 swine and 11 poultry are raised.

Fertilization: According to the results of our soil survey, the low land soils have rather high natural fertility in comparision with the soils in the basin. Even so, the application of proper quantity of chemical fertilizer is necessary in order to have the satisfactory returns by irrigation farming.

In this case, proper amount of nitrogenous fertilizer with 0.03 ton of element, phosphatic fertilizer with 0.02 ton of element, and potassic fertilizer with 0.01 ton of element are to be applied per hectare of farm land. Furthermore, it is desirable to apply 0.1 ton of calcium carbonate or calcium silicate into soils so as to neutralize the soil acidity and to increase the resistance of crops to disease damages every 10 years.

(2) Upland livestock farming unit.

Land use: The acreage is 4.50 hectares including of 4.20 hectares for cropping, 0.15 hectares for homestead, and 0.15 hectare for grassland with forest around the premises. The standard acreage of this unit should be wider than that of the paddy livestock farm unit, because the low productivity of this farm unit due to the relatively low natural fertility of upland soil has to be counterbalanced by the wider acreage.

Adapted crop and cropping pattern: Adapted crops are mostly similar to those adapted to lowland farm unit except sugar cane. Some sugar canes are planted mainly to meet the local demand for chewing. The cropping pattern for a farming unit is graphically shown in Fig.-5.2.

Rubber plant which is one of the crops much promoted by the Government at present has been usually grown without availing any irrigation water except during its seedling and replantation period at the early stage of its growth, as it has strong drought resistance due to its remarkably deep root zone depth.

Such being the case, there is no sufficient data available for evaluating the effect of irrigation on the growth of rubber plant especially on its productivity of latex.

But it is presumable that the growth of this plant will be vigorous on land where by the practice of irrigation in the dry season the soil moisture content is regulated at optimum level throughout the growing period of the plants.

Thereupon, this plant was particularly considered according to our view agreed with the opinion of the Government authorities of Viet-Nam on the promising international rubber market despite the inroads of synthetic compounds.

Livestock: 3 cows, 3 swine, and 11 fowls are raised for the productions stable manure and animal foods necessary for the improvement of farmland management.

Fertilization: According to our soil test, 80 kilograms of nitrogen, 80 kilograms of phosphoric acid, and 10 kilograms of potash are annually needed per hectare for the cropping on an irrigated farm.

According to the above proposed irrigation farming units, in lowland area, out of 2 hectares of land to be alloted to farmers, 1.8 hectares of the cultivated area will be planted with paddy rice, 0.3 hectare with maize, 0.2 hectare with kenaf, 0.2 hectare with tobacco, 0.3 hectare with peanut, 0.2 hectare with sweet poteto, 0.3 hectare with soybean, 0.2 hectare with vegetables, 0.2 hectare with green manures, 0.2 hectare with paspalum, and 0.1 hectare with orchards. In upland area, the farmers will cultivate paddy rice, maize of 0.4

hectare, kenaf of 0.5 hectare, green manure of 0.2 hectare, pasture grass of 0.75 hectare, tobacco of 0.3 hectare, vegetables of 0.2 hectare, sugar can of 0.1 hectare, orchards of 0.1 hectare, and rubber plant of 1.5 hectares in their land of 4.2 hectares for cropping

Section 2. Adapted irrigation method

(1) Lowland area.

According to the results of our investigations and soil survey, the lowland is mostly distributed on comparatively flat area, and composed soils with relatively high water holding capacity and rather low intake rate. At the practice of irrigation farming, therefore, the adapted irrigation method should be applied in conformity with the specific condition of the irrigated field, and it is recommended to take up the following method; the strip border method for paddy, the down hill small furrow method or the contour small furrow method for green bean, soybean, vegetables, etc., the down hill large furrow method or the contour large furrow for maize, kenaf, sweet potato and other row crops and for tall vegetables.

(2) Upland area.

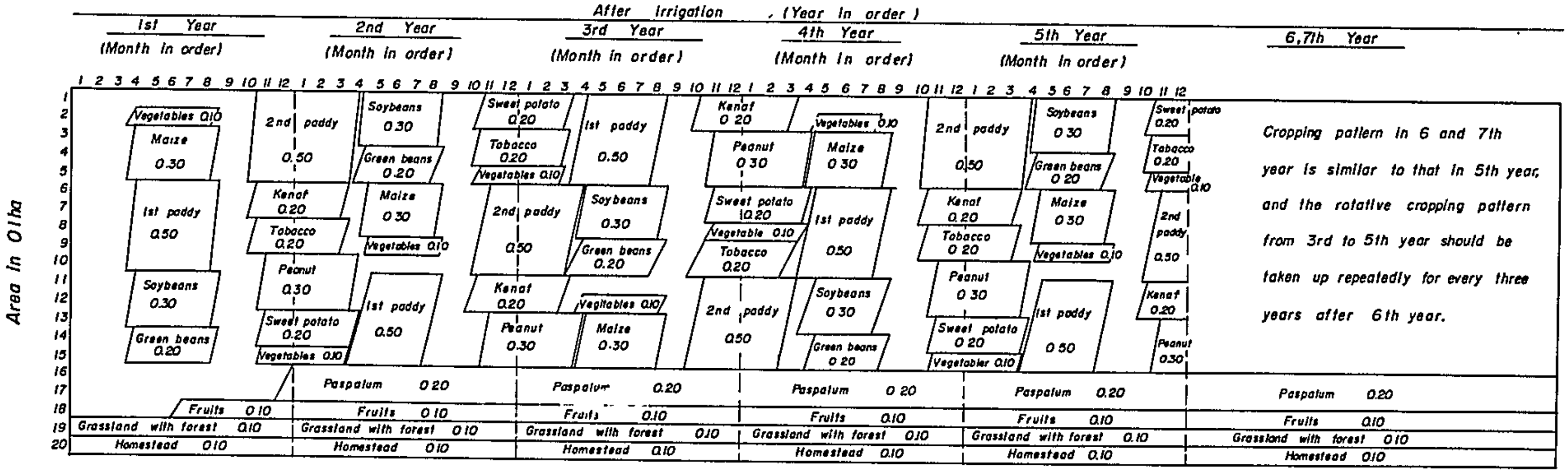
The irrigable land in the upland area has a gentle rolling topography, and composed mainly of the residual soils with basaltic origin, which have silty loam or loam texture, a slightly low water holding capacity and a rather high basic intake rate.

Therefore, such topographical and soil conditions of irrigable area should be taken into consideration in the practice of irrigation farming, and it is recommended to take up the following method; the down hill furrow or contour small furrow method for paddy, cabbage, rape, etc., the down hill large furrow method or contour large furrow method for maize, beans, fruits, etc.

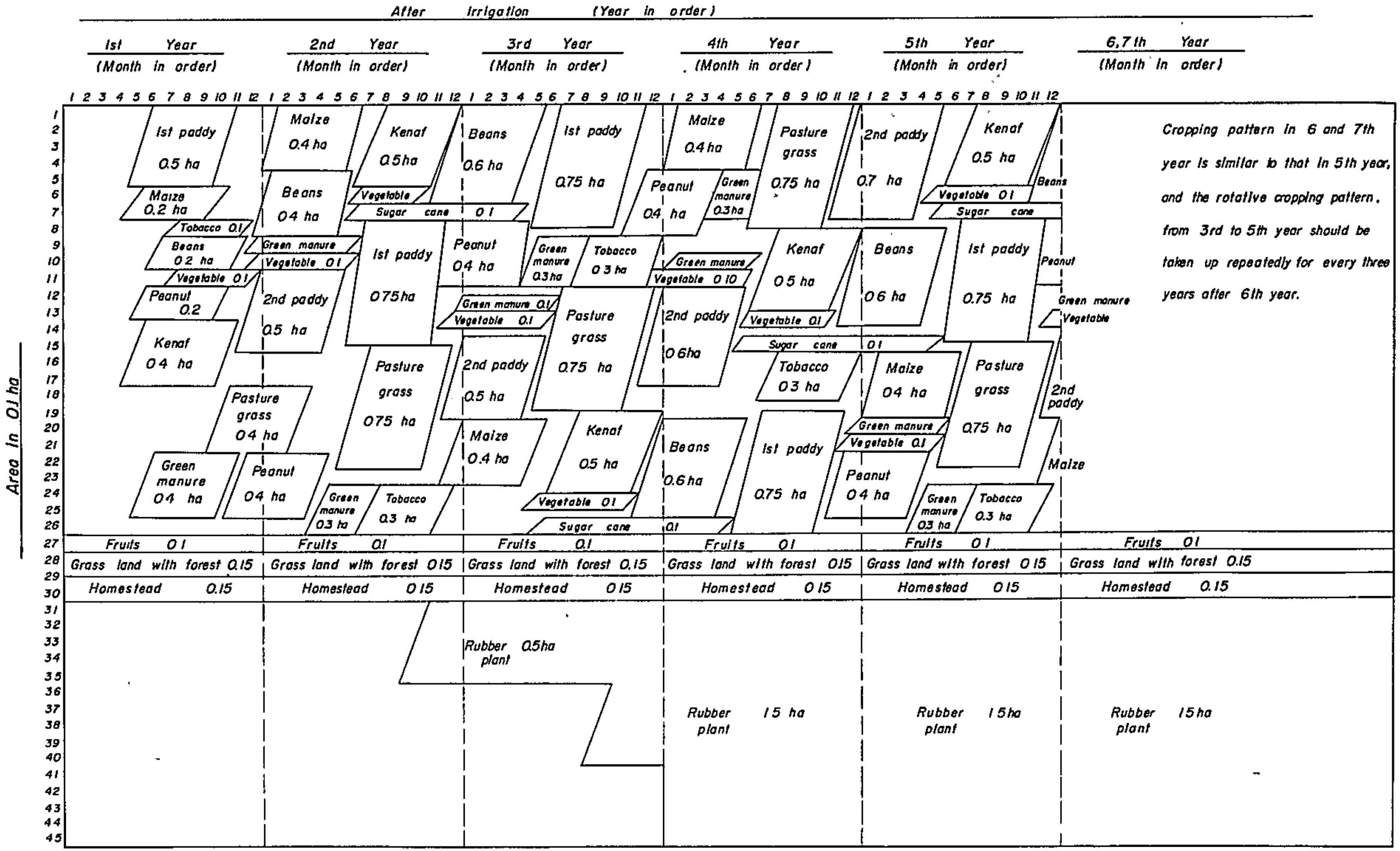
The sprinkler method can be used except the flowering and harvesting periods of paddy.

At the practical application of the above mentioned methods in both areas, lowland and upland, it is necessary to evaluate the basic factors for the methods such as the water requirements, the irrigation interval and the frequency of irrigation, etc., based on the irrigation engineering characteristics of soils and the consumptive use of water by crops in each growing periods for accomplishment of the most efficient and profitable water application.

Fig—5.1 *Cropping pattern on paddy livestock unit farm of 2 hectares during 7 years after the beginning of irrigation*



Fig—5.2 Cropping pattern on upland livestock unit farm of 4.5 hectares during 7 years after the beginning of irrigation



Section 3. Water Requirements

The water requirements are needed for determination of the adequate water supplies and for proper design of the canals and structures in planning the new irrigation projects.

Estimation of the water requirements can be made by the following procedures.

a) Computing the average consumptive use for each crop.

b) Adding the loss and waste of irrigation water during delivery and conveyance to the consumptive use of water.

Consumptive use of water for each crop: The consumptive use of each crop varies mainly with the influence of weather conditions. Based on the results of analyses of consumptive use and weather data for various kinds of crops grown in many countries of the world, the empirical curve is drawn as shown in Fig-5.3 1/. This figure shows the relation of the consumptive use-evaporation ratio to relative growth of crop and the stages of growth.

In general, the consumptive use of water is high as for rice-plant, so that we have determined the values of the normal consumptive use coefficients for several crops to rice plant as shown in the following Table-5.1.

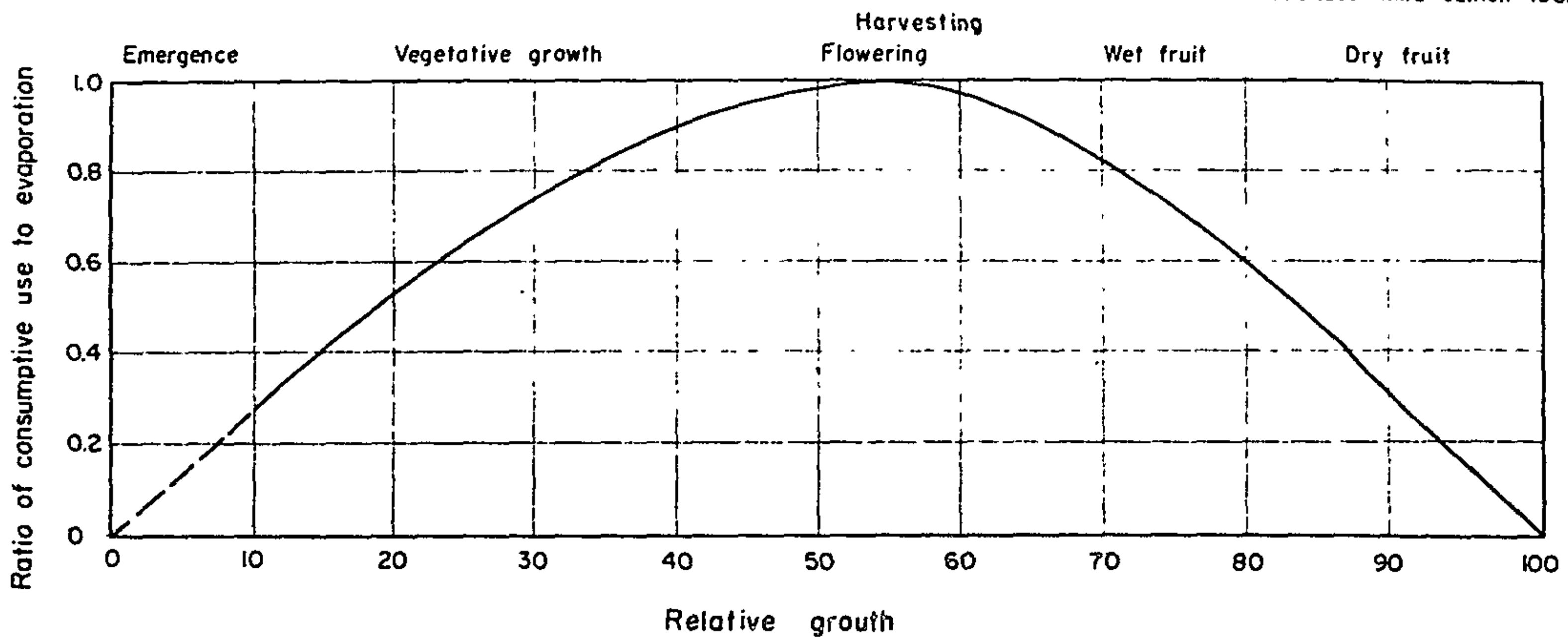
Table-5.1 Normal seasonal consumptive use coefficient for several irrigated crops in the Project area

Crops	Length of growing (average)	Consumptive use Coefficient K
Paddy rice	120 days	1.0
Sugar cane	360 days	1.0
Tobacco	150 days	0.7
Green manure	150 days	0.6
Kenaf	150 days	0.75
Maize	120 days	0.7
Beans	120 days	0.65

1/ This figure is given at P. 257 in "Irrigation Principles and Practices" by Orson W. Israelsen and Vaughn E. Hansen.

