Ministry of Water Resources and Meteorology,
Ministry of Agriculture, Forestry and Fisheries,
The Kingdom of Cambodia

THE STUDY ON COMPREHENSIVE AGRICULTURAL DEVELOPMENT OF PREK THNOT RIVER BASIN IN THE KINGDOM OF CAMBODIA

FINAL REPORT

Volume - VII
Appendixes for Feasibility Study for Priority/Urgent Projects

August 2008

JAPAN INTERNATIONAL COOPERATION AGENCY

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LIST OF VOLUMES

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APPENDIX-I: SELECTION OF PRIORITY/URGENT PROJECTS FOR FESIBILITY STUDY

I-1 Objective of Feasibility Study

Through the Master Plan study, many projects/studies are proposed to attain the strategic target of the Master Plan, i.e., "***Improvement of Agricultural productivity centering on rice***". In the next phase, a feasibility study will be carried out for the projects selected from them. The selected projects should be in the position of playing an important role toward successful implementation of the Master Plan. The objective of the feasibility study in this Study, should therefore, delineate the appropriate development plan from technically appropriate, economically sound, sociologically suitable and environmentally friendly viewpoints, keeping early implementation and production of project benefits in mind.

I-2 Development Scenarios

(1) Selection from Scheme-wise Improvement Projects

The candidate projects for the feasibility study are selected from the scheme-wise improvement projects, because scheme-wise improvement projects bear the benefits by themselves, but Subject-wise Improvement Projects are regarded rather as support projects to the Scheme-wise Improvement Projects.

(2) Project Implementation Scenarios

Downstream irrigation projects linked with upstream irrigation projects can be developed only after completion of the upstream development. Considering this time sequence of development, nine realistic project implementation scenarios related with rice production improvement were proposed in Sub-section 9.7.1 of Volume II Master Plan. Out of the nine project implementation scenarios, Scenarios-1 to 7 should receive water from the Prek Thnot River through the Roleang Chrey Regulator. Scenario-8 relies on flow from tributaries and Scenario-9 expects only rainfall.

I-3 Method for Selecting Priority/Urgent Projects for Feasibility Study

Selection of priority/urgent projects for the feasibility study was made as follows.

<u>Step-1: Screening by "Urgency"</u>

First, the nine development scenarios were screened from the viewpoint of "Urgency", considering their status and impacts on the Master Plan target. According to the survey results, the present Roleang Chrey Regulator is anticipated to malfunction within a few years. If the regulator malfunctions, agricultural production in the Target Area would be greatly decreased. In this sense, urgent improvement of the Roleang Chrey Regulator is indispensable. This means that the urgency of the Roleang Chrey Regulator related development scenarios (Scenario-1 to 7) should be high as compared with others. Thus, the other scenarios (Scenario-8 and 9) were screened out.

<u>Step-2: Prioritization by "Economic, Sociological, Technical and Environmental Justification"</u>

Secondly, Scenarios-1 to 7 were prioritized through evaluation from (i) economic, (ii) sociological, (iii) technical, and (iv) environmental aspects. Higher ranked scenarios were selected as priority/urgent projects for the feasibility study. In the feasibility study, further study will be conducted from economic, sociological, technical and environmental viewpoints. The table below shows the criteria and results of the prioritization.

Prioritization of Development Scenarios

Project Imple-mentation Scenario No.	Project Implementation Scenario	Economic aspect	Sociological aspect	Technical aspect	Environmental aspect	Overall Judge-ment
		Criteria				
		EIRR is higher than 10%	Reduces occurrence of water conflict	Development Sequence (from upstream to downstream)	Minimum land acquisition (Zone-2 development needs larger acquisition)	
1	RC	Yes	Yes	Yes	Yes	1st
2	RC + UNMC	No	Yes	Yes	Yes	2nd
3	RC + Ou Krang Ambel	No	No	No	No	4th
4	RC + UNMC +Ou Krang Ambel + LNMC	No	Yes	Yes	No	3rd
5	RC + IAIMP	Yes	Yes	Yes	Yes	1st
6	RC + IAIMP + USMC	No	Yes	Yes	Yes	2nd
7	RC + IAIMP + USCM + LSMC	No	Yes	Yes	No	2nd

Note: RC: Roleang Chrey Regulator and Intakes Improvement Project
UNMC: Upper North Main Canal Irrigated Agriculture Improvement Project
LNMC: Lower North Main Canal Irrigated Agriculture Improvement Project
IAIMP: Irrigated Agriculture Improvement Model Project
USMC: Upper South Main Canal Irrigated Agriculture Improvement Project
LSMC: Lower South Main Canal Irrigated Agriculture Improvement Project

I-4 Selected Priority/Urgent Projects for Feasibility Study

As a result, the following two most highly prioritized development scenarios are proposed as priority/urgent projects for the feasibility study.

Scenario-1: Implementation of "Roleang Chrey Regulator and Intakes Improvement Project" only

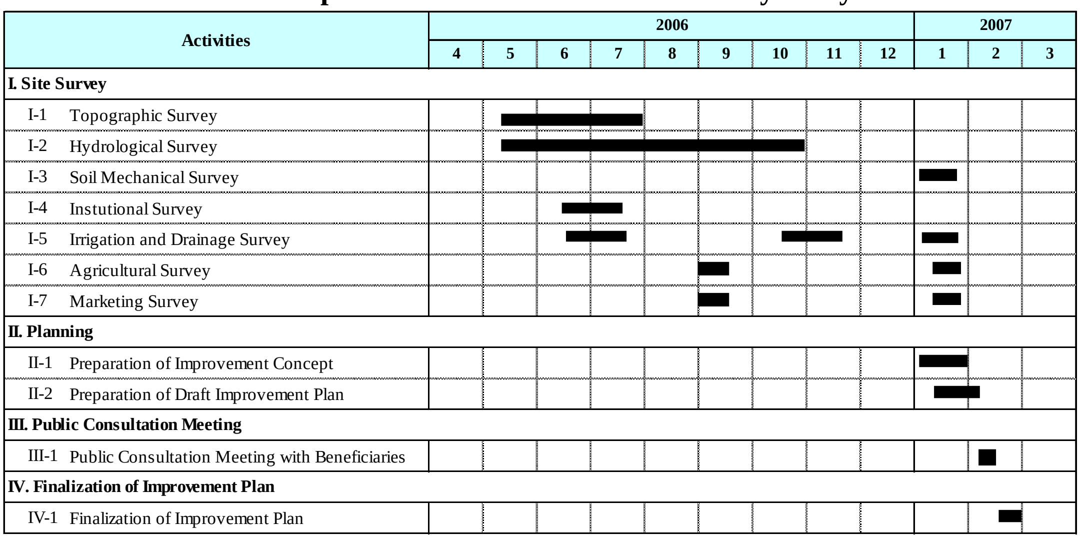
Scenario-5: Implementation of the "Roleang Chrey Regulator and Intakes Improvement Project" together with the "Irrigated Agriculture Improvement Model Project"

This selection was approved by the review committee in Japan.

I-5 Implementation Schedule of Feasibility Study

The feasibility study will be executed according to the following schedule.

Implementation Schedule of Feasibility Study



Appendix-II

ROLEANG CHREY REGULATOR AND INTAKES IMPROVEMENT PROJECT

Appendix-IIA

HYDROMETEOROLOGY

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Hydrometeorology

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APPENDIX-IIA: HYDROMETEOROLOGY

Chapter IIA-1 Prek Thnot River Basin System

IIA-1.1 General

The river basin map of the Prek Thnot river was once prepared in the 1st phase of the present study. But the river basin map was prepared based on the topographical map with the scale of 1/100,000 available at the time. Since the topographical map of the downstream basin of the Prek Thnot River was completed at the end of the 1st phase of the present study with the scale of 1/10,000, the basin system was reviewed and renewed based on the newly prepared topographical map.

IIA-1.2 Delineation of River Basin Boundary

Since the topographical map in the upstream basin is available only with the scale of 100,000, the river basin boundary delineation has been conducted based on the topographical maps with the scales of 100,000 for the upstream basin and 10,000 for the downstream basin respectively.

In the delineation, some revisions of the river basin boundary and sub-basins boundaries even in the upstream basin have been conducted with quite enlarged maps and accordingly the catchment areas of sub-basins have been needed to be revised either. The newly revised river basin boundary and sub-basins boundaries thus prepared is shown in Figure IIA-1.1.

But thus prepared river boundary map still needs to be revised more in future especially regarding the downstream basin since the map itself is not enough for the delineation of the river basin in the downstream flat area. Some additional field survey is needed for the finalization of the river basin boundary map.

In the said map, the names of sub-basins are partly newly given based on the major channels or the district names in the sub-basins.

The sub-basin areas measured on thus provisionally prepared map are as shown in the below table:

The Areas of Sub-basins of the Prek Thnot River Basin (provisional)

Name of the Sub-basin	Basin Area (km^2)
Areang	482
Trang Krang	328
Ta Sal	714
Residual	30
Phleah	264
Aoral	549
Krang Ambel	499
Tang Haong	1523
Thum	257
Bat Kmeng	342
Kandal	109
Total	5097

IIA-1.3 Runoff System of Prek Thnot River

Based on the revised river basin map thus prepared, the runoff system of the Prek Thnot River has been prepared as shown in Figure IIA-1.2.

The prepared runoff system will be used for establishment of the runoff model of the Prek Thnot River in the 3rd phase of the present study.

Chapter IIA-2 Hydrological Observation

IIA-2.1 Rainfall Observation

IIA-2.1.1 Rainfall Gauging Stations

Rainfall gauging stations set up in the Prek Thnot River basin are as follows:

Rainfall Gauging Stations

No.	Station Name	Equipment	District/Village
1	Kirirom	Automatic	Phnom Sruoch
2	Wat Kdey Lvea	Automatic	Samrongtong
3	Kong Pisey	Automatic	Kong Pisey
4	Trapeang Chour	Automatic	Aoral
5	Thpong	Automatic	Thpong
6	Peam Khley	Automatic	Phnom Sruoch
7	Phum Chum	Automatic	Aoral
8	Roleang Chrey	Automatic	Samrongtong
9	Prey Kaniech	Automatic	Phnom Sruoch
10	O Kon Trom	Automatic	Phnom Sruoch

Source: The Study on Comprehensive Agricultural Development of Prek Thnot River Basin in the Kingdom of Cambodia, Interim Report, May 2006

The locations are shown in Figure IIA-2.1

IIA-2.1.2 Rainfall Records

Rainfall records obtained at the above stations in the period of assignment of the hydrologist in this 2nd phase of the present study are shown in Table IIA-1.1.

IIA-2.2 Water Level Observation

IIA-2.2.1 Water Level Gauging Stations

Water-level gauging stations set-up in the Prek Thnot River basin are as follows:

Water Level Gauging Stations

No.	Station Name	Equipment	District/Village
1	Peam Khley Bridge	Logger & S.G.	Phnom Sruoch
2	Thnuos Luong	Logger & S.G.	Chbr Mon
3	Krang Chek	Logger & S.G.	Phnom Sruoch
4	Cheneang Kpuos	Logger & S.G.	Phnom Sruoch
5	Sangkea Tasal	Logger & S.G.	Aoral
6	Trapeang Kyorn	Logger & S.G.	Samrongtong
7	Roleang Chrey	S.G.	Samrongtong
8	Prey Mean	S.G.	Aoral

S.G. : Staff Gauge

Source: The Study on Comprehensive Agricultural Development of Prek Thnot River Basin in the Kingdom of Cambodia, Interim Report, May 2006

The locations are shown in Figure IIA-2.2.

IIA-2.2.2 Water Level Records

Water-level records at some stations among the above stations in the period of assignment of the hydrologist in this 2nd phase of the present study are obtained. Among them, the hourly water level at Peam Khley Bridge station in August 2006 is shown in Table IIA-2.1 for the reference of the flood in August 2006.

IIA-2.3 Discharge Measurement

IIA-2.3.1 Discharge Measurement Stations

Discharge measurement stations in the Prek Thnot River basin are as follows:

Discharge Measurement Stations

No.	Station Name	Equipment	District/Village
1	Peam Kley Bridge	Logger & S.G.	Phnom Sruoch
2	Thnuos Luong	Logger & S.G.	Chbr Mon
3	Krang Chek	Logger & S.G.	Phnom Sruoch
4	Cheneang Kpuos	Logger & S.G.	Phnom Sruoch
5	Sangkea Tasal	Logger & S.G.	Aoral
6	Roleang Chrey	S.G.	Samrongtong

Source: The Study on Comprehensive Agricultural Development of Prek Thnot River Basin in the Kingdom of Cambodia, Interim Report, May 2006

The locations of those gauging stations are shown in Figure IIA-2.2. The observed discharge and water-level data are shown in Table IIA-2.2.

IIA-2.3.2 Discharge Rating Curves

Based on the observed water-level and discharge data, the discharge rating curves at those stations are prepared and shown in Figures IIA-2.3 to IIA-2.8 respectively.

These discharge rating curves are prepared just based on the recent discharge measurement records. According to the “Prek Thnot Flood Relief Channel Hydrological Report in September 2001” of “Emergency Flood Rehabilitation Project”, some discharge measurements at Peam Khley site were reported to have been conducted covering rather much discharge of the river. When these discharge records are included in preparation of the discharge rating curve at Peam Khley, the discharge rating curve would be as shown in Figure IIA-2.9.

Chapter IIA-3 Present Conditions of Prek Thnot River

IIA-3.1 General

IIA-3.1.1 River Survey

River survey of the Prek Thnot River was conducted in the present study and completed at the end of the 1st phase of the Study. The river survey was conducted for the reaches between the Peam Khley bridge and the confluence with the Bassac River.

Based on the river survey results, some characteristics of the Prek Thnot River have been studied.

IIA-3.1.2 Longitudinal Slope of the River

The general longitudinal profile of the Prek Thnot River is shown in Figure IIA-3.1. As shown in the said figure, the longitudinal slope of the river is about 1/5,100 in the reaches from the confluence with the Bassac River to the Kandal Stan Weir, about 1/4,170 in the reaches from the Kandal Stan Weir to the site about 8 km downstream from the confluence of the Krang Ambel River, 1/2,720 in the reaches upstream from the site to the site of the Peam Khley Bridge. This is summarized in below table:

Longitudinal Slope of Prek Thnot River

Chainage (m)	Slope
0 – 33,446	1/5100
33,446 – 65,000	1/4170
65,000 – 73,587	1/2720
73,587 – 98,460	1/2720
98,460 – 113,411	1/2720

In the said reaches, only the Krang Ambel River joins the Prek Thnot River, and other major tributaries of the Prek Thnot join the Prek Thnot River in the reaches upstream of the Peam Khley Bridge.

IIA-3.2 Discharge Carrying Capacity of the Prek Thnot River

IIA-3.2.1 Calculation Conditions

Discharge carrying capacity of the Prek Thnot River has been estimated by conducting the non-uniform flow calculation with various discharges. The Manning’s roughness coefficients of the river channel are temporarily assumed to be 0.027 for the low-water channel and 0.050 for the high-water channel from the conservative view points. The Manning’s roughness coefficients should be verified by using the actual flood mark or by conducting some other water surface survey works. This should be conducted in near future for finalizing the Manning’s roughness coefficients of the Prek Thnot River.

IIA-3.2.2 Discharge Carrying Capacities of the Prek Thnot River

Non-uniform flow calculation of the Prek Thnot River has been conducted for the discharges of 100 m^3/s, 300 m^3/s, 500 m^3/s, 800 m^3/s, 1200 m^3/s, 1300 m^3/s, 1400 m^3/s, 1500 m^3/s, 1600 m^3/s, and 1700 m^3/s.

The longitudinal profiles of the water levels for the said discharges are shown in Figures IIA-3.2 and IIA-3.3.

From the said figures, the following conclusions on river channel discharge carrying capacities are obtained, even though the conclusions are still temporary ones and need to be verified in future:

Discharge Carrying Capacity of Prek Thnot River

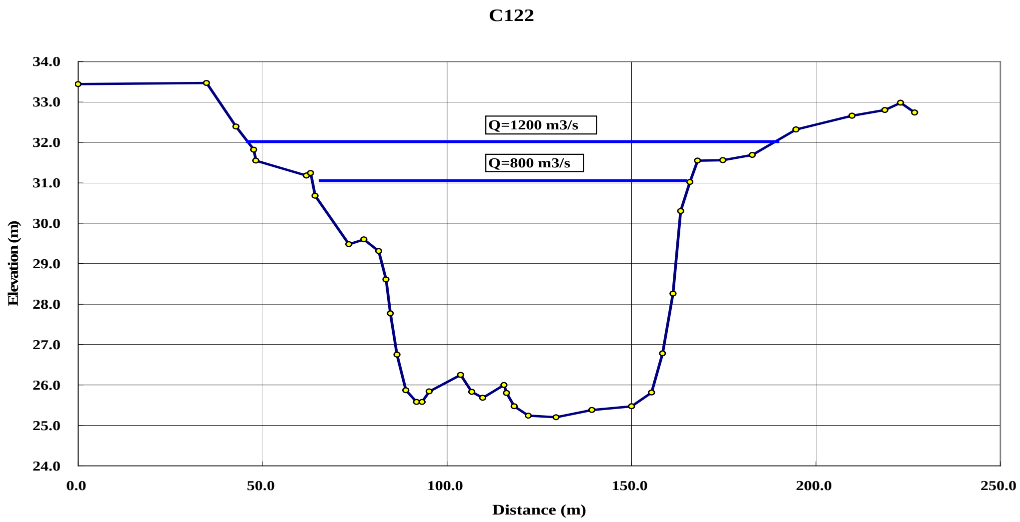
Chainage (m)	Discharge Carrying Capacity (m^3/s)
0 – Kandal Stan Weir (33,446)	200 - 500
Kandal Steung Weir – 50,000	300 – 800
50,000 – Krang Ambel River (73,587)	500 - 800
Krang Ambel River – Thnuous Luong Station (90,038)	800 – 1200
Thnuous Luong – Roleang Chrey (98,431)	1200 – 1300
Roleang Chrey -	1300 – 1500

IIA-3.2.3 Recent Inundation along the Prek Thnot River

According to the flood report on 2003 July 26-29 flood prepared by Mr. Akira Miyazaki, the chief adviser of TSC Project, the downstream area of the Prek Thnot River was inundated during the flood in July 2003 and the flood peak at that time at Peam Khley is reported to have been 900 – 1000 m^3/s. Actually according to the water level record at Peam Khley by PDOWRAM of Konpong Speu office, the maximum water level on July 26, 2003 was 7.72 m. According to the discharge rating curve at Peam Khley, this water level corresponds to the discharge of 974 m^3/s.

With this flood peak, the inundation occurred in the downstream basin of the Prek Thnot River. This corresponds to the discharge carrying capacities of the Prek Thnot River that the inundation occurred along the downstream reaches of the Prek Thnot River.

The field survey on inundation situation in August 2006 flood has been partly conducted in the present study especially in the reaches just downstream of the Roleang Chrey Regulator site. As discussed in the following chapter, the flood peak of the August 2006 is estimated to have been about 1190 m^3/s. It is reported in the said survey that the left and right bank of the Prek Thnot River was inundated at around the cross-section of C122. The following figure shows the calculated water level for the discharges of 800 m^3/s and 1200 m^3/s at the cross-section of C122 by non-uniform flow.



Chapter IIA-4 August 2006 Flood

IIA-4.1 General

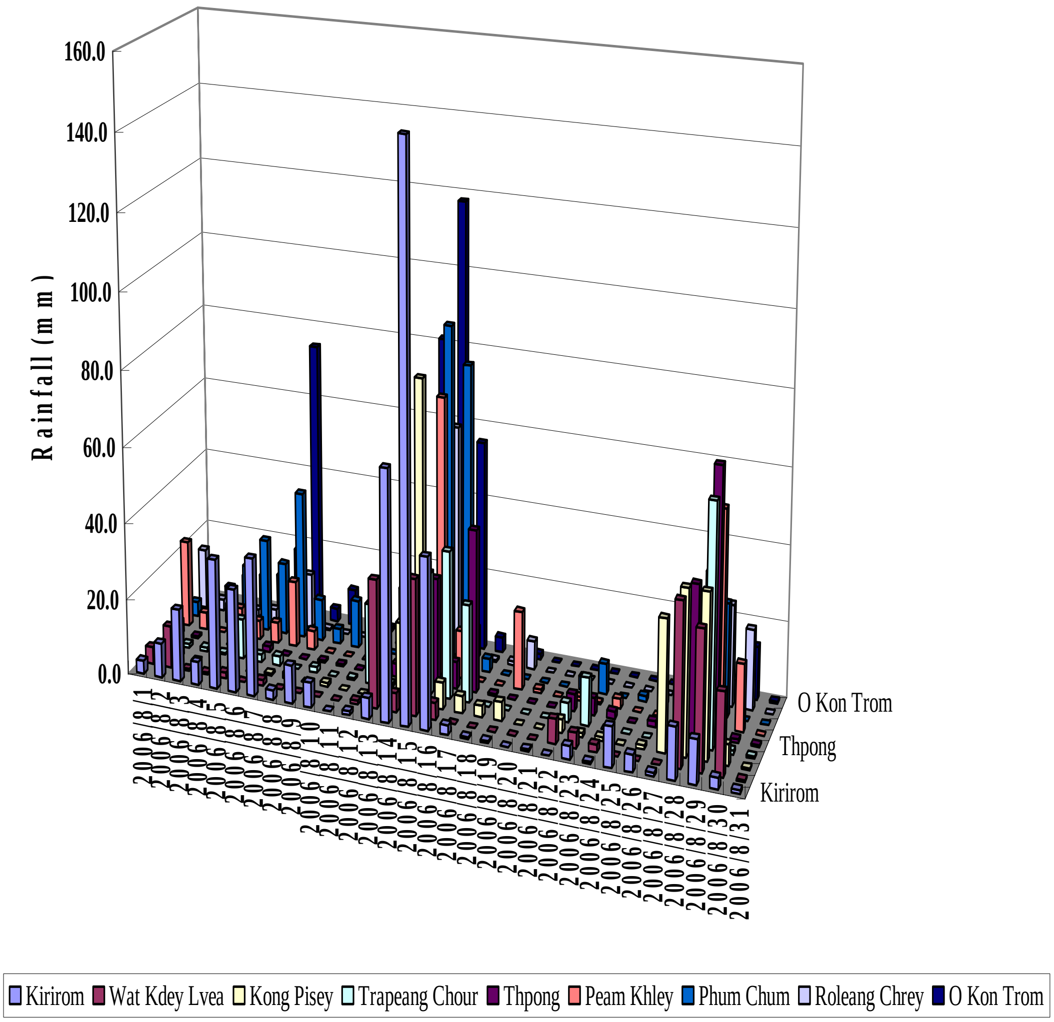
It is reported that a flood occurred in August 2006 in the Prek Thnot River basin. Inundation in the downstream basin of the Prek Thnot River started in August 16, 2006 lasting for a few days. The inundation took place in the area from the downstream reaches of the Roleang Chrey Regulator down to the upstream area of the Kandal Steung Weir.

This chapter deals with some characteristics of the said flood.

IIA-4.2 Rainfall and Water Level in August 2006

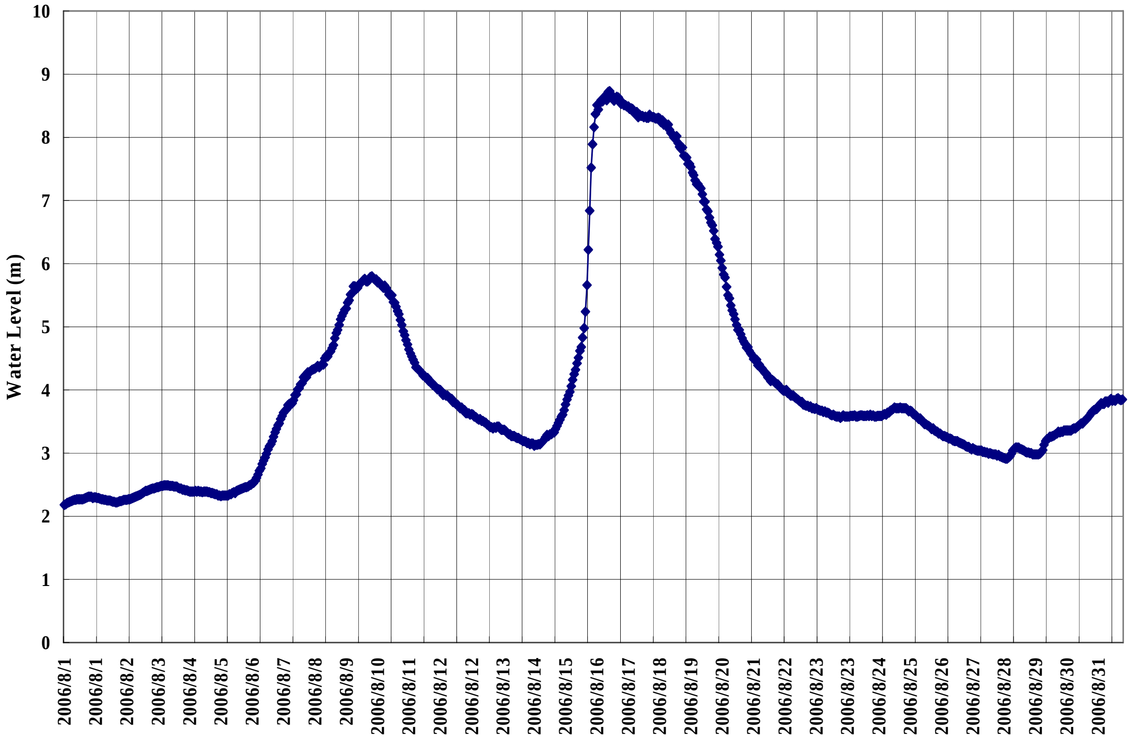
The hourly rainfall in August 2006 in the Prek Thnot River basin has been recorded with the automatic hourly rainfall gauges set up in the Prek Thnot River basin in the present study. The daily rainfall in August 2006 at those gauging stations is summarized in Table IIA-4.1. The daily rainfall distribution in August 2006 among the gauging stations in the basin is shown in the below figure.

Daily Rainfall Distribution in the Basin in August 2006



According to the rainfall in August 2006 in the Prek Thnot River basin, the river water level of the Prek Thnot River varied. The below figure shows the river water level at Peam Khley station in August 2006.

Water Level of Prek Thnot River at Peam Khley in August 2006



IIA-4.3 Rainfall and Runoff in August Flood

The daily rainfall at those gauging stations from August 12, 2006 to August 18, 2006 is shown in the below table.

Daily Rainfall in August 2006 in the Prek Thnot River Basin

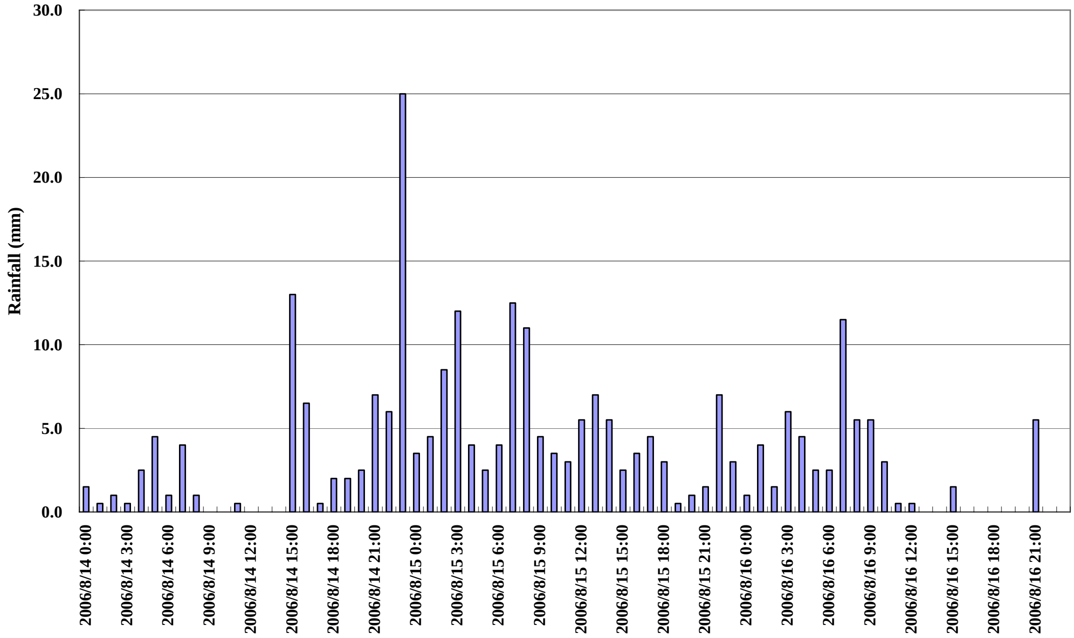
Unit: mm

	Kirirom	Wat Kdey Lvea	Kong Pisey	Trapeang Chour	Thpong	Peam Khley	Phum Chum	Roleang Chrey	O Kon Trom
2006/8/12	1.0	1.0	0.0	21.0	2.5	0.5	0.0	0.0	0.0
2006/8/13	5.5	33.5	10.0	1.0	3.5	21.0	1.0	16.0	20.0
2006/8/14	65.0	5.0	20.5	10.5	20.5	10.5	12.0	8.0	81.5
2006/8/15	147.0	35.5	84.0	32.0	28.0	73.0	89.5	61.0	118.0
2006/8/16	44.5	4.5	7.0	38.5	7.0	12.5	80.0	8.0	55.5
2006/8/17	2.5	0.0	4.5	25.5	42.5	0.0	3.5	0.5	4.0
2006/8/18	0.5	0.0	3.0	0.0	0.5	0.0	0.0	1.0	0.0
Total	266.0	79.5	129.0	128.5	104.5	117.5	186.0	94.5	279.0

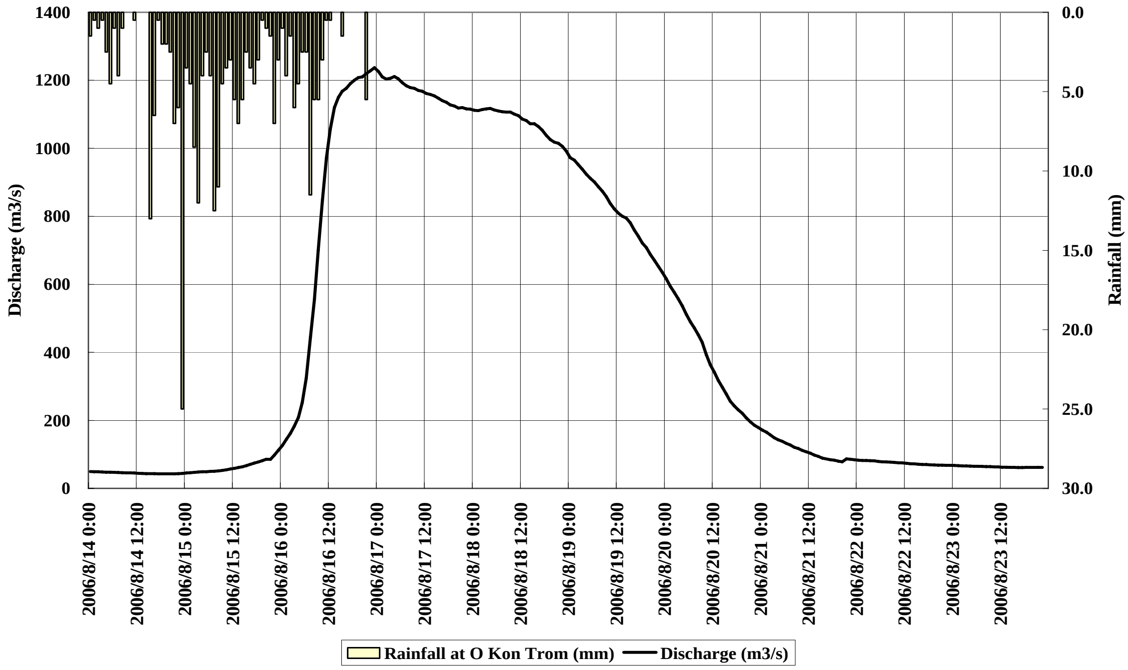
As shown in the above table, the intensive rainfall is concentrated on August 14, 15, and 16. And the maximum daily rainfall occurred on August 15, 2006. Among the above, much rainfall took place where the location elevation is high as at O Kon Trom, Kirirom, and Phum Chum that are located in the western region of the basin.

Regarding the hourly distribution of the rainfall, the maximum hourly rainfall of 25 mm at O Kon Trom was recorded at 23:00 on August 14, 2006.as shown in the below figure:

Hourly Rainfall on August 14, 15, 16 in 2006 at O Kon Trom Station



Regarding the relationship between rainfall and runoff, the following figure shows the hourly rainfall at O Kon Trom and hourly run off at Peam Khley.



As shown in the above figure, the time lag between the rainfall peak and runoff peak seems to be more than one day. This seems to be enough for people's evacuation if the rainfall information could be obtained at the real time.

The runoff discharge at Peam Khley is estimated based on the observed hourly water level and the discharge rating curve shown in Figure IIA-2.9. The discussion on flood peak will be conducted later in the next section.

IIA-4.4 Flood Peak in the Prek Thnot River

According to the water level record at the Roleang Chrey Regulator site of the Prek Thnot River, the maximum water level on the upstream side of the weir during the August 2006 flood was 7.38m. According to the caretaker of the Roleang Chrey Weir, major floods in the Prek Thnot River occurred in 1991, 2000, and 2006. Among them, the worst was the flood in 1991 in his career as the caretaker of the weir since 1969. The maximum water level on the upstream side of the weir was 8.23 m in 1991, 7.78 m in 2001, and 7.38 m in 2006.

By assuming the Manning's roughness coefficient at the Roleang Chrey Regulator site to be as 0.023 and the flow slope at the site to be 1/1000, the flood peaks at Roleang Chrey Regulator site are estimated here as follows:

Flood Peak Discharge at Roleang Chrey Regulator

Year	Discharge (m^3/s)
1991	1556
2000	1448
2006	1352

On the other hand, according to the "Prek Thnot Flood Relief Channel Hydrological Report in September 2001" of "Emergency Flood Rehabilitation Project", the flood peaks of the Prek Thnot River are reported as follows:

Flood Peak Estimate by Previous Report

Year	Discharge (m^3/s)
1996	801
1997	826
1998	507
1999	798
2000	1276
2001	788

As shown in Figure IIA-1.1, there is no major tributary that joins the Prek Thnot River in the reaches between Peam Khley and Roleang Chrey Regulator site, it is assumed that the flood peak at Peam Khley and at Roleang Chrey would be nearly the same. With this consideration and with due consideration that the discharge rating curve at Peam Khley is rather reliable in consideration of the past discharge measurement records and that in the present study, it is concluded that the flood peak of 1448 m^3/s at Roleang Chrey estimated in the present study should be converted to 1276 m^3/s. The conversion rate is just 0.881. This value doesn't seem to be a strange value. Accordingly the past major flood peaks at Roleang Chrey are converted as follows:

Revised Flood Peak Discharge at Roleang Chrey Regulator

Year	Discharge (m3/s)
1991	1371
2000	1276
2006	1191

Accordingly the flood peak at Roleang Chrey in August 2006 is estimated to have been 1191 m3/s by this method. This flood peak is bigger than that of flood in July 2003 and the relation corresponds to the actual inundation situation along the Prek Thnot River that the inundation took place even in the reaches just downstream of Roleang Chrey Regulator site. And besides, this discharge value again seems to correspond to the present discharge carrying capacities of the Prek Thnot River that have been discussed in the previous chapter.

According to the water level record at Peam Khley, the flood peak in 2006 at the site was 8.73m and this water level corresponds to 1237 m^3/s by use of the discharge rating curve shown in Figure IIA-2.9. The discharge difference between 1191m^3/s at Roleang Chrey Regulator site and 1237 m^3/s at Peam Khley site is 46 m^3/s, less than 4% f the discharges. This value doesn't seem to be a strange one. Accordingly this estimate is concluded to be a reasonable one.

Chapter IIA-5 Probable Flood at Roleang Chrey Regulator

IIA-5.1 General

It is planned that the Roleang Chrey Regulator be reconstructed soon and the design discharge is needed for designing the weir. Some discussions are given here on flood discharge at the Roleang Chrey Regulator of the Prek Thnot River.

IIA-5.2 Past Flood Discharge

As discussed in previous chapters in the present study, the past annual peak discharges of the Prek Thnot River are estimated as follows:

Past Annual Peak Discharge of Prek Thnot River

Year	Peak Discharge at Roleang Chrey (m^3/s)	Peak Discharge at Peam Kley (m^3/s)
1991	1371	
1996		801
1997		826
1998		507
1999		798
2000	1276	1276
2001		788
2002		
2003		974
2004		
2005		
2006	1191	

As mentioned in the previous chapter, according to the caretaker of the Roleang Chrey Regulator, the flood peak in 1991 was the maximum in his career as the gate caretaker since 1969. Accordingly the flood peak discharge in 1991 was the maximum in recent 38 years.

IIA-5.3 Probable Flood Peak Discharge at Roleang Chrey Regulator

As discussed in the above, the flood peak discharge of the Prek Thnot River in the past 38 years is estimated at 1371 m^3/s. This means that the probable flood peak discharge of the Prek Thnot River would be around 1400 m^3/s for the exceedence probability of about 40 years even though this may need to be studied more in future since the caretaker did not work as the caretaker in the period of 1975 to 1978 due to social and political situations in Cambodia.

On the other hand, the discharge carrying capacity of the Prek Thnot River in the upstream reaches of the Roleang Chrey Regulator site is estimated at 1300 m^3/s ~ 1500 m^3/s.

This may correspond to the past flood peak discharge of the Prek Thnot River at the Roleang Chrey Regulator site as 1369 m^3/s in the past.

The available flood peak discharge data of the Prek Thnot River in the past is too much limited to conduct the numerical probability analysis for the exceedence probability of more than 20 years.

Accordingly the probable flood peak discharge as the design discharge of the Roleang Chrey Regulator for its reconstruction would be between 1300 m^3/s and 1500 m^3/s, or between 1400 m^3/s and 1600 m^3/s from a conservative view point on the condition that any river improvement works in the upstream reaches of the weir site would not be implemented to increase the river discharge carrying capacity of the said reaches

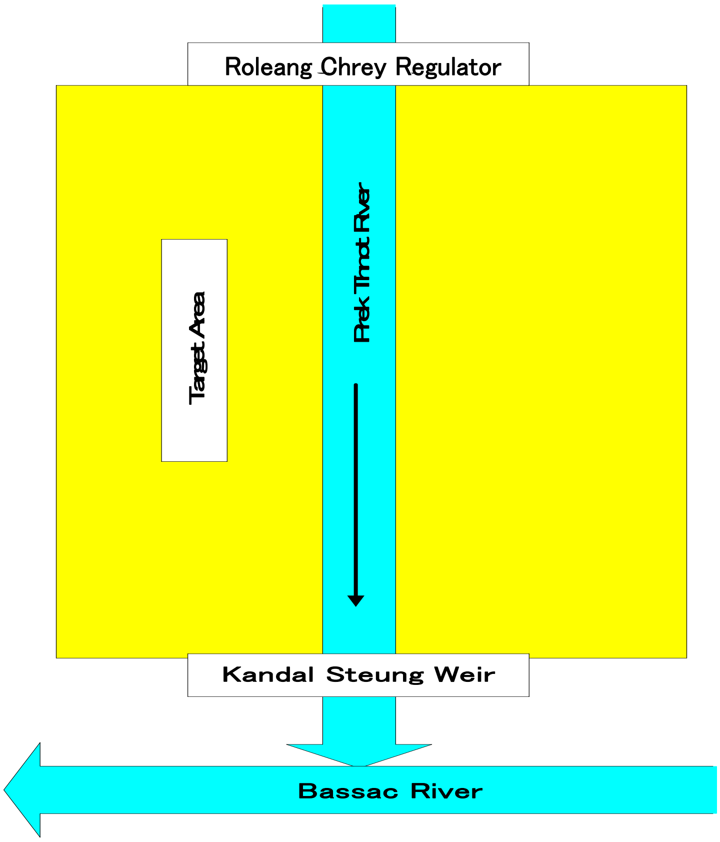
Chapter IIA-6 Gate Operations of Prek Thnot River

IIA-6.1 General

At the upstream end and the downstream end of the target area of the present study, there exist the Roleang Chrey Regulator and the Kandal Stan Weir. Some hydrological and hydraulics discussions are presented here for the gate operation of those weirs since the gate operation would have a big influence to the river water level in the target area where the agricultural land is widely expanded.

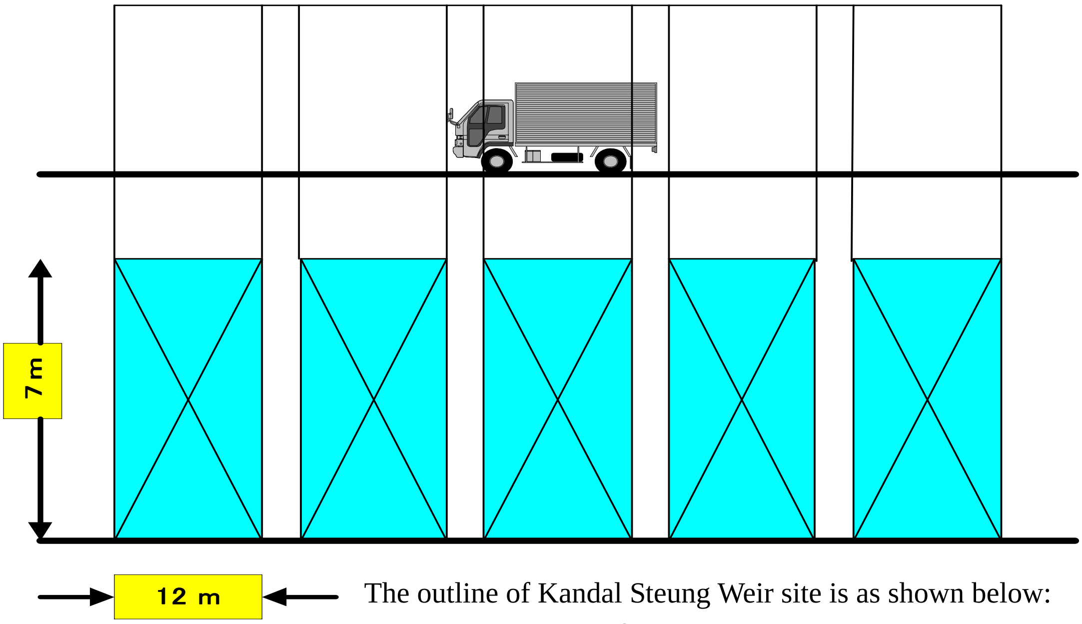
Schematically the weirs are located as shown below:

General Locations of Regulator and Weir of Prek Thnot River



The general view of the Roleang Chrey Regulator is as shown below:

General View of Roleang Chrey Regulator



The outline of Kandal Steung Weir site is as shown below:

Outline of Kandal Steung Weir Site

IIA-6.2 Conditions of Weirs

As mentioned in the above, the Roleang Chrey Regulator is planned to be totally reconstructed including the review of design discharge of the weir. On the other hand, the Kandal Stan Weir is now (December 2006) under reconstruction and the design discharge distribution of the weir is set at 240 m^3/s, and the other weirs design discharges are set as 320 m^3/s for the Thuk Thula Weir, and 270 m^3/s for the Jan. 7^{th} Weir. The Konpong Thul Weir is to be demolished in the TSC Project. The design discharge of these weirs site is planned to be 830 m^3/s in total.

In addition, the design water level at the site is planned to be 11.80 m raised from the present one of 11.26 m.

IIA-6.3 Operation of Roleang Chrey Regulator

The operation of gates of Roleang Chrey Regulator is presently as follows:

When the water level on the upstream side rises to 7.3 m on the readings of the staff gauge set on the upstream side of the weir, the gate opening should be started and the water level should be kept at this water level. The order of gates to be opened and the gate opening at each time are decided as the gate operation rule. This gate operation rule seems to have been decided so that the surrounding area of the weir would not be inundated.

Accordingly, as in the case of the flood in August 2006, the gates of the Roleang Chrey Regulator were all fully opened The flood peak is estimated at 1192 m^3/s and the river discharge carrying capacity of the Prek Thnot River is estimated at about 1300 m^3/s to 1500 m^3/s. If the gates were not fully opened, the wide surrounding area of the weir would have been inundated so much. Due to this flood, even the just downstream area of the weir had been inundated during this flood.

As can be seen from the calculation results of non-uniform flow for estimation of the river discharge carrying capacity, the downstream area have much less discharge carrying capacities compared with that in the reaches just downstream of the Roleang Chrey Regulator site. Accordingly it is a matter of course that the downstream area was widely inundated even though a limited area in.the upstream area was inundated.

IIA-6.4 Operation of Kandal Steung Weir

The operation rules of the Kandal Steung Weir site have not been established yet. As mentioned previously in this report, the design water level on the upstream side of the Kandal Stan Weir is planned to be 11.80 m.

By using this water level as the water level at the Kandal Stan Weir site and some discharges, non-uniform flow calculation of the Prek Thnot River has been conducted. According to the calculation result, the water level in the reaches upstream of the Kandal Stan Weir would be higher than the river bank elevation with the river discharge of about 300 m^3/s at some locations as shown in Figure IIA-6.1. Accordingly when the river discharge is more than 300 m^3/s, the gate opening might be needed at the Kandal Stan Weir site. This , of course, need to further study for finalization of the gate operation rule. The river flow velocity of the Prek Thnot River is shown in Figure IIA-6.2 for the discharge of 100 m^3/s to 500 m^3/s. The average flow velocity of the Prek Thnot River in the reaches from Kandal Stan Weir site and the Roleang Chrey Regulator site for the discharge of 300 m^3/s is shown in Figure IIA-6.2. According to the said figure, the approximate average of flow in the said reaches for the discharge of 300 m^3/s is about 1.3 m/s. Since the distance of these two weir site is about 65 km along the Prek Thnot River, the flood peak traveling time is about 13 hours.

Accordingly when the discharge of the Prek Thnot River increases more than 300 m^3/s, the discharge information at the Roleang Chrey Regulator site should be soon informed to the Kandal Stan Weir management office for smooth operation of the gates at the site.

Chapter IIA-7 Preparation for Flooding Analysis

IIA-7.1 General

It is planned to prepare a flood hazard map in the target area of the present study. The preparation of the flood hazard map will be done in the 3rd phase of the present study. But the flood hazard map will be prepared for some limited model area in the said target area in the present study. The selection of model area for preparation of the flood hazard map has been conducted in this 2nd phase of the study.

IIA-7.2 Methodology on Preparation of Flood Hazard Map

The flood hazard map would be prepared with the following steps:

1) decision of objective area
2) decision of objective flood scale
3) runoff analysis and calculation of runoff hydrograph for the determined flood scale
4) analysis of inundation with the flood hydrograph
5) study on evacuation center and evacuation root

Presently the runoff analysis is planned to be conducted by use of the “Storage Function Method” and analysis of inundation is planned to be conducted by use of the software of “FLO-2D”.

IIA-7.3 Parameters for Inundation Analysis

The following parameters should be prepared as basic data for conducting the inundation analysis by use of “FLO-2D”:

1) image file of objective area
2) point file on ground elevation of the objective area
3) shape file on buildings, roads and rivers
4) mesh size

Other than the above, it is preferable that satellite image of the objective area is prepared.

IIA-7.4 Objective Area and Mesh Size

Regarding the objective area for inundation analysis, the area shown in Figure IIA-7.1 is tentatively prepared as the future analysis area in consideration of the topographical conditions of the area. For selecting the model area for inundation analysis, the area surrounded by the national road No.51, the irrigation canal of the north and the south starting from the Roleang Chrey Regulator are selected. But finalization of those areas should be done in the 3rd phase of the study with the necessary field reconnaissance in the area.

The objective area should be divided into meshes for conducting the inundation calculation. The mesh size should be determined based on the extent of the objective area and the substantial computation time for completion of inundation calculation by a computer.

In the present study for the objective model area, the mesh of 500 m on a side is proposed tentatively. The mesh size would be also finalized in the 3rd phase of the present study.

Tables

Table IIA-1.1(1) Daily Rainfall Record (at Kirirom in 2006)

Unit:mm

Date	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1	-	55.0	0.0	25.0	3.5	1.5	16.0	3.0
2	-	43.0	0.0	34.0	9.0	0.0	20.5	0.0
3	-	0.0	4.0	61.5	19.0	3.0	10.0	0.0
4	-	4.5	0.0	12.0	6.0	4.0	16.0	0.0
5	-	12.5	0.0	5.0	34.0	26.0	12.5	0.0
6	-	5.0	0.5	12.0	27.0	0.0	3.5	0.0
7	38.5	0.0	0.0	1.5	36.0	0.0	0.0	0.0
8	1.0	7.5	0.0	3.0	2.5	0.0	7.5	1.5
9	0.0	0.0	0.0	1.5	10.0	0.0	7.0	0.0
10	1.0	0.0	0.0	8.5	6.5	2.5	15.5	0.0
11	1.5	0.0	0.0	0.5	0.0	2.0	15.5	0.0
12	10.5	8.0	0.0	13.5	1.0	6.0	2.5	0.0
13	4.5	0.0	0.0	8.0	5.5	0.5	10.5	0.0
14	0.0	26.5	0.5	4.5	65.0	0.0	0.5	
15	0.5	34.5	0.0	7.5	147.0	0.0	0.0	
16	0.0	0.0	0.0	14.0	44.5	39.0	0.0	
17	0.0	0.0	0.5	5.5	2.5	18.5	0.0	
18	1.0	10.0	12.0	29.5	0.5	5.5	10.0	
19	0.0	22.5	41.5	0.0	0.5	6.0	0.0	
20	0.0	64.5	0.0	1.0	0.0	2.0	0.5	
21	0.0	6.0	0.0	6.5	0.5	18.0	0.0	
22	10.5	1.0	26.5	4.5	0.0	6.5	0.0	
23	0.0	16.0	2.0	1.5	3.5	24.5	4.0	
24	3.5	0.0	17.5	4.5	0.5	22.0	2.5	
25	0.0	26.0	0.5	0.0	10.5	5.0	0.0	
26	3.0	0.0	0.5	0.5	4.5	31.0	0.0	
27	0.0	9.0	2.5	0.5	1.0	26.0	5.0	
28	0.0	0.0	10.5	0.0	13.5	12.0	0.0	
29	2.5	1.5	0.0	0.0	11.5	0.0	0.0	
30	0.0	0.0	10.5	15.5	3.0	30.5	0.0	
31	-	2.0	-	6.5	1.0	-	0.0	

Table IIA-1.1(2) Daily Rainfall Record (at Wat Kdey Lvea in 2005 & 2006)

Unit:mm

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	-	0.5	1.0	0.0	0.0	0.0	0.0	0.0	0.5	4.5	10.5
2	-	9.0	0.0	0.5	0.0	21.0	19.0	0.0	0.0	11.0	0.0
3	-	1.5	0.0	0.0	0.0	0.0	0.0	6.5	3.5	0.5	0.0
4	-	0.0	0.0	0.0	0.0	0.0	0.0	19.0	0.0	0.5	1.0
5	-	21.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	25.0
6	-	27.5	0.0	0.0	0.0	1.5	0.5	22.0	2.5	0.0	0.0
7	-	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1.5	0.0
8	-	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
9	-	0.0	0.0	0.5	0.0	0.5	0.0	0.0	0.0	0.0	0.0
10	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	-	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	19.5
12	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	4.0
13	-	0.0	0.0	0.0	1.5	34.0	11.0	1.0	1.0	33.5	19.0
14	-	0.0	0.0	0.0	22.5	0.0	0.0	0.0	0.0	5.0	0.0
15	-	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.5	35.5	0.5
16	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	1.0
17	2.0	0.0	0.0	0.0	0.0	0.0	0.0	37.5	0.0	0.0	1.5
18	27.5	0.0	0.0	0.0	0.0	0.0	6.5	2.5	4.0	0.0	0.5
19	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	57.0	0.0	0.5
20	0.0	8.5	0.0	0.0	0.0	0.0	20.5	0.0	47.5	0.0	0.5
21	0.0	0.5	0.0	0.0	0.0	0.0	0.5	0.0	12.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.5	0.0	2.5	0.0	6.5	21.0
23	0.0	0.0	0.0	17.5	0.0	0.0	10.5	4.5	0.0	4.0	0.0
24	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	2.0	0.5
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.0	0.0	0.0	6.0
26	2.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.0
27	9.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.5
28	9.5	0.0	0.0	6.0	0.0	0.0	0.0	5.5	10.0	42.0	6.0
29	0.0	0.0	0.0	-	0.0	0.0	0.5	0.0	0.0	36.0	1.5
30	1.5	0.0	0.0	-	0.0	1.5	0.5	1.5	0.0	21.5	0.0
31	-	0.0	0.0	-	0.0	-	0.5	-	1.5	0.5	-

Table IIA-1.1 (3) Daily Rainfall Record (at Kong Pisey in 2006 Unit:mm

Date	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1	-	0.0	0.0	0.0	4.0	2.5	3.0	0.0	0.0
2	-	4.5	0.0	0.0	0.0	9.0	1.5	2.0	0.0
3	-	0.0	0.5	0.0	4.5	0.0	11.5	3.0	0.0
4	-	0.0	0.0	0.5	0.5	0.0	20.5	1.0	0.0
5	-	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0
6	-	0.0	27.5	1.0	9.0	0.0	6.0	6.0	0.0
7	-	32.5	0.0	0.0	0.0	0.5	0.0	1.0	0.0
8	-	1.0	0.0	0.0	0.0	1.5	0.0	16.0	2.0
9	-	0.5	0.0	0.0	0.0	0.0	1.0	1.0	0.0
10	-	0.0	0.0	0.0	0.0	1.0	18.0	2.5	0.0
11	0.0	0.0	8.5	0.0	0.0	0.0	8.0	2.5	0.0
12	0.0	0.0	0.0	0.0	7.0	0.0	5.0	0.0	0.0
13	28.0	0.0	0.0	7.0	2.0	10.0	0.0	0.0	0.0
14	3.5	0.5	0.0	9.0	0.0	20.5	0.0	0.0	0.0
15	0.0	3.5	24.0	0.0	0.0	84.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	7.0	5.0	6.5	0.0
17	0.0	9.0	0.0	1.0	4.5	4.5	23.5	0.0	3.5
18	0.0	0.0	0.5	5.5	4.0	3.0	0.0	56.5	0.0
19	0.0	0.0	4.0	0.5	0.0	5.0	35.5	0.5	
20	0.0	0.0	24.5	0.0	7.0	0.0	1.5	3.5	
21	0.0	0.0	7.0	0.0	0.5	0.0	0.0	0.0	
22	0.0	0.0	2.5	9.0	0.0	3.5	5.0	0.0	
23	0.0	21.0	0.0	5.0	0.0	1.0	1.0	15.0	
24	0.0	0.5	0.0	0.0	0.0	1.0	0.5	5.5	
25	0.0	0.0	0.0	7.0	0.0	0.0	5.0	0.0	
26	0.0	0.0	0.0	0.0	0.0	1.0	19.5	1.0	
27	0.0	0.0	0.0	0.0	0.0	34.0	30.5	2.0	
28	3.5	0.0	0.0	0.5	0.0	42.5	2.0	0.0	
29	0.0	0.0	0.0	0.0	0.0	42.5	0.5	0.0	
30	0.0	14.0	10.5	2.5	10.0	5.5	8.0	0.0	
31	0.0	-	5.5	-	5.5	0.5	-	0.0	

Table IIA-1.1 (4) Daily Rainfall Record (at Trapeang Chour in 2006) Unit:mm

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	-	0.0	22.0	0.0	0.0	0.0	3.0	2.0	0.0
2	-	0.0	8.5	11.0	32.0	0.0	0.0	1.0	1.5
3	-	0.0	0.0	31.0	0.0	0.0	22.0	1.0	15.5
4	-	0.0	0.0	0.0	34.5	0.5	1.5	0.5	11.0
5	-	0.0	0.0	0.0	5.0	0.0	3.0	10.5	5.0
6	-	0.0	0.0	0.0	20.5	48.5	0.0	2.0	0.0
7	-	0.0	0.0	16.0	0.0	0.0	0.5	2.5	3.5
8	-	0.0	0.0	17.5	0.0	0.0	0.0	0.0	0.0
9	-	0.0	0.0	21.5	5.0	0.0	0.0	1.5	2.0
10	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
11	-	0.0	3.0	43.5	0.0	13.0	0.0	0.5	13.5
12	-	0.0	2.5	16.5	8.5	0.0	0.0	21.0	24.0
13	0.0	0.0	34.0	5.5	0.0	1.5	0.5	1.0	0.5
14	0.0	0.0	3.5	6.0	0.0	0.0	0.0	10.5	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	5.5	32.0	0.0
16	0.0	0.0	0.0	0.0	1.5	0.5	0.5	38.5	14.0
17	0.0	3.0	0.0	4.0	6.5	0.0	11.5	25.5	2.5
18	0.0	0.0	0.0	0.5	4.5	3.0	3.0	0.0	29.5
19	0.0	0.0	0.0	0.0	6.5	4.0	0.0	0.0	2.0
20	0.0	12.5	0.0	0.0	13.0	0.0	5.0	0.0	6.5
21	0.0	0.0	0.0	0.0	18.5	0.0	4.5	0.0	0.0
22	0.0	0.0	0.0	0.0	0.5	0.0	0.0	5.0	91.5
23	0.0	0.0	0.0	0.0	0.0	7.0	0.0	12.5	2.0
24	0.0	0.0	0.0	0.0	0.0	3.5	1.0	0.0	0.0
25	0.0	0.0	0.0	17.0	4.5	0.5	4.0	0.0	1.5
26	0.0	8.0	0.0	0.0	0.0	4.0	0.0	0.0	17.5
27	0.0	0.0	0.0	0.0	27.5	0.0	0.0	0.0	6.5
28	0.0	0.0	0.0	7.0	0.0	0.0	0.0	0.0	6.0
29	0.0	-	0.0	20.5	0.0	2.0	0.0	62.5	1.5
30	0.0	-	0.0	0.0	0.0	9.5	0.0	1.0	1.0
31	0.0	-	0.5	-	0.0	-	1.5	0.5	-

Table IIA-1.1(5) Daily Rainfall Record (at Thpong in 2006) Unit:mm

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1	0.0	0.0	0.0	22.0	0.0	0.0	0.0	3.5	2.5	0.0	0.0
2	0.0	0.0	0.0	3.5	0.0	15.0	4.5	0.5	18.5	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	8.5	0.0	27.5	0.5	0.0
4	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	4.5	0.0
5	0.0	0.0	0.0	0.0	0.5	3.5	0.0	0.5	55.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.5	18.5	0.0
7	0.0	0.0	0.0	20.0	12.0	9.5	0.0	0.0	0.0	0.0	0.5
8	0.0	0.0	0.0	10.5	18.0	0.0	0.0	0.0	0.0	1.5	1.0
9	0.0	0.5	0.0	7.5	0.5	0.0	0.0	0.5	0.0	6.5	4.0
10	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.5	0.0	40.5	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.5	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	63.5	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	15.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	12.5	0.5	20.5	3.0	74.5	0.0
15	0.0	0.0	0.0	0.0	2.5	0.0	1.0	28.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	9.5	0.0	7.0	14.0	0.0	0.0
17	0.0	0.0	0.0	0.0	62.5	2.0	10.5	42.5	2.5	0.0	37.0
18	0.0	0.0	0.0	0.0	6.0	2.0	1.5	0.5	14.0	47.0	6.5
19	0.0	8.0	0.0	4.5	1.5	0.0	4.0	0.0	7.5	0.0	0.0
20	0.0	5.0	0.0	0.5	7.5	0.5	4.5	0.0	1.0	0.0	0.0
21	0.0	0.0	0.0	0.0	21.0	11.5	1.0	0.0	0.0	0.0	
22	0.0	0.0	0.0	5.0	0.0	0.0	0.0	4.5	11.5	0.0	
23	0.0	0.0	0.0	0.0	0.0	16.5	0.0	4.5	0.5	6.0	
24	0.0	0.0	0.0	0.0	0.0	25.5	0.0	2.0	0.0	0.0	
25	0.0	0.0	0.0	0.0	0.0	14.5	0.0	0.0	18.0	0.5	
26	0.0	0.0	0.0	0.0	0.0	4.5	0.0	1.5	17.5	0.0	
27	0.0	0.0	0.0	0.0	12.0	0.0	0.0	0.0	18.0	0.5	
28	0.0	8.0	0.0	4.0	1.5	0.0	0.0	38.5	11.0	0.0	
29	0.0	-	1.5	0.0	0.0	2.0	0.0	69.0	1.5	0.0	
30	0.0	-	0.0	30.0	0.0	11.0	28.0	1.0	0.0	0.0	
31	0.0	-	0.0	-	4.0	-	77.5	0.5	-	0.0	

Table IIA-1.1(6) Daily Rainfall Record (at Peam Kley in 2006) Unit:mm

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	-	0.0	0.0	0.0	0.0	0.0	5.0	23.0	9.5
2	-	0.0	0.0	25.0	0.0	0.0	2.0	4.5	0.0
3	-	0.0	0.0	5.5	0.0	0.0	33.0	0.0	1.0
4	-	0.0	0.0	0.0	0.0	0.0	1.5	7.5	0.0
5	-	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0
6	-	0.0	0.0	0.0	9.0	41.5	1.0	5.5	0.5
7	-	0.0	0.0	11.5	0.0	9.5	0.0	17.5	3.0
8	-	0.0	0.0	4.0	0.0	0.0	9.0	5.0	1.5
9	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	-	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	-	0.0	0.0	0.5	0.0	0.0	0.0	0.0	27.0
12	-	0.0	0.0	14.5	0.0	0.5	20.5	0.5	3.0
13	-	0.0	7.5	0.0	0.0	1.5	2.0	21.0	0.5
14	-	0.0	1.0	0.0	0.0	0.5	0.5	10.5	7.5
15	-	0.0	0.0	0.5	0.0	0.0	2.5	73.0	0.0
16	-	0.0	0.0	0.0	11.5	0.0	0.5	12.5	0.0
17	0.0	0.0	0.0	0.0	0.0	60.5	0.5	0.0	17.0
18	0.0	0.0	0.0	0.0	6.0	44.0	2.5	0.0	2.0
19	0.0	0.0	0.0	0.0	8.5	0.0	2.0	20.5	2.5
20	0.0	0.0	0.0	0.0	25.0	2.5	3.5	1.0	0.0
21	0.0	0.0	0.0	0.0	11.0	11.5	0.5	0.0	0.0
22	0.0	0.0	0.0	14.0	0.5	30.0	1.0	1.0	72.0
23	0.0	0.0	0.0	19.5	4.0	13.5	0.0	0.5	16.5
24	0.0	0.0	0.0	1.0	0.0	0.0	0.0	2.5	0.0
25	0.0	0.0	0.0	0.0	28.5	0.5	0.0	0.0	3.0
26	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	19.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	15.0
28	0.0	0.5	0.0	0.0	0.0	7.0	0.0	13.5	6.5
29	0.0	0.0	0.0	4.0	3.5	0.0	0.0	56.0	1.0
30	0.0	0.0	0.0	2.0	1.0	1.5	0.0	17.5	0.0
31	0.0	0.0	0.0	-	0.0	-	4.0	0.0	-

Table IIA-1.1(7) Daily Rainfall Record (at Phum Chum in 2006) Unit:mm

Date	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
1	-	28.5	29.5	0.0	1.0	8.5	4.0	2.0	5.5
2	-	3.5	16.5	3.0	0.0	29.5	6.0	2.5	3.0
3	-	0.0	0.0	0.0	0.0	58.0	5.0	5.5	9.5
4	-	0.0	0.0	1.5	72.5	10.0	16.5	0.5	14.0
5	-	0.0	0.0	0.0	24.5	5.5	24.5	38.5	2.5
6	-	0.0	3.0	25.5	9.5	8.0	19.0	0.0	19.0
7	-	0.0	8.0	0.5	0.0	3.5	39.0	0.0	1.0
8	-	0.0	0.5	0.0	0.0	0.5	11.0	0.0	2.0
9	-	0.0	4.5	3.0	0.0	0.0	4.0	0.0	12.0
10	-	0.0	0.0	0.5	0.0	0.0	12.5	0.0	34.5
11	-	34.5	2.5	0.0	0.0	0.5	2.5	28.0	0.0
12	-	0.0	4.5	0.0	0.0	10.5	0.0	11.5	0.0
13	-	0.0	0.0	0.0	0.0	5.5	1.0	0.0	0.0
14	-	27.0	1.0	0.0	0.0	6.5	12.0	2.0	0.0
15	-	3.0	0.0	0.0	0.0	22.0	89.5	0.0	0.0
16	-	0.0	0.0	5.5	18.5	16.5	80.0	10.0	0.0
17	-	0.0	3.5	0.5	2.0	14.0	3.5	0.5	5.5
18	28.0	0.0	0.0	6.0	1.5	16.5	0.0	0.0	0.0
19	0.5	0.0	0.0	7.0	4.5	0.0	0.0	61.0	0.0
20	0.0	0.0	0.0	32.5	1.0	1.5	0.0	5.5	0.0
21	0.0	0.0	0.0	15.5	0.0	17.0	0.0	16.0	0.0
22	0.0	0.0	0.0	5.0	5.0	4.0	3.5	10.0	0.0
23	0.0	0.0	3.5	0.0	0.0	2.0	8.0	48.5	0.0
24	0.0	10.5	0.0	0.0	9.5	9.0	0.0	0.0	0.0
25	5.0	0.0	76.5	1.0	1.0	10.0	1.5	5.0	0.0
26	16.0	0.0	4.0	0.0	6.5	0.5	3.0	14.5	0.0
27	0.0	0.0	3.0	23.0	8.5	0.5	6.5	17.5	0.0
28	0.0	0.0	0.0	1.5	0.5	0.5	4.0	9.5	0.0
29	-	0.0	0.5	24.0	11.5	0.5	29.5	7.0	2.0
30	-	2.5	0.0	0.0	19.0	3.5	0.0	26.5	0.0
31	-	0.0	-	33.0	-	12.5	0.0	-	0.0

