APPENDIX B

SABO DAM PLAN

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SABO DAM PLAN

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CHAPTER I PRESENT LAND USE IN PROPOSED SEDIMENTATION BASIN

1.1 Summary of Present Land Use

The riverbed within the sedimentation basin will gradually rise according to the progress of sedimentation of the sabo dams after their construction. The residential houses and cultivated lands existing within the area of the proposed sedimentation basins shall be acquired or compensated prior to the construction of the sabo dams. The present land use in the proposed sedimentation basins were clarified through the field reconnaissance.

The present land use in the proposed sedimentation basins are summarized as shown in the following table.

Dam Site	Present Land Use
Cura No.1	Paddy (A=0.40 Ha)
Labugaon No.1	Naught
Solsona No.1	Paddy (at the site of dam wing)
Madongan	Naught
Papa	Paddy (A=0.75 Ha), Upland (A=0.24 Ha)

More than 10 families are living in the upstream valleys of the sabo dams. However, their houses will not be affected by the sabo dam construction since they are located at higher places.

For location of the above-mentioned cultivated lands and residences, see Fig. B.1.1.

Further, some families of ethnic minority are living in the upstream valleys of the sabo dams. Their residences and cultivated lands are also located at higher sites. Hence, the proposed sabo dams will have no adverse effects on them.

1.2 Present Land Use in Each Sedimentation Basin

1.2.1 Cura No.1 Sabo Dam

One (1) family of two (2) persons are residing in the upstream valley of the proposed No.1 sabo dam. Their house is located on the foot of the mountain 830 m upstream of the sabo dam and its elevation is about 25 m higher than the existing riverbed. However, their cultivated land of about 0.40 ha is likely to be affected by the proposed project.

Another two (2) cultivated lands were identified in the upper section of the sedimentation basin. These lands will not be affected by the project since they are both higher in elevation than the present riverbed.

1.2.2 Labugaon No.1 Sabo Dam

Ten (10) families are living in the upstream area of the proposed No.1 sabo dam. Among them, three (3) families are residing along the planned sedimentation basin as shown in Fig. B.1.1(1). Two (2) families out of the three (3) are Kalingas. Their houses and cultivated lands are situated on the flood terraces which are more than 5 m higher than the riverbed in the upstream end of the sedimentation basin. Therefore, their lands and properties will not be affected by the project.

1.2.3 Solsona No.1 Sabo Dam

One (1) family of three (3) persons is living in the upstream area of the proposed No.1 sabo dam. Their house, however, is located more than 1 km upstream of the end of the sedimentation basin.

The flood terrace is well-developed on both sides of the proposed dam site. The elevation of the terrace is more than 10 m higher than the riverbed. Therefore, the terrace will not be flooded or buried by sediments. However, the wings of the proposed sabo dam will be constructed on both sides of the terrace with the left bank being utilized as paddy. Some land acquisition in the terrace will be necessary for the construction of the wings.

1.2.4 Madongan Sabo Dam

No residents were identified in the upstream areas of the proposed sabo dam. Further, there are no cultivated lands along the planned sedimentation basin.

1.2.5 Papa Sabo Dam

No people are living in the upstream areas of the proposed sabo dam. Two (2) lots of cultivated land are located about 650 m upstream of the sabo dam as shown in Fig. B.1.1(2). One is upland and another is paddy. Both lands are cultivated by tenant farmers. These lots of 1 ha in total will be affected by the project.

CHAPTER II DESIGN CRITERIA

2.1 Basic Design Conditions

The following are the basic conditions for design such as the location from existing irrigation diversion dams/intake, design crest elevation, sedimentation slopes, present river widths, present lowest riverbed elevations, thickness of river deposits on rock base, and maximum height from rock base to dam crest of the five (5) objective sabo dams, respectively.

Sabo Dam	Location from Intake (m)	Dam Crest EL. (m)	Design Discharge (m^3/s)*	Riverbed Width (m)	Lowest River Bed EL. (m)	Thickness of River Deposits (m)	Max. Height (m)
Cura No. 1	400	118.0	1,080	150	109.5	2 - 13	15
Labugaon No. 1	250	125.0	1,580	100	114.7	1 - 7	16
Solsona No.1	2,100	143.0	1,140	25	133.0	1 - 2	11
Madongan Dam	180	133.0	2,390	120	125.5	26 - 37	46
Papa	160	145.5	820	210	139.0	3 - 8	16

* : 100-year return period

2.2 Dam Type

A gravity type structure made of stone concrete is proposed as a type of sabo dam considering the necessary height of sabo dams, geological condition, availability of construction material and volume of design discharges.

(1) Foundation

As discussed in detail in Section 3.1 afterward, the geological structures of the objective sabo dam sites consist of two (2) layers; river deposits and rock. Both of these layers are considered to have a sufficient bearing capacity suitable for the construction of gravity type sabo dams.

(2) Construction materials

Sand, gravel and boulders can be easily and plentifully obtained nearby the construction sites. Therefore, sabo dams are designed to be constructed of stone concrete to save construction cost.

(3) Design Discharge

Since the design discharges flowing on the sabo dam are relatively large, sabo dams are almost required full widths of dams for overflow, Therefore, a gravity dam is preferable.

2.3 Structural Design Criteria

Structural design criteria adopted in Japan is applied to the preliminary design of sabo dam because no available design criteria in the Philippines.

(1) Structural Component

Generally, a typical sabo dam consists of the main dam, apron, sub-dam and side walls. Apron and sidewall are provided to protect scouring/erosion of riverbed/banks by falling water from dam crest. Apron is necessary for a floating type sabo dam which bases on the river deposits consisting of sand, gravel and boulder. A sabo dam based on the rock foundation may not need the apron. Sidewall is not necessary because rocks expose at all banks of objective rivers.

(2) Design Discharge

Discharge with a 100-year return period is applied. Moreover, ten (10) % of design discharge is added to the design discharge as the sediment runoff.

(3) Slopes of Dam Body

Downstream side slope of sabo dam is 1 (horizontal) to 0.2 (vertical) to avoid the damage to the dam body by sediment runoff.

Upstream side slope is determined by the calculation of structural stability.

(4) Freeboard of Channel on Sabo Dam

A freeboard of 1.0 m shall be added on the design high water level at the overflow section of sabo dam.

(5) Crown Width

A width of 2.5 m is adopted considering the amount of floating grave and boulders.

(6) Location of Sub-dam

The distance from main dam to sub-dam is determined by the equation derived from the construction experiences of sabo dams in Japan.

CHAPTER III PRELIMINARY DESIGN

3.1 Geological Conditions of Dam Sites

Two geological investigations were carried out in/around the proposed sabo dam sites; one in the Detailed Design on INIP Phase I (1981) and the other in this JICA Study (1997).

Locally two (2) types of Igneous rocks may be expected entirely in the proposed sabo dam sites. These are the diorite (intrusive) and volcanic rock unit consists mainly of andesite and basalt with minor agglomerates.

The diorite is generally massive on wall exposures but sometimes hydrothemally altered when exposed to river water. It is generally fractured and sheared but often times exhibits tightness due to filling of secondary minerals. Sometimes, the diorite interfingers with the volcanics.

The volcanics are oftentimes fractured and sheeted and weathering leaves few meters of silty soil. The basalt is differentiated from the andesite by virtue of the darker color the former exhibits. Likewise, the basalt is fine-grained in textures and fresh surface often times exhibit velvety textures.

(1) Geological Investigation of INIP-I

The "Detailed Design on INIP Phase I (1981) performed fourteen (14) core borings in total at five (5) irrigation diversion dams (2 at Labugaoan, 4 at Solsona, 4 at Madongan, and 4 at Papa).

This investigation revealed that these diversion dam sites have two geological layers consisting of river deposits and bed rock. River deposits are mainly composed of sand, gravel and boulder. They are slightly loose, but no soft deposits such as clay and silt are observed. Gravel of the river deposits mainly consists of diorite and andesite, and the matrices are composed of medium to coarse sand. Boulders having a maximum diameter of 1.5 m almost consists of diorite. The maximum thickness of river deposits range from 3 m to 20 m, i.e., 9 m at Labugaon Diversion Dam site, 3 m at Solsona, 16 m at Madongan, and 6 m at Papa.

Fig. B.3.1 shows the results of geological investigation by drilling of INIP-I.

(2) Geological Investigation of JICA Study

JICA geological investigation for five (5) sabo dam sites was carried out by means of Electric Resistivity Method conducted during second field study in 1997. The results of investigation are shown in Fig. B.3.2.

Available borehole logs of INIP-I geological investigation were correlated to formulate the characteristics of the subsurface layers.

The maximum thickness of river deposits ranges from 1 m to 37 m on the proposed 5 sabo dams, as summarized in Section 1.1 above.

It is desirable to design the sabo dam on the rock foundation from the point of structural stability. However, in case the river deposits are deep and its bearing capacity is sufficient, the dam can be designed as a floating structure on the river deposit.

3.2 Cura No.1 Sabo Dam

Thickness of river deposits ranges from 2 m to 13 m and 6 m on an average. Therefore, two types of dam foundation, floating on the river deposits and fixed on the rock, are economically compared as follows (see Fig. B.3.3 for fixed foundation type and Fig. B.3.4 for floating type; designs of two dam types).

Foundation Type	Dam Height (m)	Necessity of Apron	Dam Volume in Total (m^3)	River Deposits Excavation Volume (m^3)	Rock Excavation Volume (m^3)	Construction Cost (million pesos)
Floating	9	Yes	15,100	30,400	1,900	46
Fixed	9 - 17	No	31,700	56,800	13,300	101

Hence, floating type foundation is employed for the design of Cura No.1 sabo dam.

Designs of sabo dam is shown in Fig. B.3.4. Major dimensions are also summarized below and details are shown in Table B.3.1.

Component	Dam Crest EL. /Apron Top EL. (m)	Dam Height /Apron Thickness (m)	Dam Crest Length /Apron Length (m)	Stone Concrete Volume (m^3)
Main Dam	118.0	9.0	183.0	9,300
Apron	110.2	1.2	22.0	3,300
Sub-dam	112.0	4.0	173.0	2,500
Total				15,100

Both abutments of sabo dam is embedded in the exposed rock.

A paddy field (0.4 ha) is necessary for construction of sabo dam. However, no house resettlement is required.

3.3 Labugaon No.1 Sabo Dam

Thickness of river deposits ranges from 1 m to 7 m and 3 m on an average. In case the dam is designed as floating type, the foundation is embedded about 2 m or more in the river deposits. Therefore, the dam is designed on the rock base.

Designs of Sabo Dam is shown in Fig. B.3.5. Major dimensions are also summarized below and details are shown in Table B.3.1.

Component	Dam Crest EL. /Apron Top EL. (m)	Dam Height /Apron Thickness (m)	Dam Crest Length /Apron Length (m)	Stone Concrete Volume (m^3)
Main Dam	125.0	17.0	118.0	14,100
Apron	-	-	-	-
Sub-dam	115.5	7.5	107.0	2,800
Total				16,900

Both abutments of sabo dam is embedded in the exposed rock. Foundation rock is weathered diorite. Therefore, it may be necessary to reinforce the foundation rock by consolidation grout and prevent permeable water by curtain grout.

No land acquisition and house resettlement are necessary for construction of sabo dam.

3.4 Solsona No.1 Sabo Dam

Thickness of river deposits ranges from 1 m to 2 m and 1 m on an average. Therefore, the dam is proposed to be fixed on the rock.

Designs of the dam is shown in Fig. B.3.6. Major dimensions are also summarized below and details are shown in Table B.3.1.

Component	Dam Crest EL. /Apron Top EL. (m)	Dam Height /Apron Thickness (m)	Dam Crest Length /Apron Length (m)	Stone Concrete Volume (m^3)
Main Dam	143.0	12.0	118.0	4,500
Apron	-	-	-	-
Sub-dam	135.0	4.0	50.0	700
Total				5,200

Both abutments of sabo dam is embedded in the exposed rock.

Land acquisition of a small paddy field/bush area (0.1 ha) on the left and right side abutments is necessary for construction of sabo dam. However, no house resettlement is required.

3.5 Madongan Sabo Dam

Thickness of river deposits ranges from 26 m to 37 m and 32 m on an average. Therefore, Madongan Sabo Dam is designed as floating type from the economical viewpoint.

Designs of Sabo Dam is shown in Fig. B.3.7. Major dimensions are also summarized below and details are shown in Table B.3.1.

Component	Dam Crest EL. /Apron Top EL. (m)	Dam Height /Apron Thickness (m)	Dam Crest Length /Apron Length (m)	Stone Concrete Volume (m^3)
Main Dam	133.0	10.5	183.0	12,100
Apron	125.7	2.2	25.0	3,100
Sub-dam	126.0	4.5	157.0	5,600
Total				20,800

Both abutments of sabo dam is embedded in the exposed rock.

No land acquisition and house resettlement are necessary for construction of sabo dam.

3.6 Papa Sabo Dam

Thickness of river deposits ranges from 3 m to 8 m and 5 m on an average. Therefore, dam foundation types are also compared as follows (see Fig. B.3.8 for fixed foundation type and Fig. B.3.9 for floating type).

Foundation Type	Dam Height (m)	Necessity of Apron	Dam Volume in Total (m^3)	River Deposits Excavation Volume (m^3)	Rock Excavation Volume (m^3)	Construction Cost (million pesos)
Floating	9	Yes	16,900	20,600	3,100	51
Fixed	10 - 17	No	34,800	52,400	11,000	108

Designs of Sabo Dam is shown in Fig. B.3.9. Major dimensions are also summarized below and details are shown in Table B.3.1.

Component	Dam Crest EL. /Apron Top EL. (m)	Dam Height /Apron Thickness (m)	Dam Crest Length /Apron Length (m)	Stone Concrete Volume (m^3)
Main Dam	145.5	9.0	233.0	11,900
Apron	137.5	1.0	16.0	2,600
Sub-dam	139.0	3.5	223.0	2,400
Total				16,900

Both abutments of sabo dam is embedded in the exposed rock.

Land acquisition of a paddy field (0.75 ha) and upland (0.24 ha) is necessary for construction of sabo dam. However, no house resettlement is required.

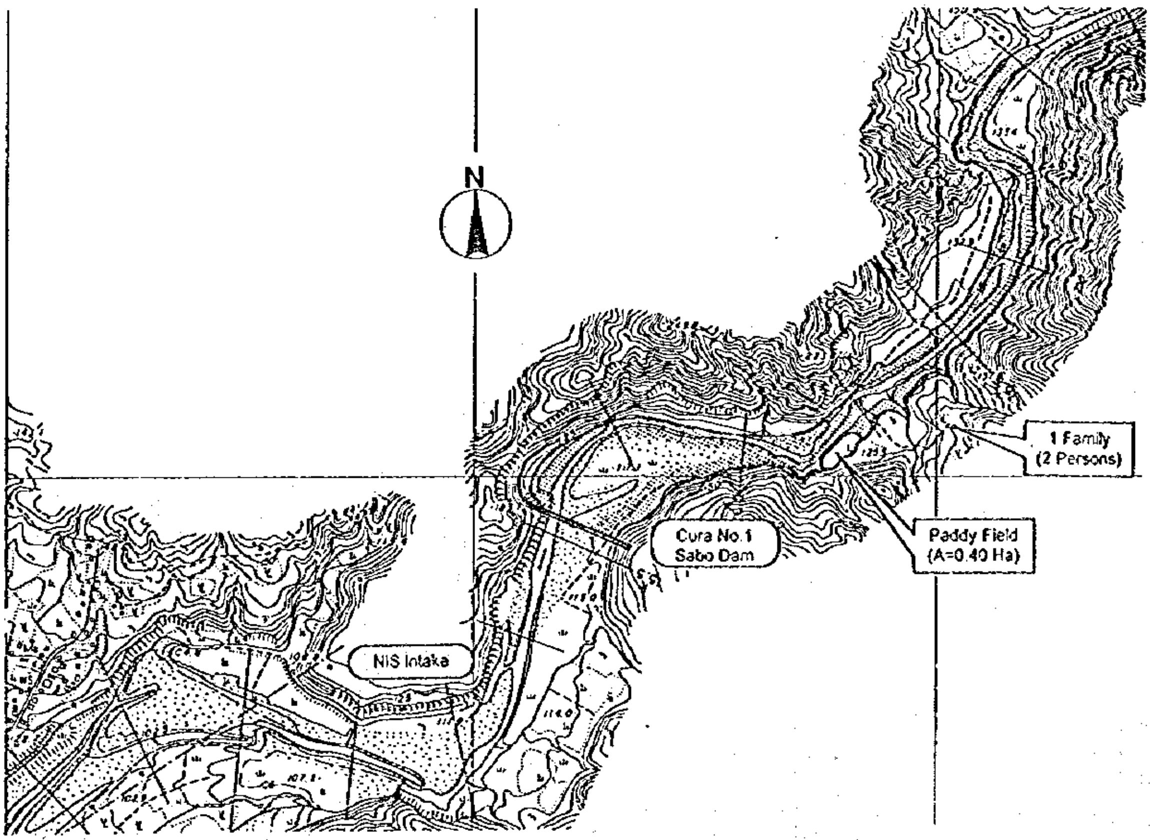
TABLES

Table B.3.1 Principal Features of Proposed Sabo Dams

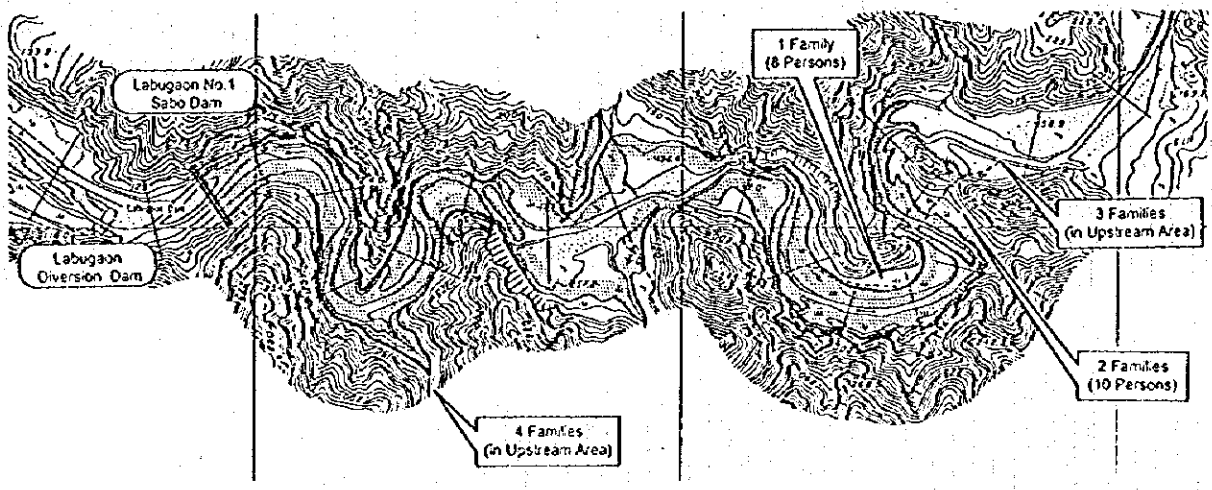
Dam	Foundation Type	Main Dam Crest EL. (m)	Main Dam Height (m)	Main Dam Crest Width (m)	Main Dam Slope (Downstream) (1.0 : m)	Main Dam Slope (Upstream) (1.0 : m)	Main Dam Crest Length (m)	Apron Length* (m)	Apron Thickness (m)	Sub-dam Crest EL. (m)	Sub-dam Height (m)	Sub-dam Crest Width (m)	Sub-dam Crest Length (m)	Stone Concrete Volume (m3) Main Dam	Stone Concrete Volume (m3) Sub-da	Stone Concrete Volume (m3) Apron	Stone Concrete Volume (m3) Total	Hydraulic Condition Design Discharge (m3/s)	Hydraulic Condition Overflow Depth (m)	Hydraulic Condition Overflow Width (m)
Cura No.1	Floating	118.0	9.0	2.5	0.2	0.60	183	22	1.2	112.0	4.0	2.5	173	9,300	2,500	3,300	15,100	1,080	2.8	150
Labugaon No.1	Fixed	125.0	17.0	2.5	0.2	0.80	118	30	-	115.5	7.5	2.5	107	14,100	2,800	-	16,900	1,580	4.9	90
Solsona No.1	Fixed	143.0	12.0	2.5	0.2	0.75	118	30	-	135.0	4.0	2.5	50	4,500	700	-	5,200	1,140	7.8	30
Madongan	Floating	133.0	10.5	2.5	0.2	0.75	183	25	2.2	126.0	4.5	2.5	157	12,100	3,100	5,600	20,800	2,390	6.0	100
Papa	Floating	145.5	9.0	2.5	0.2	0.55	233	16	1.0	139.0	3.5	2.5	223	11,900	2,400	2,600	16,900	820	1.9	200
																Total	74,900			

* : Distance from Main Dam to Sub-dam.