Fig.-5.3 Generalized curve consumptive use-evaporation ratio to relative growth of crop.

Source Orson W Israelsen and Vaughn E Hansen "Irrigation Principles and Practices" third edition 1962



Crops	Length of growing (average)	Consumptive use Coefficient K
Pasture grass	Frost free	0.55
Peanut	120 days	0.7
Fruit	Perennial	0.55
Vegetable	Variable	0.55
Sweet potato	120 days	0.65
Rubber	Perennial	0.5

An adequate irrigation period for a given crop should be determined in consideration of the stages of crop growth, especially the harvest stage.

The growth of all plants can be divided into three stages, vegetative, flowering and fruiting. The relation of these stages of growth of the consumptive use of water is shown in Fig-5.3, From this figure, it is easy to understand that the consumptive use during the vegetative stage continues to increase and the flowering occurs around the peak of the consumptive use. The fruiting stage is accompanied by a decrease in the consumptive use, until the transpiration ceases during the latter part of the formation of fruit.

Making reference to such relations of each stage of growth to the consumptive use and the concept embodied in Fig-5.3, we have determined the adequate of water irrigation period and the ratio of the seasonal consumptive use for several crops to evaporation as shown in Fig-5.4.

Thus, the calculation process of the consumptive use of water in the proposed farm units of both lowland and upland is shown in Table-5.3.

Over-all efficiency in irrigation: The over-all efficiency in irrigation combining the conveyance and irrigation efficiencies has been determined as follows after careful consideration of soil, climatic, hydrological and agricultural conditions.

	Lowland	Upland
Conveyance efficiency	70%	70%
Irrigation efficiency	70%	60%
Over-all efficiency	49%	42%

Fig.-5.4.Seasonal variation of the ratio of consumptive use to evaporation

stage	Growing period						
	180	165	150	135	120	105	90
1	0.24	0.25	0.25	0.27	0.26	0.28	0.29
2	0.41	0.45	0.47	0.54	0.56	0.65	0.69
3	0.61	0.67	0.73	0.82	0.88	1.01	1.09
4	0.77	0.90	0.97	1.11	1.20	1.31	1.39
5	1.05	1.16	1.21	1.35	1.45	1.54	1.59
6	1.21	1.33	1.40	1.53	1.59	1.67	1.68 (1)
7	1.40	1.50	1.55	1.63	1.68	1.69	1.60 (2)
8	1.52	1.59	1.64	1.68	1.68	1.60	1.33 (3)
9	1.62	1.66	1.69	1.69	1.59	1.30	0.96 (4)
10	1.68	1.68	1.68	1.55	1.40	1.00	0.51
11	1.69	1.68	1.63	1.39	1.15	0.72	0.14
12	1.68	1.64	1.48	1.19	0.85	0.35	
13	1.62	1.47	1.30	1.03	0.48		
14	1.52	1.30	1.06	0.65	0.21		
15	1.38	1.21	0.79	0.39	0.02		
16	1.21	0.90	0.53	0.16			
17	0.99	0.67	0.27				
18	0.77	0.45	0.10				
19	0.53	0.20					
20	0.34	0.03					
21	0.16						
22	0.02						

(1)–(4) Last season of irrigation

Crops havested during the different stage of growth

Vegetables

1 Vegetative: Pasture grass, Green manure → stage 11

2 Flowering: Kenaf, Tobacco → stage 13

3 Fruiting (Wet): Beans, Fruits, → stage 16

4 Fruiting (Dry): Rice, Peanut, Maize → stage 18

Maximum monthly water requirement: From Table-5.3, the maximum monthly water requirement will occur in January in lowland and also in upland. The details are as follows:

	Lowland	Upland
Net water requirements	148 m.m.	111 m.m.
Effective rainfall	0 m.m.	0 m.m.
Over-all efficiency in irrigation	49 %	42 %
Maximum monthly	302 m.m.	264 m.m.
Water requirement	$1.05 m^3$/sec/1,000 ha	$0.93 m^3$/sec/1,000 ha

Diversion requirement: The maximum diversion requirement is calculated on the basis of the maximum monthly water requirement.

1/ The maximum monthly water requirement in m^3/sec/1,000 ha.

2/ Area to be irrigated in 1,000 ha.

3/ Diversion water requirement in m^3/sec.

Table - 5.3 Calculation sheet of consumptive use of water

Farm unit : Lowland live stock farming unit

Crop	Length of Growing	K	Irrigation area	Jan.			Feb.			Mar.			Apr.			May			Jun.		
Rice	120	1.00	0.5	0.725	0.795	0.840	0.840	0.795	0.700	0.575	0.425		0.130	0.280	0.440	0.600	0.725	0.795	0.840	0.840	0.795
Kenaf	150	0.75	0.2	0.254	0.252	0.245															
Tabacco	150	0.70	0.2	0.237	0.235	0.228															
Peanut	120	0.70	0.3	0.353	0.353	0.334	0.294	0.242	0.179												
Sweet potato	120	0.65	0.2	0.218	0.207	0.182	0.150	0.111													
Vegetables	90	0.55	0.1								0.016	0.038	0.060	0.076	0.087	0.092					
Soybeans	120	0.60	0.3									0.047	0.101	0.158	0.216	0.261	0.286	0.302	0.302	0.286	0.252
Green beans	120	0.60	0.2									0.031	0.067	0.106	0.144	0.174	0.191	0.202	0.202	0.191	0.168
Maize	120	0.70	0.3										0.055	0.118	0.185	0.252	0.305	0.334	0.353	0.353	0.334
Paspalm	360	0.75	0.2	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
Fruits	360	0.55	0.1	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
Grassland with forest	360	0.55	0.1																		
Home stead	360	0.60	0.1																		
Total				1.992	2.047	2.034	1.489	1.353	1.084	0.780	0.646	0.321	0.618	0.943	1.277	1.584	1.712	1.838	1.902	1.875	1.754
f					1.125			0.727			0.324			0.527			0.951			1.024	
E					131.6			139.9			181.5			168.3			106.8			77.0	
U = E x f					148			102			59			89			102			79	

Crop	Jul.			Aug.			Sep.			Oct.			Nov.			Dec.		
Rice	0.700	0.575	0.425												0.130	0.280	0.440	0.600
Kenaf											0.038	0.071	0.110	0.146	0.182	0.210	0.233	0.246
Tabacco											0.035	0.066	0.102	0.136	0.169	0.196	0.217	0.230
Peanut													0.055	0.118	0.185	0.252	0.305	0.334
Sweet potato												0.034	0.073	0.114	0.156	0.189	0.207	0.218
Vegetables										0.016	0.038	0.060	0.076	0.087	0.092			
Soybeans	0.207	0.153																
Green beans	0.138	0.102																
Maize	0.294	0.242	0.179															
Paspalm	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
Fruits	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
Grassland with forest																		
Home stead																		
Total	1.544	1.277	0.809	0.205	0.205	0.205	0.205	0.205	0.205	0.221	0.316	0.436	0.621	0.806	1.119	1.332	1.607	1.833
f		0.672			0.114			0.114			0.180			0.471			0.882	
E		57.2			59.5			51.6			66.6			84.1			102.0	
U = E x f		38			7			6			12			40			90	

where K: Normal seasonal consumptive use coefficient.
E: Average monthly evaporation (mm)
f: Ratio of consumptive use to evaporation
U: Average monthly consumptive use of water per hectare

Farm unit: Upland livestock farming unit

Crop	Length of Growing	K	Irrigation area	Jan.			Feb.			Mar.			Apr.			May			Jun.		
Rice	120	1.00	0.75	1.260	1.260	1.193	1.050	0.863	0.638							0.195	0.420	0.660	0.900	1.088	1.193
Kenaf	150	0.75	0.50																0.094	0.176	0.274
Vegetable	90	0.55	0.10													0.016	0.038	0.060	0.076	0.087	0.092
Beans	120	0.65	0.65	0.710	0.710	0.672	0.592														
Peanut	120	0.70	0.40	0.445	0.392	0.322	0.238														
Maize	120	0.70	0.40	0.073	0.157	0.246	0.336	0.406	0.445	0.470	0.470	0.445	0.392	0.322	0.238						
Tobacco	150	0.70	0.30																		
Green manure	150	0.60	0.10 0.30	0.073	0.684	0.093	0.098	0.101					0.045	0.085	0.131	0.175	0.218	0.252	0.279	0.295	0.304
Pasture	120	0.55	0.75																0.107	0.231	0.363
Fruit	360	0.55	0.10	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
Sugar cone	360	1.00	0.10	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Rubber	360	0.50	1.50	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750
Total				3.466	4.108	3.431	3.219	2.275	1.988	1.375	1.375	1.350	1.342	1.312	1.274	1.291	1.581	1.877	2.361	2.782	3.131
f					0.846			0.608			0.333			0.321			0.386			0.673	
E					131.6			139.9			181.5			168.3			106.8			77.0	
U = E x f					111			85			60			54			41			52	

Crop	Jul.			Aug.			Sep.			Oct.			Nov.			Dec.		
Rice	1.260	1.260	1.193	1.050	0.863	0.638							0.195	0.420	0.660	0.900	1.088	1.193
Kenaf	0.364	0.454	0.525	0.581	0.615	0.634	0.630	0.611										
Vegetable													0.016	0.038	0.060	0.076	0.087	0.092
Beans													0.110	0.237	0.372	0.507	0.613	0.672
Peanut											0.073	0.157	0.246	0.336	0.406	0.445	0.470	0.470
Maize																		
Tobacco	0.053	0.099	0.153	0.204	0.254	0.294	0.326	0.344	0.355	0.353	0.342							
Green manure																		
Pasture	0.495	0.598	0.656	0.693	0.693	0.656	0.578	0.474	0.351									
Fruit	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055
Sugar cone	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Rubber	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750
Total	3.077	3.316	3.432	3.433	3.330	3.127	2.439	2.334	1.611	1.258	1.320	1.062	1.472	1.936	2.403	2.833	3.163	3.332
f		0.799			0.804			0.519			0.296			0.472			0.758	
E		57.2			59.5			51.6			66.6			84.1			102.0	
U = E x f		46			48			27			20			40			77	

Section 4. Anticipated yield

As stated in Section 1, adequate irrigation farmings in this area are the paddy livestock farming in lowland and the upland livestock farming in upland.

In lowland, by the irrigation farming practice, it is anticipated that the annual gross income of a unit farm will increase year by year and reach 721.5 US dollars (equal to 361 US dollars per hectare), which is the total sum of 554.5 US dollars of the crop yields (equal to 277 US dollars per hectare) and 167 US dollars of the products from stock-raising (equal to 84 US dollars per hectare) in the seventh year after the beginning of irrigation farming.

The farmers' annual net profit in the same year may be estimated at 188.5 US dollars (equal to 94 US dollars per hectare) by deducting the annual outgo of 533 US dollars (equal to 267 US dollars per hectare) from the above-mentioned annual gross income of 721.5 US dollars.

On the other hand, the annual net profit of 373.7 US dollars (equal to 83.5 US dollars per hectare) can be anticipated in the upland livestock farming unit after deducting the annual outgo of 704.8 US dollars (equal to 156.5 US dollars per hectare) from the annual gross income of 1,078.4 US dollars (equal to 240 US dollars per hectare), which is a total of 296.0 US dollars of livestock products (equal to 66 US dollars per hectare) and 782.4 US dollars of crop products (equal to 174 US dollars per hectare).

The details of the farmers' annual balance in the farm management of the above farming units are shown in Table-5.4 and 5.5.

In the seventh year after the beginning of the irrigation farming, an increase in agricultural products is estimated at 900,000 US dollars equivalent. The increase will be 3,980 tons of rice, 1,310 tons of beans, 360 tons of tabacco, 660 tons of corn, 660 tons of peanut, 4,100 tons of vegetables, 1,360 tons of fruits, 2,720 kilolitres of milk, 91 tons of egg (1,515,000 eggs).

With such increases of various products, the food situation of this area will be greatly improved.

Table-5.4. Annual balance sheet of a unit farm management of farmers at a paddy livestock farm unit of 2 hectares

	After irrigation (year in order)						
	1st year (US$)	2nd year (US$)	3rd year (US$)	4th year (US$)	5th year (US$)	6th year (US$)	7th year (US$)
Crop products 1/	130.0	393.2	475.2	536.5	554.5	554.5	554.5
Livestock products 2/	57	143	143	167	167	167	167
Wages	103	-	-	-	-	-	-
Total	290	536.2	618.2	703.5	721.5	721.5	721.5
Annual outgo 3/	290	379	398	491	521	533	533
Annual balance	0	+157.2	+220.2	+212.5	+200.5	+188.5	+188.5

1/ Figures are itemized in Table -5.6.

2/ Figures are itemized in Table -5.7.

3/ Figures are itemized in Table -5.10.

