MINISTRY OF ELECTRICITY, DAMS, IRRIGATION & WATER RESOURCES (MEDIWR)

THE REPUBLIC OF SOUTH SUDAN

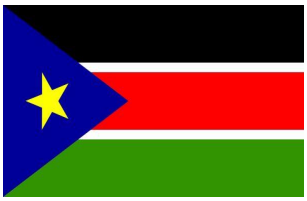
PROJECT FOR IRRIGATION DEVELOPMENT MASTER PLAN (IDMP) IN THE REPUBLIC OF SOUTH SUDAN

FINAL REPORT (ANNEXES, PART III)

DECEMBER 2015

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

SANYU CONSULTANTS INC.
ORIENTAL CONSULTANTS GLOBAL CO., LTD.
KOKUSAI KOGYO CO., LTD.



THE REPUBLIC OF SOUTH SUDAN

MINISTRY OF ELECTRICITY, DAMS, IRRIGATION & WATER RESOURCES

WATER SECTOR

IRRIGATION DEVELOPMENT MASTER PLAN

(FINAL REPORT)

ANNEX 9: IMPLEMENTATION PLANS FOR PRIORITY PROJECTS

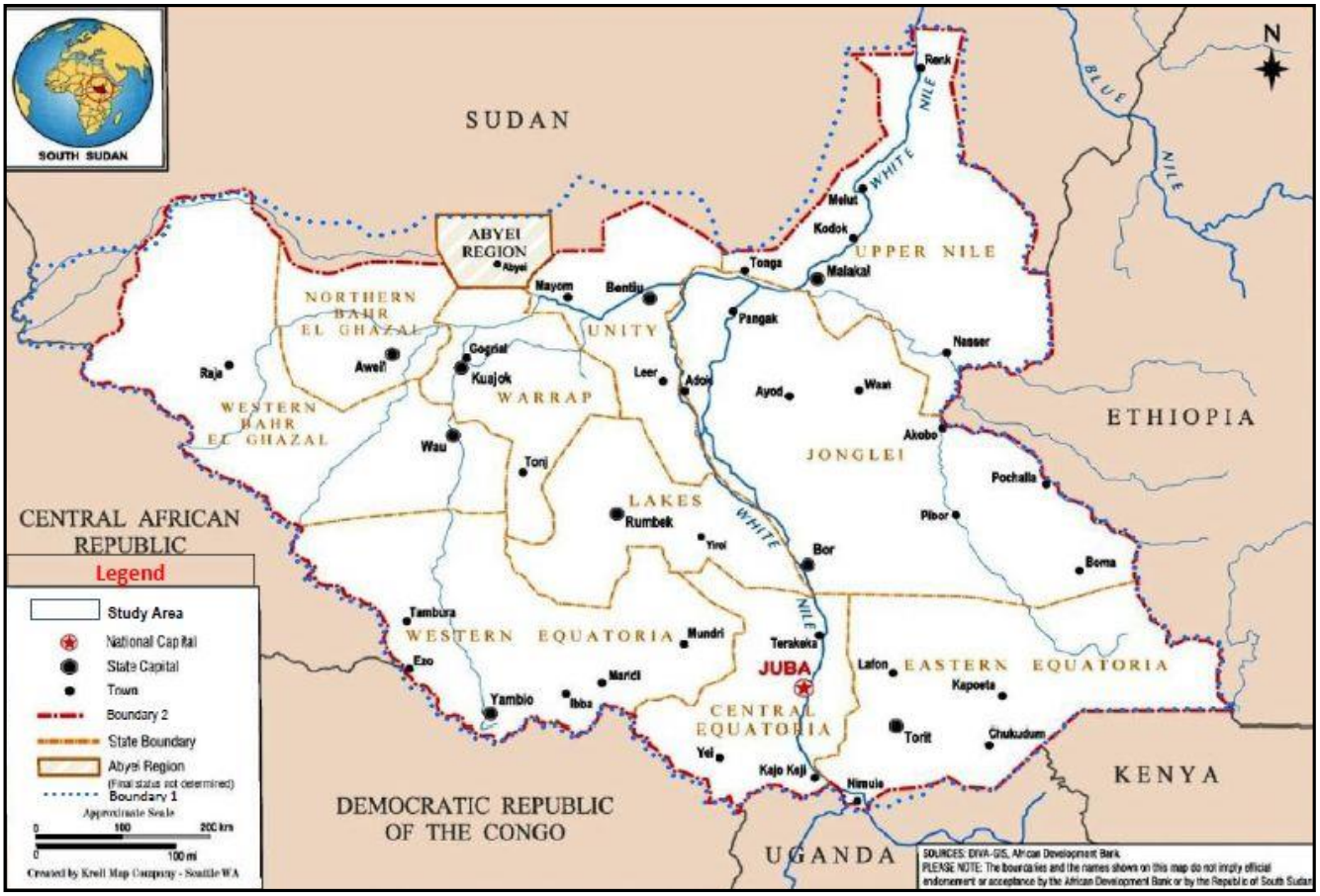
9-1: Pre-Feasibility Study of Wau Irrigation Scheme

NOVEMBER 2015

THE PROJECT FOR IRRIGATION DEVELOPMENT MASTER PLAN IN THE REPUBLIC OF SOUTH SUDAN (RSS)

LOCATION MAP

Map of the Republic of South Sudan



Location Map: Adopted from African Development Bank

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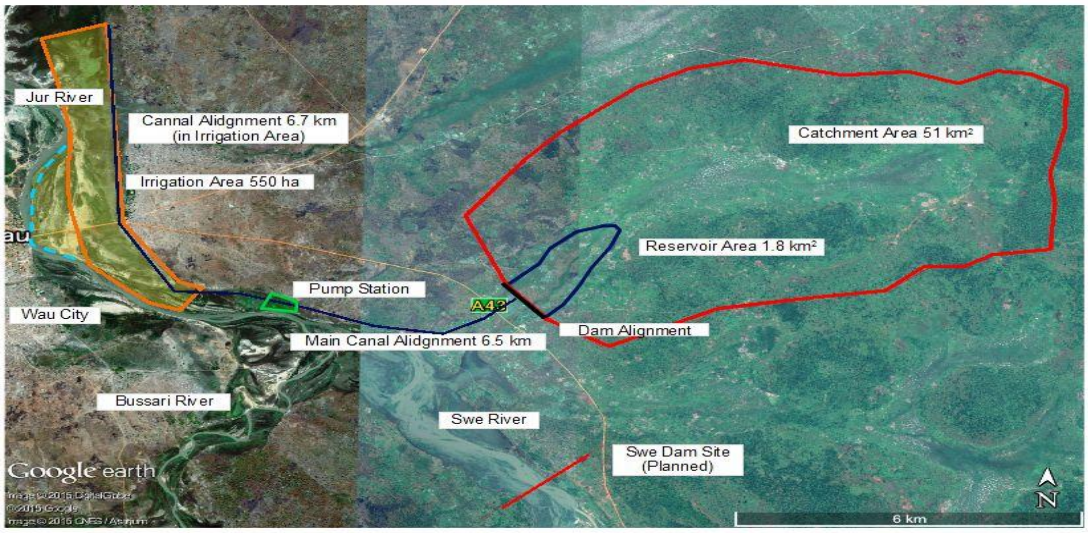
PART 1 PRESENT SITUATION OF THE PROJECT AREA

CHAPTER 1 SITE PROFILE

1.1 Location

Wau irrigation scheme site is located on the Eastern bank of River Jur very near from Wau city, where there is high demand for agricultural produces. There are three (3) big markets and one middle-size market[1] in Wau city; 1) Central Market, 2) Jou Market, 3) Sug[2] Hagar and 4) Sug Salam.

Land development in Wau and Aweil projects, was supported by UNDP and FAO, in 1974. It was supposed to be applied to Wau after Aweil, however, no activities have been carried out, because Aweil scheme has not worked properly, and the trial paddy cultivation by MAFCRD (branch office) in 2007 resulted in low yield.



Source: IDMP TT

Figure 1.1.1. Location of Project Area

1.2 Beneficiary Area and Communities

There are three (3) communities residing in the project area namely:

1. Jur (Luo) community located in the proposed dam site;
2. Eastern bank community located in the southern part of Scheme area; and
3. Koum community located in northern part of Scheme area.

Eastern bank community and Kuom community are belonged to Wau municipality. The irrigable area is located in bank of the Jur River, so the land belongs to the government, while the proposed dam site is managed by the community.

[1] The market information was collected in the site visit of phase2.
[2] ñSugòmeans market in local language.

1.3 Basic Community Profile

(1) Basic information about the communities

Table 1.3.1 shows the basic information of the communities, such as administrative organization, population, the number of the households, tribe and the means of livelihoods.

Table 1.3.1. Basic Information of the Communities

Name of community		Jur (Luo)		Eastern Bank of Wau Municipality[*1]	
				Eastern bank	Kuom
Key information (Administrative organization and population etc.)					
	State[*1*2]	WBGs		WBGs	
	County	Jur River County		Wau Municipality	
	Payam	Roc Roc Dong		Eastern Bank Office	
	Boma	Kuanya		-	
	Population	3,000		7,500	6,800
	No. of HHs	n/a		10,000	
	No. of HHs/peoples engaged in agriculture[*3]	90% of total HHs		8,000	
	Name of Tribe	Jur/Luo		Jur/Luo Dinka and Bongo	
Means of the Livelihoods		✔[*4]	Ranking/%[*5]	✔[*4]	Ranking/%[*5]
	Grazing	✔	n/a	✔	n/a
	Farming	✔	90%	✔	2
	Fishery	✔	10%	✔	1
	Hunting	✔	5%	✔	n/a
	Remittance	✔	20%	✔	n/a
	Full-time/Permanent Wage Labour	✔	1%	✔	n/a
	Part-time/Temporally Wage Labour	✔	2%	✔	n/a
	Business owner	✔	1%	✔	n/a
Livestock		✔[*4]	Ranking[*6]	✔[*4]	Ranking[*6]
	Cattle	✔	n/a	✔	n/a
	Goat	✔	n/a	✔	n/a
	Sheep	✔	n/a	✔	n/a
	Chicken	✔	n/a	✔	n/a

*1 The results of IEE study was also referred.
*2 CES stands for Central Equatoria State and WBGs stands for Western Bahr el Ghazal State.
*3 The number with parentheses shows the number of people engaged in agriculture.
*4 Check mark (✔) is put to the option found in community.
*5 In case it was answered as percentage (in Luo community), it was estimated considering the HHs which have multiple means of livelihoods.
*6 Ranking per number

The population is approximately 3,000 persons, 7,500 persons and 6,800 persons in Luo, Eastern bank and Kuom respectively. Most of the communities have farming as the main means of their livelihoods, and fishing is next major livelihood. According to the IEE study, certain brick factories are also operated in the irrigable area in dry season.

Farmers in the community have an experience of irrigated farming along river using buckets in dry season cultivating tomato, egg plant and okra. They are currently cultivating cereals such as maize, millet, sorghum and rice and cash crops such as sesame and vegetables. Their production is sometimes not enough for their own consumption because their farmland is too small.

According to the above situation, assurance of crop production for farmers themselves would have to be considered. Also cash generation by cultivating cash crops including vegetables should be brought in the farming plan.

(2) Basic agricultural status

1) Average farming land per household

Average farming land per household in Luo community counted for 8 ï 10 feddan/HH, which value was 5 ï 20 times higher than that in Jebel Lado. The data in Eastern bank of Wau Municipality was not available.

2) Produced crops

Following questions are asked to the heads of communities regarding each crop in the questionnaire;

Q1: Is the crop cultivated in your community?
Q2: Ranking of the crop as per production volume.
Q3: Production of the crop is enough for self-consumption?
Q4: Is the produced crop for selling, consumption or both?
Q5: Which is the priority purpose of the produced crop, selling or consumption?
Q6: How much was farm gate price of the crop?
Q7: What market was the crop sold to?

Table 1.3.2 shows the produced crops with their information in the communities. In Luo community, sorghum, maize and ground nut are most popular and those are produced mainly for self-consumption and also for selling; those crop production are enough for their self-consumption. While Eastern Bank of Wau Municipality answered those are not enough.

Millet is sufficiently cultivated in Eastern Bank of Wau Municipality, while production in Luo is not enough.

Sesame is also popular in the project area and cultivated mainly for selling. Farm gate price of sesame is much higher than that of cereals. The communities answered production of sesame is not enough, which means that sesame is in high demand for generating cash and also for their consumption.

Cassava is produced mainly for self-consumption in the communities. Even its production is relatively lower than sorghum, maize, ground nut and sesame; it is one of staple food for the community members.

Wheat, while, is not cultivated in any communities probably because of inadequacy of the climate condition.

Rice is also cultivated in this area; but its production is much lower than other crops.

Major vegetables are tomato, okra and Jewôs mallow. Half of the vegetables produced in Wau are for selling and the others are self-consumption.

Table 1.3.2 Produced Crops

	Sorghum							Maize							Ground nut						
	Q1*2	Q2	Q3*3	Q4*4	Q5*5	Q6	Q7	Q1*2	Q2	Q3*3	Q4*4	Q5*5	Q6	Q7	Q1*2	Q2	Q3*3	Q4*4	Q5*5	Q6	Q7
Luo	✔	1	Y	B	C	250 SSP/50kg	Juw	✔	2	N	B	C	150 SSP/50kg	Juw	✔	1	Y	B	C	292 SSP/50kg	Juw
Eastern Bank*1	✔	n/a	N	n/a	n/a	n/a	n/a	✔	n/a	N	n/a	n/a	n/a	n/a	✔	n/a	N	n/a	n/a	n/a	n/a
	Millet							Sesame							Cassava						
	Q1*2	Q2	Q3*3	Q4*4	Q5*5	Q6	Q7	Q1*2	Q2	Q3*3	Q4*4	Q5*5	Q6	Q7	Q1*2	Q2	Q3*3	Q4*4	Q5*5	Q6	Q7
Luo			N					✔	3	N	S	S	n/a	Juw	✔	3	N	C	C		
Eastern Bank*1	✔	n/a	N	n/a	n/a	n/a	n/a	✔	n/a	N	n/a	n/a	n/a	n/a	✔	n/a	N	n/a	n/a	n/a	n/a
	Wheat							Rice							Tomato						
	Q1*2	Q2	Q3*3	Q4*4	Q5*5	Q6	Q7	Q1*2	Q2	Q3*3	Q4*4	Q5*5	Q6	Q7	Q1*2	Q2	Q3*3	Q4*4	Q5*5	Q6	Q7
Luo			N					✔	5	N	C	C			✔	4	N	B	B	n/a	Juw
Eastern Bank*1			N					✔	n/a	N	n/a	n/a	n/a	n/a	✔	n/a	N	n/a	n/a	n/a	n/a
	Okra							Jew's mallow							Cow pea						
	Q1*2	Q2	Q3*3	Q4*4	Q5*5	Q6	Q7	Q1*2	Q2	Q3*3	Q4*4	Q5*5	Q6	Q7	Q1*2	Q2	Q3*3	Q4*4	Q5*5	Q6	Q7
Luo	✔	4	N	B	B	n/a	Juw	✔	4	N	B	B	n/a	Juw							
Eastern Bank*1	✔	n/a	N	n/a	n/a	n/a	n/a								✔	n/a	N	n/a	n/a	n/a	n/a
	Egg plant							Onion													
	Q1*2	Q2	Q3*3	Q4*4	Q5*5	Q6	Q7	Q1*2	Q2	Q3*3	Q4*4	Q5*5	Q6	Q7							
Luo																					
Eastern Bank*1	✔	n/a	N	n/a	n/a	n/a	n/a	✔	n/a	N	n/a	n/a	n/a	n/a							

*1 Eastern Bank is an abbreviation of "Eastern Bank of Wau Municipality.
*2 Check mark (✔) is put to crop cultivated in the community.
*3 If answer was "Yes", put "Y" and if it was "No", put "N".
*4 If answer was "Selling", put "S" , if it was "Consumption", put "C" and if it was "Both", put "B".
*5 If answer was "Selling", put "S", if it was "Consumption", put "C".

Source: IDMP-TT

3) Current farming calendar

Current farming operation calendars in Luo community are shown below; Information of East Bank of Wau Municipality was not available in the survey. Current farming operation calendars are almost same in the two (2) communities in Jebel Lado. Generally starting of farming operation in Luo (Wau) is a little bit later than in Jebel Lado because of timing of heavy rain.

Table 1.3.3 Current Farming Operation Calendar in Luo Community

Month			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
No	Crops	Rain												
1	**Sorghum**		×	○ ▲	○ ϕ ▲	▲	ϕ							×
2	**Maize**		×	○ ▲	ϕ ▲		□							×
3	**Groundnut**		×	○	▲		□							×
4	**Millet**													
5	**Sesame**		×	○	▲			□	□					×
6	**Cassava**					□ ○	□							
7	**Rice**				×				□					

〈Legend〉
Heavy Rain: Light Rain:
Land Preparation: × Seed sowing: ○Transplanting: △
Weeding: ▲ Fertilizer application: ■ Harvesting: □

4) Other information regarding farming Systems

i) Farming systems

All of the communities in Wau project area practice shifting cultivation, because of the influence from stranger or soil condition. In Eastern Bank of Wau Municipality, farmers have practiced crop rotation. They cultivate sorghum for 2 years, after that, they change it to ground nut or sesame.

ii) Experience of irrigated agriculture

The farmers in Luo and Eastern Bank of Wau Municipality have practiced irrigated agriculture along the river using buckets. The farmers in Eastern Bank of Wau Municipality cultivate vegetables such as tomato, egg plant and okra in dry season. Some of them think that irrigated agriculture is difficult in spite of their experiences. Therefore, it would be necessary to develop their understanding about irrigated agriculture.

iii) Use of agricultural inputs

Only farmers in Eastern Bank of Wau Municipality have experience of use of manure and pesticides.

iv) Constraints affecting agricultural production and income generation

All communities agreed that they have major constraints in RSS; flood, draught, birds/animals and insects. Especially, Eastern Bank of Wau Municipality answered the damage caused by flood is heavy there. In Luo, the road access to the market was raised as one of the issue farmers have.

v) Crops for irrigation scheme in future

Cash crops including vegetable are raised as the crops farmers in the community wish to cultivate in the irrigation scheme in future. All of the communities answered they are willing to accept the crop cultivation recommended by the government.

CHAPTER 2 NATURAL CONDITIONS

2.1 Topographical Survey

(1) Scope of works

For topographic survey, the following equipment was used:

- Total station (Sokkia set 510);
- Global positioning system (GPS) receiver (Sokkia GRX1 , Trimble 5800);
- Level and
- AutoCAD system (Autocad civil 3D).

Survey structure contains:

1) Dam site survey:

- Establishment of temporary benchmark (TBM)
- Longitudinal profile survey: in drawing profile use the Auto cad civil 3d and layout in (A3) paper (plan & profile in one sheet Scale: V=1/100, H=1/1,000)
- Cross-sectional Survey: any 100 m, width of section 200m, 15sections (scale: V=1/100, H=1/100)
- Plane Survey: area (1500*3300 m^2) create contour map by scale 1:4000

2) Canal route survey:

- Establishment of temporary benchmark (TBM)
- Longitudinal profile survey: in drawing profile use the Auto cad civil 3d and layout in (A3) paper (plan & profile in one sheet Scale: V=1/100, H=1/1,000)
- Cross-sectional Survey: any 200m, width of section 200m, 15sections (scale: V=1/100, H=1/10)
- Plane Survey: 4 area (200*200 m^2) create contour map by scale 1:4000

3) Command area survey:

- Establishment of temporary benchmark (TBM)
- Longitudinal profile survey: in drawing profile use the Auto cad civil 3d and layout in (A3) paper (plan & profile in one sheet Scale: V=1/100, H=1/1,000)
- Cross-sectional Survey: any 100m, width of section 200m, 15sections (scale: V=1/100, H=1/100)
- Plane Survey: area (6500*2000 m^2) create contour map by scale 1:4000

4) Pumping station survey:

- Establishment of temporary benchmark (TBM)
- Cross-sectional Survey: any 500m, width of section 500m, 15sections (scale: V=1/100, H=1/100)
- Plane Survey: area (500*300 m^2) create contour map by scale 1:4000

The survey area is described as below:

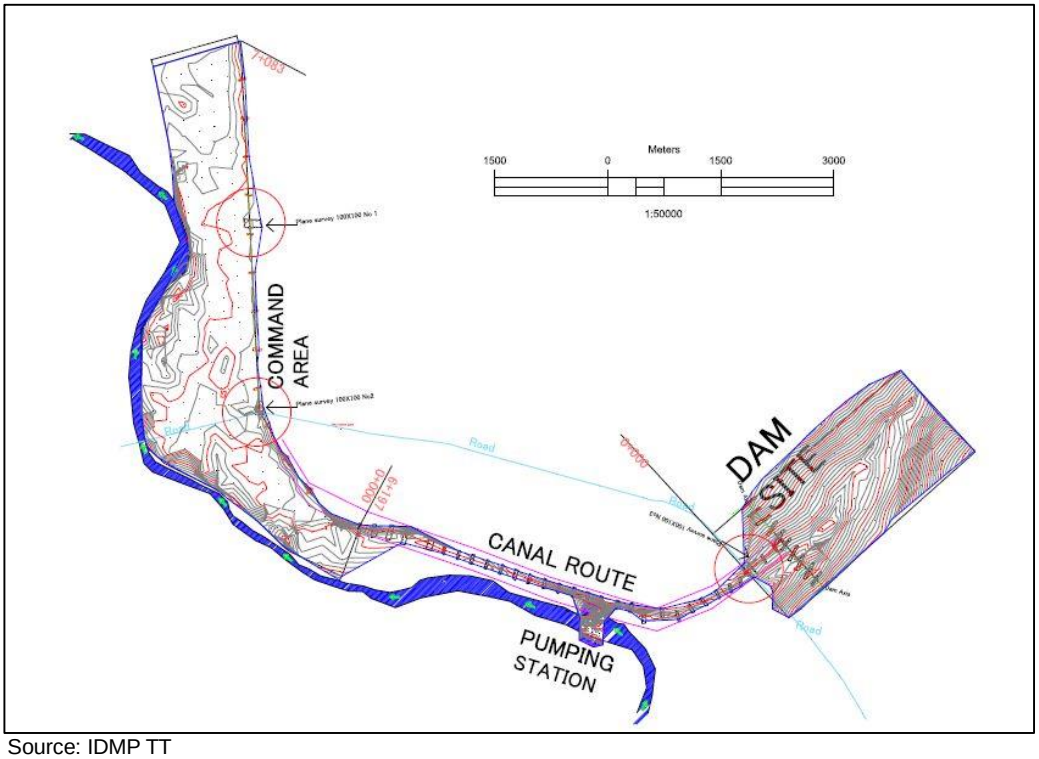
Source: IDMP TT

Figure 2.1.1 Overview of Survey Area

(2) Topographical profile

Topographic feature is drawn in Figure 2.1.2.

Command area is located beside Wau town, and has the feature of bare land without planting in the flood plain. The land is approximately flat and the land gradient toward R, Jur shows around 0.2%. Dam site is located 9.5km from Wau town. The land cover in the site is bushes and grasses. Pump station and canal line are located between the command area and dam site. There are trees, small communities, farms, etc. along the line.



Source: IDMP TT

Figure 2.1.2 Topographic Map

2.2 Geological Survey

(1) Scope of works

Geological survey and soil mechanical Investigation was made at the proposed project area in Wau by drilling seven (7) boreholes.

Scope of the works is as below: the works was carried out as follow:

1) Drilled 50m in total length for total six (7 No's) boreholes

- 11.0m (at borehole in the centre of the dam) numbered (G-DA-C-01) and 14.0m (at the second borehole in the centre of the dam) numbered (G-DA-C-02),
above two boreholes were drilled at the same location but different point cause of the follow reasons:

  1- The fieldwork commenced in borehole (G-DA-C-01) from 18/04 to 19/04/2015 at that time Drilled from 0.0 to 9.0m in soil and conducted SPT and two (2) permeability Test in soil.

  2- Very hard GNESS Rock from 9.0 to 11.0m conducted core barrel and carried out excelled core Recovery, borehole were consoled by consultant.

  3- consulted designed to conduct two more permeability below 9.0m.

  4- second borehole (G-DA-C-02) shifted just 3.0m from the first one and conducted blind drilling from 0.0 to 9.0m, conduct permeability test, and conducted the second test at depth 13.5m below ground level and finished the second borehole on 17/5/2015.

- 10m x 2 boreholes (at the right and the left abutment of the dam) numbered (G-DA-R) and (G-DA-L).
- 5m x 3 boreholes (on the canal alignment) numbers (G-CR-01), (G-CR-02) and (G-CR-03).

