



**Ministry of Water  
Resources and  
Meteorology**

**KINGDOM OF CAMBODIA  
Nation Religion King**



**Seila Program**

***Module 1***  
***Feasibility Study of Small  
Scale Irrigation Project***

**For Seila Program**  
To strengthen the capacity of Provincial-  
Municipal Technical Support Staff

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## Table of Content

Abbreviations .....	2
Units.....	3
1. Introduction.....	4
2. Introduction of the feasibility study of small scale irrigation projects.....	5
2.1. Socioeconomic aspects .....	5
2.1.1 Demography .....	5
2.1.2 Land Ownership .....	5
2.1.3 Labor .....	5
2.2 Health .....	6
2.3 Environment .....	6
2.3.1 Rare fauna and flora species.....	6
2.3.2 Ancient temples and artifacts.....	6
2.3.3 Social Recreational and Religious Users .....	6
2.4 Topography and Soils .....	6
2.4.1 Slope .....	7
2.4.2 Characteristics of soil Surface .....	7
2.4.3 Observation on types of soils at the actual worksite .....	7
2.4.4 Findings from Soil Analysis in Laboratory .....	8
2.4.5 Draining from irrigation system.....	9
2.5 Agriculture.....	9
2.5.1 Command area .....	10
2.5.2 Growing season in current situation.....	10
2.5.3 Constraints .....	10
in agricultural process .....	10
2.5.4 Marketing.....	10
2.5.5 Proposed Cropping Pattern .....	10
2.6 Irrigation Water Requirement(IR) .....	11
2.6.1 Crop Water Requirement(CR).....	11
2.6.2 Irrigation efficiency.....	15
2.6.3 Irrigation Water Requirement including the amount of water lost.....	15
2.6.4 Equivalent Water Needs of the Project .....	15
2.7 Surface Water Resources.....	15
2.7.1 Water quality .....	15
2.7.2 Channel Characteristics .....	16
2.7.3 Discharged measured during the field visit to the project .....	16
2.7.4 Flood discharge .....	18
2.7.5 Level of stream water .....	18
2.8 Groundwater Resources.....	19
2.8.1 Well .....	19
2.9 Balance of water source and needs.....	19
2.10 Irrigation infrastructure .....	19
2.10.1 Location of water diversion structure for irrigation.....	20
2.10.2 Gravity diversion structure .....	20
2.11 Water pumping for irrigation .....	20

2.12. Water Storage .....20  
 Seasonal water storage ..... **Error! Bookmark not defined.**  
 2.13 Economic indicators ..... 21  
 2.13.1 Current situation (pre-project) ..... 21  
 2.13.2 Proposed Situation..... 21  
 2.13.3 Benefits from the project ..... 21  
 2.14 Project development and operation ..... 21  
 2.14.1 Farmer Water User Community (FWUC) ..... 21  
 2.14.2 Community's contributions to small-scale irrigation scheme construction.. 22  
 2.14.3 Operation and maintenance of small-scale irrigation scheme ..... 22  
 2.14.4 FWUC Training ..... 22

**List of Table**

Table 1 Electrical Conductivity ..... 8  
 Table 2: Estimation of Crop Water Requirement/season ..... 11  
 Table 3: Crop Water Requirement ..... 13  
 Table 4: Precipitation (P) and Effective Rainfall (Pe) Measured in mm/month..... 14  
 Table 5: Water Conductivity and Reaction of Crops ..... 16

**List of Figure**

Figure 1: Part of Rainwater Lose by Deep Percolation and Surface Runoff..... 14

**Annexes**

- 1. Questionnaire Example
- 2. Questionnaire

**Abbreviations**

A	Area	P	Poorly drained soil
b, w	Stream width at Surface (normal condition)	Pe	Effective rainfall

B	Width of stream bank (flood event)	PIMD	Participatory Irrigation Management and Development
CR	Crop water requirement	Pr	Precipitation
CL	Clay loam	Q	Discharge
CS	Clay soil	FWUC	Farmer Water User Community
d	Water depth	SL	Sandy loam
dS	deciSiemens (Measure of electrical conductivity of soil)	SS	Sandy soil
EC	Electrical Conductivity	t	time
ECw	Electrical Conductivity of Water	V	Water velocity
ESP	Exchangeable Sodium Percentage	SP	Soil Preparation
f	Velocity coefficient (0.75)	S	Sowing
F	Freely drained soil	T	Seedling transplant
H	Length from edge of body water to Stream banks	G	Growth
I	Impeded drainage soil	H	Harvest
Ie	Irrigation efficiency	R	Riel currency
IR	Irrigation Water Requirement		
kW	Kilowatt		
Lo	Loam soil		
month	Month		
masl	Mean against sea level		
No	Number		

