CHAPTER 4 BASIC DEVELOPMENT CONCEPT AND APPROACH

4.1 Development Needs and Constraints for Irrigation and Drainage Development

4.1.1 Development Needs

In Cambodia, rice is a principal crop and attaining food security through increased rice production is a priority theme. As an important granary of the country, the Four River Basins have been contributing to 17% of national rice production and are expected to maintain same level of shares by increasing rice production. In addition, increased and stabilized agricultural production will contribute to poverty alleviation in the rural areas of the country as an aim of economic development elaborated in national and sector development policies. In order to materialize these policy objectives, the Government has launched the Strategic Development Plan for Water Sector 2006-2010 (Draft), emphasizing on food and drought management by way of improvement of water resource infrastructure including irrigation. Therefore, stabilization of food production at potential areas including the Four River Basins through irrigation development is surely justified in the policy target.

Afresh, maintenance of food security is of critical mission of the country particularly in a context of recent food crisis in the world, which are caused by combined reasons such as the surge of bio-ethanol production and drastic speculation toward cereal and grains. In order to alleviate vulnerable position in food supply due to recording high price of world food, ensuring food security within the country backed by rehabilitated and improved irrigation facilities is essential especially in the country's granary, the Four River Basins.

Provision of irrigation water in timely manner is able to contribute to ameliorate the quality of agricultural products. In this regard, quality of the rice in the Four River Basins particularly in Battambang Province is widely reputable within and surrounding country from the view point of its fragrance and softness. Therefore, irrigation and drainage rehabilitation will be of help in the quality improvement of rice for enhancing rice brand value leading to value-addition of the products as well as poverty alleviation in the rural farm communities.

The development needs and wishes of community members under the sub-projects also were identified and confirmed through workshop and public meeting organized with irrigation beneficiaries. All the participants expressed the highest priority on "*stabilization of water supply through rehabilitation and improvement of irrigation and drainage facilities"* followed by "*improvement of agricultural techniques*" for food security. The needs on the assistance of efficient operation and management of the irrigation facilities for ensuring food security is, therefore, justified from irrigation beneficiaries' view point as well.

4.1.2 Constraints

The irrigation rate is assumed at only 10%, and only the supplemental irrigation is practiced in the sub-project areas. No full irrigation is carried out in those areas. The constraints of the present irrigation and drainage condition are as follows:

i) Most of the existing irrigation systems in the sub-project areas were insufficiently

designed and constructed between 1975 and 1979, and have been deteriorated severely resulting in losing function.

ii) The irrigation water, even though be supplied from the river, is unstable and limited, and is not distributed efficiently to all individual paddy fields due to lack of canals and related structures.

iii) The agencies and farmers do not have nor execute suitable irrigation water management plans due to lack of irrigation facilities, training and experience.

iv) Substantial maintenance work of facilities has not been carried out due to lack of the facilities, insufficiency in capability and experience of the stakeholders and fund necessary.

4.2 Basic Concept and Approach

4.2.1 Development Objective

The development objectives of the Project are to utilize available resources under irrigation systems in effective, sustainable and equitable manner, matters of which consist of: (i) effective water resource utilization by the rehabilitation and improvement of irrigation and drainage facilities, (ii) effective land resource utilization by the protection of agricultural field from long-lasting flood and inundation and (iii) effective human resource utilization by enhancing capability of the stakeholders.

4.2.2 Development Concept and Approach

In order to achieve the objective, the basic concept of the Project is:

i) Rehabilitation and improvement of facilities in order to ensure stable water supply in equitable manner within the system,

ii) Formation and strengthening of FWUC,

iii) Practice of irrigation water management and operation and maintenance, and

iv) Extension of improved farming practice

The Project is the first phase and one of the models of the irrigation development in the Four River Basins. The lessons to be learnt in the implementation are expected to be effectively utilized in pursuing the Road Map 2020 as proposed in the M/P as well as irrigation development in other basins in the country. Approaches on materializing abovementioned concept are as follows:

(1) Rehabilitation and Improvement of facilities

Objective of irrigation and drainage plan is to determine the adequate target area for the development, to determine suitable canal layout and structures to distribute irrigation water to individual fields. To do so, basic approaches are as follows:

1) Irrigation system to be planned

The concept of irrigation and drainage system proposed is as follows comparing with present condition:

The Concept of Irrigation and Drainage System

Item	Present condition	Proposed
Irrigation area	Not clearly delineated	Clearly delineated in accordance with resource availability
Irrigation method	Gravity irrigation is very limited, Mostly portable pump irrigation by farmers	Gravity irrigation, in principle, Portable pump irrigation in some area due to local condition
Irrigation and drainage canals	Dual purpose canal	Separation of irrigation and drainage canals
Water distribution	Uneven water distribution (Water source → Main Canal → Secondary Canal → Farm plot)	Even water distribution to individual farm plots (Water source → Main Canal → Secondary Canal →Tertiary Canal → Water course → (Field Canal)→ Farm plot)
Water management	Uncontrolled water management	Controlled irrigation water distribution by gated structures

Prepared by Study Team

2) Suitable development scale based on the available resources

The command areas under the sub-projects are to be determined taking into consideration of multi-faceted aspects from technical, economic and social such as available water source, future potential development in the river basin, local conditions, economic viability etc.

A special attention is paid to the available water resources. The existing water resources are to be used up to its maximum extent. The large scale new water resources development, however, is not considered in the study due to lack of reliable long-term hydrological data. The sub-project will guarantee the wet season paddy production in a drought year that may occur once in five years. The size of each sub-project is to be determined based on the water balance study in each river basin.

3) Priority to existing paddy field, and existing irrigation and drainage facilities

The existing paddy fields amount about four times of that existing water resource potential in the Four River Basins as analyzed in the M/P. The sub-projects, therefore, are planned to concentrate on rehabilitation and improvement of the existing paddy field and irrigation systems of which most of them have lost function. The existing canals and drains are to be utilized after its necessity and technical soundness are examined because most of them need rehabilitation. This will give the various advantages such as to minimize land acquisition cost, reduce excavation cost of canals, to utilize storage and water harvesting function of canals if the existing canal has larger cross section than that required flow capacity.

4) Construction of additional facilities as necessity arises

The existing irrigation facilities are not sufficient or deteriorated to attain equitable water distribution and efficient water use in the sub-project area. Such structures are to be proposed as headworks, check structures, diversion structures, turnouts, etc.

The construction of a tertiary block will be carried out by farmers in accordance with the

government policy. The design guideline of Cambodia defines a tertiary block covers 50 ha on average in general.[1] The irrigation water is to reach smoothly to a tertiary block. For this purpose, sub-secondary canals are proposed to divide one secondary canal block into several tertiary blocks if the secondary canal block is larger than 100 ha taking into consideration site condition and economical view point. The density of tertiary canal is designed at 20m/ha at minimum to supply irrigation water to water course in the tertiary block.

5) Appropriate drainage and flood protection plan

The drainage plan is made i) to drain excess water in the sub-project area taking into account allowable flooding depth and inundation, ii) to protect the sub-project area from floods from outside of the area, iii) exclusion of habitual inundation area by Lake Tonle Sap.

a) Allowable flooding depth and inundation period

The drainage system in the sub-project area is planned to drain excess water in the paddy fields with once in five years return period. Therefore, a flooding depth and inundation period are allowed.

Paddy suffers a serious loss if it is submerged at booting stage by flood. The booting stage will start at about 6 days before flowering (heading) which occurs 30 days before harvesting. The height of paddy stem is generally more than 30 cm at the booting stage. The allowable maximum flooding depth and allowable inundation period in the paddy field is planed to be 300 mm and 3 days respectively.[2]

b) Floods from outside higher elevated areas

Collector drains are to be provided at boundary of the sub-project area to protect such flood water from outside. The small streams or existing drainage canals, if any, are used as much as topography allows. The collector drains are excavated until it joins with a larger river.

The poor drainage and habitual inundation due to high water level of the Lake Tonel Sap usually lasts more than a month. The maximum water level was recorded at about EL. 11.0m in the Lake between 1998 and 2001[3]. Should the sub-project construct canals and related structures in such area, the facilities submerge almost every year and damage is very high. A polder dikes and pump drainage is required to protect paddy and facility from inundation, resulting in high construction cost and high operation and maintenance cost. On the contrary, a different type of paddy cultivation is predominant at present and recommendable i.e. recession rice or floating rice. The area which is lower than EL. 11.0m is excluded from Ream Kon and Por Canal sub-projects.

6) Cost-effectiveness in the plan

Many parts of the existing canals are excavated canals with large section as compared with the

[1] Design Manual for Small and Medium Scale Irrigation System Planning, July 2004, prepared by MOWRAM and Leighton G. Williams and MOWRAMTF (Funded by ADB 1445 CAM (SF)

[2] Based on the study by the Ministry of Agriculture, Forestry and Fisheries of Japan.

[3] The Study on Hydro-meteorological Monitoring for Water Quantity Rules in Mekong River Basin, Final Report, March 2004, JICA

required discharge. The existing canals need to be rehabilitated and/or improved by minimum cost. The economical rehabilitation and construction of canals is to be considered. The top of canal embankment is to be raised to maintain required water level for gravity irrigation. However, the existing deep or wide section is used as much as possible so that the rehabilitation cost is reduced and the extra section can be used as a storage or water harvesting. Existing rivers and streams in the sub-project area are to be utilized for drains as much as possible to minimize construction cost. The rivers and streams are to be excavated to have enough flow capacity.

(2) Formation and Strengthening of FWUC

Objective of FWUC formation and strengthening is to realize the proper water management and O&M of secondary/sub-secondary, tertiary, water course and field canals. The general procedure of formation and strengthening of FWUC is presented in many documents published by the Government[4]. In general, the strategy is the following three general steps:

i) Set-up the structure and responsibilities,

ii) Formation of FWUC and sub-ordinates such as FWUGs and WUGs, and

iii) Capacity development by way of participatory tertiary development though community –contract approach

The suitable plan for FWUC formation and strengthening in the Project is made in accordance with the government policy, experience in Cambodia, present conditions in each sub-project area, and experience in other similar countries.

(3) Practice of Irrigation Water Management, and Operation, and Maintenance

Objective of the water management and operation is to achieve equitable and sustainable water distribution to individual fields. The objective of maintenance for canal system is to keep the good conditions of canals and related structure in order to maintain sustainable water management.

1) Responsibility sharing depending upon the level of facilities

Based on the Government policy the water management and O&M activities are to be performed by different organization in the Project in accordance with the category of canals. Therefore, water management and O&M plans are proposed by canals.

2) Stepwise transfer of O&M of irrigation system to FWUC

The Government policy indicates the handing-over of O&M activities to FWUC in five years. This policy will be also adopted to the Project. It can be summarized by cost sharing as follows:

4 "Policy for Sustainability of Operation and Maintenance Irrigation System, June 2000", and "Circular No.1 on the Implementation Policy for Sustainable Irrigation Systems", "Modules from No. 1 to 8" etc.

Share of O&M Cost

Year after completion	Government	Beneficial Farmers
One	80%	20%
Second	60%	40%
Third	40%	60%
Fourth	20%	80%
After Fifth	0%	100%

Prepared by JICA Study Team based on the Policy for Sustainability of Operation and Maintenance Irrigation System, June 2000, MOWRAM

The levels to be transferred to FWUC and general procedure are to be planned based on the capability of farmers in system O&M.

(4) Extension of Improved Farming Practice

1) Constraints

The primary agronomic constraint common in the Project area is unstable and low productivity of rice adversely affected by various factors and the primary physical constraint common is insufficient water supply, even in wet season. On the basis of the findings discussed in the preceding chapters and the results of the Socio-economic Survey on farming constraints, improvement measures and expectations as discussed earlier, major problems and constraints in agricultural development in the sub-project areas, which should duly be addressed in the present Study in an integrated manner, have been enumerated and conceivable development directions are discussed in the followings.

i) Primary constraint that is attributed to the unstable and low productivity of rice is limited and unstable availability of water because of limitation of irrigation water supply. Most rice fields in the six sub-project areas are under rainfed conditions. Further, supplemental irrigation in wet season is exclusive current irrigation status even in the irrigated fields; which should be addressed through the development and efficient utilization of available water resources to an extent possible.

ii) Single cropping of rice is a prevailing cropping pattern in the sub-project areas and annual land use intensities or cropping intensities in paddy fields are limited to 100 to 120%. Further, production of upland crops in paddy fields is negligibly limited; which should be addressed by introducing rice and upland crops/vegetables cultivation in the early wet and dry season within the availability of irrigation water resources. However, field based technology development and extension activities are essential for the promotion of upland crops production in paddy fields.

iii) Prevailing traditional farming practices are also serious problems attributed to low productivity. However, a number of factors are involved in circumstances where such practices prevail; which should be addressed through the strengthening of agricultural extension services introduced in a well integrated manner.

iv) Extensive traditional direct sowing is prevailing rice cultivation method in the sub-project areas of Ream Kon and Por Canal. Compared with transplanting method, yield levels of paddy in direct sowing are reported to be 0.5 to 1.0 ton/ha lower; which should be addressed by the technology development for productivity improvement of direct sowing

and the extension of results/findings of the development to farming communities. Technical development activities for direct sowing are been carried out by Battambang Rural Area Nurture and Development Project (BRAND), JICA. The results/findings of the same should better be verified at farmers levels and disseminated in the sub-project areas.

v) In the current post-harvest operations in the sub-project areas, marketing of field dried paddy (wet paddy) is commonly practiced because of insufficient drying spaces and no drying facilities at village level. Further, farmers' practical knowledge on the importance of post-harvest practices appears to be limited. As a result, rice millers without drying facilities (dryer) in the project districts are placed in the disadvantageous position in the competition with traders from neighboring countries. Production increase expected under the with-project condition might invite marketing competition with other producing areas in future and product quality will become an important issue for marketing.

As an initial step toward the improvement of post-harvest operations and product quality, the construction of drying yard and storage facility should better be considered under the sub-project on a pilot basis.

(2) Development Approach

The basic development strategies established for the agricultural development in all the sub-project areas are as follows;

i) Productivity improvement and production increase of rice is targeted through the introduction of irrigated farming and increase of annual cropping intensity within the availability of irrigation water supply,

ii) Improvement of productivity and increased production of rice is envisaged through the introduction of improved farming practices supported by the strengthening of agricultural extension services,

iii) Envisaging the introduction of upland crops/vegetables production under irrigation in the early wet and dry season to an extent practical by sharing available irrigation water with rice production to increase land use intensity and promote crop diversification,

iv) Strengthening of agricultural extension services accommodated as a project component for extension of improved farming practices and dissemination of upland crops/vegetables production, and

v) Current planting methods of rice, transplanting and direct sowing in the subject areas, will be maintained in the future as such planting methods have been employed by farmers dictated by their land holding sizes and availability of labor forces and alternation of planting methods will be impractical.

4.2.3 Formation of the Sub-projects and the Project

(1) Basic Consideration

The sub-projects are located in 3 provinces, and far from each other. Additionally, various

components are to be contained as described in the previous sections. The capacity development programs proposed will target staff of MOWRAM and PDOWRAM as well as farmers. The Project is to be formulated based on the following principles.

1) Harmonization of facilities rehabilitation and human resources development

The Project is to be planned and implemented in a harmony of facility rehabilitation and development of human resources.

2) Joint effort among stakeholders: MOWRAM, farmers and donors

The Project shall be implemented by effort of three major stakeholders: the Government, the farmers, and the international donor agencies, each of which is required to take its role and to perform its responsibility in the implementation.

3) Learning process in irrigation development in the basins based on the Road Map 2020

The Project is the initial phase of "the Road Map 2020" covering 21 sub-projects as proposed in the M/P. Also, the Project can be one of the models of irrigation development in the Cambodia. The performance, lessons to be learnt and output from the Project will be succeeded to the further phases.

(2) Combination of Sub-projects and Soft Components

Based on the above discussions, a sub-project consists of:

- Construction works: (i) rehabilitation and improvement of irrigation and drainage facilities, and (ii) on-farm development, and
- Soft component: (i) FWUC establishment and strengthening and (ii) agricultural extension activities.

In addition to the construction works and the soft components under the six sub-projects, the Project will involve the following three supporting programs:

- Mateo-hydrological observation strengthening program
- Capacity development program of MOWRAM, and
- Capacity development program of PDOWRAM.

The details of each sub-project and soft components are proposed in the following chapters.

CHAPTER 5 THE PROJECT

5.1 Alternative Studies and Target Areas

5.1.1 Summary

The command area of each Sub-project was selected based on the present land use, topography, existing facilities, habitual inundation by Lake Tonle Sap, etc. After this, a comparative study was made for each Sub-project as necessity arises, based on the water balance study, costs, incremental benefit of respective Sub-project. Through the comparative study, the appropriate size and location of the target area was determined for each Sub-projects.

Proposed Target Area of the Sub-projects

No.	Sub-project	Area (ha)
1	Ream Kon Rehabilitation	1,890
2	Por Canal Rehabilitation	1,940
3	Damnak Ampil Rehabilitation	2,270
4	Wat Loung Rehabilitation	2,540
5	Wat Chre Rehabilitation	1,020
6	Lum Hach Rehabilitation	3,100
	Total	12,760

Prepared by JICA Study Team

The procedure and result of the determination is described in detail in the following sections from 5.1.2 to 5.1.4. The proposed development plan is described in the following sections from 5.2 to 5.7 for each Sub-project.

5.1.2 Ream Kon and Por Canal Rehabilitation Sub-projects in the Moung Russei River Basin

(1) Water Balance Study in the Moung Russei River Basin

1) Necessity of water balance study

The most affective factor in determination of size of irrigation development project is water in the Study Area. The water source of the Sub-projects is Moung Roussei River. There are a few proposed or on-going irrigation projects in the upstream of the Moung Russei River. The Ream Kon and Por Canal Rehabilitation Sub-projects are located most downstream of the Moung Russei River Basin.

The basin-wide water balance study is executed in order to confirm availability of water resource, and to determine water-possible irrigation areas in the river basin as a whole including Ream Kon and Por Canal Rehabilitation Sub-projects.

2) Inventory Irrigation Area

The JICA Inventory Survey 2006 reported that there exist 10 small to medium irrigation systems in the Moung Russei river basin. Of them two irrigation systems are excluded from water balance study since the two are affected by high water of Lake Tonle Sap.

The total area of the eight existing irrigation systems is about 17,000 ha. The water balance study is made to confirm if the water resource in the Moung Russei river is available for the area.

3) Irrigation water requirement

a) Basic conditions

The irrigation water requirement is estimated similar procedure with that in the Master Plan Study 2007 based on the proposed cropping pattern described in the following section 5.2.1. The basic condition and figures applied are as follows:

i) Meteorological data; average of mean monthly data at Battambang and Pursat stations
ii) Percolation rate 3.5 mm/day based on the observed data
iii) Rainfall data; Daily rainfall data at Moung Russey, Svay Don Keo, and Talo stations
iv) Ratio of transplanting and direct sowing area; 50% and 50%, respectively
v) Irrigation efficiency in the tertiary unit= 85 %
vi) In the secondary canal and main canal= 88 %, respectively
vii) Overall efficiency= 85 × 88 × 88 % = 65.8 % = 66 %

b) Irrigation water requirement for tertiary and field canals

The rotational irrigation proposed for equitable and effective water distribution in the secondary canal command area. Tertiary canal blocks are divided into a few rotation blocks. The irrigation water is supplied to each rotation block in turn. The tertiary canal and water course are to have a peak flow capacity to supply water smoothly in turn. The peak water requirement is figured out at 2.00 lit/sec/ha for wet season paddy in August including irrigation efficiency of 85% at tertiary level.

c) Diversion water requirement for headworks, main canal, and secondary/sub-secondary canals

On the contrary, the flow in the headworks, main and secondary canals are almost constant. The 5-day water requirement is calculated in accordance with staggered cropping calendar. The peak diversion water requirement is estimated at 1.41 lit/sec/ha for early wet season paddy in April taking into account the overall irrigation efficiency of 66%. This number is used for design of the intake, main and secondary canals.

4) Water balance calculation of Bassac Reservoir

The main water resource for irrigation is the Bassac Reservoir which is being rehabilitated by MOWRAM under Non-project Grant Aid by the Government of Japan. In the water balance study a fluctuation of water volume in the Bassac Reservoir was estimated by comparing inflow to the reservoir and water requirements i.e., irrigation water requirement as well as the water demands for domestic and industrial use, river maintenance flow within the river basin, respectively. These water requirements which were used in the Master Plan Study in 2007 are also used in the present study.

In the calculation of water balance, several alternatives were considered: (i) to know

maximum area for wet season paddy, (ii) maximum area for dry season, iii) maximum area in early wet season, (iv) equal irrigation area in early wet and wet seasons.

Alternatives of Water Balance Study of Moung Russei River Basin

	Crops			Evaluation indicators				
Alt.	Early paddy (ha)	Medium paddy (ha)	Dry season paddy (ha)	Annual irrigation area (ha)	Develop-ment area (ha)	Annual incremental paddy production (ton)	Paddy production per Sub-project area (ton/ha)	Evaluation
1	300	10,100	200	10,600	10,100	20,289	2.01	- 2nd in annual irrigation area - Largest in development area - 2nd in annual incremental production - 4th in production per cost
2	900	1,500	5,100	7,500	5,100	19,935	3.91	- 3rd in annual irrigation area - Smallest in development area - 3rd in annual paddy production - 1st in production per cost
3	6,300	500	200	7,000	6,300	14,145	2.25	- Smallest in annual irrigation area - 3rd in development area - Smallest in annual paddy production - 3rd in production per cost
4	5,200	5,200	300	10,700	8,300*1	21,128	2.54	- 1st in annual irrigation area - 2nd in development area - 1st in annual incremental production - 2nd in production per cost

Notes:

*1 The Wet Season Paddy can not be successively cultivated in the 60% of Early Wet Season Paddy area due to overlap of the cropping area. The Sub-project area =5,200+0.6×5,200=8,320 ha

Cropping season:

Early growing paddy (by Direct sowing), Medium growing paddy (Direct sowing : Transplanting =1 : 1)

Dry season paddy means early growing paddy by direct sowing

Bassac Reservoir related data

- Catchment area: 598km^2
- Effective storage capacity: 32 MCM
- Design maximum height: 10.55m (FWL)
- Approximate reservoir area: maximum 500 ha, minimum 12 ha.

Assumptions and condition

- River Discharge: Mean 5-days discharge in the Moung Russei (Dauntri) River for over 5 years.
- Seepage loss of reservoir: 0.05% of Total Storage Volume per day
- Evaporation from reservoir: Reference crop evapotranspiration estimated by Penman-Montieth method and meteorological data.

Data on related Project

- Irrigation water requirement: Mean 5-days irrigation water requirement estimated based on the proposed cropping calendars.
- Design irrigation target area: To be determined based on the result of the water balance study

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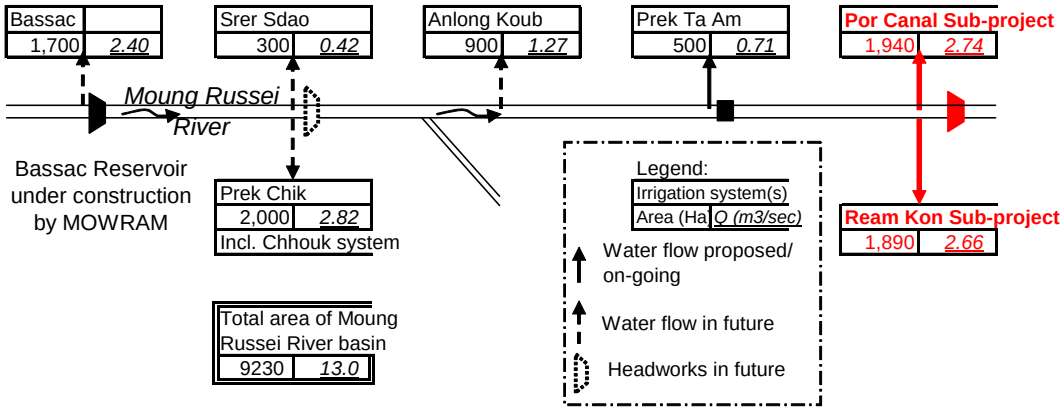
The evaluation is shown in the right column of the above table. Overall, Alternative-4 is recommendable based on the following analyses:

- Alternative-4 shows the largest incremental production, and second largest of production per Sub-project area.
- Alternative-2 shows largest production per Sub-project area, while it is very risky to propose main part of benefit to dry season paddy which is not so commonly practiced in

the study area at present.

Therefore, the total water potential area in the Moung Russei River basin is assumed to be between 8,300 ha to 10,100 ha, 9,200 ha on average, about 54% of the area "16,900 ha" that was assumed in the JICA Inventory Survey carried out in 2006. All the projects developed within the basin are expected to determine its project area referring to this proportion. The development area for two Rehabilitation Sub-projects, Ream Kon and Por Canal, will be about 3,900 ha conjunctively. The future irrigation water supply plan is shown as follows:



Prepared by JICA Study Team

Future Irrigation Water Supply Plan in the Moung Russei River Basin

(2) Delineation of Target Area for the Ream Kon Sub-project

The irrigation area for the Ream Kon Sub-project is delineated in accordance with the result of water balance study, present land use, topography, existing facilities, inundation of Lake Tonle Sap, etc., and based on the concept described in the section 4.2.

Two alternatives plans are made and compared as follows:

Alternative Study

Description	Alternative-1	Alternative-2
Concept for alternative plan	- To maintain high water level in the Main Canal to irrigate all areas by gravity.	- The Main Canal can be used for low elevated area (Main Canal-1) - To provide Main Canal-2 for high elevated area.
Proposed canal layout	- Main Canal L=9.0 km - Secondary canals L=16.4 km (11 nos.)	- Main Canal-1 L=9.0 km, Main Canal-2 L=9.1 km - Secondary canals L=12.9 km (16 nos.)
Irrigation method and area (ha)	- Gravity irrigation area=1,610 ha - Portable pump irrigation area= 0 - Total area= 1,610 ha	- Gravity irrigation area= 1,610 ha - Portable pump irrigation area= 280 ha - Total area=1,890 ha
Intake water level required	EL. 15.50m	EL. 15.50m
Water level required at end point of main canal	EL. 12.4m	EL. 11.9m
Conclusion	Higher construction cost with smaller irrigable area than Alternative-2.	The total irrigation area is 1,890 ha including portable pump irrigation area of 280 ha. Recommendable

Prepared by JICA Study Team

Based on the above comparison, the Alternative-2 is recommended, and hence the target area of the Ream Kon Sub-project is determined at 1,890 ha. The target area spreads in the east of National Road No.5 and along the right bank of the Moung Russei River.

(3) Delineation of Target Area for Por Canal Sub-project

The irrigation area for Por Canal Sub-project is delineated in accordance with the result of water balance study, present land use, topography, existing facilities, inundation due to water level fluctuation of Lake Tonle Sap, etc., and based on the concept described in the section 4.2. Owing to the downward inclination from intake structure to downstream, an irrigable area with portable pumps is negligibly small provided that the water level in canal is maintained sufficiently high by check structures.

As a result of the selection, the target area for the Por Canal Sub-project is determined at 1,940 ha. The target area is located in the east of National Road No.5 and along the left bank of the Moung Russei River.

5.1.3 Damnak Ampil, Wat Loung, and Wat Chre Rehabilitation Sub-projects in the Pursat River Basin

(1) Water Balance Study of the Pursat River

1) Necessity of water balance study

There are several proposed or on-going irrigation projects in the Pursat River basin. Damnak Ampil Headworks is one of the important structure to supply irrigation water to several irrigation projects. The basin-wide water balance study is conducted in order to confirm the availability of water resource, and to determine the size of potential irrigable area for the Damnak Ampil Headworks including the proposed Sub-projects.

2) Inventory irrigation area

The JICA Inventory Survey in 2006 reported that there exist about 21 small to large scale irrigation systems which sum up to about 41,000 ha in total in the Pursat River basin. Further, about an area of 2,200 ha spreads in the Svay Don Keo River Basin to which the Pursat River is expected to supply irrigation water in the future.

The total area of the above 41,000 ha is divided into the following sub command area:

i) Damnak Ampil Headworks: 15,000 ha; ii) The on-going Char Rek Weir Construction Project in the downstream of the Damnak Ampil Headworks: 5,000 ha to 6,000 ha; iii) The Beoun Preah Ponley irrigation system: about 8,500 ha. The remaining area will be covered by several small to medium sized irrigation systems.

3) Irrigation water requirement

a) Basic conditions

The irrigation water requirement is estimated by a similar manner that was adopted in the Master Plan Study 2007, based on the proposed cropping pattern described in the following section 5.4.1. The basic condition and figures applied are as follows:

i) Meteorological data; average of mean monthly data at Pursat station
ii) Percolation rate 2.5 mm/day based on the field observation data
iii) Rainfall data; Daily rainfall data at Boeung Khnar, Pursat, Boeung Kantout stations
iv) The transplanting method is practiced in the Sub-project area
v) Irrigation efficiency in the tertiary unit= 85 %
vi) Irrigation efficiency in the secondary canal and main canal= 88 %, respectively
vii) Overall efficiency= 85 × 88 × 88 % = 65.8 % = 66 %

b) Irrigation water requirement for tertiary and field canals

Rotational irrigation method is proposed for equitable and effective water distribution in the secondary canal command area. Tertiary canal blocks are divided into a few rotation blocks, and irrigation water is supplied to each rotation block by turn. The tertiary canal and water course are to have a peak flow capacity to supply water smoothly in turn. The peak water requirement is figured out to be 1.91 lit/sec/ha for wet season paddy in August at an irrigation efficiency of 85% at tertiary level.

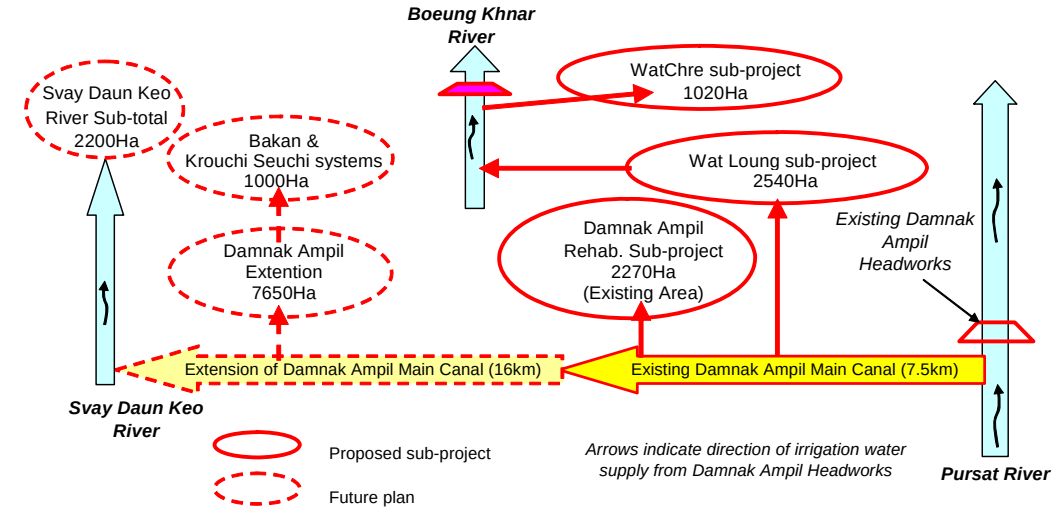
c) Diversion water requirement for headworks, main canal, and secondary/sub-secondary canals

On the contrary, the flow in the headworks, main and secondary canals are almost constant. The 5-day water requirement is calculated in accordance with staggered cropping calendar. The peak diversion water requirement in the Sub-project as a whole is figured out at 1.36 lit/sec/ha by wet season paddy in August taking into account the overall irrigation efficiency of 66%. This rate is used for design of the intake, main and secondary canals.

4) Result of water balance study

A conjunctive water balance study for the Pursat River and Svay Don Keo River Basins is conducted to confirm the potential irrigable area in these two basins. In the study, the above mentioned irrigation water requirement is applied as well as the water demands for domestic and industrial use, river maintenance flow in the two river basins are taken into account, respectively.

The result reveals that a total area of about 38,000 ha is able to be irrigated by Pursat River at 1/5 year return period. The areas of 14,480 ha in the Pursat River Basin and 2,200 ha in the Svay Don Keo Rever Basin (supplemental irrigation water supply at a rate of 1.5 m^3/sec) are irrigated by Damnak Ampil Headworks. The maximum discharge rate is assumed to be about 21 m^3/sec at peak at the Damnak Ampil Headwork. The irrigable command areas for the Damnak Ampil Headworks are illustrated in the following figure.



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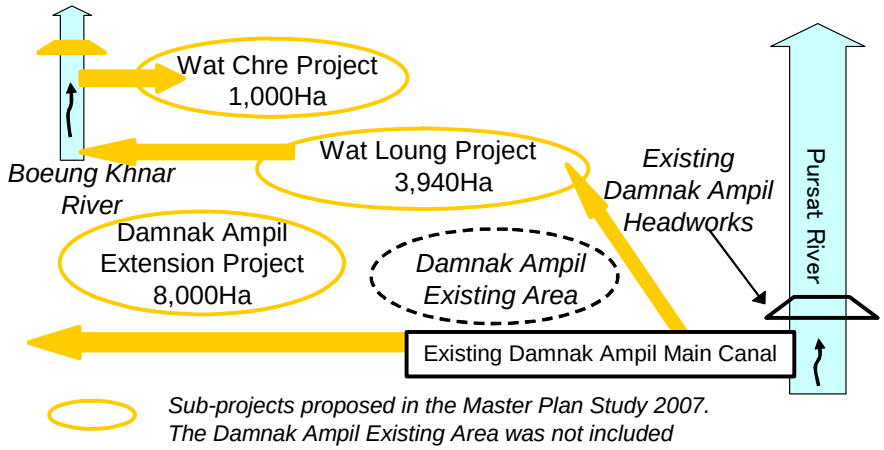
Irrigation Potential Areas by Damnak Ampil Headworks

(2) Revision of Components in Sub-projects

1) 3 Sub-projects proposed by Master Plan 2007



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3 Sub-projects proposed in the Master Plan Study 2007

In the Master Plan Study 2007, the above 3 Sub-projects, which were proposed to be irrigated by the existing Damnak Ampil weir and intake (herein after called as the Damnak Ampil Headworks) in the Pursat River Basin. In this proposed plan, existing Damnak Ampil Main Canal was also proposed to be expanded in order to irrigate the Damnak Ampil Extension Sub-project (herein after called as the Extension Sub-project) that would cover 8,000 ha in the downstream of the existing Main Canal.

2) 1st Revision of irrigation areas of Sub-projects in Pre-Feasibility Study (Pursat River Basin)

The irrigation area of the Sub-projects is delineated in accordance with present land use, topography, existing facilities, etc., and based on the concept described in section 4.2, and measured and revised by the present Pre-Feasibility study as summarized in the following table:

Revised irrigation area of three Sub-projects in the Pursat River Basin

Item	Extension Sub-project	Wat Loung Rehabilitation Sub-project	Wat Chre Rehabilitation Sub-project
Area in M/P (ha)	8,000	3,940	1,000
Revised area in Pre-F/S (ha)	7,650	2,540	1,020
Balance (ha)	-350	-1,400	+20
Reason	Measured by using ortho-photographs (1 to 10,000)	Measured by using ortho-photographs (1 to 10,000); Bakan and Krouchi Seuchi Irrigation Areas are excluded due to high ground surface elevation. These areas can be irrigated by the secondary canal from the Extension Sub-project area.	Measured by using ortho-photographs (1 to 10,000)

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The area of Extension Sub-project is measured and revised to be 7,650 ha by information obtained from ortho-photographs and field survey in the Pre-Feasibility study. Further, the following systems are found and considered to be irrigated from the Extension Sub-project taking into account the topography.

- Bakan and Krouchi Seuchi Irrigation Systems: 1,000ha (as described in the above table)
- Eight irrigation systems in Svay Don Keo River Basin: 2,200ha

3) Present condition of the Existing irrigation area

There is the existing irrigation area located between Damnak Ampil Headworks and the Extension Sub-project. The area for the existing system is to be measured at 2,270 ha by using ortho-photographs. In the Master Plan 2007, the existing area was excluded from the Extension Sub-project since the area was considered already developed in 2006. However, based on the field survey in the Pre-F/S study, it was found that the irrigation activity in the existing area is performed in the very limited part due to the following reasons:

- There are three secondary canals but not functioning, need rehabilitation, however, PDOWRAM does not have a plan to rehabilitate these canals in near future
- A FWUC was established but not registered nor active due to few irrigation water supply due to malfunction of the flood gates of the Headworks
- Farmers in the existing irrigation area do not have experience of irrigated agriculture except those along the main canal

In summary, the development in the existing area still requires the rehabilitation of facilities and soft components such as agricultural extension service and FWUC

4) Flow capacity analyses on existing Main Canal

The existing Main Canal is expected to cover the existing irrigation area and the extension area, and other areas in the Svay Don Keo River Basin. The flow capacity of the existing Main Canal for the existing irrigation area as well as in case of expansion is calculated. The results are summarized as follows accompanied with possible measures to increase the flow capacity.

Comparison of flow capacity increase by canal type and canal base width

Description	Case-1 (Existing)	Case-2	Case-3	Case-4
Canal type	Earth	Concrete lined	Earth	Concrete lined
Canal base width (m)	7.0	7.0	11.0	11.0
Roughness coefficient for Manning's formula	0.027	0.015	0.027	0.015
Canal bed slope	0.0002 (1/5000)			
Water depth (m)	1.5			
Canal inner slope	1 : 1.5			
Velocity (m/sec)	0.57	1.02	0.60	1.08
Flow capacity (m^3/sec)	8.0	14.3	12.0	21.5

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Based on the above result, the Main Canal in the existing area does not have enough capacity to supply irrigation water to the all command areas (14,480 ha + 2,200 ha). The Main Canal and related structures which have been rehabilitated in 2006 has to be enlarged further in order to develop the Extension Sub-project.

5) Final Revision of irrigation areas of Sub-projects in Pre-Feasibility Study (Pursat River Basin)

Due to the following expected difficulties, by developing the Extension Sub-project first without improvement of the current situation of the Existing area, it is proposed to replace the Extension Sub-project by Rehabilitation Sub-project; i.e., the rehabilitation of the existing area is proposed as the first phase, then the development of the extension area would be planned and carried out based on the performance and outputs of the first phase.

- The main canal and structures which have been constructed in 2006 shall be enlarged or improved again in order to convey water to the Extension Sub-project area.
- If the rehabilitation and soft components would not be executed in the existing area, the whole irrigation area under the Damnak Ampil Headworks may not perform effectively.
- The total area of the "existing" and the "extension" sums up to 14,480 ha. Since the "existing area" is not fully developed, simultaneous implementation of both areas with on-farm development, water management and agricultural extension seems to be overloaded.

Finally, in this Pre-Feasibility Study, the first phase of the development plan in the Pursat River Basin is formulated as follows:

- Damank Ampil Rehabilitation Sub-project: 2,270 ha
- Wat Loung Rehabilitation Sub-project: 2,540 ha
- Wat Chre Rehabilitation Sub-project: 1,020 ha

The irrigation water to all the above Sub-projects is supplied by Damnak Ampil Headworks. The reason and water supply route are described in detail in the following sections.

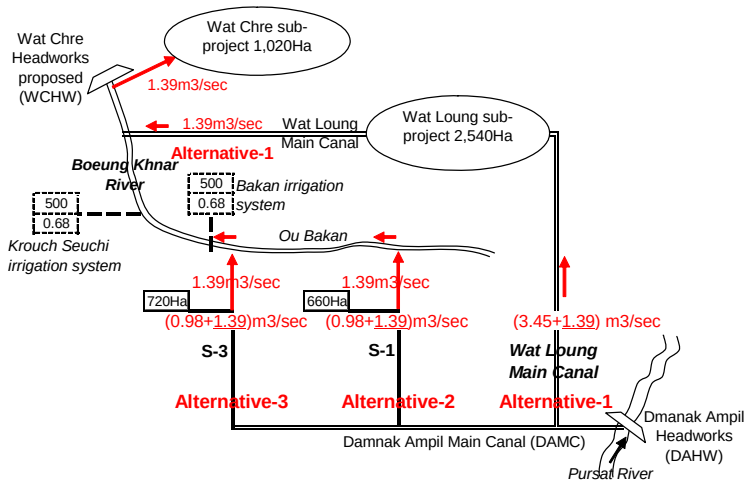
(3) Water Supply Plan to Wat Loung Rehabilitation Sub-project

The use of the existing Damnak Ampil Headworks is considered the most economical measure to supply irrigation water from Pursat River to the Wat Loung Sub-project The reasons are:

- The existing headworks for the Wat Loung Sub-project was completely washed away. Reconstruction is required. The size of the new headworks will be the same or more than the existing Damnak Ampil Headworks since the location of new headworks is about 5km downstream of the Pursat River of which the river cross section is wider than that at the existing Damnak Ampil Headworks.
- The Damnak Ampil Headworks is located only 4.5km upstream of the Wat Loung Sub-project; irrigation water supply from Damnak Ampil Headworks is more economical than reconstruction of a headworks in the Pursat River.
- The existing Damanak Ampil Headworks and Main Canal have enough capacity (8.0m^3/sec) to carry water for Wat Loung and Wat Chre Sub-projects.

(4) Water Conveyance Plan from Damnak Ampil Headworks to Wat Chre Headworks

The command area of Wat Chre Rehabilitation Sub-project is located 1.5km north from National Road No. 5 along the Boeung Khnar River which is the water source of the Sub-project. The river does not have stable runoff due to (i) its catchment area is relatively small (180km^2 approx.) and is located in the plain area in which rainfalls are not much, (ii) the most of its runoff is drainage water from Damank Ampil Rehabilitation Sub-project area.



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Plans for water supply to Wat Chre Sub-project

The irrigation water for Wat Chre Rehabilitation Sub-project is to be supplied from Pursat River which has abundant water. Since the Sub-project area is more than 20 km far from Damnak Ampil Headworks (DAHW) in a beeline, the water taken at DAHW is to be conveyed by canals and the Boeung Khnar River upto Wat Chre Headworks proposed

(WCHW). A few alternatives are studied to determine the water conveyance plan to the Sub-project as shown in the above figure and following table.