2) Permeability Test: 10 tests in total

- 4 tests x 1 borehole in borehole no. (G-DA-C) at depth 0-5m, 5-9m, 9-12m and 12-15m, in borehole at the dam site)
- 3 tests x 2 in boreholes no. (G-DA-R) and (G-DA-L) at 0-4m, 4-7m and 7-10m, in 10m-borehole at the dam site)

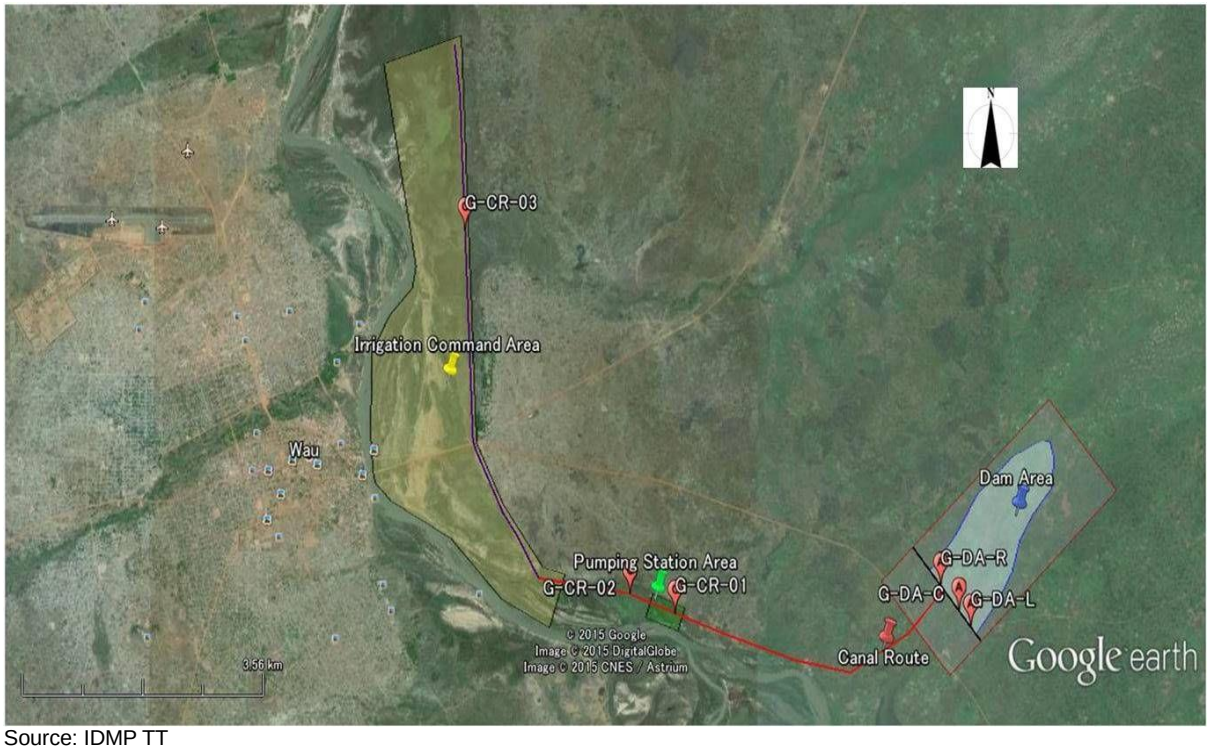
3) Standard Penetration Test (SPT): 50 tests in total

- 15 tests x 1 borehole (at 1 m interval in 15m-borehole at the dam site)
- 10 tests x 2 boreholes (at 1 m interval in 10m-borehole at the dam site)
- 5 tests x 3 boreholes (at 1 m interval in 5m-borehole on the canal alignment)

4) Laboratory Test: by 9 samples (2 samples x 3 boreholes at the dam site, 1 sample x 3 boreholes on the canal alignment)

- Grain size analysis
- Specific gravity
- Atterberg Limits (Liquid and Plastic Limits)

Locations of boreholes are shown in Figure 2.2.1.



Source: IDMP TT

Figure 2.2.1 Locations of Boreholes in the Survey area

(2) Geological profile

In the dam site, dense/ very dense layer such as sand, gravel and rock distributes below the depth of 6m at dam centre and right side. The soils classified to (SM) and (CL) are useful for dam embankment materials. In the canal line, clay or silt layer was covered on the ground surface and the subsurface soils are predominantly sand. According to N value, these soils are generally suitable for the foundation of structures.

G-DA-R & G-DA-L Samples

G-CR -01, G-CR-02, G-CR-03 Samples

Source: IDMP TT

Figure 2.2.2 Samples

2.3 Hydrology

Annual rainfall is about 1100mm, and annual river discharge of R. Jur is about 5100 MCM. In rainy season, irrigable area is flooded by water from the river.

In rainy season, irrigable area is flooded by water from Jur River. Flooded water should be controlled and cultivation period should be adjusted according to the flooding condition to avoid damage to cultivated crops. Provided that flooding can be controlled properly, it can be utilized for paddy cultivation, because paddy requires flooded condition up to maturing period.

In dry season, like Jebel Lado, high temperature continues. Hence, crops for dry season should be able to survive in high temperature, for instance, watermelon and okra, which are major vegetable cultivated in Wau[3].

Soil nutrient control is necessary in irrigable area in Wau Rice Scheme according to the chemical analysis result (Table 2.4.1). Especially phosphorus and Magnesium should be taken cared and modification of soil pH is essential. As long as soil management is implemented properly, rice and vegetables would be able to grow well.

2.4. Soil Investigation

(1) Methodology

Generally, there are two (2) ways to select survey points in certain area. The first way is just to choose points to cover the area equally, for instance by covering square mesh with certain distance and selecting the crossing as survey points. This way is applied in case no specific geological or topographic information is available. On the other hand, the second way is to select survey points according to the existing information regarding soil type distribution in the area, which is applicable only in case thereôs available information got on the ground. In case of Wau, the first way was applied, because there was no detailed information obtained on the ground.

Fig.2.4.1 shows the survey points planned in consultation with RSS-TT, and 6 points were determined as a result.

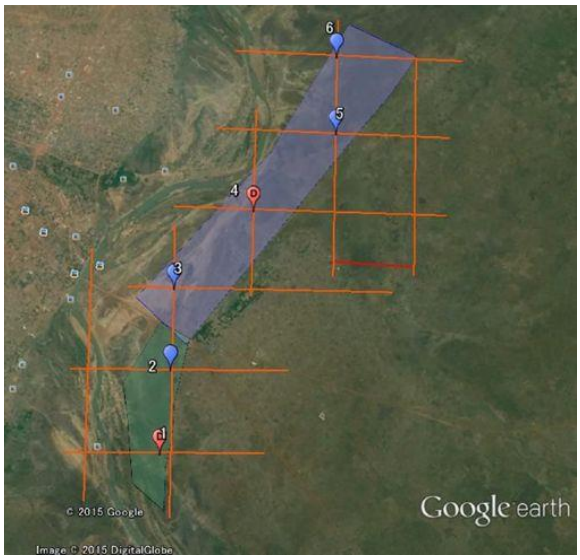


Figure 2.4.1 Soil Survey Points

* Blue points are for 50 cm depth cross section survey, and red ones are for 1 m depth.
* Distance of mesh covered over the command area is 1 km.

(2) Result of field observation (soil conditions)

Soil in the command area has whitish pale brown colour and its texture ranges mainly from Loam to Clay loam. There are several layers from the top up to 1m depth and each layer has clayish texture. Orange coloured mottles of oxidized iron were observed on the cross section (from top soil up to around 60 cm depth), which indicates the command area has been flooded and dried up repeatedly. Actually, the command area in Wau is flooded every rainy season. (See photo on the right), which means ground water level might be high in the command area but no ground water was observed up to 1m depth in dry season.

[3] Source; the site visit report of phase2

Regarding the matter related farmland consolidation, there was no gravels/stone from the top to the bottom of 1m depth but soil was very compacted from the top. In addition, there is no thick vegetation such as bushes.

Figure 2.4.2 Command Area (South Part) in Rainy Season

Figure 2.4.3 Land Scape in Command Area

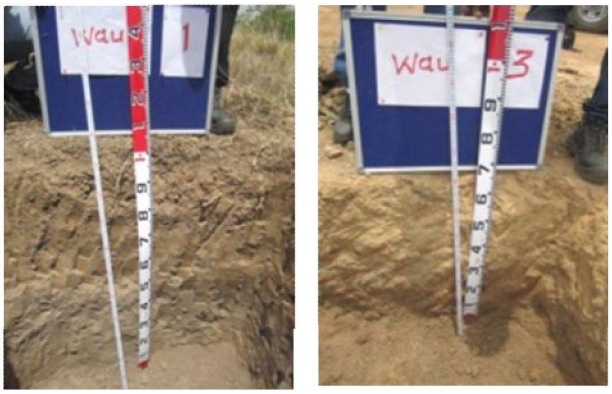


Figure 2.4.4 Soil Profile in Command area

Photo on the left shows the profile at No.1 and that on right shows that at No.3. Location of each point is shown in Fig.1 No.3 showed the lowest humus ratio among the points.

(3) Result of chemical analysis and consideration (soil chemistry)

Table 2.4.1 shows the results of chemical analysis. Humus ratio is fairly high, 2.3 % on average. Estimated CEC ranges from 7 to 16.9 me/100g. CEC value is not so low, but it seems there is still room for improvement, which should be taken care at actual practice. ;

Soil pH is considerably low ranging from 4.7 to 5.9 and its average was 5.2. Generally, pH 6 to 7 is appropriate for general crops, even though each crop has suitable pH range and some of crop such as tea tree and blueberry tend to prefer acid soil. Soil acidity will interfere with availability of some nutrient such as phosphorus and potassium and accelerate iron to be soluble.

Phosphorus content is severely low in the command area on the whole. It should be supplemented by fertilizer application. In addition, Magnesium content is relatively low, which result in the unbalanced base ratio. Generally, appropriate CaO/MgO is from 3 to 6 and MgO/K_2O is from 2 to 4. Calcium, Magnesium and Potassium are in relation with competition. Excessive amount of one element can regard othersôabsorption to crop.

Table 2.4.1 Chemical Analysis Results

	Average	Minimum value	Maximum value
Humus ratio (%)	2.3	0.8	3.5
CEC (me/100g) *1 *2	12.5	7	16.9
NO_3-N (mg/100g)	1.7	1.2	2.1
Fe_2O_3 (ppm)	5.8	2	13
P_2O_5 (mg/100g)	2.0	0	12
K_2O (mg/100g)	98.2	86	115
CaO (mg/100g)	168.7	67	257
MgO (mg/100g)	6.3	5	7
Mn (mg/100g)	2.8	1	5
pH	5.2	4.7	5.9
EC *3	0.0	0	0.06
Total N (%) *2	0.2	0.07	0.5
CN ratio *2	7.0	5.7	7.6
Base ratio			
CaO/MgO *2	19.0	9.5	29.5
MgO/K2O *2	0.1	0.1	0.1
CaO/K2O *2	2.8	1.3	4

Source: IDMP TT (Soil survey 2015)
*1 CEC is an abbreviation of Caption Exchange Capacity, which was estimated based on humus ratio.
*2 Estimated value.
*3 EC is an abbreviation of Electric conductivity.

CHAPTER 3 AGRICULTURE AND SOCIO-ECONOMIC

3.1 Methods of Agriculture and Socio-Eeconomic Survey

Agriculture and Socio-Economic Survey was conducted by interview with a questionnaire in the project areas. The three (3) related communities were targeted; namely 1) Wau Municipality, which is located southern part from the command area, the survey was conducted in villages under Block E; Nigoro, Abonybony and Eastern Bank. 2) Kuanya/Luo, which is located near from Dam site, the survey was conducted in Kuanya village, under Kuanya Boma, Rocroc-Dong Payam, Jur River county and 3) Payamet/Kuom, which is located in northern part from the command area, the survey was conducted in Kuom and Panamet villages under Kuom Boma, Marial Bari payam, Jur River county.

The survey aimed to take necessary data for making the farming plan and evaluating the priority projects from the viewpoints of socio-economic and marketing. The contents of the questionnaire consisted of 14 items, centralizing the related questions to the situation of farming and household.

The enumerators in pairs were going to hold two interviews a day, target interviewees counted 26 households. It is necessary to previously explain the survey method to the interviewees since the questions include private points, such as household income, expenditure, etc. Grasping the current situation of the target communities is indispensable for the planning of the priority projects. Hence, a preliminary workshop was held before the survey. Days of workshop and number of interviewees are given as below:

Days of Workshops : Middle of April, 2015
Number of interviewees : 26 persons (Breakdown is shown in the table below)

Table 3.1.1 Interviewees' Information

Community	Male	Female	Total
Wau Municipality	9	0	9
Kuanya/Luo	7	1	8
Panamet/Kuom	7	2	9
Total	23	3	26

Source: IDMP TT (Socio-economic survey, 2015)

The contents of the questionnaire are divided into the 14 items; 1) Background of household, 2) Land holding and land tenure, 3) Inventory of farm machinery and hiring cost of farming power, 4) Crop production and farming practices, 5) Income from other crops in home garden, livestock and other products, 6) Wages/ salary, leasing, business and other income, 7) Living expenses, 8) Present farming situation, 9) Selling of agriculture products, 10) Existing farmers' group and farmersôorganization, 11) Irrigation service charge / activity of WUA or WG, 12) Loan, 13) Agricultural services / agricultural activities, and 14) Gender/ roles and responsibilities.

In terms of the social sector, questions, such as land tenure, gender issues/roles, drinking water, cooking fuel, etc., were set in the questionnaire, referring *Handbook on Community Engagement,* April 2012, South Sudan Law Society. Though there is enough development potential of the land use, some issues, such as dealing of community land, land utilizing division of tribes, etc., have to be treated carefully.

From the viewpoints of making the planting plan, the enumerators asked the interviewees about their views for future crops based on the existing planting model. In addition to the question, the enumerators also asked their intention of the crop selection in order to grasp the needs of an irrigation project and reflect to the farming plan. Also, as for the introduction of fertilizer, concerned questions

were made based on the results of the sales conditions survey in Juba to make the agriculture input plan for the priority projects in accordance with the actual conditions.

3.2 Socio-Economic Indicators

(1) Household members

Table 3.2.1 shows the average household members with the number of children under 14 years old in Wau. The total average number of family members is 9.4 persons/ household.

Table 3.2.1 Average Household Members

Community	Adults equal/above 14			Children under 14			Total
	Male	Female	Sub Total	Male	Female	Sub Total	
Wau Municipality	1.7	1.3	3.0	1.8	2.0	3.8	6.8
Kuanya/Luo	2.6	2.9	5.5	3.0	2.9	5.9	11.4
Panamet/Kuom	2.4	2.2	4.7	2.3	3.2	5.6	10.2
Total	2.2	2.1	4.3	2.3	2.7	5.0	9.4

Source: IDMP TT (Socio-economic survey, 2015)

Intervieweesô education experiences were also asked in the questionnaire. Ten (10) answers to this question were got. Half of them have no educational background and three (3) of them have primary and two (2) have secondary or higher grade educational experiences.

(2) Income from farming and others

Table 3.2.2 shows the estimated income per annum from farming in Wau. The annual total net cash income from farming is about four (4) thousand SSP and annual net income is about 12 thousand SSP, respectively. About two (2) third of net income is consumed within household. Major components of net income are that from Ground nut, Sorghum and sesame, because of those big shares of cultivated area. On the other hand, major components of net cash income are those from Ground nut, Sorghum followed by Maize, Okra, and Tomato.

Table 3.2.2 Net Cash/Inputted Income from Farming

	Area (ha/HH)	Yield (t/ha)	Production (kg/HH)	ratio for sale	Farm gate price (SSP/kg)	Production cost (SSP/ha)	Net cash income (SSP/HH)	Net income (SSP/HH)
	(a)	(b)	(c)=(a)*(b)	(d)	(e)	(f)	(g) =(c)*(d)*(e)-(a)*(f)	(h) =(c)*(e)-(a)*(f)
Maize	0.27	0.8	221.2	34.7%	6.2	80	455	1,350
Sorghum	0.59	1.3	776.7	30.0%	4.8	98	1,061	3,670
Cassava	0.01	1.4	15.1	66.7%	5	714	43	68
Common bean	0.08	0.6	50.3	25.0%	4	111	41	192
G nut	0.80	1.6	1305.4	36.1%	4.2	266	1,766	5,269
Sesame	0.31	0.6	186.6	16.0%	4.8	102	112	864
Vegetables								
Okra	0.06	1.0	62.7	47.2%	6.4	234	175	387
Tomato	0.03	2.5	80.6	75.0%	2.7	458	148	203
Egg plant	0.01	2.1	17.2	100.0%	1	714	11	11
Water melon	0.01	2.9	22.9	85.0%	3.3	286	62	73
Jew's mallow	0.03	2.1	58.0	75.0%	2.8	286	114	154
Onion	0.02	2.4	38.2	100.0%	2	262	72	72
Total							4,060	12,315

Source: IDMP TT (Socio-economic survey, 2015)
Note: Farm-gate price in ( ) is the average of other sites due to lack of data in this site

Next table shows annual average household income from other than farming in each area. We can find that the salary income from other occupation, such as government official, company employee, driver, etc. in Wau is smaller than other areas. Instead of that, farmers in Wau earn wages as casual worker.

Figures in receipt of gifts and remittance from relatives and others were estimated, based on the monthly income.

Table 3.2.3 Average Household Income from Non-farming (SSP/year)

Areas	Salary of other occupations	Wages as casual worker	Gifts and remittance	Lease of farm land	Total
Wau	317	162	462	-	940
Jebel Lado	706	-	-	-	706
Rejaf East	3,005	-	462	38	3,505
Total	1,299	53	320	13	1,685

Source: IDMP TT (Socio-economic survey, 2015)

(3) Living expenses

Next table shows average household expenditure in a year. The annual total outlay is about 14 thousand SSP. Outlay for foods is about eight thousand SSP, which occupies 55 % of the total expenditure. Purchase of clothing is SSP 20 hundred, which is the biggest item and occupies 14 % of the total expenditure. The following big items are purchase of maize, SSP 19 hundred (13%), outlay for medical care, SSP 18 hundred (13%), purchase of sorghum, SSP 18 hundred (12%), and outlay for education, SSP 12 hundred (8%).

Table 3.2.4 Average Household Expenditure

Foods	(SSP/HH)	(%)	Other than foods	(SSP/HH)	(%)
Maize	1,885	13.0	Tobacco and Cigarettes	288	2.0
Sorghum	1,762	12.2	Soap, Shampoo	463	3.2
Cassava	-	0.0	Electricity charges	-	-
Common Beans	-	0.0	Firewood, cooking fuel and LP-gas	-	-
Ground nut	411	2.8	Lighting fuel	34	0.2
Sesame	525	3.6	Household furnishing and equipment	-	-
Other tubers and Roots	-	0.0	Repair and maintenance of house	-	-
Fish	662	4.6	Clothing	1,996	13.8
Meat and Eggs	860	5.9	Medical care	1,817	12.6
Vegetables	255	1.8	Education	1,220	8.4
Flour	312	2.2	Recreation	-	-
Bread	-	0.0	Ceremonial Occasions	49	0.3
Tea and Coffee	242	1.7	Transportation and communication	462	3.2
Milk and Yogurt	41	0.3	Remittance to relatives	125	0.9
Liquor and Soft drinks	-	0.0	Land and house rent	1	0.0
Cooking oil	530	3.7	Taxes	-	-
Sugar and Salt	537	3.7	Loan repayment	4	0.0
Spice and other foods	-	0.0	Sub total	6,458	44.6
Sub total	8,021	55.4	Grand total	14,479	100.0

Source: IDMP TT (Socio-economic survey, 2015)

(4) Loans

Question regarding loan was made in the questionnaire and 24 interviewees answered to the question. Only one (1) of them borrows money with 10% of interest rate and it was from 140 to 350 SSP. His purpose of borrowing money is to hire agricultural labor.

On the other hand, almost all of the interviewees are not borrowing money. The most major reason of not borrowing money was lack of opportunity / place to borrow money, followed by ñNot necessaryò, ñUnable to provide with collateralò and ñUnable to refundò.

(5) Farmers' groups/ organizations

There was no interviewee who was a member of an existing farmersô group/organization or water group / water users association though 26 interviewees answered to concerned questions.

(6) Roles of males, females and children

Next table shows gender rates of selling cereals in each area. We can find that the ratio of male only is higher and the ratio of female only is lower than those of other areas, Rejaf East and Jebel Lado. The reason is considered that selling amount of cereals in Wau is bigger than other areas so that the sales require male power. The ratio of ñWith Childrenò means that children participate in the sales is 12 % of the total households which answered concerned questions in Wau.

Table 3.2.5 Gender Rates of Selling Cereals (%)

Area	Male only	Female only	Both M&F	With Children
Wau	42	19	38	12
Jebel Lado	13	65	22	9
Rejaf East	19	50	31	13
Total	26	43	31	11

Source: IDMP TT (Socio-economic survey, 2015)

Next table shows gender rates of selling vegetables. The ratio of female only is higher than that of male only. The reason is considered that selling vegetables does not require male power so much, compared to the sales of cereals.

Table 3.2.6 Gender Rates of Selling Vegetables (%)

Area	Male only	Female only	Both M&F	With Children
Wau	36	48	16	8
Jebel Lado	9	78	13	9
Rejaf East	25	56	19	6
Total	23	61	16	8

Source: IDMP TT (Socio-economic survey, 2015)

Next table shows gender rates of selling livestock. We can find that most sales of livestock are conducted by men. The reasons are considered that selling livestock requires male power and that provide comparatively big money.

Table 3.2.7 Gender Rates of Selling Livestock (%)

Area	Male only	Female only	Both M&F	With Children
Wau	92	0	8	0
Jebel Lado	100	0	0	0
Rejaf East	88	0	13	19
Total	94	0	6	5

Source: IDMP TT (Socio-economic survey, 2015)

To grasp the situation of money management in households, gender rates of managing incomes are arranged in tables below. We can find that ratios of male only are higher than those of female only; especially, most income management of livestock is conducted by men. Items whose ratio of female only is comparatively high are vegetables and non-farming.

Table 3.2.8 Managing Income of Cereals (%)

Area	Male only	Female only	Both M&F
Wau	46	8	46
Jebel Lado	78	13	9
Rejaf East	44	25	31
Total	57	14	29

Source: IDMP TT (Socio-economic survey, 2015)

Table 3.2.9 Managing Income of Vegetables (%)

Area	Male only	Female only	Both M&F
Wau	42	25	33
Jebel Lado	70	13	17
Rejaf East	38	31	31
Total	51	22	27

Source: IDMP TT (Socio-economic survey, 2015)

Table 3.2.10 Managing Income of Livestock (%)

Area	Male only	Female only	Both M&F
Wau	71	4	25
Jebel Lado	100	0	0
Rejaf East	53	0	47
Total	76	2	22

Source: IDMP TT (Socio-economic survey, 2015)

Table 3.2.11 Managing Income of Non-farming (%)

Area	Male only	Female only	Both M&F
Wau	42	23	35
Jebel Lado	22	17	61
Rejaf East	38	25	38
Total	34	22	45

Source: IDMP TT (Socio-economic survey, 2015)

On the other hand, almost all works of water taking and collecting firewood are conducted by women as showing tables below.

Table 3.2.12 Gender Rates of Water Taking (%)

Area	Male only	Female only	Both M&F	With Children
Wau	4	92	4	35
Jebel Lado	0	96	4	57
Rejaf East	7	93	0	33
Total	3	94	3	42

Source: IDMP TT (Socio-economic survey, 2015)

Table 3.2.13 Gender Rates of Collecting Firewood (%)

Area	Male only	Female only	Both M&F	With Children
Wau	4	96	0	44
Jebel Lado	0	100	0	59
Rejaf East	6	94	0	31
Total	3	97	0	46

Source: IDMP TT (Socio-economic survey, 2015)

Next tables show average distances from houses to water source / collecting point of firewood, and necessary times per day/week for the works.

Table 3.2.14 Basic Data on Water Taking

Area	Distance (meter)	Times per day	Hours per time	Hours per day
Wau	830	3.1	0.7	2.1
Jebel Lado	447	3.3	0.4	1.4
Rejaf East	266	2.9	0.4	1.2
Total	556	3.1	0.5	1.7

Source: IDMP TT (Socio-economic survey, 2015)

Table 3.2.15 Basic Data on Collecting Firewood

Area	Distance (meter)	Times per week	Hours per time	Hours per week
Wau	660	3.4	2.2	7.6
Jebel Lado	820	2.1	1.5	3.3
Rejaf East	920	2.5	1.4	3.4
Total	780	2.7	1.7	4.7

Source: IDMP TT (Socio-economic survey, 2015)

(7) Land lease/borrow and land ownership

There was no interviewee who leased/ borrowed land in the case of Wau. Basically, farmers cultivate their own land and leasing/ borrowing of land are seldom conducted. Additional interview related land ownership was conducted.

Table 3.2.16 shows land tenure type of intervieweeôs cultivating land and with/without land registration. In case of Wau, almost all of the intervieweeôs agricultural lands belong to the community. Fam land of one (1) interviewee who answered ñotherò is owned by family. Registration of agricultural land is uncommonly done among the interviewees.