FIGURES



CURA NO.1 SABO DAM



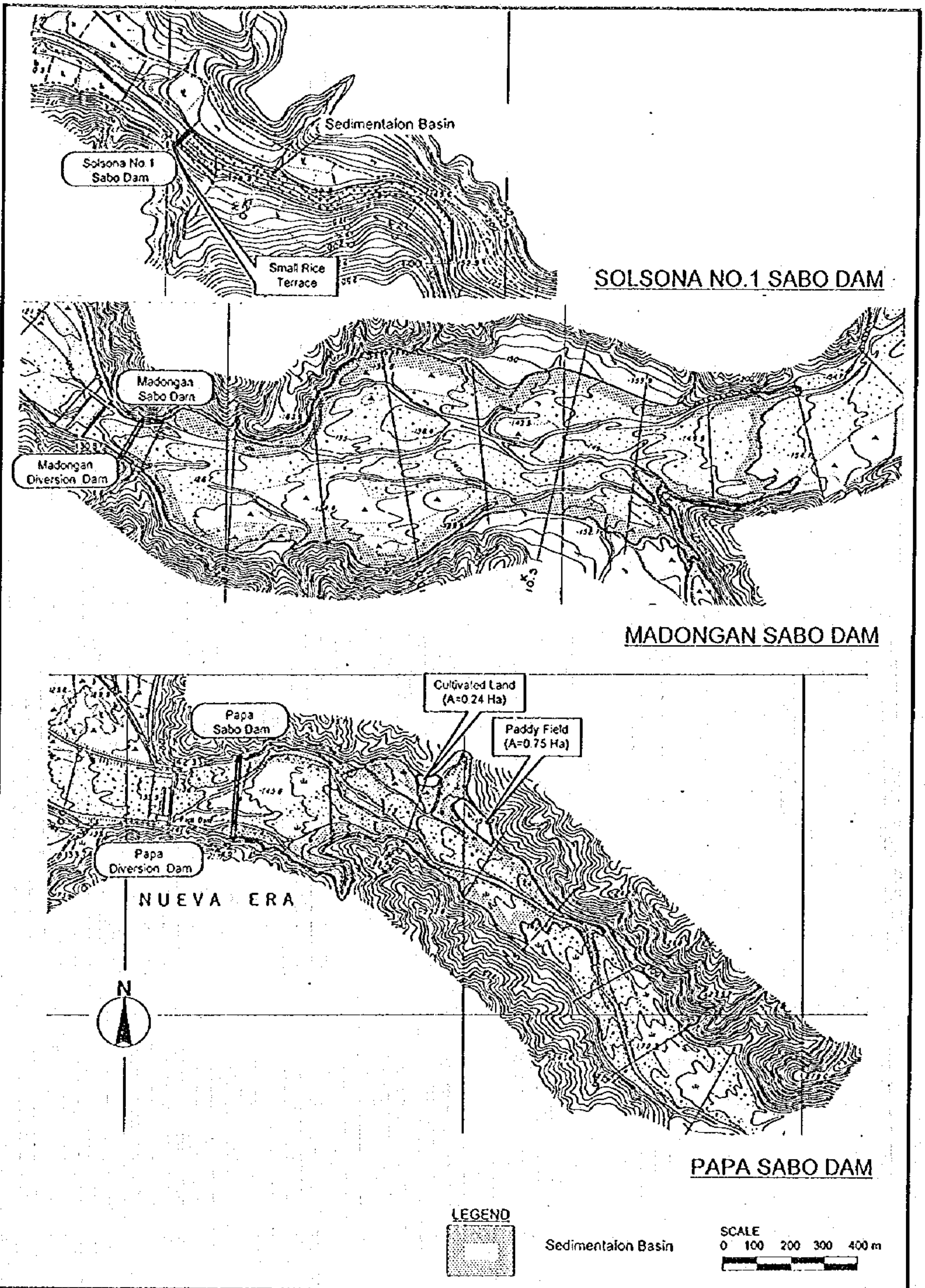
LABUGAON NO.1 SABO DAM

LEGEND

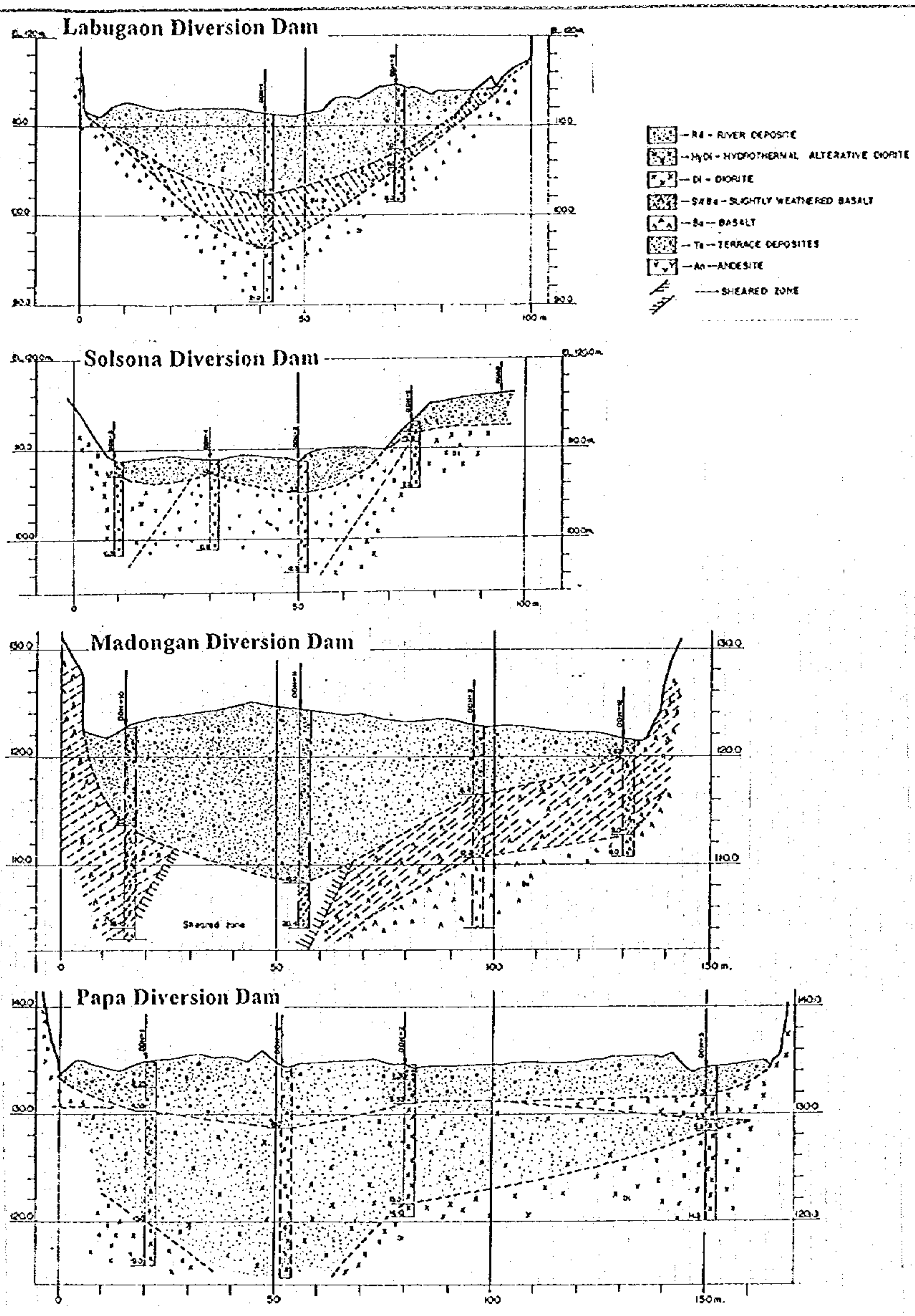
Sedimentaion Basin

SCALE
0 100 200 300 400 m

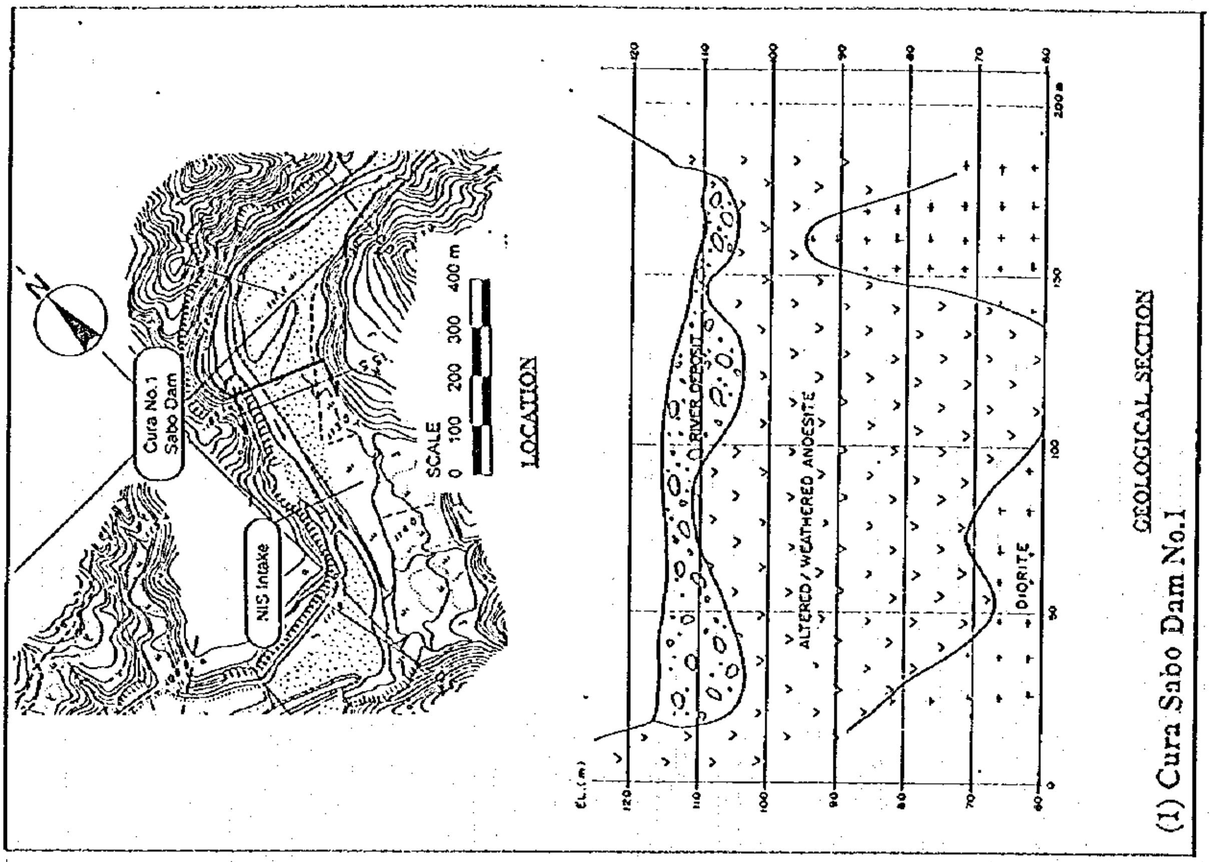
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. B.1.1 (1) Present Land Use in Proposed Sedimentation Basin (Cura, Labugaon)

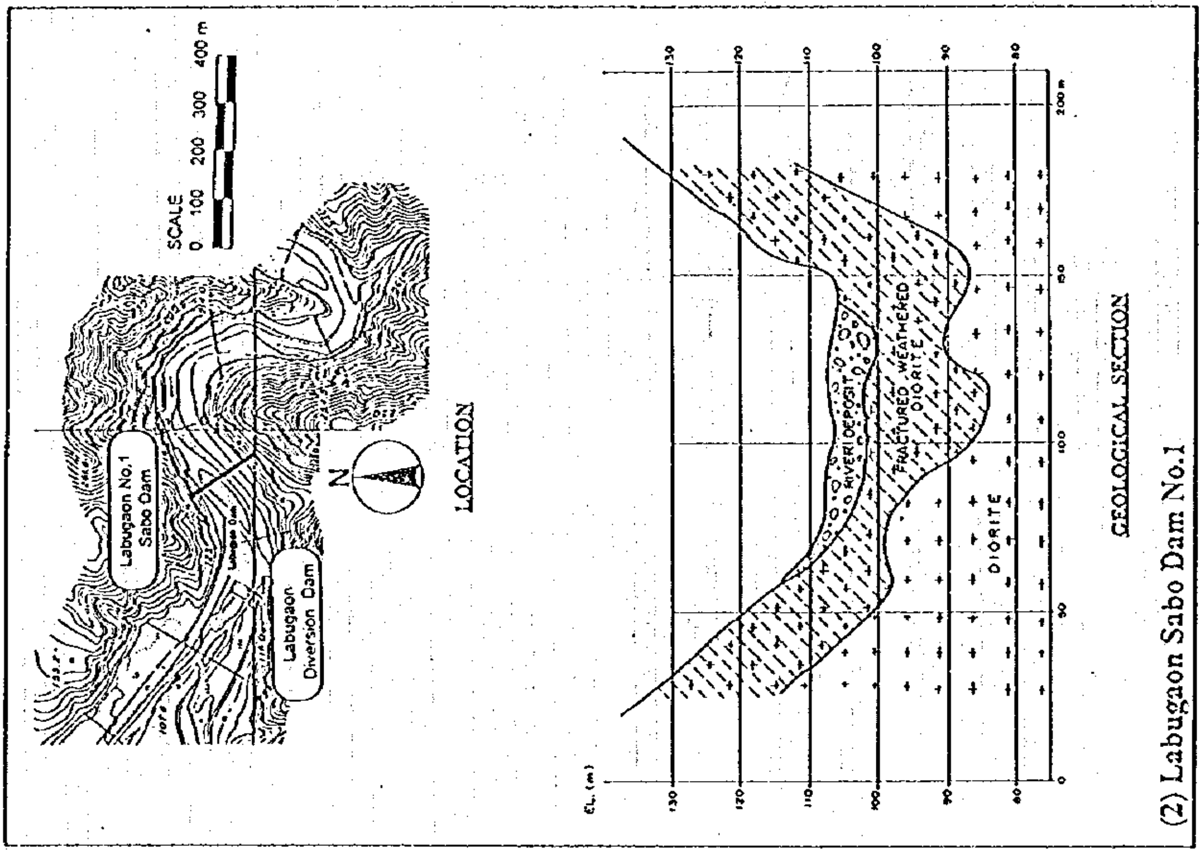


THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. B.1.1 (2) Present Land Use in Proposed Sedimentation Basin (Solsona, Madongan, Papa)

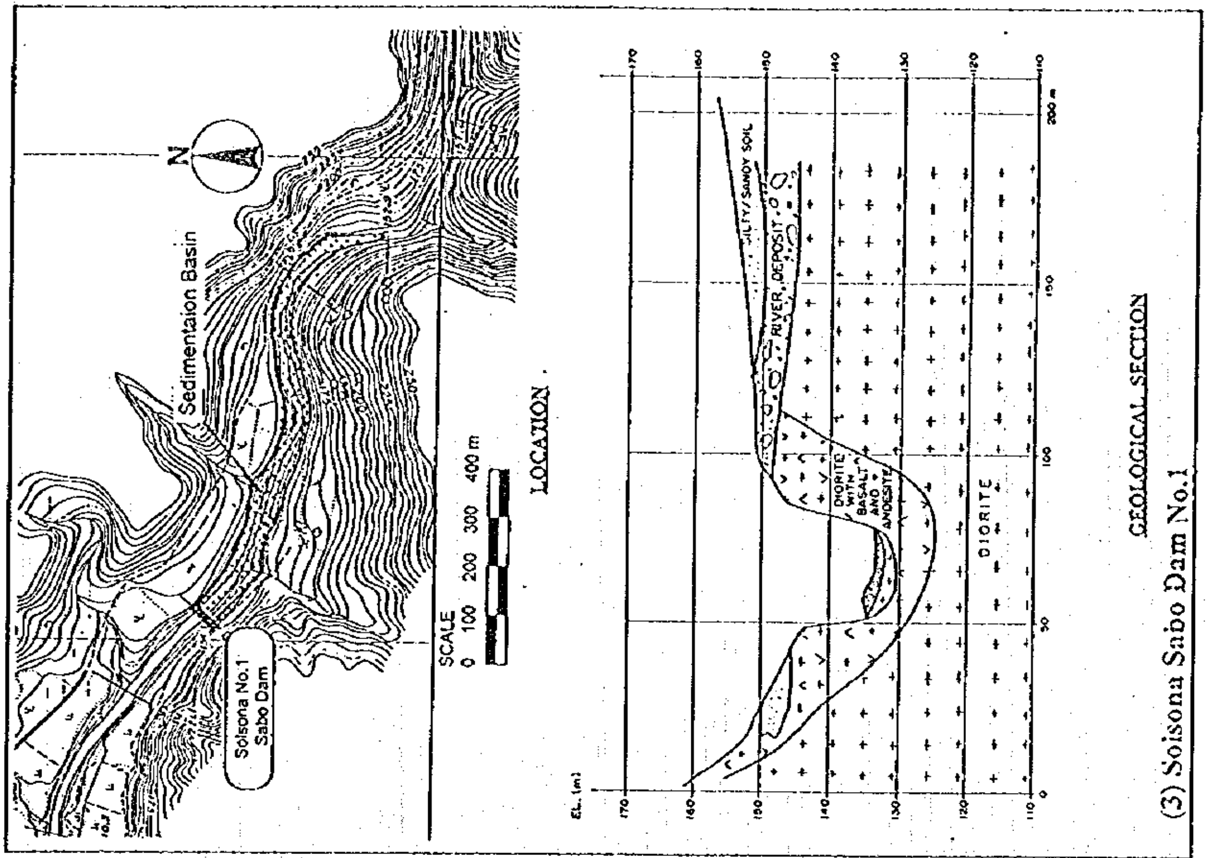


THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. B.3.1 Geological Sections of Existing Diversion Dams

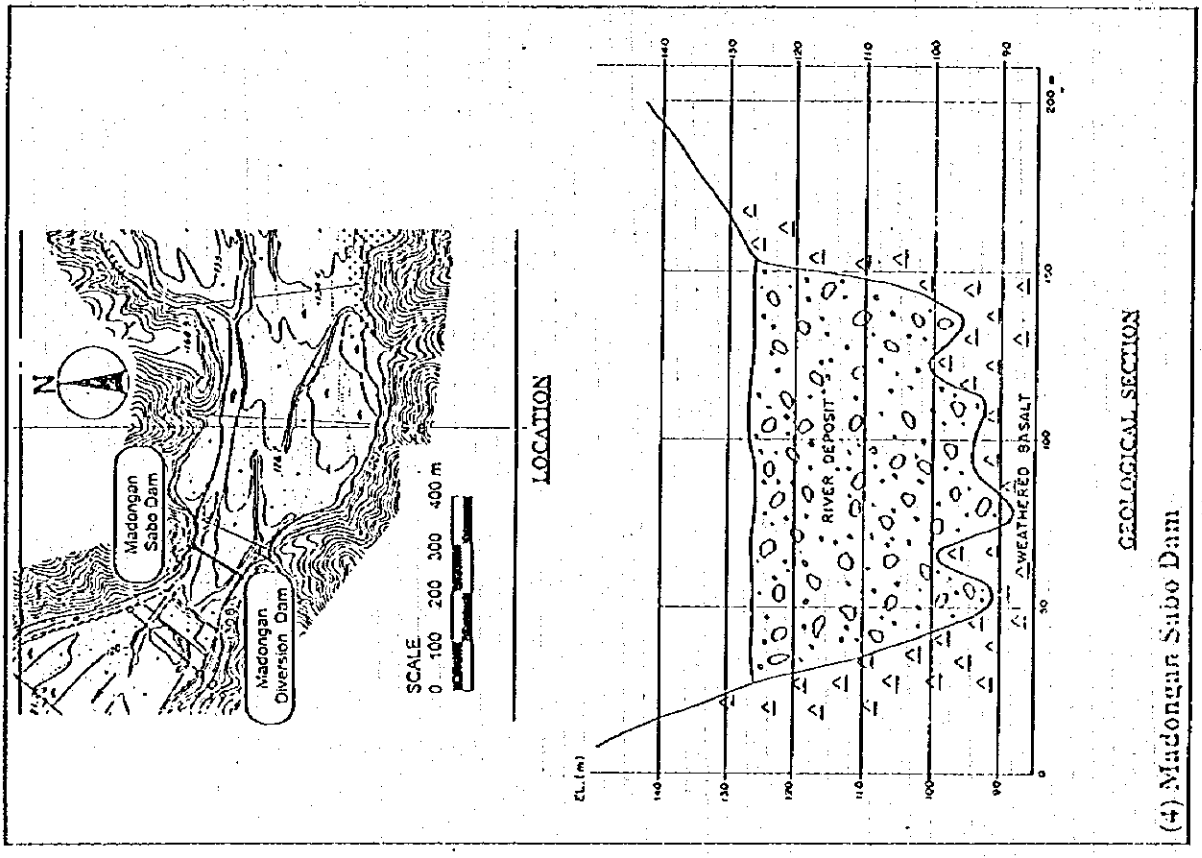




THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. B.3.2 (1)
JAPAN INTERNATIONAL COOPERATION AGENCY	Geological Sections of Proposed Sabo Dams Sites

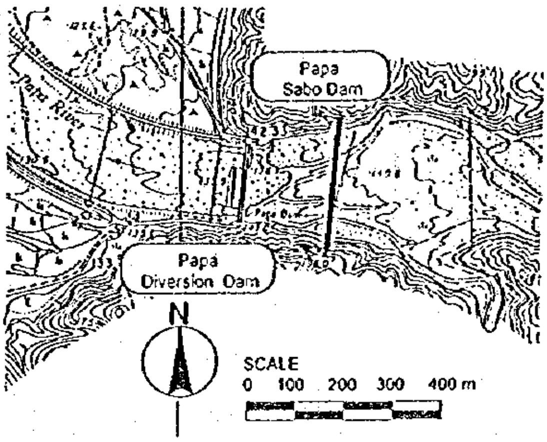


(3) Soisona Sabo Dam No.1



(4) Madongan Sabo Dam

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. B.3.2 (2) Geological Sections of Proposed Sabo Dams Sites



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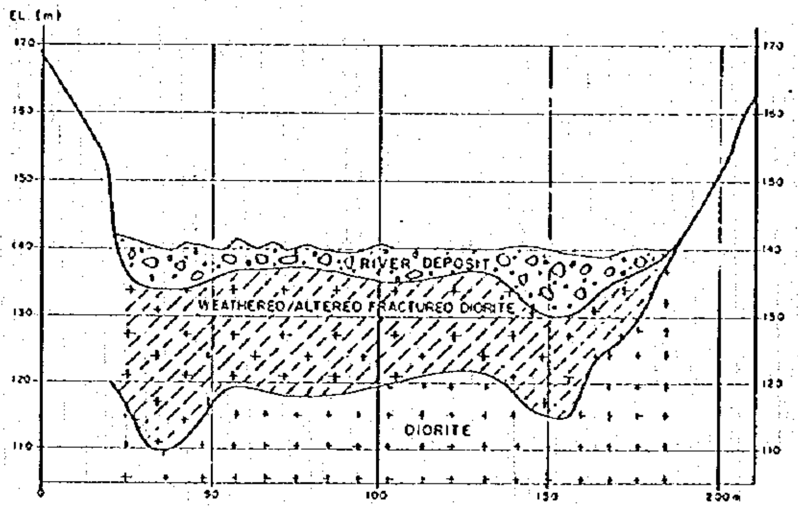
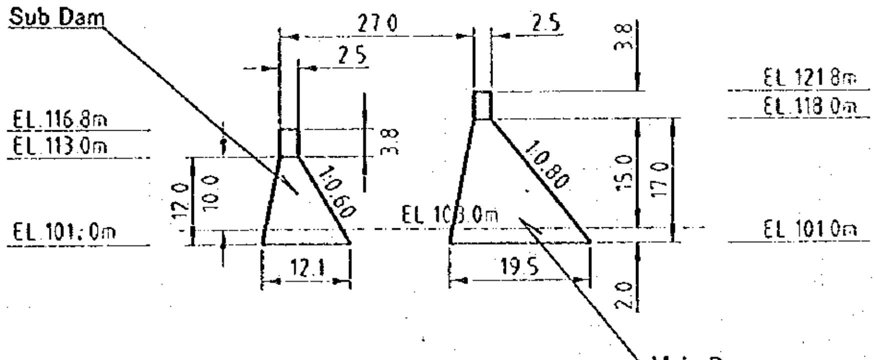


GEOLOGICAL SECTION

(5) Papa Sabo Dam

Fig. B.3.2 (3)
Geological Sections of Proposed Sabo Dams Sites



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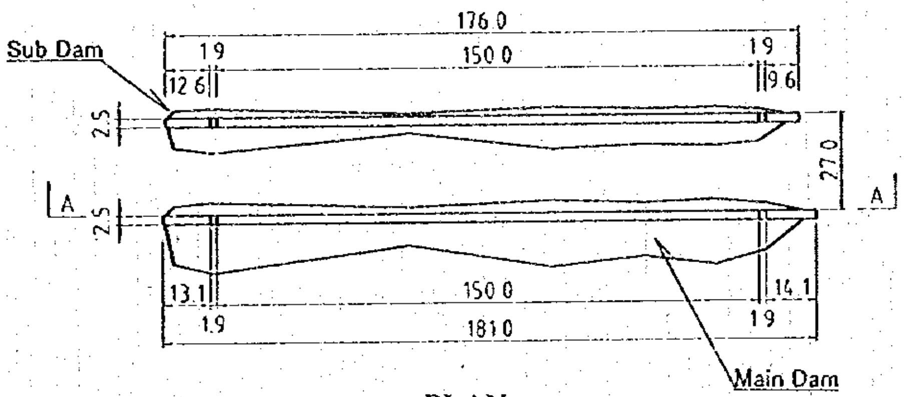
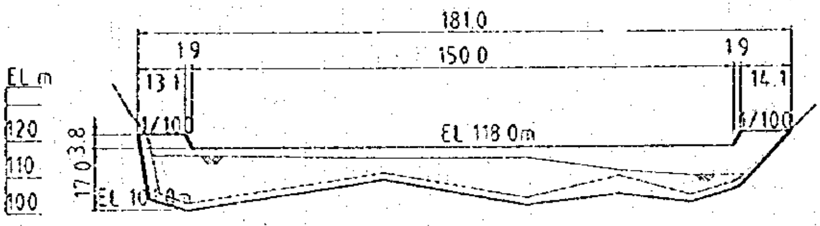


PLAN

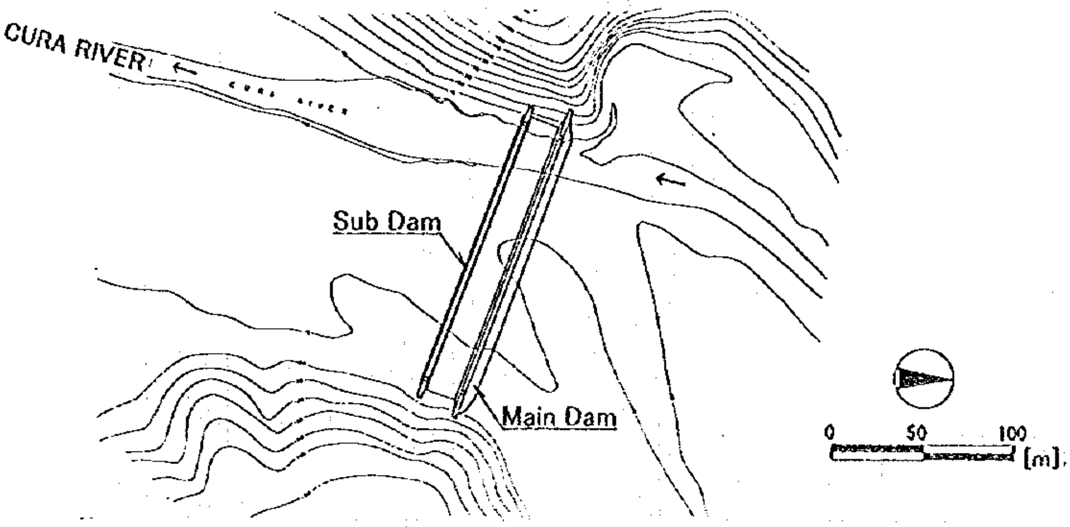


ELEVATION A-A

CURA NO.1 SABO DAM

(Unit : in meter)

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. B.3.3 Fixed Foundation Type of Cura No.1 Sabo Dam



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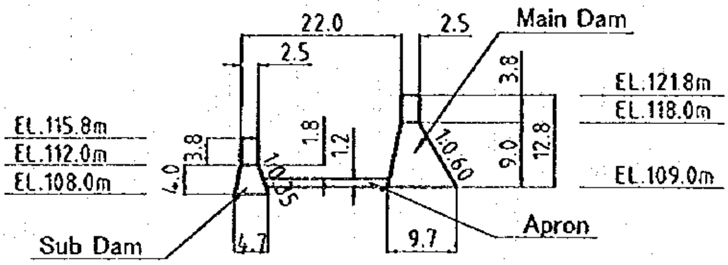

