KINGDOM OF CAMBODIA
Nation Religion King

Ministry of Water Resources and Meteorology

GMS-Flood and Drought Risk Management and Mitigation Project

Detailed Design and Construction Supervision (DDCS)

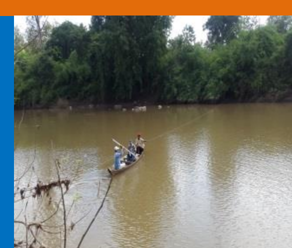
FINAL INCEPTION REPORT

Submitted in January 2016









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Project Name	Re: ADB Loan No. 2970-CAM Greater Mekong Sub-region Flood and Drought Risk Management and Mitigation Project (CAM): Contract No. GMS-FDRMMP-CS-002-Ntaional Consultants for Detailed Design and Construction Supervision (DDCS)
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Abbreviations

ADB	Asian Development Bank
AP	Affected Person
BM	Bench Mark
BME	Benefit Monitoring Evaluation
BOQ	Bill of Quantities
CADTIS	Cambodians' Action for Development
CAD	Computer Aid Drawing
CAM	Cambodia
CBDRM	Commune Base Disaster and Risk Management
CD/FWUC	Community Development / Farmer Water User Committee
CSC	Construction Sub-committees
CPMU	Center Project Management Unit
DCIS	Domnak Chheukrom Irrigation Scheme
DDCS	Detail Design Construction Supervision Construction
DDCSC	Detail Design Construction Supervision Construction Consultant
DGPS	Digital Global Positioning System
DMF	Design and Monitoring Framework
DTL	Deputy Team Leader
EIA	Environment Impact Assessment
EMP	Environment Management Plan
FB	Freeboard
Fig	Figure
FWUC	Farmer Water User Committee
GIS	Geographic Information System
GMS	Greater Mekong Sub-region
GOC	Government of Cambodia
HA	Hectare
HFL	Height Flood Level
ICB	International Competition Bidding
IEE	Initial Environmental Examinations
MC	Main Canal
MOWRAM	Ministry of Water Resources and Meteorology
NCB	National Competition Bidding
NFFC	National Flood Forecasting Center
PAM	Project Administration Manual

PIC	Project Implementation Consultant
PDOWRAM	Provincial Department of Water Resources and Meteorology
PIU	Project Implementation Unit
PPMS	Project Performance Monitoring System
PNP	Phnom Penh
PPTA	Preliminary Project Technical Assistance
PRC	Procurement Review Committee
SAWAC	SAWA Cambodia
SC	Secondary Canal
SES	Socio-Economic Survey
STP	Standard Penetration Test
SRI	System of Rice Intensification
TA	Technical Assistance
TOR	Terms of Reference
TL	Terms Leader

Executive Summary

The Kingdom of Cambodia has received a loan and grant from the Asian Development Bank for GMS-Flood Damage and Drought Risk Management Project. The Project has 4 key output's namely (i) Enhanced regional data, information and knowledge base for management of floods and drought; (ii) Upgraded water management infrastructure; (iii) Enhanced capacity for Community Based Risk Management; and (iv) Effective project implementation. MOWRAM is the Executing Agency and the Project will be executed by the Central Project Management Unit (CPMU) established in MOWRAM and two implementing agencies namely the Provincial Department of Water Resources and Meteorology in Pursat and the Department of Hydrology and River Works, see organization chart in Figure 2. The Detail Design and Construction Supervision (DDCS) component is dealing with the component 2. SAWAC Consultant Cambodia Co. Ltd is Association with CADTIS Consultant Co.,Ltd has been awarded the contract for detailed design and construction supervision of the Damnak Chheukrom Irrigation Scheme under component 2 of the project.

Detail Design Construction Construction Supervision Consultant (DDCSC) is required to assist MOWRAM in the selection, design, procurement and management of civil works contracts, construction supervision, reporting, performance monitoring, financial management, safeguards compliance, and implementation of subproject, namely the Damnak Chheukrom Irrigation Scheme. Consultancy services are for 48 months with 397 person-months of national consultants.

This inception report is prepared at the middle of November 2015, covering the activities undertaken during the inception phase of the project.

In this period, the main task completed was to collect analyses and prepare relevant data and information for the detail design of barrage structure, a more realistic alignment of the main canal (exploring for the most appropriate site and alignment), verification of existing topographical bench marks (BMs) and plan for additional surveys. Activities conducted during this inception period are as follows:

- Team mobilization and meeting with PIC, CMPU and PIU team;
- Collect and review of relevant data and information related to the project;
- Obtained information related to project administration including personnel management and office supplies including clarification of the terms of the contract;
- Site visit to major infrastructure sites, particularly the possible location of the site of the planned barrage and off take structures,
- Checked leveling of existing BM and transferred them to the other critical reference point.

- Conducted 6 cross sections along the river to redefine the barrage location for maximum intake head and favorable hydraulic conditions
- Hydrologic calculation for the design flood of the barrage structure
- Topography survey to redefine the main canal alignment, verify if it is feasible to extend the canal to part of the Battambang province and the drainage at the end of main canal at the upstream of Svay Donkeo River to divert peak flood discharge of 40 m^3/s to alleviate flood risk at Pursat provincial town.
- Present the drafted drawing design of the barrage and water for irrigation/flood diversion infrastructure
- Propose 3 design options including drawing design to be submitted to CPMU

At this stage the understanding of the consultant on the project is still limited and based mainly on the PPTA report, this will be subsequently improved with the completion of the field survey works.

1. Introduction:

Referring to contract signed on 20thAugust 2015 SAWAC Consultant LTD in association with CADTIS-Consultant., Ltd., on Re: ADB Loan No. 2970-CAM, Greater Mekong Sub-region Flood and Drought Risk Management and Mitigation Project (CAM): Contract No. GMS-FDRMMP-CS-002-Ntaional Consultants for Detailed Design and Construction Supervision (DDCS)

The DDCSC will undertake the following task:

I. Preparing the detail engineering design, assist Project Implement Unit (PIU) to verify and prepare them for implementation, including review and approval of final design;
II. Assist MOWRAM to preparing tender and contract document and evaluation of bids with particular emphasis on the large scale scheme;
III. Assist MOWRAM to address environmental and social aspects, including preparation and updating of resettlement plans where applicable;
IV. Ensure that necessary resettlement plans are updating with cost revision, prepare and implemented;
V. Implementations of the resettlement plan and payment of compensation to project affected people before issuing instruction to process to contractor;
VI. For subproject as applicable, review the economic viability of typical irrigation and flood control schemes and evolve practical guidelines for adoption;
VII. Implementations of construction work and provide advice to CPMU and PIU construction supervisors and spot-check the quality of materials and works;
VIII. Spot-check quantities and monthly payment certificates and counter-sign payment to contractor;
IX. Prepare regular reports of physical and financial progress, assist with the preparation of withdrawal application form the loan, and prepare a project completion report;
X. Environmental and social safeguard monitoring;
XI. Commissioning, training and handover and;
XII. Operation and maintenance and monitoring.

Activities related to each deliverable are described in detail in the sections below.

1-1. Project background

Pursat province is one of the Northwestern province of Cambodia located in the Tonle Sap river basin, the western part of the province is consisting of relatively high chain of mountain ranges, the Chain of Cardamom mountain ranges and the eastern part a flood plains extending from the foot of the Cardamom to the Tone Sap Great Lake. The shadow effect of the Cardamom mountain range is the main cause of early sometimes prolonged droughts period affecting large number of subsistence rice farmers of the province; while during the late month of the wet season, the eastern monsoon often brings heavy rainfall causing widespread flooding when the Great Lake is already at its full capacity and the wetland is already soaked with water. The improvement of the livelihood of the people of this region depend largely on the capacity to manage flood and droughts, particularly their increasing resilience capacity to cope with the impact of current and future climate change.

The Stung Pursat river basin has been selected as pilot project by the GOC with the assistance from ADB under the project “Greater Mekong Sub-region Flood and Drought Risk Management and Mitigation”. This project has four sub-components as mentioned above; the component 2 Detail Design and Construction Supervision (DDCS) of the Damnak Chheukrom Irrigation Sub-project has been awarded to SAWAC in association with CADTIS.

The Provincial Department of Water Resources and Meteorology of Pursat (PDOWRAM-PURSAT) will be the Implementing Agency for this component, under the overall direction of the MOWRAM’s CPMU. CPMU is responsible for the recruitment of consulting services and for awarding civil works contracts. The Director General of the General Department of Technical Affairs as head of CPMU will have overall administrative oversight of the consulting services and civil work contracts, and the designated Project Manager will have responsibility for day-to-day operations. PIC will provide guidance to Detail Design Construction Supervision Consultant (DDCSC).

The Damnak Chheukrom Irrigation Scheme, 16,100ha (DCIS), see figure 1 is the most upstream irrigation scheme in the Stung Pursat River Basin based on existing un-functional works built during Pol Pot time. Further downstream there are a number of partly functional and under planning irrigation schemes, namely:

1) The Damnak Ampil (7,650ha) with two storage reservoirs (dam 3 and dam 5) under the Chinese loan.
2) Wat Luong diversion (2,540ha)
3) Charek Irrigation Scheme (5,540 ha),

1-2. Objective and Scope of Work:

The consultant services are required to assist MOWRAM in the selection, design, procurement and management of civil works contracts, construction supervision, reporting, performance monitoring, financial management, safeguards compliance, and implementation of subprojects. Consultancy services are required for 48 months with 397 person-months of national consultants.

The scope of the work will include rehabilitation of the Damnak Chheukrom Irrigation Scheme for improved drought management and increased flood protection of Pursat Township. The scope of work will comprise detailed engineering design and construction supervision of:

(i) a new barrage located on the Pursat River about 40km upstream of Pursat Town that is designed to safely convey the 50-year flood under anticipated climate change conditions; and

(ii) an intake structure that can control river withdrawals for both command areas and flood diversion flows;

(iii) construct a 30km main canal that will convey the peak flood diversion discharge of 40m3/s from the Pursat River to the Svay Donkeo River, which comprises of: (a) rehabilitation of a 14km reach of an old non-functioning Khmer Rouge main canal; and (b) further construction of 16km of new main canal;

(iv) construction of four new main canal cross regulator structures to control flows and water levels within the main canal for diversion of command flows into the secondary canals while allowing conveyance of the peak flood discharge of 40m3/s;

(v) construction of a new outlet structure near the Svay Donkeo River;

(vi) construction of four new secondary canals with a total length of 51.5km, including check structures and outlets to the tertiary system;

(vii) construction of new tertiary and distribution canals, and new drainage systems;

(viii) construction of canal cross-drainage and overflow structures along the main canal; and,

(ix) Construction of new road bridges along the main and secondary canals.

Note: The length of canal's, area to be irrigated and number of structure to be reconstructed and rehabilitated will be finalized during survey and detail design.

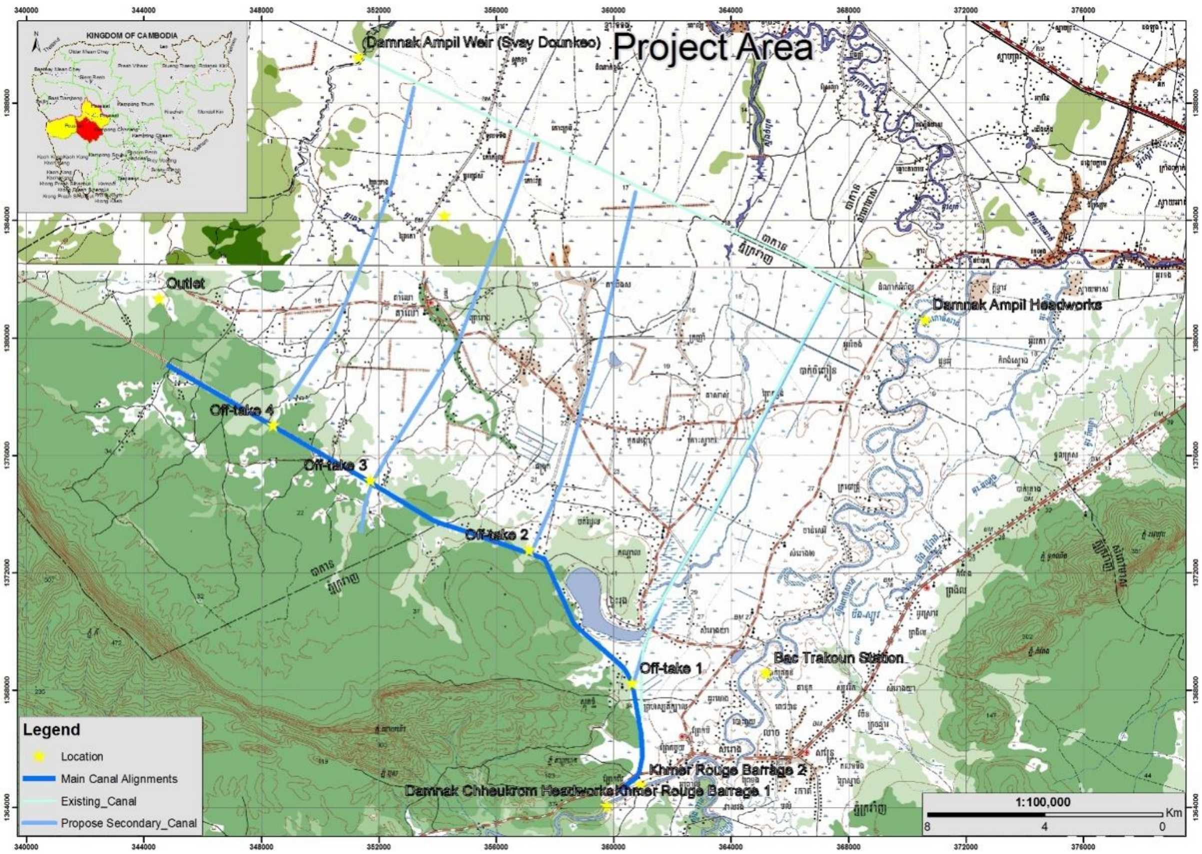


Figure 1: Location map of the Damnak Chheukrom Irrigation scheme

1-3. Key Tasks as per TOR

The following tasks will be undertaken:

(i) Preparation of detailed engineering design, assist the PIU to verify and prepare them for implementation, including review and approval of final designs;

(ii) Assist MOWRAM to prepare tender and contract documents and evaluation of bids with particular emphasis on the large-scale schemes;

(iii) Assist MOWRAM to address environmental and social aspects, including preparation and updating of resettlement plans where applicable;

(iv) Ensure that necessary resettlement plans are updated with cost revision, prepared and implemented;

(v) Implementation of the resettlement plan and payment of compensation to project affected people before issuing instruction to proceed to contractors;

(vi) For subprojects as applicable, review the economic viability of typical irrigation and flood control schemes and evolve practical guidelines for adoption;

(vii) Implementations of construction work and provide advice to the CPMU and the PIU construction supervisors and spot-check the quality of materials and works;

(viii) Spot-check quantities and monthly payment certificates and counter-sign payments to contractors;

(ix) Prepare regular reports of physical and financial progress, assist with the preparation of withdrawal applications from the loan, and prepare a Project Completion Report;

(x) Environmental and social safeguard monitoring;

(xi) Commissioning, training and handover; and

(xii) Operation and maintenance and monitoring.

Staffing and other Inputs: The following personnel will be mobilized in the DDCS team for the assignment.

