# *Appendix-C*
## *IRRIGATION AND DRAINAGE*

**BASIN-WIDE BASIC IRRIGATION AND DRAINAGE**
**MASTER PLAN STUDY**
**IN**
**THE KINGDOM OF CAMBODIA**

# FINAL REPORT

# APPENDIX-C IRRIGATION AND DRAINAGE

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# CHAPTER C1 PRESENT CONDITION OF IRRIGATION AND DRAINAGE

## C1.1 Location and Administration

### C1.1.1 Location

The six Sub-projects which were selected in the Master Plan Study for the first implementation are located in Pursat, Moung Russei, and Boribo River Basins. All Sub-project areas are located west of Lake Tonle Sap along the National Road No.5. The location of each Sub-project is summarized as follows:

**Location of Sub-project Areas**

| No. | Sub-project | River Basin | Province | Location | Coordinate of water source structure (UTM Indian Thailand approx.) |
|---|---|---|---|---|---|
| 1. | Ream Kon Rehabilitation | Moung Russei | Battambang | 238 km from Phnom Penh to Moung Russey, and 0.3 km from the Moung Russei town to northeast | N=1412840<br>E=333212<br>Right side of the Moung Russei River |
| 2. | Por Canal Rehabilitation | Moung Russei | Battambang | 280 km from Phnom Penh to Moung Russei, and 0.5 km from the Moung Russei town to northeast | N=1412599<br>E=332454<br>Left side of the Moung Russei River |
| 3. | Damnak Ampil Rehabiltiation | Pursat | Pursat | 180 km from Phnom Penh to Pursat, and 20 km from the town by rural road #148 to the existing Damnak Ampil Weir | N=1380406<br>E=370829<br>Damnak Ampil weir, Left side of the Pursat River |
| 4. | Wat Loung Rehabilitation | Pursat | Pursat | 8 km backward from the existing Damnak Ampil Weir to Pursat | N=1382468<br>E=37500<br>Left side of Pursat River |
| 5. | Wat Chre Rehabilitation | Pursat | Pursat | 204 km from Phnom Penh to Boeung Khnar, and 700m from the Boeung Khnar town to northeast | N=1397400<br>E=362500<br>Right side of the Boeung Khnar River |
| 6. | Lum Hach Rehabilitation | Boribo | Kg. Chhnang | 126 km from Phnom Penh to Boribo district, and 24 km from the Ponley town to southwest | N=1362350<br>E=425885<br>Right side of the Boribo River |

Prepared by JICA Study Team

### C1.1.2 Topography

(1) Temporary Bench Marks

JICA Study Team set Temporary Bench Mark (TBM) in every sub-project area by a concrete typical monument or at the existing permanent structure. The coordinate and elevation of the TBM are summarized in Table C1-1.

(2) Ream Kon Rehabilitation Sub-project

The Sub-project area extends in 11km from National Road No. 5 to east along right bank of the Moung Russei River, and 6km to south from right bank of the River. JICA Study Team set a Temporary Bench Mark (TBM-06) The area has a downhill slope to northeast; ground surface elevation varies from EL.15.0m to EL.10.0m. The land slope is between 1/2500 and 1/3000 from west to east, and 1/2000 and 1/2500 from south to north. The existing main canal runs from west to east, and divides the area into two i.e., northern part and southern part. The southern area has an uphill slope from main canal.

The dyke along the Moung Russei River near the existing headworks varies between EL.16.8 m and EL.17.8 m along the left bank, and EL.16.5 m and EL.16.9 m along the right bank.

(3) Por Canal Rehabilitation Sub-project

The Sub-project area is located at opposite side of Ream Kon Sub-project area, extends in 8 km to north form left bank of Moung Russei River, and 6 km in width from west to east. The area has a downhill slope to northeast; ground surface elevation varies from EL.14.7 m to EL.11.5 m. The land slope is between 1/1500 to 1/2000 from south to north, and 1/3000 from west to east.

(4) Damnak Ampil Rehabilitation Sub-project

The Sub-project area is located 3 km far from left bank of Damnak Ampil Headworks on the Pursat River.

The existing irrigation area extends in 7.3 km to west and in 6.5 km to north from Damnak Ampil main canal which was rehabilitated by MOWRAM in 2006. The area has a downhill slope to north; ground surface elevation varies from EL.16.8 m to EL.13.7 m[1]. The ground slope is between 1/2500 and 1/3000 from south to north, and 1/7500 from east to west. The existing main canal is 7.3 km long, and its base varies from EL.15.50 m to EL.14.04 m (1/5000) in accordance with the design made by MOWRAM in 2005.

The extension irrigation area extends in 13 km to west from west boundary of the existing irrigation area. It extends in 7km to north from existing canal. The ground surface varies from EL.16.2 m to EL.8.5 m; the ground slope is about 1/3000 from south to north, and 1/2500 from east to west. According to the topographic survey by the Study Team, the base of the existing canal which was excavated in 1970s varies from EL.13.4 m to EL.10.0 m in 13.4 km.

(5) Wat Loung Rehabilitation Sub-project

The Sub-project area is located left bank of Pursat River between Ou (stream) Bakan and National Road No.5. The area has a downhill slope to northwest; ground surface elevation varies from EL.15.9 m to EL.10.8 m. The ground slope is between 1/3500 and 1/3700 from south to north, and 1/2500 from east to west.

(6) Wat Chre Rehabilitation Sub-project

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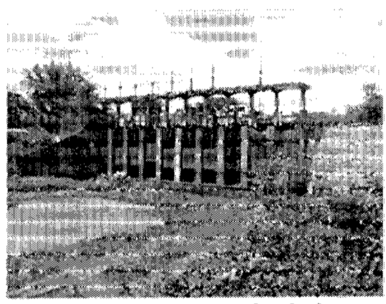
[1] There shows differences in elevation between national survey grid and design drawings of the Damanak Ampil Headworks in the Project Proposal for the Rehabilitation of Damnak Ampil Irrigation Project prepared by MOWRAM (2004). In the study, the ground surface elevation of two sub-projects: (i) the Damnak Ampil and (ii) the Wat Loung was surveyed using the data shown in MOWRAM's proposal (refer to Table C1-1).

The Sub-project area is located northern side of National Road No. 5, extends on both right and left banks of the Boeung Khnar River which is downstream of Ou Bakan. The area has a downhill slope to north and west; ground surface elevation varies from EL.13.5 m to EL.10.5 m. The ground slope is about 1/1500 from south to north, and 1/2500 from east to west.

(7) Lum Hach Rehabilitation Sub-project

The sub-project area is located middle reach of the Boribo River upto National Road No. 5. The area extends in 24 km from southwest to northeast. The ground surface elevation varies from EL.39.6 m to about EL.20.0 m. The ground slope is about 1/500 to 1/1000 in the upstream area, and 1/1500 and 1/2000 in the downstream area.

The proposed headworks site is located at narrow section of the Boribo River, and has a wide pocket in the upstream. The river bed elevation is between EL.33.0 m and 34.0 m. The top of left river bank is EL.41.0 m. On the contrary, right side bank is only EL.39.0 m.



**1. Upstream view of existing weir Gate lost function**

## C1.2 Irrigation and Drainage

### C1.2.1 Ream Kon Rehabilitation Sub-Project

(1) Outline of the Existing Irrigation System

The system was constructed between 1975 and 1978. A headworks was constructed on the Moung Russei River to utilize river water for the Ream Kon system and Por Canal system. Unfortunately, frequent floods destroyed the headworks and canal system immediately after the construction. The system does not function at present.

**2. Broken diversion facility**

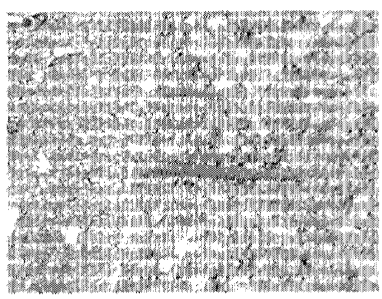
The inventory survey result is summarized in Table C1-2. There are very few important facilities such as tertiary canals, turnouts/diversions/off-takes, checks, etc.

(2) Existing Irrigation Facilities

1) Headworks

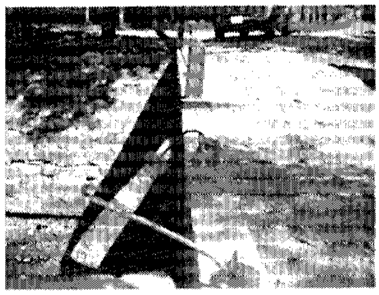
**3. Damaged concrete**

The headworks does not function to maintain the intake water level for irrigation (Right photo 1). Further, due to lost function of movable gates and high elevation of the end sill of the gates, flood water can not flow to the downstream smoothly. A diversion channel was constructed at just downstream of the Moung Russei River during the construction period. The diversion facility was completely



**4. Exposed reinforcing bars**

broken. At present most of the river water flows into the diversion channel (Right photo 2). This causes the difficulty of taking irrigation water in irrigation systems located in the downstream.



**5. Broken handrail of bridge**

The concrete structure has many cracks and reinforcing bars are exposed for a long time resulting in severe rusty. Based on the information from PDOWRAM, iron and other steel were collected from villages in order to make reinforcing bars during the construction time (Right photo 3&4)

The intake is located at the right side of the Moung Russei River, about one kilometer upstream from the headworks. No gates exist at present. The intake structure is also deteriorated even after rehabilitation in 1986. A bridge was constructed along to the intake structure. The handrail of the bridge was completely broken by collision with trucks due to the sharp curve. The alignment of road and bridge is to be modified (Photo 5).

2) Canals

The flow capacity of existing main canal is examined by applying non-uniform flow hydraulic formula to the canal sections surveyed by the Study Team. The calculation reveals that the main canal has a flow capacity between 1.5 $m^3$/sec to 0.3 $m^3$/sec. On the contrary, the water level of the main canal is too low for gravity irrigation.

Irrigation water has not flown in the secondary canals for long time. Flow capacity of the canal section is reduced by sedimentation, and is covered with grasses. The water level is also too low in the secondary canals for gravity irrigation.

3) Structures

There is a check structure and road crossing culvert in the main canal and secondary canal respectively. These are no function due to deterioration. Many additional structures are to be constructed by the sub-project.

4) Dyke

The existing dyke located upstream of the sub-project area is cut at several locations by humans. In each location, there are no water control facilities. The storage function of the dyke system is lost and people is cultivating in the former pond area (60 ha approx.).

Some sections of the dyke crest are used for rural road to connect villages. However, road condition is poor and is not accessible by jeep in most of the sections.

(3) Present Irrigation Water Use, O&M, and FWUC

According to the household survey by the JICA Study Team in August 2007, 70% of interviewees (40 households) answered they are depend on rainfall only for cultivation. Farmers wait for his land is wet and inundated by rain and flood from upstream in order to start paddy cultivation. Accordingly, floods in the early time of wet season are welcome by farmers. A 22.5% of interviewees use canal as a supplement water source. Only 7.5 % uses canal as a main water source. During the growing stage of paddy, if a long drought occurs, farmer take water which is probably inundated in the canal or stream by pump.

The situation of operation and maintenance was reported "partly functioning" by PDOWRAM in the JICA Inventory Survey in 2006. However, no O&M activities have been recently executed by PDWRAM because a full-scale rehabilitation of irrigation system is required, which requires high cost. There is no registered FWUC or FWUGs in the sub-project area.

(4) Drainage condition

There are no clear drainage canals in the sub-project area at present. The drainage water from the outside of the sub-project area such as western area (Anlong Koub Irrigation area) and southern area flows into irrigation canals breaking the canal dyke and is used for irrigation.

The 70% of interviewees replied that they are suffering from flood at least once in every year. Of them, 57.5% of interviewees answered suffer from flood in more than 4 days. The flood mainly affects paddy and human life.

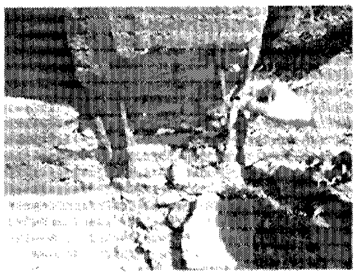
The main cause of floods is assumed to be two types: (i) flood from upstream areas and (ii) affect from high water level in the Lake Tonle Sap. The southern part of the sub-project area suffers from flood from adjacent irrigation area (Anlong Koub irrigation area). The drainage system should be developed by the sub-project in order to avoid inundation problem.

In the eastern part of the sub-project area, water level of the Lake Tonle Sap affects the drainage condition of the Moung Russei River and other tributaries (ex. Ou Anlong Rolus). High water level causes water-logging in the low-lying area.

The current direction of the Moung Russei River should be modified to the original river course after the new headworks constructed in order to supply water to the others irrigation systems located downstream.

(5) Other problems

Accessibility in the sub-project area is very poor condition. Establishment of a farm road network is necessary for transportation of agriculture input and output. The existing canal inspection road is to be rehabilitated and paved for farm road.



**1. Damaged concrete and reinforcing bars exposed**

### C1.2.2 Por Canal Rehabilitation Sub-Project

(1) Outline of the Existing Irrigation System

The system was constructed between 1975 and 1978. A headworks which was constructed on the Moung Russei River for the Ream Kon system was also used for the Por Canal Sub-project. Frequent floods destroyed the headworks and canal system. The system function in the very limited area i.e., only a few percent of the area.

**2. Crack of wing wall of intake**

The present condition of the irrigation system was reported "run-of-river type irrigation system". The inventory survey result is summarized in Table C1-3. There are very few important facilities such as tertiary canals, turnouts/diversions/off-takes, checks, etc., are lack in the system.

(2) Existing Irrigation Facilities

1) Intake

The intake for Por Canal Sub-project is located at left side of the Moung Russei River about 800m upstream from the headworks. The intake structure is seriously deteriorated by cracks and expose of reinforcing bars for a long time. The intake gate is deteriorated and not functioning well because of lack of maintenance (Photos 1 and 2). Re-construction is inevitable.

2) Canals

The flow capacity of existing main canal is examined by applying non-uniform flow hydraulic formula to the canal sections surveyed by the Study Team. The calculation reveals that the main canal has a flow capacity between 5.0m3/sec and 0.5 $m^3$/sec. On the contrary, the water level of the main canal is too low for gravity irrigation. The water level is also too low in the secondary canals for gravity irrigation. Some of canals in the area are rehabilitated recently. However, there is no water control facility on the canals.

3) Structures

There are a check structure and diversion structures in the main canal. Seven road crossing structures are fairly functioning. Many additional structures, however, need to be constructed.

(3) Present irrigation water use, O&M, and FWUC

According to the household survey by the JICA Study Team in August 2007, 80% of interviewees (40 households) answered they depend on rainfall only for cultivation. Farmers wait for rain and flood from upstream in order to start paddy cultivation. Accordingly, floods in the early wet season are welcome by farmers. A 17.5% of interviewees use canal as a supplement water source. Only 2.5% use canal as a main water source. During the growing stage of paddy, if a long drought occurs, farmer take water which is probably inundated in the canal or stream by pump.

The situation of operation and maintenance was reported "partly functioning" by PDOWRAM in the JICA Inventory Survey in 2006. Some repair work has been executed by PDOWRAM and other donors such as SEILA Program, or ECOSORN. However, no O&M activities have been recently executed by PDWRAM because a full-scale rehabilitation of irrigation system is required, which is high cost. There is no registered FWUC or FWUGs in the sub-project area.

(4) Drainage System

There are no clear drainage canals in the sub-project area at present. The excess water from the west of the sub-project area (Prek Taam Irrigation area) flow into sub-project area. The 55% of interviewees replied that they are suffering from flood at least once in every year. Of them, 42.5% of interviewees answered suffer from flood in more than 4 days. The flood mainly affects paddy and human life.

The collector drain should be developed at the western border of the sub-project in order prevent inundation.

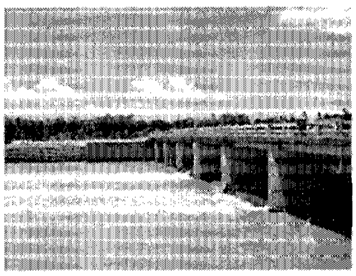
(5) Other problems

Accessibility in the sub-project area is very poor condition. Establishment of a farm road network is necessary for transportation of agriculture input and output. The existing canal inspection road is to be rehabilitated and paved for farm road.

### C1.2.3 Damnak Ampil Rehabilitation Sub-Project

(1) Outline of the Existing Irrigation System

The system was constructed left side of the Pursat River between 1975 and 1976. The system was damaged in 1979 and not functioning. A new headworks has been constructed in 2006. The first upstream of the main canal (7.3 km) was also rehabilitated in 2006 to supply irrigation water to about 2,270 ha. One check structure, nine off-takes and other structures are also constructed. The inventory survey result is summarized in Table C1-4.