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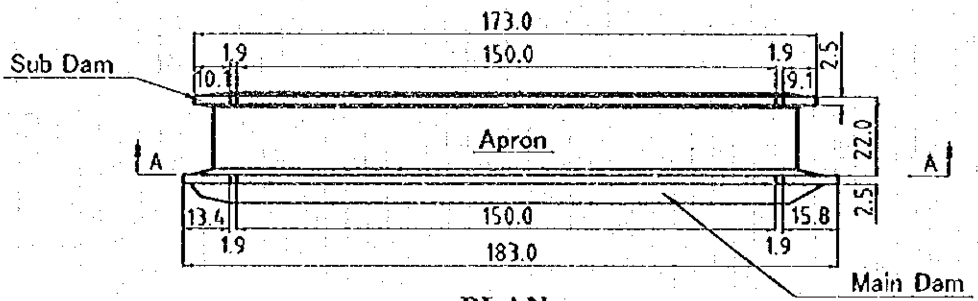
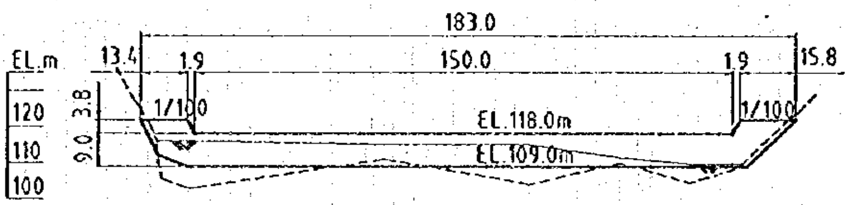


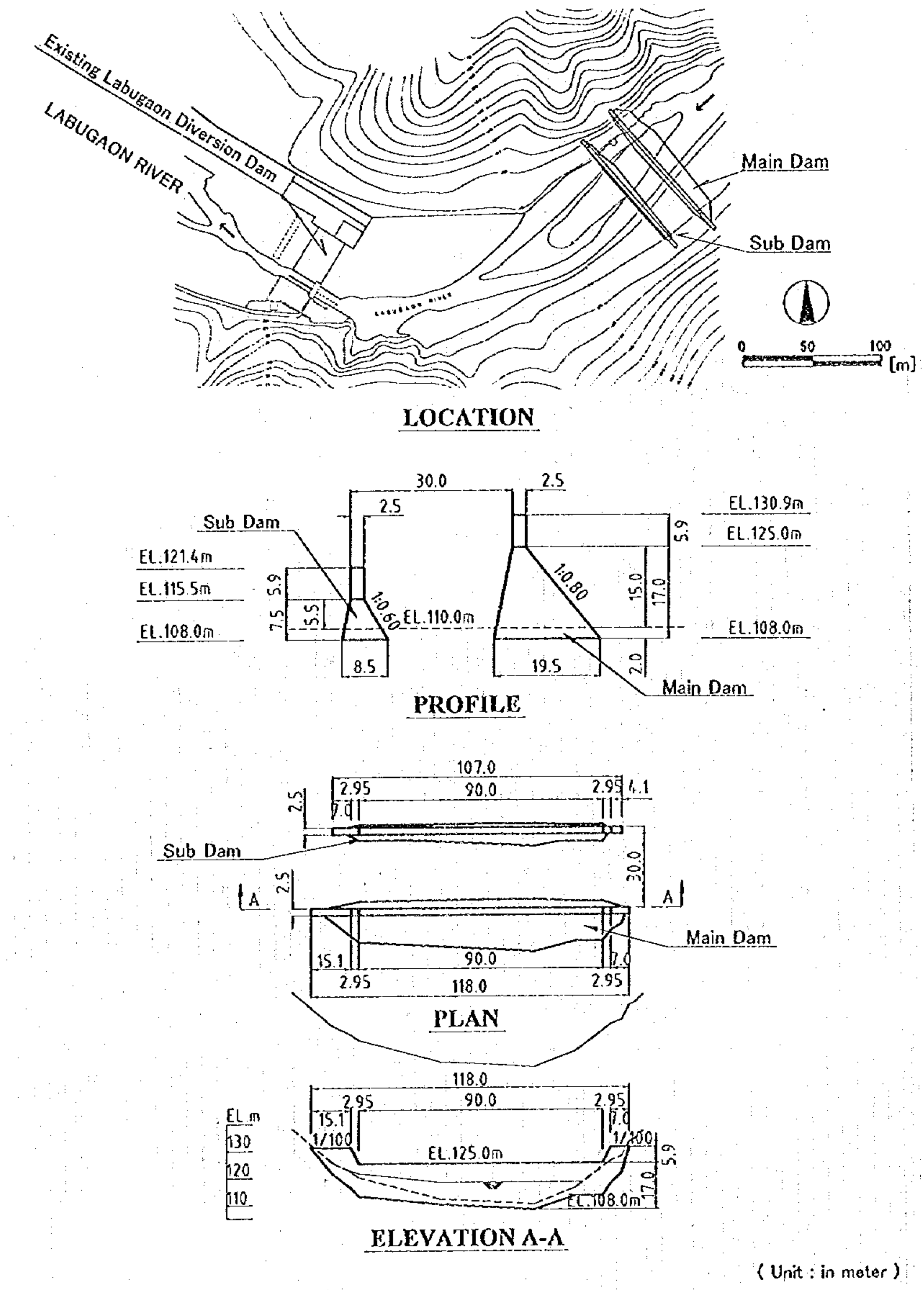
PLAN



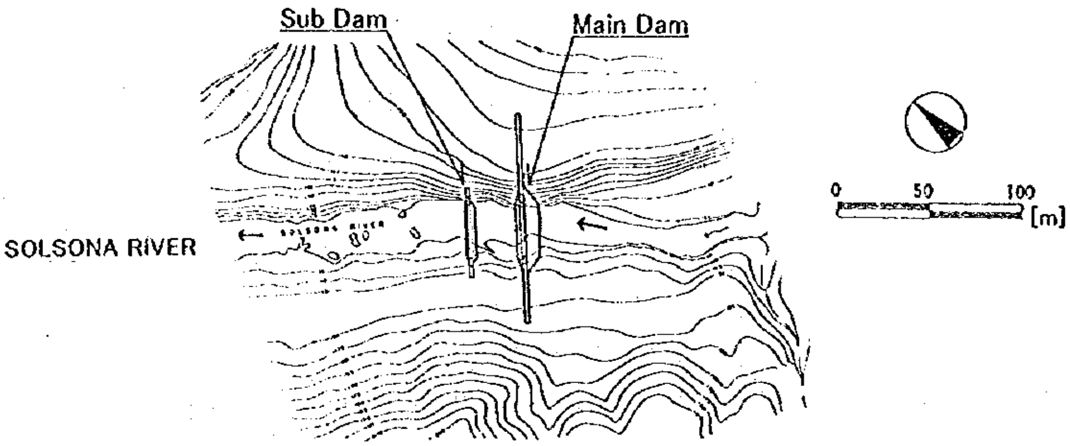
ELEVATION A-A

(Unit : in meter)

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. B.3.4 Structural Design of Proposed Cura No.1 Sabo Dam



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. B.3.5 Structural Design of Proposed Labugaon No.1 Sabo Dam
JAPAN INTERNATIONAL COOPERATION AGENCY	



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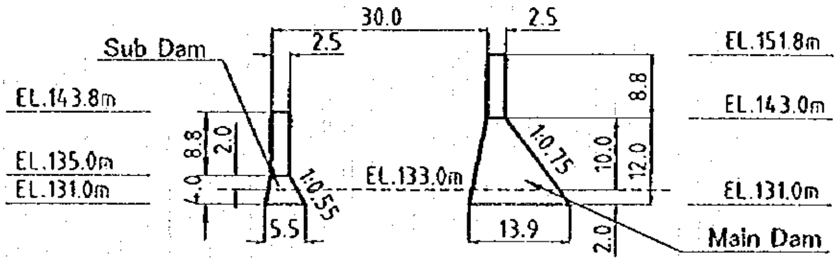

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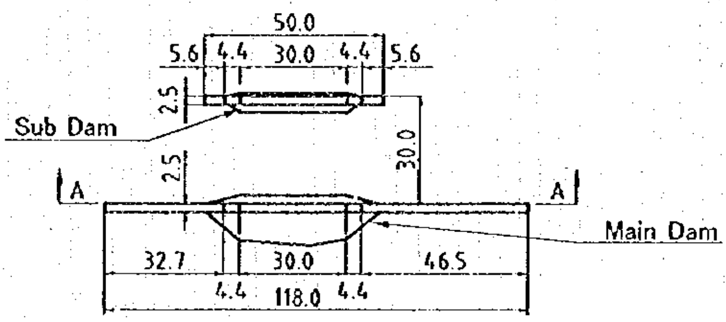

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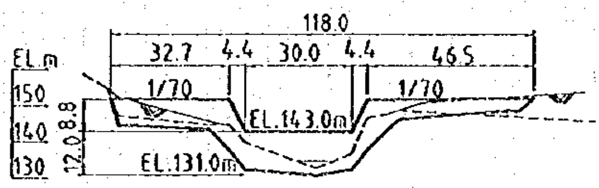
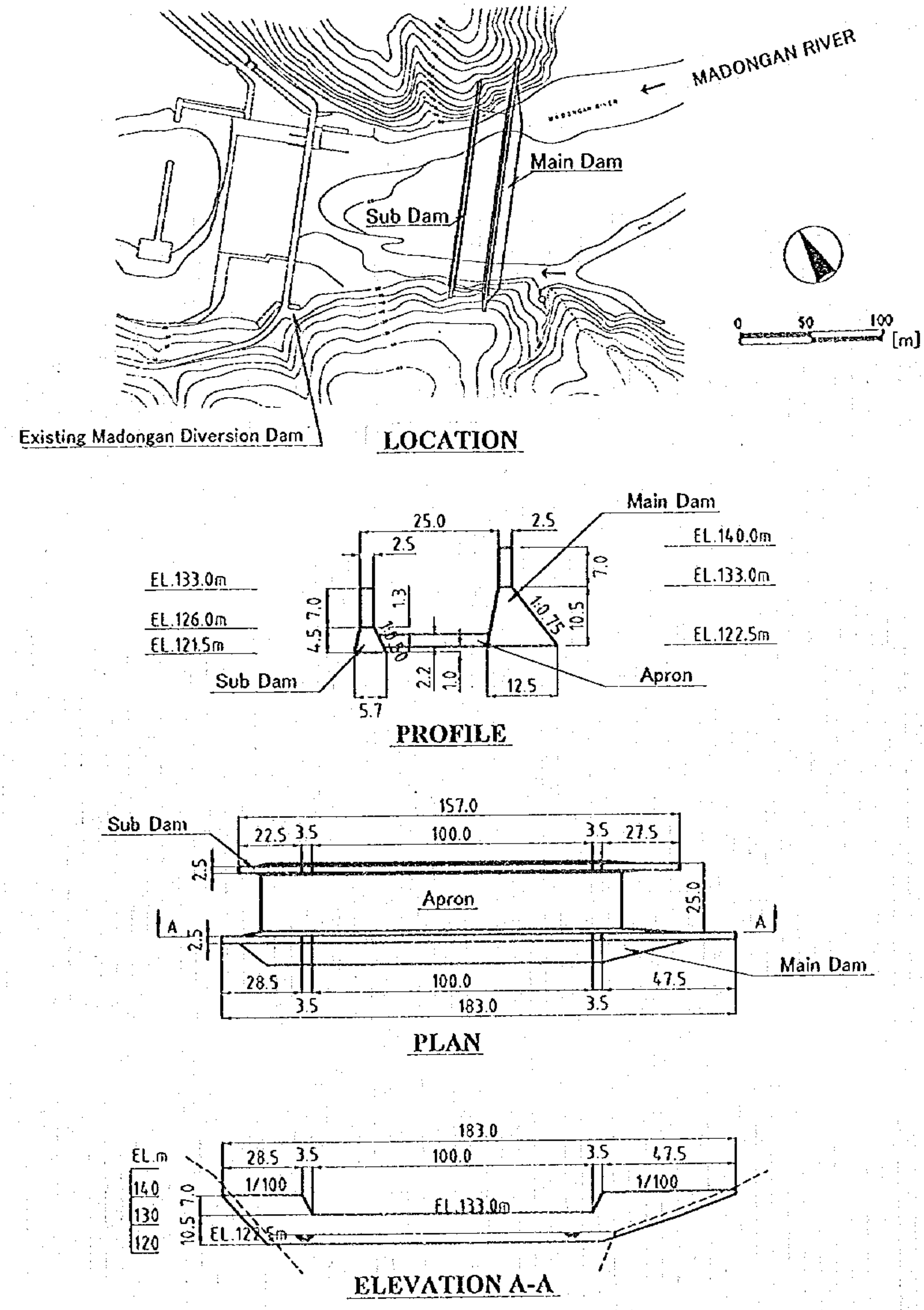


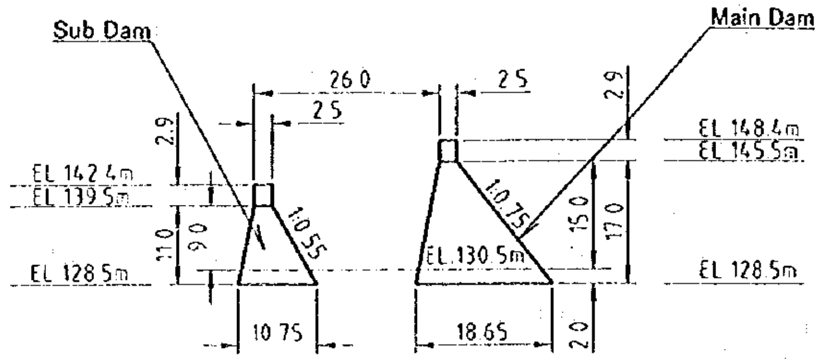
ELEVATION A-A

(Unit : in meter)

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. B.3.6 Structural Design of Proposed Solsona No.1 Sabo Dam



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. B.3.7 Structural Design of Proposed Madongan Sabo Dam
JAPAN INTERNATIONAL COOPERATION AGENCY	



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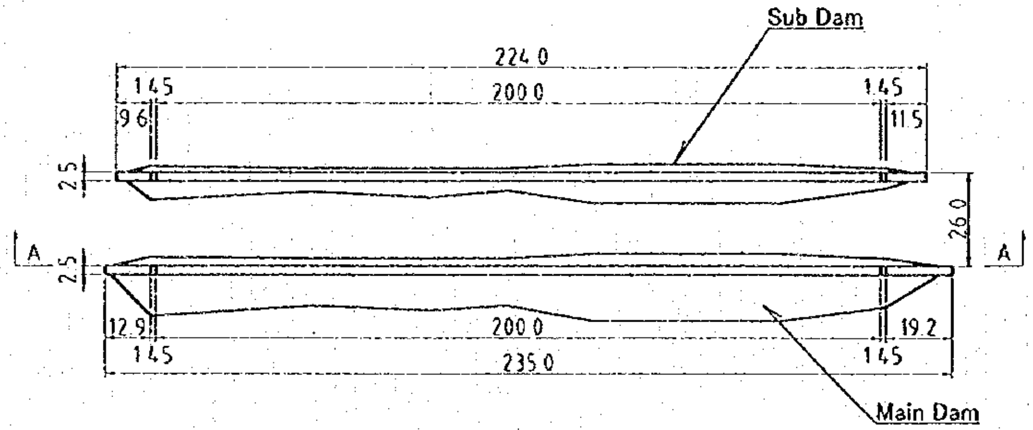
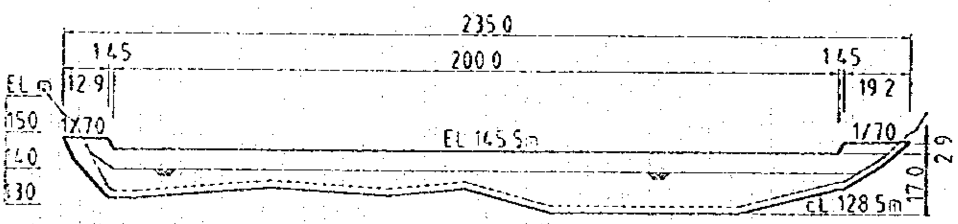


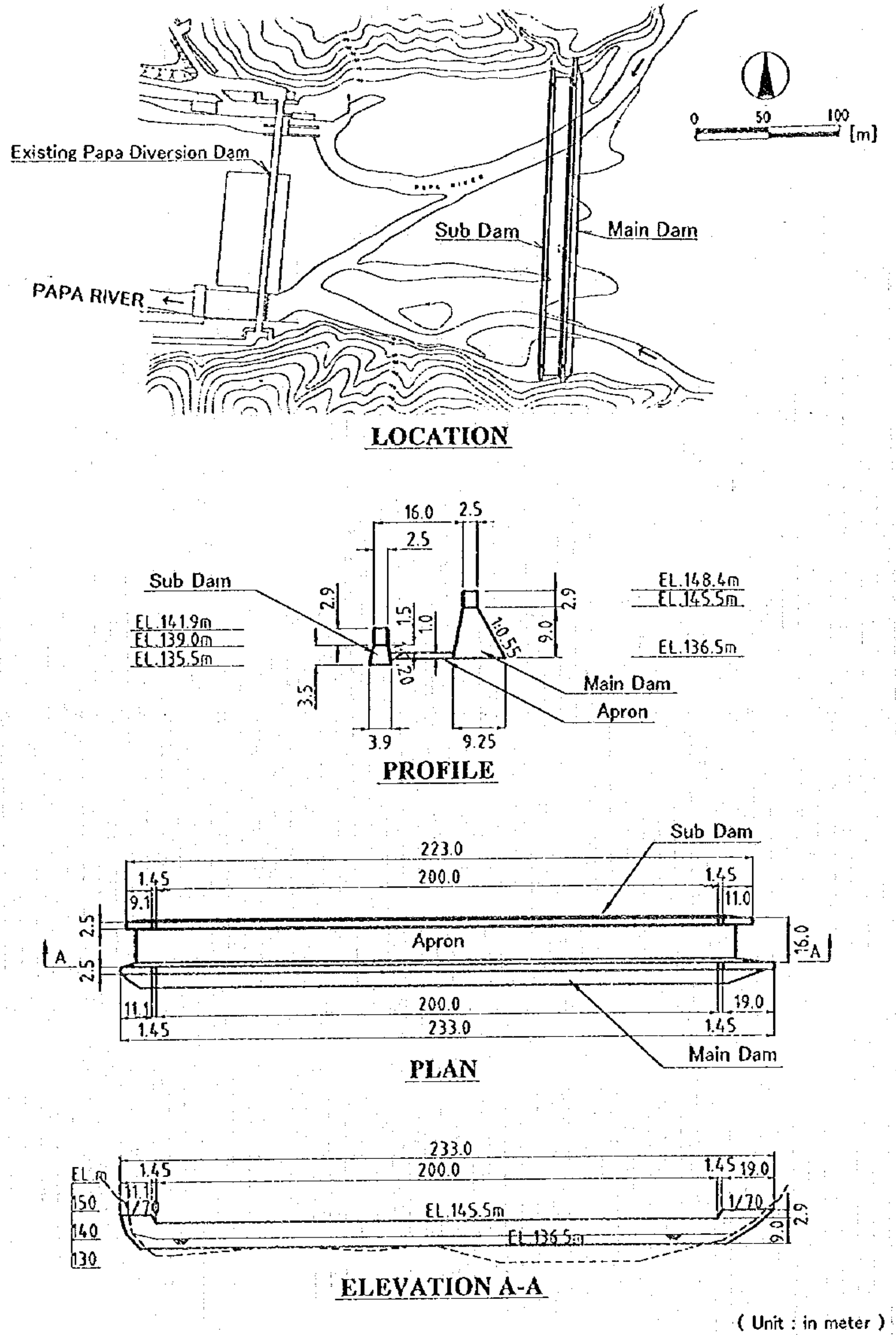
PLAN



ELEVATION A-A

PAPA SABO DAM (Unit : in meter)

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. B.3.8 Fixed Foundation Type of Papa Sabo Dam



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. B.3.9 Structural Design of Proposed Papa Sabo Dam

APPENDIX C

RIVER IMPROVEMENT PLAN

APPENDIX C

RIVER IMPROVEMENT PLAN

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CHAPTER I LAOAG-BONGO RIVER IMPROVEMENT PLAN

1.1 Priority Sub-projects

The proposed Master Plan will protect eight (8) flood protection districts along the Laoag-Bongo River by constructing flood protection dikes with bank protection works and related structures, if necessary. No river dredging and widening were proposed. The target flood protection areas are Tangid Laoag, Suyo Laoag, Poblacion Laoag, Camangaan Laoag, Poblacion San Nicolas, San Manuel Sarrat, Suyo Dingras and Poblacion Dingras. The alignment and longitudinal profiles of the river improvement proposed in the Master Plan are shown in Fig. C.1.1.

Among the eight (8) flood protection districts, three (3) river improvement sub-projects, namely, Poblacion Laoag, Poblacion San Nicolas and Poblacion Dingras are selected as the objective projects for the Feasibility Study aiming to protect the respective poblacion areas. They consist of flood protection dikes with bank protection structures and related river structures such as sluiceway, etc., if necessary.

The location and length of the necessary dikes to protect the three (3) poblacion areas were determined based on the detailed field survey. The flood protection dikes of Poblacion Laoag should be extended downward until the lower end of Suyo Laoag to completely protect Poblacion Laoag. Hence, the Suyo Laoag River Improvement is integrated into the Poblacion Laoag River Improvement.

The proposed locations and length of the necessary flood control protection dikes and the revised protected area and revised existing protected population are summarized below.

Sub-Project	Location from River Mouth (km)	Dike Length to be Constructed/ Improved (m)	Protected Area (ha)	Protected Population
Pob. Laoag R/I	4.9 - 8.3 (Right Bank)	3,490	330	6,203
Pob. San Nicolas R/I	6.9 - 11.1 (Left Bank)	4,200	230	5,835
Pob. Dingras R/I	27.6 - 33.3 (Left Bank)	5,450	550	4,221
Total		13,140	1,110	16,266

Note: Pob.; Poblacion and R/I; River Improvement.

1.2 Design Standard of Flood Protection Dikes

The dike crown elevations, structural type of dike and dike alignment are the most basic design elements of the proposed dikes.

(1) Dike Freeboard and Crown Width

The design high water levels for dikes are the same as proposed in the Master Plan.

The crown elevations of dikes are set at proper freeboad above the design high water levels.

According to the "Design Guidelines, Criteria and Standards for DPWH", freeboard is recommended corresponding to the magnitude of design flood, as shown below;

Design Discharge (m^3/s)	Freeboard (m)	Crown Width(m)
less than 200	0.6	3.0
200 - 500	0.8	3.0
500 - 2,000	1.0	4.0
2,000 - 5,000	1.2	5.0
5,000 - 10,000	1.5	6.0
more than 10,000	2.0	7.0

In this study, the freeboard of 1.0 m is adopted on the basis of the following considerations;

(a) Since diking system is not provided on the opposite bank, flood wave may become smaller compared with parallel diking system to confine the flood water.

(b) River channel/bank is frequently utilized for inhabitants. Lower freeboard, therefore, is disirable.

Regarding crown width, it follows the criteria. The width of dike is set at 7.0 m of Poblacion Laoag and Poblacion San Nicolas, and 6.0 m of Poblacion Dingras. Flood wall is provided with a top of 4.0 m width to secure a maintenance road.

(2) Structural Type of Dike

The following two (2) types of dike construction are generally applicable for the above objective river sections.

(a) Earth Dike

Earth dike is constructed on a site some distance back from the shoulder of the existing natural riverbank. No bank protection works are provided. The minimum setback distance is set at 30 to 50 m, referring to the standards in Japan. The lands necessary for the earth dike constriction must be acquired, however, land acquisition of the riverside lands of the dikes is not necessary. The dike construction will cause no adverse effects on such riverside lands; the lands can be used as they are at present.

(b) River Wall

River wall with revetment works is constricted on the shoulder of the existing natural riverbank. Land acquisition for the river wall construction is not necessary because of easement of 20 m.

The construction cost of the typical river wall is 3.7 times of that of the typical earth dike as shown below (see Fig. C.1.2).

(Unit : peso/m)

Structural Type	Construction Cost	Land Acquisition	Total
Earth Dike	7,450	230	7,680
River Wall	28,400	none (easement)	28,400

Hence, earth dikes are, in principle, applied in these sub-projects. However, river walls with revetment works are proposed for some limited sections in Poblacion Laoag and Poblacion Dingras where a considerable number of buildings exist on the riverbanks.

1.3 Poblacion Laoag River Improvement

The river improvement plan of Poblacion Laoag is shown in Fig. C.1.3. It consists of alignment of dike, longitudinal profiles and typical cross sections.