Table A. Consultants Inputs

	Position	Person-Months
A.	**Key Experts(National)**	
1	Team Leader/Irrigation Design and Construction Engineer	42
2	Deputy Team Leader - Irrigation Design and Construction Engineer	42
3	Assistant Resident Engineer (4 persons)	120
4	Structural Engineer	6
5	Hydrologist	6
6	Resettlement Specialist	12
7	Agriculture Economist	6
8	Environmental Specialist	12
9	Procurement Specialist	9
10	Community development/FWUC Specialist	12
11	O& M Engineer	12
12	Labor/Gender Specialist	12
	Total A	**291**
B.	**Non- Key Staff (National)**	
1	Surveyors (8 persons)	64
2	Financial and Account Assistant	42
	Total B	**106**
	Consulting Service Total (A+B):	**397**

1-4. Staff mobilization

Table 1: Staff mobilization

Key Expert

No	Name	Position	
1	Mr. Kam Sothun	Team Leader/Irrigation Design and Construction Engineer	1/Oct/2015
2	Mr. Phai Sokheng*	Deputy Team Leader - Irrigation Design and Construction Engineer	1/Sep/2015-18/Sep/2015
5	Mr. Cheoum Ravann	Assistant Resident Engineer (1)	
6	Ms. Din Chakriya	Assistant Resident Engineer (2)	
7	Mr. Phung Kosal	Assistant Resident Engineer (3)	
8	Mr. HENG Choung	Assistant Resident Engineer (4)	
9	Mr. KHIN Toda	Structural Engineer	2/Nov/2015
10	Mr. Chhit Kim Hor	Hydrologist Specialist	1/Oct/2015
11	Mr. OUM Sith	Resettlement Specialist	
12	Mr. CHHUN Bunmeng	Agriculture Economist	
13	Ms. SAO Sambat Morokat	Environmental Specialist	
14	Mr. Em Sochea	Procurement Specialist	
15	Mr. MOK Samoeun	Community Development / FWUC specialist	
16	Mr. HENG Ratha	O & M Engineer	
17	Ms. Bun Sary	Labor/Gender Specialist	

* Note Mr. Phai Sokheng, has resigned after working for 18 days in project citing health reasons.

Table 2: **Non Key Expert**

Non Key Expert **

1	Mr. PHORN Brorsoeur	Surveyor Manger/ Engineer- CAD Operator	1st/Sep/2015
2	Mr. LONG Vannak	Assistant Surveyor (GIS Expert)	
3	Mr. Men Vaxy	Assistant Surveyor/Engineer/ CAD Operator	19th/ Oct/2015
4	Miss. Heng Tavy	Assistant Surveyor/Engineer/ CAD Operator	2nd/Nov/2015
5	Mr. PHORN Voeun	Assistant Surveyor/Engineer/ CAD Operator	19th/ Oct/2015
6	Mr. Chan Chhorm	Assistant Surveyor/Engineer/ CAD Operator	2nd/Nov/2015
7	Mr. TOUCH Samnang	Assistant Surveyor/ Landholding/ Resettlement	
8	Mr. PHUOV Narin	Assistant Surveyor/ Landholding/ Resettlement	2nd/Nov/2015
9	Mr. UN Sothea	Financial and account assistant	1st/Sep/2015

10	Miss. Chea Marina	Support staff	1st/Sep/2015

<u> Non Key Expert</u>**

1. Mr. Bot Meng replaced by Mr. Men Vaxy,
2. Mr. Seoum Mithuna, replaced by Miss. Heng Tavy.
3. Mrs. Keo Sam An, replace by Mr. Chan Chhorm

1-5. Meetings with stakeholders and Client

A. *<u>Meeting client/stockholders and relevant sectors for data collection</u>*

- Meeting with Project Implementation Consultant (PIC) in PNH to discuss on general status of the project to obtain data/documents that are related to the project on 01 October 2015.
- Reviewed some documentations: (a) Project Administration Manual (PAM), (b) Irrigation Engineer's report (May 2012-ADB TA 6456-REG), and (c) other relevant data in PNH on 02 October 2015.
- Meeting with Project Implement Unit (PIU) in Provincial Department of Water Resource and Meteorology of Pursat (PDOWRAM-PURSAT) office that led by PIC team on 05 October 2015.
- Coordinated with SAWAC and CATIS on (a) general administration, (b) staffs mobilization, (c) preparing the budget proposal for purchasing the survey instruments and soil investigation, (in week 2 of October 2015).

B. *<u>Conduct field visit to project site to update relevant data/information</u>*

- In week 2 of October 2015, conducted field visit to project site at the Pursat River to identify the location for the barrage structure from point (X=359775,Y=1364158) at downstream to point (X=358880,Y=1363815) at the upstream, from point 1 to point 5.
- Checking the leveling of existing Bench Mark BM1 to existing BM3 and the existing BM2 was ignored, we regards BM1 as the main reference for transfer to other BM and the BM1 level was provided by MOWRAM as 29.450m, and the existing level of BM3 is 25.169m (provided by Mr.Nara, surveyor in MOWRAM) after checking its level is found to be 26.532m, (in week 2 of October 2015)
- Transferring the level from existing BM1 to establish temporary BM along the river at the upstream side covering a total length of 5.645 km, (in week 4 of October 2015).
- Conducted the topography survey 6 of cross sections from downstream to upstream to identify the best fit technical location for the barrage structure, (in week 4 of October 2015).
- Leveling calculation and designed 6 river cross sections drawing, (in week 4 2015).

- Review the relevant project materials and data on hydrology to obtain preliminary understanding the conception of project and data availability, (in week 1 & 2 of October 2015).
- Review the relevant project materials and the hydrological data at Bac Trakoun Station, re-calculate the return flow amount for 50 year return periods for Barrage structure design, (in week 2 & week 4 of October 2015)

1-6. Project organization chart

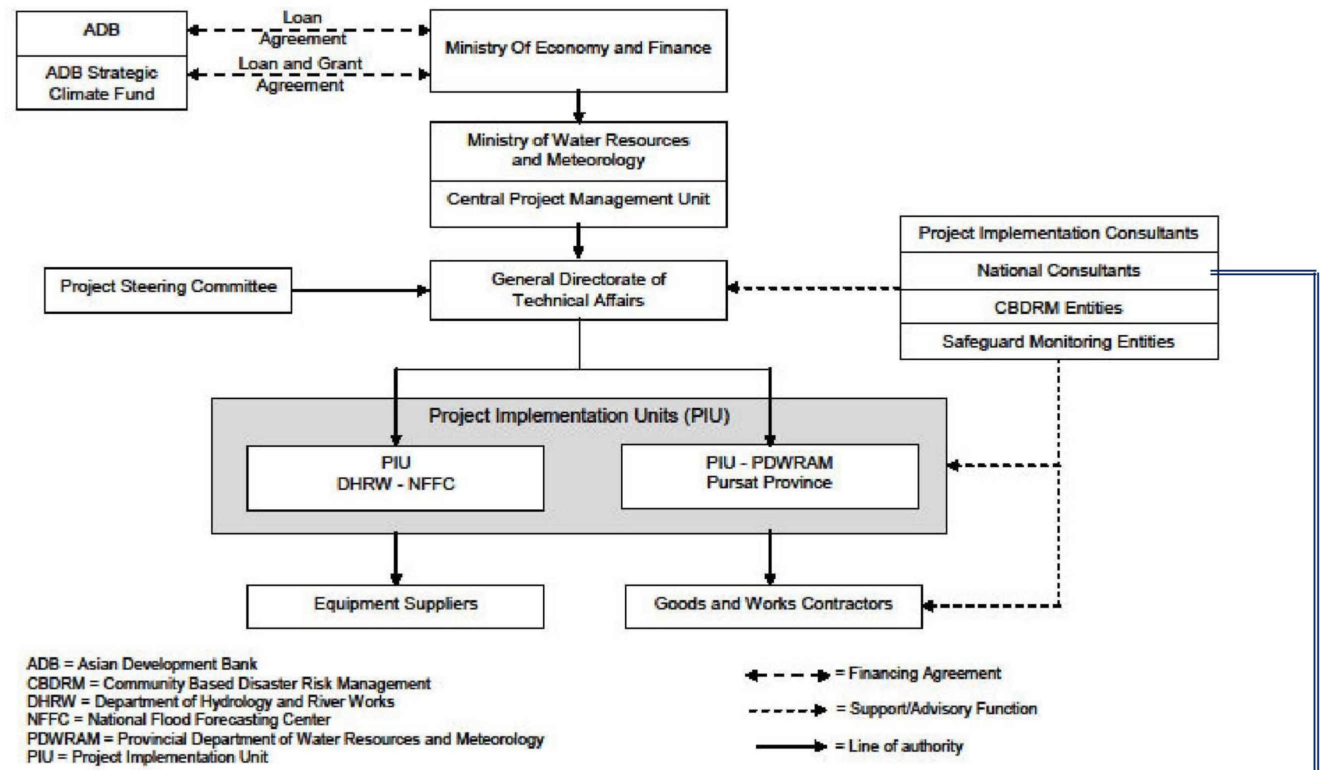


Figure 2: Project organization chart

Mr. Kam Sothun Team Leader - Irrigation Design and Construction Engineer	
Deputy Team Leader - Irrigation Design and Construction Engineer	
Key Expert	**Non Key Expert**
Mr. Cheoum Ravann Assistant Resident Engineer (1)	**Mr. PHORN Brorsoeur** Surveyor Manger/ Engineer- CAD Operator
Ms. Din Chakriya Assistant Resident Engineer (2)	**Mr. LONG Vannak** Assistant Surveyor (GIS Expert)
Mr. Phung Kosal Assistant Resident Engineer (3)	**Mr. Men Vaxy** Assistant Surveyor/Engineer/ CAD Operator
Mr. HENG Choung Assistant Resident Engineer (4)	**Miss. Heng Tavy** Assistant Surveyor/Engineer/ CAD Operator
Mr. KHIN Toda Structural Engineer	**Mr. PHORN Voeun** Assistant Surveyor/Engineer/ CAD Operator
Mr. Chhit Kim Hor	**Mr. Chan Chhorm**

Hydrologist Specialist	Assistant Surveyor/Engineer/ CAD Operator
Mr. OUM Sith Resettlement Specialist	**Mr. TOUCH Samnang** Assistant Surveyor/ Landholding/ Resettlement
Mr. CHHUN Bunmeng Agriculture Economist	**Mr. PHUOV Narin** Assistant Surveyor/ Landholding/ Resettlement
Ms. SAO Sambat Morokat Environmental Specialist	**Mr. UN Sothea** Financial and account assistant
Mr. Em Sochea Procurement Specialist	**Miss. Chea Marina** Support staff
Mr. MOK Samoeun Community Development / FWUC specialist	
Mr. HENG Ratha O & M Engineer	
Ms. Bun Sary Labor/Gender Specialist	

2. Project Description

Infrastructure development of the new Damnak Chheukrom Irrigation Scheme (DCIS) on the Pursat River is being implemented under Component 2 of the Project " Greater Mekong Sub-region Flood and Drought Risk Management and Mitigation" that has four components (PPTA TA 6456-REG): (i) strengthening regional coordination for management of climate extremes; (ii) developing and/or upgrading water management infrastructure; (iii) developing capacity among community-based flood and drought management programs; and, (iv)ensuring effective project implementation.

Under the PPTA TA 6456-REG, the preliminary design of the DCIS has taken into account (i) the proposed extension of the scheme into Battambang Province; and (ii) incorporating climate resilient measures into the scheme's design to ensure it will be resilient against impacts of anticipated climate change including: (a) increased rainfall and flood intensities; and, (b) drier and longer dry seasons.

The aim of the assignment comprises the following:

(i) an upstream controlled and supply managed irrigation scheme to provide: (a) wet season supplementary irrigation for 16,100ha of net command area in Pursat Province; and, (b) full irrigation to a smaller net command area during the dry season to be defined; (ii) identify the best location and detail design of a new head works structure that will withdraw irrigation water from the Pursat River to the command area and facilitate peak flood diversion using the scheme's main canal, comprising of: (a) a new barrage located on the Pursat River about 40km upstream of Pursat Town that is designed to safely convey the 50-year flood under anticipated climate change projection; and (b) an intake structure that can control river withdrawals for both command and flood diversion flows; (iii) detail design and supervision of the construction of a 30km main canal that will convey the peak flood diversion discharge of $40m^3/s$ from the Pursat River to the Svay Donkeo River, which comprises of: (a) rehabilitation of a 14km reach of an old non-functioning Khmer Rouge main canal; and (b) further construction of 16km of new main canal; (iv) construction of four new main cross regulator structures to control flows and water levels within the main canal for diversion of command flows into the secondary canals while allowing conveyance of the peak flood discharge of $40m^3/s$; (v) construction of a new outlet structure near the Svay Donkeo River; (vi) construction of four new secondary canals with a total length of 51.5km, including check structures and outlets to the tertiary system; (vi) construction of new tertiary and distribution canals, and new drainage systems; (vii) construction of canal cross-drainage and overflow structures along the main canal; and, (viii) construction of new road bridges along the main and secondary canals. The Battambang extension was found to be technically unfeasible however recovered non-consumed flows from the DCIS will automatically benefit the downstream DCIS which also extends into Battambang Province.

With respect to climate resilience measures the following are required: (i) maintaining the required flood design standard for hydraulic structures and Pursat Town by: (a) developing new design standards for hydraulic structures in the project area; (b) increasing the design of impacted hydraulic structures (the DCIS Barrage and two existing irrigation weirs on the Svay Donkeo River) according to the new design standards; and, (c) assessing both the increased flood impact to Pursat Town owing to anticipated climate change and subsequent potential mitigation benefits from the proposed DCIS flood diversion; and, (ii) maintaining the maximum potential dry season command areas of the DCIS by: (a) mitigating the impact of less water availability during the dry season period by retaining excess wet season runoff within an integrated existing Phtenh Rung Reservoir and provision of new traditional field reservoirs; and, (b) reducing the gross water demand through structural and non-structural measures. Explore and proposed the most viable measures to assist with reducing gross water demand include: (i) the following comprehensive programs to integrate into the design and management of the scheme: (a) modern flow monitoring to facilitate effective water management throughout the scheme; (b) broad use of System of Rice Intensification (SRI) crop and irrigation methods to reduce consumed non-beneficial and non-consumed irrigation water; and, (c) capacity development programs for the Scheme Operator and Farmer Water User Community (FWUC) to facilitate optimal management of the scheme; and, (ii) the following trial programs to assess their practicality and feasibility for later broad implementation if found successful: (a) using low pressure pipelines in the tertiary and distribution system to replace open canals; (b) conjunctive use of the surface and groundwater in the tail-end areas of the scheme to recover upstream non-consumed irrigation water; (c) drip irrigation field application for non-rice crop to reduce consumed, non-beneficial and non-consumed irrigation water; and, (d) crop diversification through growing less water consuming rice and crop varieties to reduce overall water demand particularly during the dry season.

2-1. General Plan

The plan is targeted to complete the detail design including BOQ and bidding document by end of March 2016 for barrage structure only and other will be completed by the end of August 2016. The details of the planned activities are shown in table work plan and staff scheduled. A priority has been given to the collection and confirmation of essential topographical, hydrological and geological data. The topographical data verification and collection have been started right from the project staff mobilization to Pursat. The works was consisting of identification and verification of existing reference BM and transfer them to the proposed site for infrastructures development, collect and analyses hydrology-meteorological data for their availability, consistency and plan for the computation of required parameters: design flood, water resources availability, water balance for different crop patterns and impact of projected climate change. At the same time the infrastructure design will have to start with exploring for a suitable location according to hydraulic conditions and site suitability. In parallel in the water balance studies and detail design of the main canal, secondary canal, flood diversion and water control infrastructures. It is expected that during that process maximum dry season cropping areas could be identified as well as other requirements such as environment and social safeguards including the training of the future FWUC/FWUG progressively with the design works.

And the other activities like hydrology analysis, detail engineering design, social-economic study, socio-safeguard, environment assessment, preparing of the tender and contract document, FWUC/Other committee development, construction planning and supervision, operation and maintenance and monitoring and report delivery are included in general plan.