Alternative study of irrigation water supply from Damnak Ampil Weir to Wat Chre Rehabilitation Sub-project

Description	Alternative-1	Alternative-2	Alternative-3
Discharge to be conveyed	1.39 m3/sec	1.39 m3/sec	1.39 m3/sec
Conveyance route	DAHW→ DAMC→ Wat Loung Main Canal→ Boeung Khnar River	DAHW→ DAMC→ DA Secondary Canal-1→ Boeung Khnar River	DAHW→ DAMC→ DA Secondary Canal-3→ Boeung Khnar River
Total length of canals to be used for conveyance	DAMC= 0.8km Wat Loung Main Canal= 20.3 km Total=21.1 km	DAMC= 3.1km DA Secondary Canal-1= 5.2 km Total= 8.3km	DAMC= 6.3km DA Secondary Canal-3= 8.4 km Total=14.7 km
Length of Boeung Khnar River up to WCHW	9.0 km	36.0 km	26.0 km
Total distance of the conveyance	30.3 km Shortest	44.3km Longest distance	40.7km 2nd shortest
Flow capacity of the conveyance canals	- Wat Loung Main Canal needs to increase capacity from 3.45 m^3/sec to 4.84 (140%)	- DA Secondary Canal-1 needs to increase capacity from 1.07 m^3/sec to 2.46 (230%)	- DA Secondary Canal-3 needs to increase capacity from 0.98 m^3/sec to 2.37 (240%)
Necessity of additional land acquisition	- Existing Wat Loung Main Canal has enough right-of-way for 4.84 m^3/sec, no land acquisition is required	Additional land acquisition is required for DA Secondary Canal-1	- Additional land acquisition is required for DA Secondary Canal-3
Necessity of water route improvement of Boeung Khnar	Not necessary, water route is clear.	Necessary for 27km due to unclear water route	Necessary for 17km due to unclear water route
Possibility of unauthorized water-taking in the Boeung Khnar River before WCHW	No irrigation system exists between confluence and WCHW; no unauthorized water-taking is anticipated.	- Two irrigation systems exist (Bakan and Krouch Seuchi) between canal's joining point and WCHW; unauthorized water-taking is anticipated.	- Two irrigation systems exist (Bakan and Krouch Seuchi) between joining point and WCHW; unauthorized water-taking is anticipated.
Cost for conveyance facilities	Low, because increase of flow capacity of main canal is required only	High, because increase of flow capacity of secondary canal and water route improvement are required	High, because increase of flow capacity of secondary canal and water route improvement are required

Note: DAHW means Damnak Ampil Headworks
DAMC means Damnak Ampil Main Canal
DA means Damnak Ampile
WCHW means Wat Chre Headworks proposed

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As the result of comparison described above, Alternative-1 is selected to convey irrigation water to Wat Chre Rehabilitation Sub-project. Accordingly, Wat Loung Main Canal has to have a flow capacity of 4.84 m^3/sec to convey water for Wat Loung and Wat Chre Rehabilitation Sub-projects, respectively. Wat Loung Main Canal joins with Boeung Khnar River, and supplies 1.39 m^3/sec to the river. The Boeung Khnar River conveys the 1.39 m^3/sec to the Wat Chre Headworks proposed.

5.1.4 Lum Hach Rehabilitation Sub-project in the Boribo River

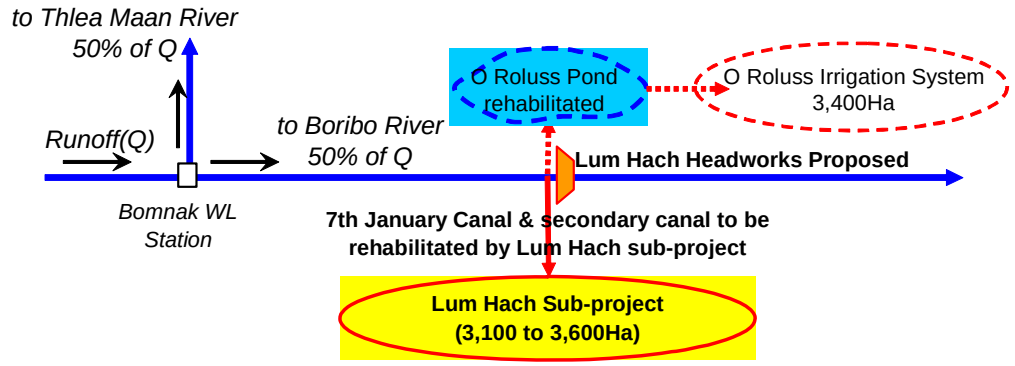
(1) Water Balance Study of the Boribo River Downstream Basin

1) Necessity of water balance study

The most affective factor in determination of Sub-project area is water. The water source of the Sub-projects is the Boribo River. The water balance study is executed in order to estimate irrigable area in the Sub-project by cropping season.

The Boribo river forks off in two directions at Bomnak water level station i.e., the Boribo River to the Kampong Chhnang Province and Thlea Maan River to the Pursat Province. There is an overflow-crest type weir at Bomnak water level station. The weir was constructed by gabion mattress to maintain water level at Bomnak water level station. At present there is no rule for distributing river runoff to two provinces. Two rivers are very important water sources in the two provinces. In the present study, 50 % of river runoff is assumed to flow into the Boribo River by diversion at Bomnak water level station.

2) Water Distribution to the on-going O Roluss Irrigation System



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Irrigation area by Lum Hach Headworks (Total 6,500 - 7,000Ha)

The above figure shows water distribution plan to the Sub-project and O Roluss Irrigation System which is located at left bank of the Boribo River, and has an irrigation area of 3,400 ha. PDOWRAM started rehabilitation of O Roluss Irrigation System which is located at left side of the Boribo River. The irrigation system expects a main water supply from the Boribo River though it has a small pond. The proposed Lum Hach Headworks will be the best water source facility to the system owing to the topographic condition. Accordingly, the water distribution to the O Roluss Irrigation System is to be considered in the water balance study. Accordingly, the irrigation area by the Lum Hach Headworks proposed is to be 6,500 ha in total.

3) Irrigation water requirement

The Sub-project area is determined at 3,100 ha of paddy fields taking into the topography and

present land use based on the ortho-photographs and field survey.

a) Basic conditions

The irrigation water requirement is estimated by a similar procedure to that used in the Master Plan Study 2007 based on the proposed cropping pattern described above. The basic condition and figures applied are as follows:

i) Meteorological data; average of mean monthly data at Pochentong International Airport in Phnom Penh
ii) Percolation rate 3.0 mm/day based on the observed data
iii) Rainfall data; Daily rainfall data at Boeung Kantout and Bamnak stations
iv) Paddy is cultivated by transplanting method in all over Sub-project area
v) Irrigation efficiency in the tertiary unit= 85 %
vi) In the secondary canal and main canal= 88 %, respectively
vii) Overall efficiency= 85 × 88 × 88 % = 65.8 % = 66 %

b) Irrigation water requirement for tertiary and field canals

The peak water requirement is figured out at 2.40 lit/sec/ha for Early Wet Season Paddy in April including irrigation efficiency of 85% at tertiary level.

c) Diversion water requirement for headworks, main canal, and secondary/sub-secondary canals

The peak diversion water requirement in the Sub-project as a whole is figured out at 2.13 lit/sec/ha by Wet Season Paddy in July taking into account the overall irrigation efficiency of 66%.

4) Water balance calculation

The possible irrigation area by Lum Hach Headworks is studied by changing high water level at the Headworks. The fluctuation of water volume in the upstream of Headworks was estimated by comparing inflow and water requirements i.e., irrigation water requirement as well as the water demands for domestic and industrial use, river maintenance flow within the river basin, respectively. These water requirements which were used in the Master Plan Study in 2007 are also used in the present study.

Based on the result of calculation, relationship between several high water levels at Lum Hach Headworks and potential irrigable areas were obtained by cropping seasons. The Wet Season Paddy can be irrigated in all the Sub-project area. On the contrary, the Early Wet Season Paddy and Dry Season Paddy vary depending on the seasonal water availability at the Headworks, respectively. Accordingly, combinations of the total annual irrigable areas vary depending on high water levels. Therefore, an incremental paddy production is calculated for each potential irrigable area combination for comparison.

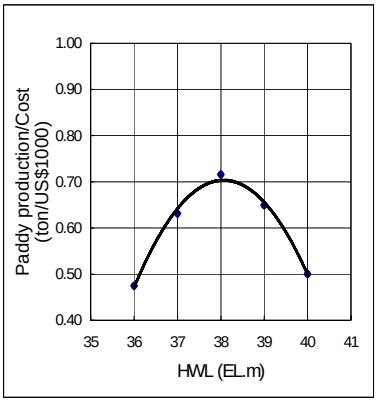
5) Comparative study

Comparative study is conducted for the Sub-project by changing design irrigation high water levels at Headworks to estimate the total costs (construction costs, land acquisition costs in the

storage area, production costs) and benefits. Then for each case, the incremental paddy production (ton) is divided by the total costs (US$), and compared as shown below.

Case study of Water Level of Lum Hach Headworks

Description	Case				
	1-1	1-2	1-3	1-4	1-5
HWL (EL.m)	36.0	37.0	38.0	39.0	40.0
LWL (EL.m)	36.0	36.0	36.0	36.0	36.0
Eff. Storage (MCM)	0.00	0.45	1.24	2.46	6.37
Development area (Ha)	3,100	3,100	3,100	3,100	3,100
Irrigable area - Early wet season (ha)	500	1,200	1,600	1,900	2,800
- Wet season (ha)	3,100	3,100	3,100	3,100	3,100
- Dry season (ha)	0	100	300	500	900
Annual irrigation area (Ha)	3,600	4,400	5,000	5,500	6,800
Annual paddy production (ton)	10,800	13,200	15,000	16,500	20,400
Incremental production (ton)	6,716	9,116	10,916	12,416	16,316
Cost - Headworks (10^3US$)	4,813	5,077	5,869	9,486	22,791
- Canals & drains*1 (10^3US$)	9,326	9,326	9,326	9,326	9,326
- Land acquistion for pond (10^3US$)	14.5	36.5	57.5	306.0	486.0
Total Cost (10^3US$)	14,154	14,440	15,253	19,118	32,603
Paddy production?Cost (ton/US$$10^3$)	0.47	0.63	0.72	0.65	0.50



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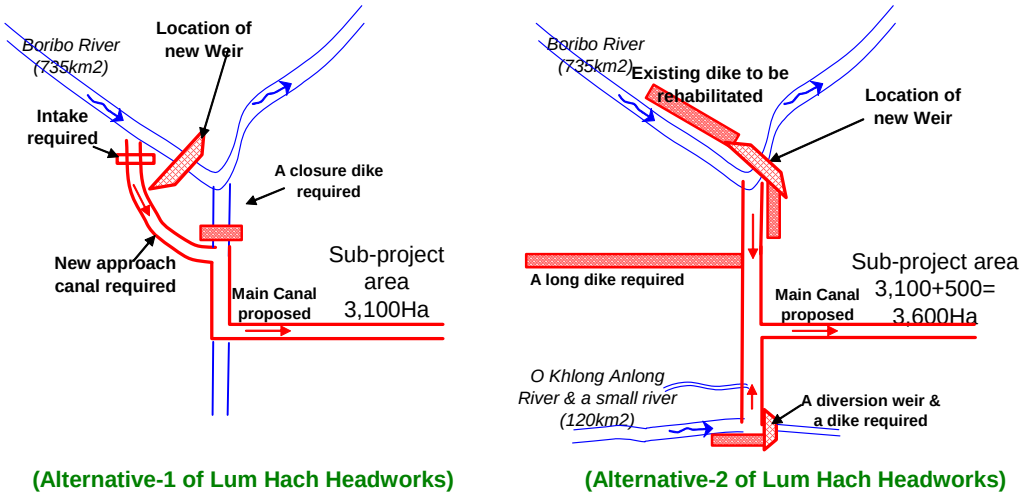
Water Level and Incremental Paddy Production per Construction Cost

As a result, the design irrigation high water level at EL. 38.0m gives the largest incremental production per cost, and is the most economical (Case 1-3). Therefore, construction of Headworks at upstream site at a design irrigation high water level at EL. 38.0m is proposed for the Sub-project. Accordingly, the command area is determined at 3,100 ha, and the seasonal cropping areas are estimated at 1,600 ha, 3,100 ha and 300 ha for Early wet season paddy, Wet season paddy, and Dry season paddy, respectively.

(2) Alternative Study of Headworks Site

The Sub-project requires a headworks on the Boribo River, and this headworks is tentatively called as Lum Hach Headworks.



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Concept of Alternative Sites

The above figure shows two alternative construction sites for the Lum Hach Headworks.

These alternatives are conceived taking into account the topography, the potential irrigable area by the Sub-project, the existing and newly required facilities, etc.

Alternative-1: Located at upstream where the Boribo River is narrow

Alternative-2: Located at about 500m downstream from Alternative-1, near the previous weir site.

1) Engineering comparison of alternative sites

The two alternatives are compared and evaluated qualitatively from engineering point of view as follows:

Comparison of alternative sites

Item	Alternative-1	Alternative-2
Location:	Upstream	Downstream, very near the previous washed-away headworks site
Topography:	River is straight and narrow, River bed EL.33.7m approx.	The river is wide, and curves at just upstream of the site, - River bed EL.29.7m approx.,
Development area in ha	3,100 ha	3,600 ha because 500ha of irrigation area is now irrigated by Khlong Anlong river.
Merit:	River course will be stable.	Water in the O Khlong Anlong river and other stream (120km^2) can be used for irrigation, Sub-project area increases by 500ha.
Demerit:		- The erosion will cluster on one side of the Boribo river due to the curve, resulting in less stability of the headworks, - The water flows alternately resulting in difficulty of water management
Engineering evaluation:	Preferable for headworks	Less preferable from engineering view point,

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2) Cost and benefit comparison

The major structures required are listed for each alternative as follows:

Major structures of alternatives

Item	Alternative-1	Alternative-2
Major structures required	- Flood discharge 430m^3/sec, - HWL = EL.38.0m, LWL = EL.36.0m - Weir (h=5m approx.), - Intake on the Boribo river, - Approach canal 0.75km, - Closure dike on 7th January Canal, - Rehabilitation of 7th January Canal 3.5km	- Flood discharge 430m^3/sec, - HWL = EL.38.0m, LWL = EL.36.0m - Weir (h=9m approx.), - 3 dikes about 5km in total along the Boribo river, - Rehabilitation of 7th January Canal 7.3km, - Weir and dike on the Khlong Anlong river

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The irrigable area in each cropping season is calculated with comparison of 5-day daily mean discharge at the headworks site and water requirements such as irrigation, domestic, maintenance flow, etc.

The construction cost and benefit are estimated for comparison as shown below:

Cost and Benefit of Alternatives

Item	Unit	Alternative-1	Alternative-2
Development Area	ha	3,100	3,600
Irrigable area in Early wet season	ha	1,600	1,600
Irrigable area in Wet season	ha	3,100	3,600
Irrigable area in Dry season	ha	300	400
Annual irrigation area	ha	5,000	5,600
Annual paddy production	Ton	15,000	16,800
Incremental production	Ton	10,916	12,057
Construction cost - Headworks	10^3US$	5,869	9,346
- Canals & drains	10^3US$	9,326	9,686
- Total cost	10^3US$	15195	20,166
Incremental paddy production／Cost	ton/US$	0.72	0.60

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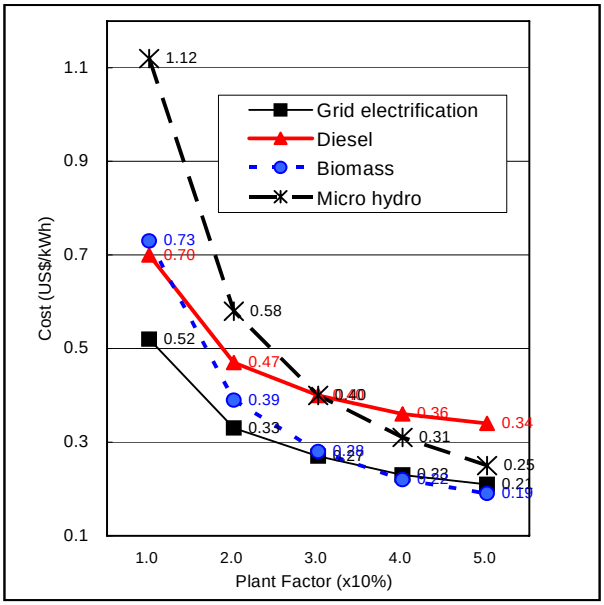
As shown in the above table, the incremental production of paddy per construction cost is higher in Alternative-1 than in Alternative-2. Further, the site of Alternative-1 is more stable and preferable from the civil engineering view point. Therefore, the Alternative-1 is selected with a target area of 3,100 ha.

(3) Power Source of Gates of the Lum Hach Headworks

The construction cost of the headworks remarkably increases if the design irrigation high water level exceeds EL.38.0m, due to a flat topography of the headworks site. Accordingly movable flood gates are recommended rather than an overflow crest type weir to keep the flood water level lower than EL.38.0m. Since the water depth at the flood gates is nearly 4m, the gates are to be operated by electric power. The power requirement for a single gate leaf operation is assumed to be about 7.5kW for flood gate with counterweights.

A possible electric power source for the gate operation is considered as follows for the Lum Hach Headworks:

- Grid electrification
- Diesel generator
- Micro-hydro power using flood water in the river



Plant Factor and Unit Costs of Electricity at the Consumer End

Source: Extracted from Final Report Master Plan Study on Rural Electrification by Renewable Energy in the Kingdom of Cambodia, JICA

The above figure shows unit costs for electricity at the consumer's end with its plant factor prepared by the "Final Report Master Plan Study on Rural Electrification by Renewable

Energy in the Kingdom of Cambodia, JICA". The plant factor is read as a ratio of the actual power generation and the possible power generation at one power plant. Grid electrification is the cheapest and the diesel generation becomes the second cheapest when the plant factor is lower than 10%.

Since the Lum Hach Headworks is located far from grid electrification, thus is not feasible. The annual operation hours of the movable gates will be far less than 10% of annual hours (365days=8,760hrs/year), because the flood gates are operated at flood time only, and the other gates such for scouring sluice and intake are operated periodically but daily base.

Based on the above consideration, the diesel generator is the most feasible power source for gate operation at the Lum Hach Headworks.

5.2 Ream Kon Rehabilitation Sub-project

5.2.1 Crop Production Plan

(1) Land Use Plan

The land use plan for the Ream Kon Rehabilitation Sub-project under the with-project condition is presented in comparison with the present/without-project land use as follows;

Present/Without-project & With-project Land Use of the Ream Kon Sub-project Area

Land Use Sub-category	Present		With-project		Increment
	(ha)	(%)	(ha)	(%)	(ha)
Paddy Field					
- Normal Irrigation Paddy Field			1,890	100	1,890
- Supplemental Irrigation Paddy Field	50	2			- 50
- Rainfed Paddy Field	1,970	98			- 1,970
Sub-total	2,020	100	1,890	100	- 130
Right-of-ways	150	7	280	13	130
Total	2,170	100	2,170	100	0

Prepared by JICA Study Team

The development of 1,890 ha of normal irrigation paddy field is aimed at under the Sub-project by the conversion of 50 ha of supplemental irrigation fields and 1,970 ha of rainfed fields. The decease of paddy fields due to land use conversion to right-of-ways is estimated at 130 ha.

(2) Proposed Cropping Pattern and Cropped Area

1) Crop Selection of Ream Kon Rehabilitation Sub-project

The crop selection under the present plan has been made based on the development concept discussed earlier as follows;

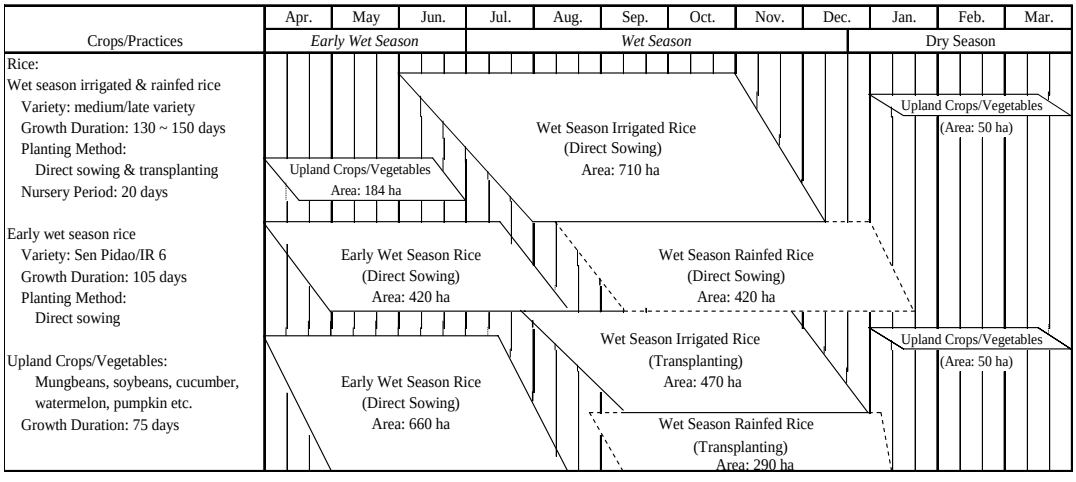
- Rice, current exclusive crop in the main cropping season, wet season, is selected as a crop to be introduced in the season as no other promising crops are conceivable and rice is a by far the most important crop and stable food in the area. Cultivation of local varieties with good quality and preferred by farming communities in the subject area or improved local

varieties is to be practiced,

- Introduction of irrigated upland crops/vegetables production in early wet and dry season aiming at: i) increasing land use intensity in paddy fields, ii) crop diversification, iii) sufficing family consumption and improvement of nutritional status of farm families by introducing pulses and iv) increasing farm income,
- Introduction of early rice in the early wet season under direct sowing as is currently practiced in the area for utilizing rainfall and irrigation water resource available in the season, and
- Candidate upland crops could include mungbeans, soybeans and corn and the same of vegetables include cucumber, water melon, pumpkin and gourd currently cultivated in and around the Sub-project area. Production of beans are selected partly aiming at sufficing domestic consumption, improving nutritional status of farm families and ameliorating soil conditions by cultivation of leguminous crops in addition to the crop diversification as discussed earlier. The current price increase of grains may justify the introduction of such crops under irrigation. However, farming practices or cultivation methods of upland crops/vegetables in paddy fields under irrigation are yet to be developed, verified and demonstrated in farmers fields. For the successful introduction of the crops, intensified extension activities should be accommodated as an essential component of the Sub-project.

2) Cropping Pattern and Cropped Area

Based on the study on the current prevailing cropping patterns, the development concept discussed earlier and the results of irrigation water balance study, the proposed cropping pattern for Ream Kon Rehabilitation Sub-project has been formulated as follows:



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Proposed Cropping Pattern: Ream Kon Sub-project

The cropping intensity targeted under the plan is as follows;

- Rice cropping intensity of 100% in wet season is planned in the pattern by assuming that rice cultivation under rainfed conditions will be carried out as is currently practiced in

non-irrigated fields (because of limitation in irrigation water supply) in the season (intensity of irrigated rice 62% & the same of rainfed rice 38%),

- Intensity of rice in the early wet season is targeted at 57%. In addition, the intensity of 10% of upland crops/vegetables under irrigation is envisaged to promote crop diversification in the Sub-project area, and
- In dry season, upland crops/vegetables cultivation under irrigation to the extent of 100 ha is planned.

The planned cropped areas and cropping intensity envisaged in the pattern are shown in Table 5.2-1 and summarized as shown in the following table.

Planned Cropped Area & Cropping Intensity under the Ream Kon Sub-project

Unit: ha & %

Crop	Cropping Season							
	Early Wet Season		Wet Season		Dry Season		Annual	
	Area	Intensity	Area	Intensity	Area	Intensity	Area	Intensity
Irrigated Rice	1,080	57	1,180	62			2,260	119
Irrigated Rice (direct sowing)	1,080	57	710	37.5			1,790	94.7
Irrigated Rice (transplanting)			470	24.9			470	24.9
Rainfed Rice			710	38			710	38
Rainfed Rice (direct sowing)			420	22.2			420	22.2
Rainfed Rice (transplanting)			290	15.3			290	15.3
Rice Total	1,080	57	1,890	100	0	0	2,970	157
Upland Crops/Vegetables	184	10			100	5	284	15
Total	1,264	67	1,890	100	100	5	3,254	172

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(3) Target Crop Yields

The target crop yields for Ream Kon Rehabilitation Sub-project under the present plan in which normal irrigation is ensured are studied based on the current yield levels at normal (full) irrigation areas and the results of the Pilot Project carried out under the Study on Comprehensive Agricultural Development in Prek Thnot River Basin, JICA and are set as shown in the following table in comparison with the present yield levels.

Target Yields and Present Yield Levels of Paddy for Ream Kon Sub-project (Unit: ton/ha)

Wet Season				Early Wet/Dry Season			
Crop 1/	**Target**	**Present**	**Increment**	**Crop 1/**	**Target**	**Present**	**Increment**
Improvement of Irrigation Status: Present: Supplemental Irrigation ⇒ With-project: Normal Irrigation 2/							
Medium Rice (T)	3.5	2.2	1.3	Early Rice (D)	3.0	2.5	0.5
Medium Rice (D)	2.8	1.5	1.3	Upland Crops 3/	1.0	-	-
Improvement of Irrigation Status: Present: Rainfed ⇒ With-project: Normal Irrigation 2/							
Medium Rice (T)	3.5	1.7	1.8	Early Rice (D)	3.0	2.5	0.5
Medium Rice (D)	2.8	1.0	1.8	Upland Crops 3/	1.0	-	-

1/: T --- transplanting; D --- direct sowing 2/: Including pump irrigation fields

3/: Upland crops: average of mungbeans & soybeans

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Yield increases of 1.3 to 1.8 ton/ha in wet season rice and 0.5 ton/ha in early wet season rice are envisaged under the plan. The target yields of irrigated upland crops and vegetables are set rather conservatively as follows;

Target Yields of Upland Crops/Vegetables of Ream Kon Sub-project

Crops	Target Yield	Crops	Target Yield
Mungbeans 1/	0.9 ton/ha	Watermelon	9.0 ton/ha
Soybeans	1.1 ton/ha	Cucumber	10.0 ton/ha

1/: Current yield level of mungbeans in the area is 0.5 ton/ha under rainfed

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(4) Crop Production Plan

The crop production plan for the Ream Kon Rehabilitation Sub-project under the with-project condition is presented in comparison with the present/without-project crop production in Table 5.2-1 and summarized as follows;

Present & With-project Crop Production of the Rem Kon Rehabilitation Sub-project Area

Land Use Sub-category/Crops		Cropped Area (ha)	Intensity (%)	Yield (t/ha)	Production (t)
I. Present/Without-project Crop Production					
Supplemental Irrigation Paddy Field: Rice		100	5	2.1	214
Rainfed Paddy Field: Wet Season Rice		2,120	105	1.4	2,897
Annual	Rice	2,220	110	1.4	3,111
	Upland Crops (mungbeans)	10	0.5	0.5	5
II. With-project Crop Production					
Normal Irrigation Paddy Field: Rice		2,260	120	3.0	6,873
Rainfed Rice 1/		710	38	1.3	913
Annual	Rice	2,970	157	2.6	7,786
	Upland Crops/Vegetables 2/	284	15	-	1,015
Increment (II – I)					
Annual	Rice	750	47	1.2	4,675
	Upland Crops/Vegetables	274	15	-	1,010

1/: Cultivation of wet season rice under rainfed conditions due to limitation of irrigation water supply

2/: Total of upland crops & vegetables, represented by mungbeans, soybeans, watermelon & cucumber.

Note: Rice figures are total of wet & early wet season rice and direct sowing & transplanting rice

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As shown in the table, the increase of overall average paddy yield of 1.2 ton/ha from 1.4 to 2.6 ton/ha and annual paddy production increase of some 4,700 tons are expected. The paddy production under the Sub-project is about 250% of the current production level in the area. Under the Sub-project, the expansion of upland crops/vegetables production is envisaged and the production volume of the crops is estimated to be 1,015 tons, increase of about 1,000 tons from the present level. Successful introduction of the crops through the proposed extension activities will further expand the cultivation of the crops in the area in the future.

(5) Proposed Farming Practices of Ream Kon Rehabilitation Sub-project

Proposed improved farming practices of paddy to be adopted are: i) proper land leveling & preparation, ii) use of quality seed and adequate seeding rate, iii) raised nursery bed, planting of younger seedling, regular planting and reduced no. of plants per hill (in transplanting), iv) fertilization (increased & timely application including compost or cow dung), v) introduction of proper on-farm water management & water saving culture, vi) intensified weeding and vii) improvement of post-harvesting practices.

5.2.2 Agricultural Extension Activities

Under the Sub-project, the substantial increases of yields and annual cropping intensity of paddy and the introduction of irrigated upland crops/vegetables production are envisaged, which dictates the introduction of intensified extension activities in the area. The proposed activities are development interventions aiming at strengthening of agricultural extension services for attaining the Sub-project targets of crop yields and cropping pattern at an earlier stage as possible. The estimated costs for the activities accommodated as Sub-project component are summarized in the following table.

Estimated Costs for Agricultural Extension Activities for Ream Kon Sub-project [1/]

Activity	Estimated Cost (US$)
Field Extension Programs	69,200
Farmer/Farmer Group Training Programs	19,600
Mass Guidance/Workshop	1,600
Support Fund for Extension Staff 2/	21,760
Staff Empowerment	4,000
Provision of Transportation Means	4,200
Total	120,360

1/: Program direct costs
2/: Provision of support for VAA (village Agriculture Extension Agent) & field staff

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Major extension activities include field programs (adaptability test, demonstration plot, farm & area, upland crops/rice seed multiplication), farmer & farmer group training programs (training course, FFS/IPM, study tour), mass guidance/workshop, staff empowerment, support fund for extension staffs and provision of transportation means.[1]

The implementation of the activities is scheduled for the period of 4 years in the Sub-project and the overall cost is estimated at US$ 120,000.-.

5.2.3 Irrigation and Drainage Plan

(1) Headworks of Ream Kon Rehabilitation Sub-project

The existing headworks is to be reconstructed due to its severely damaged condition, i.e., cracks, corrosion and insufficiency of reinforcing bars in reinforced concrete which directly affect strength of the structure, no function of gates. The design intake water level and diversion water requirement are proposed at EL. 15.50m and 2.66 m^3/sec, respectively as described in the following section.

The new headworks, tentatively called as the Moung Russei Headworks, is to be constructed at the existing site so that the existing diversion channel can be used for temporary diversion work during construction period so that the cost for temporary work is reduced. The Moung Russei Headworks has a diversion weir and two intakes for the Ream Kon and the Por Canal Rehabilitation Sub-projects, respectively.

[1] Mass guidance aims to disseminate basic farming skills to farmers by organizing training programs targeting 60-70 nos. of farmers in each program. On the other hand, farmer group training is to train farmers to be core farmers in each sub-FWUG to accelerate TOT approach, with 10-20 farmers at each program.

(2) Canal Layout

The proposed irrigation canal layout is made in accordance with concept and approach described in Chapter 4.2, and is shown in Figure 5.2-1. Two main canals are proposed to irrigate low elevated area and high elevated area, respectively. General features are summarizes in Table 5.2-2. The irrigation area diagram is shown in Figure 5.2-2.

(3) Irrigation Area by Portable Pump

The southern part of the Sub-project area which covers about 280 ha is to be irrigated by portable pump by farmers in order to reduce construction cost of Main Canal.

(4) Drainage Plan

The excess water in and around the Sub-project area is proposed to be drained by gravity to outer area. Field drains collect water from paddy fields and other type of land, and flow into tertiary drains. Tertiary drains flow into secondary or main drains in accordance with topography, then finally the secondary drains and main drains flow into the flood plain of the Lake Tonle Sap. The existing rivers and streams are used as secondary and main drains in order to lower the construction cost.

In order to protect the Sub-project area from flood from surrounding areas, drainage plan with collector drains (CD) is made as follows:

i) Collector Drain-1 (CD-1) is proposed to intercept the drainage water from southern area; it flows along southern border, then turns to northward crossing middle of the Sub-project area, and finally joins with Moung Russei River.
ii) The drainage water from Anlong Koub Irrigation area is collected by proposed Collector Drain-2 (CD-2) which flows toward and along the western border of the Sub-project area; then turns eastward along its northern border and finally joins with the Moung Russei River.
iii) The drainage water from southeastern area is collected by proposed Collector Drain-3 (CD-3) which also flows southern border of the Sub-project area, and turns to northward and finally joins with the Moung Russei River.
iv) During construction period of the headworks, the existing river diversion channel which branches from Moung Russei River at the upstream of the existing headworks and CD-2 are used as the temporary diversion channel, to lower the cost for temporary works. A side channel overflow type spillway is proposed to divert the river water to the channel, and CD-2 will be excavated in prior to the construction of the headworks.

The general feature of drainage plan is summarized in Table 5.2-2. The drainage diagram is presented in Figure 5.2-3.

(5) Drainage Water Requirement

1) Drainage water requirement from paddy field

The unit drainage water requirement, q (lit/sec/ha), from paddy field for the Ream Kon Rehabilitation Sub-project is calculated at 7.17 lit/sec/ha, based on the annual maximum rainfall in 3 consecutive days at one in 5 years return period.

$$q = 0.186 \times 10{,}000 \div (3 \times 86400) \times 1000 = 7.17$$

where, 0.186 is a probable 3 consecutive days rainfall at Moung Russey station

2) Drainage water requirement from other type of land

The Sub-project area consists of paddy field and other types of land, such as house yard, upland, right of way of irrigation canals, etc. Those lands are located adjacent to the paddy field, and are assumed to be 15% of the paddy field. Those lands do not have storage function as paddy field, thus runoff characteristics from those lands are different from that of paddy field. The unit drainage water requirement for those lands is calculated by the rational formula based on the annual maximum one day rainfall at one in 5 years return period (122 mm/day).

The calculated results of unit drainage water requirement for the other types of land with area less than 100 ha and more than 100 ha are as follows:

Qpeak = $0.25 m^3$/sec/ha from the area less than 100 ha

Qpeak = $0.19 m^3$/sec/ha from the area more than 100 ha

The above unit drainage water requirement is applied to drainage canals and collector drains shown in Figure 5.2-3.

5.2.4 Rehabilitation and Improvement of Headworks and Major Related Structures

The facilities of the Sub-project are divided into 3 categories, and discussed and explained as follows; headworks (diversion weir and intake(s)) and major related structures, in section 5.2.4, main and secondary systems (irrigation and drainage canals) in section 5.2.5, on-farm development (tertiary systems) in section 5.2.6, respectively.

(1) Components

The Moung Russei Headworks is planned to supply irrigation water to mainly two Sub-project areas; Ream kon (1,890 ha) and Por Canal (1,940 ha), respectively. Therefore, Moung Russei Headworks consists of the following components.

1) Reconstruction of Moung Russei Diversion Weir

It is proposed to re-construct Moung Russei Diversion Weir for Headworks at the same location of the existing weir, mainly due to the following viewpoints:

i) Deterioration of structure

ii) Low safety against flood due to high gate sill elevation and rather narrow spacing of the gates/piers (refer to the section 3.2.2(2)-4))

2) Reconstruction of Ream Kon Intake

It is proposed to re-construct the Ream Kon Intake at the same location of the existing intake, mainly due to the severe deterioration of concrete structure.

3) Reconstruction of Por Canal Intake (refer to Section 5.3.3)

It is proposed to re-construct the Por Canal Intake at the same location of the existing intake, mainly due to the severe deterioration of structure concrete.

4) Rehabilitation of Collector Drain-2 (CD-2)

The collector drain is proposed to protect villages along the Moung Russei river (refer to Figure 5.2-1). The CD-2, however, is to be used as a temporary river diversion channel during construction period Therefore, CD-2 should be rehabilitated (excavated) first, in prior to the construction of headworks.

5) Emergency spillway structure at the inlet of CD-2

An overflow crest type spillway structure is proposed at the entrance of CD-2 just in the upstream of the Moung Russei Diversion Weir.

6) Drainage gate at the outlet of CD-2

An outlet gate is proposed to prevent inflow of water from Moung Russei River to CD-2 when the water level in the Lake Tonle Sap is high.

7) Additional embankment of river bank

Between the Moung Russei Headworks and the bridge on the National Road No.5, additional embankment of river bank ranging from 0.5m to 1.0m as well as additional excavation of river course is proposed to deal with the design flood water level of around EL.17.0m - 17.8m.

The schematic diagram of the above components is illustrated in Figure 5.2-4.

(2) Design Condition for Moung Russei Headworks

Design condition for proposed Moung Russei Headworks is summarized as follows:

Summary of Proposed Design Condition for Moung Russei Headworks

Design Parameter	Condition	Remarks
Design Flood Discharge Q_F:	180 m^3/sec	Close to T=100 year return period
Design Flood Water Level WL_F1:	WL. 17.2m	At Weir site
Design Flood Water Level WL_F2:	WL. 17.82m	At National Road No.5 (180 m^3/s)
Design River Bank Elevation	EL. 18.00m	Between/ Weir site and National Road No.5
Design Irrigation Water Level WL1:	WL. 15.50m	Top of Gate. Allowable overflow h=0.20m
Design River bed Elevation (Upstream):	EL. 11.70m	
Design River bed Elevation (Downstream):	EL. 11.70m	
Design Gate Sill Elevation:	EL. 11.70m	
Intake discharge to Ream Kon Sub-project:	2.66 m^3/sec	Peak discharge
Intake discharge to Por Canal Sub-project:	2.74 m^3/sec	Peak discharge
Discharge of fish ladder:	$\geq$0.79 m^3/sec	River maintenance flow for 785km^2

Prepared by JICA Study Team

(3) Preliminary Design of Moung Russei Diversion Weir

1) Summary:

The Moung Russei Diversion Weir is designed based on the existing weirs in Cambodia, criteria in, MOWRAM, Japan and other countries. The major dimension proposed is summarized in the following table and also shown in the schematic diagram in Figure 5.2-5.

Major Dimension of the Moung Russei Diversion Weir

Items	Dimension/Description
Weir Type	Floating Type Movable Weir
Design Water Level	WL1: 15.5m (for Irrigation), WL_F1:17.2m (Flood water level)
Total Clear Width of Weir	ΣB=37.5m
Elevation of gate sill	EL1.= 11.70m
Total Height of Weir	10.9m
Length of Weir incl. riprap	To upstream=25.0m, To downstream=67.0m
Gate type (Flood Gate) and Nos.	Fixed wheel gate, 2 Nos. with counterweight
Gate Dimension	Clear Height H:3.8m, Clear Span B:11.5m
Gate type (Sluice scouring) and Nos.	Slide gate, 1 Nos.
Gate Dimension	H:2.0m, B:2.0m
Bridge	Effective width=3.8m, Total length=40.0m
Fish Ladder	B:5.0m (Half cone type), Δh=3.6m, L=36m

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Major components of the diversion weir is explained hereunder.

2) River Section:

Based on the topographic survey data and result of the uniform flow calculation, the longitudinal section and cross section of the Moung Russei River are proposed to design and rehabilitated as shown below, to deal with the design flood discharge of Q_F=180 m^3/sec. The typical cross section is presented in Figure 5.2-6.

Typical Dimension of River Section of the Moung Russei Diversion Weir

Canal type	Design Discharge (m^3/sec)	River bed width (m)	Bed slope	Inner side slope	Water depth (m)	Free board (m)
Earth, Trapezoidal cross section	180	16.0	1/900	1:2.0	5.4	0.6

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3) Weir Type

Weir type is determined as “floating type” in the preliminary design, due to lack of geological information along the river and the weir site. In addition, movable weir with gate is proposed in order to lower down to an adequate water level along the upstream reach of the river during floods. “Overflow crest type” weir is not appropriate due to the reason explained in the section 3.2.2(2)-4).

4) Gate

a) Gate Type

Five gate types were considered for flood gate; slide gate, fixed wheel gate, flap gate (=automatic gate with steel type and rubber textile type), radial gate. These gate types are compared from technical and economical viewpoints as shown in Table 5.2-3. As a result, fixed wheel type gate is selected for flood gate, in particular for i) its high reliability under influence of downstream back water from the Lake Tonle Sap, as well as ii) its easy operation, since those factors are important for facility management of the Project.

For scouring sluice gate, slide gate is selected, owing to i) its high reliability and ii) relatively small gate size compared to the flood gate, thus it could be operated with lower hoisting load with ease.

b) Span Length and Clear Span of Flood Gate

Span length, clear span and number of gate leaf is first referred to existing large weirs in Cambodia, such as Damnak Ampil, Roleang Chrey and Kandal Steung, and then determined by employing Japanese design criteria for headworks (and the River Control Structural ordinance), coupled with non-uniform flow hydraulic calculations for the design flood (high water) discharge of 180 m^3/sec.

As a result the “two gates with clear span of 11.5m” is selected for Moung Russei Weir .

5) Bridge

A concrete slab bridge is provided over the weir with a total span of about 40m. The elevation of slab bottom is to be EL. 18.2m, by adding a freeboard of 1.0 m to the design flood (high water) level WL_F1=17.2m at weir site. The effective width and total width of the bridge are 3.8m and 5.0m, respectively, referred to the bridge of the Damnak Ampil Weir, with regarding the adjacent provincial road class.

6) Foundation works

Due to lack of geological information for preliminary design, concrete piles with 30 cm x 30 cm (or dia. 30 cm) x L = 6.0 m are to be proposed at a maximum spacing of 3.0 m under body spillway, upstream and downstream apron and fish ladder. In addition sheet piles of L = 6.0 m are also to be installed near the edge of body spillway.

7) Fish Ladder:

For the conservation of fish and ecology of the river, a fish ladder is planned on right bank of the weir. Type of fish ladder is planned to be a “half-cone type” or a “grouted riprap cascade type”, since these types creates a variety of water depth and flow velocity, so that fish is able to choose suitable course, water depth and flow velocity in accordance with its size and swimming ability.

- discharge: 0.79m^3/sec (maintenance flow) + residual - Width: B=5.0m (common for above types) - Slope: I = 1/10 (common for above types) - Height: H=3.6m (Gate height－inlet water depth) - Length: L6=36 m (=3.6/(1/10))	 **Image: half-cone type fish ladder**

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(4) Ream Kon Intake

The Ream Kon Intake is proposed to be reconstructed at the existing intake site. Design condition and result of preliminary design are summarized in Figure 5.2-7.

(5) Collector Drain-2

It is noted that the construction period for the Moung Russei Weir is anticipated between mid-November and late-May. The maximum discharge in the above period was 8.7m^3/s in the last five years, and is far smaller than design discharge of CD-2 (30m^3/sec). Accordingly, the CD-2 can be used for temporary river diversion channel during construction, provided that the CD-2 is rehabilitated before construction start. Design condition and result of Collector Drain-2 are summarized as follows; the schmatic typical section is presented in Figure 5.2.-8:

Typical Dimension of Collector Drain-2 of Ream Kon Sub-project

Canal type	Design Temporary Discharge (m^3/sec)	River bed width (m)	Bed slope	Inner side slope	Water depth(m)	Free board (m)
Earth type, Trapzoidal section	30	13.5	1/3,000	1:2.5	2.8	0.8

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(6) Inlet Structure (Emergency Spillway) of Collector Drain-2

A concrete weir with side wall overflow type is proposed in the upstream of the Moung Russei Diversion Weir to control outflow from Moung Russei River to CD-2. The exsiting opening of about 60m is to be closed by concrete dyke which has gates. Design condition and result are summarized in Figure 5.2-9.

(7) Drainage Gate for Collector Drain-2

An outlet structure is proposed to prevent water flow from Moung Russei River to CD-2 when the water level of Lake Tonle Sap is high. Design condition and result of drainage gate at the outlet of Collector Drain-2 in Ream Kon Rehabilitation Sub-project are summarized in Figure 5.2-10.

5.2.5 Rehabilitation and Improvement of Main and Secondary Systems

(1) Irrigation Canals and Related Structures

1) Design Plan

Preliminary design work of irrigation facilities for the Ream Kon Rehabilitation Sub-project is carried out based on the following design concepts.