(1) Extent and Alignment of Proposed Dike

There exists the river wall with revetment (2.2 km long) along the urban area of Laoag City on the right bank of Laoag River. In the 1,080 m downstream section from the Gilbert Bridge the existing river wall is lower than the design high water level. Therefore, heightening of river wall is necessary. This river wall will be extended to the Cockpit Arena (160 m).

The objective area is on the ground elevation of about EL. 7.5 m. To protect this area from flood, the dike is proposed to be extended downstream until Suyo Laoag where design high water level is lower than EL. 7.5 m. Since space is available, earth dike of 2,250 m long is proposed for this extension. Hence, the river improvement for Suyo Laoag is integrated into the Poblacion Laoag River Improvement.

Alignment of dike is proposed so as to keep a river width of about 600 to 700 m.

(2) Proposed Structures

Structures such as earth dike, river wall and sluiceway are proposed as presented in Fig. C.1.3. Their typical structural designs are shown in Fig. C.1.4.

Riverbed material around site will be used for earth dike. A 2.5 m wide gravel maintenance road will be provided on the crown of dike.

River wall is also proposed to have a maintenance road on the crown, if space is available. In case space is not available near the Gilbert Bridge, reinforced concrete wall is proposed for heightening.

(3) Land Acquisition and House Resettlement

Land acquisition of urban land and farm/bush land is necessary for the construction of earth dike. No house resettlement is required.

(4) Plan Features

Items	Features	Remarks
Design Discharge	10,900 m^3/s	
Dike	3,490 m long in total	
- Earth Dike	2,250 m long	Embankment 127,800 m^3. Average 3.7 m dike height. 7.0 m crown width 2.5 m wide gravel metaling for maintenance road. Slopes of 1.0 (vertical) to 2 (horizontal).
- Heightening of River Wall only	620 m long	Reinforced concrete wall.
- Heightening of River Wall with Maintenance Road	460 m long	Grouted stone pitching revetment. 1.0 m high reinforced concrete wall. 4.0 m wide crown.
- New River Wall with Revetment and Maintenance Road	160 m long	Grouted stone pitching revetment. 1.0 m high reinforced concrete wall 4.0 m wide crown.
Sluiceway	2 units	Reinforced concrete box-culvert (1.5 m wide x 1.5 m high) with steel sluice gate.
Land Acquisition	6.1 ha in total	urban area (0.8 ha) and farm land (5.3 ha).
House Resettlement	None	

1.4 Poblacion San Nicolas River Improvement

The river improvement plan of Poblacion San Nicolas is shown in Fig. C.1.5. It consists of the alignment of dike, longitudinal profiles and typical cross sections.

(1) Extent and Alignment of Proposed Dike

Most upstream end of the proposed dike is connected to a hill where NIS Bonga Pump No. 2 is located.

Most downstream end of dike will be extended about 1.4 km downstream from the Gilbert Bridge. Therefore, National Highway No. 3 (EL. about 9.1 m) will be protected from flood.

Alignment of proposed dike is determined considering the following:

(a) To maintain the existing river width of about 600 to 700 m.

(b) To keep a distance of 30 to 50 m from edge of bank to dike for structural safety.

(c) To follow the alignment of 1 km river walls made of concrete hollow block (CHB) existing from 1.4 km upstream of the Gilbert Bridge to near Bonga Pump No. 2.

(d) To connect with the existing abutment of the Gilbert Bridge.

(2) Proposed Structures

Structures such as earth dike, hand-laid boulder spur dike and sluiceway are proposed as presented in Fig. C.1.5. Their typical structural designs are shown in Fig. C.1.4.

Hand-laid boulder spur dike is a conventional structure applied in the middle and downstream of the Laoag River. It is, however, unstable against flood water and local scouring. Hence, hand-laid boulders will be covered with wet stone masonry.

(3) Land Acquisition and House Resettlement

Land acquisition of farm/bush land is necessary for the construction of the earth dike. No house resettlement is required.

(4) Plan Features

Items	Features	Remarks
Design Discharge	10,900 m^3/s	
Earth Dike	4,200 m long	Embankment 232,500 m^3 using riverbed materials nearby. 3.5 m dike height on an average 4 m crown width 7 m wide gravel metaling for maintenance road. Slopes of 1 to 2.
Spur Dike	5 units	Hand laid boulder covered with wet stone masonry. 30 m long x 60 m interval.
Sluiceway	2 units	Drainage purpose. Reinforced concrete box-culvert (1.5 m wide x 1.5 m high) with steel sluice gate.
Land Acquisition	9.9 ha	Farmland.
House Resettlement	None	

1.5 Poblacion Dingras River Improvement

The river improvement plan of Poblacion Dingras is shown in Fig. C.1.6. It consists of the alignment of dike, longitudinal profiles and typical cross sections.

(1) Extent and Alignment of Dike

Most upstream end of proposed dike is connected with the existing dike of the irrigation canal.

Most downstream end of dike is proposed to extend near the NIS Bonga Pump No. 3 so as to protect the poblacion area from backwater.

Alignment of dike is determined to keep a distance of 30 to 50 m from edge of bank. Also, dike is planned to connect with the abutment of the existing Cauplasan Bridge.

(2) Proposed Structures

Structures such as earth dike, river wall, spur dike and sluiceway are proposed as presented in Fig. C.1.6. Their typical structural designs are shown in Fig. C.1.4.

(3) Land Acquisition and House Resettlement

Land acquisition of farm/bush land is necessary for the construction of earth dike. A few house resettlement is required.

(4) Project Features

Items	Features	Remarks
Design Discharge	8,700, 6,500 and 3,220 m^3/s	
Dike	5,450 m long in total	
- Earth Dike	5,150 m long	Embankment 321,700 m^3 using of riverbed materials nearby. 4.1 m dike height on an average 6.0 m crown width 2.5 m wide gravel metaling for maintenance road. Slopes of 1 (vertical) to 2 (horizontal).
- River Wall with Revetment	300 m long	Crown width 4.0 m for maintenance road. Grouted stone pitching revetment. 1.0 m high reinforced concrete wall.
Spur Dike	5 units	Hand-laid boulders covered with wet stone masonry. 30 m long x 60 m interval
Sluiceway	1 unit	Drainage purpose. Reinforced concrete box-culvert (1.5 m wide x 1.5 m high) with steel sluice gate.
Land Acquisition	13.0 ha	Farm land
House Resettlement	3 houses	Residential houses

CHAPTER II RIVER IMPROVEMENT PLAN IN ALLUVIAL FAN

2.1 Design Criteria of River Channel

(1) Alignment

The existing river alignment of the Solsona, Madongan and Papa is smooth and considered hydraulically adequate as experienced in the recent floods. Hence, the design alignments are set at the present conditions.

The alignment of the Cura/Labugaon River is designed as proposed through the comparative study of alignments in the Master Plan. The Cura and Labugaon rivers are designed to join at the fan apex and thereafter, to run along the existing main course of the Cura River.

(2) River Width

The present river widths of the Solsona, Madongan and Papa were evaluated as hydraulically stable ones, based on the Regime Theory in the Master Plan Study. Hence, their design river widths are set as they are at present.

Similarly, the river width of the Cura/Labugaon is designed as proposed based on the Regime Theory in the Master Plan Study.

(3) River Profile

According to the sediment transport analysis described in Appendix A, the riverbed profiles of the four (4) objective rivers are predicted to be comparatively stable in future although a certain degree of aggradation is calculated in limited lower river sections. No significant degradation is expected throughout the entire river section except in the Labugaon River, and there is no local scouring in the immediate downstream section of the existing irrigation dams.

Hence, no riverbed dredging is proposed for the Solsona, Madongan and Papa rivers, and dredging will be limited to some river sections of the Cura/Labugaon.

Design high water levels are determined to envelope the calculated river water levels under the present and future predicted riverbed conditions for a greater factor of safety (refer to Appendix A: Sediment Analysis for determination of design high water levels).

On the other hand, design riverbed elevations are not proposed because it is very difficult to maintain the design riverbed elevations of alluvial rivers.

(4) River Mouth

Sediment loads from the alluvial fan rivers of Cura, Solsona, Madongan and Papa are easily washed away to the Bongo River since the Bongo River is wide and its backwater effect on the alluvial fan rivers is small. In fact, no significant sediment deposit is identified at their river mouths.

Possible sediment deposit at the mouth of the alluvial fan rivers in future is also considered not large. The sediment deposit at the river mouths in design flood is estimated to be in the range of 1 cm in the Papa River and 8 cm in the Cura River. The long term riverbed aggradation at the river mouths after 20 years is predicted to be in the range of nil in the Cura River and 100 cm in the Solsona River. For details, refer to Appendix A Sediment Analysis in this report.

Hence, no special sediment control device is proposed for the river mouths. The river alignment at each river mouth is designed to follow the existing one.

For the proposed river alignment at river mouth is shown in Fig. C.2.1.

(5) Maintenance of Functions of Existing River Facilities

There exist such river facilities as intakes including irrigation dams, bridge and road crossings in the objective alluvial rivers. The functions of these facilities should be maintained even after the completion of the river improvements.

(a) Intake Facility

There are nineteen (19) intakes in the four (4) objective rivers; six (6) in Cura/Labugaon, three (3) in Solsona, eight (8) in Madongan and two (2) in Papa, except four (4) irrigation diversion dams constructed in the INIP I. Location, service area and structure type of these existing intakes are presented in Fig. C.2.2.

The existing intakes of Solsona, Madongan and Papa rivers were all reconstructed in the Urgent Disaster Prevention Works (UDPW) of NIA in 1992 to 1993. They are made of one (1) or two (2) reinforced box culvert(s) with a sectional size of 1.0 m by 1.6 m. Their service areas range from 10 to 770 ha. However, some intakes were damaged or washed out by the flood of Typhoon Gloring in 1996.

In the Cura/Labugaon River, there are five (5) intakes on the right bank and one (1) on the left bank. Fig. C.2.3 illustrates the existing irrigation system in the Cura/Labugaon River. All of the five (5) intakes on the right bank are functioning well. The left bank intake is structurally sound, however, it does not work fully because some sections of the connected irrigation channels were washed out by the recent flood. Hence, the farmers draw irrigation water from the branch rivers of the Labugaon River by constructing temporary intake facilities.

(b) Bridge and Road Crossing

There is only one (1) bridge in the objective improvement reaches, i.e., Bagbag II Bridge crossing the Cura River 4.5 km upstream from the confluence with the Laoag River. This features two (2) lanes (9.0 m wide in total) with the reinforced concrete girder superstructure and the substructure of pile piers. Existing total length is 315 m (21 spans x 15 m per span).

As to road crossings, there is one (1) each in the Solsona, Madongan, and Papa rivers. They were constructed of cobble concrete pavement in the UPDW in 1992 to 1993 to connect community roads. Their locations are shown in Fig. C.2.2.

2.2 Alternative Studies of Bank Protection Works

The existing temporary earth dikes along the rivers of the Solsona, Madongan and Papa were breached at many locations in the entire stretch of the rivers by Typhoon Gloring in 1996. The return period of this flood is estimated to be approximately a 15-year.

This dike breaching was caused by local scouring at the foot of the dikes in the floodwater convergence points. No overflow on the dikes occurred. Hence, the foot protection of dikes is considered essential.

The following three (3) typical measures are applicable for protection of the earth dikes in the alluvial fan rivers. These three (3) types are technically and economically compared in the following section.

(1) Revetment
(2) Spur Dikes
(3) Groundsill with Small Spur Dikes

2.2.1 Revetment

(1) General

Revetment covers the bank and prevent erosion by the direct attack of current. Wet masonry revetment with toe protection concrete blocks is proposed. The revetment must be thick and strong enough to cope with severe striking of flowing stones. The foundation of the revetment must be deep enough to cope with the local riverbed scouring caused by sandbar at flood water convergence points. The toe protection concrete blocks must be heavy enough to resist the movement force of flood flow.

(2) Foundation Depth

The design foundation depth of revetment is determined based on the existing local riverbed scouring depth at floodwater convergence points. The local scouring depth measures from sandbar crown in the objective alluvial fan rivers vary depending on the riverbed slope as shown below (see Appendix A: Sediment Analysis).

Riverbed Slope; S (%)	Scouring Depth below Sand Bar Crown (m)	Scouring Depth below Average Riverbed (m)
$S < 0.8$	1.5	$1.5 \times 0.8 = 1.2$
$0.8 < S < 1.3$	1.8	$1.8 \times 0.8 = 1.5$
$1.3 < S < 1.5$	2.4	$2.4 \times 0.8 = 2.0$
$1.5 < S$	2.8	$2.8 \times 0.8 = 2.3$

The elevation of sandbar crown is usually 20% higher than that of average riverbed. Therefore, the local possible scouring depth measured from the average riverbed elevation at the floodwater convergence points in the objective rivers is estimated as shown in the above table.

On the other hand, the existing lowest riverbed depth measured from the corresponding average riverbed elevation varies depending on the riverbed slopes. The lowest riverbed depth becomes deeper accordingly as the riverbed slope becomes steeper.

The existing lowest riverbed depth measured from the average riverbed is smaller than the possible local scouring depth estimated by the analysis of sandbar wave height at any riverbed slope. Therefore, the above possible local scouring depth is proposed as a basis for the design of the foundation depth of revetment.

The foundation depth of the revetment will be determined by lowering the above proposed local scouring depth from the lower average riverbed elevation between the existing and future ones, and further providing some allowance.

Hence, the standard design foundation depth of the revetment works is proposed, considering 1.0 m allowance as follows.

Riverbed Slope; S (%)	Scouring Depth (m)
S < 0.8	2.2
0.8 < S < 1.3	2.5
1.3 < S < 1.5	3.0
1.5 < S	3.3

(3) Typical Structural Design and Construction Cost

The typical revetment structures for the upper Madongan river reaches are designed as follows. The upper Madongan river sections are regarded as the representative ones of the objective alluvial fan rivers. The design hydraulic conditions are as follows.

- Design discharge Q = 1,970 m^3/s
- Riverbed slope : I = 1/75 (1.333%)
- River width : B = 300 m
- Water Depth : H = 2.5 m

The revetment is placed on the surface of both banks and it is provided with toe protection concrete blocks. The slope length and thickness of the revetment are assumed to be 10.1 m and 0.35 m, respectively (see Fig. C.2.4).

The volume of the wet masonry and toe protection concrete block per 1,000 m river distance (river bank distance = 2,000 m) are estimated at 7,060 m^3 and 12,000 m^3 , respectively

The direct construction cost per 1,000 m river distance is estimated to be 48.6 million pesos.

2.2.2 Spur Dike

(1) Objective Function

Spur dikes are generally constructed to prevent main flood stream from striking the dikes and to keep a safe distance between the main flood stream and dikes. In alluvial fan rivers, a series of impermeable spur dikes with a comparatively short length are usually constructed to push the main flood stream toward the river center up to the line connecting the heads of the spur dikes.

(2) Length of Spur Dike

Too long spur dikes may disturb flood stream and make it difficult to maintain the river course. Further, the spur dike structure itself is susceptible to damage. In alluvial fan rivers, it is generally recommended to place a series of short spur dikes at close intervals than to construct single long spur dikes.

Length of existing spur dikes in Japan are mostly less than approximately 10% of the river width. Spur dikes with a length exceeding 25% of the river width are very few [1].

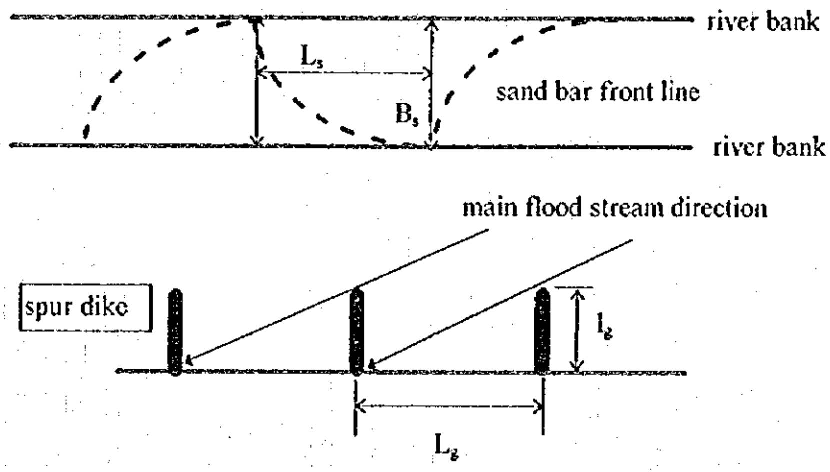
Hence, the design length of spur dikes is set at 10% of the river width. The length of spur dikes is calculated to be 15 m by assuming the average river width as 300 m since the spur dikes are provided along both side banks in principle. Construction of the spur dikes will narrow the flood flow width. However, its hydraulic effects are considered negligible.

(3) Interval of Spur Dike

The interval of spur dikes is designed based on the experiences in similar projects. No practical calculation method is available at present. Generally, the interval of spur dikes (L_s) is determined in relation to their length (l_s).

According to the inventory survey by the Ministry of Construction in Japan, the ratio of interval distance and length of the existing spur dikes in Japan mostly fall within the range of $L_g/l_g = 1.0 - 4.0$, averaging 3.0. Majority of them have a ratio of 2.0 - 3.0 [1].

On the other hand, the spur dikes are expected to prevent the main flood stream from striking against the dikes. Therefore, the interval of spur dikes is determined taking into account of the direction of main flood stream. Main flood flow generally runs along the sandbar front lines. To prevent the striking of the main flood stream against the dikes, the ratio of the length and interval of spur dike (L_g/l_g) should be less than the tangent of sandbar front lines (L_s/B_s) as shown in the following figure.



Where,

- Ls : sand bar length
- B_s : sand bar width
- L_g : spur dike interval
- l_g : spur dike length (= 15 m)

Tangents of the existing sandbar front lines (L_s/B_s) in the Solsona, Madongan and Papa rivers vary depending on the riverbed slope (S). It is summarized as follows. (See Appendix A for details)

Tangent (L_s/B_s)	Riverbed Slope (S) (%)
2 - 3	S > 0.8
4 - 5	S < 0.8

Based on the above, the design interval distance of the spur dikes (L_g) is determined as follows.

(a) For upper reaches (I > 0.8%), L_g = 30 m.

(b) For lower reaches (I < 0.8%), L_g = 60 m.

(4) Local Scouring around Spur Dikes

Apart from the local riverbed scouring caused by sandbar, another local scouring occurs around spur dikes by the flow disturbance of the spur dikes. The maximum scouring usually appears at the head of spur dike. The local scouring depth is estimated based on the previous hydraulic laboratory tests or field surveys of similar projects.

The Ministry of Construction in Japan conducted several hydraulic model tests and field survey on the scouring around spur dikes in the past. The results of the tests are summarized as follows.

(a) General Test in 1960 [1]

(i) Type of spur dike : a series of spur dikes of impermeable submerged type.

(ii) Condition : I = 1/500, Lg/lg = 0.8 - 2.4, hg/H = 0.2 - 0.5, H/d = 120 - 300.

(iii) Scouring depth at the head of the series of spur dikes except the spur dikes at the upstream end : (0.3 - 0.7)H.

Where, H = water depth and d = representative size of riverbed materials.

(b) Model Tests for Watarase River in 1985 and Shinano River in 1988 [2]

(i) Type of spur dike : a series of spur dikes of impermeable submerged type with mattress.

(ii) Riverbed slope : Watarase; I = 1/500 - 1/800 and Shinano; I = 1/600.

(iii) Test condition : $L_g/l_g = 2$, $h_g/H = 0.5$.

(iv) The scouring depth of the upstream end spur dike of the series was (0.5 - 0.6)H. The scouring depth of spur dikes decreased towards downstream of the series.

(c) Field Survey for Scouring Depth around Spur Dikes in Kurobe River in 1990 [2]

(i) Type of spur dikes : a single spur dike of permeable submerged type.

(ii) Condition : $I = 1/100$, $L_g/l_g = 10$.

(iii) Scouring depth : 1.5 m.

From the above, the scouring depth of a series of spur dikes of impermeable submerged type is roughly estimated to be 50 - 60% of river water depth except for the upstream end spur dike.

(5) Foundation Depth

The design foundation depth of spur dikes is determined in consideration of the riverbed scouring caused by sandbar and by flow disturbance of spur dike. For the riverbed scouring depth by sandbar, see the previous Section 2.2.1.

(6) Typical Structural Design and Construction Cost

The typical spur dikes for the upper Madongan river reaches are designed as follows under the same hydraulic conditions as revetment.

The spur dike made of stone concrete (boulders filled with concrete) is placed in front of both banks at an interval of 30 m. The size of one (1) unit typical spur dike is 15 m in length, 4.0 m in height, 2.0 m in crown width and 6.0 m in bottom width (see Fig. C.2.4). The stone concrete volume per 1,000 m river distance (2,000 m river bank distance) is estimated at 15,460 m^3.

The direct construction cost of spur dikes per 1,000 m river distance is estimated at 28.4 million pesos.

2.2.3 Groundsill with Small Spur Dikes

(1) Objective Function

Groundsills are generally constructed for the following purposes.

(a) Excessive sediment control in the mountains may cause a riverbed degradation accompanied by sediment yield in the upper reaches of the alluvial fan rivers. The yielded sediments may create a riverbed aggradation in the lower reaches, especially in the river sections where the riverbed slope makes a large change. Groundsills will prevent such a riverbed degradation in the upper reaches and minimize the riverbed aggradation in the lower reaches.

(b) Sandbars of a large scale are generally formed in the alluvial fan rivers. They create floodwater convergence and divergence points alternately in the longitudinal direction of river channel. As a result, local riverbed scouring is caused at the flood water convergence points. A larger scale sandbar generally causes a deeper riverbed scouring. Groundsills will disturb the formation of sandbars in the river channel and as a result, mitigate the local riverbed scouring.

No significant riverbed degradation is predicted in this project except for the Labugaon River (2 km long). Even the riverbed degradation in the Labugaon River is not large and therefore, the contribution to the aggradation in the lower reaches is small (see Appendix A: Sediment Analysis). Hence, the control of riverbed degradation by groundsills is considered unnecessary.

From the above, the groundsill construction in this project only aims to disturb the formation of sandbar in the river channel and as a result, to minimize the local riverbed scouring depth along the riverbanks.

(2) Interval of Groundsill

The Ministry of Construction in Japan conducted several hydraulic model tests on the groundsills in the river channels of steep slope in recent years. According to the tests, the space between groundsills must be shorter than the existing sandbar length to disturb the formation of sandbar by dividing a sandbar into sections.

The existing sandbar length in the objective alluvial fan rivers is summarized as follows.

Ratio (L_s/B)	Riverbed Slope (S)
2 - 3	S > 0.8 %
4 - 5	S < 0.8 %

Ls : sand bar length, B : riverbed width

Hence, the interval distance of groundsill (L) must be L < 2B for the river sections of S > 0.8% and L < 4B for river sections of S < 0.8%.

If the riverbed is degraded until it is covered by armor coats in the future, the riverbed slope will reach a statically balanced one. An armor coat is generally formed out of the selected riverbed materials with larger than 9 % size among the existing ones. On the other hand, the 90% size (diameter) of the existing riverbed materials in the typical river reaches of the project (upper Madongan river reaches) is in the range of 20 cm and 30 cm. The statically balanced slope of the riverbed consisting of gravel/pebbles with a size of 20-30 cm is estimated to be 1/110 - 1/125.

Ground-sills must control or compensate a head (difference of riverbed elevation) created by the riverbed degradation from the existing slope (1/75) to the future slope (1/110 - 1/125). The head to be controlled varies depending on the interval distance of the ground-sills. The maximum interval distance of ground-sills is estimated to be 380 - 480 m by assuming the allowable head is 2.0 m.

Further, an empirical formula of L = (1.5 - 2.0)B is widely used for small rivers in Japan [3]. Accordingly to this formula, the interval distance of ground-sills is estimated to be 450 - 600 m for the upper Madongan river reaches of 300 m river width.

From the above discussions, the interval distance of the ground-sills for the typical river reaches (upper Madongan River reaches) is set at L = 1.5B = 450 m.

(3) Hydraulic Control of Groundsill

A groundsill of single section is usually employed and its crest elevation is set at the design riverbed elevation. However, in this project, a groundsill of double section is proposed to converge the flood flow into the center of river channel.

From the model tests in Japan [4)-6)] stated above, the following hydraulic effects are generally assumed.

(a) The low water channel section of a groundsill determined to flow a 2 - 3 year flood discharge.

(b) Although main flood streams converge into the center of river channel, sub-streams with a certain velocity run down along the riverbanks. The flow velocity along the riverbanks is roughly estimated at half of that of the river center.

(c) The local scouring depth along the riverbanks is also roughly estimated at half of the scouring depth of without groundsill.

Hence, small spur dikes must be provided between groundsills.

(4) Foundation Depth

The design foundation depth of groundsills is determined in due consideration of the riverbed scouring by the flow disturbance of groundsill. The immediately downstrream riverbed in the low water channel section is susceptible to severe scouring due to a high speed flood flow. The design riverbed scouring depth is determined, referring to that of the existing irrigation dams.