Table IIA-1.1(8) Daily Rainfall Record (at Roleang Chrey in 2006) Unit:mm

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	-	0.0	0.0	6.0	0.0	0.0	1.0	16.0	7.0
2	-	0.0	0.0	6.5	2.0	0.0	1.0	3.0	0.0
3	-	0.0	0.0	3.0	1.0	0.0	20.5	0.0	12.5
4	-	0.0	0.0	0.0	3.5	0.0	1.0	2.0	2.5
5	-	0.0	0.0	0.0	0.5	0.0	0.0	3.0	0.5
6	-	0.0	0.0	0.0	1.5	0.5	4.5	3.0	1.0
7	-	0.0	0.0	27.0	0.0	4.5	2.5	14.5	1.0
8	-	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
9	-	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0
10	-	1.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5
11	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0
12	0.0	0.0	2.0	7.5	0.0	0.0	2.0	0.0	3.5
13	0.0	0.0	20.5	0.0	3.0	1.5	1.0	16.0	0.5
14	0.0	0.0	2.5	0.0	0.0	10.0	0.0	8.0	0.0
15	0.0	0.0	0.0	0.5	4.5	0.0	2.0	61.0	0.0
16	0.0	0.0	0.0	0.0	14.5	0.0	2.0	8.0	6.0
17	0.0	0.0	0.0	0.0	0.5	42.0	0.5	0.5	45.5
18	0.0	0.0	0.0	17.0	3.0	15.5	0.0	1.0	1.5
19	0.0	4.0	0.0	0.0	6.0	0.0	0.0	7.5	4.5
20	0.0	0.0	0.0	0.0	29.5	0.0	7.5	0.0	1.5
21	0.0	0.0	0.0	0.0	2.0	1.5	3.5	0.0	0.5
22	0.0	0.0	0.0	0.0	0.0	15.5	2.5	0.0	15.5
23	0.0	3.0	0.0	13.0	3.0	8.5	0.0	0.0	9.0
24	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	17.5	0.5	0.0	0.0	2.5
26	0.0	27.0	0.0	1.0	0.0	0.0	0.0	0.0	12.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	12.0
28	0.0	1.0	0.0	0.0	0.0	8.0	0.0	34.0	4.5
29	0.0	0.0	0.0	18.5	0.5	0.5	0.0	26.5	1.5
30	0.0	0.0	0.0	15.5	1.0	0.5	0.0	21.0	0.0
31	0.0	0.0	0.5	-	0.5	-	0.0	0.0	-

Table IIA-1.1(9) Daily Rainfall Record (at O Kon Trom in 2006) Unit:mm

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1	-	0.0	22.0	0.0	0.0	0.0	19.0	0.0	0.0	3.0	0.0
2	-	33.5	0.0	7.0	0.0	0.0	13.5	4.0	5.0	5.5	0.0
3	-	0.0	0.0	1.5	19.0	0.5	48.5	8.0	6.5	5.0	0.0
4	-	0.0	0.0	0.0	2.0	0.0	3.5	9.0	5.5	28.5	0.0
5	-	0.0	0.0	0.0	16.0	0.0	4.0	10.0	1.5	4.5	0.0
6	-	0.0	0.0	0.0	2.0	0.0	0.0	18.0	0.5	0.5	0.0
7	-	0.0	0.0	14.5	1.5	0.0	0.0	74.5	0.0	0.0	0.0
8	-	0.0	0.0	1.5	7.5	0.0	2.5	3.5	0.0	0.0	0.0
9	-	0.5	0.0	2.5	0.0	0.0	0.5	9.5	0.5	46.5	0.0
10	-	0.0	0.0	0.5	0.0	0.0	0.0	4.0	15.0	30.0	0.0
11	-	0.0	0.0	3.0	0.0	0.0	2.0	1.0	12.5	9.0	0.0
12	0.0	0.0	1.0	2.0	1.0	0.0	7.0	0.0	13.5	0.0	0.0
13	0.0	0.0	35.0	1.5	0.0	0.0	20.5	20.0	0.0	34.5	0.0
14	0.0	0.0	8.0	0.0	1.0	1.0	2.0	81.5	0.0	0.0	0.0
15	0.0	0.0	0.5	0.5	0.0	0.0	12.0	118.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	13.5	55.5	47.5	1.5	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	6.5	4.0	35.0	0.5	0.0
18	0.0	0.0	0.0	0.0	10.5	0.5	1.5	0.0	10.5	7.0	
19	0.0	0.0	0.0	0.0	20.0	51.0	0.0	1.5	1.0	0.0	
20	0.0	0.0	0.0	0.0	57.0	16.0	1.5	0.0	0.0	4.5	
21	0.0	0.0	0.0	0.0	8.5	0.0	2.5	0.0	16.5	0.0	
22	14.0	0.0	0.0	6.0	0.0	0.0	9.5	0.0	7.0	0.0	
23	0.0	0.0	0.0	0.0	0.0	36.5	17.0	0.0	1.5	4.0	
24	0.0	0.0	0.0	1.5	0.0	2.5	14.0	0.0	0.5	13.0	
25	0.0	0.0	0.0	1.0	50.0	1.5	1.0	0.0	34.5	0.0	
26	0.0	1.5	0.0	0.0	0.0	3.0	3.5	0.0	53.0	0.0	
27	0.0	3.0	0.0	0.0	10.0	0.5	4.0	0.5	19.5	4.5	
28	0.0	0.0	0.0	0.0	0.0	4.0	0.0	5.0	4.5	0.0	
29	0.0	-	0.0	0.0	0.0	2.5	0.0	3.0	0.0	0.0	
30	0.0	-	0.0	0.0	0.0	3.5	0.5	14.0	16.0	0.5	
31	0.0	-	4.0	-	0.0	-	1.5	0.5	-	0.0	

Unit:mm **Table IIA-2.1 Hourly Water Level at Peam Khley in August 2006**

Time \ Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0:00	2.18	2.29	2.29	2.49	2.39	2.37	3.11	4.20	4.95	5.80	4.79	4.00	3.58	3.30	3.19	4.42	8.68	8.33	7.85	6.52	4.68	4.01	3.71	3.59	3.62	3.54	3.20	3.01	3.06	3.30	3.60
1:00	2.19	2.28	2.30	2.49	2.38	2.40	3.14	4.23	5.03	5.77	4.72	3.97	3.57	3.30	3.21	4.51	8.62	8.31	7.82	6.39	4.62	3.99	3.69	3.59	3.61	3.55	3.19	2.99	3.05	3.31	3.63
2:00	2.21	2.27	2.31	2.48	2.39	2.41	3.19	4.20	5.12	5.75	4.64	3.92	3.55	3.27	3.25	4.62	8.58	8.31	7.84	6.33	4.58	3.99	3.68	3.59	3.64	3.51	3.19	3.00	3.04	3.34	3.66
3:00	2.22	2.27	2.32	2.48	2.39	2.42	3.26	4.28	5.17	5.75	4.58	3.93	3.53	3.27	3.29	4.68	8.62	8.36	7.71	6.27	4.55	4.00	3.67	3.60	3.64	3.50	3.19	2.99	3.02	3.33	3.68
4:00	2.23	2.26	2.33	2.48	2.39	2.43	3.33	4.28	5.22	5.70	4.53	3.91	3.54	3.27	3.27	4.83	8.64	8.33	7.69	6.14	4.49	3.95	3.67	3.58	3.67	3.46	3.17	2.98	3.01	3.34	3.69
5:00	2.24	2.26	2.34	2.47	2.38	2.44	3.38	4.30	5.27	5.71	4.48	3.91	3.51	3.25	3.30	4.98	8.63	8.32	7.68	6.05	4.48	3.95	3.65	3.58	3.68	3.46	3.16	2.98	3.01	3.34	3.70
6:00	2.25	2.25	2.35	2.47	2.38	2.45	3.44	4.32	5.29	5.67	4.43	3.88	3.51	3.24	3.30	5.24	8.56	8.32	7.58	5.93	4.48	3.91	3.66	3.59	3.70	3.44	3.15	2.98	3.00	3.36	3.74
7:00	2.26	2.25	2.37	2.47	2.37	2.46	3.47	4.33	5.38	5.65	4.36	3.87	3.49	3.24	3.33	5.66	8.53	8.30	7.58	5.83	4.39	3.91	3.64	3.60	3.72	3.43	3.14	2.96	3.00	3.36	3.76
8:00	2.26	2.25	2.38	2.45	2.37	2.46	3.54	4.34	5.42	5.62	4.34	3.86	3.48	3.22	3.33	6.22	8.55	8.30	7.53	5.78	4.40	3.91	3.64	3.60	3.71	3.41	3.13	2.97	2.98	3.36	3.79
9:00	2.27	2.24	2.40	2.44	2.36	2.47	3.59	4.36	5.51	5.65	4.32	3.81	3.45	3.21	3.38	6.84	8.51	8.31	7.44	5.63	4.35	3.88	3.63	3.59	3.71	3.38	3.11	2.95	2.98	3.36	3.78
10:00	2.27	2.23	2.40	2.44	2.35	2.49	3.64	4.38	5.53	5.62	4.29	3.80	3.44	3.19	3.43	7.52	8.51	8.30	7.40	5.50	4.34	3.87	3.61	3.59	3.71	3.39	3.10	2.94	2.98	3.36	3.78
11:00	2.27	2.23	2.41	2.42	2.35	2.50	3.67	4.36	5.64	5.57	4.27	3.78	3.41	3.19	3.48	7.89	8.49	8.24	7.32	5.45	4.30	3.85	3.60	3.59	3.72	3.36	3.10	2.93	2.98	3.36	3.82
12:00	2.27	2.22	2.42	2.42	2.33	2.52	3.69	4.38	5.64	5.51	4.23	3.77	3.41	3.18	3.53	8.16	8.49	8.27	7.26	5.34	4.27	3.83	3.61	3.60	3.71	3.35	3.08	2.92	2.98	3.38	3.82
13:00	2.27	2.22	2.43	2.41	2.33	2.53	3.76	4.41	5.60	5.49	4.22	3.74	3.39	3.16	3.58	8.37	8.45	8.20	7.26	5.26	4.26	3.81	3.59	3.59	3.71	3.34	3.06	2.91	2.99	3.39	3.80
14:00	2.28	2.23	2.44	2.41	2.32	2.56	3.78	4.40	5.62	5.50	4.19	3.71	3.41	3.16	3.61	8.51	8.46	8.20	7.22	5.20	4.20	3.81	3.58	3.61	3.71	3.31	3.08	2.91	3.01	3.39	3.84
15:00	2.29	2.24	2.44	2.40	2.33	2.61	3.77	4.50	5.67	5.39	4.19	3.72	3.40	3.14	3.68	8.44	8.45	8.18	7.19	5.12	4.20	3.77	3.58	3.59	3.71	3.31	3.06	2.93	3.05	3.41	3.86
16:00	2.30	2.24	2.45	2.39	2.33	2.66	3.79	4.54	5.69	5.38	4.14	3.68	3.42	3.15	3.77	8.54	8.39	8.20	7.10	5.03	4.14	3.76	3.58	3.60	3.69	3.29	3.05	2.95	3.13	3.43	3.83
17:00	2.31	2.25	2.46	2.39	2.33	2.72	3.84	4.53	5.71	5.32	4.14	3.68	3.42	3.15	3.85	8.59	8.39	8.12	6.98	4.95	4.16	3.75	3.56	3.58	3.66	3.27	3.04	2.99	3.19	3.45	3.84
18:00	2.31	2.26	2.46	2.39	2.33	2.76	3.92	4.59	5.74	5.25	4.10	3.63	3.39	3.12	3.91	8.57	8.40	8.07	6.98	4.95	4.14	3.75	3.58	3.58	3.67	3.27	3.04	3.04	3.22	3.47	3.83
19:00	2.31	2.26	2.47	2.39	2.33	2.83	3.93	4.61	5.76	5.20	4.08	3.63	3.37	3.13	3.97	8.63	8.32	8.05	6.86	4.88	4.12	3.73	3.60	3.59	3.66	3.26	3.04	3.07	3.23	3.47	3.86
20:00	2.29	2.26	2.48	2.40	2.35	2.88	4.01	4.66	5.72	5.11	4.07	3.63	3.37	3.13	4.06	8.66	8.36	8.00	6.83	4.82	4.10	3.74	3.58	3.59	3.62	3.25	3.04	3.09	3.26	3.50	3.87
21:00	2.30	2.27	2.48	2.39	2.35	2.93	4.03	4.71	5.72	5.03	4.04	3.61	3.37	3.14	4.16	8.59	8.34	7.99	6.73	4.77	4.09	3.71	3.58	3.59	3.61	3.23	3.02	3.09	3.26	3.52	3.85
22:00	2.30	2.27	2.49	2.40	2.37	2.99	4.09	4.82	5.74	4.93	4.01	3.62	3.35	3.14	4.25	8.72	8.34	8.02	6.65	4.73	4.06	3.71	3.58	3.59	3.60	3.23	3.02	3.09	3.27	3.54	3.84
23:00	2.29	2.28	2.49	2.39	2.38	3.06	4.11	4.90	5.79	4.87	4.01	3.61	3.32	3.16	4.32	8.73	8.32	7.91	6.61	4.67	4.03	3.70	3.58	3.61	3.57	3.22	3.01	3.07	3.28	3.57	3.85

Table IIA-2.2 Discharge Measurement Records

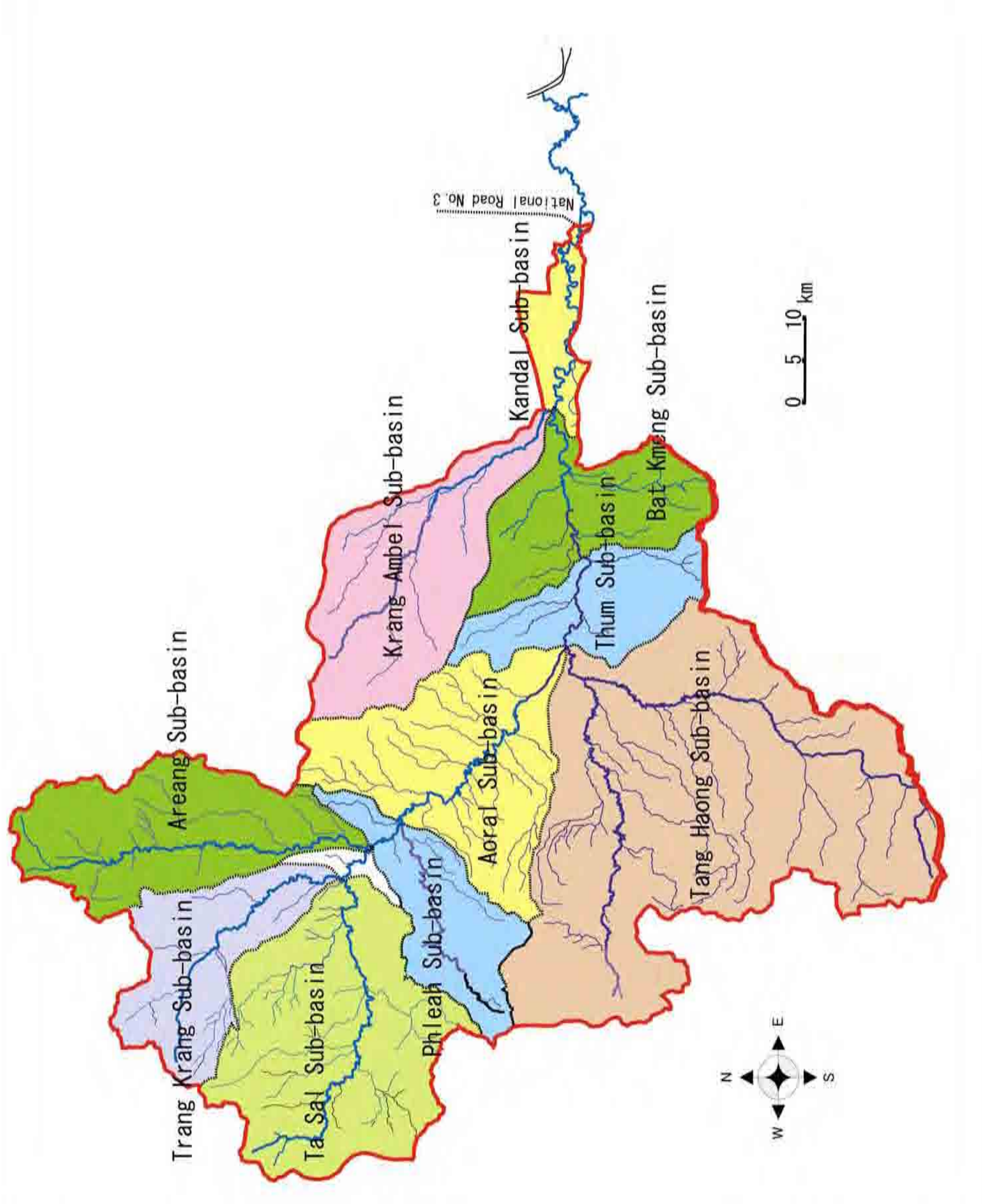
1. Peam Khley		2. Thnous Luong		3. Krang Chek		4. Chneang Kpous		5. Sangkea Tasal		6. Roleang Chrey	
H(m)	Q(m^3/s)	H(m)	Q(m^3/s)	H(m)	Q(m^3/s)	H(m)	Q(m^3/s)	H(m)	Q(m^3/s)	H(m)	Q(m^3/s)
1.70	4.71	1.90	2.53	2.00	1.12	0.69	0.14	1.31	1.59	3.11	1.52
1.23	6.21	2.21	5.74	2.10	1.72	1.25	1.44	1.18	0.97	3.50	4.46
1.80	5.63	1.91	3.21	2.98	6.27	1.26	1.50	4.36	52.89	3.31	2.30
3.34	40.88	3.59	69.77	2.60	3.86	4.23	8.80	1.49	2.98	5.63	77.09
2.05	10.23	1.80	1.22	2.59	4.11	1.85	2.66	1.70	6.66	3.10	0.91
3.05	51.84	2.85	22.90	3.00	10.00	2.80	7.68	2.10	11.43	4.34	28.26
2.00	8.37	2.02	4.36			1.78	3.00	2.65	16.47	3.40	3.72
5.50	415.44	3.25	50.74			6.86	22.32	6.38	863.30	5.13	28.03
4.40	117.20	2.95	32.28			4.15	10.73	2.10	11.43	4.50	43.76
5.00	197.10	7.80	1647.36			5.35	16.38	2.31	12.42	10.99	2133.13
3.30	52.94	3.38	73.13			3.11	6.78	3.77	37.39	5.45	47.45
2.82	26.44	3.64	73.89			2.44	4.97	3.44	34.99	5.93	105.20
3.92	76.89	3.25	49.65			3.45	7.59	2.00	7.25	5.51	79.68
3.59	60.00	3.14	40.95			3.05	6.24	4.37	49.60	5.22	47.79
4.15	105.45	3.64	68.91			4.90	16.17	4.24	44.29	6.07	96.12
3.77	70.21	3.55	72.76			4.04	11.58	4.27	45.79	5.80	39.08
3.45	59.37	3.22	37.84			3.81	10.82	1.83	5.03	4.94	34.23
2.65	22.66	2.94	29.28			2.60	4.88	1.49	3.04	4.55	29.61

Table IIA-4.1 Daily Rainfall Records in August 2006

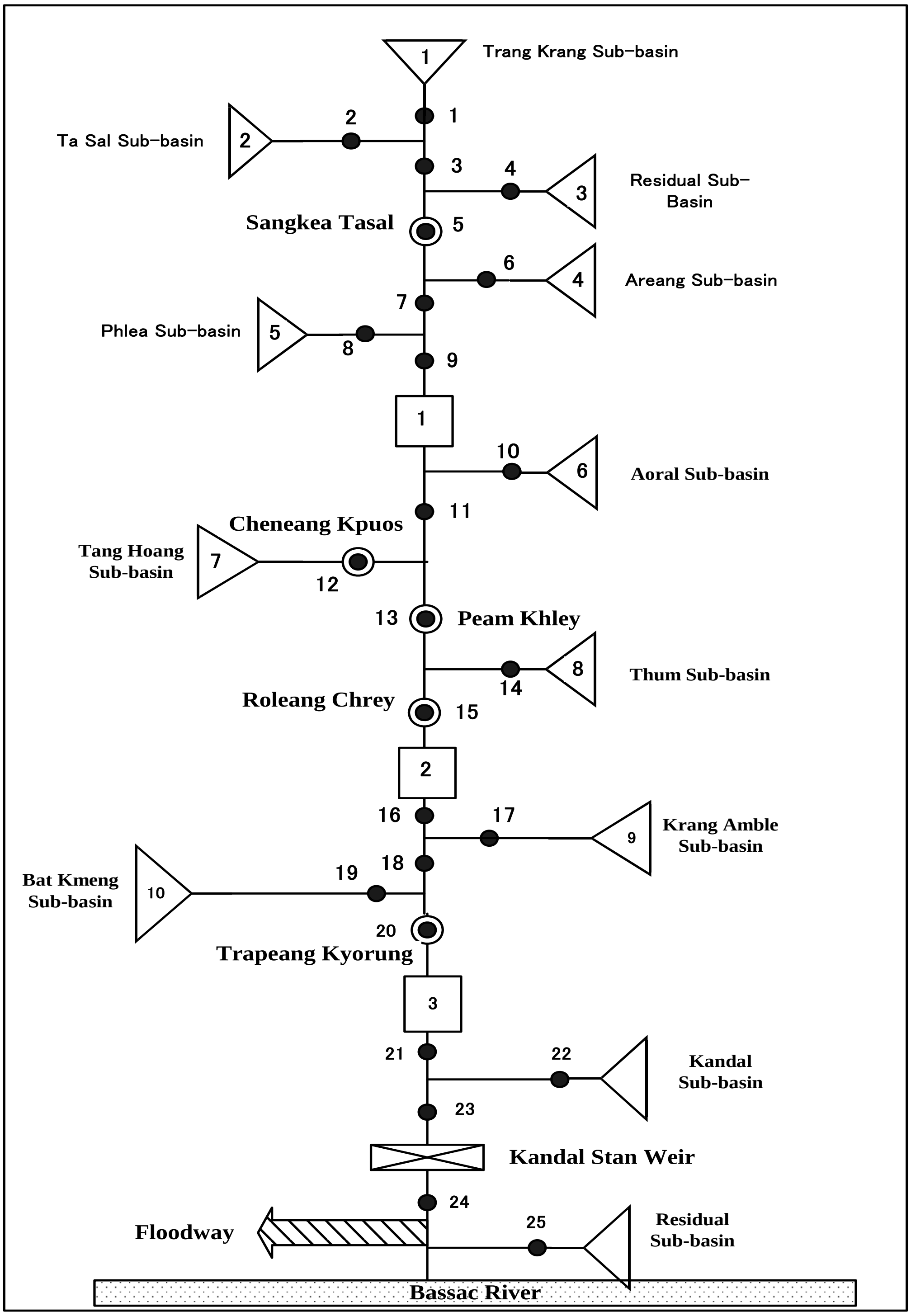
Unit: mm

	Kirirom	Wat Kdey Lvea	Kong Pisey	Trapeang Chour	Thpong	Peam Khley	Phum Chum	Roleang Chrey	O Kon Trom
2006/8/1	3.5	4.5	2.5	2.0	3.5	23.0	4.0	16.0	0.0
2006/8/2	9.0	11.0	9.0	1.0	0.5	4.5	6.0	3.0	4.0
2006/8/3	19.0	0.5	0.0	1.0	0.0	0.0	5.0	0.0	8.0
2006/8/4	6.0	0.5	0.0	0.5	0.0	7.5	16.5	2.0	9.0
2006/8/5	34.0	1.5	0.0	10.5	0.5	5.0	24.5	3.0	10.0
2006/8/6	27.0	0.0	0.0	2.0	1.5	5.5	19.0	3.0	18.0
2006/8/7	36.0	1.5	0.5	2.5	0.0	17.5	39.0	14.5	74.5
2006/8/8	2.5	0.0	1.5	0.0	0.0	5.0	11.0	0.5	3.5
2006/8/9	10.0	0.0	0.0	1.5	0.5	0.0	4.0	0.0	9.5
2006/8/10	6.5	0.0	1.0	0.0	0.5	0.0	12.5	0.0	4.0
2006/8/11	0.0	0.0	0.0	0.5	0.0	0.0	2.5	0.0	1.0
2006/8/12	1.0	1.0	0.0	21.0	2.5	0.5	0.0	0.0	0.0
2006/8/13	5.5	33.5	10.0	1.0	3.5	21.0	1.0	16.0	20.0
2006/8/14	65.0	5.0	20.5	10.5	20.5	10.5	12.0	8.0	81.5
2006/8/15	147.0	35.5	84.0	32.0	28.0	73.0	89.5	61.0	118.0
2006/8/16	44.5	4.5	7.0	38.5	7.0	12.5	80.0	8.0	55.5
2006/8/17	2.5	0.0	4.5	25.5	42.5	0.0	3.5	0.5	4.0
2006/8/18	0.5	0.0	3.0	0.0	0.5	0.0	0.0	1.0	0.0
2006/8/19	0.5	0.0	5.0	0.0	0.0	20.5	0.0	7.5	1.5
2006/8/20	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
2006/8/21	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006/8/22	0.0	6.5	3.5	5.0	4.5	1.0	3.5	0.0	0.0
2006/8/23	3.5	4.0	1.0	12.5	4.5	0.5	8.0	0.0	0.0
2006/8/24	0.5	2.0	1.0	0.0	2.0	2.5	0.0	0.0	0.0
2006/8/25	10.5	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0
2006/8/26	4.5	0.0	1.0	0.0	1.5	0.0	3.0	0.0	0.0
2006/8/27	1.0	0.0	34.0	0.0	0.0	7.0	6.5	4.5	0.5
2006/8/28	13.5	42.0	42.5	0.0	38.5	13.5	4.0	34.0	5.0
2006/8/29	11.5	36.0	42.5	62.5	69.0	56.0	29.5	26.5	3.0
2006/8/30	3.0	21.5	5.5	1.0	1.0	17.5	0.0	21.0	14.0
2006/8/31	1.0	0.5	0.5	0.5	0.5	0.0	0.0	0.0	0.5

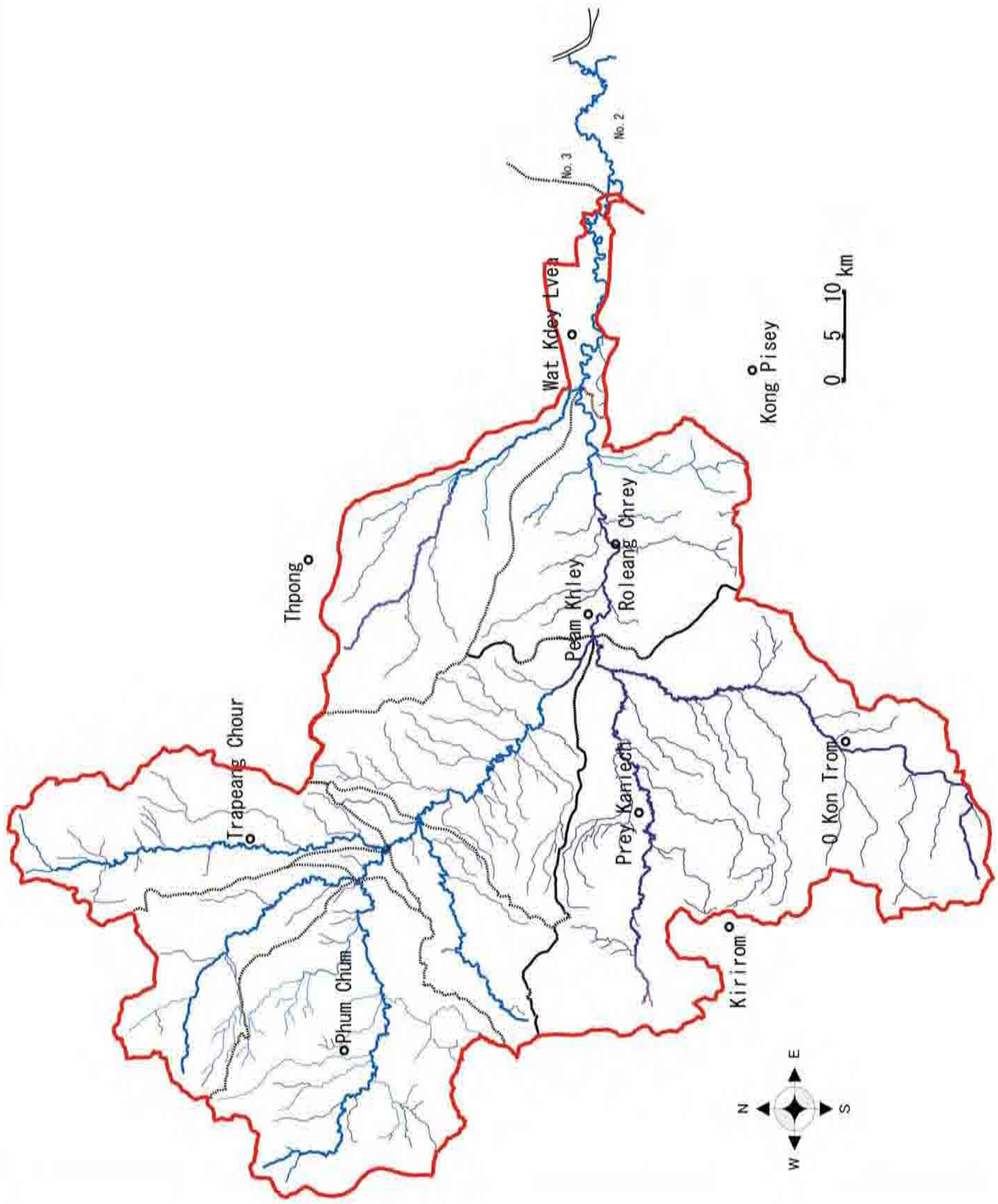
Figures



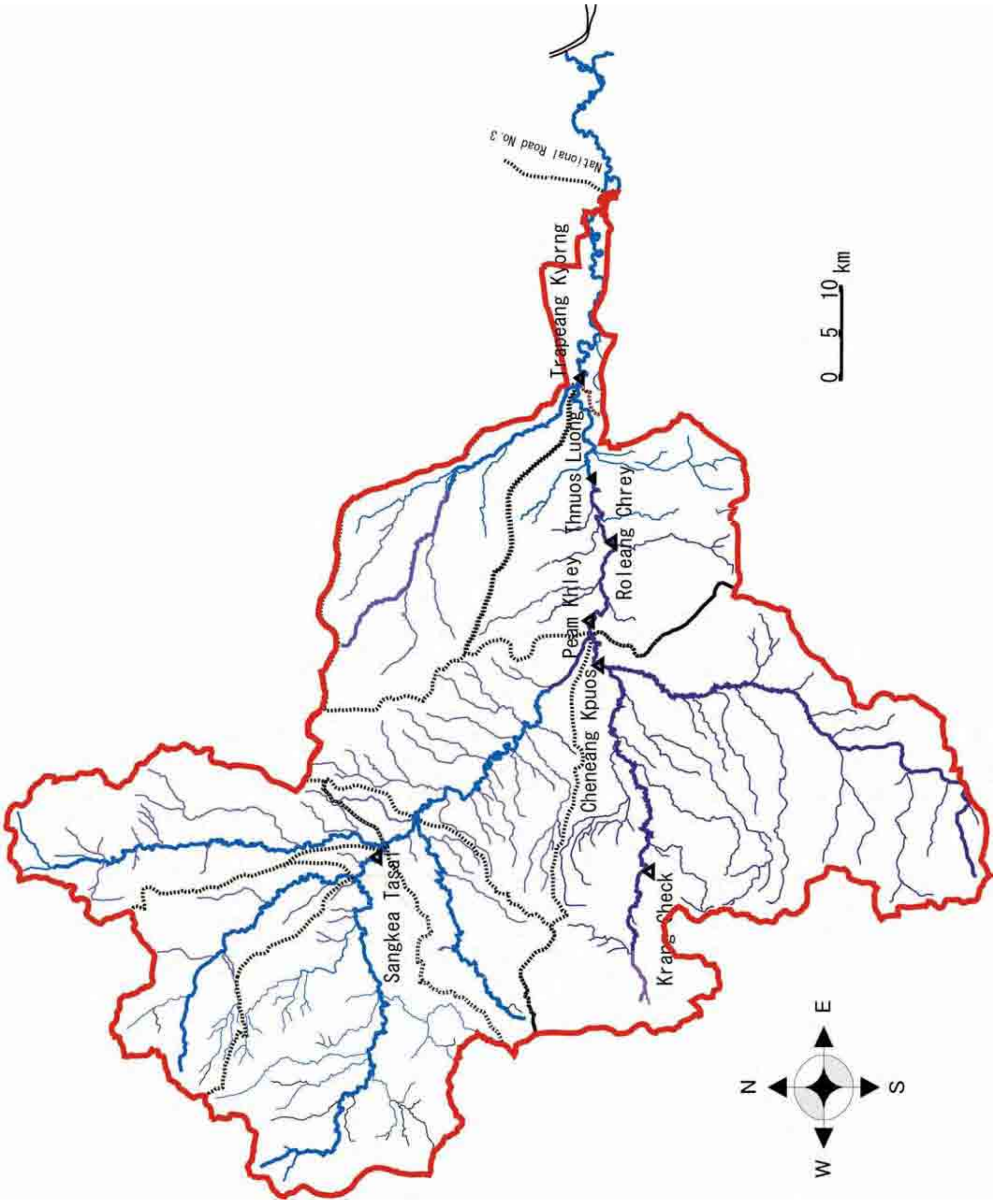
The Study on Comprehensive Agricultural Development of Prek Thnot River Basin, the Kingdom of Cambodia	Figure IIA-1.1 Prek Thnot River Basin
Japan International Cooperation Agency	



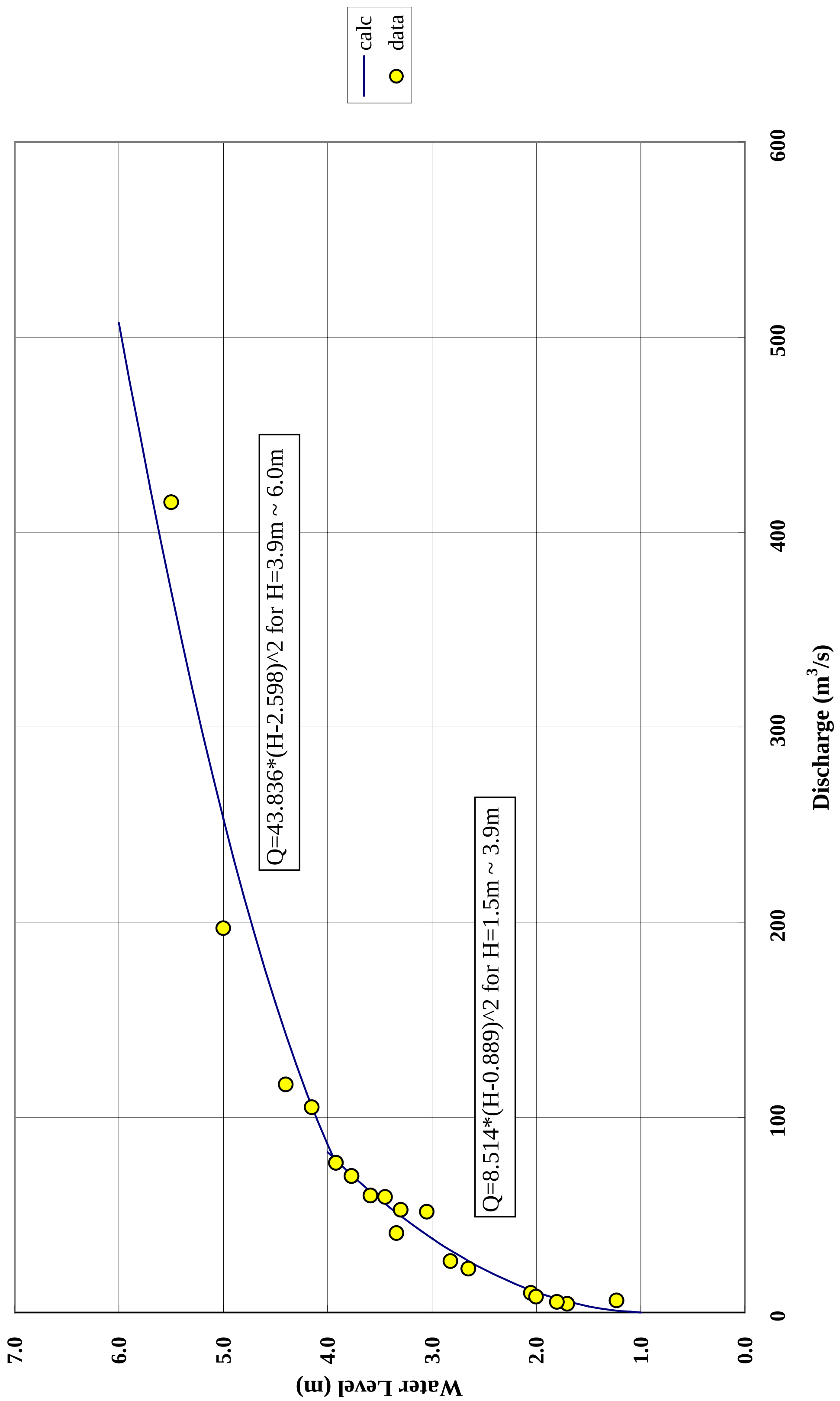
The Study on Comprehensive Agricultural Development of Prek Thnot River Basin, the Kingdom of Cambodia	Figure IIA-1.2 Runoff System of Prek Thnot River Basin
Japan International Cooperation Agency	



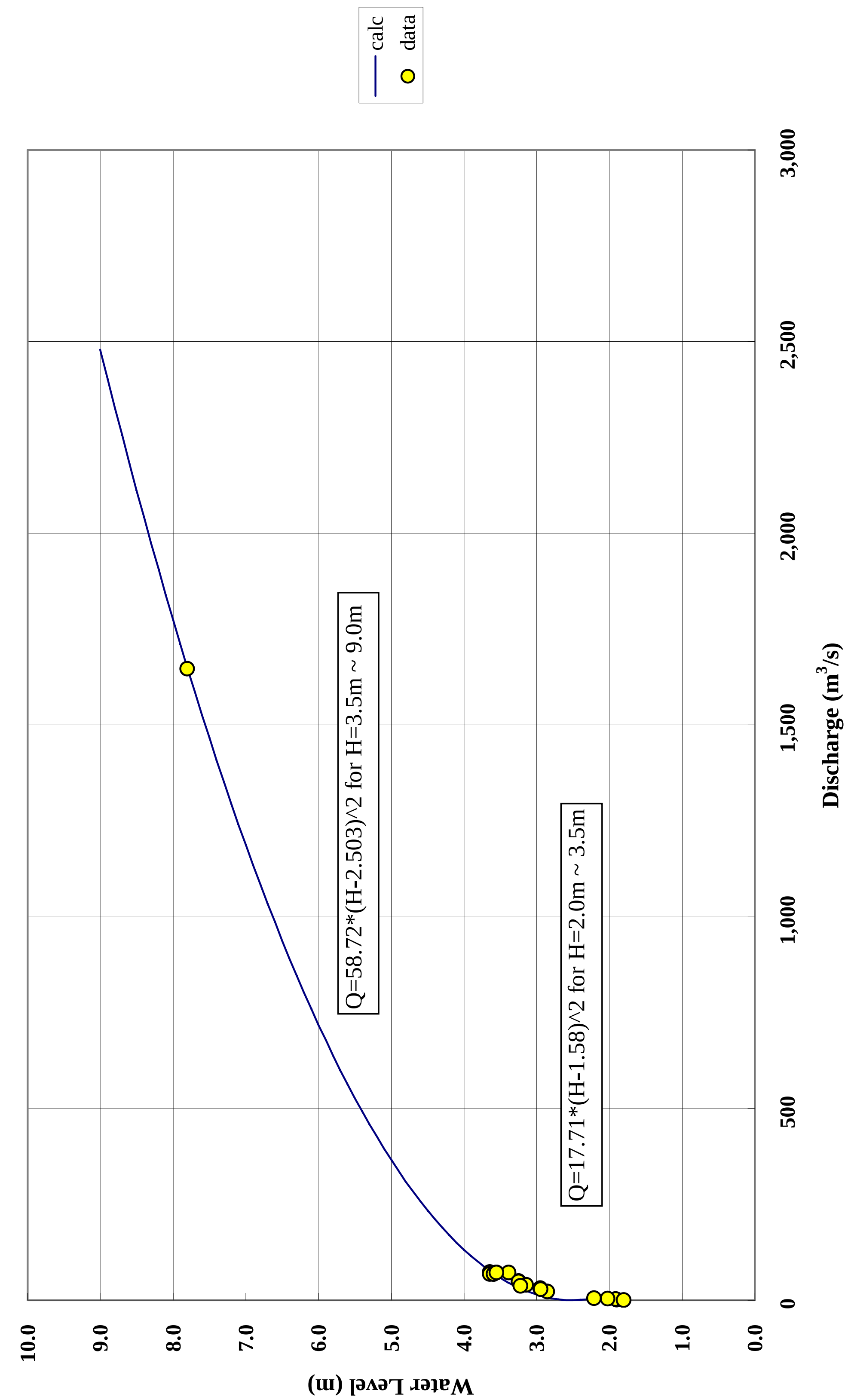
The Study on Comprehensive Agricultural Development of Prek Thnot River Basin, the Kingdom of Cambodia	Figure IIA-2.1 Location Map of Rainfall Gauging Station
Japan International Cooperation Agency	



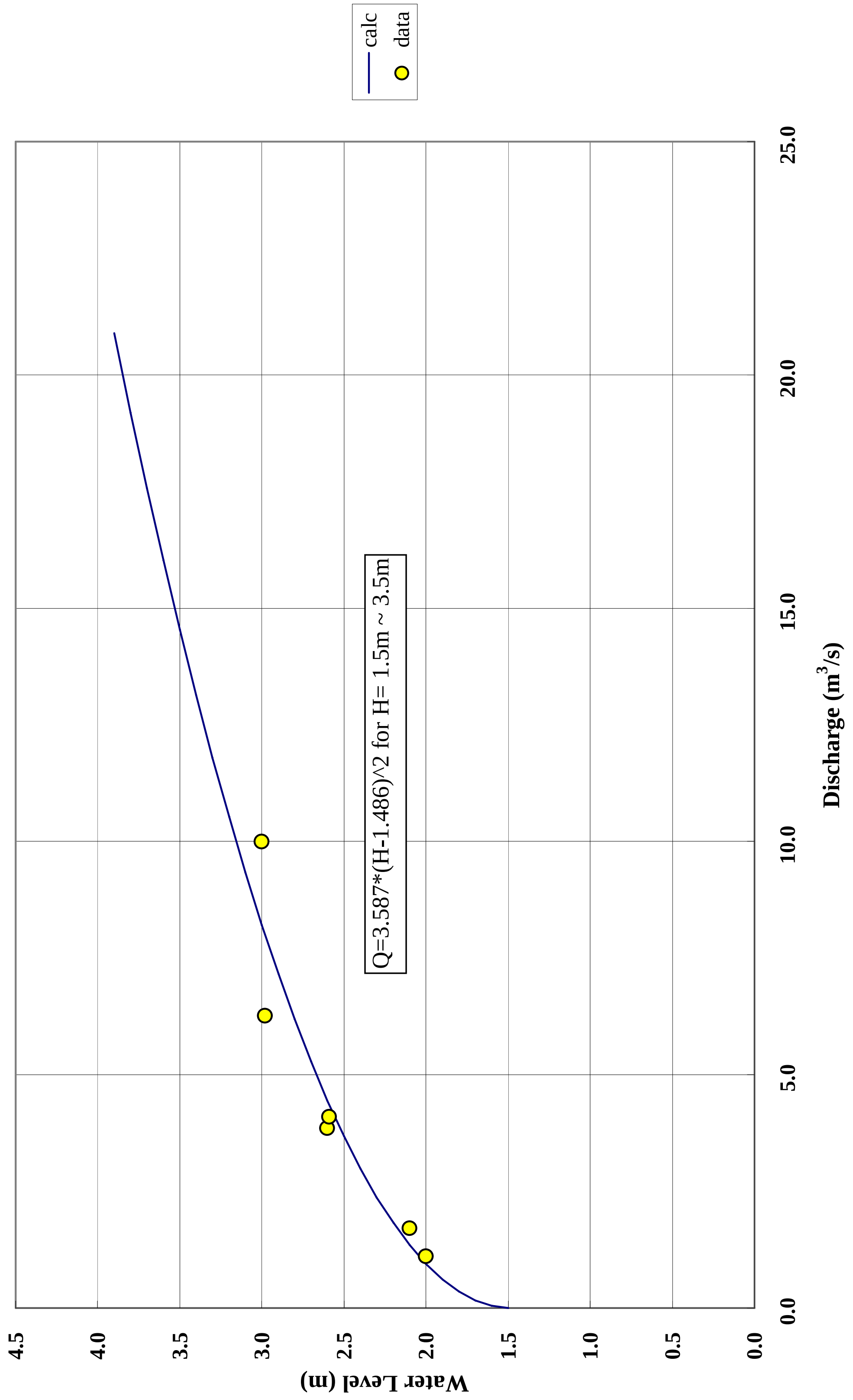
The Study on Comprehensive Agricultural Development of Prek Thnot River Basin, the Kingdom of Cambodia	Figure IIA-2.2 Location Map of Water-level Gauging Station
Japan International Cooperation Agency	



The Study on Comprehensive Agricultural Development of Prek Thnot River Basin, the Kingdom of Cambodia	Figure IIA-2.3 Discharge Rating Curve at Peam Kley Bridge (1)
Japan International Cooperation Agency	



The Study on Comprehensive Agricultural Development of Prek Thnot River Basin, the Kingdom of Cambodia	Figure IIA-2.4 Discharge Rating Curve at Thnuos Luong
Japan International Cooperation Agency	



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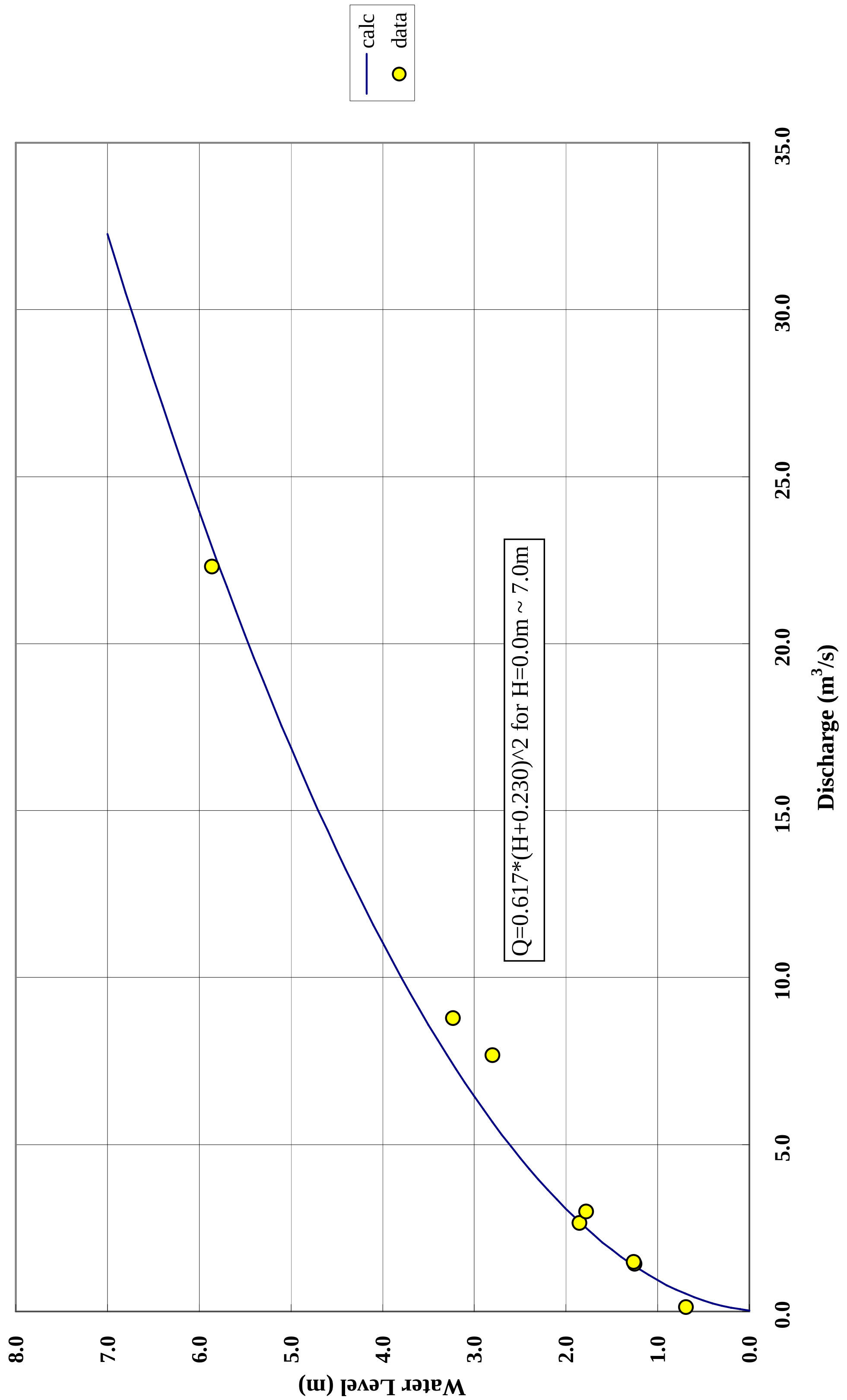
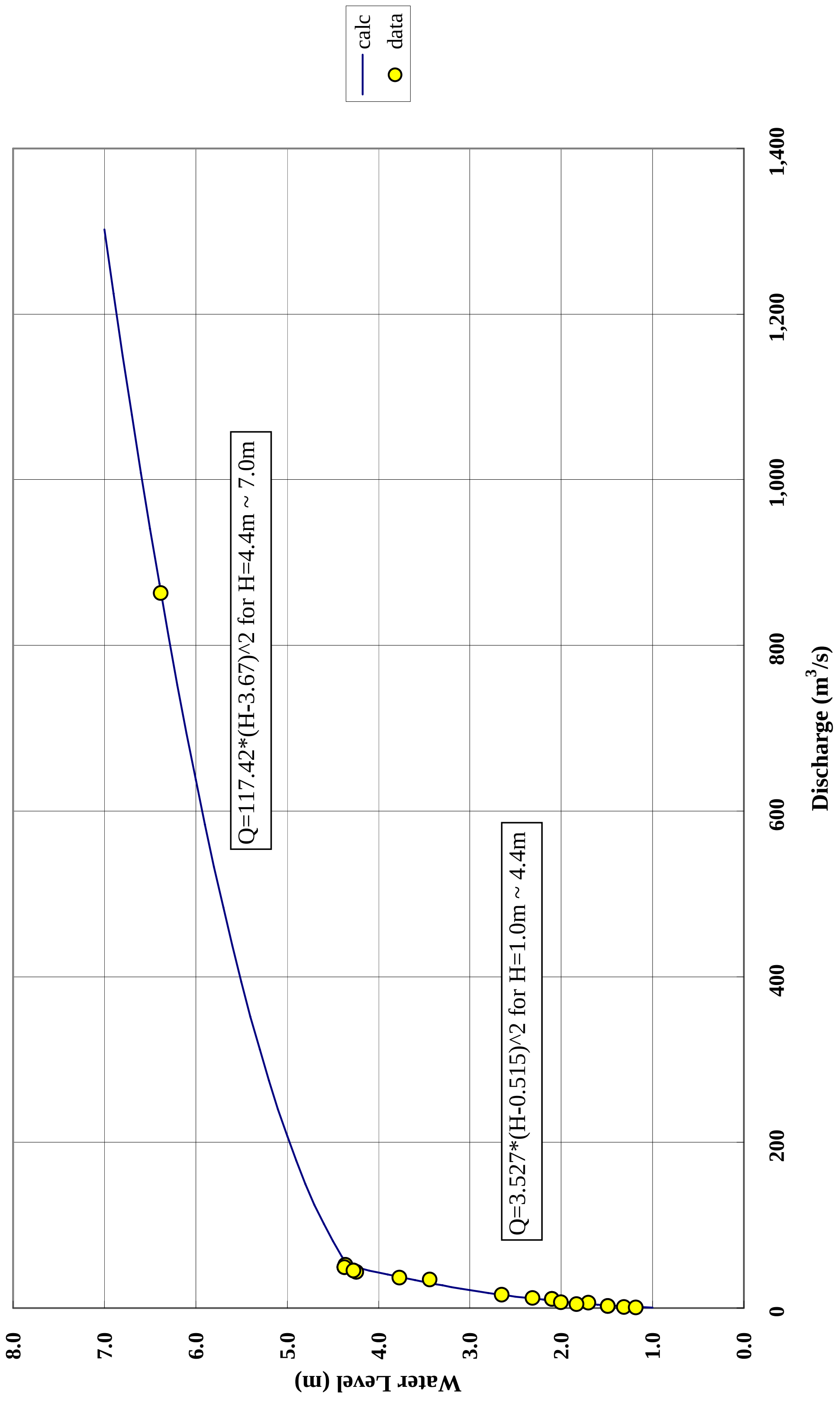
Japan International Cooperation Agency	



The Study on Comprehensive Agricultural Development of Prek Thnot River Basin, the Kingdom of Cambodia	Figure IIA-2.6 Discharge Rating Curve at Cheneang Kpuos
Japan International Cooperation Agency	



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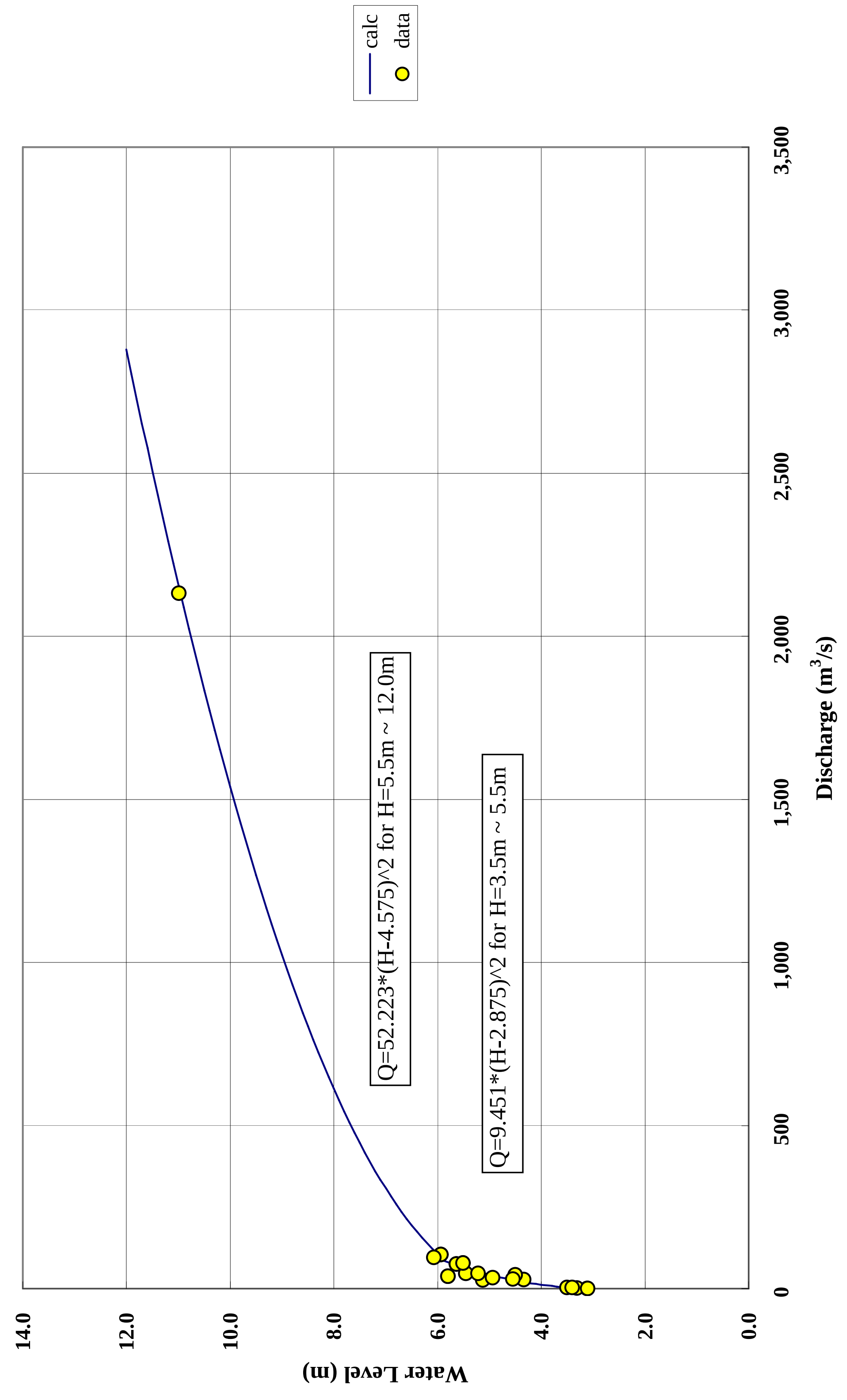
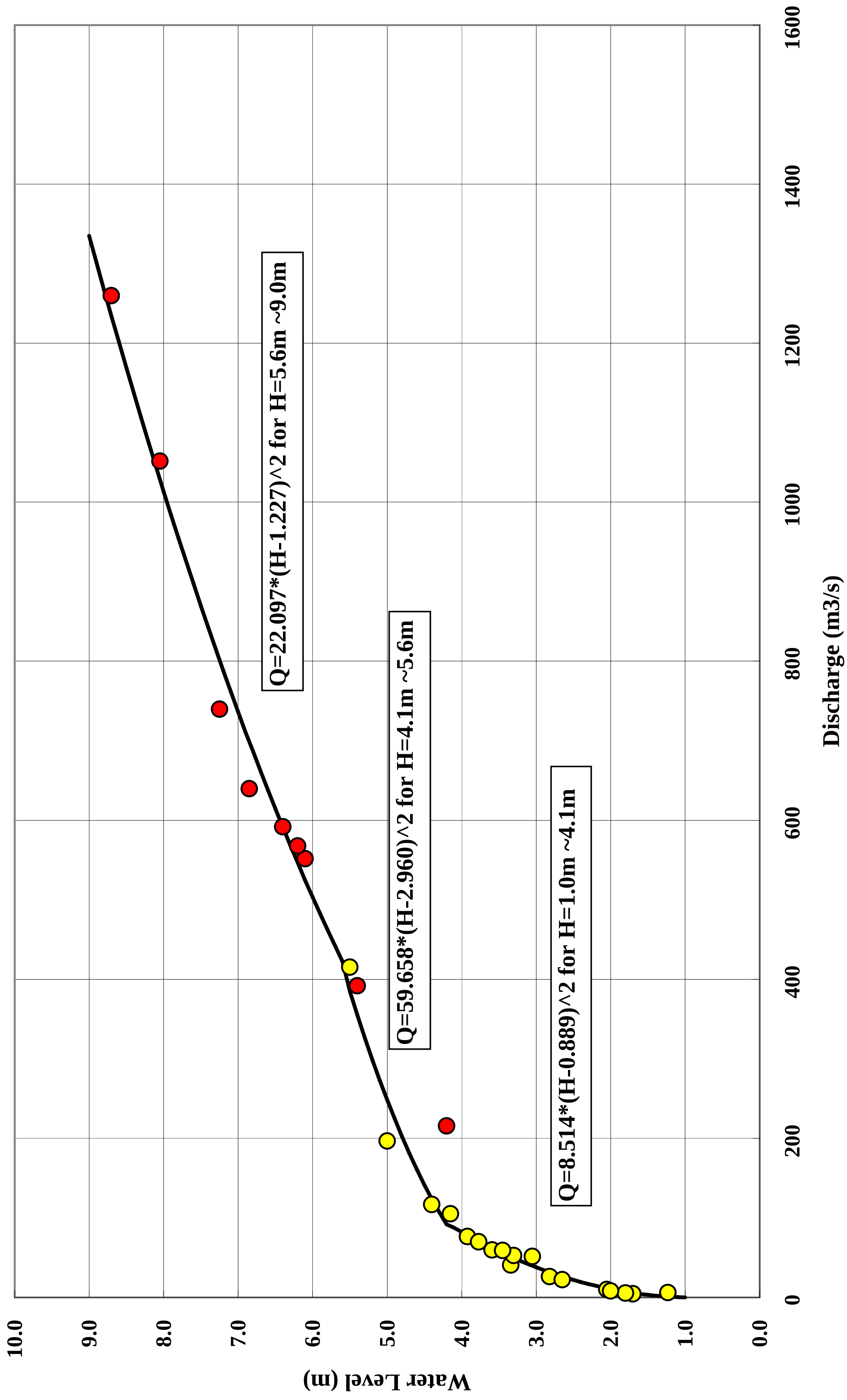
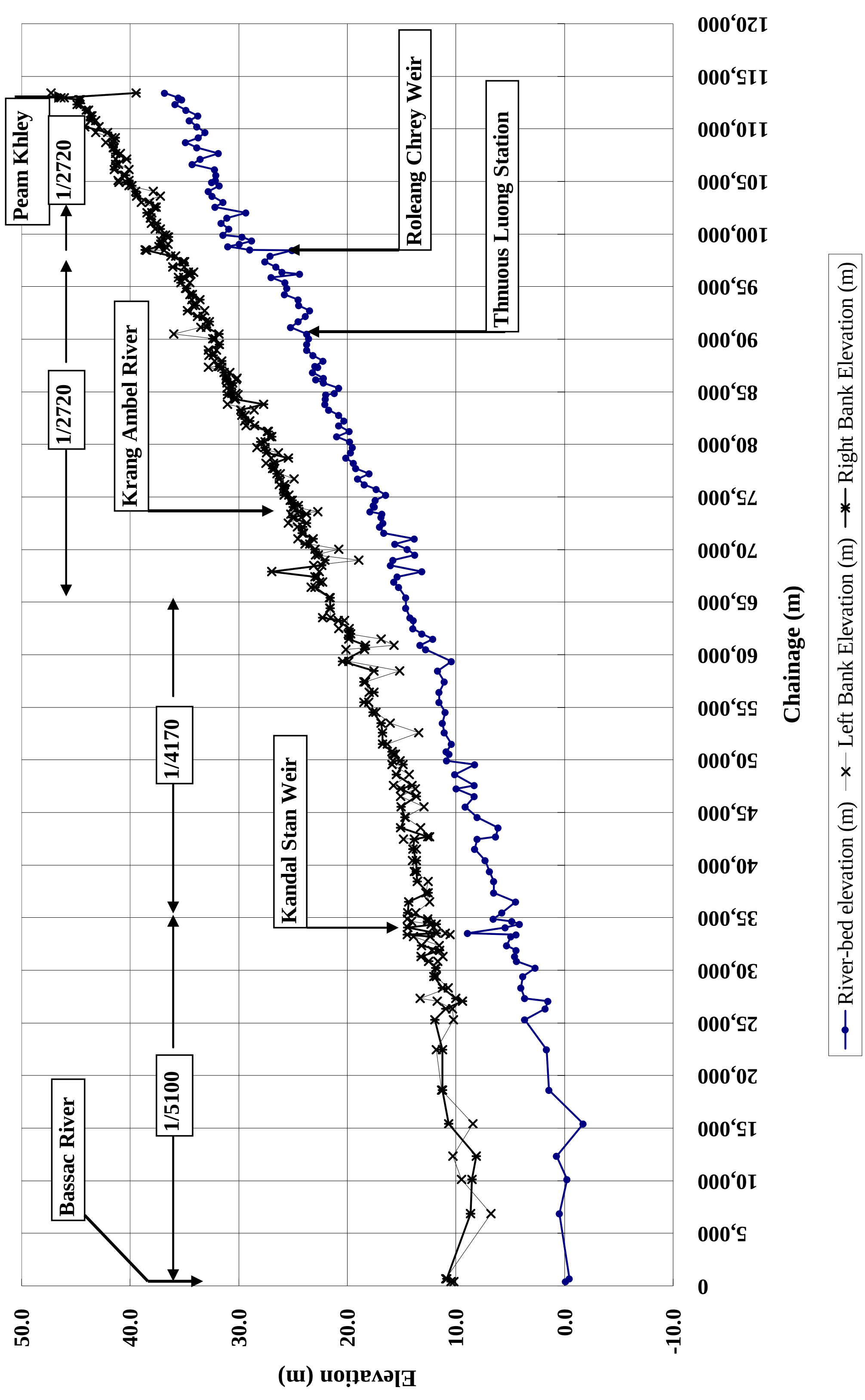
Japan International Cooperation Agency	



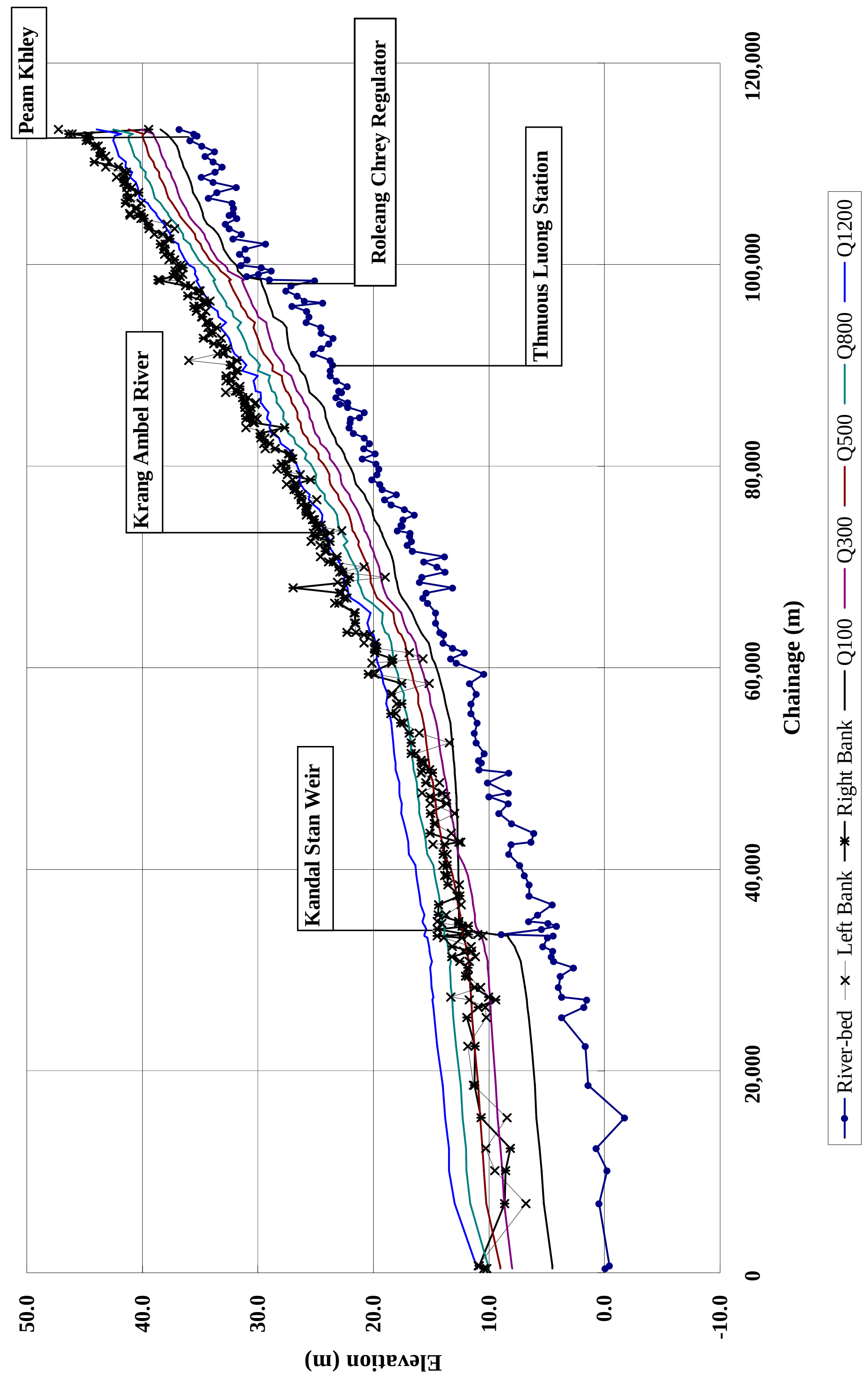
The Study on Comprehensive Agricultural Development of Prek Thnot River Basin, the Kingdom of Cambodia	Figure IIA-2.8 Discharge Rating Curve at Roleang Chrey
Japan International Cooperation Agency	