Design Concept for Rehabilitation and Improvement of Irrigation Facilities

Existing Condition	Design Concept and Plan for Rehabilitation
Irrigation Canal	
Irregular canal sections - Low canal bank - Shallow canal - Deep section - Wide section	Utilization of existing sections to the maximum extent - Reshaping and heightening of canal bank for gravity irrigation - Excavation and reshaping of canal section in the case of insufficient flow capacity - Utilizing existing section without backfilling to the deep bottom section - Utilizing existing section without making new bank on the lower lying portion
Canal Related Structure	
Free intake and free distribution without control structures	Control irrigation water by gated structures such as Intakes, Checks, and Turnouts
Poor access in the Sub-project area - Lack of road crossing	Construction of access/ inspection roads on main and secondary canals - Construction of road crossing structures such as culvert, bridge and footpath bridge

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2) Rehabilitation and Improvement of Irrigation Facilities

a) Design of Irrigation Canals

Canal structural dimensions and hydraulic parameters are stipulated in the "Design Manual for Small and Medium Scale Irrigation System Planning" prepared by MOWRAM and Leighton G. Williams and MOWRAM-TF in July, 2004.

The design parameters applied to the rehabilitation and improvement of canals in this study are summarized in the following table.

Parameters for Irrigation Canal Design

	Item	Adopted value	Remarks
1	Roughness Coefficient "n"		
	Irrigation (Earth Canal)		
	Main & Secondary	0.025	
	Tertiary	0.030	
2	Canal Side Slope		Medium Clay
	Irrigation (Earth Canal)		
	Design Q $\leq$ 5.0m^3/sec	1: 1.00	
	Design Q > 5.0m^3/sec	1: 1.25	
3	Freeboard (Earth Canal)		
	Irrigation (Earth Canal)		
	Main Canal	0.80 m	
	Secondary Canal	0.50 m	
	Tertiary Canal	0.15 m	
4	Top Width of Embankment		
	Irrigation (Earth Canal)		

Item	Adopted value	Remarks
Design Q ≦ 1.0m^3/sec	1.0 m	
DesignQ>1.0to5.0m^3/sec	1.5 m	
DesignQ>5.0m^3/sec	2.0 m	
With Access Road	4.0 m	
5 Minimum Width of Canal Bottom		
Irrigation (Earth Canal)	0.3 m	Engineer's Estimate

Source: "Design Manual for Small and Medium Scale Irrigation System Planning", MOWRAM, 2004.

As mentioned in the afore-said manual, hydraulic calculation under uniform flow condition employs the Manning's formula to estimate water depth and flow velocity. In this study, the design of new canals with uniform sections and constant canal bottom slopes also applies the Manning's formula.

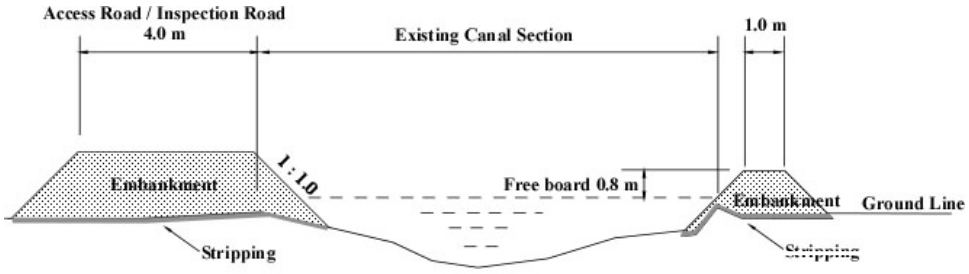
In the case of rehabilitation and improvement of an existing canal, the existing canal changes their width and depth in each section. Therefore, the equation, which applies the Bernoulli's theorem, is employed due to limitation of applicability of the Manning's formula.

In the Ream Kon Rehabilitation Sub-project, 2 main canals and 16 secondary canals are preliminarily designed. Out of 18 main and secondary canals, 2 main and 9 secondary canals have canal sections to be rehabilitated.

In this preliminary design, water levels of the existing canal sections of the Main Canal 1 are calculated by the equation for non-uniform flow condition. Water levels and flow velocity of the other canals are estimated by the Manning's formula.

Canal height of each canal is determined based on the calculated water level and freeboard. In the Main Canal 1 design, the initial water level after flowing into canal through intake is set at 15.30 m.

The following illustration shows a typical rehabilitation and improvement work for an existing canal section.



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Typical Cross Sectional Design of Main Canal (Design Q <1.0m^3/sec)

Secondary canals along the Main Canal 1 are existing canals. On the other hand, canals along the Main Canal 2 are almost new canals. The proposed canal dimensions are summarized in Table 5.2-4.

b) Design of Irrigation Canal Related Structure

Six types of irrigation related structure are preliminarily designed for the Ream Kon

Rehabilitation Sub-project. Table 5.2-5 shows the required types and numbers.

The function and feature of irrigation canal related structures are described in the following paragraphs.

Turnout

A turnout structure is proposed at the head of each canal to take regulated supplies from the parent canal. Turnout structure would consist of an inlet box, a slide gate, a closed conduit under an access road and an outlet box.

In this study, water measurement units, such as a broad crest weir or a Parshal measuring flume, are not proposed because of the following reasons.

- As mentioned in the water management section of this report, operation of the water management would be on an On-Off basis at a tertiary canal level,
- A measuring unit would require high head losses, and
- The measuring unit would increase the construction cost.

Check Structure

A check structure is proposed at the diversion point of irrigation water on main and secondary canals to keep canal water level high enough for gravity irrigation.

The water level in the canal would be controlled by adjustment of openings of the gate.

In the case that the water level would be too high in the downstream section after diversion, a drop unit would be provided.

Terminal Structure

A terminal structure is provided at the end of the Main and Secondary canals to release excessive water or un-necessary water in the canals.

The structure would consist of a spillway unit, a gate and an operation deck / slab.

Road Culvert

Road culver is a structure to convey irrigation water under a road, or dyke by means of a pipe or a box type conduit. In this study, a pipe type is employed where the design discharge is less than 3.0 m^3/s.

Bridge

Six concrete bridges are designed to cross existing breaking dyke sections and MD-1. The effective width of road surface is 3.5 m.

(2) Drainage Canals and Related Structures

1) Design Plan

Preliminary design work of drainage facilities for the Ream Kon Rehabilitation Sub-project is carried out based on the following design concepts.

Design Concept for Rehabilitation and Improvement of Drainage Facilities

Existing Condition	Design Concept and Plan for Rehabilitation
Drainage System	
Existing rivers and streams	Utilization as main or secondary canals connecting new drainage system without major improvement
Low density of drainage canals	New construction of drainage canal system up to tertiary drainage canal
Canal Related Structure	
Poor access in the Sub-project area - Lack of road crossing	- Construction of drainage culvert

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2) Rehabilitation and Improvement of Drainage Facilities

a) Design of Drainage Canals

Drainage canals are new canals excluding the following existing canals, CD-1, CD-2 and MD-1, utilizing a river diversion channel and streams.

Structural and hydraulic designs are similar to those of new irrigation canal. The following table summarizes design parameters for drainage canal. Water depth and flow velocity are calculated by the Manning's formula.

Parameters for Drainage Canal Design

Item	Adopted value	Remarks
1 Roughness Coefficient "n"		
Earth Canal	0.035	
2 Canal Side Slope		
Earth Canal	1: 1.50	
3 Freeboard (Earth Canal)		
Earth Canal		
Design Q < 1.7m^3/sec	0.10 m	
DesignQ=1.7to8.0m^3/sec	0.20 m	
DesignQ>8.0m^3/sec	0.30 m	
4 Minimum Width of Canal Bottom		
Earth Canal	0.5 m	

Source: "Design Manual for Small and Medium Scale Irrigation System Planning", MOWRAM, 2004.

The proposed drainage canal dimensions are summarized in Table 5.2-6.

b) Design of Drainage Canal Related Structures

Two types of drainage related structure are preliminarily designed for the Ream Kon Rehabilitation Sub-project. Table 5.2-7 shows the required types and numbers. The function and feature of drainage canal related structures are described in the following paragraphs.

Drainage Gate

A drainage gate is a regulator to be provided at the end-point of the Collector Drain-2 for releasing drainage water to the Moung Russei River. Total effective width of the flow section would be 7.0m equipped with 3 slide gates as described in the section 5.2.4 (7).

Drainage Culvert

Drainage culvert is a structure to carry drainage discharge across an irrigation canal or a road. The structural formation is the similar to that of road culvert. In addition to the components of a road culvert, a drainage culvert across an irrigation canal would have cutoff walls to block a waterway that may run along a conduit. A concrete lining would protect an irrigation section above a drainage culvert.

5.2.6 On-farm Development Plan

On-farm development plan for the Ream Kon Rehabilitation Sub-project is as follows.

(1) Concept

1) Irrigation Method

A tertiary block consists of a tertiary canal and several water courses in order to supply irrigation water to farm plots. A tertiary block also contains tertiary and quaternary drains. The water is supplied continuously in main and secondary canals under the Sub-project proposed and then, a rotational water supply is made in one tertiary block. The flow in the tertiary canal is controlled in accordance with water distribution plan in which FWUG and or Sub-FWUG are concerned.

2) Command Area by a Tertiary Block

A typical command area of one tertiary block is determined at 50 ha under the Sub-projects proposed referring to the Design Manual in MOWRAM[2].

3) One Tertiary Canal Governs One Tertiary Block

According to the government policy, one FWUG should be formed for one tertiary block. From the viewpoint of smooth water management for tertiary block by FWUG, one tertiary canal should command one tertiary block only.

4) Length of one Tertiary Canal

In connection with the command area of tertiary canal and in view of the canal layout the length of tertiary canal is generally 1.0km or 20m/ha. However, it is to be determined in accordance with topography in each Sub-project.

5) Division Boxes on the Tertiary Canal

Division boxes are provided on the tertiary canal at every water course point in order to control water distribution to water courses. The division box has an inlet from the tertiary canal and a few outlets to divert water into water courses and the tertiary canal. A slide gate is to be equipped at each outlet. The control of water distribution is to be made by open or close of the slide gate by a farmer. The number of outlets with a division box is a summation of the number of water courses which branch from the box and one outlet to the tertiary canal.

[2] Design Manual for Small and Medium Scale Irrigation Systems Planning July 2004, MOWRAM

The division box is made by concrete, or brick masonry which is available in the Sub-project site. The box must have grooves to install a slide gate. The slide gate can be made by steel or wood which is available and easy to handle by a farmer.

6) Command Area by one Water Course

Experiences and documents indicate a manageable size of stream of water by a farmer by hand tools is 10 lit/sec to 30 lit/sec. The peak water requirement is estimated about 2 lit/sec/ha. Accordingly one water course can simultaneously cover 10 ha to 15 ha. The average paddy field holding size per farm household in the Sub-project area ranges between 1.2 ha and 2.4 ha. Corresponding farmers to one water course is figured out between 8 and 6. It should be less than 10 in number for easy settlement and arrangement for water distribution along a water course. Thus, a water course is provided to cover 10 ha to 15 ha. Accordingly, the number of water courses ranges between 5 to 3 in one tertiary block. An average length of the water course is to be 500m.

7) Field Canals in one Water course

Field canals are to be constructed in the command area of one water course by 8 to 6 households in order to receive water by household.

(2) Development Plan

In accordance with the topography and the concept above mentioned, 47 tertiary blocks are proposed in the Ream Kon Rehabilitation Sub-project (1,890 ha). The average size of the tertiary block is figured out 40.2 ha. The typical length of a tertiary canal is 1.2km on average in accordance with the topography. The total length of the tertiary canals is assumed to be at 57km in the Sub-project. The typical length of one water course and number of water courses in the Sub-project are assumed at 340m and 188 numbers, respectively.

5.2.7 Water Management and Operation & Maintenance of Irrigation Facilities

(1) Responsible Organization

“The Policy for Sustainability of Operation and Maintenance of Irrigation System, June 2000” promotes the transfer of irrigation system to FWUC in order to mitigate financial burden for operation and maintenance (O&M). The share of responsibility of water management and O&M activities is proposed as follows taking into consideration for the policy above, size of the Sub-project, importance of facility for the Sub-project management.

Share of responsibility Proposed in the Ream Kon Sub-project

Activities \ Level	Moung Russei Headworks	Main Canal-1 & -2	Secondary canals	Tertiary canals	Water courses	Field canals
Preparation of annual O&M plan	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	-
Preparation of cropping schedule	-	-	FWUC/ FWUG	Sub-FUWG	WUG	Household
Operation of facilities	PDOWRAM	PDOWRAM	FWUG	Sub-FUWG	WUG	Household
Maintenance work	PDOWRAM	PDOWRAM	FWUG	Sub-FUWG	WUG	Household

Note O&M Manuals shall be prepared by MOWRAM/PDOWRAM and be hand over to the respective agencies responsible during hand-over period.

Prepared by JICA Study Team

(2) Water Management and Operation

1) Moung Russei Headworks and Main Canal-1 and Main Canal-2

PDOWRAM, Battambang is responsible for water management and O&M of Moung Russei Headworks and Main Canal-1 and Main Canal-2 including related structures.

The water level at the Headworks is to be kept at EL. 15.50m by controlling sluice gates which are installed at the Headworks, except for flood time. The water level shall be observed by reading a staff gauge which are installed at upstream of weir site and intake site.

The peak diversion water requirement is designed at 2.64m^3/sec. However, the amount of water taken to the Main Canal-1 is controlled by intake gates in accordance with irrigation service plan which is to be prepared by PDOWRAM Battambang. The intake gates are controlled by readings of staff gauges which are installed upstream and downstream of the intake gates. The gate opening rule shall be set up based on the relationship between water level, gate opening and discharge.

Main Canal-2 branches off from Main Canal-1. The peak discharge of Main Canal-1 and Main Canal-2 are designed at 1.16m^3/sec and 1.48m^3/sec, respectively. The water taken at intake is to be divided by the two above in accordance with the above proportion. In order to this, H-Q curve shall be developed at the diversion structure. Water supply to the Main Canal-1 and Main Canal-2 shall be continuously made throughout a year except for maintenance period which is set in March and April.

The canal base of Main Canal-1 and Main Canal-2 is designed to vary from place to place to use the existing canal section for cost saving, the flow in the main canal is not a uniform flow but non-uniform flow. Accordingly, check gates shall be operated in order to maintain the water level in the main canal for gravity irrigation. In this connection, turnout gates shall be operated carefully in order to avoid overtaking of water.

Water level in the Main Canal-1 and Main Canal-2 shall not be suddenly down except emergency case like danger to human life. This rule shall be observed to prevent the slipping of inside slopes of canal bank. And also, when water supply starts after completion of maintenance period, intake discharge shall be gradually increased up to the water demand.

In the maintenance period, the intake gates of the Headworks shall be totally closed and main canals shall be dried up for the purpose of annual maintenance. The maintenance works of Headworks and main canals are to be executed by PDOWRAM including related structures.

Box Water Supply Plan from Bassac reservoir:

Bassac Reservoir is under rehabilitation by MOWRAM through Non-project Aid of the Government of Japan. The rehabilitation will be completed in 2009. Bassac Reservoir is a main water source of all irrigation systems in the Mount Rueei River (refer to section 5.1.1).

PDOWRAM, Battambang shall make an irrigation water supply plan from Bassac Reservoir in accordance with the actual water to be stored in the reservoir at the beginning of irrigation season. The irrigation water supply plan shall contain the amount of water which will be supplied from the reservoir, and the water distribution plan to irrigation systems which take water from the Moung Russei River. The water distribution plan shall be informed to FWUCs of irrigation systems in the Moung Russei River basin and the District Governments concerned.

2) Secondary Canals

The water in the main canal is divided and flows to secondary canals. Turnouts are to be constructed to divert water to secondary canals. Gates are equipped at the turnout to control amount of water to the respective secondary canal. The discharge control is carried out by controlling the gates by reading staff gauges at the turnout. All secondary canals shall be given a continuous water supply throughout a year except maintenance period of March and April. The peak design discharge is determined in the previous section. The discharge, however, varies from time to time in accordance with irrigation service schedule.

Water level in the secondary canals shall be checked up to the design water level throughout an irrigation season. Check gates shall be operated properly in order to keep design water level at turnout, and to flow water to downstream too. If the check gates could not maintain the design water level by proper gate opening, the turnouts and check gates located in the upstream reach shall be checked and whether these turnouts overtake water.

In case the water level nearly reaches to the top of canal embankment by increase of canal water, a spillway located in the upstream reach shall be opened until the canal water level becomes down to the design water level. In this operation, careful attention shall be paid upon the gate operation of spillway so that the released discharge through spillway could not be over its drainage capacity.

During the maintenance period, the intake gates to the secondary canals shall be totally closed and all the canal systems shall be dried up for the purpose of annual maintenance.

In case of making empty of canal for maintenance, water level shall be gradually down in order to avoid the sliding of inner side slope of canal, especially paying care upon where the groundwater table is higher than the canal bed.

FWUC and its sub-ordinates are responsible for operation and maintenance of secondary, tertiary and water courses. A steering committee of FWUC shall make and inform to sub-ordinates the operation and maintenance plan from secondary up to tertiary canals under the assistance of PDOWRAM every year. FWUC, practically FWUGs are responsible for

operation and maintenance of all gates of checks, turnouts, division boxes and off-takes in the secondary canals in order to accomplish the equal water distribution. In this connection, PDOWRAM should prepare and hand-over the operation and maintenance manuals of canals and structures of secondary canals.

Although FWUC is responsible for maintenance work of all structures in the secondary canals, the responsibility for some structures such as culverts, bridges, etc., can be discussed and determined with PDOWRAM and or other local government authorities concerned in accordance with the size and importance of each structure.

3) Tertiary Canals

The water in the secondary canal is diverted to tertiary canals. Division boxes or off-takes are provided in the tertiary canal for water distribution to field canals. Small-hand gates and a staff gauge are installed at each division box or off-take, and are used for discharge control.

Rotational irrigation is proposed along one tertiary canal when the available discharge in the tertiary canal is less than the required discharge. Rotational irrigation has the following advantages:

- Equitable water distribution can be made for all farm plots.
- Rotational irrigation can maximize effective rainfall
- Application loss is less than continuous water supply.

The area covered by a tertiary canal is called as a tertiary block. A tertiary block is divided into several irrigation units so called as a quaternary Block. The rotational irrigation is executed by a combination of quaternary blocks. The period of water time in which the water is supplied to a quaternary block is determined in proportion to the area covered by a field canal.

Water management and O&M of a tertiary canal of the Sub-project are under responsibility of a FWUG or a Sub-FWUG. Gates installed in the division boxes on the tertiary canals are operated by a FWUG or a Sub-FWUG in order to achieve equal water distribution.

4) Water courses and Field Canals

WUG is responsible to water management and O&M of a water course. A household is responsible for O&M of field canal.

(3) Maintenance Work of Ream Kon Rehabilitation Sub-project

The maintenance work of Sub-project facilities is indispensable to ensure the proper and steady function and the realization of economic life of the facilities. The maintenance works are generally categorized:

- Regular maintenance works which are performed regularly to maintain the Sub-project facilities;
- Emergency repair works which include repair of occasional damage of the Sub-project facilities caused by flood, heavy rainfall or other causes; and

- Periodic and annual maintenance which contain skilled work and a large work quantity or requires special skills.

All these works are checked and listed up through daily patrol by the responsible organization. The items to be inspected in the daily patrol are as follows:

Inspection Items in Daily Patrol

Facilities	Inspection Items
(a) Headworks	Structure; Breakage/cracks, Leakage, Settlement, Sediment, Staff gauge Gate; Trash, Breakage, Rust, Greasing of spindle and hoist, Leakage through gate, Trash, Electric facilities
(b) Canals	Holes/erosion/settlement/cut of canal bank, Leakage, Sediment/ grasses/trash
(c) Structures	Breakage/cracks, Leakage, Settlement, Sediment/trash, Staff gauge
(d) Gates	Breakage, Trash, Rust, Greasing of spindle and hoist, Leakage through gate
(e) Inspection road	Holes/erosion/ruts

Prepared by JICA Study Team

1) Regular Maintenance

The regular maintenance contains the day-to-day maintenance which is to be carried out by labor groups of the responsible agency without needing special skills. It includes routine repair of embankment, sediment removal, weeding, filling of holes, oiling gates, etc. Satisfactory implementation requires an intensive daily inspection of project facilities as well.

The labor group consisting of 3 to 4 labors are to be assigned to the daily maintenance work for 3 km to 5 km of canal per day. A weekly schedule and reasonable length of canal shall be assigned to each group.

2) Emergency Repair

Damage to the project facilities hampers the normal practices of irrigation. Therefore, repair of damaged facilities should be quickly and effectively carried out under the category of the emergency repair. The damage to the Sub-project facilities may result from flood, heavy rainfall, violation acts, and destruction by animals and vehicles.

3) Periodic and Annual Maintenance

The periodic maintenance means the repair of minor damage which does not cause immediate danger or malfunction to the canal system, but needs special skills to repair the damage. The periodic maintenance will be rendered to skilled workers and/or mechanics by the responsible organization.

Annual maintenance works which involve a large work quantity or require special skills should be carried out under the category of annual maintenance. The annual maintenance is conducted in fallow season, that is March and April. In order to make annual maintenance smoothly, the annual maintenance program shall be prepared in advance. Minor improvements to the existing facilities of the system are also included in the annual maintenance.

5.3 Por Canal Rehabilitation Sub-project

5.3.1 Crop Production Plan

(1) Land Use Plan

The land use plan for the Por Canal Rehabilitation Sub-project under the with-project condition is presented in comparison with the present/without-project land use as follows;

Present/Without-project & With-project Land Use of the Por Canal Sub-project Area

Land Use Sub-category	Present		With-project		Increment
	(ha)	(%)	(ha)	(%)	(ha)
Paddy Field					
- Normal Irrigation Paddy Field			1,940	100	1,940
- Supplemental Irrigation Paddy Field	100	5			- 100
- Rainfed Paddy Field	1,970	95			- 1,970
Sub-total	2,070	100	1,940	100	- 130
Right-of-ways	160	7	290	13	130
Total	2,230	100	2,230	100	0

Prepared by JICA Study Team

As shown in the table, the development of 1,940 ha of normal irrigation paddy field is aimed at under the Sub-project by the conversion of 100 ha of supplemental irrigation fields and 1,970 ha of rainfed fields. The decease of paddy fields due to land use conversion to right-of-ways is estimated at 130 ha.

(2) Proposed Cropping Pattern and Cropped Area

1) Crop Selection

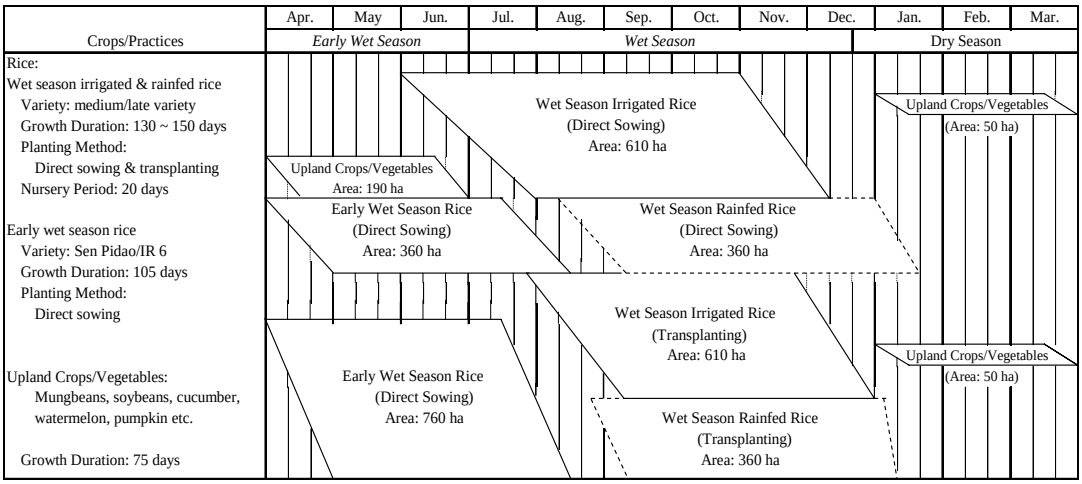
The crop selection for the Por Canal Rehabilitation Sub-project under the present plan has been made on the basis of the approaches applied for the Ream Kon Rehabilitation Sub-project discussed in the section 5.2.1(2) as follows;

- Rice, current exclusive crop in the main cropping season, wet season, is selected as a crop to be introduced in the season as no other promising crops are conceivable and rice is a by far the most important crop and stable food in the area,
- Introduction of irrigated upland crops/vegetables production in early wet and dry season aiming at: i) increasing land use intensity in paddy fields, ii) crop diversification, iii) sufficing domestic consumption and improvement of nutritional status of farm families by introducing pulses and iv) increasing farm income,
- Introduction of early rice in the early wet season under direct sowing as is currently practiced, and
- Candidate upland crops could include mungbeans, soybeans and corn and the same of vegetables include cucumber, water melon, pumpkin and gourd currently cultivated in and around the Sub-project area.

2) Cropping Pattern and Cropped Area

Based on the study on the current prevailing cropping patterns, the development concept

discussed earlier and the results of irrigation water balance study, the proposed cropping pattern for the Por Canal Rehabilitation Sub-project has been formulated as follows;



Prepared by JICA Study Team

Proposed Cropping Pattern: Por Canal Sub-project

The cropping intensity targeted under the plan is similar to the same for the Ream Kon Rehabilitation Sub-project area as follows;

- Rice cropping intensity of 100% in wet season is planned in the pattern by assuming that rice cultivation under rainfed conditions will be carried out as is currently practiced in non-irrigated fields in the season (intensity of irrigated rice 63% & the same of rainfed rice 37%),
- Intensity of rice in the early wet season is targeted at 58%. In addition, the intensity of 10% of upland crops/vegetables under irrigation is envisaged to promote crop diversification in the Sub-project area, and
- In dry season, upland crops/vegetables cultivation under irrigation to the extent of 100 ha is planned.

The planned cropped areas and cropping intensity envisaged in the pattern are shown in Table 5.3-1 and summarized as follows;

Planned Cropped Area & Cropping Intensity under the Por Canal Sub-project

Unit: ha & %

Crop	Cropping Season							
	Early Wet Season		Wet Season		Dry Season		Annual	
	Area	Intensity	Area	Intensity	Area	Intensity	Area	Intensity
Irrigated Rice	1,120	58	1,220	63			2,340	121
Irrigated Rice (direct sowing)	1,120	58	610	31.4			1,730	89.2
Irrigated Rice (transplanting)			610	31.4			610	31.4
Rainfed Rice			720	37			720	37
Rainfed Rice (direct sowing)			360	18.6			360	18.6
Rainfed Rice (transplanting)			360	18.6			360	18.6
Rice Total	1,120	58	1,940	100	0	0	3,060	158
Upland Crops/Vegetables	190	10			100	5	290	15
Total	1,310	68	1,940	100	100	5	3,350	173

Prepared by JICA Study Team

(3) Target Crop Yields

The target crop yields for the Por Canal Rehabilitation Sub-project under the present plan in which normal irrigation is ensured are set at the same levels with the Ream Kon Rehabilitation Sub-project area as shown in comparison with the present yield levels in the following table:

Target Yields and Present Yield Levels of Por Canal Sub-project (Unit: ton/ha)

Wet Season				Early Wet/Dry Season			
Crop 1/	Target	Present	Increment	Crop 1/	Target	Present	Increment
Improvement of Irrigation Status: Present: Supplemental Irrigation ⇒ With-project: Normal Irrigation							
Medium Rice (T)	3.5	2.2	1.3	Early Rice (D)	3.0	2.5	0.5
Medium Rice (D)	2.8	1.5	1.3	Upland Crops 2/	1.0	-	-
Improvement of Irrigation Status: Present: Rainfed ⇒ With-project: Normal Irrigation							
Medium Rice (T)	3.5	1.7	1.8	Early Rice (D)	3.0	2.5	0.5
Medium Rice (D)	2.8	1.0	1.8	Upland Crops 2/	1.0	-	-

1/: T --- transplanting; D --- direct sowing 2/ Upland crops: average of mungbeans & soybeans

Prepared by JICA Study Team

Yield increases of 1.3 to 1.8 ton/ha in wet season rice and 0.5 ton/ha in early wet season rice are envisaged under the plan. The target yields of irrigated upland crops and vegetables are set at the same levels with those of the Ream Kon Rehabilitation Sub-project: mungbeans 0.9ton/ha, soybeans 1.1 ton/ha, watermelon 9.0 ton/ha and cucumber 10.0 ton/ha.

(4) Crop Production Plan

The crop production plan for the Por Canal Rehabilitation Sub-project under the with-project condition is presented in comparison with the present/without-project crop production in Table 5.3-1 and summarized as follows;

Present & With-project Crop Production of the Por Canal Sub-project Area

Land Use Sub-category/Crops		Cropped Area (ha)	Intensity (%)	Yield (t/ha)	Production (t)
I. Present/Without-project Crop Production					
Supplemental Irrigation Paddy Field: Rice		200	10	2.2	435
Rainfed Paddy Field: Wet/Early Wet Season Rice		2,280	110	1.5	3,435
Annual	Rice	2,480	120	1.6	3,870
II. With-project Crop Production					
Normal Irrigation Paddy Field: Rice		2,340	121	3.1	7,203
Rainfed Rice 1/		720	37	1.4	972
Annual	Rice	3,060	158	2.7	8,175
	Upland Crops	290	15	-	1,055
Increment (II – I)					
Annual	Rice	580	38	1.1	4,306
	Upland Crops	290	15	-	1,055

1/: Cultivation of wet season rice under rainfed conditions due to limitation of irrigation water supply.
2/: Total of upland crops & vegetables, represented by mungbeans, soybeans, watermelon & cucumber.
Note: Rice figures are total of wet & early wet season rice and direct sowing & transplanting rice

Prepared by JICA Study Team

As shown in the table, the increase of overall paddy average yield of 1.1 ton/ha from 1.6 to

2.7 ton/ha and annual paddy production increase of some 4,300 tons are expected. The paddy production under the Sub-project is about 210% of the current production level in the area. Under the Sub-project, the expansion of upland crops/vegetables production is envisaged and the production volume of the crops is estimated to be about 1,100 tons.

(5) Proposed Farming Practices

Proposed improved farming practices of paddy to be adopted in the Por Canal Rehabilitation Sub-project are same as those for the Ream Kon Rehabilitation Sub-project and include proper land preparation, use of quality seed and proper seeding rate, improved nursery & planting method, proper fertilization & water management etc.

5.3.2 Agricultural Extension Activities

Under the Sub-project, the substantial increases of yields and annual cropping intensity of paddy and the introduction of irrigated upland crops/vegetables production are envisaged as is the case in the Ream Kon Rehabilitation Sub-project. The proposed activities are development interventions aiming at strengthening of agricultural extension services for attaining the Sub-project targets of crop yields and cropping pattern at an earlier stage as possible. The estimated costs for the activities accommodated as Sub-project component are summarized in the following table.

Major extension activities are as discussed in the section 5.2.2 and include field programs (including seed multiplication program), farmer & farmer group training programs mass guidance/workshop, staff empowerment, support fund for extension staffs and provision of transportation means.

Estimated Costs for Agricultural Extension Activities for Por Canal Sub-project [1/]

Activity	Estimated Cost (US$)
Field Extension Programs	69.200
Farmer/Farmer Group Training Programs	19,600
Mass Guidance/Workshop	1,600
Support Fund for Extension Staff 2/	21,760
Staff Empowerment	4,000
Provision of Transportation Means	4,200
Total	120,360

1/: Program direct costs
2/: Provision of support for VAA (village Agriculture Extension Agent) & field staff
Prepared by JICA Study Team

The implementation of the activities is scheduled for the period of 4 years in the Sub-project and the overall cost is estimated at US$ 120,000.-.

5.3.3 Irrigation and Drainage Plan

Irrigation and drainage plan for the Por canal Rehabilitation Sub-project is as follows.

(1) Headworks

Por canal Sub-project is proposed to use the Moung Russei Headworks commonly with the Ream Kon Rehabilitation Sub-project as same as present situation.

(2) Canal Layout

The proposed irrigation canal layout is made in accordance with concept and approach described in Chapter 4.2, and is shown in Figure 5.2-1 as well as the Ream Kon Rehabilitation Sub-project. Two main canals are proposed to irrigate western half and eastern half of the Sub-project area each. General features are summarized in Table 5.2-2 together with other Sub-projects. The irrigation diagram is shown in Figure 5.3-1.

(3) Drainage Plan

In order to protect the Sub-project area from flood flowing from surrounding areas, drainage plan is made as follows:

i) The drainage water from Prek Taam Irrigation System is collected by proposed Collector Drain-1 (CD-1) which flows along National Road No.5. The Collector Drain-1 meets the western edge of the Sub-project, and flows to northward to join with an existing stream (Stueng Moung).

ii) Collector Drain-2 (CD-2) is proposed to intercept the drainage water from western area located between National Road No.5 and the Sub-project area. CD-2 flows to northward, and finally connects to the CD-1.

The general feature of drainage plan is summarized in Table 5.2-2, together with other Sub-projects. The drainage diagram is presented in Figure 5.3-2.

(4) Drainage Water Requirement

1) Drainage water requirement from paddy field

The unit drainage water requirement from paddy field is calculated at 7.17 lit/sec/ha based on the annual maximum rainfall in 3 consecutive days at one in 5 years return period. The procedure is described in the previous section 5.2.3.

2) Drainage water requirement from other type of land

The calculated results of unit drainage water requirement for the other types of land with area less than 100 ha and more than 100 ha are as follows (the procedure is described in the previous section 5.2.3):

Qpeak = $0.25 m^3$/sec/ha from the area less than 100 ha

Qpeak = $0.19 m^3$/sec/ha from the area more than 100 ha

5.3.4 Rehabilitation and Improvement of Headworks and Major Related Structures

(1) Basic Concept

The Moung Russei Headworks is planned to be rehabilitated in the Ream Kon Rehabilitation Sub-project as explained in the previous section. In Por Canal Rehabilitation Sub-project (1,940 ha), an intake (Q=$2.74 m^3$/sec) is to be rehabilitated in order to supply irrigation water to this Sub-project.

(2) Por Canal Intake

The Por Canal Intake is proposed to be reconstructed at the existing intake site. Design condition and result of preliminary design are summarized in Figure 5.3-3.

5.3.5 Rehabilitation and Improvement of Main and Secondary Systems

(1) Irrigation Canals and Related Structures

1) Design Plan

Design plan of irrigation facilities is discussed and explained in section 5.2.5 (1)-1).

2) Rehabilitation and Improvement of Irrigation Facilities

a) Design of Irrigation Canals

In the Por Canal Rehabilitation Sub-project, 2 main canals and 12 secondary canals are preliminarily designed. Out of 14 main and secondary canals, 2 main and 8 secondary canals have canal sections to be rehabilitated.

In this study, rehabilitation and improvement design contains canals and structures which have been repaired by donors, because a comprehensive rehabilitation and improvement plan would be necessary to utilize these canals effectively. Water levels of the existing canal sections of the Main Canal-1 are calculated by the equation for non-uniform flow condition. Water levels and flow velocity of the other canals are estimated by the Manning's formula.

The proposed canal dimensions are summarized in Table 5.3-2. .

b) Design of Irrigation Canal Related Structures

Five types of irrigation related structure are preliminarily designed for the Por Canal Rehabilitation Sub-project. Types employed are the same as those of the Ream Kon Rehabilitation Sub-project.

Table 5.3-3 shows the required types and numbers.

The function and feature of irrigation canal related structures are described in the previous section 5.2.5 (1)-2) except for a footpath bridge.

Footpath Bridge

Five footpath bridges across the drainage canal MD-1 would be required to enter the Main Canal-2 areas from the Main Canal-1. A footpath bridge would have effective width of 2.2 m with a parapet.

(2) Drainage Canals and Related Structures

1) Design Plan

Design plan of Drainage facilities is discussed and explained in section 5.2.5 (2)-1).

2) Rehabilitation and Improvement of Drainage Facilities

a) Design of Drainage Canals

Drainage canals of Por Canal Rehabilitation Sub-project are all new canals. Structural and hydraulic designs are the same as the Ream Kon Rehabilitation Sub-project. The proposed drainage canal dimensions are summarized in Table 5.3-4.

b) Design of Drainage Canals Related Structures

New secondary drainage canals would require 9 drainage culverts to cross the existing roads in the Main Canal-1 area as shown in Table 5.3-5.

5.3.6 On-farm Development Plan

The concept of on-farm development plan such as irrigation method, command area by a tertiary block, etc., are discussed and explained in section 5.2.6.

In accordance with the topography and the concept above mentioned, 42 tertiary blocks are proposed in the Por Canal Rehabilitation Sub-project (1,940 ha) in total. The average size of the tertiary block is figured out 46.2 ha. The typical length of a tertiary canal is 1.3km on average in accordance with the topography. The total length of the tertiary canals is assumed at 55km in the Sub-project.

The typical length of one water course and number of water courses in the Sub-project are assumed to be 360 m and 168 numbers, respectively.

5.3.7 Water Management and Operation & Maintenance of Irrigation Facilities

(1) Responsible Organization

"The Policy for Sustainability of Operation and Maintenance of Irrigation System, June 2000" promotes the transfer of irrigation system to FWUC in order to mitigate financial burden for operation and maintenance (O&M). The share of responsibility of water management and O&M activities in the Por Canal Rehabilitation Sub-project is proposed as follows taking into consideration the policy above, size of the Sub-project, importance of facility for the Sub-project management.

Share of responsibility Proposed in the Por Canal Sub-project

Level / Activities	Moung Russei Headworks*1	Main Canal-1 & Main Canal-2	Secondary canals	Tertiary canals	Water courses	Field canals
Preparation of annual O&M plan	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	-
Preparation of cropping schedule	-	-	FWUC/ FWUG	Sub-FUWG	WUG	Household
Operation of facilities	PDOWRAM	PDOWRAM	FWUG	Sub-FUWG	WUG	Household
Maintenance work	PDOWRAM	PDOWRAM	FWUG	Sub-FUWG	WUG	Household

*1 The Headworks is commonly used by Ream Kon Sub-project (refer to 5.2.4).

Note O&M Manuals shall be prepared by MOWRAM/PDOWRAM and be hand over to the respective agencies responsible during hand-over period.

Prepared by JICA Study Team

(2) Water Management and Operation

Water management and operation proposed for the Por Canal Rehabilitation Sub-project is as follows.

1) Moung Russei Headworks and Main Canal-1 and Main Canal-2

The Por Canal Rehabilitation Sub-project uses Moung Russei Headworks commonly with Ream Kon Rehabilitation Sub-project. O&M of the Headworks is under responsibility PDOWRAM, Battambang.

The required water level at the intake is to be EL. 15.00m which is lower than required water level for Ream Kon Rehabilitation Sub-project (EL. 15.50m). Should the water level is kept at EL. 15.5m for at Moung Russei Headworks, the water level is high enough for the Por Canal Rehabilitation Sub-project.

The peak diversion water requirement is designed at 2.45m^3/sec. However, the amount of water taken to the Main Canal-1 is controlled by intake gates in accordance with irrigation service plan which is to be prepared by PDOWRAM Battambang. The intake gates are controlled by readings of staff gauges which are installed upstream and downstream of the intake gates. The gate opening rule shall be set up based on the relationship between water level, gate opening and discharge.

Main Canal-2 branches off from Main Canal-1. The peak discharge of Main Canal-1 and Main Canal-2 are designed at 1.25m^3/sec and 1.20m^3/sec, respectively. The water taken at intake is to be divided by the above two main canals in accordance with the design discharge proportion. In order to this, H-Q curve shall be developed at the diversion structure. Water supply to the Main Canal-1 and Main Canal-2 shall be continuously made throughout a year except for maintenance period which is set in March and April.

Other water management activity, as listed below is described in the section 5.2.7.

- Operation of check gates and turnout gates
- Water level in the canal,
- Continuous water flow in the canal,

2) Secondary Canals

The water management and operation activities in the secondary canals are described in the previous section 5.2.7(2)-2).

3) Tertiary Canals

The water management and operation activities in the tertiary canals are described in the previous section 5.2.7(2)-3).

4) Water Courser and Field Canals

The water management and operation activities in the quaternary and field canals are described in the previous section 5.2.7(2)-4).

(3) Maintenance Work

The maintenance work of the Sub-project facilities is described in the previous section 5.2.7(3).

5.4 Damnak Ampil Rehabilitation Sub-project

5.4.1 Crop Production Plan

(1) Land Use Plan

The land use plan for the Damnak Ampil Rehabilitation Sub-project under the with-project condition is presented in comparison with the present/without-project land use as follows;

As shown in the table, the development of 2,270 ha of normal irrigation paddy field is aimed at under the Sub-project by the conversion of 500 ha of supplemental irrigation fields and 1,930 ha of rainfed fields. The decease of paddy fields due to land use conversion to right-of-ways is estimated at 160 ha.

Present/Without-project & With-project Land Use of the Damnak Ampil Sub-project Area

Land Use Sub-category	Present		With-project		Increment
	(ha)	(%)	(ha)	(%)	(ha)
Paddy Field					
- Normal Irrigation Paddy Field			2,270	100	2,270
- Supplemental Irrigation Paddy Field	500	21			- 500
- Rainfed Paddy Field	1,930	79			- 1,930
Sub-total	2,430	100	2,270	100	- 160
Right-of-ways	180	7	340	13	160
Total	2,610	100	2,610	100	0

Prepared by JICA Study Team

(2) Proposed Cropping Pattern and Cropped Area

1) Crop Selection

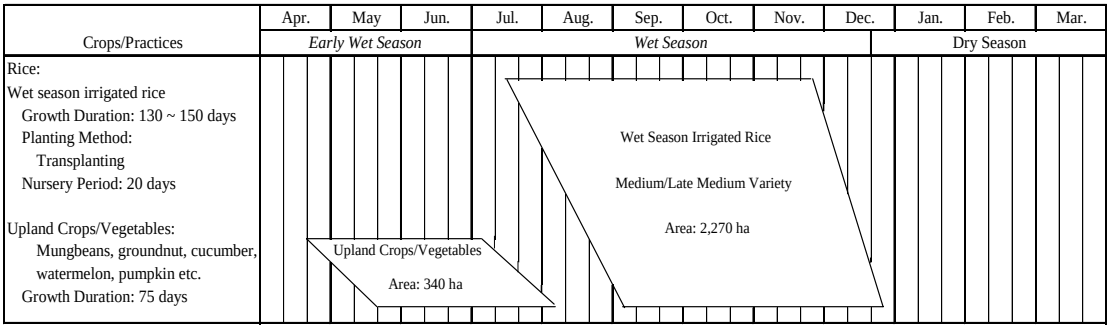
The crop selection for the Damnak Ampil Rehabilitation Sub-project under the present plan has been made basically on the basis of the development concept discussed earlier as follows:

- Rice, current exclusive crop in the main cropping season, wet season, is selected as a crop to be introduced in the season as no other promising crops are conceivable and rice is a by far the most important crop and stable food in the area,
- Introduction of irrigated upland crops/vegetables production in early wet season aiming at: i) increasing land use intensity in paddy fields, ii) crop diversification, iii) sufficing domestic consumption and improvement of nutritional status of farm families by introducing pulses and iv) increasing farm income, and
- Candidate upland crops could include mungbeans, groundnut, soybeans and corn and the same of vegetables include cucumber, water melon, pumpkin and gourd currently cultivated in and around the Sub-project area. However, for the successful introduction of the crops, intensified extension supports should be accommodated as an essential

component of the Sub-project.