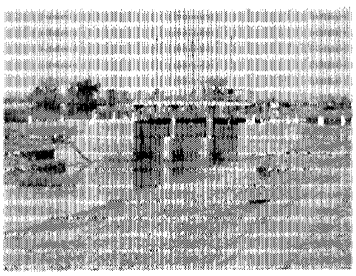


**1. Damnak Ampil Weir**

The extension of the main canal is proposed up to Svay Don Keo River (13.5 km to northwest) in order to supply irrigation water to extension area and several irrigation systems in the Svay Don Keo River in future.

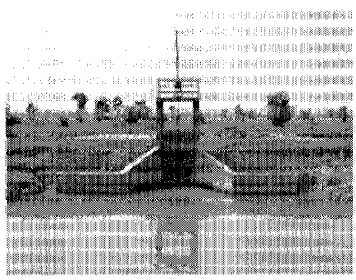
(2) Existing Irrigation Facilities

1) Headworks



**2. Check Structure on Main Canal**

The original headworks was constructed on the Pursat Riv washed away by floods in 1979. The new headworks was rec 2006 (Photo 1). It has seven automatic flood gates which are and stand in accordance with the fluctuation of water level also two sluice gates at right and left side each. The size of Table C1-4. The intake was also reconstructed in 2006. capacity at the water level EL.17.0 m. No gate is installed at intake structure.



**3. Inlet of Secondary Canal**

The automatic flood gates seem to fall down well when water le (EL.16.85 m). However, the gates hardly stand during wet water level is hardly maintained at EL.17.0 m. Based on the i reasons are considered to be:

(i) The gates are designed to stand when water level is n very low from intake water level (EL.17.0 m).

(ii) On the contrary, the water level in the river almost always more than EL.13.70 m in the wet season owing to the abundant runoff.

(iii) There is some objection or extra friction between counterweight and guide rail. It impedes smooth fall down of the counterweights.

Based on the information and request obtained, the following counter measures are to be provided to improve the behavior of the gates:

a) To increase counterweight to raise fall down water level from EL.16.85 m to EL.17.20 m

b) To provide manual or power hoist to stand gates at EL.16.50 m approx.

c) To provide some mechanical measure to make stepwise fall down in accordance with the water level

Of the above, item a) and b) are considered must, and item c) if required

2) Canals

The existing main canal runs from the Pursat River to northwestward. The canal is rehabilitated in the most upstream reach of 7.3 km in 2006. The rehabilitated canal has canal base width and water depth of 7.0 m and 1.5m, respectively, and has a flow capacity of 8.0 $m^3$/sec.

The further downstream reach of the main canal of 16 km is very deteriorated by erosion, slope sliding, sediment, etc. at present. The flow capacity is assumed less than 5 $m^3$/sec on average.

Three secondary canals were constructed in the sub-project area. However, these canals are seriously deteriorated by erosion, slope sliding and sediment. The canal base is very high. Rehabilitation is required in all secondary canals. No tertiary canals were constructed.

The existing main canal will further require rehabilitation to increase the flow capacity in the upstream.

3) Structures

Structures were constructed in 2006 including one cross regulator and nine off-takes. However, they are not used efficiently because water level in the main canal is very low (Photo 2 and 3).

(3) Present irrigation water use, O&M, and FWUC

According to the household survey by the JICA Study Team in August 2007, 70% of interviewees (30 households) answered they are depend on rainfall only for cultivation. During the growing stage of paddy, if a long drought occurs, farmer take water which is probably inundated in the canal or stream by pump.

The situation of operation and maintenance was reported "Mal function" by PDOWRAM in the JICA Inventory Survey in 2006. No O&M activities have been recently executed by PDWRAM because a full-scale rehabilitation of irrigation system is required, which is high cost. FWUC was established in 2005. Its registration is under processing. However, only 7% of interviewees answered they are member of the FWUC.

(4) Drainage condition

A 27% of interviewees replied that they are suffering from flood in every year. The 20% answered suffer from flood in more than 4 days. The flood suffering area is assumed to be near the Pursat River and another stream (Stueng Chambot) which flows northwest border of the sub-project area.

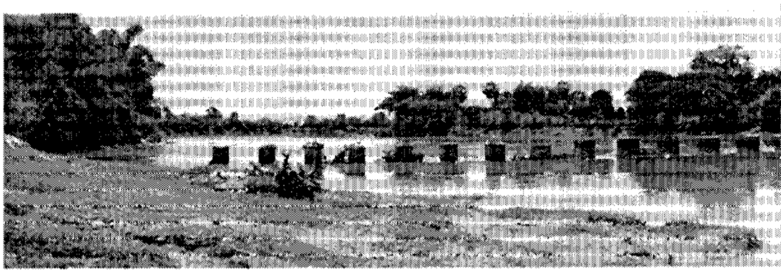
### C1.2.4 Wat Loung Rehabilitation Sub-project

(1) Outline of the Existing Irrigation System

The system was constructed left side of the Pursat River in 1977 to irrigate about 7,000 ha. The system was damaged in 1979 and not functioning. Very few structures are reported in the JICA Inventory Survey 2006. The inventory survey result is summarized in Table C1-5.

The area is located at right side of Ou Bakan and Boeung Khnar River.

(2) Existing Irrigation Facilities



**1. Ruins of pier of headworks in the Pursat River**

**2. Inlet of Wat Loung Main Canal**

1) Headworks

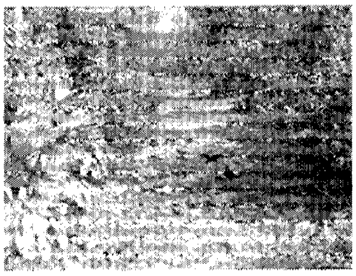
The headworks was constructed on the Pursat River in 1977, and was completely washed away by floods in 1979. At present only piers can be seen in the Pursat River (Photo 1). There is no intake structure at present. The inlet of the main canal seems to be abandoned during construction (Photo 2).

The headworks is located at 3.5 km downstream from the existing Damank Ampil Weir constructed by MOWRAM on the Pursat River in 2006. Irrigation water supply from Damnak Ampil Weir is more economical than construction of the new headworks at the existing site.

2) Canals

The existing main canal runs from the Pursat River to northwestward. The calculation reveals the main canal has a flow capacity between 0.15 $m^3$/sec to 1.0. The canal does not function well because water inflow from Pursat River is limited during flood time (Photos 3 to 5). The main canal runs 17 km from the existing intake site, and finally joins with Boeung Khnar River about 9 km upstream from Wat Chre Headworks propose. The sub-project lack secondary and tertiary canals.

**3. Main Canal: Beginning Point (BP)**



**4. Main Canal: 12.0 km from BP**

**5. Main Canal: End Point before flows to Boeung Khnar River**

The canal bends to northward, the canal base elevation is gradually down to northward.

The ground surface of the western area is lower than water level at the existing headworks. If the water level is raised at headworks site, a one meter heightening of dyke is required in the upstream.

3) Structures

There are no functioning structures in the sub-project except two bridges.

(3) Present irrigation water use, O&M, and FWUC

According to the household survey by the JICA Study Team in August 2007, 87% of interviewees (40 households) answered they are depend on rainfall only for cultivation. Farmers wait for his land is wet and inundated by rain and flood from the Pursat River in order to start paddy cultivation. Accordingly floods in the early time of wet season are welcome by farmers. During the growing stage of paddy, if a long drought occurs, farmer take water which is probably inundated in the canal or stream by pump.

The situation of operation and maintenance was reported "Mal function" by PDOWRAM in the JICA Inventory Survey in 2006. No O&M activities have been recently executed by PDWRAM because a full-scale rehabilitation of irrigation system is required, which is high cost. There is no registered FWUC or FWUGs in the sub-project area.

(4) Drainage condition

A 50% of interviewees replied that they are suffering from flood in every a few years. The 12% answered suffer from flood in more than 4 days. The flood suffering area is assumed in the most upstream area of the main canal based on the topographic condition. The flood seems to mainly come from Pursat River through the existing Wat Loung main canal.

(5) Other problems

There are four existing irrigation systems located upstream of Boeung Khnar River, which take water from the Boeung Khnar River. Of them, the Thnos Tachap system (1,200 ha approx.) is located the most upstream and can be irrigated by Wat Loung Sub-project owing to the topographic conditions. The runoff of the river is not enough for three irrigation systems because its catchment area is small and located in the plain area in which rainfall is less. Two irrigation systems i.e., Bakan and Krouchi Seuchi systems can receive water from secondary canals of Damnak Ampil Irrigation system in future. Wat Chre Sub-project is proposed to receive water from Damnak Ampil Headworks through Wat Loung Main Canal.

### C1.2.5 Wat Chre Rehabilitation Sub-Project

(1) Outline of the Existing Irrigation System

The system was constructed on the Boeung Khnar River to utilize the river water in 1977. The system was damaged between 1979 and 1980, and not functioning at present. Very few structures are reported in the JICA Inventory Survey 2006. The inventory survey result is summarized in Table C1-6.

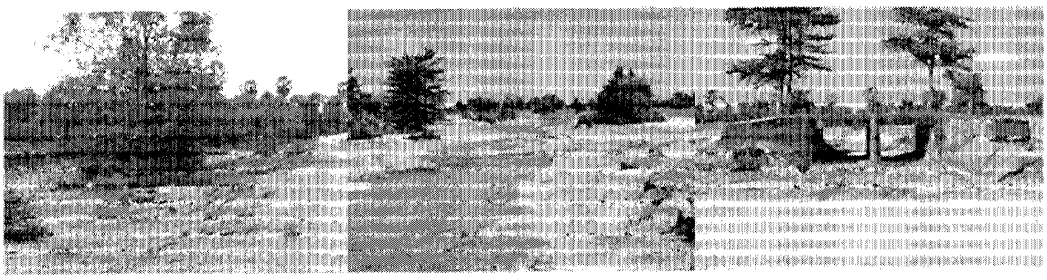
The area is divided into two areas i.e., eastern and western areas by Boeung Khanr River. The eastern part is located at right side of Boeung Khnar River and is about 1,000 ha. The western part is located at left side of the Boeung Khnar River and is about 300 ha.

(2) Existing Irrigation Facilities

1) Headworks

The headworks does not exist at present because it collapsed and was washed away by floods. There is no intake structure to control water taking from the Boeung Khnar River.

2) Canals



**1. Main canal (to southeast)** **2. Main canal (to northwest)** **3. Off-take and bridge**

Two main canals run from the headworks on the Boeung Khnar River to southeast and northwest, respectively. The bottom of one main canal is uphill to southeast in the first 1.2 km (Photo 1). The ground height in the eastern area is higher than water level at existing headwork site. The canal bends by about 90 degree to north, the canal base elevation is gradually down to north. Based on this, it is recommendable to move headwork site upstream from the present location, and to start new main canal from new headwork to connect to the existing canal, so that the uphilling canal can be used reversely as a secondary canal.

The ground surface along the other main canal to northwest area is lower than water level at the existing headworks (Photo 2)

3) Structures

There are no functioning structures in the sub-project except one bridge (Photo 3).

(3) Present irrigation water use, O&M, and FWUC

According to the household survey by the JICA Study Team in August 2007, 100% of interviewees (40 households) answered they are depend on rainfall only for cultivation. Farmers wait for his land is wet and inundated by rain and flood from upstream in order to start paddy cultivation. Accordingly floods in the early time of wet season are welcome by farmers. During the growing stage of paddy, if a long drought occurs, farmer take water which is probably inundated in the canal or stream by pump.

The situation of operation and maintenance was reported "Mal function" by PDOWRAM in the JICA Inventory Survey in 2006. No O&M activities have been recently executed by PDWRAM because a full-scale rehabilitation of irrigation system is required, which is high cost. There is no registered FWUC or FWUGs in the sub-project area.

(4) Drainage condition

A 10% of interviewees replied that they are suffering from flood at least once in every year. All of the 10% answered suffer from flood in more than 4 days. The flood mainly affects paddy, vegetables and household goods. The flood suffering area is assumed to be marsh located in the most western area in the western part of the sub-project. The ground elevation seems to be very low less than EL.10.0m. The area is excluded from the sub-project.

The Boeung Khnar River is a main drain of the sub-project area.

(5) Other problems

Four irrigation systems are identified in the Boeung Khnar River including Wat Chre sub-project. The total irrigation area is about 3,000 ha. The runoff mainly consists of drained water from Damnak Ampil sub-project area, but is not enough for four irrigation systems because its catchment area is small (300 $km^2$ approx.), and located in the plain area in which rainfall is less. A supplemental irrigation water supply is required to the systems from Pursat River.

Wat Chre sub-project is located at the most downstream of the Boeung Khnar River, and is far from the others irrigation systems. A few alternative routes should be considered to convey water from Damank Ampil Headwork to the Wat Chre Sub-project.

### C1.2.6 Lum Hach Rehabilitation Sub-Project

(1) Outline of the Existing Irrigation System

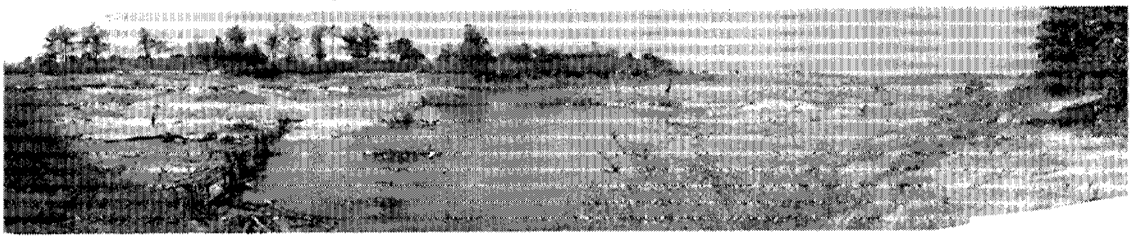
The system was constructed on the Boribo River to utilize river water between 1976 and 1977. The system was damaged between 1981 and 1982, and is functioning in the very limited area less than 300Ha. More than 30 irrigation sub-systems are mixed up under the name of Lum Hach Irrigation System in the JICA Inventory 2006; these sub-systems are irrigated by many rivers including Boribo River. The inventory survey result is summarized in Table C1-7.

Two major irrigation systems i.e., O Rolus Irrigation System and Lum Hach Irrigation System are irrigated by the Boribo River. The O Roluss Irrigation System (3,400 ha) is located at left side of the Boribo River. The main water source is expected to the Boribo River because the O Roluss stream has a very small catchment area (12.8 $km^2$). The rehabilitation work of the O Roluss Irrigation System has been started in 2006 by MOWRAM/PDOWRAM. The present study concentrates into the irrigation area located in the right side of the Boribo River. The water distribution to the O Roluss Irrigation System is to be considered in the present Study. The Lum Hach Sub-project contains irrigation area located at right side of the Boribo River and directly irrigated by the Boribo River.

(2) Existing Irrigation Facilities

1) Headworks

The headworks was constructed in the Boribo River in order to raise water level in the river and to create a small storage in the river. The headworks was completely washed away. The river bends nearly 90 degree at the location of the former headworks. The location is not preferable from the technical point of view for a new headworks.



**New Lum Hach Headworks Site**

A new headworks should be constructed at more stable site. About 500 m upstream is a candidate site (photo above). The upstream area of the headwork site has a wide area which can be used for storage. The Water level-Area-Volume relationship is assumed based on the preliminary topographic survey by the Study Team as follows.

**Water level – Area - Volume Relationship**

| Ground level (EL. m) | 35.0 | 36.0 | 37.0 | 38.0 | 39.0 | 40.0 | 41.0 | 50.0 |
|---|---|---|---|---|---|---|---|---|
| Area (Ha) | 14 | 33 | 57 | 101 | 143 | 640 | 820 | 2,450 |
| Volume ($10^6 m^3$) | 0.09 | 0.33 | 0.78 | 1.57 | 2.79 | 6.7 | 14.0 | 161.2 |

Note: The figures higher than EL.40.0m are assumed from the topographic map with a scale of 1 to 100,000 with 10m contour interval.
River length=3.5km, average width of the river route=20m
Prepared by JICA Study Team

There is no intake structure to control water taking from the Boribo River. A new intake structure should be constructed as a part of the new headworks.

Around 40 families are living in the upstream area. According to the preliminary topographic survey results, the resident areas are located at EL. 40.0 m or more. The area below EL.40.0 m consists of paddy field, pasture land/flood plain, and water-route.

2) Canals

A main canal was constructed and has been called as 7th January Canal. The total length was 27 km to convey water from the Boribo River and to collect water from small streams which flow independently. However, the canal was left unused due to collapse of headworks.

The elevation of existing main canal base is EL.36.6 m at the beginning point (herein after called as B.P.). Due to high elevation of the canal base and no water level control structure in the river, river water hardly flow in the canal at present. The canal base is gradually climbing as it goes to downstream; EL.38.0 m at the cumulative distance of 3.1 km from B.P.

Two existing secondary canals branch from the main canal in the sub-project area proposed.