Table- 5.5. Annual balance sheet of a unit farm management of farmers at an upland livestock farm unit of 4.5 hectares

	After irrigation (year in order)						
	1st year (US$)	2nd year (US$)	3rd year (US$)	4th year (US$)	5th year (US$)	6th year (US$)	7th year (US$)
Crop products 1/	215.0	499.6	638.5	760.0	782.0	782.4	782.4
Livestock products 2/	49	71	151	171	172	262	296
Wages	100	-	-	-	-	-	-
Total	366.0	570.6	789.5	931.0	954.4	1044.4	1078.4
Annual outgo 3/	361	508.5	568.25	644.75	699.75	704.75	704.75
Annual balance	+3.0	+62.1	+221.25	+286.25	+254.65	+339.65	+373.65

1/ Figures are itemized in Table -5.8.

2/ Figures are itemized in Table -5.9.

3/ Figures are itemized in Table -5.11.

Fig—56 Annual gross income due to crop products on a paddy livestock farm unit of 2 hectares during 7 years after the beginning of irrigation.

After Irrigation (Year in order)

Kind of crop product ⊿1	1st Year Area (ha)	1st Year Unit yield ⊿2 (ton/ha)	1st Year Total yield (ton)	1st Year Unit price (US$/ton)	1st Year Total price (US$)	2nd Year Area (ha)	2nd Year Unit yield ⊿2 (ton/ha)	2nd Year Total yield (ton)	2nd Year Unit price (US$/ton)	2nd Year Total price (US$)
1st paddy	0.50	2.00	1.00	40	40.0	0.50	2.50	1.25	40	50.0
2nd paddy	—	—	—	—	—	0.50	1.50	0.75	40	30
Soybeans	0.30	1.50	0.45	100	45	0.30	2.00	0.60	100	60
Green beens	0.20	1.00	0.20	100	20	0.20	1.50	0.30	100	30
Paspalum	—	—	—	—	—	0.20	40.00	8.00	1	8
Maize	0.30	1.00	0.30	50	150	0.30	1.00	0.30	50	15.0
Tobacco	—	—	—	—	—	0.20	1.00	0.20	200	40
Peanut	—	—	—	—	—	0.30	1.20	0.36	120	43.2
Kenaf	—	—	—	—	—	0.40	1.00	0.40	200	80
Sweet potato	—	—	—	—	—	0.20	10.00	2.00	5	10
Fruits	—	—	—	—	—	0.10	3.00	0.30	40	12
Vegetables	0.10	10.00	1.00	10	130	0.10	15.00	1.50	10	15
Total	1.40				130	3.10				299.2

Kind of crop product ⊿1	3rd Year Area (ha)	3rd Year Unit yield ⊿2 (ton/ha)	3rd Year Total yield (ton)	3rd Year Unit price (US$/ton)	3rd Year Total price (US$)	4th Year Area (ha)	4th Year Unit yield ⊿2 (ton/ha)	4th Year Total yield (ton)	4th Year Unit price (US$/ton)	4th Year Total price (US$)
1st paddy	0.50	3.00	1.50	40	60.0	0.50	3.00	1.50	40	60.0
2nd paddy	0.50	2.00	1.00	40	40	0.50	2.50	1.25	40	50.0
Soybeans	0.30	2.00	0.60	100	60.0	0.30	2.00	0.60	100	60.0
Green beens	0.20	2.00	0.40	100	40	0.20	2.00	0.40	100	40.0
Paspalum	0.20	40.00	8.00	1	8	0.20	50.00	10.00	1	8
Maize	0.30	1.20	0.36	50	18.0	0.30	1.50	0.45	50.0	22.5
Tobacco	0.20	1.00	0.20	200	40	0.20	1.00	0.20	200	40
Peanut	0.30	1.20	0.36	120	43.2	0.30	1.50	0.45	120	54.0
Kenaf	0.40	1.20	0.48	200	96	0.40	1.50	0.50	200	120
Sweet potato	0.20	20.00	4.00	5	20	0.20	20.00	4.00	5	20
Fruits	0.10	5.00	0.50	40	20	0.10	8.00	0.80	40	32
Vegetables	0.20	15.00	3.00	10	30	0.20	15.00	3.00	10	30
Total	3.20				367.2	3.20				416.5

Kind of crop product ⊿1	5th Year Area (ha)	5th Year Unit yield ⊿2 (ton/ha)	5th Year Total yield (ton)	5th Year Unit price (US$/ton)	5th Year Total price (US$)	6th, 7th Year Area (ha)	6th, 7th Year Unit yield ⊿2 (ton/ha)	6th, 7th Year Total yield (ton)	6th, 7th Year Unit price (US$/ton)	6th, 7th Year Total price (US$)
1st paddy	0.50	3.00	1.50	40	60.0					
2nd paddy	0.50	2.50	1.25	40	50.0					
Soybeans	0.30	2.00	0.60	100	60.0					
Green beens	0.20	2.00	0.40	100	40					
Paspalum	0.20	50.00	10.00	1	10.0					
Maize	0.30	1.50	0.45	50	22.5	(Similar to 5 th year)				
Tobacco	0.20	1.20	0.24	200	48.0					
Peanut	0.30	1.50	0.45	120	54.0					
Kenaf	0.40	1.50	0.60	200	120					
Sweet potato	0.20	20.00	4.00	5	20.0					
Fruits	0.10	10.00	1.00	40	40.0					
Vegetables	0.20	15.00	3.00	10	30.0					
Total	3.20									

⊿1 Crops are selected so as to meet with the regional demand for each crop product

⊿2 *Unit yield of crop on farm is raised with the advance of improved irrigation farming*

Table — 5.7 Annual gross income due to livestock products on a paddy livestock farm unit of 2 hectares during 7 years after the beginning of irrigation

Kind of livestock [1] product	Before irrigation			After irrigation (Year in order)														
				1st year			2nd year			3rd year			4th year			5th~7th year		
	Number	Unit price	Total price (US.$)	Number	Unit price	Total price (US $)	Number	Unit price	Total price (US.$)	Number	Unit price	Total price (US.$)	Number	Unit price	Total price (US.$)	Number	Unit price	Total price
Beef cattle	0.1	30	3	—	—	—	—	—	—	—	—	—	—	—	—	(Similar to 4th year)		
Calf	—	—	—	—	—	—	—	—	—	—	—	—	1 head	20	20			
Milk	—	—	—	—	—	—	2 kl	30	60	2 kl	30	60	2 kl	30	60			
Shoat	3 head	10	30	3 head	10	30	5 head	10	50	5 head	10	50	5 head	10	50			
Swine	0.3 head	20	6	0.3 head	20	6	0.3 head	20	6	0.3 head	20	6	0.3 head	20	6			
Egg	100	0.02	2	500	0.02	10	800	0.02	16	800	0.02	16	1000	0.02	20			
Fowl	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃			
Total			52			57			143			143			167			

[1] Kind of domestic animals should be changed or improved by introducing improved strains

Table—5.8 Annual gross income due to livestock products on an upland livestck farm unit of 4.5 hectares during 7 years after the beginning of irrigation.

Kind of livestock product ⊿	Before irrigation			After Irrigation (Year in order) 1st year			2nd year			3rd year			4th year			5th year			6th year			7th year		
	Number	Unit price	Total price (U.S.$)	Number	Unit price	Total price (U.S.$)	Number	Unit price	Total price (U.S.$)	Number	Unit price	Total price (U.S.$)	Number	Unit price	Total price (U.S.$)	Number	Unit price	Total price (U.S.$)	Number	Unit price	Total price (U.S.$)	Number	Unit price	Total price (U.S.$)
Buffalo	0.2	30	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Calf	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1 head	20	20
Milk	–	–	–	–	–	–	–	–	–	2 kl	30	60	2 kl	30	60	2 kl	30	60	2 kl	30	60	2 kl	30	60
Shoat	2 head	10	20	2 head	10	20	3 head	10	30	5 head	10	50	6 head	10	60	6 head	10	60	15 head	10	150	15 head	10	150
Swine	0.4	20	8	0.2	20	4	0.3	20	6	0.3	20	6	0.3	20	6	0.3	20	6	0.3	20	6	1	20	20
Egg	100	0.02	2	600	0.02	12	1000	0.02	20	1000	0.02	20	1500	0.02	30	1500	0.02	30	1500	0.02	30	1500	0.02	30
Fowl	6	1	6	13	1	13	15	1	15	15	1	15	15	1	15	16	1	16	16	1	16	16	1	16
Total			42			49			71			151			171			172			262			296

⊿ Kind of domestic animals should be changed or improved by introducing the improved strains

Table—5.9 Annual gross income due to crop products on an upland livestock farm unit of 4.5 hectares during 7 years after the beginning of irrigation.

After irrigation (Year in order)

Kind of crop product ⁄1	1st Year Area (ha)	1st Year Unit yield ⁄2 (ton/ha)	1st Year Total yield (ton)	1st Year Unit price (US$/ton)	1st Year Total price (US$)	2nd Year Area (ha)	2nd Year Unit yield ⁄2 (ton/ha)	2nd Year Total yield (ton)	2nd Year Unit price (US$/ton)	2nd Year Total price (US$)
1st paddy	0.50	2.00	1.00	40	40.0	0.75	2.00	1.50	40	60.0
2nd paddy	0.50	1.00	0.50	40	20.0	0.50	1.20	0.60	40	24.0
Maize	0.20	1.00	0.20	50	10	0.40	1.20	0.48	50	24
Beans	0.20	1.00	0.20	100	20	0.40	1.20	0.48	100	48
Peanut	0.20	1.00	0.20	120	24	0.40	1.20	0.48	120	57.6
Pasture grass	0.40	20.00	8.00	1	8	0.75	40.00	30.00	1	30
Green manure	0.40	20.00	8.00	1	8	0.40	40.00	16.00	1	6
Kenaf	0.20	1.00	0.20	200	40	0.30	1.20	0.36	200	72
Tobacco	0.10	1.00	0.10	200	20	0.30	1.20	0.36	200	72
Sugar cane	—	—	—	—	—	0.10	60.00	6.00	3	18
Fruits	0.10	5.00	0.50	40	20	0.10	6.00	0.60	40	24
Vegetables	0.10	5.00	0.50	10	5	0.20	12.00	2.40	10	24
Rubber	—	—	—	—	—	0.50	0.20	0.10	300	30
Total	3.10				215.0	5.30				499.6

Kind of crop product ⁄1	3rd Year Area (ha)	3rd Year Unit yield ⁄2 (ton/ha)	3rd Year Total yield (ton)	3rd Year Unit price (US$/ton)	3rd Year Total price (US$)	4th Year Area (ha)	4th Year Unit yield ⁄2 (ton/ha)	4th Year Total yield (ton)	4th Year Unit price (US$/ton)	4th Year Total price (US$)
1st paddy	0.75	2.40	1.80	40	72.0	0.75	2.80	2.10	40	84.0
2nd paddy	0.60	1.40	0.84	40	33.6	0.70	1.60	1.12	40	44.8
Maize	0.40	1.30	0.52	50	26	0.40	1.50	0.6	50	30
Beans	0.60	1.40	0.84	100	84	0.60	1.40	0.84	100	84
Peanut	0.40	1.30	0.52	120	62.4	0.40	1.40	0.56	120	67.2
Pasture grass	0.75	50.00	37.5	1	37.5	0.75	50.00	37.5	1	37.5
Green manure	0.40	50.00	20.00	1	20	0.40	50.00	20.00	1	20
Kenaf	0.30	1.30	0.39	200	78	0.30	1.40	0.42	200	84
Tobacco	0.30	1.20	0.36	200	72	0.30	1.20	0.36	200	72
Sugar cane	0.10	60.00	6.00	3	18	0.10	60.00	6.00	3	18
Fruits	0.10	7.00	0.70	40	28	0.10	10.00	1.00	40	40
Vegetables	0.20	13.00	2.60	10	26	0.20	15.00	3.00	10	30
Rubber	1.00	0.27	0.27	300	81.0	1.50	0.33	0.495	300	148.5
Total	6.10				638.5	6.70				760

Kind of crop product ⁄1	5th Year Area (ha)	5th Year Unit yield ⁄2 (ton/ha)	5th Year Total yield (ton)	5th Year Unit price (US$/ton)	5th Year Total price (US$)	6th, 7th Year Area (ha)	6th, 7th Year Unit yield ⁄2 (ton/ha)	6th, 7th Year Total yield (ton)	6th, 7th Year Unit price (US$/ton)	6th, 7th Year Total price (US$)
1st paddy	0.75	2.50	2.25	40	90.0					
2nd paddy	0.70	1.80	1.26	40	50.4					
Maize	0.40	1.50	0.60	50	30					
Beans	0.60	1.40	0.84	100	84					
Peanut	0.40	1.50	0.60	120	72	(Similar to 5th Year)				
Pasture grass	0.75	50.00	37.5	1	37.5					
Green manure	0.40	50.00	20.00	1	20					
Kenaf	0.30	1.50	0.45	200	90					
Tobacco	0.30	1.20	0.36	200	72					
Sugar cane	0.10	60.00	6.00	3	18					
Fruits	0.10	10.00	1.00	40	40					
Vegetables	0.20	15.00	3.00	10	30					
Rubber	1.50	0.33	0.495	300	148.5					
Total	6.70				782.4					

⁄1 Crops are selected so as to meet with the regional demand for each crop product

⁄2 Unit yield of crop on farm is raised with the advance of improved irrigation farming

Table-5.10. Annual outgo of farmers at a paddy livestock farm unit of 2 hectares

Item of outgo	Before irrigation Annual amount (US$)	After irrigation (year in order) 1st year Annual amount (US$)	2nd year Annual amount (US$)	3rd year Annual amount (US$)	4th year Annual amount (US$)	5th year Annual amount (US$)	6th year Annual amount (US$)	7th year Annual amount (US$)
Depreciation of buildings 1/	5	8	8	8	8	8	8	8
Depreciation of farm implements 2/	5	6	6	6	6	6	6	6
Redemption of farm reformation cost 3/	-	4	4	4	4	4	4	4
Water rates 4/	-	-	20	30	50	50	50	50
Living expense 5/	150	200	250	250	300	300	300	300
Self-supplied food	20	20	25	25	30	30	30	30
Self-supplied feed 6/	5	15	28	30	35	35	35	35
Supplementary feed 7/	5	10	5	6	7	8	10	10
Supplementary seed	-	-	5	5	5	5	5	5
Self-supplied manure 8/	-	10	10	10	15	15	15	15
Commercial fertilizer	-	10	10	15	20	30	40	40
Agricultural chemicals	-	2	3	4	6	10	10	10
Insurance	-	-	-	-	-	10	10	10
Tax and public impost	-	-	-	-	-	5	5	5
Employed labor	-	-	-	-	-	-	-	-
Miscellaneous and contingency	5	5	5	5	5	5	5	5
Total outgo	190	290	379	398	491	521	533	533

1/ Initial farm investment at the commencement of irrigation farming.
2/ Ditto
3/ Ditto
4/ The rates will be 10 US dollars per hectare for the 2nd year, 15 US dollars for the 3rd year and 25 US dollars for the 4th year and afterward.
5/ Living expense increases with the advance of irrigation farming.
6/ Most yields of maize, soybeans, pasture grass are used for self-supplied feed.
7/ Some amount of lime and salt are purchased for supplementary feed.
8/ Green manure is used for self-supplied manure.