2) Cropping Pattern and Cropped Area

Based on the study on the current prevailing cropping patterns, the development concept discussed earlier and the results of irrigation water balance study, the proposed cropping pattern for the Damnak Ampil Rehabilitation Sub-project has been formulated as follows:



Prepared by JICA Study Team

Proposed Cropping Pattern: Damnak Ampil Sub-project

The cropping intensity targeted under the plan is as follows;

- Rice cropping intensity of 100% in wet season under irrigation is planned in the pattern within the availability of irrigation water, and
- Introduction of upland crops/vegetables under irrigation in early wet season to the extent of cropping intensity of 15% is envisaged by availing irrigation water supply in the season to promote crop diversification in the Sub-project area.

The planned cropped areas and cropping intensity envisaged in the pattern are shown in Table 5.4-1 and summarized as follows:

Planned Cropped Area & Cropping Intensity under Damnak Ampil Sub-project

Unit: ha & %

Crop	Cropping Season							
	Early Wet Season		Wet Season		Dry Season		Annual	
	Area	Intensity	Area	Intensity	Area	Intensity	Area	Intensity
Irrigated Rice			2,270	100			2,270	100
Upland Crops/Vegetables	340	15					340	15
Total	340	15	2,270	100	0	0	2,610	115

Prepared by JICA Study Team

(3) Target Crop Yields

The target crop yields for the Damnak Ampil Rehabilitation Sub-project under the present plan in which normal irrigation is ensured are studied, as is the case for the other Sub-project areas, based on the current yield levels at normal (full) irrigation areas and the results of the Pilot Project carried out under the Study on Comprehensive Agricultural Development in Prek Thnot River Basin, JICA and are set as shown in the following table in comparison with the present yield levels.

Target Yields and Present Yield Levels of Damnak Ampil Sub-project (Unit: ton/ha)

Wet Season				Early Wet/Dry Season			
Crop 1/	Target	Present	Increment	Crop	Target	Present	Increment
Improvement of Irrigation Status: Present: Supplemental Irrigation ⇒ With-project: Normal Irrigation 2/							
Medium Rice (T)	3.3	2.0	1.3	Upland Crops 3/	1.1	-	-
Improvement of Irrigation Status: Present: Rainfed ⇒ With-project: Normal Irrigation 2/							
Medium Rice (T)	3.3	1.5	1.8	Upland Crops 3/	1.1	-	-

1/: T --- transplanting 2/:Including pump irrigation fields 3/ Upland crops: average of mungbeans & groundnut

Prepared by JICA Study Team

Yield increases of 1.3 to 1.8 ton/ha in wet season rice are envisaged under the plan. The target yields of irrigated upland crops and vegetables are set rather conservatively as follows;

Target Yields of Upland Crops/Vegetables of Damnak Ampil Sub-project

Crops	Target Yield	Crops	Target Yield
Mungbeans	0.9 ton/ha	Watermelon	9.0 ton/ha
Groundnut	1.3 ton/ha	Cucumber	10.0 ton/ha

Prepared by JICA Study Team

(4) Crop Production Plan

The crop production plan for the Damnak Ampil Rehabilitation Sub-project under the with-project condition is presented in comparison with the present/without-project crop production in Table 5.4-1 and summarized as follows;

As shown in the table, the increase of overall average paddy yield of 1.7 ton/ha from 1.6 to 3.3 ton/ha and annual paddy production increase of some 3,400 tons are expected. The paddy production under the Sub-project is about 185% of the current production level in the area. Under the Sub-project, the expansion of upland crops/vegetables production is envisaged and the production volume of the crops is estimated to be some 1,200 tons, increase of all from the present level. Successful introduction of the crops through the proposed extension activities will further expand the cultivation of the crops in the area in the future.

Present & With-project Crop Production of the Damnak Ampil Sub-project Area

Land Use Sub-category/Crops		Cropped Area (ha)	Intensity (%)	Yield (t/ha)	Production (t)
I. Present/Without-project Crop Production					
Supplemental Irrigation Paddy Field: Rice		500	23	2.3	1,150
Rainfed Paddy Field: Wet Season Rice		1,930	79	1.5	2,895
Annual	Rice	2,490	102	1.6	4,045
II. With-project Crop Production					
Normal Irrigation Paddy Field: Rice		2,270	100	3.3	7,491
Annual	Rice	2,270	100	3.3	7,491
	Upland Crops	340	15	-	1,214
Increment (II – I)					
Annual	Rice	- 220	- 2	1.7	3,446
	Upland Crops	340	15	-	1,214

1/: Cultivation of wet season rice under rainfed conditions due to limitation of irrigation water supply.

2/: Total of upland crops & vegetables, represented by mungbeans, groundnut, watermelon & cucumber.

Note: Rice figures are total of wet & early wet season rice and direct sowing & transplanting rice

Prepared by JICA Study Team

(5) Proposed Farming Practices

Proposed improved farming practices of paddy to be adopted in the Damnak Ampil Rehabilitation Sub-project are: i) proper land leveling & preparation, ii) use of quality seed and adequate seeding rate, iii) raised nursery bed, planting of younger seedling, regular planting and reduced no. of plants per hill, iv) fertilization (increased & timely application including compost or cow dung), v) introduction of proper on-farm water management & water saving culture, vi) intensified weeding and vii) improvement of post-harvesting practices as proposed for the other Sub-project areas.

5.4.2 Agricultural Extension Activities

Under the Sub-project, the substantial increases of paddy yields and the introduction of irrigated upland crops/vegetables production are envisaged, which dictates the introduction of intensified extension activities in the area. The proposed activities are development interventions aiming at strengthening of agricultural extension services for attaining the Sub-project target crop yields and cropping pattern at an earlier stage as possible. The estimated costs for the activities accommodated as Sub-project component are summarized in the following table.

Major extension activities include field programs (adaptability test, demonstration plot, farm & area, upland crops/rice seed multiplication), farmer & farmer group training programs (training course, FFS/IPM, study tour), mass guidance/workshop, staff empowerment, support fund for extension staffs and provision of transportation means.

The implementation of the activities is scheduled for the period of 4 years in the Sub-project and the overall cost is estimated at US$ 131,000.-.

Estimated Costs for Agricultural Extension Activities for Damnak Ampil Sub-project [1/]

Activity	Estimated Cost (US$)
Field Extension Programs	75,850
Farmer/Farmer Group Training Programs	21,200
Mass Guidance/Workshop	1,800
Support Fund for Extension Staff 2/	23,680
Staff Empowerment	4,000
Provision of Transportation Means	4,350
Total	130,880

1/: Program direct costs
2/: Provision of support for VAA (village Agriculture Extension Agent) & field staff

Prepared by JICA Study Team

5.4.3 Irrigation and Drainage Plan

Irrigation and Drainage Plan for the Damnak Ampil Rehabilitation Sub-project is as follows.

(1) Headworks

The existing Damnak Ampil Headworks have been constructed by MOWRAM in 2006, and are used for irrigation water supply to the three Sub-projects. The capacity of intake is estimated at 8.0 m^3/sec, and considered to be enough for three Sub-projects, provided that the

existing automatic flood gates are to be improved so as to keep adequate water level at intake.

(2) Canal Layout

The proposed irrigation canal layout is made in accordance with concept and approach described in Chapter 4.2, and is shown in Figure 5.4-1. The existing Main Canal (7.3 km) was rehabilitated by MOWRAM to have a flow capacity of 8.0 m^3/sec in 2006, and is used by the Sub-project. General features are summarized in Table 5.2-2. The irrigation area diagram is shown in Figure 5.4-2.

(3) Irrigation Area by Portable Pump

The water level at intake is designed at EL.17.0m by MOWRAM. The ground height of upstream area of each secondary canal is higher than water level in the Main Canal. The raising water level in the Main Canal is not economical because it requires heightening of the headworks by about 1.0 m which requires high cost, and causes inundation in the upstream of the Pursat River. The portable pump irrigation is inevitable in about 500 ha out of 2,270 ha. Those areas are located along the Main Canal, and the farmers are pumping up irrigation water using portable pumps at present. Accordingly no serious problems are expected.

(4) Drainage Plan

The excess water in the Sub-project area is proposed to be drained by gravity. Field drains collect water from paddy fields and other types of land, and flow into tertiary drains. Tertiary drains flow into secondary drains due to the topography. Secondary drains flow into Ou Bakan river. In the northwest border of the Sub-project, a small stream so called as Stueng Chambot is also used as one of the secondary drain.

(5) Drainage Water Requirement

1) Drainage water requirement from paddy field

The unit drainage water requirement, q (lit/sec/ha), from paddy field is calculated at 6.32 lit/sec/ha based on the annual maximum rainfall in 3 consecutive days at one in 5 years return period.

$$q = 0.164 \times 10{,}000 \div (3 \times 86400) \times 1000 = 6.32$$

where, 0.164 is a probable 3 consecutive days rainfall at Pursat station

2) Drainage water requirement from other type of land

The Sub-project area consists of paddy field and other type of land which are house yard, upland, right of way of irrigation canals, etc. Those lands are located adjacent to the paddy field, and are assumed to be 15% of the paddy field. Those lands do not have storage function as paddy field, and runoff characteristics from those lands are different from that from paddy field. The unit drainage water requirement from those lands is calculated by the rational formula and the annual maximum one day rainfall at one in 5 years return period (110 mm/day).

The calculated results of unit drainage water requirement for the other types of land with area

less than 100 ha and more than 100 ha are as follows (the procedure is described in the previous section 5.2.3):

Qpeak = 0.25m^3/sec/ha from the area less than 100 ha

Qpeak = 0.18m^3/sec/ha from the area more than 100 ha

The above unit drainage water requirement is applied to drainage canals and collector drains shown in Figure 5.4-3.

5.4.4 Rehabilitation and Improvement of Headworks and Major Related Structures

(1) Components

In the Damnak Ampil Rehabilitation Sub-project, mainly two components are considered to the existing Damnak Ampil Diversion Weir; i.e., improvement of the gate system and newly installation of fish ladder on the right bank side of the existing weir.

(2) Summary of Design Condition:

Design condition for improvement of the Damnak Ampil Headworks is summarized as follows:

Summary of Design Condition for Improvement of Damnak Ampil Headworks

Design Parameter	Condition	Remarks
Design Flood Discharge	1,560 m^3/sec	T=100-year return period
Design River Bank Elevation	EL. 19.00 - 20.00m	around Weir site
Design Irrigation Water Level WL1:	WL. 17.00m	Top of Gate. Overflow depth=0.2m
Design River bed Elevation (Upstream):	EL. 12.00m	Existing
Design River bed Elevation (Downstream):	EL. 12.00m	Existing
Design Gate Sill Elevation:	EL. 13.50m	Existing
Design Discharge of Intake:	7.93 m^3/sec	<8.0 (Existing design discharge)
Design Discharge of Fish Ladder:	4.71 m^3/sec	Proposed

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(3) Improvement of Gate System:

Improvement of gate system for the Damnak Ampil Divrsion Weir is summarized as follows:

- Installation of new hoisting system for assisting flood gate lifting;
- Improvement of bushing of flood gate:
- Installation of new hoisting system for assisting scouring sluice gate lifting:

1) Hoisting system for flood gate:

Flood gate has mainly two objectives, which are contrary, and it is complicated to accomplish both tasks by only counterweight:

- Lifting of gate leaves to maintain water depth for irrigation (WL=17.0m)
- Flap down of gate leaves to discharge flood water

In the improvement works, existing counterweight will be used for automatic flood gate to be flapped down, and new hoisting system is proposed to assist lifting of gate leaves after flood

events, which is quite difficult to control only by counter weight since it does not allow gate leaves to be lifted up until water level completely falls down to EL.13.70m. Therefore, a new hoisting system has a clutch system for switching “automatic gate, flapping down by counter weight” and “motorized mechanical gate lifting”. From “flood management” viewpoint, it is very important to switch back to “automatic flap” mode after every “gate lift” event. A schematic drawings for the improvement works are shown in Figure 5.4-4.

Summary of Improvement Works for Damnak Ampil Weir Flood Gate System

Items	Contents	Remarks
Installation of new hoist system (Replacement of present hoist)	7 sets	1 motor-2 drum winch type with clutch for counter weight Local control panels w/ cable network system, Hoist deck Generator 75 kVA Lightening rods with earthing network
Exchange of bushing (Replacement of present bushing)	7 sets	Bushing with larger diameter and oil-less bearing for long durability because the existing bushs do not have enough strength for mechanical lifting proposed

Prepared by JICA Study Team

2) Hoisting system for scouring sluice gate:

At present, 4 sets of slide gate with dimension of about 2 m by 3.5 m are installed for scouring sluice gate, and they are very heavy to lift up manually. Therefore, new hoisting system with motor is proposed to be installed as follows. A schematic drawing for the improvement works are also shown in Figure 5.4-5.

Summary of Improvement Works for Damnak Ampil Weir Scouring Sluice Gate System

Items	Contents	Remarks
Installation of new hoist system (Replacement of present hoist)	4 sets	Rack type hoist with motor Local control panel

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3) Installation of Fish ladder:

For the conservation of fish and ecology of the river, installation of a fish ladder is proposed on the right bank of the existing diversion weir. Type of fish ladder is planned to be “half-cone type” or “grouted riprap cascade type”,as explained in section 5.2.4(3)-7). The schematic drawing is presented in Figure 5.4-6.

- discharge: 4.71m^3/sec (maintenance flow + D&I flow) + residual
- Width: B=5.0m (common for above types)
- Slope: I = 1/10 (common for above types)
- Height: H=4.4m (Gate height-inlet water depth)
- Length: L6=44 m (=4.4/(1/10))

Prepared by JICA Study Team

5.4.5 Rehabilitation and Improvement of Main and Secondary Systems

(1) Irrigation Canals and Related Structures

1) Design Plan

Design plan of irrigation facilities is discussed in section 5.2.5 (1)-1).

2) Rehabilitation and Improvement of Irrigation Facilities

a) Design of Irrigation Canals

Three secondary canals exist in the rehabilitated section of the Damnak Ampil Main Canal. This study conducts the rehabilitation and improvement designs of these canals.

These canals change their depth and width section by section. Therefore, canal designs are carried out by applying the Bernoulli's theorem under non-uniform condition.

Water source of these canals is the Damnak Ampil Main Canal. The designed water level of the Main Canal is set at 17.0 m at the intake site. Water levels of secondary canals are designed to connect to the water level of the Main Canal. Table 5.4-2 shows summary of irrigation canals proposed.

b) Design of Irrigation Canal Related Structures

Five types of irrigation related structure are preliminarily designed for the Damnak Ampil Rehabilitation Sub-project. Table 5.4-3 shows the required types and numbers of structures.

The function and feature of irrigation canal related structures are described in the previous section 5.2.5 (1)-2) except for a regulator on a temporary basis.

Regulator (provided on a temporary basis)

This structure with stop-logs would function as a regulator to keep Main Canal water level to be high enough for the Secondary Canal-3. This regulator would be constructed temporarily in consideration of a future extension plan of the Damnak Ampil Rehabilitation Sub-project.

(2) Drainage Canals and Related Structures

1) Design Plan

Design plan of Drainage facilities for the Damnak Ampil Rehabilitation Sub-project is discussed in section 5.2.5 (2)-1).

2) Rehabilitation and Improvement of Drainage Facilities

a) Design of Drainage Canals

Four secondary drainage canals would be necessary in the Sub-project area. Three secondary drainage canals, namely SD-1, SD-2 and SD-3, would be new canal, and SD-4 would be an existing stream. This study designed to utilize an existing stream as SD-4 without rehabilitation. The proposed drainage canal is summarized in Table 5.4-4.

b) Design of Drainage Canal Related Structures

Nine drainage culverts are preliminarily designed on Secondary Canals. Moreover, 26 drainage culverts would be necessary in tertiary blocks as shown in Table 5.4-5.

5.4.6 On-farm Development Plan of Damnak Ampil Rehabilitation Sub-project

The concept of on-farm development plan such as irrigation method, command area by a tertiary block, etc., are discussed in section 5.2.6.

In accordance with the topography and the concept above mentioned, 50 tertiary blocks are proposed in the Damnak Ampil Rehabilitation Sub-project (2,270 ha) in total. The average size of the tertiary block is figured out to be 45.4 ha. The typical length of a tertiary canal is 1.7 km on average in accordance with the topography. The total length of the tertiary canals is assumed at 85km in the Sub-project.

The typical length of one water course and number of water courses in the Sub-project are assumed to be 270 m and 200 numbers, respectively.

5.4.7 Water Management and Operation & Maintenance of Irrigation Facilities

(1) Responsible Organization

"The Policy for Sustainability of Operation and Maintenance of Irrigation System, June 2000" promotes the transfer of irrigation system to FWUC in order to mitigate financial burden for operation and maintenance (O&M). The share of responsibility of water management and O&M activities in the Damnak Ampil Rehabilitation Sub-project is proposed as follows taking into consideration the policy above, size of the Sub-project, importance of facilities for the Sub-project management.

Share of responsibility Proposed in the Damnak Ampil Sub-project

Level / Activities	Damnak Ampil Headworks	Main Canal	Secondary canals	Tertiary canals	Water courses	Field canals
Preparation of annual O&M plan	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	-
Preparation of cropping schedule	-	-	FWUC/ FWUG	Sub-FUWG	WUG	Household
Operation of facilities	PDOWRAM	PDOWRAM	FWUG	Sub-FUWG	WUG	Household
Maintenance work	PDOWRAM	PDOWRAM	FWUG	Sub-FUWG	WUG	Household

Note O&M Manuals shall be prepared by MOWRAM/PDOWRAM and be hand over to the respective agencies responsible during hand-over period.

Prepared by JICA Study Team

(2) Water Management and Operation

1) Damnak Ampil Headworks

PDOWRAM, Pusrsat is responsible for water management and O&M of the Damnak Ampil Headworks and Main Canal including related structures.

The water level at the intake is designed at EL.17.00m. Scouring sluice gates are controlled to

keep the design water level except for flood events. The water level shall be observed by reading a staff gauge which are installed at upstream of weir site and intake site.

The Damank Ampil Headworks is a main water source for 3 Sub-projects proposed, i.e., the Damank Ampil Rehabilitation Sub-project, the Wat Loung Rehabilitation Sub-project, the Wat Chre Rehabilitation Sub-project (refer to section 5.4.3). The water to Wat Loung and Wat Chre Sub-projects are diverted at 800 m downstream of the Damnak Ampil Main Canal, where a diversion structure is proposed The peak diversion water is designed at 7.93m^3/sec. The amount of water taken to the Main Canal, however, is to be controlled by the gates installed at the regulator in accordance with irrigation service plan of the 3 Sub-projects, which is to be prepared by PDOWRAM, Pursat. The regulator gates are controlled by readings of staff gauges which are installed upstream and downstream of the gates. The gate opening rule shall be set up based on the relationship between water level, gate opening and discharge.

2) Damnak Ampil Main Canal

Damnak Ampil Main Canal shall supply water to Wat Loung Main Canal which branches off at the first turnout (640 m downstream from Headworks). The peak design discharges in the Damnak Ampil Main Canal and Wat Loung Main Canal are 3.09m^3/sec and 4.84 m^3/sec, respectively. The water distribution of the two canals above is to be executed in proportion with the peak design discharge by controlling the turnout gates. In order to this, H-Q curve shall be developed at the turnout. Water supply to the above two canals shall be continuously made throughout a year except for maintenance period which is set in March and April.

In the Main Canal, check gates are fully opened in case a discharge exceeds the design discharge flows. However, check gates should be operated if discharge in the Main Canal is lower than the design discharge in order to maintain the water level in the Main Canal for gravity irrigation. In this connection, turnout gates shall be operated carefully in order to avoid overtaking of water.

Water level in the main canal shall not be suddenly down except emergency case like danger to human life. This rule shall be observed to prevent the slipping of inner side slopes of canal bank. And also, when water supply starts after completion of maintenance period, intake discharge shall be gradually increased up to the water demand.

In the maintenance period, the intake gates of the Headworks shall be totally closed and main canal shall be dried up for the purpose of annual maintenance. The maintenance works of Headworks and main canal are to be executed by PDOWRAM including related structures.

3) Secondary Canals

The water management and operation activities in the secondary canals are described in the previous section 5.2.7(2)-2).

4) Tertiary Canals

The water management and operation activities in the tertiary canals are described in the previous section 5.2.7(2)-3).

5) Water Courses and Field Canals

The water management and operation activities in the quaternary and field canals are described in the previous section 5.2.7(2)-4).

(3) Maintenance Work

The maintenance work of the Damnak Ampil Rehabilitation Sub-project facilities is described in the previous section 5.2.7(3).

5.5 Wat Loung Rehabilitation Rehabilitation Sub-project

5.5.1 Crop Production Plan

(1) Land Use Plan

The land use plan for the Wat Loung Rehabilitation Sub-project under the with-project condition is presented in comparison with the present/without-project land use as follows;

Present/Without-project & With-project Land Use of the Wat Loung Sub-project Area

Land Use Sub-category	Present		With-project		Increment
	(ha)	(%)	(ha)	(%)	(ha)
Paddy Field					
- Normal Irrigation Paddy Field			2,540	100	2,540
- Supplemental Irrigation Paddy Field	130	5			- 130
- Rainfed Paddy Field	2,590	95			- 2,590
Sub-total	2,720	100	2,540	100	- 180
Right-of-ways	200	7	380	13	180
Total	2,920	100	2,920	100	0

Prepared by JICA Study Team

The development of 2,540 ha of normal irrigation paddy field is aimed at under the Sub-project by the conversion of 130 ha of supplemental irrigation fields and 2,590 ha of rainfed fields. The decease of paddy fields due to land use conversion is estimated at 180 ha.

(2) Proposed Cropping Pattern and Cropped Area

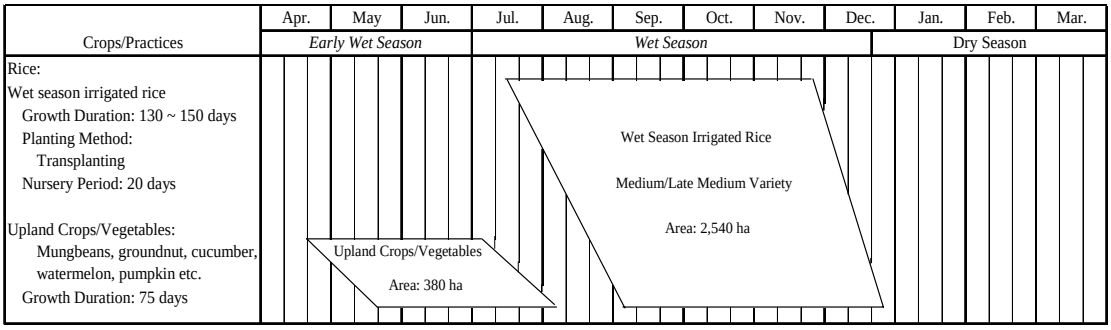
1) Crop Selection

The crop selection for the Wat Loung Rehabilitation Sub-project under the present plan has been made on the basis of the approaches applied for the Damnak Ampil Rehabilitation Sub-project discussed in the section 5.4.1 (2) as follows:

- Rice, current exclusive crop in the main cropping season, wet season, is selected as a crop to be introduced in the season as no other promising crops are conceivable, and
- Introduction of irrigated upland crops/vegetables production in early wet season aiming at: i) increasing land use intensity, ii) crop diversification, iii) sufficing domestic consumption and improvement of nutritional status of farm families by introducing pulses and iv) increasing farm income. Candidate upland crops could include mungbeans, groundnut, soybeans and corn and the same of vegetables are cucumber, water melon, pumpkin and gourd currently cultivated in the area.

2) Cropping Pattern and Cropped Area

Based on the study on the current prevailing cropping patterns, development concept and irrigation water balance study, the proposed cropping pattern for the Wat Loung Rehabilitation Sub-project has been formulated as follows;



Prepared by JICA Study Team

Proposed Cropping Pattern: Wat Loung Sub-project

The cropping intensity for the Wat Loung Rehabilitation Sub-project targeted under the plan is similar to that of the Damnak Ampil Rehabilitation Sub-project area as follows;

- Rice cropping intensity of 100% in wet season under irrigation is planned in the pattern within the availability of irrigation water, and
- Introduction of upland crops/vegetables under irrigation in early wet season to the extent of cropping intensity of 15% is envisaged by availing irrigation water supply in the season to promote crop diversification in the Sub-project area.

The planned cropped areas and cropping intensity envisaged in the pattern are shown in Table 5.5-1 and summarized as follows;

Planned Cropped Area & Cropping Intensity under the Wat Loung Sub-project

Unit: ha & %

Crop	Cropping Season							
	Early Wet Season		Wet Season		Dry Season		Annual	
	Area	Intensity	Area	Intensity	Area	Intensity	Area	Intensity
Irrigated Rice			2,540	100			2,540	100
Upland Crops/Vegetables	380	15					380	15
Total	380	15	2,540	100	0	0	2,920	115

Prepared by JICA Study Team

(3) Target Crop Yields

The target crop yields for the Wat Loung Rehabilitation Sub-project under the present plan in which normal irrigation is ensured are set at the same levels with the Damnak Ampil Rehabilitation Sub-project as shown in the following table in comparison with the present yield levels.

Target Yields and Present Yield Levels of Wat LoungSub-project (Unit: ton/ha)

Wet Season				Early Wet Season			
Crop 1/	**Target**	**Present**	**Increment**	**Crop**	**Target**	**Present**	**Increment**
Improvement of Irrigation Status: Present: Supplemental Irrigation ⇒ With-project: Normal Irrigation 2/							
Medium Rice (T)	3.3	2.0	1.3	Upland Crops 3/	1.1	0.5	0.3
Improvement of Irrigation Status: Present: Rainfed ⇒ With-project: Normal Irrigation 2/							
Medium Rice (T)	3.3	1.5	1.8	Upland Crops 3/	1.1	0.5	0.3

1/: T – transplanting 2/: Including pump irrigation fields 3/: Upland crops average of mungbeans & groundnut

Prepared by JICA Study Team

Yield increases of 1.3 to 1.8 ton/ha in wet season rice are envisaged under the plan. The target yields of irrigated upland crops and vegetables are set rather conservatively: mungbeans 0.9 ton/ha, groundnut 1.3 ton/ha, watermelon 9.0 ton/ha and cucumber 10.0 ton/ha (current yield level: watermelon 5.5 ton/ha & cucumber 6.0 ton/ha under rainfed condition).

(4) Crop Production Plan

The crop production plan for the Wat Loung Rehabilitation Sub-project under the with-project condition is presented in comparison with the present/without-project crop production in Table 5.5-1 and summarized as shown in the following table.

Present & With-project Crop Production of the Wat Loung Sub-project Area

Land Use Sub-category/Crops		Cropped Area (ha)	Intensity (%)	Yield (t/ha)	Production (t)
I. Present/Without-project Crop Production					
Supplemental Irrigation Paddy Field: Rice		175	6	2.1	373
Rainfed Paddy Field: Wet Season Rice		2,590	95	1.5	3,885
Annual	Rice	2,765	102	1.5	4,258
	Upland Crops	30	1		174
II. With-project Crop Production					
Normal Irrigation Paddy Field: Rice		2,540	100	3.3	8,382
Annual	Rice	2,540	100	3.3	8,382
	Upland Crops 2/	380	15	-	1,342
Increment (II – I)					
Annual	Rice	- 225	- 2	1.8	4,125
	Upland Crops	350	14	-	1,168

1/: Cultivation of wet season rice under rainfed conditions due to limitation of irrigation water supply.
2/: Total of upland crops & vegetables, represented by mungbeans, groundnut, watermelon & cucumber.
Note: Rice figures are total of wet & early wet season rice and direct sowing & transplanting rice
Prepared by JICA Study Team

As shown in the table, the increase of overall average paddy yield of 1.8 ton/ha from 1.5 to 3.3 ton/ha and annual paddy production increase of some 4,100 tons are expected. The paddy production under the Sub-project is about 200% of the current production level in the area. Under the Sub-project, the expansion of upland crops/vegetables production is envisaged and the production volume of the crops is estimated to be some 1,300 tons, increase of about 1,200 tons from the present level.

(5) Proposed Farming Practices

Proposed improved farming practices of paddy to be adopted in the Wat Loung Rehabilitation Sub-project are same with the practices proposed for the Damnak Ampil Rehabilitation Sub-project and include proper land preparation, quality seed & proper seeding rate, improved nursery & planting method, proper fertilization & water management etc., as discussed in the section 5.4.1(5).

5.5.2 Agricultural Extension Activities

The proposed activities are development interventions aiming at strengthening of agricultural extension services for attaining the Sub-project target crop yields and cropping pattern at an earlier stage as possible. The estimated costs for the activities accommodated as Sub-project

component are summarized in the following table.

Major extension activities for the Wat Loung Rehabilitation Sub-project are as discussed in the section 5.4.2 and include field programs including seed multiplication program, farmer & farmer group training programs mass guidance/workshop, staff empowerment, support fund for extension staffs and provision of transportation means.

Estimated Costs for Agricultural Extension Activities of Wat Long Sub-project [1/]

Activity	Estimated Cost (US$)
Field Extension Programs	87,550
Farmer/Farmer Group Training Programs	21,700
Mass Guidance/Workshop	2,000
Support Fund for Extension Staff 2/	28,800
Staff Empowerment	4,000
Provision of Transportation Means	6,000
Total	150,050

1/: Program direct costs
2/: Provision of support for VAA (village Agriculture Extension Agent) & field staff
Prepared by JICA Study Team

The implementation of the activities is scheduled for the period of 4 years in the Sub-project and the overall cost is estimated at US$ 150,000.-.

5.5.3 Irrigation and Drainage Plan

(1) Canal Layout Proposed

The command area of the Wat Loung Rehabilitation Sub-project is located along the left bank of the Pursat River, and several kilometer downstream from the Damnak Ampil Headworks. The command area lies from south-east to north-west between Ou Bakan stream and the National Road No.5. The proposed irrigation canal layout is made in accordance with concept and approach described in Chapter 4.2, and is shown in Figure 5.4-1 together with the Damank Ampil and the Wat Chre Rehabilitation Sub-projects. General features of the Sub-project are summarized in Table 5.2-2, together with the others two Sub-projects in the Pursat River Basin. The irrigation area diagram is shown in Figure 5.5-1.

(2) Headworks

The Wat Loung Rehabilitation Sub-project is proposed to use the existing Damnak Ampil Headworks commonly with the Damnak Ampil Rehabilitation Sub-project as discussed in section 5.1.3 (3).

(3) Wat Loung Main Canal

The new Wat Loung Main Canal branches from the Damnak Ampil Main Canal at cumulative distance of 800 m from Damnak Ampil Headworks. It runs about 7.6 km along rural road and joins with the existing Main Canal. After joining, the existing Main Canal after rehabilitation is used by the Sub-project until it joins with the Boeung Khnar River (12.7 km).

The diversion water requirement is estimated at 3.45m^3/sec. The Wat Loung Main Canal also conveys irrigation water to the Wat Chre Rehabilitation Sub-project (1.39 m^3/sec) as explained

in section 5.1.3(4). Accordingly, the Wat Loung Main Canal has a flow capacity of 4.84m^3/sec.

(4) Irrigation Water Requirement

The irrigation water requirement for the Wat Loung Rehabilitation Sub-project is considered same as that of the Damnak Ampil Rehabilitation Sub-project since these Sub-projects are located in the similar climatic and other natural conditions.

The peak water requirement for tertiary and field canals is figured out at 1.91 lit/sec/ha in August including irrigation efficiency of 85%.

The peak diversion water requirement in the Sub-project is figured out at 1.36 lit/sec/ha for wet season paddy in August taking into account for the overall irrigation efficiency of 66%.

(5) Irrigation Area by Portable Pump

The ground height of upstream area along the Wat Loung Main Canal is higher than water level in the canal. The raising of water level in the Main Canal is not economically feasible because it also requires raising of gate height of the Damnak Ampil Headworks by about 1.0m which results in higher cost, and causes inundation in the upstream of the Pursat River unless the river banks are also heightened. Therefore, irrigation using portable pumps is inevitable in about 800 ha out of 2,540 ha. Those areas are located along with the Wat Loung Main Canal, and farmers are familiar with portable pump irrigation.

(6) Drainage Plan

The excess water in the Wat Loung Rehabilitation Sub-project area is proposed to be drained by gravity. Field drains collect water from paddy fields and other types of land, and flow into tertiary drains. Tertiary drains flow into secondary drains due to the topography. Secondary drains flow into the Boeung Khnar River in the downstream.

The general feature of drainage plan is summarized in Table 5.2-2. The drainage diagram is presented in Figure 5.5-2. The drainage water requirement is also summarized in Table 5.2.2.

(7) Drainage Water Requirement

1) Drainage water requirement from paddy field

The unit drainage water requirement from paddy field for the Wat Loung Rehabilitation Sub-project is calculated at q=6.32 lit/sec/ha based on the annual maximum rainfall in 3 consecutive days at one in 5 years return period. The procedure is described in the previous section 5.4.3(7).

2) Drainage water requirement from other types of land

The calculated results of unit drainage water requirement for the other types of land with area less than 100 ha and more than 100 ha are as follows (the procedure is described in the previous section 5.4.3(7)):

Qpeak = 0.25m^3/sec/ha from the area less than 100 ha

Qpeak = 0.18m^3/sec/ha from the area more than 100 ha

5.5.4 Rehabilitation and Improvement of Main and Secondary Systems

(1) Irrigation Canals and Related Structures

1) Design Plan

Design plan of irrigation facilities in the Wat Loung Rehabilitation Sub-project is discussed in section 5.2.5 (1)-1).

2) Rehabilitation and Improvement of Irrigation Facilities

a) Design of Irrigation Canals

The new Wat Loung Main Canal is proposed to branch from the Damnak Ampil Main Canal. The diversion structure is located at just downstream section of the first gated regulator with a bridge on the upper reach of the Damnak Ampil Main Canal.

The new Wat Loung Main Canal runs along the left bank of existing trunk road by the Pursat River for the first 4.2 km. The canal section would be deeply excavated.

The new Main Canal would meet the existing Wat Loung Main Canal at the distance of 4.5 km from the mouth of the Pursat River. The proposed canal dimension is summarized in Table 5.5-2.

b) Design of Irrigation Canal Related Structures

Seven types of irrigation related structure are preliminarily designed in the Wat Loung Rehabilitation Sub-project. Table 5.5-3 presents the required types and numbers.

The function and feature of irrigation canal related structures are described in the previous section 5.2.5 (1) except for a syphon.

Syphon

The new Main Canal crosses the Ou Bakan River at approximately 2.5 km point from the beginning. In order to cross the natural stream safely, a syphon having a concrete box type conduit with an effective inner dimension of 2.5 m x 2.5 m is proposed. Conduit length would be 60 m.

(2) Drainage Canals and Related Structures

1) Design Plan

Design plan of Drainage facilities in the Wat Loung Rehabilitation Sub-project is discussed in section 5.2.5 (2)-1).

2) Rehabilitation and Improvement of Drainage Facilities

a) Design of Drainage Canals

Drainage canals would be new canals. Structural and hydraulic designs are the same as the Ream Kon Rehabilitation Sub-project as described in section 5.2.5 (2).

Table 5.5-4 shows proposed dimension of drainage canals. Water depth and flow velocity are calculated by the Manning's formula.

b) Design of Drainage Canal Related Structures

Drainage Culvert

Five drainage culverts across the main canal are required to drain out excessive water from the southern area. Eight drainage culverts are also necessary to cross the existing trunk roads.

Footpath Bridge

There are lots of footpaths, which are not shown in the topographic map, in secondary canal commanding areas. Eight footpath bridges are designed for these footpaths to cross natural stream or depressions. Locations of these footpath bridges would be investigated in a next stage. Type and number of drainage structures are summarized in Table 5.5-5.

5.5.5 On-farm Development Plan

The concept of on-farm development plan for the Wat Loung Rehabilitation Sub-project such as irrigation method, command area by a tertiary block, etc., are discussed in section 5.2.6.

In accordance with the topography and the concept above mentioned, 54 tertiary blocks are proposed in the Wat Loung Rehabilitation Sub-project (2,540 ha) in total. The average size of the tertiary block is figured out to be 47.0 ha. The typical length of a tertiary canal is 1.5 km on average in accordance with the topography. The total length of the tertiary canals is assumed to be 81 km in the sub-project. The typical length of one water course and number of water courses in the Sub-project are assumed to be 320 m and 216 numbers, respectively.

5.5.6 Water Management and Operation & Maintenance of Irrigation Facilities

(1) Responsible Organization

"The Policy for Sustainability of Operation and Maintenance of Irrigation System, June 2000" promotes the transfer of irrigation system to FWUC in order to mitigate financial burden for operation and maintenance (O&M). The share of responsibility of water management and O&M in the Wat Loung Rehabilitation Sub-project activities is proposed as follows taking into consideration the policy above, size of the Sub-project, importance of facility for the Sub-project management.

Share of responsibility Proposed in the Wat Loung Sub-project

Activities \ Level	Damnak Ampil Head works/ Main Canal *1	Wat Loung Main Canal	Secondary canals	Tertiary canals	Water courses	Field canals
Preparation of annual O&M plan	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	-
Preparation of cropping schedule	-	-	FWUC/ FWUG	Sub-FWUG	WUG	Household
Operation of facilities	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	Household
Maintenance work	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	Household

Note O&M Manuals shall be prepared by MOWRAM/PDOWRAM and be hand over to the respective agencies responsible during hand-over period.

*1 Wat Loung Sub-project commonly uses the Damnak Ampil Headworks and Main Canal (about 700m) together with Damnak Ampil Sub-project and Wat Chre Sub-project.

Prepared by JICA Study Team

(2) Water Management and Operation

1) Damnak Ampil Headworks and Main Canal

Damnak Ampil Main Canal will supply water to the Wat Loung Main Canal at the first diversion structure as described in section 5.1.3 (4).

2) Wat Loung Main Canal

PDOWRAM, Pursat is responsible for water management and O&M of the Wat Loung Main Canal including related structures.

The peak design discharge for the Wat Loung Main Canal is 4.84 m^3/sec, respectively. The Wat Long Main Canal is proposed to transport irrigation water to the Wat Chre Rehabilitation Sub-project safely. The design discharge above contains 1.39 m^3/sec which shall be supplied to the Wat Chre Rehabilitation Sub-project. At the end of the Wat Loung Main Canal where the canal meets the Boeung Khnar River, the design discharge of 1.39 m^3/sec shall flow into Boeung Khnar River. The water is taken by the Wat Chre Headworks which is proposed at about 9 km downstream of confluence point. Water supply to the Wat Chre Rehabilitation Sub-project shall be continuously made throughout a year except for maintenance period which is set in March and April.

The canal base of the Wat Loung Main Canal is designed to vary from place to place to use the existing canal section for cost reduction, thus the flow in the Main Canal is not a uniform flow but non-uniform flow. Accordingly, check gates shall be operated in order to maintain the water level in the Main Canal for gravity irrigation. In this connection, turnout gates shall be operated carefully in order to avoid overtaking of water.

Water level in the Main Canal shall not be suddenly lowered except for an emergency case such as danger to human life. This rule shall be observed to prevent the slipping of inner side slopes of canal bank. And also, when water supply starts after completion of maintenance period, intake discharge shall be gradually increased to meet the water demand.

In the maintenance period, the intake gates of the Headworks shall be totally closed and the Main Canals shall be dried up for the purpose of annual maintenance. The maintenance works of the Headworks and Main Canals are to be implemented by PDOWRAM including related structures.

3) Secondary Canals

The water management and operation activities in the secondary canals are described in the previous section 5.2.7(2)-2).

4) Tertiary Canals

The water management and operation activities in the tertiary canals are described in the previous section 5.2.7(2)-3).

5) Water Courses and Field Canals

The water management and operation activities in the quaternary and field canals are described in the previous section 5.2.7(2)-4).

(3) Maintenance Work

The maintenance work of Sub-project facilities is described in the previous section 5.2.7(3).

5.6 Wat Chre Irrigation Rehabilitation Sub-project

5.6.1 Crop Production Plan

(1) Land Use Plan

The land use plan for the Wat Chre Rehabilitation Sub-project under the with-project condition is presented in comparison with the present/without-project land use as follows;

Present/Without-project & With-project Land Use of the Wat Chre Sub-project Area

Land Use Sub-category	Present		With-project		Increment
	(ha)	(%)	(ha)	(%)	(ha)
Paddy Field					
- Normal Irrigation Paddy Field			1,020	100	1,020
- Supplemental Irrigation Paddy Field	60	6			- 60
- Rainfed Paddy Field	1,030	94			- 1,030
Sub-total	1,090	100	1,020	100	- 70
Right-of-ways	80	7	150	13	70
Total	1,170	100	1,170	100	0

Prepared by JICA Study Team

As shown in the table, the development of 1,020 ha of normal irrigation paddy field is aimed at under the Sub-project by the conversion of 60 ha of supplemental irrigation fields and 1,030 ha of rainfed fields. The decease of paddy fields due to land use conversion to right-of-ways is estimated at 70 ha.

(2) Proposed Cropping Pattern and Cropped Area

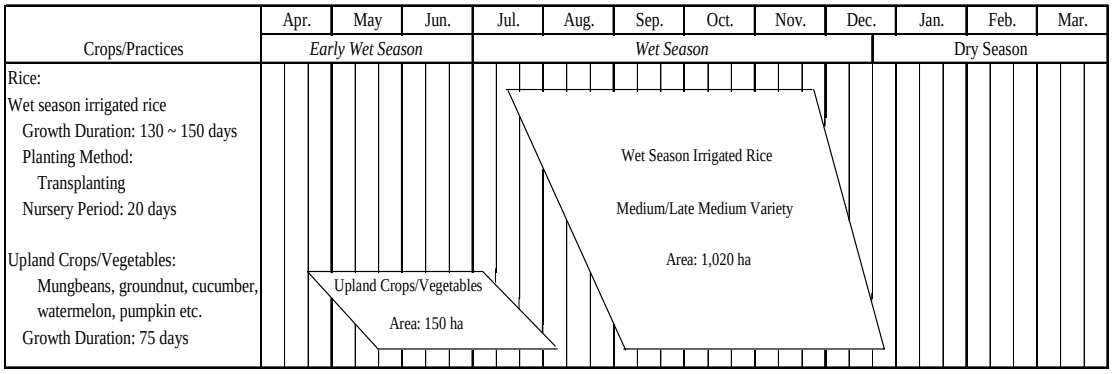
1) Crop Selection

The crop selection for the Wat Chre Rehabilitation Sub-project under the present plan has been made on the basis of the approaches applied for the Damnak Ampil Rehabilitation Sub-project discussed in the section 5.4.1(2) as follows;

- Rice, current exclusive crop in the main cropping season, wet season, is selected as a crop to be introduced in the season as no other promising crops are conceivable and rice is a by far the most important crop and stable food in the area. Cultivation of local varieties with good quality and preferred by farming communities in the subject area or improved local varieties is to be practiced,
- Introduction of irrigated upland crops/vegetables production in early wet season aiming at: i) increasing land use intensity in paddy fields, ii) crop diversification, iii) sufficing domestic consumption and improvement of nutritional status of farm families by introducing pulses and iv) increasing farm income.
- Candidate upland crops could include mungbeans, groundnut, soybeans and corn and the same of vegetables include cucumber, water melon, pumpkin and gourd currently cultivated in and around the Sub-project area.