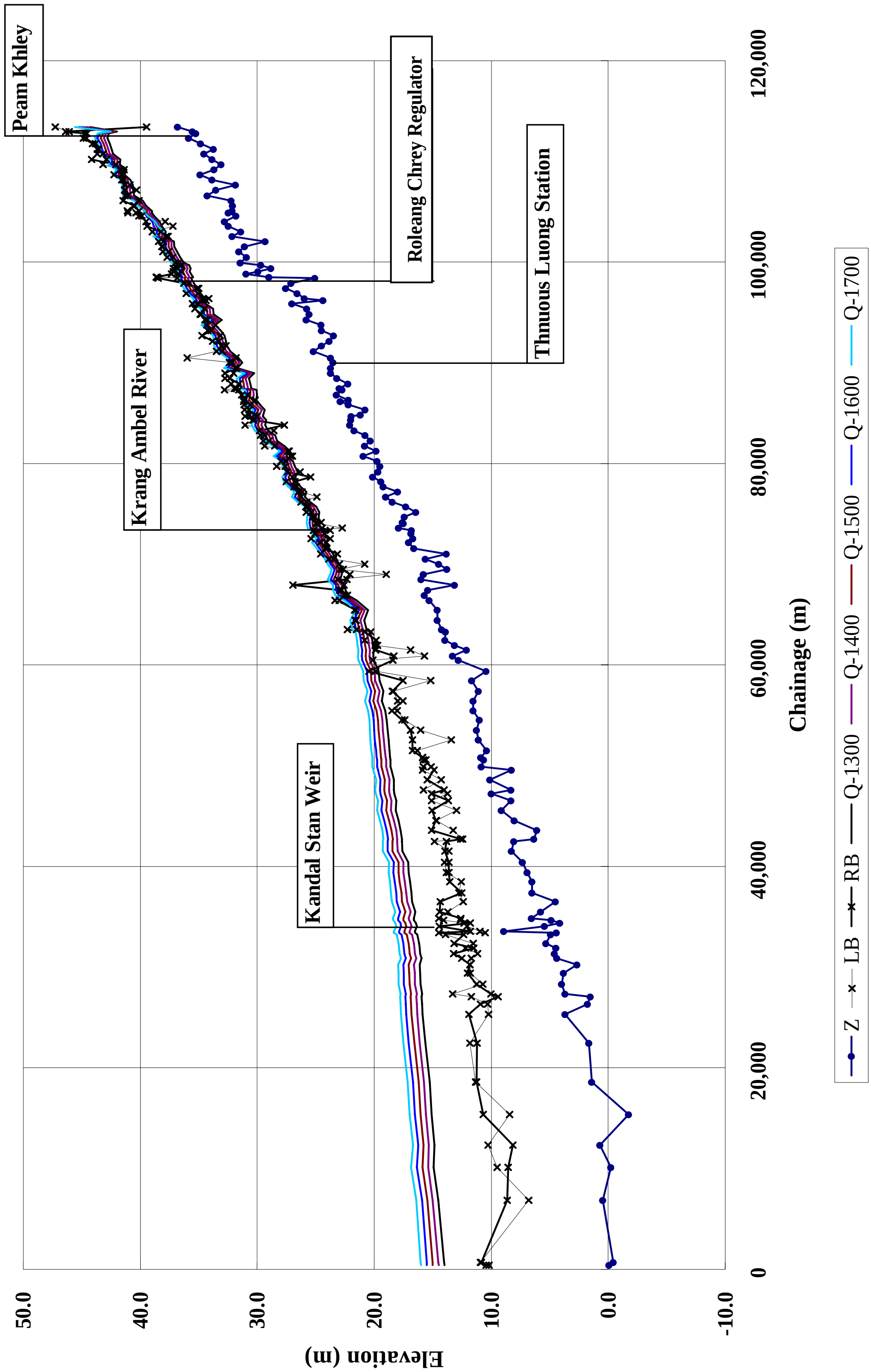
The Study on Comprehensive Agricultural Development of Prek Thnot River Basin, the Kingdom of Cambodia	Figure IIA-2.9 Discharge Rating Curve at Peam Kley Bridge (2)
Japan International Cooperation Agency	



The Study on Comprehensive Agricultural Development of Prek Thnot River Basin, the Kingdom of Cambodia	Figure IIA-3.1 Longitudinal Profile of Prek Thnot River
Japan International Cooperation Agency	



The Study on Comprehensive Agricultural Development of Prek Thnot River Basin, the Kingdom of Cambodia	Figure IIA-3.2 Longitudinal Profile of Water Level of Prek Thnot River (1)
Japan International Cooperation Agency	



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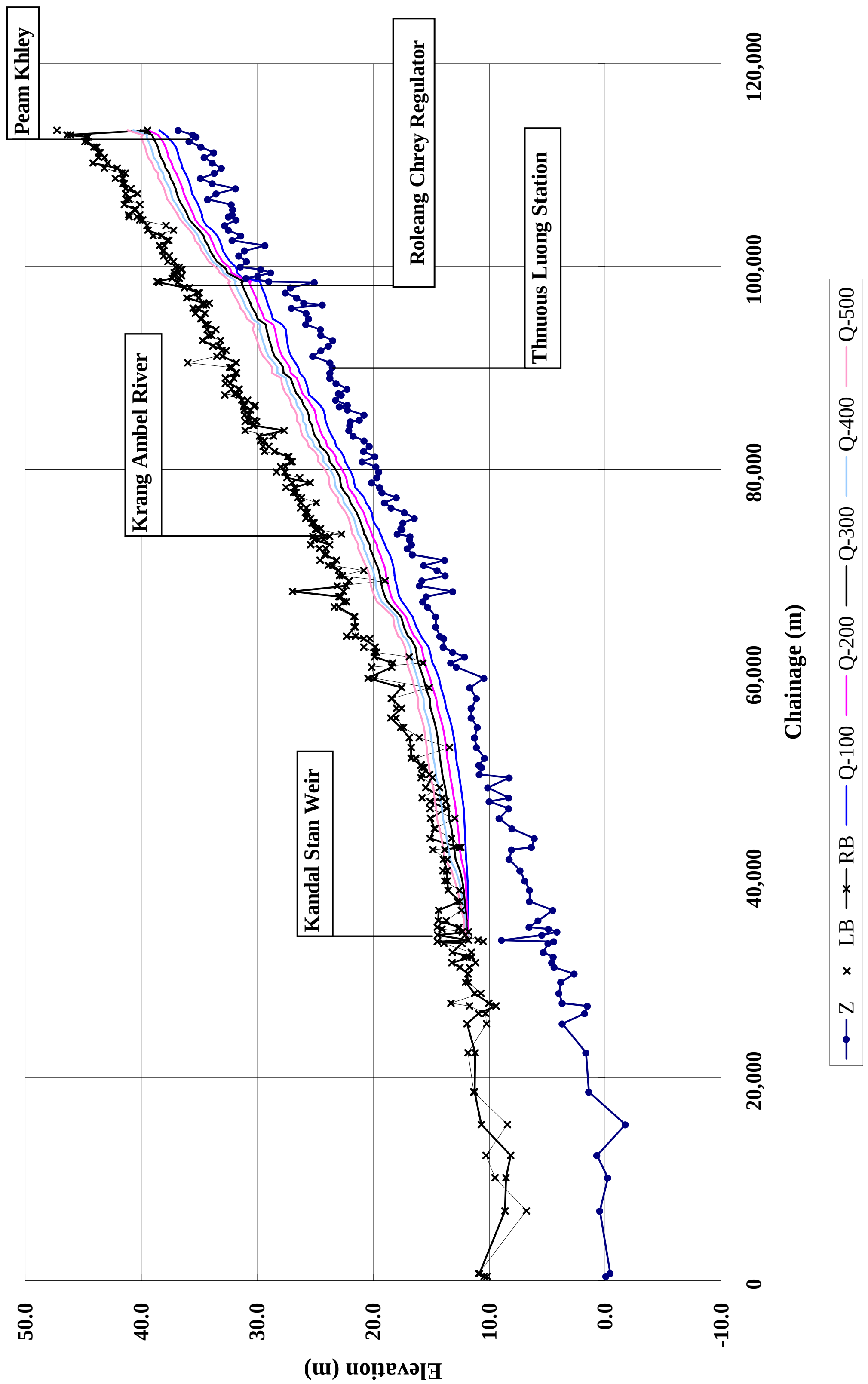
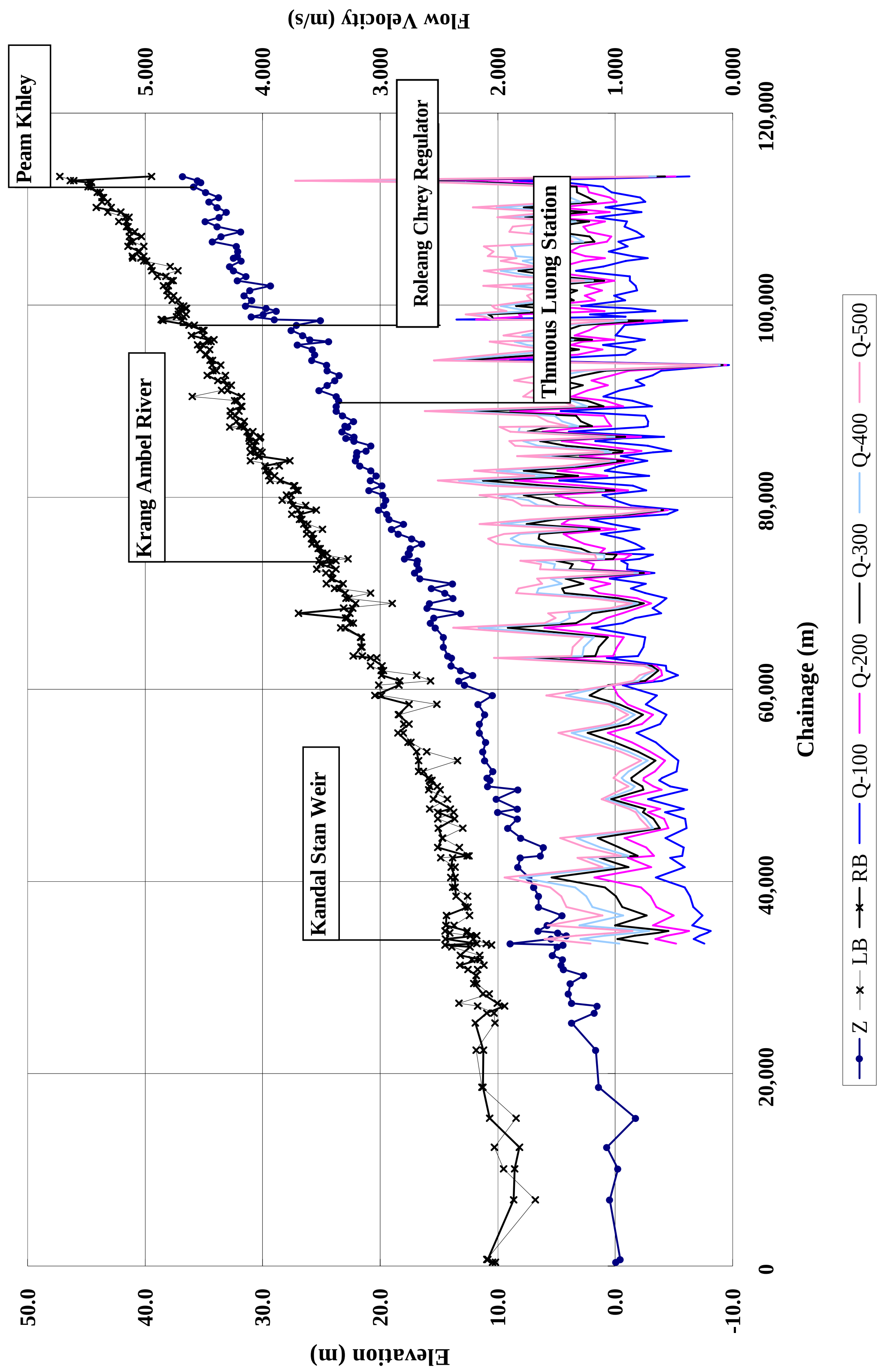
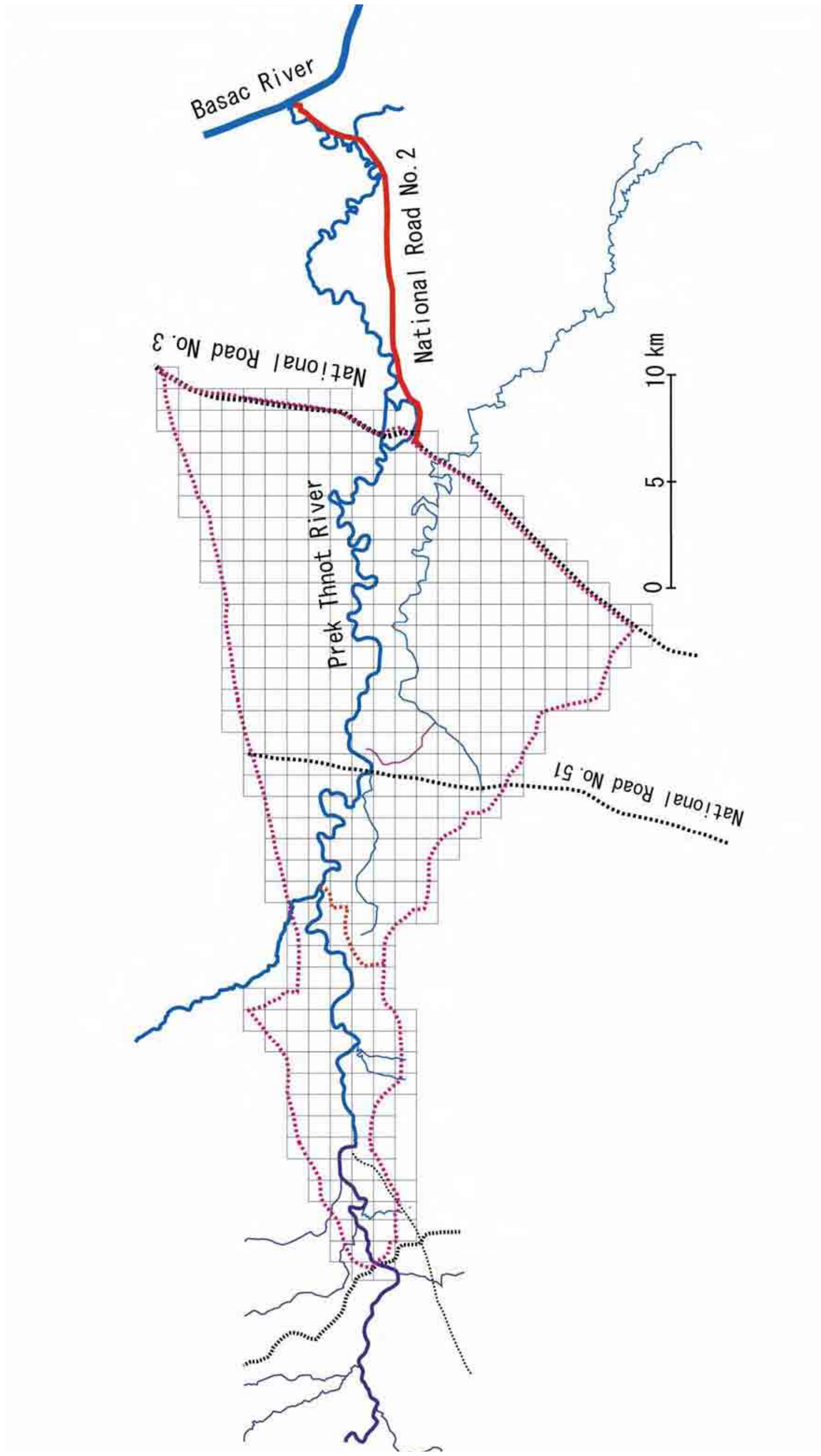
Japan International Cooperation Agency	



The Study on Comprehensive Agricultural Development of Prek Thnot River Basin, the Kingdom of Cambodia	Figure IIA-6.1 Longitudinal Profile of Water Level from Kandal Steung Weir
Japan International Cooperation Agency	



The Study on Comprehensive Agricultural Development of Prek Thnot River Basin, the Kingdom of Cambodia	Figure IIA-6.2 Longitudinal Profile of Flow Velocity of Prek Thnot River
Japan International Cooperation Agency	



The Study on Comprehensive Agricultural Development of Prek Thnot River Basin, the Kingdom of Cambodia	Figure IIA-7.1 Tentative Objective Area for Inundation Analysis
Japan International Cooperation Agency	

Appendix-IIB

ROLEANG CHREY REGULATOR AND INTAKES

THE STUDY
ON
COMPREHENSIVE AGRICULTURAL DEVELOPMENT
OH
PREK THNOT RIVER BASIN
IN
THE KINGDOM OH CAMBODIA

FINAL REPORT

Volume-VII: Appendixes for Feasibility Studies for Priority/Urgent Projects

Appendix-IIB

Roleang Chrey Regulator and Intakes

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APPENDIX-IIB: ROLEANG CHREY REGULATOR AND INTAKES

Chapter IIB-1 Present Structural Condition of Roleang Chrey Regulator and Intakes

IIB-1.1 Hydro-mechanical Works

IIB-1.1.1 Roleang Chrey Regulator

The Roleang Chrey Regulator is a key structure for irrigated agriculture development in the Target Area. It is presently observed that some portions are deteriorated rather than damaged. In particular, the gates, which are indispensable for proper water abstraction and flood control, are in such a crucially severe condition that they do not function appropriately.

(1) General Information

General Information on hydro-mechanical Works for Roleang Chrey Regulator

Items	General Information
(a) Type	Fixed wheel gate
(b) Number	5
(c) Clear span	12.5 m
(d) Height	6.7 m
(e) Hoist	Electric driven, wire rope winding, one motor two drum, with counter weight

(2) Present Conditions and Findings

Through site inspection and review on the detailed drawings for the Roleang Chrey Regulator, the clarified present conditions and obtained findings are as follows:

Clarified Present Conditions and Obtained Findings

Place	Present Conditions and Findings
(a) Gate Leaves	- Almost all the main wheels cannot rotate due to high resistance caused by rusting of the shafts. - Much water leakages are observed due to aging and cracks in the rubber seal. - The paint on the gate leaves peels off. - The four wheels installed in a side girder could not smoothly rotate, so that gate movement is obstructed.
(b) Guide Frame	- The guide frame is sound, and no problem is found accordingly.
(c) Hoist	- Electric motors, speed reducers, counter shafts and winding drums are still in working condition. - All of the brakes, position indicators and limit switches do not function at all. - The hoist wire ropes are still in service.

In addition, it was found that release of small discharge to downstream reach could not be mechanically ensured by the present gates because of their large size. Thus, the countermeasure to release the small discharge for some irrigation projects such as Kandal Stung Irrigation Project, Dangkor Pump Irrigation Project and Tonle Bati Irrigation Project, should be considered

IIB-1.1.2 Andong Sla Intake

The Andong Sla Intake was constructed in 1974 together with the Roleang Chrey Regulator. The general information of it is given below:

(1) General Information

General Information on hydro-mechanical Works for Andong Sla Intake

Items	General Information
(a) Type	Steel radial gate, four sealing edges
(b) Number	4
(c) Clear span	4.0 m
(d) Height	2.7 m
(e) Hoist	Electric driven, wire rope winding, one motor two drum

(2) Present Conditions and Findings

Through site inspection and review on the detailed drawings for the Andong Sla Intake, the present conditions are clarified and some problems are found as follows:

Clarified Present Conditions and Obtained Findings

Place	Present Conditions and Findings
(a) Gate Leaves	- No serious corrosion was found on the gate leaves. - Water is much leaking through seals and wire rope holes of the gate leaf.
(b) Guide Frame	- Serious corrosion was not observed on the guide frame.
(c) Hoist	- The hoisting wire ropes are damaged. - The cables of transmission line are missed.

As can be seen in the above table, serious problem are not found for the gate leaves and guide frame except hoist. However, this steel radial gate has originally the following structural weak points.

- Gate leaf is extremely slender which would result in structural unstableness.
- Almost all the structural members are usually submerged in backwater or in wet condition due to leaked water, and corrosion would get worse, which would lead to unstableness of gate leaf.
- Proper maintenance is impossible because it is always submerged
- Good sealing is structurally so difficult for this radial gate even if the seal rubber is not damaged.

IIB-1.1.3 Vat Krouch Intake

The Vat Kruoch Intake was constructed in 2002. The general information of it is given below:

(1) General Information

General Information on hydro-mechanical Works for Vat Kruoch Intake

Items	General Information
(a) Type	Steel radial gate, four sealing edges
(b) Number	1
(c) Clear span	4.00 m
(d) Height	2.54 m
(e) Hoist	Manually operated wire rope hoist

(2) Present Conditions and Findings

Through site inspection for the Vat Kruoch Intake, the present conditions are clarified and some problems are found as follows:

Clarified Present Conditions and Obtained Findings

Place	Present Conditions and Findings
(a) Gate Leaves	- Corrosion was not observed although the paint is damaged. - No water leakage is observed.
(b) Guide Frame	- Guide frame is sound.
(c) Hoist	- Wire ropes are damaged, and steel wire is used temporally.

IIB-1.2 Civil Works

IIB-1.2.1 Roleang Chrey Regulator

The Roleang Chrey Regulator was constructed in 1974.

Retaining wall located at upstream side of the Roleang Chrey Regulator does not show any problem and this is in stable condition as far as site inspection is conducted.

Gate piers, operation deck and bridge are in firm condition, and any rehabilitation is not required.

The present downstream apron itself is in good condition, however its length is too short because the Roleang Chrey Regulator was designed under the condition that the Prek Thnot Multipurpose Dam was constructed. The study results that the length of downstream apron would stand against around 1/5 years flood only. In fact, the topographic survey shows that riverbed after the downstream apron is eroded about 2 m in depth. Thus, the countermeasure to this erosion should be considered although geological boring is essential at detailed design stage to confirm the foundation condition.

Side slope protection at downstream side is severely damaged for not only left side, but also right side. In connection with the riverbed protection for the eroded portion, this side slope protection should be rehabilitated.

The gates could not be operated for small release discharge to the downstream reach. To ensure such release discharge, especially in the dry season, an appropriate countermeasure should be examined from technical and economical viewpoints.

IIB-1.2.2 Andong Sla Intake

As for the intake structure, gate piers, operation deck and bridge are not envisaged with structural problem. However, downstream portion of the intake is severely eroded and rehabilitation is absolutely needed. As mentioned above, the gates do not function properly, so that the intake structure would be required to be totally replaced into new one according to the selected gate type.

The existing intake structure bears the more head loss due to four sealing edges of gate, which results in one of constraints for introduction of gravity irrigation

IIB-1.2.3 Vat Krouch Intake

The Vat Krouch Intake is structurally stable, but the downstream portion is severely eroded.

Since the Vat Krouch Intake is equipped with one steel radial gate of four sealing edges, head loss is large, which is one of constraints for introduction of gravity irrigation.

IIB-1.2.4 Approach Cannel from Prek Thnot River to Andong Sla and Vat krouch Intake

(1) Approach channel to Andong Sla Intake

According to the hydraulic calculation based on the topographic survey results, the approach channel has enough capacity to flow the design discharge mentioned later, and also does not show the severe erosion at its side slope.

(2) Approach channel to Vat Krouch Intake

The approach channel from the Prek Thnot River to the Vat Krouch Intake is unlined and has not adequate section to flow the design discharge which is discussed later. Serious erosion is not seen at the side slope of channel.

IIB-1.3 O&M

IIB-1.3.1 Hydro-mechanical Works

(1) Operation

Kampong Speu PDOWRAM is in charge of the O&M for gates and accessories for the Roleang Chery Regulator, Andong Sla Intake and Vat Krouch Intake. But, O&M has not been properly conducted by the PDOWRAM mainly due to financial constraint. Even O&M manual is not available now.

As for gate operation for Roleang Chrey Regulator, in general small opening of gate for long period is not mechanically allowed due to high possibility of damage by vibration. The operator does not know such operation rule at all. Generally, gates for the regulator are kept closed, and at flood time, are opened by observing the upstream water level in front of gates and also information on water level at Peam Khley The gate opening at flood time is made when the upstream water level becomes over EL 35.7 m. This is a sole rule for gate operation for Roleang Chrey Regulator.

On the other hand, gate operation of Andong Sla Intake and Vat Krouch Intake is carried out on the demand basis, but not based on the irrigation schedule.

(2) Maintenance

Regular maintenance for Roleang Chrey Regulator, Andong Sla Intake and Vat Krouch Intake are hardly made by the Kampong Speu PDOWRAM. Emergency repair such as replacement of wire is made not permanently but temporally. In particular, severe erosion around structures is not repaired at all. Such erosion is therefore progressing now.

In 2006, replacement of wire ropes connecting with counter-weight and installation of diesel generator for Roleang Chrey Regulator were made under financial assistance of JICA. In addition, minor repairs such as replacement of magnetic conductor and switch, were conducted at own budget.

IIB-1.3.2 Civil Works

As for structures of Roleang Chrey Regulator, Andong Sla and Vat Krouch Intakes, the severe damages have not been made. Therefore the maintenance for these structures has not been made since construction of structures.

Chapter IIB-2 Improvement Plan of Roelang chrey Regulator and Intakes

IIB-2.1 General

The Project aims to provide a stable water supply to the North Main Canal and South Main Canal, and also to downstream area.

In consideration of the current conditions and importance of the Roleang Chrey Regulator, Andong Sla Intake with approach channel and Vat Krouch Intake with approach channel and to attain the aims, the JICA Study Team has elaborated a development concept of "***Realization of Proper Gate Operation through Improvement of Related Facilities***" for the Project. Thus, the improvement plan of each facility should be worked out keeping this concept in mind.

IIB-2.2 Need of Improvement

The Roleang Chrey Regulator and the Andong Sla Intake and its approach channel for North Main Canal, were constructed in 1974, aiming to irrigate 35,000 ha on the left riparian area of the Prek Thnot River. Presently, these facilities are severely deteriorated and do not function well. All gates of Roleang Chrey Regulator could not be easily closed if being opened one time. Effective water control of the Prek Thnot River is not thus expected at all. The riverbed protection just after downstream apron and the side slope protection at downstream site are severely eroded away.

The Andong Sla Intake has four steel radial gates, but two gates are totally damaged and left closed. The remaining two gates function with difficulty due to much leakage. The hoisting wire ropes are damaged and temporally repaired using steel wires. Electric driven system is totally damaged.

The Vat Krouch Intake was constructed in 2002 as an intake facility for the South Main Canal. One radial gate equipped is currently in working condition although wire ropes are damaged and temporally repaired. This radial gate makes the much head loss to abstract design discharge of 16.3m^3/sec from the river, which would bring about the difficulty in introduction of gravity irrigation system.

The current conditions of the Roleang Chrey Regulator, Andong Sla Intake and Vat Krouch Intake, are so serious as mentioned above, and if leaving they are, it is sure that water supply to each command area would be difficult, or rather impossible, and then the strategic target for the Master Plan, improvement of agricultural productivity centering on rice, could not be materialized by 2015. To ensure the stable water supply and also to achieve the said strategic target, improvement of them is urgently needed.

IIB-2.3 Basic Concept of Improvement

(1) Roleang Chrey Regulator

In preparing the improvement plan of Roleang Chrey Regulator, the following points are taken into account:

- Maximum Use of Existing Facility

As the result of site inspection and topographic survey, some existing facilities such as gate leafs, guide frame, operation deck, piers, retaining walls, apron and bridges are still in working condition. These facilities shall be used without any improvement in the Project, to save cost.

- Easy Maintenance

In the review of current condition of existing facilities, it was found that lack of proper maintenance was one of major reasons why these functioned well. The improvement plan shall be therefore prepared paying attention upon the easy maintenance.

- Easy Operation

Irrigation water requirement varies time to time. The gate operation on intake shall be so made as to satisfy this requirement, aiming at effective water use although it should be simplified to some extent. This operation should be conducted by combination of regulator gates with intake gates. Introduction of remote control is one of effective ways since new generator of 75kVA was recently installed.

- Ensuring of Safety for Regulator

Structural stability is an important issue for regulator which is a linchpin of water utilization, because the Prek Thnot River has frequent flood in the rainy season. Thus, excess hydraulic energy by floods should be dissipated within the firm structure.

- Smooth Release of Required Discharge to Downstream Area

There are some irrigation projects such as Kandal Stung Irrigation Project and Tonle Bati Irrigation Project, located downstream from the Roleang Chrey Regulator. It is necessary to release the required discharge to these projects as well as river maintenance. Since the present fixed wheel gates are so large to control such discharge, an appropriate measure should be taken into consideration.

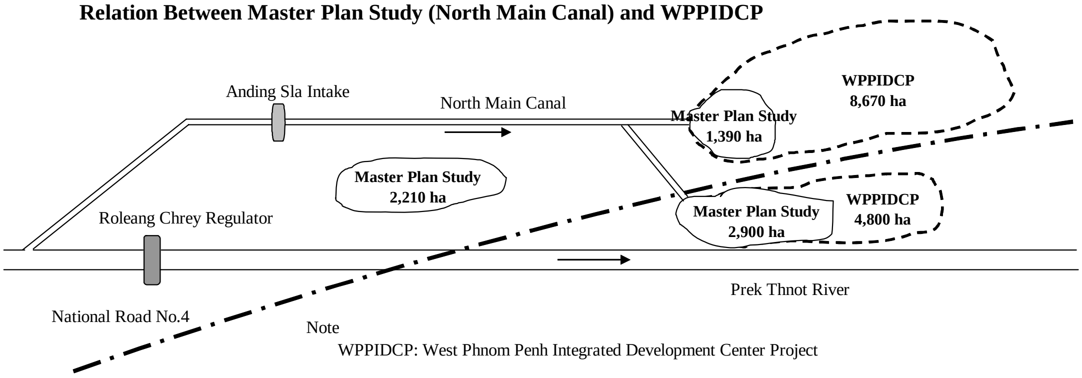
(2) Andong Sla Intake

In preparing the improvement plan of Andong Sla Intake and its approach channel, the following points are taken into account:

- On-going Command Area Development Plan

As mentioned previously, the Andong Sla Intake and its approach channel were constructed in 1974 under the Prek Thnot Multipurpose Dam Project, aiming to irrigate 35,000 ha. The constructed Andong Sla Intake was equipped with four radial gates (4 m wide and 2.2 m high each) and has large flow capacity. But, this project was discontinued due to the political change. In 2001, the government has started the Western Phnom Penh Integrated Development Center Project (WPPIDCP) at own budget. Under this project, the North Main Canal after Andong Sla Intake has been constructed aiming to irrigate 13,470 ha of downstream area, provided that new water resource would be developed. At present, implementation of this project has progressed, but so slow. In the Master Plan Study in 2005, the command area of the North Main Canal was re-studied through the water balance calculation, and is estimated at 6,500 ha only using the available discharge of the Prek Thnot River, which is a precondition of the Study. The relation between the Master Plan Study and the WPPIDCP in command area is figured as follows:

Relation Between Master Plan Study (North Main Canal) and WPPIDCP



Note
WPPIDCP: West Phnom Penh Integrated Development Center Project

As the government has a strong intension of implementing the WPPIDCP, it should be reflected upon the improvement plan of Andong Sla Intake and its approach channel.

- Less Hydraulic Impact to Downstream Portion

The upstream and downstream portions of the Andong Sla Intake have the large canal section, say about 50 m wide, as compared with the design discharge of 10.4 m3/sec. If at the Andong Sla Intake, the flow section is drastically reduced, head loss would be larger and also impact to the downstream portion would be larger which would cause the severe erosion at side slope and bottom of canal. To prevent such erosion, firm protection work would be required. In the improvement of Andong Sla Intake, consideration should be given to such hydraulic phenomenon.

- Selection of Appropriate Gate Type

The intake gate is required to be frequently operated based on water demand which fluctuates time to time. In this sense, the applied gate should be reliable and easily operative. In particular, the Andong Sla Intake has a function of check gate for the South Main Canal from its location. This function requires the high reliability and easy operation.

- Backwater Effect by Flood

Flood is controlled by Roleang Chrey Regulator by observing the upstream water level and river discharge at Peam Khley. Even this control, backwater occurs at flood time. This backwater effect should be considered for determination of gate height in connection with gate type selection.

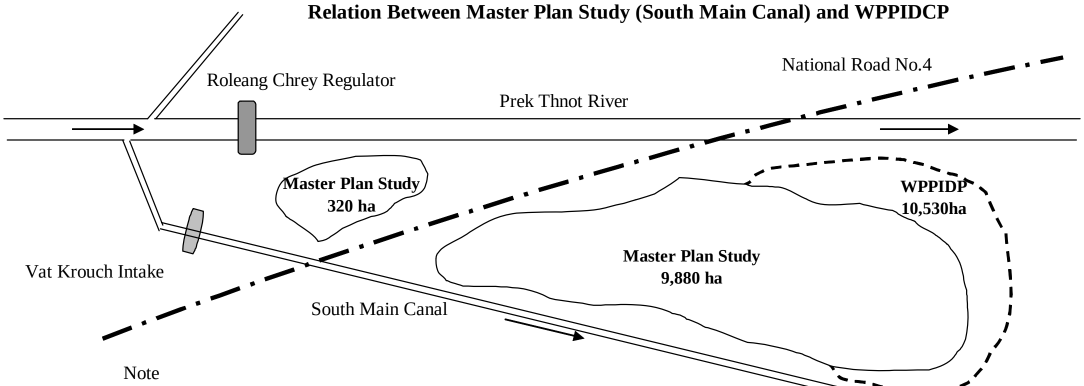
(3) Vat Krouch Intake

In preparing the improvement plan of Vat Kruoch Intake and its approach channel, the following points are taken into consideration:

- On-going Command Area Development Plan

The Vat Kruoch Intake was constructed for supplying water to the South Main Canal in 2002. The South Main Canal was partly constructed in the Pol Pot's regime, and is subsequently constructed under the WPPIDCP mentioned above, aiming at water supply to 10,530 ha. In the Master Plan Study, irrigable area of the South Main Canal was estimated at 10,200 ha in the same manner with that of the North Main canal. The irrigable areas are almost same, but 320 ha out of 10,200 estimated in the Master Plan Study is located outside from 10,530 ha aimed in the WPPIDCP. The relation between the Master Plan Study and the WPPIDCP in command area is illustrated as follows:

Relation Between Master Plan Study (South Main Canal) and WPPIDCP



Note
WPPIDCP: West Phnom Penh Integrated Development Center Project

The government will implement the South Main Canal System as well as the North Main Canal System, the improvement plan for the Vat Krouch Intake and its approach channel should be prepared paying attention on this WPPIDCP.

- Application of Appropriate Gate Type

The Vat Krouch Intake Gate as well as the Andong Sla Intake, required to be frequently operated based on water demand from irrigation which fluctuates time to time. In this sense, the applied gate should be reliable and easily operative.

- Backwater Effect by Flood

The backwater effect by flood should be considered for determination of gate dimension in relation to the selection of gate type.

IIB-2.4 Design Condition

IIB-2.4.1 Flood Discharge

According to the flood analysis, the flood peak discharge of the Prek Thnot River at Roleang Chrey Regulator in the past 38 years is at 1,369m3/sec. This means that the probable flood peak discharge of the Prek Thnot River would be around 1,400m3/sec for the exceedence probability of about 40 years. On the other hand, the non-uniform calculation shows that the discharge carrying capacity of the Prek Thnot River in the upstream reach would be between 1300 m3/s and 1500 m3/s. From these study results, it is concluded that the probable flood peak discharge as the design discharge of the Roleang Chrey Regulator for its improvement would be between 1300 m3/s and 1500 m3/s, or between 1400 m3/s and 1600 m3/s from a conservative view point. Following this conclusion, it is proposed to apply the design flood discharge of 1,600m3/sec for improvement of Roleang Chrey Regulator.

IIB-2.4.2 Other Design Conditions

(1) Andong Sla Intake

The design discharge for improvement of Andong Sla Intake and its approach channel is 10.4m^3/sec to irrigate the command area of 6,500 ha, which was determined through a water balance calculation without consideration of new water resource development. On the other hand, the government has another development plan at downstream area of 13,470 ha, although 4,290 ha are overlapped with the said command area. The required discharge becomes to 25.1 m^3/sec (= 1.60 lit/sec/ha x 15,680 ha/1000).

(2) Vat Krouch Intake

According to the Master Plan Study, the required discharge for the South Main Canal is 16.3 m^3/sec, but it becomes 17.4 m^3/sec (=1.60 lit/sec/ha x 10,850 ha/1,000). Since the difference is only1.1 m^3/sec, such increased discharge does not much influence to the determination of gate size or cost. Furthermore, backwater from Roleang Chrey Regulator at flood time should be one of factors to determine the gate height. From these study results and taking into account the difficulty in frequent improvement, it is proposed that gate capacity should be determined using the discharge of 17.4 m^3/sec.

IIB-2.5 Design of Improvement Works

IIB-2.5.1 Roleang Chrey Regulator

(1) Civil Works

As mentioned in Sub-clause IIB-1.2.1, the Roleang Chrey Regulator except downstream side slope protection, are presently in stable condition although small-scale scouring is observed at immediately after downstream apron. To keep or rather heighten such stable condition and to ensure the reliable release to downstream reach, it is proposed to conduct the following works:

(a) Provision of Downstream Apron

The Roleang Chrey Regulator was designed and constructed subject to construction of the Prek Thnot Multipurpose Dam upstream. This means that the Roleang Chrey Regulator was designed only considering the flood from the area out of catchments area of the dam. In fact, the hydraulic calculation for the existing length of downstream apron shows that it could stand only against about 300 m^3/sec flood. It is deemed that the reason that the Roleang Chrey Regulator is still stable is to construct it on the firm foundation. Anyhow, the regulator was structurally and hydraulically examined using the design flood of 1,600 m^3/sec. As a result, the downstream apron with baffle block and end sill should be provided additionally. Its required length is 23.48 m. Besides, backfill concrete for excavated portion and riprap will be provided to protect the river bed from the scouring.

The USBR III type dissipater to dissipate the hydraulic energy within downstream apron is selected due to inflow velocity and Fruede number given by hydraulic calculation.

The discharge of the gate is given by following formula, and the hydraulic calculation for downstream apron is made by Bernoulli formula.

$Q = C \cdot B \cdot d \, (2g(h1 - d/2))^{0.5}$

Where, C = flow index = 0.65
B = width of gate (m)
d = gate opening in meter
h1 = water depth at upstream (m).

The hydraulic calculations for gate and downstream apron are shown in Attachment IIB-1.

The depth of hydraulic jump of 6.93m is resulted by this calculation. The water level at this water depth is lower than a flood water level of EL.36.515m at downstream of Roleang Chrey Regulator resulted by non-uniform calculation for Prek Thnot River using a flood discharge of 1600m3/sec.

The bottom elevation of downstream apron is provided at EL.26.00 based on the topographic survey that shows the existing river bed elevation is from EL.26.00 to EL.27.00.

The main features of downstream apron are as follows, and the general plan of rehabilitation for Roleang Chrey Regulator is shown in Drawings.

- Length = 23.48m
- Bottom elevation = EL.26.00m
- Baffle block Height = 2.25m
  Width = 1.70m
  Space = 1.70m
  Slope = 1:1.00
- End sill Height = 2.50m
  Slope = 1:1.50

(b) Provision of Retaining Wall

In connection with provision of additional downstream apron, the retaining wall of inverted T-shape type is provided for 23.48 m in length. Its required height ranges from 11 m to 12 m. In addition, embankment supported by this retaining wall is covered with riprap. The stability and structural calculation of the retaining wall is shown in Attachment IIB-2.

(c) Construction of By-pass

To ensure the release of small discharge for the downstream reach, it is proposed to construct a by-pass, which was selected as a suitable method from technical and economical viewpoints in the Master Plan Study. The capacity of by-pass is 10 m^3/sec. The by-pass consists of inlet, pipe conduit and stilling basin. The inlet is equipped with two slide gates of four sealing edges. The pipe conduit has two pipes of 1.0 m diameter and its length is 92.42 m. The pipe will be lined by reinforced concrete. The stilling basin is of box type with end sill, and is provided with the broad-crest weir for discharge measurement.

The hydraulic calculation for the gate of By-pass inlet and Pipe conduit, the structural calculation for conduit and inlet structure is shown in Attachment IIB-1, Attachment IIB-2, respectively. The design drawings are shown in Drawings.

(2) Hydro-mechanical works

In consideration of the present conditions of gates and accessories as explained in Sub-clause IIB-1.1.1, the required improvement works are composed of four items; closing of sluiceway, improvement of gate leaves, replacement of hoists and improvement of operation system.

(a) Repair of Gates

There are three major works for repair of gates:

- Repair of Wheels

To improve wheel resistance, the bearing metals shall be replaced by oilless bearings and wheel shafts by corrosion resisting steel shafts. A grease supply hole with nipple shall be equipped for the shaft for easy maintenance.

- Painting

Gate leaves shall be painted after cleaning by sand blasting.

- Repair of Seal Rubber

Rubber seals shall be removed and replaced with new ones.

- Renewal of Hoist

Whole hoisting equipment shall be replaced with newly designed ones.

- Control System

For the convenience and easiness of the gate operation, it is proposed to employ the remote control system at operator house, in addition to the local operation. The operation system for Roleandg Chrey Regulator, Andong Sla Intake and Vat Krouch Intake is shown by Figure IIB-2.5.1.

IIB-2.5.2 Andong Sla Intake

(1) Civil Works

(a) Improvement plan of gate

Taking into consideration as mentioned in Sub-clause IIB-2.4.2, it is proposed to apply the following improvement plan:

- To design the four gate portions.
- Out of them, to install two gates to ensure the discharge of 10.4 m3/sec in this study.
- To provide a concrete wall for remaining two portions, so as to enable to install a gate each in the future.

The width of gate is 4.0m as same with existing gate. The gate height of 4.8m is applied taking into account of maximum flood water level of EL.36.48m at Andon Sla Intake in the past.

- Height of gate =Flood water level of EL.36.48m - Design bed elevation of EL.32.00m + free board of 0.30m = 4.80m

(b) Retaining Wall

The retaining wall will be provided at left and right banks. The retaining wall will be of L-shaped reinforced concrete type.

(c) Gate Piers

Three gate piers are designed to install the fixed wheel gate and also to function as abutment of bridge. The gate pier is made of reinforced concrete, and its dimensions are 10.2 m long, 5.4 m high and 1.2 m thick. The height of abutment is determined taking into account the clearance of 1.0m between maximum water level of El.35.60 and bridge.

(d) Downstream Apron

The reinforced-concrete-made downstream apron will be constructed. The apron is provided with baffle block and end sill as USBR III type due to hydraulic calculation to dissipate the hydraulic energy within the apron. After the apron, concrete protection slab and gabion mattress will be provided to avoid scouring by sudden change of roughness coefficient. The hydraulic calculation for downstream apron is shown in Attachment IIB-1.

(e) Concrete Bridge

The reinforced concrete bridge with T-shape girder will be provided. The effective width is 4.0 m. This bridge consists of two spans with span length of 10.24m.

(f) Approach Channel

Since the approach channel has a flow capacity of about 70 m3/sec according to the hydraulic calculation, which is larger than not only the design discharge of 10.4 m3/sec, but also the future water demand of 25.1 m3/sec, any expansion is not required. In addition, no erosion is found at the side slope of channel, so that rehabilitation is not required.

The design drawings for Andong Sla Intake are shown in Drawings.

(2) Hydro-mechanical works

(a) Gate Type Selection

Three gate types are considered; radial gate, fixed wheel gate and slide gate. These gate types are compared from technical and economical viewpoints as shown below:

Comparison of Three Gate Types

Item	Radial Gate		Fixed Wheel Gate		Slide Gate	
	Characteristics	Judge	Characteristics	Judge	Characteristics	Judge
Downstream water level	Influence	△	No influence	◎	No influence	◎
Operation	Easy	◎	Easy	◎	So difficult	△
Maintenance	Slightly difficult	○	Slightly difficult	○	Easy	◎
Pier height	Low	◎	High	△	High	△
Cost	High	○	High	○	Low	◎
Hoisting load	Light	◎	Moderate	○	Large	△
Vibration	Occurrence	○	No	◎	No	◎
Reliability	Low	△	High	◎	High	◎
Height/width ratio	Influence	△	No influence	◎	No influence	◎

As can be seen in the above table, the fixed wheel type is the most suitable one judging from overall viewpoints. In particular, the fixed wheel type is superior to others on easy operation and reliability which are important factors for the Project management. Thus, the fixed wheel type is selected as intake gate.

(b) Design of Intake Gate

The design of intake gate is shown in Drawings. The general information of designed fixed wheel gate is given below:

General Information on Intake Gate for Andong Sla

Item	General Information
Type	Vertical lift fixed wheel gate
Quantity	Guide frame: 4
	Gate leaf and hoist: 2
	Guide frame for stoplog: 4
	Stoplog leaf: 1
Clear span	4.00 m
Height	4.80 m
Design head	4.50m
Hoist	Electric driven wire rope winding hoist, one motor two drum
Control system	Local and remote control from Roleang Chrey Regulator

IIB-2.5.3 Vat Krouch Intake

(1) Civil Works

(a) Gate size

The required gate is 2 nos. and its size is 5.0 m high and 4.0 m wide. The height of 5.0m is applied taking into account of maximum flood water level of EL.36.93m at Vat Krouch Intake in the past.

- Height of gate =Flood water level of EL.36.93m - Design bed elevation of EL.32.21m + free board of 0.30m = 5.00m

(b) Upstream and Downstream Transitions

To smoothly connect the gated box culvert with upstream and downstream canal with trapezoidal section, the reinforced concrete transition is provided at the both side slopes of canals. The canal bed at transition is protected with gabion mattress.

(c) Gate Pier and Box Culvert

Gate pier combined with box culvert is proposed to save construction cost. The employed gate pier is 5.3 m high and 1.3 m wide, and box culvert is of double box type with 4.6 m high and 4.0 m wide each. This dimension of box culvert is determined using the discharge of 17.4 m3/sec, in connection with gate capacity. The width of top slab of box culvert is also determined with consideration that it is used as Bridge. On the bottom slab of box culvert, baffle block and end sill are provided to dissipate the hydraulic energy. The height of box culvert is determined taking into account the clearance of 1.0m between maximum water level of El.35.60 and top slab of box culvert.

The hydraulic calculation for Vat Krouch Intake is shown in Attachment IIB-1.

(d) Protection of Upstream and Downstream Canal Beds

Gabion mattress is provided on the canal bed before and after the transition, to protect the canal bed from scouring.

(e) Rehabilitation of Approach Channel

The present flow capacity of approach channel is only 13.6 m3/sec, and is too small to flow the design discharge of 16.3 m3/sec. Thus, the existing section needs to be enlarged. Sod-facing is proposed to mitigate erosion at side slope of channel.

(2) Hydro-mechanical works

(a) Gate Type

The Vat Krouch Intake is also provided with the fixed wheel type similarly to that for the Andong Sla Intake.

(b) Design of Intake Gate

The design of intake gate is shown in Drawings. The general information of designed fixed wheel gate is given below:

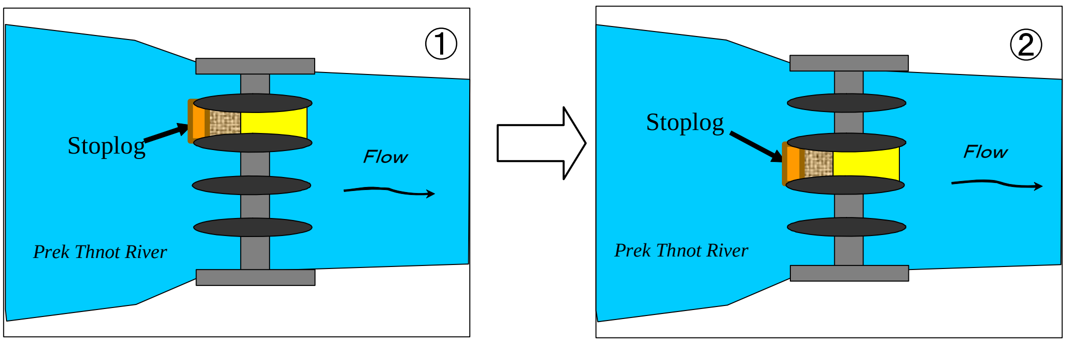
General Information on Intake Gate for Vat Krouch

Item	General Information
Type	Vertical lift fixed wheel gate
Quantity	Gate and hoist: 2
	Guide frame for stoplog; 2
	Stoplog leaf: 1
Clear span	4.00 m
Height	5.00 m
Design head	4.72 m
Hoist	Electric driven wire rope winding hoist, one motor two drum
Control system	Local and remote control from Roleaing Chrey Regulator

IIB-2.6 Construction Method

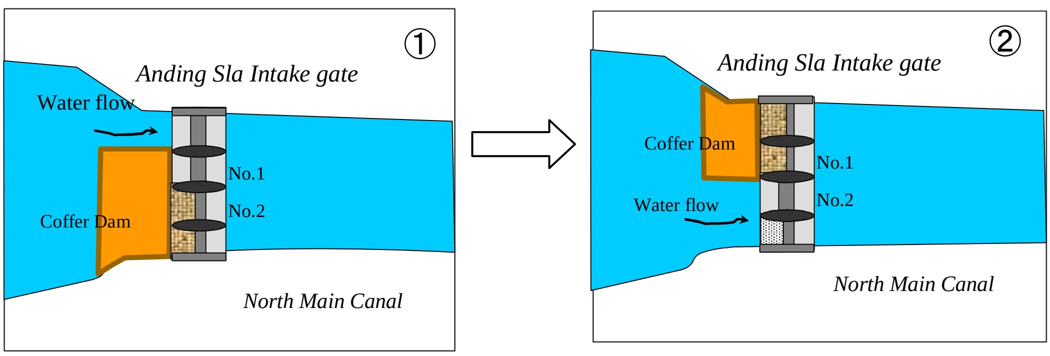
(1) Roleang Cherey Regulator

While the improvement works of the gate leaf, the gate leaf shall be raised up to top hoisting level. Since the reservoir water level shall not be lowered during construction, the sluiceway of said gate shall be fully closed. Two measures are considered for closing the sluiceway; construction of coffer dam and use of a stoplog (floating gate type). After comparison of these measures mainly from technical viewpoint such as easiness of work and risk in rainy season, it is proposed to apply the stoplog for closing the sluiceway. This method has another advantage which the stoplog will be used for the maintenance in future. The closing of sluiceway by stoplog is illustrated as follows:



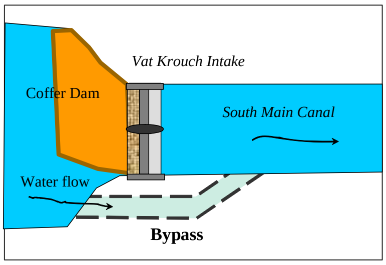
(2) Andong Sla Intake

Taking into consideration the width of existing canal and use of canal water during construction time, the following partially closing diversion method is proposed.



(3) Vat Krouch Intake

Since the canal width is not enough to apply the partially closing diversion method, a by-pass will be constructed so as no to interfere the agricultural activities during construction time as shown in the right figure.

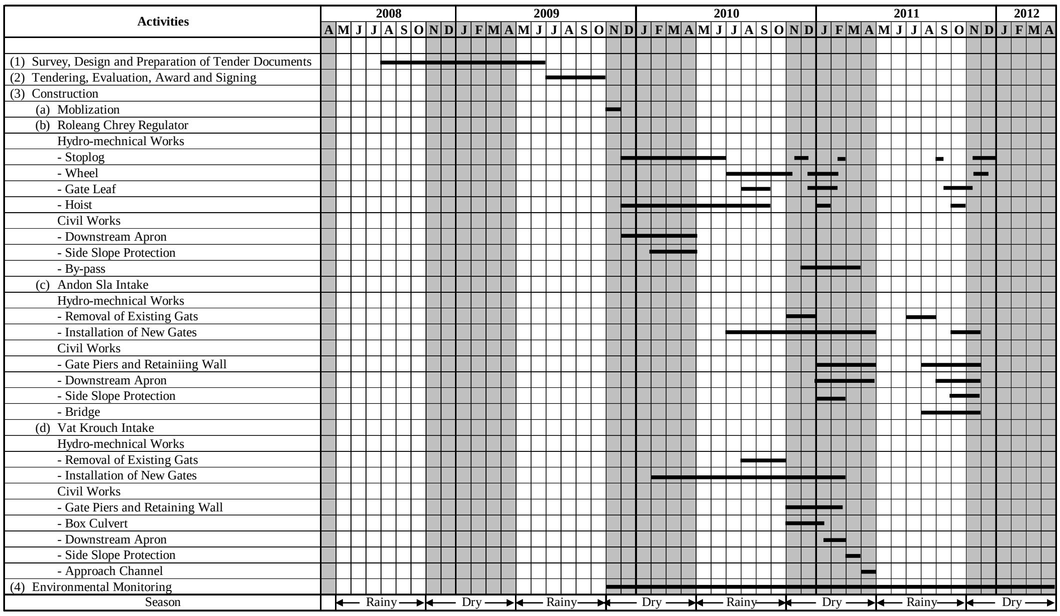


Chapter IIB-3 Implementation Plan

IIB-3.1 Implementation Schedule

The implementation schedule for the Project works is shown below:

Implementation Schedule of Project Works



The Project works are divided into four parts; (a) survey and design works including preparation of tender documents, (b) tendering work, (c) construction work, and (d) environmental monitoring work.

The survey and design work will be carried out on the contract basis and would require about 11 months from August 2007. Immediately after completion of design work, tendering work would be started and about 4 months would be needed by the contract signing with the successful tenderer.

In succession, the construction work would be started. The construction work consists of mobilization, Roleang Chrey Regulator, Andong Sla Intake and Vat Krouch Intake and its approach channel. The mobilization is planned to be one month taking into consideration the scale of construction work. The construction work for Roleang Chrey Regulator would require 25 months from December 2008 to December 2010. In the construction work for Roleang Chrey Regulator, the critical path is to arrange the stoplog. The civil work such as construction of downstream apron, rehabilitation of side slope protection and by-pass would be carried out in the 1st and 2nd dry seasons.

The construction work for the Andong Sla Intake would start in July 2009 and completed in November 2010. The critical path in the construction work for the Andong Sla Intake would be the procurement and installation of 5 new gates. The civil work such as construction of gate piers, retaining wall, downstream apron, side slope protection and bridge would be completed for 11 months from January 2010 to November 2010.

The construction work for the Vat Krouch Intake and its approach channel would be commenced in February 2009 and completed by April 2010. The civil work such as construction of gate piers, retaining wall, box culvert, downstream apron, side slope protection and rehabilitation of approach channel, would be completed in one dry season from November 2009 to April 2010.

Prior to commencement of construction work, say November 2008, the environmental monitoring would be conducted by MOWRAM until April 2011, to examine the environmental impact by construction work.

IIB-3.2 Executing Agency for Project Implementation

MOWRAM is an overall executing agency for implementation of the Project.

Since the components of the Project are only the engineering works such as improvement of the Roleang Chrey Regulator, Andong Sla Intake and Vat Krouch Intake and their approach channels, the relevant departments of MOWRAM under the Secretary of State of MOWRAM, will be directly in-charge of respective stages of the Project.

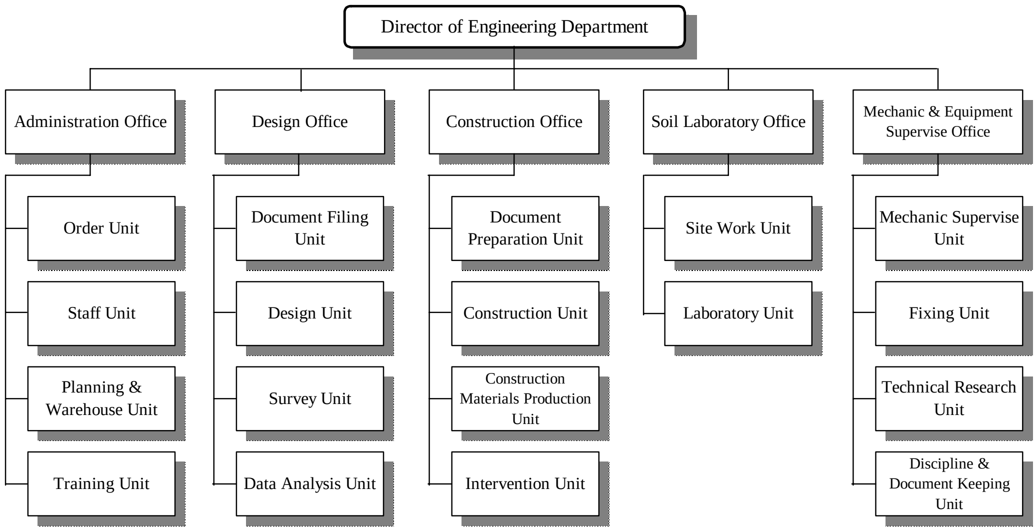
IIB-3.3 Organization and Staff Required

There are three stages for the project implementation; design stage, construction stage and O&M stage. Out of them, the Engineering Department will be responsible for design and construction stages and the Department of Irrigated Agriculture for O&M stage.

(1) Design and Constriction Stages

The present structure of the Engineering Department is as follows:

Present Structure of Engineering Department



The Design Office will be responsible for the design works for the Project. The required design works do not need the high sophisticated technology; it is deemed that the present staff of Design Office could fulfill them. However, it is proposed that the design works will be conducted on the contract basis, to complete them urgently.

The Construction Office will be responsible for construction work for the Project. The construction works will be conducted on the contract basis, so that the mission of the Construction Office will be to supervise the contractor. The Project Site is about 25 km away from the Engineering Department. It is thus proposed to establish a Construction Office at the Kampong Speu PDOWRAM. The required staff for construction supervision should be assigned from not only the Engineering Department, but also the Kampong Speu PDOWRAM.

(2) O&M Stage

The Department of Irrigated Agriculture is responsible for O&M for the Project facilities. Currently, O&M works for the Project facilities are carried out by the Kampong Speu PDOWRAM under support from the Department of Irrigated Agriculture. This system is acceptable. However, Kampong Spue PDOWRAM should be so strengthened as to realize the proper O&M for the Project facilities, which is not presently made.

The Kampong Spue PDOWRAM has five offices under the director, such as administration, water management, agricultural hydrology, water sanitation and meteorology, and there is no office for O&M for the Project facilities. Taking it into consideration that the Project facilities are the key structures for irrigating the command area of 16,700 ha, one office for O&M for Rolenang Chrey Regulator and two Intakes should be established additionally. At least, one mechanical engineer and one electrician should be assigned for this office.

Chapter IIB-4 Cost Estimate

IIB-4.1 Condition of Cost Estimate

The basic conditions and assumptions employed for cost estimation of the Project are as follows.

- Cost estimate refers to the prices as of January 2007.
- Unit prices of labor, construction materials, engineering works, etc., were collected from MOWRAM and market.
- Construction is undertaken on the contract basis.
- The Investment Cost consists of i) engineering service cost, ii) direct construction cost, iii) administration cost, iv) environmental monitoring cost, and v) physical and price contingencies.
- Administration cost during construction time is assumed to be 10% of direct construction cost.
- The physical contingency is assumed to be 10% of the investment cost.
- Price escalation is evaluated based upon 4.5% per annum for foreign currency portion and 7.0% per annum for local currency portion.
- Conversion rate is assumed at US$ 1.0 = Riel 4,060 (as of January 2007)

Labor wage, rental charge of equipment, unit price of construction materials and unit price of steel slide gate, which are used for cost estimate of the Project, is as shown in Table IIB-4.1.1, 4.1.2, 4.1.3 and 4.1.4.

IIB-4.2 Investment Cost

The investment cost consists of i) engineering service cost, ii) direct construction cost, iii) administration cost, iv) environmental monitoring cost, and v) physical and price contingencies. The total amount of investment cost is estimated at US$ 4,991,000 equivalent to Riel 20,263,460. The summary of the investment cost is given below, and its detail is shown in Table IIB-4.2.1.

Summary of Investment Cost

(unit:'000)

Item	US$	Riel (equivalent)
(1) Engineer Services	652	2,647,120
(2) Direct Construction Cost	2,943	11,948,580
(3) Administration Cost	294	1,193,640
(4) Environmental Monitoring	3	12,180
Total	3,892	15,801,520
(5) Physical Contingency	389	1,579,340
(6) Price Contingency	710	2,882,600
Total	4,991	20,263,460

Table IIB-4.2.2 shows the annual disbursement schedule for the investment cost which was prepared based on the implementation schedule of project works.

The break down of engineering service cost is as shown in Table IIB-4.2.3.

IIB-4.2.1 Hydro-mechanical Works

The cost for hydro-mechanical works out of direct construction cost is estimated at US$ 1,993,000 equivalent to Riel 8,091,580,000. The summary of hydro-mechanical works is as follows, and its detail is shown in Table IIB-4.2.4.

Summary of cost of Hydro-mechanical works

(unit:'000)

Item	US$	Riel (equivalent)
(1) Roleang Chrey Regulator	1,389	5,639,340
(2) Inlet at Roleang Chrey Regulator	12	48,720
(3) Andong Sla Intake	294	1,193,640
(4) Vat Krouch Intake	298	1,209,880
Total	1,993	8,091,580

IIB-4.2.2 Civil Works

The cost for civil works out of direct construction cost is estimated at US$ 950,000 equivalent to Riel 3,857,000,000. The summary of cost of civil works is as follows.

Summary of cost of Hydro-mechanical works

(unit:'000)

Item	US$	Riel (equivalent)
(1) Roleang Chrey Regulator	488	1,981,280
(2) Inlet at Roleang Chrey Regulator	101	410,060
(3) Andong Sla Intake	188	763,280
(4) Vat Krouch Intake	101	410,060
(5) Approach channel of south main canal	72	292,320
Total	950	3,857,000

IIB-4.3 Administration Cost

The administration cost, which is 10% of the direct construction cost, is estimated at US$ 199,000 equivalent to Riel 1,194,188,000.

IIB-4.4 Replacement Cost

The following replacement cost occurs during the Project life of 50 years:

Summary of Replacement Cost

(unit:'000)

Item	Replacement Year	US$	Riel (equivalent)
(1) Roleang Chrey Regulator			
- Gate Leaves	25th year	428.4	1,739,304
- Accessories	25th year	752.4	3,054,744
(2) Andong Sla Intake			
- Accessories	25th year	85.5	347,130
(3) Vat Krouch Intake			
- Accessories	25th year	107.9	438,074

The details of replacement cost are given in Table IIB-4.4.1.

Generally, the gate leaves would have life years of 60 years if maintenance work is properly conducted. As for the gate leaves of Roleang Chrey Regulator, 32 years have already passed since 1974 when Roleang Chrey Regulator was constructed. The remaining life year of gate leaves was therefore estimated at 25 years from conservative viewpoint considering the past maintenance condition.

IIB-4.5 O&M Cost

The annual O&M cost for the Project which consists of 3 categories of Hydro-mechanical works, Civil works and Daily inspection is estimated at US$ 9,300 equivalent to Riel 37,758,000, of which details are as shown in Table IIB-4.5.1.

IIB-4.5.1 Hydro-mechanical Works

The annual O&M cost for Hydro-mechanical works is estimated at US$ 6,448 equivalent to Riel 26,178,880. Its detail is as shown in Table IIB-4.5.1.

IIB-4.5.2 Civil Works

The annual cost for civil works is estimated at US$ 1,806 equivalent to Riel 7,332,360. The details are as shown in Table IIB-4.5.2.