The design foundation depth of small spur dikes is determined according to the design criteria of the spur dikes discussed in the previous Section 2.2.2. The riverbed scouring depth by sandbar will be decreased to half of the existing one due to the effects of groundsill. For the existing riverbed scouring depth by sandbar, see the previous Section 2.2.2.

(5) Typical Structural Design and Cost

The typical groundsill with spur dikes for the upper Madongan river reaches is designed as follows under the same hydraulic conditions as revetment and spur dikes.

The double-section groundsill made of stone concrete is proposed at an interval of 450 m. The crest elevation of groundsill is set at the design riverbed elevation for the low water channel section and 1.25 m above the design riverbed elevation for the high water channel section.

The size of one (1) unit groundsill is 306 m in length, 3.0 m in height at central section (see Fig. C.2.4). The groundsill concrete and riverbed protection blocks per 1,000 m river distance are estimated to be 2,330 m^3 and 4,060 m^3, respectively.

Between the groundsills, small stone concrete spur dikes are placed in front of both side dikes at an interval of 30 m. The size of one (1) unit spur dike with trapezoid section is 15 m in length, 3.0 m in height, 2.0 m in crown width and 5.0 m in bottom width. The volume of stone concrete per 1,000 m river distance (2,000 m riverbank distance) is estimated to be 8,900 m^3.

The construction cost of the groundsill with spur dikes per 1,000 m river distance is estimated at 53.3 million pesos.

2.2.4 Evaluation of Alternatives

The above three (3) alternatives are compared and evaluated as follows.

(1) The direct construction cost per 1,000 m river distance of the three (3) bank protection works for the representative river reaches in the alluvial fan rivers (upper Madongan River reaches) are compared as follows. Spur dikes are economically most recommendable.

Works	Construction Cost (million pesos/km)
(1) Revetment	48.6
(2) Spur Dikes	28.4
(3) Groundsill with Spur Dikes	53.3

(2) The hydraulic control effect of groundsills is large. However, it is considered too early to construct groundsills that will fix the riverbed elevation and slope in this stage. Detailed and accurate prediction of the future riverbed elevation and slope is difficult at present. The groundsills will prevent the degradation of riverbed. However, the riverbed degradation in the upper reaches of the alluvial fan is considered more preferable for flood damage reduction.

It is considered preferable to construct groundsills in the future after the riverbed slope becomes stable.

(3) Construction of a perfect bank protection structure which requires no maintenance works is considered difficult in these alluvial fan rivers. However, the scale of structural damage at one site and annual required maintenance cost must be below a certain level in view of the technical and financial limitation of the responsible agency for maintenance.

Each spur dike unit is structurally independent. Damage of one unit will not cause chain reacting damages of other units and its adverse effect on river hydraulic condition will be limited within a local area. Hence, the scale of structural damage of spur dike at one site is considered smaller than those of the other alternatives.

(4) Among the three (3) alternatives of bank protection works, the maintenance requirement of the spur dikes is considered the least. The major maintenance problem of the spur dikes is only that their heads are susceptible to damage by a local scouring exceeding the design criteria, especially at the upstream end of a series of spur dikes. However, the spur dikes will function as planned even if the head of the spur dike is broken as far as the broken head is not carried away by flood flow.

According to the US Corps of Engineers, the critical size (diameter) of a stone/pebble which is carried away by the flood flow of a velocity (V) is evaluated by the following formula: $D = V^2/23.9$.

The main stream velocity of the design flood in the upper Madongan River reaches is estimated to be 5.5 m/s. Therefore, the critical size of a stone is calculated to be D = 3.0 m (stone volume : 15 m^3, stone weight - 40 ton) by assuming the velocity at the tip of spur dikes is 1.5 times of the main stream velocity of river channel.

On the other hand, the broken head of spur dike is estimated as heavy as more than 70 tons by assuming that the spur dike is broken at 2.0 m from the tip. The head will not be carried away by flood water. Critical Flow velocity which will carry down the broken head is roughly estimated at 9.5 m/s.

From the above discussions, spur dikes are recommended for the dike protection of the project.

2.2.5 Design Criteria of Proposed Bank Protection Works

Spur dikes are employed for protection of the proposed earth dikes. Their design criteria are summarized as follows.

(1) Length and Interval Distance

The length of all the spur dikes is set at 15 m. The interval distance of spur dikes is designed to vary according to riverbed slope as follows.

(a) 30 m for the river sections with a riverbed slope steeper than 0.8%.
(b) 60 m for the river sections with a riverbed slope gentler than 0.8%.

(2) Foundation Depth and Crown Elevation

The foundation depth of spur dikes is designed in consideration of the riverbed scouring caused by sandbar and by the flow disturbance of spur dikes.

The riverbed scouring by sand bar varies depending on the riverbed slope as mentioned before. The average design foundation depth of spur dikes is set as shown below by assuming that the riverbed scouring depth by the flow disturbance of spur dikes varies from 0.5 m near the riverbank to 1.5 m at the spur dike head with an average of 1.0 m.

Riverbed Slope (%)	Foundation Depth below Existing/Future Average Riverbed	Structural Type
S < 0.8	2.2	Type-A
0.8 < S < 1.3	2.5	Type-B
1.3 < S < 1.5	3.0	Type-C
1.5 < S	3.3	Type-D

The crown elevation of spur dikes is set at 1.0 m below the design high water levels in principle.

Higher spur dikes make the roughness of riverbed larger and as a result, make the flow velocity on high water channel smaller. However, they are susceptible to a deeper riverbed scouring at their heads. The optimum height and shape of spur dikes will be determined through a hydraulic model test in the detailed design stage.

(3) Location of Spur Dike Construction

The spur dikes will be provided according to the following principles.

(a) Both banks will be protected in the river section with double sandbars where floodwater convergence point is not fixed. The interval distance of spur dike will be set at 30 m or 60 m, depending on the riverbed slope.

(b) The bank of floodwater convergence side will mainly be protected in the river section with single sandbars where floodwater convergence point is almost fixed. The interval distance will be set at 30 m or 60 m, depending on the riverbed slopes. The opposite side bank will be provided with spur dikes of long interval distance (60 m) to meet secondary flood water streams as required.

(c) The banks in the following river sections will be protected as required.

   (i) River sections with no dike.

   (ii) River section where background inundation area is comparatively small or high in elevation.

   (iii) River section which is affected by backwater of the Laoag-Bongo River.

2.3 Cura/Labugaon River Improvement

The existing Cura/Labugaon River consists of a number of distributaries with braided river streams. As formulated in the Master Plan Study, the existing braided channels with 600 to 1,200 m in width are proposed to be one (1) channel with a width of 340 m confined by diking system along the existing main stream. The Labugaon River is designed to join the Cura River at the fan apex. New channel is designed in the existing river area as much as possible to minimize the land acquisition.

The proposed alignment, profiles, typical cross-sections of the proposed river improvement are shown in Fig. C.2.5.

In addition to the design criteria of river channel mentioned in Section 2.1 above, the following should be noted.

Dike Alignment

Section	Considerations
Bagbag II Bridge (4.5 km upstream from the confluence)	Right dike is proposed to connect with the right abutment of bridge because there exists a 1.5 km Bagbag Dike upstream from bridge on the right bank.
Barangay St. Maria (9.0 km upstream)	One tributary (San Antonio River) flows into the Cura River. Proposed right dike will be connected with high place in St. Maria.
Right Bank between St. Maria and San Julian (9.0 - 13.0 km upstream)	No provision of dike is proposed because the lands are relatively higher than design high water levels and there is a existing dike along irrigation canal 100 m far from the river.
Lower Labugaon River	About 2.0 km long dike is proposed on the left bank connecting hill side at mostupstream end. This dike is curved by about 40 degree so that. This curved section will be severely eroded. Hence, wide dike is designed using the material of channel excavation. No dike is provided on the right because of mountain area.

Longitudinal Profiles

New channel is proposed to follow the present main stream as much as possible. Some sections of proposed channel are required to provide a pilot channel by excavation of the bed for smooth flow. The sections are located especially in the vicinity of the confluence with the Laoag River and lower Labugaon River. Moreover, the channel will be entirely excavated to obtain the materials for dike embankment.

Thus, large channel excavation is not proposed. Design high water levels are determined under the conditions of provision of diking system, limited channel excavation, and existing and future predicted riverbed.

(1) Plan Features

The improvement length, design width, design discharges and design slopes of high water levels are as below.

River	River Section	Design Discharge (m^3/s)	Improvement Length (km)	River Width (m)	Slopes of H.W.L
Cura	Lower /Middle	2,360	11.0	340	0.138 - 0.813
	Upper	850	none	-	-
Labugaon	Lower	1,260	2.0	250	0.864, 0.948

(2) Work Volumes

The river improvement plan include the following works.

Works	Quantity	Remarks
Excavation	992,000 m^3	Entire reaches.
Dikes	21.5 km	Earth dike (992,000 m^3). Use of riverbed material. 4 m top width.
Spur Dikes	349 units	Entire reaches. 172 pieces at left dike and 109 pieces at right bank of Cura River and 68 pieces at left dike of Labugaon River.
Groundsill	1 unit	Stone concrete material Immediate downstream of Labugaon Diversion Dam
Sluiceways	4 units	Intake purpose Reinforced concrete box culvert with sluice gate.
Extension of Bridge	1 unit	Bagbag II Bridge 90 m long x 9.0 wide

(3) Design of Proposed Structures

The typical structural design of the earth dike, stone concrete spur dike, intake sluiceway, groundsill and extension of bridge are shown in Fig. C.2.6.

Regarding the freeboard and crown width of dike in the Labugaon, Solsona, Madongan and Papa rivers having design discharge between 500 m^3/s and 2,000 m^3/s, freeboard of 1.0 m and crown width of 4.0 m are adopted in accordance with the DPWH criteria as described in Section 1.2. In Cura River, the above figures are also adopted, since the design discharge exceeds a little more than 2,000 m^3/s.

A groundsill is provided immediately downstream of the existing INIP-1 Labugaon diversion dam to maintain the existing condition of these structures.

Existing four (4) irrigation intakes in the improved reaches will be replaced by reinforced concrete box culverts with steel sluice gate.

The Bagbag II Bridge will be extended by 90 m in accordance width the river improvement plan. Extension is designed in the same manner as the existing one: 6 spans x 15 m per span, reinforced concrete girders and pile piers.

(4) Land Acquisition and House Resettlement

Land acquisition of farm/bush land (10.0 ha) is required for the improvement works, while no house resettlement is necessary.

2.4 Solsona River Improvement

The proposed plan will strengthen the existing dikes over the entire river reaches and heighten them in the lowermost reaches coordinate with the design high water level.
The proposed alignment, profiles, and typical cross-sections of the proposed river improvement are shown in Fig. C.2.7.

(1) Plan Features

The improvement length, design width, design discharges and design slopes of high water levels are as below.

River Section	Design Discharge (m^3/s)	Improvement Length (km)	River Width (m)	Slopes of H.W.L (%)
Lower	3,490	0.5	330	0.152
Middle	1,120	5.5	230	0.071 - 0.879
Upper	1,030	4.0	230	1.446, 1.542

(2) Work Volumes

The river improvement plan include the following works.

Works	Quantity	Remarks
Heightening of Existing Dikes	202,000 m^3	16 km in total. Rverbed materials.
Repairing of Existing Dikes	5,000 m^3	Use of riverbed materials.
Spur Dikes	302 units	Entire reaches 154 pieces at left dike and 148 pieces at right dike. Stone concrete materials.
Groundsill	1 unit	Stone concrete material. Immediate downstream of Solsona Diversion Dam.
Sluiceways	3 unit	Intake purpose. Reinforced concrete box culvert with sluice gate

(3) Design of Proposed Structures

The typical structural designs of the dike, spur dike, and intake sluiceway are shown in Fig. C.2.6.

A groundsill is provided to prevent the degradation of riverbed in the immediate downstream of the Solsona Diversion Dam.

Existing intake sluiceways have insufficient structural strength. They will be replaced by new reinforced concrete box culvert with steel sluice gate.

(4) Land Acquisition and House Resettlement

No land acquisition is required for heightening of dike. No house resettlement is also necessary.

2.5 Madongan River Improvement

The proposed plan will also strengthen the existing dikes over the entire river reaches.
The proposed alignment, profiles, and typical cross-sections of the proposed river improvement are shown in Fig. C.2.8.

(1) Plan Features

The improvement length, design width, design discharges and design slopes of high water levels are as below.

River Section	Design Discharge (m^3/s)	Improvement Length (km)	River Width (m)	Slopes of H.W.L (%)
Entire	1,970	9.0	300	0.233 - 1.372

(2) Work Volumes

The river improvement works mainly include the following.

Works	Quantity	Remarks
Heightening of Existing Dikes	110,000 m^3	10.0 km in total. Use of riverbed materials.
Repairing of Existing Dikes	18,000 m^3	Use of riverbed materials.
Spur Dikes	394 units	Entire reaches. 222 units at left dike and 172 units at right dike. Stone concrete materials.
Groundsill	1 unit	Stone concrete material. Immediate downstream of existing Madongan Diversion Dam.
Sluiceways	8 units	Intake purpose. Reinforced concrete box culvert with sluice gate.

(3) Design of Proposed Structures

The typical structural design of the dike, spur dike, groundsill and intake sluiceway are shown in Fig. C.2.6.

(4) Land Acquisition and House Resettlement

No land acquisition is required for heightening of dikes. No house resettlement is also necessary for the improvement works.

2.6 Papa River Improvement

The river improvement of Papa River also aims the strength of existing dikes.
The proposed alignment, profiles, typical cross-sections of the improved river are shown in Fig. C.2.9.

(1) Plan Features

The improvement length, design width, design discharges and design slopes of high water levels are as below.

River Section	Design Discharge (m^3/s)	Improvement Length (km)	River Width (m)	Slopes of H.W.L (%)
Entire	690	7.0	223	0.496 - 1.854

(2) Work Volumes

The improvement works include the following.

Works	Quantity	Remarks
Heightening of Existing Dikes	20,000 m^3	4.5 km in total. Use of riverbed materials.
Repairing of Existing Dikes	6,800 m^3	Use of riverbed materials.
Spur Dikes	283 units	Entire reaches. 143 units at left dike and 140 units at right dike. Stone concrete materials.
Groundsill	1 unit	Stone concrete material. Immediate downstream of existing Papa Diversion Dam
Sluiceways	2 units	Intake purpose. Reinforced concrete box culvert with sluice gate.

(3) Design of Proposed Structures

The typical structural design of the dike, spur dike, groundsill and intake sluiceway are shown in Fig. C.2.6.

(4) Land Acquisition and House Resettlement

No land acquisition and house resettlement is necessary for the improvement works.

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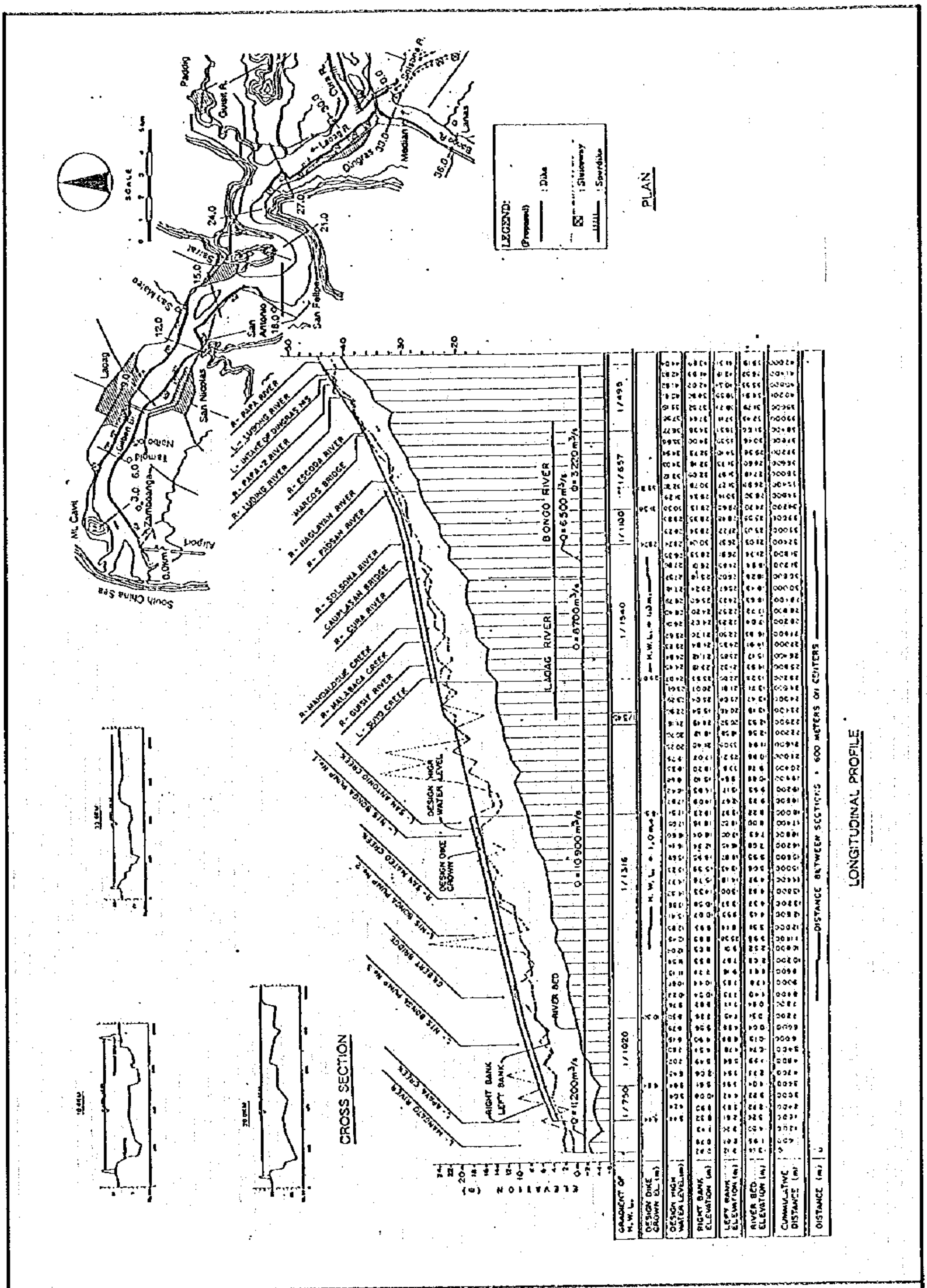
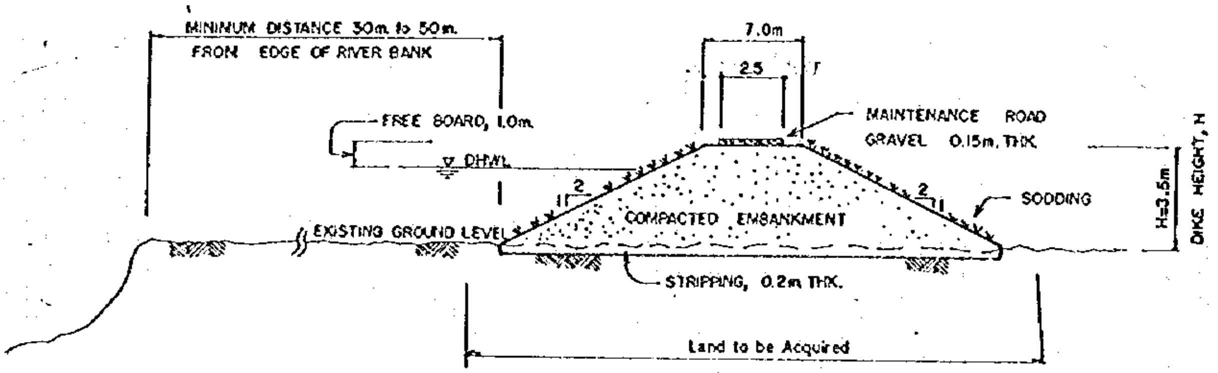
FIGURES

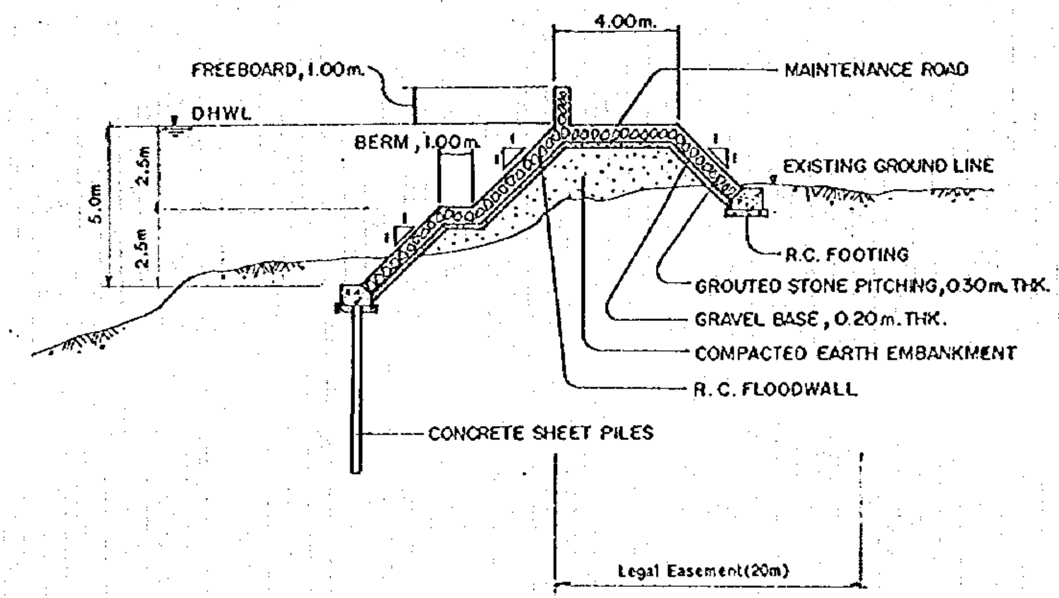


THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C.1.1 Master River Improvement Plan (Laoag-Bongo River)