Table 3.2.16 Land Tenure and Registration

Land tenure type of cultivating land		
Community	Private	Others
24	1	1
Registration of agricultural land		
Registered	Not registered	Partial
1	24	-

Source: IDMP TT (Socio-economic survey, 2015)

Table 3.2.17 shows land control access situation of communal and private land. Regarding selling rights of communal and private land, sometimes interviewees can make a decision to sell their land without getting permission from any authority. On the other hand, some of interviewees answered permission is necessary for selling land. In case of communal land, traditional attorney was the major answer as the authority from which farmers have to get permission. In case of Private land, interviewees seem to have to get permission from both of traditional and public attorney. County land authorities are recognized as public attorney to give them permissions. It indicates that land control authorities customarily are exercised by both of traditional and county authorities at county level.

Regarding change of land use type and change of crop to cultivate are totally up to the interviewees, namely to those who are actual land users.

Table 3.2.17 Land Control Situation

	Y	N	Traditional attorney	Public total	Land commission	County land authorities	Payam land councils	Others
For landôs tenure as ñCommunityò								
i) "if you want to sell land, can you decide yourself?"								
	15	8	7	1	-	1	-	-
ii) "if you want to change land use type, can you decide yourself?"								
	24	-	-	-	-	-	-	-
iii) "if you want to change the currently cultivating crop, can you decide yourself?"								
	24	-	-	-	-	-	-	-
For landôs tenure as ñPrivateò								
	Y	N	Traditional attorney	Public total	Land commission	County land authorities	Payam land councils	Others
i) "if you want to sell land, can you decide yourself?"								
	8	8	6	7	-	7	-	-
ii) "if you want to change land use type, can you decide yourself?"								
	16	-	-	-	-	-	-	-
iii) "if you want to change the currently cultivating crop, can you decide yourself?"								
	17	-	-	-	-	-	-	-

Source: IDMP TT (Socio-economic survey, 2015)

24 interviewees, out of 25 interviewees who answered the question, answered that their cultivating land is hereditary land. Those successors are generally intervieweeôs son. This means their land can be inherited to normally son and sometimes to brother even though those lands owner is community.

In addition, following questions are asked in the questionnaire;

1) If irrigation network is passing through your private land, how do you coordinate with the surrounding land belonging to other people for its smooth operation?
2) If the planned irrigation canal is passing through your land, will you accept to let it pass through?

Interviewees generally gave positive response to the above questions. To first one above, following answer was given by the interviewee; ñI will deal with them normally.ò

(8) Effect caused by the conflict

In the question number one of the Survey, Q-1 Background of Household, a question asked about problems that caused by the conflict occurred in December 2013. However, the answer in Wau was ñNo problemò. It means that the target area was not dragged into the civil war directly and did not suffer from serious impact of the conflict. Also, considering some problems answered in the other sites, market economy or commercial farming seems not to be developed well around the command area in Wau.

3.3 Farm Land and Cropping Pattern

(1) Farm land area

Table 3.3.1 shows the average farm land holding area per household with its breakdown; 1) irrigated, 2) non-irrigated and 3) homestead. The data is compared with other two priority projects. On average, 83.6 % of farmland is non-irrigated. Average irrigated land area per household is the lowest among the three (3) priority project sites. On the other hand, average total farmland area is the largest due to the large area of non-irrigated farmland. There are several farmers who own more than 12 feddans (nearly equal to 5 ha) in total and the maximum land holding area was 32 ha.

Table 3.3.1 Average of Farm Land Area **(fed/HH)**

	Total area						
		Irrigated		Non-irrigated		Homestead	
Jebel Lado	4.3	0.6	(14.0%)	3.1	(72.0%)	0.6	(14.0%)
Wau	**6.7**	**0.2**	**(3.0%)**	**5.6**	**(83.6%)**	**0.9**	**(13.4%)**
Rejaf East	5.5	2.7	(49.1%)	1.6	(29.1%)	1.2	(21.8%)

Source: IDMP TT (Socio-economic survey, 2015)

(2) Cropping pattern

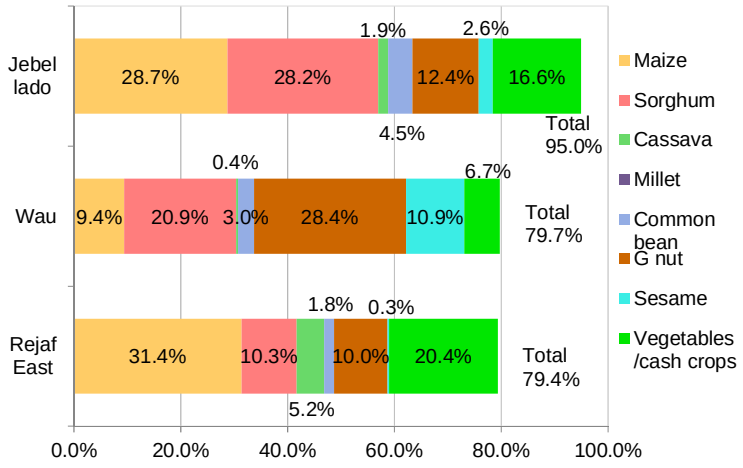
Figure 3.3.1 shows the cropping pattern in Wau, and Figure 3.3.2 shows summarized land use ratio of crops in three (3) priority project sites. The overall cropping intensity is 79.7 %, which is lower than that of Jebel Lado. Ground nut and Sorghum are cultivated as major crops in the site, whose land use ratio are 28.4 % and 20.9 % respectively. Land use ratio of maize is much lower than that in the other two (2) sites. Ground nut and Sesame are relatively cultivated widely and these self-supplied amounts per person are larger compared to other two (2) sites. Land use ratio of vegetable is only 6.7 % in total and the most popular one was Okra, 2.1 % of land use ratio.

As same as other two (2) sites, Maize, sorghum, Ground nut and Sesame are cultivated in rainy season and other vegetables / cash crops are cultivated both in rainy and dry season.

Month / Rainy season / Crop name	Land use %*1	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	No. of Answers*2
Maize	9.4%		L		L	S	S	W	W	H				18
Sorghum	20.9%	L			L	S	S	W	W	H		H		23
Cassava	0.4%	L		L	S	W		S	W					2
Common bean	3.0%			L	S		L	W	S	W		H		3
Ground nut	28.4%	L			S	L	S	W	W	H		H		24
Sesame	10.9%	L			S	S	L	W	W	H				18
Vegetables/Cash crops	6.7%													
Okra	(2.1%)	2.7months/season				3.7months/season								10
Tomato	(1.1%)	3.5months/season												4
Egg plant	(0.3%)						3.0months/season							1
Water melon	(0.3%)	6.0months/season												1
Jew's mallow	(1.0%)						4.3months/season							6
Cowpea	(0.9%)	2.3months/season												
Onion	(0.6%)	6.0months/season												2
Others	(0.4%)													3

Source: IDMP TT (Socio-economic survey, 2015)
*1: Parenthesized numbers show the breakdown of the above percentage.
*2: Parenthesized numbers shows the breakdown of the above number
*3: Cultivation period of vegetables shown in the figure above, is the average period of each cropsô samples.

Figure 3.3.1 Cropping Pattern



Source: IDMP TT (Socio-economic survey, 2015)

Figure 3.3.2 Land Use Ratio in 3 Priority Project Sites

3.4 Farming Practices

(1) Agricultural inputs procurement

Table 3.4.1 shows the sources of agricultural inputs procurement. No information regarding agro-chemicals, fertilizer and fuel for tractor was available due to their limited use among the interviewees.

The most common way to obtain cereal, bean and vegetables seeds is to make it by themselves, and the second popular ways are to obtain it from other farmers and to purchase it from town shop.

Table 3.4.1 Sources of Agricultural Inputs Procurement (no. of Answers)

	Agro-chemicals	Fertilizer	Seed (Cereal)	Seed (Bean)	Seed (vegetables)	Fuel for tractor
Government	-	-	1	-	-	-
NGO	-	-	4	-	-	-
Town shop	-	-	4	6	6	-
Village shop	-	-	1	-	-	-
Trader	-	-	-	-	-	-
Other farmers	-	-	7	6	6	-
FarmersôOrganization	-	-	1	-	-	-
Others	-	-	1	-	-	-
Made by themselves	-	-	16	14	10	-
Total	-	-	33	26	22	-

Source: IDMP TT (Socio-economic survey, 2015)
* The questionnaire allowed multiple answers to the interviewee.

Table 3.4.2 shows the problems in obtaining farm inputs expressed by the interviewee. Unstable availability is mentioned as serious issue the farmers are facing to in obtaining agro-chemicals, fertilizer and seeds. In addition, regarding procurement of seeds, it was expressed as problem that those prices are too expensive for them and some of the farmers feel he/she is in lack of finance for obtaining cereal seed. As same as other two (2) sites, low quality of cereal seed is one of issues, which may be caused by reproducing seeds over years by themselves.

Table 3.4.2 Problems in Obtaining Farm Inputs (no. of Answers)

	Agro-chemicals	Fertilizer	Seed (Cereal)	Seed (Bean)	Seed (vegetables)	Fuel for tractor
Non availability	-	-	8	-	-	-
Not available when needed	6	6	1	1	7	-
Available in small quantities only	-	-	7	-	-	-
Expensive	-	-	7	6	6	-
Transport problems	-	-	-	-	-	-
Lack of finance	-	-	11	1	1	-
Low quality	-	-	7	-	-	-
Total	6	6	41	8	14	-

Source: IDMP TT (Socio-economic survey, 2015)
* The questionnaire allowed multiple answers to the interviewee

(2) Agro chemicals use

It seems to be few farmers use agro-chemicals such as fertilizers or pesticide as same as other two (2) sites. Among the interviewees in Wau Rice scheme, no one noted the use of agro chemicals even in vegetable cultivation, while there is some information of agro chemical use in other two (2) sites. It might be because of unavailability of such agrochemicals, not basically because of unaffordability.

(3) Labour

As same as other two (2) sites, necessary labour for farming operation is supplied mainly from family,

but sometimes farmers work as group. In other word, they help each other without any physical payment. Required working days for major farming operation was surveyed in the socio-economic survey. Declared working days vary widely and tend to be longer than that is considered as normal, because farmers repeatedly practice same operation such as land preparation or seeding with trial and error. Farmers often failed to start or continue cultivation due to deficit of rainfall or unexpected delay of rainy season.

(4) Farm machinery/tools

Table 3.4.3 shows the inventory of farm machinery and tools the farmers own. One (1) farmer in Wau municipality owns a 4-wheel tractor with 60HP individually, which costs 1,500 SSP /year for maintenance. Although in the interview, many farmers are expressed their willingness to hire or purchase a tractor, they cannot utilize it for the present because of unaffordability or unavailability

Regarding other farming equipment, there are two (2) farmers who borrowed agricultural equipment from their neighbours. Its rental fee was 150 SSP/day. One borrowed draft animal for one (1) day to plow one (1) feddan, another rented water pump for 2 days paying 60 SSP/day.

Table 3.4.3 Inventory of Owned Farm Machinery/Tools

	No. of HHs owning machineries (no.)				Average no. of machinery (no./HH)
	Wau municipality	Kuanya /Luo	Panamet /Kuom	Total	Total
4-wheel tractor	1			1	1
Hand tractor					
Hand sprayer					
Engine sprayer					
Weedier					
Seeder					
Hoe	5	5	6	16	4.3
Shovel	3	3	1	7	1.4
Manual thresher	2	3	4	9	3.2
Engine thresher					
Oxen-drawn plow					
Water pump(Oil)	1			1	1.0
Water pump (Electric)					
Milling machine					
Agro well	1			1	3
Mobile phone	5	4	4	13	1.5
Spade	2	2	2	6	1.2
Ax	2	2	3	7	1.7
Panga		1		1	4.0
Moloda	2	4	5	11	4.8
Gudum					
Knife		1		1	4.0

Source: IDMP TT (Socio-economic survey, 2015)

(5) Livestock rearing

Average numbers of livestock in the owners and average numbers of livestock in the total of samples are shown in the tables below. Cow, bull/ox and goats in Wau are much more than those in other areas, so that we can clearly find weight of livestock in Wau is higher than other areas.

Table 3.4.4 Average Number of Livestock with the Owners

Area	Cow	Bull/Ox	Sheep	Goats	Pigs	Chicken	Ducks
Wau	14.9	3.5	8.9	13.2	-	12.3	-
Jebel Lado	3.0	-	6.4	8.8	-	14.0	2.0
Rejaf East	2.0	-	11.3	5.9	1.0	8.4	10.0
3 areas	12.7	3.5	8.7	10.3	1.0	12.4	6.0

Source: IDMP TT (Socio-economic survey, 2015)

Table 3.4.5 Average Number of Livestock in the Samples

Area	Cow	Bull/Ox	Sheep	Goats	Pigs	Chicken	Ducks
Wau	8.0	1.1	5.2	9.2	-	8.0	-
Jebel Lado	0.3	-	1.4	3.4	-	11.0	0.1
Rejaf East	0.1	-	1.3	2.0	0.0	2.3	0.4
3 areas	2.9	0.4	2.7	4.9	0.0	6.9	0.2

Source: IDMP TT (Socio-economic survey, 2015)

3.5 Productivity

(1) Crop yields

Table 3.5.1 shows average crop yields in Wau irrigation rice scheme. Crop yields are almost same as an average yield of the two(2) sites except vegetables. On the other hand, vegetablesôyields tend to be lower than average of two (2) other sites.

Table 3.5.1 Crop Yields

Crop	Average Yield (t/ha)	Minimum Yield (t/ha)	Maximum Yield (t/ha)	No. of sample	(Average yield of 3 sites) (t/ha)
Maize	0.8	0.1	3.6	11	0.7
Sorghum	1.3	0.2	5.7	12	1.2
Cassava	1.4	1.4	1.4	1	1.6
Common bean	0.6	0.2	1.2	3	0.6
G nut	1.6	0.4	7.9	23	1.5
Sesame	0.6	0.0	1.5	18	0.6
Vegetables					
Okra	1.0	0.0	3.8	10	1.8
Tomato	2.5	0.0	6.0	4	2.8
Egg plant	2.1	2.1	2.1	1	1.8
Water melon	2.9	2.9	2.9	1	2.9
Jew's mallow	2.1	0.1	4.8	5	3.1
Onion	2.4	2.4	2.4	2	2.5

Source: IDMP TT (Socio-economic survey, 2015)
* No. of samples are only that of Wau Rice scheme

Table 3.5.2 shows the important causes of pre-harvest damage or loss in cereal and other crops cultivation which was expressed by the farmers in Wau. The farmers expressed almost all of the options raised in the questionnaire, except shortage of irrigation water, as crucial issues causing loss of produce before harvesting.

Table 3.5.2 Important Causes of Pre-harvest Damage or Loss(no. of Answers)

	Cereal	Other crop
Domestic animals	16	15
Birds	16	14
Other wild animals	16	16
Pest	14	11
Disease	15	11
Too much rain	16	8
Too little rain	13	7
Shortage of irrigation water	7	7
Others		
Total	113	89

Source: IDMP TT (Socio-economic survey, 2015)
*1 :The questionnaire allowed multiple answers to the interviewee

(2) Produces use

Table 3.5.3 shows crop products' use in Wau. Crops except cassava and vegetables are mainly consumed for household use. About half to three (3) quarters of produces of vegetables are sold to market. There is no use of produce for loan payment or land tenant fee. In addition, post-harvest loss is not mentioned by the interviewee.

Table 3.5.3 Crop Produces Use

	Household use	Self-consumption	Stock for seed	Loan payment	Land tenant fee	Post-harvest losses	Others	Sold to market	No. of samples
Maize	65.3%	47.3%	12.4%	-	-	-	5.6%	34.7%	11
Sorghum	70.0%	55.3%	9.2%	-	-	-	5.5%	30.0%	13
Cassava	33.3%	33.3%	-	-	-	-	-	66.7%	1
Common bean	75.0%	50.0%	16.7%	-	-	-	8.3%	25.0%	3
G nut	63.9%	48.3%	12.1%	-	-	-	3.5%	36.1%	23
Sesame	84.0%	68.4%	11.3%	-	-	-	4.3%	16.0%	18
Vegetables									
Okra	47.6%							47.2%	9
Tomato	25.0%							75.0%	4
Egg plant	0.0%							100.0%	1
Water melon	15.0%							85.0%	1
Jew's mallow	25.0%							75.0%	5
Onion	0.0%							100.0%	2

Source: IDMP TT (Socio-economic survey, 2015)

(3) Profitability

Table 3.5.4 shows net/gross cash income and production cost per ha in Wau Rice scheme. Net income of Maize, Sorghum, Cassava and Groundnut are greatly higher than those average values of three (3) sites, even though those cropsôhousehold use is large. Production cost is not so considerably low, so it would be due to high value of gross cash income of those crops. However, those yields are not greatly high. Actually, farm gate prices in Wau Rice scheme tend to be higher (e.g. farm gate price of maize; 6.2 SSP/kg in Wau, 3.9 SSP/kg in Jebel Lado and 3.7 SSP/kg on average, respectively) than that in other sites, which is one of the causes resulting in high gross cash income.

On the contrary, net cash incomes of vegetables tend to be lower than an average of three (3) sites. It would also reflect low farm gate price of vegetable in Wau Rice scheme. Even though production cost of vegetables in Wau Rice scheme are generally lower than the average of three (3) sites and those yields are fair compared to the average, low farm gate price results in low profitability of vegetable

production.

Table 3.5.4 Net Cash Income, Gross Cash Income and Production Cost per ha

	Net cash income (SSP/ha)		Gross cash income (SSP/ha)		Production cost (SSP/ha)		No of samples
	Wau	(Average of 3 sites)	Wau	(Average of 3 sites)	Wau	(Average of 3 sites)	
Maize	3,007	(791)	3,087	(917)	80	(125)	7
Sorghum	2,595	(959)	2,693	(1,058)	98	(99)	3
Cassava	4,048	(1,537)	4,762	(1,958)	714	(420)	1
Common bean	563	(1,064)	675	(1,139)	111	(75)	1
G nut	2,719	(1,713)	2,985	(1,955)	266	(242)	4
Sesame	689	(643)	791	(735)	102	(92)	2
Vegetables							
Okra	4,995	(10,058)	5,230	(10,661)	234	(603)	7
Tomato	7,558	(10,335)	8,016	(10,949)	458	(614)	3
Egg plant	1,429	(7,949)	2,143	(8,552)	714	(602)	1
Water melon	7,810	(7,810)	8,095	(8,095)	286	(286)	1
Jew's mallow	5,690	(9,557)	5,976	(10,112)	286	(555)	4
Onion	4,500	(2,508)	4,762	(5,079)	262	(2,571)	2

Source: IDMP TT (Socio-economic survey, 2015)
*1 Each unit values of net cash income, gross cash income and production cost were calculated respectively excluding invalid/unavailable values, hence net cash income value is not equivalent to the reminder after deducting unit production cost from unit gross income.
*2 Breakdown of vegetable production cost are Seed, fertilizer and agro-chemical obtains.
*3 No. of samples are only that of Wau Rice scheme

In addition to net cash income, the results of net income calculated are listed in the following table:

Table 3.5.5 Net Income Estimate

Crop	Unit Yield (t/ha)	Farm-gate Price SSP/kg	Gross Income SSP/ha	Production Cost SSP/ha	Net Income SSP/ha
Maize	0.8	6.2	4,960	80	4,880
Sorghum	1.3	4.8	6,240	98	6,142
Cassava	1.4	5	7,000	714	6,286
Common bean	0.6	4	2,400	111	2,289
Groundnut	1.6	4.2	6,720	266	6,454
Sesame	0.6	4.8	2,880	102	2,778
Vegetables					
Okra	1	6.4	6,400	234	6,166
Tomato	2.5	2.7	6,750	458	6,292
Egg plant	2.1	1	2,100	714	1,386
Jew's mallow	2.1	2.8	5,880	286	5,594
Onion	2.4	2	4,800	262	4,538
Water melon	2.9	3.3	9,570	286	9,284

Source: IDMP TT (Socio-economic survey, 2015)
Note: Farm-gate price in ( ) is the average of other sites due to lack of data in this site

3.6 Selling of Produces

Farmers in Wau Rice scheme are selling their produce mainly at Wau market and Jou market, which are located about 4-5 km away from the communities.

Table 3.6.1 shows the mode of transport that the farmers use for transporting their commodities to Wau market. Major ways of transport are motorbike, bicycle and on foot, while some are using public bus.

Table 3.6.1 Mode of Transport

Mode of transport	No. of answers
Public bus	3
Tractor	-
Private car	-
Motorbike	15
Bicycle	14
On foot	12
No need	-
Total	44

Source: IDMP TT (Socio-economic survey, 2015)
* The questionnaire allowed multiple answers to the interviewee

Table 3.6.2 shows the problems in marketing of produce raised by the farmers in Wau. All options shown in table were expressed as problems that farmers are facing in marketing the produce. Among them, low selling prices, lack of transportation, storage facilities and packing materials are most common amng the farmers.

Table 3.6.2 Problems in Marketing of Produces

Problems in marketing of produce	No. of answers
Low selling prices	14
Lack of transportation facilities	14
High cost of transportation	6
Lack of storage facilities	14
Quality problems of products	6
Lack of packing material	13
Total	67

Source: IDMP TT (Socio-economic survey, 2015)
* The questionnaire allowed multiple answers to the interviewee

CHAPTER 4 DEVELOPMENT CONSTRAINTS AND POTENTIALS

Table 4.1.1 shows the problems of farming practices in Wau Rice scheme. Damage by pests and disease / wild animal and water shortage are mentioned by the farmers most commonly. Protection from pests and disease or wild / domestic animals is common issue among three (3) sites. In addition, lack of opportunity of selling produce is also recognized by many farmers.

Table 4.1.1 Problems in Farming

Problems in farming	No. of answers
Water shortage	22
Drought damage	18
Low yield of crops	17
Drainage problems	8
Damage by pests and diseases	23
Weed damage	18
Damage by wild animal	22
Difficulty in hiring animal/mechanical power	10
Labour shortage	9
Difficulty in obtaining seeds	15
Difficulty in purchasing agro-chemicals	8
Difficulty in purchasing fertilizer	10
Lack of farm roads	19
Damage by domestic animal	18
Shortage of selling opportunity	17
Lack of storage facilities	14
Problems related to loans	11
Others	5
Total	264

Source: IDMP TT (Socio-economic survey, 2015)
* The questionnaire allowed multiple answers to the interviewee

Table 4.1.2 shows the items recognized as necessary items to be improved in Wau. Corresponding to Table 4.1.1, crop protection from animals and disease / pest is considered as highly required items. Secondly highly recognized items are acquisition of irrigation water, improved seeds with high quality and mechanized practice.

Table 4.1.2 Items Needed to be Improved

Items needed to be improved	No. of answers
To acquire irrigation water	20
To improve irrigation facilities	7
To drain out excess water	7
To prevent pests and diseases	25
To prevent damage by animal	22
To prevent weed damage	22
To improve supplying system of farm inputs	9
To improve farm road	15
To improve transportation of products	12
To introduce improved seed/plant varieties	22
To improve farming practices	21
To introduce mechanized farming	25
To strengthen agricultural extension services	16
To improve and expand agricultural credit	8
To construct drying yard	8
To construct processing facilities	11
To construct storage facilities	11
Others	8
Total	269

Source: IDMP TT (Socio-economic survey, 2015)
* The questionnaire allowed multiple answers to the interviewee

Summarized findings/features in the present agricultural situation in Wau

- ✓ Non-irrigated farmland share/area was the largest among the sites.
- ✓ Ground nut, sorghum and sesame are considerably popular occupying largely total farmland, while vegetable cultivation is less popular than other sites.
- ✓ Above major crops are consumed mainly in household.
- ✓ Cash generation from cereal and oil crop production is considerably large due to these high farm gate prices in Wau market and low production cost.
- ✓ Production costs are generally low in Wau but cash generation from vegetable production is low because of low yield/market price.
- ✓ There are few farmers having an experience in using agricultural machinery and agro-chemicals.

PART 2 IRRIGATION SCHEME DEVELOPMENT PLAN

CHAPTER 5 INSTITUTIONAL SET-UP OF THE IRRIGATION SCHEME

5.1 Demarcation of Stakeholders' Roles

MEDIWR takes primal responsibility to develop Wau Irrigation Scheme, including feasibility study, design works, implementation, O&M of the main structures, and monitoring and evaluation of the project.

Key directorates of MEDIWR in development of the Wau Irrigation Scheme are six which, include; Directorate of Irrigation and Drainage (DID), Directorate of Planning and Programmes (DPP), Directorate of Water Resources Management (DWRM), Directorate of Power Engineering and Grid (DPEG), and Directorate of Hydrology and Survey (DHS). Their main functions in development of the Wau Irrigation Scheme are summarized in Table 5.1.1.