Table 5.11. Annual outgo of farmers at an upland livestock farm unit of 4.5 hectares

Item of outgo	Before irrigation	After irrigation (year in order)						
	Annual amount (US$)	1st year Annual amount (US$)	2nd year Annual amount (US$)	3rd year Annual amount (US$)	4th year Annual amount (US$)	5th year Annual amount (US$)	6th year Annual amount (US$)	7th year Annual amount (US$)
Depreciation of building 1/	5	8	8	8	8	8	8	8
Depreciation of farm implements 2/	5	7	7	7	7	7	7	7
Redemption of farm reformation cost 3/	-	6	6	6	6	6	6	6
Water rates 4/	-	-	37.5	56.25	93.75	93.75	93.75	93.75
Living expense 5/	150	220	250	250	250	300	300	300
Self-supplied food	15	25	25	25	35	30	30	30
Self-supplied feed 6/	5	32	64	64	78	78	78	78
Supplementary feed 7/	5	8	10	10	10	10	15	15
Supplementary seed 8/	-	10	10	10	10	10	10	10
Self-supplied manure	-	16	20	20	20	20	20	20
Commercial fertilizer	5	20	60	80	100	100	100	100
Agricultural chemicals	2	4	6	10	15	15	15	15
Insurance	-	-	-	10	10	10	10	10
Tax and public impost	-	-	-	7	7	7	7	7
Employed labor	-	-	-	-	-	-	-	-
Miscellaneous and contingency	5	5	5	5	5	5	5	5
Total outgo	197	361	508.5	568.25	644.75	699.75	704.75	704.75

1/ 2/, 3/ Initial farm investment at the beginning of irrigation farm.

4/ The water rates in farm land used for cropping will be 10 US dollars per hectare for the 2nd year, 15 US dollars for the 3rd year, the 4th year and afterward. The rate of land for rubber plant will be 5 US dollars per hectare for the 2nd year, 7.5 US dollars for the 3rd year and 12.5 US dollars for the 4th year and afterward.

5/ Living expense increases with the advance of irrigation farming.

6/ Most of maize, soybeans, pasture grass are used for self-supplied feed.

7/ Some amount of lime and salt are purchased for supplementary feed.

8/ Green manure is used for self-supplied manure.

Section 5. Reservoir designs

Determination of the storage capacity of Lower Krong Buk reservoir: In order to determine the required capacity of the Lower Krong Buk reservoir, the following basic factores are required.

2.1. Irrigation water requirements

The water requirements in each month are computed from the Table-5. 3 "Calculation of consumptive use of water."

The results of that computation regarding the Lower Krong Buk reservoir system with an irrigation area of 3,500 hectares are as shown in the following Table-5.4. Figures in this table include all irrigation losses.

Table-5.12 Irrigation water requirements in each month

Irrigable area	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Lowland 2,100 ha.	2.21	1.52	0.88	1.33	1.52	1.18	0.57	0.10	0.09	0.18	0.60	1.34
Upland 1,400 ha.	1.30	1.00	0.70	0.65	0.48	0.61	0.54	0.56	0.32	0.23	0.47	0.90
Total 3,500 ha.	3.51	2.52	1.58	1.96	2.00	1.79	1.11	0.66	0.41	0.41	1.07	2.24

2.2. Effective rainfall on farmland

The effective rainfall in each month on farmland is assumed at 60 percent of the monthly rainfall, while it is assumed to be zero in case the monthly rainfall is less than 15 millimeters.

2.3. Estimated runoff at the damsite

The estimated runoff at the damsite is mentioned in Appendix III.

Calculation of the required storage capacity of the reservoir: The amount of water to be supplied from the reservoir during irrigation period is computed by deducting the monthly effective rainfall on farmland, and the monthly inflow into the reservoir from the irrigation water requirements in each month.

Therefore, the required storage capacity of the reservoir is calculated by accumulating these supplies of water in each month during irrigation period. Then, we have made estimation of the required storage for a period of 5 years from 1959 to 1963.

Table-5.13 shows the results and process of such computation for the Lower Krong Buk irrigation system. As can be seen in this table, the maximum required storage capacity of 9.86 cubic meters per second per month appears in 1963. It may be considered that this is the required storage capacity in a probable droughly year at recurrence interval of 5 years.

Design storage capacity: From the standpoint of the economical planning of the reservoir, it is generally desirable to calculate the design storage capacity on the basis of an extent of water-shortage in a probable dry year at recurrence internal of 5 years. Therefore, taking the adequate allowances for unavoidable losses of stored water by leakage and evaporation, we have determined the design storage capacity of the Lower Krong Buk reservoir as follows:

The maximum required storage capacity is 9.86 cubic meters per second per month, that is, equivalent to about 25,540,000 cubic meters in volume. Now, assuming that the high water level of the reservoir is 473.10 meters, the total storage capacity of 36,200,000 cubic meters is to be obtained from the storage-elevation curve shown in Fig.-5.3.

On the other hand the amount of water loss during storage is estimated at 5,430,000[1/] cubic meters by leakage and 1,800,000[2/] cubic meters by evaporation. Furthermore, it is necessary to take into account the dead water storage estimated at 2,700,000 cubic meters to maintain adequate head for the conveyance of irrigation water. Therefore, the available storage capacity for irrigation use is calculated at 36,200,000 - (5,430,000 + 1,800,000 + 2,700,000) = 26,270,000 cubic meters, which covers the maximum required storage capacity of 25,540,000 cubic meters as stated above.

1/ The loss of water by leakage has been estimated on the assumption that it is equivalent to 15 percent of the total storage capacity at a given water surface.

2/ This figure is calculated on the basis of the results studied in Appendix II.

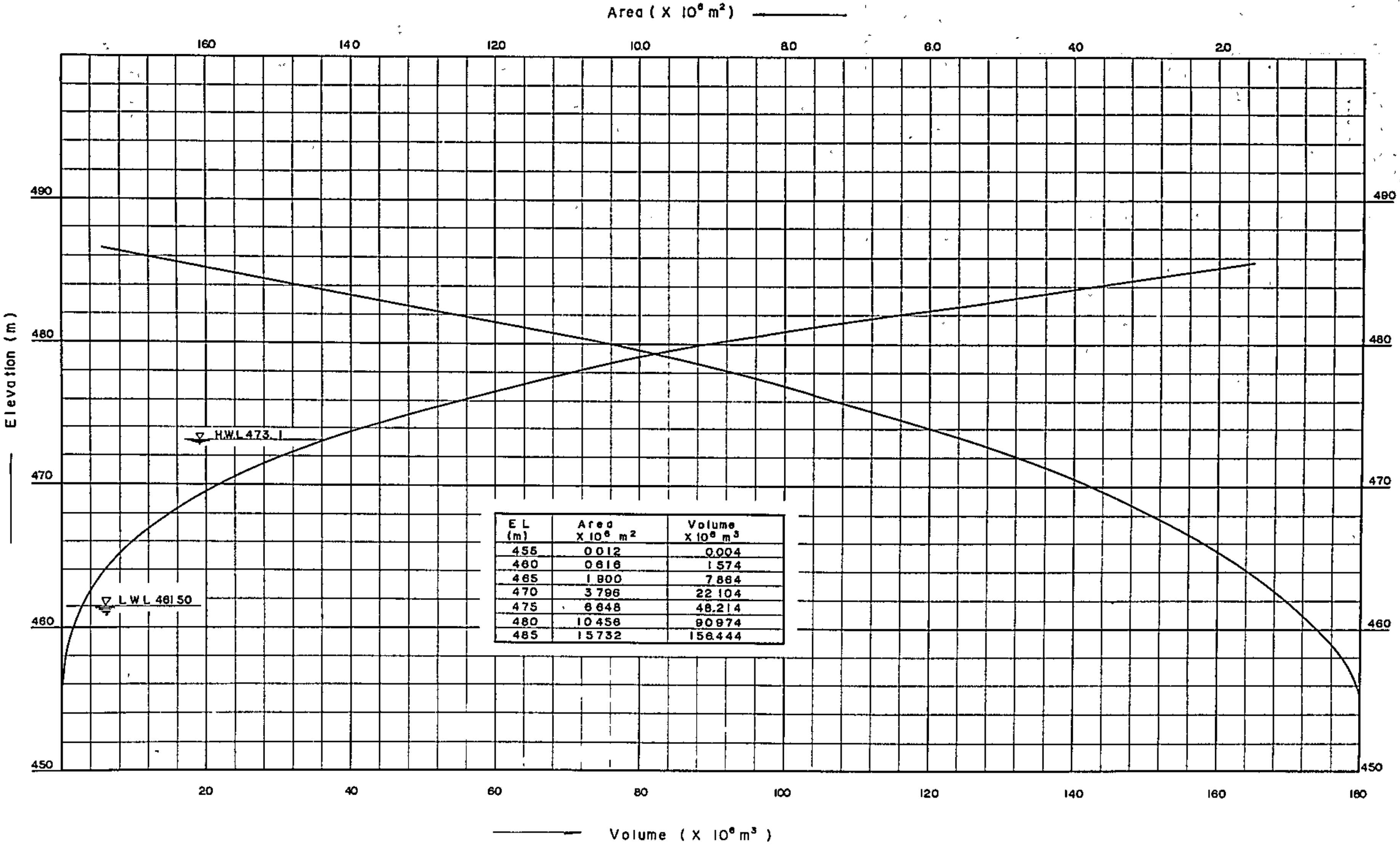
Accordingly, we have determined that the design total storage capacity of the Lower Krong Buk reservoir is 26,200,000 cubic meters at a high water level of 473.10 meters.

Table—5.18 Calculation of the required capacity of reservoir

Year	1959						1960						1961					
Month	Water Requirement (1)	Effective Rainfall (2)	Supplementary water (1)-(2)	Run-off (3)	Discharge to be supplied from Reservoir (1)-(2)-(3)	Accumulated Discharge	Water Requirement (1)	Effective Rainfall (2)	Supplementary water (1)-(2)	Run-off (3)	Discharge to be supplied from Reservoir (1)-(2)-(3)	Accumulated Discharge	Water Requirement (1)	Effective Rainfall (2)	Supplementary water (1)-(2)	Run-off (3)	Discharge to be supplied from Reservoir (1)-(2)-(3)	Accumulated Discharge
Apr.	1.96	0.64	1.32	0.65	0.67	0.67	1.96	0.44	1.52	0.73	0.79	0.79	1.96	1.15	0.81	0.88	-	-
May	2.00	1.99	0.01	0.70	-	0.67	2.00	2.30	-	0.85	-	0.79	2.00	1.97	0.03	0.95	-	-
Jun.	1.79	1.40	0.39	0.81	-	0.67	1.79	1.73	-	0.90	-	0.79	1.79	2.37	-	1.10	-	-
Jul.	1.11	1.96	-	1.24	-	0.67	1.11	2.25	-	1.46	-	0.79	1.11	2.71	-	1.58	-	-
Aug.	0.67	2.20	-	2.88	-	0.67	0.67	1.33	-	3.38	-	0.79	0.67	2.20	-	3.66	-	-
Sep.	0.41	1.51	-	3.67	-	0.67	0.41	3.32	-	4.44	-	0.79	0.41	1.84	-	4.81	-	-
Oct.	0.41	1.35	-	6.09	-	0.67	0.41	1.42	-	8.55	-	0.79	0.41	1.80	-	7.33	-	-
Nov.	1.07	0.70	0.37	3.09	-	0.67	1.07	0.90	-	4.62	-	0.79	1.07	0.28	0.79	3.72	-	-
Dec.	2.24	0.20	2.04	1.24	0.80	1.47	2.24	-	2.24	1.34	0.90	1.69	2.24	-	2.24	1.49	0.75	0.75
Jan.	3.51	-	3.51	0.87	2.64	4.11	3.51	-	3.51	1.03	2.48	4.17	3.51	-	3.51	1.12	2.39	3.14
Feb.*	2.52	-	2.52	0.65	1.87	5.98	2.52	-	2.52	0.78	1.74	5.91	2.52	-	2.52	0.84	1.68	4.82
Mar.	1.58	-	1.58	0.39	1.19	7.17	1.58	0.51	1.07	0.46	0.27	6.18	1.58	-	1.58	0.50	1.08	5.90

Year	1962						1963					
Month	Water Requirement (1)	Effective Rainfall (2)	Supplementary water (1)-(2)	Run-off (3)	Discharge to be supplied from Reservoir (1)-(2)-(3)	Accumulated Discharge	Water Requirement (1)	Effective Rainfall (2)	Supplementary water (1)-(2)	Run-off (3)	Discharge to be supplied from Reservoir (1)-(2)-(3)	Accumulated Discharge
Apr.	1.96	0.33	1.63	0.39	1.24	1.24	1.96	-	1.96	0.34	1.62	1.62
May	2.00	1.18	0.82	0.41	0.41	1.65	2.00	0.86	1.14	0.36	0.78	2.40
Jun.	1.79	0.88	0.91	0.48	0.43	2.08	1.79	1.08	0.71	0.42	0.29	2.69
Jul.	1.11	3.10	-	1.19	-	2.08	1.11	1.72	-	1.29	-	2.69
Aug.	0.67	1.95	-	2.74	-	2.08	0.67	2.84	-	2.99	-	2.69
Sep.	0.41	1.74	-	3.60	-	2.08	0.41	3.37	-	3.92	-	2.69
Oct.	0.41	1.86	-	6.08	-	2.08	0.41	1.29	-	5.85	-	2.69
Nov.	1.07	0.88	0.19	6.90	-	2.08	1.07	0.16	0.91	2.97	-	2.69
Dec.	2.24	-	2.24	3.24	-	2.08	2.24	-	2.24	1.19	1.05	3.74
Jan.	3.51	-	3.51	0.85	2.66	4.74	3.51	-	3.51	0.71	2.80	6.54
Feb.	2.52	-	2.52	0.58	1.94	6.68	2.52	-	2.52	0.48	2.04	8.58
Mar.	1.58	-	1.58	0.35	1.23	7.91	1.58	-	1.58	0.30	1.28	9.86

Fig-5.5 LOWER KRONG BUK RESERVOIR



EL (m)	Area $\times 10^6$ m^2	Volume $\times 10^6$ m^3
455	0.012	0.004
460	0.616	1.574
465	1.800	7.864
470	3.796	22.104
475	6.648	48.214
480	10.456	90.874
485	15.732	156.444

Section 6. Prospective irrigation for the entire Upper Srepok Basin

The basin of the Upper Srepok and its tributaries has an area of about 7,800 square kilometers. It consists of several drainage areas of the Ea Krong Ana, Krong Buk, Krong Pach, Krong Bound and Krong Kno. These drainage areas have generally gently rolling topography with some spots of hilly land. In the Project area, the wide gentle slopes between the stream channels are under cultivation and some rubber, tea and coffee plantations are included among these cultures.