### Units

<b>dS/m</b>	deciSiemens/metre		
<b>ha</b>	Hectare		
<b>kg</b>	Kilogram		
<b>kg/ha</b>	Kilogram per hectare		

<b>L</b>	Liter		
<b>L/s</b>	Liter per second		
<b>mm/mth</b>	Milliliter per month		
<b>mm</b>	Milliliter		
<b>m</b>	Meter		
<b>m/s</b>	Meter per second		
<b>m<sup>2</sup></b>	Square meter		
<b>m<sup>3</sup></b>	Cubic meter		
<b>m<sup>3</sup>/mth</b>	Cubic meter per month		
<b>m<sup>3</sup>/s</b>	Cubic meter per second		
<b>s</b>	Second		

## 1. Introduction

The feasibility study of this project was conducted primarily to gather any necessary data related to the proposed project, to improve (either the construction or reconstruction), and to finally develop reports on the feasibility study of the project.

To be able to collect these data, an engineer or technician should conduct field visit to the actual worksite. Analysis of the data gathered will lead to a common recommendation on whether the project could be integrated into the development program of small scale irrigation projects.

## **2. Introduction of the feasibility study of small scale irrigation projects**

The study of a project feasibility deals with the study of social economic aspect, environment, landform, land type, agriculture, need for water, source of surface water, source of ground water, the condition of the existing irrigation infrastructure, economy indicator, and the future vision in operating the project.

### **2.1. Socioeconomic aspects**

It is very important to determine the match of the proposed project against the socioeconomic context in that target village or district for development. In this regard, land ownerships and labor are examples of what should be studied jointly in the village/commune. The commune council is an important place to contact; however, district/provincial office or other non-governmental organizations which are already carrying out activities in those target communes may also be contacted for information and experience exchange.

#### **2.1.1 Demography**

Information on the number of population in the beneficiary area is necessarily vital. In addition to this, information on age, sex and number of members in a family is important as well. However, it is difficult to obtain accurate information on those who often migrate.

#### **2.1.2 Land Ownership**

The development of irrigation system may affect the lands of the farmers. Therefore, the knowledge of the land belonging to each family will be convenient in understanding and solving problems (in case of any impact) within the community.

#### **2.1.3 Labor**

Developing irrigation system may require more labor than usual. The cause of the increase in labor is due to (1) the increase of productive area and (2) the increased growing times in growing season, from once to twice or thrice a year. In fact, it is difficult to determine the accurate number of the additional need for labor because of the inaccurate information farmers give. Nevertheless, the present need for labor in busy season shall be studied, followed by evaluation on the increase of land and growing season compared to the existing labor so as to determine whether the community has enough labor to meet the required number of labor in the construction and operation of the project.

## **2.2 Health**

Information on water-borne diseases is very important in observing the side effects of the project. The engineer organizing the project shall take measures to reduce the chance that favor mosquito reproduction.

## **2.3 Environment**

We may learn about the aspect of environment by discussing with the elders in the community, individuals and community leaders, medical physicians and teachers, etc.

### **2.3.1 Rare fauna and flora species**

The technician shall gather data on the possibility of rare fauna and flora species in the community. If the irrigation development project runs into the discovery of rare fauna and flora species, the project designer shall protect that area and record the result of the survey conducted both above and below the dam such as the biodiversity area or wetland etc.

### **3.3.2 Ancient temples and artifacts**

If there are ancient temples or other artifacts close to the irrigation development area, the technician shall make thorough observations and assessment whether the construction or operation of the irrigation system may affect those temples or ancient objects. If any affect is expected, measures must be taken to protect and prevent destruction to those objects. The technician shall report any unregistered ancient object to the competent authority in order to cooperate and take legal measures to collect those objects for safety.

### **2.3.3 Social Recreational and Religious Users**

Any objects the community has used and is using for their recreation or worship are all important to them. For example, ancient tombs and graveyard of the community are places that should be protected.

## **2.4 Topography and Soils**

It is very important that we study the types of soil since the inception of the study project to determine the physical and chemical characteristics of the soil in the irrigation development area so as to find out whether or not it is suitable for agricultural irrigation development. Soil-related problems are soil erosion, infertile soil, salty soil (containing excessive amount of salt deposits), alkaline soil, and soil with high infiltration capacity. Soils suitable for irrigated agriculture development

are soils that are composed of matters ranging from loam (Lo) to clay soil (CS) and which have pH from 4.5 to 8.5 (for rice).

### 2.4.1 Slope

In the encounter of sloping land from 1/50 above or in other words, 2% slope (meaning that the height is 1 meter different within the distance of 50 meters), that field shall be leveled first before modern irrigation system can be applied.