The target completion is proposed to move from February 2019 to July 2019.

2-2. Overall Approach

For topographical survey teams will use automatic level, total station, DGPS equipment to carry out the surveys activities as planned by the design team to collect necessary design data, the geotechnical investigation and soil testing also data requirement for detail design work, the hydrology analysis, detail engineering design, social-economic study, socio-safeguard, environment assessment will follow the ADB guideline. The FWUC/Other committee development and training will be closely coordinated with other components namely CBDRM and NFFC. The supervision of construction works will follow the standard procedures provided by the ADB since this will involve international contractors. construction planning and supervision, operation and maintenance and monitoring will be carried out to barrage structure, main canal and associated structure, secondary canal and associated structure, tertiary canal and associate structure and other.

2-3. Previous Survey and Studies

Since starting project the service provider (SP) has received information/reports and data from CMPU/PIC as:

1. Project map
2. ADB report TA 6456-REG: PREPARING THE GREATER MEKONG SUBREGION FLOOD AND DROUGHT RISK MANAGEMENT AND MITIGATION PROJECT IRRIGATION ENGINEER'S REPORT (MAY 2012)
3. Inception report of Project Implementation Consultant (PIC) (Yooshin, 2015).
4. Sub-decree on the Establishment , Dissolution, Roles and Duties of FWUCs

All previous project map documents are useful for project information mapping is to identify all relevant stakeholders directly or indirectly involving in water resource and irrigation sectors in project. This will provide a clear view of who is involved in these sectors and what kind of communication should be developed and improved for a better cooperation and connection in the future.

PPTA document from previous study is more important the present study undertook a comprehensive redesign of the key infrastructure of the DCIS including its: (i) barrage; (ii) intake structure; (iii) main canal and alignment; and, (iv) cross regulator structures.

3. Key Tasks/Outputs and Methodology

Based on the ToR provided,we understand that the deliverables could be subdivided into two main important components (1) rehabilitation/construction of the Damnak Chheukrom Irrigation System for improved drought management and (2) increased flood protection of Pursat Township

The service provider (SAWAC and its association CADTIS) are aware that this project is under direct management and of the Provincial Department of Water Resources and Meteorology of Pursat (PDOWRAM-PURSAT) and under the overall supervision of the MOWRAM's CPMU. CPMU that is responsible for the recruitment of consulting services and to award civil works contracts. The Director General of the General Department of Technical Affairs as head of CPMU will have overall administrative oversight of the consulting services and civil work contracts, and the designated Project Manager will have responsibility for day-to-day operations. PIC will provide guidance to Detail Design Construction Supervision Consultant (DDCSC).

In order to carry out the assignment, the service provider will prepare and organize the work as phase:

Phase I:

Engineering and Community part:

- Construct one new barrage, one new intake structure, rehabilitate/construction of one main canal and four secondary canals including water level regulators, new flood outlet structure, new tertiary, distribution canals, new drainage systems; construction of cross-drainage canal and overflow structures along the main canal; and Construction of new road bridges along the main and secondary canals.
- Support for stakeholders involved in the implementation of the irrigation sector policy. Support for government stakeholders and Support for non-governmental stakeholders.

Phase II:

Construction supervision

- O & M manual
- FWUC Training for handover and financial management

3-1. Detailed Engineering Design

The DDCS with the supported and guidance from PIC team will carry out detailed design and prepare drawings for all sub-components of the sub-project in consultation with the Project Implementation Unit (PIU).

Thus, the DDCS will prepare detailed design for the barrage structure, main canal, secondary, tertiary and drainage canals with all associated structures, with drawings, bill of quantities and technical specification.

3.1.1 Site Survey

Preparing working maps to assist the surveyors in identifying locations and planning the field work. This phase includes checking the existing BM and transferring the leveling to benchmarks at the sub-project sites. The surveyor's team will have to work quickly and the data sent to the project offices for processing immediately. The survey data collected will be used by the structural engineer that is assisted by PIC engineer for preparation of the detailed design in CAD format, typically this will include layout plans, barrage structure, main canal alignment survey, comment area survey, secondary canal survey, Pursat and Svay Donkeo survey (only checking) and in the work plan all these activities will be completed by March 2016.

3.1.2 Topographical Survey

Survey Principle

- All benchmarks shall be fixed by using leveling machine. Checking of instrument before leveling shall be done by two-peg method. Printed level books shall be used and shall be kept in the office for record. Benchmarks should be fixed by double fly leveling. The values obtained by double fly leveling shall be checked by single fly leveling. The survey party for double fly leveling shall be headed by the senior surveyor having adequate experience.
- Bench Marks (BMs) may be established at suitable interval and engraved on the existing structures like bridge/culvert or important structures (usually at the fly leveling routes). BM should be referenced (tied) to known Survey BMs as far as possible. If no such BMs are available, a local datum should be defined.
- An inventory of exiting hydraulic/irrigation structures (location, size, invert level etc.) and other important features (e.g. settlements, cultivated areas, forest) in the surveyed areas is to be made. A base map of the project area (based on the topographical survey of the barrage, irrigation canals or river areas locating cross-sections survey points and other features) is to be prepared with the updated information and surveyed data.
- While surveying river cross sections, elevations of observed high flood level (HFL) in streams/rivers should also be surveyed and presented in the Longitudinal Profile elevations drawings. HFLs should be surveyed based on the flood marks or interviewing people**.**
- A survey report should be prepared containing the survey methodology and necessary maps and drawings. The reports should include digital photographs of key locations and features.

1) Barrage Site

- Fixing of permanent benchmarks along the river banks for river L-section, X-section and contour survey. 1st benchmark level shall be the same as provided by MOWRAM.
- A contour plan of the area around the proposed site of the barrage with contour intervals of not more than 0.5m, up to an elevation of at least 2.5 m above the high flood level.
- The contour plan shall extend up to 3 km on the upstream and 0.5Km down stream on the proposed site and upto an adequate distance on both flanks up to which the effect of back-water is likely to extend under all conditions.
- Cross-sections of the river at the proposed site and at intervals of 200 m on upstream up to 3km and downstream up to at least 0.50 km from the proposed site (s). Besides these, cross-sections of the river at 500m intervals shall be taken up to the distance, the back

water effect of ponding is likely to extend on the upstream of the site. If the topography the topography indicates appreciable fall in the river slope, cross-sections shall be taken at closer intervals depending on site conditions.

- Longitudinal section of the river with observed water levels along the deep current for a distance from 1 km downstream of the site up to 5km or the distance up to which the backwater effect is likely to extend upstream of the site whichever is more.

2) Main Canal Survey

- Checking of benchmarks level which are already established by MOWRAM If there is no change in the levels of benchmarks the survey data provided by MOWRAM shall be used for the design works. No further survey needed for the same point/location.
- Selection of best alignment shall be done considering cutting and filling to be minimum. During the selection of best alignment, if the previous alignment selected by MOWRAM changes, detailed survey work shall be conducted for the new alignment.
- The longitudinal section shall be taken at 100m interval and partial distance of each cross section points shall be at interval of 5m for same terrain cross slope. The total width of the cross section shall not be less than 100m i.e. 50m each toward right side and left side provided that the width may be more up to 200m where there will be the option of best alignment to be chosen.
- X (easting) and Y (northing) data shall be taken in 100m grid interval.
- If the cross terrain changes, then partial distance point to point shall be taken as per the actual topography of the ground.
- If the survey data provided by MOWRAM are more than (100x100) m interval, then intermediate cross-section shall be taken.
- The width of the cross-section survey shall be fixed in such a way that it will be more beneficial to select the best canal alignment. For example, if the level toward left side from center level (provided by the designer) of the canal alignment is higher elevation than toward the right side then more width to the right shall be taken than to the left side and vice versa.
- During cross section survey, the surveyor should take data like: soil type, house, farm, no of trees (mentioning diameter of tree), road (highway, district road, village road etc.,), drainage, village name in some particular area and any other data which may be helpful for design and cost estimate purpose.
- Where there is drainage work, bridge work etc., block leveling shall be done at 50 m interval longitudinally within the periphery.

- If the direction of the alignment changes abruptly then 3 cross section at that point shall be taken, two additional cross-sections one at 30m u/s and another at 30m d/s of the canal alignment.

3) Secondary Canal Survey

- Alignment shall be chosen after discussion with commune/farmer groups and topographical survey
- Same procedure shall be followed as in Main Canal survey
- The cross-section shall be taken at 50m interval and partial distance at 3m each point. Other principle will be the same.
- Survey detail will be the same as described for MC survey
- The survey grid shall be prepared in (50x50) m

4) Drainage Survey

a) Cross drainage

- L-section and X-section data shall be taken for the drainage
- X-section shall be taken at each 25m interval up to 500m to 2Km upstream and 50 to 200 m downstream depending upon the size of the drainage and partial distance between points shall be 3m to each point.

- Flood marks high flood level shall be taken from local enquiry to each x-section.
- Type of drainage bed material shall be found out.

b) Escape channel drainage

As 40 m^3/s discharge is proposed as the design capacity of the Main Canal to divert flood water during the flood season, the escape channel drainage locations have to be found out and survey should be done to know the drainage capacity of the existing drainages. If existing drainages are incapable to convey this discharge of 40 m^3/s then new additional drainage survey shall be done with locations to be proposed.

- L-section X-section survey throughout
- Interval of X-section at 200m interval
- All details as described in above surveys
- If extra drainage will be proposed, then land area to be acquired.

5) Command Area Survey

Two sample command area survey under secondary canal 1 and 3 shall be carried out. Block leveling in 50 m grid shall be completed to cover an area of about 500 ha to each block. The levels shall be plotted with a contour interval of 0.25m. The alignment of entire distributary system comprising of tertiary and field channels shall be drawn on the block command plan, for preparing the cost estimates for distributary system. The estimates then, could be adopted for the entire command area work. The block area map shall be prepared to scale 1: 10,000.

6) Flood Management Survey

- To manage the high flood, X-sections of river Pursat up to Pursat town shall be taken at 2 Km interval after DCIS barrage location.
- Similarly, x-sections at 2 km intervals shall be surveyed of Svay Donkeo River (from 2 km upstream of the point where the main canal discharges to downstream upto the point the river meets a major drainage system.

Other Surveys

1. Construction Material Investigations

Necessary quarry surveys have to be conducted to assess the availability of construction materials and their quality.

2. Borrow Area Survey

Soils from canal excavation are proposed for formation of embankments. Where the earth from excavation is found to be inadequate, it will be proposed to borrow the earth from the nearby fields. Based on broad soil classification the soils could be classified as (i) soft black cotton soils, (ii) ordinary gravel, (iii) red earth, (iv) hard red earth (v) hard gravel which are considered to be suitable for construction of embankment in part filling and cutting reaches.

3. Disposal Area Survey (if required)

In case the excavated materials are more than the volume needed for the embankments, location survey of disposal sites shall also be carried out.

3.1.3 Geotechnical Survey

The scheme wills withdraw irrigation water to command area and facilitate peak flood diversion which comprise of main barrage crossing the Pursat River for flood control and withdraw for both command and flood diversion flows by main canal and structures.

For safely design and protection structures include main barrage cross river, intake structure, Cross Regulator structures on main canal and others, the proposed soil investigation survey should be carry out:

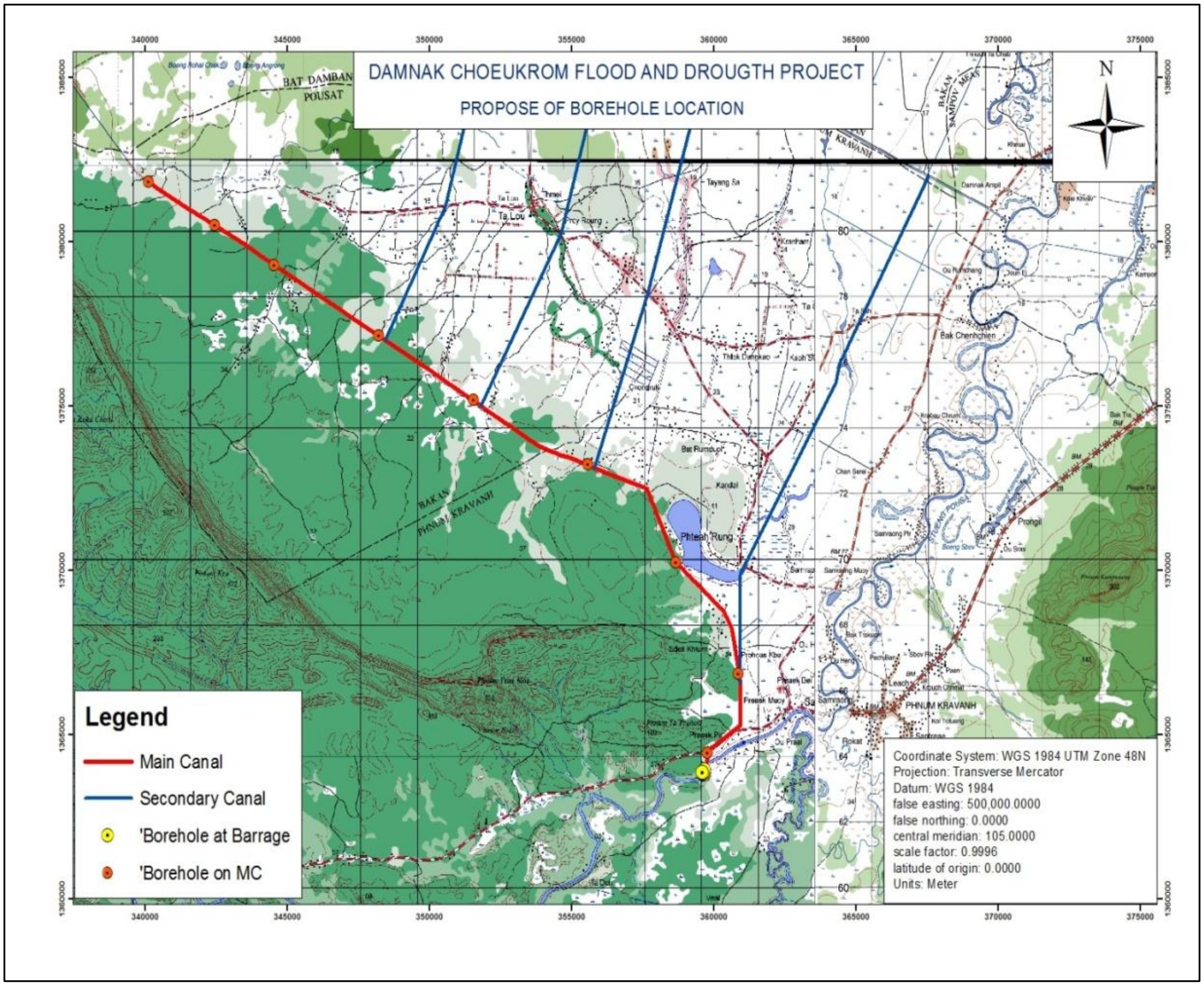
1. Drilling on river bank and in river for Barrage structure 4 holes: Drilling and Standard Penetration Test (SPT) every 1.50m with maximum 20m depth include laboratory test of Natural Moisture Content, Densities test, Atterberg Limit, Sieve test
2. Drilling by hand auger with maximum 7m depth along Main Canal 9 holes

List of Propose Soil Investigation Borehole Location for Barrage Structure and MC,

No.	Easting	Northing	Structure Name	Remarks
1	359101	1363708	Barrage	Left Side near the river center
2	359590	1363720	Barrage	Left side
3	359633	1363660	Barrage	Right side at river bank
4	359628	1363737	Barrage	40m to down from river center
5	359,808	1,364,447	Main Canal	Existing Bridege on road 146
6	360,880	1,366,860	Main Canal	Cross Regulator SC1
7	358,690	1,370,225	Main Canal	
8	355,580	1,373,220	Main Canal	Cross Regulator SC2
9	351,555	1,375,175	Main Canal	Cross Regulator SC3
10	348,230	1,377,145	Main Canal	Cross Regulator SC4
11	344,550	1,379,299	Main Canal	Cross Regulator MC2
12	342,450	1,380,516	Main Canal	
13	340,133	1,381,825	Main Canal	

3. Borrow pit test 9 holes with maximum 5m depth include laboratory test of Natural Moisture Content, Densities test, Atterberg Limit, Sieve test, Linear Shrinkage, Erodibility Criteria and Standard compaction test, for location of borrow pit test will be point in the next.