**B.P. of 7th January Canal (proposed main canal)**

The Secondary Canal No. 1 branches at 0.77 km downstream from the B.P. of the existing main canal. The canal is used as a secondary canal in the sub-project with rehabilitation. The ground elevation ranges from EL.38.0 m to EL.39.3 m. The Secondary Canal No. 2 branches at 3.1 km from the B.P. of the existing main canal. The canal is to be rehabilitated and expanded, and to be used as the downstream part of the proposed main canal of the sub-project in order to cover all irrigation areas in the downstream. However, paddy field elevation ranges from EL.39.3 m to EL. 35.0 m in the upstream reach 2 km.

3) Structures

An existing off-take structure on the exiting Secondary Canal No.1 is extraordinary large for the irrigation area, and gate sill elevation is higher than main canal by more than 2.0 m. The structure should be removed and a new off-take structure is to be constructed. There is a check structure in the main canal at the cumulative distance of 3.1 km. Gates are not installed, and structure is seriously deteriorated. This location is to be the end of the proposed main canal. A new end structure is to be added to the existing structure. Bridges and culverts exist and fairly functioning in the secondary canal. Many additional structures are to be constructed by the sub-project.

(3) Present irrigation water use, O&M, and FWUC

According to the household survey by the JICA Study Team in August 2007, 97% of interviewees (60 households) answered they are depend on rainfall only for cultivation. Farmers wait for his land is wet and inundated by rain and flood from upstream in order to start paddy cultivation. Accordingly floods in the early time of wet season are welcome by farmers. A 3% of interviewees use canal as a supplement water source. No households uses canal as a main water source. During the growing stage of paddy, if a long drought occurs, farmer take water which is probably inundated in the canal or stream by pump.

The situation of operation and maintenance was reported "partly functioning" by PDOWRAM in the JICA Inventory Survey in 2006. However, no O&M activities have been recently executed by PDOWRAM because a full-scale rehabilitation of irrigation system is required, which is high cost. There is no registered FWUC or FWUGs in the sub-project area.

(4) Drainage condition

Only 8% of interviewees replied that they are suffering from flood at least once in every year. Of them, 5% of interviewees answered suffer from flood in more than 4 days. The flood mainly affects paddy. This reveals that drainage or flood problems are not serious in the sub-project area.

There are two drainage canals in the sub-project area at present though they are not reported in the JICA Inventory 2006. Those drains seem to have double function of irrigation and drainage. The total length of the two existing drains is assumed at 6.0 km, respectively. The existing drains finally flow into the Boribo River at the downstream edge of the sub-project area. The Boribo River, however, sometimes intrudes to the drains and causes inundation in the sub-project area when the water level is high in the river. A water control structure should be provided at the junction.

(5) Other problems

The main rural roads are in fair condition except for wet season. In the wet season, the rural roads get muddy and not passable even by 4WD vehicle. Establishment of a stable farm road network is necessary for transportation of agriculture input and output. The existing canal inspection road is to be rehabilitated and paved for farm road.

# CHAPTER C2 BASIC DEVELOPMENT CONCEPT AND APPROACH

## C2.1 Constraints for Irrigation and Drainage Development

The actual irrigation rate is assumed at only 10 %, and only the supplemental irrigation is practiced in the Sub-project areas. No full irrigation is executed 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 relates structures.

iii) The agencies and farmers can not have and execute suitable irrigation water management plans due to sufficient irrigation facilities, training and experience.

iv) No substantial maintenance work of facilities is observed due to lack of the objective facilities, training, experience, and fund.

## C2.2 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.

A fresh, 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 integrated 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.

### C2.3 Basic Approach to Irrigation and Drainage Plan

(1) Objective

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

(2) Strategy of Development of Main and Secondary Canal System

1) Priority given to existing irrigation system and paddy area

The existing paddy fields are about four times of 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 irrigation systems of which most of them have lost function. The present paddy fields and irrigation area are given first priority.

The most important crop in the sub-projects is considered to be wet season paddy as explained hereunder. A first priority is put on the improvement of irrigation condition for wet season paddy.

2) Suitable development scale based on the available water resources

The size of each Sub-project is to be determined based on the water balance study in each river basin in the M/P. The command areas under the Sub-projects are 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.

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. Under the project design, the sub-project will guarantee the wet season paddy production in a drought year that may occur once in five years.

3) Application of gravity irrigation method

At present the water level in the most of the canals is lower than the ground level of paddy field, so that irrigation water can not be supplied to paddy field by gravity. The portable pump is widely utilized in the Study Area. It is however, difficult to cover large areas and also it requires higher operation cost. The Study, therefore, put the first priority on the gravity irrigation through raising water level in the canals by means of additional check structures.

The portable pump irrigation method is also considered taking into consideration the local conditions in each sub-project in order to fit local condition.

4) Appropriate density of canals

It is obvious the existing irrigation facilities are not sufficient to attain equivalent water distribution and efficient water use in the command area. The design guideline of Cambodia defines a tertiary block covers 50 ha on average.[1] The construction of a tertiary block will be executed by farmers in accordance with the government policy. 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 20 m/ha at minimum in order to supply irrigation water to filed canals in the tertiary block.

5) Provision of necessary canal related structures

In the Study Area, important structures for irrigation are lack or deteriorated. Check structures (or cross regulators) are proposed at necessary location in the canal to raise and maintain appropriate water level for gravity irrigation. Diversion structures, turnouts and or off-takes are also required at where a sub-ordinary canal starts for smooth water distribution. Most of the existing structures are to be removed and reconstructed due to severe deterioration and lost function.

At present people in the Study Area constructed a large number of log bridges to cross the canal. Those log bridges frequently damage canal embankment. The log bridges and other deteriorated bridges are to be reconstructed so as to ensure current network within community in the command area.

6) Effective use of existing canal route

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.

7) Minimum rehabilitation/improvement of canals

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

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[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)

rehabilitation cost is reduced and the extra section can be used as a storage or water harvesting.

8) Construction of Headworks

A headworks primarily consisting of a diversion weir and intake structure is a key facility of run-of-river type irrigation systems. Since the headworks is located at the middle or downstream reach of the respective rivers, flood water level should not be remarkably higher than that at present to avoid remarkable raising existing river dike in the upstream. A diversion weir equipped with movable gate will be proposed after careful study at every Sub-project.

9) Drainage and Flood Protection Plan

The drainage plan of the sub-project 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 by making reference with the study by Ministry of Agriculture, Forestry and Fishery of Japan.

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.

c) Habitual inundation area caused by high water level in the Lake Tonle Sap

The poor drainage and habitual inundation due to high water level of the Lake Tonle Sap usually lasts more than a month. The maximum water level was recorded at about EL. 11.0 m in the Lake between 1998 and 2001[2]. 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 dykes 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. 11.0 m is excluded from Ream Kon and Por Canal Sub-projects.

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

10) Cost-effectiveness in the plan

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.

(3) Concept of On-farm Development

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 FWUG and or Sub-FWUG 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[3].

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 1.0 km or 20 m/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 to water courses and the tertiary canal. A slide gates 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 of one division box is a summation of the number of water courses which branch from the box and one outlet to the tertiary canal.

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

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

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. A length of the water course averages 500 m.

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 by house hold.

## C2.4 Basic Approach to Establishment and Practice of Irrigation Water Management, Operation and Maintenance (O&M)

(1) Objective

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.

(2) Strategy

1) Responsibility sharing depending upon the level of facilities

"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). Based on the 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. In general Responsibilities of construction and O&M of the irrigation and drainage facilities are set up as follows:

**Responsibilities of Construction and O&M**

| Phase / Level | Construction | O&M |
|---|---|---|
| Main | MOWRAM / PDOWRAM | PDOWRAM / MOWRAM |
| Secondary | MOWRAM / PDOWRAM | FWUG supported by local authorities |
| Tertiary and below | FWUC (and/or FWUG) supported by MOWRAM / PDOWRAM and Local Authorities | FWUG (and/or sub-FWUG) |

Note: FWUC= Farmers Water Users Community, FWUG= Farmers Water Users Group

Prepared by JICA Study Team

ii) 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:

**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.

(3) Concept for Water Management and Operation

1) Headworks and main canal system

In general, PDOWRAM is responsible for water management and O&M of headworks, main canal including related structures.

The water level at the headworks is to be kept at the proposed water level 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 intake will have a flow capacity of the peak diversion water requirement proposed. The amount of water taken to the main canal, however, is controlled by intake gates in accordance with irrigation service plan which is to be prepared by PDOWRAM. 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 during detailed design and construction stage.

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 inside 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.

(4) Concept for Maintenance Work

The maintenance work of irrigation and drainage 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<br>Gate: Trash, Breakage, Rust, Greasing of spindle and hoist, Leakage through gate, Trash, Electric facilities |
| (b) Canals | Holes/erosion/settlement/cut of canal bank,<br>Leakage, Sediment/grasses/trash |
| (c) Structures | Breakage/cracks, Leakage, Settlement, Sediment/trash, Staff gauge |
| (c) Gates | Breakage, Trash, Rust, Greasing of spindle and hoist, Leakage through gate |
| (d) 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 each 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.

### C2.5 Basic Approach to FWUC Formation and Strengthening

(1) Objective

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.

(2) Strategies

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.

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

# CHAPTER C3 IRRIGATION AND DRAINAGE PLAN OF REAM KON REHABILITATION SUB-PROJECT

## C3.1 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 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 irrigable areas in the river basin as a whole including Ream Kon and Por Canal Sub-projects.

(2) Irrigation water requirement

1) Basic conditions

The irrigation water requirement is estimated similar procedure with that described in the section D2.3 in Volume-II Appendix-D Irrigation and Drainage. The basic condition and figures applied to the Moung Russei River Basin are same with those in the same section D2.3 Volume-II Appendix-D Irrigation and Drainage, and extracted 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 Russei, 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 %

The irrigation water requirement is estimated based on the proposed cropping pattern described in the Volume-III Appendix-B Agriculture. The sample calculation for wet season paddy is presented in Table C3-1. The water requirement in the table is applied to Ream Kon and Por Canal Sub-projects.

The above figure is applied to planning of irrigation facilities. On the contrary, in the water balance study, a half of irrigation loss or 17 % (=(100-66)÷2) from upstream irrigation area and or a system was conservatively assume to be re-used in the downstream irrigation system. Accordingly, the irrigation efficiency of 83 % (=66+17) was applied in the water balance study.

2) Irrigation water requirement for tertiary and field canals

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.

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

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 %.

(3) Inventory Irrigation Area

The JICA Inventory Survey 2006 reported the existing irrigation systems as follows.

List of Irrigation Systems in Moung Russei River Basin

| Name of irrigation project/system | Existing irrigation area (Ha) | Potential irrigation area (Ha) | Location | Remarks |
|---|---|---|---|---|
| Bassac | 0 | 3,500 | U | Just downstream of the Bassac Res. |
| Prek Chik | 490 | 2,600 | U | NWISP (ADB) selected as one of Initial candidate irrigation Sub-project |
| Anlong Koub | 0 | 1,860 | U | |
| Prek Ta Am | 400 | 1,000 | U | The intake structure was rehabilitated under Flood Emergency Rehabilitation Project AB-IDA in 2004. |
| Srer Sdao | 0 | 500 | U | |
| Chhouk | 0 | 240 | U | |
| Ream Kon | 190 | 4,700 | - | Target system in the present study, 10 Ha recession rice |
| Por Canal | 400 | 2,500 | - | Target system in the present Study |
| Don Try | 70 | 1,550 | D | 20 Ha recession rice, Likely affected by high water of Lake Tonle Sap |
| Sdei | 0 | 400 | D | Likely affected by high water of Lake Tonle Sap |
| Total | 1,550 | 16,900* | | |

Source: JICA Inventory Survey 2006 except for Remarks made by the Study Team
Note: Upstream (U) or downstream (D) of Ream Kon
* Don Try and Sdei systems are not counted because likely affected by high water level of Lake Tonel Sap

(4) River Runoff and Other Water Requirements

The main water resources for irrigation is the Bassac Reservoir which is being rehabilitated by MOWRAM under Non-project Grant Aid by the Government of Japan. The 5-day Inflow to the Bassac Reservoir and river runoff between the Bassac Reservoir and the Moung Russei Headworks proposed are estimated in Volume III Appendix A Meteorology and Hydrology.

The irrigation water requirement described in the above paragraph is used in the calculation. The domestic and industrial water, river maintenance flow which were estimated in the Volume II Appendix D Irrigation and Drainage are used in the water balance calculation. The other factors such as evaporation and seepage loss from the reservoir which were estimated in the Volume II Appendix D Irrigation and Drainage are also used in the present study.

(5) Water balance calculation of Bassac Reservoir

In the water balance study a 5-day fluctuation of water volume in the Bassac Reservoir was checked by comparing inflow to the reservoir and water requirements i.e. 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. In the above alternatives, the area in 1/5 year return period of drought was considered.

| | **Crops** | | | **Evaluation indicators** | | | | |
|---|---|---|---|---|---|---|---|---|
| Alt. | Early paddy (ha) | Medium paddy (ha) | Dry season paddy (ha) | Annual irrigation area (ha) | Deve-lopment 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<br>- Largest in development area<br>- 2nd in annual incremental production<br>- 4th in production per cost |
| 2 | 900 | 1,500 | 5,100 | 7,500 | 5,100 | 19,935 | 3.91 | - 3rd in annual irrigation area<br>- Smallest in development area<br>- 3rd in annual paddy production<br>- 1st in production per cost |
| 3 | 6,300 | 500 | 200 | 7,000 | 6,300 | 14,145 | 2.25 | - Smallest in annual irrigation area<br>- 3rd in development area<br>- Smallest in annual paddy production<br>- 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<br>- 2nd in development area<br>- 1st in annual incremental production<br>- 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 Early growing paddy, Direct sowing

Bassac Reservoir related data

- Catchment area: 598km2
- 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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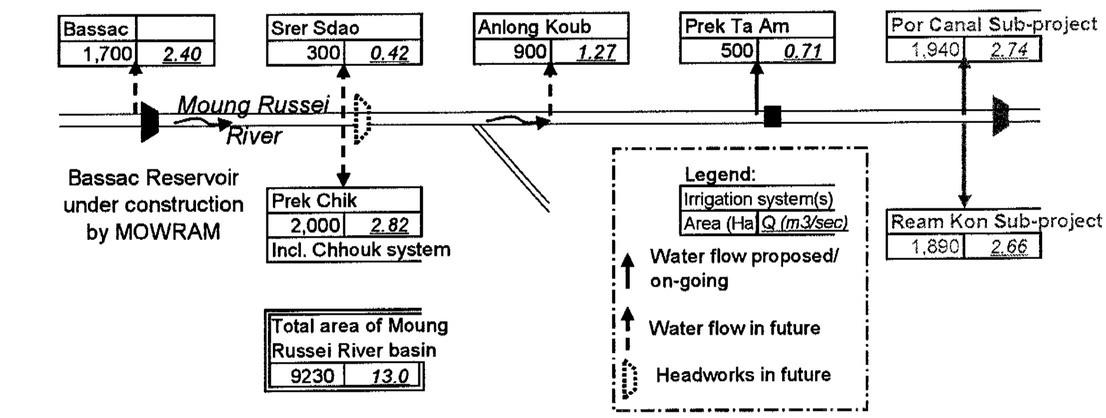
The evaluation is made the right column in the above table. Alternative-4 is recommendable because:

i) Alternative-4 shows the largest incremental production, and second largest of production per Sub-project area.

ii) Alternative-2 shows largest production per Sub-project area. However, 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.

Based on the above evaluation, the Alternative-4 is the most recommendable.

Based on the above study the total potential irrigation area in the Moung Russei River basin can be assumed between 8,300 ha to 10,100 ha, 9,200 ha on average, namely about 54% of the JICA Inventory area (16,900 ha). All development projects in the basin are expected to determine its project area referring to this proportion. The development area of Ream Kon and Por Canal Sub-projects will be about 3,900 ha conjunctively. The future irrigation water supply plan is shown as follows:

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**Potential Irrigation Areas in the Moung Russei River Basin**

## C3.2 Irrigation and Drainage Plan

(1) Basic Plan

1) Demarcation of Sub-project area

The Sub-project area is selected and determined based on the present land use, topography, and in proportion to the estimated water potential irrigation area in the Moung Russei River basin as a whole with rehabilitation of Bassac reservoir. The area which is lower than EL. 11.0 m is excluded from the Sub-project area due to habitual inundation by high water level of Lake Tonle Sap.

2) Headworks

The existing headworks is to be reconstructed due to severe cracks of concrete, severe corrosion and lack of reinforcing bars which directly affect strength of the structure, no function of gates. The 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 which is 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 Ream Kon and Por Canal Sub-project.

3) Existing dike and pond

The existing broken dyke and pond will not be repaired because the resettlement problem will occur and the pond is not absolutely necessary in the Sub-project. The irrigation water can be supplied by the new headworks.

(2) Alternative Study of canal layout

The irrigation area of Ream Kon is demarcated based on the following concept.

i) The Sub-project area can be selected up to the water potential area about 3,900 ha together with Por Canal Sub-project.

ii) Gravity irrigation is given to first priority; pump irrigation can be considered in a limited area

iii) The land which is lower than EL.11.0 m is excluded.