According to the reconnaissance of major tributaries of the Mekong which was undertaken by the Government of Japan, six projects for irrigation or power or for both are contemplated in the development plan of the Upper Srepok. Among them, the top priority is given to the irrigation project of the low-lying marshy land in the Darlac region. The field investigations of this project were undertaken by the Japanese team during Japan's fiscal year 1962, and the feasibility report on the Darlac Irrigation Project had been submitted to the Mekong Committee in January 1964.

Moreover, the Government of Japan has decided to undertake the investigations and preliminary design of the Krong Buk irrigation scheme and the studies of a general development plan for the Upper Srepok Basin with its 1963-year budget. Then, based on the results of the investigations that have been made so far, the prospective irrigation plans within the Upper Srepok Basin are given below:

(1) Krong Pach irrigation scheme (irrigation area 9,000 ha.)

The Ea Krong Pach is situated upstream of the Ea Krong Ana; it is one of the rivers originating in the Annam Cordillera, flowing first westward and then turning southward to join the Ea Krong Ana.

There is a suitable dam site at a point about two kilometers east of B. Rok where the catchment area is estimated at about 490 square kilometers.

According to the geological investigations on the dam site, the rock-bed of sandstone lies beneath the silt deposits of about 10 meters in thickness. At this site, the reservoir with a total storage capacity of about 170 million cubic meters will be created by constructing the fill type dam of 18.5 meters in height. Out of about 170 million cubic meters of a total storage capacity, 72 million cubic meters of water may be used for the irrigation of about 9,000 hectares of flat land extending on both banks of the lower Krong Pach.

According to the above plan, the construction cost may be estimated at about 6,300,000 US dollars equivalent that equals to 700 US dollars per hectare.

(2) Krong Boung irrigation scheme (irrigation area 6,000 ha.)

On the Ea Krong Boung which commands a basin area of about 790 square kilometers east of the Ea Krong Ana, there is a suitable site for dam construction at a point some 4 kilometers upstream from its confluence with the Ea Krong Ana. Here a dam could be constructed with the height of about 21 meters (Crest EL. 450 m. H.W.L. EL. 447.5 m.), by which a total storage capacity of about 170 million cubic meters will be secured. This will enable regulation of flood, and water of about 10 cubic meters per second will be secured throughout the year. With this, about 6,000 hectares of lowland within the Ea Krong Ana flood regulating reservoir site could be irrigated, and the discharge of the Ea Krong Ana in the dry season will increase.

The construction cost will be estimated at about 4,000,000 US dollars.

(3) Darlac irrigation scheme (irrigation area 8,000 ha.)

As stated in the feasibility report of the Darlac Irrigation Project which had been submitted in January 1964, the irrigation of about 8,000 hectares of lowland in the Darlac region will be contemplated. We also reported that since this project area is situated in the lower reaches of the Upper Srepok and will be greatly improved by the flood control works for the upstream reaches, it is absolutely necessary to consider it as a link in the chain of the Comprehensive Upper Srepok Project. The development of the upper projects and the Krong Kno project will make it possible to regulate the flood discharge of the Ea Krong to about 800 cubic meters per second. Consequently, the lowland of about 6,000 hectares in the Darlac region may be saved from the damage of periodic flood in the rainy season. Then, the final design of irrigation and drainage system in the Darlac low-lying land will be required.

As stated in the feasibility report of the Darlac Irrigation Project, the irrigation of about 8,000 hectares of land including about 4,400 hectares of existing farm land will be realized successfully.

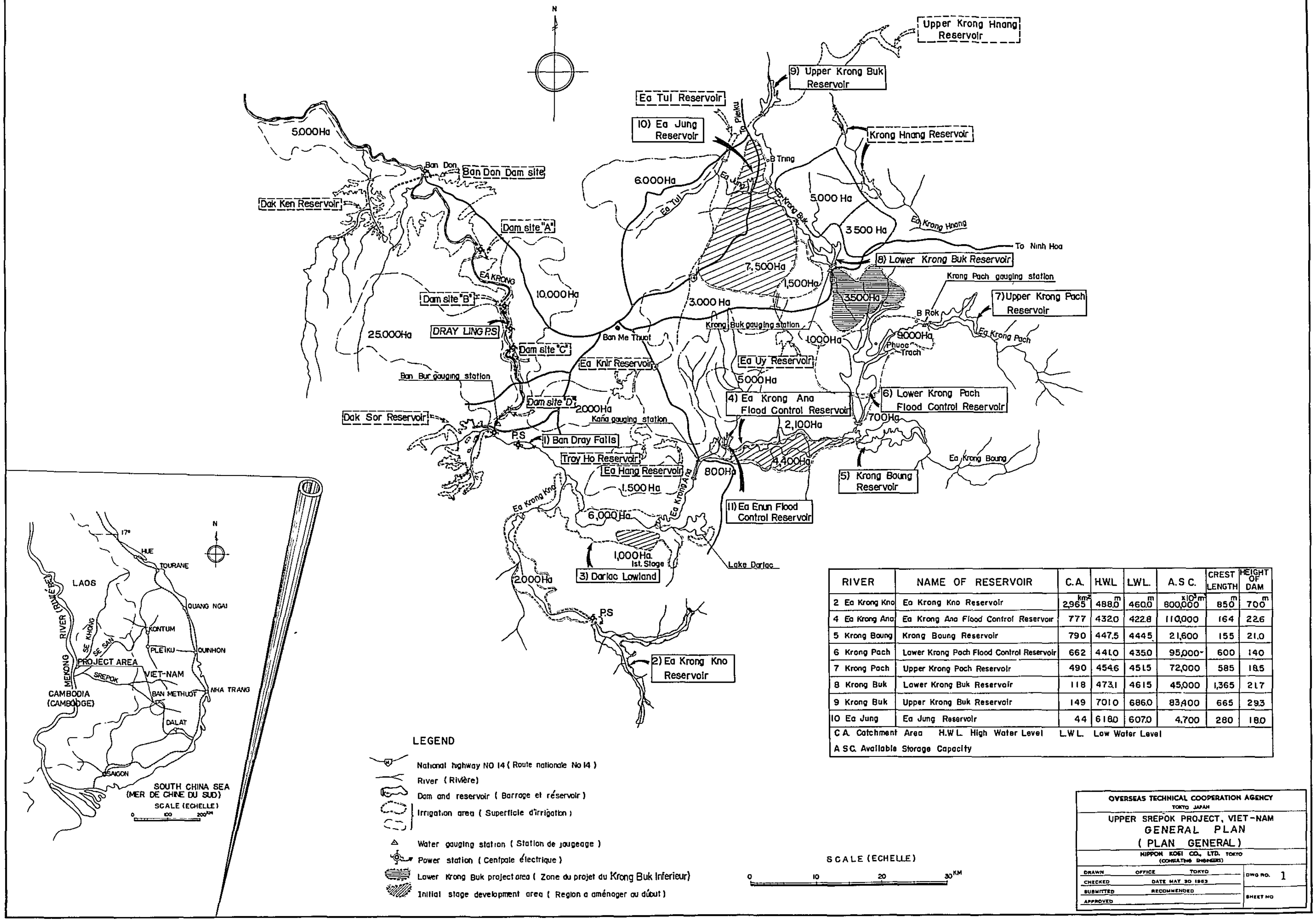
The outline of development plan in the Darlac region at the present stage is as follows:

Irrigation facilities:

Pump station	5 stations
Main irrigation canals	84 km.
Laterals	86 km.
Reclamatiin of land:	3,600 ha.

(4) Krong Kno irrigation scheme (irrigation area 2,000 ha.)

A reservoir with an available storage capacity of about 800 million cubic meters will be created in the upstream reaches of the Ea Krong Kno, which is one of the largest tributaries of the Upper Srepok. By means of this reservoir, the discharge of about 60 cubic meters per second needed for power generation of about 25,000 kilowatts and for irrigation of the downstream area of about 2,000 hectares will be secured throughout the year.



RIVER	NAME OF RESERVOIR	C.A. (km²)	H.W.L (m)	L.W.L. (m)	A.S.C. (x10³m³)	CREST LENGTH (m)	HEIGHT OF DAM (m)
2 Ea Krong Kno	Ea Krong Kno Reservoir	2,965	488.0	460.0	800,000	850	70.0
4 Ea Krong Ana	Ea Krong Ana Flood Control Reservoir	777	432.0	422.8	110,000	164	22.6
5 Krong Boung	Krong Boung Reservoir	790	447.5	444.5	21,600	155	21.0
6 Krong Pach	Lower Krong Pach Flood Control Reservoir	662	441.0	435.0	95,000	600	14.0
7 Krong Pach	Upper Krong Pach Reservoir	490	454.6	451.5	72,000	585	18.5
8 Krong Buk	Lower Krong Buk Reservoir	118	473.1	461.5	45,000	1,365	21.7
9 Krong Buk	Upper Krong Buk Reservoir	149	701.0	686.0	83,400	665	29.3
10 Ea Jung	Ea Jung Reservoir	44	618.0	607.0	4,700	280	18.0

C.A. Catchment Area H.W.L. High Water Level L.W.L. Low Water Level

A.S.C. Available Storage Capacity

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN

UPPER SREPOK PROJECT, VIET-NAM

GENERAL PLAN

(PLAN GENERAL)

NIPPON KOEI CO., LTD. TOKYO
(CONSULTING ENGINEERS)

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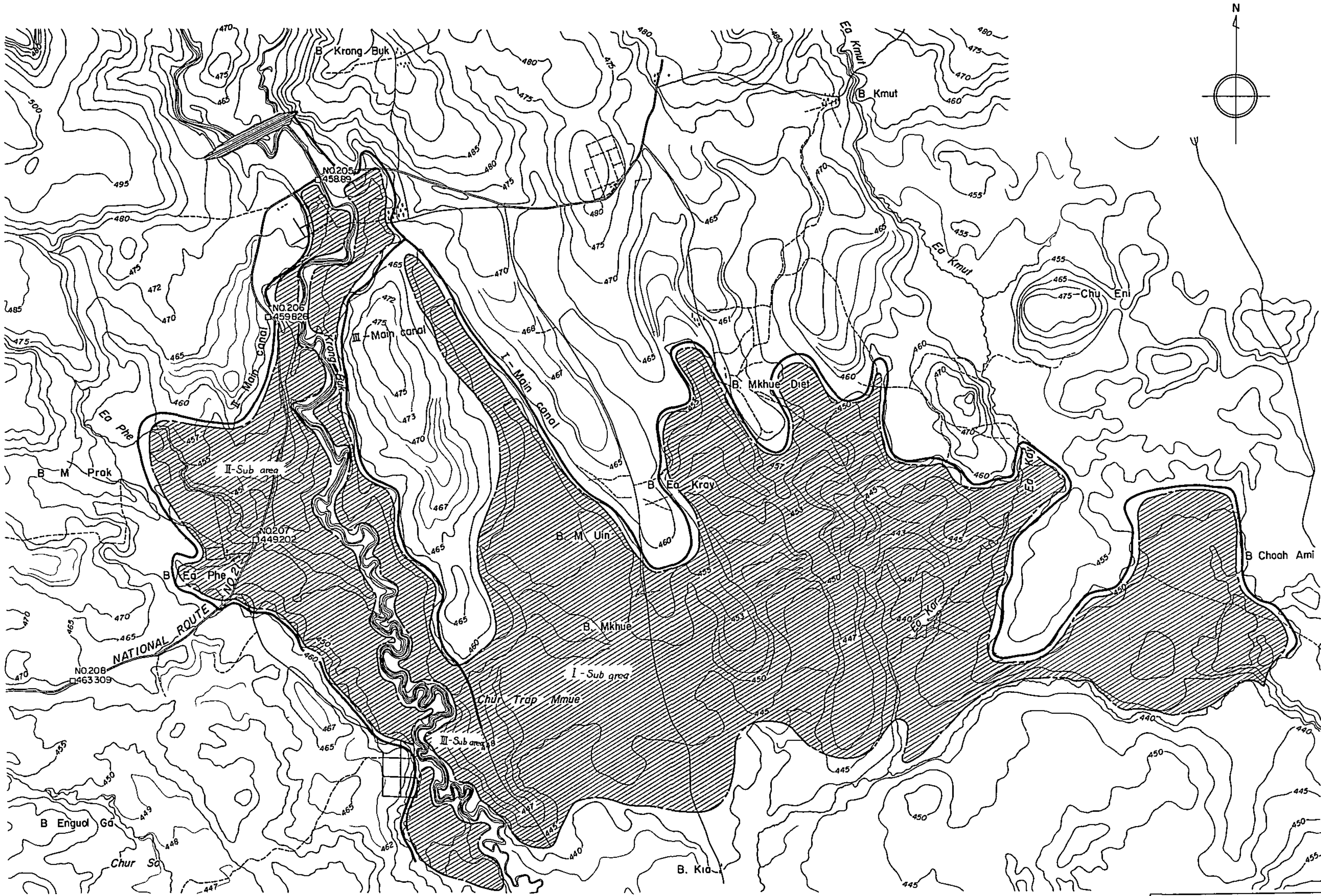