2) Cropping Pattern and Cropped Area

Based on the study on the current prevailing cropping patterns, the development concept discussed earlier and the results of irrigation water balance study, the proposed cropping pattern for the Wat Chre Rehabilitation Sub-project has been formulated as shown in the following figure.



Prepared by JICA Study Team

Proposed Cropping Pattern: Wat Chre Sub-project

The cropping intensity targeted under the plan is similar to the same for the Damnak Ampil and the Wat Loung Rehabilitation Sub-project areas as follows:

- Rice cropping intensity of 100% in wet season under irrigation is planned in the pattern within the availability of irrigation water, and

- Introduction of upland crops/vegetables under irrigation in early wet season to the extent of cropping intensity of 15% is envisaged by availing irrigation water supply in the season to promote crop diversification in the Sub-project area.

The planned cropped areas and cropping intensity envisaged in the pattern are shown in Table 5.6.1-1 and summarized as follows;

Planned Cropped Area & Cropping Intensity under the Wat Chre Sub-project

Unit: ha & %

Crop	Cropping Season							
	Early Wet Season		Wet Season		Dry Season		Annual	
	Area	Intensity	Area	Intensity	Area	Intensity	Area	Intensity
Irrigated Rice			1,020	100			1,020	100
Upland Crops/Vegetables	150	15					150	15
Total	150	15	1,020	100	0	0	1,170	115

Prepared by JICA Study Team

(3) Target Crop Yields

The target crop yields for the Wat Chre Rehabilitation Sub-project under the present plan in which normal irrigation is ensured are set at the same levels with the Damnak Ampil and the Wat Loung Rehabilitation Sub-projects as shown in the following table in comparison with the present yield levels.

Target Yields and Present Yield Levels Wat Chre Sub-project (Unit: ton/ha)

Wet Season				Early Wet Season			
Crop 1/	**Target**	**Present**	**Increment**	**Crop**	**Target**	**Present**	**Increment**
Improvement of Irrigation Status: Present: Supplemental Irrigation With-project: Normal Irrigation 2/							
Medium Rice (T)	3.3	2.0	1.3	Upland Crops 3/	1.1	-	-
Improvement of Irrigation Status: Present: Rainfed With-project: Normal Irrigation 2/							
Medium Rice (T)	3.3	1.5	1.8	Upland Crops 3/	1.1	-	-

1/: T – transplanting 2/: Including pump irrigation fields 3/:Upland crops: average of mungbeans & groundnut
Prepared by JICA Study Team

Yield increases of 1.3 to 1.8 ton/ha in wet season rice are envisaged under the plan. The target yields of irrigated upland crops and vegetables are set rather conservatively: mungbeans 0.9 ton/ha, groundnut 1.3 ton/ha, watermelon 9.0 ton/ha and cucumber 10.0 ton/ha (current yield level: watermelon 5.5 ton/ha & cucumber 6.0 ton/ha under rainfed condition).

(4) Crop Production Plan

The crop production plan for the Wat Chre Rehabilitation Sub-project under the with-project condition is presented in comparison with the present/without-project crop production in Table 5.6-1 and summarized as follows;

Present & With-project Crop Production of the Wat Chre Sub-project Area

Land Use Sub-category/Crops		Cropped Area (ha)	Intensity (%)	Yield (t/ha)	Production (t)
I. Present/Without-project Crop Production					
Supplemental Irrigation Paddy Field: Rice		60	6	2.0	120
Rainfed Paddy Field: Wet Season Rice		1,030	94	1.5	1,545
Annual	Rice	1,090	100	1.5	1,665
	Upland Crops	30	3	-	174
II. With-project Crop Production					
Normal Irrigation Paddy Field: Rice		1,020	100	3.3	3,366
Annual	Rice	1,020	100	3.3	3,366
	Upland Crops 2/	150	15	-	585
Increment (II – I)					
Annual	Rice	- 70	0	1.8	1,701
	Upland Crops	120	12	-	411

1/: Cultivation of wet season rice under rainfed conditions due to limitation of irrigation water supply.
2/: Total of upland crops & vegetables, represented by mungbeans, groundnut, watermelon & cucumber.
Note: Rice figures are total of wet & early wet season rice and direct sowing & transplanting rice
Prepared by JICA Study Team

As shown in the table, the increase of overall average paddy yield of 1.8 ton/ha from 1.5 to 3.3 ton/ha and annual paddy production increase of some 1,700 tons are expected. The paddy production under the Sub-project is about 200% of the current production level in the project area. Under the Sub-project, the expansion of upland crops/vegetables production is envisaged and the production volume of the crops is estimated to be about 600 tons, increase of about 400 tons from the present level.

(5) Proposed Farming Practices

Proposed improved farming practices of paddy to be adopted in the Wat Chre Rehabilitation Sub-project are the same with the practices proposed for the Damnak Ampil Rehabilitation Sub-project and include proper land preparation, quality seed & proper seeding rate, improved nursery & planting method, proper fertilization & water management etc., as discussed in the section 5.4.1(5).

5.6.2 Agricultural Extension Activities

The proposed activities in the Wat Chre Rehabilitation Sub-project are development interventions aiming at strengthening of agricultural extension services for attaining the Sub-project target crop yields and cropping pattern at an earlier stage as possible. The estimated costs for the activities accommodated as Sub-project component are summarized in the following table.

Estimated Costs for Agricultural Extension Activities of Wat Chre Sub-project [1/]

Activity	Estimated Cost (US$)
Field Extension Programs	36,000
Farmer/Farmer Group Training Programs	12,800
Mass Guidance/Workshop	800
Support Fund for Extension Staff 2/	10,880
Staff Empowerment	3,200
Provision of Transportation Means	2,100
Total	65,780

1/: Program direct costs

2/: Provision of support for VAA (village Agriculture Extension Agent) & field staff

Prepared by JICA Study Team

Major extension activities are as discussed in the section 5.4.2 and include field programs including seed multiplication program, farmer & farmer group training programs mass guidance/workshop, staff empowerment, support fund for extension staffs and provision of transportation means.

The implementation of the activities is scheduled for the period of 4 years in the Sub-project and the overall cost is estimated at US$ 66,000.-.

5.6.3 Irrigation and Drainage Plan

(1) Wat Chre Headworks

The new headworks site is proposed at one kilometer upstream from the existing weir in the Boeung Khnar River, to avoid the correction of canal bed slope of the existing canal which currently flows to reverse direction around the existing ruined weir. The river bed and river bank is about EL.9.5 m and EL.13.0 m, respectively. The river width at the new proposed site ranges from 15 m at its bottom to about 45 m at its top. The intake water level is determined taking into consideration the lowest existing bank height in the upstream and paddy field elevation in the irrigation area:

- Paddy field elevation = EL. 13.2m approx at highest point
- Bank height = EL. 13.0m approx at lowest point

In order to irrigate all the target area by gravity, the water level at the Headwork is set to be higher than 13.5m. It requires raising of the existing river dike by about 1.0 m. The height of existing river dike ranges between EL.12.4m and EL.14.2m. The heightening of the dike requires higher construction cost and land acquisition. Based on the above reason and condition, the intake water level at the Wat Chre Headworks is determined at EL. 13.0m.

(2) Wat Chre Main Canal

The proposed Wat Chre Main Canal consists of the following two portions; newly construction portion, upstream reach of L=700 m, starts in the upstream of the new Wat Chre Headworks, connecting to the existing Main Canal; and rehabilitation portion utilizing the existing Main Canal, which runs toward northeast. Since a part of the existing Main Canal runs to northwest toward the existing ruined weir with a downward slope, this part is to be

utilized effectively as a secondary canal.

(3) Canal Layout

The proposed irrigation canal layout for the Wat Chre Rehabilitation Sub-project is prepared in accordance with concept and approach described in Chapter 4.2, and is shown in Figure 5.4-1 together with the Damnak Ampil and the Wat Loung Rehabilitation Sub-projects. The area is divided into two sites, west site on left bank and east site on the right, by Boeung Khnar River. A secondary canal must cross the Boeung Khnar River to convey and irrigate the west site on the left bank. General features of the Sub-project are summarized in Table 5.2-2. The irrigation area diagram is shown in Figure 5.6-1.

(4) Irrigation Area by Portable Pump

In the Wat Chre Rehabilitation Sub-project, about 400 ha out of 1,020 ha requires pump irrigation in the upstream area of the Main Canal due to topography. The raising water level in the main canal is not economically feasible as describe in the above section.

(5) Drainage Plan

The excess water in the Wat Chre Rehabilitation Sub-project area is proposed to be drained by gravity. Field drains collect water from paddy fields and other types of land, and flow into tertiary drains. Tertiary drains flow into secondary drains, then finally secondary drains flow into the Boeung Khnar River.

The general feature of drainage plan is summarized in Table 5.2-2. The drainage diagram is presented in Figure 5.6-2.

(6) Drainage Water Requirement

1) Drainage water requirement from paddy field

The unit drainage water requirement, q (lit/sec/ha), from paddy field for the Wat Chre Sub-project is calculated at q=6.32 lit/sec/ha based on the annual maximum rainfall in 3 consecutive days at one in 5 years return period. The procedure is described in the previous section 5.4.3.

2) Drainage water requirement from other types of land

The calculated results of unit drainage water requirement for the other types of land with area less than 100 ha and more than 100 ha are as follows (the procedure is described in the previous section 5.4.3):

Qpeak = $0.25 m^3$/sec/ha from the area less than 100 ha

Qpeak = $0.18 m^3$/sec/ha from the area more than 100 ha

5.6.4 Rehabilitation and Improvement of Headworks and Major Related Structures

(1) Basic Consideration

The Wat Chre Headworks is planned to supply irrigation water only to the Wat Chre Rehabilitation Sub-project area (1,020 ha). Components of the Headworks are as follows:

a) Re-construction of the Wat Chre Diversion Weir

b) Re-construction of Wat Chre Intake

c) Additional embankment of river bank and excavation of river

d) Rehabilitation of Main Irrigation Canal for temporary river diversion and irrigation

The schematic diagram of the above components is illsutrated in Figure 5.6-3.

(2) Design Condition for Headworks

Design condition proposed for the Wat Chre Headworks is summarized as follows:

Summary of Design Condition for Wat Chre Headworks Proposed

Design Parameter	Condition	Remarks
Design Flood Discharge Q_F:	65 m^3/sec	T=100 year return period
Design Flood Water Level WL_F1:	WL. 13.6m	at Weir site
Design Flood Water Level WL_F2:	WL. 14.2m	at the Bridge on National Road No.5
Design River Bank Elevation	EL. 14.30 - 15.00m	betw/ Weir site and National Road No.5
Design Irrigation Water Level WL1:	WL. 13.00m	Top of Gate. Overflow depth=0.2m
Design River bed Elevation (Upstream):	EL. 9.60m	
Design River bed Elevation (Downstream):	EL. 9.60m	
Design Gate Sill Elevation:	EL. 9.60m	
Intake Discharge to Wat Chre Sub-project:	1.39 m^3/sec	Peak discharge
Discharge of fish ladder	$\geq$0.18m^3/sec	River maintenance flow for180 km^2

Prepared by JICA Study Team

(3) Preliminary Design of Wat Chre Diversion Weir

1) Summary:

The Wat Chre Diversion Weir is designed based on the existing weirs in Cambodia, criteria in MOWRAM, Japan, and other similar countries. The major dimension proposed is summarized in the following table and in the schematic diagram in Figure 5.6-5.

Major Proposed Dimension of Wat Chre Diversion Weir

Items	Dimension
Weir Type	Floating Type Movable Weir
Design Water Level	WL1: 13.0m (for Irrigation), WL_F1:13.6m (Flood water level)
Total Clear Width of Weir	ΣB=27.5m
Elevation of gate sill	EL1.= 9.60m
Total Height of Weir	8.8m
Length of Weir incl. riprap	To upstream=43.0m, To downstream=20.0m
Gate type (Flood Gate) and nos.	Fixed wheel gate with counterweight, 1 nos.
Gate Dimension	Clear Height= 3.4m, Clear Span= 12.5m
Gate type (Scouring sluices) and Nos.	Slide gate, 2 Nos.
Bridge	Effective width=3.8m, Total length=40m
Fish Ladder	B:5.0m (Half cone type), Δh=3.3m, L=33m, I1/10

Prepared by JICA Study Team

Major components of the diversion weir are explained hereunder.

2) River Section:

Based on the topographic survey data and uniform flow hydraulic caculation, the longitudinal section and cross section of the river are determined as shown below. It is proposed to rehabilitate the river course of the Boeung Khnar River with the following dimension to deal with the design flood discharge of Q_F=65m^3/sec. The typical cross section is presented in Figure 5.6-4.

Typical Dimension of River Section in the Downstream of the Wat Chre Diversion Weir

Canal type	Discharge (m^3/sec)	River bed width (m)	Bed slope	Inner side slope	Water depth(m)	Free board (m)
Earth, Trapezoidal cross section	65	15.0	1/3000	1:2.5	3.3	0.6

Prepared by JICA Study Team

3) Weir Type:

Weir type is determined as “floating type” in the preliminary design, due to lack of geological information along the river and the weir site. In addition, a movable weir with gate is proposed in order to control flood water level at an adequate water level along the upstream reach of the river during floods. An "Overflow crest type" weir is not appropriate due to the following reasons:

- The river bank from the weir to the Bridge on the National Road No.5 which is located upstream of the weir needs re-heightening of dyke; it needs high construction cost
- The above re-heightening work requires not only land acquisition but also moving private houses along the river in about 3 km; this will be a burden to the government.

4) Gate

a) Gate Type

Five gate types were compared from technical and economical viewpoints as shown in Table 5.2-3. As a result, fixed wheel type gate is selected for flood gate, in particular for its high reliability under influence of downstream back water from the Lake Tonle Sap, as well as its easy operation, since those factors are important for facility management of the Project.

For scouring sluice gate, a slide gate is selected, owing to its high reliability and relatively small gate size compared to the size of the flood gate, thus it could be operated with lower hoisting load with ease.

b) Span Length and Clear Span of Flood Gate

Span length, clear span and number of gate leaf is first referred to existing large weirs in Cambodia, such as Damnak Ampil, Roleang Chrey and Kandal Steung, and then determined by employing Japanese design criteria for headworks (and the River Control Structural ordinance), coupled with non-uniform flow hydraulic calculations for design flood (high water) discharge of 65 m^3/sec.

As a result, “one gate with clear span of 12.5m” is selected for the Wat Chre Weir.

5) Bridge

A concrete slab bridge is installed over the weir with a total span of about 40m. The elevation of slab bottom is to be EL. 14.6m, by adding a freeboard of 1.0 m to the design flood (high water) level of WL_F1=13.6m at weir site. The effective width and total width of the bridge are 3.8m and 5.0m, respectively, referred to the bridge of the Damnak Ampil Weir, with regarding the adjacent provincial road class.

6) Foundation works

Due to lack of geological information for preliminary design, concrete piles with 30 cm x 30 cm (or dia. 30 cm) x L = 6.0 m are to be installed at a maximum spacing of 3.0 m under body spillway, upstream and downstream apron and fish ladder. In addition, sheet piles of L = 6.0 m are also to be installed near the edge of body spillway.

7) Fish Ladder:

For the conservation of fish and ecology of the river, installation of a fish ladder is planned on the right bank of the weir. Type of fish ladder is planned to be "half-cone type" or "grouted riprap cascade type". The feature of the above fish ladder is referred to section 5.2.4 (3)-7).

- discharge: 0.18m^3/sec (maintenance flow) + residual - Width: B=5.0m (common for above types) - Slope: I = 1/10 (common for above types) - Height: H=3.3m (Gate height - inlet water depth) - Length: L6=33 m (=3.3/(1/10))	 Image: half-cone type fish ladder

Prepared by JICA Study Team

(4) Wat Chre Intake

The Wat Chre Intake is proposed to be reconstruct at about 100m upstream from the Wat Chre Diversion Weir. Design condition and result for the Wat Chre Intake are summarized in Figure5.6-6.

(5) Main Irrigation Canal (Temporary River Diversion during construction work)

i) Summary of Design Condition and Result:

The design discharge for the Wat Chre Main Canal (MC) is at 1.39 m^3/sec for irrigation purpose. On the other hand, the MC is proposed to be used as a temporary river diversion channel during the construction work of the Wat Chre Headworks. The construction period for the Headworks is anticipated between mid-November and late-May, and the maximum discharge observed in the above period is at 3.0m^3/sec in the last five years. Therefore, the design temporary flood discharge during the construction period is set at 3.0 m^3/sec. Based on the uniform-flow hydraulic calculation, the MC with dimension shown below is capable to convey the design temporary flood discharge using free board of the MC. The design

condition and result are summarized as follows and presented in Figure 5.6-7.

Typical Dimension of River Section of Wat Chre Diversion Weir

Canal type	Design Discharge (m^3/sec)	Canal base width (m)	Bed slope	Inner side slope	Water depth (m)	Free board (m)
Earth, Trapezoidal cross section	1.39 3.00	2.6	1/3000	1:1.0	0.81 1.25	0.8 0.0

Prepared by JICA Study Team

5.6.5 Rehabilitation and Improvement of Main and Secondary Systems

(1) Irrigation Facilities

1) Design Plan

Design plan of irrigation facilities is discussed in section 5.2.5 (1)-1).

2) Rehabilitation and Improvement of Irrigation Facilities

a) Design of Irrigation Canals

One main, five secondary and one sub-secondary canals are preliminary designed.

The first section of 700m of the Wat Chre Main Canal is designed as a new canal with the design discharge 3.0 m^3/sec as described in 5.6.4(5)). The remaining 4,000 m of the Main Canal consists of the existing main and secondary canals after rehabilitation and improvement.

Table 5.6-2 shows the canal dimensions designed preliminarily in this study.

b) Design of Irrigation Canal Related Structures

Six types of irrigation related structure are preliminarily designed. Table 5.6-3 shows the required types and numbers.

The function and feature of irrigation canal related structures are described in the previous section 5.2.5 (1)-2) except for a syphon.

Syphon

The Secondary Canal-1 (SC-1), a pipe type syphon with a diameter of D=0.6 m is planned to cross the Boeung Khnar River and convey irrigation water.

(2) Drainage Canals and Related Structures

1) Design Plan

Design plan of Drainage facilities in the Wat Chre Rehabilitation Sub-project is discussed in section 5.2.5 (2)-1).

2) Rehabilitation and Improvement of Drainage Facilities

a) Design of Drainage Canals

Secondary drainage canals are designed as new canals except for the SD-2. An existing canal alignment would be utilized for the SD-2.

Table 5.6-4 summarizes design parameters for drainage canals. Water depth and flow velocity are estimated by the Manning's formula.

b) Design of Drainage Canal Related Structures

As shown in Table 5.6-5, 14 drainage culverts are designed at the crossing point with existing roads. At the end point of SD-3, existing culvert would be utilized.

5.6.6 On-farm Development Plan

The concept of on-farm development plan such as irrigation method, command area by a tertiary block, etc., are discussed in section 5.2.6.

In accordance with the topography and the concept above mentioned, 27 tertiary blocks are proposed in the Wat Chre Rehabilitation Sub-project (1,020 ha) in total. The average size of the tertiary block is figured out 37.8 ha. The typical length of a tertiary canal is 1.0 km on average in accordance with the topography. The total length of the tertiary canals is assumed to be 27 km in the Sub-project.

The typical length of a single water course and the number of water courses in the Sub-project are assumed to be 380 m and 189 numbers, respectively.

5.6.7 Water Management and Operation & Maintenance of Irrigation Facilities

(1) Responsible Organization

"The Policy for Sustainability of Operation and Maintenance of Irrigation System, June 2000" promotes the transfer of irrigation system to FWUC in order to mitigate financial burden for operation and maintenance (O&M). The share of responsibility of water management and O&M activities for the Wat Chre Rehabilitation Sub-project is proposed as follows taking into consideration the policy above, size of the Sub-project, importance of facility for the Sub-project management.

Share of responsibility Proposed in the Wat Chre Sub-project

Level / Activities	DAHW, DAMC, & WLMC *1	Wat Chre Headworks	Wat Chre Main Canal	Secondary canals	Tertiary canals	Water courses	Field canals
Preparation of annual O&M plan	PDOWRAM	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	-
Preparation of cropping schedule	-	-	-	FWUC/ FWUG	Sub-FWUG	WUG	House hold
Operation of facilities	PDOWRAM	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	House hold
Maintenance work	PDOWRAM	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	House hold

Note O&M Manuals shall be prepared by MOWRAM/PDOWRAM and be hand over to the respective agencies responsible during hand-over period.

*1 DAHW means Damnak Ampil Headworks, DAMC means Damnak Ampil Main Canal, WLMC means Wat Loung Main Canal; Wat Chre Sub-project commonly uses the Damnak Ampil Headworks/Main Canal (about 700m), and Wat Loung Main Canal together with Damnak Ampil and Wat Loung Sub-projects.

Prepared by JICA Study Team

(2) Water Management and Operation of Wat Chre Rehabilitation Sub-project

1) Damnak Ampil Headworks/Main Canal, and Wat Loung Main Canal

Irrigation water for the Wat Chre Rehabilitation Sub-project is supplied from the Damnak Ampil Headworks through the Damnak Ampil Main Canal and the Wat Loung Main Canal, then flows into the Boeung Khnar River, and reaches at the proposed Wat Chre Headworks. The peak irrigation water requirement for the Wat Chre Rehabilitation Sub-project is estimated at 1.39m^3/sec. Water management of the Damnak Ampil Headworks and the Main Canal is described in section 5.4.7. Water management of the Wat Loung Main Canal is described in section 5.5.7.

2) Wat Chre Headworks and Main Canal

PDOWRAM, Pusrsat is responsible for water management and O&M of the Wat Chre Headworks and the Wat Chre Main Canal including related structures.

The water level at the intake is designed at EL.13.00. Sluice gates are controlled to keep the design water level except for flood time. The water level shall be observed by reading a staff gauge which are installed at upstream of weir site and intake site.

The amount of water taken to the Wat Chre Main Canal is controlled by intake gates in accordance with irrigation service plan which is to be prepared by PDOWRAM, Pursat. The intake gates are controlled by readings of staff gauges which are installed upstream and downstream of the intake gates. The gate operation rule shall be set up based on the relationship between water level, gate opening and discharge.

The canal base of the Wat Chre Main Canal is designed to vary from place to place to use the existing canal section for cost reduction, thus flow in the Main Canal is non-uniform flow. Accordingly, check gates shall be operated in order to maintain the water level in the main canal for gravity irrigation. In this connection, turnout gates shall be operated carefully in order to avoid overtaking of water.

Water level in the Main Canal shall not be suddenly down except for an emergency case such as danger to human life. This rule shall be observed to prevent the slipping of inner side slopes of canal bank. And also, when water supply starts after completion of maintenance period, intake discharge shall be gradually increased up to the water demand.

Water supply to the Main Canal shall be continuously made throughout a year except for maintenance period which is set in March and April. In the maintenance period, the intake gates of the Headworks shall be totally closed and main canals shall be dried up for the purpose of annual maintenance. The maintenance works of the Headworks and the Main Canals are to be executed by PDOWRAM including related structures.

3) Secondary Canals

The water management and operation activities in the secondary canals are described in the previous section 5.2.7(2)-2).

4) Tertiary Canals

The water management and operation activities in the tertiary canals are described in the previous section 5.2.7(2)-3).

5) Water Courses and Field Canals

The water management and operation activities in the quaternary and field canals are described in the previous section 5.2.7(2)-4).

(3) Maintenance Work

The maintenance work of the Wat Chre Rehabilitation Sub-project facilities is described in the previous section 5.2.7(3).

5.7 Lum Hach Rehabilitation Sub-project

5.7.1 Crop Production Plan

(1) Land Use Plan

The land use plan for the Lum Hach Rehabilitation Sub-project under the with-project condition is presented in comparison with the present/without-project land use as follows;

Present/Without-project & With-project Land Use of the Lum Hach Sub-project Area

Land Use Sub-category	Present		With-project		Increment
	(ha)	(%)	(ha)	(%)	(ha)
Paddy Field					
- Normal Irrigation Paddy Field			3,100	100	3,100
- Supplemental Irrigation Paddy Field	200	6			- 200
- Rainfed Paddy Field	3,120	94			- 3,120
Sub-total	3,320	100	3,100	100	- 220
Right-of-ways	250	7	470	13	220
Total	3,570	100	3,570	100	0

Prepared by JICA Study Team

As shown in the table, the development of 3,100 ha of normal irrigation paddy field is aimed at under the Sub-project by the conversion of 200 ha of supplemental irrigation fields and 3,120 ha of rainfed fields. The decease of paddy fields due to land use conversion to right-of-ways is estimated at 220 ha.

(2) Proposed Cropping Pattern and Cropped Area of Lum Hach Rehabilitation Sub-project

1) Crop Selection of Lum Hach Rehabilitation Sub-project

The crop selection under the present plan has been made basically on the basis of the development concept discussed earlier as follows;

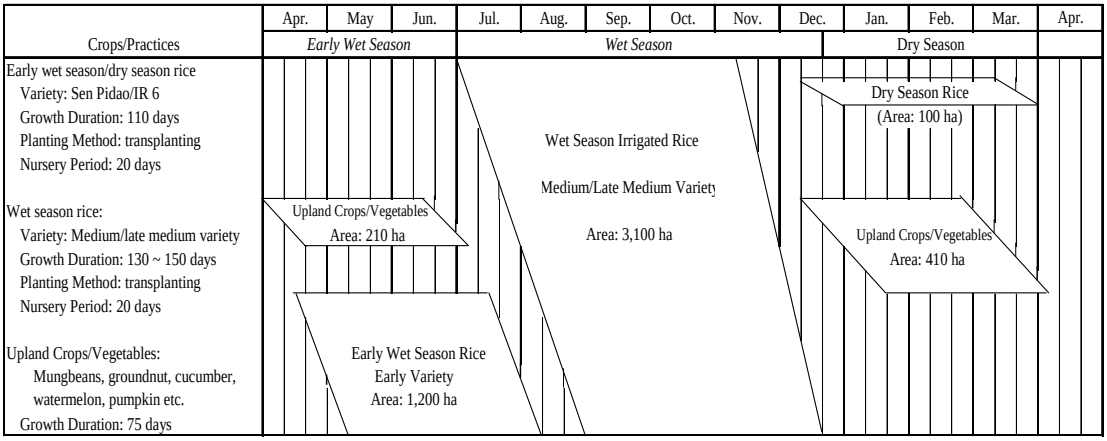
- Rice, current exclusive crop in the main cropping season, wet season, is selected as a crop to be introduced in the season as no other promising crops are conceivable and rice is a by far the most important crop and stable food in the area,
- In early wet and dry season, cultivation of early rice is planned by sharing available

irrigation water in the seasons with upland crops/vegetables,

- Introduction of irrigated upland crops/vegetables production in early wet and dry season aiming at: i) increasing land use intensity in paddy fields, ii) crop diversification, iii) sufficing domestic consumption and improvement of nutritional status of farm families by introducing pulses and iv) increasing farm income, and
- Candidate upland crops could include mungbeans, groundnut, soybeans and corn and the same vegetables include cucumber, water melon, pumpkin and gourd currently cultivated in and around the Sub-project area. However, for the successful introduction of the crops, intensified extension supports should be accommodated as an essential component of the Sub-project.

2) Cropping Pattern and Cropped Area

Based on the study on the current prevailing cropping patterns, the development concept discussed earlier and the results of irrigation water balance study, the proposed cropping pattern for the Lum Hach Rehabilitation Sub-project has been formulated as follows:



Prepared by JICA Study Team

Proposed Cropping Pattern: Lum Hach Sub-project

The cropping intensity targeted under the plan is as follows:

- Rice cropping intensity of 100% in wet season is planned in the pattern as is currently practiced,
- Intensity of rice in the early wet season is targeted at 39% within the availability of irrigation water supply after sparing some water for upland crops/vegetables production. In dry season, an intensity of rice is limited to 3% by allocating available irrigation water to upland crops/vegetables cultivation, and
- The annual intensity of 20% of upland crops/vegetables under irrigation is envisaged to promote crop diversification in the Sub-project area. The targeted cropping intensity of the crops is 7% in early wet season and 13% in dry season.

The planned cropped areas and cropping intensity envisaged in the pattern are shown in Table 5.7-1 and summarized as follows;

Planned Cropped Area & Cropping Intensity under the Lum Hach Sub-project

Unit: ha & %

Crop	Cropping Season							
	Early Wet Season		Wet Season		Dry Season		Annual	
	Area	Intensity	Area	Intensity	Area	Intensity	Area	Intensity
Irrigated Rice	1,200	39	3,100	100	100	3	4,400	142
Upland Crops/Vegetables	210	7			410	13	620	20
Total	1,410	45	3,100	100	510	16	5,020	162

Prepared by JICA Study Team

(3) Target Crop Yields

The target crop yields for the Lum Hach Rehabilitation Sub-project under the present plan in which normal irrigation is ensured are studied, as is the case in the other Sub-project areas, based on the current yield levels at normal (full) irrigation areas and the results of the Pilot Project carried out under the Study on Comprehensive Agricultural Development in Prek Thnot River Basin, JICA and are set as shown in the following table in comparison with the present yield levels.

Target Yields and Present Yield Levels (Unit: ton/ha)

Wet Season				**Early Wet/Dry Season**			
Crop 1/	**Target**	**Present**	**Increment**	**Crop 1/**	**Target**	**Present**	**Increment**
Improvement of Irrigation Status: Present: Supplemental Irrigation With-project: Normal Irrigation 2/							
Medium Rice (T)	3.0	1.7	1.3	Early Rice (T)	3.0	-	-
				Upland Crops 3/	1.1	-	-
Improvement of Irrigation Status: Present: Rainfed With-project: Normal Irrigation 2/							
Medium Rice (T)	3.0	1.2	1.8	Upland Crops 3/	1.1	-	-

1/: T -- transplanting 2/: Including pump irrigation fields 3/:Upland crops: average of mungbeans & groundnut

Prepared by JICA Study Team

Yield increases of 1.3 to 1.8 ton/ha in wet season rice are envisaged under the plan. Target yield of early wet and dry season rice is set at 3.0 ton/ha and the same of irrigated upland crops and vegetables are set rather conservatively: mungbeans 0.9 ton/ha, groundnut 1.3 ton/ha, watermelon 9.0 ton/ha and cucumber 10.0 ton/ha.

(4) Crop Production Plan

The crop production plan for the Lum Hach Rehabilitation Sub-project under the with-project condition is presented in comparison with the present/without-project crop production in Table 5.7-1 and summarized as follows:

Present & With-project Crop Production of the Lum Hach Sub-project Area

Land Use Sub-category/Crops		Cropped Area (ha)	Intensity (%)	Yield (t/ha)	Production (t)
I. Present/Without-project Crop Production					
Supplemental Irrigation Paddy Field: Rice		200	6	1.7	340
Rainfed Paddy Field: Wet Season Rice		3,120	94	1.2	3,744
Annual	Rice	3,320	100	1.2	4,084
	Upland Crops	40	1	-	232
II. With-project Crop Production					
Normal Irrigation Paddy Field: Rice		4,400	142	3.0	13,200
Annual	Rice	4,400	142	3.0	13,200
	Upland Crops 2/	620	20	-	2,194
Increment (II – I)					
Annual	Rice	1,080	42	1.8	9,116
	Upland Crops	580	19	-	1,962

1/: Cultivation of wet season rice under rainfed conditions due to limitation of irrigation water supply.
2/: Total of upland crops & vegetables, represented by mungbeans, groundnut, watermelon & cucumber.
Note: Rice figures are total of wet & early wet season rice and direct sowing & transplanting rice
Prepared by JICA Study Team

As shown in the table, the increase of overall average paddy yield of 1.8 ton/ha from 1.2 to 3.0 ton/ha and annual paddy production increase of some 9,100 tons are expected. The paddy production under the Sub-project is about 320% of the current production level in the project area. Under the Sub-project, the expansion of upland crops/vegetables production is envisaged and the production volume of the crops is estimated to be some 2,200 tons, increase of about 2,000 tons from the present level. Successful introduction of the crops through the proposed extension activities will further expand the cultivation of the crops in the area in the future.

(5) Proposed Farming Practices

Proposed improved farming practices of paddy to be adopted in the Lum Hach Rehabilitation Sub-project are the same with the practices proposed for the Damnak Ampil Rehabilitation Sub-project and include proper land preparation, quality seed & proper seeding rate, improved nursery & planting method, proper fertilization & water management etc., as discussed in the section 5.4.1(5).

5.7.2 Agricultural Extension Activities

Under the Sub-project, the substantial increases of yields and annual cropping intensity of paddy and the introduction of irrigated upland crops/vegetables production are envisaged, which dictates the introduction of intensified extension activities in the area. The proposed activities are development intervention aiming at strengthening of agricultural extension services for attaining the Sub-project targets of cropping pattern and crop yields at an earlier stage as possible. The estimated costs for the activities accommodated as Sub-project component are summarized in the following table.

Major extension activities include field programs (adaptability test, demonstration plot, farm & area, upland crops/rice seed multiplication), farmer & farmer group training programs (training course, FFS/IPM, study tour), mass guidance/workshop, staff empowerment, support

fund for extension staffs and provision of transportation means.

Estimated Costs for Agricultural Extension Activities of Lum Hach Sub-project [1/]

Activity	Estimated Cost (US$)
Field Extension Programs	109,700
Farmer/Farmer Group Training Programs	24,400
Mass Guidance/Workshop	2,400
Support Fund for Extension Staff 2/	32,640
Staff Empowerment	4,000
Provision of Transportation Means	6,300
Total	179,400

1/: Program direct costs
2/: Provision of support for VAA (village Agriculture Extension Agent) & field staff
Prepared by JICA Study Team

The implementation of the activities is scheduled for the period of 4 years in the Sub-project and the overall cost is estimated at US$ 179,500.-.

5.7.3 Irrigation and Drainage Plan

(1) Canal Layout

In the Lum Hach Rehabilitation Sub-project, the most upper reach (3.5 km) of the existing 7th January Canal is proposed to be used as the Main Canal after rehabilitation. The existing secondary canal which branches from the 7th January Canal at 3.5 km point is rehabilitated and proposed to be used also as the middle reach of the Main Canal. On the contrary, the further downstream of the existing 7th January Canal is not used in the Sub-project. General features of the Sub-project are summarized in Table 5.2-2. The irrigation area diagram is shown in Figure 5.7-1.

(2) Irrigation Area by Portable Pump

In the Lum Hach Rehabilitation Sub-project, the command areas of 410 ha along the proposed Secondary Canal-1 (SD-1) and Secondary Canal-2 (SD-2) are relatively high elevated (EL.35.0m to 39.3m approx.). In order to irrigate these areas by gravity, it requires to raise water level at headworks up to EL. 41.0 m. On the contrary, about 820 ha will be submerged at the same water level in the upstream of the proposed Headworks. After comparing the merit (increase in gravity irrigation area) and the demerit (increase in submerged area) of raising design water level, irrigation by portable pumps is recommended, to reduce the impact. Finally, the irrigation area by portable pump is estimated at about 440 ha.

(3) Drainage Plan

The excess water in the Lum Hach Rehabilitation Sub-project area is proposed to be drained by gravity. Field drains collect water from paddy fields and other types of land, and flow into tertiary drains. Tertiary drains flow into secondary drains or main drain due to the topography. Secondary drains and main drains finally flow into the Boribo River or other small streams.

In order to protect the Sub-project area from flood entering from surrounding areas, drainage plan is made as follows:

i) The Boribo River is used as the Main Drain of the Sub-project.

ii) The existing streams such as Ou Kab Chen, Ou Khang Tuol, Stueng Si, etc., are used as Secondary Drains.

iii) Water in the Boribo River sometimes flows reversely into the Sub-project area at the confluence of the Secondary Drain and the River, when the water level in the Boribo River is relatively high. Therefore, a drainage gate is proposed at the said confluence in order to regulate the water inflow from the Boribo River.

The general feature of drainage plan is summarized in Table 5.2-2. The drainage diagram is presented in Figure 5.7-3.

(4) Drainage Water Requirement

1) Drainage water requirement from paddy field

In the Lum Hach Rehabilitation Sub-project, the unit drainage water requirement, q (lit./sec/ha), from paddy field is calculated at 6.83 lit/sec/ha based on the annual maximum rainfall in 3 consecutive days at one in 5 years return period.

$$q = 0.177 \times 10{,}000 \div (3 \times 86400) \times 1000 = 6.83$$

where, 0.177 is a probable 3 consecutive day-rainfall at Kampong Chhnang station

2) Drainage water requirement from other type of land

The Sub-project area consists of paddy field and other types of land such as house yard, upland, right of way of irrigation canals, etc. Those lands are located adjacent to the paddy field, and are assumed to be 15% of the paddy field. Those lands do not have storage function as paddy field, and runoff characteristics for those lands are different from that of paddy field. The unit drainage water requirement from those lands is calculated by the rational formula and the annual maximum one day rainfall at one in 5 years return period (118 mm/day).

The calculated results of unit drainage water requirement for the other types of land with area less than 100 ha and more than 100 ha are as follows:

Qpeak = $0.27 m^3$/sec/ha from the area less than 100 ha

Qpeak = $0.19 m^3$/sec/ha from the area more than 100 ha

5.7.4 Rehabilitation and Improvement of Headworks and Major Related Structures

The facilities in the Lum Hach Rehabilitation Sub-project are divided into 3 categories; (1) headworks (diversion weir and intake(s)) and major related structures are explained in this section 5.7.4, (2) main and secondary systems (irrigation and drainage canals and related structures) are explained in the next section 5.7.5, (3) on-farm development plan is explained in the following section 5.7.6, respectively.

(1) Components

The Lum Hach Headworks is planned to supply irrigation water to the Lum Hach Rehabilitation Sub-Project area (3,100 ha), and an existing “O Roluss Canal Irrigation System

(3,440 ha)", respectively. Therefore, the Lum Hach Headworks consists of the following components:

a) Construction of the Lum Hach Diversion Weir

b) Construction of the Lum Hach Intake

c) Construction of the O Roluss Intake

d) Construction of the Lum Hach Approach Canal (LHAC) from the Lum hach Intake to the Main Canal (existing 7th January Canal): During the construction of Lum Hach Headworks in the dry season, the LHAC as well as part of the Main Canal will be utilized as a temporary river diversion channel in order to reduce construction cost.

e) Construction of an closure dike having an overflow section at outlet of the existing 7th January Canal to the Boribo River

f) Additional excavation of river and embankment of river bank

The schematic diagram of the above components is illustrated in Figure 5.7-4.

(2) Design Condition for Headworks

Design condition for proposed Lum Hach Headworks is summarized as follows:

Summary of Proposed Design Condition for Lum Hach Headworks

Design Parameter	Condition	Remarks
Design Flood Discharge Q_F:	430 m^3/sec	T=100 year return period
Design Flood Water Level WL_F1:	WL. 38.00m	at Weir site
Design River Bank Elevation	EL. 39.00m	betw/ Weir site and LHAC
Design Irrigation Water Level WL1:	WL. 38.00m	Top of Gate. Overflow depth=0.2m
Design River bed Elevation (Upstream):	EL. 11.70m	
Design River bed Elevation (Downstream):	EL. 11.70m	
Design Gate Sill Elevation:	EL. 34.00m	
Intake discharge for Lum Hach Sub-project:	6.60 m^3/sec	Maximum discharge
Intake discharge for O Roluss irrigation systems:	5.70 m^3/sec	Maximum discharge
Discharge of fish ladder:	0.88 m^3/sec	River maintenance flow 0.74 for 735 km^2, domestic & industrial use 0.14

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(3) Preliminary Design of Lum Hach Diversion Weir

1) Summary:

The Lum Hach Diversion Weir is designed based on the existing weirs in Cambodia, criteria in Japan, and other similar countries. The Major dimension proposed is summarized in the following table and in the schematic diagram in Figure 5.7-5.

Major Dimension of Lum Hach Diversion Weir

Items	Dimension
Weir Type	Floating Type Movable Weir
Design Water Level	WL1: 38.0m (Irrigation), WL_F1:38.0m (Flood)
Total Clear Width of Weir	65.0m
Elevation of gate sill	EL. 34.00m
Total Height of Weir	10.0m
Length of Weir incl. riprap	To upstream=24.0m, To downstream=55.0m
Gate type (Flood Gate)	Fixed wheel gate
Gate Dimension and Nos.	Clear Height H:4.0m, Clear Span B:15.0m, 3nos.
Gate type (Scouring sluice)	Slide gate
Gate Dimension and Nos.	H:2.0m, B:3.0m, 2nos.
Fish Ladder	B:5.0m (Half cone type), Δh=3.8m, L=38m

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Major components of the diversion weir are explained hereunder.

2) River section

Based on the topographic survey data and result of uniform flow hydraulic calculation, the longitudinal section and cross section of the river are designed as shown below. It is proposed to rehabilitate the river course of the Boribo River with the following dimension to deal with the design flood discharge of Q_F=430m^3/sec. The typical section of the river course is presented in Figure 5.7-6.

Typical Dimension of River Section for downstream of Lum Hach Diversion Weir

Canal type	Design Flood Discharge (m^3/sec)	River bed width (m)	Bed slope	Inner side slope	Water depth (m)	Free board (m)
Earth, Trapezoidal cross section	430	25.0	1/250	1:1.0 (R) 1:0.4 (L)	3.4	0.6

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3) Weir Type

Weir type is determined as “floating type” in the preliminary design, due to lack of geological information along the river and the weir site. A movable weir with gate is proposed to be constructed in order to control the flood water level at below EL. 39.0 m in the upstream reach of the river during flood events. An "overflow crest type" weir is not recommendable for the river course of the Boribo River due to the following reasons:

- At the confluence of the Boribo River and Ou Lea Pong, one of the tributaries of the Boribo River (hereinafter, “the mouth”), and its upstream area is topographically rather flat and low as discussed in section 3.8.3. It will be seriously affected if the water level at the weir exceeds EL. 39.0 m.
- If the design irrigation water level as well as the design water level are determined at EL. 39.0 m or more, a long dyke with length of more than several hundred meters and top elevation of higher than EL.39.0 is required to avoid the river water flowing out over the low land adjacent to “the mouth”; i.e., in order to confine the river water and regulate

irrigation water level at an adequate level at the Headworks.

- Therefore, the high water level for irrigation as well as design flood water level are determined to be at about WL. 38.0 m to minimize the length of concrete dyke installed along the mouth.
- Non-uniform flow hydraulic calculation also shows that it may enhance the overtopping of concrete dyke by installation of an overflow crest weir at “the mouth”.