Tables

Table IIB-4.1.1 Labor Wage

(Unit : US$)

Description	Unit	Wage	Remarks
Common Labor	Man / day	2.5	8hour/day
Skilled Labor	Man / day	6.0	- ditto -
Foreman	Man / day	15.0	- ditto -
Operator, Heavy Equipment	Man / day	10.0	- ditto -
Assistant Operator, Heavy Equipment	Man / day	8.0	- ditto -
Operator, Light Equipment	Man / day	8.0	- ditto -
Assistant Operator, Light Equipment	Man / day	7.0	- ditto -
Driver, Dump Track	Man / day	8.0	- ditto -
Driver, Others	Man / day	7.0	- ditto -
Mechanic, Repair	Man / day	12.0	- ditto -
Assistant Mechanic, Repair	Man / day	10.0	- ditto -
Welder	Man / day	15.0	- ditto -
Electrician	Man / day	12.0	- ditto -
Carpenter	Man / day	10.0	- ditto -
Mason, Skilled	Man / day	10.0	- ditto -
Mason, common	Man / day	8.0	- ditto -
Plasterer	Man / day	8.0	- ditto -
Concrete Worker	Man / day	4.0	- ditto -
Steel Worker	Man / day	5.0	- ditto -

Table IIB-4.1.2 Rental Charge of Construction Equipment

(Unit : US$)

Description	Unit	Charge
Bulldozer (3ton)	nos. /month	2,000
Bulldozer (7ton)	nos. /month	2,500
Bulldozer (11ton)	nos. /month	3,000
Bulldozer (15ton)	nos. /month	3,500
Back Hoe ($0.4m^3$)	nos. /month	2,500
Back Hoe ($0.7m^3$)	nos. /month	3,000
Tractor Shovel (Wheel Type, $1.7m^3$)	nos. /month	3,500
Dump Track (6ton)	nos. /month	1,500
Dump Track (11ton)	nos. /month	2,000
Truck (4ton)	nos. /month	1,500
Truck (11ton)	nos. /month	2,000
Truck Crane (4.8 ton)	nos. /month	2,000
Truck Crane (10 ton)	nos. /month	2,500
Truck Crane (15 ton)	nos. /month	3,500
Vibration Hammer (40kw)	nos. /month	2,500
Pick hammer ($1.2m^3$/min)	nos. /month	200
Concrete Breaker (20kg)	nos. /month	300
Motor Grader (3.1m)	nos. /month	4,000
Vibration Roller (6.0 ton)	nos. /month	2,500
Vibration Roller (2.5 ton)	nos. /month	1,000
Concrete Plant ($30m^3$/h)	nos. /month	1,200
Truck Mixer ($3.0m^3$)	nos. /month	3,000
Truck Mixer ($4.5m^3$)	nos. /month	3,500
Water Tank Truck (6kl)	nos. /month	1,700
Air Compressor ($3.5m^3$)	nos. /month	1,500
Air Compressor ($10.5m^3$)	nos. /month	2,000
Submersible Pump (100mm)	nos. /month	150

Description	Unit	Charge
Generator Set (35 kV)	set / month	8,000
Generator Set (75 kV)	set / month	10,500
Generator Set (125 kV)	set / month	14,000
Generator Set (200 kV)	set / month	25,000
Generator Set (300 kV)	set / month	30,000
Concrete Mixer ($0.2m^3$)	nos. / month	600

Table IIB-4.1.3 Unit Price of Construction Material

(Unit : US$)

Description	Unit	Unit Price
Cement	ton	70.0
Cement Admixture	kg	1.3
Fine Aggregate	m^3	15.0
Coarse Aggregate	m^3	14.0
Crushed Stone (50-100mm)	m^3	13.0
Crushed Stone (100-200mm)	m^3	12.0
Crushed Stone (300-500mm)	m^3	11.0
Sand	m^3	8.0
Gravel	m^3	22.0
Round Bar	ton	500.0
Deformed Bar	ton	490.0
L-Shape Steel	ton	800.0
I-Shape Steel	ton	900.0
H-Shape Steel	ton	900.0
Steel Plate (t=3.2 - 4.5mm)	ton	900.0
Checkered plate	ton	900.0
Galvanized steel plate (t=4mm)	m^2	50.0
Band Wire (#16)	kg	0.7
Barbed Wire (#14)	kg	0.75
Nail	kg	0.7
Steel sheet pile	ton	830.0
Timber , Plank (high quality)	m^3	500.0
Timber , Plank (low quality)	m^3	350.0
Timber , Square (high quality)	m^3	500.0
Timber , Square (low quality)	m^3	350.0
Plywood (t=4mm)	m^2	2.5
Plywood (t=6mm)	m^2	3.5
Plywood (t=12mm)	m^2	5.0
Form oil	Liter	1.2
Concrete Pipe (φ=1,500mm)	m	120.0
Concrete Pipe (φ=1,300mm)	m	100.0
Concrete Pipe (φ=1,000mm)	m	62.0
Concrete Pipe (φ=600mm)	m	24.0
Concrete Pipe (φ=500mm)	m	20.0
Galvanized steel pipe (φ=200mm)	m	25.0
Galvanized steel pipe (φ=100mm)	m	5.0
Galvanized steel pipe (φ=75mm)	m	3.0
Galvanized steel pipe (φ=50mm)	m	1.8
PVC Pipe (φ=75mm)	m	2.7
PVC Pipe (φ=50mm)	m	1.1
Description	Unit	Unit Price
PVC Water Stop (w=150mm)	m	9.0
PVC Water Stop (w=300mm)	m	11.0
Gasoline	Liter	0.92
Light oil	Liter	3.0
Heavy oil	Liter	3.0
Engine oil	Liter	3.0
Gabion (0.5 x 1.2 x 2.0m)	nos.	28.0
Sand Bug (0.6 x 0.9m)	nos.	0.4
Plastic Sheet (t=0.4mm)	m^2	0.4
Jute Bag (for concrete curing)	m^2	0.5
Turf (Sod)	m^2	2.0

Table IIB-4.1.4 Unit Price of Steel Slide Gate

(Unit : US$)

Description	Dimension	Unit	Unit Price
Steel slide gate	2.0 x 3.0	nos.	7,200
	1.0 x 2.6	nos.	4,500
	1.0 x 1.85	nos.	3,600
	1.0 x 1.0	nos.	3,000
	0.6 x 1.2	nos.	2,490
	0.6 x 0.6	nos.	1,605
	0.5 x 1.0	nos.	2,265
	0.5 x 0.6	nos.	1,175
	0.4 x 0.5	nos.	925
	0.3 x 0.4	nos.	725

Table IIB-4.2.1 Investment Cost

(Unit : '000)

Item		Roleang Chrey	
		US$	Riel
(1)	Engineering service cost	652	2,647,120
(2)	Direct construction Cost		
	Roleang Chrey Regulator	1,877	7,620,620
	Inlet at Roleang Chrey Regulator	113	458,780
	Andong Sla Intake	482	1,956,920
	Vat krouch Intake	399	1,619,940
	Approach canal of south main canal	72	292,320
	sub-total	2,943	11,948,580
(3)	Administration cost	294	1,193,640
	Sub-total (1)+(2)+(3)	3,889	15,789,340
(4)	Environmental monitoring cost	3	12,180
	Sub-total (1)+(2)+(3)+(4)	3,892	15,801,520
(5)	Physical contingency	389	1,579,340
(6)	Price Contingency	710	2,882,600
Total		**4,991**	**20,263,460**

Table IIB-4.2.2 Annual Disbursement Schedule

(Unit : '000)

Description		2007		2008		2009		2010		Total	
		US$	Riel	US$	Riel	US$	Riel	US$	Riel	US$	Riel
(1)	Engineering service cost	130	527,800	196	795,760	163	661,780	163	661,780	652	2,647,120
(2)	Direct construction cost	0	0	147	596,820	1,602	6,569,080	1,176	4,774,560	2,941	11,948,580
(3)	Administration cost	0	0	15	60,900	162	657,720	117	475,020	294	1,193,640
(4)	Environmental monitoring cost	0	0	1	4,060	1	4,060	1	4,060	3	12,180
(5)	Contingency										
	1) Physical contingency	13	52,780	36	146,160	194	787,640	146	592,760	389	1,579,340
	2) Price Contingency	7	28,420	47	190,820	323	1,311,380	333	1,347,920	710	2,882,600
Total		**150**	**609,000**	**442**	**1,794,520**	**2,463**	**9,999,780**	**1,936**	**7,860,160**	**4,991**	**20,263,460**

Table IIB-4.2.3 Engineering Service Cost

Item	Unit	Quantity	Unit cost (US$)	Amount US$	Amount Riel
Engineering service cost					
(1) Design stage					
- T/L (F)	M/M	2	20,000	40,000	162,400,000
- Design engineer (F)	M/M	3	15,000	45,000	182,700,000
- Mechanical engs. (F)	M/M	1	15,000	15,000	60,900,000
- Electrical engs. (F)	M/M	1	15,000	15,000	60,900,000
- Spec writer. (F)	M/M	1	15,000	15,000	60,900,000
- Assistant engs. (L)	M/M	6	3,000	18,000	73,080,000
Sub-total				148,000	600,880,000
(2) Construction stage					
- T/L (F)	M/M	12	20,000	240,000	974,400,000
- Construction engineer (F)	M/M	8	15,000	120,000	487,200,000
- Mechanical engs. (F)	M/M	2	15,000	30,000	121,800,000
- Electrical engs. (F)	M/M	1	15,000	15,000	60,900,000
- Construction supervisor (L)	M/M	14	3,000	42,000	170,520,000
Sub-total				447,000	1,814,820,000
(3) - Survey equipment, computer, office equipment				10,000	40,600,000
- Office supporting staff such as draft men, computer operators				20,000	81,200,000
- Topographic survey sub-contract (main, secondary, tertiary for D/D)	LS			12,500	50,750,000
- Geological survey (Boring 4nos. 5m/nos. with SPT) 700US$/m	m	20	700	14,000	56,840,000
Sub-total				56,500	229,390,000
Total				652,000	2,647,120,000

Table IIB-4.2.4 Cost of Hydro-mechanical Works

Roleang Chrey Regulator		Unit	Quantity	Unit price	Amount US$	Amount Riel
(1)	Supply of roller pin	nos	40	290	11,600	47,096,000
(2)	Repair of roller	nos	40	810	32,400	131,544,000
(3)	Supply of Stoplog (floating gate)	set	1	135,000	135,000	548,100,000
(4)	Installation of stoplog	set	5	27,000	135,000	548,100,000
(5)	Sand blast and painting	set	5	9,000	45,000	182,700,000
(6)	Hoist removal and supply	set	5	180,000	900,000	3,654,000,000
(7)	Supply local control panel	nos	5	19,350	96,750	392,805,000
(8)	Supply of remote control panel	nos	1	19,080	19,080	77,464,800
(9)	Supply of spare parts	set	1	14,400	14,400	58,464,000
Total					1,389,230	5,640,273,800

Andong Sla Intake Gate		Unit	Quantity	Unit price	Amount US$	Amount Riel
(1)	Gate leaf	nos.	2	21,850	43,700	177,422,000
(2)	Guide frame	nos.	4	6,550	26,200	106,372,000
(3)	Hoist	nos.	2	52,210	104,420	423,945,200
(4)	Stoplog	set	1	18,210	18,210	73,932,600
(5)	Stoplog guide frame	nos.	4	4,370	17,480	70,968,800
(6)	380V transmission line	km	1.0	27,480	27,480	111,568,800
(7)	Local control panel	nos.	2	18,210	36,420	147,865,200
(8)	Remote control panel	nos.	1	14,560	14,560	59,113,600
(9)	Spare parts	set	1	5,500	5,500	22,330,000
Total					293,970	1,193,518,200

Vat Krouch Intake Gate		Unit	Quantity	Unit price	Amount US$	Amount Riel
(1)	Gate leaf	nos.	2	22,590	45,180	183,430,800
(2)	Guide frame	nos.	2	7,290	14,580	59,194,800
(3)	Hoist	nos.	2	52,260	104,520	424,351,200
(4)	Stoplog	set	1	18,950	18,950	76,937,000
(5)	Stoplog guide frame	nos.	2	4,370	8,740	35,484,400
(6)	380V transmission line	km	1.8	27,500	49,500	200,970,000
(7)	Local control panel	nos.	2	18,220	36,440	147,946,400
(8)	Remote control panel	nos.	1	14,580	14,580	59,194,800
(9)	Spare parts	set	1	5,500	5,500	22,330,000
	Total				297,990	1,209,839,400

Table IIB-4.4.1 Replacement Cost

(Unit : '000)

Item		Unit	Quantity	Unit price	Amount	
					US$	Riel
(1) Roleang Chrey Regulator	Gate leaf	nos.	5	122,400	428.4	1,739,304
	Hoist	nos.	5	180,000	630.0	2,557,800
	Local control panel	nos.	5	21,500	75.3	305,718
	Remote control panel	nos.	1	21,200	14.8	60,088
	Diesel generator	nos.	1	30,200	21.1	85,666
	Spare parts	set	1		11.2	45,472
	sub-total				1,180.8	4,794,048
(2) Andong Sla Intake	Local control panel	nos.	2	26,500	37.1	150,626
	Remote control panel	nos.	1	21,200	14.8	60,088
	Transmission line	km	1.0	40,000	28.0	113,680
	Spare parts	set	1		5.6	22,736
	sub-total				85.5	347,130
(3) Vat Krouch Intake	Local control panel	nos.	2	26,500	37.1	150,626
	Remote control panel	nos.	1	21200	14.8	60,088
	Transmission line	km	1.8	40,000	50.4	204,624
	Spare parts	set	1		5.6	22,736
	sub-total				107.9	438,074
Total					1,374	5,578,440

Table IIB-4.5.1 O&M Cost

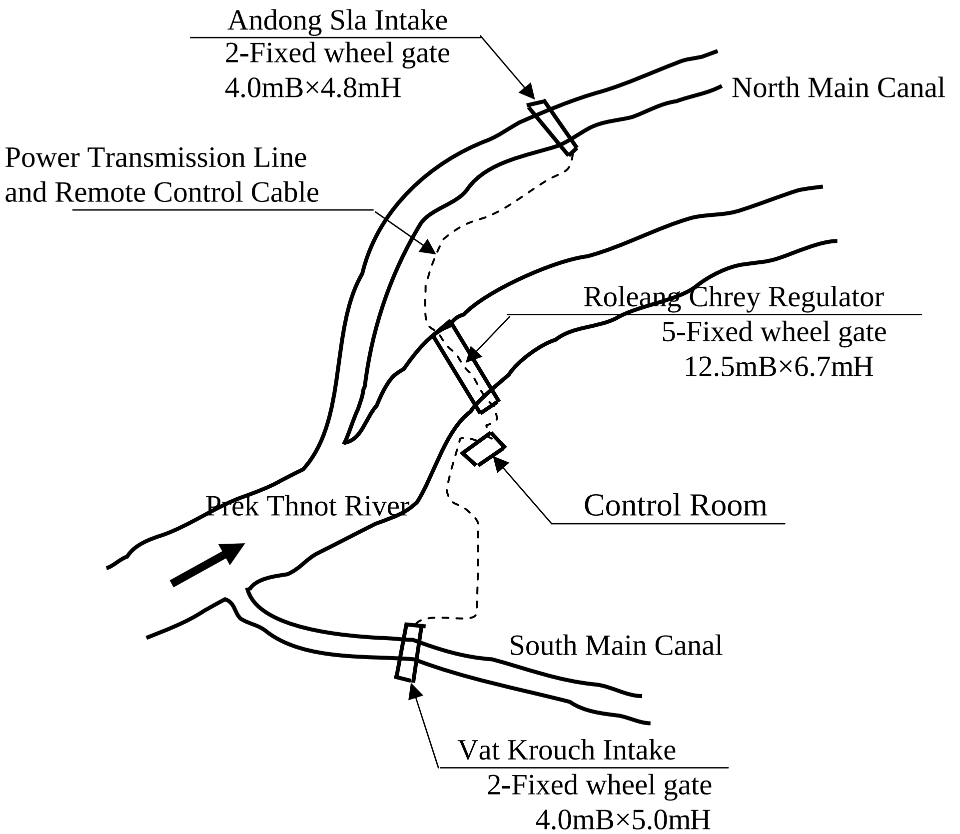
Item		Cost / year	
		US$	Riel
1. Hydro-mechanical works			
(1) Personal expense	Mechanic	390	1,583,400
	Electrician	390	1,583,400
	Operator	360	1,461,600
	sub-total	1,140	4,628,400
(2) General expense		162	657,720
(3) Cost of consumables	Fuel	702	2,850,120
	Lub.Oil	114	462,840
	Grease	180	730,800
	sub-total	996	4,043,760
(4) Repair cost	Roleang Chrey Regulator	3,250	13,195,000
	Andong Sla Intake	450	1,827,000
	Vatkrouch Intake	450	1,827,000
	sub-total	4,150	16,849,000
Total 1.		6,448	26,178,880
2. Civil works		1,806	7,332,360
3. Daily Inspection	200days/year	1,060	4,303,600
Total (1. +2. +3.)		9,314	37,814,840
	=	9,300	37,758,000

Table IIB-4.5.2 O&M Cost for Civil Works

I. O&M cost for civil work Roleang Chrey Reguratior and Intakes Improvement Project

No.	Component	Unit	Quantity	Unit Price	Amount	
					US$	Riel
A.	LABOUR					
1	Foreman	MD	21.0	15.0	315.0	1,278,900
2	Common labour	MD	105.0	2.5	262.5	1,065,750
3	Operator	MD	7.0	10.0	70.0	284,200
4	Assistant operator	MD	7.0	8.0	56.0	227,360
5						
	Sub Total				703.5	2,856,210
B.	MATERIAL					
1	Fuel	liter	28.0	0.92	25.8	104,586
2	Concrete	m^3	7.0	28.7	200.9	815,654
3						
	Sub Total				226.7	920,240
C.	EQUIPMENT					
1	Excavator $0.6m^3$	Hour	49.0	12.5	612.5	2,486,750
2	Portable concrete mixer $0.25m^3$	Hour	28.0	4.2	117.6	477,456
3						
4	Miscellaneous				146	592,760
	Sub Total				876	3,556,966
	Total (A+B+C)				1,806	7,332,360

Figure



<u>Electric Power</u>

Electric power for gate operation is transmitted from control room to gates by 380 V transmission line. The electric power source is diesel generators of 75 kVA and 23.9 kVA installed in control room.

<u>Operation</u>

Operation of all gates is available at:

side of gate by using local control panel, and

control room by using remote control panel.

<u>Operation in case of emergency</u>

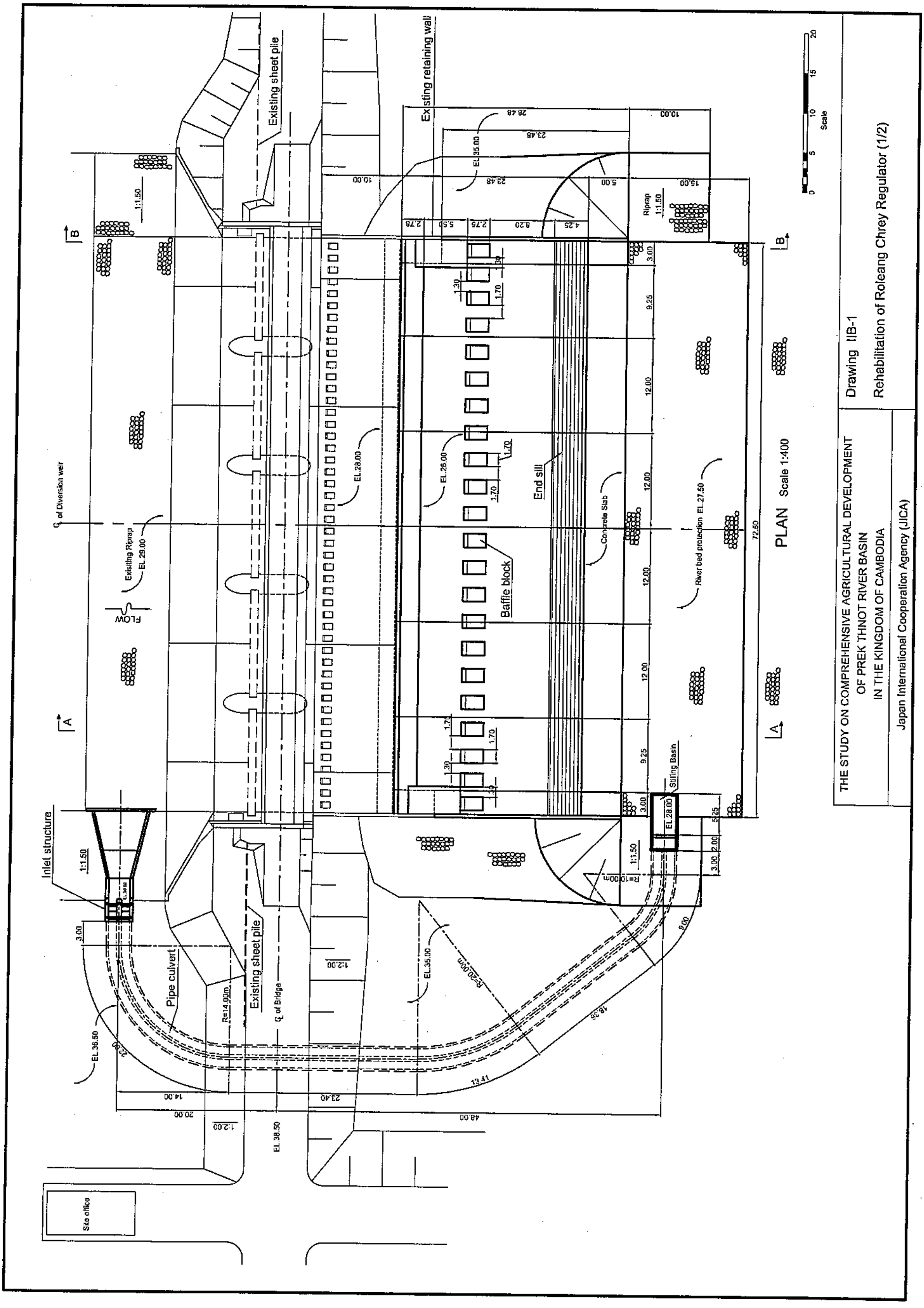
In case of flood or storm, the gates can be operated from control room by using remote contol panel.

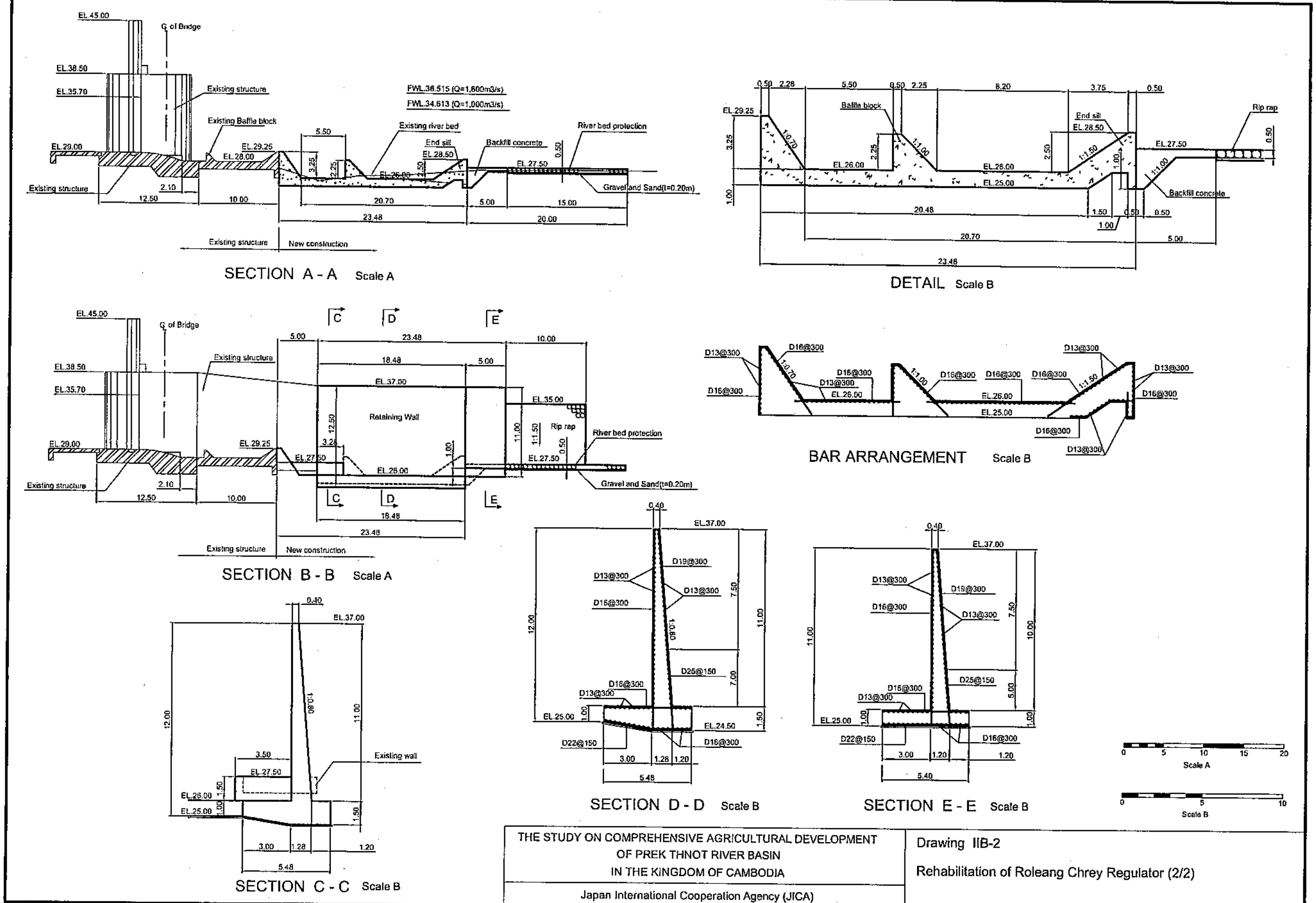
In case of electric power failure or damage of electrical component, the gate may be operated by using manual handle, althugh the movement is very slow.

The Study on Comprehensive Agricultural Development of Prek Thnot River Basin, The Kingdom of Cambodia	**Figure IIB-2.5.1** Operation System of Gate
Japan International Cooperation Agency	

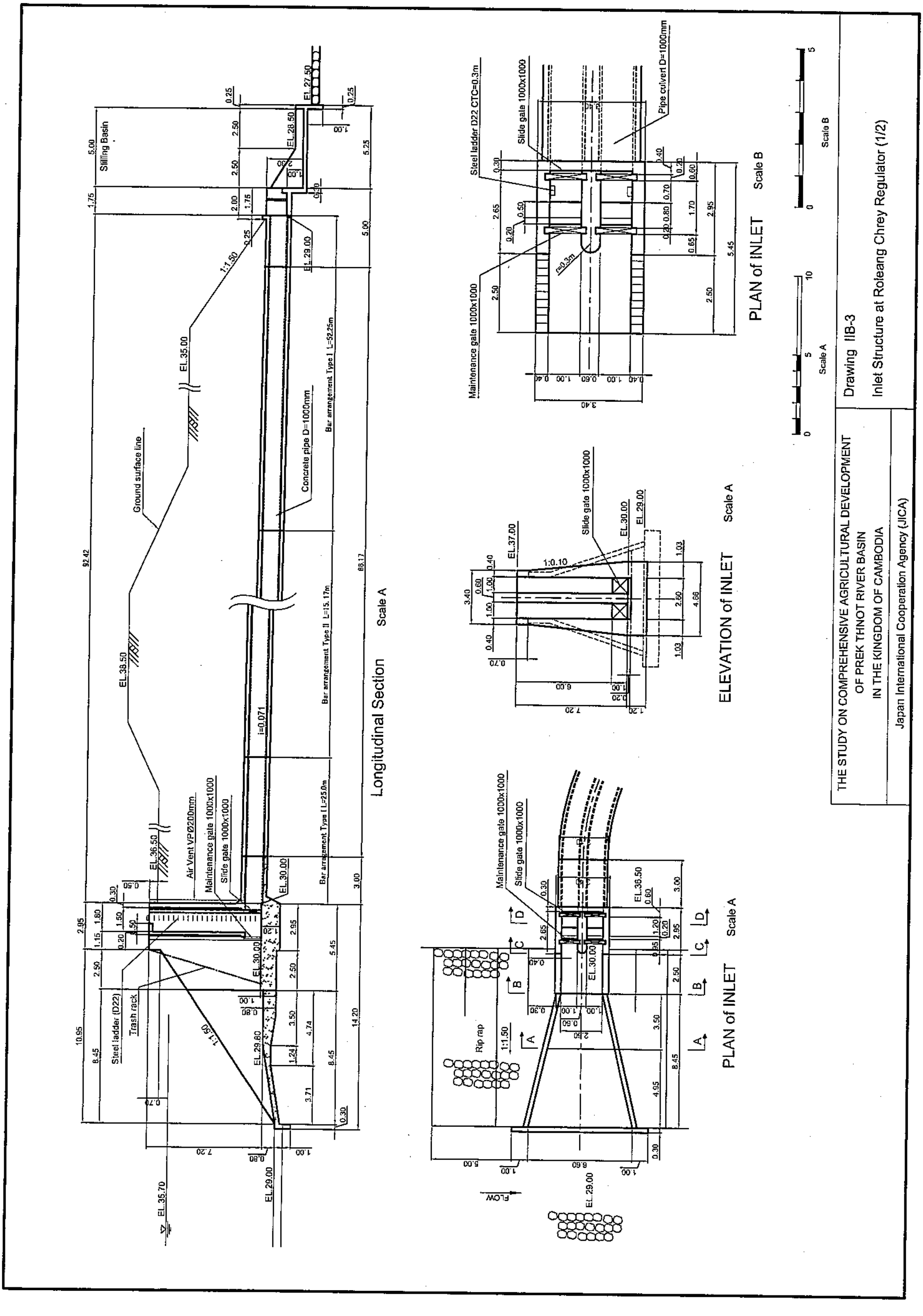
Drawings

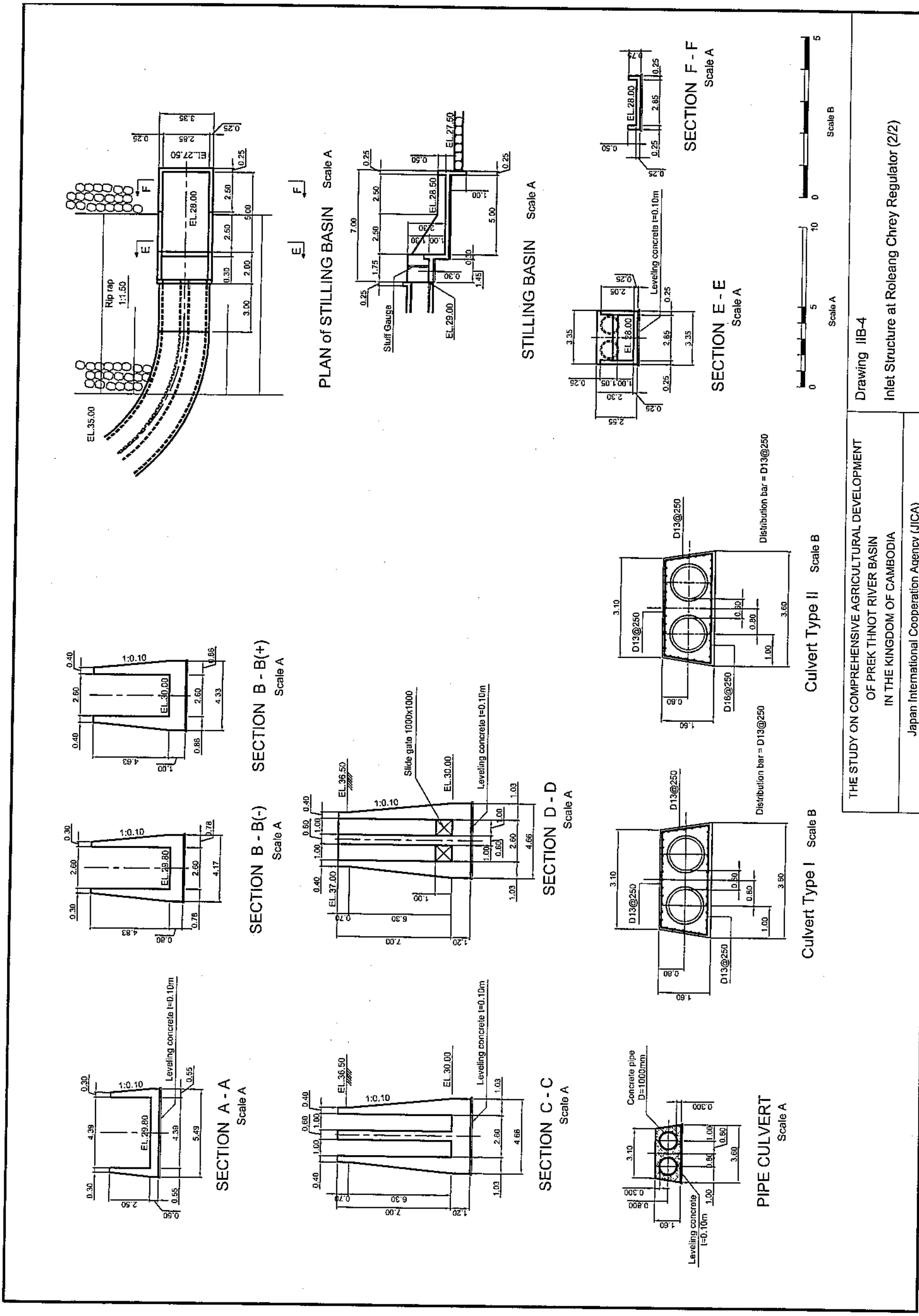
List of Drawings


THE STUDY ON COMPREHENSIVE AGRICULTURAL DEVELOPMENT
OF PREK THNOT RIVER BASIN
IN THE KINGDOM OF CAMBODIA
Japan International Cooperation Agency (JICA)
Drawing IIB-1
Rehabilitation of Roleang Chrey Regulator (1/2)
PLAN Scale 1:400
Scale
Existing sheet pile
Existing retaining wall
Inlet structure
Pipe culvert
FLOW
Existing Riprap EL.29.00
of Diversion weir
of Bridge
EL.28.00
Baffle block
End sill
Concrete Slab
River bed protection EL.27.50
Stilling Basin
EL.28.00
Riprap
1:1.50
EL.35.00
EL.36.50
EL.38.50
R=14.00m
R=20.00m
R=10.00m
Site office



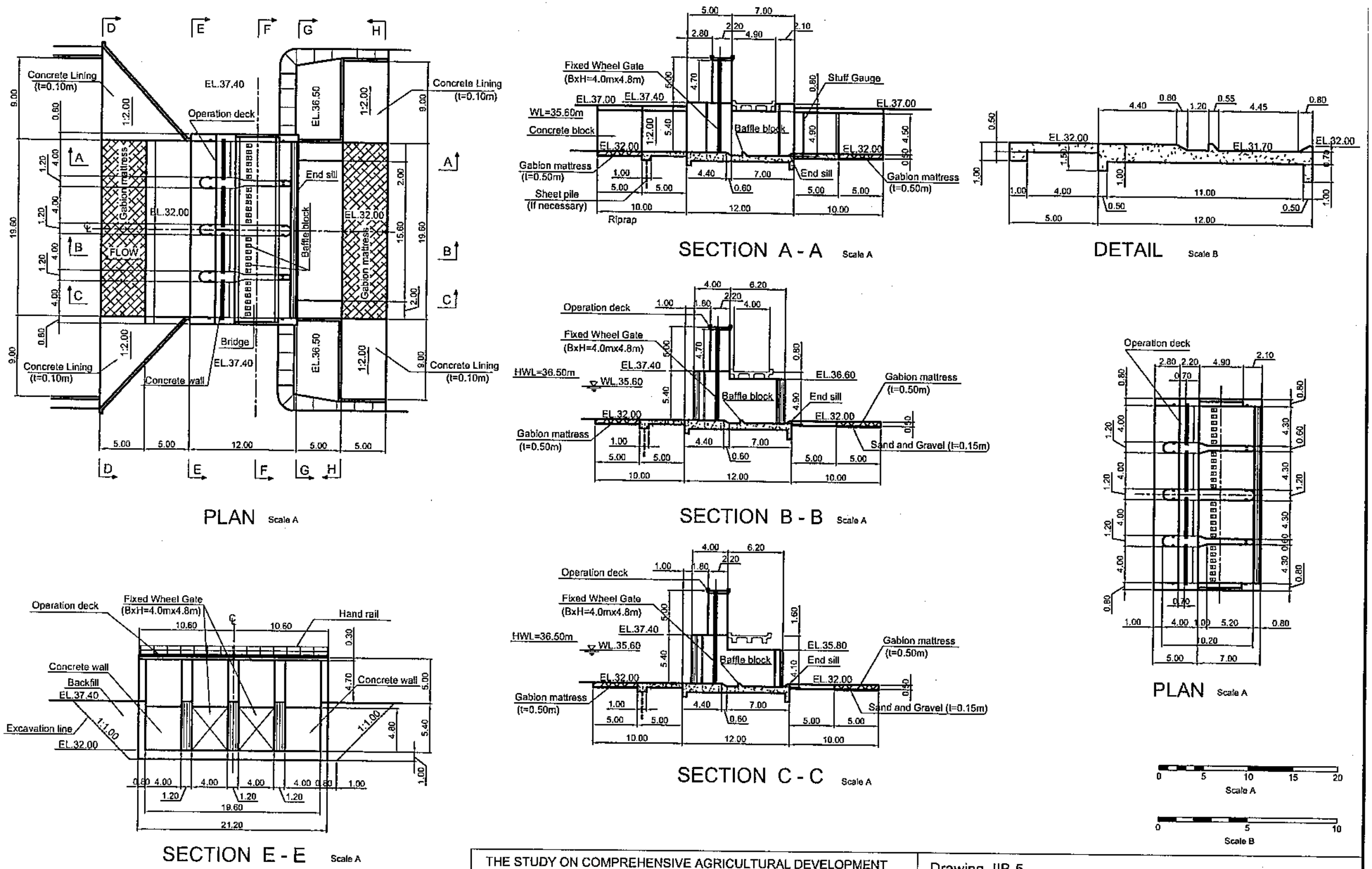
THE STUDY ON COMPREHENSIVE AGRICULTURAL DEVELOPMENT OF PREK THNOT RIVER BASIN IN THE KINGDOM OF CAMBODIA	Drawing IIB-2
Japan International Cooperation Agency (JICA)	Rehabilitation of Roleang Chrey Regulator (2/2)


THE STUDY ON COMPREHENSIVE AGRICULTURAL DEVELOPMENT
OF PREK THNOT RIVER BASIN
IN THE KINGDOM OF CAMBODIA
Japan International Cooperation Agency (JICA)
Drawing IIB-3
Inlet Structure at Roleang Chrey Regulator (1/2)
Longitudinal Section
Scale A
ELEVATION of INLET
Scale A
PLAN of INLET
Scale A
PLAN of INLET
Scale B
Scale A
Scale B
Stilling Basin
Ground surface line
Concrete pipe D=1000mm
Bar arrangement Type I L=52.25m
Bar arrangement Type II L=15.17m
Bar arrangement Type I L=25.0m
Air Vent VPØ200mm
Maintenance gate 1000x1000
Slide gate 1000x1000
Steel ladder (D22)
Trash rack
Steel ladder D22 CTC=0.3m
Pipe culvert D=1000mm
Rip rap
FLOW
EL.35.00
EL.38.50
EL.36.50
EL.35.70
EL.30.00
EL.29.80
EL.29.00
EL.26.50
EL.27.50
EL.37.80
i=0.071
1:1.50
1:0.10



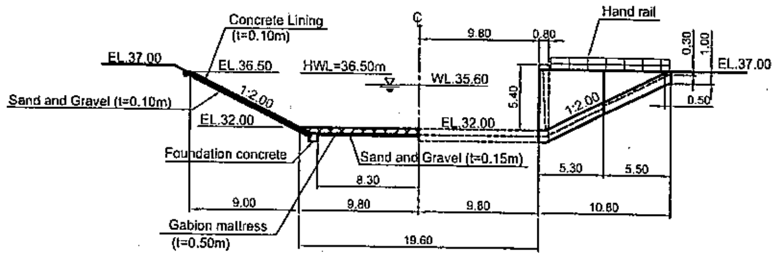
PLAN of STILLING BASIN Scale A
STILLING BASIN Scale A
SECTION F - F Scale A
SECTION E - E Scale A
SECTION A - A Scale A
SECTION B - B(-) Scale A
SECTION B - B(+) Scale A
SECTION C - C Scale A
SECTION D - D Scale A
PIPE CULVERT Scale A
Culvert Type I Scale B
Culvert Type II Scale B
Rip rap 1:1.50
Stuff Gauge
Slide gate 1000x1000
Leveling concrete t=0.10m
Concrete pipe D=1000mm
Distribution bar = D13@250
THE STUDY ON COMPREHENSIVE AGRICULTURAL DEVELOPMENT OF PREK THNOT RIVER BASIN IN THE KINGDOM OF CAMBODIA
Japan International Cooperation Agency (JICA)
Drawing IIB-4
Inlet Structure at Roleang Chrey Regulator (2/2)

INTAKE STRUCTURE



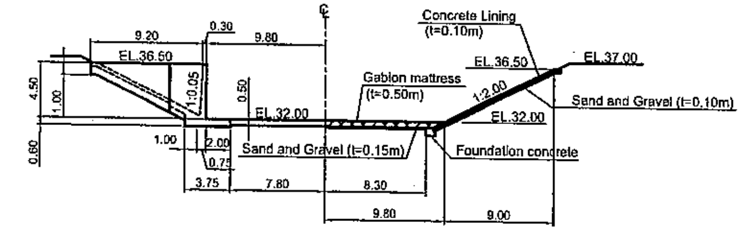
THE STUDY ON COMPREHENSIVE AGRICULTURAL DEVELOPMENT OF PREK THNOT RIVER BASIN IN THE KINGDOM OF CAMBODIA	Drawing IIB-5
Japan International Cooperation Agency (JICA)	Andong Sla Intake Structure for North Main Canal (1/2)

INTAKE STRUCTURE



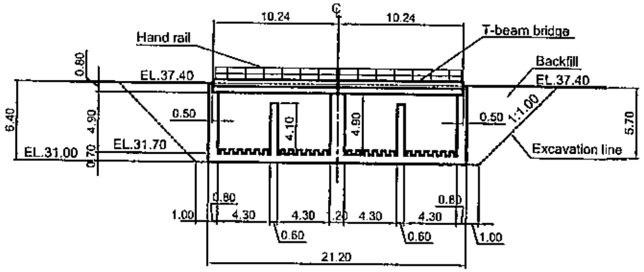
SECTION D - D

Scale A



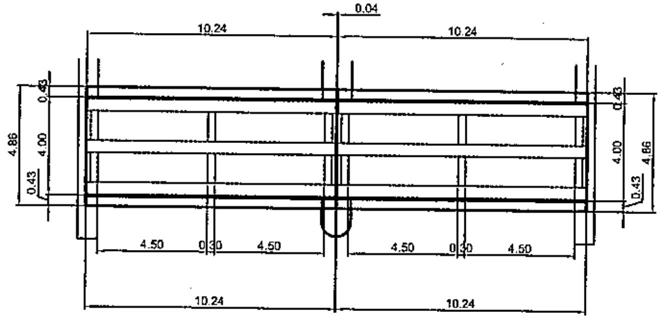
SECTION H - H

Scale A



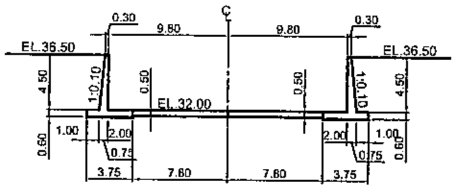
SECTION F - F

Scale A



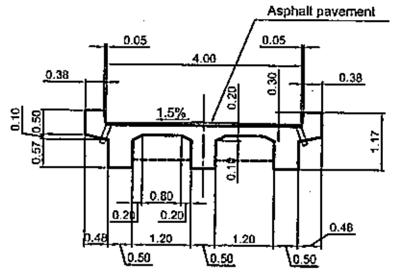
PLAN of BRIDGE

Scale B



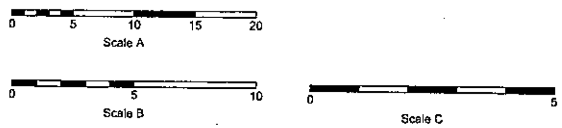
SECTION G - G

Scale A



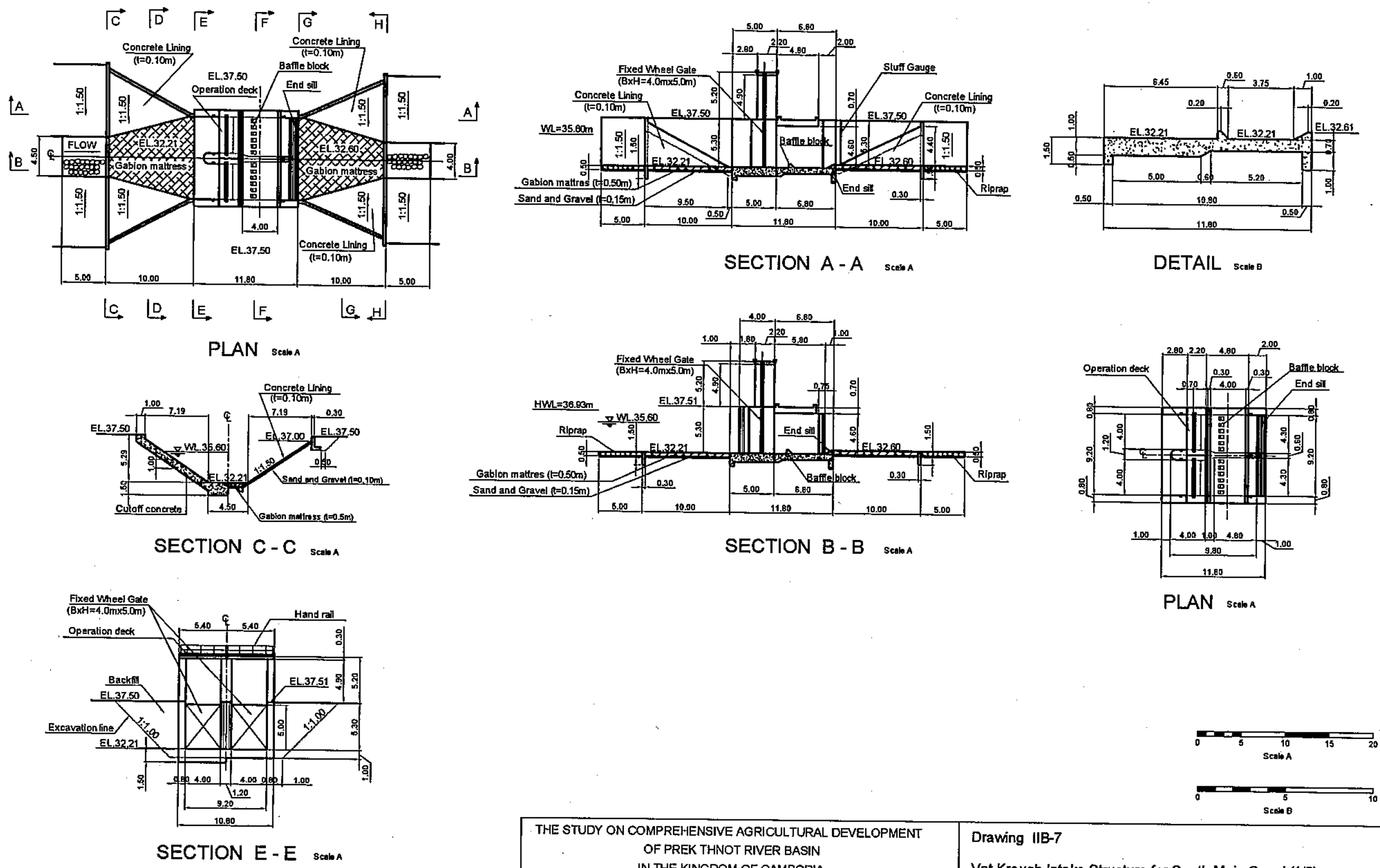
SECTION of BRIDGE

Scale C



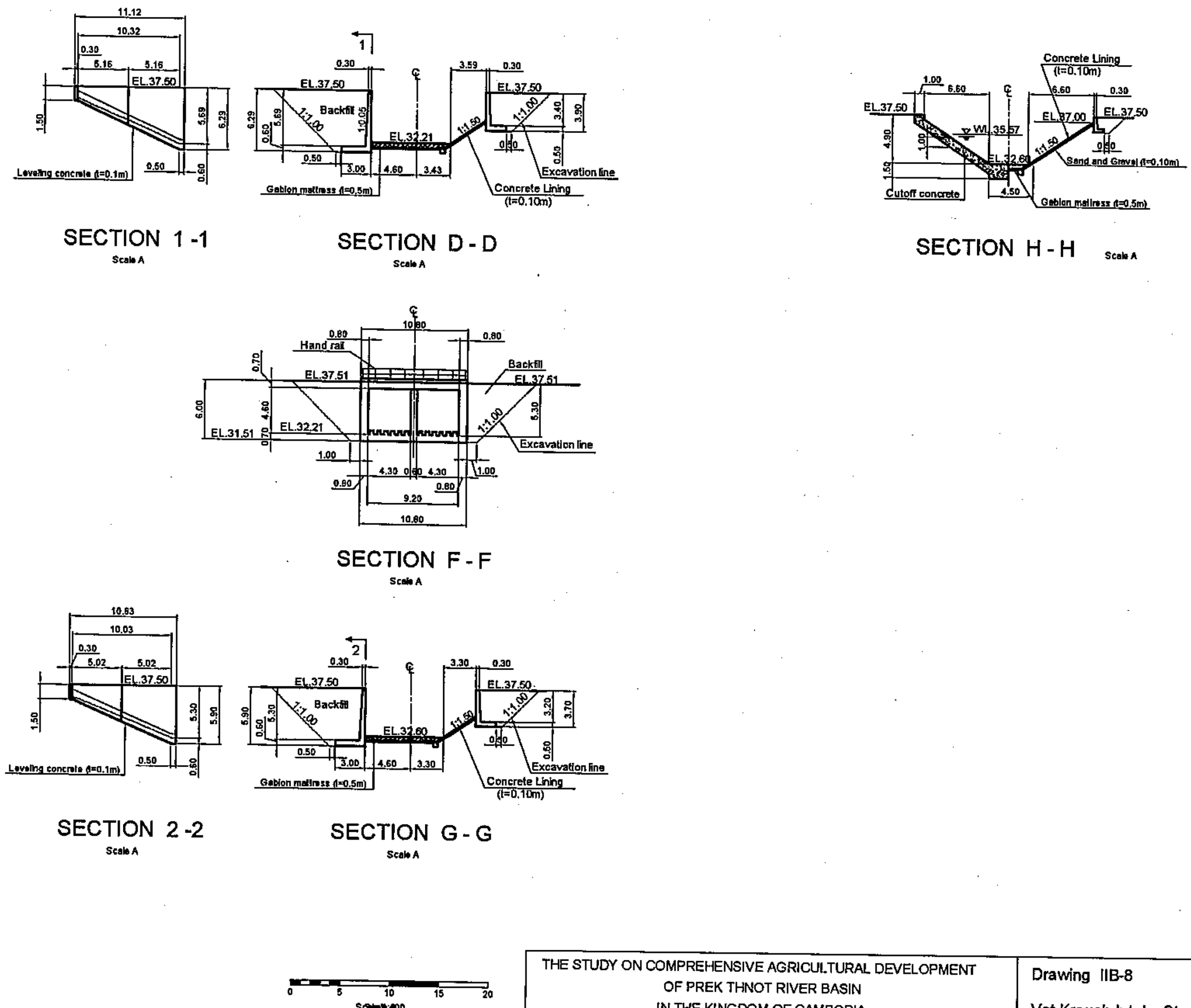
THE STUDY ON COMPREHENSIVE AGRICULTURAL DEVELOPMENT OF PREK THNOT RIVER BASIN IN THE KINGDOM OF CAMBODIA	Drawing IIB-6
Japan International Cooperation Agency (JICA)	Andong Sla Intake Structure for North Main Canal (2/2)

INTAKE STRUCTURE



THE STUDY ON COMPREHENSIVE AGRICULTURAL DEVELOPMENT OF PREK THNOT RIVER BASIN IN THE KINGDOM OF CAMBODIA	Drawing IIB-7
Japan International Cooperation Agency (JICA)	Vat Krouch Intake Structure for South Main Canal (1/2)

INTAKE STRUCTURE

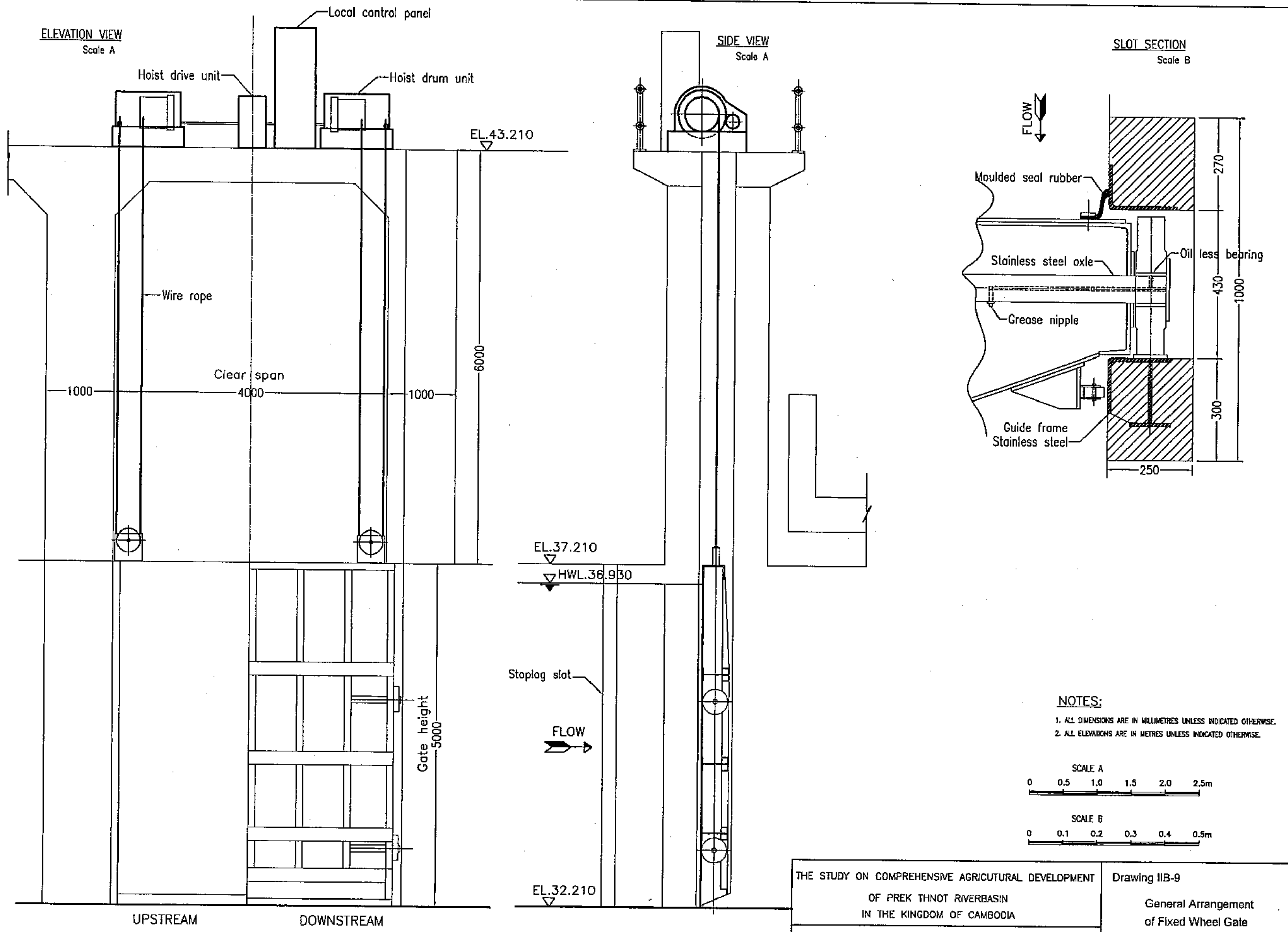


THE STUDY ON COMPREHENSIVE AGRICULTURAL DEVELOPMENT
OF PREK THNOT RIVER BASIN
IN THE KINGDOM OF CAMBODIA

Japan International Cooperation Agency (JICA)

Drawing IIB-8

Vat Krouch Intake Structure for South Main Canal (2/2)



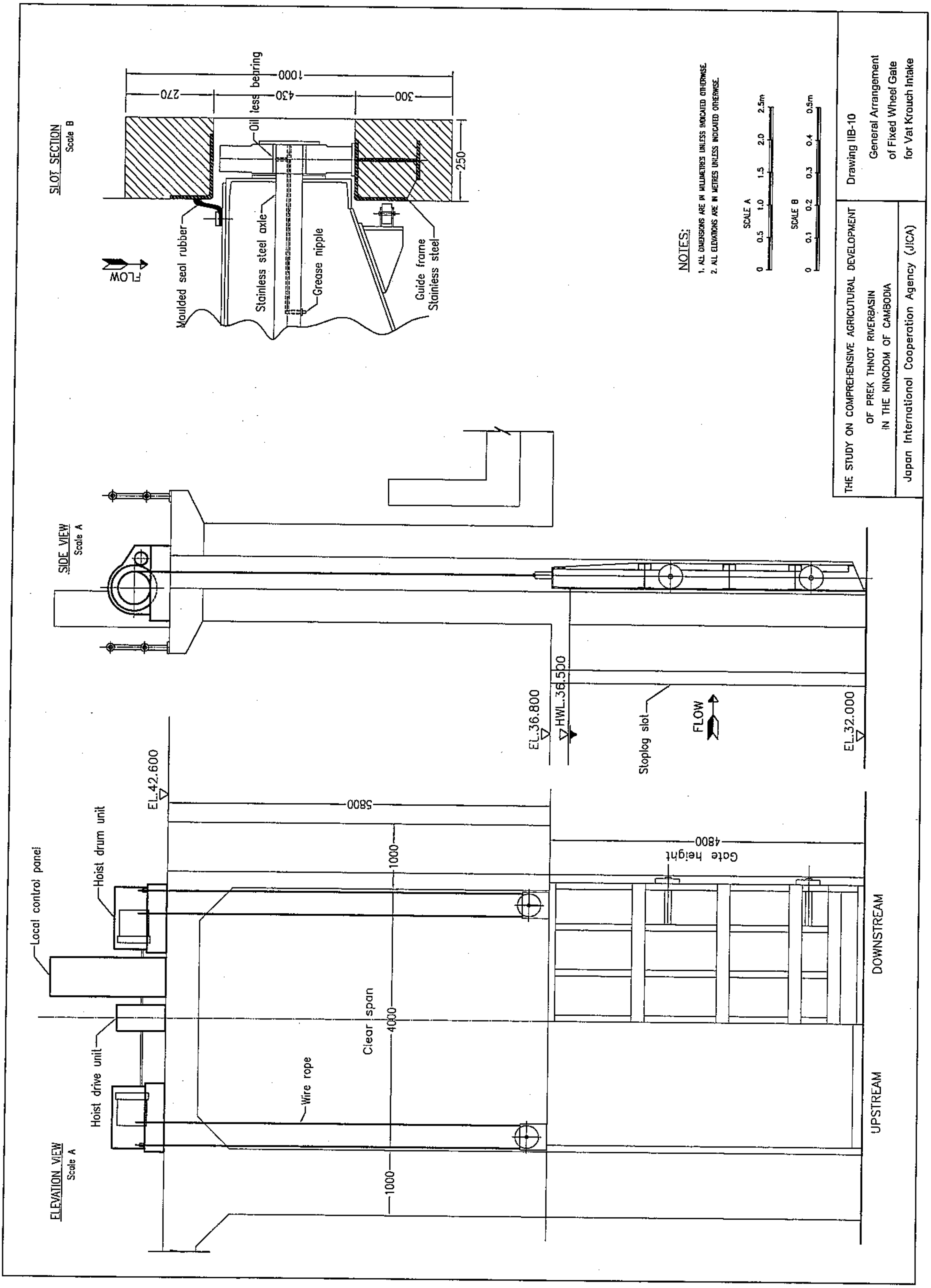
NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS INDICATED OTHERWISE.
2. ALL ELEVATIONS ARE IN METRES UNLESS INDICATED OTHERWISE.

SCALE A: 0 0.5 1.0 1.5 2.0 2.5m

SCALE B: 0 0.1 0.2 0.3 0.4 0.5m

THE STUDY ON COMPREHENSIVE AGRICUTURAL DEVELOPMENT OF PREK THNOT RIVERBASIN IN THE KINGDOM OF CAMBODIA	Drawing IIB-9
Japan International Cooperation Agency (JICA)	General Arrangement of Fixed Wheel Gate for Andon Sla Intake


ELEVATION VIEW
Scale A
Hoist drive unit
Local control panel
Hoist drum unit
EL.42.600
5800
1000
Clear span
4000
1000
Wire rope
Gate height
4800
DOWNSTREAM
UPSTREAM
SIDE VIEW
Scale A
EL.36.800
HWL.36.500
Stoplog slot
FLOW
EL.32.000
SLOT SECTION
Scale B
1000
270
430
300
250
Oil less bearing
Moulded seal rubber
Stainless steel axle
Grease nipple
Guide frame
Stainless steel
FLOW
NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS INDICATED OTHERWISE.
2. ALL ELEVATIONS ARE IN METRES UNLESS INDICATED OTHERWISE.
SCALE A
0 0.5 1.0 1.5 2.0 2.5m
SCALE B
0 0.1 0.2 0.3 0.4 0.5m
THE STUDY ON COMPREHENSIVE AGRICUTURAL DEVELOPMENT
OF PREK THNOT RIVERBASIN
IN THE KINGDOM OF CAMBODIA
Japan International Cooperation Agency (JICA)
Drawing IIB-10
General Arrangement
of Fixed Wheel Gate
for Vat Krouch Intake

Attachments

Attachment IIB-1

Hydraulic Calculation

Hydraulic calculation of Roleang Chrey Regulator

The discharge at gate is given by the equation:

$Q = Cd \times d \times B \times \{2g(h_1 - d/2)\}^{0.5}$ ...... 1)

where: Cd = flow index = 0.65
B = width of gate in meter
d = gate opening in meter

$h_0 = Ca \cdot d$ ...... 2)

where: Ca = coefficient of Vena contracta (=0.61)

$h_3 = 1/2\ \{(1 + 8Fr_2^2)^{0.5} - 1\} \cdot h_2$

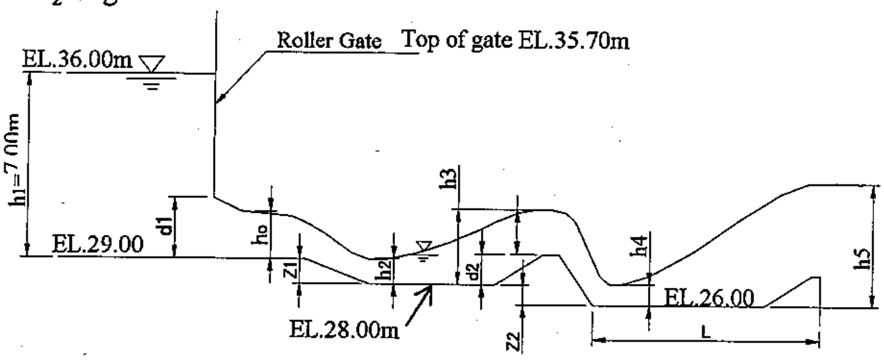
$h_5 = 1/2\ \{(1 + 8Fr_4^2)^{0.5} - 1\} \cdot h_4$

where: Fr = Froude number
$Fr_4 = V_4 / \sqrt{g \cdot h_4}$
V_4 = flow velocity (m/sec)

$h_0 + hv_0 + Z = h_2 + hv_2$

$hv_0 = V_0^2 / 2g$

$hv_2 = V_2^2 / 2g$



Numbers of gate = 5 nos.
Width of gate = 12.5 m
Height of gate = 6.7 m

Flood discharge (m^3/sec)	1600	
Discharge per unit width in meter q1 (m^3/sec/m)	25.60	
d1 (m)	3.97	
q2 by equation 1) (m^3/sec/m)	25.60	q1=q2
h_1 (m)	7.00	
h_0 (m)	2.42	
V_0 (m/sec)	10.56	
hv_0 (m)	5.69	
Z1 (m)	1.00	
h_2 (m)	2.20	(1)-(2)=0
V_2 (m/sec)	11.64	
hv_2 (m)	6.92	
Fr	2.509	

d2 (m)	1.250
h_3 (m)	6.777
V_3 (m/sec)	3.777
hv_3 (m)	0.728
Z2 (m)	2.000
h_4 (m)	2.129
V_4 (m/sec)	12.024
hv_4 (m)	7.377
Fr	2.632
h_5 (m)	6.933
Length of stilling basin =3h	20.798

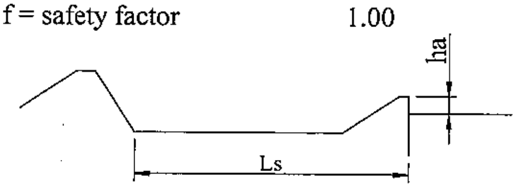
(USBR Type III)

q1 - q2	(0.00)
h_0+hv_0+Z1 ...(1)	9.116
h_2+hv_2.......(2)	9.116
(1) - (2)	0.000

h_3+hv_3+Z2 ...(1)	9.505
h_4+hv_4.......(2)	9.506
(1) - (2)	(0.000)

Energy Dissipater (USBR Type III)

Flood discharge	q =	25.6 $m^3/s/m$		
Width of gate	B =	12.5 m		
Inflow Velocity	V_4 =	12.02 m/s		
Inflow depth	h_4 =	2.129 m		
Froude number	$Fr = V_4 / \sqrt{(g \times h_4)}$	2.632		
	g =	9.8 m^2/s		
Depth of hydraulic jump	$h_5 = h_4/2 \times (\sqrt{(1+8F_r^2)}-1)$	6.931 m		
Length of stilling basin	$Ls = 3 \times h_5$	20.793	20.8	m
Baffle block				
height	$h_b = (0.17 \cdot F_r + 0.6) \cdot h_2$	2.230	2.25	m
width	$W_b = 0.75 \cdot h_b$	1.673	1.70	m
space	$S_b = 0.75 \cdot hb$	1.673	1.70	m
fractional space	$= 0.375 \cdot h_b$	0.814	0.85	m
width of crest	$= 0.2 \cdot h_b$	0.450	0.50	m
space between chute block and baffle block	$= 0.8 \cdot h_5$	5.545	5.55	m
slope	= 1 : 1.0			
End sill				
height	$h_e = (0.056 \cdot F_r + 1.0) \cdot h_2$	2.443	2.50	m
width of crest	$W_e = 0.2 \cdot h_e$	0.490	0.50	m
slope	= 1 : 2.0			
River bed protection				
length	$L = Lb - La$	19.88	20.00	m
	$Lb = 0.67C\sqrt{ha \times q} \times f$	40.68 m		
	$La = Ls$	20.80 m		
	C = Bligh's coefficient	12		
	ha	1.00 m		
	f = safety factor	1.00		



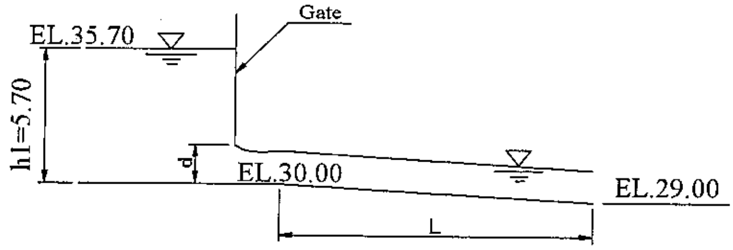
Hydraulic calculation of Inlet Structure at Roleang Chrey Regulator

1. Gate dimensions

The discharge at gate is given by the equation:

$Q = Cd \times d \times B \times \{2g\ (h1 - d/2)\}^{0.5}$

where: Q =	discharge	10.0	(m^3/sec)
Cd =	flow index =	0.65	
B =	width of gate in meter	1.0	m
d =	gate opening in meter.		
h1 =	5.70	m	
Full water level =	35.70	m	



Number of gate		nos.	2	2	2	2
Width of gate in meter	B	(m)	0.6	0.8	0.9	1.0
Gate opening in meter	d	(m)	0.48	0.64	0.72	0.80
Discharge	Q	(m^3/sec)	3.87	6.83	8.62	10.60
						ok

The gate B x H = 1.0 x 1.0, Number of gate is 2.