### 2.4.2 Characteristics of soil Surface

In some cases, there may be many types of soil in one same irrigation system. In this case, conclusion shall be made, based on the type of soil covering the largest area, approximately 50% or more. However, other types of soil covering more than 20% of the area shall also be included in the reports on types of soil of the project. Each type of soil is observed differently by digging roughly one-meter deep holes whose intervals from each other are 50 hectares. Each layer of the soil dug is call *soil profile*<sup>1</sup>. The note on variable characteristics of the soil layers should be prepared including the topsoil downwards at least to the depth of 1 meter.

### 2.4.3 Observation on types of soils at the actual worksite

**Depth:** So crops root down to the depth of more than 1 meter. For the crops receiving water through irrigation (crops besides rice), to be convenient for draining water, the depth of infiltrated layer of the soil is not less than 1,5 meters, so that the water will go down through the root layer. In general, the *Surface Irrigation*<sup>2</sup> could be practiced on the soil that the water can percolate downwards to the depth of 500 millimeters.

**Texture of soils:** Soil is classified into 5 main types as follows:

**Sandy Soil (SS):** Sandy soil is not suitable for *surface irrigation* because of its high infiltration rate and low capacity to restore water in the zone of aeration and because some compounds in the sandy soil can be easily dissolved in water and blown by the wind.

**Sandy loam (SL):** is not really suitable for *surface irrigation* because this type of soil has low capacity in restoring water in the zone of aeration, high water infiltration rate in the topsoil, and is easily eroded by water flow. Such soil is not suitable for rice because of its high water infiltration rate.

**Clay Soil (CS):** Clay soil is suitable for rice. But it is less convenient for other crops because the clay has low water infiltration. For red clay, it has high oxidation by climate and high erosion caused by water flow, so it is considered improper for the rice growing unless there is cogent evidence that the local farmers have ever collected successful harvest of rice from such type of soil.

**Loam Soil<sup>3</sup> (Lo), Clay Loam Soil (CL):** These types of soil are completely proper for the rice crop such as small paddy field cultivation because this soil has

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<sup>1</sup> *Soil Profile*

<sup>2</sup> *Surface Irrigation* means submerging the rice trunk.

<sup>3</sup> Loam Soil: is the soil abundant with organic materials and is the rich soil for the rice.

high water absorbency capacity in the root layer and every root layer will be infiltrated by the water through this soil, and also it is not sticky.

**Color, Internal Drainage:** The soil color is a main indicator for soil infiltration capacity. The soil infiltration capacity is divided as following:

*Freely drained Soil (F):* is the lower layer of soil with red, brown, or yellow color, without grey or other color, whose depth is more than 1 meter.

*Impeded drainage Soil (I):* is the soil whose about 1 meter lower layer has compositions which interfere the downward water infiltration. The layer has grey color with mixed compositions.

*Poorly drained Soil (P):* is the soil most of which has grey, green, or blue color. This type of soil is proper for the rice, but is not proper for other crops unless the draining system is perfectly constructed.

#### 2.4.4 Findings from Soil Analysis in Laboratory

There are many key indicators related to the soil chemical characteristics analyzed in the laboratory. For this intention, analyzed components should be drilled out from at least 1 meter depth.

**Acidity and Alkalinity:** If pH is less than 4.5, it means that the soil has high acidity and aluminum which are poisonous for most of the crops. For the soil which has pH = 3, it is the soil which has much sulfurous acid. To improve the acid soil, much technology and budget such as limestone and pH increase to the appropriate level for the crop are required. Moreover, although pH is increased to the appropriate level, the soil does not yet have adequate fertilizers for the rice crop.

If pH 4.5 – 8.5, it is the best for the rice and the other crops. The crop will grow well in this pH level.

If pH 8.5 – 9.0, the rice and the other crops will not grow well in this soil because of its mixed sodium, but it might be improved with modern technology.

If pH > 9.0, it is called alkaline soil with high sodium. This type of soil might be improved by decreasing the pH to normal level, but long time and much budget are required. So, if the irrigation system development project is intended to take place on this type of soil, the project shall not be approved.

**Salty Soil:** The salinity in the soil disturbs the growth of the crop for two reasons (1) it deceases the water absorbency capacity of the root (2) the salinity builds poison. The salinity in the soil is classified based on the outcome of measurement through *Electrical Conductivity* of the soil, expressed in deciSiemens/metre (Ds/m) in the water-soil ratio of 1:5. The below table indicates reaction of the crop in different levels of *Electrical Conductivity*.

Table 1 Electrical Conductivity

EC <sub>1:5</sub> (dS/m)		
0.1 – 0.4	Salt free	Most of the crop yield high output
0.4 – 0.8	Slightly saline	The crop yields little output

0.8 – 1.6	Moderately saline	Most of the crop yield minimum output
> 1.6	High salinity	Inappropriate for most of the crop

The salinity is always the obstacle of draining, and if the soil has  $EC_{1:5} > 0.4$  dS/m, the further detailed study shall be required to find proper solutions.