Two alternatives plans were made and compared.

| 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)<br>- To provide Main Canal-2 for high elevated area. |
| Proposed canal layout | - Main Canal L=9.0 km<br>- Secondary canals L=16.4 km (11 nos.) | - Main Canal-1 L=9.0 km, Main Canal-2 L=9.1 km<br>- Secondary canals L=12.9 km (16 nos.) |
| Irrigation area (ha) | - Gravity area= 1,610 ha<br>- Pumping area= 0<br>- Total area= 1,610 ha | - Gravity area= 1,610 ha<br>- Pump irrigation area= 280 ha<br>- Total area=1,890 ha |
| Intake water level required | EL. 15.50 m | EL. 15.50 m |
| Water level required at end point of main canal | EL. 12.4 m | EL. 11.9 m |
| Conclusion | Not recommendable due to higher construction cost and smaller irrigation area than Alternative 2. | Recommendable. The total irrigation area is proposed to be 1,890 ha including pump irrigation area of 280 ha. |

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The Alternative-2 is recommended after comparison.

(3) The Sub-project area and canal layout proposed

The Sub-project area is determined at 1,890 ha. The proposed canal layout of irrigation and drainage is shown in Figure C3-1. Two main canals are proposed to irrigate low elevated area and high elevated area respectively. General features are summarizes in Table C3-2 together with other Sub-projects. The irrigation area diagram is shown in Figure C3-2A. The southern part of the sub-project area of 280 ha is to be irrigated by portable pumps.

(4) Drainage plan

The excess water in the Sub-project area is proposed to be drained by gravity. Field drain collects water from paddy fields and other type of land, and flows into a tertiary drain. Tertiary drains flow into a secondary drain or main drain in accordance with topography. Secondary drains and main drains flow to flood plain of Lake Tonle Sap. The existing rivers and streams are used as secondary and main drains to save construction cost.

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

i) The existing river diversion channel which branches from Moung Russei River at the existing headworks is used as the temporary diversion during the headworks construction period, and will be used as a drainage canal after construction period. A side channel overflow type spillway is proposed to divert the river water to the channel.

ii) A collector drain (CD-1) is proposed to intercept the drainage water from southern area, the collector drain flows to north crossing middle of the Sub-project area, and finally joins with Moung Russei River.

iii) The drainage water from Anlong Koub Irrigation area is collected by proposed collector drain (CD-2) which flows southern border of the Sub-project area, and flows to north to join drainage canal 1) above

iv) The drainage water from southern area is collected by proposed collector drain (CD-3) which also flows southern border of the Sub-project area, and flows to north to join drainage canal 1) above

The general feature of drainage plan is summarized in Table C3-2 together with other Sub-projects. The drainage area diagram is presented in Figure C3-2B.

(5) 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 the 3 consecutive days with 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
q is the drainage water requirement (lit./sec/ha)

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 at 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 Rational formula and annual maximum one day rainfall with one in 5 years return period (122 mm/day).

The unit diversion water requirement is calculated for the area less than 100 ha and more than 100 ha.

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

Qpeak=0.19m$^3$/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 C3-2B

## C3.3 Rehabilitation and Improvement of Facilities

The facilities of the Sub-project are divided into 3 categories; (1) headworks (diversion weir and intake(s)) and major related structures, (2) irrigation facilities for main and secondary systems, (3) drainage facilities for main and secondary systems, respectively.

### C3.3.1 Headworks and Major Related Structures

(1) Basic Consideration

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.

a) Rehabilitation of Moung Russei Diversion Weir

b) Rehabilitation of Ream Kon Intake

c) Rehabilitation of Por Canal Intake (explained in Section C4.3)

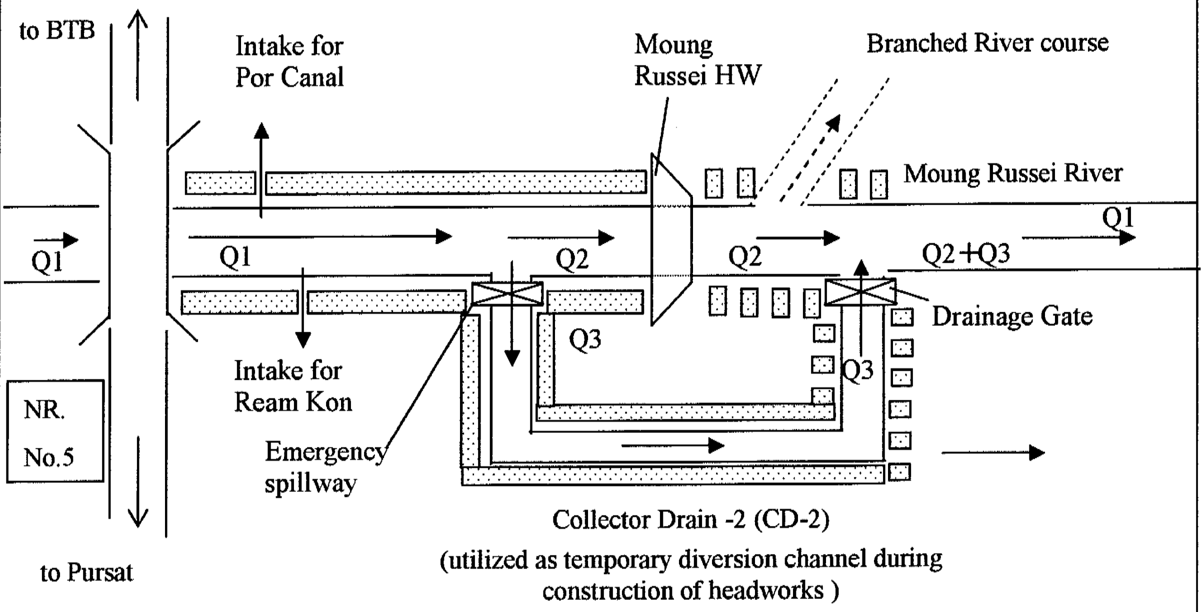
In addition, the following facilities are also planned to be rehabilitated/ newly constructed in order to protect the headworks and the surrounding area in the Ream Kon Sub-project. These facilities are depicted in the following schematic diagram:

d) Rehabilitation of Collector Drain-2 (CD-2),

e) Emergency spillway system at the inlet of CD-2,

f) Drainage gate at the outlet of CD-2

g) Additional embankment of river bank and excavation of river




Q1:Design Flood Discharge =180m³/sec　　: Additional Embankment

Q2:Design Flood Discharge for HW=180-150m³/sec　　:Additional Embankment if needed

Q3:Design Discharge for Emergency Spillway

and CD-2=0-30m³/sec

Prepared by JICA Study Team

**Schematic Diagram of Moung Russei Headworks and Ream Kon Sub-Project**

2) Flow Capacity of the River and Design Flood:

The flow capacity of the Moung Russei River at the bridge on the National Road No.5 (NR. No.5, hereinafter) is studied by non-uniform flow hydraulic calculation (results in next pages):

- It is found that the flow capacity of the Moung Russei River in the downstream of the NR. No.5 after construction of a new headworks is estimated at as follows:

  150 m³/sec: when a freeboard of 0.6 m is considered for the safety of the bridge, i.e., a design high water level at an elevation of 17.22m or below.

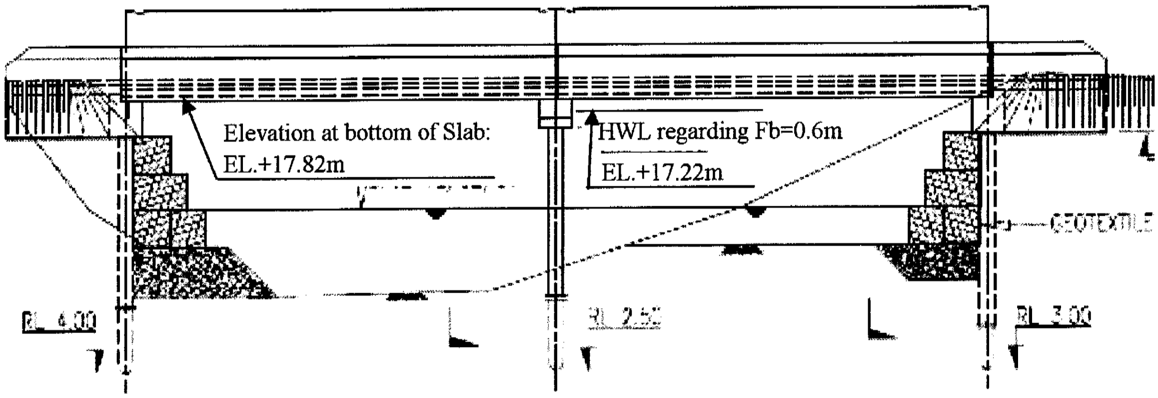
  180 m³/sec: when a freeboard is not considered for the safety of the bridge, i.e., a design high water level at an elevation of 17.82m or below, which is the same elevation as the present slab-bottom of the bridge.

- Therefore, for the safety of the bridge on the NR. No.5, either measure is to be implemented along the Moung Russei River;

  a) Excavation and enlargement of the downstream of NR. No.5;

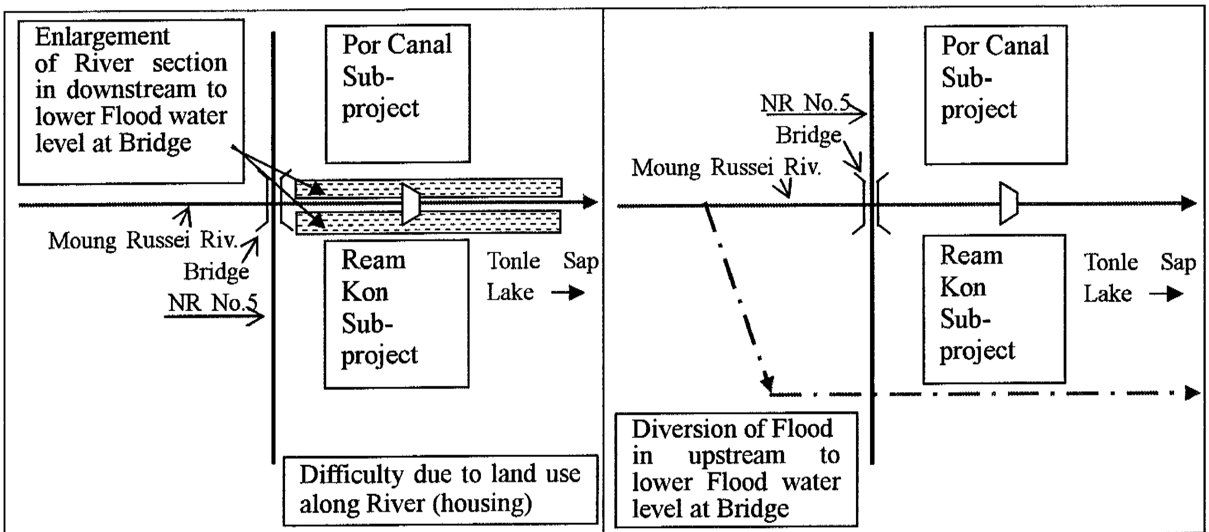
  b) Installation of permanent diversion system in the upstream NR. No.5

- In this study, a design flood discharge of T=100 year return period is employed as a design condition, considering both the importance of bridge and headworks, which is commonly employed in Japan for important infrastructures.




Prepared by JICA Study Team based on field survey and information from Ministry of Public Works

**Schematic Diagram of Design Flood Level and Bridge on NR. No.5**

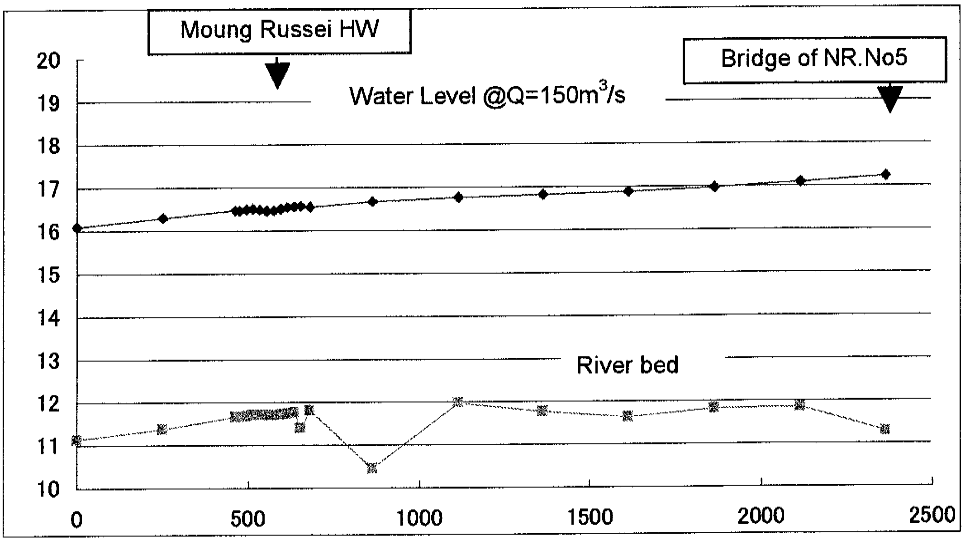



| Measure a) Excavation and enlargement of the downstream of NR. No.5; | Measure b) Installation of permanent diversion system in the upstream NR. No.5 |
|---|---|

Prepased by JICA Study Team

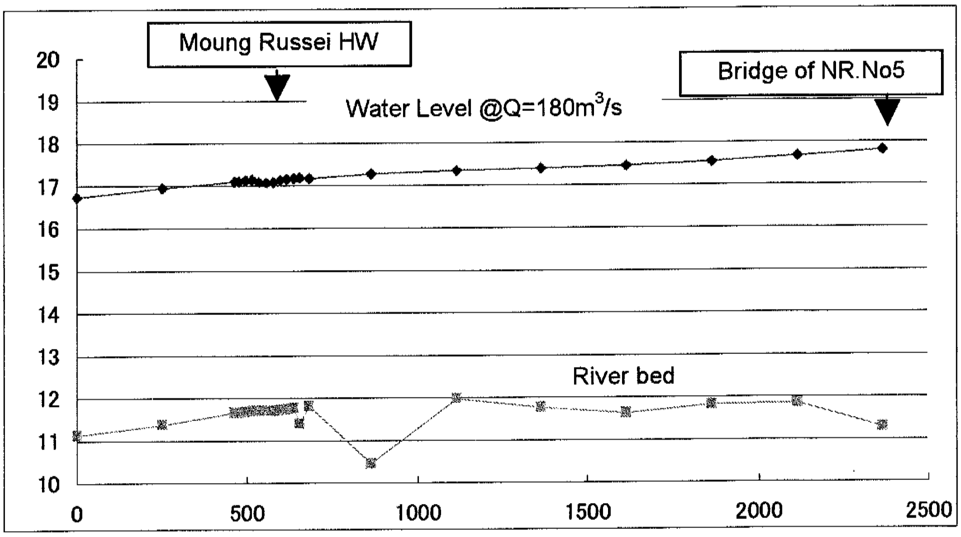
**Schematic Diagram of Measures for Lowering Flood Water Level at Bridge on NR. No.5**

- Since implementation of "measure a)" seems to be difficult due to the present land use condition along the river (housing), this preliminary design is carried out with the design flood discharge of T=100 year return period, under expectation for the implementation of "measure b) (installation of permanent diversion structure in the upstream)", in the future in accordance with the protection of the expanding town of Moung Russei.




Prepared by JICA Study Team

**Hydraulic Calculation Result of Non-uniform flow for Proposed Weir Section at Q=150m$^3$/s (with Gate fully open )**

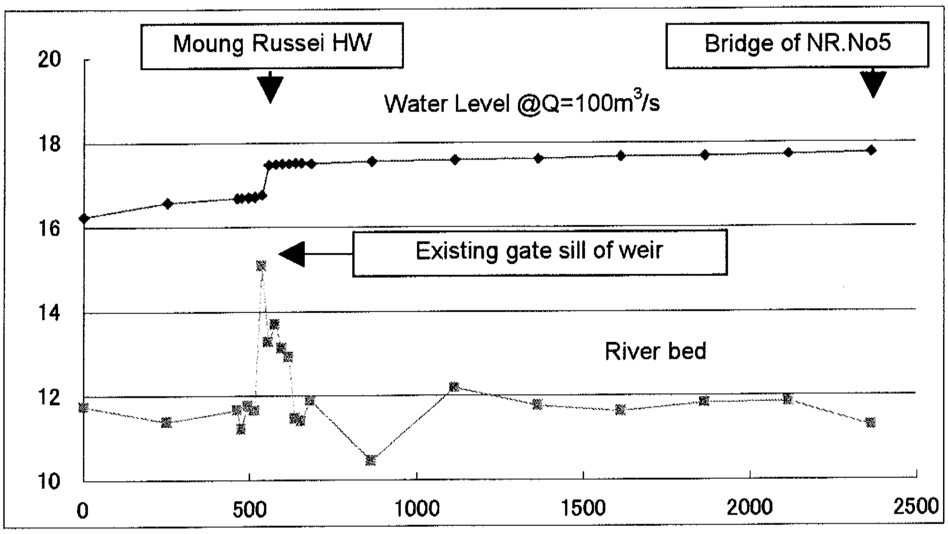



Prepared by JICA Study Team

**Hydraulic Calculation Result of Non-uniform flow for Proposed Weir Section at Q=180m$^3$/s**

**(with Gate fully open )**

Present river condition: It is revealed by non-uniform flow calculations that the water level at the bridge on NR No.5 easily reaches up to the elevation of EL.17.8m (freeboard=0), at a flood discharge of 100m$^3$/s (equivalent to discharge for return period of 2 to 5 year). This is mainly caused by a high elevation of the existing gate sill. Therefore, it is recommended to lower the gate sill of the weir by re-construction of the weir, in order to lower the water level to an adequate elevation to protect the important infrastructure such as bridge on NR. No.5 as well as villages along the river against flooding.