Propose Borehole Location map



3.1.4 Material Source Survey

The material source survey also carries out for specifying and applying to the technical specification, borrow pit test 9 holes with maximum 5m depth include laboratory test of Natural Moisture Content, Densities test, Atterberg Limit, Sieve test, Linear Shrinkage, Erodibility Criteria and Standard compaction test are conducted.

3.1.5 Socio-economic Survey

Economic and financial assessments will be undertaken for all sub-projects and will be included in the detail design, and in particular to verify the EIRR for each scheme. The economic analysis of irrigation projects focuses on future losses avoided and, through construction of irrigation scheme infrastructure and improving connectivity, such projects will improve the welfare of affected people and businesses. They will also directly generate jobs and incomes through construction activities. Thus, the project TA teams will collect basic social and economic data and information from each sub-project to allow final analyses. Monitoring will be carried out on a yearly basis starting from Q1, 2016.

3.1.6 Hydraulic Structure Design and Drawings

3.1.6.1 Barrage

The design criteria, including formulae, coefficients and constants will be used in all hydraulic design as applicable.

3.1.6.2 Factors affecting the Design of Barrage are as follows:

1. Estimation of Design Flood
2. Hydraulic Units
3. Width of Barrage
4. Afflux
5. Tail Water Rating Curve
6. Crest Levels
7. Discharges through a barrage (Free Flow Condition)
8. Discharges through a barrage (Submerged Flow Condition)
    1. Fane's Curve
    2. Gibson's Curve

3.1.6.3 Estimation of Design Flood

Basic of Estimation

The design flood for any given return period is usually estimated by the frequency analysis method. Appropriate type of frequency distribution will be selected from among the following:

1. Person & Log Person Type III distributions
2. Gumbel's Extreme Value distributions
3. Normal & Log Normal distributions

It is pertinent to point out that Log Person Type III distribution has been adopted by United States Federal Agencies whereas Gumbel's distributions have generally been found to be suitable for most of the stream.

3.1.6.4 Design Return Period

A return period of 50 years is generally adopted in the design of important and costly barrage structures where possible consequences of failure are very serious. Accordingly, the estimation of design flood will be carried out for various return periods of 100 years, 200 years and 500 years subject to Client's concurrence. However, the acctual recorded peak flood discharge will be reviewed for design if it exeeds the discharge calculated for the concerned return period.

3.1.6.5 Hydraulic Units

The dimensions and units of properties used in solving hydraulic problems are expressed in three fundamental quantities of Mass (M), Length (L), and time (T). All analyses and design will be carried out in the Meter-kN-Second of SI Units.

3.1.6.6 Width of Barrage

Three consideration govern the width of a barrage. They are the design flood, the Lacey design width and the looseness factor. It is generally thought that by limiting the waterway, the shoal formation upstream can be eliminated. However, it increases the intensity of discharge and consequently the section of the structure become heavier with excessive gate heights and cost increases, though the length of the structure is reduced.

The design flood is discussed in section (4.2 Hydrology analysis) and the other two considerations are discussed in the following sections.

3.1.6.7 Lacey's Design Width

The Lacey's Design or Stable width for single channel is expressed as:

$$W=4.75\sqrt{Q}$$

Where:

- Q is the Design Discharge in cumecs (m^3/s)
- W is the design width (m)

The Barrage is designed for a width exceedign W, partly to accommodate the flood plain discharge and partly to take advantage of the channel flow induced by the obstruction caused by the barrage itself.

3.1.6.8 The Looseness Factor

The ratio of actual width to the regime width is the "looseness factor", the third parameter affecting the barrage width. The value used have varied from 1.9 to 0.9, the larger factor being applied in the earlier design, Generally it varies from 1.1 to 1.5. From the performance of these structures, a feeling arises in certain quarters that with high Looseness Factor, there is a tendency for shoal formation upstream of the structures, which causes damages and maintenance problems. The Consultants will use the most appropriate looseness factor to provide reasonable flexibility keeping the ill effects to the minimum.

3.1.6.9 Afflux

The rise in maximum flood level of the river upstream of the barrage as a result of its construction is defined as Afflux. Aff lu x, though confined in the beginning to a short length of the river above the barrage, extends gradually very far up till the final slope of the river upstream of the barrage is established.

In the design of barrages/weirs founded on alluvial sands, the afflux is limited to a saft value of 1.0 to 1.2 meters, more commonly 1.0 meter. The amount of afflux will determine the top levels of guide banks and their legths, and the top levels and sections of flood protection bunds,. It will govern the dynamic action, as greater the afflux or fall of levels from upstream to downstream the greater will be the action. It will also control the depth and location of standing wave. By providing a high afflux the width of the barrage can be narrowed but the cost of training work will go up and the risk of failure by out flanking will increase. Selection and adoption of a realistic medium value is imperative.

3.1.6.10 Tail Water Rating Curve

Tail water rating curve for the barrage will be established through analysis of gauge discharge data. The proposed tail water levels for new designs will be established by substructing the designed retrogression values from the existing average tail water levels.

3.1.6.11 Crest Levels

Fixation of crest level is clearly related with the permissible looseness factor and the discharge intensity in terms of discharge per meter of the overflow section of the barrage. After considering all the relevant factors and the experience on similar structures the crest levels will be fixed in order to pass the design flood at the normal pond level with all the gates fully open.

3.1.6.12 Discharges through a Barrage (Free flow conditions)

The discharges through a Barrage under free flow conditions shall be obtained from the following formula:

$$Q=C.L.H^{3/2}$$

Where,

Q= discharge in cubic meter per second

C= Coefficient of discharge

L= Clear waterway of the barrage (m)

H= Total Head causing the flow in (m)

The value C is generally taken as 3.09 but may approach a maximum value of 3.8 for modular weir operation (Gibson). However to design a new barrage will determined by physical model studies.

3.1.6.13 Discharges through a Barrage (Submerged flow conditions)

The flow over the weir is modular when it is independent of variations in downstream water level. For this to occur, the downstream energy head over crest (E_2) must not rise beyond eighty (80) percent of the upstream energy head over crest (E_1). The ratio (E_2/E_1) is the "modular ratio" and the "modular limit" is the value (E_2/E_1=0.80) of the modular ratio at which flow ceases to be free.

3.1.6.14 Fane's Curve

For submerged (non-modular) flow the discharge coefficient in equation (1) above should be multiplied by a reduction factor. The reduction factor depends on the modular ratio (E_2/E_1) and the value of reduction (C_r) given in the table below are from Fane's curve (Ref:2.3) which is applicable to eirs having upstream ramp and sloping downstream with slope 2H:1V or flatter:

"E_2/E_1"	Value of "C_r"
0.8	0.99
0.85	0.99
0.9	0.98
0.92	0.96
0.94	0.9
0.95	0.84
0.96	0.77
0.97	0.71
0.98	0.61

The submerged discharge is given by the equation:

$$Q = 3.09.C_r.b.E_1^{1.5}$$

Gibson's Curve

$$Q = C'bE^{1.5}$$

Where:

Q = submerged discharge over crest

C' = submerged discharge coefficient

B = width of weir

E_1 = upstream energy head above crest $E_1 = h_1 + V_1^2/2g$

For submerge discharges the free flow discharge coefficient (C=3.80) is multiplied by a reduction factor (C'/C). The coefficient factor depends on the modular ratio (h/E), where h is downstream of flow above crest. The values of reduction factor "C'/C" given in the table below are from Gibson curve applicable to the broad crest weir:

h/E	C'/C	C'
0.7	0.86	3.27
0.8	0.78	2.96
0.9	0.62	2.36
0.95	0.44	1.67

3.1.6.15 Regime scour depths

The river bed is scoured during flood flows and large scour holes may develop progressively adjacent to the concrete aprons which may cause undermining of the weir structure. Such flood scour depth below HFL corresponding to a regime width (The Lacey's Design width equation) is called régime scour depth (or more precisely régime hydraulic radius), Rs, estimated by the following (Lacey's) formula

$$Rs = 0.475(Q/f)^{1/3}$$

if the actual waterway provided is greater or equal to the régime width (The Lacey's Design width equation) and

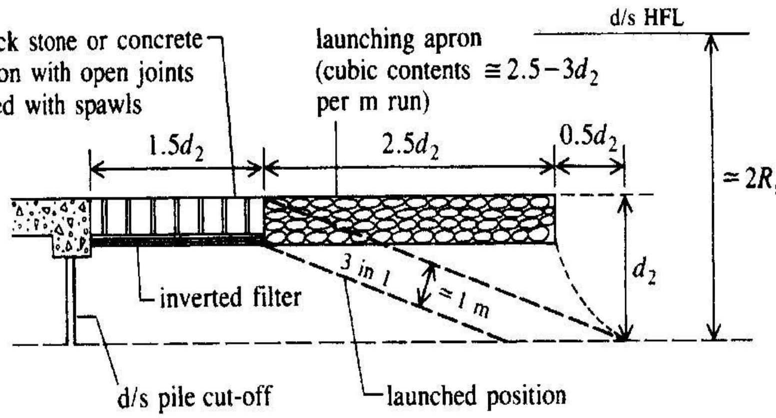
$$Rs = 1.35(q^2/f)^{1/3}$$

if the waterway provided is less than the régime width, where Rs is measured from the high flood level (HFL) and f is Lacey's silt factor (Singh, 1975):

$$f = 1.75d^{1/2}$$

where d is the mean diameter of the bed material (in mm) and q is the discharge per unit width of channel. Weir failure due to scour can be prevented by extending the sheet-pile cut-offs to a level sufficiently below the régime scour depth across the full width of the river (Fig.1).

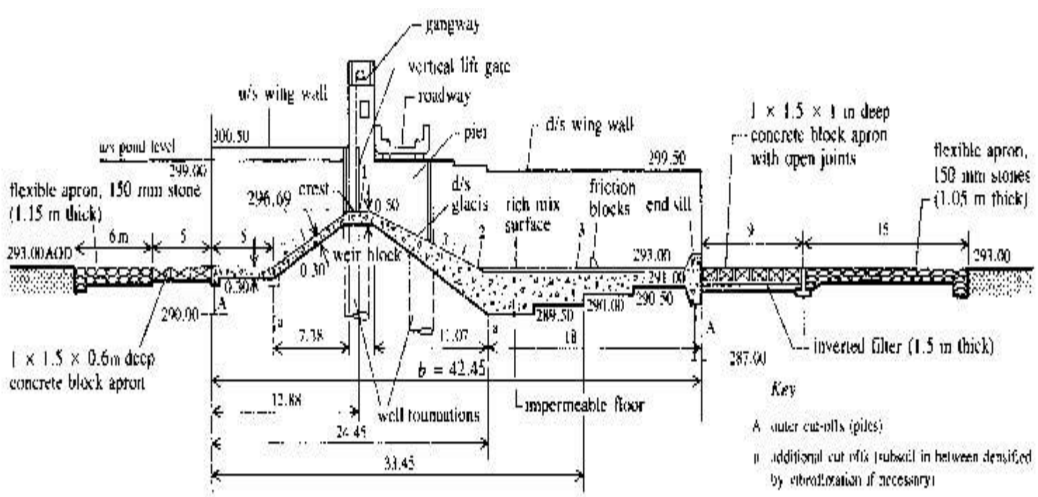
Fig. 1 Inverted filter and flexible (launching) apron



3.1.6.16 Concrete aprons and inverted filter

The aprons are of plain concrete blocks of about 1 m X 1.5 m X 0.75 m deep, cast in situ. The downstream apron is laid with 70–100 mm open joints filled with spawls (broken stones), so that the uplift pressure is relieved. An inverted filter of well-graded gravel and sand is placed under the concrete apron (Fig. 1. Inverted filter and flexible (launching) apron) in order to prevent the loss of soil through the joints. The upstream apron is laid watertight so that the uplift pressure and downward flow is reduced (due to the increase in creep length). Aprons of boulder or stone are laid downstream and upstream of the concrete aprons (Fig. 2.).

Figure 2: **Cross-section through a barrage showing details of the foundations**



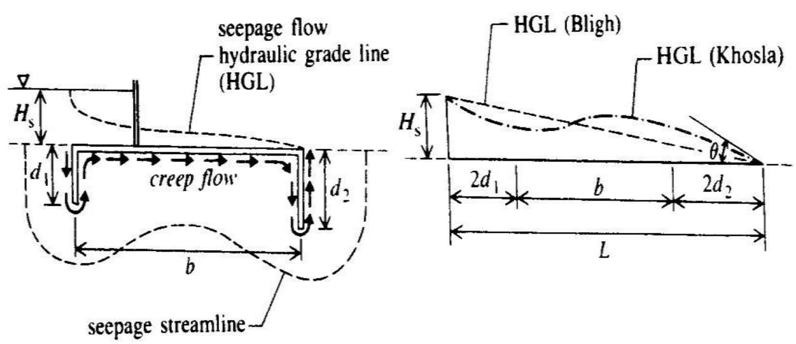
3.1.6.17 Failures of weir foundations on permeable soils and their remedies

(a) Exit gradient (G_e) and piping

The exit gradient is the hydraulic gradient (Fig. 3.) of the seepage flow under the base of the weir floor. The rate of seepage increases with the increase in exit gradient, and such an increase would cause ‘boiling’ of surface soil, the soil being washed away by the percolating water. The flow concentrates into the resulting depression thus removing more soil and creating progressive scour backwards (i.e. upstream). This phenomenon is called ‘piping’, and eventually undermines the weir foundations. The exit gradient (tan θ; Fig. 3.) according to the creep flow theory proposed by Bligh (Khosla, Bose and Taylor, 1954) is

$$Ge = Hs/L$$

Fig. 3. Seepage flow hydraulic gradients



where L is the total creep length equal to $2d_1 + b + 2d_2$, d_1 and d_2 being the depths of the upstream and downstream cut-off piles respectively and b the horizontal floor length between the two piles; H_s, the seepage head, is the difference in the water levels upstream and downstream of the weir.

The piping phenomenon can be minimized by reducing the exit gradient, i.e. by increasing the creep length. The creep length can be increased by increasing the impervious floor length and by providing upstream and downstream cut-off piles (Fig. 3.).

(b) Uplift pressures

The base of the impervious floor is subjected to uplift pressures as the water seeps through below it. The uplift upstream of the weir is balanced by the weight of water standing above the floor in the pond (Fig. 4), whereas on the downstream side there may not be any such balancing water weight. The design consideration must assume the worst possible loading conditions, i.e. when the gates are closed and the downstream side is practically dry.

The impervious base floor may crack or rupture if its weight is not sufficient to resist the uplift pressure. Any rupture thus developed in turn reduces the effective length of the impervious floor (i.e.

reduction in creep length), which increases the exit gradient.

The provision of increased creep lengths and sufficient floor thickness prevents this kind of failure. Excessively thick foundations are costly to construct below the river bed under water. Hence, piers can sometimes be extended up to the end of the downstream apron and thin reinforced-concrete floors provided between the piers to resist failure by bending.