Table 5.1.1 Key Directorates of MEDIWR for National Irrigation Development Programme

Organization	Stakeholders	Key Functions in Irrigation Development
MEDIWR	Directorate of Irrigation and Drainage (DID)	Construction and operation of irrigation scheme; including dam, pump station, canals, farm lots and flood control structures.
	Directorate of Planning and Programmes (DPP)	Coordinate staff training including State government staff; Coordinate planning process; Monitoring and Evaluation of the project implementation, Harmonize budgeting procedure for effective budget execution.
	Directorate of Water Resources Management (DWRM)	Establishment of institutional framework; Integrated Water Resources Management approach; Pollution prevention and mitigation.
	Directorate of Power Engineering and Grid (DPEG)	Coordination with Sue Dam Project which will be implemented upstream of Sue River, and is under feasibility study stage.
	Directorate of Hydrology and Survey (DHS)	Resource assessment, feasibility studies, information management and research; Establishment of centralized hydromet and water use/abstraction information management system; Accumulation of long time historical Hydromet and water use/abstraction data/information using hydromet equipment installed at the Wau Irrigation Scheme.

Source: Main Functions of directorates MWRI
Strategic Plan 2012-2017, MWRI
Programme Profile of IDMP, National Irrigation Development Programme (NISDP)

In addition to MEDIWR, MAFCRD, MLFI, MOE, MWLCT and etc. are also important stakeholders in development of the Wau Irrigation Scheme. At the planning stage, MAFCRD is required to develop water demand plan for crops related to the project. MAFCRD also takes responsibility for on-farm level irrigation management, including allocation of farm plot to farmers, preparation of cropping calendar, estimation of water demand, extension of irrigation farming, and O&M of irrigation facility at on-farm level.

MWLCT also plays important role for conservation of wild life in and around the project site, while MOE is a primal ministry for environmental protection including watershed conservation. Table 5.1.2 shows stakeholders and their key functions in Wau Irrigation Scheme development.

Table 5.1.2 Stakeholders Involved in National Irrigation Development Programme

Organization	Stakeholders	Key Functions in Irrigation Development
FSC	Food Security Council	Create a national food security policy to ensure adequate food availability throughout South Sudan.
MAFCRD	Directorate of Agriculture Production and Extension Services (DAPES)	Promote development and adaptation of appropriate technology for irrigation farming; Establish and manage an effective agricultural extension service; Human resource training in the field.
	Directorate of Cooperatives (DC)	Provide guidance to establish cooperatives and issuance of the registration certificate if necessary.
	Directorate of Rural Development (DRD)	Provide technical assistance and training to State governments and other local governments to build their capacity to assume their responsibilities for irrigated agriculture.
	Directorate of Planning (DP)	Formulate registration, policies, standards and plans for irrigated agriculture development.
	Directorate of Special Projects and Donors Coordination (DAPDC)	On-farm level irrigation management, including allocation of farm plot to farmers, preparation of cropping calendar, estimation of crop water requirement, and instruction to farmers for O&M of irrigation facility at on-farm level.
MOE	Ministry of Environment	Conduct EIA of irrigation projects; Environmental protection including watershed conservation; Advice and support States and local governments in their responsibilities for environmental protection.
MWLCT	Directorate of Wild Life Conservation	Develop water demand plan for wildlife and other conservation purposes if any.
MLHPP	Ministry of Lands, Housing and Physical Planning	Surveying and mapping of the project area and safe keeping maps ad documents; Establish and oversee the operation of the land registry.
LC	Land Commission	Establish and oversee the operation of the Land Registry.
NBS	National Bureau of Statistics	Provide socio-economic data/information for irrigation development plan and M&E.
MTRB	Ministry of Transport, Roads and Bridges	Construction of Farm-To-Market road to improve market accessibility of irrigation command areas; Permit common use of road/bridge for irrigation scheme development and Hydromet equipment installation.
MGCSW	Ministry of Gender, Child and Social welfare	Promote income generating activities of vulnerable groups; Plan and implement repatriation, relief, resettlement and reintegration of internally displaced persons and refugees.
MFEP	Ministry of Finance and Economic Planning	Budgetary arrangement for irrigation development; Supporting donor buying process for irrigation development.
MTII	Ministry of Trade, Industry and Investment	Promotion of Public Private Partnership and private sector investment in future.
MLFI	Directorate of Animal Production and Range Management (DAPRM)	Coordinate participation of livestock keepers in irrigation planning; Develop water demand plan for dipping and watering facilities for livestock if necessary.
	Directorate of Livestock and Fisheries Research Development (DLFRD)	Provision of research results to mitigate conflict between farmers and pastoralists so as to sustain irrigation water use among stakeholders.
	Directorate of Extension and pastoralists Development (DEPD)	Coordinate participation of pastoralists in irrigation planning; Develop water demand plan for pastoralistsô watering points if necessary.
	Directorate of Fisheries and Aquaculture Development (DFAD)	Coordinate participation of fisher folks and aquaculture business entity in irrigation planning if any; Develop water demand plan for fisheries and aquaculture related facilities if any
	Directorate of Investments Planning and Statistics (DIPS)	Collection and provision of necessary data/information for irrigation development plan and M&E.
WRMA	Water Resources Management Authority (WRMA)	【After the Water Bill being enacted】 Regulate the management; Development and use of water resources; Issue regulation on water resources allocation and the

Organization	Stakeholders	Key Functions in Irrigation Development
		issuance of permits; Issue permits for inter-basin water transfer; Provide guidelines to BWB on the pricing strategy for charges to be levied under the Water Bill; Ensure collection, analysis and dissemination of data and information on water resources, etc.
BWB	Basin Water Boards (BWB)	【After the Water Bill being enacted】Protecting water resources and increasing water availability, Receiving permit applications for water abstraction, for water use and recharge, determining, issuing and varying water permits and enforce the conditions of those permits; Receiving permit applications for the construction of works, and determining, issuing and enforcing the conditions of those permits; Enforcing regulations; Coordinate and facilitate the formation and activities of WUAs; Setting the level of charges to be levied under this Act in accordance with the pricing strategy and guidelines issued by the WRMA; Collecting water permit and water use charges; etc.
IB	Irrigation Boards (IB)	【After the Water Bill being enacted】Protecting water resources and increasing irrigation water availability, Receiving permit applications for irrigation water users, for water use and recharge, determining, issuing and varying water permits and enforce the conditions of those permits; Receiving permit applications for the construction of irrigation and drainage facilities, and determining, issuing and enforcing the conditions of those permits; Enforcing regulations; Coordinate and facilitate the formation and activities of WUAs; Setting the level of charges to be levied under this Act in accordance with the pricing strategy and guidelines issued by the WRMA; Collecting irrigation fee for O&M of irrigation facilities; etc.
C/WC	Catchments/Watersheds Committees	【After the Water Bill being enacted】To formulate catchment or sub-catchment integrated water resources management plans; To resolve water resources conflicts in the catchment or sub-catchment; To perform other functions delegated by the BWB.
WUA	Water Users Association (WUA)	Manage, distribute and conserve water from a source/facility used jointly by the members of the WUA; Resolve conflicts between members of the association; Collect water user fees on behalf of the BWB; Represent the special interests and values arising from water used for both public and private purposes.
SDWS	State Directorate of Water and Sanitation (SDWS)	Coordination between central government, counties and communities concerned to formulate irrigation development plan, implementation and O&M of the project; participation in M&E of the project.
SDALFF (SLMALFF)	State Directorate of Agriculture, Livestock, Fisheries and Forestry (SDALFF)	Coordination between central government, counties and communities concerned to formulate irrigation development plan, implementation and O&M of the project; participation in M&E of the project.
SDC/RD (SLMC/RD)	State Directorate of Cooperatives, Rural/Community Development	Coordination between central government, counties and communities concerned to formulate irrigation development plan, implementation and O&M of the project; participation in M&E of the project.
SDLS (SLMLS)	State Directorate of Land and Survey	Coordination between central government, counties and communities concerned to formulate irrigation development plan, implementation and O&M of the project; participation in M&E of the project.
CDWS (LG)	County Department of Water and Sanitation (CDWS)	Coordination between central government, state and communities concerned to formulate irrigation development plan, implementation and O&M of the project; participation in M&E of the project.
CDALFF	County Department of	Coordination between central government, state and

Organization	Stakeholders	Key Functions in Irrigation Development
(LG)	Agriculture, Livestock, Fisheries and Forestry (CDALFF)	communities concerned to formulate irrigation development plan, implementation and O&M of the project; participation in M&E of the project.
CDC/RD	County Department of Cooperatives, Community/Rural Development	Coordination between central government, state and communities concerned to formulate irrigation development plan, implementation and O&M of the project; participation in M&E of the project.
At Community Level	Farmers/Pastoralists Union, Cooperatives Society, Fishing Folks, Civil Society	Participation in irrigation development planning, implementation and O&M of the project; participation in M&E of the project.

Source: Main Functions of directorates MWRI
Roles, Functions and Responsibilities of the National Ministries, Ministry of Cabinet Affairs, November 4th, 2013.
Programme Profile of IDMP, National Irrigation Development Programme (NISDP)

5.2 Category of Irrigation Scheme

The Wau Irrigation Scheme will be developed under the National Irrigation Scheme Development Programme (NISDP). The NISDP is owned by the national government with large/medium scale command area and irrigation facilities and is developed by the national government. Definition of the NISDP is summarized in Table 5.2.1.

Table 5.2.1 Categorization of the Irrigation Scheme

Programme	Definition	Capital Investment (funding source)	Implementation (Construction)	Owner	O&M /a	Responsible Organization of Land Allocation	Technical Assistance	Supervision of Scheme Management
National Irrigation Scheme Development Programme (NISDP)	- Large (more than 500 ha) - Land property belongs to National	National/ Private Sector (Bank)/ International Development Bank/ DPs (grant)	National	National	National (Scheme Management Office)/ WUA	National/ Community	National/ DPs/ NGOs	National

Note: a/ Operation and maintenance of irrigation scheme could transfer to local government in the long-term, depending on their capability.

5.3 Division of Roles within the Irrigation Schemes

MEDIWR takes primal responsibility to develop the Wau Irrigation Scheme, from planning, designing, implementation, and O&M. The line ministries of the MEDIWR at state government and local government also play key roles in irrigation development planning in terms of coordination among grassroots level stakeholders, and M&E of the irrigation programmes/projects.

Community participation in planning, implementation, operation and maintenance of on-farm level irrigation scheme is a key for successful implementation of the irrigation development. In some cases, land belongs to communities, and the government cannot start any irrigation development procedures without permission and participation of communities. Table 5.3.1 shows role and responsibility for implementation of the Wau Irrigation Scheme development project.

Table 5.3.1 Roles and Responsibilities in Programmes/Projects Implementation

Type of programme/project	Responsibilities				
	National Government/DPs	State Government/DPs	County or LG	Community	Private Sector
National programme/project (Nationally planned and nationally implemented)	・Planning ・Financing ・Implementation ・M&E	・Coordination ・M&E	・Coordination ・M&E	・Contribution ・Coordination ・M&E	

5.4 Private Sector Involvement

In irrigation development, there are several types of private sector involvement including participatory irrigation management (PIM), irrigation management transfer (IMT), and public private partnership (PPP). In the Republic of South Sudan, the irrigation development under the current government has just started through the IDMP, and establishment of organizational structure and capacity development of the government officials has just started at the national level. Technical and administrative capacity development at state, county and community level will be conducted afterward.

When we consider current constraints on irrigation development including sophisticated land holding system, capacity of the government in terms of financial and human resources, introduction of PIM must be necessary to promote the irrigation development to nationwide. In this regard, community participation in irrigation development from planning stage till operation and maintenance of irrigation facilities at least on-farm level is required. Following table shows range of institutional arrangement of PIM. Among them, the shared management is suitable for the Wau Irrigation Scheme.

Table 5.4.1 Range of Institutional Arrangements for PIM

Activity	Full Agency Control	Agency O&M (User Input)	**Shared Management**	WUA Owned (Agency Regulation)	Full WUA Control	Irrigation Management Company Board
Regulation	Agency	Agency	**MEDIWR**	Agency	WUA	Agency
Ownership of Structure & Assets	Agency	Agency	**MEDIWR**	WUA	WUA	Private Company
O&M Responsibility	Agency	Agency	**Scheme Management Office/ WUA**	WUA	WUA	Private Company
Collection of Water Charges	Agency	Agency	**Scheme Management Office/ WUA**	WUA	WUA	Private Company
Unit of Representation	Agency	WUA	**WUA**	WUA	WUA	Company & User Committee

Source: Arranged by the IDMP-TT based on ñParticipatory Irrigation Managementò, J. Raymond Peter, Executive Director, International Network on Participatory Irrigation Management, Washington DC (INWEPF/SY/2004(06))

CHAPTER 6 AGRICULTURAL PLANING

6.1 Basic Concept of Agricultural Planning for Priority Projects

The priority project areas will be the model of irrigated agriculture in RSS in future after IDMP actually start working. Therefore, the farming plans of priority project areas should have form that can contribute to the strategic plan specified in the governmental policies related to agricultural sector. In addition, it would be necessary to examine the agricultural potential of each project areas from various aspects, such as natural condition, marketing, and beneficiariesôcapacity and their technical potential.

Government plans to be considered

Agricultural Sector Policy Framework (2012-2017) with its setting vision of ñFood security for all the people of the Republic of South Sudan, enjoying improved quality of life and environmentò. Food insecurity is the most critical issue for South Sudanese and sustainable irrigation infrastructure and flood management system is expected to improve agricultural productivity and food security enhancement. This document also addressed some key issues as the mission of MAFCRD for instance acceleration of food and agricultural production through commercial smallholder and large scale agriculture, using mechanized and irrigation technology.

In addition, the comprehensive national development plan initiated just after the independence, namely ñSouth Sudan Development plan (SSDP) 2011-2013ò prioritizes the agricultural sector for economic development. In fact, main means of livelihoods of South Sudanese are agriculture and animal husbandry. To achieve basic improvement of peopleôs livelihoods, commercial agriculture should be promoted for future economic growth.

To make farming systems of priority project areas to follow the above strategic plan of the government, followings should be incorporated into the farming plans.

- ✓ Mechanized and intensive farming system
- ✓ To grow staple crops for subsistence giving priority to the crops with high water requirement
- ✓ To grow commercial crops for cash generation

With setting the above as basic concept of farming plan for priority project areas, crops to be cultivated for each area are examined considering the specific conditions, such as natural condition, marketing, and beneficiariesôcapacity and their technical potential.

6.2 Agricultural Planning (Cropping Pattern)

Firstly it should be mentioned that the command area in Wau Rice scheme belong to the government, that is to say Public land. Hence, irrigation scheme in Wau Rice scheme would probably be managed by the government at least the first stage of its establishment. Settlers from outside would be the beneficiaries of the future irrigation scheme, but it is highly recommended to involve the communities around the scheme somehow to share the benefits of project. Considering the above situation assumed, organized farming plan would be suitable for Wau Rice scheme. It is because new settlers, expected major farmers in the scheme, have no social connection each other, sometimes farmers and pastoralists can be involved together, therefore government is supposed to play a role to assist and facilitate settlers to be organized to achieve productive farming in effective way. From this aspect, organized farming and collective marketing is a way of leading to success.

Apart from the consideration above, the important matter to be taken care is the flood occurring in

rainy season every year. Under flooded condition, upland crops cannot be grown, but paddy grow preferably as far as appropriate management of excess water is done. Furthermore, demand of rice is increasing, especially in urban area recently because of its high and balanced nutrient contents and long life for storage. It means there is a potential for market with paddy cultivation. In addition, post-harvest processing is necessary for rice (e.g. seed drying/cleaning, milling), therefore, collective handling of post-harvest operation would be efficient.

Also, like other two (2) sites, leafy vegetable which is daily consumed is high potential crop for cash generation. It is because leafy vegetables do not have to compete with that from neighbouring countries. Leafy vegetables from long distance away cannot reach to the market because of its perishability. Leafy vegetable for daily consumption is in high demand especially in urban area and nearest city; Wau is large city with relatively high population.

The other essential things to be considered regarding natural condition is high temperature in dry season, soil type and soil acidity. From these aspects, unfavourable crops have been excluded. As a result, Tomato, Eggplant, and Water melon has been remained. Among them, water melon has higher tolerance to acid soil and it is estimated that it has relatively high profitability.

Taking into consideration the above reasons, Paddy, Water melon and Jewôs mallow have been selected for farming plan for irrigation scheme in Wau Rice scheme.

Figure 6.2.1 shows the planned cropping pattern with project for Wau Rice scheme.

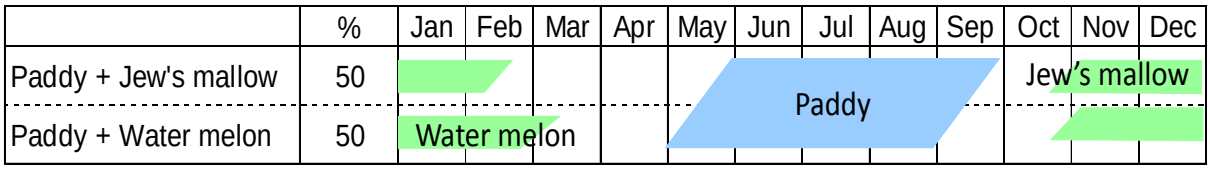


Figure 6.2.1 Planned Cropping Pattern

CHAPTER 7 IRRIGATION AND DRAINAGE PLAN

7.1 Parameters Affecting Crop Water Requirement

7.1.1 Climate and Weather Parameters

(1) Meteorological stations

The nearest meteorological stations for the priority project site are shown as below (figure 7.1.1). These meteorological stations have the data, such as rainfall, temperature, relative humidity, and wind speed and so on. Though the sunshine hour data cannot be found at the meteorological stations, it should be estimated by ñFAO Irrigation and Drainage Paper No.24ò.

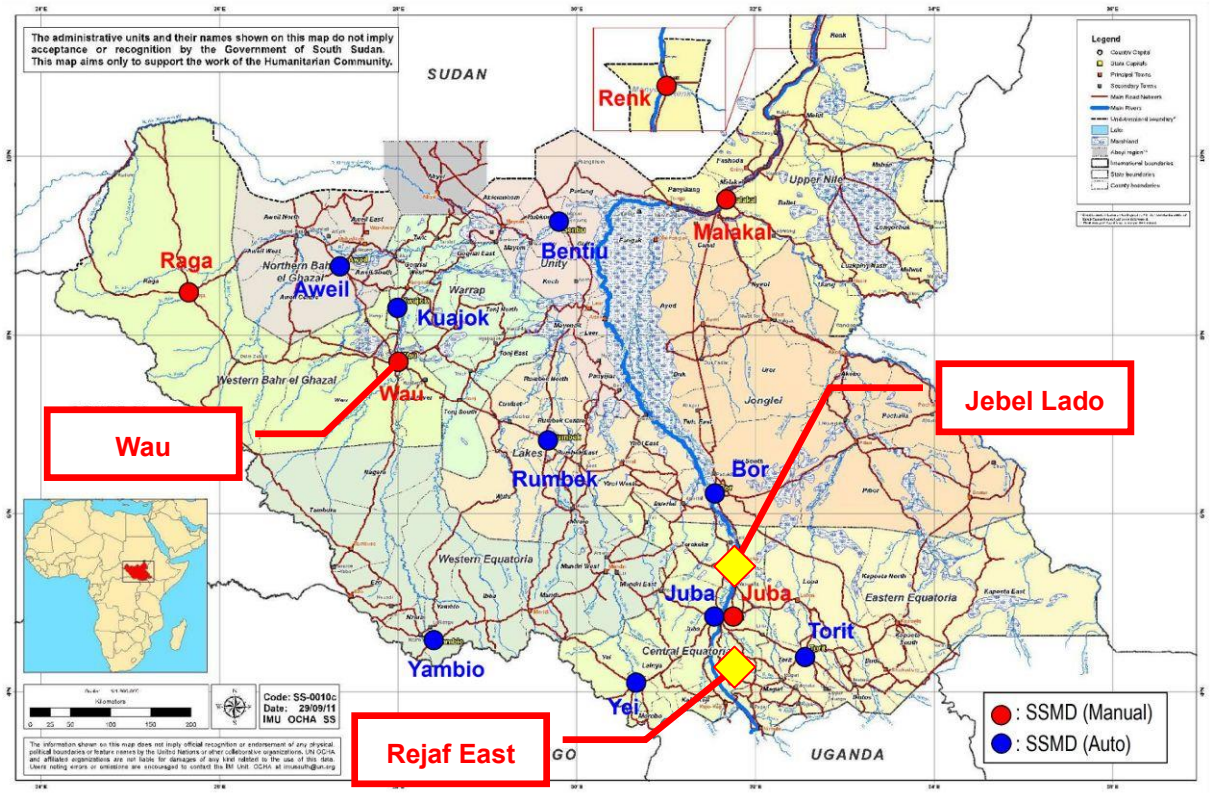


Figure 7.1.1 Meteorological Stations in South Sudan

Table 7.1.1 Meteorological Stations for Necessary Climate Data

Priority Project Site	Climate Data	Meteorological Station	Remarks
Wau	Temperarure, Rainfall	Wau	
	Relative Humidity, Wind Speed	Kauajok	No data in Wau meteorological station
Jebel Lado	Temperarure, Rainfall Relative Humidity Wind Speed	Juba	The nearest meteorological station
Rejaf East	Temperarure, Rainfall Relative Humidity Wind Speed	Juba	The nearest meteorological station

(2) Rainfall

The priority project areaôs climate belongs to the equatorial subtropical type. According to the data, it

is categorized that Apr-Oct period is ñRainy seasonò, and Nov-Mar period is ñDry seasonò. And it is characterized by mean annual rainfall of about 1,000 mm distributed in one rainy seasons, high temperatures and whereby consequently high evaporation. The mean monthly rainfall for the Wau station is given in Table 7.1.2 and Figure 7.1.2.

Table 7.1.2 Mean Monthly Rainfall at Wau

Meteorological Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Wau (mm)	0.7	3.4	19.4	65.8	127.8	168.1	192.8	212.0	170.7	123.3	13.4	0.3	1,098

Source: Meteorological Station Data (1901-2012 complied from several data sources)

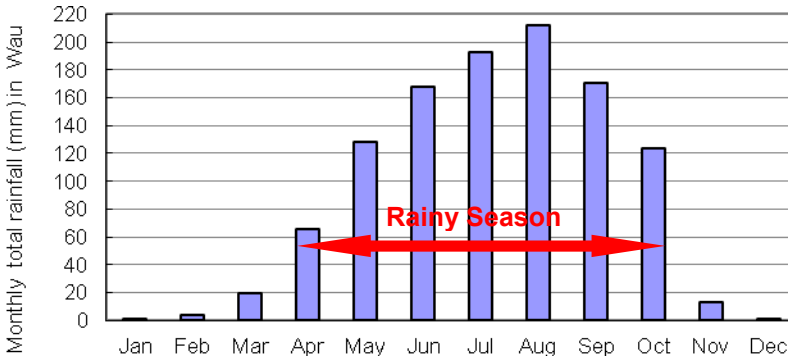


Figure 7.1.2 Mean Monthly Rainfall at Wau

(3) Temperature

The temperature in Wau area does not vary much throughout year. The hottest temperature appears in Feb -Mar, which corresponds to the end of the dry season. In both area, the mean monthly maximum temperature varies between 30 °C and 38 °C while the minimum temperature varies between 19 °C and 24 °C (see Table 7.1.3, Figure 7.1.3).

Table 7.1.3 Monthly Mean Max and Min Temperatures at Wau

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Min Temp (°C)	19.0	19.9	22.6	24.0	22.7	22.2	22.4	21.8	21.7	21.6	21.1	19.3	21.5
Max Temp (°C)	34.7	36.7	38.2	37.3	34.8	32.7	31.6	31.8	32.5	34.4	35.9	36.0	34.7

Source: Meteorological Station Data (2006-2008 SSMD Manual provided by FAO)

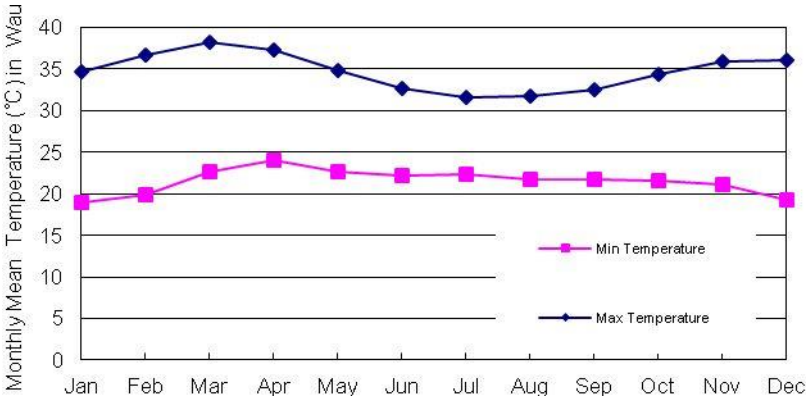


Figure 7.1.3 Mean Monthly Max and Min Temperatures at Wau

(4) Sunshine hours

Average sunshine hour is given in Table 7.1.4 estimated by FAO Irrigation and Drainage Paper No.24. By using the table by FAO, the shine hour can be estimate on a pro-rata basis of the latitude. It can be said that throughout the year, the isolation in priority area is long and strong, and the annual average keeps about 12 hours per day.