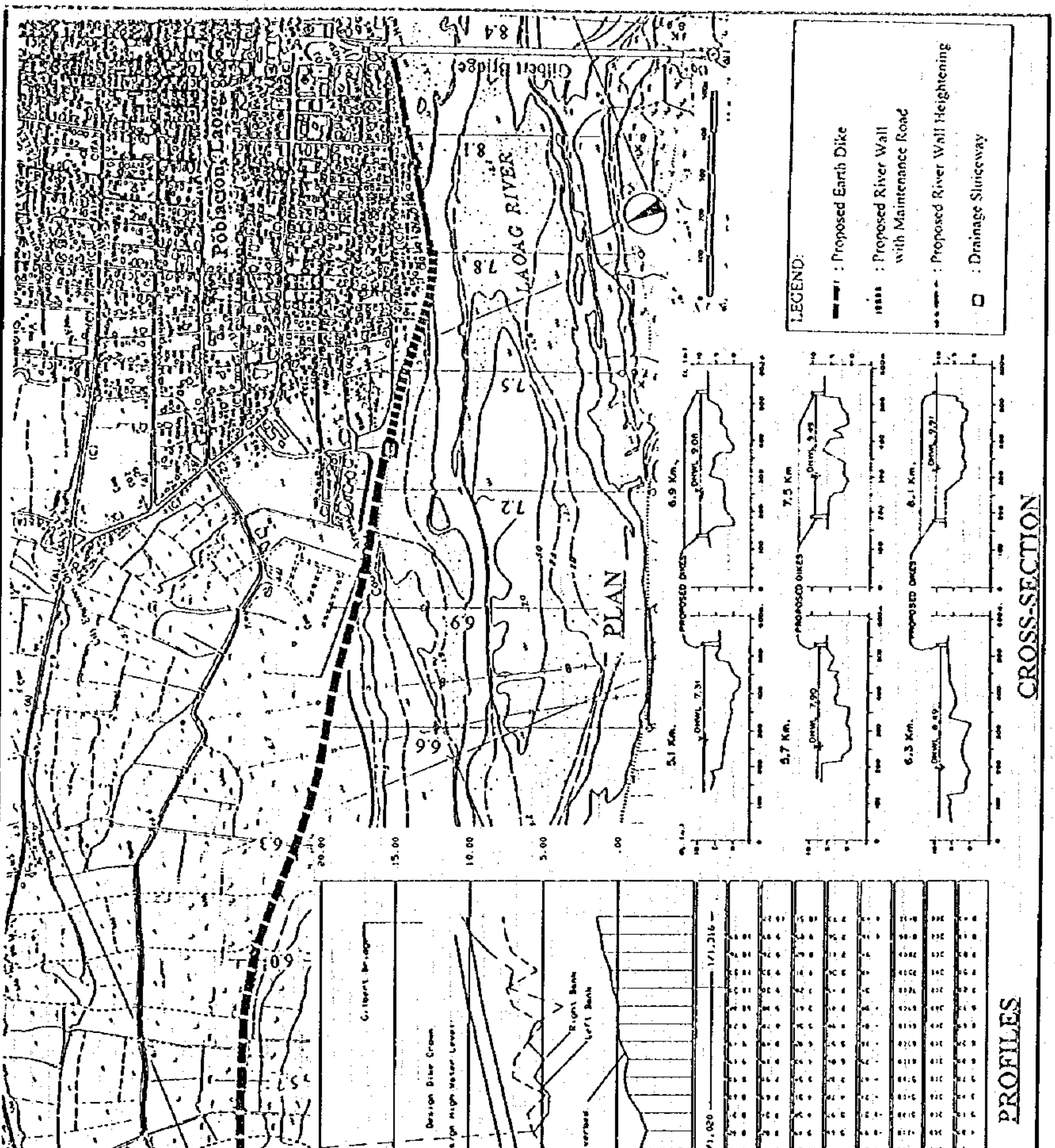
(1) Earth Dike



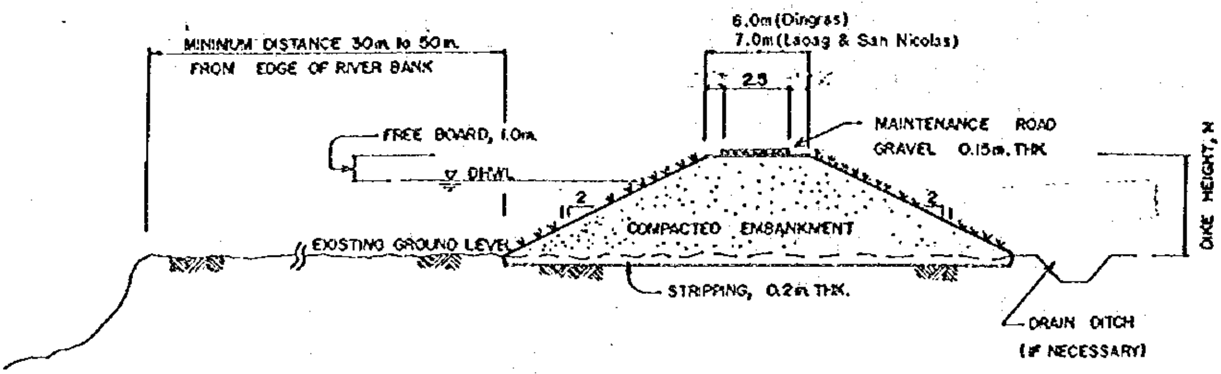
(2) River Wall



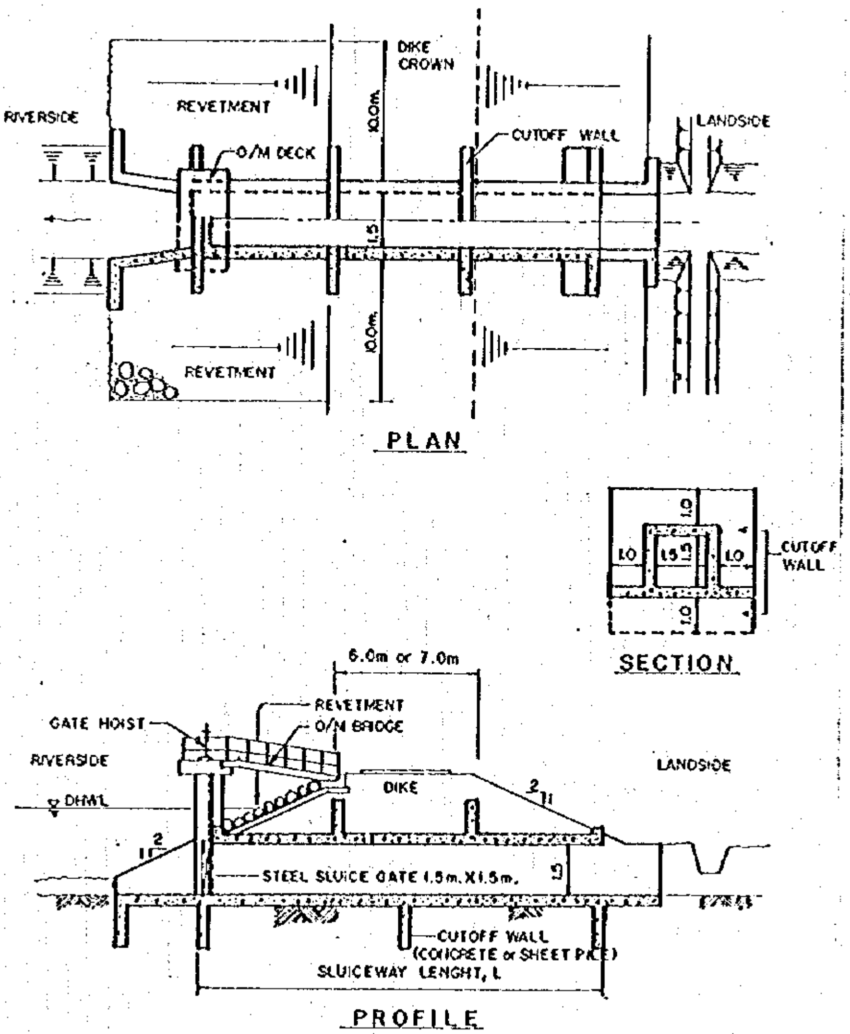
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C.1.2 Comparison of Dike Type



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C.1.3 River Improvement Plan of Poblacion Laoag

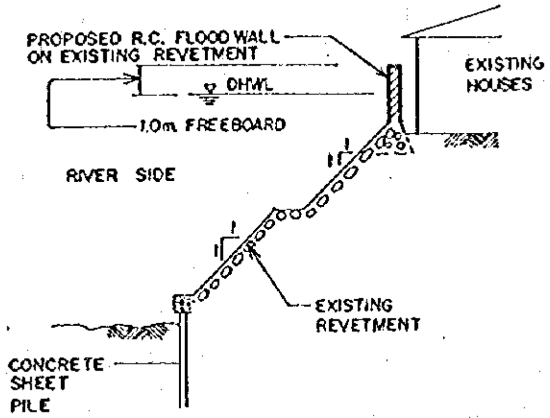


Earth Dike

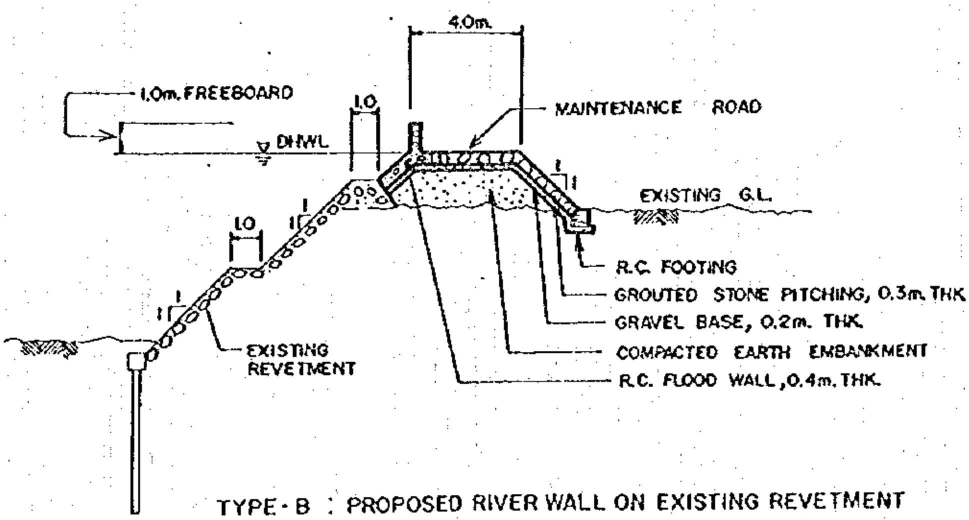


Drainage Sluiceway

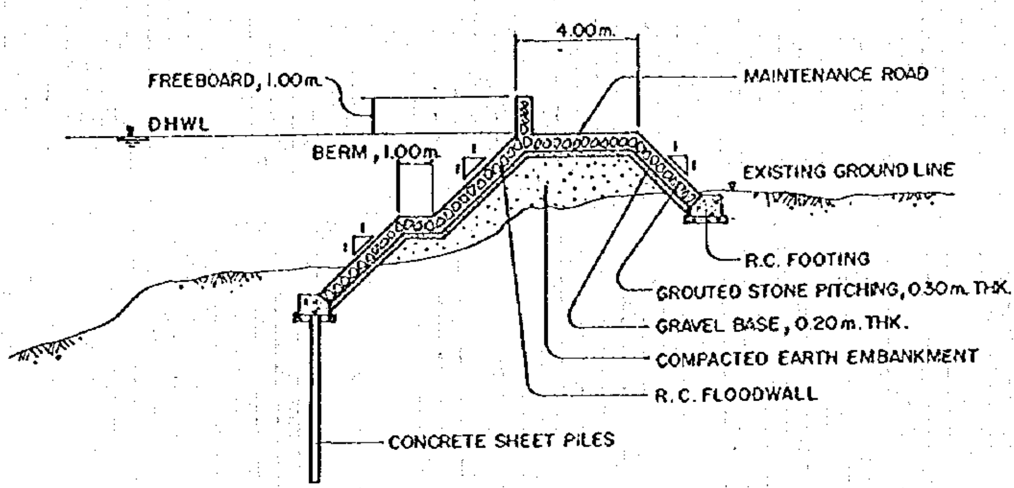
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C.1.4 (1) Proposed Structures for Laoag-Bongo River Improvement



TYPE-A : PROPOSED HEIGHTENING WALL

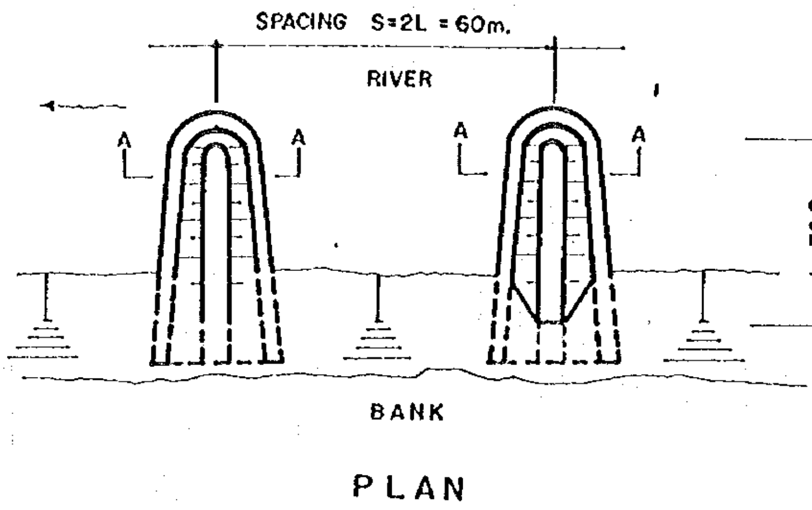


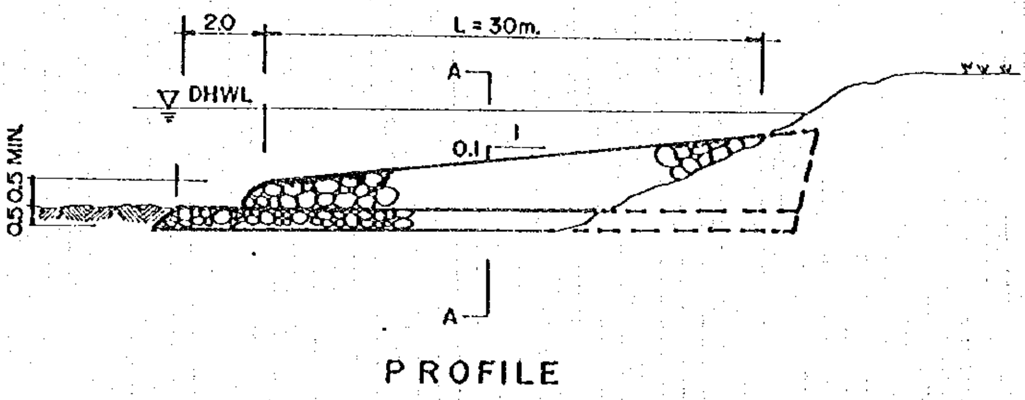
TYPE-B : PROPOSED RIVER WALL ON EXISTING REVETMENT

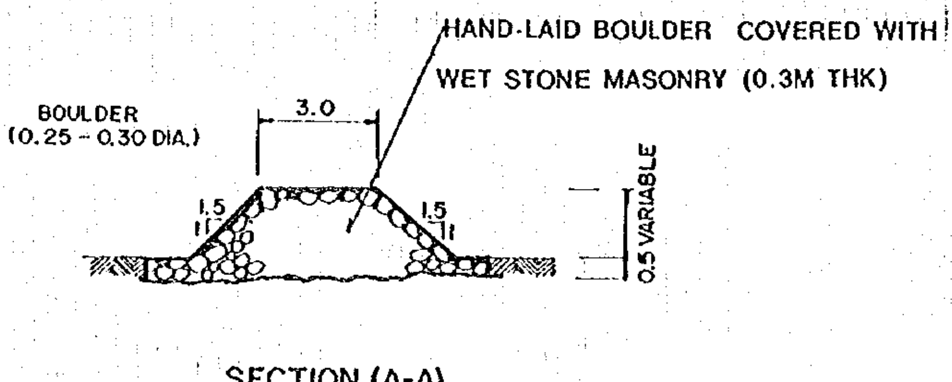


TYPE-C : PROPOSED RIVER WALL

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C.1.4 (2) Proposed Structures for Laoag-Bongo River Improvement

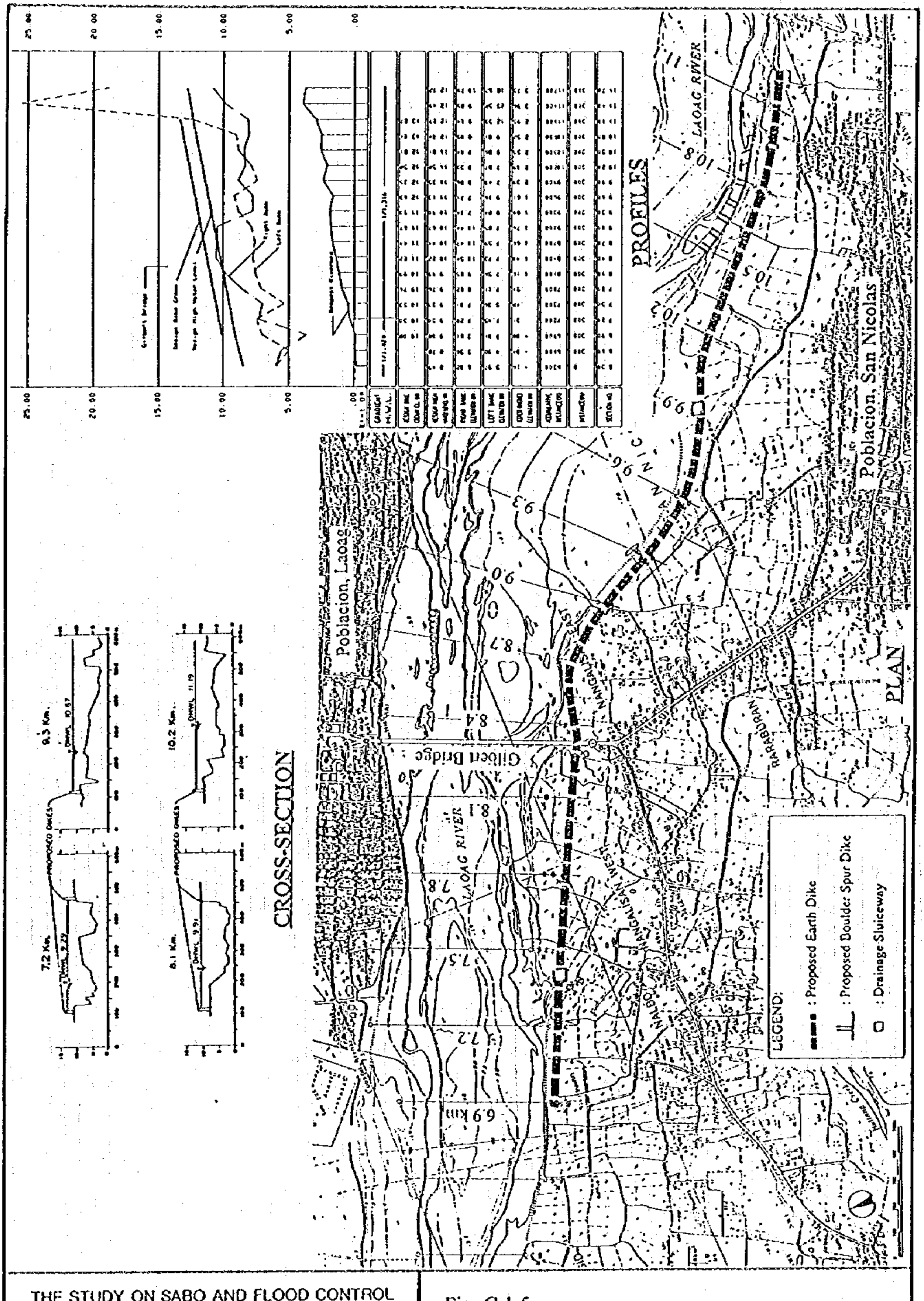






Boulder Spur Dike

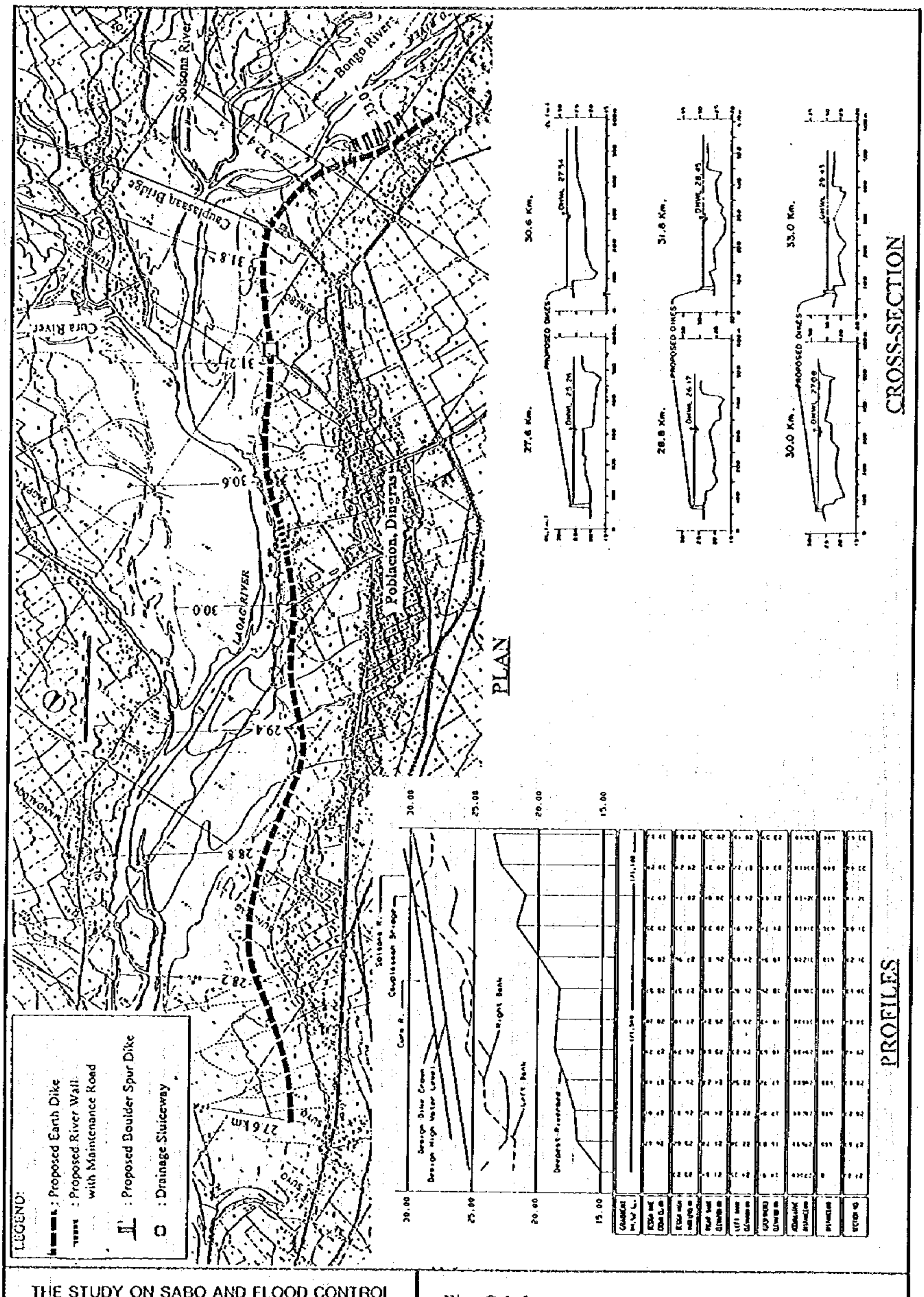
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C.1.4 (3) Proposed Structures for Laoag-Bongo River Improvement



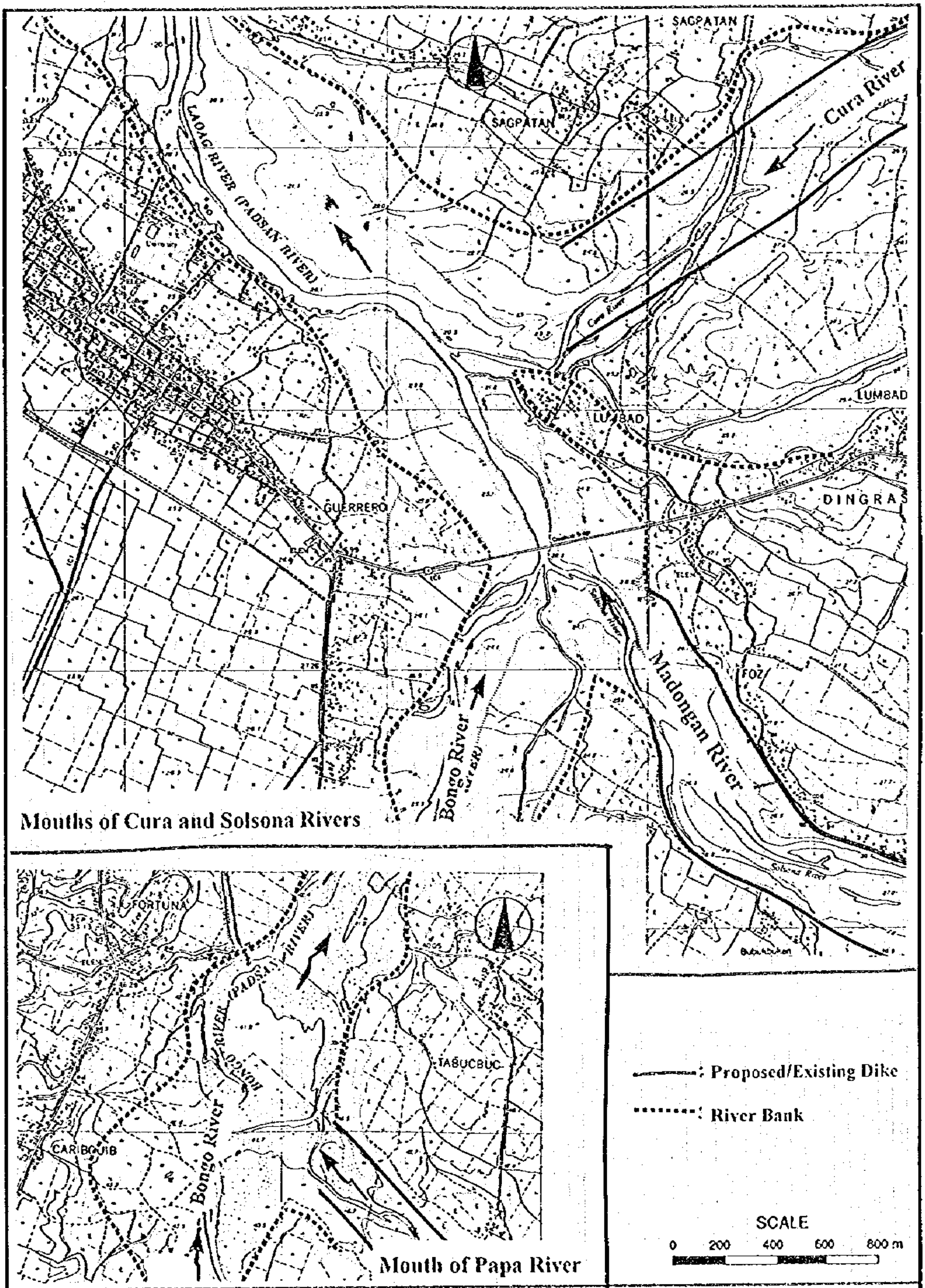
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. C.1.5
River Improvement Plan of Poblacion San Nicolas