2.Hydraylic calculation of pipe culvert 2 lane

$V = 1/n \cdot I^{1/2} R^{2/3}$ (m/sec) (Maning fomula)

$Q = A \cdot V$ (m^3/sec)

where: V = flow velocity (m/sec)

n = coefficient of roughness = 0.015

I = hyadraulic gradient

R = hydraulic radius

A = flow area (m^2)

Length of pipe culvert	L =	94.2	m
EL. at entrance	EL.	30.0	m
EL. at exit	EL.	29.0	m

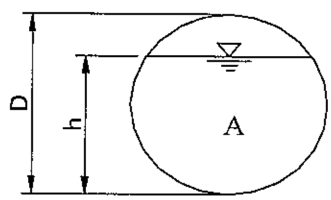
When h is 0.938D, the maximum discharge flows.

D = 1.0m

h = 0.94m

A = 0.765m2

R = 0.290



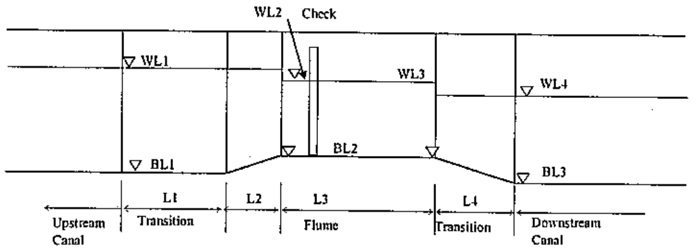
I = dh / L = (5.70 + (30.0 - 29.0)) / 94.2 = 0.071

$V = 1/n \cdot I^{1/2} R^{2/3} =$ 7.79 m/sec

$Q = A \cdot V \cdot$ 2 lane = 11.92 m^3/sec > 10.0 ok

Hydraulic Calculation of Andong Sla Intake

Canal Name: North main canal
Structure No.



1 Dimension and Hydraulic Conditions

Upstream Design Discharge Qu=	10.400 m3/sec	Pier Width Bp=	1.200 m	Approach Length to rectanglar section L2= 3.50 m
Downstream Design Discharge Qd=	10.400 m3/sec	Gate Width B=	4.000 m	Length of Flume L3= 7.70 m
Discharge per Flume q=Qd/N	5.200 m3/sec	Total width Bc =N*B+(N-1)Bp=	9.20 m	
Nof of Gates N=	2 nos	Effective Width Be = N*B=	8.00 m	

		Upstream channel		BP Rectangler Section		EP Rectangler Section		EP of D/s Transition		Downstream Canal		
Design Discharge per channel	(m3/sec)		10.40		10.40		10.40		10.40		10.40	
Bottom Width	(m)	B1 =	4.00	B2 =	8.00	B3 =	8.00	B4 =	4.00	B5 =	4.00	
Side Slope 1:m		m=	2.00	m=	0.00	m=	0.00	m=	2.00	m=	1.50	
Water Depth	(m)	H1 =	3.600	H2 =	3.596	H3 =	3.593	H4 =	3.594	H5 =	3.594	
Water Surface Width		W1 =	18.400	W2 =	8.000	W3 =	8.000	W4 =	18.376	W5 =	14.782	
Flow Area	(m2)	A1 =	40.320	A2 =	28.765	A3 =	28.741	A4 =	40.211	A5 =	33.753	
Velocity	(m/s)	V1 =	0.258	V2 =	0.362	V3 =	0.362	V4 =	0.259	V5 =	0.308	
Velocity Head	(m)	hv1 =	0.003	hv2 =	0.007	hv3 =	0.007	hv4 =	0.003	hv5 =	0.005	
Energy Head	(m)	E1 =	3.603	E2 =	3.602	E3 =	3.599	E4 =	3.597	E5 =	3.599	
Head losses	(m)			h1 =	0.0011	h2=	0.0030	h3=	0.0017			0.0058
dE = Eu - (Ea + hi)	(m)			ok	0.0000	ok	0.0000	ok	0.0001			
				target	0	target	0	target	0			
Wetted Perimeter P = B + 2H(m^2+1)^0.5	(m)	P1 =	20.0997	P2 =	15.1912	P3 =	15.1853	P4 =	20.0732	P5 =	16.9587	
Hydraulic Radius R = A/P	(m)	R1 =	2.0060	R2 =	1.8935	R3 =	1.8927	R4 =	2.0032	R5 =	1.9903	
Roughness Coefficient		n=	0.025	n=	0.015	n=	0.015	n=	0.016	n=	0.0250	
Roughness Coefficient K												
Hydraulic Gradient I =[n V/R ^(2/3)]^2		I1=	1.64E-05	I2 =	1.25555E-05	I3 =	1.25836E-05	I4 =	6.7812E-06	I5 =	2.3702E-05	

Transition = 1.92098 (Wu-Wc)/2		9.9891	Transition =2.41421 (Wu-Wc)/2	12.525 m
Length of Transition	say L1 =	10.00	say L4 =	13.00 m
	Designed	10.00	Designed	12.00 m

note: Vc shall be in between "Vu" and 3.0 m/sec.

	At BP of Transition		At BP of Rectangular Section		At EP of Rectangler section	
Energy Level (m)	EL1 = WL1 + hv1 =	35.603	EL2 = EL1 - h1 =	35.602	EL3 = EL2 - h2 =	35.599
Water Level (m)	WL1 = EL1 - hv1 =	35.600	WL2 = EL2 - hv2 =	35.596	WL3 = EL3 -hv3 =	35.593
Floor Level (m)	BL1 = WL1 - H1=	32.000	BL2 = WL2 - H2=	32.000	BL3 = WL3 - H3=	32.000

	At BP of Downstream Channel			
Energy Level (m)	EL4 = EL3 - h3=	35.598		
Water Level (m)	WL4 = EL4-hv4=	35.594		
Floor Level (m)	BL4 = WL4 - H4=	32.000		

Transition Angle
U/stream 27'30
D/stream 22'30

2 Calculation of Head Loss

1) Loss at Transition Channel = h1
Gradual contraction hgc = fgc (hv2-hv1) =
hgc = fgc (hv2-hv1) 0.000982 m
fgc = 0.3
Friction hfc=L1(I1+I2)/2 = 0.000145 m
h1=hfc + hdt 0.001127 m

2) Head loss due to pier =hp
hp=a[b/H2^2-c/(H2+hp)^2] 0.002858 m
a=Qd^2/19.6= 5.518367
b=1/(0.92^2*Be^2)= 0.018461
c=1/Bc^2= 0.011815
hp'= 0.002845
hp-hp' = 1.37E-05 ok

Friction in Flume hf3=L3*(I2+I3)/2= 9.68E-05 m
head loss h2= 0.002955

3) Downstream transition
Gradual enlargement loss
hgc = fge (hv3-hv4) 0.001634 m
fge = 0.5
Friction in transition hf3=L4(I3+I4)/2= 0.000116 m
head loss h3=hfe+hf3= 0.00175 m

4) Total Head Loss

Δh=Σhi= 0.005833 m
check 0.0058

Hydraulic calculation for Apron of Andong Sla Intake

Condition; Just after open the gate

The discharge is given by the equation:

$Q = Cd \times d \times B \times \{2g(h_1 - d/2)\}^{0.5}$ ...... 1)

where: Cd = flow index = 0.65
B = width of gate in meter
d = gate opening in meter

$h_0 = Ca \cdot d$ ...... 2)

where: Ca = coefficient of Vena contracta (=0.61)

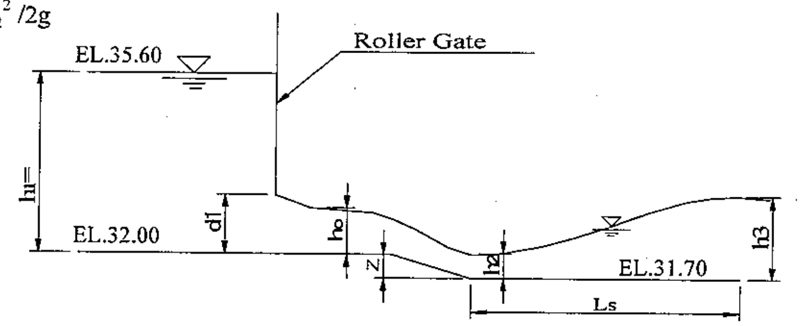
$h_3 = 1/2\ \{(1 + 8Fr^2)^{0.5} - 1\} \cdot h_2$

where: Fr = Froude number
$Fr = V_2/\sqrt{g \cdot h_2}$
V_2 = flow velocity (m/sec)

$h_0 + hv_0 + Z = h_2 + hv_2$

$hv_0 = V_0^2 / 2g$

$hv_2 = V_2^2 / 2g$



Numbers of gate =	2 nos.
Width of gate =	4.0 m
Height of gate =	4.8 m
Water level at upstream	EL. 35.60
Canal bed elevation at upstream	EL. 32.00
Canal bed elevation at downstream	EL. 31.70

Flood discharge (m^3/sec)	10.4	
Discharge per unit width in meter q1 (m^3/sec/m)	1.30	= 10.4 / 2 / 4.0
d (m)	0.24	
q2 by equation 1) (m^3/sec/m)	1.30	
h_1 (m)	3.60	
h_0 (m)	0.15	
V_0 (m/sec)	8.80	
hv_0 (m)	3.95	
Z (m)	0.30	
h_2 (m)	0.14	
V_2 (m/sec)	9.13	
hv_2 (m)	4.26	
Fr	7.733	
h_3 (m)	1.49	
$L = 4.5h_3$ (m)	6.69	
Length of stilling basin $=3h_3$	4.46	

(USBR Type III)

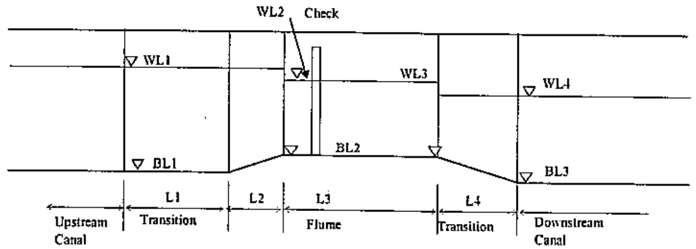
q1 - q2	0.00
h_0+hv_0+Z ...(1)	4.398
h_2+hv_2.......(2)	4.398
(1) - (2)	0.000

Andong Sla Intake of North main canal

Energy Dissipater	USBR III type				
Flood discharge	Q	=	10.4 m^3/s		
Width of gate	B	=	4.0 m		
	g	=	9.8 m^2/s		
Velocity of incoming flow	V_2		9.13 m/s		
Depth of incoming flow	h_2		0.142 m		
Froude number	Fr	$= v / \sqrt{(g \cdot h_2)}$	7.733		
Depth of hydraulic jump	h_3	$= h_2/2 \times (\sqrt{(1+8F_r^2)}-1)$	1.487 m		
Length of stilling basin	L	= 3 * h3	4.461	4.5	m
Chute block					
height	h_s	$= h_2$	0.142	0.15	m
width	W_s	$= h_2$	0.142	0.15	m
space between each blocks	S_s	$= h_2$	0.142	0.15	m
fractional space		$= h_2/2$	0.071	0.10	m
Baffle block					
height	h_b	$= (0.17 \cdot F_r + 0.6) \cdot h_2$	0.273	0.30	m
width	W_b	$= 0.75 \cdot h_b$	0.205	0.25	m
space	S_b	$= 0.75 \cdot hb$	0.205	0.25	m
fractional space		$= 0.375 \cdot h_b$	0.100	0.10	m
width of crest		$= 0.2 \cdot h_b$	0.060	0.10	m
space between chute block and baffle block		$= 0.8 \cdot h_2$	1.190	1.20	m
slope		= 1 : 1.0			
End sill					
height	h_e	$= (0.056 \cdot F_r + 1.0) \cdot h_2$	0.204	0.25	m
width of crest	W_e	$= 0.2 \cdot h_e$	0.050	0.05	m
slope		= 1 : 2.0			

Hydraulic Calculation of Vat Kouch Intake

Canal Name: Model project South main canal Chainage
Structure No.



1 Dimension and Hydraulic Conditions

Upstream Design Discharge Qu=	17.400 m3/sec	Pier Width Bp=	1.200 m
Downstream Design Discharge Qd=	17.400 m3/sec	Gate Width B=	4.000 m
Discharge per Flume q=Qd/N	8.700 m3/sec	Total width Bc =N*B+(N-1)Bp=	9.20 m
No.f of Gates N=	2 nos	Effective Width Be = N*B=	8.00 m

Approach Length to rectanglar section L2= 3.50 m
Length of Flume L3= 7.70 m

		Upstream channel		BP Rectangler Section		EP Rectangler Section		EP of D/s Transition		Downstream Canal		
Design Discharge per channel	(m3/sec)		17.40		17.40		17.40		17.40		17.40	
Bottom Width	(m)	B1 =	4.50	B2 =	8.00	B3 =	8.00	B4 =	4.00	B5 =	4.00	
Side Slope 1:m		m=	1.50	m=	0.00	m=	0.00	m=	1.50	m=	1.50	
Water Depth	(m)	H1 =	3.390	H2 =	3.377	H3 =	3.367	H4 =	3.370	H5 =	2.970	
Water Surface Width		W1 =	14.670	W2 =	8.000	W3 =	8.000	W4 =	14.111	W5 =	12.910	
Flow Area	(m2)	A1 =	32.493	A2 =	27.016	A3 =	26.940	A4 =	30.520	A5 =	25.111	
Velocity	(m/s)	V1 =	0.500	V2 =	0.644	V3 =	0.646	V4 =	0.570	V5 =	0.693	
Velocity Head	(m)	hv1 =	0.013	hv2 =	0.021	hv3 =	0.021	hv4 =	0.017	hv5 =	0.024	
Energy Head	(m)	E1 =	3.403	E2 =	3.398	E3 =	3.389	E4 =	3.387	E5 =	2.994	
Head losses	(m)			h1 =	0.0047	h2=	0.0094	h3=	0.0018			0.0158
dE = Eu - (Ea + hi)	(m)			ok	0.0000	ok	0.0000	ok	0.0000			
				target	0	target	0	target	0			
Wetted Perimeter P = B + 2H(m^2+1)^0.5	(m)	P1 =	16.7228	P2 =	14.7539	P3 =	14.7349	P4 =	16.1520	P5 =	14.7085	
Hydraulic Radius R = A/P	(m)	R1 =	1.9430	R2 =	1.8311	R3 =	1.8283	R4 =	1.8896	R5 =	1.7073	
Roughness Coefficient		n=	0.022	n=	0.015	n=	0.015	n=	0.016	n=	0.0220	
Roughness Coefficient K												
Hydraulic Gradient I =[n V/R ^(2/3)]^2		I1=	0.00005	I2 =	4.16649E-05	I3 =	4.19861E-05	I4 =	3.5618E-05	I5 =	0.0001	

Transition = 1.92098 (Wu-Wc)/2 6.4065 Transition =2.41421 (Wu-Wc)/2 7.377 m
Length of Transition say L1 = 7.00 say L4 = 8.00 m
Designed 10.00 Designed 10.00 m

note: Vc shall be in between "Vu" and 3.0 m/sec.

	At BP of Transition		At BP of Rectangular Section		At EP of Rectangler section	
Energy Level (m)	EL1 = WL1 + hv1 =	35.613	EL2 = EL1 - h1 =	35.608	EL3 = EL2 - h2 =	35.599
Water Level (m)	WL1 = EL1 - hv1 =	35.600	WL2 = EL2 - hv2 =	35.587	WL3 = EL3 -hv3 =	35.577
Floor Level (m)	BL1 = WL1 - H1=	32.210	BL2 = WL2 - H2=	32.210	BL3 = WL3 - H3=	32.210

	At BP of Downstream Channel			
Energy Level (m)	EL4 = EL3 - h3=	35.597		
Water Level (m)	WL4 = EL4-hv4=	35.580		
Floor Level (m)	BL4 = WL4 - H4=	32.210		

Transition Angle
U/stream 27'30
D/stream 22'30

2 Calculation of Head Loss

1) Loss at Transition Channel = hl
Gradual enlargement loss
hge = fge (hv1-hv2) 0.004193 m
fge = 0.5
Friction hfc=L1(I1+I2)/2 = 0.000458 m
hl=hfc + hdl 0.004651 m

2) Head loss due to pier =hp
hp=a[b/H2^2-c/(H2+hp)^2] 0.009066 m
a=Qd^2/19.6= 15.44694
b=1/(0.92^2*Bc^2)= 0.018461
c=1/Bc^2= 0.011815
hp'= 0.009088
hp-hp' = -2.1E-05 ok

Friction in Flume hf3=L3*(I2+I3)/2= 0.000322 m
head loss h2= 0.009388

3) Downstream transition
Gradual contraction hc = fc (hv4-hv3) =
hgc = fgc (hv4-hv3) 0.00141 m
fgc = 0.3
Friction in transition hf3=L4(I3+I4)/2= 0.000388 m
head loss h3=hfc+hf3= 0.001798 m

4) Total Head Loss
Δh=Σhi= 0.015837 m
check 0.0158

Hydraulic calculation at gate of Vat Krouch Intake for South main canal

Condition; Just after open the gate

The discharge is given by the equation:

$Q = Cd \times d \times B \times \{2g(h_1 - d/2)\}^{0.5}$ ...... 1)

where: Cd = flow index = 0.65
B = width of gate in meter
d = gate opening in meter

$h_0 = Ca \cdot d$ ...... 2)

where: Ca = coefficient of Vena contracta (=0.61)

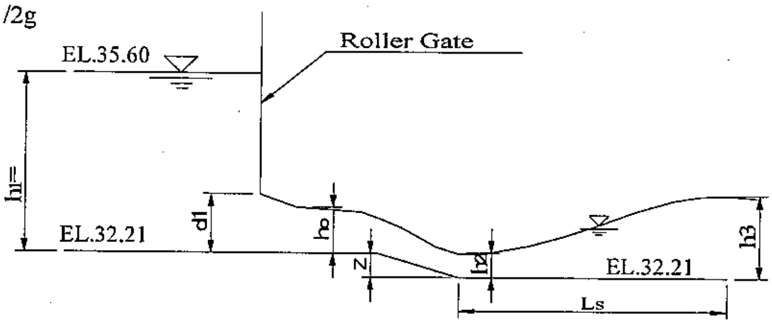
$h_3 = 1/2\ \{(1 + 8Fr^2)^{0.5} - 1\} \cdot h_2$

where: Fr = Froude number
$Fr = V_2/\sqrt{g \cdot h_2}$
V_2 = flow velocity (m/sec)

$h_0 + hv_0 + Z = h_2 + hv_2$

$hv_0 = V_0^2 / 2g$

$hv_2 = V_2^2 / 2g$



Numbers of gate =	2 nos.
Width of gate =	4.0 m
Height of gate =	5.0 m
Water level at upstream	EL. 35.60
Canal bed elevation at upstream	EL. 32.21
Canal bed elevation at downstream	EL. 32.21

Flood discharge (m^3/sec)	17.4	
Discharge per unit width in meter q1 (m^3/sec/m)	2.18	= 17.4 / 2 / 4.0
d (m)	0.42	
q2 by equation 1) (m^3/sec/m)	2.17	
h_1 (m)	3.39	
h_0 (m)	0.26	
V_0 (m/sec)	8.41	
hv_0 (m)	3.61	
Z (m)	0.00	
h_2 (m)	0.26	
V_2 (m/sec)	8.41	
hv_2 (m)	3.61	
Fr	5.283	
h_3 (m)	1.81	
$L = 4.5h_3$ (m)	8.13	
Length of stilling basin $=3h_3$	5.42	

(USBR Type III)

q1 - q2	(0.00)
$h_0 + ha_0 + Z$ ...(1)	3.867
$h_2 + ha_2$.......(2)	3.867
(1) - (2)	(0.000)

Vat Krouch Intake for South main canal

Energy Dissipater USBR III

Flood discharge	Q	=	17.4		m^3/s
Width of gate	B	=	4.0		m
	g	=	9.8		m^2/s
Velocity of incoming flow	V_2		8.41		m/s
Depth of incoming flow	h_2		0.259		m
Froude number	Fr	$= v / \sqrt{(g \cdot h_2)}$	5.283		
Depth of hydraulic jump	h_3	$= h_2/2 \times (\sqrt{(1+8F_r^2)}-1)$	1.807		m
Length of stilling basin	L	= 3 * h3	5.421	5.5	m
Chute block					
height	h_s	$= h_2$	0.259	0.30	m
width	W_s	$= h_2$	0.259	0.30	m
space between each blocks	S_s	$= h_2$	0.259	0.30	m
fractional space		$= h_2/2$	0.129	0.15	m
Baffle block					
height	h_b	$= (0.17 \cdot F_r + 0.6) \cdot h_2$	0.387	0.40	m
width	W_b	$= 0.75 \cdot h_b$	0.290	0.30	m
space	S_b	$= 0.75 \cdot hb$	0.290	0.30	m
fractional space		$= 0.375 \cdot h_b$	0.141	0.15	m
width of crest		$= 0.2 \cdot h_b$	0.080	0.10	m
space between chute block and baffle block		$= 0.8 \cdot h_2$	1.446	1.45	m
slope		= 1 : 1.0			
End sill					
height	h_e	$= (0.056 \cdot F_r + 1.0) \cdot h_2$	0.335	0.35	m
width of crest	W_e	$= 0.2 \cdot h_e$	0.070	0.10	m
slope		= 1 : 2.0			

Flow capacity of present approach channel of South main canal

1. Uniform flow calculation

Manning's formula

$V_1 = 1/n \cdot R^{2/3} \cdot I^{1/2}$

where, V_1 = flow velocity (m/sec)
n = roughness coefficient
R = hydraulic radius (m)
I = hydraulic gradient.

$Q = V_1 \cdot A$

where, Q = design discharge (m^3/sec)
A = flow area (m^2)

$n = \{1/\Sigma p\,(p_1 \cdot n_1^{3/2} + p_2 \cdot n_2^{3/2} + \cdots + pi \cdot ni^{3/2})\}^{2/3}$

pi = wetted perimeter (m)

Free board

$Fb = 0.05h + \beta \cdot hv + hw$

where, h = water depth (m)
β = coefficient = 1.0
hv = velocity head (m)
hw = free board for waving =0.10 m

Q = 13.58 (m^3/sec)
L = 1256 distance (m)
dh = 0.44 elevation difference of water surface
I = 0.00035 = 1/2,855.00
n_1 = 0.025 = roughness coefficient of side slope
n_2 = 0.025 = roughness coefficient of canal bed
n = 0.025
p_1= 12.2 m = wetted perimeter

water depth h_1 (m)	A (m^2)	R (m)	V_1 (m/s)	Q (m^3)	Free board (m)
3.00	15.450	1.272	0.879	13.58	0.29

Attachment IIB-2

Structural Calculation

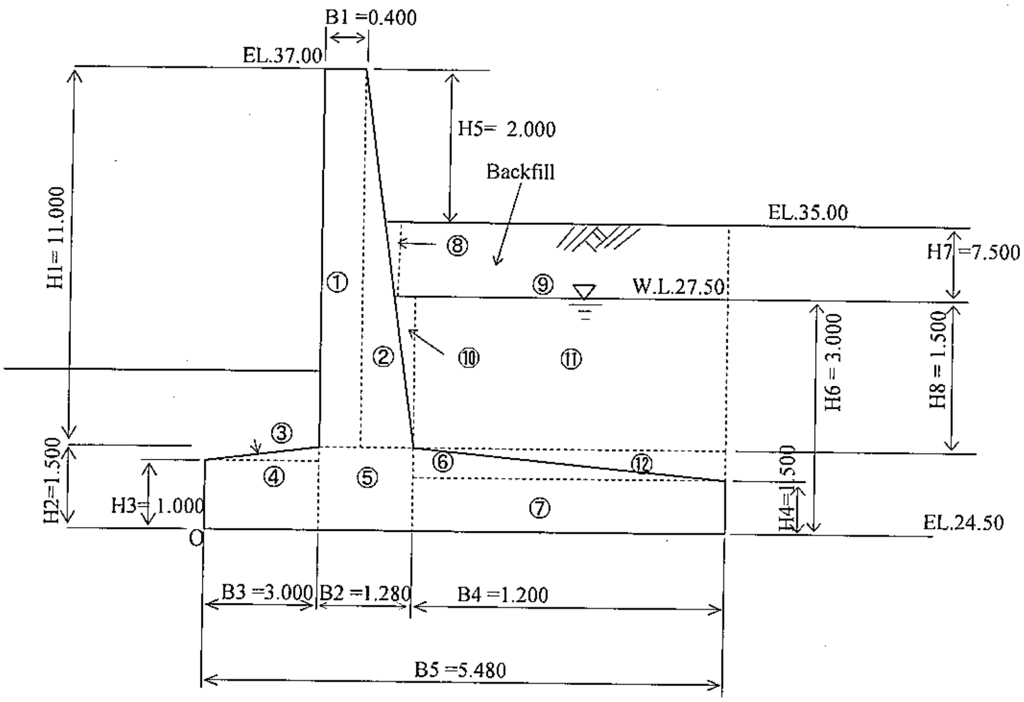
Structure Calculation of Retaining Wall at downstream abutment at Roleang Chrey Regulator

1. Design Condition

Unit Weight Reinforced concrete	γc	24.5	kN/m^3
Backfill (Wet)	γt	18.0	kN/m^3
Backfill (Saturated)	γsat	20.0	kN/m^3
Water	γw	10.0	kN/m^3
Internal friction angle of backfill	φ	35.000	°
Embanked Slope of Backfill	β	0.000	°
Live Load under normal condition		0.0	kN/m^2
under seismic condition		0.0	kN/m^2
Seismic coefficient	Kh	0.150	
Coefficient of friction	f	0.700	tan(35°)
Sheering strength of foundation	τ	350.0	kN/m^2
Bearing Capacity of foundation	qa	600.0	kN/m^2

Design strength of concrete	σck	21	N/mm^2
Yielding point of reinforcement bar	σsy	300.0	N/mm^2
Allowable stress			
Tensile Stress (reinforcing bar)	σsa	157.0	N/mm^2
Compressive Stress (concrete)	σca	8.0	N/mm^2
Shearing Stress (concrete)	τa	0.42	N/mm^2
Adhesive Stress	τoa	1.5	N/mm^2
Young's modulus	n	15	
Coefficient of Passive erath pressure		0	
(CM,CL)			
(CM class)			

2. Dimensions



H1 =	11.000	m
H2 =	1.500	m
H3 =	1.000	m
H4 =	1.500	m
B1 =	0.400	m
B2 =	1.280	m
B3 =	3.000	m
B4 =	1.200	m
B5 =	5.480	m

H5 =	2.000	m
H6 =	3.000	m
H7 =	7.500	m
H8 =	1.500	m

Slope of Wall (Back side) 0.080

Covering depth of reinforcement bar (m)

Vertical wall	0.07
Invert (bottom slab)	0.10

3. Coefficient of Earth Pressure Ka

(1) Coefficient of active earth pressure

Coulomb's Formula shall be applied for calculation of earth pressure.

$$Ka = \frac{\cos^2(\phi - \alpha - \theta)}{\cos\theta \cdot \cos^2\alpha \cdot \cos(\alpha + \delta + \theta)\left\{1 + \sqrt{\frac{\sin(\phi+\delta)\cdot\sin(\phi-\beta-\theta)}{\cos(\alpha+\delta+\theta)\cdot\cos(\alpha-\beta)}}\right\}^2}$$

Where;
- Ka ; Coefficient of active earth pressure
- ϕ ; Internal friction angle =35°
- δ ; Angle of wall friction (wall and soil)
- α ; Wall angle to vertical surface
- β ; Slope angle of backfill
- θ ; $= \tan^{-1}Kh$
- Kh ; Horizontal seismic coefficient =0.15

1) Angle of wall friction (δ)

	Stability Analysis between soil and soil	Calculation of Member between concrete and soil
Under normal condition	β	$2/3 \cdot \phi$
	0 °	23.333 °
Under seismic condition	$\tan\delta = \frac{\sin\varphi \cdot \sin(\theta+\Delta-\beta)}{1-\sin\varphi\cdot\cos(\theta+\Delta-\beta)}$ $\sin\Delta = \frac{\sin(\beta+\theta)}{\sin\varphi}$	$1/2 \cdot \phi$
	25.77 °	17.5 °

		Stability Analysis		Calculation of Member	
		Under normal condition	Under seismic condition	Under normal condition	Under seismic condition
Internal friction angle	ϕ	35.00	35.00	35.00	35.00
Angle of wall friction	δ	0.00	25.77	23.33	17.50
Wall angle to vertical surface	α	0.00	0.00	4.57	4.57
Slope angle of backfill	β	0.00	0.00	0.00	0.00
$\tan^{-1}Kh$	θ	0.00	8.53	0.00	8.53

2) Coefficient of earth pressure for stability analysis under normal condition

$$Ka = \frac{\cos\text{^}2\ (35+0)}{\cos 0\text{^}2 \cdot \cos(0+0) \times \left\{1 + \sqrt{\frac{\sin(35+0)\cdot\sin(35-0.00)}{\cos(0+0)\cdot\cos(0-0.00)}}\right\}^2} = 0.271$$

- Coefficient of horizontal earth pressure Kah

Kah = Ka·cos(δ+α) = 0.271 · cos (0.00 + 0.00) = 0.271

- Coefficient of vertical earth pressure Kav

$Kav = Ka \cdot \sin(\delta+\alpha) \quad = 0.271 \cdot \sin\ (0.00 + 0.00) \quad = \quad 0.000$

The coefficient of earth pressure of every case shall be calculated by means above mentioned, and are shown in table below.

		Stability analysis	Calculation of member	Remarks
Under normal condition	Ka	0.271	0.278	
	Kah	0.271	0.246	$Ka \cdot \cos(\delta+\alpha)$
	Kav	0.000	0.130	$Ka \cdot \sin(\delta+\alpha)$
Under seismic condition	Ka	0.345	0.378	
	Kah	0.311	0.350	$Ka \cdot \cos(\delta+\alpha)$
	Kav	0.150	0.142	$Ka \cdot \sin(\delta+\alpha)$

(2) Coefficient of passive earth pressure

$$Kp = \frac{\cos^2(\phi+\alpha-\theta)}{\cos\theta \cdot \cos^2\alpha \cdot \cos(\alpha-\delta-\theta)\left\{1-\sqrt{\dfrac{\sin(\phi+\delta)\cdot\sin(\phi+\beta-\theta)}{\cos(\alpha-\delta-\theta)\cdot\cos(\alpha-\beta)}}\right\}^2}$$

where ; $\delta = 0$

		Stability analysis	Remarks
Under normal condition	Kp	3.690	
	Kph	3.690	$Ka \cdot \cos(\delta+\alpha)$
	Kpv	0.000	$Ka \cdot \sin(\delta+\alpha)$
Under seismic condition	Kp	3.391	
	Kph	3.391	$Ka \cdot \cos(\delta+\alpha)$
	Kpv	0.000	$Ka \cdot \sin(\delta+\alpha)$

4. Stability Analysis

(1) Self weight

		Area (m^2)	A	Unit Weight γ (kN/m^3)	Weight W(kN)	Remark
Reversed T type Wall	①	0.40 x 11.00	4.400	24.5	107.800	
	②	(1.28-0.40) x 11.00/2	4.840	24.5	118.580	
	③	(1.50-1.00) x 3.00/2	0.750	24.5	18.375	
	④	1.00 x 3.00	3.000	24.5	73.500	
	⑤	1.50 x 1.28	1.920	24.5	47.040	
	⑥	0	0.000	24.5	0.000	
	⑦	1.50 x 1.20	1.800	24.5	44.100	
Backfill	⑧	7.50 x 0.080 x 7.50/2	2.250	18.0	40.500	
	⑨	(1.50 x 0.080+1.20) x 7.50	9.900	18.0	178.200	
	⑩	1.50 x 0.08 x 1.50/2	0.090	20.0	1.800	
	⑪	1.50 x 1.20	1.800	20.0	36.000	
	⑫	0	0.000	20.0	0.000	
Total			30.750		665.895	

(2)Center of Gravity

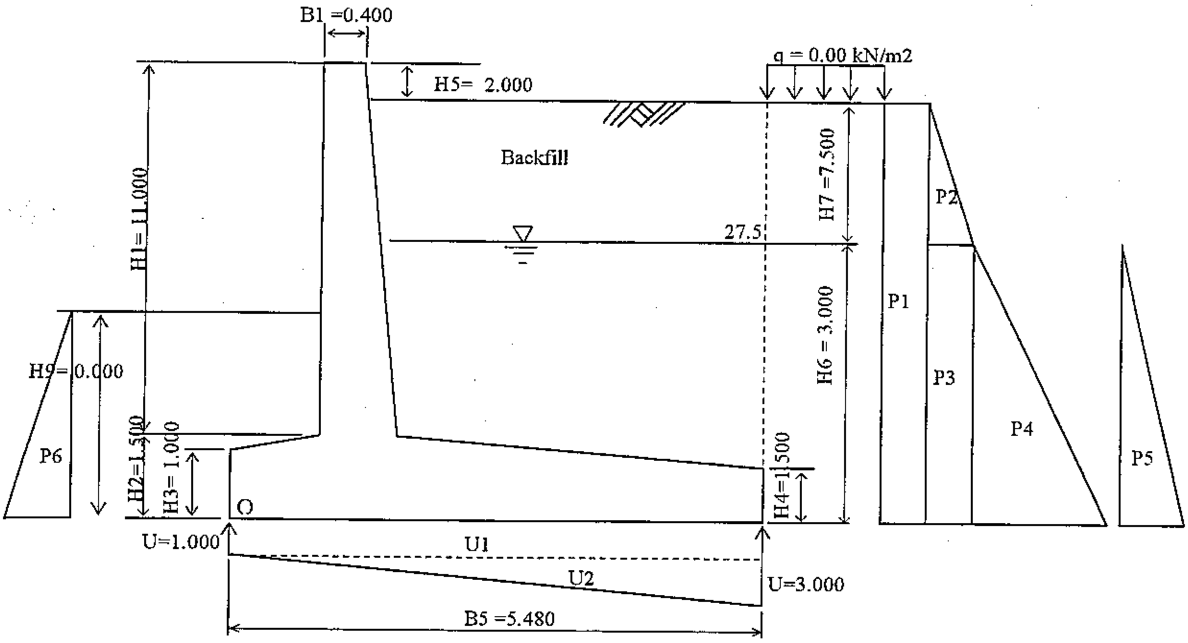
		Weight W(t)	Arm Length (m) X	Y	Moment(kN·m) W·x	W·y	Remark
Reversed T type Wall	①	107.800	3.200	7.000	344.960	754.600	
	②	118.580	3.693	5.167	437.916	612.703	
	③	18.375	2.000	1.167	36.750	21.444	
	④	73.500	1.500	0.500	110.250	36.750	
	⑤	47.040	3.640	0.750	171.226	35.280	
	⑥	0.000	4.680	1.500	0.000	0.000	
	⑦	44.100	4.880	0.750	215.208	33.075	
Backfill	⑧	40.500	3.960	8.000	160.380	324.000	
	⑨	178.200	4.820	6.750	858.924	1202.850	
	⑩	1.800	4.240	2.500	7.632	4.500	
	⑪	36.000	4.880	2.250	175.680	81.000	
	⑫	0.000	5.080	1.500	0.000	0.000	
	Total	665.895			2518.926	3106.202	

Center of Gravity

Xo = ΣW · x / ΣW
= 2518.926／665.895
= 3.783m

Yo = ΣW · y / ΣW
= 2518.926／665.895
= 4.665m

(3) Stability analysis under normal condition



1) Active earth pressure

Kah = 0.271

P1=q x (H6+H7) x Kah=	0.00 x (3.000 + 7.500) x 0.271 =	0.0 kN/m
P2= Kah x γt x $H7^2$ x 1/2 =	0.271 x 18.00 x 7.500^2 x 1/2 =	137.2 kN/m
P3= Kah x γt x H7 x H6 =	0.271 x 18.00 x 7.500 x 3.000 =	109.8 kN/m
P4= Kah x γsub x $H6^2$ x 1/2 =	0.271 x 10.00 x 3.000^2 x 1/2 =	12.2 kN/m

2) Passive earth pressure

Kph = 0.000

P6= Kph x γsub x $H9^2$ x 1/2 = 0.000 x 10.00 x 0.000^2 x 1/2 = 0.0 kN/m

3) Water pressure

P5= γw x $H6^2$ x 1/2 = 10.00 x 3.0^2 /2 = 45.0 kN/m

4) Uplift

U1=1.000 x 5.480 x 10.0 = 54.8 kN/m

U2 = (3.000-1.000) x 5.480 x 1/2 x 10.0 = 54.8 kN/m

		Force (kN/m)		Arm length(m)		Moment (kN.m)	
		Vertical(V)	Horizontal(H)	X	Y	Mx = V x X	My = H x Y
Self weight (Ws)		665.9	-	3.783	-	2518.9	-
Earth pressure	P1	-	0.0	-	5.250	-	0.0
	P2	-	137.2	-	5.500	-	754.6
	P3	-	109.8	-	1.500	-	164.6
	P4	-	12.2	-	1	-	12.2
	P6	-	0.0	-	0.333	-	0.0
Water pressure	P5	-	45.0	-	1	-	45.0
Up-Lift	U1	-54.8	-	2.740	-	-150.2	-
	U2	-54.8	-	3.653	-	-200.2	-
Total		556.3	304.1			2168.6	976.4

Length of bottom slab	B	5.480	m
Coefficient of friction	f	0.700	
Cohesion of foundation	τ	350.0	kN/m^2
Bearing capacity of foundation	qa	600.0	kN/m^2

5) Over turning

e = B / 2 - (ΣMx - ΣMy) / ΣV

= 5.480 / 2 -(2168.6 − 976.4) / 556.3 = 0.597m < B/6 =0.913 m -------- OK

6) Sliding

Fs = (f x ΣV + τ x B) / ΣH

= (0.700x556.3 + 350.0x5.480) / 304.1 = 7.587 > 1.50 -------- OK

7) Overstressing

q = ΣV / B x (1±6 e/ B)

= 556.3 / 5.480 x (1 ± 6 x 0.597 / 5.480) = 167.9 kN/m2 (max) < 600.0 kN/m2 ------- OK

35.2 kN/m2 (min)

(4) Stability analysis under seismic condition

1) Active earth pressure

- Horizontal earth pressure -

Kah = 0.311

P2= Kah x γt x $H7^2/2$ = 0.311 x 18.00 x 7.500^2 x 1/2 = 157.4 kN/m

P3= Kah x γt x H7 x H6 = 0.311 x 18.00 x 7.500 x 3.000 = 126.0 kN/m

P4= Kah x γsub x $H6^2$ /2 = 0.311 x 10.00 x 3.000^2 x 1/2 = 14.0 kN/m

- Vertical earth pressure -

Kav = 0.150

P2= Kav x γt x $H7^2/2$ = 0.150 x 18.00 x 7.500^2 x 1/2 = 75.9 kN/m

P3= Kav x γt x H7 x H6 = 0.150 x 18.00 x 7.500 x 3.000 = 60.8 kN/m

P4= Kav x γsub x $H6^2$ /2 = 0.150 x 10.00 x 3.000^2 x 1/2 = 6.8 kN/m

2) Passive earth pressure

- Horizontal earth pressure -

Kph = 0.000

P6= Kph x γsub x $H9^2$ x 1/2 = 0.000 x 10.000 x 0.000^2 x 1/2 = 0.0 kN/m

3) Water pressure

P5= γw x $H6^2$ /2 = 10.00 x 3.0^2 /2 = 45.0 kN/m

4) Seismic force F = Ws x Kh = 665.895 x 0.15 = 99.9 kN/m

5) Uplift U1= 54.8 kN/m

U2= 54.8 kN/m

		Force (kN/m)		Arm length(m)		Moment (kN.m)	
		Vertical(V)	Horizontal(H)	X	Y	Mx = V x X	My = H x Y
Self weight(Ws)		665.9	99.9	3.783	4.665	2518.9	465.9
Earth pressure	P2	75.9	157.4	5.480	5.500	416.1	865.9
	P3	60.8	126.0	5.480	1.500	332.9	188.9
	P4	6.8	14.0	5.480	1.000	37.0	14.0
	P6	-	0.0	-	0.333	-	0.0
Water pressure	P5	-	45.0	-	1.000	-	45.0
Uplift	U1	-54.8	-	2.740	-	-150.2	-
	U2	-54.8	-	3.653	-	-200.2	-
Total		699.7	442.3			2954.6	1579.8

Length of bottom slab	B	5.480	m
Coefficient of friction	f	0.700	
Cohesion of foundation	τ	350.0	kN/m^2
Bearing capacity of foundation	qa	900.0	kN/m^2

6) Over turning

X = (ΣMx - ΣMy) / ΣV = 1.965m

e = B / 2 - (ΣMx - ΣMy) / ΣV

= 5.480 / 2 -(2954.6－1579.8) / 699.7 = 0.775m < B/3 =1.827 m -------- OK

7) Sliding

Fs = (f x ΣV + τ x B) / ΣH

= (0.700x699.7 + 350.000x5.480) / 442.3 = 5.444 > 1.20 -------- OK

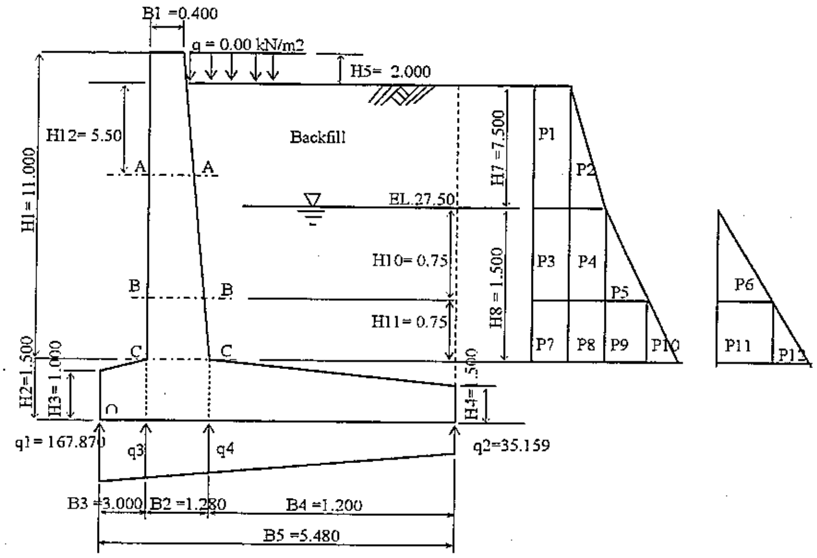
8) Ground reaction

q = ∑V / B x (1±6 e/ B)

= 699.7 / 5.480 x (1 ± 6 x 0.775 / 5.480) = 236.0 kN/m2 (max) < 900.0 kN/m2 ------- OK

19.3 kN/m2 (min)

5. Structural calculation

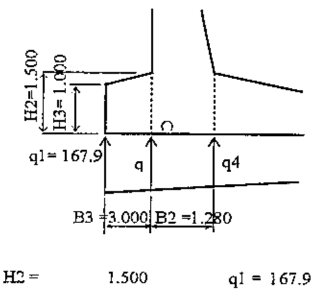


(1) Bending moment and Sheering strength

a) Vertical Wall

		Coefficient of earth pressure Kah	Unit weight γ (kN/m³)	Horizontal force H (kN/m)	Arm length (m) A-A	B-B	C-C	Bending moment (kN.m) A-A	B-B	C-C	Sheering strength (kN/m) A-A	B-B	C-C
Earth pressure	P1	0.246	-	0.000	3.750	4.500	5.250	0.000	0.000	0.000	0.000	0.000	0.000
	P2	0.246	18.000	66.974	1.833	-	-	122.763	-	-	66.974	-	-
				124.538	-	3.250	4.000	-	404.749	498.152	-	124.538	124.538
	P3	0.246	-	0.000	-	0.375	1.125	-	0.000	0.000	-	0.000	0.000
	P4	0.246	18.000	24.908	-	0.375	1.125	-	9.341	28.022	-	24.908	24.908
	P5	0.246	10.000	0.692	-	0.250	1.000	-	0.173	0.692	-	0.692	0.692
Water pressure	P6	-	10.000	2.813	-	0.250	1.000	-	0.703	2.813	-	2.813	2.813
Earth pressure	P7	0.246	-	0.000	-	-	0.375	-	-	0.000	-	-	0.000
	P8	0.246	18.000	24.908	-	-	0.375	-	-	9.341	-	-	24.908
	P9	0.246	10.000	1.384	-	-	0.375	-	-	0.519	-	-	1.384
	P10	0.246	10.000	0.692	-	-	0.250	-	-	0.173	-	-	0.692
Water pressure	P11	-	10.000	5.625	-	-	0.375	-	-	2.109	-	-	5.625
	P12	-	10.000	2.813	-	-	0.250	-	-	0.703	-	-	2.813
Total								122.763	414.966	542.524	66.974	152.951	188.373

b) Toe of bottom slab



H2 =	1.500	q1 =	167.9
B3 =	3.000	q2 =	35.2
B5 =	5.480	q3 =	95.2

- Sheering strength -

Self weight W = (1.500 + 1.000) x 1/2 x 3.000 x 24.5 = -91.9 kN/m

Ground reaction q = (167.9+95.2) x 1/2 x 3.000 = 394.6 kN/m

Total 302.8 kN/m

- Bending moment -

Self weight M1 = (1.500-1.000) x 3.000x 1/2 x 24.5 x 3.000 x1/3

= -18.4 kN.m

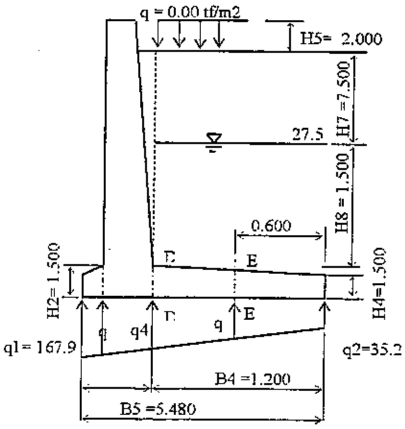
M2 = 1.000 x 3.000 x 24.5 x 3.000 x 1/2 = -110.3 kN.m

Ground reaction M3 = 95.2 × 3.000^2 ÷ 2 = 428.5 kN.m

M4 = (167.9-95.2) x 3.000^2 x 1/3= 218.0 kN.m

Total 517.8 kN.m

c) Heel of bottom slab



H2 =	1.500	q1 =	167.9
B4 =	1.200	q2 =	35.2
B5 =	5.480	q4 =	64.2
H4 =	1.500	q5 =	49.7
Q =	0.000		

Section D - D

- Sheering strength -

Self weight	W1 = (1.500 + 1.500) x 1/2 x 1.200 x 24.5 =	-44.1 kN/m
Backfill	W2 = 7.500 x 1.200 x 18.0 =	-162.0 kN/m
	W3 = 1.500 x 1.200 x 20.0 =	-36.0 kN/m
	W4 = 0.000 x 1.200 x 1/2 x20.0 =	0.0 kN/m
Live load	Q = 1.200 x 0.00 =	0.0 kN/m
Ground reaction	q = (35.2+64.2) ÷2×1.200 =	59.6 kN/m
	Total	-182.5 kN/m

- Bending moment -

Self weight	M1 = 1.500 x 1.200 x 24.5 x 1.200x 1/2 =	-26.5 kN.m
	M2 = 0.000x1.200x 1/2 x 24.5x1.200x 1/3 =	0.0 kN.m
Backfill	M3 = -162.0 x 1.200 x 1/2 =	-97.2 kN.m
	M4 = -36.0 x 1.200 x 1/2 =	-21.6 kN.m
	M5 = 0.0 x 1.200 x 2/3 =	0.0 kN.m
Live load	M6 = 0.0 x 1.200 x 1/2 =	0.0 kN.m
Ground reaction	M7 = 35.2 × 1.200^2 ÷ 2 =	25.3 kN.m
	M8 = (64.2-35.2) x 1.200^2 x 1/2 x 1/3 =	7.0 kN.m
	Total	-113.0 kN.m

Section E -E

- Sheering strength -

Self weight	-22.1
Backfill	-99
Live load	0.0
Ground reaction	25.5
Total	-95.6 kN/m

- Bending moment -

Self weight	-6.615
Backfill	-29.7
Live load	0
Ground reaction	7.2
Total	-29.1 kN.m

	Vertical wall			Toe of bottom slab	Heel of bottom slab	
	A-A	B-B	C-C		D-D	E-E
Bending moment (kN.m)	122.8	415.0	542.5	517.8	-113.0	-29.1
Sheering strength (kN/m)	67.0	153.0	188.4	302.8	-182.5	-95.6

(2) Bar arrangement

			Vertical wall			Toe of bottom slab	Heel of bottom slab	
			A-A	B-B	C-C		D-D	E-E
Allowable Stress	Tensile Stress (reinforcing bar)	σsa (N/mm²)	157.0	157.0	157.0	157.0	157.0	157.0
	Compressive Stress (concrete)	σca (N/mm²)	8.0	8.0	8.0	8.0	8.0	8.0
	Shearing Stress	τa (N/mm²)	0.42	0.42	0.42	0.42	0.42	0.42
	Adhesive Stress	τoa (N/mm²)	1.50	1.50	1.50	1.50	1.50	1.50
	Neutral axis ratio	k=n·σca/(n·σca+σsa)	0.433	0.433	0.433	0.433	0.433	0.433
		j=1-3/k	0.856	0.856	0.856	0.856	0.856	0.856
	Young's modulus	n	15	15	15	15	15	15
	Width of member	B (m)	1.00	1.00	1.00	1.00	1.00	1.00
Section force	Bending moment	M (kN·m)	122.8	415.0	542.5	517.8	113.0	29.1
	Axial force	N (kN)	0.0	0.0	0.0	0.0	0.0	0.0
	Shearing force	S (kN)	67.0	153.0	188.4	302.8	182.5	95.6
	Thickness of member	h (m)	1.00	1.22	1.28	1.50	1.50	1.50
	Protective covering	d1 (m)	0.07	0.07	0.07	0.10	0.10	0.10
	Coefficient of required thickness of member	$C1=(2/(\sigma ca \cdot k \cdot j))^{0.5}$	0.26	0.26	0.26	0.26	0.26	0.26
	coefficient of bar arrangement	$C2=\sigma ca/(2*\sigma sa)*((6*n)/(2*n*\sigma ca+3*\sigma sa))^{0.5}$	0.0029	0.0029	0.0029	0.0029	0.0029	0.0029
	Effective height	d(m)=h-d1	0.93	1.15	1.21	1.40	1.40	1.40
	Eccentric distance	e(m)=M/N	0.000	0.000	0.000	0.000	0.000	0.000
	Active moment	M1 (kN·m)=M+N·(d-h/2)	122.8	415.0	542.5	517.8	113.0	29.1
	Resisting moment	$M2\ (kN \cdot m)=0.5 \cdot \sigma ca \cdot k \cdot j \cdot B \cdot d^2$	1282.3	1960.7	2170.7	2905.9	2905.9	2905.9
	Compression bar content	As'(cm²)	0	0	0	0	0	0
	Tension bar content	As (cm²)=M1/(σsa·j·d)-N/σsa	9.82	26.85	33.36	27.52	6.00	1.55
	Required thickness of member	$d'(m)=C1 \cdot (M1/B)^{0.5}$	0.288	0.530	0.606	0.592	0.276	0.140
Bar arrangement	arrangement position		back	back	back	lower side	upper surface	upper surface
	Content of required reinforcement As (cm²)	M/(σsa·j·d)	9.82	26.85	33.36	27.52	6.00	1.55
	Bar arrangement	Diameter D (mm)	19	25	25	22	16	13
		Spacing (cm)	30	15	15.0	15	30.0	30
			D19 @ 30	D25 @ 15	D25 @ 15.0	D22 @ 15	D16 @ 30.0	D13 @ 30
	Reinforcement content As (cm2)		9.45	32.73	32.73	25.34	6.70	4.42
	Total perimeter U(cm)		19.90	52.36	52.36	46.08	16.76	13.61
Coefficient		$x=-n \cdot As/B+((n \cdot As/B)^2+2n/B \cdot As \cdot d)^{1/2}$	14.88	29.05	29.91	29.04	15.80	12.98
	Steel ratio	p=As/(B·d)	0.00102	0.00285	0.00270	0.00181	0.00048	0.00032
	Neutral axis ratio	$k=((n \cdot p)^2+2 \cdot n \cdot p)^{0.5}-n \cdot p$	0.160	0.253	0.247	0.207	0.113	0.093
		j=1-k/3	0.947	0.916	0.918	0.931	0.962	0.969
Calculation of stress	Tensile stress	σs =n·σc·(d-x)/x (N/mm²)	147.6 OK	120.4 OK	149.3 OK	156.8 OK	125.1 OK	48.5 OK
	Compressive stress	σc = M/(B·x/2·(d-x/3)) (N/mm²)	1.87 OK	2.71 OK	3.27 OK	2.74 OK	1.06 OK	0.33 OK
	Shearing stress	τ = S/(b·j·d) (N/mm²)	0.08 OK	0.15 OK	0.17 OK	0.23 OK	0.14 OK	0.07 OK
	Adhesive stress	τo = S/(U·j·d) (N/mm²)	0.38 OK	0.28 OK	0.32 OK	0.50 OK	0.81 OK	0.52 OK

STRUCTURAL CALCULATION OF BOX CULVERT

Type: B1.00m x H1.00m x 2 T-14 Load
Soil Cover Depth: 7.5 m

Dimensions and Parameters

Basic Parameters

Ka:	Coefficient of static earth pressure	0.5	
γw:	Unit weight of water	10.0	kN/m^3
γt:	Unit weight of soil (dry)	18.0	kN/m^3
γsat:	Unit weight of soil (saturated)	20.0	kN/m^3
γc:	Unit weight of reinforced concrete	24.5	kN/m^3
σck:	Concrete Design Strength	21.0	N/mm^2
σca	Allowable Compressive Stress of Concrete	8.0	N/mm^2
τa:	Allowable Shearing Stress of Concrete	0.42	N/mm^2
σsy:	Yielding Point of Reinforcement Bar	300	N/mm^2
σsa:	Allowable Tensile Stress of Reinforcement Bar	157	N/mm^2
n:	Young's Modulus Ratio	15	
Fa:	Safety factor against uplift	1.2	

Basic Conditions

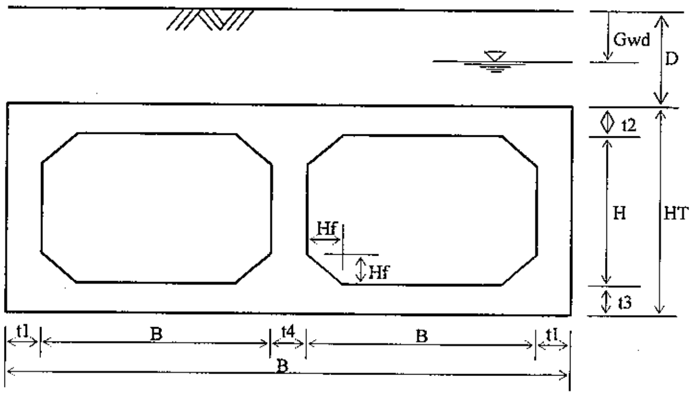
	Classification of Live load by truck	T - 14	
PTR:	Truck load of Rear tire	55.00	kN
Ii:	Impact coefficient (D≧4.0m:0, D<4.0m:0.3)	0	
am:	Ground contact length of Rear Tire	0.20	m
bm:	Ground contact width of Rear Tire	0.50	m
PTF:	Truck load of Front tire	13.50	kN
ar:	Ground contact length of Front Tire	0.20	m
br:	Ground contact width of Front Tire	0.50	m
Q:	Surcharge load	0.00	kN/m^2

Basic Dimensions

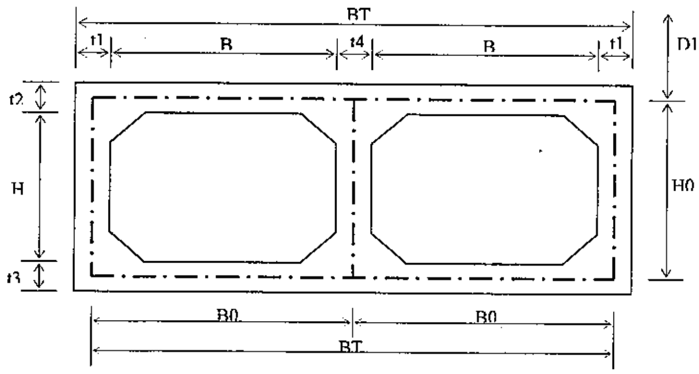
H:	Internal Height of Box Culvert		1.00	m	
B:	Internal Width of Each Box Culvert		1.00	m	
Hf:	Fillet Height		0.15	m	
t1:	Thickness of Side Wall		0.30	m	($\geq$ 0.25m)
t2:	Thickness of Top Slab		0.30	m	($\geq$ 0.25m)
t3:	Thickness of Invert (Bottom Slab)		0.30	m	($\geq$ 0.25m)
t4:	Thickness of Partition wall		0.40	m	($\geq$ 0.25m)
BT:	Gross Width of Box Culvert		3.00	m	
HT:	Gross Height of Box Culvert		1.60	m	
D:	Earth covering depth		7.50	m	($\geq$ 0.5m)
Gwd:	Underground Water Depth	for Case 1, 2	7.50	m	(= D)
hiw:	Internal Water Depth	for Case 1, 2	0.00	m	
		for Case 3, 4	1.00	m	

Cover depth of R-bar

Side Wall d1	0.07	m
Top Slab d2	0.07	m
Bottom Slab d3	0.10	m
Partition Wall d4	0.07	m

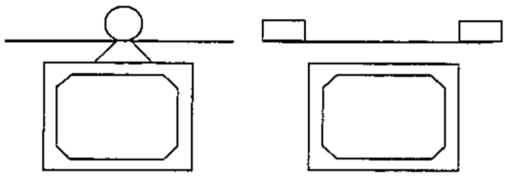


dimensions of frame



H0:	Height of frame	t2/2 + H + t3/2	1.300	m
BT0:	Width of whole frame	2B + t1 + t4	2.700	m
D1:	Covering depth at middle of top slab	D + t2/2	7.650	m
B0:	Width of each conduit	B+t1/2+t4/2	1.350	m

Load distribution of truck tire



(1) Middle tire's acting point: center of the top slab

a) distributed load of rear tire

Pvtm:	distributed load of middle tire	2PTM(1+Ii)/(am'bm') =	0.420 kN/m^2,	B = 2.700 m
ar':	length of distributed load	2D+1.75+bm =	17.250 m	
br':	width of distributed load	2D+am =	15.200 m	

b) distributed load of front tire

Pvtf:	distributed load of front tire	2PTF(1+Ii)/(af'bf')	0.107 kN/m^2,	B = 2.700 m
af':	length of distributed load	2D+1.75+bf =	16.750 m	
bf':	width of distributed load	2D+af =	15.000 m	

(4) Combination of load distribution of truck tire

Case.L1:	Rear tire	Pvt1 = 0.420 kN/m^2,	B = 2.700 m	
	Front tire	Pvt2 = 0.107 kN/m^2,	B = 2.700 m	
Case.L2:		Wel = 7.000 kN/m^2,	(if T-25, Wel=10kN/m^2, if T-14 or 10, Wel = 7kN/m^2)	

Classification of Live load by truck T-25

In the case of covering depth (D) is over 4.0m, uniform load of 10 kN/m^2 is applied on the top slab of culvert instead of live load calculated above.

Classification of Live load by truck T-14, T-10

In the case of covering depth (D) is over 3.5m, uniform load of 7.0 kN/m^2 is applied on the top slab of culvert instead of live load calculated above.

Stability Analysis Against Uplift

Analysis is made considering empty inside of box culvert.