**Obstacles caused by Alkalinity:** As mentioned earlier, if pH of the soil is higher than 8.5, there is always the presence of sodium. The more sodium the soil has, the more its structure is destroyed, and the crop will not grow well. The variable for defining whether the soil is proper for the irrigated agriculture is called *Exchangeable Sodium Percentage (ESP)*. The soil infiltration capacity will decrease if ESP increases. The soil with  $ESP > 15$  shall be improved by decreasing ESP, so that the soil is loose and soil infiltration capacity will increase.

#### 2.4.5 Draining from irrigation system

**Groundwater:** It is very necessary to build the natural earthen draining scheme. The groundwater which possibly emerges upwards might cause the soil wet and be accumulated with the salt. The rice crop will not be impacted by the groundwater if the groundwater is not salty. However, the understanding on the height of the groundwater in the proposed scheme is very vital. Usually, in a short period prior to the rainy season, the height of the groundwater is low; in the recent end of rainy season, the height of the groundwater is very high. The height of the groundwater is predicted to be likely to increase 1 meter higher than its normal height.

**Flood:** The information on flood, its source, and target location for irrigation system should be collected. For the small scale irrigation scheme, the followings are defined:

- Most Frequently flooded : Many times per year
- Frequently flooded : One time per 2 or 3 years
- Non-Frequently flooded : Less than 1 time per 5 years
- Rarely flooded : Less than 1 time per 20 years

In any cases, the flood size calculation of the project is essential.

### 2.5 Agriculture

The awareness of the existing agricultural process in the proposed irrigation system is helpful for preparation on project information, the comparison with the

new project, and the analysis on the impacts of the project post to the construction. All the agricultural activities are always conducted by both male and female farmers, so all the discussions shall be taken part by the farmers from both sexes.

### **2.5.1 Command area**

The benefits of the proposed project and the impacts on the land of the farmers who are the effected people shall be understood through the information on irrigated paddy fields. It is very important that the farmer shall acknowledge their land boundaries, so that it will be easy to process the system and to organize the water using farmer community. If the community has disputes on the land in the system, it will adversely impact on the process of the project, and it is likely to bring failure for the project.

### **2.5.2 Growing season in current situation**

In Cambodia, agricultural activities are taken place based on the seasons which are called *Growing Season*. The agricultural activities of Cambodia farmers include rice growing and farming. The growing season varies by the rainfall and the flood of Mekong River. In some areas, the *rice growing season* is in rainy season, but in some areas, the *rice growing season* in the dry season, while in other areas, the rice farming activity is carried out both in the dry season and the rainy season.

### **2.5.3 Constraints in agricultural process**

Unless there is specific solution to the present challenges facing the irrigation system rehabilitation project like pests, diseases, lack of labor and fertilizers, and agricultural extension, etc., these problems will persist following the completion of this mentioned rehabilitation project. In such case, these should be consideration of these issues raised here in order that solutions could be explored and incorporated in the project proposal.

### **2.5.4 Marketing**

The nearby market is sometimes not suitable for sale of crops the farmers harvest from this planned irrigation system. Thus, the bigger one is needed, for example, wholesale buyers from a bigger market. If there is any irrigation system which already has market, we shall ask for information because it is helpful for our project. The market price is the core information that we have to know to fix competitive price for our agricultural products.

### **2.5.5 Proposed Cropping Pattern**

The determination of the planed growing season is related not only the farming factor but also related to the essence of the agricultural products from irrigation and rainfall, and the reasons for household's food security. The determination of the growing season is mainly focused on the increase of the farmer's income. Hence, the discussion should be made with the farmers to help them to make proper growing season plan to the proposed system. A technician

should have good knowledge about growing period in a certain month. During the planting period, the technician shall take about 1 month of the end of dry season as reserve for channel or various construction reparations in the system. The discussion about the manpower for the busiest season is very important. In some community, it might be shortage of manpower in the season needing irrigation for various reasons such as abundance of the old or the young, etc., which is the cause of manpower shortage in the busiest season.

## 2.6 Irrigation Water Requirement (IR)

*The irrigation water requirement<sup>4</sup> is the differences between the crop water requirements<sup>5</sup> and the precipitation efficiency<sup>6</sup>.*

### 2.6.1 Crop Water Requirement (CR)

The amount of water needed for crops depends heavily on:

1. Climate: For example, in the area with hot climate, the quantity of the crop water requirement per day is larger than in the area with cool climate.
2. Types of plant: A plant such as rice or sugarcane needs higher amount of water than bean.
3. Growth stage: A plant in its full growing stage needs higher amount of water than the newly-grown one.