Prepared by JICA Study Team

**Hydraulic Calculated Result of Non-uniform flow for Present River Section at Q=100m³/s**

**(with existing Gate fully open )**

3) Additional Consideration aginst Flood:

Additional works in the Ream Kon Sub-project, based on the design discharge of 180m³/s, are as follows:

- Additional embankment of 0.5m - 1.0 m is needed on both river banks along the river between Moung Russei Headworks and NR No.5, to deal with the design flood water level of around EL. 17.0m - 17.8m.
- While waiting for the installation of permanent diversion works in the upstream of NR. No.5, CD-2 is to be excavated and utilized as a temporary emergency diversion channel during flood occasions in order to protect river-bank and village by reducing the flood water level in the river. Therefore, structures are to be installed at both inlet (emergency spillway) and outlet (drainage gate) of CD-2 for regulating diversion discharge.
- The size of the Moung Russei river course as well as the CD-2 should be rehabilitated with consideration of present land use; i.e., since villagers live along both the river and the canal, their size should fit into present river or canal boundary, in order to minimize resettlement.
- During the construction of Moung Russei Headworks in the dry season, CD-2 will be also utilized as a temporary diversion channel for construction, in order to reduce construction cost. Therefore, CD-2 will be rehabilitated (excavated) first, in prior to the construction of headworks. Excavated soil will be utilized for additional embankment along the river and CD-2.

(2) Design Condition for Headworks

1) Summary of Design Condition:

Design condition proposed for 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 | T=100 year return period |
| Design Flood Water Level $WL_F1$: | WL. 17.2 m | At Weir site |
| Design Flood Water Level $WL_F2$: | WL. 17.82 m | at NR. No.5 w/o diversion (180 $m^3$/sec) |
| Design Flood Water Level $WL_F2'$: | WL. 17.22 m | at NR. No.5 w/ future diversion (150 $m^3$/sec) |
| Design River Bank Elevation | EL. 18.00 m | betw/ Weir site and NR. No.5 |
| Design Irrigation Water Level WL1: | WL. 15.50 m | Top of Gate |
| | (WL. 15.70 m) | WL1+max. Overflow depth=0.2m |
| Design River bed Elevation (Upstream): | EL. 11.70 m | |
| Design River bed Elevation (Downstream): | EL. 11.70 m | |
| Design Gate Sill Elevation: | EL. 11.70 m | |

Prepared by JICA Study Team

2) Design condition for flood:

A design flood discharge ($Q_F$): $Q_F$ =180 $m^3$/sec is practically determined as a flood discharge of T=100 year return period, by flow capacity of the bridge on NR No.5 with no freeboard. This is close to the estimated value of 190 $m^3$/sec (T=100years) for the Moung Russei River based on the meteo-hydrological study explained in section A5.5, in Appendix A, Volume III.

-Design flood discharge ($Q_F$): $Q_F$ =180 $m^3$/sec (equivalent to T=100 year return period)

b) Qp'=180 $m^3$/sec: Flood discharge obtained by non-uniform flow calculation along Moung Russei River, between upstream of weir site and bridge on National Road No.5, at high water level of just below bridge slab (about EL.17.8m, no free board)..

- Design flood water level ($HWL_F$):

$HWL_F1$=17.2m at weir site,

$HWL_F2$=17.82m at bridge on National Road No.5.

$HWL_F2'$=17.22m -do- with consideration of Free board (Fb=0.6m)

(By installation of a permanent diversion in the upstream of NR. No.5, maximum design flood discharge $Q_F$ will be lowered to 150 $m^3$/s, thus the high water level will be lowered to $HWL_F2'$= 172.22m)

3) Design condition for irrigation:

Design water level (WL1) and design discharge ($Q_I1$, $Q_I2$) for irrigation is determined as follows for each sub-project site (refer to sub-section "5.1.1 Irrigation and Drainage Plan").

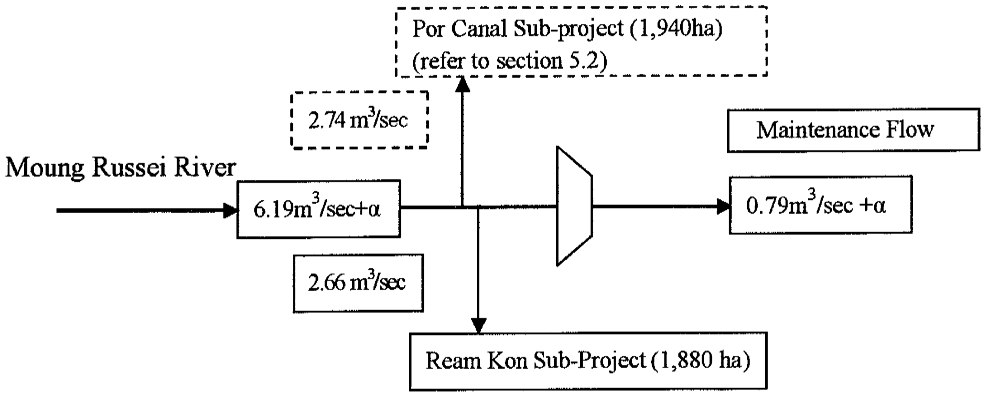
In addition, "maintenance flow" discharge ($Q_M$) is determined by unit discharge of 0.1 $m^3$/sec per 100km$^2$ and catchment area at the location of headworks (CA=785 km$^2$):

- WL1=+15.50m (=elevation for top of the gate of the weir)

  ( WL1+ maximum allowable overflow water depth of h: 0.2m=15.70 m)

- $Q_I1$ =2.66 m$^3$/sec for Ream kon (1,890 ha)
- $Q_I2$ =2.74 m$^3$/sec for Por Canal (1,940 ha)
- $Q_M$ =0.79 m$^3$/sec =Maintenance flow discharge for downstream through "fish ladder"

  (=0.1m$^3$/sec/100 km$^2$ x Catchment Area=785 km$^2$ )

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**Design Condition for Irrigation**

(3) Preliminary Design of Headworks

1) Location:

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

a) Deterioration of structure

b) Low safety against flood due to rather high gate sill elevation and rather narrow spacing of the gates/piers (referred to calculation result on top of page C-36)

2) Preliminary Design of River Course:

Based on the topographic survey data, longitudinal section of the river would be rehabilitated with the river bed slope of I=1/900. By employing the uniform flow calculation, it is proposed to rehabilitate the river course of Moung Russei River with the following dimension to deal with the flood discharge of $Q_F$=180m$^3$/sec.

**Hydraulic Calculated Result of Uniform flow for Preliminary designed River Section**

| Item | Symbol | Unit | Equation | Case-1 | Case-2 | Case-3 |
|---|---|---|---|---|---|---|
| Design discharge | Q1 | (m3/s) | <Input> | 100.000 | 150.000 | 180.000 |
| Base width | B1 | (m) | <Input> | 16.000 | 16.000 | 16.000 |
| Water depth | h | (m) | <Input> | 3.500 | 4.350 | 4.788 |
| Design bed slope | I | | <Input> | 1/900 | 1/900 | 1/900 |
| Roughness coef. | n | | <Input> | 0.050 | 0.050 | 0.050 |
| Side slope | αL | | <Input> | 2.0 | 2.0 | 2.0 |
| Side slope | αR | | <Input> | 2.0 | 2.0 | 2.0 |
| Wet-perimeter | P | (m) | $B+[(1+\alpha L^2)^{0.5}+(1+\alpha R^2)^{0.5}]*h$ | 31.653 | 35.453 | 37.414 |
| Cross-section area | A | (m2) | $B\cdot h+0.5\alpha h^2$ | 80.505 | 107.442 | 122.471 |
| Hydr. Mean depth | R | (m) | A/P | 2.543 | 3.031 | 3.273 |
| Velocity | v | (m/s) | (R^(2/3)×I^(1/2))/n | 1.242 | 1.396 | 1.470 |
| Calc. discharge | Q | (m3/s) | A・v | 100.000 | 150.000 | 180.000 |
| Free board | Fb | (m) | <Input> | 0.600 | 0.600 | 0.600 |
| Total height | H | (m) | h+Fb | 4.200 | 5.000 | 5.400 |
| Total width | B2 | (m) | B1+2*α*H | 32.800 | 36.000 | 37.600 |
| Remarks | | | | Flood (2yr) | Flood (35yr) | Flood (100yr) |

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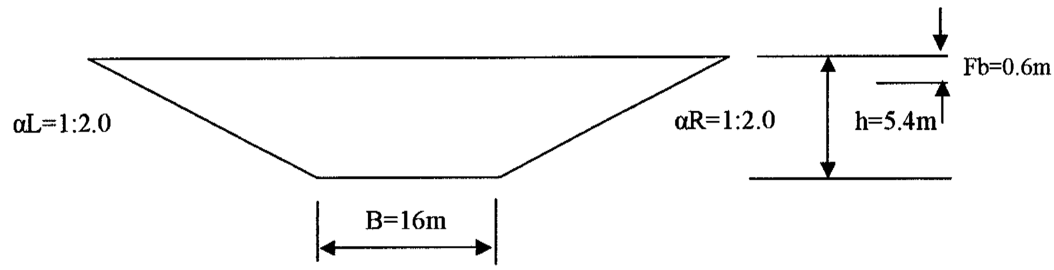


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**Proposed Typical Cross Section of Moung Russei River**

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 maintain an adequate water level along the upstream reach of the river during floods. An "overflow crest type" is not appropriate due to the reason explained in page C-36)

4) Gate Type:

Five gate types were considered for flood gate; slide gate, fixed wheel gate, flap gate (=automatic gate, steel type, rubber textile type), radial gate. These gate types are compared from technical and economical viewpoints as shown below. 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 Lake Tonle Sap, as well as its easy operation, since those factors are important for facility management of the Project.

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

**Selection of Gate Type for Moung Russei Diversion Weir**

| Item | Slide Gate | | Fixed Wheel Gate | | Flap Gate (Steel) | | Flap Gate (Rubber Textile) | | Radial Gate | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Charac-teristic | Judge | Charac-teristic | Judge | Charac-teristic | Judge | Charac-teristic | Judge | Charac-teristic | Judge |
| Downstream water level | No influence | ◎ | No influence | ◎ | Influence | △ | Influence | △ | Influence | △ |
| Operation | So difficult | △ | Easy | ◎ | Easy | ◎ | Easy | ○ | Easy | ◎ |
| Maintenance | Easy | ◎ | Slightly difficult | ○ | Slightly difficult | ○ | Slightly difficult | ○ | Slightly difficult | ○ |
| Pier height | High | △ | High | △ | Low | ◎ | Low | ◎ | Low | ◎ |
| Cost | Low | ◎ | High | ○ | High | ○ | Moderate | ○ | High | ○ |
| Hoisting load | Large | △ | Moderate | ○ | Large | △ | Large | △ | Light | ◎ |
| Vibration | No | ◎ | No | ◎ | Moderate | ○ | Moderate | ○ | Occurence | △ |
| Reliability | High | ◎ | High | ◎ | Low | △ | Low | △ | Low | △ |
| Height/width ratio | No influence | ◎ | No influence | ◎ | Influence | △ | Influence | △ | Influence | △ |
| Over-all Evaluation | Hoisting load becomes large for large sized gate leaf and operation will be difficult | | Reliability is high and hoist load is relatively low for large sized gate | | Reliability is low under influence of downstream water level/ back water of Lake Tonle Sap | | Reliability is low under influence of downstream water level/ back water | | Reliability is low under influence of downstream water level/ back water | |
| | | | ◎ | | | | | | | |

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5) Dimension of Weir:

Dimension of the Moung Russei Diversion Weir will be proposed as the followings, based on the criteria shown in table below:

**Dimension of Moung Russei Diversion Weir**

| Items | Dimension | Remarks |
|---|---|---|
| Weir Type | Floating Type Movable Weir | See i), iii) |
| Design Water Level | WL1: 15.5m (Irrigation)<br>$WL_F1$:17.2m (Flood) | See 2) i) - iii) |
| Design Flood Discharge | $Q_F$=180.0m$^3$/s | See 2) ii) (T=100 year Return period) |
| Total Clear Width of Weir | ΣB=37.5m | Flood gate: 11.5 x 2 +2.5 + 2 x 2=29.5m<br>Sluice gate: 2 x 1 + 1 = 3m<br>Fish ladder: 5.0 m |
| Elevation of gate sill | EL1.= 11.70m | Longitudinal design of river bed |
| Total Height of Weir | Dp:10.9m | Based on Japanese design criteria above; (EL2.=22.6m) - (EL1.=11.7m) = 10.9 |
| Length of Weir | L1=13.0m(Body Spillway)<br>L2=27.0m (Downstream)<br>L3=11.0m (Upstream) | See Schematic Drawing on next page |
| | L4=40.0m (DS Riprap)<br>L5=12.0m (US Riprap) | |

| Items | Dimension | Remarks |
|---|---|---|
| Gate type (Flood Gate) | Fixed wheel gate | See iv) |
| Gate Dimension | Clear Height H:3.8m,<br>Clear Span B:11.5m | H:3.8m = WL1=15.50m – EL.11.70m (Sill)<br>B: Refer to weirs in Cambodia, Japanese design criteria for headworks and hydraulic calculation |
| Number of Gate | 2 nos. | |
| Number of Pier and width | 1 nos. tp = 2.5m<br>(Pier for counter weight) | Referrence: weirs w/ counter weight (Damnak Ampil, Roleang Chrey, Kandal Steung ) |
| Gate type (Sluice scouring) | Slide gate | See iv) |
| Gate Dimension | H:2.0m, B:2.0m | Referred to Damnak Ampil w/ consideration of river size |
| Number of Gate | 1 nos. | |
| Fish Ladder | B:5.0m (Half cone type)<br>Δh=3.6m<br>L=36m | EL. difference:Δh=(15.5-0.2)-11.7=3.6m<br>Slope for ladder=1:10,<br>L=Δh/(1/10)=3.6/0.1=36m |

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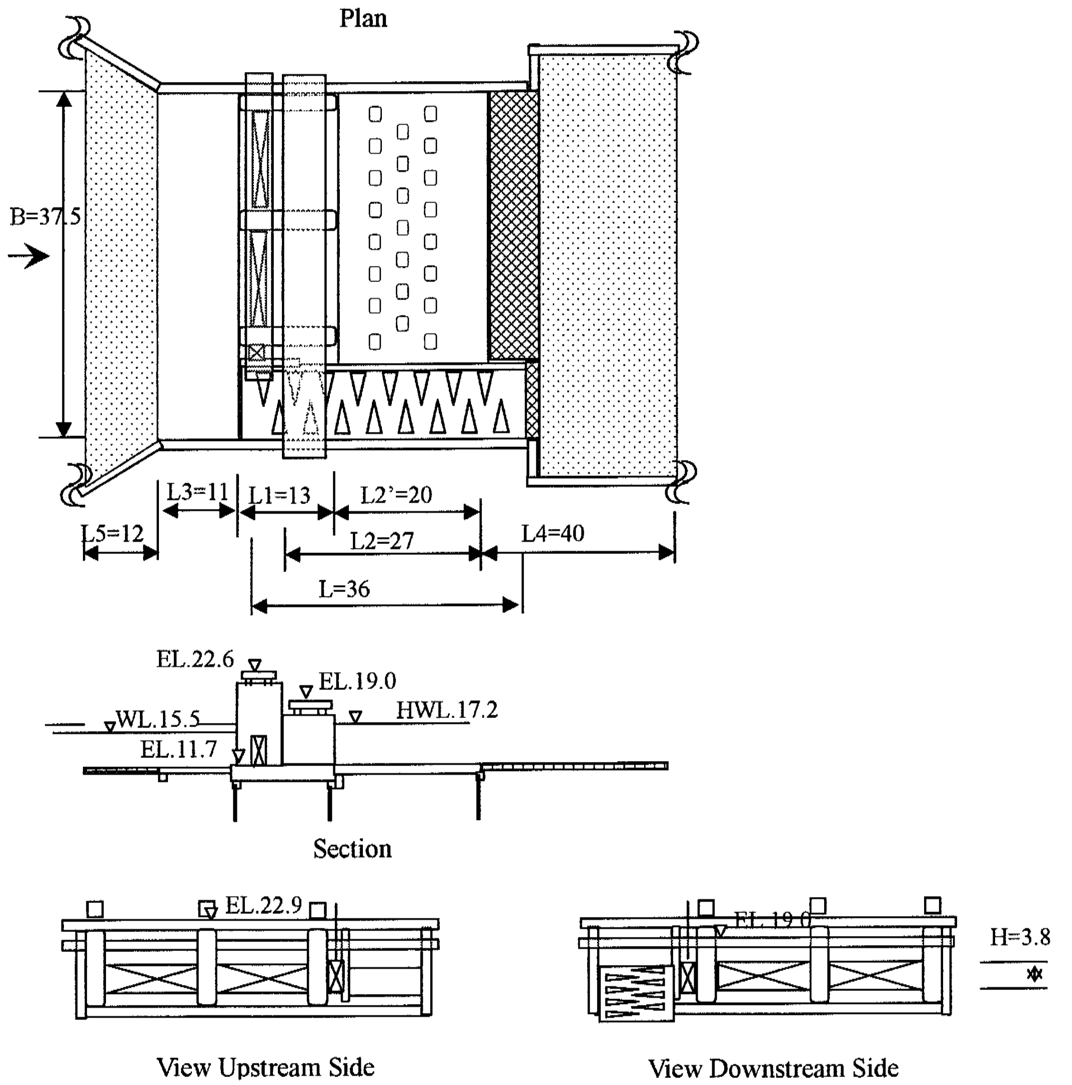