SCALE

METERS 1,000 0 1,000 2,000 3,000 METERS

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN

KRONG BUK IRRIGATION SCHEME
GENERAL MAP

NIPPON KOEI CO., LTD TOKYO
(CONSULTING ENGINEERS)

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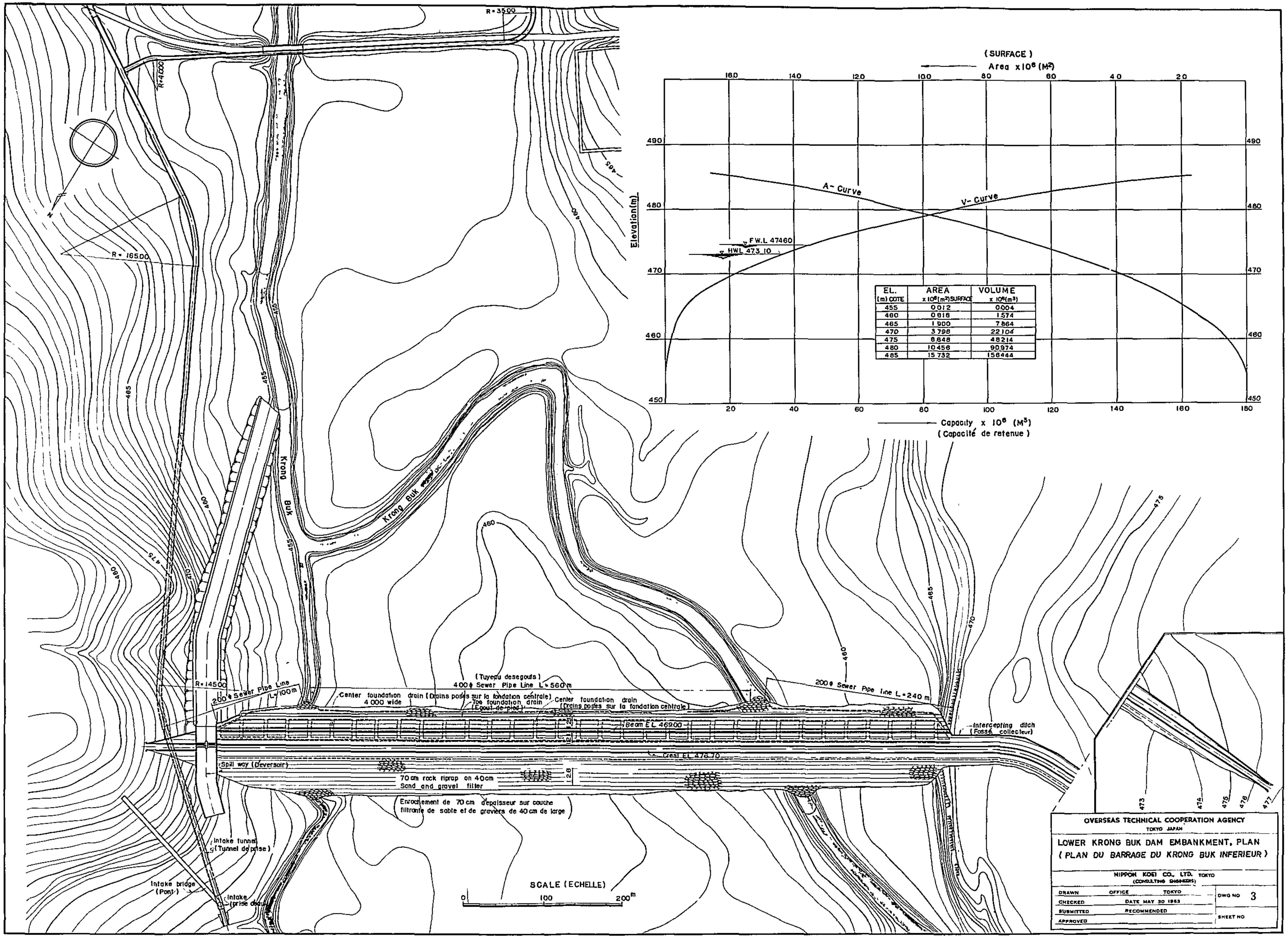

EL. (m) COTE	AREA x 10⁶ (m²) SURFACE	VOLUME x 10⁶ (m³)
455	0 012	0.004
460	0 616	1.574
465	1 900	7 864
470	3 798	22 104
475	6.648	48 214
480	10 456	90.974
485	15 732	156444

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN

LOWER KRONG BUK DAM EMBANKMENT, PLAN
(PLAN DU BARRAGE DU KRONG BUK INFERIEUR)

NIPPON KOEI CO., LTD. TOKYO
(CONSULTING ENGINEERS)

DRAWN OFFICE TOKYO		DWG NO 3
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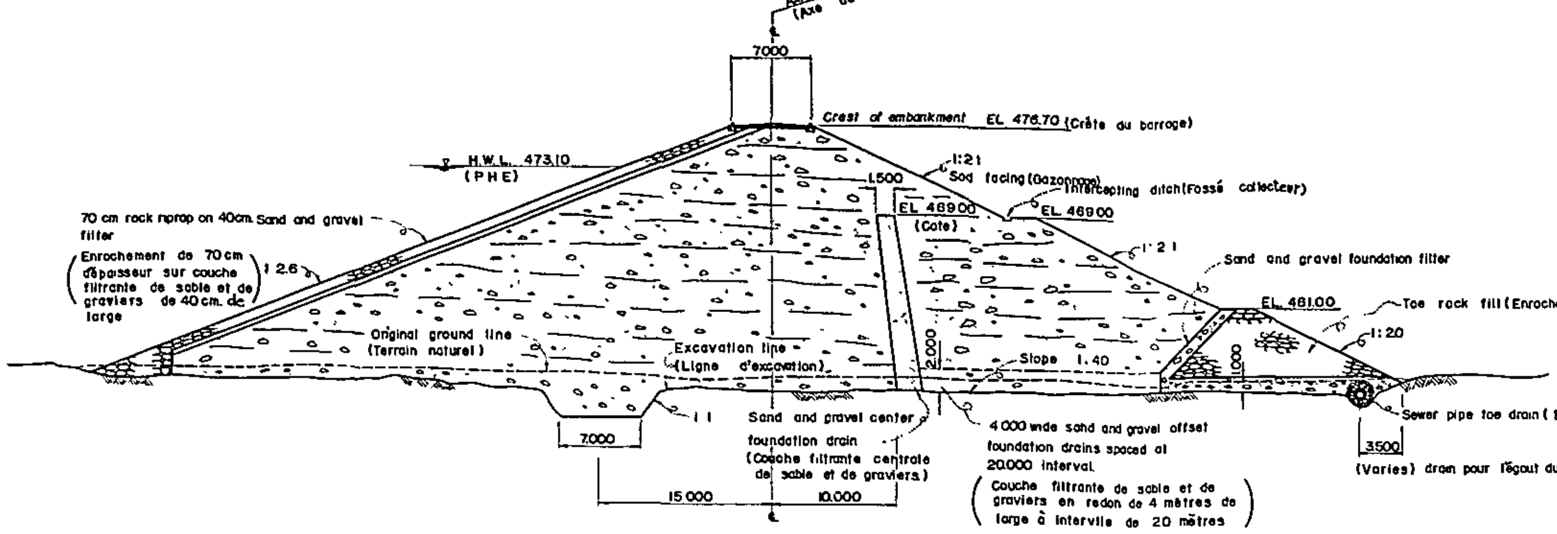
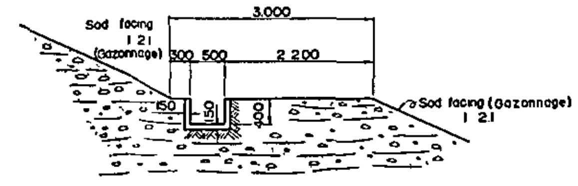
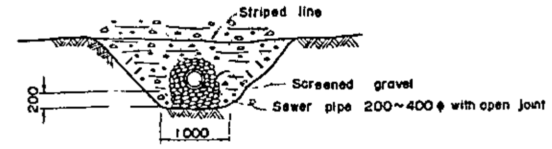


TYPICAL SECTION OF DAM EMBANKMENT
(COUPE TRANSVERSALE-TYPE DU BARRAGE)

SCALE (ECHELLE)
0 5 10 15 20 25 30m

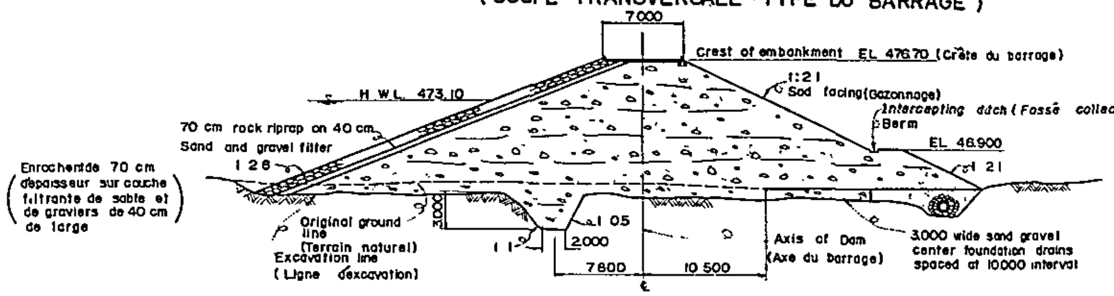


DETAIL OF INTERCEPTING DITCH
(DETAIL SUR LE FOSSE COLLECTEUR)

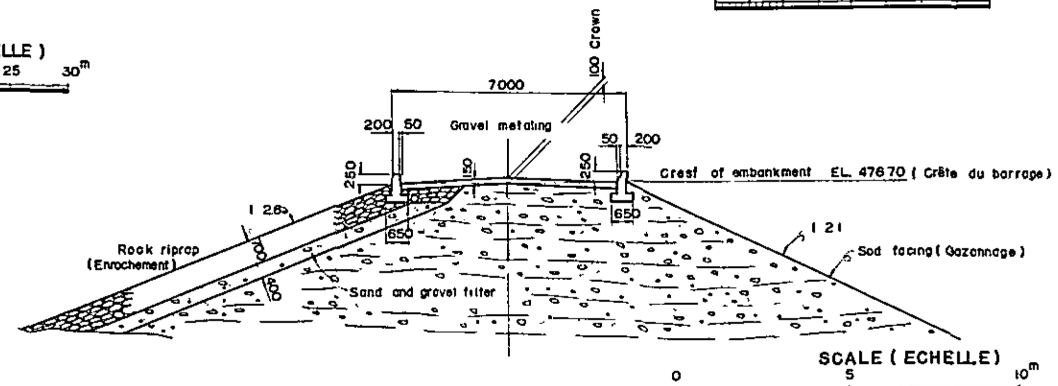


DETAIL OF TOE DRAIN
(DETAIL SUR L'EGOUT DU PIED D'AVAL)

SCALE (ECHELLE)
0 1 2 3 4m

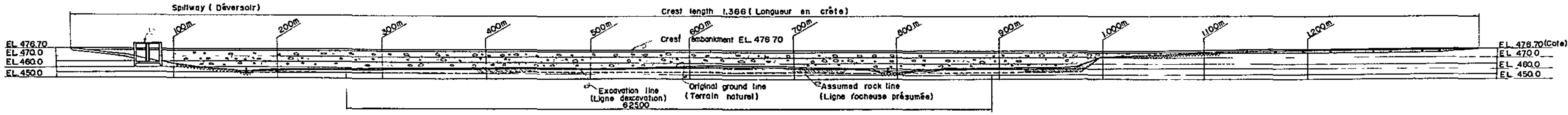


ABUTMENT SECTION OF DAM EMBANKMENT
(COUPE TRANSVERSALE DES BUTÉES)



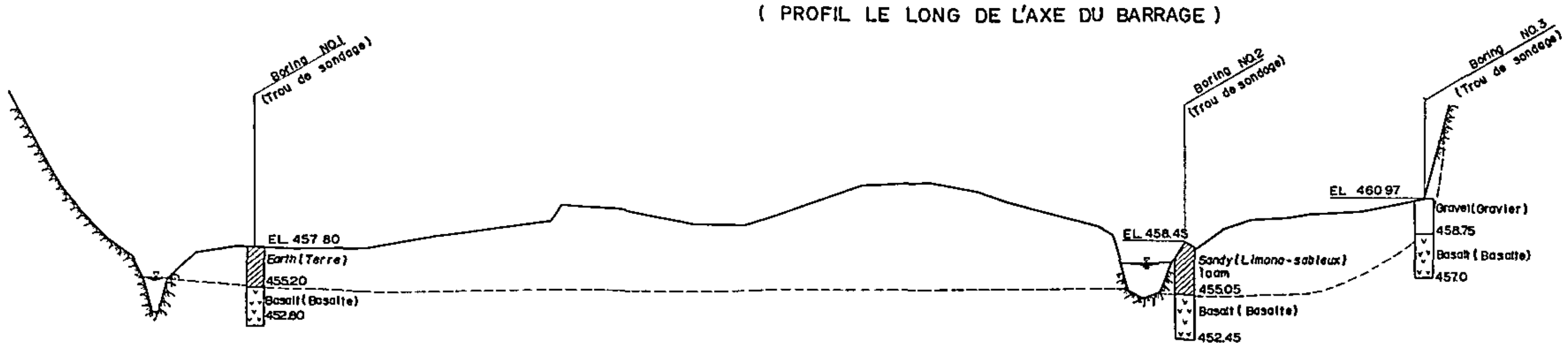
SCALE (ECHELLE)
0 5 10m

DETAIL OF CREST
(DETAIL SUR LA CRETE DU BARRAGE)