Table 2: Estimation of Crop Water Requirement/season

No.	Plant	Water Need (mm/season)
1	banana	1200-2200

<sup>4</sup> *The irrigation water requirement* is the quantity of the water expressed in millimeter needed for irrigation to the rice or other crops.

<sup>5</sup> *The crop water requirements* is the quantity of the water expressed in millimeter that the plant need for its growth.

<sup>6</sup> *The precipitation efficiency* is the quantity of the rainfall expressed in millimeter that falls over the plant and percolates into the root level and is absorbed by the plant for its growth.

2	bean	300-500
3	cabbage	350-500
4	hesperidium	900-1200
5	cotton	700-1300
6	corn	500-800
7	onion	350-550
8	peanut	500-700
9	pea	350-500
10	pepper	600-900
11	white potato	500-700
12	rice	450-700
13	soybean	450-700
14	sugarcane	1500-2500
15	sunflower	600-1000
16	tomato	400-800

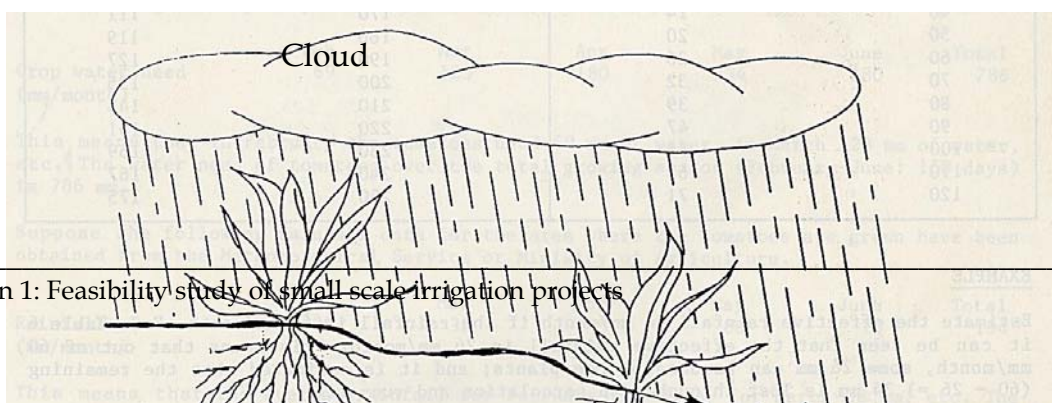
Now, come up with the calculation of total crop water requirements during the whole *growing season* (taking into account water loss by *evaporation, etc.*). For rice, the *Crop water requirement (CR)* might be calculated for 1 day. Thus, we just later need to know the total irrigation area in each month. For rice, the water need should count from the sowing, soil preparation, transplant in second, third, fourth, and fifth month until the time for harvest.

Table 3: Crop Water Requirement

Growing Season	Stage	Coefficient	CR (mm)
1 <sup>st</sup> month	seedling	0.074	54
2 <sup>nd</sup> month	soil preparation and rice transplant	0.29	200
3 <sup>rd</sup> month	growth	0.22	160
4 <sup>th</sup> month	growth	0.22	160
5 <sup>th</sup> month	growth	0.15	100
5 <sup>th</sup> month	harvesting	0.037	26

For other crops, the calculation of irrigation water requirement in the phase of project feasibility study and detailed project design from the seedling until the harvesting.

**Effective Rainfall ( $P_e$ ):** If there is not any rain, all the crop water requirements will be supplied through the irrigation. If there is some rain, but not enough for the water need of the plant, the additional water will be supplied through the irrigation in any way that the precipitation and irrigation shall be enough for the water need of the plant. This is called *supplement irrigation* which is defined as the quantity of water irrigation supplement or additional to the precipitation. Some part of the precipitation is percolated deeply under the root layer of the plant and other part is run off on the surface to far distance, which is called runoff (see figure 1). The deep percolation and the runoff go beyond the use of the plants. Or we can say that some part of the precipitation is inefficient. The rest precipitation is thus stored in the root layer, which is then used by the plant. This part of precipitation is called *Effective Rainfall*.



Rain

Root layer

Figure 1: Part of Rainwater Lose by Deep Percolation and Surface Runoff

Table 4: Precipitation (P) and Effective Rainfall (Pe) Measured in mm/month

$P_r$	$P_e$	$P_r$	$P_e$
0	0	130	79
10	0	140	87
20	2	150	95
30	8	160	103
40	14	170	111
50	20	180	119
60	26	190	127
70	32	200	135
80	39	210	143
90	47	220	151
100	55	230	159
110	63	240	167
120	71	250	175

**Irrigation Water Requirement:** For wet rice, Effective rainfall is subtracted from Irrigation water requirement of the rice. In dry season, no rainfall is expected.

$$IR = CR - P_e$$

Formula (1)

## 2.6.2 Irrigation efficiency

The general *irrigation efficiency* of the irrigation system in Cambodia, if including the source of water and paddies to be irrigated, is approximately from 40% to 50% only.