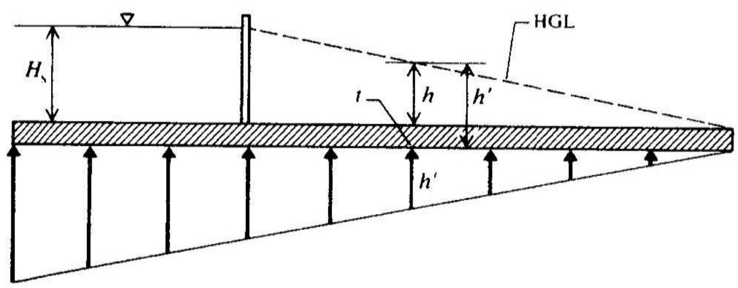
The two criteria for the design of the impervious floor are as follows.

1) Safety against piping. The creep length is given by

$$L = cHs$$

where c is the coefficient of creep (= 1/Ge).

Fig. 4. Uplift pressure under impervious floor



2) **Safety against uplift pressure**

(Fig.4) If hb is the uplift pressure head at a point under the floor, the pressure intensity is

$$p = pgh' \ (N\ m\text{-}2)$$

This is to be resisted by the weight of the floor, the thickness of which is t and the density pm (for concrete, pm =2240 kg m-3). Therefore,

$p_m gt = pgh'$

giving

$h' = S_m t$

where S_m is the relative density of the floor material. Thus we can write

$h' - t = S_m t - t$

Which gives

$t = (h' - t)/(S_m - 1) = h/(S_m - 1)$

Where h is the pressure head (ordinate of hydraulic gradient) measured above the top of the floor. A safety factor of around 1.5 is usually adopted, thus giving the design thickness of the concrete floor as

$$t = 1.2h.$$

The design will be economical if the greater part of the creep length

(i.e. of the impervious floor) is provided upstream of the weir where nominal floor thickness would be sufficient.

The stilling basin area of the weir is subjected to low pressures (owing to high velocities) which, when combined with excessive uplift pressures, may rupture the floor if it is of insufficient thickness. Usually, the floor is constructed in mass concrete without any joints, and with a hard top surface to resist the scouring velocities over it.

3.1.7 Main Canal, Secondary Canal and Tertiary Canal:

3.1.7.1 Discharge capacity

The capacity of irrigation canals will be calculated based on delivery to the fields at a time. This flow rate is a typical or average value appropriate for Cambodian flow rate of 2 l/s/ha conditions. It includes for percolation losses below flooded fields, field application efficiency, and tertiary block distribution efficiency. However, additional allowance must be added for secondary and primary canals for water management efficiency and canal seepage losses.

3.1.7.2 Velocity

As a general rule to avoid siltation, operational velocity will be not less than 0.5 m/s. Because of flat terrain it will probably not be possible to satisfy this requirement for all locations and flows, in which case channels will be designed to achieve the closest match possible at the design discharge. Since water is supplied from a reservoir the sediment load in the canals will be reduced. The design will be adjusted to maintain consistent velocities throughout the system and avoid intermediate reaches with slower velocity which would be prone to siltation. Erosion can be minimized by limiting the maximum velocity to 0.7m/s. However for erodible soils the maximum velocity will be checked against the values in Table5.1 and the design changed if necessary. There are two columns for maximum velocity in Table 5.1 because when the water carries sediment the soils can withstand higher velocity than when water is clean. This is because the capacity of the flow to pick up sediment has been partially satisfied.

Table 1: Maximum velocity from different bed materials

Bed material	Maximum velocity m/s	
	No material carried in suspension	Material carried in suspension
Fine sand	0.45	0.75
Sandy Clay	0.55	0.75
Soft clays	0.60	0.90
Muds	0.75	1.05
Coarse sand	0.75	1.50
Medium clay	1.15	1.50
Gravel	1.20	1.85
Shingle	1.50	1.70
Hard clay	1.85	1.85

3.1.7.3 Slope

The ideal situation for an irrigation canal is when the water surface slope is the same as the ground slope. At very flat ground, a minimum slope of 500 mm per kilometre (5%) will be used.

3.1.7.4 Water management efficiency

An allowance must be made for water wasted due to operation of the canal system; this is known as management efficiency. The flow rate will be increased to include allowance for management efficiency as in Table 2.

Table 2: Water management efficiencies for irrigation canals

Canal type	Flow rate and loses
Tertiary canals:	Losses included in flow rate of 2 l/s/ha
Secondary canals:	Increase flow rate by 10%
Main canals:	Increase flow rate by 5%

3.1.7.5 Canal seepage losses

Water will seep into the ground from unlined canals; this is called seepage loss. Where high seepage losses are foreseen consideration will be given to canal lining. Seepage loss will be calculated for the primary and secondary canals on a kilometer basis. The seepage is dependent on the soil type. Table 5.3 gives typical values of canal seepage losses. This is expressed as flow in m/s per million m2 of wetted perimeter (wetted canal bed and bank) or l/s/km per meter wetted perimeter. In practice a loss of 3 l/s/km/m of wetted perimeter will be typical of losses for most locations.

Table 3: Canal seepage losses

Type of soil	l/s/km/m of wetted perimeter
Rock	< 0.5
Impervious clay loam	0.8 to 1.2
Medium clay loam	1.2 to 1.7
Clay loam or silty soil	1.7 to 2.7
Gravelly clay loam or sandy clay	2.7 to 3.5
Gravel cemented with clay	2.7 to 3.5
Sandy loam	3.5 to 5.2
Sandy soil	5.2 to 6.4
Sandy soil with gravel	6.4 to 8.6
Pervious gravelly soil	8.6 to 10.4
Gravel with some earth	10.4 to 20.8

3.1.7.6 Full water supply level

The highest water level in the supplied canal decides the full supply water level in the canal. The bed width with respect to water depth can be chosen from Table 3. Once these requirements are met, the final levels are chosen so that the head required for modular working of the outlet is available.

3.1.7.7 Bed width and depth of water

The bed width with respect to water depth can be chosen from Table 4. In practice it is not possible to match these requirements exactly and the tabulated ratios will be used for guidance rather than applied rigidly.

Table 4: Bed to depth ration for trapezoidal canals

Canal type	Flow (m3/s)	Bed : Depth Ratio
Primary and Secondary		
	< 0.3	2
	0.3 to 0.6	4
	> 0.6	6
Tertiary and Quaternary	Any	1

3.1.7.8 Bed level

The designed bed levels (elevation) shall be calculated by deducting the full supply depth from the designed full supply water levels (elevation).

3.1.7.9 Freeboard

The method of deciding freeboard (fb) will be different for unlined canals, lined canals, and conveyance structures:

- For unlined (earth) canals bank freeboard will be used which is the elevation of top of earth bank minus elevation of water surface at design discharge.

- For lined canal lining freeboard will be used which is the elevation of top of lining minus elevation of water surface at design discharge.
- For conveyance structures freeboard will be the elevation of top of earth bank minus elevation of water surface at design discharge.

For earth canals freeboard is decided by the type of canal. For lined canals freeboard is decided by the flow. The recommended minimum free board for unlined and lined canals is listed in Table 5. The free board can be larger than these minimum values if there is a reason, for example if the irrigation canal is also used as a drain for flood water.

Table 5: Design criteria for free board

Design case	Freeboard fb (m)
Bank freeboard (earth canals)	
For main canal	0.80
For secondary canal	0.50
For Tertiary and Quaternary canals	0.15
Lining freeboard (lined canals)	
For design discharge < 1.5 m3/s	0.15
For design discharge ? 10.0 m3/s	0.25
For design discharge > 10.0 m3/s at design discharge 0.30	
For design discharge > 10.0 m3/s when there is no flow but water is standing	0.20
For conveyance structures (section 7)	
Open channels	0.30
Inlet to conveyance and drop structures	0.30

3.1.7.10 Side slope

Side slopes for an unlined trapezoidal cross section canal will be chosen according to the type of soil through which the canal is cut. Flatter slopes are needed where soils are weaker and less resistant to erosion. If too steep a slope is used there will be frequent bank failures. Side slope in unlined and lined trapezoidal canals shall be as Table 6. Slopes are defined as the ratio of the vertical height to the horizontal.

Table 6 Side slopes for irrigation canals

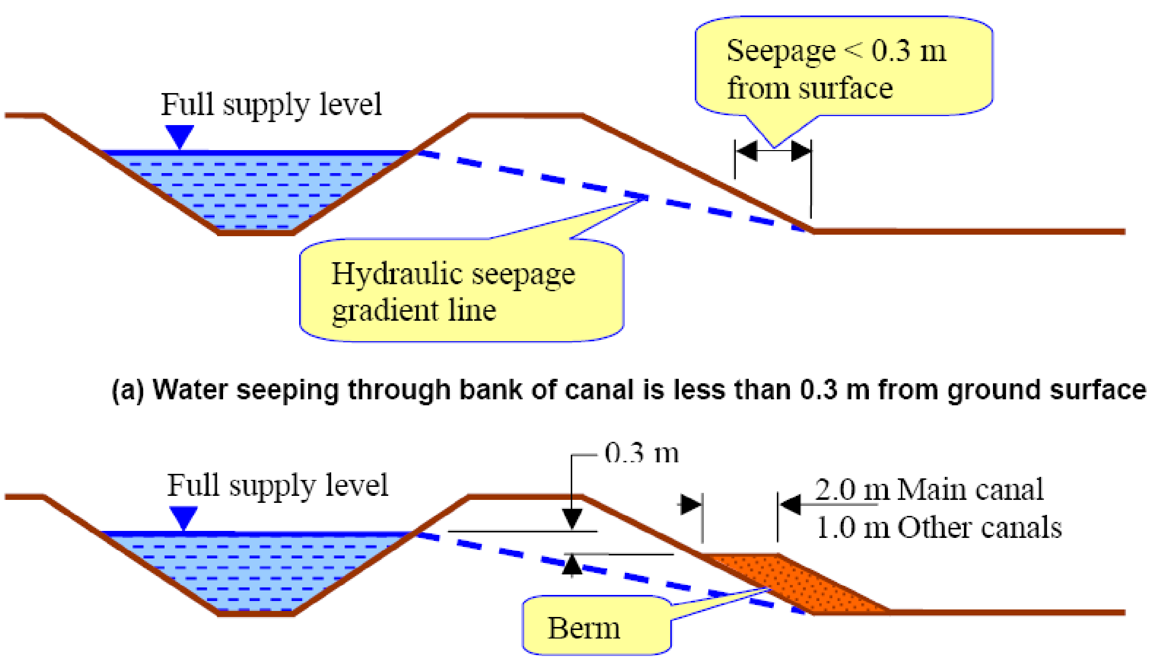
Type of bank	Slope (V:H) Flow (m3/s) 0.1 to 5.0	5.0 to 10.0	10.0 to 20
Hard Clay	1:1	1:1	1:1
Soft Clay	1:1.5	1:1.5	1:2
Silt	1:1.5	1:2	1:2
Sandy soil	1:1.5	1:2	1:2.5
Lined	1:1	1:1.5	1:1.5

3.1.7.11 Seepage gradient

The hydraulic seepage gradient line from unlined canals will be limited not to rise within 0.3 m of the finished ground surface at any place.

If the height of the canal and embankment mean seepage water will rise within 0.3 m of the surface then additional earth shall be put on the outer toe of the embankment as an external beam. The external berm top must be kept 0.3 m below the full supply level and its width at the top shall be 2 m in case of main canal and 1 m in all other cases.

Figure 5: Hydraulic seepage gradients from an irrigation cannel



b) Berm ensures water seepage is always than 0.3 below ground surface

3.1.7.12 Combined irrigation canals and drains

The purpose and design of drainage canals is covered separately by section 3.1.4. However, if it is decided to combine the function so that irrigation canals must also be designed to function as drains, the design should satisfy the design criteria given here for irrigation canals and at section 3.1.4 for drainage canals.

3.1.8 Drainage Systems

General requirements

The design of drain canals requires a combination of width, depth, slope and water depth to pass a flow that varies up to, and occasionally exceeding the design flow. If velocity is too fast, the bed and banks will scour, if it is too slow the drain will shut up and become overgrown. This makes the design of a drain more complicated than an irrigation canal because most of the time the drain will flow slowly but when it rains it will flow fast, whereas an irrigation canal is designed for a limited range of steady continuous flow. In theory the variable discharge can be managed by movable gates or dam boards to control flow velocity, but if these are provided they must be simple to use and some people must be taught how to use them correctly. It should also be remembered that the gates may need to be operated at any time during the day or the night. For all candidates of subprojects such measures are not practical, and the best option for minimizing problems with the drainage system will be to follow the design criteria given herein. Important factors influencing the design of earth drain canals are: the size of the soil particles in the bed and banks; the amount of vegetation; and available slope. Slope and channel section must be designed to ensure a mean velocity slightly higher than the non-silting and non-scouring velocity. As a general rule if the water surface slope is chosen to give a flow velocity of between 0.5 and 0.9 m/s the canal will work well without silting or scour. Therefore the minimum velocity for operational drainage flow will be 0.5 m/s and for flood conditions the maximum velocity will be 0.9 m/s.

Hydraulic Design

Drain canals can be designed using Manning's formula as used for the design of irrigation canals. The value of Manning's n is dependent upon the surface conditions of the wetted perimeter of the drain. Poor maintenance will encourage the growth of vegetation, thus increasing the value of n and the channel will not carry the design flow without overtopping its banks. In the design of various drain reaches, a value of n equal to 0.035 is representative of future conditions assuming sub-standard maintenance.

Design discharge

Drainage canals will be designed for a normal drainage discharge of 3.5l/s/ha. As was the case for irrigation canals this is a typical discharge will be confirmed as appropriate for the project. Drainage flow is determined from excess rainfall; drain canals 1 in 5 years rainfall, drain structures 1 in 25 years rainfall. Basically, drains will be large enough for most of the time, flooding once every five years or so is acceptable but flooding every time there is heavy rain is not, and a larger drain will be needed. It is also important that a drain is not too large or seldom flows because then it will become silted up and overgrown, which may cause problems when there is a flood. Building oversize drains is also a waste of money and land. The normal drainage flow applies only to drainage from the irrigation scheme. It does not apply to flows arriving from outside the scheme area. It will therefore not be used for design of reservoir and dam spillways or drains conveying flow from outside the command area; these will be subject to a separate hydrological evaluation.

Water surface hydraulic slope and velocity

Velocity in the channel, and thus flow, is controlled by water surface hydraulic slope, which is generally governed by the bed slope. Where velocities are too high these will be reduced by building drop structures using either gabions or reinforced concrete. The use of drop structures may also help to reduce the volume of excavation. In the case of natural streams used as a drain canal, no limit on the minimum or maximum bed slope shall be fixed as this will be examined along with other factors such as velocity and discharge. Attention will be paid to maintenance of existing bed slopes so not to disturb channel regime.

Maximum velocity

As a general guide velocity will be limited to 0.90 m/s to prevent scour. The maximum velocity in a channel before scour occurs depends upon many factors, such as the type and quantity of sediment load, discharge and bed slope of the channel. Table 7 gives further guidance on the maximum permissible velocities for different types of soil. On first sight this may seem inconsistent with the suggested maximum of velocity of 0.9 m/s, but it must be remembered that drainage water will normally carry sediment and colloidal (clay sized particle) material in suspension, and therefore the limiting velocities in the right hand will probably apply. Also the velocities in the table are for bare soils, most drainage canals will have vegetation growing on their banks, and this binds soil particles together so that it can withstand higher velocities.