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**Schematic Drawing of Moung Russei Diversion Weir**

a) Design criteria employed for Span Length, Clear Span

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 180 $m^3$/sec as follows:

Existing large weirs in Cambodia: Clear span of 10-15m with plural gate leaves;

Japanese design criteria for headworks (and the River Control Structural Ordinance);

- Span length (=distance between the center lines of adjoining piers of the weir):

For rivers with design flood (high water) discharge of less than 500 $m^3$/s

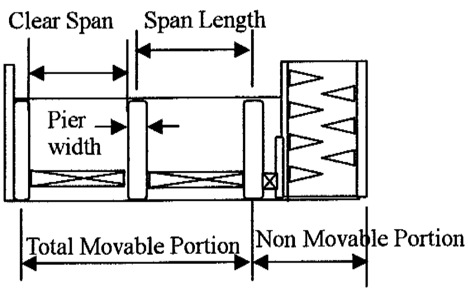
Minimum Span length =15m (for weirs with movable portion length>= 30m)

Minimum Span length =12.5m (for weirs with movable portion length < 30m)

**Span Length of Movable Weir**

| Design Flood Discharge ($m^3$/s) | Minimum Span Length (m) | Remarks |
|---|---|---|
| Less than 500 | 15<br>(12.5) | <br>(for total movable portion less than 30m) |
| 500 or more, less than 2,000 | 20 | |
| 2,000 or more, less than 4,000 | 30 | |
| 4,000 or more | 40 | |

Prepared by JICA Study Team, based on original source
Japanese design criteria for headworks (and the River Control Structural Ordinance)




Prepared by JICA Study Team based on original source
Japanese design criteria for headworks (and the River Control Structural Ordinance)

**Explanatory Plan for Weir**

- Obstruction ratio of pier (total width of pier(s) to movable portion length of weir):

For all rivers, Obstruction ratio of pier $\leqq 0.1$ (10 %)

(exception: rivers with reservoir or lake in the upstream that can prevent flooding)

b) Determination of Span Length, Clear Span

Based on the above criteria and regarding the present size of the river (top-width 30-40 m), it is assumed that number of gate leaf is two, clear span is 11.5m as follows:

- Obstruction ratio of pier =Σ pier width /(Movable portion length including Σ pier)

  = ((2.5 x1) / (2 x 11.5 + 2.5) =0.098 < 0.1 OK

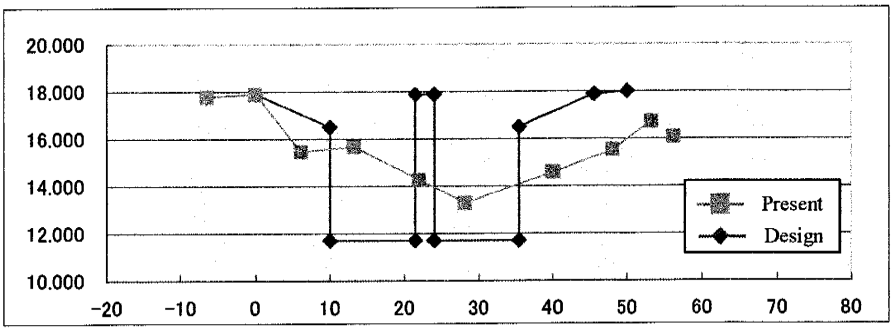
  Thus, minimum clear span = 11.5m

- Span length =clear span of gate leaf +Σ(1/2 pier width)

  =11.5 + 1/2 x (2.5 (center pier) + 2.0 (side pier)) =13.75 > 12.5 OK

- Hydraulic Calculation:

  First trial is conducted for clear span: 11.5m, number of leaf: two, pier: 1 (width 2.5m). The result shows that design high water level at bridge $WL_F2$=17.803m < 17.82m (maximum allowable high water level).



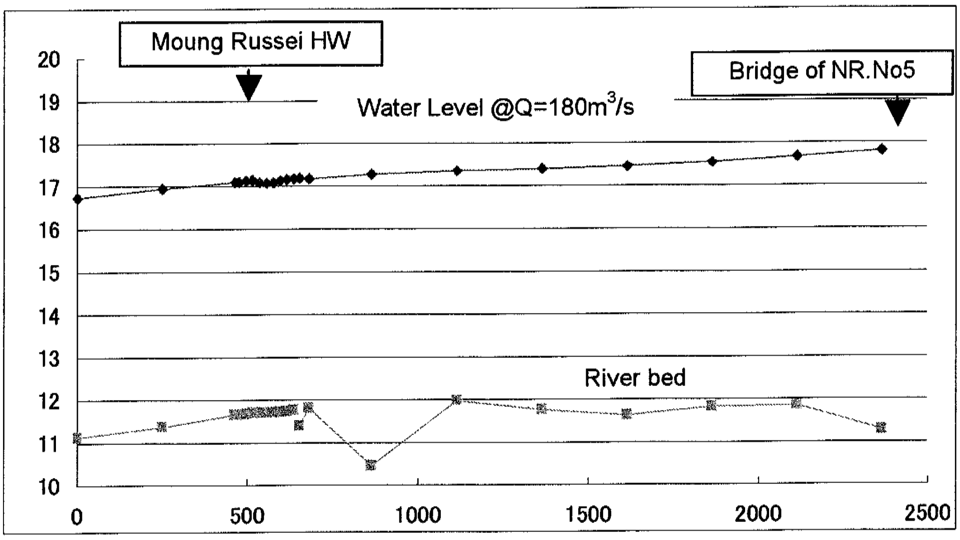

Section at existing weir (shown in pink line), is to be excavated and lowered to design line (blue).
Prepared by JICA Study Team

**Trial Cross-Section of Moung Russei Weir**

- Determination of Dimension:

  A total of three trial results are shown in table below, with the maximum gate clear span of 15.0m, considering total clear width of structure (including fish ladder) and present river section with top width of about 40m. The result shows that design high water level at bridge $WL_F2$=17.803-17.804m is below maximum allowable water level of 17.82m, however the situation does not improve by widening the clear span of gate.

  Therefore, "two gates with clear span of 11.5m" is selected for Moung Russei Weir.




Prepared by JICA Study Team

**Hydraulic Calculation Result of Non-uniform flow for Proposed Weir Section at Q=180m$^3$/s (with Gate fully open )**

**Summary of Trial Calculation Result**

| Gate Nos. | Clear Span (m) | Span Length (m) | PierDist Ratio (%) | Total Clear Width (m) | Elevation of Gate sill EL. (m) | Water level (m) at weir, up and downsteram 92mDS | Weir | Bridge | Remarks WL<=17.82m |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 11.50 | 13.75 | 9.8 | 37.50 | 11.70 | 17.10 | 17.13 | 17.803 | OK |
| | 12.50 | 14.75 | 9.1 | 39.50 | 11.70 | 17.10 | 17.13 | 17.803 | OK |
| | 15.00 | 17.25 | 7.7 | 44.50 | 11.70 | 17.10 | 17.13 | 17.804 | OK |

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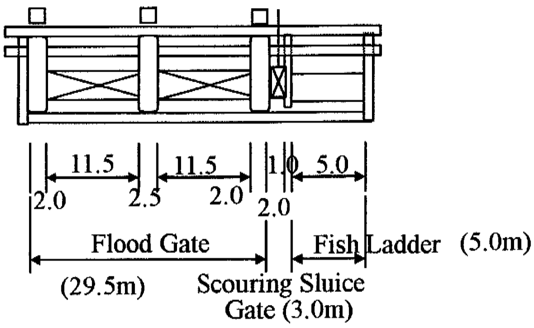


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**Schematic Drawing of Moung Russei Diversion Weir (Upstream View)**

c) Special Remarks:

As explained at the beginning of this sub-section, it is strongly recommended to lower the high water level at bridge as low as possible by installation of a permanent diversion structure in its upstream in order to protect the bridge on NR. No.5, an important infrastructure for Cambodian economy. The design high water at the bridge is desirable at least 0.6 m – 0.8m below the slab bottom.

d) Length of Weir

- Body Spillway : L1 = Operation deck and miscellaneous width + Bridge width

  = (7.0m + 6.0m) =13.0 m

  Slab thickness t1 = 2.1 m

- Downstream (D.S) Apron: L2 = 0.9 C (D) $^{1/2}$ =

  = 0.9 x 15 x (3.8) $^{1/2}$ = 27.0 m

  Slab thickness t2 = 1.2 m

  Where, C: Bligh's coefficient (C=15 for fine sand), D: Gate height 3.8 m

- Upstream (U.S) Apron: L3 = 2 h2

  = 2 x 5.5 =11.0 m (Where, h2: water depth in U.S)

  Slab thickness t3 = 0.8 m

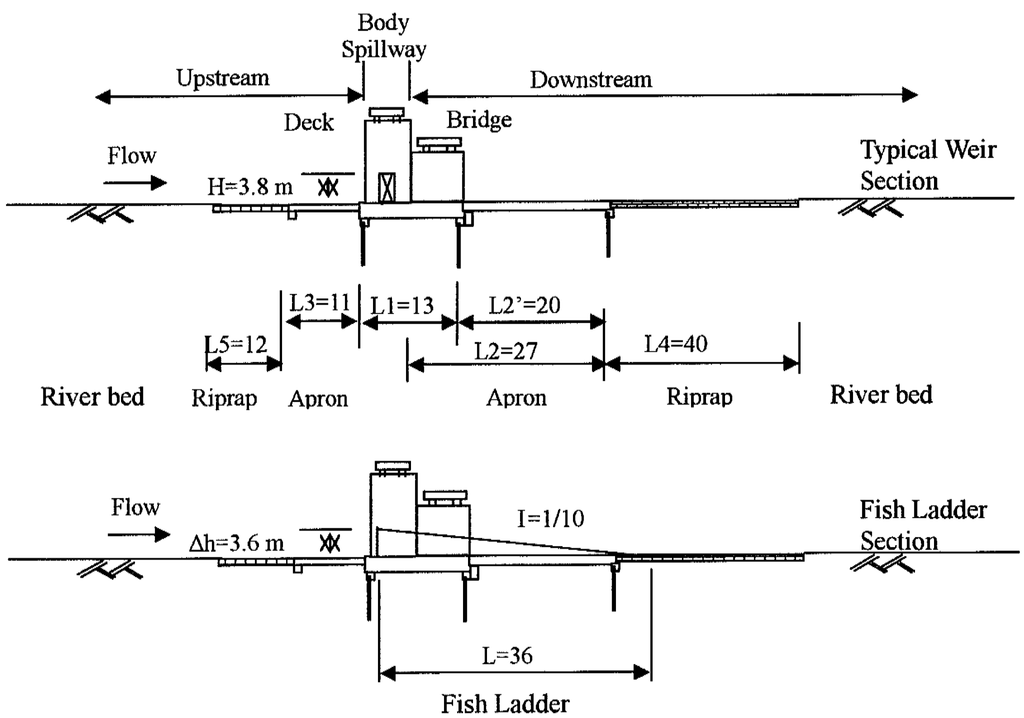
- DS Riprap: L4 = L - L2, L = 0.67 C (Ha q) $^{1/2}$ f

  L = 0.67 x 15 x (3.6 x (180/ 23)) $^{1/2}$ x 1.5 =80m, L4=80–27 = 50m

  Where, C: Bligh's coefficient (C=15 for fine sand), q: flood discharge/m ($m^3$/s/m)

  Ha: Gate height 3.8 m –min. DS water depth 0.2 = 3.6m

- US Riprap: L5 = L3 = 11.0 m

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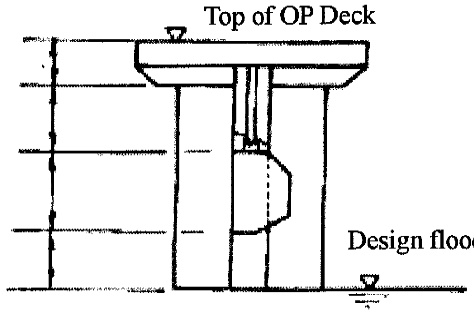
**Schematic Drawing (Section) of Moung Russei Diversion Weir**

It is noted that for the lengths of DS apron and DS riprap, "Bligh's equation" has been applied since it was slightly longer and safer than the lengths calculated by USBR Type equation.

e) Total Height of Weir

- Total height : Dp $= (HWL_F1 + Fb1 + \text{gate height} + Fb2) - \text{gate sill EL.}$

$= 17.2 + 0.6 + 3.8 + 1.0 - 11.70 = 10.9$ m




Prepared by JICA Study Team
Originaal source in Japanese Design Criteria for Headworks

**Explanatory Profile for Crest Elevation of Pier**

f) Thickness of Pier

- Pier for counter weight: 2.5 m (Roleang Chrey, Kandal Steung) – 3.1 m (Damnak Ampil)

$tp = 2.5\text{ m} > 1.9\text{ m}$ OK

- range of thickness: $tp = 0.12 \times (Dp + 0.2\ Bi) \pm 0.25$

$= 0.12 \times (10.9 + 0.2 \times 13.5) \pm 0.25$

$= 1.4\text{ m} < tp < 1.9\text{ m}$

Where, Bi = Span Length (m)

g) 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. 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.

h) 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.

i) Fish Ladder:

Fish ladder is planned on right bank of the weir. Type of fish ladder is planned to be "half-cone type" or "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 (commonly for above types)
- Height: H=3.6m (Gate height-inlet water depth)
- Length: L6=36 m (=3.6/(1/10) )

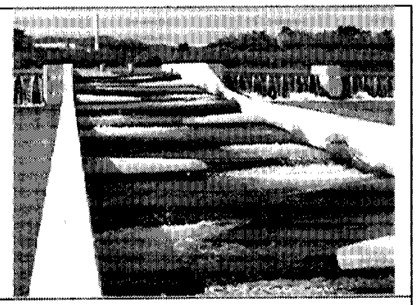


Image: half-cone type fish ladder

(4) Ream Kon Intake

1) Summary of Design Condition and Result:

Design condition and result for Ream Kon Intake are summarized as follows:

**Summary for Design of Ream Kon Intake**

| Design Parameter | Condition | Remarks |
|---|---|---|
| Design Intake Discharge rate: | Q: 2.66 m$^3$/sec | Ream kon Sub-project A=1,890 ha |
| Irrigation Water Level WL1: | WL. 15.50 m | Top of Gate (=NWL) |
| Elevation at Inlet (River bed): | EL. 11.70 m | |
| Elevation at Inlet (Intake): | EL. 14.30 m | |
| Gate Sill Elevation: | EL. 14.30 m | |
| Width, Height and Length | Width: 3.5 m<br>Height: 3.5 m<br>Length: 7.0 m<br>(+ Apron length) | Breast wall is installed between EL. 15.4 and EL.17.8 to prevent the entrance of flood water. |
| Gate Type and<br>Gate Size, nos. | Slide gate,<br>B:1.0 x H:1.2 x 2 nos. | |
| Bridge | Total width 4.0 m | |

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2) Design Elevation of Intake Inlet:

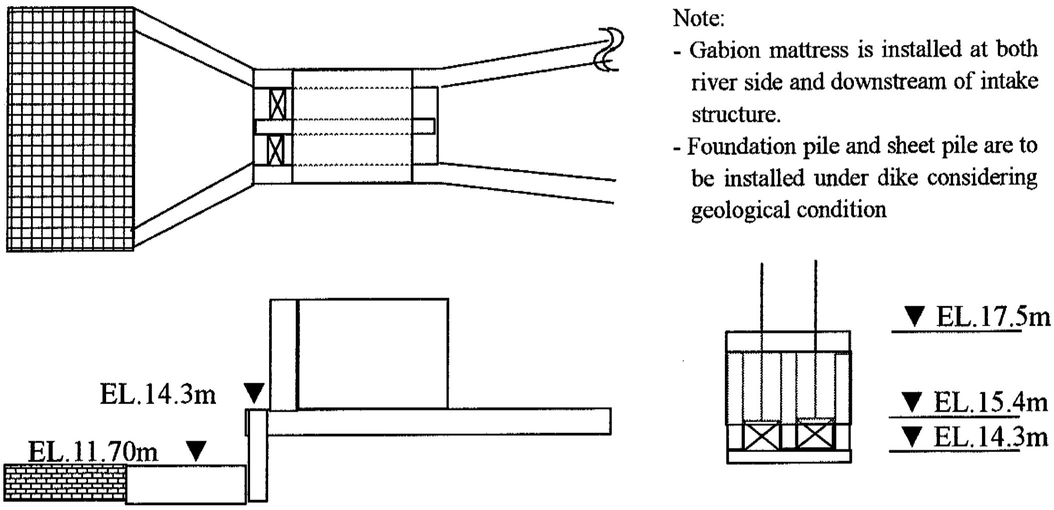
Elevation of an intake is to be designed, considering the design water depth of the both river and intake at inlet, in order to reduce and minimize the entrance of suspended particle (sediment). Water depth at inlet of intake is desirable to be within upper 0.4 of that of river (referring to Japanese design criteria for headworks):

- Water depth at river, H: 3.8 m (= NWL .15.50m – EL.11.70 m)

Elevation of intake inlet ≧ NWL - 0.4 x H=15.50 –0.4 x 3.8 = 14.0

- Water depth at intake, h: 1.10 m (refer to "rehab. of irrigation and drainage facilities")

Elevation of intake inlet = NWL- head loss – h = 15.50 –0.1 –1.1 = 14.3 > 14.0 OK




Note:
- Gabion mattress is installed at both river side and downstream of intake structure.
- Foundation pile and sheet pile are to be installed under dike considering geological condition

Prepared by JICA Study Team

**Schematic Drawing of Ream Kon Intake**

3) Design of Gate:

Design of intake gate (gate size and numbers of gate) is given as follows:

(reference: "Booklet of Hydraulic Formula", 1999 edition, Japanese Society of Civil Eng.,pp.255)

- Discharge rate Q ($m^3/s$) for 1 gate leaf (N=1):

$$Q = C\,a\,B\,(2\,g\,h0)^{1/2}$$

$$= 0.51 \times 0.56 \times 1.0 \times (2 \times 9.8 \times 1.1)^{1/2} = 1.34\ (m^3/s)$$

- Discharge rate Q' ($m^3/s$) for 2 gate leaf (N=2):

$$Q' = 2 \times 1.34 = 2.68 > 2.66\ (m^3/s) = \text{Design discharge rate} \quad \text{OK}$$

- Gate size and number(N): B=1.0m, H=1.2 m, N=2

Where,

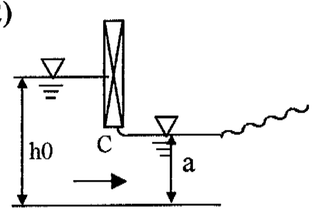
C: coefficient (C=0.51, when a / h0 =2)

a: gate opening (m)

B: width of gate (m)

g: gravity acceleration ($m/s^2$)

h0: water depth (river side)



(5) Collector Drain-2

1) Summary of Design Condition and Result:

Design condition and result of Collector Drain-2 are summarized as follows. It is noted that the construction period for the Moung Russei Weir is anticipated between mid-November and late-May, thus the discharge rate for temporary diversion during construction is estimated at 8.7m$^3$/s, which is the maximum discharge of the above period in last five years:

**Summary for Design of Collector Drain-2 (CD-2)**

| Design Parameter | Condition | Remarks |
|---|---|---|
| Design Discharge rate: | Q1: 30.0 m$^3$/sec | Maximum Diversion discharge |
| Design Temporary Discharge | Q2: 8.7 m$^3$/sec | Max. during Mid-Nov. – End. May |
| Canal bed Inclination | 1/ 3,000 | Refer to landscape |
| Canal Base width, top width | B1:13.5 m, B2:28.5 m | Considering land use |
| Canal Side Slope, Maning's n coefficient Freeboard | m : 1:2.5<br>n : 0.035<br>Fb: 0.8 m | MOWRAM design criteria for Irr. main canal class with sandy soil applied. |
| Canal Height, | H: 3.0m, | Present condition |
| Water Depth | h1: 2.2m (Q1=30 m$^3$/sec)<br>h2: 1.1m (Q2=8.7 m$^3$/sec)<br>hmax:3.0 m(Qmax=54 m$^3$/sec) | hmax: Fb=0 |

Prepared by JICA Study Team

**Hydraulic Calculation Result (Uniform flow) of Collector Drain-2 (CD-2)**

| Item | Symbol | Unit | Equation | Case-1 | Case-2 | Case-3 | Remarks |
|---|---|---|---|---|---|---|---|
| Design discharge | Q1 | (m3/s) | <Input> | 8.700 | 30.000 | 30.000 | |
| Base width | B1 | (m) | <Input> | 13.500 | 13.500 | 13.500 | |
| Water depth | h | (m) | <Input> | 1.092 | 2.200 | 3.000 | |
| Canal bed slope | I | | <Input> | 1/3000 | 1/3000 | 1/3000 | |
| Roughness coef. | n | | <Input> | 0.035 | 0.035 | 0.035 | MOWRAM,Earth,Main |
| Side slope | αL | | <Input> | 2.5 | 2.5 | 2.5 | -Ditto- |
| Side slope | αR | | <Input> | 2.5 | 2.5 | 2.5 | -Ditto- |
| Wet-perimeter | P | (m) | $B+[(1+\alpha L^2)^{0.5}+(1+\alpha R^2)^{0.5}]*h$ | 19.381 | 25.347 | 29.655 | |
| Cross-section area | A | (m2) | $B\cdot h+0.5\alpha h^2$ | 17.723 | 41.800 | 63.000 | |
| Hydr. Mean depth | R | (m) | A/P | 0.914 | 1.649 | 2.124 | |
| Velocity | v | (m/s) | (R^(2/3)×I^(1/2))/n | 0.491 | 0.728 | 0.862 | |
| Calc. discharge | Q | (m3/s) | A・v | 8.710 | 30.435 | 54.309 | |
| Free board | Fb | (m) | <Input> | 0.800 | 0.800 | 0.000 | MOWRAM,Earth,Main |
| Canal total height | H | (m) | h+Fb | 1.900 | 3.000 | 3.000 | ≦3.000 |
| Canal total width | B2 | (m) | B1+2*α*H | 23.000 | 28.500 | 28.500 | |
| Remarks | | | | Flood (dry) | Flood Div. | Flood Div.Fb=0 | |

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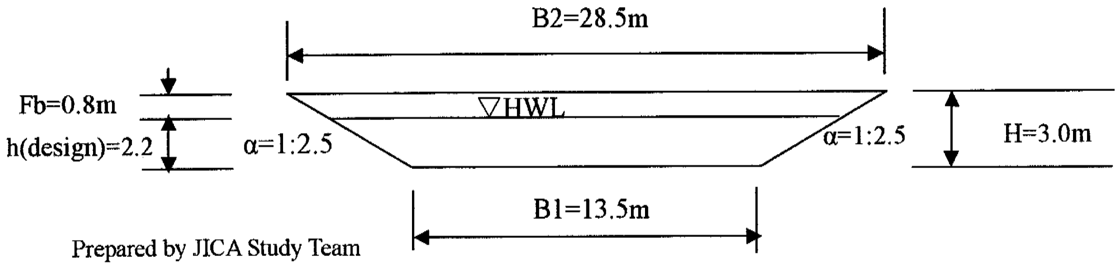


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**Schematic typical section of Collector Drain-2**

**Discharge Observation data for MoungRussei River in Dry Season (Top 5 in Early Dec. to following End of May)**

| No. | Discharge ($m^3$/sec) Observed in Dry season of 2001-2005 | Remarks (December 1st- June 30th) |
|---|---|---|
| 1. | 8.70 | May, 2002 |
| 2. | 7.85 | June, 2004 |
| 3. | 7.69 | June, 2005 |
| 4. | 7.09 | June, 2005 |
| 5. | 6.86 | December, 2005 |

Prepared by JICA Study Team, based on Table A.5.4.1 in Appendix A

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

1) Summary of Design Condition and Result:

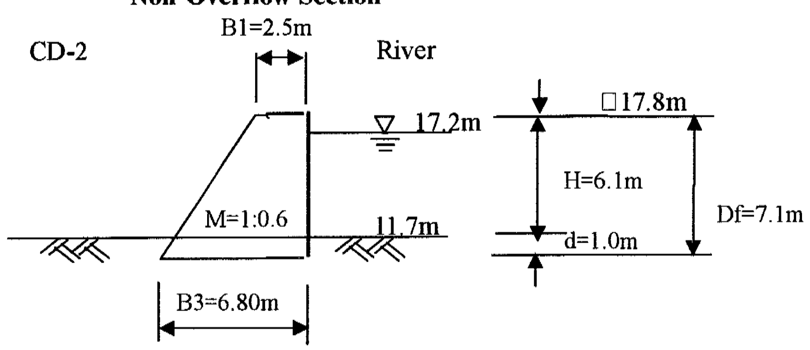
Design condition and result of inlet structure for Collector Drain-2 in Ream Kon Sub-project are summarized as follows:

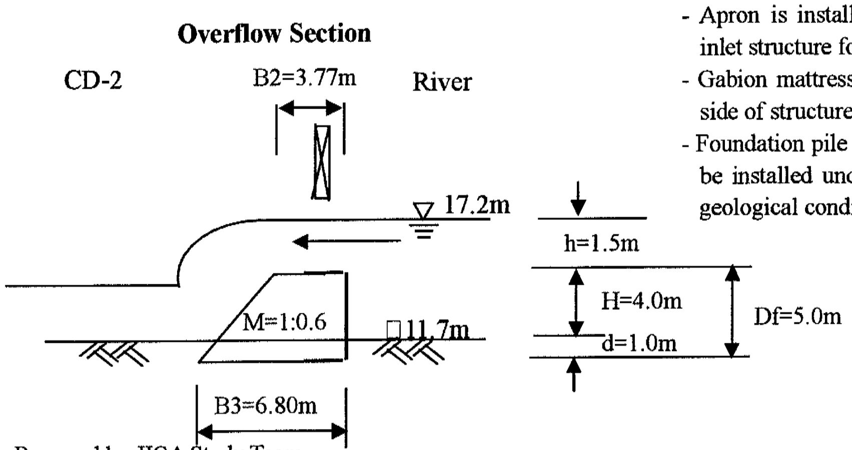
**Summary for Design of Inlet Structure for CD-2**

| Design Parameter | Condition | Remarks |
|---|---|---|
| Design Discharge rate: | Q1: 30.0 $m^3$/sec | Maximum Diversion discharge |
| Type of Structure | Concrete Dyke with gate | |
| Elevation of Dyke Non-overflow section<br>Overflow section | EL1.: 17.8m<br>EL2.: 15.7m | > $HWL_F1$.= 17.20 m<br>(Design NWL+0.2m) > NWL.15.5 m |
| Elevation of River Bed | EL3.: 11.7m | 30 m Upstream of Weir |
| Elevation of Dyke Bottom | EL4.: 10.7m | EL3. – 1.0 m |
| Height of Dyke Non-overflow section<br>Overflow section | H1: 7.1 m (6.1 m)<br>H2: 5.0 m (4.0 m) | Apparent height in ( ) |
| Width Top of Non-overflow section<br>Top of Overflow section<br>Bottom of section | B1: 2.5 m<br>B2: 3.77m<br>B3: 6.8 m | Slope M=1:0.6 |
| Length Top of Non-overflow section<br>Top of Overflow section<br>Bottom of section | L1: 38.5 m<br>L2: 20.0 m<br>L3: 38.5 m | Actual length 32.5 m + 3.0 x both side |
| Gate Type, Dimension, nos. | Slide Gate<br>H:1.5 m x B:4 m x 5 nos. | Pier width 0.7 m |
| Elevation of Operation Deck | EL5.: 19.0 m | |

Prepared by JICA Study Team

**Non-Overflow Section**






Note:
- Apron is installed at CD-2 side of inlet structure for protection.
- Gabion mattress is installed at river side of structure.
- Foundation pile and sheet pile are to be installed under dike considering geological condition

Prepared by JICA Study Team

**Schematic Drawing of Inlet Structure for CD-2**

(6) Drain Gate for Collector Drain-2

1) Summary of Design Condition and Result:

Design condition and result of drainage gate at the outlet of Collector Drain-2 in Ream Kon Sub-project are summarized as follows:

**Summary for Design of Drainage Gate for CD-2**

| Design Parameter | Condition | Remarks |
|---|---|---|
| Design Discharge rate: | Q1: 30.0 $m^3/s$ | Maximum Diversion discharge |
| Design Elevation of Drain outlet base | EL. 11.20m | |
| Water Level WLD1: | WL. 13.40m | Maximum |
| Gate Sill Elevation: | WL. 11.20m | |
| Design Width, Height and Length | Width: 7.6m<br>Height: 4.8m<br>Length: 7.0m<br>(+ Apron length) | Breast wall is installed between EL. 13.0m and EL.16.0m to prevent entrance of flood water. |
| Design Gate Type and Gate Size, nos. | Slide gate,<br>B:1.8 x H:1.8 x 3 nos. | |
| Bridge | Total width 4.0 m | |

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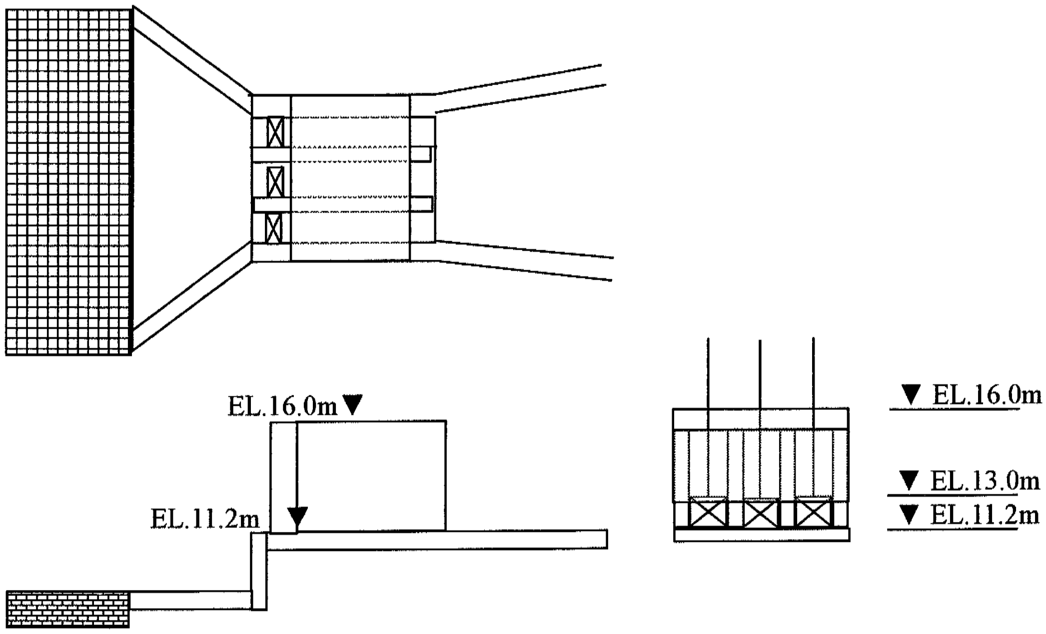
The dimension of the above drainage gate is assuming free discharge condition. It is noted that the water level in the river may be risen under influence of Lake Tonle Sap, so that it is not insured that the design discharge of 30$m^3$/s flows out under such influence. Therefore, permanent diversion structure should be installed at some point upstream of the National Road. No.5.