Fs=Vd/U > Fa		Fs=	9.913 > 1.2 ok		
where, Vd:	Total dead weight (t/m)	Vd=	475.805 kN/m		
U:	Total uplift (t.m)				
	U=BT*HT*γw	U=	48.000 kN/m		
Ws:	Weight of covering soil	Ws =	BT*{(D-Gwd)*γsat+Gwd*γτ}	=	405.000 kN/m
Wc:	Self weight of box culvert	Wc =	(HT*BT-2*H*B+4*Hf^2)*γc	=	70.805 kN/m
Fa:	Safety factor against uplift	Fa=	1.2		

Load calculation

Case 1: Box Culvert Inside is Empty, Underground Water up to Top slab, Track load Case. L1

1) vertical load against top slab

Acting Load			(kN/m2)
Self weight	Wtop= (t2*BT+2*Hf^2)*γc/BT0	Wtop=	8.575
Soil on top slab	Pvd=Gwd*gt+(D-Gwd)*gsat	Pvd=	135.000
Surcharge load		Q=	0.000
		Pv1=	143.575

Acting Load			(kN/m2)
Traffic load	Pvt1	Pvt1=	7.000
	Pvt2	Pvt2=	0.000
		Pv2=	7.000

2) horizontal load at top of side wall

Acting Load			(kN/m2)
Traffic load	P1=Ka*we1	P1=	3.500
Earth pressure	P2=Ka*gt*Gwd	P2=	67.500
	P3=Ka*(gsat-gw)*(D1-Gwd)	P3=	0.750
Surcharge load	P4=Ka*Q	P4=	0.000
Water pressure	P5=gw*(D1-Gwd)	P5=	1.500
		Ph1=	73.250

Horizontal pressure by track tire
we1= 7.000 kN/m^2,

3) horizontal load at bottom of side wall

Acting Load			(kN/m2)
Traffic load	P1=Ka*we1	P1=	3.500
Earth pressure	P2=Ka*γτ*Gwd	P2=	67.500
	P3=Ka*(γsat-γw)*(D1+H0-Gwd)	P3=	7.250
Surcharge load	P4=Ka*Q	P4=	0.000
Water pressure	P5=γw*(D1+H0-Gwd)	P5=	14.500
		Ph2=	92.750

4) self weight of side wall and partition wall

Acting Load			(kN/m)
Side wall	Wsw=t1*H*γc	Wsw=	7.350
Partition wall	Wpw=t4*H*γc	Wpw=	9.800

5) ground reaction

Acting Load				(kN/m2)
Self weight	invert	Wbot=(t3*BT+2*Hf^2)*γc/BT0	Wbot=	8.575
	top slab	Wtop	Wtop=	8.575
	side and partition wall	Ws=(Wsw*2+Wpw)/BT0	Ws=	9.074
Soil on top slab		Pvd	Pvd=	135.000
Traffic load		Pvt1	Pvt1=	7.000
		Pvt2	Pvt2=	0.000
Surcharge load		Q	Q=	0.000
Internal water		Wiw=2*(hiw*B-2Hf^2)*γw/BT0	Wiw=	0.000
Uplift		Up=-U/BT0	U=	-17.778
			Q=	150.446

hiw: internal water depth 0.00 m

summary of resistance moment

Item		V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/m)
Self weight	top slab	23.153	-	1.350	-	31.256
	side wall (left)	7.350	-	0.000	-	0.000
	side wall (right)	7.350	-	2.700	-	19.845
	partition wall	9.800	-	1.350	-	13.230
	invert	23.153	-	1.350	-	31.256
Load on top slab	Pvd	364.500	-	1.350	-	492.075
	Pvt1	18.900	-	1.350	-	25.515
	Pvt2	0.000	-	1.350	-	0.000
Surcharge load	Q	0.000	-	1.350	-	0.000
Holizontal pressure	side wall (left)	-	107.900	-	0.625	67.389
	side wall (right)	-	#######	-	0.625	-67.389
Internal water pressure		0.000	-	1.350	-	0.000
Uplift		-48.000	-	1.350	-	-64.800
total		406.205				548.377

acting point of resultant force
X = ΣM/ΣV = 1.350 m
e = BT0/2 - X = 0.000 m

ground reaction
q1 = ΣV/BT0 + 6ΣVe/BT0^2 150.446 kN/m^2,
q2 = ΣV/BT0 - 6ΣVe/BT0^2 150.446 kN/m^2,

6) load against invert

(without self weight of bottom slab, internal water and uplift)

Acting Load		(kN/m2)
Soil on top slab	Pvd	135.000
Traffic load	Pvt1	7.000
	Pvt2	0.000
Surcharge load	Q	0.000
Self weight of top slab	Wtop	8.575
Self weight of side wall	Ws	9.074
	Pq=	159.649

Case 2: Box Culvert Inside is Empty, Underground Water up to Top slab, Track load Case. L2

1) **vertical load against top slab**

Acting Load			(kN/m2)
Self weight	Wtop= (t2*BT+2*Hf^2)*γc/BT0	Wtop=	8.575
Soil on top slab	Pvd=Gwd*gd+(D-Gwd)*gs	Pvd=	135.000
		Pv1=	143.575

Acting Load			(tf/m2)
Traffic load	Pvt1	Pvt1=	0.000
	Pvt2	Pvt2=	0.000
		Pv2 =	0.000

2) **horizontal load at top of side wall**

Acting Load			(kN/m2)
Traffic load	P1=Ka*we1	P1=	3.500
Earth pressure	P2=Ka*gt*Gwd	P2=	67.500
	P3=Ka*(gsat-gw)*(D1-Gwd)	P3=	0.750
Water pressure	P4=gw*(D1-Gwd)	P4=	1.500
		Ph1=	73.250

Horizontal pressure by track tire
we1= 7.000 kN/m^2,

3) **horizontal load at bottom of side wall**

Acting Load			(kN/m2)
Traffic load	P1=Ka*we1	P1=	3.500
Earth pressure	P2=Ka*γτ*Gwd	P2=	67.500
	P3=Ka*(γsat-γw)*(D1+H0-Gwd)	P3=	7.250
Water pressure	P4=γw*(D1+H0-Gwd)	P4=	14.500
		Ph2=	92.750

4) **self weight of side wall and partition wall**

Acting Load			(kN/m)
Side wall	Wsw=t1*H*γc	Wsw=	7.350
Partition wall	Wpw=t4*H*γc	Wpw=	9.800

5) **ground reaction**

Acting Load				(kN/m2)
Self weight	invert	Wbot=(t3*BT+2*Hf^2)*γc/BT0	Wbot=	8.575
	top slab	Wtop	Wtop=	8.575
	side and partition wall	Ws=(Wsw*2+Wpw)/BT0	Ws=	9.074
Soil on top slab		Pvd	Pvd=	135.000
Traffic load		Pvt1	Pvt1=	0.000
		Pvt2	Pvt2=	0.000
Internal water		Wiw=2*(hiw*B-2Hf^2)*γw/BT0	Wiw=	0.000
Uplift		Up=-U/B0	U=	-17.778
			Q=	143.446

hiw: internal water depth 0.00 m

summary of resistance moment

Item		V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/m)
Self weight	top slab	23.153	-	1.350	-	31.256
	side wall (left)	7.350	-	0.000	-	0.000
	side wall (right)	7.350	-	2.700	-	19.845
	partition wall	9.800	-	1.350	-	13.230
	invert	23.153	-	1.350	-	31.256
Load on top slab	Pvd	364.500	-	1.350	-	492.075
	Pvt1	0.000	-	1.350	-	0.000
	Pvt2	0.000	-	1.350	-	0.000
Holizontal pressure	side wall (left)	-	107.900	-	0.625	67.389
	side wall (right)	-	#######	-	0.625	-67.389
Internal water pressure		0.000	-	1.350	-	0.000
uplift		-48.000	-	1.350	-	-64.800
total		387.305				522.862

acting point of resultant force
X = ΣM/ΣV = 1.350 m
e = BT0/2 - X = 0.000 m

ground reaction
q1 = ΣV/BT0 + 6ΣVe/BT0^2 143.446 kN/m^2,
q2 = ΣV/BT0 - 6ΣVe/BT0^2 143.446 kN/m^2,

6) **load against invert**

Acting Load		(kN/m2)
Soil on top slab	Pvd	135.000
Traffic load	Pvt1	0.000
	Pvt2	0.000
Self weight of top slab	Wtop	8.575
Self weight of side wall	Ws	9.074
	Pq=	152.649

(without self weight of bottom slab, internal water and uplift)

Case 3: Box Culvert Inside is Full, Underground Water up to invert, Track load Case. L1

1) vertical load against top slab

Acting Load			(kN/m2)
Self weight	Wtop= (t2*BT+2*Hf^2)*γc/BT0	Wtop=	8.575
Soil on top slab	Pvd=Gwd*gt+(D-Gwd)*gsat	Pvd=	135.000
Surcharge load		Q=	0.000
		Pv1=	143.575

Acting Load			(kN/m2)
Traffic load	Pvt1	Pvt1=	7.000
	Pvt2	Pvt2=	0.000
		Pv2=	7.000

2) horizontal load at top of side wall

Acting Load			(kN/m2)
Traffic load	P1=Ka*we1	P1=	3.500
Earth pressure	P2=Ka*γt*D1	P2=	68.850
Surcharge load	P3=Ka*Q	P3=	0.000
Internal water pressure	WP=-γw*0	P4=	0.000
		Ph1=	72.350

Horizontal pressure by track tire
we1= 7.000 kN/m^2,

3) horizontal load at bottom of side wall

Acting Load			(kN/m2)
Traffic load	P1=Ka*we1	P1=	3.500
Earth pressure	P2=Ka*γd*(D1+H0)	P2=	80.550
Surcharge load	P3=Ka*Q	P3=	0.000
Internal water pressure	WP=-γw*H	P4=	-10.000
		Ph2=	74.050

4) self weight of side wall

Acting Load			(kN/m)
Side wall	Wsw=t1*H*γc	Wsw=	7.350
Partition wall	Wpw=t4*H*γc	Wpw=	9.800

5) ground reaction

Acting Load				(kN/m2)
Self weight	invert	Wbot=(t3*BT+2*Hf^2)*γc/BT0	Wbot=	8.575
	top slab	Wtop	Wtop=	8.575
	side and partition wall	Ws=(Wsw*2+Wpw)/BT0	Ws=	9.074
Soil on top slab		Pvd	Pvd=	135.000
Traffic load		Pvt1	Pvt1=	7.000
		Pvt2	Pvt2=	0.000
Surcharge load		Q	Q=	0.000
Internal water		Wiw=2*(hiw*B-2Hf^2)*γw/BT0	Wiw=	7.074
Uplift		Up=0	U=	0.000
			Q=	175.298

hiw: internal water depth 1.00 m

summary of resistance moment

Item		V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/m)
Self weight	top slab	23.153	-	1.350	-	31.256
	side wall (left)	7.350	-	0.000	-	0.000
	side wall (right)	7.350	-	2.700	-	19.845
	partition wall	9.800	-	1.350	-	13.230
	invert	23.153	-	1.350	-	31.256
Load on top slab	Pvd	364.500	-	1.350	-	492.075
	Pvt1	18.900	-	1.350	-	25.515
	Pvt2	0.000	-	1.350	-	0.000
Surcharge load	Q	0.000	-	1.350	-	0.000
Holizontal pressure	side wall (left)	-	95.160	-	0.647	61.615
	side wall (right)	-	-95.160	-	0.647	-61.615
Internal water pressure		19.100	-	1.350	-	25.785
Uplift		0.000	-	1.350	-	0.000
total		473.305				638.962

acting point of resultant force
X = ΣM/ΣV = 1.350 m
e = BT0/2 - X = 0.000 m

ground reaction
q1 = ΣV/BT0 + 6ΣVe/BT0^2 175.298 kN/m^2,
q2 = ΣV/BT0 - 6ΣVe/BT0^2 175.298 kN/m^2,

6) load against invert

Acting Load		(kN/m2)
Soil on top slab	Pvd	135.000
Traffic load	Pvt1	7.000
	Pvt2	0.000
Surcharge load	Q	0.000
Self weight of top slab	Wtop	8.575
Self weight of side and partition wall	Ws	9.074
	Pq=	159.649

(without self weight of bottom slab, internal water and uplift)

Case 4: Box Culvert Inside is Full, Underground Water up to invert, Track load Case. L2

1) vertical load against top slab

Acting Load			(kN/m2)
Self weight	Wtop= (t2*BT+2*Hf^2)*γc/BT0	Wtop=	8.575
Soil on top slab	Pvd=D*γt	Pvd=	135.000
		Pv1=	143.575

Acting Load			(kN/m2)
Traffic load	Pvt1	Pvt1=	0.000
	Pvt2	Pvt2=	0.000
		Pv2=	0.000

2) horizontal load at top of side wall

Acting Load			(kN/m2)
Traffic load	P1=Ka*we1	P1=	3.500
Earth pressure	P2=Ka*γt*D1	P2=	68.850
Internal water pressure	WP=-γw*0	P3=	0.000
		Ph1=	72.350

Horizontal pressure by track tire
we1= 7.000 kN/m²,

3) horizontal load at bottom of side wall

Acting Load			(kN/m2)
Traffic load	P1=Ka*we1	P1=	3.500
Earth pressure	P2=Ka*γt*(D1+H0)	P2=	80.550
Internal water pressure	WP=-γw*H	P3=	-10.000
		Ph2=	74.050

4) self weight of side wall

Acting Load			(kN/m)
Side wall	Wsw=t1*H*γc	Wsw=	7.350
Partition wall	Wpw=t4*H*γc	Wpw=	9.800

5) ground reaction

Acting Load				(kN/m2)
Self weight	invert	Wbot=(t3*BT+2*Hf^2)*γc/BT0	Wbot=	8.575
	top slab	Wtop	Wtop=	8.575
	side and partition wall	Ws=(Wsw*2+Wpw)/BT0	Ws=	9.074
Soil on top slab		Pvd	Pvd=	135.000
Traffic load		Pvt1	Pvt1=	0.000
		Pvt2	Pvt2=	0.000
Internal water		Wiw=(hiw*B-2Hf^2)*γw/BT0	Wiw=	7.074
Uplift		Up=0	U=	0.000
			Q=	168.298

hiw: internal water depth 1.00 m

summary of resistance moment

Item		V (kN/m)	H (kN/m)	x (m)	y (m)	M (kN.m/m)
Self weight	top slab	23.153	-	1.350	-	31.256
	side wall (left)	7.350	-	0.000	-	0.000
	side wall (right)	7.350	-	2.700	-	19.845
	partition wall	9.800	-	1.350	-	13.230
	invert	23.153	-	1.350	-	31.256
Load on top slab	Pvd	364.500	-	1.350	-	492.075
	Pvt1	0.000	-	1.350	-	0.000
	Pvt2	0.000	-	1.350	-	0.000
Holizontal pressure	side wall (left)	-	95.160	-	0.647	61.615
	side wall (right)	-	-95.160	-	0.647	-61.615
Internal water pressure		19.100	-	1.350	-	25.785
Uplift		0.000	-	1.350	-	0.000
total		454.405				613.447

acting point of resultant force
X = ΣM/ΣV = 1.350 m
e = BT0/2 - X = 0.000 m

ground reaction
q1 = ΣV/BT0 + 6ΣVe/BT0^2 168.298 kN/m²,
q2 = ΣV/BT0 - 6ΣVe/BT0^2 168.298 kN/m²,

6) load against invert

Acting Load		(kN/m2)
Soil on top slab	Pvd	135.000
Traffic load	Pvt1	0.000
	Pvt2	0.000
Self weight of top slab	Wtop	8.575
Self weight of side and partition wall	Ws	9.074
	Pq=	152.649

(without self weight of bottom slab, internal water and uplift)

Summary of Load Calculation

Case \ Item	Pv1 (kN/m2)	Pv2 (kN/m2)	Ph1 (kN/m2)	Ph2 (kN/m2)	Pq (kN/m2)	Wsw (kN/m)	Wpw (kN/m)	q1 (kN/m2)
Case.1	143.575	7.000	73.250	92.750	159.649	7.350	9.800	150.446
Case.2	143.575	0.000	73.250	92.750	152.649	7.350	9.800	143.446
Case.3	143.575	7.000	72.350	74.050	159.649	7.350	9.800	175.298
Case.4	143.575	0.000	72.350	74.050	152.649	7.350	9.800	168.298

4 Analysis of Plane Frame

Case 1: Box Culvert Inside is Empty, Underground Water up to Top slab, Track load Case. L1

1) Calculation of Load Term

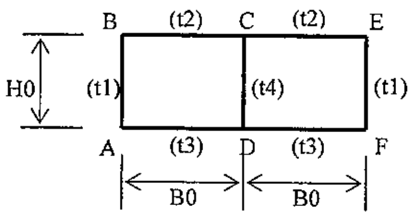
Ph1	Horizontal Pressure at top of side wall	73.250	kN/m^2
Ph2	Horizontal Pressure at bottom of side wall	92.750	kN/m^2
Ph3	Horizontal Pressure at top of side wall	73.250	kN/m^2
Ph4	Horizontal Pressure at bottom of side wall	92.750	kN/m^2
Pv1+Pv2	Vertical Pressure on top slab	150.575	kN/m^2
Q1=Pq	Reaction to bottom slab	159.649	kN/m^2
H0	Height of plane frame	1.300	m
B0	Width of plane frame	1.350	m
t1	Thickness of side wall	0.300	m
t2	Thickness of top slab	0.300	m
t3	Thickness of bottom slab	0.300	m
t4	Thickness of partition wall	0.400	m
γc	Unit weight of reinforcement concrete	24.500	kN/m^3
L1	Height of side wall	1.000	m

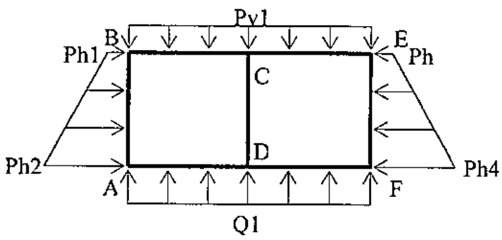
$C_{AB} = C_{FE} = (2Ph3+3Ph4)H_0^2/60$ = 11.964 kN.m

$C_{BA} = C_{EF} = (3Ph3+2Ph4)H_0^2/60$ = 11.415 kN.m

$C_{BC} = C_{CB} = C_{CE} = C_{EC} = Pv1B_0^2/12$ = 22.869 kN.m

$C_{DA} = C_{AD} = C_{FD} = C_{DF} = Q1B_0^2/12$ = 24.247 kN.m





2) Calculation of Bending Moment at joint

k1 = 1.0

$k2 = H0*t_2^3/(B0*t_1 =$ 0.963

$k3 = H0*t_3^3/(B0*t_1 =$ 0.963

$k4 = H0*t_4^3/(H0*t_1 =$ 2.370

As load has bilateral symmetry, the equation shown below is formed.

$\theta_A = -\theta_F$ $\theta_B = -\theta_E$ $\theta_C = \theta_D = 0$ R = 0

$$\begin{bmatrix} 2(k1+k3) & k1 & -3k3 \\ k1 & 2(k1+k2) & -3k2 \\ k3 & k2 & -2(k2+k3) \end{bmatrix} \begin{bmatrix} \theta_A \\ \theta_B \\ R \end{bmatrix} = \begin{bmatrix} C_{AB} - C_{AD} \\ C_{BC} - C_{BA} \\ C \end{bmatrix}$$

$R_{BC} = B0*Pv1 / 2 \quad = \quad 101.638$ kN

$P = t1*L1*\gamma c \quad = \quad 7.350$ kN/m

$C = [C_{BC} - C_{CB} + C_{DA} - C_{AD} + (R_{BC} - B0Q1/2 + P)B0]/3 \quad = \quad 0.551$ kN.m

$$\begin{bmatrix} 3.92593 & 1.00000 & -2.88889 \\ 1.00000 & 3.92593 & -2.88889 \\ 0.96296 & 0.96296 & -3.85185 \end{bmatrix} \begin{bmatrix} \theta_A \\ \theta_B \\ R \end{bmatrix} = \begin{bmatrix} -12.28291 \\ 11.45404 \\ 0.55125 \end{bmatrix}$$

By solving above equation, the result is led as shown below;

$\theta_A = -4.29411 \qquad R = -0.262010$

$\theta_B = 3.81852$

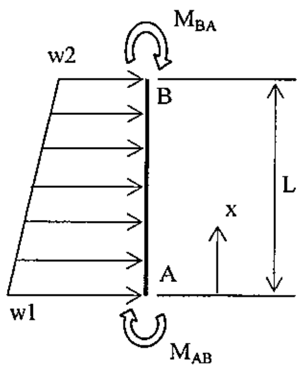
$M_{AB} = -M_{FE} = k1(2\theta_A + \theta_B) - C_{AB}$	=	-16.733 kN.m	
$M_{BA} = -M_{EF} = k1(2\theta_B + \theta_A) + C_{BA}$	=	14.757 kN.m	
$M_{BC} = -M_{EC} = k2(2\theta_B + \theta_C - 3R) - C_{BC}$	=	-14.757 kN.m	
$M_{CB} = -M_{CE} = k2(2\theta_C + \theta_B - 3R) + C_{CB}$	=	27.303 kN.m	
$M_{DA} = -M_{DF} = k3(2\theta_D + \theta_A - 3R) - C_{DA}$	=	-27.625 kN.m	
$M_{AD} = -M_{FD} = k3\ (2\theta_A + \theta_D - 3R) + C_{AD}$	=	16.733 kN.m	
$\Sigma M_A = M_{AB} + M_{AD}$	=	0.000 kN.m	o.k.
$\Sigma M_B = M_{BA} + M_{BC}$	=	0.000 kN.m	o.k.
$M_{CD} = k4(2\theta_C + \theta_{D)}$	=	0.000 kN.m	
$M_{DC} = k4(2\theta_D + \theta C_)$	=	0.000 kN.m	

2) Calculation of Design Force

2-1) Side Wall

a) Shearing Force at joint

w1	Load at end A	92.750	kN/m^2
w2	Load at end B	73.250	kN/m^2
M_{AB}	Bending moment at end A	-16.733	kN.m
M_{BA}	Bending moment at end B	14.757	kN.m
L	Length of member	1.300	m
ch	Protective covering height	0.070	m
t	Thickness of member (height)	0.300	m
d	Effective height of member	0.230	m



$S_{AB} = (2w1+w2)L/6 - (M_{AB}+M_{BA})/L$

$= \quad 57.583$ kN

$S_{BA} = S_{AB} - L(w1+w2)/2 \quad = \quad -50.317$ kN

b) Shearing Force at 2d point from joint

Shearing force at the point with a distance of 2d from joint is calculated by following equation.

$Sx = S_{AB} - w1x - (w2 - w1)x^2/(2L)$

(i) In case of x1 = 0.46 m

$Sx1 = 16.505$ kN

(ii) In case of x2 = 0.84 m

$Sx2 = -15.035$ kN

c) Bending Moment

$M_A = M_{AB}$ = -16.733 kN.m

$M_B = -M_{BA}$ = -14.757 kN.m

The maximum bending moment occurs at the point of that shearing force equal to zero.

$Sx = 0 = S_{AB} - w1x - (w2 - w1)x^2/(2L)$

= 57.58 -92.7500 x + 7.5000 x^2 x = 11.7111
0.6556

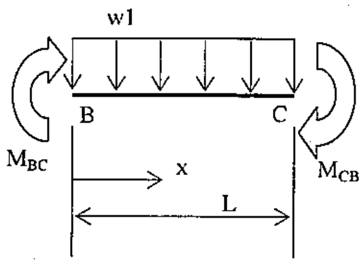
Bending moment at x 0.6556 m is;

$Mmax = S_{AB}x - w1x^2/2 - (w2-w1)x^3/(6L) + M_{AB}$ = 1.790 kN.m

2-2) Top Slab

a) Shearing Force at joint

w1	Uniform load on top slab	150.575 kN/m^2
M_{BC}	Bending moment at end B	-14.757 kN.m
M_{CB}	Bending moment at end C	27.303 kN.m
L	Length of member	1.350 m
ch	Protective covering height	0.070 m
t	Thickness of member (height)	0.300 m
d	Effective height of member	0.230 m



$S_{BC} = w1L/2-(M_{BC}+M_{CB})/L$ = 92.345 kN

$S_{CB} = S_{BC} - w1L$ = -110.931 kN

b) Shearing Force at 2d point from joint

Shearing force at the point with a distance of 2d from joint is calculated by following equation.

$Sx = S_{BC} - w1x$

(i) In case of x1 = 0.460 m
Sx1 = 23.081 kN

(ii) In case of x2 = 0.89 m
Sx2 = -41.666 kN

c) Bending Moment

$M_B = M_{BC}$ = -14.757 kN.m

$M_C = -M_{CB}$ = -27.303 kN.m

$Sx = S_{BC} - w1x$ = 92.345 - 150.575 x = 0 , x = 0.6133

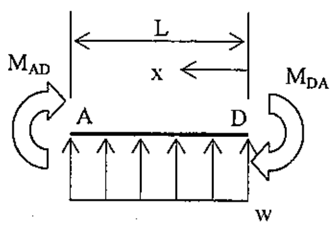
Bending moment at x 0.6133 m is;

$Mmax = S_{BC}x - w1x^2/2 + M_{BC}$ = 13.560 kN.m

2-3) Invert (Bottom Slab)

a) Shearing Force at joint

w1	Reaction to bottom slab	159.649 kN/m^2
M_{DA}	Bending moment at end B	-27.625 kN.m
M_{AD}	Bending moment at end C	16.733 kN.m
L	Length of member	1.350 m
ch	Protective covering height	0.100 m
t	Thickness of member (height)	0.300 m
d	Effective height of member	0.200 m



$S_{DA} = w1L/2 - (M_{DA}+M_{AD})/L$

= 115.831 kN

$S_{AD} = S_{DA} - Lw1$ = -99.695 kN

b) Shearing Force at 2d point from joint

Shearing force at the point with a distance of 2d from joint is calculated by following equation.

$Sx = S_{DA} - w1x$

(i) In case of x1 = 0.400 m

Sx1 = 51.971 kN

(ii) In case of x2 = 0.950 m

Sx2 = -35.836 kN

c) Bending Moment

$M_D = M_{DA}$ = -27.625 kN.m

$M_A = -M_{AD}$ = -16.733 kN.m

$Sx = S_{DA} - w1x$ = 115.831 - 159.649 x = 0 , x = 0.7255

Bending moment at x 0.7255 m is;

$Mmax = S_{DA}x - w1x^2/2 + M_{DA}$ = 14.395 kN.m

2-4) Partition Wall

a) Shearing Force at joint

w1	Load at end C	0.000 kN/m^2
w2	Load at end D	0.000 kN/m^2
M_{CD}	Bending moment at end C	0.000 kN.m
M_{DC}	Bending moment at end D	0.000 kN.m
L	Length of member	1.300 m
ch	Protective covering height	0.070 m
t	Thickness of member (height)	0.400 m
d	Effective height of member	0.330 m

$S_{CD} = w1L/2 - (M_{CD}+M_{DC})/L$

= 0.000 kN

$S_{DC} = S_{CD} - Lw1$ = 0.000 kN

b) Shearing Force at 2d point from joint

Shearing force at the point with a distance of 2d from joint is calculated by following equation.

$Sx = S_{CD} - w1x$

(i) In case of x1 = 0.660 m

Sx1 = 0 kN

(ii) In case of x2 = 0.640 m

Sx2 = 0 kN

c) Bending Moment

$M_C = M_{CD}$ = 0.000 kN.m

$M_D = -M_{DC}$ = 0.000 kN.m

$Sx = S_{CD} - w1x$ = 0.000 - 0.000 x = 0 , x = -

Bending moment at x 0.6500 m is;

$Mmax = S_{CD}x - w1x^2/2 + M_{CD}$ = 0.000 kN.m

Case 2: Box Culvert Inside is Empty, Underground Water up to Top slab, Track load Case. L2

1) Calculation of Load Term

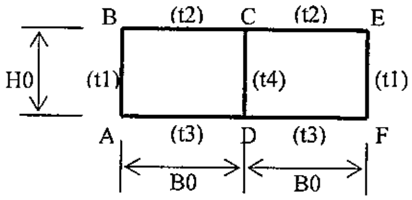
Ph1	Horizontal Pressure at top of side wall	73.250	kN/m^2
Ph2	Horizontal Pressure at bottom of side wall	92.750	kN/m^2
Ph3	Horizontal Pressure at top of side wall	73.250	kN/m^2
Ph4	Horizontal Pressure at bottom of side wall	92.750	kN/m^2
Pv1+Pv2	Vertical Pressure(1) on top slab	143.575	kN/m^2
Q1=Pq	Reaction to bottom slab	152.649	kN/m^2
H0	Height of plane frame	1.300	m
B0	Width of plane frame	1.350	m
t1	Thickness of side wall	0.300	m
t2	Thickness of top slab	0.300	m
t3	Thickness of bottom slab	0.300	m
t4	Thickness of partition wall	0.400	m
γc	Unit weight of reinforcement concrete	24.500	kN/m^3
L1	Height of side wall	1.000	m

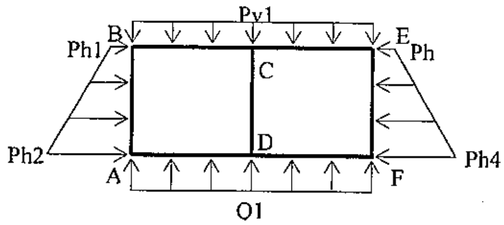
$C_{AB} = C_{FE} = (2Ph3+3Ph4)H_0^2/60$ = 11.964 kN.m

$C_{BA} = C_{EF} = (3Ph3+2Ph4)H_0^2/60$ = 11.415 kN.m

$C_{BC} = C_{CB} = C_{CE} = C_{EC} = Pv1B_0^2/12$ = 21.805 kN.m

$C_{DA} = C_{AD} = C_{FD} = C_{DF} = Q1B_0^2/12$ = 23.184 kN.m





2) Calculation of Bending Moment at joint

k1 = 1.0

$k2 = H0t_2^3/(B0t_1^3)$ = 0.96296

$k3 = H0t_3^3/(B0t_1^3)$ = 0.96296

$k4 = H0t_4^3/(H0t_1^3)$ = 2.37037

As load has bilateral symmetry, the equation shown below is formed.

$\theta_A = -\theta_F$ $\qquad \theta_B = -\theta_E$ $\qquad \theta_C = \theta_D = 0$ $\qquad R = 0$

$$\begin{pmatrix} 2(k1+k3) & k1 & -3k3 \\ k1 & 2(k1+k2) & -3k2 \\ k3 & k2 & -2(k2+k3) \end{pmatrix} \begin{pmatrix} \theta_A \\ \theta_B \\ R \end{pmatrix} = \begin{pmatrix} C_{AB} - C_{AD} \\ C_{BC} - C_{BA} \\ C \end{pmatrix}$$

$R_{BC} = B0Pv1/2 \quad = \quad 96.913$ kN
$P = t1L1\gamma c \quad = \quad 7.350$ kN/m

$C = [C_{BC} - C_{CB} + C_{DA} - C_{AD} + (R_{BC} - B0Q1/2 + P)B0]/3 \quad = \quad 0.551$ kN.m

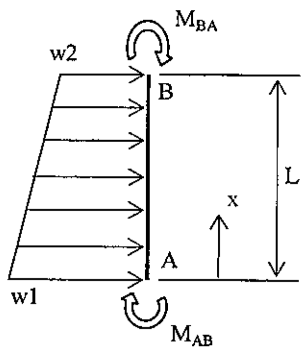
$$\begin{bmatrix} 3.92593 & 1.00000 & -2.88889 \\ 1.00000 & 3.92593 & -2.88889 \\ 0.96296 & 0.96296 & -3.85185 \end{bmatrix} \begin{bmatrix} \theta_A \\ \theta_B \\ R \end{bmatrix} = \begin{bmatrix} -11.2198 \\ 10.3909 \\ 0.5513 \end{bmatrix}$$

By solving above equation, the result is led as shown below;

$\theta_A = -3.9308 \qquad R = -0.2620$
$\theta_B = 3.4552$

$M_{AB} = -M_{FE} = k1(2\theta_A + \theta_B) - C_{AB} = -16.370$ kN.m
$M_{BA} = -M_{EF} = k1(2\theta_B + \theta_A) + C_{BA} = 14.394$ kN.m
$M_{BC} = -M_{EC} = k2(2\theta_B + \theta_C - 3R) - C_{BC} = -14.394$ kN.m
$M_{CB} = -M_{CE} = k2(2\theta_C + \theta_B - 3R) + C_{CB} = 25.890$ kN.m
$M_{DA} = -M_{DF} = k3(2\theta_D + \theta_A - 3R) - C_{DA} = -26.212$ kN.m
$M_{AD} = -M_{FD} = k3\,(2\theta_A + \theta_D - 3R) + C_{AD} = 16.370$ kN.m
$\Sigma M_A = M_{AB} + M_{AD} = 0.000$ kN.m o.k.
$\Sigma M_B = M_{BA} + M_{BC} = 0.000$ kN.m o.k.
$M_{CD} = k4(2\theta_C + \theta_D) = 0.000$ kN.m
$M_{DC} = k4(2\theta_D + \theta C) = 0.000$ kN.m

2) Calculation of Design Force
2-1) Side Wall
a) Shearing Force at joint



w1	Load at end A	92.750 kN/m^2
w2	Load at end B	73.250 kN/m^2
M_{AB}	Bending moment at end A	-16.370 kN.m
M_{BA}	Bending moment at end B	14.394 kN.m
L	Length of member	1.300 m
ch	Protective covering height	0.070 m
t	Thickness of member (height)	0.300 m
d	Effective height of member	0.230 m

$S_{AB} = (2w1+w2)L/6 - (M_{AB}+M_{BA})/L$
$= 57.583$ kN
$S_{BA} = S_{AB} - L(w1+w2)/2 = -50.317$ kN

b) Shearing Force at 2d point from joint
Shearing force at the point with a distance of 2d from joint is calculated by following equation.
$Sx = S_{AB} - w1x - (w2 - w1)x^2/(2L)$
(i) In case of x1 = 0.46 m
$Sx1 = 16.505$ kN
(ii) In case of x2 = 0.84 m
$Sx2 = -15.035$ kN

c) Bending Moment
$M_A = M_{AB} = -16.370$ kN.m
$M_B = -M_{BA} = -14.394$ kN.m

The maximum bending moment occurs at the point of that shearing force equal to zero.

$Sx = 0 = S_{AB} - w1x - (w2 - w1)x^2/(2L)$

= 57.58 -92.7500 x + 7.50000 x^2 , x = 11.7111
0.6556

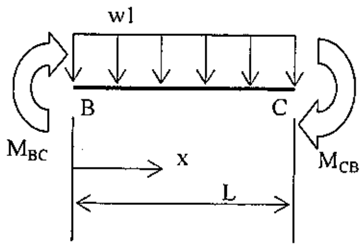
Bending moment at x 0.6556 m is;

$Mmax = S_{AB}x - w1x^2/2 - (w2-w1)x^3/(6L) + M_{AB}$ = 2.153 kN.m

2-2) Top Slab

a) Shearing Force at joint

w1	Uniform load on top slab	143.575 kN/m^2
M_{BC}	Bending moment at end B	-14.394 kN.m
M_{CB}	Bending moment at end C	25.890 kN.m
L	Length of member	1.350 m
ch	Protective covering height	0.070 m
t	Thickness of member (height)	0.300 m
d	Effective height of member	0.230 m



$S_{BC} = w1L/2-(M_{BC}+M_{CB})/L$ = 88.398 kN

$S_{CB} = S_{BC} - w1L$ = -105.428 kN

b) Shearing Force at 2d point from joint

Shearing force at the point with a distance of 2d from joint is calculated by following equation.

$Sx = S_{BC} - w1x$

(i) In case of x1 = 0.460 m

Sx1 = 22.353 kN

(ii) In case of x2 = 0.89 m

Sx2 = -39.384 kN

c) Bending Moment

$M_B = M_{BC}$ = -14.394 kN.m

$M_C = -M_{CB}$ = -25.890 kN.m

$Sx = S_{BC} - w1x$ = 88.39798 - 143.575 x = 0 , x = 0.6157

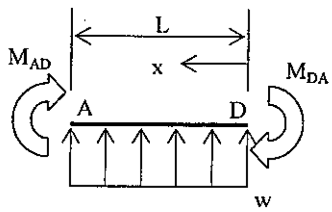
Bending moment at x 0.6157 m is;

$Mmax = S_{BC}x - w1x^2/2 + M_{BC}$ = 12.819 kN.m

2-3) Invert (Bottom Slab)

a) Shearing Force at joint

w1	Reaction to bottom slab	152.649 kN/m^2
M_{DA}	Bending moment at end B	-26.212 kN.m
M_{AD}	Bending moment at end C	16.370 kN.m
L	Length of member	1.350 m
ch	Protective covering height	0.100 m
t	Thickness of member (height)	0.300 m
d	Effective height of member	0.200 m



$S_{DA} = w1L/2 - (M_{DA}+M_{AD})/L$ = 110.328 kN

$S_{AD} = S_{DA} - Lw1$ = -95.748 kN

b) Shearing Force at 2d point from joint

Shearing force at the point with a distance of 2d from joint is calculated by following equation.

$Sx = S_{DA} - w1x$

(i) In case of x1 = 0.400 m

Sx1 = 49.269 kN

(ii) In case of x2 = 0.950 m

Sx2 = -34.688 kN

c) Bending Moment

$M_D = M_{DA}$ = -26.212 kN.m

$M_A = -M_{AD}$ = -16.370 kN.m

$Sx = S_{DA} - w1x$ = 110.328 - 152.649 x = 0 ; x = 0.723

Bending moment at x 0.723 m is;

$Mmax = S_{DA}x - w1x^2/2 + M_{DA}$ = 13.658 kN.m

2-4) Partition Wall

a) Shearing Force at joint

w1	Load at end C	0.000 kN/m^2
w2	Load at end D	0.000 kN/m^2
M_{CD}	Bending moment at end C	0.000 kN.m
M_{DC}	Bending moment at end D	0.000 kN.m
L	Length of member	1.300 m
ch	Protective covering height	0.070 m
t	Thickness of member (height)	0.400 m
d	Effective height of member	0.330 m

$S_{CD} = w1L/2 - (M_{CD}+M_{DC})/L$

= 0 kN

$S_{DC} = S_{CD} - Lw1$ = 0 kN

b) Shearing Force at 2d point from joint

Shearing force at the point with a distance of 2d from joint is calculated by following equation.

$Sx = S_{CD} - w1x$

(i) In case of x1 = 0.660 m

Sx1 = 0.000 kN

(ii) In case of x2 = 0.640 m

Sx2 = 0.000 kN

c) Bending Moment

$M_C = M_{CD}$ = 0.000 kN.m

$M_D = -M_{DC}$ = 0.000 kN.m

$Sx = S_{CD} - w1x$ = 0 - 0.000 x = 0 , x = -

Bending moment at x 0.6500 m is;

$Mmax = S_{CD}x - w1x^2/2 + M_{CD}$ = 0.000 kN.m

Case 3: Box Culvert Inside is Full, Underground Water up to invert, Track load Case. L1

1) Calculation of Load Term

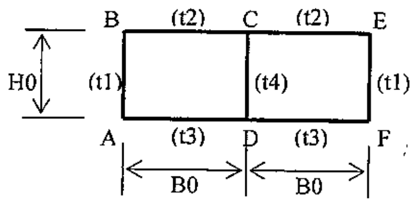
Ph1	Horizontal Pressure at top of side wall	72.350	kN/m^2
Ph2	Horizontal Pressure at bottom of side wall	74.050	kN/m^2
Ph3	Horizontal Pressure at top of side wall	72.350	kN/m^2
Ph4	Horizontal Pressure at bottom of side wall	74.050	kN/m^2
Pv1+Pv2	Vertical Pressure(1) on top slab	150.575	kN/m^2
Q1=Pq	Reaction to bottom slab	159.649	kN/m^2
H0	Height of plane frame	1.300	m
B0	Width of plane frame	1.350	m
t1	Thickness of side wall	0.300	m
t2	Thickness of top slab	0.300	m
t3	Thickness of bottom slab	0.300	m
t4	Thickness of partition wall	0.400	m
γ c	Unit weight of reinforcement concrete	24.500	kN/m^3
L1	Height of side wall	1.000	m

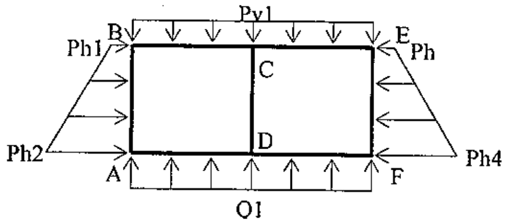
$C_{AB} = C_{FE} = (2Ph3+3Ph4)H_0^2/60$ = 10.333 kN.m

$C_{BA} = C_{EF} = (3Ph3+2Ph4)H_0^2/60$ = 10.285 kN.m

$C_{BC} = C_{CB} = C_{CE} = C_{EC} = Pv1B_0^2/12$ = 22.869 kN.m

$C_{DA} = C_{AD} = C_{FD} = C_{DF} = Q1B_0^2/12$ = 24.247 kN.m





2) Calculation of Bending Moment at joint

$k1 = 1.0$

$k2 = H0t_2^3/(B0t_1^3) = 0.96296$

$k3 = H0t_3^3/(B0t_1^3) = 0.96296$

$k4 = H0t_4^3/(H0t_1^3) = 2.37037$

As load has bilateral symmetry, the equation shown below is formed.

$\theta_A = -\theta_F$ $\quad\theta_B = -\theta_E$ $\quad\theta_C = \theta_D = 0$ $\quad R = 0$

$$\begin{pmatrix} 2(k1+k3) & k1 & -3k3 \\ k1 & 2(k1+k2) & -3k2 \\ k3 & k2 & -2(k2+k3) \end{pmatrix} \begin{pmatrix} \theta_A \\ \theta_B \\ R \end{pmatrix} = \begin{pmatrix} C_{AB} - C_{AD} \\ C_{BC} - C_{BA} \\ C \end{pmatrix}$$

$R_{BC} = B0Pv1/2$ = 101.638 kN

$P = t1L1\,\gamma c$ = 7.350 kN/m

$C = [C_{BC} - C_{CB} + C_{DA} - C_{AD} + (R_{BC} - B0Q1/2 + P)B0]/3$ = 0.55125 kN.m

$$\begin{pmatrix} 3.92593 & 1.00000 & -2.88889 \\ 1.00000 & 3.92593 & -2.88889 \\ 0.96296 & 0.96296 & -3.85185 \end{pmatrix} \begin{pmatrix} \theta_A \\ \theta_B \\ R \end{pmatrix} = \begin{pmatrix} -13.91376 \\ 12.58352 \\ 0.55125 \end{pmatrix}$$

By solving above equation, the result is led as shown below:

θ_A = -4.83782   R = -0.29801

θ_B = 4.21822

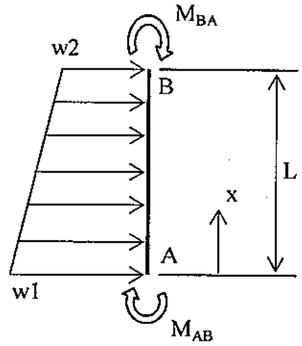
$M_{AB} = -M_{FE} = k1(2\theta_A + \theta_B) - C_{AB}$	= -15.790 kN.m	
$M_{BA} = -M_{EF} = k1(2\theta_B + \theta_A) + C_{BA}$	= 13.884 kN.m	
$M_{BC} = -M_{EC} = k2(2\theta_B + \theta_C - 3R) - C_{BC}$	= -13.884 kN.m	
$M_{CB} = -M_{CE} = k2(2\theta_C + \theta_B - 3R) + C_{CB}$	= 27.791 kN.m	
$M_{DA} = -M_{DF} = k3(2\theta_D + \theta_A - 3R) - C_{DA}$	= -28.044 kN.m	
$M_{AD} = -M_{FD} = k3(2\theta_A + \theta_D - 3R) + C_{AD}$	= 15.790 kN.m	
$\Sigma M_A = M_{AB} + M_{AD}$	= 0.000 kN.m	o.k.
$\Sigma M_B = M_{BA} + M_{BC}$	= 0.000 kN.m	o.k.
$M_{CD} = k4(2\theta_C + \theta_D)$	= 0.000 kN.m	
$M_{DC} = k4(2\theta_D + \theta C)$	= 0.000 kN.m	

2) Calculation of Design Force

2-1) Side Wall

a) Shearing Force at joint

w1	Load at end A	74.050 kN/m²
w2	Load at end B	72.350 kN/m²
M_{AB}	Bending moment at end A	-15.790 kN.m
M_{BA}	Bending moment at end B	13.884 kN.m
L	Length of member	1.300 m
ch	Protective covering height	0.070 m
t	Thickness of member (height)	0.300 m
d	Effective height of member	0.230 m



$S_{AB} = (2w1 + w2)L/6 - (M_{AB} + M_{BA})/L$

= 49.231 kN

$S_{BA} = S_{AB} - L(w1 + w2)/2$ = -45.929 kN

b) Shearing Force at 2d point from joint

Shearing force at the point with a distance of 2d from joint is calculated by following equation.

$Sx = S_{AB} - w1x - (w2 - w1)x^2/(2L)$

(i) In case of x1 = 0.46 m

Sx1 = 15.306 kN

(ii) In case of x2 = 0.84 m

Sx2 = -12.510 kN

c) Bending Moment

$M_A = M_{AB}$ = -15.7904 kN.m

$M_B = -M_{BA}$ = -13.8837 kN.m

The maximum bending moment occurs at the point of that shearing force equal to zero.

$Sx = 0 = S_{AB} - w1x - (w2 - w1)x^2/(2L)$

= 49.23 -74.0500 x + 0.65385 x^2 , x = 112.584
0.669

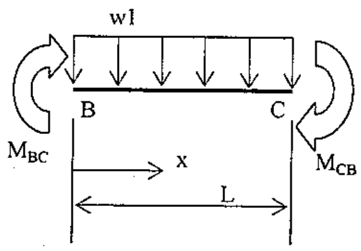
Bending moment at x 0.6688 m is;

$Mmax = S_{AB}x - w1x^2/2 - (w2-w1)x^3/(6L) + M_{AB}$ = 0.639 kN.m

2-2) Top Slab

a) Shearing Force at joint

w1	Uniform load on top slab	150.575	kN/m^2
M_{BC}	Bending moment at end B	-13.884	kN.m
M_{CB}	Bending moment at end C	27.791	kN.m
L	Length of member	1.350	m
ch	Protective covering height	0.070	m
t	Thickness of member (height)	0.300	m
d	Effective height of member	0.230	m



$S_{BC} = w1L/2-(M_{BC}+M_{CB})/L$ = 91.336 kN

$S_{CB} = S_{BC} - w1L$ = -111.940 kN

b) Shearing Force at 2d point from joint

Shearing force at the point with a distance of 2d from joint is calculated by following equation.

$Sx = S_{BC} - w1x$

(i) In case of x1 = 0.460 m

Sx1 = 22.072 kN

(ii) In case of x2 = 0.89 m

Sx2 = -42.676 kN

c) Bending Moment

$M_B = M_{BC}$ = -13.884 kN.m

$M_C = -M_{CB}$ = -27.791 kN.m

$Sx = S_{BC} - w1x$ = 91.3360 - 150.575 x = 0 , x = 0.6066

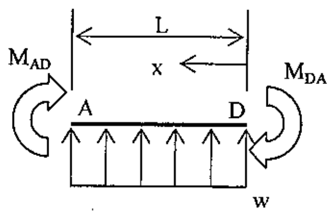
Bending moment at x 0.6066 m is;

$Mmax = S_{BC}x - w1x^2/2 + M_{BC}$ = 13.8177 kN.m

2-3) Invert (Bottom Slab)

a) Shearing Force at joint

w1	Reaction to bottom slab	159.649	kN/m^2
M_{DA}	Bending moment at end B	-28.044	kN.m
M_{AD}	Bending moment at end C	15.790	kN.m
L	Length of member	1.350	m
ch	Protective covering height	0.100	m
t	Thickness of member (height)	0.300	m
d	Effective height of member	0.200	m



$S_{DA} = w1L/2 - (M_{DA}+M_{AD})/L$

= 116.840 kN

$S_{AD} = S_{DA} - Lw1$ = -98.686 kN

b) Shearing Force at 2d point from joint

Shearing force at the point with a distance of 2d from joint is calculated by following equation.

$Sx = S_{DA} - w1x$

(i) In case of x1 = 0.400 m

Sx1 = 52.981 kN

(ii) In case of x2 = 0.950 m

Sx2 = -34.826 kN

c) Bending Moment

$M_D = M_{DA}$ = -28.044 kN.m

$M_A = -M_{AD}$ = -15.790 kN.m

$Sx = S_{DA} - w1x$ = ######## - 159.649 x = 0 , x = 0.7319

Bending moment at x 0.7319 m is;

$Mmax = S_{DA}x - w1x^2/2 + M_{DA}$ = 14.711 kN.m

2-4) Partition Wall

a) Shearing Force at joint

w1	Load at end C	0.000 kN/m^2
w2	Load at end D	0.000 kN/m^2
M_{CD}	Bending moment at end C	0.000 kN.m
M_{DC}	Bending moment at end D	0.000 kN.m
L	Length of member	1.300 m
ch	Protective covering height	0.070 m
t	Thickness of member (height)	0.400 m
d	Effective height of member	0.330 m

$S_{CD} = w1L/2 - (M_{CD}+M_{DC})/L$

= 0.000 kN

$S_{DC} = S_{CD} - Lw1$ = 0.000 kN

b) Shearing Force at 2d point from joint

Shearing force at the point with a distance of 2d from joint is calculated by following equation.

$Sx = S_{CD} - w1x$

(i) In case of x1 = 0.660 m

Sx1 = 0 kN

(ii) In case of x2 = 0.640 m

Sx2 = 0 kN

c) Bending Moment

$M_C = M_{CD}$ = 0.000 kN.m

$M_D = -M_{DC}$ = 0.000 kN.m

$Sx = S_{CD} - w1x$ = 0 - 0.000 x = 0 , x = -

Bending moment at x 0.6500 m is;

$Mmax = S_{CD}x - w1x^2/2 + M_{CD}$ = 0.000 kN.m

Case 4: Box Culvert Inside is Full, Underground Water up to invert, Track load Case. L2

1) Calculation of Load Term

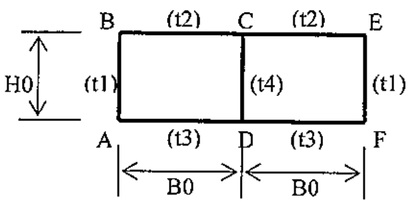
Ph1	Horizontal Pressure at top of side wall	72.350 kN/m^2
Ph2	Horizontal Pressure at bottom of side wall	74.050 kN/m^2
Ph3	Horizontal Pressure at top of side wall	72.350 kN/m^2
Ph4	Horizontal Pressure at bottom of side wall	74.050 kN/m^2
Pv1+Pv2	Vertical Pressure(1) on top slab	143.575 kN/m^2
Q1=Pq	Reaction to bottom slab	152.649 kN/m^2
H0	Height of plane frame	1.300 m
B0	Width of plane frame	1.350 m
t1	Thickness of side wall	0.300 m
t2	Thickness of top slab	0.300 m
t3	Thickness of bottom slab	0.300 m
t4	Thickness of partition wall	0.400 m
γc	Unit weight of reinforcement concrete	24.500 kN/m^3
L1	Height of side wall	1.000 m

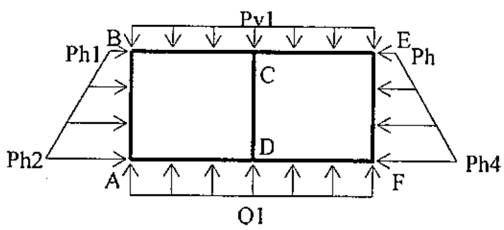
$C_{AB} = C_{FE} = (2Ph3+3Ph4)H_0^2/60$ = 10.333 kN.m

$C_{BA} = C_{EF} = (3Ph3+2Ph4)H_0^2/60$ = 10.285 kN.m

$C_{BC} = C_{CB} = C_{CE} = C_{EC} = Pv1B_0^2/12$ = 21.805 kN.m

$C_{DA} = C_{AD} = C_{FD} = C_{DF} = Q1B_0^2/12$ = 23.184 kN.m





2) Calculation of Bending Moment at joint

$k1 = 1.0$

$k2 = H0t_2^3/(B0t_1^3) = 0.96296$

$k3 = H0t_3^3/(B0t_1^3) = 0.96296$

$k4 = H0t_4^3/(H0t_1^3) = 2.37037$

As load has bilateral symmetry, the equation shown below is formed.

$\theta_A = -\theta_F$ $\qquad \theta_B = -\theta_E$ $\qquad \theta_C = \theta_D = 0$ $\qquad R = 0$

$$\begin{bmatrix} 2(k1+k3) & k1 & -3k3 \\ k1 & 2(k1+k2) & -3k2 \\ k3 & k2 & -2(k2+k3) \end{bmatrix} \begin{bmatrix} \theta_A \\ \theta_B \\ R \end{bmatrix} = \begin{bmatrix} C_{AB} - C_{AD} \\ C_{BC} - C_{BA} \\ C \end{bmatrix}$$

$R_{BC} = B0Pv1/2$ = 96.913 kN

$P = t1L1\gamma c$ = 7.350 kN/m

$C = [C_{BC} - C_{CB} + C_{DA} - C_{AD} + (R_{BC} - B0Q1/2 + P)B0]/3$ = 0.551 kN.m

$$\begin{bmatrix} 3.92593 & 1.00000 & -2.88889 \\ 1.00000 & 3.92593 & -2.88889 \\ 0.96296 & 0.96296 & -3.85185 \end{bmatrix} \begin{bmatrix} \theta_A \\ \theta_B \\ R \end{bmatrix} = \begin{bmatrix} -12.85064 \\ 11.52039 \\ 0.55125 \end{bmatrix}$$

By solving above equation, the result is led as shown below;

θ_A = -4.47447　　　　R = -0.29801

θ_B = 3.85487

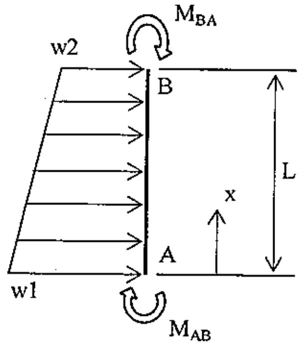
$M_{AB} = -M_{FE} = k1(2\theta_A + \theta_B) - C_{AB}$	=	-15.427 kN.m	
$M_{BA} = -M_{EF} = k1(2\theta_B + \theta_A) + C_{BA}$	=	13.520 kN.m	
$M_{BC} = -M_{EC} = k2(2\theta_B + \theta_C - 3R) - C_{BC}$	=	-13.520 kN.m	
$M_{CB} = -M_{CE} = k2(2\theta_C + \theta_B - 3R) + C_{CB}$	=	26.378 kN.m	
$M_{DA} = -M_{DF} = k3(2\theta_D + \theta_A - 3R) - C_{DA}$	=	-26.631 kN.m	
$M_{AD} = -M_{FD} = k3\ (2\theta_A + \theta_D - 3R) + C_{AD}$	=	15.427 kN.m	
$\Sigma M_A = M_{AB} + M_{AD}$	=	0.000 kN.m	o.k.
$\Sigma M_B = M_{BA} + M_{BC}$	=	0.000 kN.m	o.k.
$M_{CD} = k4(2\theta_C + \theta_D)$	=	0.000 kN.m	
$M_{DC} = k4(2\theta_D + \theta C)$	=	0.000 kN.m	

2) Calculation of Design Force

2-1) Side Wall

a) Shearing Force at joint

w1	Load at end A	74.050 kN/m^2
w2	Load at end B	72.350 kN/m^2
M_{AB}	Bending moment at end A	-15.427 kN.m
M_{BA}	Bending moment at end B	13.520 kN.m
L	Length of member	1.300 m
ch	Protective covering height	0.070 m
t	Thickness of member (height)	0.300 m
d	Effective height of member	0.230 m



$S_{AB} = (2w1+w2)L/6 - (M_{AB}+M_{BA})/L$ = 49.231 kN

$S_{BA} = S_{AB} - L(w1+w2)/2$ = -45.929 kN

b) Shearing Force at 2d point from joint

Shearing force at the point with a distance of 2d from joint is calculated by following equation.

$Sx = S_{AB} - w1x - (w2 - w1)x^2/(2L)$

(i) In case of x1 = 0.46 m

Sx1 = 15.306 kN

(ii) In case of x2 = 0.84 m

Sx2 = -12.510 kN

c) Bending Moment

$M_A = M_{AB}$ = -15.427 kN.m

$M_B = -M_{BA}$ = -13.520 kN.m

The maximum bending moment occurs at the point of that shearing force equal to zero.

$Sx = 0 = S_{AB} - w1x - (w2 - w1)x^2/(2L)$

= 49.23 -74.0500 x + 0.65385 x^2 , x = 112.584
0.669

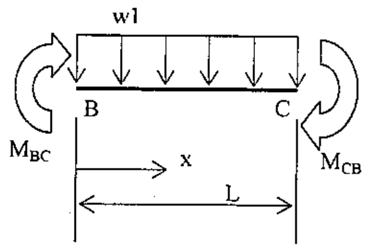
Bending moment at x 0.6688 m is;

$Mmax = S_{AB}x - w1x^2/2 - (w2\text{-}w1)x^3/(6L) + M_{AB}$ = 1.003 kN.m

2-2) Top Slab

a) Shearing Force at joint

w1	Uniform load on top slab	143.575 kN/m^2
M_{BC}	Bending moment at end B	-13.520 kN.m
M_{CB}	Bending moment at end C	26.378 kN.m
L	Length of member	1.350 m
ch	Protective covering height	0.070 m
t	Thickness of member (height)	0.300 m
d	Effective height of member	0.230 m



$S_{BC} = w1L/2\text{-}(M_{BC}+M_{CB})/L$ = 87.389 kN

$S_{CB} = S_{BC} \text{-}w1L$ = -106.438 kN

b) Shearing Force at 2d point from joint

Shearing force at the point with a distance of 2d from joint is calculated by following equation.

$Sx = S_{BC}\text{-} w1x$

(i) In case of x1 = 0.460 m

Sx1 = 21.344 kN

(ii) In case of x2 = 0.89 m

Sx2 = -40.393 kN

c) Bending Moment

$M_B = M_{BC}$ = -13.520 kN.m

$M_C = \text{-}M_{CB}$ = -26.378 kN.m

$Sx = S_{BC} - w1x$ = 87.3886 - 143.575 x = 0 , x = 0.6087

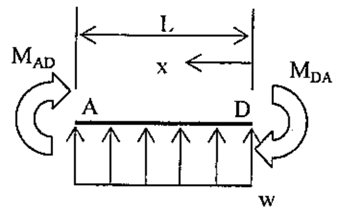
Bending moment at x 0.6087 m is;

$Mmax = S_{BC}x - w1x^2/2 + M_{BC}$ = 13.075 kN.m

2-3) Invert (Bottom Slab)

a) Shearing Force at joint

w1	Reaction to bottom slab	152.649 kN/m^2
M_{DA}	Bending moment at end B	-26.631 kN.m
M_{AD}	Bending moment at end C	15.427 kN.m
L	Length of member	1.350 m
ch	Protective covering height	0.100 m
t	Thickness of member (height)	0.300 m
d	Effective height of member	0.200 m



$S_{DA} = w1L/2 - (M_{DA}+M_{AD})/L$ = 111.338 kN

$S_{AD} = S_{DA} - Lw1$ = -94.739 kN

b) Shearing Force at 2d point from joint

Shearing force at the point with a distance of 2d from joint is calculated by following equation.

$Sx = S_{DA} - w1x$

(i) In case of x1 = 0.400 m

Sx1 = 50.278 kN

(ii) In case of x2 = 0.950 m

Sx2 = -33.679 kN

c) Bending Moment

$M_D = M_{DA}$ = -26.631 kN.m

$M_A = -M_{AD}$ = -15.427 kN.m

$Sx = S_{DA} - w1x$ = 111.338 - 152.649 x = 0 , x = 0.7294

Bending moment at x 0.7294 m is;

$Mmax = S_{DA}x - w1x^2/2 + M_{DA}$ = 13.972 kN.m

2-4) Partition Wall

a) Shearing Force at joint

w1	Load at end C	0.000 kN/m^2
w2	Load at end D	0.000 kN/m^2
M_{CD}	Bending moment at end C	0.000 kN.m
M_{DC}	Bending moment at end D	0.000 kN.m
L	Length of member	1.300 m
ch	Protective covering height	0.070 m
t	Thickness of member (height)	0.400 m
d	Effective height of member	0.330 m

$S_{CD} = w1L/2 - (M_{CD}+M_{DC})/L$

= 0.000 kN

$S_{DC} = S_{CD} - Lw1$ = 0.000 kN

b) Shearing Force at 2d point from joint

Shearing force at the point with a distance of 2d from joint is calculated by following equation.

$Sx = S_{CD} - w1x$

(i) In case of x1 = 0.660 m

Sx1 = 0 kN

(ii) In case of x2 = 0.640 m

Sx2 = 0 kN

c) Bending Moment

$M_C = M_{CD}$ = 0.000 kN.m

$M_D = -M_{DC}$ = 0.000 kN.m

$Sx = S_{CD} - w1x$ = 0 - 0.000 x = 0 , x = -

Bending moment at x 0.650 m is;

$Mmax = S_{CD}x - w1x^2/2 + M_{CD}$ = 0.000 kN.m

5 Calculation of Required Reinforcement Bar

Goal Seek

5-1 Calculation of Required Reinforcement Bar

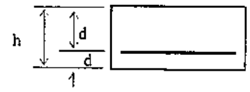
1) At Joint "A" of side wall

Case.1

M=	16.733 kN.m	σca =	8.0 N/mm²	h =	0.30 m (height of member)
N=	99.695 kN	σsa =	157 N/mm²	d =	0.23 m (effective height of member)
S0=	57.583 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	16.505 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.168 m

Solving the formula shown below, σc 3.829 N/mm² (0.00082 N/mm²) o.k.



σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.299 σc^2 -29.330 σc -153.510

s = nσc/(nσc+σsa) = 0.2679

Asreq = (σc*s/2 - N/(bd))bd/σsa = 1.163 cm2

Case.2

M=	16.370 kN.m	σca =	8.0 N/mm²	h =	0.30 m (height of member)
N=	95.748 kN	σsa =	157 N/mm²	d =	0.23 m (effective height of member)
S0=	57.583 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	16.505 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.171 m

Solving the formula shown below, σc 3.766 N/mm² (0.00098 N/mm²) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.337 σc^2 -28.530 σc -149.290

s = nσc/(nσc+σsa) = 0.2646

Asreq = (σc*s/2 - N/(bd))bd/σsa = 1.200 cm2

Case.3

M=	15.790 kN.m	σca =	8.0 N/mm²	h =	0.30 m (height of member)
N=	98.686 kN	σsa =	157 N/mm²	d =	0.23 m (effective height of member)
S0=	49.231 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	15.306 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.160 m

Solving the formula shown below, σc 3.733 N/mm² (3.1E-07 N/mm²) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.357 σc^2 -28.120 σc -147.150

s = nσc/(nσc+σsa) = 0.263

Asreq = (σc*s/2 - N/(bd))bd/σsa = 0.904 cm2

Case.4

M=	15.427 kN.m	σca =	8.0 N/mm²	h =	0.30 m (height of member)
N=	94.739 kN	σsa =	157 N/mm²	d =	0.23 m (effective height of member)
S0=	49.231 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	15.306 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.163 m

Solving the formula shown below, σc 3.669 N/mm² (4.4E-07 N/mm²) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.395 σc^2 -27.310 σc -142.930

s = nσc/(nσc+σsa) = 0.260

Asreq = (σc*s/2 - N/(bd))bd/σsa = 0.940 cm2

The maximum requirement of reinforcement bar is 1.200 cm2 in Case 2 from above calculation.

Case.	1	2	3	4	
Requirement	1.163	1.200	0.904	0.940	(cm2)

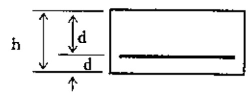
2) At Joint "B" of side wall

Case.1

M=	14.757 kN.m	σca =	8.0 N/mm²	h =	0.30 m (height of member)
N=	92.345 kN	σsa =	157 N/mm²	d =	0.23 m (effective height of member)
S0=	50.317 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	15.035 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.160 m

Solving the formula shown below, σc 3.586 N/mm² (6.6E-07 N/mm²) o.k.



σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.444 σc^2 -26.290 σc -137.580

s = nσc/(nσc+σsa) = 0.255

Asreq = (σc*s/2 - N/(bd))bd/σsa = 0.821 cm2

Case.2

M=	14.394 kN.m	σca =	8.0 N/mm²	h =	0.30 m (height of member)
N=	88.398 kN	σsa =	157 N/mm²	d =	0.23 m (effective height of member)
S0=	50.317 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	15.035 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.163 m

Solving the formula shown below, σc 3.520 N/mm² (9.2E-07 N/mm²) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.483 σc^2 -25.480 σc -133.360

s = nσc/(nσc+σsa) = 0.252

Asreq = (σc*s/2 - N/(bd))bd/σsa = 0.858 cm2

Case.3

M=	13.884 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	91.336 kN	σsa =	157 N/mm^2	d =	0.23 m (effective height of member)
S0=	45.929 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	12.510 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.152 m

Solving the formula shown below, σc 3.493 N/mm^2 (1.1E-06 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.498 σc^2 -25.160 σc -131.650

s = nσc/(nσc+σsa) = 0.250

Asreq = (σc*s/2 - N/(bd))bd/σsa = 0.585 cm2

Case.4

M=	13.520 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	87.389 kN	σsa =	157 N/mm^2	d =	0.23 m (effective height of member)
S0=	45.929 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	12.510 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.155 m

Solving the formula shown below, σc 3.426 N/mm^2 (1.5E-06 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.537 σc^2 -24.350 σc -127.430

s = nσc/(nσc+σsa) = 0.247

Asreq = (σc*s/2 - N/(bd))bd/σsa = 0.623 cm2

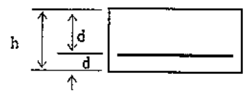
The maximum requirement of reinforcement bar is 0.8580 cm2 in Case 2 from above calculation.

Case.	1	2	3	4	
Requirement	0.821	0.858	0.585	0.623	(cm2)

3) At Joint "B" of top slab

Case.1

M=	14.757 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	50.317 kN	σsa =	157 N/mm^2	d =	0.23 m (effective height of member)
S0=	92.345 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	23.081 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m



e = M/N = 0.293 m

Solving the formula shown below, σc 3.252 N/mm^2 (3.5E-06 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.635 σc^2 -22.300 σc -116.690

s = nσc/(nσc+σsa) = 0.237

Asreq = (σc*s/2 - N/(bd))bd/σsa = 2.443 cm2

Case.2

M=	14.394 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	50.317 kN	σsa =	157 N/mm^2	d =	0.23 m (effective height of member)
S0=	88.398 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	22.353 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.286 m

Solving the formula shown below, σc 3.215 N/mm^2 (4.2E-06 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.655 σc^2 -21.870 σc -114.440

s = nσc/(nσc+σsa) = 0.235

Asreq = (σc*s/2 - N/(bd))bd/σsa = 2.330 cm2

Case.3

M=	13.884 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	45.929 kN	σsa =	157 N/mm^2	d =	0.23 m (effective height of member)
S0=	91.336 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	22.072 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.302 m

Solving the formula shown below, σc 3.126 N/mm^2 (6.6E-06 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.704 σc^2 -20.840 σc -109.080

s = nσc/(nσc+σsa) = 0.230

Asreq = (σc*s/2 - N/(bd))bd/σsa = 2.340 cm2

Case.4

M=	13.520 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	45.929 kN	σsa =	157 N/mm^2	d =	0.23 m (effective height of member)
S0=	87.389 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	21.344 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.294 m

Solving the formula shown below, σc 3.088 N/mm^2 (7.9E-06 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.725 σc^2 -20.410 σc -106.830

s = nσc/(nσc+σsa) = 0.228

Asreq = (σc*s/2 - N/(bd))bd/σsa = 2.227 cm2

The maximum requirement of reinforcement bar is 2.4430 cm2 in Case 1 from above calculation.

Case.	1	2	3	4	
Requirement	2.443	2.330	2.340	2.227	(cm2)

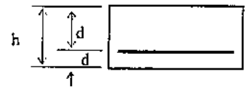
4) At Joint "A" of invert

Case.1

M=	16.733 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	57.583 kN	σsa =	157 N/mm^2	d =	0.20 m (effective height of member)
S0=	99.695 kN	n =	15	d' =	0.10 m (protective covering depth)
S2d=	35.836 kN			c =	0.05 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.291 m

Solving the formula shown below, σc 3.943 N/mm^2 (0.00058 N/mm^2) o.k.



σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.229 σc^2 -30.790 σc -161.140

s = nσc/(nσc+σsa) = 0.274

Asreq = (σc*s/2 - N/(bd))bd/σsa = 3.205 cm2

Case.2

M=	16.370 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	57.583 kN	σsa =	157 N/mm^2	d =	0.20 m (effective height of member)
S0=	95.748 kN	n =	15	d' =	0.10 m (protective covering depth)
S2d=	34.688 kN			c =	0.05 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.284 m

Solving the formula shown below, σc 3.899 N/mm^2 (0.00066 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.256 σc^2 -30.220 σc -158.160

s = nσc/(nσc+σsa) = 0.271

Asreq = (σc*s/2 - N/(bd))bd/σsa = 3.072 cm2

Case.3

M=	15.790 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	49.231 kN	σsa =	157 N/mm^2	d =	0.20 m (effective height of member)
S0=	98.686 kN	n =	15	d' =	0.10 m (protective covering depth)
S2d=	34.826 kN			c =	0.05 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.321 m

Solving the formula shown below, σc 3.776 N/mm^2 (0.00095 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.331 σc^2 -28.660 σc -149.960

s = nσc/(nσc+σsa) = 0.265

Asreq = (σc*s/2 - N/(bd))bd/σsa = 3.241 cm2

Case.4

M=	15.427 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	49.231 kN	σsa =	157 N/mm^2	d =	0.20 m (effective height of member)
S0=	94.739 kN	n =	15	d' =	0.10 m (protective covering depth)
S2d=	33.679 kN			c =	0.05 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.313 m

Solving the formula shown below, σc 3.731 N/mm^2 (3.2E-07 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.358 σc^2 -28.090 σc -146.980

s = nσc/(nσc+σsa) = 0.263

Asreq = (σc*s/2 - N/(bd))bd/σsa = 3.109 cm2

The maximum requirement of reinforcement bar is 3.241 cm2 in Case 3 from above calculation.

Case.	1	2	3	4	
Requirement	3.205	3.072	3.241	3.109	(cm2)

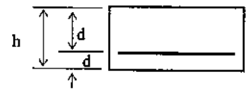
5) At Middle of side wall (between A and B)

Case.1

M=	1.790 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	95.989 kN	σsa =	157 N/mm^2	d =	0.23 m (effective height of member)
		n =	15	d' =	0.07 m (protective covering depth)
				c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.019 m

Solving the formula shown below, σc 2.193 N/mm^2 (0.00061 N/mm^2) o.k.



σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +15.163 σc^2 -11.240 σc -58.830

s = nσc/(nσc+σsa) = 0.173

Asreq = (σc*s/2 - N/(bd))bd/σsa = 0.000 cm2 **Tensile is on inside of member**

Case.2

M=	2.153 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	92.041 kN	σsa =	157 N/mm^2	d =	0.23 m (effective height of member)
		n =	15	d' =	0.07 m (protective covering depth)
				c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.023 m

Solving the formula shown below, σc 2.199 N/mm^2 (0.00059 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +15.16 σc^2 -11.300 σc -59.120

s = nσc/(nσc+σsa) = 0.174

Asreq = (σc*s/2 - N/(bd))bd/σsa = 0.000 cm2 **Tensile is on inside of member**

Case.3

M= 0.639 kN.m σca = 8.0 N/mm^2 h = 0.30 m (height of member)
N= 94.905 kN σsa = 157 N/mm^2 d = 0.23 m (effective height of member)
n = 15 d' = 0.07 m (protective covering depth)
c = 0.08 m (distance from neutral axis)
b = 1.00 m

e = M/N = 0.007 m
Solving the formula shown below, σc 2.027 N/mm^2 (8.6E-07 N/mm^2) o.k.
σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0
0 = σc^3 +15.233 σc^2 -9.770 σc -51.140
s = nσc/(nσc+σsa) = 0.162
Asreq = (σc*s/2 - N/(bd))bd/σsa = 0.000 cm2 **Tensile is on inside of member**

Case.4

M= 1.003 kN.m σca = 8.0 N/mm^2 h = 0.30 m (height of member)
N= 90.957 kN σsa = 157 N/mm^2 d = 0.23 m (effective height of member)
n = 15 d' = 0.07 m (protective covering depth)
c = 0.08 m (distance from neutral axis)
b = 1.00 m

e = M/N = 0.011 m
Solving the formula shown below, σc 2.034 N/mm^2 (8.1E-07 N/mm^2) o.k.
σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0
0 = σc^3 +15.23 σc^2 -9.830 σc -51.440
s = nσc/(nσc+σsa) = 0.163
Asreq = (σc*s/2 - N/(bd))bd/σsa = 0.000 cm2 **Tensile is on inside of member**

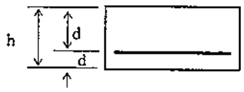
The maximum requirement of reinforcement bar is 0.000 cm2 in Case 1 from above calculation.

Case.	1	2	3	4	
Requirement	0.000	0.000	0.000	0.000	(cm2)
Side	inside	inside	inside	inside	

6) At Middle of top slab (between B and C)

Case.1

M= 13.560 kN.m σca = 8.0 N/mm^2 h = 0.30 m (height of member)
N= 50.317 kN σsa = 157 N/mm^2 d = 0.23 m (effective height of member)
n = 15 d' = 0.07 m (protective covering depth)
c = 0.08 m (distance from neutral axis)
b = 1.00 m



e = M/N = 0.269 m
Solving the formula shown below, σc 3.129 N/mm^2 (6.5E-06 N/mm^2) o.k.
σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0
0 = σc^3 +14.703 σc^2 -20.880 σc -109.250
s = nσc/(nσc+σsa) = 0.230
Asreq = (σc*s/2 - N/(bd))bd/σsa = 2.070 cm2 **Tensile is on inside of member**

Case.2

M= 12.819 kN.m σca = 8.0 N/mm^2 h = 0.30 m (height of member)
N= 50.317 kN σsa = 157 N/mm^2 d = 0.23 m (effective height of member)
n = 15 d' = 0.07 m (protective covering depth)
c = 0.08 m (distance from neutral axis)
b = 1.00 m

e = M/N = 0.255 m
Solving the formula shown below, σc 3.051 N/mm^2 (9.5E-06 N/mm^2) o.k.
σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0
0 = σc^3 +14.745 σc^2 -20.000 σc -104.650
s = nσc/(nσc+σsa) = 0.226
Asreq = (σc*s/2 - N/(bd))bd/σsa = 1.840 cm2 **Tensile is on inside of member**

Case.3

M= 13.818 kN.m σca = 8.0 N/mm^2 h = 0.30 m (height of member)
N= 45.929 kN σsa = 157 N/mm^2 d = 0.23 m (effective height of member)
n = 15 d' = 0.07 m (protective covering depth)
c = 0.08 m (distance from neutral axis)
b = 1.00 m

e = M/N = 0.301 m
Solving the formula shown below, σc 3.119 N/mm^2 (6.8E-06 N/mm^2) o.k.
σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0
0 = σc^3 +14.708 σc^2 -20.770 σc -108.670
s = nσc/(nσc+σsa) = 0.230
Asreq = (σc*s/2 - N/(bd))bd/σsa = 2.320 cm2 **Tensile is on inside of member**

Case.4

M= 13.075 kN.m σca = 8 N/mm^2 h = 0.30 m (height of member)
N= 45.929 kN σsa = 157 N/mm^2 d = 0.23 m (effective height of member)
n = 15 d' = 0.07 m (protective covering depth)
c = 0.08 m (distance from neutral axis)
b = 1.00 m

e = M/N = 0.285 m
Solving the formula shown below, σc 3.041 N/mm^2 (1E-05 N/mm^2) o.k.
σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0
0 = σc^3 +14.75 σc^2 -19.880 σc -104.060
s = nσc/(nσc+σsa) = 0.225
Asreq = (σc*s/2 - N/(bd))bd/σsa = 2.089 cm2 **Tensile is on inside of member**

The maximum requirement of reinforcement bar is 2.320 cm2 in Case 3 from above calculation.

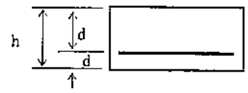
Case.	1	2	3	4	
Requirement	2.070	1.840	2.320	2.089	(cm2)
Side	inside	inside	inside	inside	

7) At Middle of invert (between D and A)

Case.1

M=	14.395 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	57.583 kN	σsa =	157 N/mm^2	d =	0.20 m (effective height of member)
		n =	15	d' =	0.10 m (protective covering depth)
				c =	0.05 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.250 m



Solving the formula shown below, σc 3.653 N/mm^2 (4.7E-07 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.404 σc^2 -27.120 σc -141.930

s = nσc/(nσc+σsa) = 0.259

Asreq = (σc*s/2 - N/(bd))bd/σsa = 2.353 cm2 **Tensile is on inside of member**

Case.2

M=	13.658 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	57.583 kN	σsa =	157 N/mm^2	d =	0.20 m (effective height of member)
		n =	15	d' =	0.10 m (protective covering depth)
				c =	0.05 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.237 m

Solving the formula shown below, σc 3.559 N/mm^2 (7.6E-07 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.46 σc^2 -25.960 σc -135.880

s = nσc/(nσc+σsa) = 0.254

Asreq = (σc*s/2 - N/(bd))bd/σsa = 2.085 cm2 **Tensile is on inside of member**

Case.3

M=	14.711 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	49.231 kN	σsa =	157 N/mm^2	d =	0.20 m (effective height of member)
		n =	15	d' =	0.10 m (protective covering depth)
				c =	0.05 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.299 m

Solving the formula shown below, σc 3.640 N/mm^2 (5E-07 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.412 σc^2 -26.960 σc -141.090

s = nσc/(nσc+σsa) = 0.258

Asreq = (σc*s/2 - N/(bd))bd/σsa = 2.848 cm2 **Tensile is on inside of member**

Case.4

M=	13.972 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	49.231 kN	σsa =	157 N/mm^2	d =	0.20 m (effective height of member)
		n =	15	d' =	0.10 m (protective covering depth)
				c =	0.05 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.284 m

Solving the formula shown below, σc 3.546 N/mm^2 (8.1E-07 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.468 σc^2 -25.800 σc -135.020

s = nσc/(nσc+σsa) = 0.253

Asreq = (σc*s/2 - N/(bd))bd/σsa = 2.580 cm2 **Tensile is on inside of member**

The maximum requirement of reinforcement bar is 2.848 cm2 in Case 3 from above calculation.

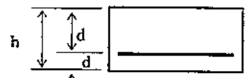
Case.	1	2	3	4	
Requirement	2.353	2.085	2.848	2.580	(cm2)
Side	inside	inside	inside	inside	

8) At Top of partition wall (joint C)

Case.1

M=	27.303 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	50.317 kN	σsa =	157 N/mm^2	d =	0.23 m (effective height of member)
S0=	110.931 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	41.666 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.543 m



Solving the formula shown below, σc 4.425 N/mm^2 (0.00014 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +13.923 σc^2 -37.190 σc -194.630

s = nσc/(nσc+σsa) = 0.297

Asreq = (σc*s/2 - N/(bd))bd/σsa = 6.425 cm2

Case.2

M=	25.890 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	50.317 kN	σsa =	157 N/mm^2	d =	0.23 m (effective height of member)
S0=	105.428 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	39.384 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.515 m

Solving the formula shown below, σc 4.301 N/mm^2 (0.0002 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.003 σc^2 -35.510 σc -185.850

s = nσc/(nσc+σsa) = 0.291

Asreq = (σc*s/2 - N/(bd))bd/σsa = 5.970 cm2

Case.3

M=	27.791 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	45.929 kN	σsa =	157 N/mm^2	d =	0.23 m (effective height of member)
S0=	111.940 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	42.676 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.605 m

Solving the formula shown below, σc 4.436 N/mm^2 (0.00013 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +13.916 σc^2 -37.350 σc -195.490

s = nσc/(nσc+σsa) = 0.298

Asreq = (σc*s/2 - N/(bd))bd/σsa = 6.748 cm2

Case.4

M=	26.378 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	45.929 kN	σsa =	157 N/mm^2	d =	0.23 m (effective height of member)
S0=	106.438 kN	n =	15	d' =	0.07 m (protective covering depth)
S2d=	40.393 kN			c =	0.08 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.574 m

Solving the formula shown below, σc 4.313 N/mm^2 (0.00019 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +13.996 σc^2 -35.680 σc -186.710

s = nσc/(nσc+σsa) = 0.292

Asreq = (σc*s/2 - N/(bd))bd/σsa = 6.294 cm2

The maximum requirement of reinforcement bar is 6.748 cm2 in Case 3 from above calculation.

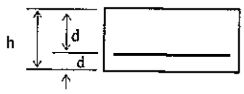
Case.	1	2	3	4	
Requirement	6.425	5.970	6.748	6.294	(cm2)

9) At Bottom of partition wall (joint D)

Case.1

M=	27.625 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	57.583 kN	σsa =	157 N/mm^2	d =	0.20 m (effective height of member)
S0=	115.831 kN	n =	15	d' =	0.10 m (protective covering depth)
S2d=	51.971 kN			c =	0.05 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.480 m



Solving the formula shown below, σc 5.179 N/mm^2 (1.3E-05 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +13.412 σc^2 -47.890 σc -250.630

s = nσc/(nσc+σsa) = 0.331

Asreq = (σc*s/2 - N/(bd))bd/σsa = 7.252 cm2

Case.2

M=	26.212 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	57.583 kN	σsa =	157 N/mm^2	d =	0.20 m (effective height of member)
S0=	110.328 kN	n =	15	d' =	0.10 m (protective covering depth)
S2d=	49.269 kN			c =	0.05 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.455 m

Solving the formula shown below, σc 5.027 N/mm^2 (2.1E-05 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +13.518 σc^2 -45.670 σc -239.020

s = nσc/(nσc+σsa) = 0.324

Asreq = (σc*s/2 - N/(bd))bd/σsa = 6.720 cm2

Case.3

M=	28.044 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	49.231 kN	σsa =	157 N/mm^2	d =	0.20 m (effective height of member)
S0=	116.840 kN	n =	15	d' =	0.10 m (protective covering depth)
S2d=	52.981 kN			c =	0.05 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.570 m

Solving the formula shown below, σc 5.179 N/mm^2 (1.3E-05 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +13.412 σc^2 -47.890 σc -250.650

s = nσc/(nσc+σsa) = 0.331

Asreq = (σc*s/2 - N/(bd))bd/σsa = 7.784 cm2

Case.4

M=	26.631 kN.m	σca =	8.0 N/mm^2	h =	0.30 m (height of member)
N=	49.231 kN	σsa =	157 N/mm^2	d =	0.20 m (effective height of member)
S0=	111.338 kN	n =	15	d' =	0.10 m (protective covering depth)
S2d=	50.278 kN			c =	0.05 m (distance from neutral axis)
				b =	1.00 m

e = M/N = 0.541 m

Solving the formula shown below, σc 5.027 N/mm^2 (2.1E-05 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +13.518 σc^2 -45.680 σc -239.040

s = nσc/(nσc+σsa) = 0.324

Asreq = (σc*s/2 - N/(bd))bd/σsa = 7.254 cm2

The maximum requirement of reinforcement bar is 7.784 cm2 in Case 3 from above calculation.

Case.	1	2	3	4	
Requirement	7.252	6.720	7.784	7.254	(cm2)

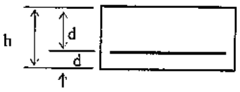
10) At Middle of partition wall

Case.1

M=	0.000 kN.m	σca =	8.0 N/mm^2	h =	0.40	m	(height of member)
N=	226.762 kN	σsa =	157 N/mm^2	d =	0.33	m	(effective height of member)
S0=	0.000 kN	n =	15	d' =	0.07	m	(protective covering depth)
				c =	0.13	m	(distance from neutral axis)
				b =	1.00	m	

e = M/N = 0.000 m

Solving the formula shown below, σc 2.776 N/mm^2 (3.7E-05 N/mm^2) o.k.



σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.888 σc^2 -17.000 σc -88.970

s = nσc/(nσc+σsa) = 0.210

Asreq = (σc*s/2 - N/(bd))bd/σsa = 0.000 cm2

Case.2

M=	0.000 kN.m	σca =	8.0 N/mm^2	h =	0.40	m	(height of member)
N=	215.757 kN	σsa =	157 N/mm^2	d =	0.33	m	(effective height of member)
S0=	0.000 kN	n =	15	d' =	0.07	m	(protective covering depth)
				c =	0.13	m	(distance from neutral axis)
				b =	1.00	m	

e = M/N = 0.000 m

Solving the formula shown below, σc 2.698 N/mm^2 (5.4E-05 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.927 σc^2 -16.170 σc -84.650

s = nσc/(nσc+σsa) = 0.205

Asreq = (σc*s/2 - N/(bd))bd/σsa = 0.000 cm2

Case.3

M=	0.000 kN.m	σca =	8.0 N/mm^2	h =	0.40	m	(height of member)
N=	228.780 kN	σsa =	157 N/mm^2	d =	0.33	m	(effective height of member)
S0=	0.000 kN	n =	15	d' =	0.07	m	(protective covering depth)
				c =	0.13	m	(distance from neutral axis)
				b =	1.00	m	

e = M/N = 0.000 m

Solving the formula shown below, σc 2.791 N/mm^2 (3.4E-05 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.881 σc^2 -17.150 σc -89.760

s = nσc/(nσc+σsa) = 0.210

Asreq = (σc*s/2 - N/(bd))bd/σsa = 0.000 cm2

Case.4

M=	0.000 kN.m	σca =	8 N/mm^2	h =	0.40	m	(height of member)
N=	217.775 kN	σsa =	157 N/mm^2	d =	0.33	m	(effective height of member)
S0=	0.000 kN	n =	15	d' =	0.07	m	(protective covering depth)
				c =	0.13	m	(distance from neutral axis)
				b =	1.00	m	

e = M/N = 0.000 m

Solving the formula shown below, σc 2.713 N/mm^2 (5E-05 N/mm^2) o.k.

σc^3+{3σsa/(2n) - 3N(e+c)/(bd^2)}σc^2 - 6N(e+c)σsaσc/(nbd^2) - 3N(e+c)σsa^2/(n^2bd^2) = 0

0 = σc^3 +14.92 σc^2 -16.330 σc -85.440

s = nσc/(nσc+σsa) = 0.206

Asreq = (σc*s/2 - N/(bd))bd/σsa = 0.000 cm2

The maximum requirement of reinforcement bar is 0.000 cm2 in Case 1 from above calculation.

Case.	1	2	3	4	
Requirement	0.000	0.000	0.000	0.000	(cm2)

11) Summary of required reinforcement

Required reinforcement for design is the maximum required reinforcement calculated above in 1) - 4).

Item	Side wall	Side wall	Top slab	Invert	Side wall	Top slab	Invert	Top slab	Invert	Par. Wall	
Point	bottom	top	end	end	middle	middle	middle	joint C	joint D	middle	
Side	outside	outside	outside	outside	inside	inside	inside	outside	outside	both	
Calculation	1)	2)	3)	4)	5)	6)	7)	8)	9)	10)	
Requirement	1.200	0.858	2.443	3.241	0.000	2.320	2.848	6.748	7.784	0.000	(cm2)

6 Bar Arrangement and Calculation of Stress

Type: B1.00m x H1.00m x 2 Goal Seek

			Side wall			Top slab		
			bottom	middle	top	end	middle	joint C
			outside	inside	outside	outside	inside	outside
Bending moment	M	kN.m	16.370	1.790	14.394	14.757	13.818	27.791
Shearing force (joint)	S	kN	57.583	0.000	50.317	92.345	0.000	111.940
Shearing force (2d)	S2d	kN	16.505	-	15.035	23.081	-	42.676
Axial force	N	kN	95.748	95.989	88.398	50.317	45.929	45.929
Height of member	h	cm	30.0	30.0	30.0	30.0	30.0	30.0
Covering depth	d'	cm	7.0	7.0	7.0	7.0	7.0	7.0
Effective height	d	cm	23.0	23.0	23.0	23.0	23.0	23.0
Effective width	b	cm	100	100	100	100	100	100
Effective area	bd	cm^2	2300	2300	2300	2300	2300	2300
Young's modulus ratio	n	-	15	15	15	15	15	15
Required R-bar	Asreq	cm^2	1.200	0.000	0.858	2.443	2.320	6.748
R-bar arrangement			13@250	13@250	13@250	13@250	13@250	13@250
Reinforcement	As	cm^2	5.31	5.31	5.31	5.31	5.31	5.31
Perimeter of R-bar	U	cm	16.34	16.34	16.34	16.34	16.34	16.34
M/N	e	cm	17.10	1.86	16.28	29.33	30.08	60.509
Dist. from neutral axis	c	cm	8.00	8.00	8.00	8.00	8.00	8.00
	a'		6.3	-39.4	3.8	43.0	45.3	136.5
	b'		119.9	47.1	116.0	178.4	182.0	327.4
	c'		-2758.6	-1084.3	-2669.1	-4103.1	-4186.2	-7530.4
	x	cm	9.87	38.91	10.25	7.42	7.36	6.21
			0.000	0.000	0.000	0.001	0.001	0.000
(check)			ok	ok	ok	ok	ok	ok
Compressive stress	σc	N/mm^2	2.47	0.49	2.14	2.47	2.31	4.84
Allowable stress	σca	N/mm^2	8.00	8.00	8.00	8.00	8.00	8.00
			ok	ok	ok	ok	ok	ok
Tensile stress	σs	N/mm^2	49.29	0.00	39.94	77.58	73.82	196.61
Allowable stress	σsa	N/mm^2	157.00	157.00	157.00	157.00	157.00	157.00
			ok	ok	ok	ok	ok	check
Shearing stress at joint	τ	N/mm^2	0.25	0.00	0.22	0.40	0.00	0.49
Allowable stress	τa	N/mm^2	0.84	0.84	0.84	0.84	0.84	0.84
			ok	ok	ok	ok	ok	ok
Shearing stress at 2d	τ2d	N/mm^2	0.07	-	0.07	0.10	-	0.19
Allowable stress	τ2da	N/mm^2	0.42	-	0.42	0.42	-	0.42
			ok	-	ok	ok	-	ok
p = As/(bd)			0.00231	0.00231	0.00231	0.00231	0.00231	0.00231
k = (2np+(np)^2)^0.5-np			0.23081	0.23081	0.23081	0.23081	0.23081	0.23081
j = 1-k/3			0.92306	0.92306	0.92306	0.92306	0.92306	0.92306
Resisting Moment	Mr	kN.m	41.786	41.842	40.081	31.622	30.686	30.686
Mr for compression	Mrc	kN.m	46.257	46.262	46.117	45.520	45.466	45.466
x for Mrc		m	0.065	0.065	0.064	0.059	0.058	0.058
σs for Mrc		N/mm^2	306.8	306.6	313.3	348.8	353.0	353.0
Mr for tensile	Mrs	kN.m	41.786	41.842	40.081	31.622	30.686	30.686
x for Mrs		m	0.089	0.089	0.087	0.077	0.075	0.075
σc for Mrs		N/mm^2	6.57	6.58	6.35	5.23	5.10	5.10
Distribution bar (>As/6 and >Asmin)			13@250	13@250	13@250	13@250	13@250	13@250
Reinforcement	As	cm^2	5.31	5.31	5.31	5.31	5.31	5.31
			ok	ok	ok	ok	ok	ok
Reinforcement bar for fillet			13@250		13@250			13@300
Reinforcement	As	cm^2	5.31		5.31			4.42

Minimum requirement of reinforcement bar As min = 4.5 cm2

			Invert			Partition wall
			end	middle	joint D	middle
			outside	inside	outside	both sides
Bending moment	M	kN.m	15.790	14.711	28.044	0.000
Shearing force (joint)	S	kN	99.695	0.000	116.840	0.000
Shearing force (2d)	S2d	kN	35.836	-	52.981	-
Axial force	N	kN	49.231	49.231	49.231	226.762
Height of member	h	cm	30.0	30.0	30.0	40.0
Covering depth	d'	cm	10.0	10.0	10.0	7.0
Effective height	d	cm	20.0	20.0	20.0	33.0
Effective width	b	cm	100	100	100	100
Effective area	bd	cm^2	2000	2000	2000	3300
Young's modulus ratio	n	-	15	15	15	15
Required R-bar	Asreq	cm^2	3.241	2.848	7.784	0.000
R-bar arrangement			13@250	13@250	16@250	13@300
Reinforcement	As	cm^2	5.31	5.31	8.04	4.42
Perimeter of R-bar	U	cm	16.34	16.34	20.11	13.61
M/N	e	cm	32.07	29.88	56.97	0.00
Dist. from neutral axis	c	cm	5.00	5.00	5.00	13.00
	a'		51.2	44.6	125.9	-60.0
	b'		177.2	166.7	448.4	51.7
	c'		-3543.5	-3333.9	-8967.6	-1706.6
	x	cm	6.45	6.60	6.70	59.61
			0.000	0.000	0.000	0.000
(check)			ok	ok	ok	ok
Compressive stress	σc	N/mm^2	3.17	2.92	5.12	0.75
Allowable stress	σca	N/mm^2	8.00	8.00	8.00	8.00
			ok	ok	ok	ok
Tensile stress	σs	N/mm^2	99.86	88.98	152.35	-5.04
Allowable stress	σsa	N/mm^2	157.00	157.00	157.00	157.00
			ok	ok	ok	ok
Shearing stress at joint	τ	N/mm^2	0.50	0.00	0.58	0.00
Allowable stress	τa	N/mm^2	0.84	0.84	0.84	0.84
			ok	ok	ok	ok
Shearing stress at 2d	τ2d	N/mm^2	0.18	-	0.26	-
Allowable stress	τ2da	N/mm^2	0.42	-	0.42	-
			ok	-	ok	-
p = As/(bd)			0.00266	0.00266	0.00402	0.00134
k = (2np+(np)^2)^0.5-np			0.24519	0.24519	0.29217	0.18137
j = 1-k/3			0.91827	0.91827	0.90261	0.93954
Resisting Moment	Mr	kN.m	30.164	30.164	42.767	79.964
Mr for compression	Mrc	kN.m	37.285	37.285	43.151	79.964
x for Mrc		m	0.055	0.055	0.064	0.091
σs for Mrc		N/mm^2	319.1	319.1	256.2	313.6
Mr for tensile	Mrs	kN.m	30.164	30.164	42.767	87.091
x for Mrs		m	0.071	0.071	0.082	0.137
σc for Mrs		N/mm^2	5.78	5.78	7.26	7.40
Distribution bar (>As/6 and >Asmin)			13@250	13@250	13@250	13@250
Reinforcement	As	cm^2	5.31	5.31	5.31	5.31
			ok	ok	ok	ok
Reinforcement bar for fillet					13@300	
Reinforcement	As	cm^2			4.42	

Minimum requirement of reinforcement bar As min = 4.5 cm2

Summary of Internal forces

Member	Case	Check Point	M (kN.m)	N (kN)	S (kN) at joint	S (kN) at 2d
Side wall (left)	Case.1	A	-16.733	99.695	57.583	16.505
		Middle	1.790	95.989	0.000	-
		B	-14.757	92.345	-50.317	-15.035
	Case.2	A	-16.370	95.748	57.583	16.505
		Middle	2.153	92.041	0.000	-
		B	-14.394	88.398	-50.317	-15.035
	Case.3	A	-15.790	98.686	49.231	15.306
		Middle	0.639	94.905	0.000	-
		B	-13.884	91.336	-45.929	-12.510
	Case.4	A	-15.427	94.739	49.231	15.306
		Middle	1.003	90.957	0.000	-
		B	-13.520	87.389	-45.929	-12.510
Top slab (left)	Case.1	B	-14.757	50.317	92.345	23.081
		Middle	13.560	50.317	0.000	-
		C	-27.303	50.317	-110.931	-41.666
	Case.2	B	-14.394	50.317	88.398	22.353
		Middle	12.819	50.317	0.000	-
		C	-25.890	50.317	-105.428	-39.384
	Case.3	B	-13.884	45.929	91.336	22.072
		Middle	13.818	45.929	0.000	-
		C	-27.791	45.929	-111.940	-42.676
	Case.4	B	-13.520	45.929	87.389	21.344
		Middle	13.075	45.929	0.000	-
		C	-26.378	45.929	-106.438	-40.393
Partition wall	Case.1	C	0.000	221.862	0.000	0.000
		Middle	0.000	226.762	0.000	-
		D	0.000	231.662	0.000	0.000
	Case.2	C	0.000	210.857	0.000	0.000
		Middle	0.000	215.757	0.000	-
		D	0.000	220.657	0.000	0.000
	Case.3	C	0.000	223.880	0.000	0.000
		Middle	0.000	228.780	0.000	-
		D	0.000	233.680	0.000	0.000
	Case.4	C	0.000	212.875	0.000	0.000
		Middle	0.000	217.775	0.000	-
		D	0.000	222.675	0.000	0.000
Invert (left)	Case.1	D	-27.625	57.583	115.831	51.971
		Middle	14.395	57.583	0.000	-
		A	-16.733	57.583	-99.695	-35.836
	Case.2	D	-26.212	57.583	110.328	49.269
		Middle	13.658	57.583	0.000	-
		A	-16.370	57.583	-95.748	-34.688
	Case.3	D	-28.044	49.231	116.840	52.981
		Middle	14.711	49.231	0.000	-
		A	-15.790	49.231	-98.686	-34.826
	Case.4	D	-26.631	49.231	111.338	50.278
		Middle	13.972	49.231	0.000	-
		A	-15.427	49.231	-94.739	-33.679

Member	Case	Check Point	M (kN.m)	N (kN)	S (kN) at joint	S (kN) at 2d
Top slab (right)	Case.1	C	-27.303	50.317	110.931	41.666
		Middle	13.560	50.317	0.000	-
		E	-14.757	50.317	-92.345	-23.081
	Case.2	C	-25.890	50.317	105.428	39.384
		Middle	12.819	50.317	0.000	-
		E	-14.394	50.317	-88.398	-22.353
	Case.3	C	-27.791	45.929	111.940	42.676
		Middle	13.818	45.929	0.000	-
		E	-13.884	45.929	-91.336	-22.072
	Case.4	C	-26.378	45.929	106.438	40.393
		Middle	13.075	45.929	0.000	-
		E	-13.520	45.929	-87.389	-21.344
Side wall (right)	Case.1	E	-14.757	92.345	50.317	15.035
		Middle	1.790	95.989	0.000	-
		F	-16.733	99.695	-57.583	-16.505
	Case.2	E	-14.394	88.398	50.317	15.035
		Middle	2.153	92.041	0.000	-
		F	-16.370	95.748	-57.583	-16.505
	Case.3	E	-13.884	91.336	45.929	12.510
		Middle	0.639	94.905	0.000	-
		F	-15.790	98.686	-49.231	-15.306
	Case.4	E	-13.520	87.389	45.929	12.510
		Middle	1.003	90.957	0.000	-
		F	-15.427	94.739	-49.231	-15.306
Invert (right)	Case.1	F	-16.733	57.583	99.695	35.836
		Middle	14.395	57.583	0.000	-
		D	-27.625	57.583	-115.831	-51.971
	Case.2	F	-16.370	57.583	95.748	34.688
		Middle	13.658	57.583	0.000	-
		D	-26.212	57.583	-110.328	-49.269
	Case.3	F	-15.790	49.231	98.686	34.826
		Middle	14.711	49.231	0.000	-
		D	-28.044	49.231	-116.840	-52.981
	Case.4	F	-15.427	49.231	94.739	33.679
		Middle	13.972	49.231	0.000	-
		D	-26.631	49.231	-111.338	-50.278

Appendix-IIC

PROJECT EVALUATION

THE STUDY
ON
COMPREHENSIVE AGRICULTURAL DEVELOPMENT
OF
PREK THNOT RIVER BASIN
IN
THE KINGDOM OF CAMBODIA

FINAL REPORT
Volume-VII: Appendixes for Feasibility Studies for Priority/Urgent Projects
Appendix-IIC
Project Evaluation

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APPENDIX-IIC: PROJECT EVALUATION

Chapter IIC-1 Objectives and Evaluated Project

IIC-1.1 Objectives

The objectives of project evaluation for Feasibility Study is to evaluate the anticipated economic and social impacts of the prioritized projects in the Master Plan with higher degree of accuracy and updated data, as well as from different angles other than quantifiable monetary terms but from qualitative terms. The project evaluation for Feasibility Study consists of three different types of evaluation approaches with each of them focusing on different aspects of the project, as listed below.

Evaluation Approaches Applied and Their Objectives

Evaluation Approaches	Objectives
(1) Economic Evaluation	To evaluate the economic impact of the Project in quantifiable, monetary terms from the viewpoint of "national economy"
(2) Financial Evaluation	To evaluate the financial viability of the Project in quantifiable, monetary terms from viewpoint(s) of project entity and/or beneficiaries
(3) Socio-Economic Impact Evaluation	To evaluate the Project's socio-economic impacts in non-monetary, qualitative terms

IIC-1.2 Evaluated Project

Based on the results of economic evaluation at Master Plan stage, 2 out of 9 proposed projects were selected for Feasibility Study, they are;

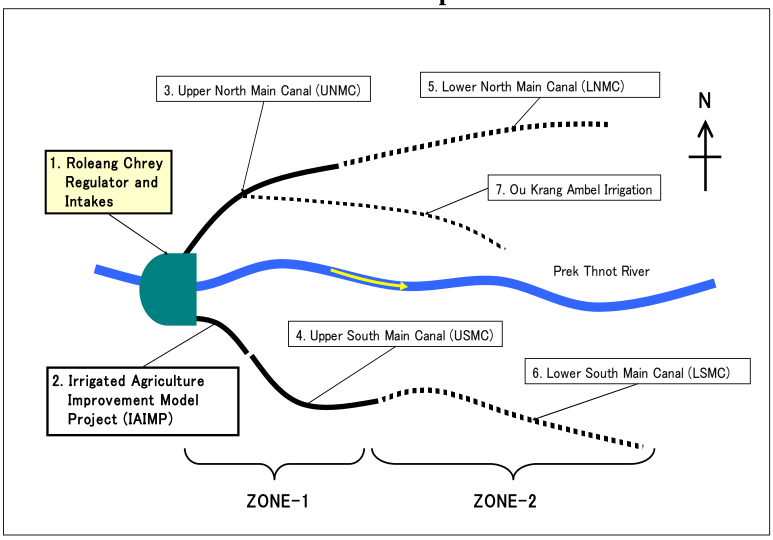
(1) Roleang Chrey Regulator and Intakes Improvement Project, and

(2) Irrigated Agriculture Improvement Model Project.

In this Appendix-IIC, **Roleang Chrey Regulator and Intakes Improvement Project** (hereinafter referred to as "the Project") will be evaluated.

As it can be seem in the schematic map in right, Roleang Chrey Regulator and Intakes is situated at the upper-most stream of the Prek Thnot River in the Target Zone, and is the KEY STRUCTURE for all connected irrigation schemes in the down stream. Therefore all connected schemes are assuming the improvement of Roleang Chrey Regulator and Intakes, as the precondition for their own improvements.

Schematic Map



Chapter IIC-2 Economic Evaluation

IIC-2.1 Evaluation Procedures

The purpose of economic evaluation is to quantitatively assess the overall impact of a project in contributing national economic objectives. Therefore, the impact of the project is assessed in the context of national economy rather than in the context of the project entity or the beneficiaries. The project economic evaluation was carried out through the standard methodology in project appraisal, i.e. estimation of Economic Internal Rate of Return (EIRR), Cost-Benefit Ratio (B/C), and Benefit minus Cost (B-C).

All prices for Feasibility Study evaluation were expressed in constant prices as of January 2007, applying the average monthly official exchange rate of USD 1.0 = Riel 4,060. The economic life of the project is assumed to be 50 years beginning from year 2008, the proposed commencement year for construction.

Economic farm gate prices of internationally traded agricultural inputs and outputs were based on their export and import parity prices derived from the World Bank Commodity Price Forecasts as of October 2006. The long-run projected prices in 2010 at 2007 constant prices were used in the analysis. The average of export and import parity prices of farm products of rice, maize, and import parity prices of fertilizer were calculated and applied for the economic prices as shown in Table IIC-1 (1/5 to 3/5).

A standard conversion factor (SCF) of 0.98 and shadow wage rates (SWR) were applied for the adjustment of prices and labor costs reflecting the market distortion, as shown in Table IIC-1 (4/5 to 5/5). Economic prices applied for preparation of crop production budgets were summarized in Table IIC-2.

Transfer payment such as tax, duty, subsidy, interest, etc., were excluded in estimating the economic costs and benefits. Financial construction costs were converted into economic values by applying the construction conversion factors (CCFs).

IIC-2.2 Economic Benefit

Irrigation and drainage benefit will be accrued from increase in cropping areas and productivity of target crops comprising paddy and upland crops such as mungbean and vegetables. The economic benefit is usually estimated as the increment of net production value between future “with” and present “without” project conditions. However, for the evaluation of the Project, the economic benefit is estimated as the SAVING of net production value between future “with” and “without” project conditions.

The reason why saving of net production value is looked at is that Roleang Chrey Regulator is assuming complete malfunctioning of its gate from 2008 which requires the urgent improvement.[1] Its present status is judged quite serious and with very high probability, the gates will become inoperable before long. Thereby the net production values for the case of this very project, ‘with’ and ‘without’ mean ‘action taken’ case and ‘no action taken’ case. <u>The Project is aiming at maintaining the present production level in all connected command areas by preventing the irrigation water supply deterioration</u>. In other words, this is a project to save costs of no action.

The economic crop budgets of respective crops under present condition were prepared in Table IIC-3, by applying requirements for farm inputs and total labor, unit crop yields, and their economic prices. The irrigation and drainage benefit for the Project (“saving” of net production value) was estimated as follows (for details, see Table IIC-4).[2]

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[1] In October 2006, Roleang Chrey Regulator received an urgent treatment of counterweight wire replacement and supply of an additional generator. However, it is band-aid-like treatment and its effect is assumed to last only temporary.

[2] Although Lower South Main Canal irrigation (LSMC) scheme is connected to Roleang Chrey Regulator and Intakes, improvement of regulator and intakes won’t affect LSMC’s cropping pattern unless the lower part of south main canal is

Economic Benefit of the Project

Project Area (ha)	Cropping Intensity (%)		Net Production Value (Million Riels)		
	Without Project	With Project	Without Project	With Project	Saving
16,925*	**100.8	**103.3	7,084.7	8,618.2	**1,533.5**

* Assuming the implementation of all proposed projects, 16,700ha was used at the time of MP Study.
** Weighted average of connected irrigation schemes.

Annual economic benefit flow was estimated, though since the very decision to implement this project virtually means the immediate derivation of its benefit, the benefit flow is quite simple (Table IIC-5).

IIC-2.3 Negative Benefit

No negative benefit is anticipated with the implementation of this project.

IIC-2.4 Economic Cost

(1) Cost for Project Investment

The economic construction cost was classified by (i) preparatory works, (ii) direct construction, (iii) O&M equipment, (iv) administration, (v) environmental monitoring, (vi) engineering services, and (vii) physical contingencies (See Table IIC-6). The economic project investment cost was estimated by applying relevant conversion factors to the components of financial foreign and local currency costs comprising equipments, materials and labor. The total economic project cost was estimated as follows.

Economic Investment Cost of the Project

Project Area (ha)	Economic Investment Cost (Riel, Million)	Cost Per ha (Riel '000)
16,925	13,819	816

(2) O&M Cost

The financial O&M cost was converted to economic value by applying relevant conversion factors to the components of financial foreign and local currency costs, in the way same as the project investment costs. The O&M cost of the Project was estimated as follows (Table IIC-7).

Economic O&M Cost of the Project

Project Area (ha)	O & M Cost (Riel, Million/year)	Cost Per ha (Riel)
16,925	29.9	1,767

(3) Replacement Cost

The replacement cost of the project facilities and equipments was estimated by applying the conversion factors to the respective financial cost for replacement. The useful life of the gates of the Project is 25 years and their economic replacement cost was estimated as 4,518.5 Million Riels (Table IIC-8).

IIC-2.5 Economic Evaluation Results

The economic cost and benefit stream comprising (i) the cost for project investment, O&M and replacement, and (ii) the benefit from irrigation and drainage, as well as negative benefit was prepared for the economic life of the Project (Table IIC-9).

Economic internal rate of return (EIRR) and other indicators were calculated and summarized as follows.

rehabilitated. Therefore LSMC is excluded from Table IIC-4.

Economic Benefit of the Project

EIRR (%)	NPV (Riel, Million) (7% discount rate)			B/C
	Benefit	Cost	B-C	
14.9	19,779	12,007	7,772	1.6

IIC-2.6 Sensitivity Analysis

The project sensitivity in terms of EIRR was analyzed in respect of changes in project cost and benefit as follows:

(1) Project cost increase 30%
(2) Project benefit decrease 30%
(3) Project cost increase 20% and benefit decrease 20%
(4) Delay of project benefit derivation for 2 years

The result of sensitivity test is summarized as follows.

Sensitivity of the Project

Cases of Change	Change in Variation	EIRR (%)	Switching Value EIRR: 7.0 %
Base case	-	14.9	-
- Cost increased	+ 30 %	10.2	+69
- Benefit decreased	- 30 %	8.7	-39
- Cost increased & benefit decreased	+ 20 % - 20 %	8.2	-
- Delay of benefit derivation	2 years	10.9	7 years

The sensitivity test revealed that the Project is relatively more sensitive to the benefit reduction rather than cost increase, though it can accommodate considerable changes in these variables.

Chapter IIC-3 Financial Evaluation

IIC-3.1 Cash Flow Analysis

The cash flow analysis was made under the following conditions and on the assumption that MOWRAM implements the Project under the financial cooperation from foreign aid agency.

(1) Loan conditions of foreign aid agency

1) Interest rate : 2.3% per year

2) Grace period : 10 years

3) Repayment period : 30 years (including grace period)

4) Items not eligible for financing are listed below.

- General administration expense
- Taxes and duties
- Purchase of land and other real property
- Compensation
- Other indirect items

(2) Raising capital other than foreign loan: the national treasury covers all the costs other than foreign-aid loans under the condition of no interest and no repayment.

Based on these conditions, the total fund requirement and internal capital raising amount were estimated as follows.

Capital Cost to be raised of the Project

(Unit: Riel, Million)

	External Loan	National Budget	Total
a) Rehabilitation and improvement of regulator and intakes facilities	11,949	-	11,949
b) Administration cost	-	1,194	1,194
c) Environmental monitoring cost	-	12	12
d) Engineering service cost	2,647	-	2,647
e) Physical Contingency	1,460	119	1,579
f) Price contingency	2,652	231	2,883
Total	18,708	1,556	20,264

As shown in above table, the loan requirement from the foreign aid agency was estimated at about Riel 18,708 Million (US$ 4.6 Million). The MOWRAM's cash flow statement to this loan amount is presented in Table IIC-10. The annual repayment of the fund is estimated to be Riel 1,366-957 million during the repayment period from 11^{th} to 30^{th} year. Repayment of the fund will have to be made by subsidy from government.

IIC-3.2 Farm Budget Analysis

Farm budget analysis of typical farms on net returns from paddy field under the present 'with' and future 'without'-project condition has been made for the financial analysis of the Project. The assumptions involved in the analysis are as follows;

Assumptions for Farm Economic Analyses

Typical Farms	Holding size of paddy field: 0.7 ha per farm household
Subject of Analysis	Net return from paddy field under without-project condition
Without-project & Present (with-project) Farm Net Return from Paddy Field	Present (with-project) & without-project crop budgets are applied for estimation

The results of the analyses are presented in Table IIC-11 and summarized in the following table.

Results of Farm Economic Analyses (unit: Riel)

Zone/Project	1. Present (with-project) Net Return from Paddy Field per Farm	2. Without-project Net Return from Paddy Field per Farm	Increment (saving of The loss) per farm (1 – 2)
Zone-1 [1/]			
- Model Project	791,000	424,000	367,000
- UNMC	552,000	417,000	135,000
- USMC	486,000	417,000	68,000
Zone-2	469,000	417,000	51,000

[1/]: Irrigated Agricultural Improvement Model Project
Upper North Main Canal Irrigated Agricultural Improvement Project (UNMC)
Upper South Main Canal Irrigated Agricultural Improvement Project (USMC)

As shown in above table, the anticipated incremental net return (i.e. return to-be-saved from losses caused by complete malfunctioning of the regulator) from paddy field under the with-project condition are estimated at the range of Riel 367,000 to 51,000 per farming household. In terms of proportion, it can be expressed that from 46 to 10% of the total farming incomes per household are at stake with impending malfunctioning of the regulator.

Chapter IIC-4 Socio-economic Impact

IIC-4.1 Socio-economic Impact

The primary objective of the Project is to prevent its impending malfunctioning and negative repercussions from occurring. While the anticipated negative impacts on agricultural production in quantitative terms have been discussed in previous chapters, other impacts that should be paid attention also exist, since Roleang Chrey regulator deeply relates to the daily livelihoods of the residents in the area.

IIC-4.1.1 Poverty Incidence

It is not difficult to imagine that the poverty incidence in the area will rise if the Project is not implemented, due to decreased (in some part, drastically) agricultural production. Poverty incidence affects not only those households but also society as a whole, for its integrity as well as security.

IIC-4.1.2 Household Water Supply

Not a small number of populace in the area rely heavily or partially on the water flowing in the canal diverted from Roleang Chrey Regulator for their daily livelihood. Therefore the population to face the household water shortage due to the regulator's malfunctioning is considered to be large. This negative impact not only affects the convenience aspect of the livelihoods in relation to water, i.e. washing, etc. but also for their health status. Unhygienic living condition to be created by the water shortage, especially during the dry season would affect the illness rates in the area.

IIC-4.1.3 Gender Aspect

The water shortage to be caused by the malfunctioning of regulator would also influence the gender relationship in the area. Women in the area are charged with relatively higher responsibility for household affairs than men and spend more time dealing with household water needs. Therefore the household water shortage may directly and immediately puts additional burdens on women in the area.

IIC-4.1.4 Small Fishes as Supplementary Protein Source

Catching of small fishes along the canal is quite popular daily activity in the area, and is considered to be important supplementary source of protein. Malfunctioning of regulator would severely influence this activity, too.

IIC-4.2 Indispensable Precondition for Present and Future Socio-economic Welfare in the Area

As discussed above, "maintaining" the present condition and preventing the anticipated negative impacts from occurring by the implementation of the Project has a special significance for the social and economic welfares of the people in the area.

Moreover, its significance encompasses not only in maintaining the present status but also as the foundation stone for the future improvements of various irrigation blocks connected. Implementation of this project is the precondition for preserving the area's agricultural potential that one day in the future may come into blossom, for the further improvement of the socio-economic welfares of the populace.

Tables

Table IIC-1 Economic Price Estimate for Traded Goods, F/S Study (1/5)

Item		Import Parity Price			Export Parity Price		
		Operation	Unit	Price	Operation	Unit	Price
I. Rice/Paddy							
1. Projected 2010 World Price (in 1990 price) /a			US$/ton	225		US$/ton	225
2. Projected 2010 World Price (in 2007 price) /a			US$/ton	258.0		US$/ton	258
3. Quality Adjustment		x	%	90	x	%	90
4. CIF/FOB Price at Kompong Som Port /b		=	US$/ton	232.2	=	US$/ton	232.2
5. Port Charge, Handling and Warehousing		+	US$/ton	13.2	-	US$/ton	13.2
6. Price at Kompong Som Port		=	US$/ton	245.4	=	Riel/kg	219.0
Equivalent in Riel / kg /c		=	Riel/kg	996	=	Riel/kg	889
7. Transportation Cost /d	(Kampong Som-Phnom Penh)	+	Riel/kg	26			
	(Kampong Speu-Kampong Som)				-	Riel/kg	22
	(Kampong Speu -Phnom Penh`	-	Riel/kg	3			
8. Ex-Mill /Wholesale Price in Kampong Speu		=	Riel/kg	1,019	=	Riel/kg	867
9. Milling Cost and Margin /d		-	Riel/kg	23	-	Riel/kg	23
10. Processing Ratio		x	%	66	x	%	66
11. By-Products through Processing /e		+	Riel/kg	70	+	Riel/kg	70
12. Millgate Paddy Price		=	Riel/kg	727	=	Riel/kg	627
13. Transport/Handling from Farmgate /d		-	Riel/kg	16	-	Riel/kg	16
14. Farmgate Price		=	Riel/kg	711	=	Riel/kg	611
		50%			50%		
17. Weighted average economic farm gate price			Riel/kg	661			
II. Maize							
1. Projected 2010 World Price (in 1990 price) /a			US$/ton	91		US$/ton	91
2. Projected 2010 World Price (in 2007 price) /a			US$/ton	104.3		US$/ton	104.3
3. International Shipping and Handling		+	US$/ton	35.0			
4. CIF/FOB Price at Kompong Som Port		=	US$/ton	139.3	=	US$/ton	104.3
5. Port Charge, Handling and Warehousing		+	US$/ton	13.2	-	US$/ton	13.2
6. Price at Kompong Som Port		=	US$/ton	152.5	=	Riel/kg	91.1
Equivalent in Riel / kg /c		=	Riel/kg	619	=	Riel/kg	370
7. Transportation Cost /d	(Kampong Som-Phnom Penh)	+	Riel/kg	26			
	(Kampong Speu -Kampong Som)				-	Riel/kg	22
	(Kampong Speu -Phnom Penh`	-	Riel/kg	3			
8. Price in Kampong Speu		=	Riel/kg	642	=	Riel/kg	348
9. Transport/Handling from Farmgate /d		-	Riel/kg	16	-	Riel/kg	16
10. Farmgate Price		=	Riel/kg	626	=	Riel/kg	332
		50%			50%		
17. Weighted average economic farm gate price			Riel/kg	480			

Note : /a ; Based on the World Bank, Global Commodity Forecast, **Oct. 2006**
The projected prices in 1990 constant US$ were adjusted by the factor of 1.147 (MUV)
to allow for price escalation between 1990 and **2007**.
Paddy : Thai, milled, 5% broken, FOB Bangkok
Maize : US No.2, Yellow, FOB Gulf Ports
/b ; Assumed at the same price at Bangkok port in Thailand
/c ; Exchange rate : US$ = Riel 4,060
/d ; Adjusted with SCF of 0.98
/e ; Rice bran : Riel 300 /kg of rice bran, 18% of paddy weight
Broken rice: Riel 320 /kg of broken rice, 5 % of paddy weight.

Table IIC-1 Economic Price Estimate for Traded Goods, F/S Study (2/5)

Item		Import Parity Price			Export Parity Price		
		Operation	Unit	Price	Operation	Unit	Price
III. Soybean							
1. Projected 2010 World Price (in 1990 price) /a			US$/ton	220		US$/ton	220
2. Projected 2010 World Price (in 2007 price) /a			US$/ton	252.2		US$/ton	252.2
3. International Shipping and Handling		+	US$/ton	35.0			
4. CIF/FOB Price at Kompong Som Port		=	US$/ton	287.2	=	US$/ton	252.2
5. Port Charge, Handling and Warehousing		+	US$/ton	13.2	-	US$/ton	13.2
6. Price at Kompong Som Port		=	US$/ton	300.4	=	Riel/kg	239.0
Equivalent in Riel / kg /b		=	Riel/kg	1,220	=	Riel/kg	970
7. Transportation Cost /c	(Kampong Som-Phnom Penh)	+	Riel/kg	26			
	(Kampong Speu -Kampong Som)				-	Riel/kg	22
	(Kampong Speu -Phnom Penh)	-	Riel/kg	3			
8. Trade Price in Kampong Speu		=	Riel/kg	1,243	=	Riel/kg	948
9. Transport/Handling from Farmgate /c		-	Riel/kg	16	-	Riel/kg	16
10. Farmgate Price		=	Riel/kg	1,227	=	Riel/kg	932
		50%			50%		
11. Weighted average economic farm gate price			Riel/kg	1,080			
IV. Groundnut							
1. Projected 2010 World Price (in 1990 price) /a			US$/ton	687		US$/ton	687
2. Projected 2010 World Price (in 2007 price) /a			US$/ton	787.6		US$/ton	787.6
3. Conversion to Shelled Groundnuts (50%)			US$/ton	393.8		US$/ton	393.8
4. International Shipping and Handling		+	US$/ton	35.0			
5. CIF/FOB Price at Kompong Som Port		=	US$/ton	428.8	=	US$/ton	393.8
6. Port Charge, Handling and Warehousing		+	US$/ton	13.2	-	US$/ton	13.2
7. Price at Kompong Som Port		=	US$/ton	442.0	=	Riel/kg	380.6
Equivalent in Riel / kg /b		=	Riel/kg	1,795	=	Riel/kg	1,545
8. Transportation Cost /c	(Kampong Som-Phnom Penh)	+	Riel/kg	26			
	(Kampong Speu-Kampong Som)				-	Riel/kg	22
	(Kampong Speu -Phnom Penh)	-	Riel/kg	3			
9. Trade Price in Kampong Speu		=	Riel/kg	1,818	=	Riel/kg	1,523
10. Transport/Handling from Farmgate /c		-	Riel/kg	16	-	Riel/kg	16
11. Farmgate Price	- Without Shell	=	Riel/kg	1,802	=	Riel/kg	1,507
	- With Shell (80%)	=	Riel/kg	1,442	=	Riel/kg	1,206
		50%			50%		
12. Weighted average economic farm gate price			Riel/kg	1,324			

Note : /a ; Based on the World Bank, Global Commodity Forecast, Oct. 2006
* The projected prices in 1990 constant US$ were adjusted by the factor of 1.147 (MUV)
to allow for price escalation between 1990 and 2007.
Soybeans, Groundnut oil : CIF Rotterdam
/b ; Exchange rate : US$ = Riel 4,060
/c ; Adjusted with SCF of 0.98

Table IIC-1 Economic Price Estimate for Traded Goods, F/S Study (3/5)

Item	Import Parity Price		
	Operation	Unit	Price
V. Fertilizer			
(1) Urea			
1. Projected 2010 World Price (in 1990 price) /a		US$/ton	173.0
2. Projected 2010 World Price (in 2007 price) /a		US$/ton	198.3
3. International Shipping and Handling	+	US$/ton	40.0
4. CIF Price at Kompong Som Port	=	US$/ton	238.3
5. Port Charge, Handling and Warehousing	+	US$/ton	13.2
6. Price at Kompong Som Port	=	US$/ton	251.5
Equivalent in Riel / kg /b	=	Riel/kg	1,021
7. Transportation Cost /c (Kampong Som-Kampong Speu)	+	Riel/kg	22
8. Trade Price in Kampong Speu	=	Riel/kg	1,043
9. Transport/Handling to Farmgate /c	+	Riel/kg	16
10. Farmgate Price	=	Riel/kg	1,059
Price of Nutrient (N) /e		Riel/kg	2,302
(2) DAP (Diammonium Phosphate)			
1. Projected 2010 World Price (in 1990 price) /a		US$/ton	190
2. Projected 2010 World Price (in 2007 price) /a		US$/ton	217.8
3. International Shipping and Handling	+	US$/ton	45.0
4. CIF Price at Kompong Som Port	=	US$/ton	262.8
5. Port Charge, Handling, Warehousing and Bagging	+	US$/ton	13.2
6. Price at Kompong Som Port	=	US$/ton	276.0
Equivalent in Riel / kg /b	=	Riel/kg	1,121
7. Transportation Cost /c (Kampong Som-Kampong Speu)	+	Riel/kg	22
8. Trade Price in Kampong Speu	=	Riel/kg	1,143
9. Transport/Handling to Farmgate /c	+	Riel/kg	16
10. Farmgate Price	=	Riel/kg	1,159
Price of Nutrient (P) /e		Riel/kg	2,520
Price of Nutrient (N) /e		Riel/kg	6,439
(3) Potassium Chloride (KCL) /d			
1. Projected 2010 World Price (in 1990 price) /a		US$/ton	124.0
2. Projected 2010 World Price (in 2005 price) /a		US$/ton	142.2
3. International Shipping and Handling	+	US$/ton	40.0
4. CIF Price at Kompong Som Port	=	US$/ton	182.2
5. Port Charge, Handling, Warehousing and Bagging	+	US$/ton	13.2
6. Price at Kompong Som Port	=	US$/ton	195.4
Equivalent in Riel / kg /b	=	Riel/kg	793
7. Transportation Cost /c (Kampong Som-Takeo)	+	Riel/kg	22
8. Trade Price in Takeo	=	Riel/kg	815
9. Transport/Handling to Farmgate /c	+	Riel/kg	16
10. Farmgate Price	=	Riel/kg	831
Price of Nutrient (K) /e		Riel/kg	1,385

Note : /a ; Based on the World Bank, Global Commodity Forecast, Oct. 2006

* The projected prices in 1990 constant US$ were adjusted by the factor of 1.147 (MUV) to allow for price escalation between 1990 and 2007.

Urea : Bagged, FOB Black Sea

DAP : Bulk, FOB US Gulf

KCL : Bulk, FOB Black Sea

/b ; Exchange rate : US$ = Riel 4,060

/c ; Adjusted with SCF of 0.98

/d ; Potassium Chloride (Muriate of Potash)

/e ; Nutrient content is 46%, 46%(18-46-0), and 60%, respectively for Urea, DAP and KCL.

Table IIC-1 Economic Price Estimate for Traded Goods, F/S Study (4/5)

VI. Estimation of Standard Conversion factors

Year	Total Import Value to Cambodia (CIF)	Total Export Value from Cambodia (FOB)	Import Subsidy /a	Import Tax /b	Export Subsidy	Export Tax	Standard Conversion Factor
	(Unit ; US$ Million)						
	I	E	Is	It	Es	Et	SCF
1998	1,262	802		98.7		0.7	0.955
1999	1,723	1,130		108.9		4.3	0.965
2000	2,096	1,397		96.7		4.1	0.974
2001	2,270	1,571		92.8		2.5	0.977
2002	2,554	1,770		104.0		3.7	0.977
2003	2,888	2,087		117.1		4.5	0.978
2004	3,538	2,589		153.3		4.8	0.976
2005	4,254	2,910		134.3		4.6	0.982
Average Standard Conversion Factor (SCF)							
1998-2004							0.973
1998-2003							0.971
2001-2005							**0.978**

Note : SCF = (I+E) / [(I-Is+It)+(E+Es-Et)]

/a ; Import subsidy is accounted at the import tax exemption.

/b ; Custom duties are accounted.

Sources : Ministry of Planning, Cambodia Statistical Yearbook 2006

Table IIC-1 Economic Price Estimate for Traded Goods, F/S Study (5/5)

VII. Estimate of Shadow Wage Factor in the Study Area

Item	Operation		Unit	2005	2010	2020
1. Total Population in the Study Area			Person	322,706	357,658	441,610
(Population growth rate)/a			(%)		(1.73)	(2.13)
2. Labor Force Population			Person			
Total /b	(37.6%)			121,300	134,500	166,000
For agriculture				78,800	80,700	91,300
				(65.0%)	(60.0%)	(55.0%)
3. Annual Available Person-Day	236 (P.day/person/year)		P.day/year	18,596,800	19,045,200	21,546,800
4. Net Annual Available Person-Day for Agriculture	(50%)		P.day/year	9,298,400	9,522,600	10,773,400
5. Agricultural Labor Input /c		Distribution	P.day/year			
5.1 Present/Without Project Condition	(41,500ha)					
1) Wet season paddy (irrigated)	(580ha)	1.40%			69,600	69,600
2) Wet season paddy (supplement)	(5,420ha)	13.06%			525,740	525,740
3) Wet season paddy (rainfed)	(35,500ha)	85.54%			2,769,000	2,769,000
4) Diversified crop (rainfed)						
Mungbean	(1,250ha)	3.00%			62,500	62,500
Other cereals/vegetables	(1,660ha)	4.00%			149,400	149,400
(1) + 2) + 3) + 4))	(44,410ha)	107.00%			3,576,240	3,576,240
5) Other farm works	(30% of cropping)				1,072,900	1,072,900
Total (1), 2), 3), 4) and 5))					4,649,140	4,649,140
5.2 Future/With Project Condition	(17,300ha)					
A. Upper North & South Main Canal (MC	(5,660ha)					
1) Wet season paddy (irrigated)	(570ha)	10.07%			71,250	71,250
2) Wet season paddy (supplement)	(5,090ha)	89.93%			559,900	559,900
3) Wet season paddy (rainfed)	(0ha)	0.00%			0	0
4) Diversified crop (irrigated/rainfed)						
Mungbean	(170ha)	3.00%			10,200	10,200
Vegetables	(230ha)	4.00%			20,880	20,880
(1) + 2) + 3) + 4))	(6,060ha)	107.00%			662,230	662,230
5) Other farm works	(30% of cropping)				198,700	198,700
Total (1, 2, 3, 4 and 5)					860,930	860,930
B. Lower North & South MC and Ou Kra	(11,040ha)					
1) Wet season paddy (irrigated)	(0 ha)	0.00%			0	0
2) Wet season paddy (supplement)	(11,040 ha)	100.00%			1,159,200	1,159,200
3) Wet season paddy (rainfed)	(0 ha)	0.00%			0	0
4) Diversified crop (irrigated/rainfed)						
Mungbean	(330 ha)	3.00%			19,800	19,800
Vegetables	(440 ha)	4.00%			39,600	39,600
(1) + 2) + 3) + 4))	(11,810ha)	107.00%			1,218,600	1,218,600
3) Other farm works	(30% of cropping)				365,600	365,600
Total (1), 2), 3), 4) and 5))					1,584,200	1,584,200
C. Water Harvesting Irrigated Ag.	(600ha)					
1) Wet season paddy (irrigated)	(0 ha)	0.00%			0	0
2) Wet season paddy (supplement)	(300 ha)	50.00%			31,500	31,500
3) Wet season paddy (rainfed)	(300 ha)	50.00%			27,000	27,000
4) Diversified crop (irrigated/rainfed)						
Mungbean	(20 ha)	3.00%			1,200	1,200
Vegetables	(20 ha)	4.00%			1,800	1,800
(1) + 2) + 3) + 4))	(640ha)	107.00%			61,500	61,500
3) Other farm works	(30% of cropping)				18,500	18,500
Total (1), 2), 3), 4) and 5))					80,000	80,000
D. Rainfed Ag. Improvement	(23,980ha)					
1) Wet season paddy (rainfed)	(23,980 ha)	100.00%			2,158,200	2,158,200
2) Diversified crop (rainfed)						
Mungbean	(10 ha)	1.00%			600	600
Vegetables	(10 ha)	1.00%			900	900
(1) + 2))	(24,000ha)	102.00%			2,159,700	2,159,700
3) Other farm works	(30% of cropping)				647,900	647,900
Total (1), 2), and 3))					2,807,600	2,807,600
Total (A + B + C + D)						5,332,730
6. Shadow Wage Factors						
Without Project Condition					0.49	0.43
With Project Condition					0.56	0.49
7. Shadow Wage Rate						
(Standard conversion factor :	0.98	)				
Without Project Condition					0.48	0.42
With Project Condition					0.55	0.49

Note : /a ; Estimated by data from: Statistical Year Book 2006, NIS, Ministry of Planning, and First Revision, Population Projection for Cambodia 1998 - 2020, NIS, Ministry of Planning.