Table 7: Limiting velocities at bed level for various soils

Bed material	Limiting velocity m/s	
	No material carried carried in suspension	Colloidal material in suspension
Fine sand	0.45	0.75
Sandy Clay	0.55	0.75
Soft clays	0.60	0.90
Muds	0.75	1.05
Coarse sand	0.75	1.50
Medium clay	1.15	1.50
Gravel	1.20	1.85
Shingle	1.50	1.70
Hard clay	1.85	1.85

Minimum velocity

As far as possible, the lowest velocity that can cause sedimentation and induce weed growth in the channel will be avoided. For water carrying a small percentage of silt, a mean velocity of not less than 0.50 m/s will usually prevent fine silt and sand deposits, weeds and grasses.

Bed width

The bed width should not be so narrow as to allow scouring of the bed, nor so wide as to induce meandering at low flows. Generally, the minimum bed width will be 1 m to accommodate future maintenance but for small collectors or the upstream end of drains, with only one or two inlets, it may be desirable to reduce the bed width to 0.5 m.

Depth of drain

The depth of any drain will not be less than 0.50 m.

Freeboard

The design water levels will be set at least 0.30 m below ground level at the drain inlets, and below ground level at all points by at least the freeboard depths given in Table 8.

Table 8: Freeboard for drains

Design discharge (m3/s)	Freeboard (m)
0 to 1.7	0.10
1.7 to 8.0	0.20
> 8.0	0.30

Bends

The minimum radius of curvature will be taken as Rmin, and will not be less 15 × Ws where Ws is water surface width at the design discharge.

Side Slopes

Generally, a side slope of 1:1.5 will be used for drain canals unless there is clear evidence that shallower slopes are needed or that steeper slopes are possible. The following will be considered when deciding whether to vary the side slope of drain canals:

- The type of soil because this controls bank stability.
- Existing side slope and whether these are stable or have small landslips.
- Bends in the canal; and whether natural meander patterns have developed on existing canals.
- The extra land required for more gentle side slopes.
- Location of the various reaches of the drains in relation to dwellings and other existing infrastructure such as roads. So that the maximum area of land will be available for agriculture it is desirable to maintain the side slopes as steep as possible while maintaining stability and making allowance for the effects of possible erosion.

3-2. Tendering, Contract Management and Bids Evaluation

The DDCS will assist the CPMU to prepare the bid documents for the civil works using national competitive bidding (NCB) procedure or international competitive bidding (ICB). The procurement for the civil works will follow the procedures for NCB or ICB as instructed in Project Implementation Manual (PAM), August 2014,

The bidding documents provided with the Government's Procurement Manual shall be used to the extent possible. Documentation prepared for the first contract under NCB arrangements shall be submitted for ADB review and approval, regardless of the estimated contract amount, in accordance with agreed review procedures (prior and post review). Once accepted, the ADB-approved procurement documents will then be used as a model for all similar procurement financed by ADB, and need not be subjected to further review unless specified in the procurement plan. For ICB standard ADB bidding documents shall be used. All ICB documents will require prior approval of ADB.

Refer to the size of project and timeline schedule, the procurement of civil works will be proposed in to 4 packages.

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3.2.1 Package 1: Barrage Structure:

The barrage structure and some its associate output proposed to regards as the package 1 for preparing the tendering document, as the mention in work plan for barrage structure will prepare and finalize the tendering document in Q1 -2016.

3.2.2 Package 2: Main Canal and associated structure:

The main canal and its associated structure proposed to package II in preparing the tendering document, as the mention in work plan for main canal and associated structure will prepare and finalize the tendering document in Q2 -2016.

3.2.3 Package 3: Secondary Canal and associated structure:

The secondary canal and its associated structure proposed to package III in preparing the tendering document, as the mention in work plan for secondary canal and associated structure will prepare and finalize the tendering document in Q3 -2016

3.2.4 Package 4: Tertiary Canal, Drainage and associated structure:

Tertiary canal, drainage and its associated structure proposed to package IV in preparing the tendering document, as the mention in work plan for tertiary canal, drainage and associated structure will prepare and finalize the tendering document in Q3 -2016.

3-3. Social Safeguards and Resettlement Plan

Safeguard compliance is an important part of the project's overall approach to implementation and includes:

Resettlement

In dealing with externally-financed projects, the Government has adopted on a project-by project basis, the resettlement policies of donors. Projects supported by external agencies are governed by the resettlement policies of donors, and relevant laws and government regulations not consistent with donor policies are waived. As the DDCS do not have a resettlement policy and framework. In most respects it is similar to the framework used on ADB projects. Involuntary Resettlement Impact Checklists following the ADB format will be used to screen the subprojects during the feasibility study phase that will permit basic resettlement categorization. Subproject selection criteria minimizes land acquisition and involuntary resettlement. Any impacts noted during detail design will be minimized by considering technical and construction method alternatives. During detailed design the resettlement aspect will be reviewed and resettlement plans produced as necessary, for subprojects with interventions or facilities requiring land acquisition or which have other major resettlement issues.

Socio-economic information of affected households will be obtained through a socio-economic survey (SES).

Where no significant resettlement is foreseen, the resettlement specialist will aim at achieving voluntary contribution through a participatory resolution process.

3-4. Environmental Assessment

Rapid Environmental Assessment Checklists for Irrigation Infrastructure will be carried out for the selected sub-projects. Where a sub-project has minimal or no adverse environmental impact, an EIA and IEEs may not be required. EMPs plans will be included in the construction package. The IEEs will be carried out by the PDWRAMs and MOWRAM assisted by the Consultant, ensuring that adequate environmental mitigation measures are incorporated into detailed design and contract specifications, as well as monitored and reported in the monthly reports.

3-5. Construction Planning and Supervision

The DDCS will assist directly to PDOWRAM/CPMU within the time frame of the agreement with the management and monitoring of the consultants to be engaged for supervising civil works contracts, compliance and reporting. Thus, supervision of construction of civil works was not included in the agreed services.

At this stage there are 4 assistance residence engineers will be awarded to DDCS consulting team to provide field level construction supervision, contract management services and surveys. The DDSC team will assist PIU/CPMU with project management and this will include monitoring of the consultants supervising construction of the civil works and in the supporting and assisting from PIC team.

3-6. Financial Management

Referring to this project ToR, we have organized team as below to manage the financial:

1. Team leader – overall manage, request and approve all spending

2. Financial and account - who is assist responsible to:
3. Admin secretary assistant - who is assist responsible to:
    - Assist in prepare disbursement voucher;
    - Prepare monthly timesheet
    - Monthly claim and reports
    - Prepare cash receipt;
    - Follow up the bank accounts very months;
    - Prepare bank reconciliation;
    - Budget elaboration of specific activities;
    - Prepare the monthly payroll;
    - Assist in cash flow control of project daily expenditure;
    - Assist in open and close banking account;
    - Assist in monthly budget plan and request with the support document to director and admin chief of SAWAC/CADTIS;
    - Provide administrative support to project staff;
    - Maintain all document, files, folders…etc.
    - Handling incoming and outgoing phone calls;
    - Follow up any staff medical benefit and insurance,
    - Prepare and distribute the insurance cards to all staff, personal accident claim, beneficiary forms.
    - Records and update all staff leaves.
    - Keep updating staff movement.
    - Assist in coordinating any visitor and travel plan and arrangement as required.
    - Develop all personnel filing systems and to make sure all required documents are well maintained in coordination with Phnom Penh office and Project Team Leader.
4. SAWAC/CADTIS – admin/finance
    - Facilitate all budget/financial flow between head office and sub office
    - Coordinate and facilitate with CMPU account/finance for all budget arrangement
    - Prepare all report /claim
    - Prepare all request and get sign by firm Director/President and submit to CPMU for further approval
    - Perform all procurement according to ADB procedure/guideline
    - Collect and deposit money

- Set up account system

3-7. Commissioning, Training and Handover

The initial step towards capacity building is the preparation of a training plan. And a training plan means definition of target groups, of objectives for each group, and of strategies and methods to reach these objectives. It is understood from the TOR that the main target group for on-the job training activities under the guidance of international CD/FWUC specialist in PIC.

On-the-job training will take place through staff participation in selected activities during implementation of the project. Some of these may require a more formal approach whereby the subject is discussed in small half day workshops that may be carried out in the provinces with PDWRAM staff. The Consultant team will need to propose a list of participants and a number of persons for each training activity, in order to reach a maximal efficiency by keeping a balance between the need to involve in Project activities as many persons as possible, and the intensity of the training during the time available for it. The level of previous knowledge on the topics to be presented must also be evaluated to define the form and the content of the training material to be used MOWRAM and PDWRAM will need capacity building in project management, contracts, procurement procedures, specific MEF procedures included in the SOP, institutional arrangements, socio-economic data collection and analysis, economic analysis, construction contract progress monitoring and civil works supervision etc. as detailed further below:

- Training on preparation of sub-project profiles including baseline data survey:
- Training on preparation of initial environmental examinations (IEEs)
- Training on preparation of feasibility study and detailed design, including data collection and collation
- Training on civil work supervision including monitoring of progress
- Training on irrigation system Operation & maintenance (O&M)
- Training on Monitoring and Evaluation system using Benefit Monitoring Evaluation (BME)

3-8. Operation and Monitoring and Monitoring

The term O&M is often misunderstood and sometimes taken to mean maintenance or repair of facilities. O&M in the context of irrigation works is concerned with the requirements for operation as well as the maintenance. Indeed, it is fundamental that design of irrigation facilities takes into consideration operational requirements and this requires an operational plan prior to design.

The subproject profiles in the feasibility reports will summarize and document the subproject socio-economic data, hydrology, existing situation, resettlement and environmental categorization as well as operational requirements for the proposed interventions.

The technical capacity of the targeted PDWRAMs and the FWUCs will be improved through capacity building. The capacity of PDWRAMs in O&M will commence at design stage while formulating the operational plans for design and continue with the O&M manuals that will need to be produced during design for each sub-project. In the case of the FWUCs, O&M is already.

The DDCS team that supporting and assisting from PIC will need to review past experiences in O&M from lessons learned and new ideas that are emerging at present to ensure that the necessary steps for sustainable O&M are followed right from the time the rehabilitation and/or development of an irrigation scheme is being considered and designed.

4. Initial Findings and Progress to Date

4-1. Topography Survey:

- Checking the leveling of existing Bench Mark (CM1) to existing BM (RCR3) that existing (RCR2) was ignored, we regards CM1 as the main level for transfer to other BM at its leveling that provided by MOWRAM is 29.450m, for existing level of RCR3 is 25.169m (provided by Mr.Nara, surveyor in MOWRAM) after checking its level is 26.532m, (in week 2 of October 2015)
- Transferring the level from existing BM (CM1) at the downstream to temporary BM along the river at the upstream that its length is 5.645 km, (in week 4 of October 2015)
- Conducted the topography survey 6 cross sections from downstream to upstream to find the fit technical location for barrage structure, (in week 4 of October 2015)
- Transfer elevation from BM to TBM and do cross section for drainages at the end of main canal at Svay Don Kev River, there are 3 lines completed: lines no.1 its length is 830m and did 6 cross sections, line no.2 its length 3970m did 19 cross sections, lines no.3 its length is 2385m did 14 cross section
- Installation concrete Bench Mark (BM) around the barrage location and transfer the elevation to them, it completed 6 BM.
- Checked the elevation of section of Pursat river at the downstream far from MOWRAM proposed location 1.250 km.

4-2. Hydrology Analysis:

- Collection on the crops calendar data and meteorology data at the actual commend area for calculation crop water requirement, these activities are ongoing.
- Prepared and compiled collected data, typing and converted in to soft copy, these activities are ongoing.
- Reviewing on calculation of the return period flood in Pursat River follow to PIC's comments.

4-3. Detail Engineering Design and Drawing:

- Calculation the capacity discharge of stream and then created rating curve of stream on option 2 section for design barrage and compute barrage crest length.
- Hydraulic design for Barrage structure to be stable with surface and under-ground water flow.
- Scheck the first draft general drawing of barrage structure that included plan layout and long section.
- Designed 3 options of frame of drawing and submitted to CPMU for seeking to approval, CPMU approved on the option 2.

5. Work plan and Staff Schedule

GMS-Flood and Drought Risk Management and Mitigation Project

Project Number: 40190, Loan and Grant Number: L2970; G0330; L8262

Detail Design and Construction Supervision Consultant, (DDCSC), Work Plan

N°	Activities	2015				2016												2017												2018													2019							Month
		9	#	#	#	1	2	3	4	5	6	7	8	9	#	#	#	1	2	3	4	5	6	7	8	9	#	#	#	1	2	3	4	5	6	7	8	9	#	#		#	1	2	3	4	5	6	7	
INCEPTION PHASE:																																																		
A-1	**Team Mobilization**	1																																																1
A-2	**Inception Activities**	1	1																																															2
	Meet client/stakeholders and relevant sectors to get data/ documents		1																																															
	Review feasibility study, PPTA studies and relevant study		1																																															
	Conduct field visit to project site get relevant to update data/information		1																																															
	Collect data on hydrology, previous topo surveys etc		1																																															
DESIGN AND BIDDING PHASE:																																																		
A-3	**Site Survey and Preparatory Work for**																																																	8
	Topographical Surveys		1	1	1	1	1	1	1	1																																								
	Establish control points, bench marks			1	1	1	1																																											
	Barrage survey		1	1	1																																													
	Main canal alignment survey				1	1	1																																											
	Secondary canals survey						1	1	1																																									
	Command area survey						1	1	1	1																																								
	Pursat and Svay Donkeo River								1	1																																								
	Geotechnical investigation and soil testing				1	1																																												

		Other surveys - construction materials, borrow and disposal area								1	1																																							
A-4	**Hydrological Analysis**																																																		**6**
		Flood analysis		1	1																																													
		Long-tern runoff analysis				1				1																																							
		Water balance and irrigation requirement				1				1	1	1																																					
		Flood routing and stage-discharge				1				1	1	1																																					
		Development of storage-area-elevation			1	1																																											
		Flood analysis in Pursat and Svay Donkea								1	1	1																																					
A-5	**Detail Engineering Design**																																																		**10**
		Barrage Structure																																															
		Detail Design Work			1	1	1	1	1																																							
		Prepare of design drawings				1	1	1	1																																							
		Preparation BoQ for cost estimation & Technical Specification						1	1																																							
		Main canal and associated structures																																															
		Detail Design Work							1	1	1																																						
		Prepare of design drawings							1	1	1																																						
		Preparation BoQ for cost estimation & Technical Specification								1	1																																						
		Secondary canals, tertiary canal and																																															
		Detail Design Work									1	1	1	1																																			
		Prepare of design drawings									1	1	1	1																																			
		Preparation BoQ for cost estimation & Technical Specification										1	1	1																																			

A-6	**Socio-economic Study** (***)																																																	**8**
	Preparing subproject profiles and review sub-project based on the profiles, focusing on costs and benefits						1	1	1	1	1	1	1	1																																			
	Collect socio-economic data required for completing economic analysis						1	1	1	1	1	1	1	1																																			
	Revise economic analysis and estimate EIRR, report preparing.						1	1	1	1	1	1	1	1																																			
A-7	**Social Safeguards**																																																	**12**
	Update Resettlement Plan						1	1	1	1	1	1	1	1																																			
	Timely submission of reports Inter-ministerial Resettlement Committee (IRC)						1						1																																				
	Monitor and report on the progress of the RPs and their implementation									1			1																																				
	Preparation of the right of way (ROW) or reservation width alignments drawings									1		1	1						1	1											1	1																	
	Claiming mechanism is in place whereby affected persons (AP) may have their claims registered									1		1	1						1	1											1	1																	
	Land holding mapping and registration of ownership data as necessary along embankment or canal alignments, or structures where resettlement plans							1	1	1		1	1						1	1											1	1																	
A-8	**Environment Assessement**																																																	**12**
	Review IEE and identify data requirements						1	1	1			1	1	1																																			
	Revise the IEE and prepare EMPs according to ADB's SPS 2009						1	1	1			1	1	1																																			