Table 7.1.4 Average Sunshine Hours Estimated by FAO Irrigation and Drainage Paper No.24

North Latitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
50°	8.5	10.1	11.8	13.8	15.4	16.3	15.9	14.5	12.7	10.8	9.1	8.1	
40°	9.6	10.7	11.9	13.3	14.4	15.0	14.7	13.7	12.5	11.2	10.0	9.3	
30°	10.4	11.1	12.0	12.9	13.6	14.0	13.9	13.2	12.4	11.5	10.6	10.2	
20°	11.0	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.7	11.2	10.9	
10°	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5	
7.7° (Wau)	11.7	11.8	12.0	12.3	12.5	12.6	12.5	12.4	12.1	11.9	11.7	11.6	12.1
5.1° (Jebel Lado)	11.8	11.9	12.0	12.2	12.3	12.4	12.3	12.3	12.1	12.0	11.9	11.8	12.1
5°	11.8	11.9	12.0	12.2	12.3	12.4	12.3	12.3	12.1	12.0	11.9	11.8	
0°	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	

Source : FAO Irrigation and Drainage Paper No.24

(5) Relative humidity

The yearly mean relative humidity is calculated at 51% for Wau. At Wau, it has 18 % in February, which is the month with the minimum humidity, and has 89% in September with the maximum. The monthly relative humidity data is given in Table 7.1.5 and in Figure 7.1.4, and as shown it is characterized by equatorial subtropical type.

Table 7.1.5 Monthly Mean Relative Humidity at Wau

Meteorological Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Wau (%)	31	18	15	37	56	74	72	78	89	64	39	43	51

Source : Meteorological Station Data (2009-2012 provided by SSMD)

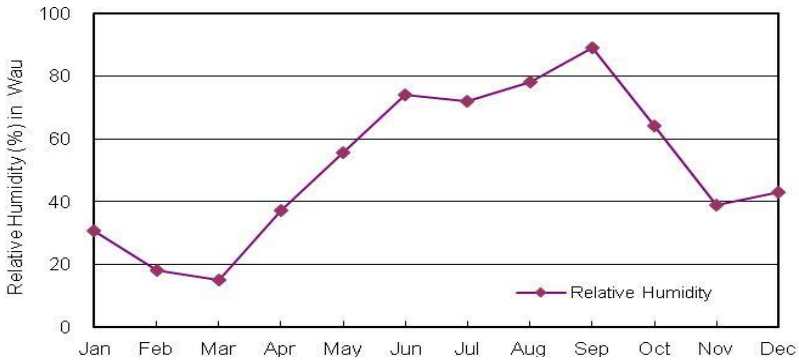


Figure 7.1.4 Mean Monthly Relative Humidity at Wau

(6) Wind speed

Mean annual velocity exceeds 70 km/s and even reaches as high as 4 m/s speed during the dry months (refer to Table 7.1.6 and Figure 7.1.5). The wind conditions are determined mainly by the breeze effect from the Indian Ocean. Night winds originate in gales which start blowing during the previous afternoon on the Somalian Coast.

Table 7.1.6 Monthly Mean Wind Speed at Wau

Meteorological Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Wau (km/day)	72	69	78	112	104	95	95	69	78	78	78	75	83.5

Source : Meteorological Station Data (2009-2012 provided by SSMD)

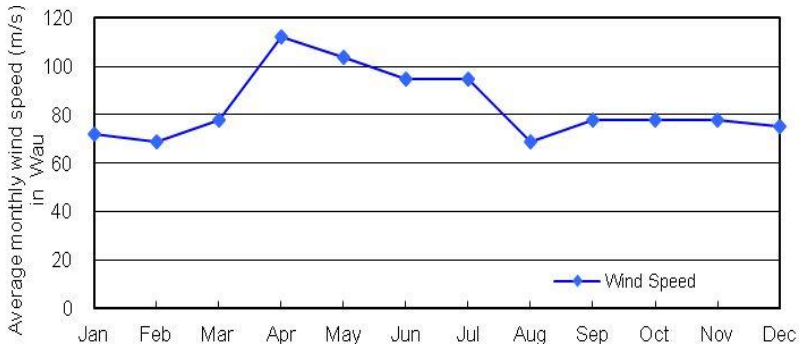


Figure 7.1.5 Mean Monthly Wind Speed at Wau

(7) Summary of the necessary climate and weather data

Priority Project : Wau
Station : Wau (Temp, Rainfall), Kauajok (Humidity, Wind)
Altitude :433m, Latitude : 7° 43'N, Longitude : 28° 1'E

Table 7.1.7 Summary of the Climate Data at Wau

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average Total
Min Temp (°C)	19.0	19.9	22.6	24.0	22.7	22.2	22.4	21.8	21.7	21.6	21.1	19.3	21.5
Max Temp (°C)	34.7	36.7	38.2	37.3	34.8	32.7	31.6	31.8	32.5	34.4	35.9	36.0	34.7
Humidity (%)	31	18	15	37	56	74	72	78	89	64	39	43	51
Wind (km/day)	72	69	78	112	104	95	95	69	78	78	78	75	83
Sunshine (hours)	11.7	11.8	12.0	12.3	12.5	12.6	12.5	12.4	12.1	11.9	11.7	11.6	12.1
Rainfall (mm)	0.7	3.4	19.4	65.8	127.8	168.1	192.8	212.0	170.7	123.3	13.4	0.3	1,098

7.1.2 Cropping Pattern Plan in the Farmlands

The crop type, variety and development stage should be considered when assessing the evapotranspiration from crops grown in large, well-managed fields. Differences in resistance to transpiration, crop height, crop roughness, reflection, ground cover and crop rooting characteristics result in different ET levels in different types of crops under identical environmental conditions. The Cropping Pattern Plan in Wau Farmlands is shown in Table 7.1.8.

Table 7.1.8 Cropping Plan

Project site	Rainy season	Dry season
Wau	Rice	Leafy vegetable (Jewʒs mallow)

7.1.3 Crop Coefficient Factor

Most of the effects of the various weather conditions are incorporated into the ETo estimate. Therefore, as ETo represents an index of climatic demand, Kc varies predominately with the specific crop characteristics and only to a limited extent with climate. This enables the transfer of standard values for Kc between locations and between climates.

7.2 Estimation of Crop Water Requirement

To estimate the crop water requirements, guidelines were developed and published by FAO ñFAO Irrigation and Drainage Paper No. 24, Crop Water Requirementsò.

7.2.1 Reference Evapo-transpiration (ETo)

(1) Estimation method

The evapo-transpiration rate from a reference surface, not short of water, is called the reference crop evapo-transpiration or reference evapo-transpiration and is denoted as ETo. The reference surface is a hypothetical grass reference crop with specific characteristics. The only factors affecting ETo are climatic parameters. Consequently, ETo is a climatic parameter and can be computed from weather data. ETo expresses the evaporating power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors.

Although several methods exist to determine ETo such as 1) Blaney-Criddle, 2) Radiation, 3) Modified Penman and 4) Pan evaporation methods as shown in Table 7.1.9. The modified Penman method was considered to offer the best results with minimum possible error in relation to a living grass reference crop. It was expected that the pan method would give acceptable estimate, depending on the location of the pan. The radiation method was suggested for areas where available climatic data include measured air temperature and sunshine, cloudiness or radiation, but not measured wind speed and air humidity. Finally, the publication proposed the use of the Blaney-Criddle method for areas where available climatic data cover air temperature data only.

Table 7.2.1 Water Requirement Estimation Methods by FAO

Estimation Methods	Feature	Necessary data	Remarks	Adoption
1) Blaney-Criddle	The most simplest method	Temperature		
2) Radiation	Simple method	Temperature, Sunshine		
3) Modified Penman (Penman-Montieth)	Suggested method by FAO	Temperature, Humidity, Wind, Sunshine	Calculated by CROPWAT 8.0	The Project Team adopted this method.
4) Pan evaporation	Actual Measurement method	Evaporation		

The FAO Penman-Monteith method is recommended as the sole standard method. It is a method with strong likelihood of correctly predicting ETo in a wide range of locations and climates and has provision for application in data-short situations. Therefore the project team adopted this Penman-Montieth method as the estimation method of the water requirement.

(2) Monthly values of reference (potential) evapo-transpiration (ETo)

Monthly values of potential/reference evapo-transpiration (ETo) can be estimated using

Penman-Monteith method. Data used in estimating the potential/reference evapo-transpiration using Penman-Monteith method are the mean monthly values of temperature, relative humidity, ratio of actual sunshine duration to the maximum possible one, and wind speed. Together with the climate data recorded at Wau meteorological station and employed in estimating the ETo, the monthly ETo values are given in Table 7.2.2, which range from 5 mm to about 7 mm per day:

Table 7.2.2 Evapo-transpiration (ETo) at Wau Estimated by Penman-Monteith

Particulars	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min Temperature (°C)	19.0	19.9	22.6	24.0	22.7	22.2	22.4	21.8	21.7	21.6	21.1	19.3
Max Temperature (°C)	34.7	36.7	38.2	37.3	34.8	32.7	31.6	31.8	32.5	34.4	35.9	36.0
Relative Humidity (%)	31	18	15	37	56	74	72	78	89	64	39	43
Wind speed (km/day)	72	69	78	112	104	95	95	69	78	78	78	75
Sunshine (hours)	11.7	11.8	12.0	12.3	12.5	12.6	12.5	12.4	12.1	11.9	11.7	11.6
Radiation (MJ/m2/day)	24.9	26.5	27.9	28.5	27.9	27.4	27.5	28.1	27.9	26.8	25.1	24.2
ETo (mm/day)	4.88	5.09	5.72	6.74	6.21	5.67	5.59	5.60	5.58	5.55	5.25	5.00

Source: JICA Team based on meteorological data recorded at Wau station.

7.2.2 Crop Coefficient (Kc)

The crop coefficient is depended on the crop development stages. The crop coefficient curve is shown (Kc curve) to Figure 7.2.1. The crop coefficient (Kc) estimated is as shown in Table 7.2.3, which varies from the initial stage to the peak stage. Estimation of crop coefficient (Kc) refers to the recommended figures in the ñCrop Water Requirements No.24 FAO Irrigation and Drainage paperò.

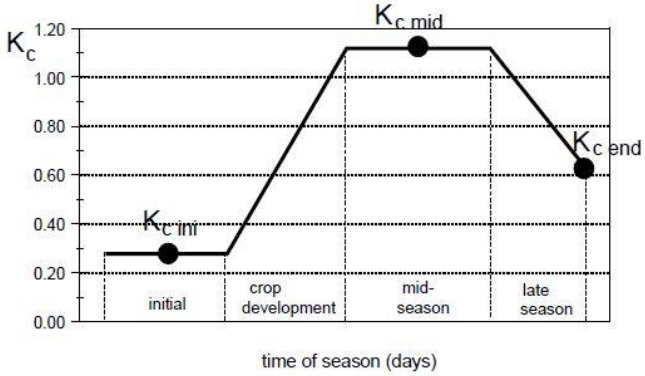


Figure 7.2.1 Crop Coefficient Curve

Table 7.2.3 Crop Coefficient by Each Crop

Crop	Kc ini	Kc mid	Kc end
Rice	1.10	1.10	0.95
Maize	0.90	1.15	0.60
Egg plant	0.90	1.05	0.85
Tomato	0.90	1.20	0.65
Jewôs mallow*	0.90	1.10	1.10

Note: Kc of Jewôs mallow is applied Kc of celery

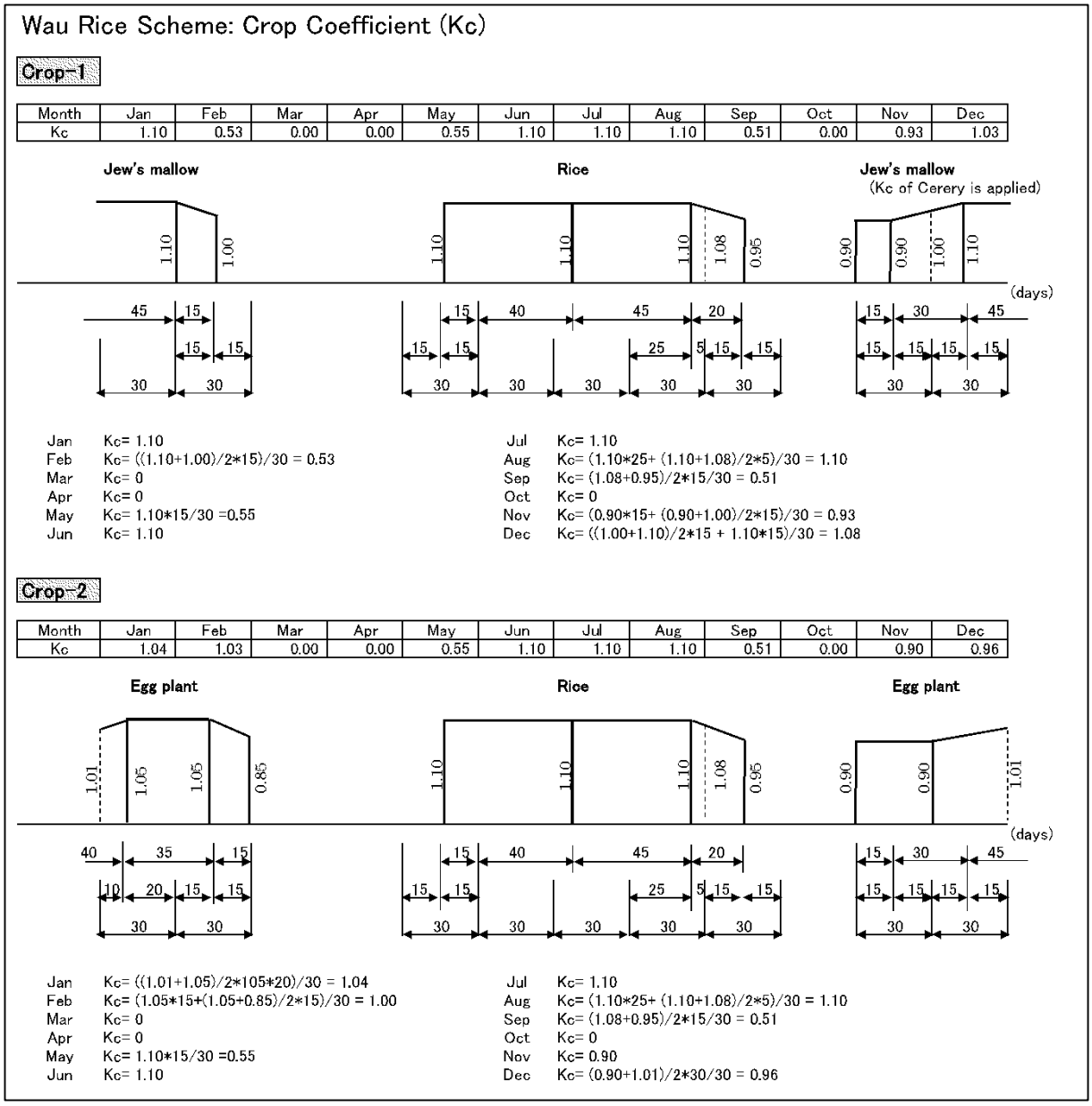


Figure 7.2.2 Crop Coefficient

7.2.3 Crop Evapo-transpiration under standard conditions (ETc)

The crop evapotranspiration under standard conditions, denoted as ETc, is the evapotranspiration from disease-free, well- fertilized crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions. Crop evapotranspiration can be calculated from climatic data and by integrating directly the crop resistance, albedo and air resistance factors in the Penman-Monteith approach. As there is still a considerable lack of information for different crops, the Penman-Monteith method is used for the estimation of the standard reference crop to determine its evapotranspiration, ETc = Kc ETo.

7.3 Estimation of Irrigation Water Requirements

7.3.1 Calculation of Consumptive Irrigation Requirements (CIR)

The consumptive irrigation requirement is the quantity of water actually required by the plant.

CIR = Consumptive use ï effective rainfall
CIR = ETc ï Eff. rainfall

(1) Effective rainfall (dependable rainfall)

Effective rainfall should be estimate by ñDependable Rainfall (Pd)ò. The ñDependable Rainfall (Probability=80%)ò is used for the design of irrigation system capacity. The ñDependable Rainfall (80%)ò is corresponding to 80% probability of exceedance and representing a dry year.

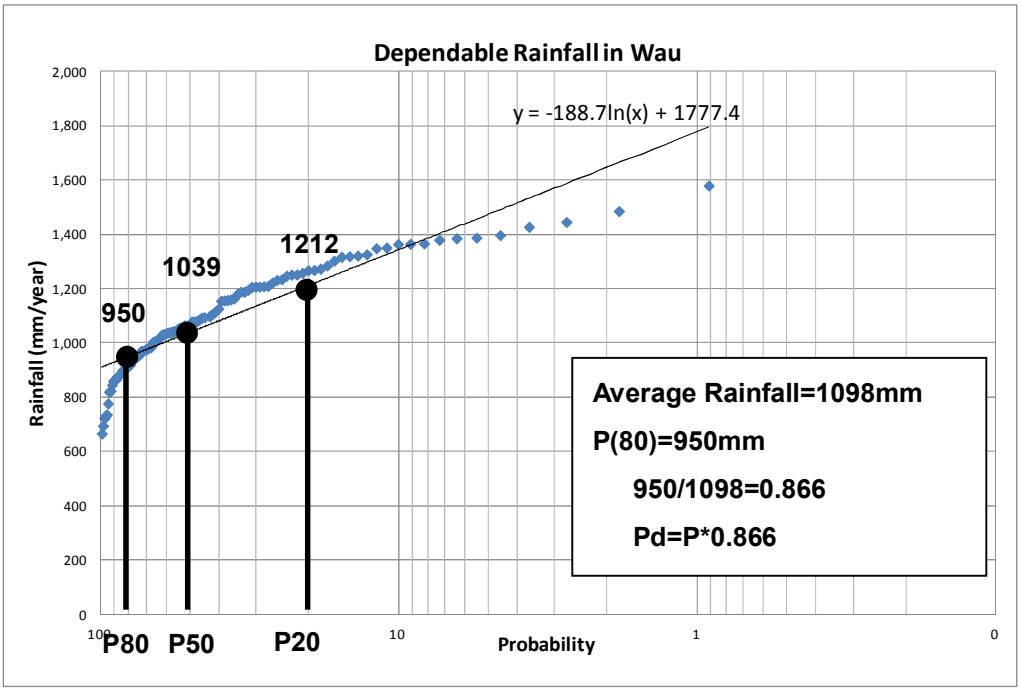


Figure 7.3.1 Dependable Rainfall at Wau

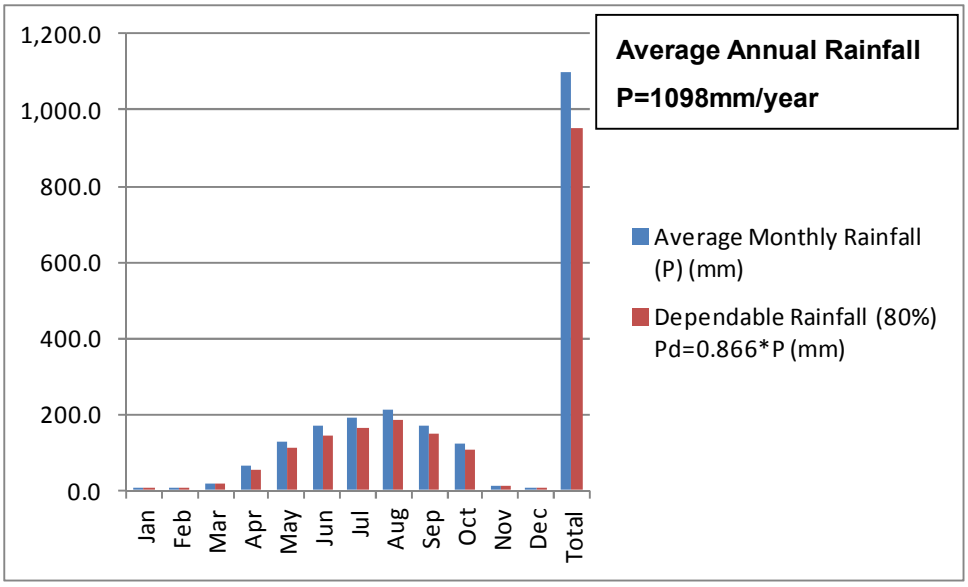


Figure 7.3.2 Effective Rainfall at Wau

(2) Estimation of the effective rainfall

Effective rainfall should be estimate by the formula suggested by FAO.

FAO Method (Suggested Method), Pd: Dependable Rainfall (Probability=80%)

Pe=0.6*Pd-10 (Pd≦70mm/month)

Pe=0.8*Pd-24 (Pd＞70mm/month)

The estimated effective rainfall for Wau scheme is shown in Table 7.3.4.

7.3.2 Calculation of Net Irrigation Requirements (NIR)

The net irrigation requirement (NIR) is equal to consumptive irrigation requirement plus the water required for other purpose, such as leaching of alkaline or salty soils.

NIR = CIR + Le

Where Le is the water required for leaching and other purposes.

The calculated NIR (ETcrop1 and ETcrop2) for Wau scheme is shown in Table 7.3.4.

7.3.3 Calculation of Field Irrigation Requirements (FIR)

The field irrigation requirement (FIR) is the amount of water required to be applied to the field. It is equal to the net irrigation requirements plus the amount of applied water lost as surface runoff, evaporation and deep percolation.

FIR = NIR + Water application losses

FIR = NIR/Ea

Where Ea is field application efficiency

7.3.4 Calculation of Gross Irrigation Requirements (GIR)

The gross irrigation requirement is the quantity of water required at the head of the canal; is greater than the field irrigation requirements because there are always some transit (conveyance) losses.

GIR = FIR + Conveyance losses

GIR = FIR/ Ec

7.3.5 Calculation of Irrigation Water Requirements

Irrigation is required when rainfall is insufficient to compensate for the water lost by evapotranspiration. The primary objective of irrigation is to apply water at the right period and in the right amount. By calculating the soil water balance of the root zone on a daily basis, the timing and the depth of future irrigations can be planned.

The daily water balance, expressed in terms of depletion at the end of the day is:

Dr, i = Dr, i-1 - (P - RO)i - Ii - CRi + ETc, i + DPi

Where

Dr, i: root zone depletion at the end of day i [mm],

Dr, i-1: water content in the root zone at the end of the previous day, i-1 [mm],

Pi: precipitation on day i [mm],

ROi: runoff from the soil surface on day i [mm],

Ii: net irrigation depth on day i that infiltrates the soil [mm],

Cri: capillary rise from the groundwater table on day i [mm],

ETc, i: crop evapotranspiration on day i [mm],

Dpi: water loss out of the root zone by deep percolation on day i [mm].

During this Pre-feasibility study for Wau scheme most of the soil water balance parameter were negligent but they must be considered during feasibility study stage.

Therefore the daily water balance is expressed as follow:

0 = 0 - (P - 0)i - Ii - 0 + ETc, i + 0

Ii = ETc,I ï Pi or

NIR = ETc ï Eff. rainfall

There is no leaching required; the CIR equal to NIR

The scheme/farm irrigation requirement is equal to net irrigation requirements plus field application losses, filed canal losses and conveyance losses.

Scheme/farm irrigation water requirement = Net Irrigation requirement/Ep

Where Ep is Overall Irrigation Efficiency

Ep= Ec.Eb.Ea

Where Ec is Conveyance efficiency, Eb is field canal efficiency and Ea field application efficiency.

(1) Overall irrigation efficiency

Overall irrigation efficiency, so-called project irrigation efficacy, is composed of 1) conveyance efficiency (Ec), 2) field canal efficiency (Eb) or distribution efficiency, and 3) field application efficiency (Ea). The project irrigation efficiency is estimated by multiplying these 3 efficiencies. Table 7.3.1 presents the efficiencies applied in the target project with reference to the recommended efficiencies in the ôFAO Irrigation and Drainage Paper No.24, Crop Water Requirementsõ as; 0.90 for the conveyance efficiency, 0.90 for the field canal efficiency, 0.32 for the field application efficiency in Wau rice scheme, whereby the project irrigation efficiency comes to 0.26 for Wau. Basin irrigation methods are adopted in the farmlands because of rice farming.