/b ; Percentage of economically active population aged 10 and over (Kampong Speu) 51.9 % (1)
Percentage of population aged 10 and over (Kampomg Speu) ; 72.5 % (2)
Labor force population ratio ; (1 x 2) 37.6 %

/c ; Labor requirement per ha

Crops	Person-day/ha Present	With Project IAIMP	UP-NS	LW-NS&OK	W-har
Paddy					
Rainfed	78	0	0	90	90
Irrigated	120	125	125	0	0
Supplement	97	0	110	105	105
Mungbean	50	60	60	60	60
Vegetables	90	150	90	90	90

Table IIC-2 Summary of Financial and Economic Prices Applied, F/S Study

Particulars	Unit	Financial Price Applied /a	Conversion	Economic Price Applied
1. **Farm Products**				
Dry Paddy	(Riel/kg)			
- High yielding varieties (Dec. 2006)		550	b	661
- Improved local varieties		600	b	661
Maize/Corn	(Riel/kg)	600	b	480
Mungbean	(Riel/kg)	1,500	c	1,470
Vegetable average	(Riel/kg)	519	c	509
2. **By-Products**				
Rice straw	(Riel/kg)	28	c	27
By-products of Mung B & M	(Riel/kg)	30	c	29
3. **Seeds**				
Paddy (degraded HYV)	(Riel/kg)	630	c	617
Paddy (local variety)	(Riel/kg)	710	c	696
Paddy (improved variety)	(Riel/kg)	900	c	882
Maize	(Riel/kg)	2,000	c	1,960
Mungbean	(Riel/kg)	1,400	c	1,372
Vegetable average	(Riel/kg)	1,000	c	980
4. **Fertilizer**				
Urea	(Riel/kg)	1,500	b	1,059
DAP	(Riel/kg)	1,600	b	1,159
KCL	(Riel/kg)	1,400	b	831
Compost	(Riel/ton)	15,000	d	6,300
5. **Chemical**	(Riel/litre)	10,000	c	9,800
6. **Tool and Equipment**				
	5% of the cost for inputs and draft animals			
7. **Labor, Animal Power and Machinery**				
Labor	(Riel/Person-day)	6,000	d	2,520
Animal	(Riel/Animal-day	10,000	d	4,200
8. **Transportation**				
Farmgate to Kampong Speu	(Riel/kg)	30	c	29

Remarks:
/a ; **Dec. 2006 prices**
/b ; Economic price estimate based on the WB Commodity Markets Forecast
/c ; Financial prices are converted to economic value multiplying by SCF of 0.98
/d ; Multiplied by shadow wage rate of 0.42
Based on the shadow wage rate factor 0.43) multiplied by SCF 0.98

Table IIC-3 Economic Crop Budget, Present Condition, F/S Study

Name of crops		Paddy (H.Y.V) Gravty Irrig.			Paddy (Impr. Local V.) Gravity Irrig.			Paddy (Local V. for Rainfed)			Paddy (H.Y.V) Pump Irrig.			Paddy (Impr. Local V.) Pump Irrig.		
	Unit	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)
1. Gross Income	**Riel**			**1,651**			**1,582**			**1,307**			**1,651**			**1,586**
Main products	kg	2,400	661	1,586	2,300	661	1,520	1,900	661	1,256	2,400	661	1,586	2,300	661	1,520
By-product	kg	2,400	27	65	2,300	27	62	1,900	27	51	2,400	27	65	2,300	29	66
		(straw)			(straw)			(straw)			(straw)			(straw)		
2. Production Cost	**Riel**			**653**			**676**			**606**			**910**			**888**
2.1 Inputs	**Riel**			**186**			**205**			**205**			**186**			**205**
Seed	kg	40	617	25	50	696	35	80	696	56	40	617	25	50	696	35
Farm manure (compost)	ton	2	6,300	11	2	6,300	11	2	6,300	11	2	6,300	11	2	6,300	11
Fertilizer Urea	kg	70	1,059	74	80	1,059	85	60	1,059	64	70	1,059	74	80	1,059	85
DAP	kg	60	1,159	70	60	1,159	70	60	1,159	70	60	1,159	70	60	1,159	70
KCL	kg	0	831	0	0	831	0	0	831	0	0	831	0	0	831	0
Agro-chemicals	liter	1	9,800	6	0	9,800	4	0	9,800	4	1	9,800	6	0	9,800	4
2.2 Labor	**P-d**			**290**			**302**			**252**			**290**			**302**
Hired labor	P-d	23	2,520	58	24	2,520	60	20	2,520	50	23	2,520	58	24	2,520	60
Family labor	P-d	92	2,520	232	96	2,520	242	80	2,520	202	92	2,520	232	96	2,520	242
2.3 Draft animal	**Riel**			**146**			**137**			**120**			**146**			**143**
Land preparation	Ani-d	18.0		76	18		76	18		76	18.0		76	18		76
Plowing	Ani-d	15.0	4,200	63	15.0	4,200	63	15.0	4,200	63	15.0	4,200	63	15.0	4,200	63
Paddling	Ani-d	3.0	4,200	13	3.0	4,200	13	3.0	4,200	13	3.0	4,200	13	3.0	4,200	13
Transportation	Ani-d	2,400.0	29	70	2,100.0	29	61	1,500.0	29	44	2,400.0	29	70	2,300.0	29	67
2.4 Pumping Cost	**Riel**												**245**			**196**
2.5 Tool/Equipment	**Riel**			**31**			**32**			**29**			**43**			**42**
3. Net Return	**Riel**			**998**			**906**			**701**			**741**			**698**
(N.Return/P. Cost Ratio)				**1.53**			**1.34**			**1.16**			**0.81**			**0.79**

Name of crops		Paddy (H.Y.V) G + P Irrig.			Paddy (Impr. Local V.) G+P Irrig.			Mungbean			Vegetables (average)		
	Unit	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)	Q'ty	Price (Riel)	Value (1000Riel)
1. Gross Income	**Riel**			**1,651**			**1,586**			**675**			**4,708**
Main products	kg	2,400	661	1,586	2,300	661	1,520	450	1,470	662	9,250	509	4,708
By-product	kg	2,400	27	65	2,300	29	66	450	29	13	9,250	0	0
		(straw)			(straw)			(waste bean)			(stem and waste nuts)		
2. Production Cost	**Riel**			**782**			**785**			**274**			**1,570**
2.1 Inputs	**Riel**			**186**			**205**			**97**			**733**
Seed	kg	40	617	25	50	696	35	50	1,372	69	166	980	163
Farm manure (compost)	ton	2	6,300	11	2	6,300	11	0	6,300	0	15	6,300	95
Fertilizer Urea	kg	70	1,059	74	80	1,059	85	15	1,059	16	177	1,059	187
DAP	kg	60	1,159	70	60	1,159	70	10	1,159	12	215	1,159	249
KCL	kg	0	831	0	0	831	0	0	831	0	0	831	0
Agro-chemicals	liter	1	9,800	6	0	9,800	4	0	9,800	0	4	9,800	39
2.2 Labor	**P-d**			**290**			**302**			**126**			**376**
Hired labor	P-d	23	2,520	58	24	2,520	60	15	2,520	38	53	2,520	132
Family labor	P-d	92	2,520	232	96	2,520	242	35	2,520	88	97	2,520	244
2.3 Draft animal	**Riel**			**146**			**143**			**38**			**318**
Land preparation	Ani-d	18.0		76	18		76			25			50
Plowing	Ani-d	15.0	4,200	63	15.0	4,200	63	5.0	4,200	21	10.0	4,200	42
Paddling	Ani-d	3.0	4,200	13	3.0	4,200	13	1.0	4,200	4	2.0	4,200	8
Transportation	Ani-d	2,400.0	29	70	2,300.0	29	67	450.0	29	13	9,250.0	29	268
2.4 Pumping Cost	**Riel**			**123**			**98**						
2.5 Tool/Equipment	**Riel**			**37**			**37**			**13**			**143**
3. Net Return	**Riel**			**870**			**801**			**401**			**3,138**
(N.Return/P. Cost Ratio)				**1.11**			**1.02**			**1.46**			**2.00**

Table IIC-4 Economic Irrigation and Drainage Benefit, F/S Study (1/5)

I. ZONE-I: Upper North Main Canal (UNMC) Area

(1) Present/With Project Condition (2007)

Crops	Planted Area (ha)	Net Production Value Per ha (Riel '000)	Net Production Value Total (Riel 'Million)
Paddy	2,445		2,097.7
Early Wet Season Rice			
- Early Variety (HYV)	215	998	214.6
Wet Season Rice			
- Early Variety (HYV)	0	0	0.0
- Medium Variety (irrigated)	1,560	906	1,413.4
- Medium Variety (rainfed)	670	701	469.7
Upland Crop	20		13.5
Upland Crops	18	401	7.2
Vegetables	2	3,138	6.3
Total	2,465		2,111.2
Total Physical Area	2,230	C. Intensity	111%
NPV per ha		Riel '000	US$
		946.7	233.2
Note : Riel	4,060	/US$	

(2) Future/Without Project Condition (2008 -)

Crops	Planted Area (ha)	Net Production Value Per ha (Riel '000)	Net Production Value Total (Riel 'Million)
Paddy	2,230		1,563.2
Early Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
Wet Season Rice			
- Early Variety (HYV)	0	0	0.0
- Medium Variety (irrigated)	0	906	0.0
- Medium Variety (rainfed)	2,230	701	1,563.2
Upland Crop	20		13.5
Upland Crops	18	401	7.2
Vegetables	2	3,138	6.3
Total	2,250		1,576.7
Total Physical Area	2,230	C. Intensity	101%
NPV per ha		Riel '000	US$
		707.0	174.1
Note : Riel	4,060	/US$	

(3) Saving (With - Without 2008-)

Crops	Planted Area (ha)	Net Production Value Per ha (Riel '000)	Net Production Value Total (Riel 'Million)
Paddy	215		534.5
Early Wet Season Rice			
- Early Variety (HYV)	215	998	214.6
Wet Season Rice			
- Early Variety (HYV)	0	0	0.0
- Medium Variety (irrigated)	1,560	906	1,413.4
- Medium Variety (rainfed)	-1,560	701	-1,093.5
Upland Crop	0		0.0
Upland Crops	0	401	0.0
Vegetables	0	3,138	0.0
Total	215		534.5
Total Physical Area	2,210	C. Intensity	10%
NPV per ha		Riel '000	US$
		239.7	59.1

Table IIC-4 Economic Irrigation and Drainage Benefit, F/S Study (2/5)

II. ZONE-I: Upper South Main Canal (USMC) Area

(1) Present/With Project Condition (2007)

Crops	Planted Area (ha)	Net Production Value Per ha (Riel '000)	Total (Riel 'Million)
Paddy	2,905		2,416.7
Early Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
Wet Season Rice			
- Early Variety (HYV)	0	0	0.0
- Medium Variety (irrigated)	1,855	906	1,680.6
- Medium Variety (rainfed)	1,050	701	736.1
Upland Crop	10		6.7
Upland Crops	9	401	3.6
Vegetables	1	3,138	3.1
Total	2,915		2,423.4
Total Physical Area	2,905	C. Intensity	100%
NPV per ha		Riel '000	US$
		834.2	205.5
Note : Riel	4,060	/US$	

(2) Future/Without Project Condition (2008 -)

Crops	Planted Area (ha)	Net Production Value Per ha (Riel '000)	Total (Riel 'Million)
Paddy	2,905		2,036.4
Early Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
Wet Season Rice			
- Early Variety (HYV)	0	0	0.0
- Medium Variety (irrigated)	0	906	0.0
- Medium Variety (rainfed)	2,905	701	2,036.4
Upland Crop	10		6.7
Upland Crops	9	401	3.6
Vegetables	1	3,138	3.1
Total	2,915		2,043.1
Total Physical Area	2,905	C. Intensity	100%
NPV per ha		Riel '000	US$
		703.3	173.2
Note : Riel	4,060	/US$	

(3) Saving (With - Without 2008-)

Crops	Planted Area (ha)	Net Production Value Per ha (Riel '000)	Total (Riel 'Million)
Paddy	0		380.3
Early Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
Wet Season Rice			
- Early Variety (HYV)	0	0	0.0
- Medium Variety (irrigated)	1,855	906	1,680.6
- Medium Variety (rainfed)	-1,855	701	-1,300.3
Upland Crop	0		0.0
Upland Crops	0	401	0.0
Vegetables	0	3,138	0.0
Total	0		380.3
Total Physical Area	2,870	C. Intensity	0%
NPV per ha		Riel '000	US$
		130.9	32.3

Table IIC-4 Economic Irrigation and Drainage Benefit, F/S Study (3/5)

III. ZONE-1: Irrigated Agriculture Improvement Model Project (IAIMP) Area

(1) Present/With Project Condition (2007)

Crops	Planted Area (ha)	Net Production Value Per ha (Riel '000)	Net Production Value Total (Riel 'Million)
Paddy	783		674.6
Early Wet Season Rice			
- Early Variety (HYV): Gravity	107	998	106.8
- Early Variety (HYV): Pump	29	741	21.5
- Early Variety (HYV): G & P	67	870	58.3
Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
- Medium Variety: Gravity	306	906	277.2
- Medium Variety: Pump	84	698	58.6
- Medium Variety: G & P	190	801	152.2
- Medium Variety (rainfed)	0	701	0.0
Upland Crop	0		0.0
Upland Crops	0	401	0.0
Vegetables	0	3,138	0.0
Total	783		674.6
Total Physical Area	580	C. Intensity	135%
NPV per ha		Riel '000	US$
		1,163.1	286.5
Note : Riel	4,060	/US$	

(2) Future/Without Project Condition (2008 -)

Crops	Planted Area (ha)	Net Production Value Per ha (Riel '000)	Net Production Value Total (Riel 'Million)
Paddy	580		406.6
Early Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
- Medium Variety (irrigated)	0	906	0.0
- Medium Variety (rainfed)	580	701	406.6
Upland Crop	0		0.0
Upland Crops	0	401	0.0
Vegetables	0	3,138	0.0
Total	580		406.6
Total Physical Area	580	C. Intensity	100%
NPV per ha		Riel '000	US$
		701.0	172.7
Note : Riel	4,060	/US$	

(3) Saving (With - Without 2008-)

Crops	Planted Area (ha)	Net Production Value Per ha (Riel '000)	Net Production Value Total (Riel 'Million)
Paddy	203		268
Early Wet Season Rice			
- Early Variety (HYV): Gravity	107	998	106.8
- Early Variety (HYV): Pump	29	741	21.5
- Early Variety (HYV): G & P	67	870	58.3
- Early Variety (HYV)	0	998	0.0
Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
- Medium Variety: Gravity	306	906	277.2
- Medium Variety: Pump	84	698	58.6
- Medium Variety: G & P	190	801	152.2
- Medium Variety (irrigated)	0	1,478	0.0
- Medium Variety (rainfed)	-580	701	-406.6
Upland Crop	0		0.0
Upland Crops	0	401	0.0
Vegetables	0	3,138	0.0
Total	203		268.0
Total Physical Area	570	C. Intensity	35%
NPV per ha		Riel '000	US$
		462.1	113.8

Table IIC-4 Economic Irrigation and Drainage Benefit, F/S Study (4/5)

IV. ZONE-2: Lower North Main Canal Area

(1) Present/With Project Condition (2007)

Crops	Planted Area (ha)	Net Production Value Per ha (Riel '000)	Net Production Value Total (Riel 'Million)
Paddy	1,400		1,094.2
Early Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
- Medium Variety (irrigated)	550	906	498.3
- Medium Variety (rainfed)	850	701	595.9
Upland Crop	10		9.5
Upland Crops	8	401	3.2
Vegetables	2	3,138	6.3
Total	1,410		1,103.7
Total Physical Area	1,400	C. Intensity	101%
NPV per ha		Riel '000	US$
		788.4	194.2
Note : Riel	4,060	/US$	

(2) Future/Without Project Condition (2008 -)

Crops	Planted Area (ha)	Net Production Value Per ha (Riel '000)	Net Production Value Total (Riel 'Million)
Paddy	1,400		981.4
Early Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
- Medium Variety (irrigated)	0	906	0.0
- Medium Variety (rainfed)	1,400	701	981.4
Upland Crop	10		9.5
Upland Crops	8	401	3.2
Vegetables	2	3,138	6.3
Total	1,410		990.9
Total Physical Area	1,400	C. Intensity	101%
NPV per ha		Riel '000	US$
		707.8	174.3
Note : Riel	4,060	/US$	

(3) Saving (With - Without 2008-)

Crops	Planted Area (ha)	Net Production Value Per ha (Riel '000)	Net Production Value Total (Riel 'Million)
Paddy	0		112.8
Early Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
- Medium Variety (irrigated)	550	906	498.3
- Medium Variety (rainfed)	-550	701	-385.5
Upland Crop	0		0.0
Upland Crops	0	401	0.0
Vegetables	0	3,138	0.0
Total	0		112.8
Total Physical Area	0	C. Intensity	0%
NPV per ha		Riel '000	US$
		80.6	19.9

Table IIC-4 Economic Irrigation and Drainage Benefit, F/S Study (5/5)

V. ZONE-2: Ou Krang Ambel Irrigation Area

(1) Present/With Project Condition (2007)

Crops	Planted Area (ha)	Net Production Value Per ha (Riel '000)	Net Production Value Total (Riel 'Million)
Paddy	2,930		2,291.8
Early Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
Wet Season Rice			
- Early Variety (HYV)	0	0	0.0
- Medium Variety (irrigated)	1,160	906	1,051.0
- Medium Variety (rainfed)	1,770	701	1,240.8
Upland Crop	20		13.5
Upland Crops	18	401	7.2
Vegetables	2	3,138	6.3
Total	2,950		2,305.3
Total Physical Area	2,930	C. Intensity	101%
NPV per ha		Riel '000	US$
		786.8	193.8
Note : Riel	4,060 /US$		

(2) Future/Without Project Condition (2008 -)

Crops	Planted Area (ha)	Net Production Value Per ha (Riel '000)	Net Production Value Total (Riel 'Million)
Paddy	2,930		2,053.9
Early Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
Wet Season Rice			
- Early Variety (HYV)	0	0	0.0
- Medium Variety (irrigated)	0	906	0.0
- Medium Variety (rainfed)	2,930	701	2,053.9
Upland Crop	20		13.5
Upland Crops	18	401	7.2
Vegetables	2	3,138	6.3
Total	2,950		2,067.4
Total Physical Area	2,930	C. Intensity	101%
NPV per ha		Riel '000	US$
		705.6	173.8
Note : Riel	4,060 /US$		

(3) Saving (With - Without 2008-)

Crops	Planted Area (ha)	Net Production Value Per ha (Riel '000)	Net Production Value Total (Riel 'Million)
Paddy	0		237.9
Early Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
Wet Season Rice			
- Early Variety (HYV)	0	998	0.0
- Medium Variety (irrigated)	1,160	906	1,051.0
- Medium Variety (rainfed)	-1,160	701	-813.1
Upland Crop	0		0.0
Upland Crops	0	22	0.0
Vegetables	0	22	0.0
Total	0		237.9
Total Physical Area	2,900	C. Intensity	0%
NPV per ha		Riel '000	US$
		81.2	150.8

Table IIC-5 Annual Incremental Economic Benefit Flow, F/S Study

Roleang Chrey Regulator with Intakes

Year in Order	Year	Area under Irrigation (ha)	Build-Up Ratio (%)	Benefit Build-Up (Riel Million) Year 2008 Area	Year 2009 Area	Year 2010 Area	Year 2011 Area	Total
1	2010	16,925	100		1,534			**1,534**
2	2011	16,925			1,534			1,534
3	2012	16,925			1,534			1,534
4	2013	16,925			1,534			1,534
5	2014	16,925			1,534			1,534
6	2015	16,925			1,534			1,534
7	2016	16,925			1,534			1,534
8	2017	16,925			1,534			1,534
9	2018	16,925			1,534			1,534
10	2019	16,925			1,534			1,534
11	2020	16,925			1,534			1,534

Note : Incremental net production value (Rp.'000/ha 1,533.5

Table IIC-6 Economic Investment Cost, F/S Study

Roleing Chrey Regulator and Intakes (RC)

(Unit : Riel; Million)

Description	Financial Cost			Conversion	Economic Cost									
	F/C	L/C	Total	Factors	Total	2008	2009	2010	2011	2012	2013	2014	2015	2016
1. Preparatory Works	167	72	239	0.80	191		29	162						
2. Direct Construction Cost	8,197	3,513	11,710	0.76	8,899		445	3,560	4,895					
3. O&M Equipment	0	0	0	-	0									
4. Administration Cost	836	358	1,194	0.77	919		46	414	460					
5. Environmental Monitoring Cost	2	10	12	0.94	12		1	5	6					
6. Engineering Services	1,853	794	2,647	0.96	2,541	381	381	889	889					
Total (1 to 6)	11,055	4,747	15,802	0.80	12,562	381	902	5,030	6,250					
7. Physical Contingencies (10% of 1 to 6)	1,110	470	1,580		1,256	38	90	503	625					
8. Price Contingencies	2,652	231	2,883											
Grand Total	14,817	5,448	20,265		13,819	419	992	5,533	6,875					

Table IIC-7 Economic Annual O&M Cost, F/S Study

Roleang Chrey Regulator and Intakes Improvement

(1) Economic Annual O&M Cost at Full Stage

Item	Financial Cost (Riel Million)	Conversion Factor	Economic Cost (Riel Million)
1. Materials	3.8	0.83	3.2
2. Equipment	3.8	0.75	2.9
3. Labor	7.6	0.48	3.7
4. O&M Staff	22.9	0.88	20.1
Total (ha) 16,925	38.13		29.9
Per ha (Riel)			1,767

(2) Annual Disbursement of Economic O&M Cost

Year in Order	Year	Area under Cultivation (ha)	Annual O&M Cost (Riel Million)
1	2009	16925	
2	2010	16925	
3	2011	16925	29.9
4	2012	16925	29.9
5	2013	16925	29.9
6	2014	16925	29.9
7	2015	16925	29.9
8	2016	16925	29.9
9	2017	16925	29.9
10	2018	16925	29.9
11	2019	16925	29.9
12	2020	16925	29.9
13	2021	16925	29.9
14	2022	16925	29.9
15	2023	16925	29.9

Table IIC-8 Economic Replacement Cost, F/S Study

Roleang Chrey Regulator and Intakes

(1) Economic Replacement Cost by Item

Item	Useful Life (year)	Financial Cost (Riel Million)	Conversion Factor	Economic Cost (Riel Million)
1. Project Facilities				
1) Gates of R.C Reg. and N & S Intakes				
- Gate	25	5,578	0.81	4,518.5

(2) Annual Replacement Cost

(Unit : Riel Million)

Year in Order	Year	With 5 Years'	With 10 Years'	With 25 Years'	Total	Year in Order	Year	With 5 Years'	With 10 Years'	With 25 Years'	Total
1	2009					26	2034				
2	2010					27	2035			4,518.5	4,518.5
3	2011					28	2036				
4	2012					29	2037				
5	2013					30	2038				
6	2014					31	2039				
7	2015					32	2040				
8	2016					33	2041				
9	2017					34	2042				
10	2018					35	2043				
11	2019					36	2044				
12	2020					37	2045				
13	2021					38	2046				
14	2022					39	2047				
15	2023					40	2048				
16	2024					41	2049				
17	2025					42	2050				
18	2026					43	2051				
19	2027					44	2052				
20	2028					45	2053				
21	2029					46	2054				
22	2030					47	2055				
23	2031					48	2056				
24	2032					49	2057				
25	2033					50	2058				

Table IIC-9 Economic Cost and Benefit Stream, F/S Study

I. Roleang Chrey Regulator with Intakes (RC)

EIRR : 14.9%	**Net Present Value (Riel Million)**	*Benefit*	*Cost*	*B/C Ratio*
	(7.00 % discount rate)	19,779	12,077	1.6

(Unit : Riel Million)

Year in Order	Year	Economic Cost				Economic Benefit			Net Cash Flow
		Project Invest-ment	O&M	Replace-ment	Total	Irri. & Drainage	Production Foregone	Total	
0	2009	419.1			419.1			0.0	-419.1
1	2010	992.2			992.2	1,533.5		1,533.5	541.3
2	2011	5,533.0			5,533.0	1,533.5		1,533.5	-3,999.5
3	2012	6,875.0	29.9		6,904.9	1,533.5		1,533.5	-5,371.4
4	2013		29.9		29.9	1,533.5		1,533.5	1,503.6
5	2014		29.9		29.9	1,533.5		1,533.5	1,503.6
6	2015		29.9		29.9	1,533.5		1,533.5	1,503.6
7	2016		29.9		29.9	1,533.5		1,533.5	1,503.6
8	2017		29.9		29.9	1,533.5		1,533.5	1,503.6
9	2018		29.9		29.9	1,533.5		1,533.5	1,503.6
10	2019		29.9		29.9	1,533.5		1,533.5	1,503.6
11	2020		29.9		29.9	1,533.5		1,533.5	1,503.6
12	2021		29.9		29.9	1,533.5		1,533.5	1,503.6
13	2022		29.9		29.9	1,533.5		1,533.5	1,503.6
14	2023		29.9		29.9	1,533.5		1,533.5	1,503.6
15	2024		29.9		29.9	1,533.5		1,533.5	1,503.6
16	2025		29.9		29.9	1,533.5		1,533.5	1,503.6
17	2026		29.9		29.9	1,533.5		1,533.5	1,503.6
18	2027		29.9		29.9	1,533.5		1,533.5	1,503.6
19	2028		29.9		29.9	1,533.5		1,533.5	1,503.6
20	2029		29.9		29.9	1,533.5		1,533.5	1,503.6
21	2030		29.9		29.9	1,533.5		1,533.5	1,503.6
22	2031		29.9		29.9	1,533.5		1,533.5	1,503.6
23	2032		29.9		29.9	1,533.5		1,533.5	1,503.6
24	2033		29.9		29.9	1,533.5		1,533.5	1,503.6
25	2034		29.9		29.9	1,533.5		1,533.5	1,503.6
26	2035			4,518.5	4,518.5	1,533.5		1,533.5	-2,985.0
27	2036		29.9		29.9	1,533.5		1,533.5	1,503.6
28	2037		29.9		29.9	1,533.5		1,533.5	1,503.6
29	2038		29.9		29.9	1,533.5		1,533.5	1,503.6
30	2039		29.9		29.9	1,533.5		1,533.5	1,503.6
31	2040		29.9		29.9	1,533.5		1,533.5	1,503.6
32	2041		29.9		29.9	1,533.5		1,533.5	1,503.6
33	2042		29.9		29.9	1,533.5		1,533.5	1,503.6
34	2043		29.9		29.9	1,533.5		1,533.5	1,503.6
35	2044		29.9		29.9	1,533.5		1,533.5	1,503.6
36	2045		29.9		29.9	1,533.5		1,533.5	1,503.6
37	2046		29.9		29.9	1,533.5		1,533.5	1,503.6
38	2047		29.9		29.9	1,533.5		1,533.5	1,503.6
39	2048		29.9		29.9	1,533.5		1,533.5	1,503.6
40	2049		29.9		29.9	1,533.5		1,533.5	1,503.6
41	2050		29.9		29.9	1,533.5		1,533.5	1,503.6
42	2051		29.9		29.9	1,533.5		1,533.5	1,503.6
43	2052		29.9		29.9	1,533.5		1,533.5	1,503.6
44	2053		29.9		29.9	1,533.5		1,533.5	1,503.6
45	2054		29.9		29.9	1,533.5		1,533.5	1,503.6
46	2055		29.9		29.9	1,533.5		1,533.5	1,503.6
47	2056		29.9		29.9	1,533.5		1,533.5	1,503.6
48	2057		29.9		29.9	1,533.5		1,533.5	1,503.6
49	2058		29.9		29.9	1,533.5		1,533.5	1,503.6
50	2059		29.9		29.9	1,533.5		1,533.5	1,503.6

Table IIC-10 Cash Flow Statement - Development Plan of Roleang Chrey Regulator and Intakes Improvement Project

(Unit: Riel. Million)

Year in Order	Year	Cash Outflow							Cash Inflow			Balance
		Initial Investment Cost	Loan Repayment *2			O&M Cost *3	Replace-ment Cost *1	Total	Loan from Foreign Aid	Govern-ment Budget *4	Total	
		Total Investment Cost	Capital	Interest	Total							
1	2008	609.0	-		-	-	-	609.0	609.0	-	609.0	-
2	2009	1,794.5	-	14.0	14.0	-	-	1,808.5	1,243.4	565.1	1,808.5	-
3	2010	9,999.8	-	42.6	42.6	-	-	10,042.4	9,427.8	614.6	10,042.4	-
4	2011	7,860.1	-	259.4	259.4	38.1	-	8,157.6	7,427.8	729.8	8,157.6	-
5	2012	-	-	430.3	430.3	38.1	-	468.4	-	468.4	468.4	-
6	2013	-	-	430.3	430.3	38.1	-	468.4	-	468.4	468.4	-
7	2014	-	-	430.3	430.3	38.1	-	468.4	-	468.4	468.4	-
8	2015	-	-	430.3	430.3	38.1	-	468.4	-	468.4	468.4	-
9	2016	-	-	430.3	430.3	38.1	-	468.4	-	468.4	468.4	-
10	2017	-	-	430.3	430.3	38.1	-	468.4	-	468.4	468.4	-
11	2018	-	935.4	430.3	**1,365.7**	38.1	-	1,403.8	-	1,403.8	1,403.8	-
12	2019	-	935.4	408.8	1,344.2	38.1	-	1,382.3	-	1,382.3	1,382.3	-
13	2020	-	935.4	387.3	1,322.7	38.1	-	1,360.8	-	1,360.8	1,360.8	-
14	2021	-	935.4	365.7	1,301.1	38.1	-	1,339.2	-	1,339.2	1,339.2	-
15	2022	-	935.4	344.2	1,279.6	38.1	-	1,317.7	-	1,317.7	1,317.7	-
16	2023	-	935.4	322.7	1,258.1	38.1	-	1,296.2	-	1,296.2	1,296.2	-
17	2024	-	935.4	301.2	1,236.6	38.1	-	1,274.7	-	1,274.7	1,274.7	-
18	2025	-	935.4	279.7	1,215.1	38.1	-	1,253.2	-	1,253.2	1,253.2	-
19	2026	-	935.4	258.2	1,193.6	38.1	-	1,231.7	-	1,231.7	1,231.7	-
20	2027	-	935.4	236.7	1,172.1	38.1	-	1,210.2	-	1,210.2	1,210.2	-
21	2028	-	935.4	215.1	1,150.5	38.1	-	1,188.6	-	1,188.6	1,188.6	-
22	2029	-	935.4	193.6	1,129.0	38.1	-	1,167.1	-	1,167.1	1,167.1	-
23	2030	-	935.4	172.1	1,107.5	38.1	-	1,145.6	-	1,145.6	1,145.6	-
24	2031	-	935.4	150.6	1,086.0	38.1	-	1,124.1	-	1,124.1	1,124.1	-
25	2032	-	935.4	129.1	1,064.5	38.1	-	1,102.6	-	1,102.6	1,102.6	-
26	2033	-	935.4	107.6	1,043.0	38.1	-	1,081.1	-	1,081.1	1,081.1	-
27	2034	-	935.4	86.1	1,021.5	38.1	5,578.0	6,637.6	-	6,637.6	6,637.6	-
28	2035	-	935.4	64.5	999.9	38.1	-	1,038.0	-	1,038.0	1,038.0	-
29	2036	-	935.4	43.0	978.4	38.1	-	1,016.5	-	1,016.5	1,016.5	-
30	2037	-	935.4	21.5	**956.9**	38.1	-	995.0	-	995.0	995.0	-
31	2038	-	-	-	-	38.1	-	38.1	-	38.1	38.1	-
32	2039	-	-	-	-	38.1	-	38.1	-	38.1	38.1	-

*1 Including price contingency and VAT.
*2 Interest rate: 2.3%/year Grace period: 10 year Prepayment period: 30 years including grace period
*3 O&M cost of regulator and intakes
*4 All deficit is covered by the Government budget.

Table IIC-11 Farm Economic Analysis of Typical Farms

	Items	Zone-1 1/									Zone-2		
		Model Project			Upper North Main Canal			Upper South Main Canal			LNMC & Ou Krang		
		With	without	Increment	With	without	Increment	With	without	Increment	With	without	Increment
Typical Farm	Holding Size of Paddy Field (ha)												
	- Irrigated Field	0.35	0.00	-0.35	0.07	0.00	-0.07	0.00	0.00	0.00	0.00	0.00	0.00
	- Supplementary Irrigated Field	0.35	0.00	-0.35	0.42	0.00	-0.42	0.45	0.00	-0.45	0.30	0.00	-0.30
	- Rainfed Field	0.00	0.70	0.70	0.21	0.70	0.49	0.25	0.70	0.45	0.40	0.70	0.30
	Total	0.70	0.70	0	0.70	0.70	0.00	0.70	0.70	0	0.70	0.70	0
Net Return from Paddy Field													
1. Cropped Area (ha)													
	- Early Rainy Season												
	Early Rice	0.35	0.00	-0.35	0.07	0.00	-0.07	0.00	0.00	0.00	0.00	0.00	0.00
	- Rainy Season												
	Early Rice	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Medium Rice (irrigated)	0.70	0.00	-0.70	0.50	0.00	-0.50	0.40	0.00	-0.40	0.30	0.00	-0.30
	Medium Rice (rainfed)	0.00	0.70	0.70	0.20	0.70	0.50	0.30	0.70	0.40	0.40	0.70	0.30
	Total	1.05	0.70	-0.35	0.77	0.70	-0.07	0.70	0.70	0.00	0.70	0.70	0.00
	- Upland Crops/Vegetable	0.04	0.04	0.00	0.03	0.03	0.00	0.03	0.03	0.00	0.03	0.03	0.00
2. Net Return per Ha (Riel 1,000)													
	- Early Rainy Season												
	Early Rice	706	574	-132	706	574	-132	706	574	-132	706	574	-132
	- Rainy Season												
	Early Rice	706	574	-132	706	574	-132	706	574	-132	706	574	-132
	Medium Rice (irrigated)	739	739	0	739	739	0	739	739	0	739	739	0
	Medium Rice (rainfed)	568	568	0	568	568	0	568	568	0	568	568	0
	- Upland Crops/Vegetable 1/	663	663	0	663	663	0	663	663	0	663	663	0
3. Net Return per Farm (Riel 1,000)													
	- Early Rainy Season												
	Early Rice	247	0	-247	49	0	-49	0	0	0	0	0	0
	- Rainy Season												
	Early Rice	0	0	0	0	0	0	0	0	0	0	0	0
	Medium Rice (irrigated)	517	0	-517	370	0	-370	296	0	-296	222	0	-222
	Medium Rice (rainfed)	0	398	398	114	398	284	170	398	227	227	398	170
	- Upland Crops/Vegetable 1/	27	27	0	20	20	0	20	20	0	20	20	0
Net Return per Farm (Riel 1,000)		**791**	**424**	**-367**	**552**	**417**	**-135**	**486**	**417**	**-68**	**469**	**417**	**-51**

1/: Weighted average of upland crops & vegetables

Appendix-IID

ENVIRONMENT

THE STUDY
ON
COMPREHENSIVE AGRICULTURAL DEVELOPMENT
OF
PREK THNOT RIVER BASIN
IN
THE KINGDOM OF CAMBODIA

FINAL REPORT

Volume-VII: Appendixes for Feasibility Studies for Priority/Urgent Projects

Appendix-IID

Environment

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APPENDIX-IID: ENVIRONMENT

Chapter IID-1 Environment of the Project Site

IID-1.1 Social Environment

(1) People/ Community

Characteristics of the people and communities in and around the Project Site are summarized as below.

(a) Population

The Project Site is located in Andong Sla Village of Tang Krouch commune, Kahaeng village and Roleng Chrey village of Kahaeng commune. The population of these villages is 1,547 in 2005 according to SEILA Commune Data Base, 2005 as show below. The working population which means the population between 15 and 65 years old corresponds to 861. The annual growth rate is not changed so mach for the past few years.

Population of the Project Site

District	Commune	Village	No. of Families	Population	Working population*	Average family size
Samraong Tong	Tang krouch	Andong Sla	121	619	289	5.2
	Kahaeng	Roleang Chrey	90	492	297	5.5
		Kahaeng	93	436	275	4.7
Total			304	1,547	861	5.1

Note: 15-65 years old*
Source: SEILA Commune Data Base 2005

(b) Ethnic Group and Religion

The majority of ethnic group is Kumer and most of them are Buddhist. Pagodas as religious facilities for Buddhist have spread out around their life space.

(c) Education

As shown below, illiterate people over 15 yeas old account for 1.5% for man and 3.5% for woman. Almost 100% of children go to school.

Illiterate People and Educated Children

Commune	Village	Number of Illiterate People (over 15 years old)		Rate of children who goes to school (6-14 years old)	
		Man	Female	Man	Female
Tang krouch	Andong Sla	0	0	98%	100%
Kahaeng	Roleang Chrey	4	12	100%	100%
	Kahaeng	7	16	100%	100%
Total		11	28		

Source: SEILA Commune Data Base 2005

(2) Land Use

Within the bounds of 1km of the Project Site, paddy fields account for about 20% of the land, while grass and shrub cover 50% and resettlement area occupied about 20%.

(3) Public Facilities/Services

(a) Water Usage for Domestic

In terms of domestic water source of three villages in the Project Site, 41% of households rely on pond, river and rain water. 33% use private facilities such as piped water and private pump well and rest of 26% use communal facilities.

Water Source of Three Villages in the Project Site

Commune	Village	No. of Families			
		Piped water, private pump well, private ring well, usable year round, less than 150m.	Communal tap, pump well ring well, usable year around, within 150m	Most common source of water for other families (pond, river, rain water, other)	Total
Tang krouch	Andong Sla	11	60	50	121
Kahaeng	Roleang Chrey	50	20	20	90
	Kahaeng	40	0	53	93
Total (%)		101 (33%)	80 (26%)	123 (41%)	304

Source: SEILA Commune Data Base 2005

(b) Usage of Bridge

In and around the Project Site, maintenance bridge of Roleang Chrey Regulator is only one bridge across the Prek Thnot River. According to the gate operator of Roleang Chrey Regulator, around 450-660 people per day across the bridge for school, job, purchase and so on as shown below.

Construction work caused to passage limitation

People	Purpose	Average number per day	Period of time to across the bridge (popular time)
Children	Go to school	200-300	6:30-10:30, 11:00
Ordinary people	-	200-300	5:00-6:00, 10:30-11:00, 16:00-17:00, 18:00-20:00
Housewives	Go to market	50-60	7:00-8:00, 11:00-12:00
Total	-	450-660	

Source: Interview to the gate operator of Roleang Chrey Regulator, 2007

(4) Agricultural Activity

Most of the people living in three villages where the Project Site is located are farmers. As shown below, around 90% of farmers own irrigated rice land and cattle/buffalo.

Agricultural Activity

Commune	Village	No. of Families			
		Total	Irrigated Rice Land	Cattle/Buffalo	Pigs
Tang krouch	Andong Sla	121	98 (81%)	121 (100%)	98 (65%)
Kahaeng	Roleang Chrey	90	80 (89%)	63 (70%)	27 (30%)
	Kahaeng	93	91 (98%)	91 (98%)	71 (76%)
Total		304	269 (88%)	275 (91%)	196 (65%)

Source: SEILA Commune Data Base 2005

IID-1.2 Natural Environment

(1) Forest and Wildlife

As described above, there is no major forest area in and around the Project Site. In figure, 50% is covered by grass and shrub land, where most people collect firewood for cooking fuel. Some shrub land is extended along the Prek Thnot River as shown in the right picture.

Downstream from Roleang Chrey Regulator

Though there is no specific data or record, bio-diversity seems poor in and around the Project Site because of its limited habitat as far as the site inspection.

(2) Fish and its habitat

Major water resources as fish habitat around the Project Site are Prek Thnot River and irrigation canals. According to the local people, there were many fishes both in the rainy and dry seasons in the past, however the amount and variety of fish are decreasing presently. The one reason was pointed out by the local people that people started using electric fishing gears, which have wiped out the fish. In addition, exotic species discharged are changing aquatic-diversity around.

According to relevant people including Department of Fishery, MAFF, the following spices of fish exist in the Prek Thnot River.

Existing Fish in the Prek Thnot River

	Khmer Name	English name	Scientific Name	indigenous/exotic
1	Tilapia	Nile tilapia	*Oreochromis niloticus*	Exotic
2	Kranh Srai	Climbing perch	*Anabas testudineus*	Indigenous
3	Phtuok/Rous	Snakehead	*Channa striata*	Indigenous
4	Trey Andaing Roueng	Walking catfish	*Clarias batrachus*	Indigenous
5	Andaing Tonle	Gray eel-catfish	*Plotosus canius*	Indigenous
6	Kanhtor	Snake-skin gourami	*Trichogaster pectoralis*	Indigenous
7	Chhpin	--	*Hypsibarbus pierrei*	Indigenous
8	Trey Raw	Snakehead murrel	*Channa striata*	Indigenous
9	Trey chhpin	Silver barb	*Barbodes gonionotus*	Indigenous
10	Trey chhlonh chhnoht	Peacock eel	*Macrognathussiamensis*	Indigenous
11	Trey krormorm	Butter catfish	*Ompok bimaculatus*	Indigenous
12	Carp sor	Silver carp	*Hypophthalmichthys molitrix*	Exotic
13	Carp samanh	Common carp	*Cyprinus carpio*	Exotic
14	Kulriang	Giant barb	*Catlocapio siamensis*	Exotic
15	Klia	Finescale tigerfish	*Datnioides microlepis*	Indigenous
16	Crobey	Crocodile catfish	*Bagarius suchus*	Indigenous

Source; Interview to Provincial Office of Fishery, PDE of Kampong Speu Province, the local people, 2006

IID-1.3 Pollution

(1) Water Quality/ Pollution

There are no analyzable data on water quality of the Prek Thnot River in and around the Project Site except those at Kampong Toul in the Kandal Province more than 70km downstream. PDOWRAM had monitored water quality of the Prek Thnot River at Kampong Toul station located in crossing of National Road No.3 since 1996 for eight years. The results of analysis of 2003 are presented in the following table.

Water Quality Monitoring Data in 2003

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Standard[1]
pH	7.28	6.57	7.30	7.03	7.03	7.15	6.90	6.41	6.50	6.52	6.67	6.72	6.5-8.5
TSS[2]	43	55	25	60	150	93	303	172	119	175	21	32	25-100
DO[3] (mg/L)	8.25	6.33	7.74	7.58	6.34	7.64	6.20	7.38	6.50	6.20	6.72	7.40	2.0-7.5

Note: 1 Under the sub-decree on water pollution control, water quality standard in river for bio-diversity conservation is defined, 2 TSS: Total Suspended Solids, 3 DO: Dissolved Oxygen
Source: PDOWRAM Kandal Province, 2003

In four months from July to October, the TSS (Total Suspended Substance) exceeds the standard value defined as water quality standard in river for bio-diversity conservation. As for pH, almost all the data in every month are under the standard values except in August. As for DO, in January and March are beyond the standard value.

(2) Other Pollution

There are no available records about other pollution condition such as air quality around the Project Site. As far as the site inspection was concerned, no serious problems of air pollution, noise and vibration have been observed because pollution source can not be recognized around there.

Chapter IID-2 Environmental Study of the Project

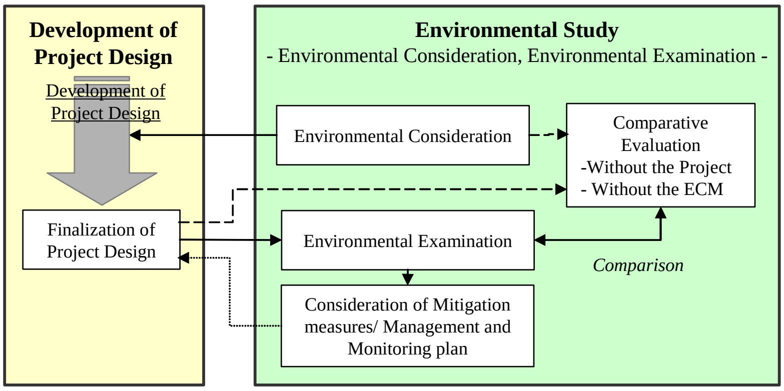
IID-2.1 General

Framework of environmental study for the Project is shown in the following figure.

In the process of formulation of improvement Plan, a series of environmental considerations were conducted in order to develop the Project more environmental friendly and sustainably.

Toward the developed Project design including a series of environmental consideration, environmental examination of the Project was preliminary implemented so as to examine potential impacts and consider mitigation measures and management/monitoring plan for minimization of negative impacts. It is noted that the Project don't require EIA study under the Sub-decree on EIA process in Cambodia.

In parallel, environmental impact on a condition without implementation of the Project was compared with the impact on a condition with the Project so as to analyze comparative evaluation of the Project design. In a similar way, contents of environmental considerations were evaluated by comparing condition with environmental considerations to condition without the considerations under the Project.



Framework of Environmental Study under the Project

IID-2.2 Environmental Consideration

In the process of preparation of various improvement plans mentioned above, a series of environmental considerations were conducted in order to implement the Project more environmental friendly and sustainably. The considerable points under the Project were i) water availability during construction phase, ii) lining method of approach channels, and iii) air pollution by transportation of construction vehicle.

(1) Water Availability during Construction Phase

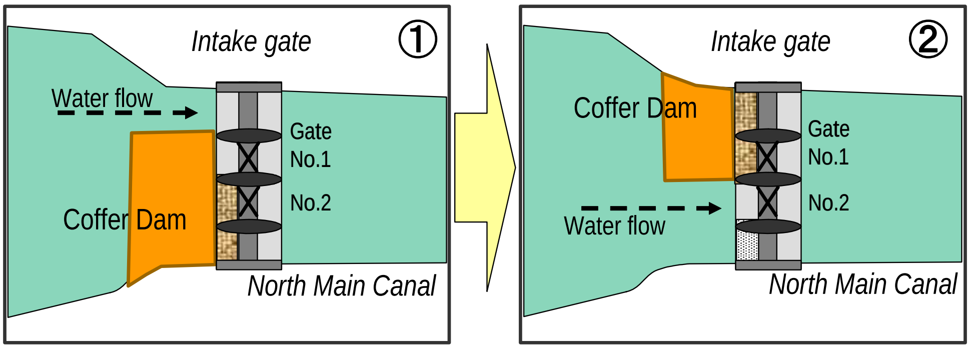
Currently, canal water in both the North and South Main Canals is used not only for agriculture but also for domestic use and drinking. Socio-Economic Survey results, which conducted in 2007 for 100 sample household living in the Project Area, shows that about 40% of households are taking canal water for domestic use in the dry season. Moreover, 10% of households are taking canal water for drinking in the dry season.

When considering rehabilitation works of Andong Sla Intake Gate and Vat Krouch Intake Gate, which require 15 and 11months respectively, stop of water flow might cause significant impacts toward both agricultural activities and people's lives. Therefore, the following work methods were proposed in order to avoid stopping water flow in canals;

<u>Andong Sla Intake Gate</u>

Rotational construction work of Andong Sla Intake Gate was proposed to avoid interruption of water flow as shown below. Rotation work would be conducted as two-stage works. In the first stage, coffer dam will be temporary constructed to stop water in order to construct new structure and reinstall gate No.2. As for the second stage, coffer dam will be shifted in order to construct new structure and reinstall gate No.1. It is noted that passage will not be avoided by the construction work.

By adopting this way, water flow in the North Main Canal will not stop even in the construction period of Andong Sla Intake Gate.

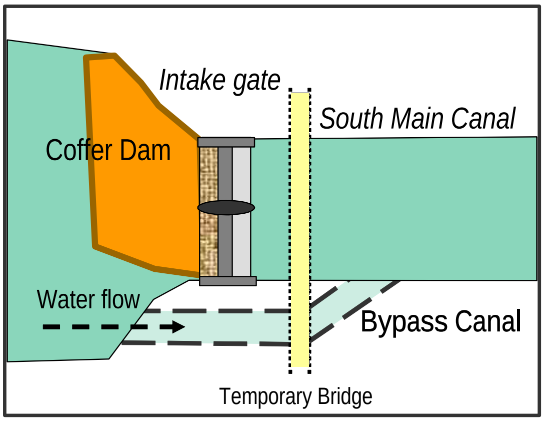


Rotational Construction Work of Andong Sla Intake Gate

<u>Vat Krouch Intake Gate</u>

During construction work of Vat Krouch Intake Gate, temporary bypass canal for water flow will be established in South Main Canal as shown below. It is noted that temporary bridge over the bypass and South Main Canal will also be provided to avoid to obstruct passage to across the canal.

By adopting this way, water flow in South Main Canal will not stop even in the construction period of Vat Krouch Intake Gate.



Construction of Temporary Bypass Canal at Vat Krouch Intake Gate

<u>Approach Channels of North and South Main Canals</u>

As for rehabilitation work of approach channels, it requires to stop water flows in canals by any means during work period, which duration will be about few months. As a conclusion, rehabilitation work of approach channels would be conducted in fallow period from December to March intensively in order not to impact to agricultural activities once.

Though the duration is not long compared with intake gate rehabilitation work, it impacts somehow to people who rely on canal water for drinking and domestic use directly. In order to deal with this impact, detailed survey toward the affected people will be conducted in order to make clear about possibility of other alternative water source for drinking and domestic use during construction period. Toward the people who do not have any alternative water source, countermeasure such as distribution by water tanker would be proposed.

(2) Lining Method of Approach Channels

Two canal lining methods, i.e. concrete lining and earth lining were examined in consideration of environmental aspects.

As a conclusion, lining of approach channels in both North and South Main Canal would be rehabilitated by earth, instead of concrete. In case of concrete lining, concrete work will cause alkalified water that affect negatively on the aquatic-biodiversity. In addition, biodiversity will be in risk of damaging by artificial surface of the canals. In that respect, earth lining will minimize these kinds of negative impact to environment.

Moreover, block sodding along the canal bank will be conducted in order to keep up the bank and avoid land sliding by environmental friendly method.

(3) Air Pollution by Transportation of Construction Vehicle

Because most of roads around the Project Site are earthen road, dust is spread in the air especially in the dry season by running of vehicles.

During construction phase, construction vehicle will increase to run the road so that the dust problem will become more serious.

To cope with the dust problem, regular sprinkling activity to the road by watering vehicle was included into the construction work items.


Earthen road around the Project Site

IID-2.3 Environmental Examination

(1) General

Environmental impacts caused by implementation of the Project will not be serious as a whole. However, it is preferable to minimize the likely negative impacts in order to make the Project more environmental friendly and sustainably. Thus, environmental examination of the Project was preliminarily conducted for integration of desirable mitigation measures and management/monitoring framework into the Project.

(2) Environmental and Social Elements to be examined

Based on available information on natural and social environment, environmental scoping for the Project were undertaken to identify anticipated impacts on environment to be examined as shown below.

When considering the scoping elements, the following issues were taken into consideration as assumption.

Designing Phase

The project will not require any land acquisition and involuntary resettlement.

Construction Phase

No massive construction works are likely, because most construction works are rehabilitation of existing structures and new construction works that are not large scale.

Currently, three structures, i.e. Roleang Chrey Regulator, Andong Sla Intake Gate and Vat Krouch Intake Gate are used as bridge by the people. During construction work of Andong Sla Intake Gate and Vat Krouch Intake Gate, passage across the canal will be ensured. On the other hand, construction work of Roleang Chrey Regulator will obstruct people’s passage in a while.

Operation Phase

The Project consists of not only development of hardware but also engineering supporting services including i) preparation of operation rule and manuals of facilities, and ii) reinforcement of organization for operation and maintenance of the project facility.

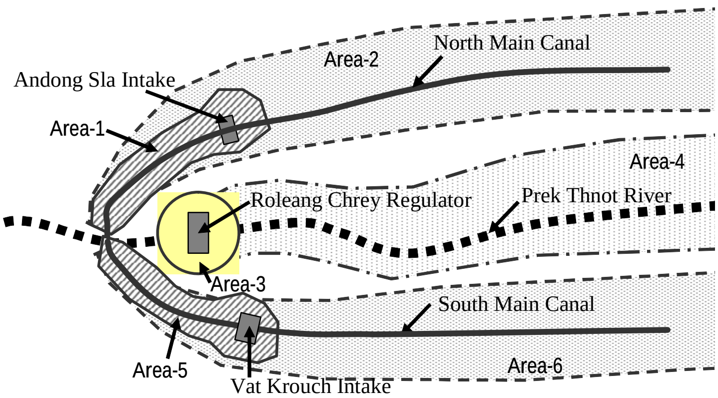
The result of extracted elements to be examined is shown below.

Environmental and Social Elements to be examined

Potential Impact		Phase	
		Construction	Operation
Social Environment	Inflow of Construction Workers	- Degradation of sanitation condition and security due to inflow of construction workers	—
	Accessibility	- Limitation of accessibility on bridges	—
	Water Availability	- Limitation of water usage in downstream of north and south canals during construction work of approach channels	—
Pollution	Air Pollution	- Air pollution caused by emission gas	—
	Water Pollution	- Runoff of alkalified water by concrete work	—
	Noise and Vibration	- Noise and vibration caused by construction vehicle and heavy equipment	—

Taking into consideration of these potential impacts, scoping area to be examined was set up by dividing five areas;

- Area-1: Andong Sla Intake and approach channel, and those surrounding
- Area-2: Command area of North Main Canal
- Area-3: Roleang Chrey Regulator and its surrounding
- Area-4: Downstream of the Prek Thnot River from Roleang Chrey Regulator
- Area-5: Vat Krouch Intake and approach channel, and those surrounding
- Area-6: Command area of South Main Canal



Scoping Area to be examined

(3) Consideration of Environmental/Social Impacts and Mitigation Measures

The results of examination toward each extracted conditions and proposed mitigation measures are shown below.

Inflow of Workers (Construction Phase)

Activity	- Construction/Rehabilitation work of Andong Sla Intake and approach channel of North Main Canal - Rehabilitation work of Roleang Chrey Regulator - Construction/Rehabilitation work of Vat Krouch Intake and approach channel of South Main Canal
Affected Area	Area-1: Andong Sla Intake and approach channel, and those surrounding Area-3: Roleang Chrey Regulator and its surrounding Area-5: Vat Krouch Intake and approach channel, and those surrounding

<table>
<tr><td>Projected Impact</td><td>Due to inflow of construction workers from outside during construction phase, following impacts were anticipated; i) deterioration of sanitation condition, ii) deterioration of public security, iii) increase of risk of diseases including AIDS/HIV, iv) local conflict among people and workers. Construction scale at the Project Site is not large and duration is at most 25 months.
Duration of Construction Work
<table>
<tr><th>Project Site</th><th>Area</th><th>Duration of Construction Work</th><th>Total month</th></tr>
<tr><td>Andong Sla Intake and approach channel</td><td>Area-1</td><td>Dec.2008-Dec.2010</td><td>25</td></tr>
<tr><td>Roleang Chrey Regulator</td><td>Area-3</td><td>Dec.2008-June.2010</td><td>19</td></tr>
<tr><td>Vat Krouch Intake and approach channel</td><td>Area-5</td><td>Dec.2008-June.2010</td><td>19</td></tr>
</table></td></tr>
<tr><td>Mitigation Measure</td><td>- To improve sanitary condition of workers by proper arrangement of accommodation, installation of toilets, proper water supply and garbage treatment.
- To implement education program toward workers about sanitation, security and rules/discipline of daily activities
- To implement periodical patrol of workers in order to avoid both occurrence of local conflict and epidemics of diseases
- To hold a series of public meetings for surrounding people in order to explain construction work and its schedule.</td></tr>
<tr><td>Conclusion of Examination</td><td>Because the people around the Project Site are not familiar to construction workers from other areas, great attention toward management of construction workers and construction fields are significant. However, taking into consideration of work scale, the numbers of construction workers will not be large. Therefore, serious negative impacts are not envisaged with proper implementation of mitigation measure.</td></tr>
</table>

Accessibility (Construction Phase)

<table>
<tr><td>Activity</td><td>- Rehabilitation work of Roleang Chrey Regulator</td></tr>
<tr><td>Affected Area</td><td>Area-3: Roleang Chrey Regulator and its surrounding</td></tr>
<tr><td>Projected Impact</td><td>In case of rehabilitation work of Roleang Chrey Regulator, passage on maintenance bridge of Roleang Chrey Regulator by both people and vehicles will be obstructed for several hours per day during a part of construction phase. The construction period to the temporary passage prohibition is in total around 6 mounts; July-Sep 2009 (3month), Oct-Nov 2009 (1month), Dec 2009-Feb 2010 (2month).

Passage on maintenance bridge of Roleang Chrey Regulator

According to the gate operator of Roleang Chrey Regulator, around 450-660 people per day across the bridge for school, job, purchase and so on. Moreover, the distance to neighboring bridge is around 8km downstream.</td></tr>
<tr><td>Mitigation Measure</td><td>- To hold a series of public consultation meetings for surrounding people in order to explain, discuss and find the way of passage prohibition or other.
- To post a bill to inform impassable duration to commune council, village chief, social facilities like schools, pagodas and hospitals, after the work schedule is fixed with people's consensus.
- To establish a temporary bridge, if possible.</td></tr>
<tr><td>Conclusion of Examination</td><td>Because local people go across the bridge everyday and neighboring bridge is located far away, some sort of limitation of people's life might be expected. Consultation with surrounding people and distributing information to the affected people will be necessary before the construction work will start.</td></tr>
</table>

Water Availability (Construction Phase)

<table>
<tr><td>Activity</td><td>- Rehabilitation work of approach channel of North Main Canal
- Rehabilitation work of approach channel of South Main Canal</td></tr>
<tr><td>Affected Area</td><td>Area-2: Command area of North Main Canal
Area-6: Command area of South Main Canal</td></tr>
<tr><td>Projected Impact</td><td>Rehabilitation works of approach channels of both North Main Canal and South Main Canals will stop water flow in canals for few months in fallow period from December to March intensively. However, people living in command area of both North and South Main Canals will be faced with limitation/nothing of canal water in the period. By rough estimation, around 5,000 people living in command area of both North and South Main Canals will be affected for short of drinking water, while 20,000 people for short of water for domestic use.</td></tr>
</table>

Mitigation Measure	- To conduct construction work in fallow period intensively as much as possible. - To hold a series of public meetings when detailed construction work schedule will be planned in order to discuss the work schedule and decide it with the affected people. - To consider other source of water for drinking and domestic use, e.g. distribution by water tanker, toward the affected people by detailed survey or consultation meetings with them.
Conclusion of Examination	Though impact on water availability can be minimized by implementation of the work in fallow period intensively, at most 20,000 people will be affected to water availability by the work of approach channels for few months in fallow period. Therefore careful attention with proposed mitigation measure will be necessary.

Air Pollution (Construction Phase)

Activity	- Construction/Rehabilitation work of Andong Sla Intake and approach channel of North Main Canal - Rehabilitation work of Roleang Chrey Regulator - Construction/Rehabilitation work of Vat Krouch Intake and approach channel of South Main Canal
Affected Area	Area-1: Andong Sla Intake and approach channel, and those surrounding Area-3: Roleang Chrey Regulator and its surrounding Area-5: Vat Krouch Intake and approach channel, and those surrounding
Projected Impact	Running of construction vehicles and transportation/operation of heavy equipment, such as dump truck, excavator, bulldozer, truck crane, roller for flat and watering lorry, will exhaust emission gas including nitrogen dioxide (NO_2) and suspended particulate matter (SPM).
Mitigation Measure	- To educate construction workers for minimizing idling of construction vehicles
Related regulation	Sub-decree on Air and Noise Control (June 10, 2000); Ambient air quality standard (CO, NO_2, SO_2, Ozon, Pb, TSP)
Conclusion of Examination	Because most of the construction works are small scale rehabilitation, the numbers of both heavy equipment and construction vehicle for the work will not be many. Therefore the impact to air quality will not be serious with proper management and mitigation measures.

Water Pollution (Construction Phase)

Activity	- Construction work of Andong Sla Intake - Rehabilitation work of Roleang Chrey Regulator - Construction work of Vat Krouch Intake
Affected Area	Area-2: Command area of North Main Canal Area-4: Downstream of the Prek Thnot River from Roleang Chrey Regulator Area-6: Command area of South Main Canal
Projected Impact	Construction works of Andong Sla Intake and Vat Krouch Intake and rehabilitation work of Roleang Chrey Regulator require concrete works. Therefore, alkalified water caused by the concrete works will be eliminated during construction phase. Total amount of concrete to be used is roughly 900t at Andong Sla Intake, 3,700t at Roleang Chrey Regulator and 500t at Vat Krouch Intake. These concrete will be brought from concrete manufacture to the Project Site by concrete mixer truck.
Mitigation Measure	- To dilute or neutralize alkalified water from concrete mixer trucks by pooling regulating pond, before water throws the canals. - In case the concrete plant will be set up near from the Project Site, it is necessary to pool discharging water from the plant for dilution or neutralization. - To install adequate treatment system for alkalified water in construction field.
Related regulation	Sub-decree on Water Pollution Control (April 6, 1999); Water quality standard in public water areas for bio-diversity conservation (pH, BOD, SS, DO, Coliform, TN, TP), Water quality standard in public water areas for public health protection (DDT, Cadmium, Lead, and so on)
Conclusion of Examination	Because amount of concrete to be used is not large, alkalified water flowing out from the concrete in the canals might be diluted by canal water. However if alkalified water is observed, it is necessary to install adequate treatment system for alkalified water in the canal/river.

Noise and Vibration (Construction Phase)

Activity	- Construction/Rehabilitation work of Andong Sla Intake and approach channel of North Main Canal - Rehabilitation work of Roleang Chrey Regulator - Construction/Rehabilitation work of Vat Krouch Intake and approach channel of South Main Canal
Affected Area	Area-1: Andong Sla Intake and approach channel, and those surrounding Area-3: Roleang Chrey Regulator and its surrounding Area-5: Vat Krouch Intake and approach channel, and those surrounding
Projected Impact	During construction phase, transportation of heavy equipment will cause noise and vibration. Types of heavy equipment would be dump truck, excavator, bulldozer, roller for flat and watering lorry. The distance from the Project Site to neighboring house is close; approximately 20m in Area-1, 60m in Area-3 and 60m in Area-4.
Mitigation Measure	- To limit construction time. e.g. at daytime only - To hold public meetings to obtain consensus about the construction time with surrounding people.
Related regulation	Sub-decree on Air and Noise Control (June 10, 2000); Maximum permitted noise level in residential area is 60dB from 6am to 6pm, 50 from 6pm to 10pm and 45 from 10pm to 6am.
Conclusion of Examination	Because most of the construction works are small scale rehabilitation with less number of heavy equipment, the impact to noise and vibration will not be serious with proper management and mitigation measures.

IID-2.4 Environmental Management and Monitoring Framework

As a whole, serious environmental impacts will not be expected as explained above. However there is uncertainty regarding water quality during construction phase. Therefore, water quality monitoring is proposed as environmental management and monitoring plan. Brief summary of the proposed plan is as follows.

Water Quality Monitoring Plan

Items	General Outline
Background	During construction phase, concrete work will be conducted at Andong Sla and Vat Krouch Intake, and Roleang Chrey Regulator. Though mitigation measure toward inflow of alkalified water will be conducted, there is still uncertainty regarding water pollution. Alkalified water might affect aquatic-diversity. In addition, people are taking water from canals for both drinking and domestic use in command area of both North and South Main Canals.
Objectives	- To monitor water quality during construction phase
Sampling Point	Water quality should be monitored at three points such as i) Downstream of Andong Sla Intake Gate in North Main Canal, ii) Downstream of Vat Krouch Intake Gate in South Main Canal, and iii) Downstream of the Prek Thnot River
Items to be surveyed	i) pH, ii) transparency (turbidity), iii) water temperature, odor, appearance
Frequency	Once a month
Monitoring period	Nov 2008-April 2011 (total 30 months) (from one month before construction works, to four months after completion of all construction works)
Executing Agency	PDOWRAM Kampong Speu Province

If alkalified water is observed or other environmental parameter is beyond water quality standard value in public water areas set up by Sub-decree on Water Pollution Control, it is necessary to install adequate treatment system for alkalified water in the canals or consider other countermeasures.

IID-2.5 Comparative Evaluation of the Project

(1) Examination of the Condition without the Project

The following table shows supposed condition under the “Without the Project” case compared with the “with the Project” case. It was assumed that Roleang Chrey Regulator will be out of order in near future in the “without the Project” condition. It is noted that in the case of “with the Project” mitigation measures assumes to be implemented properly under the Project implementation.

Condition without Project and with the Project Case

Item	Without the Project	With the Project
Water Availability	- No/few water in North and South Main Canal because of breakdown of Roleang Chrey gate and no rehabilitation of Intakes (Andong Sla Intake and Vat Krouch Intake).	- Proper management of Roleang Chrey Regulator and Intakes. - Proper water distribution to North and South Main Canal and downstream of Prek Thnot River.
Agriculture	- Decrease of agricultural productivity in command area of both North and South Main Canal. - No expansion of paddy fields because of shortage of water in main canals.	- Increase of agricultural productivity in command area of both North and South Main Canal. - Expansion of paddy fields because, as next step, expansion of secondary/ tertiary canals will be expected.
Fishery	- Decrease of fishery because of water shortage.	- No drastic change by the Project

The following table shows the comparison of potential impacts between with and without the Project.

As a result of comparison, it is expected that the improvement Plan will arise or increase positive impacts related to water usage, agricultural activities local society and land use condition. On the contrary, under "without the Project" condition, water availability of canals might decline than current condition and local economy and their lives will be negatively impacted accordingly.

Comparison between With and Without the Project

	Activity / Potential Impact	Without Project	With Project	Remarks
	Social Environment			
1	Involuntary Resettlement			
2	Local economy (employment, livelihood etc)	--/A	++/B	Limitation of agriculture and fishery because of no/few water in canals (w/o)
3	Land use and utilization of local resources	--/B	++/B	Waste of water flow (w/o)
4	Social institutions	--/B	*	Failure of FWUC/FWUGs because of no/few water in canals (w/o)
5	Existing social infrastructures and services	--/A	++/C	Breakdown of regulator, intakes (w/o)
6	The poor, indigenous and ethnic people	--/C	*	Difficulty to find alternative water source (w/o)
7	Misdistribution of benefit and damage	--/C	*	Regional gap of water availability (w/o)
8	Cultural heritage			
9	Local conflict of interests	--/B	*	Expansion of regional gap (w/o)
10	Water Usage	--/A	++/A	No/few water in canals because of breakdown of Roleang Chrey gate (w/o)
11	Sanitation			
12	Hazards (Risk), Infectious diseases			
	Natural Environment			
13	Topography and Geographical features			
14	Soil Erosion			
15	Groundwater			
16	Hydrological Situation (Hydraulic)	=/B	=/B	
17	Flora, Fauna and Biodiversity			
18	Meteorology			
19	Landscape			
20	Global Warming			
	Pollution			
21	Air Pollution	*	--/C	Construction work (w/)
22	Water Pollution	*	--/C	Construction work (w/)
23	Soil Contamination			
24	Waste			
25	Noise and Vibration	*	--/C	Construction work (w/)
26	Ground Subsidence	--/B	*	Excess of groundwater usage because of no/few water in canals(w/o)
27	Offensive Odor	*	*	

Potential Impact / Activity		Without Project	With Project	Remarks
28	Bottom sediment	*	*	
29	Accidents	*	*	

*Note) --/B: left-hand side of each cell represents a direction of impact, right-hand side represents a magnitude of impact. ++: Positive impact, --: Negative Impact, =: Neutral Impact, A: relatively significant impact, B: relatively medium-size impact, C: relative small impact, *: No impact or no corresponding impact, w/: with the Project, w/o: without the project*

(2) Examination of the Condition without Environmental Considerations

In the process of formation of improvement plan, a series of environmental considerations were conducted in order to develop the Project environmental friendly and sustainably as mentioned in SectionII-2.8. In order to examine affectivity and validity of the Project component from a viewpoint of environment, these environmental considerations were evaluated by comparing condition with environmental considerations under the Project with condition without environmental considerations. Project components in the case of without any considerations are shown below.

Project Component Without Environmental Considerations

Items	Project Component Without Environmental Considerations
A) Water Availability during Construction Phase	Rehabilitation work of intake gates will stop water flow in canals for about 7-8 months. In addition, rehabilitation work of approach channels will be conducted in the rainy season without any consideration of water usage.
B) Lining Method of Approach Channels	Lining of approach channels will be rehabilitated by concrete without earth and block sodding.
C) Air Pollution by Transportation of Construction Vehicle	Water sampling toward the dust spread by construction vehicle will not be managed.

The following table shows the comparison of potential impacts between with and without environmental considerations. Main difference of impact between them is water availability that will cause relatively significant impacts to people’s life and agricultural activity directly. In addition, earth lining of canals will mitigate impact to aquatic-biodiversity, however proper management of canals is necessary in order to keep using canals appropriately. As conclusion, it is clear that these considerations might be effective and valid to local people directly and natural environment.

Potential Impact with and without Environmental Considerations

Potential Impacts	Without Considerations	With Considerations
A) Water Availability during Construction Phase		
Water availability during construction phase	People living in command area of both North and South Main Canals cannot access to canal water at least 7-8 months because of stop of water flow in the canals during rehabilitation work of intakes and approach channels.	People living in command area of both North and South Main Canals will be limited to canal water for few months in fallow period.
Local economy during construction phase	Agricultural activities in command areas of both North and South Canals (in total around 17,000ha) will be limited during cultivation time once.	Few/no impact to agricultural activities by construction work
B) Lining Method of Approach Channels		
Water pollution during construction phase	Alkalified water caused by the concrete works during construction phase will affect negatively on the biodiversity. People using canal water for drinking will be also affected in any way by alkalified water.	Murky water will increase in canals during construction phase. However the impact will not be serious to biodiversity.
Impact to biodiversity during operation phase	Biodiversity will be in risk of damaging by artificial surface of the canals.	Impact will be negligible during operation phase.
Breakdown of the canal during operation phase	Few impact	Canal is at slight risk of land sliding and breakdown of the embankment.
Disruption of water flow by grasses	No impact	Without any management of canals by farmers, water flow will be disrupted or stopped.
C) Air Pollution by Transportation of Construction Vehicle		

Potential Impacts	Without Considerations	With Considerations
Air pollution by dust during construction phase	The dust will be spread especially in the dry season. People living along the road which is transported by construction vehicle will be affected by the dust.	Little dust will be spread if any.

IID-2.6 Conclusion of the Examination

Initial environmental examination of the Project concludes as follows;

- As a whole, the Project Plan was evaluated to be acceptable from an environmental viewpoint, if proper mitigation measures presented previously are undertaken.
- Some of likely negative impacts on both social and natural environment were pointed out such as limitation of accessibility and water availability during construction phase. Therefore, proper management with proposed mitigation measures and monitoring plan should be implemented in order to avoid/mitigate anticipated negative impacts as much as possible.

Chapter IID-3 Summary of the Activities and Recommendation

(1) Capacity Development Activities

Continuously from Phase I of the Study, capacity development activities were conducted through a series of workshops for environmental counterpart of MOWRAM and MAFF in the first half of Phase II. Main objectives of the activities in this phase were to practice initial environmental examination toward Feasibility Study Projects so as to manage and supervise an environmental impact assessment study as executing agency in future.

The target staff of MAFF, who are belonging to EIA Office, has started to join several activities related to environment, i.e. review of EIA report of hydropower, since the activities of Phase I. However, there are still few active role of EIA Office in MAFF. On the other hand, the target staff of MOWRAM has not worked any activities related to environment because of other heavy duty.

In the first half of Phase II, total three times of workshops were conducted with active participation by them. Under the workshops, field exploration in and around the Project Area, environmental scoping and initial examination of the anticipated negative impact toward the two Projects were practically implemented.

(2) Interim Results and Recommendation

Through capacity development activities in Phase I and first half of Phase II, basic idea of environmental impact assessment and framework/procedure of EIA study were transferred to the counterparts through practical examinations.

In practical examination of the environmental impacts, it reveals that counterparts could consider social environmental impacts well such as problems of limitation of accessibility and water usage during construction phase. On the other hand, it was difficult for them to understand technical issues related to physical environment and its proper management method such as water pollution by concrete works and its countermeasures.

In fact, MOWRAM (PDOWRAM) and MAFF (PDA), as executing agencies, should conduct environmental management and monitoring activities properly, when the projects of M/P including the Projects of F/S will be implemented. In the projects of F/S, several management and monitoring plans were proposed to be undertaken by the executing agency during construction and operation phases.

This signified that it seems essential for them to acquire i) basic knowledge of causes and mechanisms of the environmental issues related to water resource management and agricultural practice, and ii) proper management method related to environment in their fields. Therefore, it is expected that basic environmental management ideas related to water resource management and agricultural practices should be transferred to the both staff of ministerial level and provincial level.