		Monitor implementation of EMPs																		1				1				1				1						1						1							
		Prepare periodic monitoring reports																		1				1				1				1						1						1							
A-9	**Preparation of Tender and Contract**																																																		9
		Package I: Barrage Structuer																																																	
		Preparation of tender documents						1	1																																										
		Tendering and bid evaluation							1	1																																									
		Preparing contract document and contract award									1																																								
		Package II: Main Canal with associated																																																	
		Preparation of tender documents								1	1																																								
		Tendering and bid evaluation									1	1																																							
		Preparing contract document and contract award										1																																							
		Package III: Secondary Canal with																																																	
		Preparation of tender documents											1	1																																					
		Tendering and bid evaluation												1	1																																			
		Preparing contract document and contract award													1																																			
		Package IV: Tertiary Canal and other																																																	
		Preparation of tender documents											1	1																																					
		Tendering and bid evaluation												1	1																																			
		Preparing contract document and contract award													1																																			
A-10	**FWUC/Other committee development**																																																		12
		Training of communities and farmers																		1	1	1	1																												

	FWUCs and Construction Sub-committees (SCS) formation and strengthenning																				1	1	1						1	1	1											1	1	1	1					
	Implementation of Gender Action Plan																						1						1	1	1											1	1	1	1					
CONSTRUCTION AND IMPLEMENTATION PHASE:																																																		
A-11	**Construction Planning and Supervision**																																																	**30**
	Review and prepare costruction work plan															1	1											1	1																					
	Follow up and supervise construction																1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
	Commissioning, training and handover																																									1	1	1	1	1	1	1	1	
A-12	**Operation and Maintenance and**																																																	**12**
	Review the existing O&M arrangements for each scheme,																												1	1																				
	Estimate annual O&M requirements,																												1	1																				
	Prepare O&M plans and manual																													1	1	1	1	1															
	Prepare and conduct trainings of farmers on O&M, and																																		1	1						1			1				
	Capacity building to government staff though on-the-job and other trainings.																												1	1	1	1	1	1	1	1						1	1	1	1				
	Performance and monitoring,																																									1	1	1	1				
REPORTING																																																		
A-13	**Deliverables (REPORTS)**																																																	**42**
	Inception report			1																																														
	Monthly Progress Report	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	
	Draft Engineering Design and Drawings after 8 months								1																																									

		Final Engineer Design and Feasibility Study after 10 months											1																																						
		Bid document and construction schedule after 12 months											1	1	1																																				
		Bid evaluation reports									1	1			1	1																																			
		Monthly Construction Supervision reports and																1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
		Completion report																																															1	
		(***) *This activities are considering*																																																

TEAM COMPOSITION, ASSIGNMENT, AND KEY EXPERTS' INPUT, Revised by December-2015

Non Key Expert							2016												2017												2018												2019								
No	**Name**	**Position**	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	Rev.	Ori.
1	Mr. Kam Sothun	Team Leader/Irrigation Design and Construction Engineer		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1		1	1	1	1	1	1	1	1		1	1		1	1	1	1	1	1	1	1	42	42
2	Mr. Phai Sokheng	Deputy Team Leader - Irrigation Designand Construction Engineer	1				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	42	42
5	Mr. Cheoum Ravann	Assistant Resident Engineer (1)															1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1	29	30
6	Ms. Din Chakriya	Assistant Resident Engineer (2)															1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1	29	30
7	Mr. Phung Kosal	Assistant Resident Engineer (3)															1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	29	30
8	Mr. HENG Choung	Assistant Resident Engineer (4)															1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	1	29	30
3	Mr. KHIN Toda	Structural Engineer			1	1	1	1	1	1	1	1	1	1	1	1	1	1																																14	6
4	Mr. Chhit Kim Hor	Hydrologist Specialist		1	1	1				1	1	1																																						6	6
9	Mr. OUM Sith	Resettlement Specialist						1	1	1	1	1	1	1	1	1	1	1	1																															12	12
10	Mr. CHHUN Bunmeng	Agriculture Economist						1	1	1	1	1	1																																					6	6
11	Ms. SAO Sambat Morokat	Environmental Specialist						1	1	1	1	1	1	1	1	1	1																																	10	12
12	Mr. Em Sochea	Procurement Specialist						1	1	1	1	1	1	1	1	1																																		9	9
13	Mr. MOK Samoeun	Community Development / FWUC specialist																		1	1	1	1	1						1	1	1													1	1						10	12
14	Mr. HENG Ratha	O & M Engineer																													1	1	1	1	1	1	1	1					1	1	1	1				12	12
15	Ms. Bun Sary	Labor/Gender Specialist																		1	1	1	1	1				1	1		1	1		1	1	1														12	12
																																																		291	**291**

Non Key Expert																																																			
1	Mr. PHORN Brorsoeur	Surveyor Manger/ Engineer- CAD Operator	1	1	1	1	1	1	1	1	1							1													1																			11	8
2	Mr. LONG Vannak/ Ms. Din Chakriya	CAD Operator				1		1	1	1	1	1	1	1																																				8	8
3	Mr. BOT Meng/Men Vanxy	Assistant Surveyor/Engineer/ CAD Operator		1	1	1	1	1	1	1	1																																							8	8
4	Mr. Soeun Mithuna/ Ms.Heng Thavy	CAD Operator		1	1	1	1	1	1	1	1	1	1																																					10	8
5	Mr. PHORN Voeun	Assistant Surveyor/Engineer/ CAD Operator		1	1	1	1	1	1	1	1																																							8	8
6	Ms. KEO Sam An/ Chan Chhorm	Assistant Surveyor/Engineer/ CAD Operator			1	1	1	1	1	1	1	1																																						8	8
7	Mr. TOUCH Samnang	Assistant Surveyor/ Landholding/ Resettlement						1	1	1	1	1	1	1	1																																			8	8
8	Mr. PHUOV Narin	Assistant Surveyor/ Landholding/			1				1	1																																								3	8
9	Mr. UN Sothea	Financial and account assistant					1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	41	42
																																																		64	**64**

Note: (1) Person-month (pm)
(2) Reduct input of assistance residence engineer 4 pm (1 pm per a expert from 30 pm to 29 pm)
(3) Adding input to structural Engineer from 6 persons-month to 12 persons-month (adding from 6 pm to 8 pm for existing expert and adding one expert more that his input is 4 pm)
(4) Reduct input of environmental specialist and FWUC specialist from 12 pm to 10pm for each expert.
(5) Adding to toposurvey manager input from 8 pm to 11pm
(6) Adding input to one CAD operator from 8 pm to 10 pm.

6. Conclusions and Recommendations

6-1. The resignation of the Deputy Team Leader and the delay in appointing a suitable replacement fast affected the progress of detailed design work.

6-2. Topography survey activities was delayed than planned, due to:

- The number of rainy days and obstruction by vegetation around the location
- Delay in the approval of the submission and approval of the survey budget due to not being proposed in the bidding document
- Difficulties with the borrowed topography instrument, with some seeing errors

6-3. The survey instrument was approved by CPMU/MOWRAM at the end of the month, so our surveyor team uses the equipment from MOWRAM.

7. Reference:

- ADB TA 6456-REG: Preparing the GMS-Flood and Drought Risk Management and Mitigation Project, Irrigation Engineer's Report, May 2012
- Project Implementation Manual (PAM): GMS-Flood and Drought Risk Management and Mitigation Project, August 2014.
- Final Inception Report of Project Implementation Consultant (PIC), GMS-Flood and Drought Risk Management and Mitigation Project, August 2015.
- Hydraulic Structures 4th Edition, Year 2007, by P. Novak, A.I.B. Moffat, C. Nalluri and R. Narayanan
- West Tonle Sap Irrigation and Drainage, Rehabilitation and Improvement Project, Water balance study report, Annex B (Irrigation Water Requirements in 3 River Basins, JICA, August 2012.

Annexes

Annex A. TOR for Staffs

C. Key Experts:

Team Leader /Irrigation and Construction Engineer

2. The Team Leader /Irrigation Specialist (TL/IE) will cover overall team leadership and management of the consulting services, and assisting the Project Director (PD) in implementation matters to ensure conformity with ADB procedures and adherence to the conditions specified in the Loan Agreement. He/she will be an internationally qualified civil/irrigation engineer with preferably 15 years' experience, and with experience as Team Leader for one similar project and fully aware of the requirements and responsibilities for an ADB supported Project, and provide effective leadership of the team and communication with the PIU.

3. Under the overall guidance of the Director General of Technical Affairs of MOWRAM, the TL/IE will work directly with the PIU headed by the Project Manager, established in MOWRAM, for the project to administer construction contracts. Inputs are expected to be intermittent during the entire period of the project. The TL/IE will coordinate the inputs of the total team, and will be key to linking monitoring and progress reporting and coordination of activities. Specific tasks will include:

(i) Provide direct technical support to the team for finalizing detailed design of the subprojects,
(ii) Assist with finalizing contract packages, related bid documents, and bill of quantities of the selected subprojects, providing detailed guidance to PIU staff as necessary.
(iii) Assist with the bid evaluations and timely preparation of bid evaluation reports, and provide guidance to the Procurement Review Committee (PRC) to avoid delays in the approval process.
(iv) Provide advice and guidance on any required design modifications that might arise during the construction phase of the facilities of selected irrigation schemes, and supervise construction.
(v) Provide input to PIC for monthly and quarterly progress reports and project performance management system (PPMS).
(vi) Estimate annual O&M cost of the irrigation system and support PIC in preparing O&M plan.

Deputy Team Leader /Irrigation Design and Construction Engineer

4. A nationally qualified professional engineer with 10 years' experience in irrigation works will be required to be the irrigation design engineer and to undertake the role of Deputy Team Leader. Duties as the design engineer will be undertaken to assist in the preparation of the detailed design and production of documents. The Deputy Team Leader will be responsible for the day to day management/coordination of the national team and their activities under the overall direction of the Team Leader. He will also assist the Team Leader in monitoring progress and reporting. The specific tasks will be in line with those of the TL/IE.
He/She will be a nationally qualified professional engineer with preferably 10 years' experience design and construction of hydraulic structures particularly irrigation systems. The role is to supervise survey; prepare the detailed design of the reconstruction/rehabilitation works, tender drawings, bill of quantities, cost estimates, bidding documents, procurement documents, and any other documents required to complete the works. For the detailed design of the project design engineer will undertake the following tasks:

i. Administer and supervise site investigation and design and documentation activities for irrigation scheme improvement civil works contracts.
ii. Confirm detailed design guidelines and specifications in collaboration with MOWRAM.
iii. Confirm in association with the Irrigation engineer and Hydrologist the design criteria for design.
iv. Arrange with the Surveyor for necessary topographic surveys for design and documentation works; establish control points, benchmarks and reference beacons as required to prepare detailed engineering designs and to enable estimation of construction quantities.
v. Review the need for safety measures based on the findings and design appropriately.
vi. Review existing typical specifications for irrigation scheme construction and apply any modifications that are essential
vii. Assist in the preparation of construction schedules showing anticipated progress of works and expenditures for the rehabilitation contract package. The schedules will reflect seasonal weather effects at the work sites;

viii. Assist with the preparation of a suitable environmental management plans (EMPs) to mitigate adverse environmental impacts including those encountered during construction;

ix. Prepare detailed engineering designs and bills of quantities, and calculate detailed cost estimates for civil works

x. Ensure that the bid documents for works include specific provisions to avoid resettlement and minimize disruption/damage to local settlements due to construction;

xi. Prepare construction drawings.

xii. Assist with the preparation of the bid documents and tender documentation for procurement under international competitive bidding and national competitive bidding procedures in accordance with ADB's Procurement Guidelines.

xiii. Assist with the appraisal of bids as part of the bid evaluation process.

xiv. Assist with on-the-job training to engineers appointed to the PIU

Assistant Resident Engineer (4 persons)

5. Resident supervision of the construction works in field. Each ARE will be a qualified civil engineer with preferably 5 years of experience in construction of irrigation/drainage works. The engineer will be experienced in the supervision of qualified contractors, and meet the Engineers' responsibilities. AREs will prepare daily progress report of the activities in the work schedule and report to the TL through DTL. They will also be responsible for verifying the bills of the contractors through filed measurements and quality checks for ensuring adherence to the design specifications.

Structural Engineer

6. A professional structural engineer with bachelor degree in civil engineering and preferably 5 years of experience in designing hydraulic structure, preparing tender documents, preparing BOW and tender drawings is required to:

(i) Design structure according to internationals specifications,
(ii) Prepare drawings,
(iii) Assist in preparation of tender documents,
(iv) Prepare bill of quantities (BOQ), and
(v) Prepare cost estimates.

Hydrologist

7. A qualified hydrologist with bachelor degree and preferably 8 years of experience in estimating flows and extreme flood events in Cambodia will need to work closely with the Team Leader and design engineers during the detailed design stage to review hydrologic data and documentation, measure and check the adequacy of the existing hydraulic facilities with respect to their position, alignment and capacity to ensure any deficiencies are detected and rectifications are included in the detailed design.

Resettlement Specialist

8. A national resettlement specialist will be required to assist the IRC-MEF in updating the resettlement plan, revising cost of resettlement, execution of resettlement plans (RP), and monitoring of resettlement activities during constructions with guidance from the resettlement specialist in PIC. The specialist will have experience of preferably one ADB financed project and fully aware of ADB's SPS 2009, specific tasks include:

(i) Preparation of resettlement plans for identified sub-projects and in particular ensure timely submission of these to the Inter-ministerial Resettlement Committee (IRC)
(ii) Monitor and report on the progress of the RPs and their implementation
(iii) Assist with the preparation of the right of way (ROW) or reservation width alignments drawings
(iv) Ensure that a claim mechanism is in place whereby affected persons (AP) may have their claims registered
(v) Assist with land holding mapping and registration of ownership data as necessary along embankment or canal alignments, or structures where resettlement plans are required.

Agriculture Economist

9. Master degree in economics and preferably 8 years of experience in carrying out economic analysis of irrigated agriculture projects, experience of one ADB financed project and familiarity with ADB's guideline on economic analysis is required. The key tasks to be completed include following.

(i) Preparing subproject profiles and review the feasibility of sub-project based on the profiles, focusing on costs and benefits;
(ii) Revise economic analysis and estimate EIRR;
(iii) Collect socio-economic data required for completing economic analysis.

Environment Specialist

10. The environment specialist will have master degree in environment with preferably 8 years of experience in carrying out EIA, IEE and preparing environment management plans (EMP). Experience of preferably two ADB projects is required. The environment specialist will:

(i) Revise the IEE and prepare EMPs for each contract according to ADB's SPS 2009.
(ii) Monitor implementation of EMPs
(iii) Prepare periodic monitoring reports.

Procurement specialist

11. Procurement expert with relevant qualifications and 5 years of procurement experience particularly experience of one ADB financed project is required. The specialist should be fully familiar with ADB's procurement guideline for works contracts. The specialist will work closely with the Team Leader and with the PIU and in particular with the MOWRAM Procurement Officer and with the Procurement committee. The activities include but are not limited to:

(i) Prepare bidding documents for ICB and NCB contracts
(ii) Assist in evaluation of bids and preparation of bid evaluation reports

Community Development/FWUC Specialist

12. A community development specialist with bachelor degree in social sciences and preferably 5 years of experience in community mobilization, forming farmer water user communes (FWUC), and training of communities is required. The specialist will work under the guidance of the international CD/FWUC Specialist in PIC with the field survey teams and the

Agriculture Economist and liaise with the design team to ensure farmers' participation in the design and construction of canals. He/She will assist PIC in collecting socio-economic data and forming FWUCs and Construction Sub-committees (CSC) of the FWUCs.