PROFILE ALONG CENTER LINE
(PROFIL LE LONG DE L'AXE DU BARRAGE)

SCALE (ECHELLE)
0 50 100m



GEOLOGICAL SECTION
(GEOLOGIE DU SITE DU BARRAGE)

OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO JAPAN	
LOWER KRONG BUK DAM EMBANKMENT TYPICAL SECTION AND PROFILE (COUPE TRANSVERSALE-TYPE ET PROFIL DU BARRAGE DU KRONG BUK INFERIEUR)	
NIPPON KOEI CO., LTD. TOKYO (CONSULTING ENGINEERS)	
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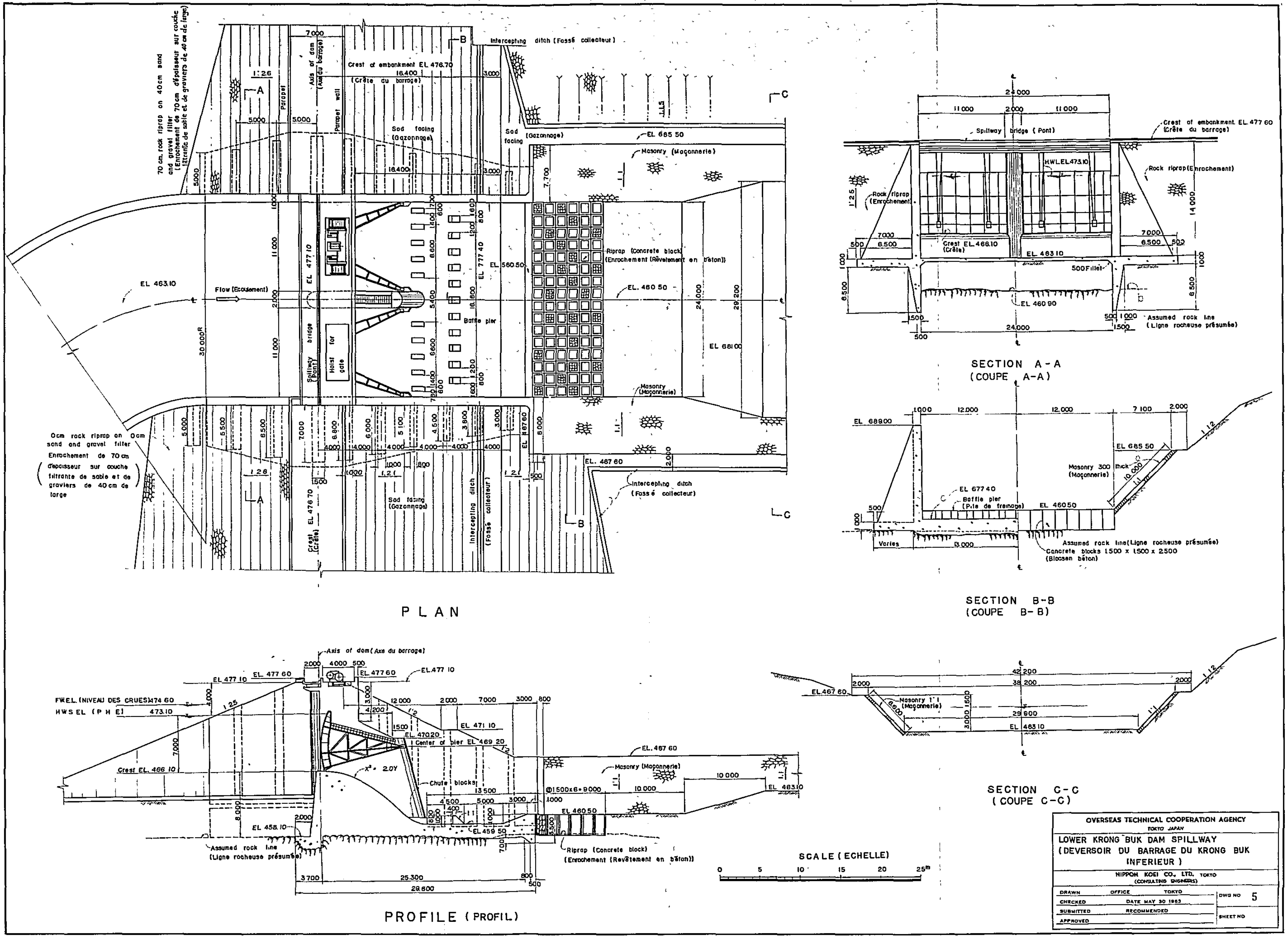
PLAN
PROFILE (PROFIL)
SECTION A-A
(COUPE A-A)
SECTION B-B
(COUPE B-B)
SECTION C-C
(COUPE C-C)
SCALE (ECHELLE)
0 5 10 15 20 25m
Crest of embankment EL 476.70
(Crête du barrage)
Axis of dam (Axe du barrage)
Parapet wall
Parapet
Intercepting ditch (Fossé collecteur)
Sod facing (Gazonnage)
EL 685 50
Masonry (Maçonnerie)
Riprap (Concrete block)
(Enrochement (Revêtement en béton))
EL. 460 50
EL 681 00
EL 463.10
Flow (Ecoulement)
Spillway bridge (Pont)
Hoist for gate
Baffle pier
EL 477 10
EL 560.50
EL 777 40
EL. 467 60
EL 467 60
70 cm rock riprap on 40 cm sand and gravel filter
(Enrochement de 70 cm d'épaisseur sur couche filtrante de sable et de graviers de 40 cm de large)
Crest EL 476.70 (Crête)
Crest of embankment EL 477 60 (Crête du barrage)
Spillway bridge (Pont)
H.W.L. EL 473.10
Rock riprap (Enrochement)
Crest EL 466.10 (Crête)
EL 463.10
500 Fillet
EL 460 90
Assumed rock line (Ligne rocheuse présumée)
EL 689.00
EL 685 50
Masonry 300 thick (Maçonnerie)
EL 677 40
Baffle pier (Pile de freinage)
EL 460.50
Assumed rock line (Ligne rocheuse présumée)
Concrete blocks 1.500 x 1.500 x 2.500 (Blocs en béton)
Varies
Masonry 1:1 (Maçonnerie)
F.W.E.L. (NIVEAU DES CRUES) 474 60
H.W.S.EL (P.H.E) 473.10
EL 477 10
EL 477 60
EL 477 10
EL 471 10
EL 470.20
Center of pier EL 469 20
Crest EL 466 10
$x^2 = 20Y$
Chute blocks
@1500x6=9000
EL 460 50
EL 459 50
EL 458.10
EL 463.10
EL 467 60
Masonry (Maçonnerie)
Assumed rock line (Ligne rocheuse présumée)
Riprap (Concrete block)
(Enrochement (Revêtement en béton))
OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN
LOWER KRONG BUK DAM SPILLWAY
(DEVERSOIR DU BARRAGE DU KRONG BUK INFERIEUR)
NIPPON KOEI CO., LTD. TOKYO
(CONSULTING ENGINEERS)
DRAWN
OFFICE TOKYO
CHECKED
DATE MAY 30 1963
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RECOMMENDED
APPROVED
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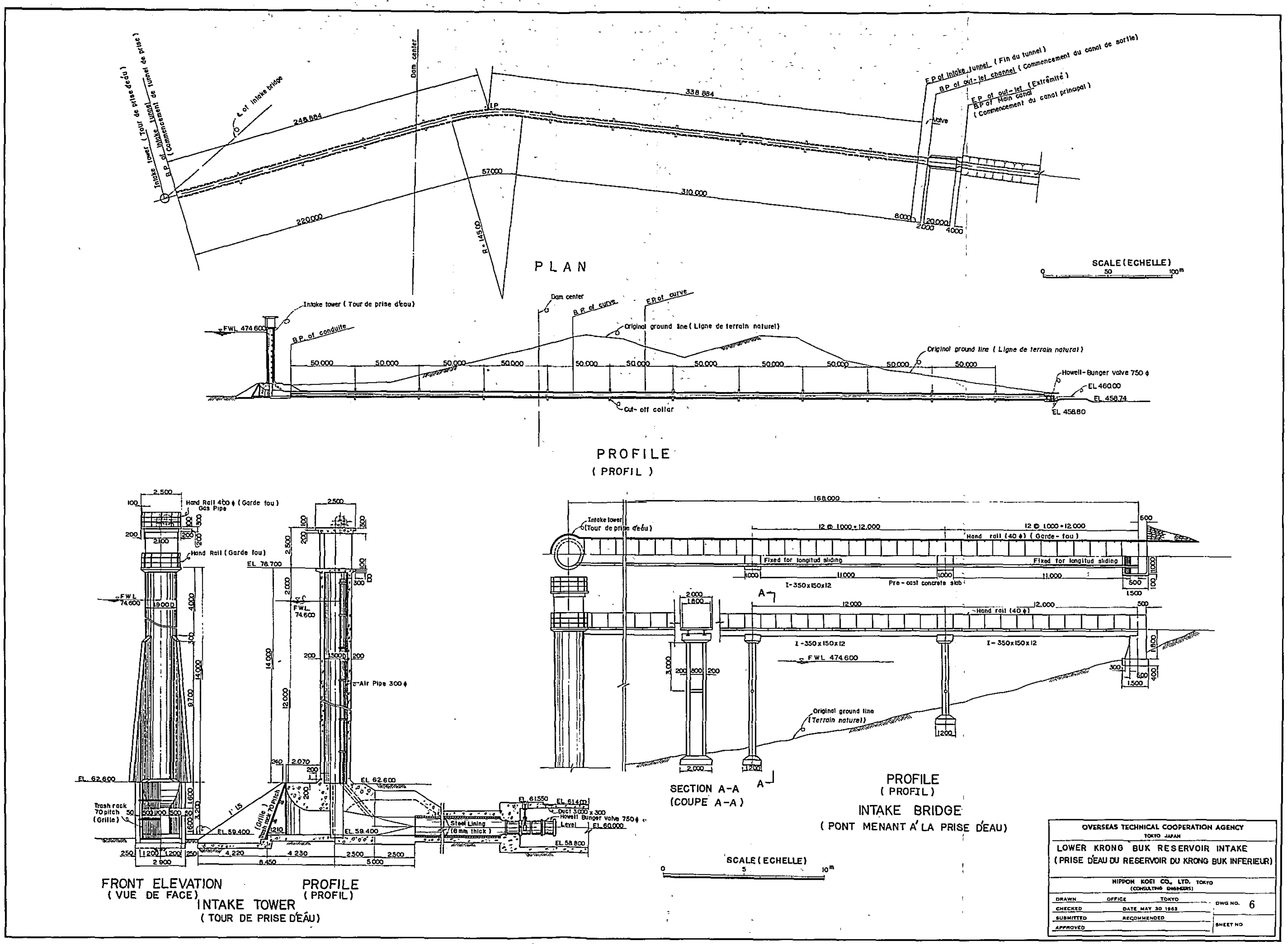
SHEET NO



OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN

LOWER KRONG BUK RESERVOIR INTAKE
(PRISE D'EAU DU RESERVOIR DU KRONG BUK INFERIEUR)

NIPPON KOEI CO., LTD. TOKYO
(CONSULTING ENGINEERS)

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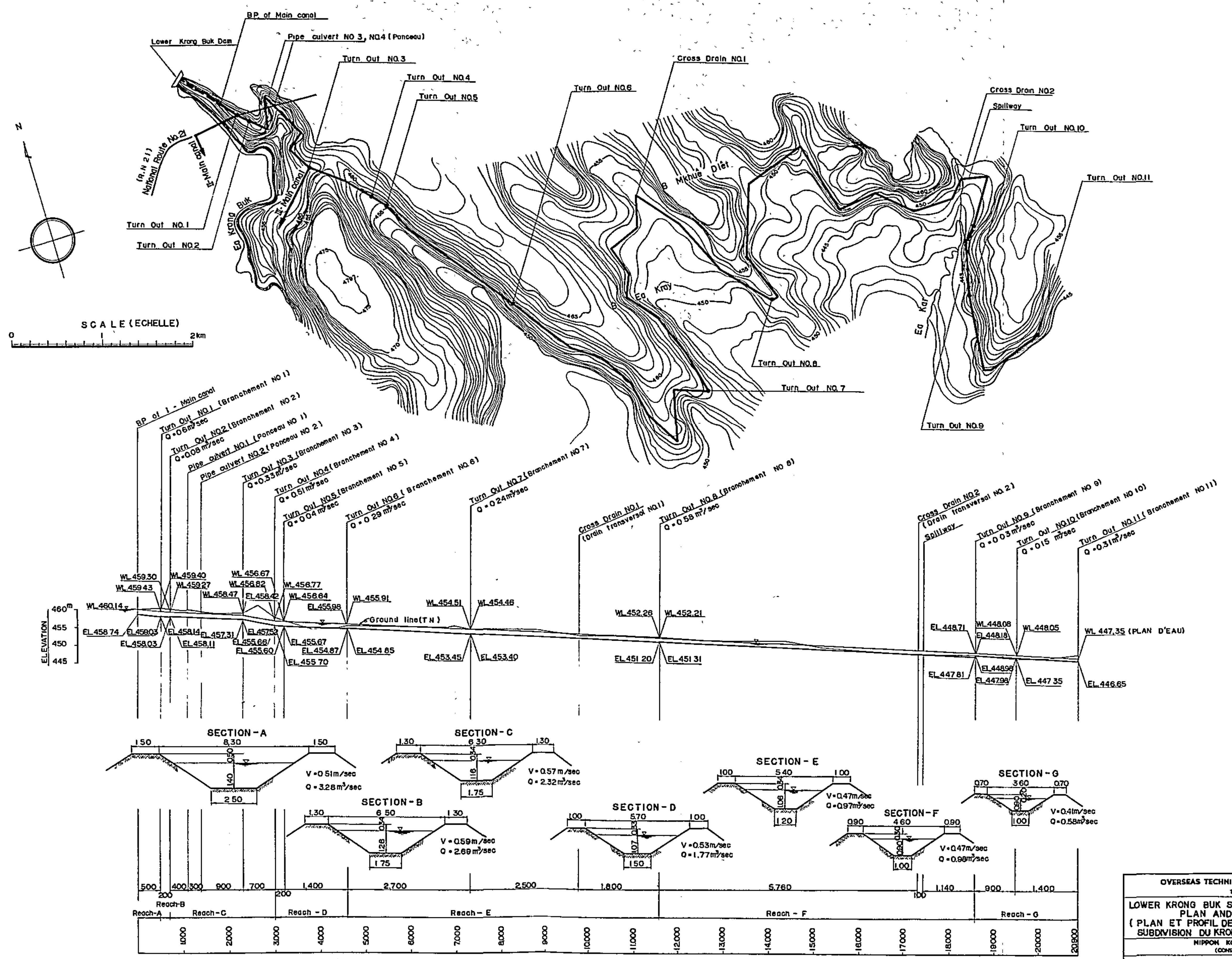