4) Gate

a) Gate Type

As shown in Table 5.2-2, five gate types were considered and compared for flood gate; As a result, fixed wheel type gate is selected for flood gate, in particular for its high reliability as well as its easy operation, since those factors are important for facility management of the Project.

For scouring sluice gate, slide gate is selected, owing to its high reliability and relatively small gate size compared to the flood gate, thus it could be operated with lower hoisting load with ease.

b) Span Length and Clear Span of Flood Gate

Span length, clear span and number of gate leaf is first referred to the existing large weirs in Cambodia, such as Damnak Ampil, Roleang Chrey and Kandal Steung, and then determined by employing Japanese design criteria for headworks (and the River Control Structural ordinance), coupled with non-uniform flow hydraulic calculations for design flood (high water) discharge of 430 m^3/sec.

As a result, “three gates with clear span of 15.0m” is selected for the Lum Hach Diversion Weir.

5) Bridge

A concrete slab bridge is installed over the weir with a total span of about 40m. The elevation of slab bottom is to be EL. 39.7m, by adding a freeboard of 1.5 m to the design irrigation water level WL_I1’=38.2m at the weir site. The effective width and total width of the bridge are 3.8m and 5.0m, respectively, referred to the bridge of the Damnak Ampil Weir, with regarding the adjacent provincial road class.

6) Foundation works

Due to lack of geological information for preliminary design, concrete piles with 30 cm x 30 cm (or dia. 30 cm) x L = 6.0 m are to be installed at a maximum spacing of 3.0 m under body spillway, upstream and downstream apron and fish ladder. In addition, sheet piles of L = 6.0 m are also to be installed near the edge of body spillway.

7) Fish Ladder:

For the conservation of fish and ecology of the river, installation of a fish ladder is planed on

the right bank of the weir. Type of the fish ladder is planned to be a “half-cone type” or a “grouted riprap cascade type”, since these types creates a variety of water depth and flow velocity, so that fish is able to choose suitable course, water depth and flow velocity in accordance with its size and swimming ability.

- discharge: 0.88m^3/sec (maintenance flow 0.74 +Industry & Domestic flow 0.14) + residual - Width: B=5.0m (common for above types) - Slope: I = 1/10 (common for above types) - Height: H=3.8m (Gate height－inlet water depth) - Length: L6=38 m (=3.8/(1/10))	 Image: half-cone type fish ladder

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(4) Lum Hach Intake

The Lum Hach Intke is proposed to be reconstructed in the upstream of the diversion weir, on the right bank of the Boribo River. The design condition and result for the Lum Hach Intake are summarized if Figure 5.7-7.

(5) O Roluss Intake

As discussed in section 5.7.4(1), the O Roluss Intake is proposed to be constructed on the left bank of the Boribo River. The design condition and result for the O Roluss Intake are summarized in Figure 5.7-8.

(6) Lum Hach Approach Canal (LHAC)

The Lum Hach Approach Canal (LHAC) is proposed to connect the Lum Hach Intake and the existing 7th January Canal which will be used as the Main Canal of the Sub-project. The LHAC is used for temporary river diversion channel during construction period for the Lum Hach Headworks is anticipated in between early-November and late-May. The maximum discharge in the above period was 30.3m^3/sec in last five years: Thus, the design discharge for LHAC is determined at 30 m^3/sec though the maximum irrigation water requirement is only 6.6 m^3/sec. The design condition and result are summarized in Figure 5.7-9.

(7) Closure Dyke at Outlet of the Existing 7 th January Canal to the Boribo River

The 7th January Canal is to be rehabilitated and used as the Main Canal after it meets with the Lum Hach Approach Canal. Therefore, “the existing entrance” of 7th January Canal from the Boribo River, a closure dyke is proposed in order to prevent irrigation water form flow out as well as prevent the water form Boribo River to intrude. At “the entrance”, only unforeseeable excess water in the Main Canal is to be spilt out. Design condition and result of closure dyke at the outlet of 7th January Canal are summarized in Figure 5.7-10.

5.7.5 Rehabilitation and Improvement of Main and Secondary Systems

(1) Irrigation Canals and Related Structures

1) Design Plan

Design plan of irrigation facilities is discussed in section 5.2.5 (1)-1).

2) Rehabilitation and Improvement of Irrigation Facilities

a) Design of Irrigation Canals

In the Lum Hach Rehabilitation Sub-project, one main, nine secondary and two sub-secondary canals are designed preliminarily.

The existing 7 th January canal and the existing secondary canal are to be graded up to the Main Canal in the upstream stretch. The main canal would start from the junction of the Lum Hach Approach Canal and the existing 7 th January Canal. The existing large cross section of the 7th January Canal is not to be reduced in order to save construction cost. Due to the large flow section, the flow velocity is less than 10 cm/sec.

About 750 m downstream of the above juntion, the Main Canal is to be excavated because of higher bottom elevation of the existing canal (around EL. 35.0 m) than the designed water surface level (around EL. 39.0 m at Lum Hach Iintake). Secondary canals are all new canals.

Table 5.7-2 shows the canal dimensions designed proposed in this study.

b) Design of Irrigation Canal Related Structure

Six types of irrigation related structure are designed preliminarily. Table 5.7-3 shows the required types and numbers. The function and feature of irrigation canal related structures are described in the previous section 5.2.5 (1)-2).

(2) Drainage Canals and Related Structures

1) Design Plan

Design plan of Drainage facilities for the Lum Hach Rehabilitation Sub-projectis discussed in section 5.2.5 (2)-1).

2) Rehabilitation and Improvement of Drainage Facilities

a) Design of Drainage Canals

SD-8 and SD-10 are to be rehabilitated. Other drainage canals are designed as new canals. Table 5.7-4 shows drainage canal dimenstion designed in this study.

b) Design of Drainage Canal Related Structure

Three types of drainage related structure are preliminarily designed. Table 5.7-5 shows the required types and numbers.

Drainage Culvert

Nine culverts are designed to cross proposed irrigation canals and sixteen drainage culverts

are designed to cross existing roads.

Drainage Gate

A drainage gate is designed at the end-point of the SD-1 for releasing drainage water to the Boribo River. Total effective width of the flow section would be 7.0m equipped with 3 slide gates.

Footpath Bridge

A footpath bridge would be provided for each household along SD-2 and SD-3 to cross a drainage canal.

5.7.6 On-farm Development Plan

The concept of on-farm development plan such as irrigation method, command area by a tertiary block, etc., are discussed in section 5.2.6.

In accordance with the topography and the concept above mentioned, 67 tertiary blocks are proposed in the Lum Hach Rehabilitation Sub-project (3,100ha) in total. The average size of the tertiary block is figured out 46.3 ha. The typical length of a tertiary canal is 1.0 km on the average. The total length of the tertiary canals is assumed to be 67 km in the Sub-project.

The typical length of a single water course and the number of water courses in the Sub-project are assumed to be 470 m and 268 numbers, respectively.

5.7.7 Water Management and Operation & Maintenance of Irrigation Facilities

(1) Responsible Organization

"The Policy for Sustainability of Operation and Maintenance of Irrigation System, June 2000" promotes the transfer of irrigation system to FWUC in order to mitigate financial burden for operation and maintenance (O&M). The share of responsibility of water management and O&M activities in the Lum Hach Rehabilitation Sub-project is proposed as follows taking into consideration the policy above, size of the Sub-project, importance of facility for the Sub-project management.

Share of responsibility Proposed in the Lum Hach Sub-project

Level / Activities	Lum Hach Headworks	Main Canal	Secondary canals	Tertiary canals	Water courses	Field canals
Preparation of annual O&M plan	PDOWRAM	PDOWRAM	FWUG	Sub-FWUG	WUG	-
Preparation of cropping schedule	-	-	FWUC/ FWUG	Sub-FUWG	WUG	Household
Operation of facilities	PDOWRAM	PDOWRAM	FWUG	Sub-FUWG	WUG	Household
Maintenance work	PDOWRAM	PDOWRAM	FWUG	Sub-FUWG	WUG	Household

Note O&M Manuals shall be prepared by MOWRAM/PDOWRAM and be hand over to the respective agencies responsible during hand-over period.

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(2) Water Management and Operation of Lum Hach Rehabilitation Sub-project

1) Lum Hach Headworks and Main Canal

PDOWRAM, Kampong Chhnang is responsible for water management and O&M of Lum Hach Headworks and Main Canal including related structures.

The water level at the Headworks is to be kept at EL. 38.0 m by controlling sluice gates which are installed at the Headworks, except for flood time. The water level shall be observed by reading a staff gauge which are installed at the upstream of weir site and intake site.

The peak diversion water requirement is designed at 6.6 m^3/sec. The amount of water taken to the Main Canal is controlled by intake gates in accordance with irrigation service plan which is to be prepared by PDOWRAM, Kampong Chhnang. The intake gates are controlled by readings of staff gauges which are installed upstream and downstream of the intake gates. The gate opening rule shall be set up based on the relationship between water level, gate opening and discharge. Water supply to the Main Canal shall be continuously made throughout a year except for maintenance period which is set in March and April.

The canal base of Main Canal is designed to vary from place to place to utilize the existing canal section for cost reduction, thus the flow in the Main Canal is non-uniform flow. Accordingly, check gates shall be operated in order to maintain the water level in the Main Canal adequate for gravity irrigation. In this connection, turnout gates shall be operated carefully in order to avoid overtaking of water.

Water level in the Main Canal shall not be suddenly lowered except for an emergency case such as danger to human life. This operation rule shall be observed to prevent the slipping of inner side slopes of canal bank. And also, when water supply starts after completion of maintenance period, intake discharge shall be gradually increased up to meet the water demand.

In the maintenance period, the intake gates of the Headworks shall be totally closed and main canals shall be dried up for the purpose of annual maintenance. The maintenance works of Headworks and main canals are to be executed by PDOWRAM including related structures.

2) Secondary Canals

The water management and operation activities in the secondary canals are described in the previous section 5.2.7(2)-2).

3) Tertiary Canals

The water management and operation activities in the tertiary canals are described in the previous section 5.2. 7(2)-3).

4) Water Courses and Field Canals

The water management and operation activities in the quaternary and field canals are described in the previous section 5.2.7(2)-4).

(3) Maintenance Work

The maintenance work of the Lum Hach Rehabilitation Sub-project facilities is described in the previous section 5.2.7(3).

5.8 Institutional Development Plan

5.8.1 General

Responsibilities of construction and O&M of the Sub-project is tabulated as follows in accordance with the Policy for Sustainability of Operation and Maintenance Irrigation System.

Responsibilities of Construction and O&M

Phase / Level	Construction	O&M
Main	MOWRAM / PDOWRAM	PDOWRAM / MOWRAM
Secondary		FWUG supported by local authorities
Tertiary and below	FWUC (and/or FWUG) supported by MOWRAM / PDOWRAM and Local Authorities	FWUG (and/or sub-FWUG)

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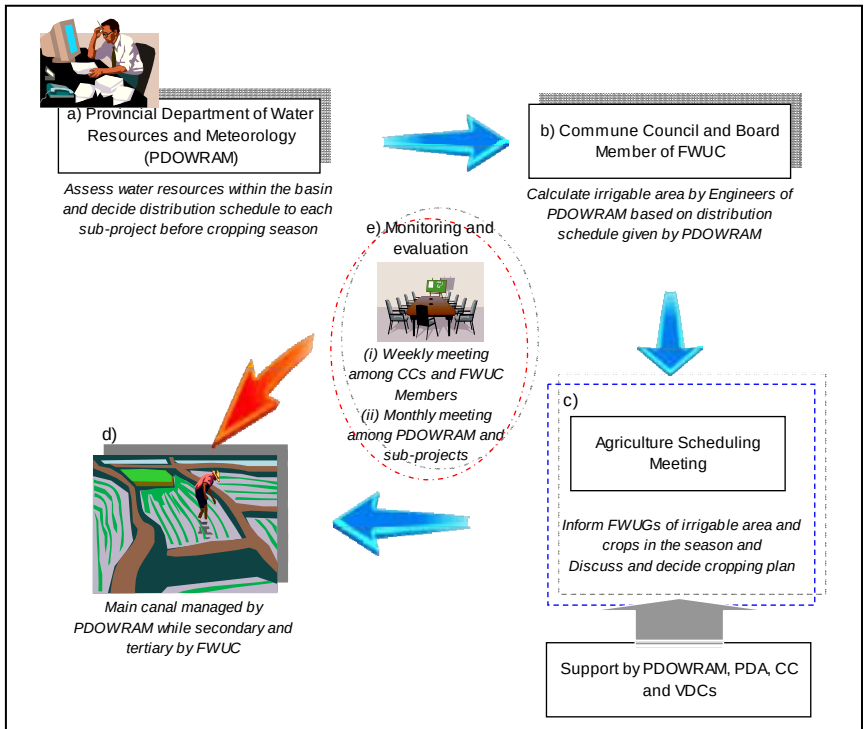
Construction

Main and secondary level facilities are the responsibility of MOWRAM and PDOWRAM while the responsibility on tertiary and below level facilities are the FWUC supported by MOWRAM, PDOWRAM and Local Authorities.

Operation and Maintenance (O&M)

O&M would consists of: (i) facilities maintenance and (ii) irrigation water management. After facilities are constructed and/or rehabilitated, O&M of main facilities are supposed to be carried out by PDOWRAM with the support of



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General Procedure of Irrigation Scheduling and Water Management

MOWRAM while secondary and below facilities are on the responsibility of FWUC. In addition, on the basis of Policy for Sustainability of Operation and Maintenance Irrigation System, all the O&M responsibility is transferred to FWUCs after five years. As for the water management under the Sub-projects, for example, following general procedure is proposed.

According to the discussion above, Sub-project needs to be constructed, operated and managed by MOWRAM, PDOWRAM and FWUC based on clear demarcation of responsibilities among those parties to be determined by regulations as well as capabilities. Therefore, establishment of ***co-administrative system*** is necessary in the institutional development plan to effectively operate and maintain irrigation and drainage facilities jointly among MOWRAM, PDOWRAM and FWUCs in order to finally materialize target goals through institutional development.

5.8.2 Government Institutional Development Plan

(1) Executing Agency for Rehabilitation Works

National Project Management Office (NPMO) in MOWRAM will be the executing agency for the rehabilitation of irrigation and drainage facilities under the Sub-projects. MOWRAM will be required to coordinate all activities of the relevant government agencies and regional administrative organizations having connection with the Project implementation. National Project Management Office (NPMO) of Projects in North Western Area under NPMO will have direct responsibility at the central level for the project implementation including engineering, construction works and project support programs. The Project Implementation Unit (PIU) under PDOWRAM, Battambang, Pursat and Kampong Chhnang, will respectively manage and coordinate the construction works of the Project at the Provincial level on behalf of NPMO. The main tasks of these offices will be as follows:

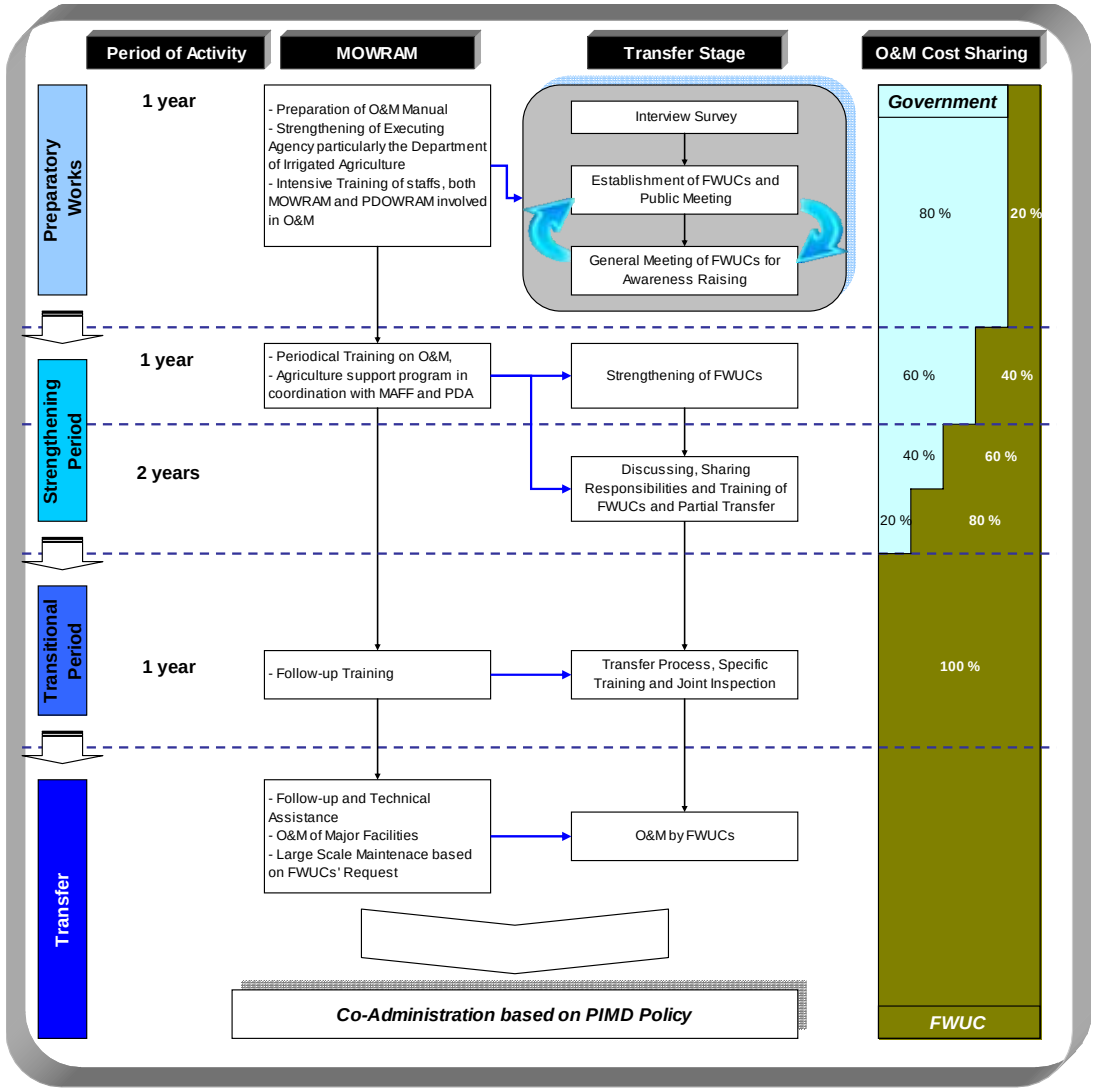
- Financial arrangements needed for the engineering and construction works of the Project,
- Design and construction supervision of all the works,
- Coordination among the Government Authorities concerned with the implementation of the Project,
- Arrangements for staff required during the detailed design and construction stages (NPMO will be required to dispatch at least one civil engineer to each PDOWRAM for supervision of rehabilitation and/or construction works),
- Progress and quality controls of the rehabilitation and/or construction works; and
- Preparation of O&M manuals.

(2) Transfer of O&M of Irrigation Systems to FWUC

At present, MOWRAM has a plan for the handing-over of O&M to FWUC in accordance with the Policy for Sustainability of Operation and Maintenance Irrigation System. In this policy, the handing-over period has been set at 5 years. Although the contents of this plan can be adopted basically to the Project, the period and the procedure should be determined taking

into account the actual situations of FWUCs' ability and the experience of MOWRAM / PDOWRAM's front line staffs who directly take charge of transferring works. It would be possible to transfer of O&M to FWUCs within 5 years, if those FWUCs attain a good progress in the training program. However, as stated in the Policy, transfer level needs to be determined by considering the capacity of FWUCs. Before the project, farmers have no experiences on O&M of irrigation facilities as a group and all the FWUC under the six Sub-projects will be almost newly established. It would be realistic if only main, secondary and lower levels of canals and drains are firstly transferred in this five-year period. On the other hand, O&M of major facilities such as headworks (Ream Kon, Damnak Ampil, Wat Chre and Lum Hach) will be remaining in the responsibility of MOWRAM and PDOWRAM.

As illustrated as follows: the proposed transfer process consist of: (i) preparatory works (1year), (ii) strengthening period (3 years), and (iii) transitional period (1 year) and finally facilities are transferred to FWUC.



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Transfer Process of O&M of the Sub-Projects

(4) Training Programme of the Government Officials for O&M

Prior to the transfer of O&M of irrigation and drainage facilities, FWUCs needs to be established and strengthened through capacity development programs. For this purpose, a wide scale of training program will be carried out. Namely, the training programs will be implemented not only for the farmers in the Sub-projects but also for the officers of MOWRAM and PDOWRAM to be involved in O&M. In addition, as elaborated in the next section, 5.8.3, it is proposed that the community-contract approach in tertiary development be carried out to strengthen FWUCs as well as the government staffs in facilitation, support and monitoring skills.

The Technical Service Centre (TSC) of MOWRAM would be playing a hub roll to implement training programs as varieties of programs already developed. The training programs are tabulated as follows:

Training Programs required for Government Officials

No.	Trainees	Contents
1	Senior officials of MOWRAM involved in O&M	• Outline of O&M and strengthening of FWUCs, • Outline of agricultural support services, • Farmers' participation in system management, • Facilitation skills of FWUCs in tertiary development through community-contract approach, • Coordination among relevant agencies etc.
2.	Officers involved in O&M (Technical staffs of MOWRAM and PDOWRAM)	• Estimation of water requirement, • Preparation of irrigation schedule, • O&M of facilities and transfer process, • Strengthening of the FWUCs, • Duties of MOWRAM and PDOWRAM and the FWUCs for O&M, • Facilitation skills of FWUCs in tertiary development through community-contract approach, • Monitoring system, measuring and surveying methods, • Administrative services to FWUCs • Coordination among relevant agencies etc.
3.	Officials involved in irrigated agriculture in other agencies (PDA, Commune Councils and Village Development Committees	• Objectives and outline of O&M by the FWUCs, • Activities of FWUCs, • Required agricultural support services, • Facilitation skills of FWUCs in tertiary development, • Coordination among relevant agencies etc.

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The following-up training for specific items is carried out occasionally after transfer of O&M to FWUCs based on regular monitoring and training needs assessment.

(5) Establishment of Monitoring System

In order to sustain O&M through the co-administrative system between the Government and

FWUCs, and to make further significant improvement of O&M after transfer, it is proposed to establish and strengthen a monitoring system in MOWRAM and PDOWRAM. The organizations relevant would be: (i) the Department of Irrigated Agriculture, (ii) the Department of Hydrology and River Works and (iii) the Department of Meteorology at the Central Level, and (iv) PIU at the Provincial Level.

The monitoring items necessary for these purposes are:

- Meteo-hydrological data including rainfall, temperature, evaporation, humidity at the Sub-project level,
- River water level and runoff for the water source,
- Water management,
- O&M of facilities, and
- Activities of FWUCs.

5.8.3 FWUC Strengthening Plan

(1) Objectives of FWUC Strengthening

MOWRAM policy shows that FWUCs are required to carry out O&M of secondary and tertiary level irrigation and drainage facilities by themselves from both technical and financial view points after facilities are rehabilitated and transferred from the Government to farmers. In particular, on the basis of PIMD strategy, development of FWUCs in their managerial, technical and financial capability is crucial for sustainable irrigation system O&M.

(2) Organizations and Activities

One FWUC is established at one Sub-project. Except for the Damnak Ampil Sub-project, no FWUCs have been established under the Sub-projects. FWUCs establishment procedure has been already proposed in the "Training manual for Participatory Irrigation and Management (PIMD) in Cambodia prepared and issued by MOWRAM as a prototype to be adopted for any irrigation projects, steps of which are shown as follows:

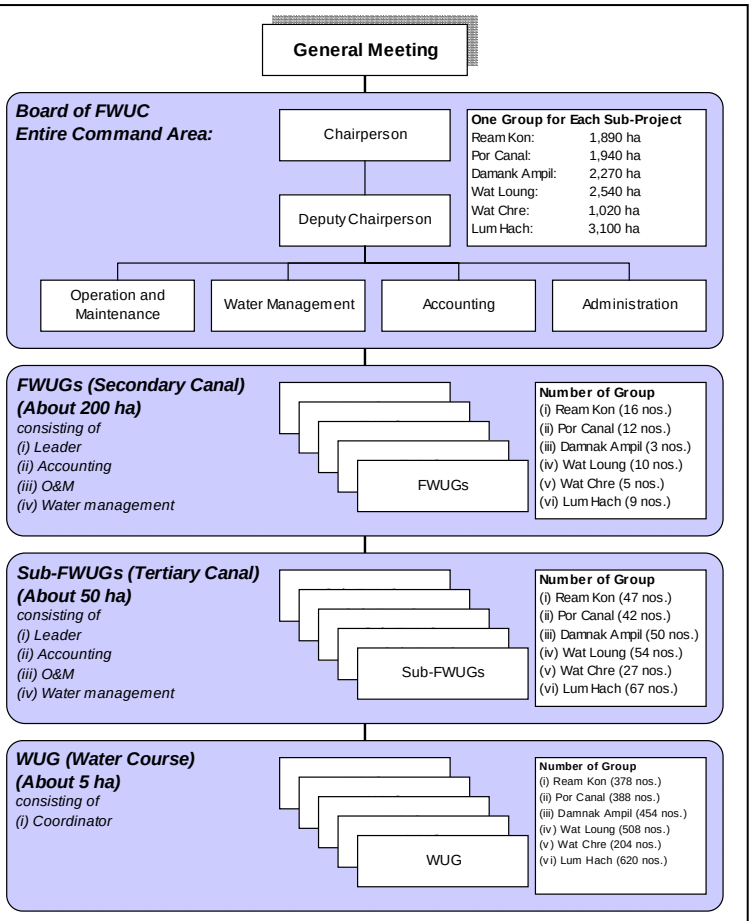
Step 1:	Initial Meeting to identify constraints and opportunities within communities
Step 2:	Identify irrigation area and potential members for FWUCs through Participatory Rural Appraisal (PRA)
Step 3:	Consensus building among FWUCs for activities plan
Step 4:	Preparation of FWUC statute and by-laws
Step 5:	Establishment of FWUCs and selection of leaders
Step 6:	Capacity building of FWUCs for preparation of irrigation service plan
Step 7:	Finalization of irrigation service plan
Step 8:	Preparation and adoption of management transfer agreement
Step 9:	Rehabilitation of systems through FWUCs participation
Step 10:	Provision of periodical support services to continue FWUC capacity building based on lessons learned from above activities

By referring to the purpose and the function of FWUC as well as the opinion of farmers

through the workshop and the public meeting, following principles need to be considered.

- ***Main and Secondary Level***: One FWUC is established at each Sub-project consisting of several FWUGs, each of which takes charge of O&M of a secondary canal with the area of approximately 200 ha.
- ***Tertiary level***: Under FWUGs, there needs to be sub-FWUGs in tertiary level, each of which covers 50 ha.
- ***Water Course Level***: Under sub-FWUGs, WUGs are established for water courses covering 5 to 10 ha.
- Overall farmers' activities: (i) O&M of facilities and (ii) Water Management as main function of FWUC needs to be supervised at the board level of FWUC.
- Representatives of relevant communes will be board members of FWUC. Necessary position would be based on needs for irrigation system O&M: (i) O&M, (ii) water management, (iii) accounting and (iv) administration.

On the basis of the above-principles, proposed FWUC organization is interposed as follows:



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General Organizational Structure of FWUC

During the process of FWUC establishment and strengthening, following issues would be considered based on the lessons obtained from pilot project under the Prek Thnot:[1]

- Preparation of the cadastre and cadastral map through PRA and a participatory mapping,
- Training programs starting from how to organize and facilitate meetings,
- Construction of office building,
- Intensive training on financial management,
- Information dissemination in the community through, such as, FWUC magazines,

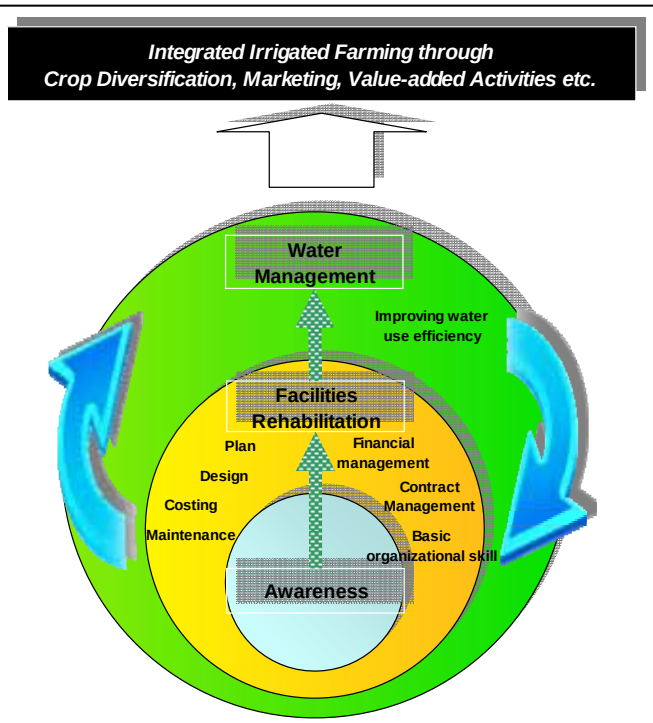
[1] JICA (2005-2008), The Study on Comprehensive Agricultural Development of Prek Thnot River Basin

- Management transfer by the initiative of the government staffs with the assistance of FWUC,
- Training on simple feasibility study, and
- Continuous support services by PDOWRAM.

(3) Capacity Development through Community-Contract for Tertiary Development

Within the framework of existing procedure described in "Training Manual for Participatory Irrigation and Management (PIMD) in Cambodia and lessons learnt from previous support activities such as TSC and JICA Prek Thnot Study, community-contract approach is proposed to promote tertiary development leading to strengthening of FWUCs under the Sub-project.

Tertiary development is promoted in conjunction with main and secondary facilities by subletting the work to FWUCs to be established. From this approach, MOWRAM and PDOWRAM staffs are to reorient management strategy for tertiary level facilities from comprehensive to supportive and facilitative manner, the skills for which would include participatory planning, communication skills with farmers, skills on technology transfer and facilitation. The general work procedure is illustrated in Figure 5.8.1.



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Approach on FWUCs Strengthening through Community-contract Approach

FWUCs are empowered for participatory rehabilitation, prospective contents of which involves broader points from planning to O&M such as participatory planning, joint walk-through, basic plan, design and cost estimate, contract management for construction works, field inspection, preparation of document for rehabilitation and construction, O&M fee collection etc., which will be necessary to carry out appropriate irrigation water management.

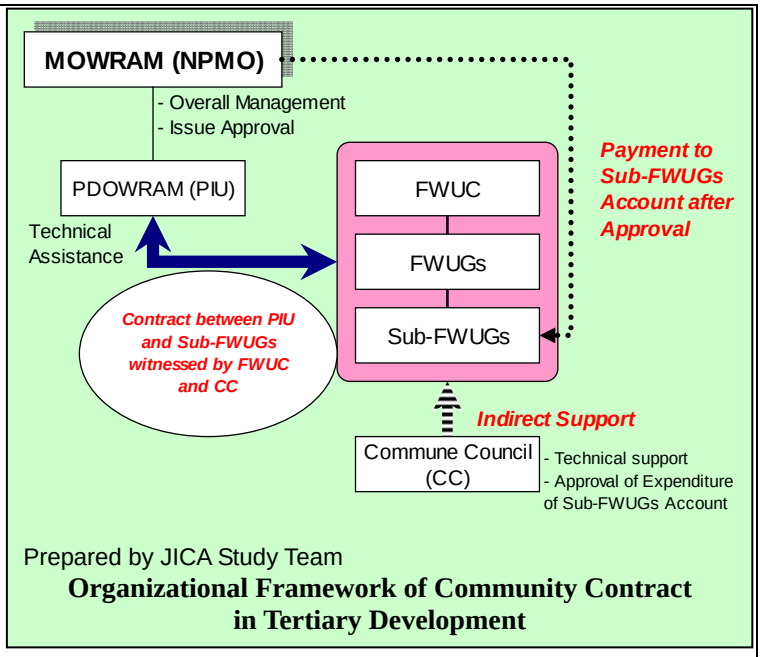
As above-shown figure, this process is not one-way but interactive and gradual scaling-up to increase awareness of FWUC and empower community participatory management framework.

Not all the works will be implemented with the community-contract basis. The coverage of sublet work to FWUCs will depend upon the capability of the group. Such works as: (i)

determination of canal alignment, (ii) construction of small tertiary-related structures, (iii) excavation of canals etc. will be expected to be sublet to FWUCs while comparatively large volume of works would be carried out by the contractors.

Procedure on Community-contract in Tertiary Development

1. *Establishment of FWUC at each Sub-project*: FWUC is established on the basis of guidelines issued by MOWRAM. Training program consisting of awareness program, organizational management, financial management etc,. is provided to consolidate the foundation of FWUC to implement community-contract in tertiary development.



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Organizational Framework of Community Contract in Tertiary Development

2. *Preparation of Tertiary Development Plan and Selection of Sub-FWUGs*: Overall tertiary development implementation plan is prepared by PDOWRAM with the support of local authorities. FWUGs with higher awareness and motivation will be firstly selected for the implementation.
3. *Joint-walk-through*: Joint-walk-through is carried out among PDOWRAM staffs, local authorities and the representative of Sub-FWUGs to determine the alignment of tertiary canals.
4. *Design and Cost Estimate*: Design and cost estimate will be carried out generally by PDOWRAM through the assistance of technical consultants. In conjunction with this stage, land acquisition will be made through discussion with local authorities and farmers, if necessary, the Resettlement Unit of MOWRAM. Work schedule will be prepared by Sub-FWUGs with the assistance of PDOWRAM.
5. *Contract between PIU and Sub-FWUGs*: Contract agreement is made between PIU under PDOWRAM and Sub-FWUGs witnessed by FWUC and Commune Council. Only administrative cost for the work is disbursed firstly to Sub-FWUGs to carry out the work while construction cost is generally managed by NPMO under MOWRAM.
6. *Construction of Tertiary Canals by FWUGs*: Construction works are carried out by Sub-FWUGs with the monitoring and the assistance of PIU.
7. *Inspection of the work completion*: The work is inspected and approved by PIU. Payment is made to Sub-FWUGs account as seed money to expand their activities for crop diversification, value-added activities etc. As for the account management, since the involvement of commune councils in local-based activities are familiar based on SEILA program, it can be recommended that commune council be entitled to issue approval of expenditure from the bank account by FWUC so as to ensure transparency of transaction in Sub-FWUGs account.

Box: Participatory Tertiary Development supported by Technical Service Centre (MOWRAM)

TSC has been developing and accumulating the skills in participatory tertiary development through PDOWRAM support. The trial construction has been carried out at Pursat Province in pilot basis. The work commence from (i) workshop to raise awareness of farmers by discussing the problem in target area followed by (ii) study tour to successful sites, (iii) share the findings from the study tour, (iv) establishment of FWUGs, (v) participatory map preparation showing water flow, troubled area together with problem solving, (vi) workshop for problem solution and construction planning and (vii) construction and/or rehabilitation of tertiary canals. Although the activities still remain at the pilot level in Pursat Province, such experiences are expected to be shared within MOWRAM and to expand other areas.

Source: Presentation material for tertiary development prepared by TSC

Box: Pilot Project under the Study on Comprehensive Agricultural Development of Prek Thnot River Basin

The pilot project consist of: (i) Irrigated Agriculture On-farm Technology Improvement Project and (ii) Rainfed Agriculture Improvement Pilot Project in the selected Zones. Through the implementation of pilot project under the Study, it was recommended that the support from PDOWRAM and PDA is remarkably important in tertiary development as well as enhanced agricultural activities backed by sufficient financial sources. In addition, in order to maintain sustainability, transparency of managing ISF is important among FWUCs.

Source: JICA (2005-2008), The Study on Comprehensive Agricultural Development of Prek Thnot River Basin

(4) Irrigation Service Fee (ISF)

All O&M costs for tertiary level facilities are covered by ISF collected from the member farmers. In addition, after 5years from the completion of the construction, O&M of main and secondary facilities are transferred to FWUC as explained in the section 5.8.2. Therefore, such O&M will be also shouldered by FWUC. It would be suggested that the collection of ISF commence after facilities are constructed.

The amount of ISF is estimated by each FWUC, and includes basically the annual O&M costs and contribution to the Community Board. ISF is collected before every cropping season. FWUC collect ISF from farmers through each FWUG chief.

To achieve smooth collection of ISF, it is recommended to adopt the following punishment rule and incentive to the farmers.

- Farmers who fail to pay ISF on time are imposed a fine equivalent to some percentage of the total ISF amount per month during the non-payment period.

- Farmers who pay the ISF amount in full and on time are entitled to reimbursement of some percentage of the full ISF amount in the next cropping season as an incentive.

(5) Training Programme for FWUCs on O&M

As above-explained community-contract approach in tertiary development is expected not only to upgrade skills in O&M but also to reorient attitude among farmers toward O&M. Although it would be polished by training needs assessment with FWUC, training programs proposed are generally as follows:

Training Programs for FWUCs on O&M

No.	Trainees	Contents
1	Farmers' level including leaders of FWUC and FWUGs, and informal rural leaders	• Awareness programs, • O&M of facilities, water requirement, water delivery etc. • Irrigation schedule and cropping calendar, • FWUC organizational management including accounting, book keeping and auditing, • Articles and by-laws for O&M, • Duties of MOWRAM / PDOWRAM and FWUCs in O&M, • Community-contract approach in tertiary development, • Monitoring system, measuring and surveying methods, • Group loan, purchasing farm inputs etc.
2.	Chief of Commune Councils, Villages, elder people in the village etc.	• Awareness programs, • Outline of O&M by the FWUCs, • Organization and activiteis of FWUCs, • Community-contract approach in tertiary development, • Duties of MOWRAM / PDOWRAM and FWUCs in O&M etc.

Prepared by JICA Study Team

CHAPTER 6 PROJECT SUPPORTING PROGRAMS

6.1 Meteo-Hydrological Observation Strengthening Program

(1) Program description:

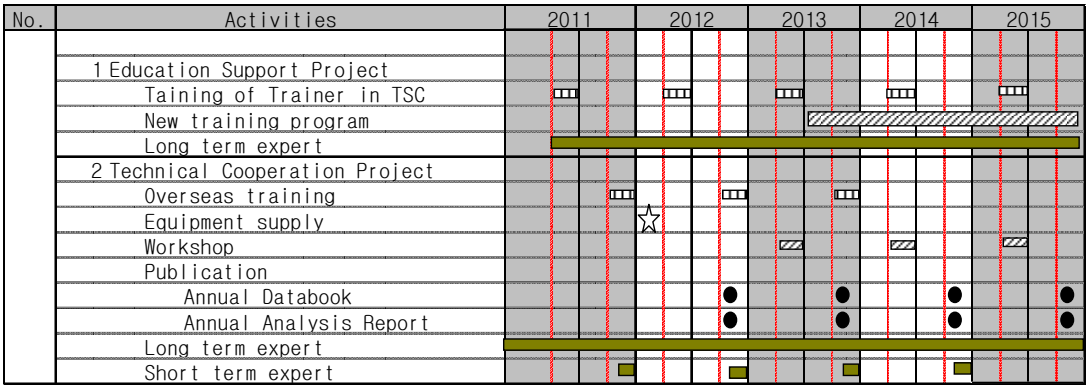
Item	Description
1.1 Location	MOWRAM /PDWRAM (Battambang, Pursat, Kampong Chhnang)
1.2 River basin/ water source	Four River Basins (Battambang, Moung Russey, Pursat and Boribo)
1.3 Target group	1) Technical staff of MOWRAM and PDWRAM
1.4 Objective of the project or program	1) to increase technical ability of MOWRAM and PDWRAM staff in meteo-hydrological observation, data processing and analysis 2) to strengthen publication capacity 3) to strengthen drought and flood forecast and warning system 4) to strengthen planning ability in the sector
1.5 Type of project or program	1) Capacity development
1.6 Target area	Not available
1.7 Necessity of project/program	Meteo-hydrological observation and analysis are not active, because number of the staff with required technology is not enough, the staff cannot concentrate to their primary works, the budget for O&M is not sufficient and so on. The activities, being often accompanied with cooperation projects at present, tend to be inactive after the project concerned. Without such cooperation projects, the observation would be poorer than before. To improve these situations, the program consisting of several projects is considered essentially necessary from practical viewpoint.

(2) Program scope:

Item	Description
1. Hydrological and Meteorological Education Support Project	Reinforced TSC training program and support to additional new course establishment in existing institute
2. Technical Cooperation Project	Through dispatch of expert, training in Japan, equipment supply and workshops, publish annual data book and analysis report

(3) Implementation Schedule

5 years from 2011 (Please see the figure below):



6.2 Capacity Development Program of MOWRAM

(1) Program description:

Item	Description
1.1 Location	MOWRAM
1.2 River basin/ water source	Four River Basins particularly six-sub-projects under West Tonle Samp Irrigation and Drainage Rehabilitation and Improvement Project
1.3 Target group	1) Technical staff of MOWRAM, especially design staff
1.4 Objective of the project or program	1) to increase technical capability of MOWRAM staff in irrigation and drainage planning, design, construction management, and operation and maintenance.
1.5 Type of project or program	1) Capacity development through technical cooperation
1.6 Target area	Four River Basins particularly six-sub-projects
1.7 Necessity of project/program	***Promotion of Irrigation Development in Technically-Appropriate Manner*** MOWRAM published the "Design Manual for Small and Medium Scale Irrigation" in 2004 targeting at technical staff with little formal training or experience in irrigation engineering. The manual mainly deals with irrigation system planning and hydraulic design of irrigation facilities. For the project design in the four river basins, detailed design manual including structural design would be necessary for technical staff who mastered previously mentioned design manual. Draft design manual will be expected to be prepared through joint efforts of senior technical staff of MOWRAM and experienced foreign consultants. Modification of draft manual would be required based on the lessons to be learnt in construction stage. ***Promotion of Co-Administrative System in Irrigation*** As MOWRAM is promoting transfer of O&M of irrigation systems to FWUC based on PIMD policy, it is required to establish co-administrative system in irrigation among MOWRAM, PDOWRAM and FWUCs. The co-administrative system needs not only capacity development of FWUCs but also reorientation of skills and attitude of government staffs for the facilitation of FWUC participation in irrigation development and O&M. Community-contract approach in tertiary development based on regulatory backing and support from the government is one of the alternative in upgrading FWUCs capability as well as establishment of basis in co-administrative system in irrigation.