O&M Engineer

13. The O&M engineer will be a qualified civil engineer with preferably 8 years of experience. He/She will work closely with the representatives of FWUCs and WUGs for irrigation system O&M, under the supervision of the Deputy Team Leader/ irrigation engineer. The specific taskes to be completed are as follows.

(i) review the existing O&M arrangements for each scheme,
(ii) estimate annual O&M requirements,
(iii) prepare O&M plans,
(iv) prepare an O&M manual,
(v) prepare and conduct trainings of farmers on O&M, and
(vi) improve the capacity of government staff though on-the-job and other trainings.

Labor and Gender Specialist

14. The labor and gender specialist will have a relevant degree with preferably 8 years of experience in gender and development. Experience of one ADB project is required. The specialist will implement gender action plan (GAP) of the project and ensure achieving the targets outlined in the design and monitoring framework (DMF) of the Project.

Annex B. Official letter on staff mobilization:

SAWAC CONSULTANTS CAMBODIA LTD in Association with CADTIS-Consultant Co., Ltd

31 August 2015

H.E. Ponh Sachak
Project Director
CPMU-FDRMMP
Ministry of Water Resources and Meteorology
#364, Monivong Blvd, Sangkat Phsar Deum Thkov,
Chamkamorn, Phnom Penh, Cambodia
Fax: 855-23-210 202

Ref. No.: **GMS-FDRMMP-CS-002-15-001**

Re: ADB Loan No. 2970-CAM
Greater Mekong Subregion Flood and Drought Risk Management and Mitigation Project (CAM): Contract No. GMS-FDRMMP-CS-002-National Consultants for Detail Design and Construction Supervision

Subject: **Mobilization of the National Experts**

Dear Sir,

Referring to your letter dated August 21, 2015 concerning to Key Staff Availability for Mobilization, we would like to inform you that our Staffs will be mobilized as follows:

Mr. KOAM Sothun /Team Leader, starts from October 1, 2015
Mr. PHAI Sokheng / Deputy Team Leader, starts from September 1, 2015, and
Mr. POUN Brosor / Survey Manager/CAD Operator, starts from September 1, 2015.

Your kind approval on this matter would be highly appreciated.

Yours sincerely,

SAWAC CONSULTANTS (CAMBODIA) Co., Ltd.
KINGDOM OF CAMBODIA

UCH Saroeun
Managing Director

1, St. 259, P.O. Box 851, Phnom Penh, Tel/Fax: 855-23-883 545, Tel: 855-23-991 074; E-mail: sawacam@online.com.kh

SAWAC CONSULTANTS CAMBODIA LTD in Association with CADTIS-Consultant

30 October 2015

H.E. Ponh Sachak
Project Director
CPMU-FDRMMP
Ministry of Water Resources and Meteorology
#364, Monivong Blvd, Sangkat Phsar Deum Thkov,
Chamkamorn, Phnom Penh, Cambodia
Fax: 855-23-210 202

Ref. No.: **GMS-FDRMMP-CS-002-15-004**

Re: ADB Loan No. 2970-CAM
Greater Mekong Subregion Flood and Drought Risk Management and Mitigation Project (CAM): Contract No. GMS-FDRMMP-CS-002-National Consultants for Detail Design and Construction Supervision

Subject: Mobilization of the National Experts and None Key Experts

Dear Sir,

Referring to the contract signed on 20th August 2015. In consultation with our project Team Leader, We would like to inform you that we have mobilized our staff as following:

I. Key Expert

No	Name	Position	Date of Mobilization	Duration
1	Mr. CHHIT Kimhor	Hydrologist	1st Oct 2015	6 Months
2	Mr. KHIN Toda	Structural Engineer	2nd Nov 2015	6 Months

II. None Key Expert

No	Name	Position	Date of Mobilization	Duration
1	Mr. PHORN Voeun	Assistant Surveyor /CAD Operator	19th Oct 2015	8 Months
2	Mr. BOT Meng/ Men Vaxy	Assistant Surveyor /CAD Operator	19th Oct 2015	8 Months
3	Mr. SoeumMithuna/HengThavy	Assistant Surveyor /CAD Operator	2nd Nov 2015	8 Months
4	Ms. Keo Sam An/Chan Chhorm	Assistant Surveyor /CAD Operator	2nd Nov 2015	8 Months
5	Mr. Phouv Narin	Assistant resettlement/land surveyor.	2nd Nov 2015	8 Months

Your kindly approved on this matter would be highly appreciated.

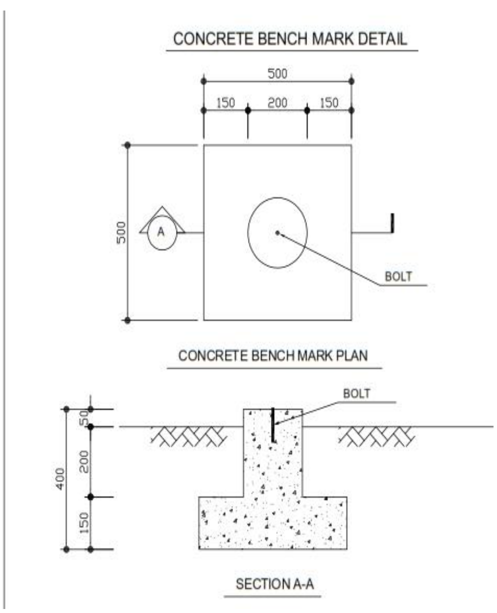
Yours Sincerely,

SAWAC CONSULTANTS (CAMBODIA) Co., Ltd. KINGDOM OF CAMBODIA

UCH Saroeun
Managing Director

1, St. 259, P.O. Box 851, Phnom Penh, Tel/Fax: 855-23-883 545, Tel: 855-23-991 074; E-mail: sawacam@online.com.kh

Annex C. Concrete Bench Mark installation and its elevation



No.	BM Name	GPS Coordinates		Elevation (m)	Remarks
		Easting	Northing		
1	PS1	359714.429	1364214.466	25.137	At Cross Section I
2	PS2	359422.830	1363791.150	31.311	Near Water Tank
3	PS3	359621.240	1363802.250	29.434	At Cross Section II
4	PS4	359446.800	1363687.940	29.659	At Cross Section III
5	PS5	359191.500	1363630.460	29.923	At Cross Section IV
6	PS6	355744.180	1363328.620	32.641	At Cross Section VI

Annex D. Estimation the discharge flow at the barrage structure

Projected the available stream flow at Bak TrouKoun station for different return periods in current climate condition.

The following is the formula for calculation:

$K = -1.2777 - 2.167 LogLog(T/(T-1))$

$Q_T = Q_{mean} + K*STDEV$

Where: K - Frequency Factor

T - Return Period, Years

Q_T- The T-Years annual maximum stream flow amount, m^3/sec

Q_{mean} - Mean of Annual Maximum Stream flow in m^3/sec

STDEV- Standard Deviation of Stream flow

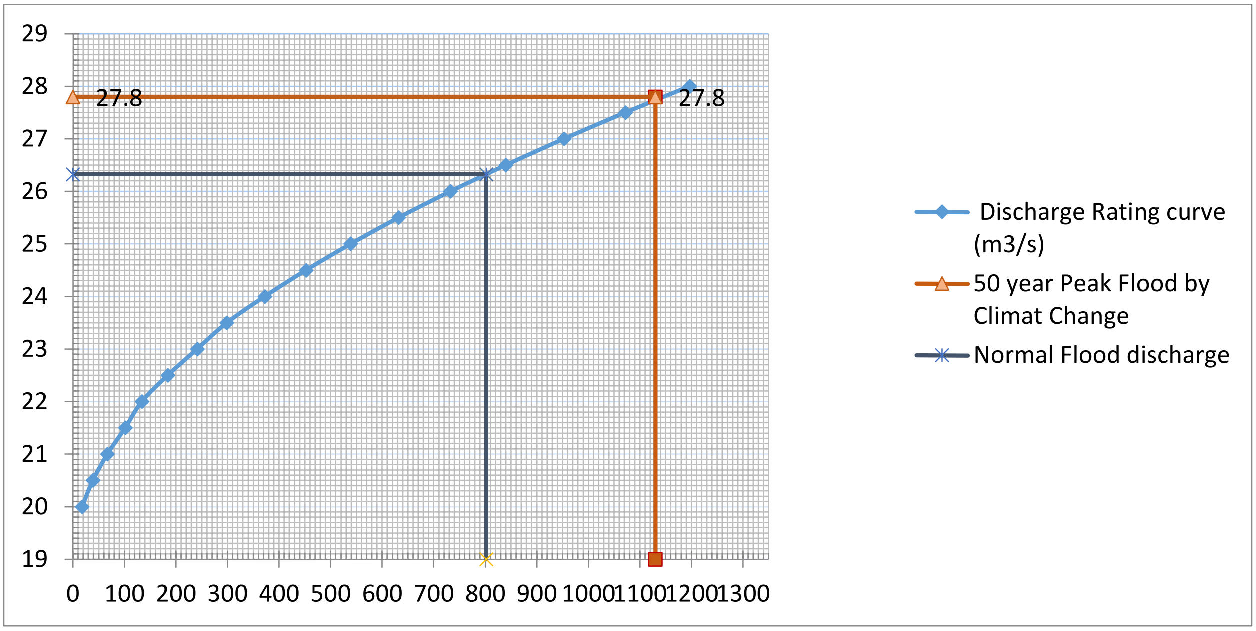
Based on the daily stream flow at Bak Trokoun station from 1 October 1994 till 31 December 2011 that provided by Mr. Sok Seng IM, the return flow estimation is calculated in the following table:

Return Period T, Years	Return Period Stream Flow, m^3/sec
2	313.75
5	471.91
10	576.62
15	635.70
20	677.07
25	708.93
30	734.86
50	**807.09**
100	904.52
200	1001.59
300	1058.29
500	1129.66

Annex E. Barrage Design

Design step: Capacity of stream, Capacity discharge of barrage, Hydraulic design of structure and Detail Design structure

<u>1 Capacity of stream</u>: by Stage Discharge Curve (Flow Rating Curve).



- From the above rating curve, it is found that the high flood level corresponding to 1130 m^3/s flood discharge will be 27.800 m before construction of barrage and the normal flood level 26.325 m (as marked by local people) gives flood discharge as 802 m^3/s.
- The barrage structure will be designed for this flood level 27.800m corresponding to high flood discharge as 1130 m^3/s as reported in the PPTA report. But this discharge should be verified by the hydrologist of the present study.

<u>2 Capacity discharge of barrage:</u>

<u>Design data:</u>

Flood discharge : 1130 m^3/s

HFL before construction: 27.800 m

Pond Level : 27.575 m

Average river bed level : 19.095 m

Canal discharge : 40 m^3/s

River L-section and X-section

Assumption Made

HFL after construction : 28.220 m

Crest level of under sluice : 21.50 m

Crest level of barrage bays : 22.50 m

Crest level of canal head regulator : 26.00 m

Canal bed level : 25.00 m

Canal FSL : 27.00 m

Dimensions calculated:

Sharp crest barrage with glacis slope is proposed for the barrage:

Under sluice portion

bays each of span 2.8 m having 1 pier of thickness 1.50m

Under sluice waterway = 7.10 m

Fish ladder and divide wall one unit of 6m span

Barrage bays

bays each of 4.70 m span having pier thickness 1.50m

Barrage bays waterway = 48.10 m.

Hydraulic design of structure:

For the stability of structure, the barrage will be designed against hydraulic forces which occurred both at surface water flow and underground water flow:

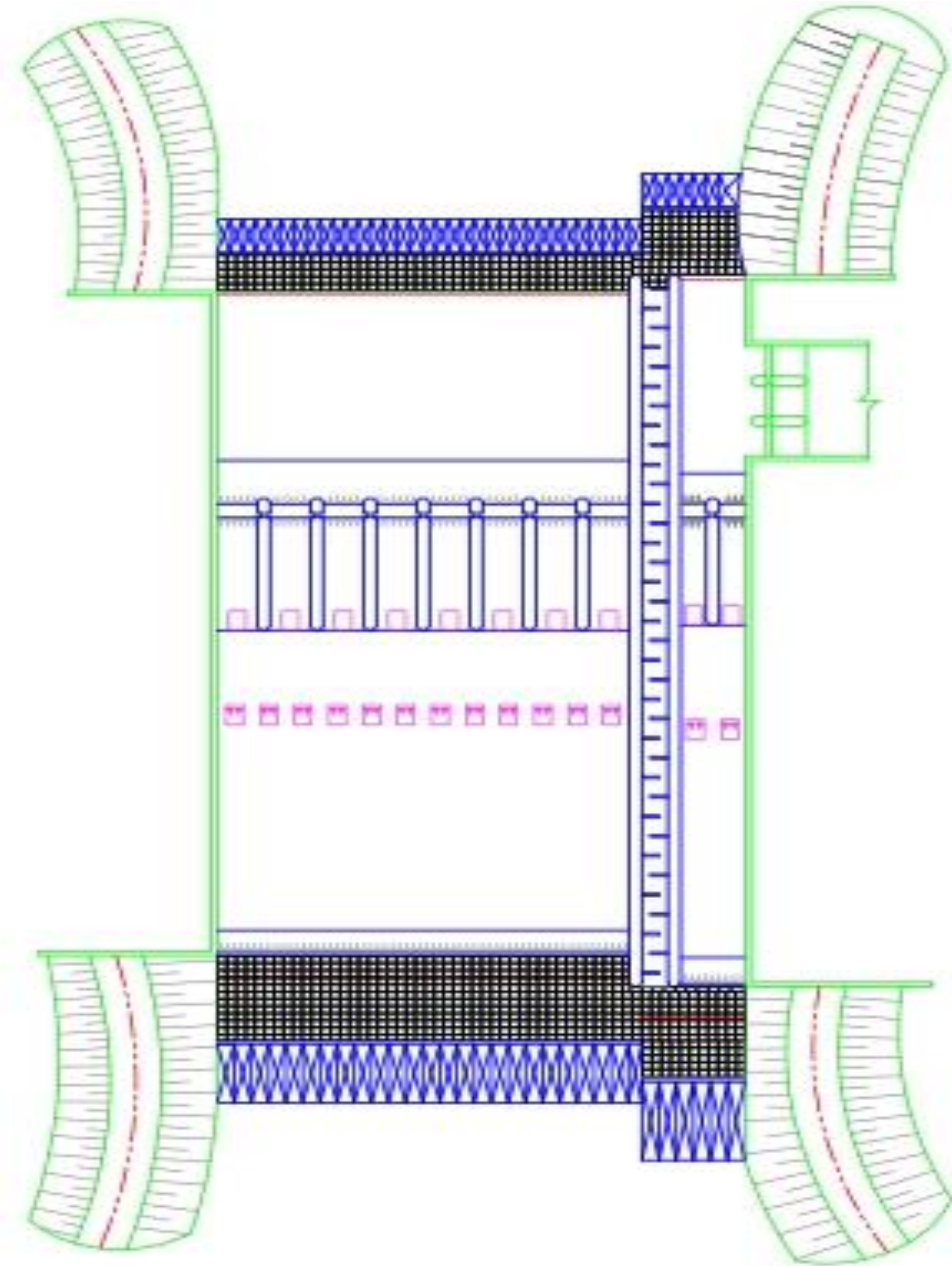
Surface water flow: u/s and d/s apron length and thickness, scour depth (cutoff), chute block, baffle block and end sill…

Underground water flow: The failures of structure by underground water flow are mostly cause by Uplift force, Overturning, Sliding and Piping.

Detail Design structure:

Detail design structure will be carried out for durability and materials use of Retaining wall with counter fort, Deck slab, Operation Deck, Piers, Abutment, Foundation, Apron slab and Gate….

Annex F. Scheck of drawing



Annex G. Frame of drawing