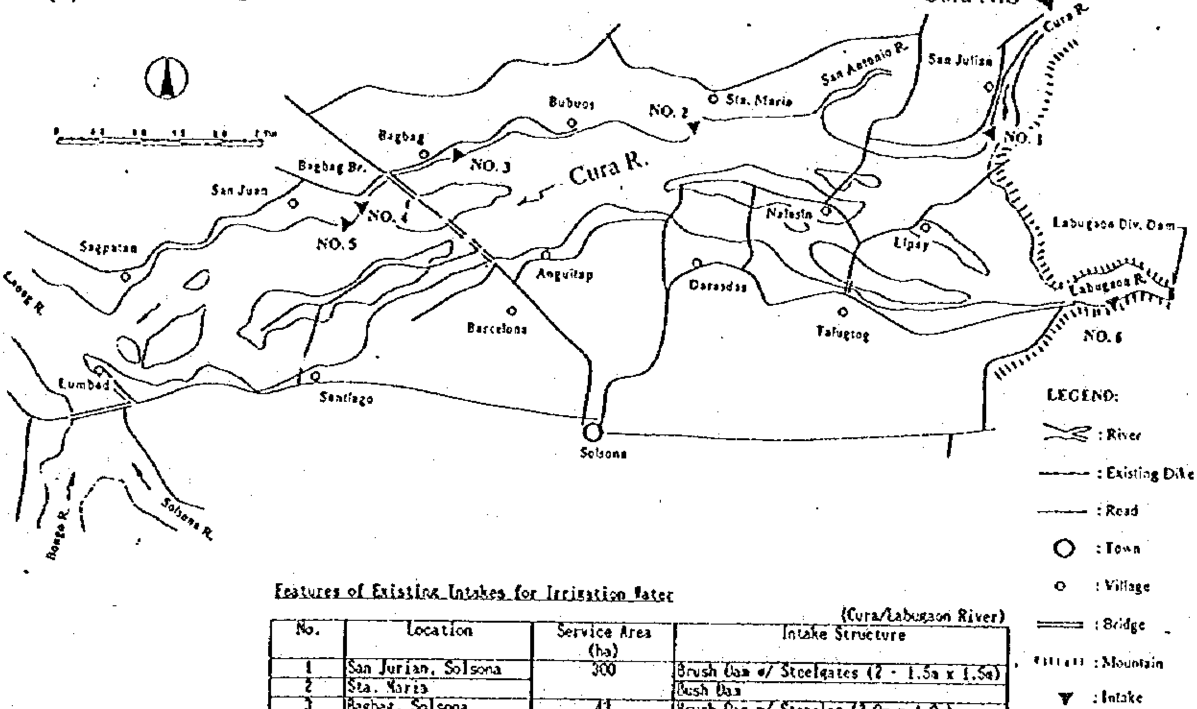


THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C.1.6 River Improvement Plan of Poblacion Dingras



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C.2.1 Proposed Alignment of River Mouth

(1) Cura/Labugaon River

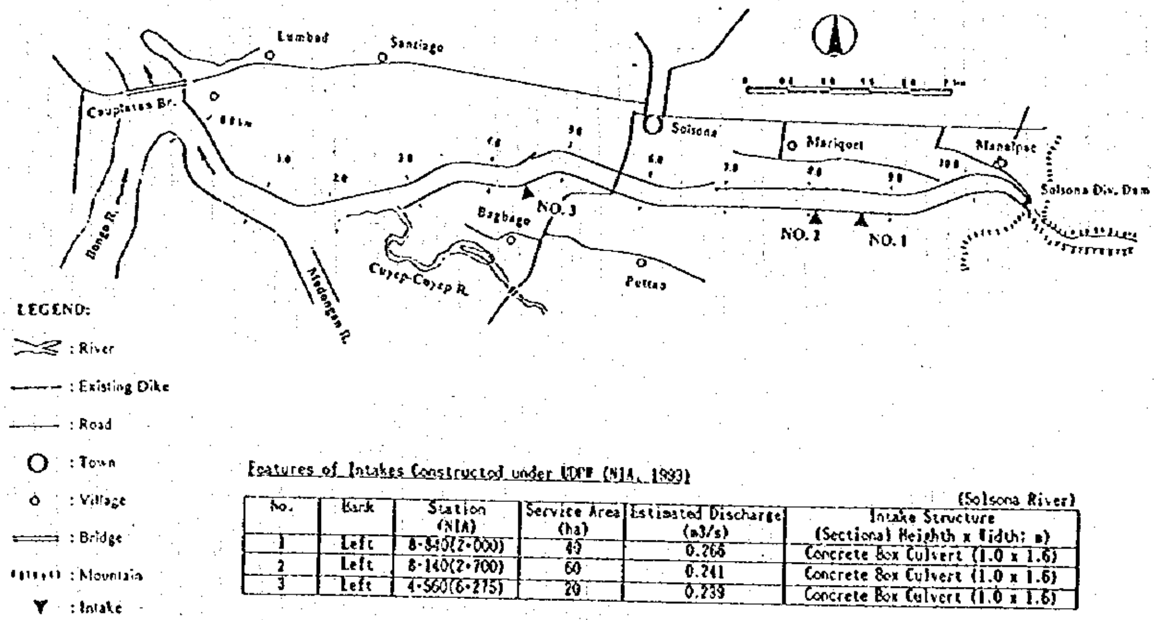


Features of Existing Intakes for Irrigation Water

(Cura/Labugaon River)

No.	Location	Service Area (ha)	Intake Structure
1	San Jurian, Solsona	300	Brush Dam w/ Steelgates (2 - 1.5m x 1.5m)
2	Sta. Maria		Bush Dam
3	Bagbag, Solsona	43	Brush Dam w/ Stop-log (2.0m x 1.0m)
4	San Juan, Solsona	85	Brush Dam
5	San Juan, Solsona	45	Brush Dam
6	Left Bank of Labugaon near Labugaon Div. Dam	302	Brush Dam w/ Steelgates

(2) Solsona River



Features of Intakes Constructed under UDPF (NIA, 1993)

(Solsona River)

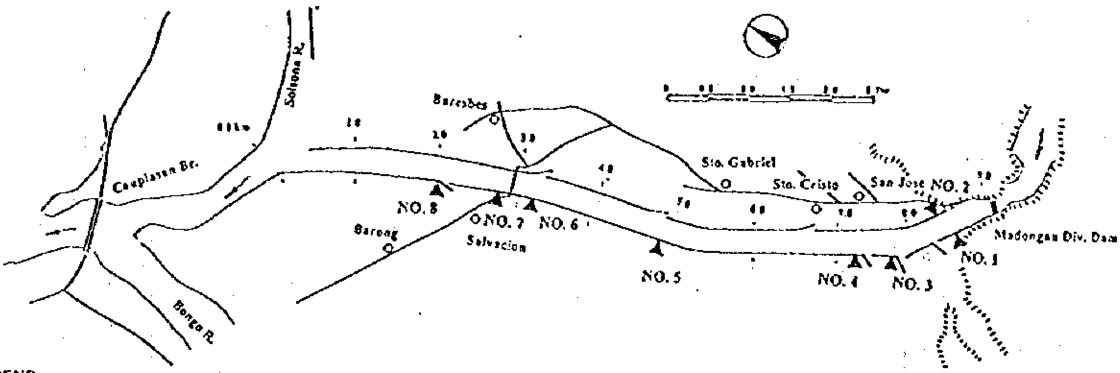
No.	Bank	Station (NIA)	Service Area (ha)	Estimated Discharge (m3/s)	Intake Structure (Sectional Heighth x Width; m)
1	Left	8-840(2+000)	49	0.266	Concrete Box Culvert (1.0 x 1.6)
2	Left	8-140(2+700)	60	0.241	Concrete Box Culvert (1.0 x 1.6)
3	Left	4-560(6+275)	20	0.239	Concrete Box Culvert (1.0 x 1.6)

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. C.2.2 (1)
Location of Existing Irrigation Intakes

(3) Madongan River



LEGEND:

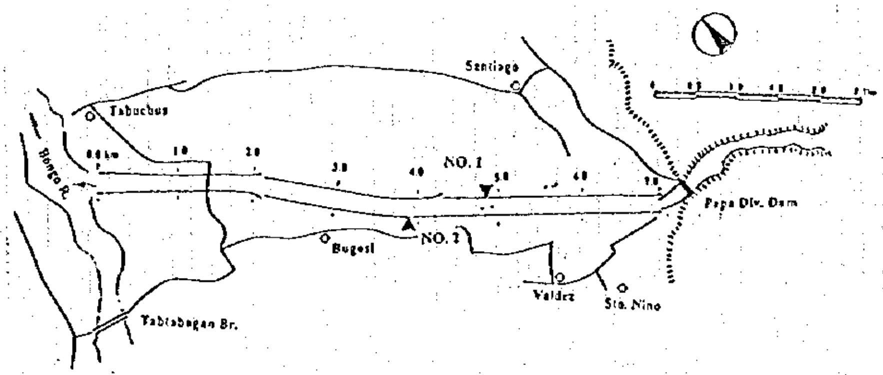
: River
: Existing Dike
: Road
: Town
: Village
: Bridge
: Mountain
: Intake

Features of Intakes Constructed under UOF? (NIA, 1993)

(Madongan River)

No.	Bank	Station (NIA)	Service Area (ha)	Estimated Discharge (m3/s)	Intake Structure (Sectional Height x Width: m)
1	Left	8+520(0+575)	400	2.912	Concrete Box Culvert (2 - 1.0 x 1.6)
2	Right	8+350(0+750)	766	5.310	Concrete Box Culvert (2 - 1.0 x 1.6)
3	Left	7+750(1+340)	415	3.021	Concrete Box Culvert (2 - 1.0 x 1.6)
4	Left	7+240(1+858)	715	5.205	Concrete Box Culvert (2 - 1.0 x 1.6)
5	Left	4+850(4+245)	441	3.210	Concrete Box Culvert (2 - 1.0 x 1.6)
6	Left	3+300(5+800)	25	0.182	Concrete Box Culvert (1.0 x 1.6)
7	Left	2+800(6+300)	14	0.102	Concrete Box Culvert (1.0 x 1.6)
8	Left	2+050(7+050)	110	0.762	Concrete Box Culvert (1.0 x 1.6)

(4) Papa River



LEGEND:

: River
: Existing Dike
: Road
: Town
: Village
: Bridge
: Mountain
: Intake

Features of Intakes Constructed under UOF? (NIA, 1993)

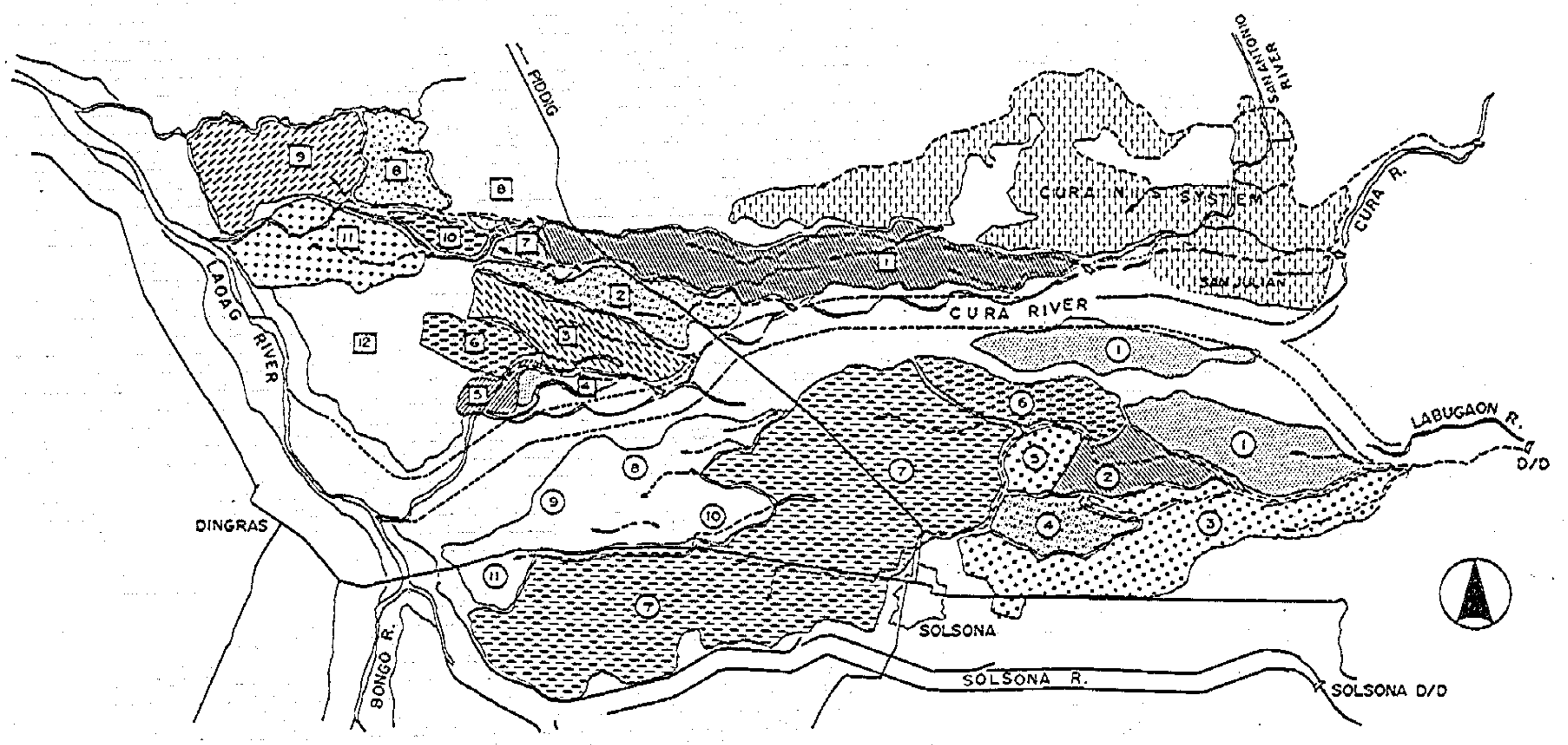
(Papa River)

No.	Bank	Station (NIA)	Service Area (ha)	Estimated Discharge (m3/s)	Intake Structure (Sectional Height x Width: m)
1	Right	4+910(2+325)	64	0.471	Concrete Box Culvert (1.0 x 1.4)
2	Left	3+640(3+600)	115	0.779	Concrete Box Culvert (1.0 x 1.6)

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. C.2.2 (2)
Location of Existing Irrigation Intakes



List of Zanjeras and Communal Irrigation Systems

Right Bank of Cura River

1	Grand Association Zanjera de Bagbag Incorporation
2	BagBag
3	Besang-Camogan-cabalasangan-Dalipawen Inc
4	San Roque
5	Cabayaoasan
6	Manapaya-Caboroan
7	Caboroan - Capagued CIS
8	Bowbow - Casabean CIS
9	Madupayas CIS
10	Caenseyan CIS
11	San Juan- Bagut- Maaroc CIS
12	Zanjeras which get reuse water

Left Bank of Cura River

(1)	Zanjera De Original Inc
(2)	Calaloma et.al. Irrigators Assosiacion Inc
(3)	Zanjera Dona Laza et al. Inc
(4)	Zanjera De Matayag Inc.
(5)	Darasdas Centro Irrigators Assosiacion Inc
(6)	Nagkaykayaa Irrigators Association Inc
(7)	Sodin Tina Flame Bearer Federated Zanjeras Inc
(8)	Zanjera Camogan-Kaboan
(9)	Zanjera Bad-badoc-Capidigan
(10)	Zanjera Santiago
(11)	Zanjera Lumbad-Kaar-Mzsin-Poton-Bisangen

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN

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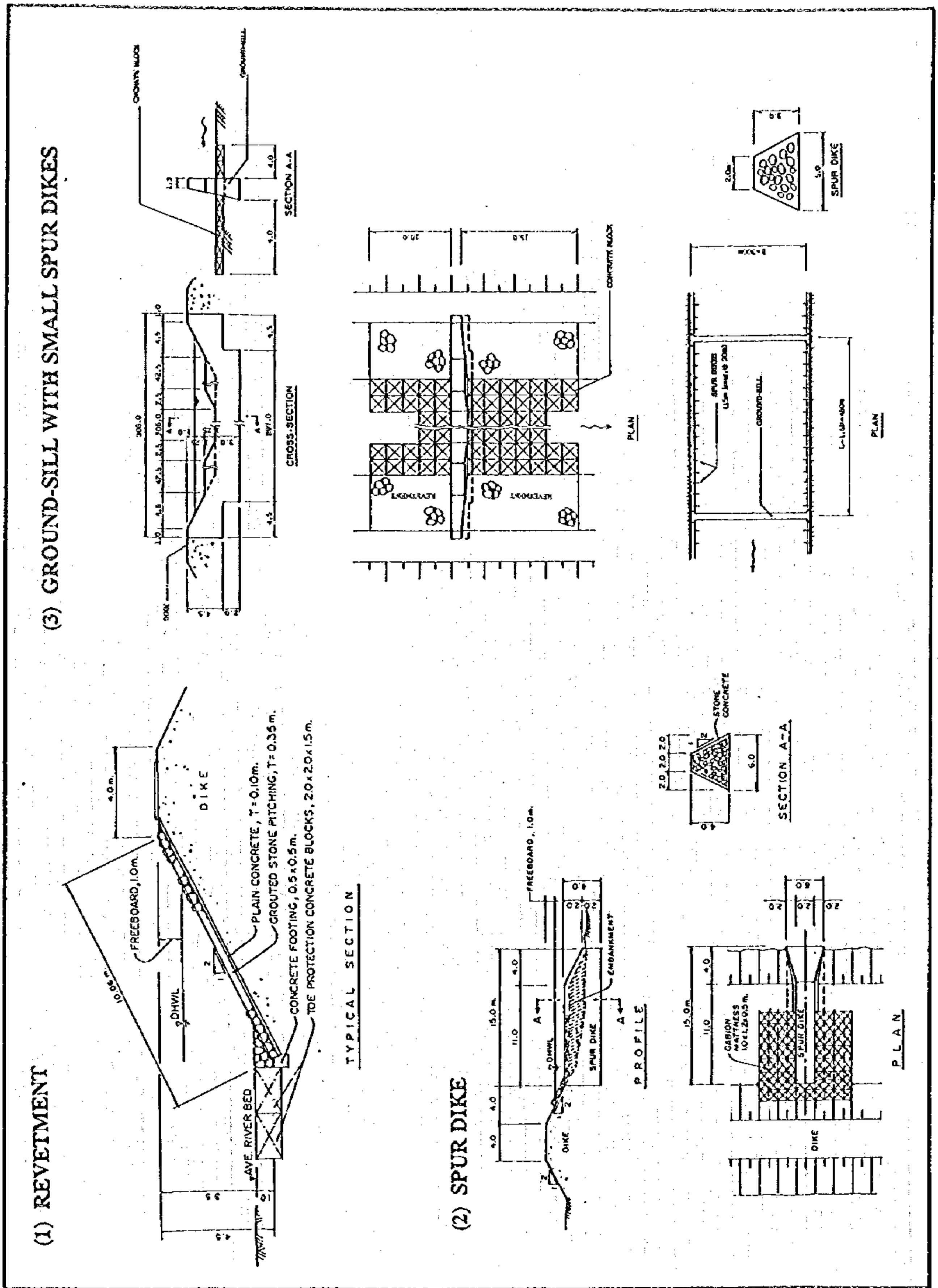
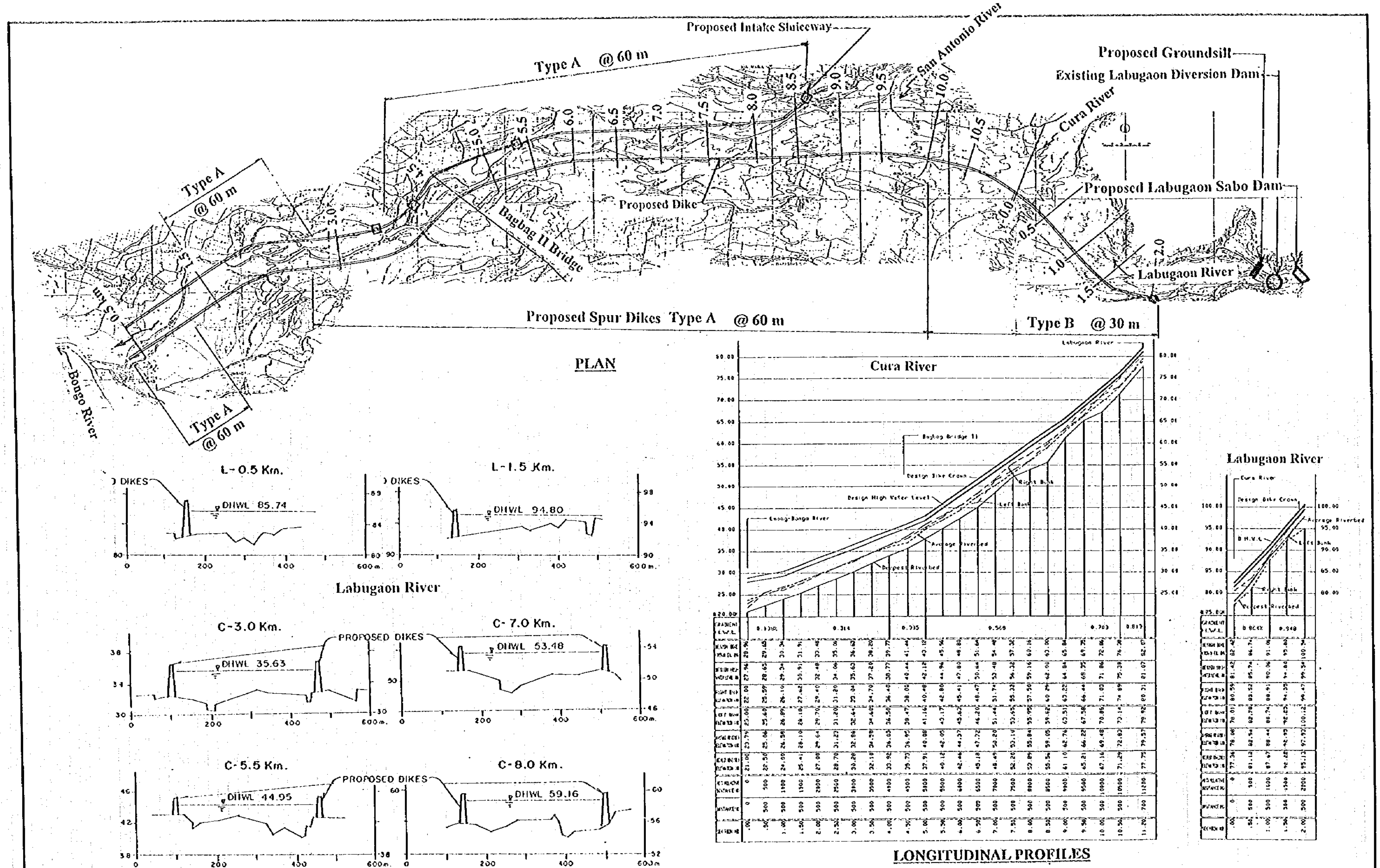
Fig. C.2.3
Cura/Labugaon River Irrigation System



THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C.2.4 Comparison of Bank Protection Works



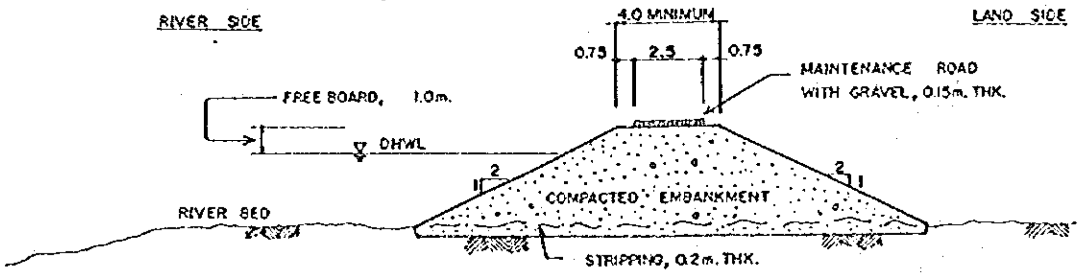
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN

JAPAN INTERNATIONAL COOPERATION AGENCY

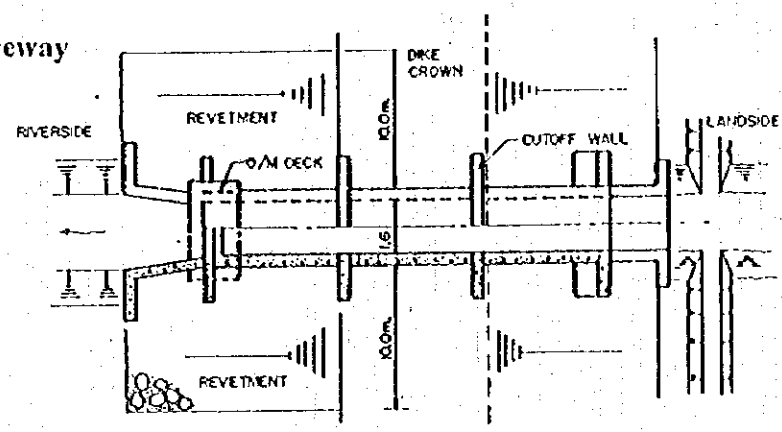
Fig. C.2.5

Cura/Labugaon River Improvement Plan

(1) Dike

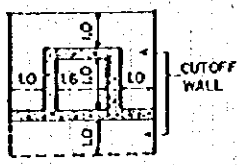


(2) Intake Sluiceway

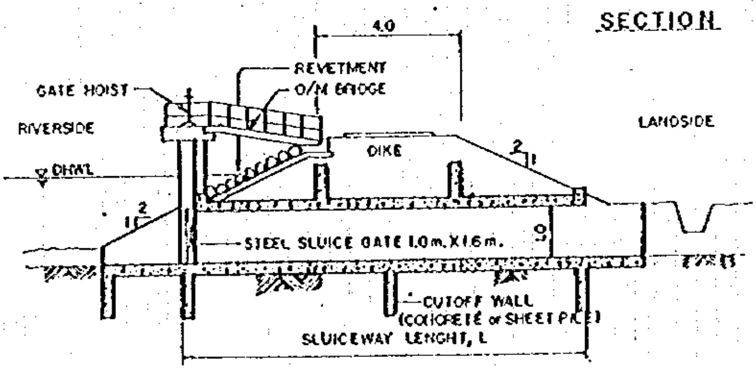


PLAN

TYPE	NO. OF BOX
A	1
B	2



SECTION



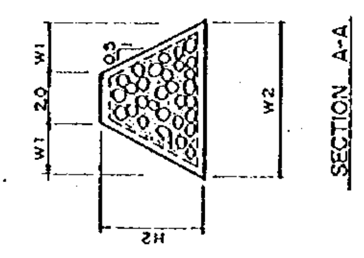
PROFILE

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN

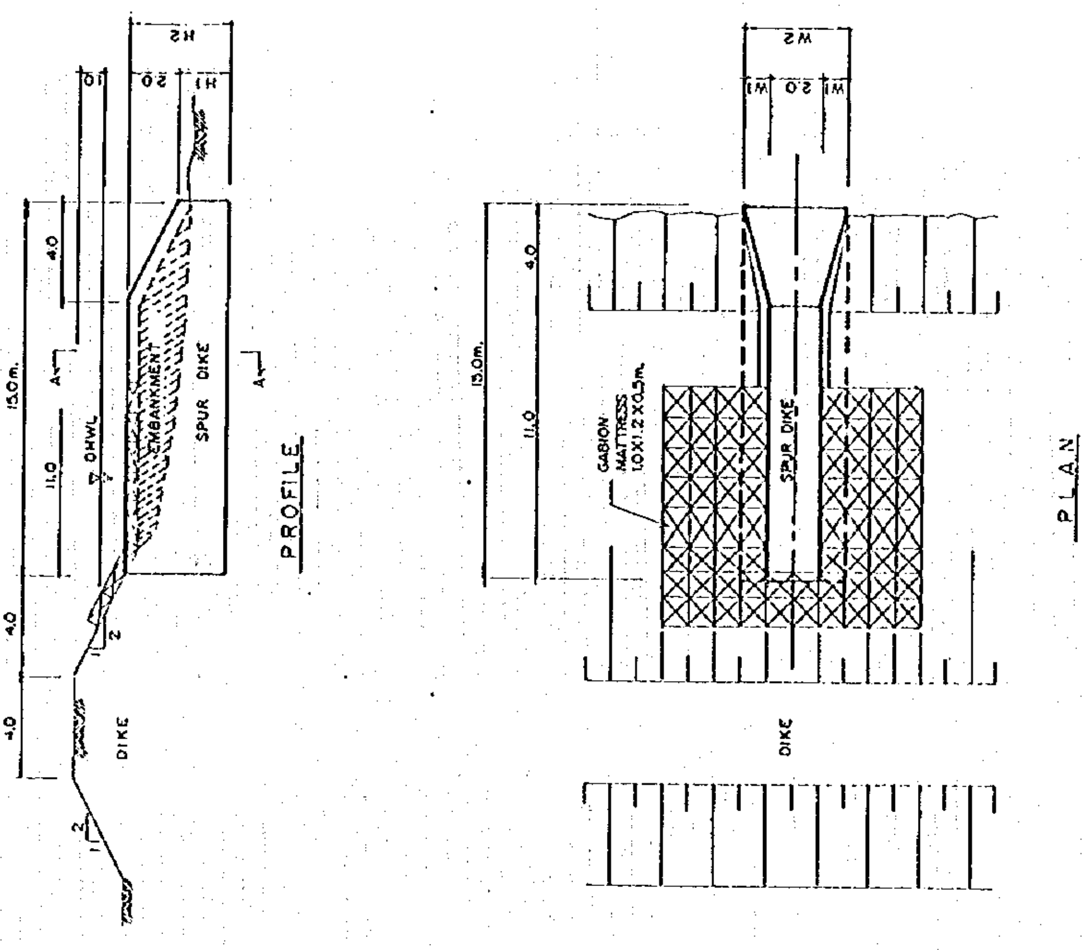
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. C.2.6 (1)
Structural Design of Proposed Structures for Alluvial Fan River Improvement

(3) Stone Concrete Spur Dike

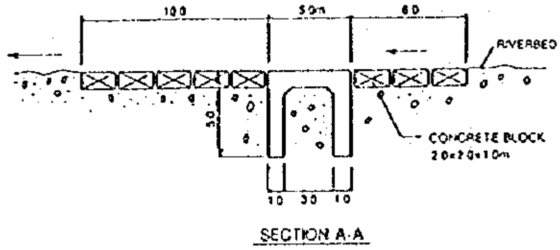


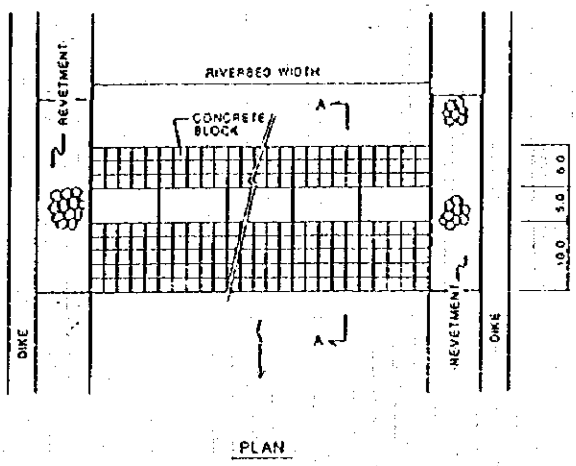
TYPE	H1	H2	W1	W2
A	1.20	3.20	1.60	5.20
B	1.50	3.50	1.75	5.50
C	2.00	4.00	2.00	6.00
D	2.30	4.30	2.15	6.30



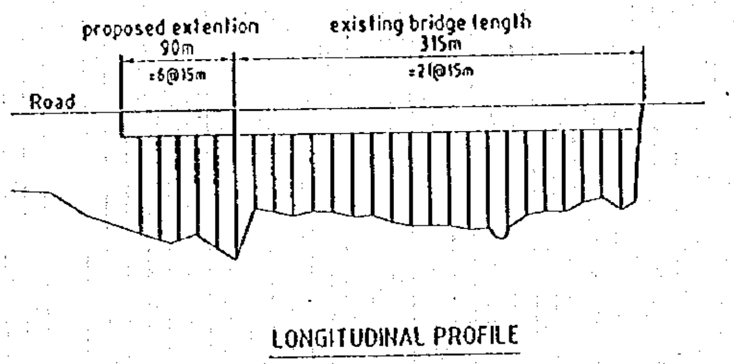
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. C.2.6 (2) Structural Design of Proposed Structures for Alluvial Fan River Improvement
JAPAN INTERNATIONAL COOPERATION AGENCY	

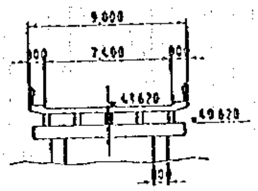
(4) Groundsill

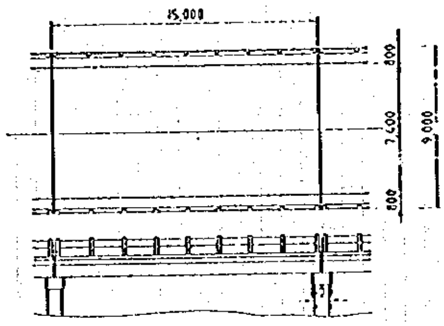




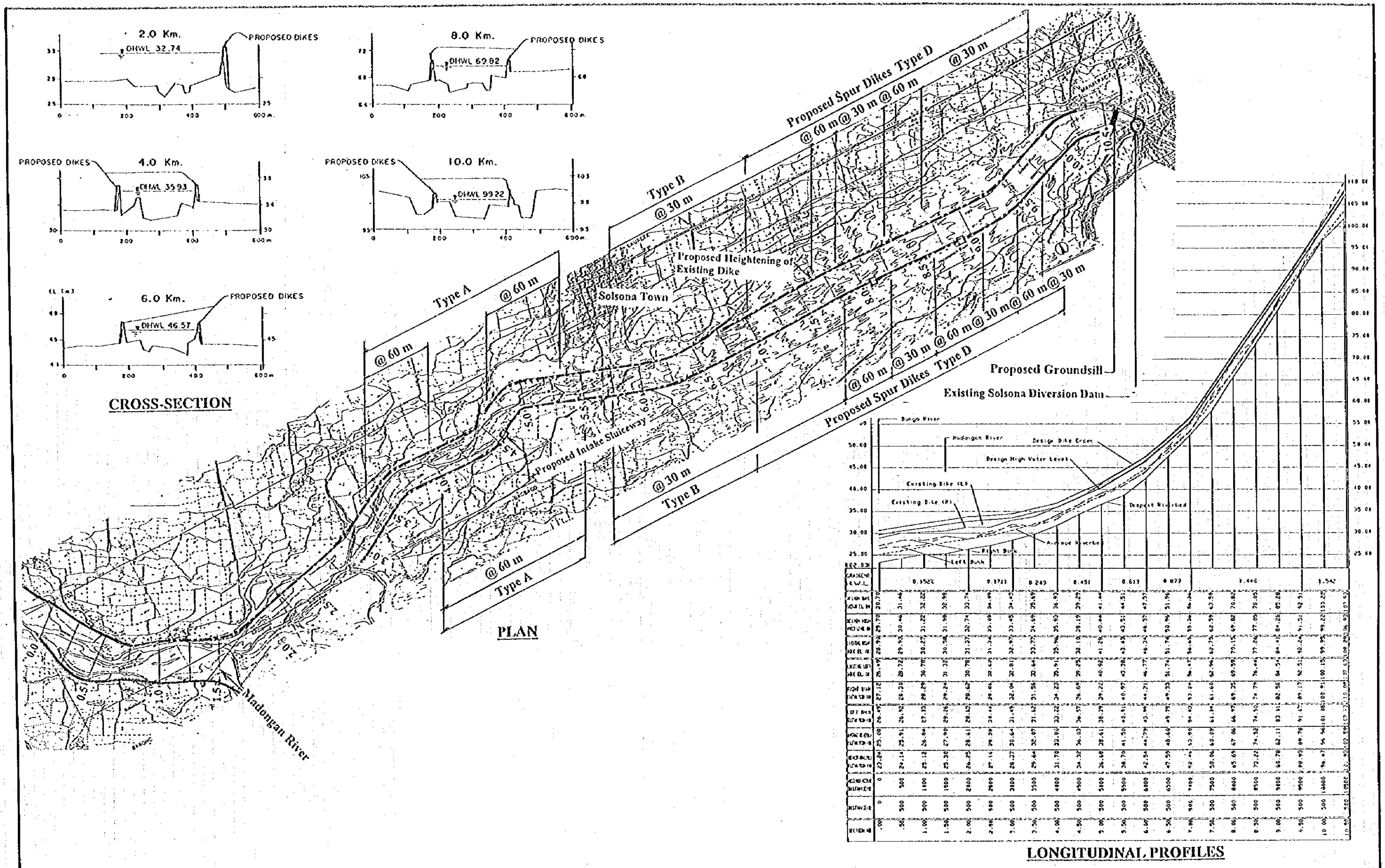
(5) Bagbag Br. Extension



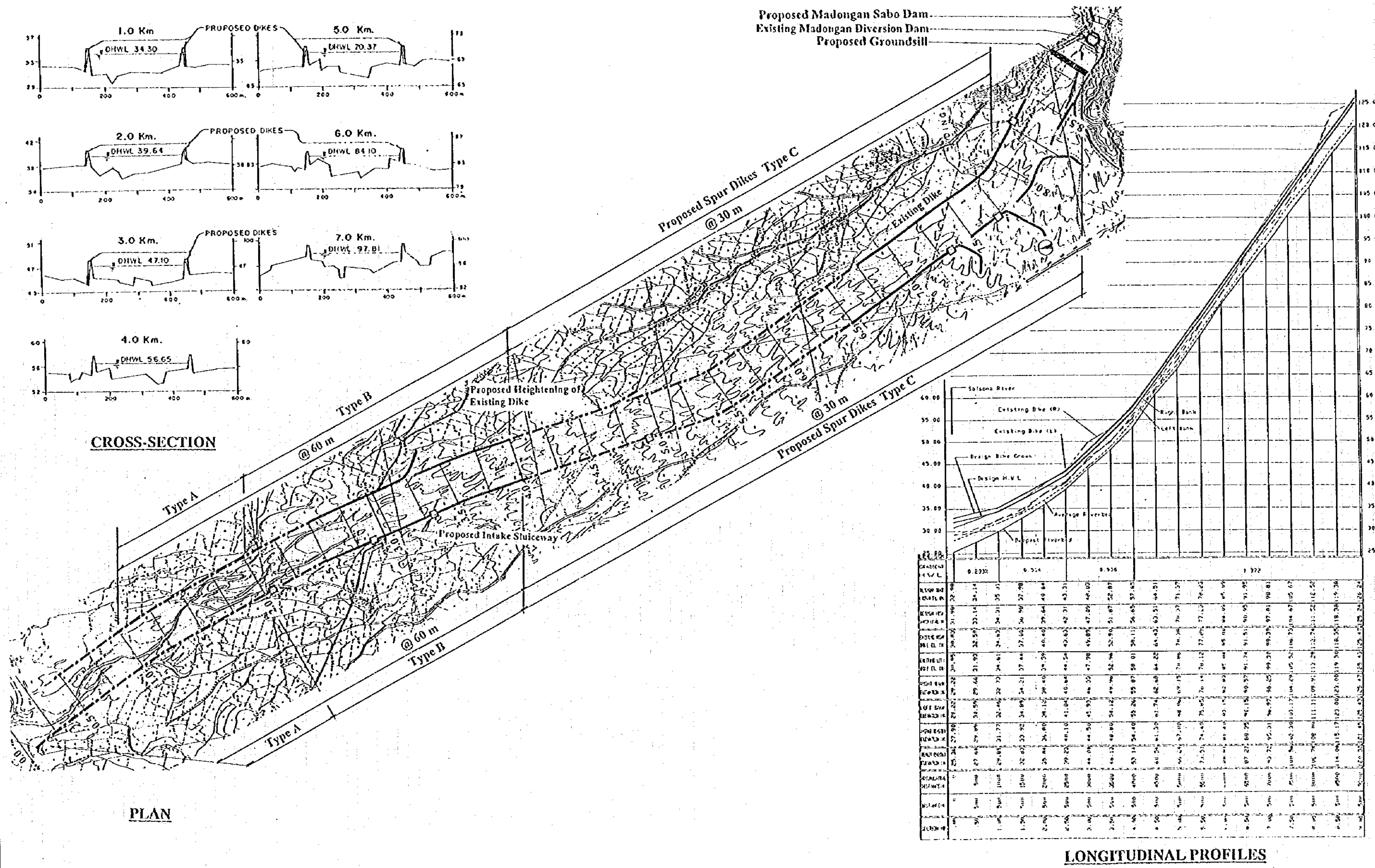




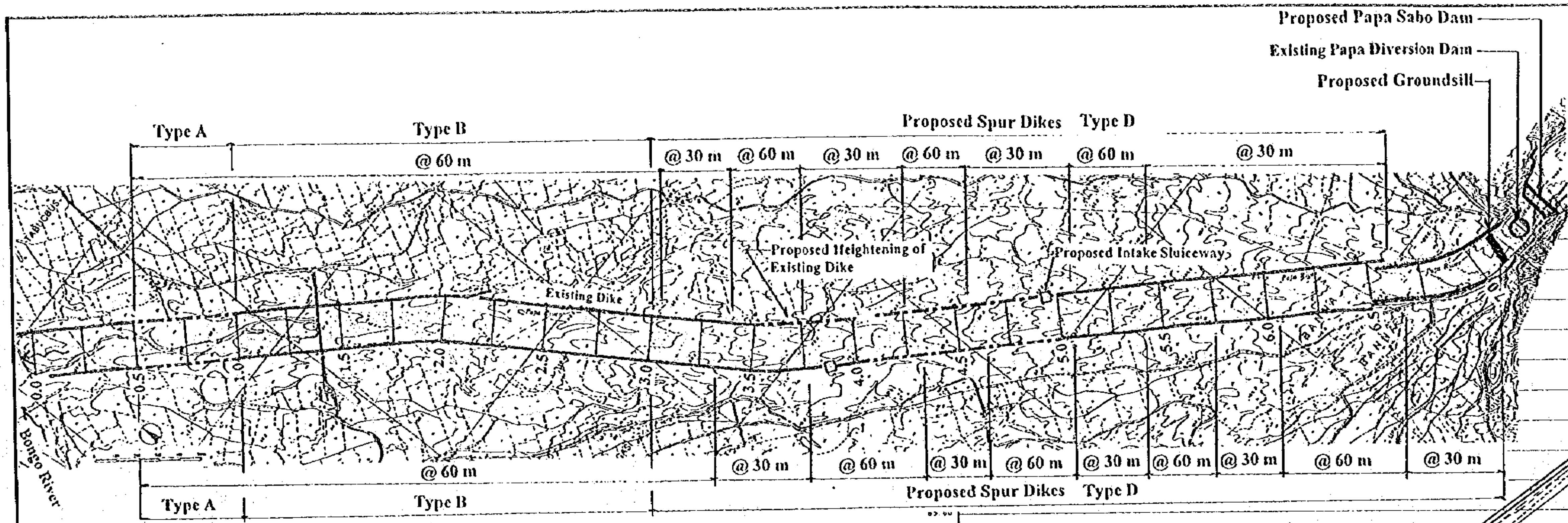
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. C.2.6 (3) Structural Design of Proposed Structures for Alluvial Fan River Improvement



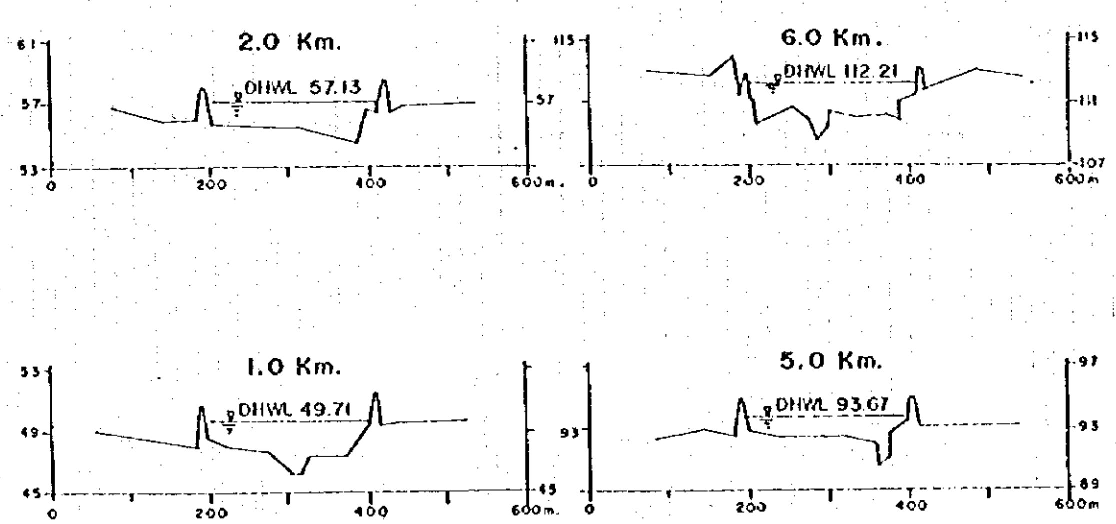
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. C.2.7
JAPAN INTERNATIONAL COOPERATION AGENCY	Solsona River Improvement Plan



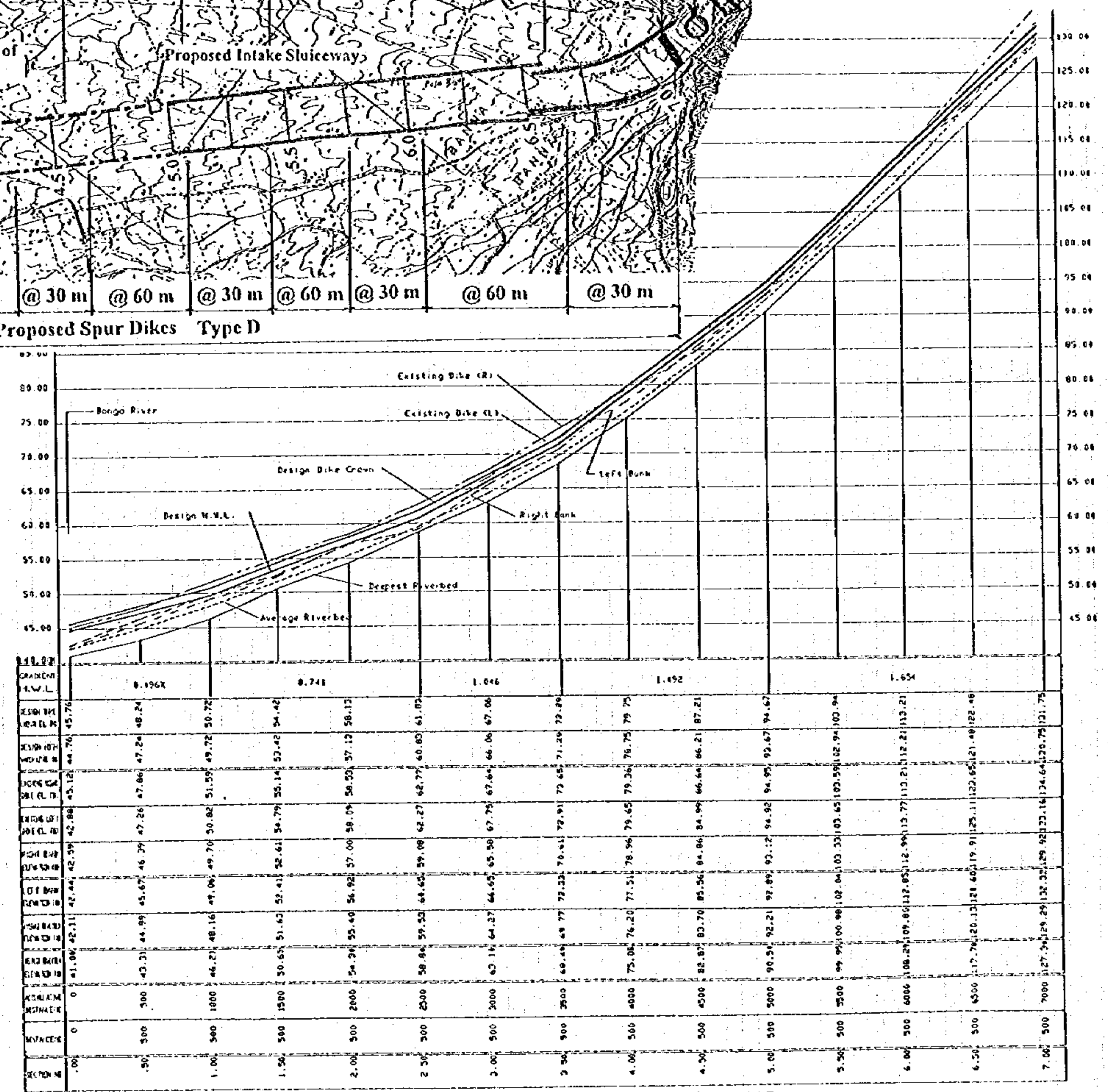
THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. C.2.8 Madongan River Improvement Plan
JAPAN INTERNATIONAL COOPERATION AGENCY	



PLAN



CROSS-SECTION



LONGITUDINAL PROFILES

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN	Fig. C.2.9
JAPAN INTERNATIONAL COOPERATION AGENCY	Papa River Improvement Plan