Table 7.3.1 Irrigation Efficiencies of Rice Cropping

Efficiency	E	Remarks
1) Conveyance Efficiency (Ec)	0.90	Continuous supply
2) Field Cancel Efficiency (Eb)	0.90	Blocks larger than 20 ha
3) Field Application Efficiency (Ea)	0.32	Rice Scheme
Project Irrigation Efficiency	0.26	Overall irrigation efficiency

Source: JICA Project Team based on Crop water requirements No.24 FAO irrigation and drainage paper

Irrigation Project Efficiency or Overall Irrigation Efficiency = Ec.Eb.Ea

The overall efficiency of Rice for Wau Scheme = 0.9*0.9*0.32 = 0.26

The overall efficiency of Vegetables for Wau Scheme = 0.9*0.9*0.7 = 0.57

7.3.6 Calculation of Scheme/Farm Water Requirements

q = NIR/Ep

Where q is The Scheme irrigation water requirements, NIR is Net irrigation water requirements and Ep is overall irrigation efficiency.

NIR (ETcrop1, ETcrop2 and ETcrop3) is expressed in average mm/day, in mm/month and in l/s/ha.

Therefore q = NIR (mm/day)/Ep = NIR ((mm*ha)/(24 hr*ha))/Ep

= NIR ((mm*(10000 m^2))/((24*60*60 s)*ha))/Ep

= NIR (($(10^{-3}$ m)*(10000 m^2))/((86400 s)*ha))/Ep

= NIR ((10^{-3} *10^4 m^3)/((86400 s) *ha))/Ep

= NIR (10 m^3)/(86400 s)/ha/Ep

= NIR (10*(1000 l)/(86400 s)/ha/Ep

= NIR (10000 l)/(86400 s)/ha/EP

= NIR ((10000/86400) l/s/ha)/Ep

= NIR ((1/8.64) l/s/ha)/EP = NIR (0.1157 l/s/ha)/Ep

C.F = 1/8.64 = 0.1157

Hence q = NIR ((C.F) l/s/ha)/Ep

Where C.F is Conservation factor from mm/day to l/s/ha

Table 7.3.2 Irrigation Efficiencies of Vegetable Cropping

Efficiency	E	Remarks
1) Conveyance Efficiency (Ec)	0.90	Continuous supply
2) Field Cancel Efficiency (Eb)	0.90	Blocks larger than 20 ha
3) Field Application Efficiency (Ea)	0.70	Referred to the case of basin irrigation, vegetables
Project Irrigation Efficiency	0.57	Overall irrigation efficiency

Source: JICA Project Team based on Crop water requirements No.24 FAO irrigation and drainage paper

(2) Calculated water requirement

The calculation of Wau scheme irrigation water requirement is shown in Table 7.3.3 and Table 7.3.4.

Table 7.3.3 Wau Scheme Irrigation Water Requirements

1. Site	Wau Rice Scheme
2. Command Area	500 ha
3. Water Source	Dam/Reservoir or River
3. Irrigation Facility	Combination of Dam/Reservoir and Pump
4. Irrigation Water Requirement	Dam 5,000,000 m^3/year (Vegetables, dry season) Pump 0.70 m^3/s (Rice, rainy season) q= 1.400 l/s/ha

Table 7.3.4 Calculation of Irrigation Water Requirement per Month for Wau Scheme

Water Requirement: Wau

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
		Dry Season				Rainy Season						Dry Season		
(1) ETcrop														
Min Temperature	(°C)	19.0	19.9	22.6	24.0	22.7	22.2	22.4	21.8	21.7	21.6	21.1	19.3	21.5
Max Temperature	(°C)	34.7	36.7	38.2	37.3	34.8	32.7	31.6	31.8	32.5	34.4	35.9	36.0	34.7
Relative Humidity	(%)	31	18	15	37	56	74	72	78	89	64	39	43	51.3
Wind speed	(km/day)	72	69	78	112	104	95	95	69	78	78	78	75	83.5
Sunshine	(hours)	11.7	11.8	12.0	12.3	12.5	12.6	12.5	12.4	12.1	11.9	11.7	11.6	12.1
Radiation	(MJ/m2/day)	24.9	26.5	27.9	28.5	27.9	27.4	27.5	28.1	27.9	26.8	25.1	24.2	26.9
ETo	(mm/day)	4.88	5.09	5.72	6.74	6.21	5.67	5.59	5.60	5.58	5.55	5.25	5.00	CropWar8.0
Crop 1		Jew's mallow					Rice	Rice	Rice			Jew's mallow (leafy veg		
Crop 2		Egg plant (fruit vege.)					Rice	Rice	Rice			Egg plant (fruit vege.)		
Crop coeffient 1	Kc1	1.10	0.55	0.00	0.00	0.55	1.10	1.10	1.10	0.51	0.00	0.93	1.03	
Crop coeffient 2	Kc2	1.04	1.03	0.00	0.00	0.55	1.10	1.10	1.10	0.51	0.00	0.90	0.96	
Etcrop 1 (ET_0 x Kc1)	(mm/day)	5.37	2.80	0.00	0.00	3.42	6.24	6.15	6.16	2.85	0.00	4.88	5.15	
Etcrop 2 (ET_0 x Kc2)	(mm/day)	5.08	5.24	0.00	0.00	3.42	6.24	6.15	6.16	2.85	0.00	4.73	4.80	
(2) Effective Rainfall (Pe)														
Monthly Mean Rainfall	(mm/month)	0.7	3.4	19.4	65.8	127.8	168.1	192.8	212.0	170.7	123.3	13.4	0.3	1,097.7
Dependable Rainfall (80%)	(mm/month)	0.6	2.9	16.8	57.0	110.7	145.6	166.9	183.6	147.8	106.8	11.6	0.3	950.6
Effective Rainfall (ER)	(mm/month)	0.0	0.0	0.0	24.0	65.0	92.0	110.0	123.0	94.0	61.0	0.0	0.0	569.0
Effective Rainfall (ER)	(mm/day)	0.0	0.0	0.0	0.8	2.2	3.1	3.7	4.1	3.1	2.0	0.0	0.0	
(3) Groundwater Contribution (Ge)	(mm/day)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
(4) Stored Soil Water (Wb)	(mm/day)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
(5) Etcrop - (Pe+Ge+Wb)														
Etcrop 1	(mm/day)	5.37	2.80	0.00	0.00	1.22	3.14	2.45	2.06	0.00	0.00	4.88	5.15	
Etcrop 2	(mm/day)	5.08	5.24	0.00	0.00	1.22	3.14	2.45	2.06	0.00	0.00	4.73	4.80	
(6) Total Efficiency														
Conveyance Efficiency	Ec	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	
Field Canal Efficiency	Eb	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	Lining canal
Field Application Efficiency	Ea	0.70	0.70	0.70	0.70	0.32	0.32	0.32	0.32	0.32	0.70	0.70	0.70	
Total Irrigation Efficiency	Ep	0.57	0.57	0.57	0.57	0.26	0.26	0.26	0.26	0.26	0.57	0.57	0.57	
(7) Irrigation Hour	(hour)	24	24	24	24	24	24	24	24	24	24	24	24	
(8) Unit Water Requirement														
Crop 1	(l/s/ha)	1.09	0.57	0.00	0.00	0.54	1.40	1.09	0.92	0.00	0.00	0.99	1.05	
Crop 2	(l/s/ha)	1.03	1.06	0.00	0.00	0.54	1.40	1.09	0.92	0.00	0.00	0.96	0.97	
(9) Command Area														
Crop 1	(ha)	250	250	250	0	250	250	250	250	250	0	250	250	
Crop 2	(ha)	250	250	250	0	250	250	250	250	250	0	250	250	
Total	(ha)	500	500	500	0	500	500	500	500	500	0	500	500	
(10) Water Requirement for Pump														
Crop 1	(m3/s/Crop1)	0.27	0.14	0.00	0.00	0.14	0.35	0.27	0.23	0.00	0.00	0.25	0.26	
Crop 2	(m3/s/Crop2)	0.26	0.27	0.00	0.00	0.14	0.35	0.27	0.23	0.00	0.00	0.24	0.24	
Total	(m3/s/Total)	0.53	0.41	0.00	0.00	0.27	0.70	0.55	0.46	0.00	0.00	0.49	0.51	
(11) Water Requirement for Reservoir	(m3/month/Total)	1,373,760	1,056,240	0	0	699,840	1,814,400	1,412,640	1,192,320	0	0	1,263,600	1,308,960	10,121,760
							Required Pump Capacity (from May to Sep)					0.70	(m3/s)	
							Required Reservoir Capacity (from Nov to Apr)					5,002,560	(m3/year)	

CHAPTER 8 FACILITY PLAN AND DESIGN

8.1 General

8.1.1 Outline of Main Facilities

Main facilities planed in Wau Rice Scheme are as follows;

- Command area: A=500ha
- Dam: 1 place
- Pump station: 1 place
- Distribution canal: L=6.2km
- Main canal (command area): L=7.1km
- Secondary canal, drainage, road, etc. .in command area: 1 L.S
- Main drainage Canal: L=7.3km
- Flood Protection Dike: L=9.7km

Pump facility are operated during the rice cropping term in rainy season, and the reserved water in the dam is used during vegetable cropping term in dry season, considering the operation cost of the pump and the hydrology condition in the site.

8.1.2 Command Area

Command area is located beside Wau town, and has the feature of bare land without planting in the flood plain. The land is approximately flat and the land gradient toward R, Jur shows around 0.2%. Dam site is located 9.5km from Wau town. The land cover in the site is bushes and grasses. Pump station and canal line are located between the command area and dam site. There are trees, small communities, farms, etc. along the line.

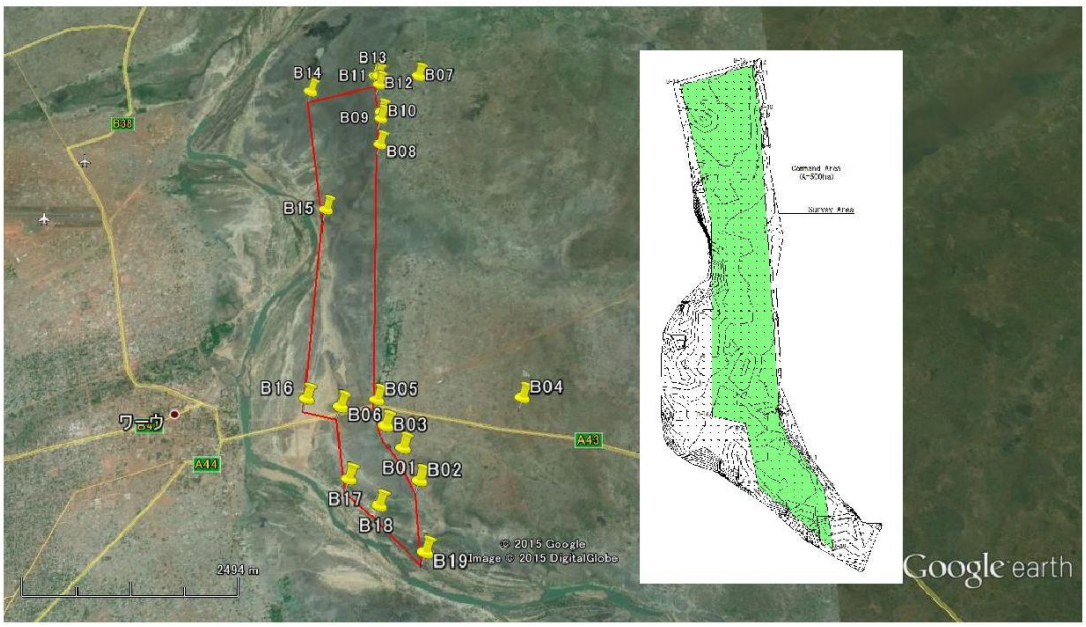


Figure 8.1.1 Command Area

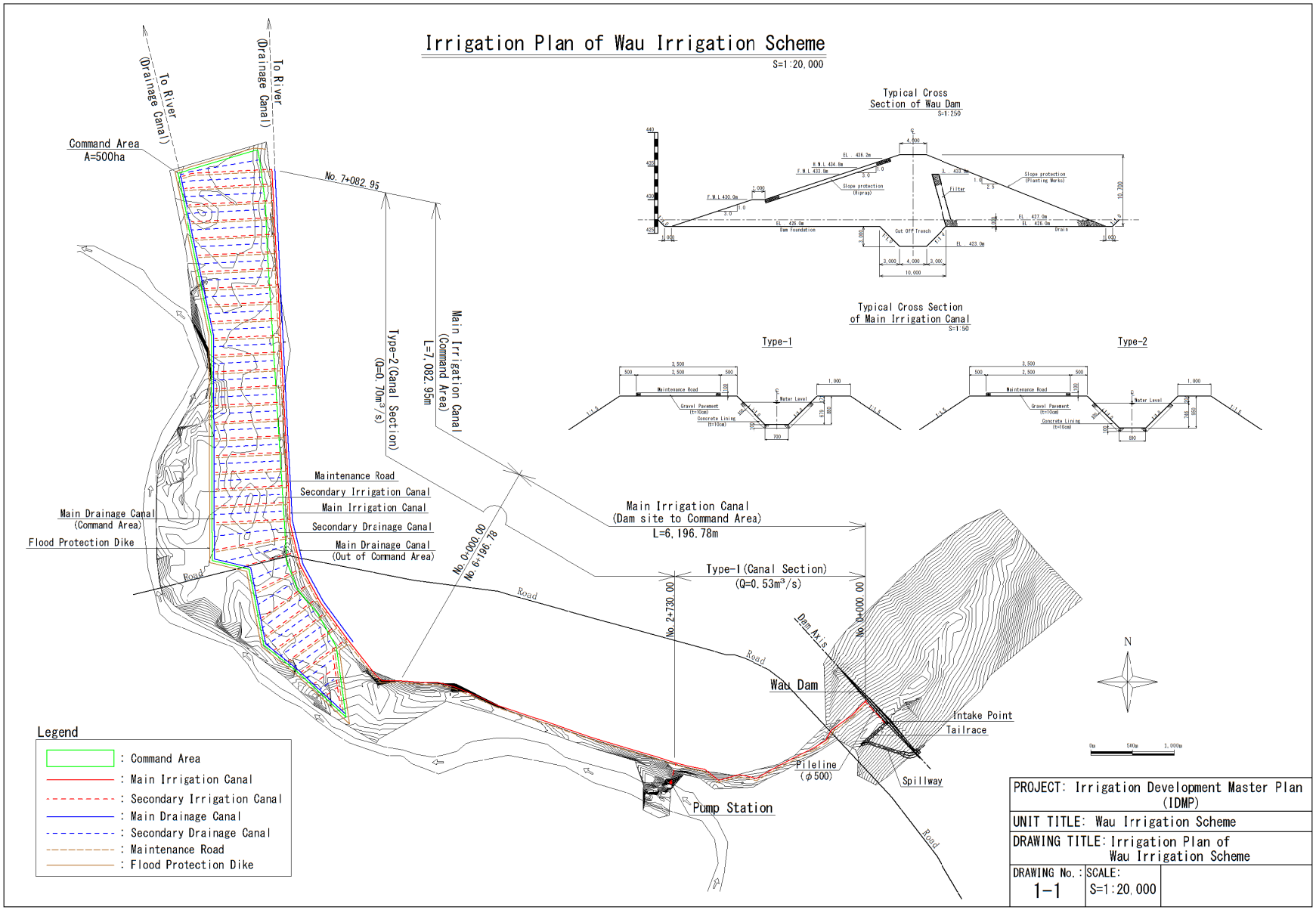


Figure 8.1.2 Location Map

8.2 Dam

(1) Outline of irrigation plan at Wau

The Wau Irrigation system consists of the reservoir, the main canal and the irrigation area. The water resource is planed the small scale reservoir which the height is 10.7 m and the dam length is 1,500 m. The reservoir has approximate 5.3 million m3 of the capacity and 51 km2 of the catchment area.

The map of the irrigation area is shown at Figure 8.2.1.

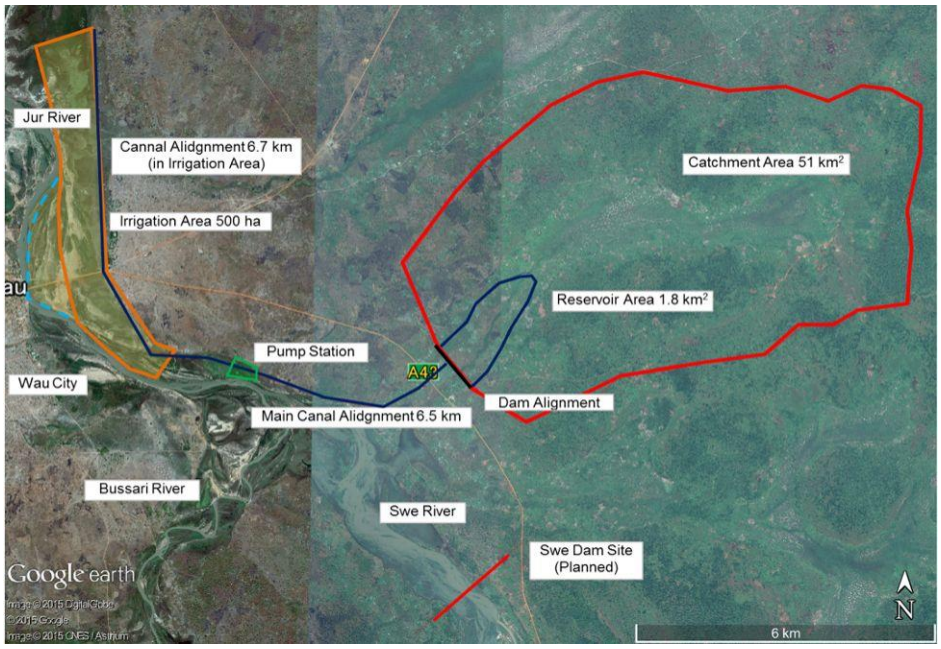


Figure 8.2.1 Location Map

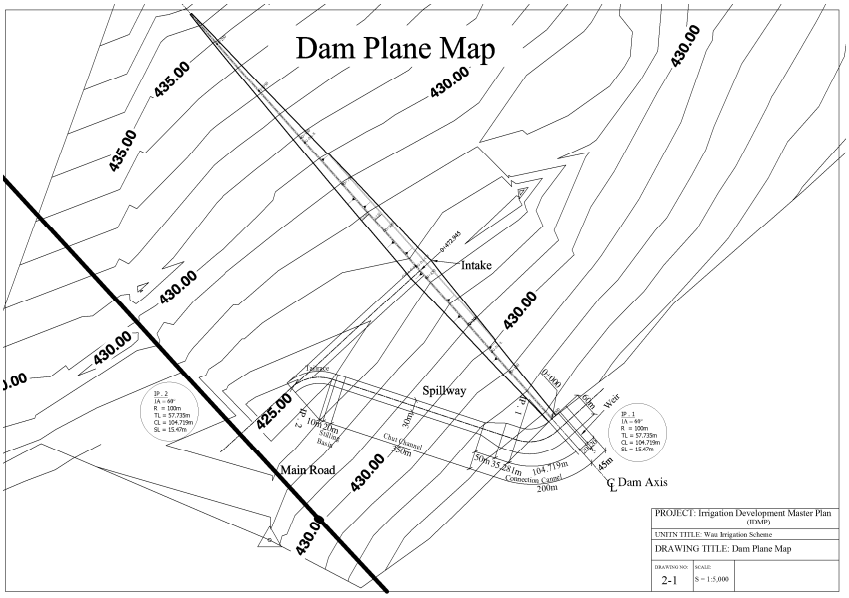


Figure 8.2.2 Dam Plane Map

Table 8.2.1 Specifications

Facility		Specification	Remarks
General	Location	7 km upstream from Wau	
	River name	Tributary of Swe River	
	Foundation geology	River Gravel & Sand Base Rock: Gneiss (Granite?)	
	Purpose	Irrigation	
Reservoir	Catchment area	51 km^2	
	Average annual inflow	5,340,000 m^3	
	Reservoir area at FWL	1.8 km^2	
	Total storage capacity	5,300,000 m^3	
	High water level	H.W.L. 434.8 m	
	Full water level	F.W.L. 433.8 m	
	Minimum operation water level	L.W.L. 427.0 m	
	Available depth	7.8 m	
Dam	Dam type	Fill type	
	Dam height	10.7 m	
	Dam length	1,500 m	
	Dam crest width	4 m	
	Dam crest level	E.L. 436.7 m	
	Foundation treatment	Cutoff	
	Dam volume	270,000 m^3	
Spillway	Spillway type	Weir type	
	Dissipater type	End-sill	
	Discharge (200 year return period)	108 m^3/sec	
	Weir crest water depth	1.0 m	
	Weir crest length	60.0 m	
Intake	Intake type	Drop inlet	
	Emergency Outlet discharge	Maximum 7.7 m^3/sec	
	Irrigation Intake	0.53 m^3/sec	
	Penstock	ϕ 1100	
	Irrigation	ϕ 700	
	River maintaining	ϕ 500	
Diversion	Type	Half closure of river	
	Construction	Dry season work	

(2) Geology

1) Site geology

The dam project area is covered by the sedimentary layer, the silty clay and the gravel sand which are thick layer and their thicknesses are 8m ~ 10 m, and the maximum thickness is 14 m at the river portion of the dam site (Borehole No. G-DA-C (2)). The foundation of the base rock is gneiss but the depth of the layer is deeper than 10 m.

The N value of the sedimentary layer is about 30 at the depths of 3m ~ 4m and the permeability is less than K = 5×10-5 cm/sec. The layer of the silty clay and the gravel sand is firm for the low dam as the 10 m height and impervious for the dam foundation.

2) Boreholes at dam site

There are three borings at the dam alignment, the right abutment (10 m in depth), the river portion (11 m and 14 m in depth) and the left abutment (10 m in depth) as Table 8.2.2.

Table 8.2.2 Boreholes at Dam Site

Borehole	Coordinates		Drilling Depth (m)	Dam Axis
	Northing	Easting		
G-DA-L	7°40′48″	28°5′24″	10.0	0+215
G-DA-C (1)	7°40′59″	28°5′13″	11.0	0+485
G-DA-C (2)			14.0	0+488
G-DA-R	7°41′13″	28°5′4″	10.0	0+885

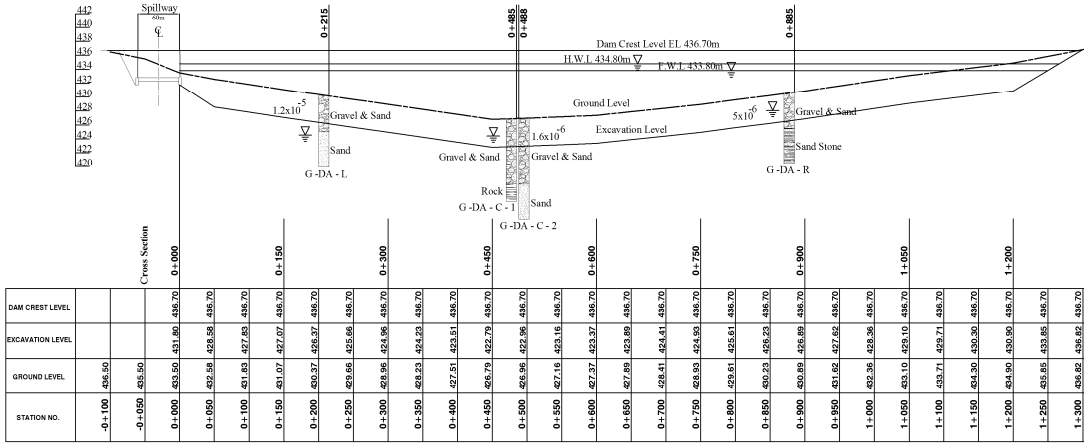


Figure 8.2.3 Longitudinal Section

(3) Dam capacity

The dam capacity of the Wau is decided by the required water of the irrigation area and the main crops of the irrigation area are planed of paddy field, designed by rice scheme area.

1) Required irrigation water

The required irrigation water for the irrigation (500 ha) of dry season is calculated as followed:

Required Irrigation water (500 ha): 4,900,000 m^3 (dry season)

0.53 ^{3}/ sec (Maximum required water)

2) Annual inflow

Average amount of annual specific yield for last 30 years (SY30) is calculated by the following formula.

$SY_{30} = Q_{30} / A \times 1{,}000$

SY_{30}: Average annual specific yield for last 30 years (mm/year)

Q_{30}: Average annual river discharge for last 30 years at the exit of the catchment area (MCM/year)

A: Catchment Area (km^2)

And then,

$Q_{30} = SY_{30} \times A \times 1{,}000$

The Wau dam site is situated at G1105 (Wau) and G113 (Swe River) and the values of the Specific

Runoff Yield (SY30) are 104.6 and 97.2 respectively. The annual river discharges (Q30) are calculated with the annual specific yield (SY30) as follows:

G1105 (Wau): $Q_{30} = SY_{30} \times A \times 1{,}000$ (A = 51 km^2: catchment area)

$= 104.6 \times 51 \times 1{,}000$

$= 5{,}334{,}600\ m^3 > 4{,}900{,}000\ m^3$ (Required Irrigation Water)

The annual river discharges (Q30) with the Specific Runoff Yield (SY30) are more than the required irrigation water at the Wau dam site and the storage capacity of the Wau dam is decided as 5.3 MCM (million cubic meter).