## 2.6.3 Irrigation Water Requirement including the amount of water lost

The total irrigation water requirement requirement ( $IR_{total}$ ) within each month is gained by dividing the irrigation water requirement in that month by the general irrigation efficiency of the system. The irrigation water requirement is measured in mm/month.

$$IR_{total} = \frac{IR}{I_e} \quad \text{Formula 2} \quad (2)$$

Irrigation water requirement in m<sup>3</sup>/month/hectare:

$$IR_{(m^3)} = IR_{(mm)} \times A \times 10 \quad \text{Formula 3} \quad (3)$$

## 2.6.4 Equivalent Water Needs of the Project

Besides irrigation, the project can also produce water for household consumption and animals. Once the source of water for the project is thoroughly studied, the actual need for water for the present and the predicted need for water shall be estimated after the renovation and construction of the system from which water stored in the upper or lower section will be pumped or discharged. If the project runs into a major stream, a number of discharges called *environmental flows*<sup>7</sup> should be reserved for supply of the dam and the biodiversity system of the water source.

## 2.7 Surface Water Resources

Study the source of surface water for the project in order to identify the potential of projected irrigation system. The water quality shall be especially examined to see whether it is suitable for rice crops.

### 2.7.1 Water quality

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<sup>7</sup> Environmental discharge means the water discharge stored in the reservoir or whose 20% amount of the project's total discharge is drained into the stream in order to feed the biodiversity and fish.

An important parameter in checking the quality of water is the amount of salt in the water like the level of *sodium, chloride, and especially boron*. Irrigation water containing many of such compounds is not good for the growth of rice or crops and even destroys the soil's structure.

**Conductivity<sup>8</sup>:** Electrical Conductivity of Water ( $EC_W$ ) can be measured by a device called *Conductivity Meter*.

Table 5: Water Conductivity and Reaction of Crops

$EC_W$ (dS/m)	Crops' reaction
< 1	Suitable for most crops
1 - 3	Unsuitable for perishable crops
> 3	Unsuitable for most crops

**Chemical Analysis of Water:** To analyze water chemicals, samples from the location of the project are required. These samples have to be kept in plastic bottles of 1-liter capacity and each bottle must be labeled with details of location, name of river or stream, date and time, and name of these samples collector.

**Sediment:** Sediments that settle at the bottom of the dam, stream or canal caused by irrigation must be drained, which is one part of regular irrigation system maintenance program. Logging and disordered land clearing within the watershed are all signs leading to excessive deposits of sediments eroded by the flow of rain water which brings sediments to the bottom of the dam or stream.

**Float Vegetation:** Gather information of pieces of wood or litter that may be brought along by flowing water and that may collide with or settle on the construction, thus affecting or blocking discharge which may cause serious destruction to the whole system.

### 2.7.2 Channel Characteristics

Studying the characteristic of the river/stream which is the source of water for irrigation system is important in organizing the system in order to get water for use and irrigation need. What we should be aware of are the discharge of the stream, the minimum flood discharge of the stream, and the flood history of the stream.

### 2.7.3 Discharge measured during the field visit to the project

The discharge of the stream may be measured during the project's field visit by measuring the water flow where base of water flow is known. Floats are used to measure the water flow where the distance from one base to another of the stream is known. Choose a place at the stream in order to measure the correct speed of water flow  $V_s$ . Measure the cross section of two streams which have to be at least 10 meters

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<sup>8</sup> Conductivity literally means the transmission in Khmer language (for example, electricity transmission of any object)

away from one another and then drift the floats to the surface of the water, starting from first point to the second one where their cross sections are known. Do this as many times as possible in order to get satisfactory result. It should be noted that floats can be pieces of cork or other light materials that can be easily seen but resistant to wind. To measure the discharge, the following steps are to be followed:  
 Step 1 : Find the average duration the float travels from the 1<sup>st</sup> point to the 2<sup>nd</sup> point.

**Floating of suspended particles:**

Frequency of floats	1	2	3	4	5	6	7	8	9
Travel speed: t (s)	68.26	67.48	48.42	42.67	59.26	51.41	72.94	55.72	92.46

**Find out average term:**

$$t = \frac{68.2 + 67.48 + 59.26 + 72.94 + 55.72}{5} = 64.72 \text{ minutes}$$

Step 2: Calculate mean velocity

$$V_s = \frac{10m}{64.72} = 0.15m/s$$

$$V_{mean} = V_s \times 0.75 = 0.15 \times 0.75 = 0.11m/s$$

Step 3: Calculate average base of water flow surface (A)