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN

LOWER KRONG BUK SUB AREA I-MAIN CANAL PLAN AND PROFILE
(PLAN ET PROFIL DE CANAL PRINCIPAL NO.1 DE LA SUBDIVISION DU KRONG BUK INFERIEUR)

NIPPON KOEI CO., LTD. TOKYO
(CONSULTING ENGINEERS)

DRAWN	OFFICE TOKYO	DWG NO	7
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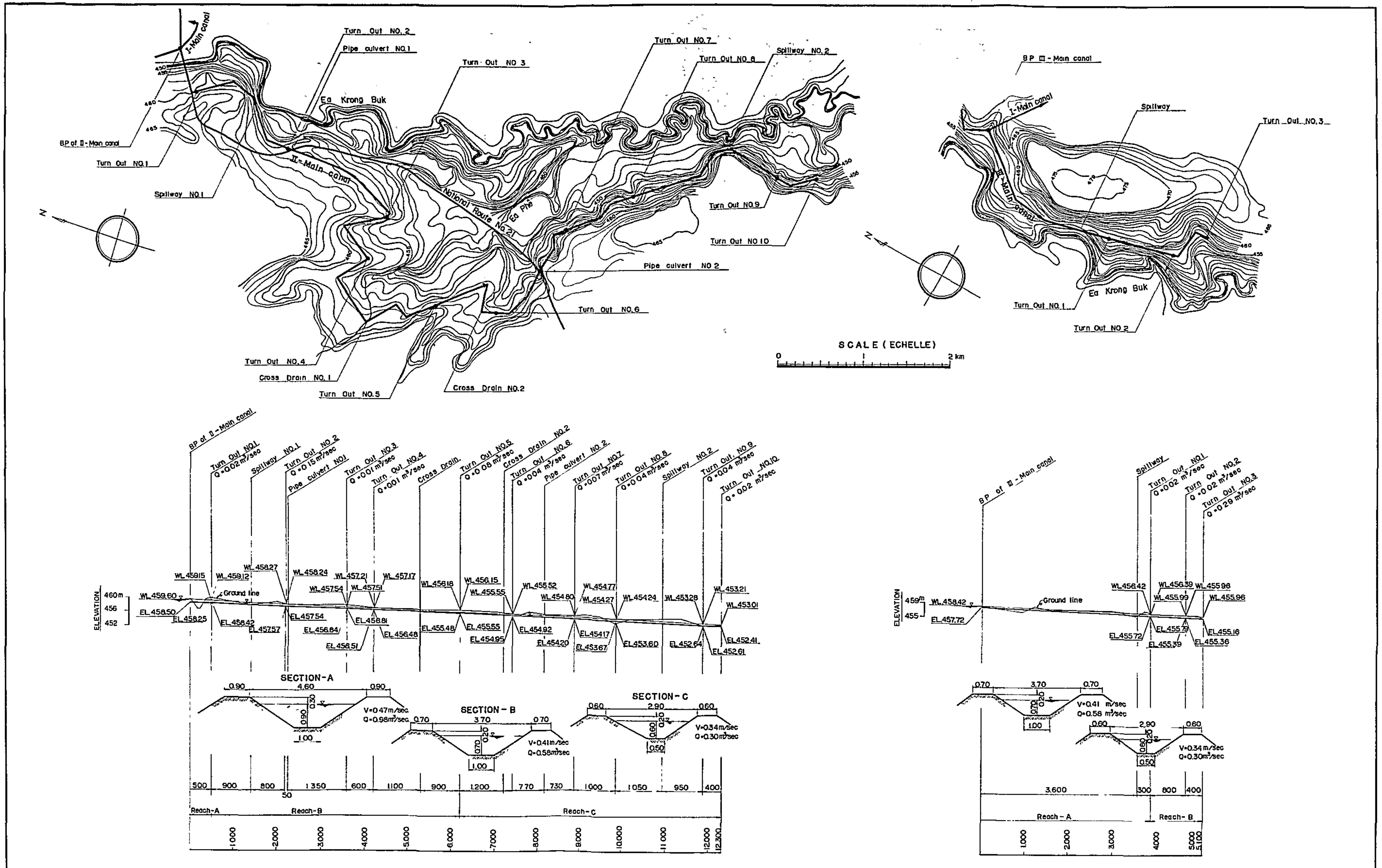
APPROVED			



OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN

LOWER KRONG BUK SUB AREA II-MAIN CANAL AND III-MAIN CANAL PLAN AND PROFILE
(PLAN ET PROFIL DES CANAUX PRINCIPAUX NO.II ET III DE LA SUBDIVISION DU KRONG BUK INFERIEUR)

NIPPON KOEI CO., LTD. TOKYO
(CONSULTING ENGINEERS)

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APPROVED			

DETAILED - RECONNAISSANCE

SOIL MAP

LOWER KRONG BUK PROJECT AREA

VIET - NAM

(CARTE SEMI-DETAILLEE DE SOL DE LA ZONE DU PROJET DU KRONG BUK INFERIEUR AU VIET NAM)

SPECIAL SYMBOLS (SYMBOLES SPECIAUX)

- National highway (Route Nationale)
- Motor road (Autoroute)
- Trail (Sentier)
- River (Rivière)
- Town or village (Ville ou village)
- Lake or pond (Lac ou étang)

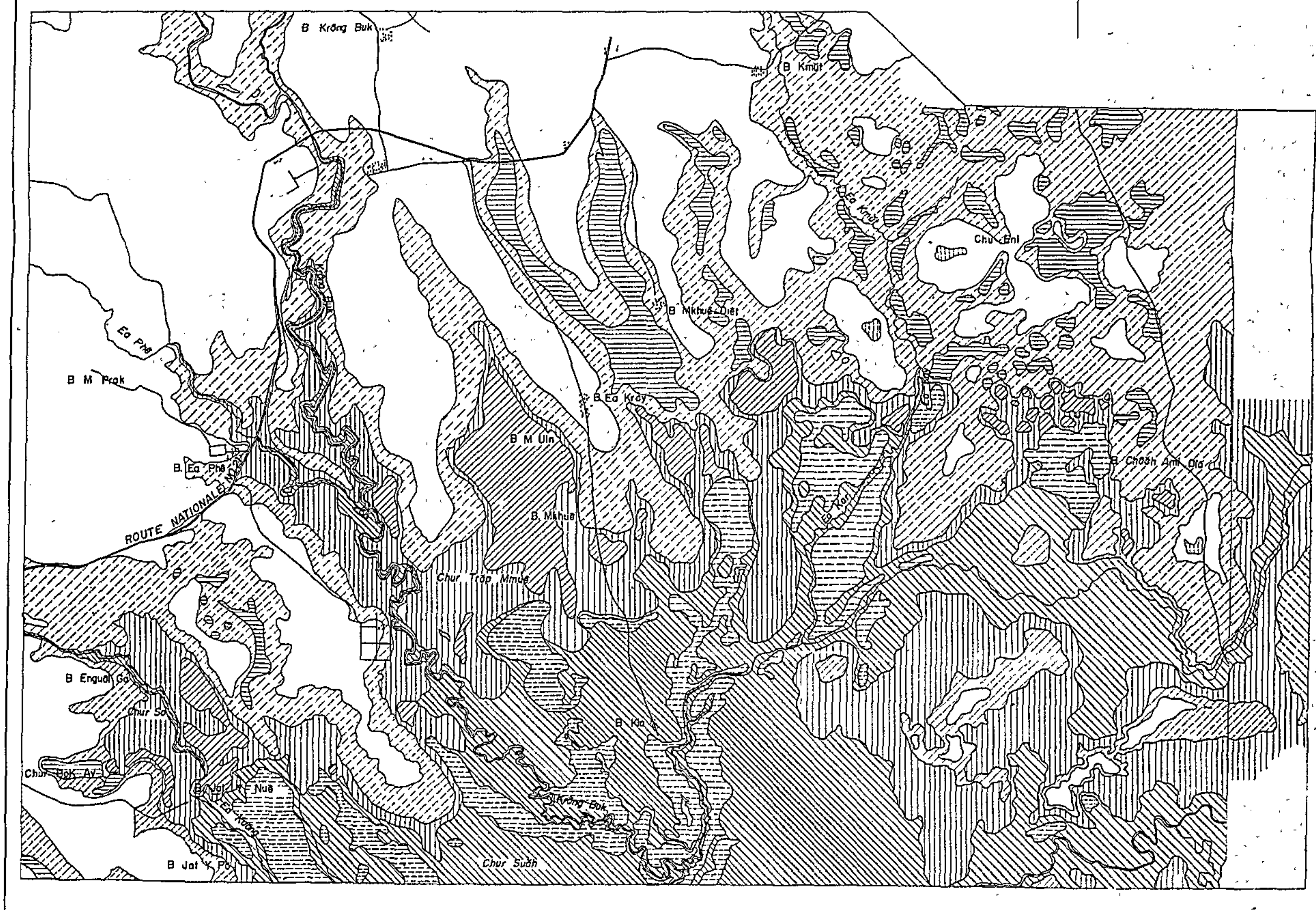
LEGEND

LEGENDE

ESSENTIAL CHARACTERISTICS OF MAIN SOIL GROUP

ESSENTIAL CARACTERISTIQUES DES PRINCIPAUX GROUPES DE SOL

MAP SYMBOL	SOIL GROUP / GROUPE DE SOLS	TOPOGRAPHY / TOPOGRAPHIE	TEXTURE / TEXTURE	REACTION (PH in H_2O) / REACTION (par pH dans H_2O)	BASIC INTAKE RATE (mm/hr) / PROPORTION DE PENETRATION DE L'EAU (mm/hr)	WATER HOLDING CAPACITY (% by volume) / CAPACITE DE RETENTION EN EAU (%)	ADAPTED IRRIGATION METHOD / Méthode adaptable à irrigation
	Undifferentiated recent alluvial soils / Récents sols alluviaux non-différenciés	Nearly flat to gently sloping / Presque plat à en pente douce	Clay loam or sandy clay loam / Limono-argileuse, ou limono-argilo-sableuse	5.5 - 6.0	5 - 30	20 - 24	Strip border method. Downhill furrow method. Irrigation par calants; Irrigation par ruissellement à rigoles perpendiculaires aux courbes de niveau.
	Humic gley recent alluvial soils / Récents sols alluviaux à gley humique	Nearly flat / Presque plat	Light clay or heavy clay / Argileuse lourde ou argileuse légère.	5.8 - 6.2	5 - 10	22 - 25	Strip border method. Downhill furrow method. Irrigation par calants; Irrigation par ruissellement à rigoles perpendiculaires aux courbes de niveau.
	Gray podzolic ancient alluvial soils / Anciens sols alluviaux gris podzoliques	Gently sloping to undulating / Pente douce à ondulée	Fine sandy loam or silt loam / Limono-sableuse fine ou limono-silteuse.	5.0 - 5.4	30 - 100	15 - 20	Contour furrow method. Sprinkler method. Irrigation par ruissellement à rigoles parallèles aux courbes de niveau. Irrigation par aspersion.
	Low humic gley ancient alluvial soils / Anciens sols alluviaux à gley peu humiques.	Gently sloping / En pente douce	Sandy clay or silty clay / Argilo-sableuse ou argilo-silteuse	4.8 - 5.4	10 - 30	20 - 24	Do. - Id -
	Yellowish brown basaltic latosols / Latosol basaltique brun-jaunâtre	Undulating to rolling / Ondulé à mamelonné	Silty clay loam or sandy clay / Limono-argilo-silteuse ou argilo-sableuse	4.5 - 5.0	40 - 120	18 - 22	Contour furrow methods. Sprinkler methods. Contour ditch methods. Irrigation par ruissellement à rigoles parallèles aux courbes de niveau; Irrigation par ruissellement à fossés d'irrigation parallèles aux courbes de niveau; Irrigation par aspersion.
	Dark brown gley basaltic latosols / Latosol basaltique brun foncé à gley.	Gently sloping / En pente douce	Sandy clay or silty clay / Argilo-sableuse ou argilo-silteuse	4.4 - 5.2	20 - 50	20 - 24	Do. - Id -
	Reddish brown basaltic latosols / Latosol basaltique brun-rougeâtre.	Undulating to rolling / Ondulé à mamelonné	Light clay or silty clay / Argileuse légère ou argilo-silteuse	4.5 - 5.0	50 - 130	20 - 24	Do. - Id -
	Red and yellow podzolic soils / Sols rouges et jaunes podzoliques	Rolling to steep sloping / Accidenté à pentes raides	Fine sandy loam or coarse sandy loam / Limono-sableuse fine ou limono-sableuse grossière	4.0 - 4.5	60 - 150	15 - 18	Do. - Id -
	Complex of lithosols / Complexe de lithosols	Steep sloping / A pentes raides	Fine sandy loam or loam / Limono-sableuse fine ou limoneuse	4.0 - 4.5	—	—	—



SCALE 1 20,000

MILE 1 0 1 MILE

METERS 1000 0 1000 2000 3000 METERS

FORM LINE INTERVAL 1 METER

OVERSEAS TECHNICAL COOPERATION AGENCY
TOKYO JAPAN

SOIL MAP

LOWER KRONG BUK PROJECT AREA

NIPPON KOEI CO., LTD. TOKYO
CONSULTING ENGINEERS

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