3) Dam capacity

The dam capacity is decided by the relation curve (H ~ Q curve) between the dam height and the dam quantity at the dam site. The Full Water Level (F.W.L.) is EL. 433.8 m, because the dam capacity is planned as 5,300,000 m3 (See Figure 8.2.4).

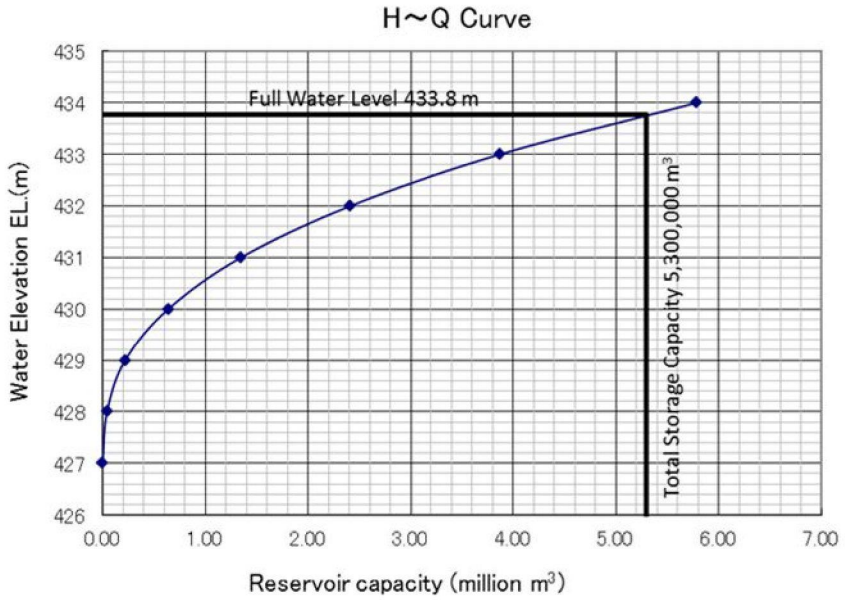


Figure 8.2.4 H - Q Curve

(4) Dam design

1) Dam location

The location of the Wau dam is 8km toward east as follow's survey map. The length of the dam arraignment is 1.5 km and the reservoir area of the dam is 1.8 km2.

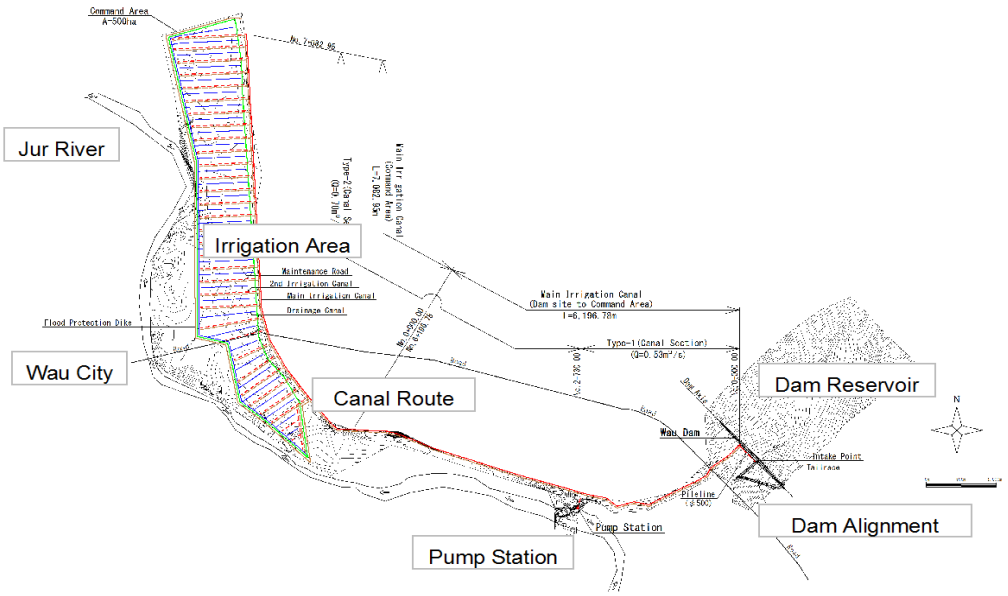


Figure 8.2.5 Location Map of Wau Area

2) Dam type

At the decision of dam type, it is important point to figure out the topography and geological conditions. We have mentioned the site conditions of Wau Dam site.

a) The geography of the dam site is gentle slope and hillside.

b) The dam arraignment is long as 1.5 km and the dam height is less than 15 m as the small dam by the H ~ Q curve of the dam.

c) The dam foundation is consisting of the gravel and silty sand.

d) There is no quarrel site but it seems that borrow sites are near the site.

According to the site conditions which are the wide and hilly topography and have the soil foundation, the dam type is selected the fill dam and the homogenous type.

3) Water level of reservoir

A. Full Water Level

Full water level is decided by the H ~ Q curve of the dam and its elevation is F.W.L. 433.8 m.

B. Dead Water Level

Dead water level is decided by H ~ Q curve of the dam and its elevation is L.W.L. 427.0 m.

C. High Water Level

Estimation of high water level is computed by using 200 years return period flood and it is considered storage effect of the reservoir. The calculation of the flood flow has been made and the results are shown follows:

Flood flow calculation results (200 years return period): Q = 108 m^3/sec

High Water Level ---------- H. L.W. 434.8 m (Over flow depth = 1.0 m)

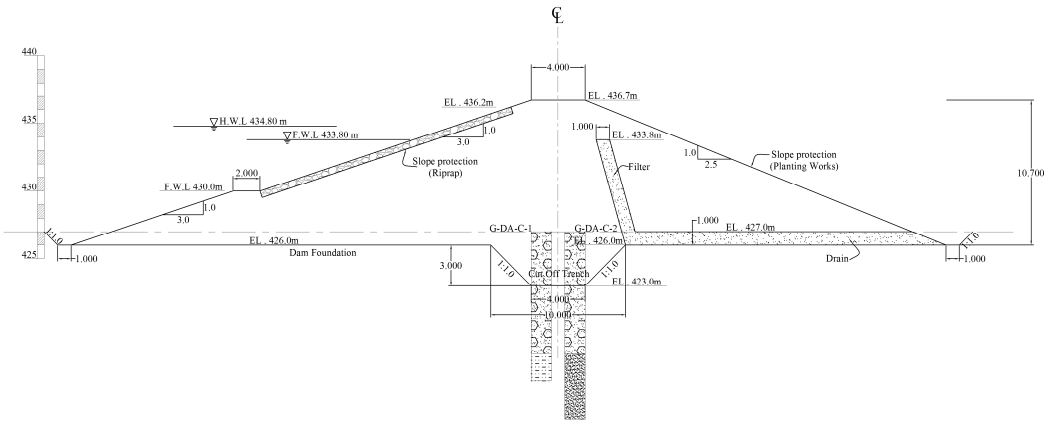


Figure 8.2.6 Typical Cross Section of Dam

4) Dam materials

The Wau dam is homogeneous dam type and the dam-body consists of impervious zone and filter and drain zone.

1 Selected Impervious zone (GC or CH, CL)

2 Filter and Drain zone (GW or GP)

(5) Appurtenant facility

1) Spillway

Spillways are the facilities provided to ensure the safety of dams against floods. Therefore, spillways should be of such structure that outlet capacity of spillway is sufficient to release safety the design flood discharge.

The design flood flow of the spillway (200 years return period) and the standard level of the reservoir are as follows:

Full water level	F.W.L. 433.8 m
The design flood flow	Qd (= 108 m^3/s by flood flow calculation result)

The spillway location of the dam site is constructed at the left abutment and the standard type.

2) Design of intake

The specifications of Wau dam are as follows:

1)	Dam crest level	E.L. 436.7 m
2)	High water level	H.W.L. 434.8 m
3)	Full water level	F.W.L. 433.8 m
4)	Low water level	L.W.L. 427.0 m
5)	Capacity	5,300,000 m^3
6)	Maximum Intake Discharge	0.53 m^3/sec
7)	Emergency Release Discharge	7.7 m^3/sec

The types of intake are mainly divided into inclined conduit and intake tower or drop inlet and the type of waterway are also mainly divided into tunnel and conduit.

The type of the intake at Wau dam is selected as the type of the drop inlet, because the type of the inclined conduit has long pipe line and spindle of gates along dam slope and this type is more costly than the drop inlet.

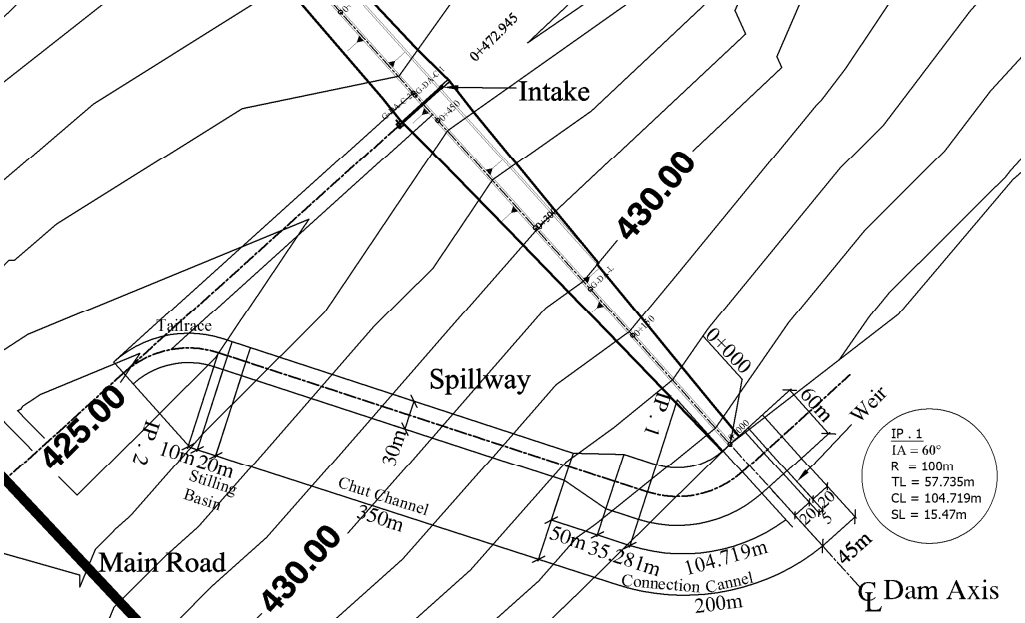


Figure 8.2.7 Location of Spillway and Intake

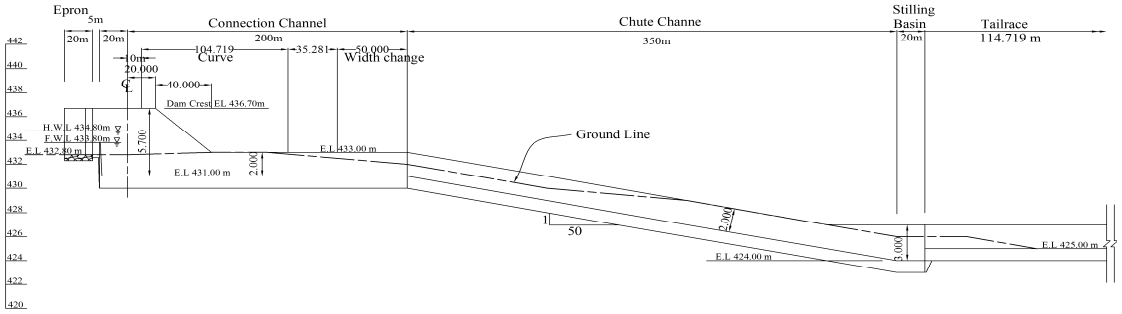


Figure 8.2.8 Longitudinal Section of Spillway

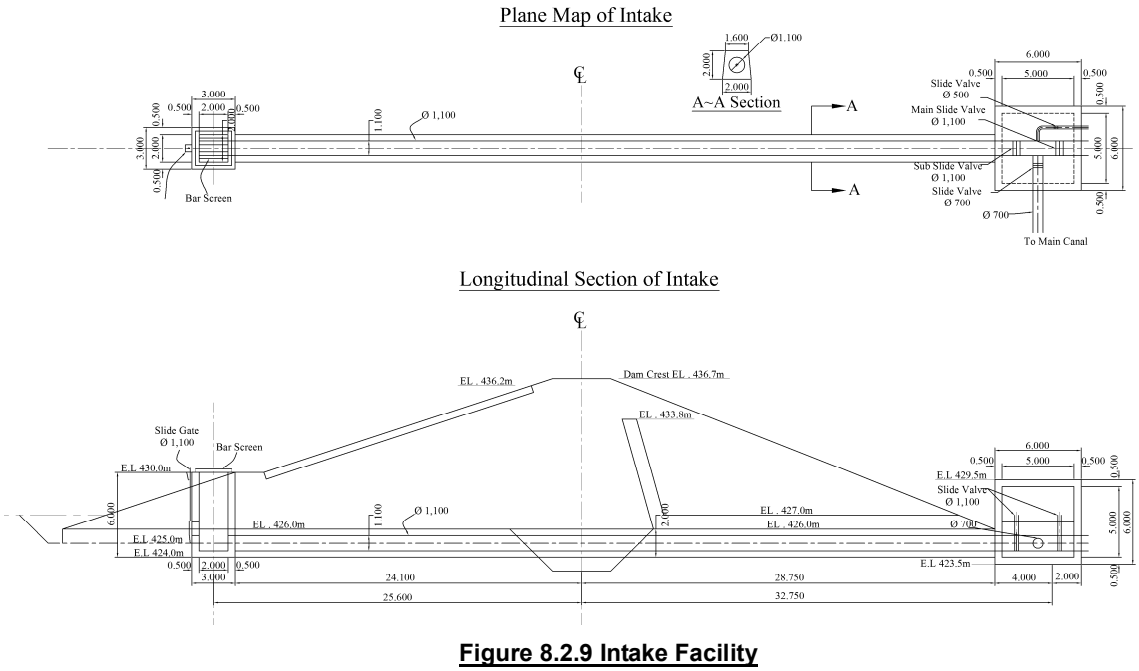


Figure 8.2.9 Intake Facility

8.3 Pump Station

(1) Location

The location of pump station should be selected at the safe place, considering the area of the floodplain. The maximum water level of River Jur seems to rise to about WL. 424m at the pump site based on the record of Wau gauge station, which is located about 7km downstream from the pump station.

The pump station shall be built from 50m far from the river at the ground elevation of more than EL. 424m shown in the below figure 8.3.1, and the connection channel shall be planned to conduct the river water to the pump station stably.

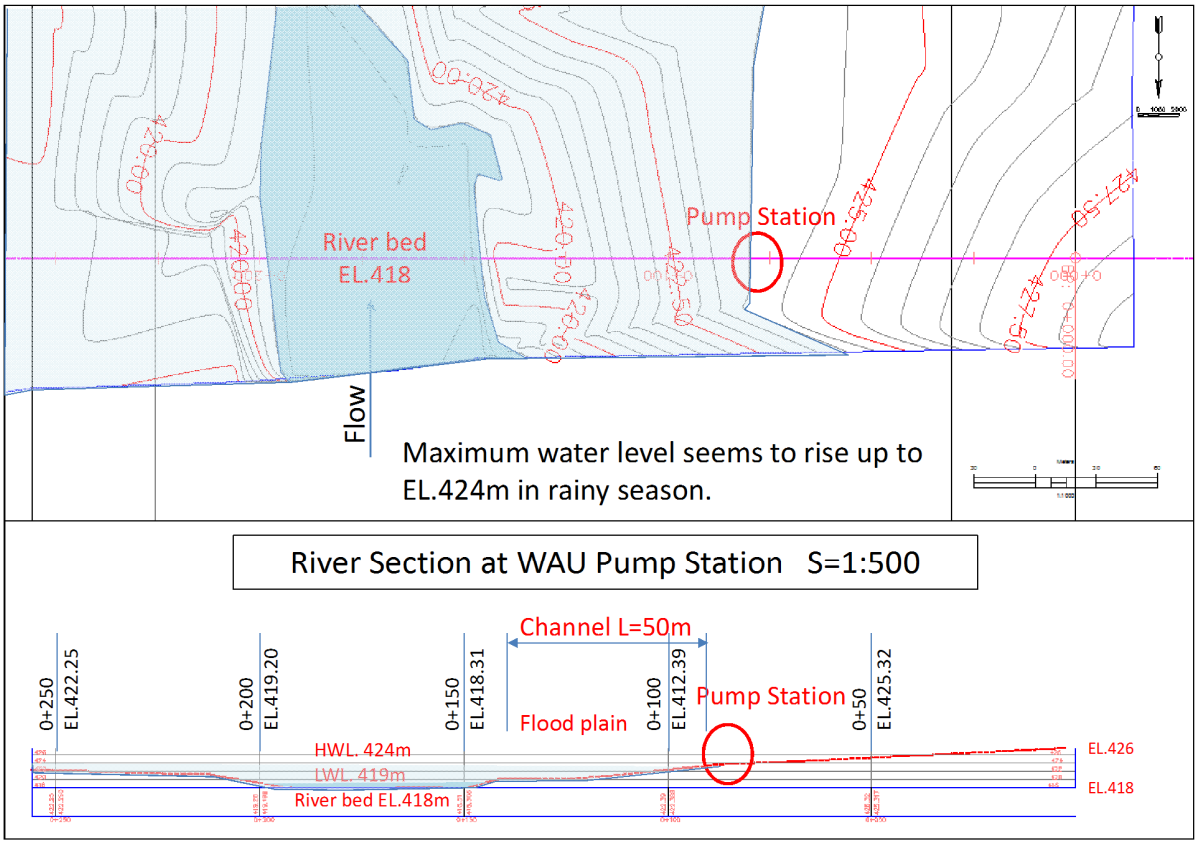


Figure 8.3.1 Location of Pump Station

(2) Connection channel

The purpose of connection channel is to conduct the river water to the pump station stably.

- The design discharge: Q=0.70m3/s (the same as pump capacity)
- Structure type: Gabion wall (height 0.5 m~ 4.0m), and reinforced concrete (height 4.0m ~ 6.0m)
- Foundation of structure should be studied in the future design stage because of no geological data at the site.

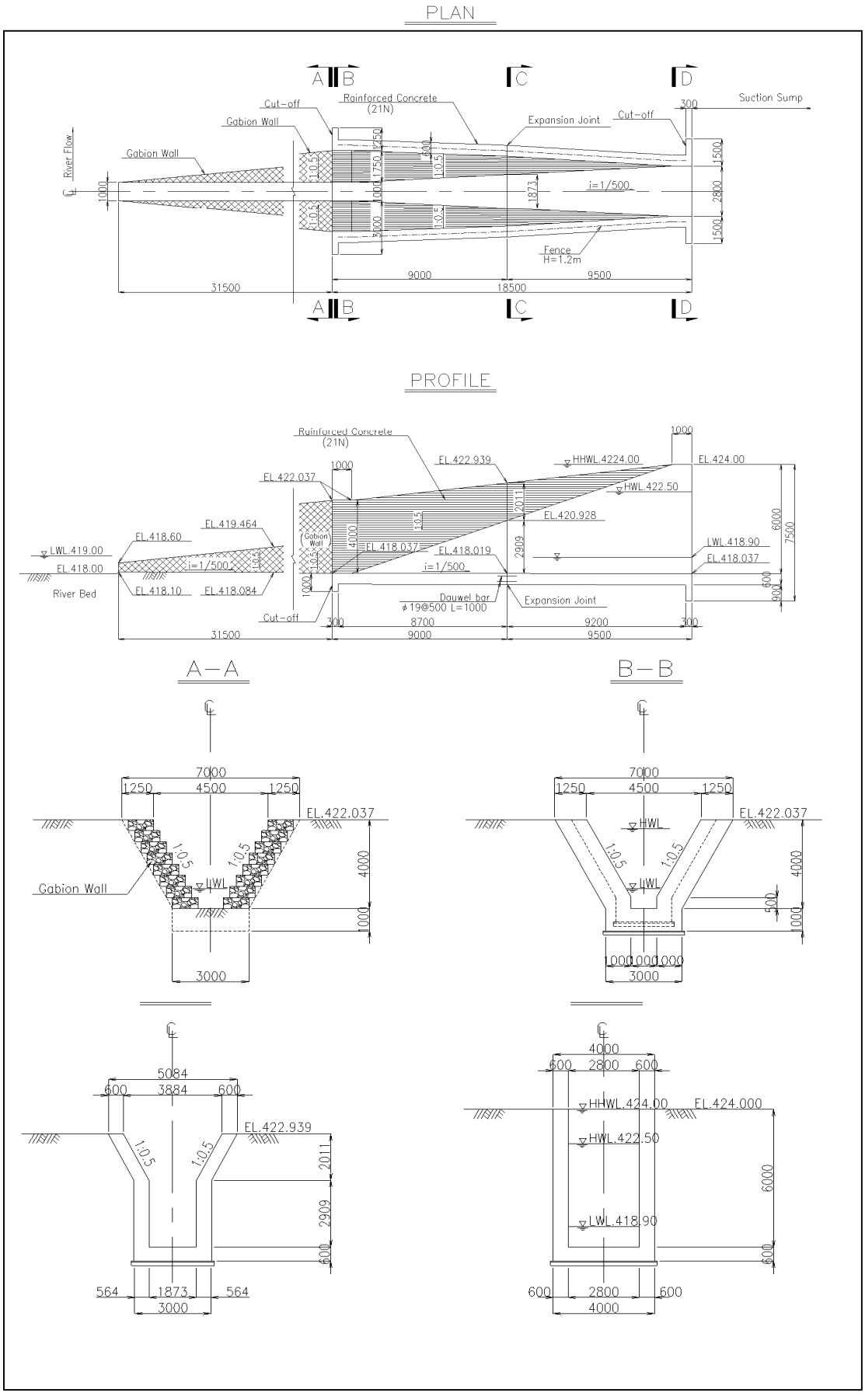


Figure 8.3.2 Connection Channel

(3) Suction sump

The shape of suction sump shall be avoided to generate the whirlpool in the sump. The screen shall be installed to avoid the inflow of the float dust and grasses, etc. to the pump inside. The plan and section of suction sump are planned as shown in the Figure 8.3.3.

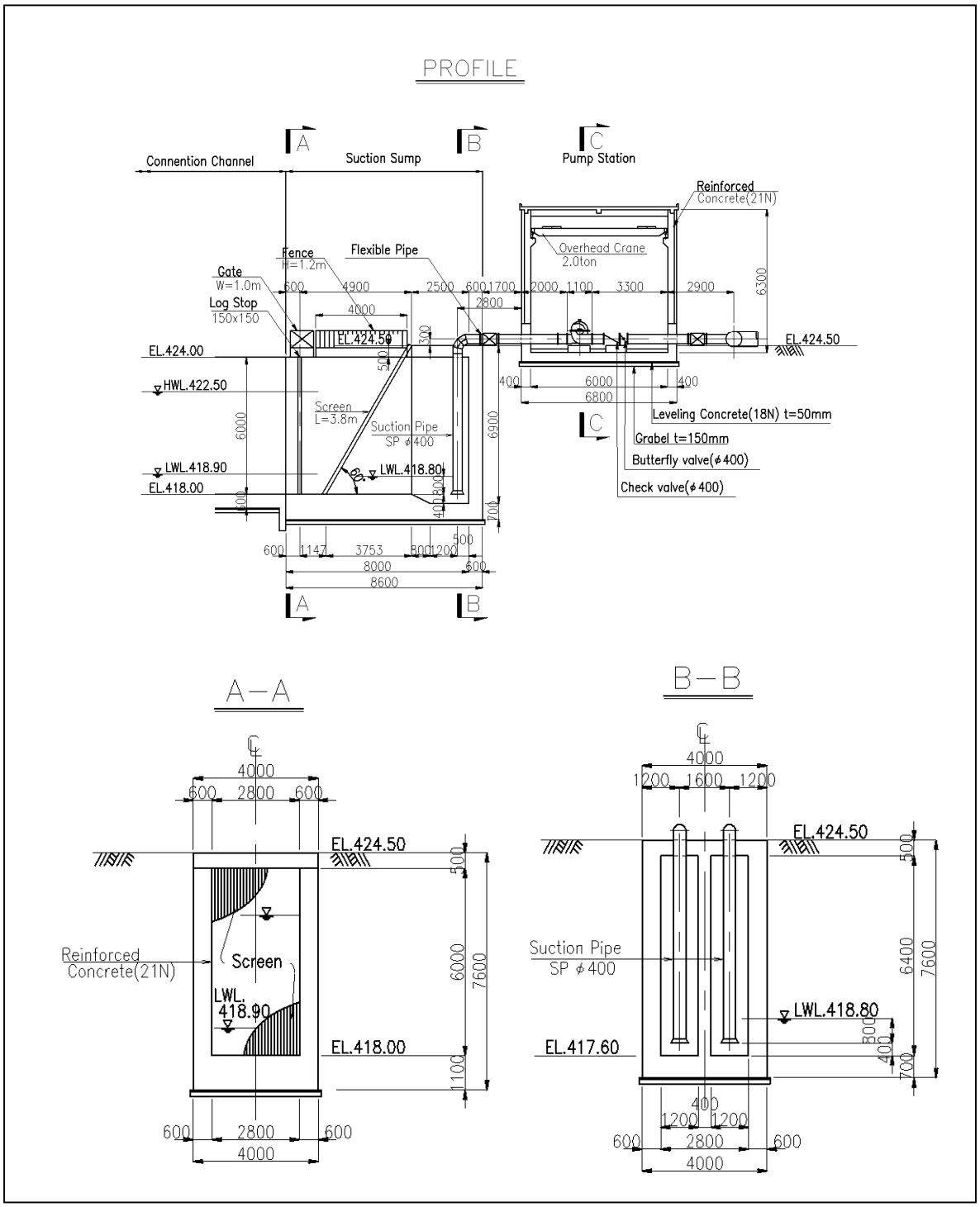


Figure 8.3.3 Suction Sump

(4) Pump facilities

1) Pump type and number of pump

For the pump type, the horizontal centrifugal and double suction is adopted as it is commonly used with high suction efficiency.