**Base of point 1**

Length (m)	0	1	2	3	4	5	6	7	8	9	9.8
Depth from water surface to streambed (m)	0	0.56	0.58	0.54	0.47	0.34	0.22	0.16	0.16	0.21	0

$$A_1 = 3.19m^2$$

**Base of point 2**

Length (m)	0	1	2	3	4	5	6	7	8	9	10
Depth from water surface to streambed (m)	0	0.51	0.55	0.47	0.53	0.21	0.22	0.23	0.28	0.26	0

$$A_2 = 2.77m^2$$

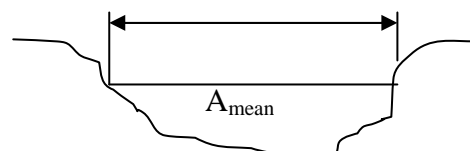
$$\text{Mean base of water flow surface: } A_{mean} = \frac{A_1 + A_2}{2} = 2.98m^2$$

Following formulae are used to calculate the discharge:

$$Q_{visit} = A \times V$$

Formula (4)

b



Hence, the discharge measured during project visit is  $Q = A_{\text{mean}} \times V_{\text{mean}} = 2.98 \times 0.11 = 0.33 \text{ m}^3/\text{s} = 330 \text{ l/s}$  ¶

If the discharge is measured in million cubic meter/month, it should be calculated based on Formula 5 below:

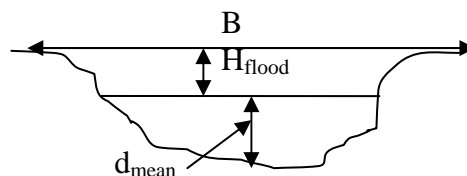
$$Q_{\text{visit}} = A \times V \times 2.6 \quad \text{Discharge measured in million m}^3/\text{month} \quad \text{Formula (5)}$$

If velocity head is measured by current meter, the meter is to be placed as high as 0,4m above the streambed. In such case, F coefficient is not necessarily applied.

### 2.7.4 Flood discharge

The prediction of flood discharge is done based on the observation of the previous flood water marks left along the stream bank. The formula for flood discharge prediction is written as follows:

$$Q_{\text{flood}} = B \times (H_{\text{flood}} + d_{\text{mean}}) \times V_{\text{flood}} \quad \text{Formula (6)}$$



### 2.7.5 Level of stream water

The data of minimum and maximum levels of the stream water should be collected to create the base level for comparison when designing the entire irrigation system and to find out this information, the advice from the local elderly having good knowledge about the history of the stream should be sought for. Following is necessary information to be aware of:

- Monthly level of stream (regular year);
- Fluctuation level of water in a month (year deemed irregular) and extraordinary rise of water and so on;
- Historical maximum rise of flood water in that stream

A technician should take some notes in the special case of minimum and maximum stream water in each month, in particular, the month in which the stream is historically inundated, thus causing damage to the property and to evaluate if there is a possibility for this development project, the plan for project development should include water measurement by current meter along both ends of the main structures in order to do the calculation of the discharge moving through the structures or canals. The stream level should be recorded and documented on a daily basis. The data on water level may be used for verification and is important to the system operation.

## **2.8 Groundwater Resources**

The significance of this section is to identify the potential source of underground water for small scale irrigation scheme. If the technician finds that there is a shortage of surface water in that area and that groundwater source could be replaced, thus detailed study on groundwater should be conducted in the stage of project study feasibility in order to make clarification of its quantity and quality to meet the needs for use and irrigation.

### **2.8.1 Well**

The collection of data on number of wells, well depth, water depth in the well and depth from the mouth of a well to the water source in case the well is yet to be dug for use, and the prediction of discharge of the well should be done. The map drawn should indicate the location of irrigation and domestic wells.

## **2.9 Balance of water source and needs**

This section studies about the efficiency of water sources in response to the need of the project for water consumption, including the amounts and consumption rate. If it is discovered that the need for water consumption is higher than the amount supplied by the water source, the area for irrigation should be rearranged especially during the poor rainfall season. The supply of stream water in the rainy season is mostly higher than the need for irrigation, which is quite different from the dry season that there is a paucity of irrigation water. Therefore, it is of vital importance to construct a reservoir to hold surplus amount of water from the rainy season for use in the rainy season.

## **2.10 Irrigation infrastructure**

To meet the irrigation water requirement distributed from various sources of water, following methods should be applied:

- Structure built to divert the gravity<sup>6</sup> water such as overflow structure and sluice gate structure etc.
- Pumping machine, trough-shaped bailing instrument, and waterwheel etc.

It is shown based on the practices that in case of the irrigation need of small-scale irrigation scheme with the capacity to irrigate an area of 100 hectares or below, it is unlikely that the discharge is above 200 liters/minute. The head structure of canal head and irrigation canal and water depth should be in excess of 0,50m.