(2) Program scope:

Item		Description
1. Promotion of Irrigation Development in Technically-Appropriate Manner		
1-1	Design Manual Preparation Draft-up	Preparation of a draft detailed design manual
1-2	Dissemination Workshop	Technical workshop in order to disseminate technical know-how in irrigation plan, design and construction management to technical staffs
1-3	Periodical Revision and Update of Design Manual	Regular revision and update of design manuals on the basis of lessons to be learnt from six sub-projects under the West Tonle Sap Irrigation Rehabilitation and Improvement Project

2.	***Promotion of Co-Administrative System in Irrigation***	
2-1	Training Programs	Implementation of trainings such as: (i) facilitation, (ii) training management, (iii) awareness of participatory community development approach, (iv) transfer of O&M responsibility to FWUCs etc.
2-2	Support PDOWRAM Staffs in the Facilitation of Community-contract Tertiary Development	Upgrading the skills of MOWRAM staff in technical support to PDOWRAM staffs in the facilitation of tertiary development by FWUCs

(3) Implementation Schedule

Manual preparation and dissemination, training program etc.: 5 years,

(4) Training Subject

	Category	Contents	Trainees	Trainer
1.	Guideline Dissemination	• Plan, design, construction management of main and secondary level facilities • Study tour	• MOWRAM staffs particularly the staff in top-management level, PMOs, Irrigated Agriculture Department and Engineering Department	• TSC
2	Facilitation	• Importance of facilitation • Facilitation procedures and methods • Role of the officials • Study tour	• MOWRAM staffs particularly the staff in Irrigated Agriculture Department and Engineering Department	• TSC • Out-sourcing
3.	Training Management	• Training program management method	• MOWRAM staffs particularly the staff in Irrigated Agriculture Department	• TSC • Out-sourcing
4.	Transfer of O&M Responsibility to FWUCs	• Awareness on transfer of O&M • Function of facilities in different level • Maintenance planning and its implementation • Monitoring and follow-up	• MOWRAM staffs particularly the staff in top-management level, PMOs, Irrigated Agriculture Department and Engineering Department	• TSC
5.	Support in Community Participatory Approach in Tertiary Development	• Outline of O&M and strengthening of FWUCs • Institutional framework in the support of community participatory approach • Coordination among relevant agencies	• MOWRAM staffs particularly the staff in Irrigated Agriculture Department	• TSC • Out-sourcing

6.3 Capacity Development Program of PDOWRAM

(1) Program description:

Item	Description
1.1 Location	PDOWRAM in Battambang, Pursat and Kampong Chhnang
1.2 River basin	Four River Basins
1.3 Target group	1) Technical staff of PDOWRAM Battambang, Pursat and Kampong Chhnang
1.4 Objective of the project or program	1) to increase technical ability of PDWORAM staff in O&M of irrigation facilities, and river basin management.
1.5 Type of program	1) Capacity development
1.6 Objective area	Four River Basins including three PDOWRAMs in Battambang, Pursat and Kampong Chhnang
1.7 Necessity of project/program	***Province-initiative Irrigation Development and Management*** The number and technical level of PDOWRAM staff are limited. In order to operate and maintain irrigation facilities properly, capacity development of PDOWRAM staff is inevitable. In addition to the capacity development, a well-considered technical tool such as an O&M manual would be necessary. Technical service center for irrigation system supported by JICA drafted the manual titled "Operation and maintenance of irrigation facilities" in 2005. The manual focused on FWUS establishment and water management at on-farm level. For future maintenance activities of field staff, it would be necessary for the manual to add descriptions of maintenance activities, and to prepare forms for operation and maintenance records. Preparation of O&M manual would require joint efforts of MOWRAM technical staff, PDOWRAM staff as a field user and experienced foreign consultants. The O&M manual should be prepared for each project in consideration of irrigation and drainage facilities constructed and site conditions. ***Facilitation of FWUCs Strengthening through Community-contract approach in Tertiary Development*** As MOWRAM is promoting transfer of O&M of irrigation systems to FWUC based on PIMD policy, it is required to establish co-administrative system in irrigation among MOWRAM, PDOWRAM and FWUCs. PDOWRAM needs to take initiatives in properly implement irrigation system O&M through supporting FWUCs. Not only O&M of main and secondary level facilities to be managed firstly by PDOWRAM, capacity development of PDOWRAM staffs in the facilitation of FWUCs in tertiary development is required. In order to do so, community-contract approach would be proposed to upgrade FWUCs skills as well as to maintain group's incentives contributing to O&M transfer in the five years as stipulated in: (i) Circular No. 1 on the Implementation Policy for Sustainable Irrigation Systems and (ii) Policy for Sustainability of Operation and Maintenance Irrigation Systems.  Public Meeting at Ream Kon Sub-Project (February 7th, 2008)

(2) Program scope:

Item		Description
1.	***Province-initiative Irrigation Development and Management***	
1-1	O&M Manual Preparation Program	Preparation of a draft operation of maintenance manual
1-2	Dissemination activities	Technical workshop and Transfer of technology through field training
1-3	Periodical Revision and Update of Design Manual	Regular revision and update of design manuals on the basis of lessons to be learnt from six sub-projects under the West Tonle Sap Irrigation Rehabilitation and Improvement Project
2.	***Facilitation of FWUCs Strengthening through Community-contract approach in Tertiary Development***	
2-1	Training Programs	Implementation of trainings such as: (i) facilitation, (ii) training management, (iii) awareness of participatory community development approach, (iv) transfer of O&M responsibility to FWUCs etc.

(3) Implementation Schedule

Manual preparation and dissemination and trainings 5 years

(4) Manual and Training Subject

Expected manual and training subject are as follows:

Table of Contents for the Manual

Basic Concept and Approach in Irrigation Planning and Design
- General planning and design procedure
- Development purpose and approach
- Development type

Water Resources
- Water Resources development
- Estimate of water availability
- Water balance study

Agriculture
- Outline of agricultural planning
- Coordination of MAFF and PDA in irrigation plan

Institution
- Responsibilities of relevant agencies in irrigation development and O&M consisting of: (i) MORAM, (ii) PDOWRAM and (iii) FWUC
- Organizational set-up for irrigation system development and O&M
- Coordination with relevant agencies and institutions
- By-laws and articles of FWUCs

Construction Management
- Schedule Management
- Quality Management
- Safety Management

Operation and Maintenance
- Irrigation scheduling
- Water management
- Maintenance of irrigation facilities
- Irrigation service fee

Environmental Management
- Monitoring of river basin and individual irrigation system
- Water and soil quality and conservation

- River maintenance flow
- Activity of quarry for sand in a river
- Illegal water use
- Conflict resolution over resource allocation

Project Evaluation

- Price estimate
- Economic and financial evaluation

Forms for Planning and Monitoring

Training Subject

	Category	Contents	Trainees	Trainer
1.	Guideline Dissemination	• Plan, design, construction management of main and secondary level facilities • Study tour	• PDOWRAM Staffs	• TSC • MOWRAM Staffs
2	Facilitation	• Importance of facilitation • Facilitation procedures and methods • Role of the officials • Study tour	• PDOWRAM Staffs	• TSC • MOWRAM Staffs • Out-sourcing
3.	Training Management	• Training program management method	• PDOWRAM Staffs	• TSC • MOWRAM Staffs • Out-sourcing
4.	Transfer of O&M Responsibility to FWUCs	• Awareness on transfer of O&M • Function of facilities in different level • Maintenance planning and its implementation • Monitoring and follow-up	• PDOWRAM Staffs	• TSC • MOWRAM Staffs
5.	Support in Community Participatory Approach in Tertiary Development	• Outline of O&M and strengthening of FWUCs • Institutional framework in the support of community participatory approach • Coordination among relevant agencies	• PDOWRAM Staffs	• TSC • MOWRAM Staffs • Out-sourcing

CHAPTER 7 ENVIRONMENTAL ASSESSMENT AND MANAGEMENT PLAN

7.1 General

7.1.1 Screening of the Sub-Project Component

The Project components primarily consist of: (i) rehabilitation and improvement of irrigation and drainage facilities, (ii) FWUC establishment and strengthening and (iii) agriculture support. Main subjects of FWUC establishment and strengthening and agriculture support are: (i) awareness program, (ii) module development, (iii) training, (iv) small-scale pilot exercise in agriculture and irrigation rehabilitation etc., therefore, adverse potential impact toward environment in and around the Project area is completely none or negligible or small. Thus activities (ii) and (iii) are screened out from IEIA. IEIA in the Study concentrates on potential impact from the rehabilitation and the improvement of irrigation and drainage facilities.

7.1.2 Scoping

An IEIA is carried out using matrix focusing on the aspect of: (i) social environment, (ii) natural environment and (iii) pollution as listed as follows on the basis of proposed component:

Social Environment

(1) Involuntary resettlement and/or land acquisition
(2) Local economy (employment and income generation)
(3) Land use and resource mobilization
(4) Social capital and traditional institution
(5) Social infrastructure and services
(6) The poor, indigenous and minority group
(7) Unequal distribution of damage and benefit
(8) Cultural heritage
(9) Local conflict over interest
(10) Water use
(11) Sanitation
(12) Risk against infectious diseases

Natural Environment

(13) Topography and geographical features
(14) Soil erosion
(15) Groundwater
(16) Hydrology
(17) Coastal area such as mangrove, coral reef and tidal area
(18) Flora, fauna and biodiversity
(19) Meteorology
(20) Landscape
(21) Global warming

Pollution

(22) Air pollution
(23) Water pollution

(24) Soil Contamination
(25) Waste
(26) Noise and vibration
(27) Ground subsidence
(28) Offensive odor
(29) Sedimentation
(30) Accidents

7.2 Potential Negative Environmental Impact

Prospective negative environmental impacts for six sub-projects identified are summarized in the table of next page and listed as follows:

Potential Negative Environmental Impact Anticipated

Item	Remarks
Social Environment	
(i) Involuntary resettlement and/or land acquisition	Land Acquisition for main, secondary and tertiary facilities
(ii) Unequal distribution of damage and benefit	In Damnak Ampil (downstream area excluded) and Lum Hach (land acquisition for upstream of headworks)
(iii) Local conflict over interest	Due to unequal allocation of irrigation water in the O&M stage
(iv) Water use	due to stoppage of irrigation water supply in the construction stage
(v) Sanitation	Deterioration during construction
(vi) Risk against infectious diseases	During construction
Natural Environment	
(i) Coastal area such as mangrove, coral reef and tidal area	By the increase of agricultural input under irrigated conditions
(ii) Flora, fauna and biodiversity	Disturbance of fish sprawling by the construction of headworks
Pollution	
(i) Air pollution	By the operation of construction machineries
(ii) Water pollution	By the construction works and the increase of agricultural input in the O&M stage
(iii) Soil contamination	By the increase of agricultural input in the O&M stage
(iv) Waste	By the construction works
(v) Noise and vibration	By the operation of construction machineries
(vi) Accidents.	By the operation of construction machineries

Prepared by JICA Study Team

Environmental Impact Matrix for Six Sub-Projects

Item \ Sub-Project		Ream Kon	Por Canal	Damnak Ampil	Wat Loung	Wat Chre	Lum Hach
Social Environment							
1.	Involuntary Resettlement and/or Land Acquisition	-/C	-/C	-/C	-/C	-/C	-/C
2.	Local Economy (Employment and Income Generation)	+/B	+/B	+/B	+/B	+/B	+/B
3.	Land Use and Resource Mobilization	+/B	+/B	+/B	+/B	+/B	+/B
4.	Social capital and Traditional Institutions	X	X	X	X	X	X
5.	Social Infrastructure and Services	X	X	X	X	X	X
6.	The poor, indigenous and minority group	X	X	X	X	X	X
7.	Unequal Distribution of Damage and Benefit	X	X	-/C	X	X	-/C
8.	Cultural Heritage	X	X	X	X	X	X
9.	Local conflict over interest	-/C	-/C	-/C	-/C	-/C	-/C
10.	Water Use Construction	-/C	-/C	-/C	-/C	-/C	-/C
	O&M	+/A	+/A	+/A	+/A	+/A	+/A
11.	Sanitation	-/C	-/C	-/C	-/C	-/C	-/C
12.	Risk against infectious diseases	-/C	-/C	-/C	-/C	-/C	-/C
Natural Environment							
13.	Topography and Geographical Features	X	X	X	X	X	X
14.	Soil Erosion	X	X	X	X	X	+/B
15.	Groundwater	X	X	X	X	X	X
16.	Hydrology	X	X	X	X	X	X
17.	Coastal Area such as Mangrove, Coral Reef and Tidal Area	-/C	-/C	-/C	-/C	-/C	-/C
18.	Flora, Fauna and Biodiversity	-/C	X	-/C	X	-/C	-/C
19.	Meteorology	X	X	X	X	X	X
20.	Landscape	X	X	X	X	X	X
21.	Global Warming	X	X	X	X	X	X
Pollution							
22.	Air Pollution	-/C	-/C	-/C	-/C	-/C	-/C
23.	Water Pollution	-/C	-/C	-/C	-/C	-/C	-/C
24.	Soil Contamination	-/C	-/C	-/C	-/C	-/C	-/C
25.	Waste	-/C	-/C	-/C	-/C	-/C	-/C
26.	Noise and Vibration	-/C	-/C	-/C	-/C	-/C	-/C
27.	Ground Subsidence	X	X	X	X	X	X
28.	Offensive Odor	X	X	X	X	X	X
29.	Sedimentation	X	X	X	X	X	X
30.	Accidents	-/C	-/C	-/C	-/C	-/C	-/C

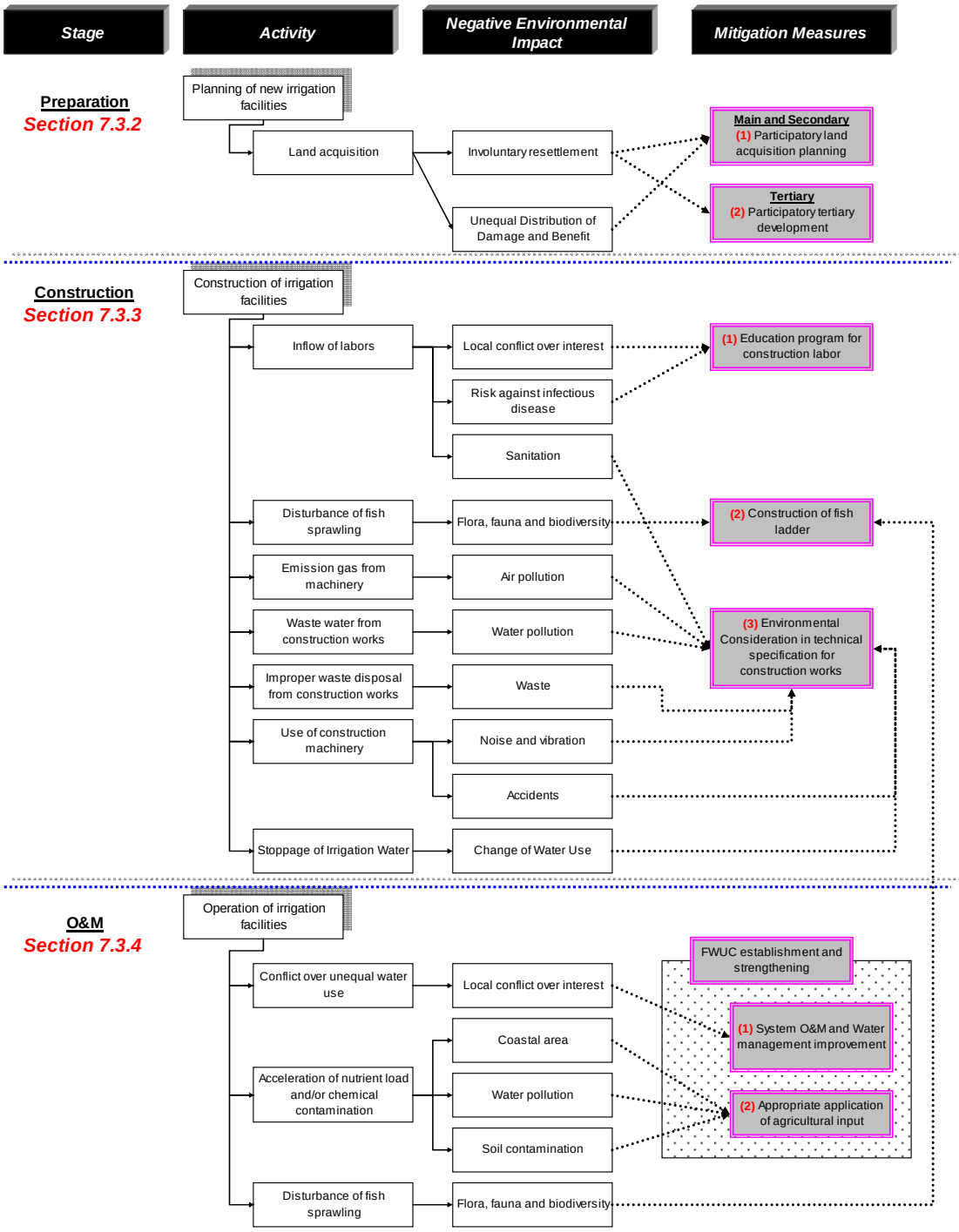
Note - : Adverse Impact,
X : No Impact
+ : Positive Impact
A : Great Impact
B : Medium Impact
C : Small Impact

Prepared by JICA Study Team

7.3 Environmental Management Plan

7.3.1 General

Environmental impact from the Project is identified from the view point of: (i) social environment, (ii) natural environment and (iii) pollution in the previous section. Causal relations of the negative impact and possible mitigation measures are shown as follows:



Prepared by JICA Study Team

Causal Relationship of Negative Environmental Impacts and those Mitigation Measures

On the basis of the result of IEIA, this section outlines proposed measures required to mitigate or eliminate adverse impacts where identified likely arise respectively in (i) preparation stage, (ii) construction stage and O&M stage. Certain other measures that could enhance environmental quality are also discussed. The negative impacts identified in the IEIA are not only particular problems in the Project area, but also they can be found in the whole country. The measures in this section, therefore, should be placed as models for the future sustainable development in the irrigation sector in Cambodia.

7.3.2 Preparation Stage

(1) Involuntary Resettlement and/or Land Acquisition, and Unequal Distribution of Damage and Benefit: Main and Secondary Level Facilities

Land acquisition is an important and a sensitive matter for irrigation project and the six sub-project are not left out. In general, the sub-project aims at the rehabilitation of existing irrigation and drainage facilities, therefore, there will be no significant resettlement and/or land compensation necessary for its implementation. In addition, the sub-project dose not expect to have specific impacts on ethnic minority, therefore, it does not require preparation of the plan for consideration of an ethnic minority.

Land acquisition necessary under the sub-projects is, in particular, for the construction of: (i) main and secondary facilities and (ii) tertiary facilities, which needs to consider different approaches elaborated as follows:

Main and secondary level facilities – Participatory Land Acquisition Planning

Activity
Expansion and/or new construction of facilities (Main, secondary and sub-secondary canals) and those related facilities
Sub-Project
All the Six Sub-Projects
Negative environmental impact anticipated

Land acquisition will be necessary for the expansion and/or new construction of irrigation and drainage facilities as well as inspection roads along main and secondary canals, which will be of varying length and width among the level of canals and drains based on the size of command areas. Preliminary estimate of the necessary areas for the acquisition is as follows:

Sub-Project	Area to be Affected (ha)			
	Headworks	Main and Secondary Systems	Drains	Total
Ream Kon Rehabilitation	-	13.6	17.9	31.5
Por Canal Rehabilitation	-	21.4	12.0	33.4
Damnak Ampil Rehabilitation	-	7.6	17.7	25.3
Wat Loung Rehabilitation	-	42.9	23.2	66.1
Wat Chre Rehabilitation	-	12.3	17.7	30.0
Lum Hach Rehabilitation	85.8	90.3	29.5	205.6
Grand Total	-	-	-	391.9

"*Unequal distribution of damage and benefit*" would be anticipated in two sub-projects: (i) Damnak Ampil and (ii) Lum Hach.

(i) Damnak FWUC has been established and under registration process in Damnak Ampil sub-project, the organization of which includes downstream communes although there are no activities observed at

present. Proposed plan, however, covers only upstream existing portion originally constructed by MOWRAM in 2006, and the downstream will be left for expansion in the future stage.
(ii) Proposed headworks of Lum Hach sub-project will create submerged area in the upstream of headworks which needs land acquisition; however, farmers residing in the upstream areas are not necessarily benefited from the sub-project.

Mitigation measures

- The alignment of the proposed canals should follow the original canals as facilities so as to minimize land acquisition.
- It is of necessity to facilitate coordination among Inter-ministerial Resettlement Committee (IRC) and local-based authorities to properly carry out: (i) asset valuation at replacement cost and resettlement cost estimation to be affected through the implementation and (ii) compensation measures.
- Compensation rate for land loss and value of land based on field interview carried out in June 2008 is approximately US$ 0.3/m^2 for agricultural field. This replacement cost will be updated by MOWRAM prior to the implementation of the Project based on market price.
- Step-wise consensus building needs to be conducted with affected people and communities through workshop for: (i) canals and drains alignment, (ii) compensation measures and (iii) support necessary for sustainable O&M.
- Although not necessarily physical compensation needed in accordance with the land-related laws and regulations, consensus building should be made with farmers currently doing cultivation in the main canal.
- Training program would be effective for IRC members, particularly MOWRAM and PDOWRAM staff, curriculum of which primarily consist of: (i) participatory and community development skills, (ii) conflict resolution and mediation, (iii) risk assessment and management, and (iv) resettlement planning.
- Workable organizational structure of FWUC needs to be established by considering existing organization as well as proposed command area under FWUC supporting program at Damnak Ampil sub-project. Information on proposed project plan and future development plan for downstream part should be shared within community members.
- On the basis of Land Law, MOWRAM has drafted *Sub-Decree on Addressing Socio-Economic Impacts caused by Development Projects* (2007). This Sub-Decree clearly explains resettlement and land acquisition management by categorizing: (i) type of loss (16 categories), (ii) application, (iii) type of entitled person and (iv) compensation policy. For the Project, permanent loss (construction of main and secondary facilities) and vegetable (or agricultural products due to the construction and/or stoppage of irrigation water during construction) would be primarily applied, samples of which are as tabulated as follows.

Type of Loss (Sample) Stipulated in the Sub-Decree

No.	Type of Loss	Application	Type of Entitled Person	Compensation Policy
1.	Permanent Loss	Categorized into: (i) marginal and (ii) severe.	Lawful owner	Cash compensation for the acquired land/part of land at 100 % of replacement cost plus service charge
			Legal user of affected private land with lease, usufruct, other land use contracts	Cash assistance proportional to the rent for the remaining contractual term or maximum 3 months of rent based on the contractual rate in the authentic contract
2.	Vegetable (annual and non-perennial crops)	Affected vegetable crops	Owner of the affected crops	Compensation in cash for estimated value of the crops at farm gate price of the crops

Prepared by JICA Study Team based on MOWRAM (2007)

It would be of necessity that the compensation is made on the basis of the policy in the sub-decree. However, any conflicts arise in the compensation process, consensus building needs to be carried out by IRC through the Resettlement Unit of MOWRAM.

Stakeholders
➢ Inter-ministerial Coordination Committee (IRC) ➢ MOWRAM ➢ PDOWRAM ➢ Commune Council ➢ Village Development Committee ➢ Representative of farmers ➢ Affected Farmers

Prepared by JICA Study Team

Box: Resettlement Example at Stung Chinit Irrigation and Rural Infrastructure Project

Stung Chinit Irrigation Project in Kampong Thom Province assisted by ADB is one of the successful projects in resettlement process. The project consisted of the rehabilitation of irrigation systems and the associated upgrading of its infrastructure covering 2,960 ha as a priority area.

The Project involved an iterative process of survey and design requiring for some of the irrigation system an inventory of losses and consultation with affected persons and resettlement measures agreed and carried out during implementation. On the basis of ADB's resettlement guideline, loss of agricultural land will, at the choice of Affected Persons, be compensated by land for land of equal productive capacity or compensation in cash permitting land purchase by APs of equal quality and productivity to that lost. This entitlement will apply to all land lost in the COI of secondary canals and drains. Losses of land in tertiary canals and drains, as well as losses to quaternary systems and to ox-cart tracks, are voluntarily lost in the self-managed creation of the tertiary block irrigation system, and will be voluntarily replaced through the farmer managed process of land adjustment.

The resettlement plan was based on institutional collaboration through consultation with the Inter-Ministerial Resettlement Committee (IRC) of RGC, Ministry of Economy and Finance (MEF) and the Ministry of the Interior, with other concerned ministries, and with people affected by the Project. Such consultations also included the Provincial Governor's Office, Provincial Resettlement Sub-Committee of the Province of Kampong Thom and the Provincial Project Steering Committee, which is represented in the IRC, and PDOWRAM Project Implementation Unit (PIU).

Source: ADB (2004), Resettlement Planning Document, Stung Chinit Irrigation and Rural Infrastructure Project (Loan No. 1753-CAM (SF))

(2) Involuntary Resettlement and/or Land Acquisition: Tertiary Level Facilities

Currently, no tertiary level facilities have been developed in the Project command area. In order to materialize effects of facilities rehabilitation and development at the main and secondary level, construction of tertiary canals and drains together with inspection roads needs to be concurrently promoted. Different from main and secondary level facilities, however, tertiary level development is the responsibility of local authorities and communities technically supported by MOWRAM and PDOWRAM. Therefore, local-based consensus building, planning and implementation is of great importance for the development of tertiary level facilities.

Tertiary level facilities – Participatory Tertiary Development

Activity
Construction of tertiary level facilities (Canals and drains)
Sub-Project
All the Six Sub-Projects
Negative environmental impact anticipated

The necessary land acquisition for the construction of tertiary facilities is estimated as follows:

Sub-Project	Area to be Affected (ha)
	Tertiary Systems
Ream Kon Rehabilitation	39.5
Por Canal Rehabilitation	40.8
Damnak Ampil Rehabilitation	47.7
Wat Loung Rehabilitation	53.4
Wat Chre Rehabilitation	21.5
Lum Hach Rehabilitation	65.1
Total	268.0

No Tertiary Canals Developed at Por Canal Sub-Project (February 8th, 2008)

Mitigation measures

- Appropriate procedure for tertiary development is essential including compensation measures for affected farmers, if necessary.
- The canals and drains will be proposed through joint-walk-through survey among engineers of PDOWRAM, affected farmers and local authorities such as commune council and village development committee. The alignment will generally follow existing bund wherever possible so as to minimize the area of land acquisition.
- Cooperation among local communities such as commune council and village development committee needs to be enhanced in the process.
- Training program would be required for the members of local authorities particularly commune council, village development committee and representative of farmers, curriculum of which consist of the subjects in mentioned in "the main and secondary facilities" plus: (i) facilitation skills, (ii) preliminary design of tertiary level facilities including canals, drains and appurtenant structures, and (iii) monitoring and evaluation of the activities at the local level.

Stakeholders

- MOWRAM
- PDOWRAM
- Commune Council
- Village Development Committee
- Representative of farmers
- Member farmers of secondary and tertiary blocks (FWUGs and sub-FWUGs)

Prepared by JICA Study Team

7.3.3 Construction Stage

In the construction stage, negative environmental impacts to be expected are: (i) local conflict over interest, (ii) risk against infectious disease, (iii) impact to flora, fauna and biodiversity, (iv) air pollution, (v) water pollution, (vi) waste disposal, (vii) noise and vibration and (viii) accidents, those of which are mutually and closely correlated.

(1) Local Conflict Over Interest and Risk Against Infectious Disease

Education Program for Construction Labor

Activity
Construction of Irrigation and Drainage facilities (Canals and drains)
Sub-Project
All the Six Sub-Projects
Affected area and people
In and around sub-project area
Negative environmental impact anticipated
Because of the inflow of construction workers from outside of sub-project area, following negative impact is expected such as: (i) deterioration of security, (ii) deterioration of sanitary condition, (iii) increase of infectious disease etc.
Mitigation measures
➢ Education program should be carried out for the workers in order to maintain security, sanitary condition and to follow community rules. ➢ Public meeting should be organized for community people so as to explain about construction schedule. ➢ Information on construction works is disseminated to the communities through poster and/or brochure to raise awareness. ➢ Technical specification of the construction works, as explained afterward, "*Environmental Consideration in Technical Specification for Construction Works.*" needs to include obligation of contractors for the preparation of appropriate base camp and facility for construction labors.
Stakeholders
➢ Contractors ➢ Construction Workers ➢ Community People ➢ Local Authority ➢ MOWRAM ➢ PDOWRAM

Prepared by JICA Study Team

(2) Flora, Fauna and Biodiversity

Construction of Fish Ladder

Activity
Construction and/or Improvement of Headworks
Sub-Project
Four Sub-Projects (Ream Kon, Damnak Ampil, Wat Chre and Lum Hach Rehabilitation Sub-Projects)
Affected area and people
Fishers presently doing fishing in the River
Negative environmental impact anticipated
There are, currently, some fishers carrying out fishing in the water source river especially in the wet season. The ecological resources of the stream serve as habitat for several black fish species. Under the above-listed four sub-projects, the headworks are proposed to be newly constructed and/or improved as a part of main irrigation facilities. It would disturb fish sprawling in the River thereby decreasing fish yield of fishers. Without appropriate measures, in addition, such ecological resources in the river will be affected.
Mitigation measures
➢ In conformity with the rehabilitation and/or improvement of headworks, the construction of fish ladder needs to be considered in order to maintain downstream flows and upstream migration to the sustainability of fish catches as well as ecological resources. ➢ Features to be taken into account before implementation of the Project include the biological and physiological characteristics of migrating species as well as the course, speed, width and depth of the fish pass. Previous lessons for the effectiveness of fish ladder constructed in other projects

needs to be reviewed and assessed such as the fish path constructed for the Stung Chinit Reservoir under the Stung Chinit Irrigation and Rural Infrastructure Project (ADB).
Stakeholders
➢ MOWRAM ➢ PDOWRAM ➢ Community People particularly Fishers ➢ Local Authority

Prepared by JICA Study Team

(3) Sanitation, Water Use, Air Pollution, Water Pollution, Waste, Noise and Vibration and Accidents

Environmental Consideration in Technical Specification for Construction Works

Activity
Rehabilitation and/or Construction of Irrigation and Drainage facilities
Sub-Project
All the Six Sub-Projects
Affected area and people
In and around sub-project area
Negative environmental impact anticipated
All the negative impacts are directly related with the construction works, particularly the operation of construction machinery during construction works. Potential adverse impacts are as described respectively as follows: ***Sanitation***: Inflow of construction labor would increase possibilities on sanitary deterioration in and around sub-project area by disposing of domestic waste. ***Water Use***: Cropping during construction period will be affected if irrigation water supply is completely terminated. In addition, although current percentages are limited, community members using river water for drinking and domestic use would be affected when river water flow change due to temporary works such as diversion and coffer dam for canal construction. ***Air pollution***: Emission gas will be exhausted by the transportation of construction machinery such as excavator, bulldozer, watering lorry and so forth. ***Water pollution***: In particular, water in the downstream of the sub-project will be affected by water pollution through improper damping of construction waste. In addition, poor de-watering from, for example, borrow areas affect water quality in surrounding areas, for which appropriate measures needs to be taken. ***Waste disposal***: Solid waste will be created from waste from construction materials and machinery. There needs to be appropriate management measures put in place for waste to be generated. ***Noise and vibration***: Construction machinery will create noise and vibration during construction. In particular, site of intake and beginning of main canal is the nearest to the village which needs to be considered. ***Accident***: Through the operation of construction machinery, consideration to the mitigation of accidents in and around sub-project areas especially access between national road No. 5 and the sub-project site needs to be carefully carried out.
Mitigation measures
➢ In the technical specification of the construction works, obligation of the contractors for the consideration of: (i) water use for agriculture, drinking and domestic use, (ii) air pollution, (iii) water pollution and treatment, (iv) waste disposal, (v) noise and vibration and (vi) accidents needs to be clearly specified. Sample specification with the preliminary level is introduced afterward. ➢ On the basis of specification, education programs for construction workers should be carried out under the obligation of the contractors. ➢ Periodical patrol and monitoring needs to be carried out by the staffs of PDOWRAM and local authorities to ensure environment-friendly ways in construction works.
Stakeholders

➢ PDOWRAM ➢ Local Authority ➢ Contractors ➢ Community People ➢ MOWRAM

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Technical specification for the construction works needs to consider matters in the table below to mitigate negative environmental impact in and around the sub-project site during construction period. The contents consist of: (i) general, (ii) earth work, (iii) care of water, (iv) sod facing, (v) site clearing, and (vi) operation of temporary labor camp.

Subjects to be Considered for Environmental Impact Mitigation for the Construction Works

No.	Clause	Sub-Clause
I-01	General	-
I-02	Earth Work	✓ Safeguarding excavated and natural slope ✓ Spoil disposal
I-03	Care of Water	✓ Design ✓ Dewatering during construction ✓ Drinking and irrigation water supply during construction
I-04	Sod Facing	-
I-05	Site Clearing	✓ Disposal of material
I-06	Operation of Temporary Labor Camp	✓ Operation, maintenance and removal of camp

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7.3.4 O&M Stage

Adverse environmental impacts anticipated during O&M stage are related with increased and improved irrigation water use after implementation of the sub-project. Measures would be FWUC establishment and strengthening, which are sub-categorized into two: (i) system O&M and water management improvement and (ii) appropriate application of agricultural input. They are relevant to overall O&M and agricultural support, therefore, activities proposed here should be carried out in comprehensive support programs.

(1) Local Conflict over Interest

System O&M and Water Management Improvement

Activity
Operation of Rehabilitated and/or Constructed Irrigation and Drainage facilities
Sub-Project
All the Six Sub-Projects
Affected area and people
In and around sub-project area including downstream areas
Negative environmental impact anticipated
Unequal water allocation would be anticipated if proper water management is not carried out in the sub-project command areas. This issue is related not only within command area but also with other irrigation systems particularly located in the downstream of the sub-projects.
Mitigation measures
➢ Farmer Water User Community (FWUC) needs to be established and strengthened to carry out appropriate irrigation system O&M and water management. ➢ FWUC establishment should be through stepwise approach as stipulated in PIMD Module: (i) initial Meeting to identify constraints and opportunities within communities, (ii) identify irrigation area and potential members for FWUCs through Participatory Rural Appraisal (RRA),

(iii) consensus building among FWUCs for activities plan, (iv) preparation of FWUC statute and by-laws, (v) establishment of FWUCs and selection of leaders, (vi) capacity building of FWUCs for preparation of irrigation service plan, (vii) finalization of irrigation service plan, (viii) preparation and adoption of management transfer agreement, (ix) rehabilitation of systems through FWUCs participation and (x) provision of periodical support services to continue FWUC capacity building based on lessons learned from above activities.

- Training on system O&M and water management needs to be carried out, contents of which are briefed as follows:

Category	Sub-category	Training Items
System O&M	Community Participatory O&M and Rehabilitation	• Community participatory rehabilitation (Awareness program, planning, designing, contract management, financial management and construction management) • Maintenance planning • Establishment of O&M fund
Water Management	Proper Water Management at Tertiary level	• Awareness on water management • Preparation of irrigation schedule • Gate operation, monitoring (discharge measurement, recording and reporting), rotational irrigation & role gate operator • Drainage improvement • Participatory M&E for water management • Conflict resolution with other systems

Stakeholders

- MOWRAM
- PDOWRAM
- Community People including those of downstream irrigation systems
- Local Authority
- NGOs, if necessary

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(2) Coastal Area Pollution, Water Pollution, and Soil Contamination

Appropriate Application of Agricultural Input

Activity
Implementation of irrigated agriculture using Rehabilitated and/or Constructed Irrigation and Drainage facilities
Sub-Project
All the Six Sub-Projects
Affected area and people
In and around sub-project area including downstream areas
Negative environmental impact anticipated
Good quantity of the irrigation water (high oxygen levels, low nutrient and dissolved salts concentration) is not conductive to excessive growth of algae and water weeds, and will neither lead to soil salinization problems. Excessive use of these are known to harm the balance of nature, damage aquatic life, cause eutrophication and create problems to downstream water users as well. With the expected transfer of improved farming technology and the expansion of the arable land based on the rehabilitation of irrigation facilities, it would encourage farmers to use higher level of agro-chemicals and fertilizers so as to ensure higher agricultural productivity at a future point of time. Therefore, adverse impacts on water quality in the downstream of irrigation systems need to be considered in the O&M Stage, particularly nutrient load and/or chemical contamination in the water.
Mitigation measures
➢ It is proposed to carry out a support program for appropriate farming particularly chemical and fertilizer application, and processing of compost by farmers. ➢ Pesticides in Cambodia are classified into three categories: (i) banned, (ii) restricted and (iii)

permitted by the announcement of MAFF, the criteria of which is based on WHO.[1] An awareness among farmers in the short-term on the hazards of using toxic chemicals should be created. Community-based mutual checking systems should be established among FWUC members for proper chemical and fertilizer application on this guideline basis supported by extension agent. ➢ Integrated pest management (IPM) will be introduced in a step-wise manner on methodology with the active involvement of relevant organizations (PDA, PDOWRAM and local authorities). ➢ Periodical water quality monitoring should be carried out within the canals in the command area and downstream areas by PDOWRAM.
Stakeholders
➢ MOWRAM ➢ MAFF ➢ PDOWRAM ➢ PDA ➢ Community People including those of downstream irrigation systems ➢ Local Authority

Prepared by JICA Study Team

(3) Flora, Fauna and Biodiversity

Fishing in Moung Russei River using fishing net (Ream Kon Sub-Project)
(February 8th, 2008)

An impact on flora, fauna and biodiversity is to be caused due to disturbance of fish sprawling by the construction and/or improvement of headworks in the Moung Russei, Pursat and Boribo River respectively. As having already explained in the previous section, construction of fish ladder for four sub-projects consisting of: (i) Ream Kon, (ii) Damnak Ampil, (iii) Wat Chre and (iv) Lum Hach needs to be considered during preparation and construction phase in appropriate plan, design and construction process. In addition, effectiveness of fish ladder and fish yield should be monitored and evaluated in the O&M stage by local agencies and communities.

7.3.5 Environmental Monitoring Plan

In the previous sections, seven measures are proposed in order to mitigate adverse environmental impact from social and natural view points:

Preparation Stage

- Participatory land acquisition planning for main and secondary facilities development,
- Participatory tertiary development,

Construction Stage

- Education program for construction labors,
- Construction of fish ladder,
- Environmental consideration in technical specification for construction works,

[1] The announcement No. 598 (December 15th 2003) issued by MAFF stipulated that there are three categories of pesticides classified by their toxic level: (i) 116 nos. of banned, (ii) 40 nos. of restricted and (iii) 136 nos. of permitted pesticides.

O&M Stage

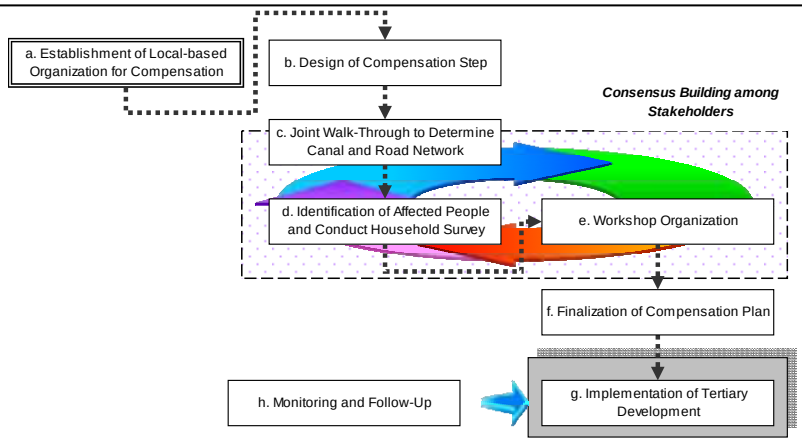
- System O&M and water management improvement, and
- Appropriate application of agricultural input.

As for the environmental monitoring, two plans are proposed: (i) participatory land compensation process for tertiary development and (ii) soil and water quality monitoring, both of which are relevant to all the six sub-projects. They should be monitored in the long-term in order to materialize project effect through social and natural environment-friendly manner.

(1) Participatory Land compensation Process for Tertiary Development

Land compensation for the construction of main and secondary level will be the responsibility of the Government with IRC, the role of which is determination of entitlements, value of the lands and follow-up appropriate compensation process through information disclosure, detailed compensation planning and public consultation. The process of land acquisition for tertiary level development, however, has not been stipulated at the Central Government level. Instead, they are the responsibility on local authorities such as commune councils.

Land acquisition would be sensitive issues, therefore, careful design of the process needs to be carried out so as to ensure sustainability of the project in sociologically suitable way. In this process, full public participation and meaningful consultation with the people and communities who may have potential adverse impacts from development activities is one of the important keys to success. Proposed land acquisition and compensation process at tertiary level is illustrated above and explained afterward:



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Participatory Process of Tertiary Level Facilities Development

a. ***Establishment of local-based organization for compensation***: Locally-based compensation committee should be established in charge of tertiary level land acquisition consisting of PDOWRAM, PDA, Provincial Department of Land Management, Urban Planning and Construction (PDLMUPC), Commune Council, Village Development Committee, FWUC etc.

b. ***Design of compensation step***: Among committee members, compensation step is discussed and designed taking land tenure and local economic conditions into consideration.

c. ***Joint walk-through to determine the alignment of canal and road network***: Joint walk-through is carried out involving PDOWRAM engineer, representatives from village and farmers to design optimum canal and road network, process of which needs both social and technical consideration. Local consultants and/or NGOs familiar to each sub-project can be also resource persons to facilitate this process.

d. ***Identification of affected people and conduct household survey***: This step is coherent with

joint walk-through in the preceding step. Through joint walk-through survey using designed checklist, affected areas are identified, therefore, affected people are confirmed. Socio-economic survey, then, is conducted to collect information on socio-economic conditions, their opinions, impacts by land acquisition etc. Consensus among affected people should be built through this process.

e. ***Workshop organization***: Public consultation and information disclosure would be of critical importance in land acquisition as well as tertiary development planning. Therefore, draft plan is disclosed to get feed-back from stakeholders by organization of the workshop. Affected asset valuation is also agreed through this process, if any, although physical compensation is not stipulated in the regulation for tertiary development.

f. ***Finalization of compensation plan***: Land acquisition, compensation as well as tertiary development plan are finalized on the basis of stakeholders' opinion in the workshop.

g. ***Implementation of tertiary development***: Based on the implementation plan agreed in the preceding steps, tertiary development is carried out including land acquisition and construction.

h. ***Monitoring and follow-up***: Compensation committee is responsible for the monitoring during the implementation of land acquisition. In particular, progress of tertiary development is periodically monitored by the committee.