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**Schematic Drawing of Drainage Gate for CD-2**

2) Design of Gate:

Design of the drainage gate (gate size and numbers of gate) is given as follows:

(reference: "Booklet of Hydraulic Formula", 1999 edition, Japanese Society of Civil Eng.,pp.255)

- Discharge rate Q ($m^3/s$) for 1 gate leaf (N=1):

$$Q = C\,a\,B\,(2\,g\,h0)^{1/2}$$

$$= 0.5 \times 1.7 \times 1.8 \times (2 \times 9.8 \times 2.2)^{1/2} = 10.05\ (m^3/s)$$

- Discharge rate Q' ($m^3/s$) for 3 gate leaf (N=3):

$$Q' = 3 \times 10.05 = 30.15 > 30.0\ (m^3/s) = \text{Design discharge rate} \quad \text{OK}$$

- Gate size and number(N): B=1.8m, H=1.8 m, N=3

Where,

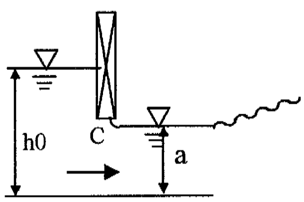
C: coefficient (C=0.5, when a / h0 =1)

a: gate opening (m)

B: width of gate (m)

g: gravity acceleration ($m/s^2$)

h0: water depth (river side)



### C3.3.2 Irrigation and Drainage Facilities

(1) Irrigation Facilities

1) Design Plan of Irrigation Facilities

Preliminary design work of irrigation facilities 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 | Utilization of existing sections to the maximum extent |
| - Low canal bank | - Reshaping and heightening of canal bank for gravity irrigation |
| - Shallow canal | - Excavation and reshaping of canal section in the case of insufficient flow capacity |
| - Deep section | - Utilizing existing section without backfilling to the deep bottom section |
| - Wide section | - Utilizing existing section without making new bank on the low-lying portion |
| **Canal Related Structure** | |
| Free intake and free distribution without control structures | Controlled irrigation water by gated structures such as Intakes, Checks , ans Turnouts |
| Poor access in the sub-project area | Construction of access/inspection roads on main and secondary canals |
| - Lack of road crossing | - Construction of road culver, bridge, and footpath bridge |

Prepared by JICA Study Team

2) Rehabilitation and Improvement of Irrigation Facilities

a) Design of Irrigation Canal

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.

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.

**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 | | |
| | Irrigation (Earth Canal) | | Medium Clay |
| | Design Q = < 5.0 m3/sec | 1 : 1.00 | |
| | Design Q > 5.0 m3/sec | 1 : 1.25 | |
| 3 | Freeboard ( Earth Canal) | | |
| | Irrigation (Earth Canal) | | |
| | Main Canal | 0.80 m | |
| | Secondary Canal | 0.50 m | |
| | Teriary Canal | 0.15 m | |
| 4 | Top Width of Embankment | | |
| | Irrigation (Earth Canal) | | |
| | Design Q = < 1.0 m3/sec | 1.0 m | |
| | Design Q = 1.0 to 5.0 m3/sec | 1.5 m | |
| | Design Q > 5.0 m3/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

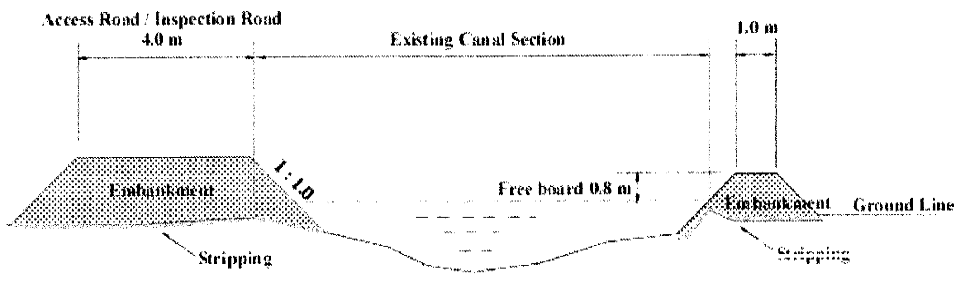
In the case of rehabilitation and improvement of an existing canal, the existing canal change their width and depth in each section. Therefore, the equation, which applies the Bernoulli's theorem, is employed due to limitation of applicability of the Manning's formula.

In the Ream Kon 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 < 1.0 $m^3/s$)

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 following shows the canal dimensions designed preliminarily in this study.

**Summary of Canal Design**

| Irrigation Canal | Canal Length | | | Design | | | | |
|---|---|---|---|---|---|---|---|---|
| | Total | Rehab. | New | Discharge Q (m3/s) | Bottom Width | Height | Left Bank Top Width | Right Bank Top Width |
| Main Canal 1 | 9,100 | 8,100 | 1,000 | | | | | |
| Sec 1 | | | 1,000 | 2.66 | 3.2 m | 1.9 m | 4.0 m | 1.5 m |
| Sec 2 - 10 | | 8,100 | | 1.16-0.08 | 7.0 m - 2.0 m | 1.2 m - 2.4 m | 4.0 m | 1.5 m - 1.0 m |
| S1 - 1 | 700 | 400 | 300 | 0.09 | 0.7 m | 0.8 m | 1.0 m | 4.0 m |
| S1 - 2 | 1,400 | 1,100 | 300 | 0.18 | 0.9 m | 0.9 m | 1.0 m | 4.0 m |
| S1 - 3 | 2,000 | 600 | 1,400 | 0.31 | 1.1 m | 1.0 m | 1.0 m | 4.0 m |
| S1 - 4 | 1,600 | 0 | 1,600 | 0.24 | 1.0 m | 1.0 m | 1.0 m | 4.0 m |
| S1 - 5 | 700 | 700 | 0 | 0.11 | 0.7 m | 0.9 m | 1.0 m | 4.0 m |
| S1 - 6 | 700 | 700 | 0 | 0.11 | 0.7 m | 0.9 m | 1.0 m | 4.0 m |
| S1 - 7 | 700 | 700 | 0 | 0.09 | 0.7 m | 0.8 m | 1.0 m | 4.0 m |
| Total of S1 | 7,800 | 4,200 | 3,600 | | | | | |
| Main Canal 2 | 9,300 | 3,800 | 5,500 | | | | | |
| Sec 1 | | | 1,400 | 1.48 | 2.6 m | 1.7 m | 4.0 m | 1.5 m |
| Sec 2 - 4 | | 1,800 | | 1.31 - 1.06 | 2.6 m - 2.4 m | 1.7 m - 1.6 m | 4.0 m | 1.5 m |
| Sec 5 - 7 | | | 4,100 | 0.80 - 0.41 | 2.2 m - 1.2 m | 1.5 m - 1.4 m | 4.0 m | 1.0 m |
| Sec 8 - 9 | | 2,000 | | 0.35 - 0.10 | 1.2 m - 1.0 m | 1.4 m- 1.3 m | 4.0 m | 1.0 m |
| S2L - 1 | 700 | 0 | 700 | 0.11 | 0.7 m | 0.9 m | 1.0 m | 4.0 m |
| S2L - 2 | 500 | 0 | 500 | 0.14 | 0.8 m | 0.9 m | 1.0 m | 4.0 m |
| S2L - 3 | 500 | 0 | 500 | 0.14 | 0.8 m | 0.9 m | 1.0 m | 4.0 m |
| S2L - 4 | 500 | 0 | 500 | 0.14 | 0.8 m | 0.9 m | 1.0 m | 4.0 m |
| S2L - 5 | 500 | 0 | 500 | 0.13 | 0.8 m | 0.9 m | 1.0 m | 4.0 m |
| S2L - 6 | 500 | 500 | 0 | 0.13 | 0.8 m | 0.9 m | 1.0 m | 4.0 m |
| S2L - 7 | 500 | 500 | 0 | 0.10 | 0.7 m | 0.9 m | 1.0 m | 4.0 m |
| S2R - 1 | 700 | 0 | 700 | 0.11 | 0.7 m | 0.9 m | 4.0 m | 1.0 m |
| S2R - 2 | 700 | 0 | 700 | 0.11 | 0.7 m | 0.9 m | 4.0 m | 1.0 m |
| Total of S2 | 5,100 | 1,000 | 4,100 | | | | | |

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b) Design of Irrigation Canal Related Structure

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

Sub-Project. The following table shows the required types and numbers.

**Type and Number of Irrigation Related Structures**

| Structure | nos. | Structure | nos. |
|---|---|---|---|
| Combined Regulator | 1 | Terminal Structure | 18 |
| Turnout | 63 | Road Culvert | 7 |
| Check | 25 | Bridge | 6 |

Prepared by JICA Study Team

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

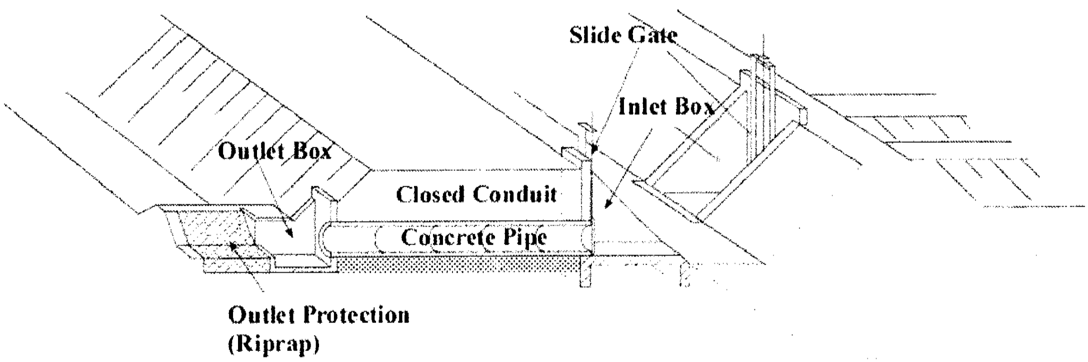
Turnout

A turnout structure would be provided 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 parshall 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.

The following illustration shows an image of a turnout structure.




Prepared by JICA Study Team

**Image of a Turnout Structure**

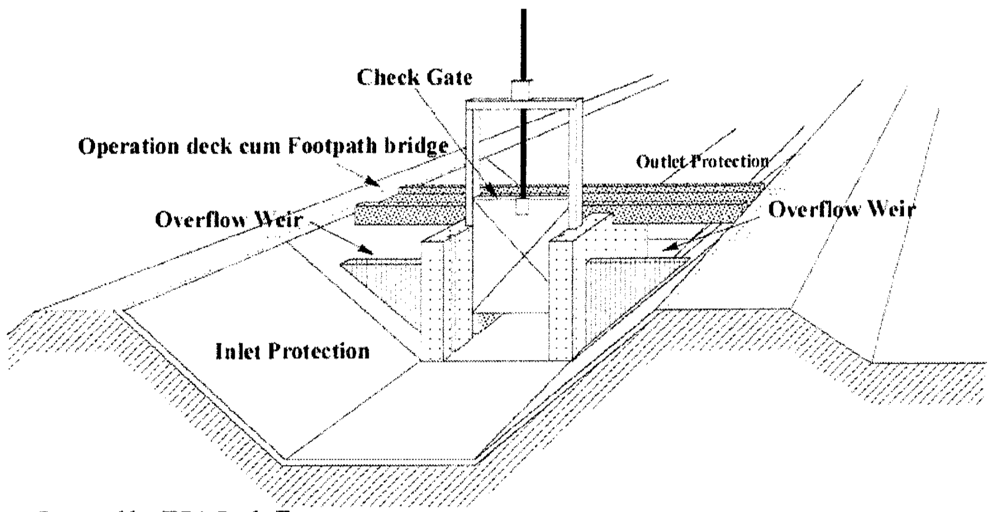
Check Structure

A check structure would be provided 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.

The following illustration shows an image of a check structure.




Prepared by JICA Study Team

**Image of Check Structure**

Terminal Structure

A terminal structure would be 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 $m^3$/sec.

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 Facilities

1) Design Plan of Drainage Facilities

Preliminary design work of drainage facilities 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<br>- Lack of road crossing | - Construction of drainage culvert |

Prepared by JICA Study Team

2) Rehabilitation and Improvement of Drainage Facilities

a) Design of Drainage Canal

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 < 1.7 m3/sec | 0.10 m | |
| | Design Q = 1.7 to 8.0 m3/sec | 0.20 m | |
| | Design Q > 8.0 m3/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

**Summary of Drainage Canal Design**

| Drainge Canal | Canal Length | | | Design | |
|---|---|---|---|---|---|
| | Total | Rehab. | New | Bottom Width | Height |
| MD 1 | 7,200 | 0 | 7,200 | 10.0 m - 7.5 m | 2.8 m - 2.6 m |
| CD-1 | 9,400 | 0 | 9,400 | 7.0 m - 5.0 m | 2.1 m - 1.9 m |
| CD-2 | 6,400 | 3,800 | 2,600 | 10.0 m - 5.0 m | 1.7 m |
| CD-3 | 3,600 | 0 | 3,600 | 7.0 m | 2.2 m |
| Sub-Total | 26,600 | 3,800 | 22,800 | | |
| SD-1 | 4,100 | 0 | 4,100 | 2.2 m | 1.2 m |
| SD-2 | 4,100 | 0 | 4,100 | 2.6 m | 1.4 m |
| SD-3 | 3,600 | 0 | 3,600 | 2.6 m | 1.4 m |
| SD-4 | 3,100 | 0 | 3,100 | 2.8 m | 1.5 m |
| SD-5 | 3,400 | 0 | 3,400 | 4.0 m | 1.6 m |
| SD-6 | 2,500 | 0 | 2,500 | 2.8 m | 1.5 m |
| SD-7 | 1,500 | 0 | 1,500 | 2.0 m | 1.0 m |
| SD-8 | 1,400 | 0 | 1,400 | 2.0 m | 1.0 m |
| SD-9 | 1,400 | 0 | 1,400 | 2.2 m | 1.2 m |
| Total of SD | 25,100 | 0 | 25,100 | | |
| Grand Total | 51,700 | 3,800 | 47,900 | | |

Prepared by JICA Study Team

b) Design of Drainage Canal Related Structure

Two types of drainage related structure are preliminarily designed for the Ream Kon Sub-Project. The following table shows the required types and numbers.

**Type and Number of Drainage Related Structures**

| Structure | nos. | Structure | nos. |
|---|---|---|---|
| Drainage Culvert | 29 | Drainage Gate | 1 |

Prepared by JICA Study Team

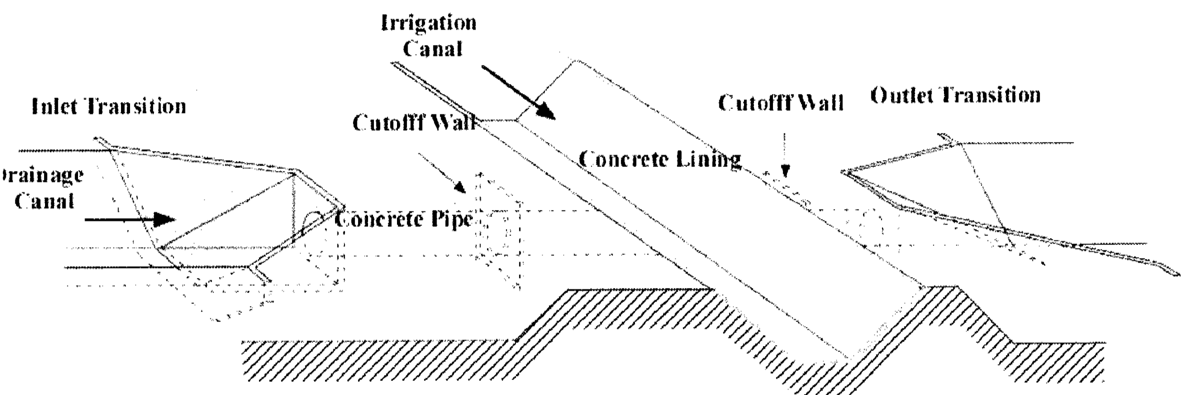
The function and feature of drainage canal related structures are described in the following paragraphs.

Drainage Gate

A drainage gate is a regulator to be provided at the end-point of the CD (Collector Drain) No.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.

Drainage Culvert

Drainage culver 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.




Prepared by JICA Study Team

**Image of a Drainage Culvert**

## C3.4 On-farm Development Plan

In accordance with the topography and the concept mentioned in the previous section C2.3 (3), 47 tertiary blocks are proposed in the Ream Kon 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 at 57 km 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.

## C3.5 Water Management and Operation & Maintenance of Irrigation Facilities

(1) Responsible Organization

The share of responsibility of water management and O&M activities is proposed as follows taking into consideration the policy above, size of the Sub-project, importance of facility for the Sub-project management.

| Level / Activities | 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, Battambangis responsible for water management and O&M of Moung Rusei Headworks and Main Canal-1 and Main Canal-2 including related structures.

The water level at the Headworks is to be kept at EL. 15.50 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 upstream of weir site and intake site.

The peak diversion water requirement is designed at 2.64 $m^3$/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-2. The peak discharge of Main Canal-1 and Main Canal-2 are designed at 1.16$m^3$/sec and 1.48$m^3$/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 -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 Russei River (refer to section C3.1).

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 Mount 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 management in the secondary canal is described in the previous section C2.4 (3)

3) Tertiary Canals

The water management in the tertiary canal is described in the previous section C2.4 (3)

4) Water courses and Field Canals

The water management in the tertiary canal is described in the previous section C2.4 (3)

(3) Maintenance Work

The water management in the tertiary canal is described in the previous section C2.4 (4)