### **2.10.1 Location of water diversion structure for irrigation**

To reduce any possible damage to and wear and tear of the structures caused by water current, a gravity diversion structure should be built at the less slopy and straight area of the stream bed. Also, the stream bank and bed should be that ground with most clay mixture.

### **2.10.2 Gravity diversion structure**

If the water source is a stream, the diversion structure may be overflow or intercepting structures with a sluice gate. If it is an overflow structure, a suitable sluice gate is installed to the overflow structure to carry away silts in the bed deposited in front of the structure. However, the level of overflow structure should be carefully determined to prevent the flooding of upstream stream bank. The structure built at the head of canal may be that made of circular concrete pipe or side culvert (box culvert) with a sluice gate to control the flow of water.

### **2.11 Water pumping for irrigation**

For some irrigation systems, gravity irrigation would not reach all areas; hence, water pump is needed to pump water from main canal to irrigate the highland rice paddies. In such case, a small water pump may be used to drain water from the canal or stream with low bank. 2.5 kW pump may be used to pump water at the level of 10m and discharge of approximately 40m<sup>3</sup>/hour or to do the pumping 6 hours/day to irrigate 3 ha. of land.

### **2.12. Water Storage**

The irrigation water requirement may range from 5,000m<sup>3</sup>/ha. to 10,000m<sup>3</sup>/ha. or higher. Whether small or large basin, the establishment of earthen dam and construction of water releasing and irrigation structure is always expensive, thus, it should be thoroughly studied, taking into consideration the economic value.

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<sup>6</sup> Gravity refers to the movement of water from one place to another by earth gravity.

## **2.13 Economic indicators**

The comparison between pre-project situation and post-project estimation provides an indicator of economic value and benefits of the project for the beneficiaries. Yet, the estimation is not an easy task and post-project benefits should not be overestimated.

### **2.13.1 Current situation (pre-project)**

The current rice yield is an average of the yields in recent years including years with good and poor yields. The present outcome should not only include income from farming and livestock raising, but also inclusive of income earned from other activities, which is likely the result from the proposed project. Income from the production of rice or crops and livestock raising is to be entered in the record of the feasibility study of the project.

### **2.13.2 Proposed Situation**

The prediction of post-project rice yield should be done on well-grounded basis and compared to any of other irrigation project situated near that proposed project. If new crops are involved, the costs/ha should be calculated in accordance with the practices of the nearby irrigation project. As far as livestock raising and other activities are concerned, the income should be assumed like that in the current situation.

### **2.13.3 Benefits from the project**

The comparison of the current income and that of post-project constitutes an economic indicator of the project. Identification of benefit per hectare from the project (benefit/ha.) enables us to evaluate the proposed irrigation scheme against the strategic target of the Royal Government towards the decision on the development.

## **2.14 Project development and operation**

In this section, it is necessary to explore the farmers' interest in the development and process of the proposed project and to collect their feedbacks on the participation and to accept the development plan.

### **2.14.1 Farmer Water User Community (FWUC)**

The Ministry of Water Resources and Meteorology has introduced a policy to ensure the sustainable development of irrigation sector, that is, PIMD through which a Farmer Water User Community was established at each irrigation system in order that those systems are well operated and maintained. The irrigation projects do of

course need active participation from all beneficiaries and concerned institutions. Therefore, it should be well aware, during the stage of project feasibility study, of the structure of existing community, development partner of the community and make the structure of Farmer Water User Community in place before the project implementation. The organization of Farmer Water User Community should follow the PIMD and is the duty of the ministry or provincial/municipal departments of water resources and meteorology, the implementing agency.

#### **2.14.2 Community's contributions to small-scale irrigation scheme construction**

Some areas are in need of irrigation system which is out of the ability of the farmers to make construction on their own. So, if there is a proposed project, farmers could share some contributions to their actual ability, particularly through the Farmer Water User Community, in order to build a certain infrastructure of irrigation system in their irrigation system. In this regard, a technician should provide them with technical support, cost estimates and have thorough discussion with them about how to participate.

#### **2.14.3 Operation and maintenance of small-scale irrigation scheme**

The Farmer Water User Community has the role to direct the farmers who are the project's beneficiary in the sustainable operation and maintenance of the irrigation scheme. Normally, FWUC is held liable for small repairs made on a regular basis and according to its requirements and if necessary, FWUC may ask for technical support from the concerned provincial/municipal specialized department.

#### **2.14.4 FWUC Training**

A specific training has to be provided for those farmers who lack the knowledge of *agricultural irrigation* to ensure the realization of the project goals. Moreover, if noticed of the poor management of the system by FWUC due to lack of knowledge about irrigation, the training program should be established, focusing primarily on the techniques in irrigation, water management and operation of FWUC etc.