(2) Water and Soil Quality Monitoring

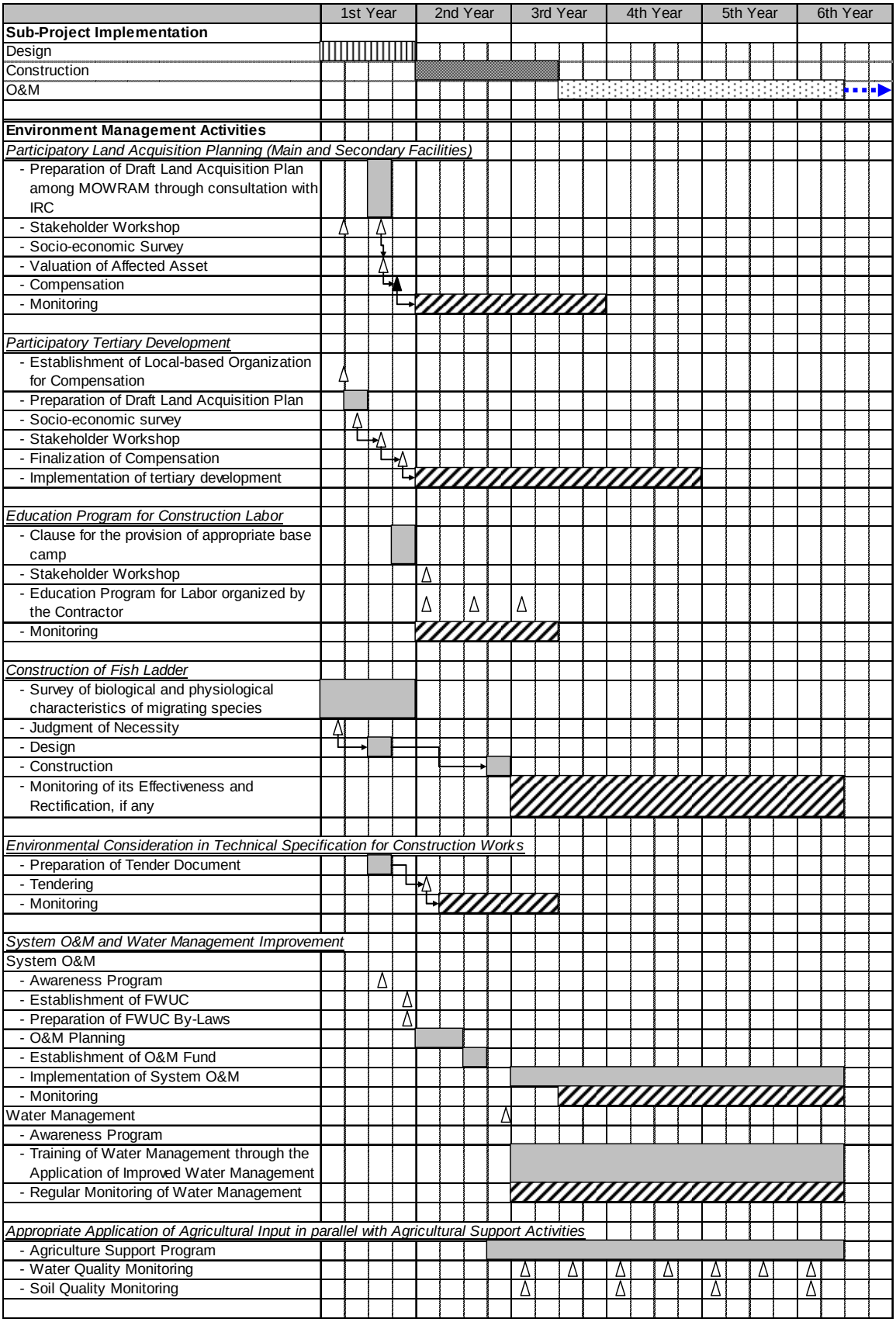
Water quality monitoring has been being carried out only at Bac Plea station of Battambang River since August 2004 by the Water Quality Analysis Office of the Hydrology and River Works Department under MOWRAM. No monitoring has not been conducted by PDOWRAM in and around the sub-projects including the water source, the Moung Russei, the Pursat and the Boribo River. Training of farmers for appropriate application of chemicals and fertilizer are to be supported under agricultural support program. In addition, a regular monitoring of soil and water quality needs to be concurrently carried out. The index of soil and water quality monitoring framework are tabulated as follows:

Soil and Water Quality Monitoring for the Projects

No.	Indicators	Method	Frequency	In-Charge
1.	pH	pH meter	Two times a year (dry and wet season respectively)	PDOWRAM/PDOE
2.	Electric Conductivity	EC meter		PDOWRAM/PDOE
3.	DO, Coliform, Nitrite, BOD, Total Nitrogen	Gas membrane electrodes		MOWRAM/PDOWRAM/ PDOE
4.	Total Phosphorous	Spectrophotometer		MOWRAM/PDOWRAM/ PDOE
5.	Metals, Nutrients, COD, Total Organic Carbon	Colorimeters		MOWRAM/PDOWRAM/ PDOE

Prepared by JICA Study Team

Environmental mitigation measures and monitoring plans are discussed above, which are of critical importance to be responsible by the Government. As the general timeframe of proposed activities depicted in the next page, the Government is required to carry out appropriate step-wise management. In particular, land acquisition, although impact is not significant since the Project targets only rehabilitation with no large scale resettlement, needs to be carefully carried out, activities of which consist of: (i) preparation of land acquisition plan including the set of cut-off date/final dateline, (ii) stakeholder workshop for consensus building, (iii) socio-economic survey, (iv) valuation of affected asset and (v) continuous monitoring so that the Project is sustainable from social and environmental points of view.



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General Timeframe of Environment Management Activities under the Project

7.4 Comparison Between "With" and "Without" Project

7.4.1 Comparison Between "With" and "Without" Conditions

Comparison of conditions between "With" and "Without" Project from the view point of: (i) Water and land resource mobilization, (ii) agriculture and (iii) institution is tabulated as follows:

Comparison between "With" and "Without" Conditions

Aspect	Without Projects	With Projects
Water and Land Resource Mobilization	• Irrigation water is quite limited. • Water is delivered only in the flood period through the irrigation facilities. • Ineffective resource utilization for irrigation is practiced without appropriate irrigation facilities, O&M and support services.	• Irrigation water increase for agriculture through permanent headworks and rehabilitated canals. • Water use during the construction will be affected due to stoppage of irrigation water in some period. • Meteo-hydrological monitoring system is strengthened so as to prepare irrigation service plan and to effectively carry out river basin management.
Agriculture	• Cropping area under the six sub-projects is only 1,040 ha in total with limited irrigation water as supplemental irrigation. • Paddy yield remains low ranging from 1.0 t/ha (rainfed condition) to 2.5 t/ha (supplemental irrigation). • Cultivation of high-valued crops is negligibly small.	• Cropping area under command area of the Project increases to 12,760 ha with irrigated conditions, therefore, agricultural production increases. • Yield is expected to reach 2.8 t/ha to 3.5 t/ha under normal and/or pump irrigated conditions contributing to the increase of farmers' income. • High-valued crops are introduced under the support program for the promotion of value-added agriculture.
Institution	• There are no FWUCs in the command areas. In addition, no substantial group activities for water management exist at present. • O&M of irrigation systems through group collaborative action is still not observed.	• FWUCs are established at each irrigation system for carrying out O&M through FWUC support program. • Coordination among local organizations is expected to be strengthened to utilize effective resource mobilization through the support programs.

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7.4.2 Comparison of Potential Negative Impacts Between "With" and "Without" Project

Potential negative environmental impacts are analyzed under "With" and "Without" Projects implementation as summarized in the table below:

Comparison of Potential Negative Impact between "With" and "Without" Projects

	Potential Impact	Without	With	Remarks
	Social Environment			
1	Involuntary Resettlement and/or Land Acquisition	X	-/C	Land acquisition necessary for construction of main, secondary and tertiary facilities
2	Local Economy (Employment and Income Generation)	-/A	+/A	Effective resource use materialization with better irrigation O&M
3	Land Use and Resource Mobilization	-/A	+/A	Irrigation water increase
4	Social capital and Traditional Institutions	-/A	+/A	Enhanced through FWUC support program
5	Social Infrastructure and Services	-/A	+/A	Improved irrigation rehabilitation
6	The poor, indigenous and minority group	-/A	X	Population pressure in future

Potential Impact		Without	With	Remarks
7	Unequal Distribution of Damage and Benefit	-/A	X	Population pressure in future
8	Cultural Heritage	X	X	No cultural heritage in and/or around the command area
9	Local conflict over interest	-/A	+/A	Effective resource use if mitigation measures are properly carried out
10	Water Use	-/A	+/A	Irrigation water increase by rehabilitated facilities
11	Sanitation	X	X	
12	Risk against infectious diseases	X	X	No significant impact if mitigation measures are carried out
	Natural Environment			
13	Topography and Geographical Features	X	X	
14	Soil Erosion	-/B	+/B	Mitigated particularly by drainage improvement
15	Groundwater	X	X	Since proposed cropping intensity is 144%, fertilizer and chemical can be absorbed in the soil, therefore, no significant impact is given to ground water.
16	Hydrology	X	X	
17	Coastal Area such as Mangrove, Coral Reef and Tidal Area	X	X	
18	Flora, Fauna and Biodiversity	X	X	
19	Meteorology	X	X	
20	Landscape	X	X	
21	Global Warming	X	X	
	Pollution			
22	Air Pollution	X	-/C	During construction although small impact
23	Water Pollution	X	-/C	During construction although small impact
24	Soil Contamination	X	-/C	During construction although small impact
25	Waste	X	-/C	During construction although small impact
26	Noise and Vibration	X	-/C	During construction although small impact
27	Ground Subsidence	X	X	
28	Offensive Odor	X	X	
29	Sedimentation	X	X	
30	Accidents	X	-/C	During construction

Note: - : Adverse Impact X: No Impact +: Positive Impact
A: Great Impact B: Medium Impact C: Small Impact
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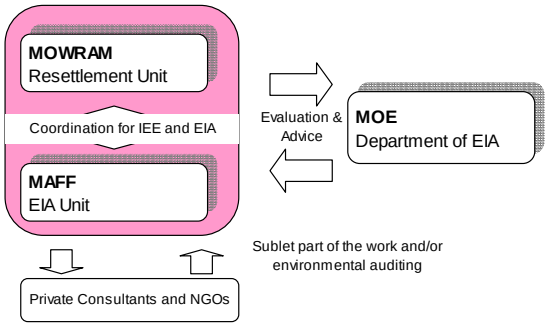
Without implementing the Project, the livelihood of the people will most likely continue at their present levels. Each time the fertility of the plot of land comes to unproductive levels excessive intensity of production if future population pressure is considered. The implementation of the Project will mitigate the present instability in farming by providing irrigation water through rehabilitated facilities. It will make way for farming in more stabilized manner, improve living standards and provide additional income. It will gradually bring about a balance in resource use and reduce land degradation.

Producing sufficient rice for domestic consumption is a priority policy of the government of Cambodia. Food security will be improved through increasing rice production which is one of the most important objectives of the sub-project.

7.5 Strengthening of Institutional Capacity for Environmental Management

7.5.1 Organizational Structure

The Strategic Development Plan 2006-2010 (Draft) has accentuated the importance of "*having a comprehensive capacity to develop and apply procedures for social and environmental impact assessment and mitigation*" as shown in MOWRAM Goal 11.[2] At present, Resettlement Unit is in charge of handling social environmental impact particularly resettlement issues associated with irrigation development projects under MOWRAM. However, practical knowledge and experience in Environmental Impact Assessment (EIA) and environmental management remains limited.



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Conceptual Framework for IEIA/EIA Organization

In order to properly carry out EIA, prepare environmental management plan and pursue its implementation for irrigation development in the future, coordination is required between the Resettlement Unit under MOWRAM and EIA unit of MAFF. In addition, out-sourcing of the part of EIA work to private consulting firm should be also considered.

7.5.2 Capacity Development Plan for Environmental Management

Strengthening the staff capability of MOWRAM, PDOWRAM and village authorities in terms of environmental awareness and practical impact mitigation measures through in-service training and study visits to model areas would be important and beneficial for sustainable irrigation development and management for the Project. Training models such as cascading style of training where trainees at one level become trainers at the other level, and the mechanism for information shares and feedback from lower to higher levels is evident. These activities will create a different kind of institutional organization and communities which has the capacity to retain its abilities to facilitate, as well as to respond to environmental awareness and management. Training programs proposed for environmental management is as follows:

(1) On-the-Job Training for IEIA and preparation of TOR for EIA

- To understand procedure of IEIA and EIA on the basis Sub-Decree on Environmental Impact Assessment Process
- To carry out basic field environmental survey such as field interview, on-site water and soil sampling and quality analysis etc.
- To develop IEIA capabilities through case studies of irrigation projects
- To visit construction sites of irrigation development project

[2] Planning and International Cooperation Department, MOWRAM (2005), Strategic Development Plan 2006-2010 (Draft of 23 May, 2005)

- To prepare checklist for IEIA and carry out IEIA based on checklist
- To execute training program and seminar for strengthening staffs' capabilities on the preparation of Terms of Reference (TOR) for EIA

(2) Training for Environmental Impact Mitigation and Management Planning

- To clarify causal relation of environmental impact from irrigation development
- To prepare appropriate management plan of adverse environmental impact
- To prepare environmental monitoring and evaluation plan

7.6 Conclusions

From the field studies, other information gathered and discussion presented in the preceding chapters, it is concluded that the Project will be extremely beneficial to the communities living in the command area. There will be a better productivity and an improved livelihood if the project is to be implemented.

No serious adverse environmental impacts are predicted for the Projects since all of them is existing and no large scale of expansion and/or new development is included under the component. Mitigation and enhancement measures are suggested where necessary and these will bring about an overall improvement in environmental quality. Indeed, once completed, well managed irrigation systems should enhance the long-term sustainability of the rural environment.

In view of the above conclusions arising out of the IEIA of the sub-projects, a full scale Environmental Impact Assessment (EIA) is not considered necessary if abovementioned proposed mitigation measures are concurrently carried out.

CHAPTER 8 PROJECT IMPLEMENTATION PLAN

8.1 General

Project implementation plan is proposed on the basis of present organizational structure and tasks of relevant agencies stipulated, policy and guidelines for project implementation of MOWRAM.

8.2 Implementation Organization

8.2.1 Organization of Project Executing Agencies

Project implementation organization is illustrated in Figure 8.2-1. Within the organization of MOWRAM, Northwestern Area Unit of the National Project Management Office (NPMO) will be in charge of project implementation with the collaboration and cooperation of relevant technical departments. At the Provincial Level, Project Implementation Unit (PIUs) will be established under Battambang, Pursat and Kampong Chhnang PDOWRAMs respectively to supervise rehabilitation and construction works. At the field level, support programs such as agriculture extension activities and FWUC establishment and strengthening support will be carried out with the guidance and supervision of PIU in collaboration with the local authorities including commune councils (CCs) and village development committees (VDCs) relevant to sub-project command areas. Such activities are proposed to be facilitated and assisted by technical consultants and NGOs.

After project is completed, the system will be operated and managed jointly by PDOWRAM and FWUCs, latter of which will be established and strengthened with the assistance by the Department of Irrigated Agriculture, MOWRAM as responsible agency at the central level. As explained in Chapter 5, system O&M will be transferred gradually in five years to FWUCs through designed procedure.

Three proposed project supporting programs: (i) MOWRAM Staff Capacity Development, (ii) PDOWRAM Staff Capacity Development and (iii) Meteo-hydrological Observation Strengthening will be implemented by the Technical Service Centre of Irrigation System Meteorology (TSC) under MOWRAM.

8.2.2 Staff Required for Design, Construction Works and O&M

MOWRAM needs to assign professional engineers to the NPMO backed by relevant technical departments at the central level and PIU at the provincial level to be responsible for implementing and managing the project. The following full-time staffs would be required for design, construction works and O&M for the project respectively.

Staffs Required for Design, Construction Works and O&M

	Stage					
	Design		Construction		O&M	
	Position	Nos.	Position	Nos.	Position	Nos.
Central Level National Project Management Office (NPMO)						
	Manager	1	Manager	1	Manager	1
	Irrigation	1	Irrigation	1	Irrigation/O&M	1
	Gate	1	Civil	1		
			Quality control	1		
			Gate	1		
	Land Acquisition	1	Land Acquisition	1	Land Acquisition	1
Sub-total (Central Level) (=1)		4		6		3
Provincial Level Project Implementation Unit (PIU)						
- Battambang Province	Chief	1	Chief	1	Chief	1
	Irrigation	1	Irrigation	1	Irrigation/O&M	1
			Civil	1	Gate operator	1
			Gate	1		
			Quality control	1		
	Land Acquisition	1	Land Acquisition	1		
Sub-Total of Battambang (=2)		3		6		3
- Pursat Province	Chief	1	Chief	1	Chief	1
	Irrigation	2	Irrigation	2	Irrigation/O&M	2
			Civil	2	Gate operator	2
			Gate	1		
			Quality control	1		
	Land Acquisition	2	Land Acquisition	2		
Sub-Total of Pursat (=3)		5		9		5
- Kampong Chhnang Province	Chief	1	Chief	1	Chief	1
	Irrigation	1	Irrigation	1	Irrigation/O&M	1
			Civil	1	Gate operator	1
			Gate	1		
			Quality control	1		
	Land Acquisition	1	Land Acquisition	1		
Sub-Total of Kampong Chhnang (=4)		3		6		3
Sub-total (Provincial Level) (=5=2+3+4)		11		21		11
Grand Total (=1+5)		**15**		**27**		**14**

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In addition, other necessary officers such as tendering, environmental monitoring etc. will be proposed to be assigned through on-call basis from the technical departments, engineering, irrigated agriculture, meteorology, hydrology and river works and others, within MOWRAM according to the need during the project implementation.

8.3 Implementation Schedule

8.3.1 Proposed Works under the Project

The proposed rehabilitation works and supporting programs will be listed as follows:

(1) Ream Kon Rehabilitation Sub-Project

Rehabilitation and/or reconstruction of irrigation facilities

- Reconstruction of headworks,
- Rehabilitation and construction of main, secondary canals,
- Participatory construction of tertiary canals,
- Construction of drains, and

Soft component

- Project support activities consisting of agriculture extension activities and FWUC establishment and strengthening.

(2) Por Canal Rehabilitation Sub-Project

Rehabilitation and/or reconstruction of irrigation facilities

- Rehabilitation and construction of main, secondary canals,
- Participatory construction of tertiary canals,
- Construction of drains, and

Soft component

- Project support activities consisting of agriculture extension activities and FWUC establishment and strengthening.

(3) Damnak Ampil Rehabilitation Sub-Project

Rehabilitation and/or reconstruction of irrigation facilities

- Improvement of headworks (gate and fish ladder),
- Rehabilitation and construction of main, secondary canals,
- Participatory construction of tertiary canals,
- Construction of drains, and

Soft component

- Project support activities consisting of agriculture extension activities and FWUC establishment and strengthening.

(4) Wat Loung Rehabilitation Sub-Project

Rehabilitation and/or reconstruction of irrigation facilities

- Rehabilitation and construction of main, secondary canals,
- Participatory construction of tertiary canals,
- Construction of drains, and

Soft component

- Project support activities consisting of agriculture extension activities and FWUC establishment and strengthening.

(5) Wat Chre Rehabilitation Sub-Project

Rehabilitation and/or reconstruction of irrigation facilities

- Reconstruction of headworks,
- Rehabilitation and construction of main, secondary canals,
- Participatory construction of tertiary canals,
- Construction of drains, and

Soft component

- Project support activities consisting of agriculture extension activities and FWUC establishment and strengthening.

(6) Lum Hach Rehabilitation Sub-Project

Rehabilitation and/or reconstruction of irrigation facilities

- Reconstruction of headworks,
- Rehabilitation and construction of main, secondary canals,
- Participatory construction of tertiary canals,
- Construction of drains, and

Soft component

- Project support activities consisting of agriculture extension activities and FWUC establishment and strengthening.

(7) Project Supporting Programs to be implemented at the Central and the Provincial Level

- Meteo-hydrological observation strengthening program,
- MOWRAM staff capacity development program, and
- PDOWRAM staff capacity development program.

8.3.2 Implementation Schedule

The project is expected to be implemented over 7 years from 2010 to 2016. The proposed project implementation schedule is shown in Figure 8.3-1.

Detail design will commence from the middle of 2010 over 1.5 years followed by rehabilitation works with approximately 4 years.

Two soft components: (i) agriculture extension activities and (ii) FWUC establishment and strengthening will be attached and implemented for each sub-project. Agriculture extension activities will be for the period of four years commencing in parallel with the rehabilitation of main and secondary systems. On the other hand, FWUC establishment and strengthening will commence before the tertiary development. The proposed period of FWUC support will be 3.5 years.

Three project supporting programs will be substantially implemented by TSC of MOWRAM as a hub agency to support upgrading irrigation performance of the sub-projects as well as enhancement of capability of MOWRAM and PDOWRAM to continue irrigation development in other areas, period of which are planned to be five years staring in the beginning of 2011.

Project formulation study stretching one year in 2014 will have the purpose of implementing feasibility study for potential projects in other areas in the Four River Basins: (i) Battambang, (ii) Moung Russey, (iii) Pursat and (iv) Kampong Chhnang effectively using lessons to be learnt from the implementation of six-sub projects.

O&M transfer is proposed based on the policy of MOWRAM, initial transfer process, approximately 2 years after completion, will be assisted by the Project while activities in successive 3 years will be carried by MOWRAM initiative.

CHAPTER 9 COST ESTIMATE

9.1 Basic Conditions for Cost Estimate

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

- Cost estimate refers to the prices as of September 2008.
- Exchange rate applied is as of September 2008, and they are as follows:

  1 US Dollar (US$) = 4,107 Riel

  = 107.99 Yen

- Unit prices of labor, construction materials, engineering works, etc., were collected from MOWRAM and market.
- Construction is undertaken on the contract basis, and V.A.T is excluded from construction costs.
- The Initial Investment cost consists of the following items, and assumptions and contents of each item are explained in table below:

Items and Assumptions for Initial Investment Costs for the Project

Item No.	Item Descriptions	Assumption (%) and Key Items	Contents for Item / Remarks
1.	Construction Cost	See Section 9.2.3	1-1 Headworks and Major Related Structures 1-2 Main and Secondary Sysytems 1-3 On-farm Development
2.	Project Supporting Pograms Cost	5 % of Item 1	2-1 Meteo-hydrological Observation Strengthening Program 2-2 MOWRAM Staff Capacity Development 2-3 PDOWRAM Staff Capacity Development
3.	Physical Contingencies	10 % of Items (1+2)	
4.	Sub-Total	Items (1+2+3)	
5.	Consulting Services Cost		5-1 Detail Design (D/D) 5-2 Construction Supervision (C/S) 5-3 FWUC Establishment and Strengthening 5-4 Agricultural Extension Activities
6.	Tax & Duty	10 % of Items (4+5)	
7.	Land Acquisition Cost	See Section 9.2.4	For anticipated area
8.	Project Administration Cost	10 % of Item 4	
9.	Price Escalation	5 % /annum of Item 4	Referred to IMF World Economic Outlook Database, October 2007

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- Price escalation rate (Item 9) is assumed to be at 5.0 %/annum; i.e., based on the average of annual change ratio of consumer price in Cambodia between year 2003 and 2008.
- Construction costs are divided into foreign currency portion (FC) and local currency portion (LC). Ratios of the FC and the LC are estimated for each content, referring to similar types of the projects in Cambodia:

9.2 Cost Estimate

9.2.1 Initial Investment Cost

The initial investment cost for the Project are summarized and shown in the following table. The initial investment cost is estimated at about US$ 97.95 millions, which is equivalent to Riel. 402 billions.

Initial Investment Costs for the Project

No.	Item	Amount (US$ 1,000)	Remarks
1.	Construction Cost	48,764	See Sub-Section 9.2.2 for detail
2.	Project Supporting Programs Cost	2,438	5 % of Item 1
3.	Physical Contingencies	5,120	10 % of Items (1+2)
4.	Sub-Total	56,322	Items (1+2+3)
5.	Consulting Services Cost	14,332	
6.	Tax & Duty	7,065	10 % of Item (4+5)
7.	Land Acquisition Cost	841	For 391.9 ha
8.	Project Administration Cost	5,632	10 % of Item 4
9.	Price Escalation	13,762	5 %/annum of Item 4
10.	Grand Total	97,954	Items 4+5+6+7+8+9

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9.2.2 Disbursement Schedule

The annual disbursement schedule for the Project is shown in the table.

Annual Disbursement Schedule for the Project

No.	Item	Amount (US$ 1,000)							
		Total	2010	2011	2012	2013	2014	2015	2016
1.	Construction Cost	48,764	0	3,428	23,449	18,587	3,149	151	0
2.	Project Supporting Programs Cost	2,438	0	610	488	488	488	364	0
3.	Physical Contingencies	5,120	0	404	678	1,908	364	50	0
4.	Sub-Total	56,322	0	4,442	26,331	20,983	4,001	565	0
5.	Consulting Services Cost	14,332	2,150	3,153	5,016	2,723	860	287	143
6.	Tax & Duty	7,056	215	760	3,134	2,371	486	85	14
7.	Land Acquisition Cost	841	252	589	-	-	-	-	-
8.	Project Administration Cost	5,632	0	0	2,633	2,098	400	57	0
9.	Price Escalation	13,762	0	0	5,674	5,797	1,361	230	0
10.	Grand Total	97,954	2,617	10,088	42,788	33,972	7,108	1,224	157

Years 2008, 2009, 2017 are omitted from the above table due to no disbursement scheduled.

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9.2.3 Construction Cost

Cost estimates of construction costs (Item 1) were carried out for the following components of each sub-project. Construction cost includes costs for general items, miscellaneous works and contractor's expense, such as overhead.

Item 1-1: Headworks and Major Related Structures

Diversion weir, intake structures and other important major structures for each sub-project

Item 1-2: Main and Secondary Systems

Irrigation and drainage canals including related structures.

Item 1-3: On-farm Development

Tertiary systems and their related facilities, including FWUC office, drying yards and storage for paddy for each sub-project.

The construction cost for the Project and each sub-project are summarized in the following table. It ranges from US$ 15.2 millions, equivalent to Riel. 62.4 billions (for Lum Hach), to US$ 4.0 millions, equivalent to Riel. 16.6 billions (for Wat Chre). The Construction cost becomes relatively higher for the sub-projects in which the headworks systems are to be rehabilitated/ re-constructed.

Construction Cost for the Sub-Project

No.	Item	Amount	Remarks			
			Cost Breakdown of Item 1			
		(US$ 1,000)	(US$ 1,000)			
1.	Construction Cost	Total	1-1	1-2	1-3	
	A. Ream Kon Rehabilitation Sub-Project	10,586	3,747	5,805	1,034	w/ HW
	B. Por Canal Rehabilitation Sub-Project	5,175	57	4,058	1,060	
	C. Damnak Ampil Rehabilitation Sub-Project	6,371	3,348	1,791	1,232	w/ HW
	D. Wat Loung Rehabilitation Sub-Project	7,403	-	6,030	1,373	
	E. Wat Chre Rehabilitation Sub-Project	4,034	1,774	1,680	580	w/ HW
	F. Lum Hach Rehabilitation Sub-Project	15,195	5,869	7,660	1,666	w/ HW
	Total Construction Cost	48,764	14,795	27,024	6,945	

w/HW: Headworks will be re-built in the particular sub-projects.

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9.2.4 Land Acquisition Cost

Land acquisition cost for the Project is estimated based on the actual anticipated area for each sub-project. Total area of the land acquisition is expected to be 391.9 ha (details are referred to Chapter 7), and cost is estimated at about US$ 0.84 million, which is equivalent to about Riel. 3.45 billions.

9.2.5 O & M Cost

O & M cost for the major facilities, such as headworks, main and secondary systems of each sub-project is divided into the following 2 categories under conditions and assumptions explained below:

- Annual O&M cost: Estimated at about 2 % of the construction costs for the major facilities (Items 1-1 and 1-2).
- Major repair cost: Major repair including replacement will be executed every 10 years, and the cost is assumed to be 10 % of the construction costs for the major facilities (Items 1-1 and 1-2).

The annual O & M cost for the Project is estimated at about US$ 836,000, which is equivalent to Riel 3,435 millions. In addition, major repair cost for the Project is estimated at about US$ 4.18 millions, which is equivalent to Riel 17.2billions. The summary of the O & M cost is given in table below.

O&M Costs for the Project

No.	Item	Amount	Remarks			
			Cost Breakdown of Item 1			
		(US$ 1,000)	(US$ 1,000)			
1.	Construction Cost		1-1	1-2	1-3	
	A. Ream Kon Rehabilitation Sub-Project	9,552	3,747	5,805	-	w/ HW
	B. Por Canal Rehabilitation Sub-Project	4,115	57	4,058	-	
	C. Damnak Ampil Rehabilitation Sub-Project	5,139	3,348	1,791	-	w/ HW
	D. Wat Loung Rehabilitation Sub-Project	6,030	-	6,030	-	
	E. Wat Chre Rehabilitation Sub-Project	3,454	1,774	1,680	-	w/ HW
	F. Lum Hach Rehabilitation Sub-Project	13,529	5,869	7,660	-	w/ HW
	Total Construction Cost	41,819	14,795	27,024	-	
12-A	Annual O&M Cost (every year)	836 (Riel.3,435 millions)	2 % of Items (1-1, 1-2)			
12-B	Major repair Cost (every 10 year, including replacement)	4,182 (Riel.17.2 billions)	10 % of Items (1-1, 1-2)			

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CHAPTER 10 PROJECT EVALUATION

10.1 Economic Evaluation

10.1.1 Evaluation Procedure

In estimating the both project cost and benefit, all the prices are expressed in constant prices as of September 2008, and the foreign currency exchange rate is fixed at USD 1.00 = Riel 4,107. The project life is assumed to be 50 years starting from 2010 when the project implementation is proposed to be commenced.

Citing the World Bank Commodity Price Forecasts as of August 2008, economic farm gate prices of internationally traded agricultural inputs and outputs are calculated in the form of export and import parity prices. Referring to relevant sources[1], a standard conversion factor (SCF) and a shadow wage rate (SWR) are determined at 0.986 and 0.303, respectively, for the adjustment of prices and labor costs reflecting the market distortion. The financial construction costs estimated in Chapter 9 are converted to economic values by applying conversion factors of 0.81 for material costs and 0.73 for equipment costs to foreign currency portion as well as 0.94 for material costs and 0.85 for equipment costs to local currency portion, all of which are estimated by excluding transfer payments such as taxes, duties, subsidies, interest, land acquisition cost, etc. included in the financial construction costs.

10.1.2 Economic Benefit

In the six sub-projects, irrigation benefits are expected to be derived from the increase in the paddy field area under normal irrigation and pump irrigation conditions coupled with the increase in paddy yield and cultivation area of upland crops and vegetables in irrigated paddy field. The economic benefit is defined as the incremental net benefit between the present "Without Project" condition and the future "With Project" condition. In constructing proposed irrigation and drainage facilities, some part of existing paddy field will be acquired. Such change in the "right of way" area has been taken into account in formulating the future land use plan. In this regard, no production foregone as negative benefit is considered in estimating the annual economic benefit.

The project benefit is assumed to be realized from the early wet crop season of the next year after construction works are finished according to the construction schedule set up in Chapter 9. The target crop yield is also assumed to be fully realized at the fifth crop season. Based on these assumptions, the irrigation benefit of each sub-project is estimated as follows:

- Ream Kon Rehabilitation Sub-project: The build-up period of irrigation benefit is to start in 10% of 1,890-ha command areas from 2012, another 50% from 2013, the remaining 38% from 2014 and finally 2% from 2015;
- Por Canal Rehabilitation Sub-project: The build-up period of irrigation benefit is to start in 15% of 1,940-ha command areas from 2012, another 60% from 2013, the

[1] Cambodia Statistical Yearbook 2006, NIS, Ministry of Planning; First Revision, Population Projection for Cambodia 1988 – 2020; SEIRA Commune Database 2005, Ministry of Interior; and Cambodia Selected Issues and Statistical Appendix, August 2007, IMF

remaining 22% from 2014 and finally 3% from 2015;

- Damnak Ampil Rehabilitation Sub-project: It is to start in 25% of 2,270-ha command area from 2012, another 65% from 2013, the remaining 7% from 2014 and finally 3% from 2015;
- Wat Loung Rehabilitation Sub-project: It is to start in 55% of 2,540-ha command area from 2013, another 40% from 2014 and the remaining 5% from 2015;
- Wat Chre Rehabilitation Sub-project: It is to start in 60% of 1,020-ha command area from 2014 and the remaining 40% from 2015; and
- Lum Hach Rehabilitation Sub-project: It is to start in 45% of 3,100-ha command area from 2013, another 50% from 2014, further 4% from 2015 and the remaining 1% from 2016.

Based on the above assumptions, the annual increase in irrigation area, paddy production and incremental net benefit are estimated as shown below, and the project benefit is fully realized from 2020 onward.

Annual Increase in Project Benefits

Annual Increase	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020~
Cropped area under irrigation	(ha)	950	7,541	12,517	13,343	13,385	13,385	13,385	13,385	13,385
Paddy production	(ton)	420	4,660	10,760	15,700	20,570	25,020	27,050	27,360	27,370
Increment economic benefit	(M. Riel)	682	6,290	12,852	17,369	21,580	25,426	27,180	27,450	27,462
	(*'000 US$*)	*166*	*1,532*	*3,129*	*4,229*	*5,254*	*6,191*	*6,618*	*6,684*	*6,687*

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10.1.3 Economic Cost

The economic investment cost items are composed of (i) direct construction cost including head works and major related structures rehabilitation, main and secondary system rehabilitation, on-farm development, miscellaneous works and contractor's expense, (ii) project supporting program cost, (iii) consulting services cost, and (iv) physical contingencies. The economic investment cost is estimated by applying relevant conversion factors to each cost components like materials, equipment, common labor and skilled labor of the both foreign and local currency portions.

According to the construction schedule, the implementation period of the project is planned to be seven years between 2010 and 2016. The annual disbursement schedule of the estimated economic investment cost as shown below.

The annual O&M cost and major repairing cost are also converted to economic values in the same manner. The latter is allocated every 10 years.

Annual Disbursement of Economic Cost

Unit: Million Riel

Economic Cost	2010	2011	2012	2013	2014	2015	2016	Total	2025	2026
Initial investment cost	0	9,150	62,267	49,237	8,330	404	0	129,389	-	-
Supporting program cost	0	738	590	590	590	443	0	2,951	-	-
Physical contingency, 10%	0	989	6,286	4,983	892	85	0	13,235		
Consulting services cost	4,255	6,240	9,928	5,389	1,702	567	284	28,365	-	-
Total economic cost	4,255	17,117	79,071	60,199	11,514	1,499	284	173,939	-	-
(*'000 US$*)	*1,036*	*4,168*	*19,253*	*14,658*	*2,804*	*365*	*69*	*42,353*	-	-
Annual O&M cost	-	-	27	99	169	181	182	-	182	182
Major repairing cost	-	-	-	-	-	-	-	-	6,983	3,366

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10.1.4 Economic Evaluation and Sensitivity Analysis

In conducting economic evaluation, the economic cost and benefit stream is prepared for the project life period of 50 years, comprising the project investment cost, annual O&M cost and major repairing cost for the cost stream as well as annual irrigation and drainage benefit in the build-up and full swing stages for the benefit stream.

Sensitivity analysis is made for the following four cases:

- Case-1: Construction cost 10% up;
- Case-2: Irrigation water supply 1 year delay;
- Case-3: Target yield of crops 10% down; and
- Case-4: Case-1 combined with Case-3.

The results of economic evaluation and sensitivity analysis are expressed by the economic internal rate of return (EIRR), surplus between net present values of benefit and cost (B–C) at discount rate of 8% and benefit-cost ratio (B/C) as summarized in the following table.

Results of Economic Evaluation and Sensitivity Analysis

Item		EIRR	Net Present Value (8% discount rate)			
			Benefit	Cost	B-C	B/C Ratio
		(%)	(Million Riel)			
Economic Evaluation		12.8	229,181	141,526	87,655	1.62
Sensitivity Analysis	Case-1	11.9	229,181	153,398	75,783	1.49
	Case-2	11.6	211,661	141,504	70,157	1.50
	Case-3	10.3	182,329	141,504	40,825	1.29
	Case-4	9.5	182,329	153,398	28,931	1.19

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As seen in the above, it can be said that the proposed project is economically feasible under the conditions set up as described.

10.2 Financial Evaluation

The prospected impact of the proposed project on beneficiary farmers' capacity to pay is indicated by estimating farm budget based on typical farm size and farming practice type of each sub-project area. The increase in net return between the present "Without Project" and future "With Project" conditions reveals that how much additional capacity to pay after

deducting farming cost beneficiary farmers can expect to gain through participation to the proposed project.

To estimate the farm budget on the financial price basis, actual farm gate prices of all farm inputs and outputs as of September 2008 are to be used. Further, the balance between non-farm income and family expenditure is estimated. Then the sum of net return to be gained from farm operation and balance of non-farm activities is calculated as net surplus which can be defined as farmer's capacity to pay.

The result shows that beneficiary farmers will be able to gain additional net surplus ranging from 604,000 Riel/ha or 147 US$/ha to 2,182,000 Riel/ha or 531 US$/ha. This reveals that every participated farmer in the proposed project may fully shoulder the annual O&M cost of their on-farm facilities and also pay water charge if it is set up at affordable rate.

Increase in Farmers' Capacity to Pay

Sub-project	Crop Season, Planting and Irrigation	Farm Size ha	Net Surplus W/O '000 R	Net Surplus W/P '000 R	Increased Capacity to Pay Amount '000 R	Amount TR/ha	Amount *US$/ha*	Rate times
Ream Kon Rehabilitation	WT-Normal	2.2	569	3,940	3,371	1,532	*373*	6.9
	WT-Pump	2.2	569	2,521	1,952	887	*216*	4.4
	WD-Normal	2.2	-243	3,071	3,314	1,506	*367*	33.1
	WD-Pump	2.2	-243	2,349	2,592	1.178	*287*	25.9
Por Canal Rehabilitation	WT-Normal	2.4	1,593	5,126	3,533	1,472	*358*	3.2
	WD-Normal	2.4	271	3,634	3,363	1,401	*341*	13.4
Dam Nak Ampil Rehabilitation	WT-Normal A	1.2	192	1,491	1,294	1,083	*264*	7.8
	WT-Pump A	1.2	192	917	725	604	*147*	4.8
	WT-Normal B	1.2	685	1,491	806	672	*164*	2.2
Wat Loung Rehabilitation	WT-Normal	1.4	632	2,372	1,740	1,243	*303*	3.8
	WT-Pump	1.4	632	1,701	1,069	764	*186*	2.7
Wat Chre Rehabilitation	WT-Normal	1.6	670	2,831	2,161	1,351	*257*	4.2
	WT-Pump	1.6	670	2,064	1,394	871	*212*	3.1
Lum Hach Rehabilitation	WT-Normal	1.4	266	3,321	3,055	2,182	*531*	12.5
	WT-Pump	1.4	266	2,235	1,969	1,406	*342*	8.4

Note: W/O; Present/Without project condition, W/P; With project condition, R; Riel, TR; 1,000 Riel,
WT; Wet season transplanting, and WD; Wet season direct sowing
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10.3 Indirect Benefit, Intangible Benefit and Socio-economic Impacts

10.3.1 Indirect Benefit

As described in Chapter5.3 and 5.6, supplemental irrigation water supply can be expected to downstream paddy fields of the Damnak Ampil Main Canal as well as the left bank area of the Lum Hach Head Works. In the both cases, surplus of discharge to be created at off-peak irrigation water supply time to Damnak Ampil, Wat Loung and Wat Chre sub-projects as well as Lam Hach sub-project can be used by farmers who are growing paddy in the areas where the surplus discharge can take in through the said canal or head works. These areas are excluded in defining a direct benefit to born by irrigation water supply by the proposed rehabilitation works of the existing irrigation structures. By utilizing the surplus discharge, however, paddy yield in the concerned areas will be able to be raised to a certain extent. If it is assumed to make the present paddy yield level increase by 0.5 ton for the wet season through

practicing the use of surplus discharge by farmers, the following increase in paddy production is anticipated as indirect benefits of the proposed sub-project implementation. This increasing paddy yield is equivalent to the yield difference between supplemental irrigation paddy field and rain-fed paddy field.

Anticipated Indirect Benefit

Existing Structure to be Rehabilitated by Project	Scheme Indirectly Benefited	Command Area (ha)	Increase in Paddy Production (ton)
Damnak Ampil Main Canal	Damnak Ampil Extension	7,650	3,825
	Bakan & Krouchi Seuchi	1,000	500
	Svay Daun Keo River	2,200	1,100
Lum Hach Head Works	O Roluss Irrigation	3,400	1,700

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10.3.2 Intangible Benefit

Though rehabilitation works of the existing irrigation and drainage systems in the six sub-project areas, the annual paddy production can be expected to go up from 21,000 tons before implementation of the proposed sub-projects to 48,400 tons after the implementation. In addition to such prospected increase in paddy production as the tangible benefit of the proposed sub-projects, it can be considered that the availability of rice processed products like rice flour and ancillary business chances as typical intangible benefits attribute to the project implementation will be enhanced to a large extent. As a result, such increasing availability will be able to heighten a contribution degree to rural and individual farm economies through increase in inputs to be purchased and transported as well as value addition of outputs in the course of processing, transporting and transacting of rice and its product.

10.3.3 Socio-economic Impacts

Citing the socio-economic survey findings, the average labor force is presumed at 2.5 persons a farm family in the six sub-project areas and total farm households are estimated at around 8,300. If the annual working day of one family labor force is assumed to be 236 days, the available annual family labor force of 8,300 farm households is estimated at 4.9 million man-days. On the other hand, the annual farm labor requirement in the whole command area of the six sub-projects is estimated at approximately 1.5 million man-days under the present/without project condition based on the result of farm survey.

Although the both estimates show that the whole farm labor requirement for the present farm operation can be covered by the available family labor force of farm households in the six sub-project command areas, the said farm survey result also points out such fact that 8 to 18 hired labors per 1 ha are used by every farm household at peak times of farm operation like transplanting and harvesting. Furthermore, the proposed rice cultivation practice under the normal or pump irrigation condition needs more farm labor inputs than as it is for the peak time farm operation.

From this viewpoint, it can be considered that a sustainable socio-economic impact attribute to improvement of rice cultivation under irrigated condition as one of prospected fruits of the proposed project implementation is to provide jobless workers in rural areas with seasonal

opportunities to earn a certain incomes. Based on the farm labor requirements for different cropping patterns proposed to the respective sub-projects, therefore, necessary hired labor inputs are to be calculated and then increased hired labor inputs are estimated as an indicator of socio-economic impact. The estimated increase in the total hired labor inputs for each sub-project is tabulated as below.

In view of socio-economy in the proposed six sub-subject areas, the impact of project implementation can be expressed by increasing hired labor inputs by 82,370 persons or 54% every year. This increase reveals that employment opportunities even though temporary will be created at the peak time of farm operation like transplanting and harvesting in three rice cropping seasons consisting of early wet season, wet season and dry season.

Increase in Hired Labor Inputs as Socio-economic Impact Indicator

Sub-project	Present Condition		Future Condition		Increased
	Cropped Area (ha)	Hired Labor Input (No.)	Cropped Area (ha)	Hired Labor Input (No.)	Hired Labor Input (No.)
Ream Kon Rehabilitation	2,230	33,804	3,254	53,969	20,165
Por Canal Rehabilitation	2,480	38,335	3,350	56,565	18,230
Dam Nak Ampil Rehabilitation	3,360	20,540	5,020	27,380	6,840
Wat Loung Rehabilitation	2,795	22,550	2,920	30,630	8,080
Wat Chre Rehabilitation	1,120	8,990	1,170	12,295	3,305
Lum Hach Rehabilitation	3,360	27,040	5,020	52,790	25,750
Total	15,345	151,259	20,734	233,629	82,370

Prepared by JICA Study Team