The unit capacity (Discharge) of per pump varies depending on the planned number of pumps to be equipped for a scheme. In order to operate the pumps effectively and to minimize the running cost in conformity with the fluctuating supply demands, a combination of pumps with different capacities can be considered possible, however, it is judged to be more advantageous to apply a certain number of pumps with the same capacity taking into such viewpoints as 1) reducing of pump procurement cost, 2) possible equalization in running pumps and 3) need for harmonious collaboration of pump operation with the pump equipment.

Therefore the two (2) same capacity pumps are planned to provide at the site.

$0.35 m^3/s$ (unit capacity) × 2 set = $0.70\ m^3/s$

Table 8.3.1 Water Requirement

Month	May	Jun.	Jul.	Aug	Average
Water Requirement（m^3/s）	0.35	0.70	0.55	0.46	0.50

2) Total head of pump

The actual head is given as the difference between the discharge water level and the suction water level. The total head is obtained by adding various losses in pipes to the actual head.

Table 8.3.2 Total Head of Pump

Items	Unit	Dimension
Pump Capacity per Unit	Q (m^3/s)	0.35
Design outlet Water level	DWL (m)	426.20
Design Intake Water Level	LWL (m)	418.80
Actual head	Ha (m)	7.40
Total Head Loss	(m)	3.71
Total Head	(m)	11.11
Design Total Head	H (m)	12.00

3) Pump shaft power and planned diesel engine output

No electricity is in the pump station site. Therefore the diesel engine is adapted for the pump operation. The pump shaft power required the capacities of 57kw depending on the calculation.

(5) Pump building

1) Style of building

Pump station building is constructed for the purpose to protect the equipment and O&M works from winds and rains, and the structure and layout shall be of percolation-proof from outer and inner basin as well as rain water.

Based on the considerations of the space of installation for the pumps, engines, valves and auxiliary equipment and the required space for effective O&M works, the plan and section of pump station building are planned as shown in the Figure 8.3.4 and Figure 8.3.5.

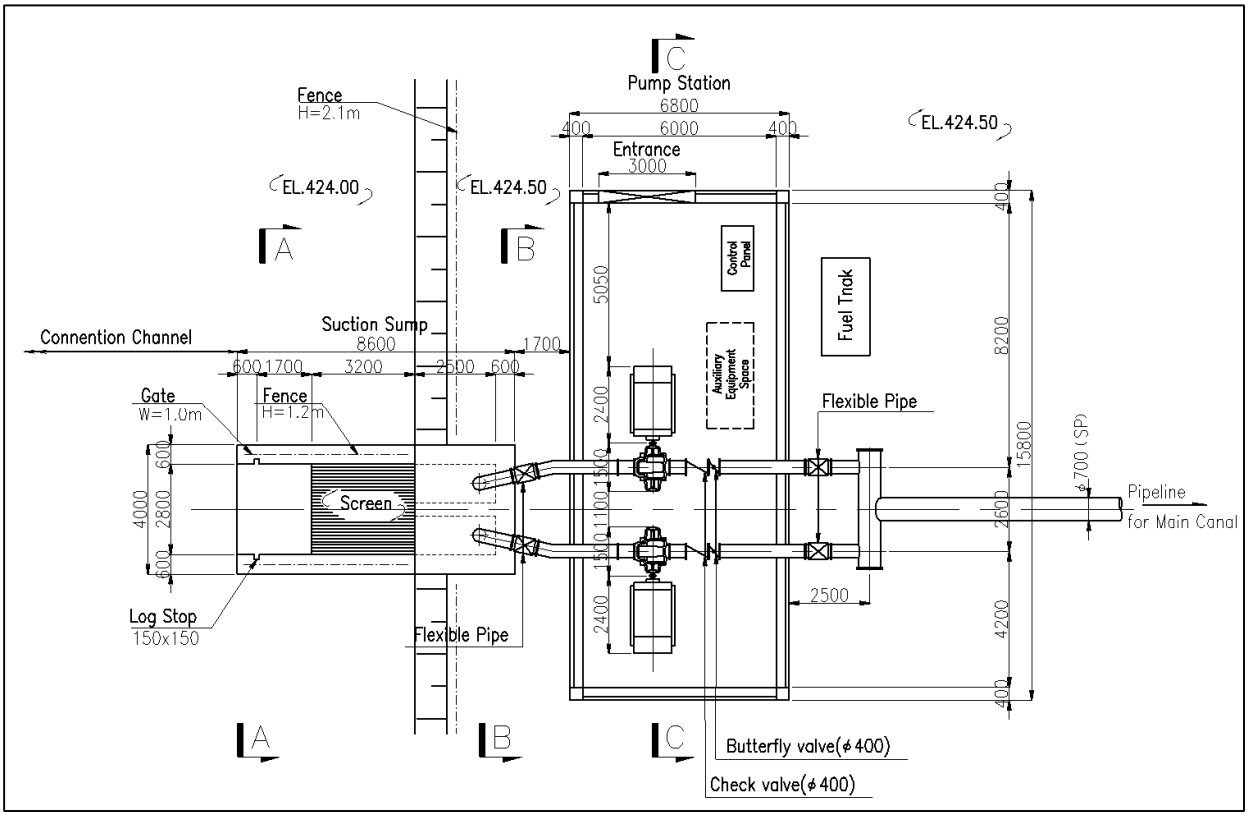


Figure 8.3.4 Plan and Section of Pump Station Building (Plan)

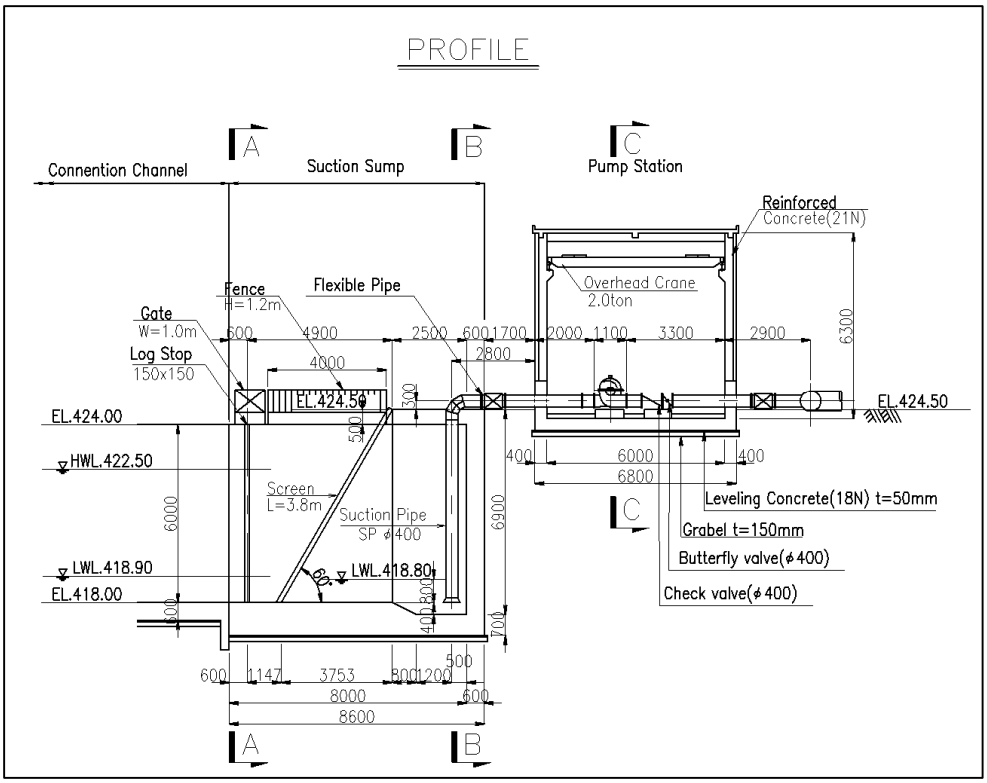


Figure 8.3.5 Plan and Section of Pump Station Building (Profile)

2) Structure of building

The structure type of pump station building shall be of reinforced concrete which is superior in the characteristics of fire-proofing, durability and anti-wind, though concrete blocks shall be used for the wall body on ground.

3) Foundation work

For reference, there is a boring log nearest the pump station, which is located far about 150m from the pump station. The general condition seems to be adequate as the spread foundation for structures. However, after conducting the additional geological investigation at the just pump station in the future design stage, the allowable bearing capacity shall be examined to judge whether the spread foundation type can be adopted or not.

(6) Pipeline

1) Typical section

The irrigation water lifted by the pump is carried to the discharge chamber, which is located at the intermediate point of the irrigation canal, through the pipeline of 700mm diameter. The pipe diameter is to be so determined that the flow velocity inside pipe would be in the range of 1.5-2.5 m/s in general considering such factors as protection of turbulent flow and sedimentation as well as economy.

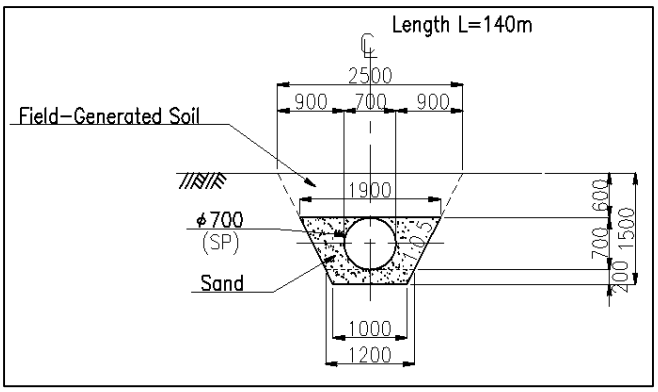


Figure 8.3.6 Typical Section of Pipeline

2) Discharge chamber

The discharge chamber is to dissipate the flow from discharge pipe, change the flow direction and divert the flow to the downstream canal so that the pressure fluctuation accompanying the sudden change of flow quantity as caused by the start and stop of pump operation can be absorbed in the chamber as the change of water level in the chamber.

In the discharge chamber, tractive force will occur due to the disturbance of flow and the high velocity. Therefore, the structure shall be of firm reinforced concrete type.

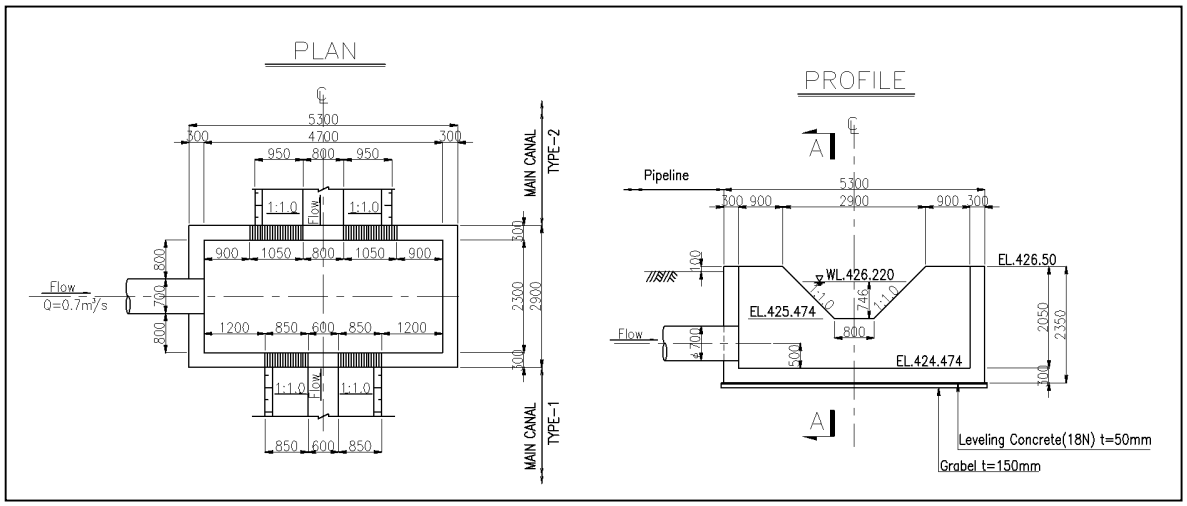


Figure 8.3.7 Discharge Chamber

8.4 Irrigation Canal and Drainage

(1) Main irrigation canal

Main canal shall be constructed to conduct the irrigation water from Wau Dam at the east side of command area. Main canal is mainly separated two sections. Upper section lies between the Wau Dam and command area (L=6.2km), and lower section go through the command area (L=7.1km). And the pipeline, which conducts the irrigation water from pump station located at the bank of Nile River, shall connect to main canal at the 2.7km lower from Wau Dam.

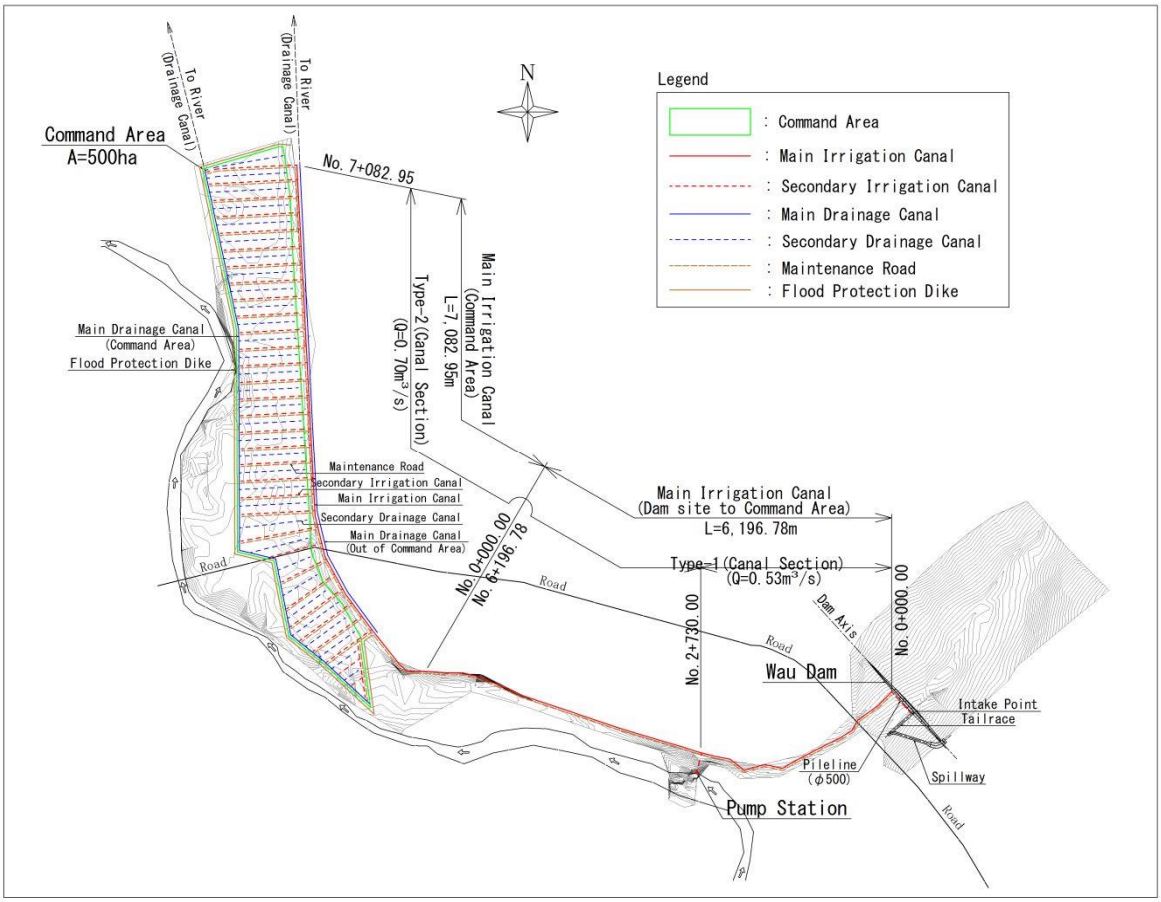


Figure 8.4.1 Location Map

The station number, length, and design discharge of each section is shown in the Table 8.4.1

Table 8.4.1 Main Canal

Type	Station	Length (m)	Design Discharge (m3/s)
Main Canal (Dam Site to Command Area)		6.197	
Type-1	No. 0+0.00 ~ No. 2+730.00	2730	0.53
Type-2	No. 2+730.00 ~ No. 6+196.78	3,467	0.70
Main Canal (Command Area)		7,083	
Type-2	No. 0+0.00 ~ No. 7+082.95	7,083	0.70

Canal profile and canal section are shown in the Figure 8.4.2, Figure 8.4.3 and Figure 8.4.4.

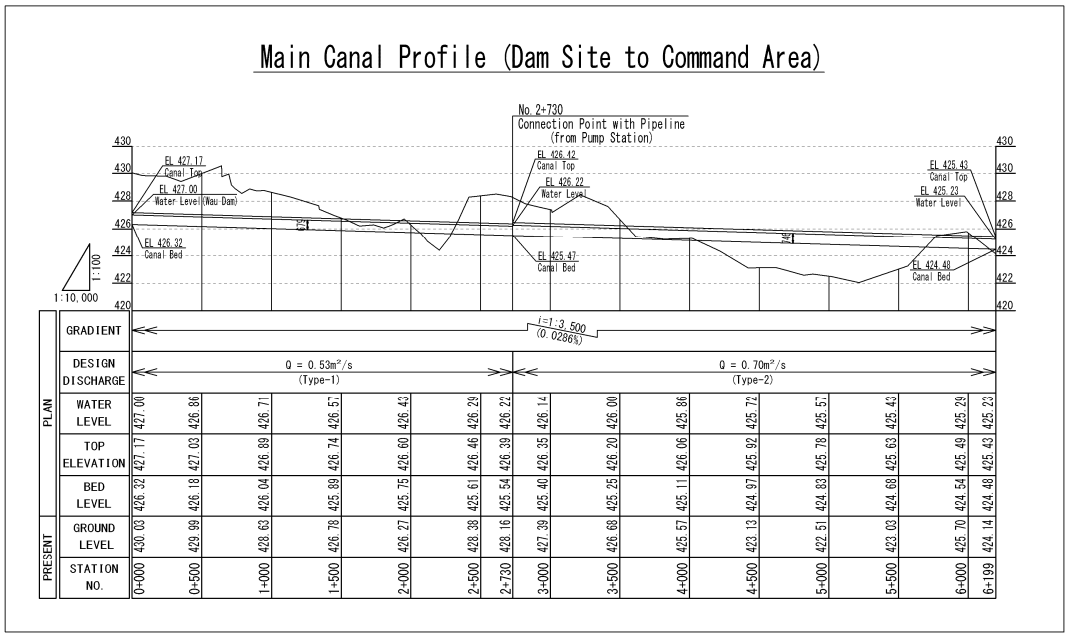


Figure 8.4.2 Main Canal Profile (Dam Site to Command Area)

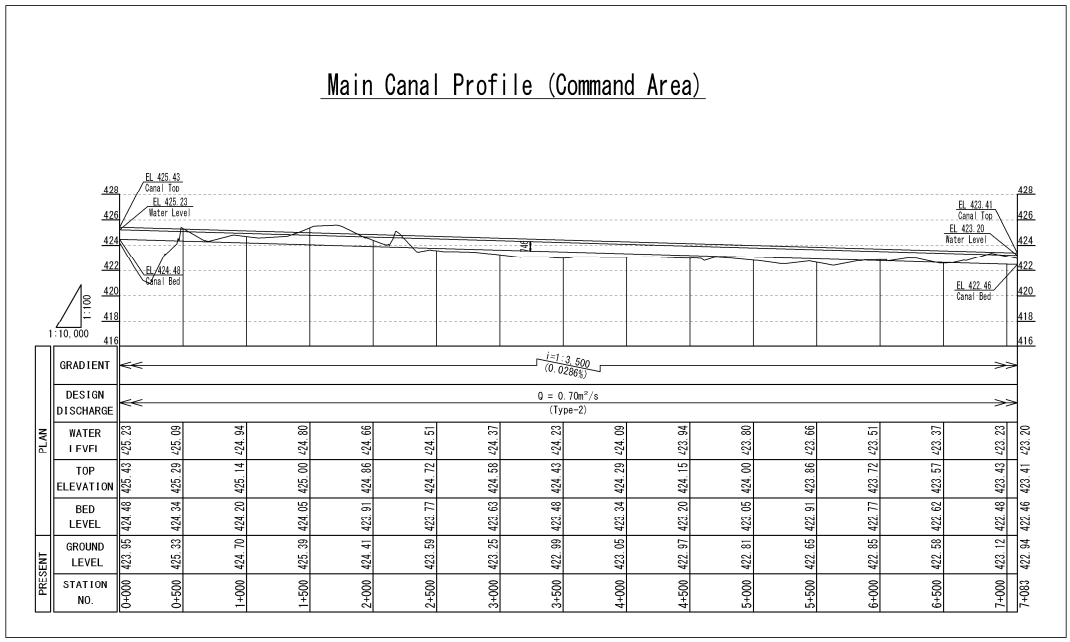


Figure 8.4.3 Main Canal Profile (Command Area)

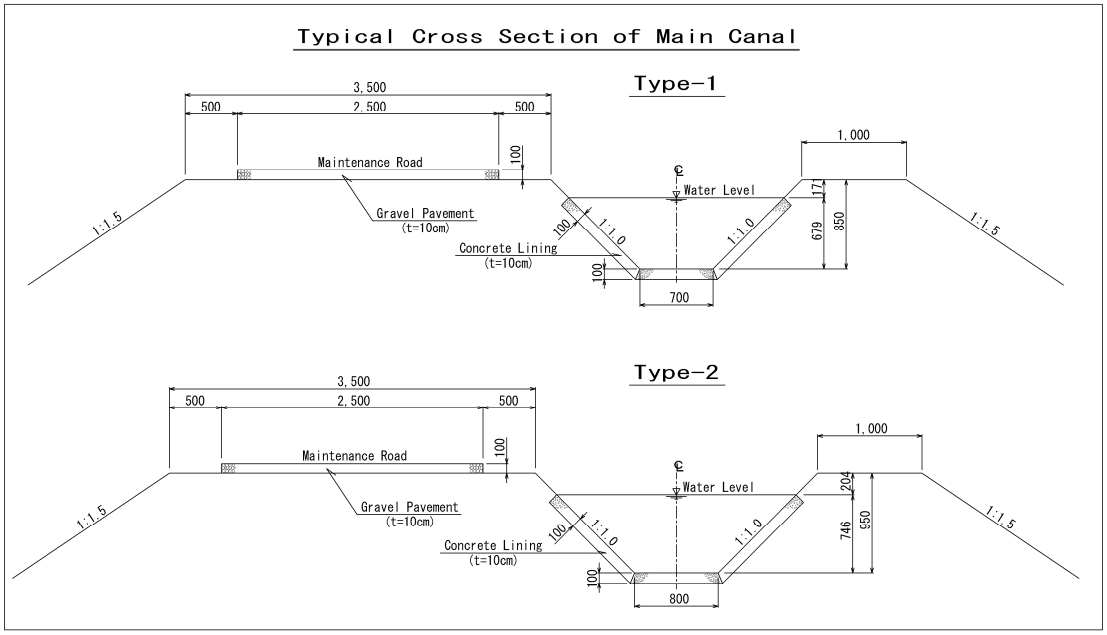


Figure 8.4.4 Typical Cross Section of Main Canal

(2) Secondary canal and drainage in command area

Secondary canal and drainage are planned in the command area for the distribution of irrigation water to the farms and the evacuation of surplus water including rainfall from the farms. The total length of secondary canal and drainage in command area is almost 49km and 23km respectively.

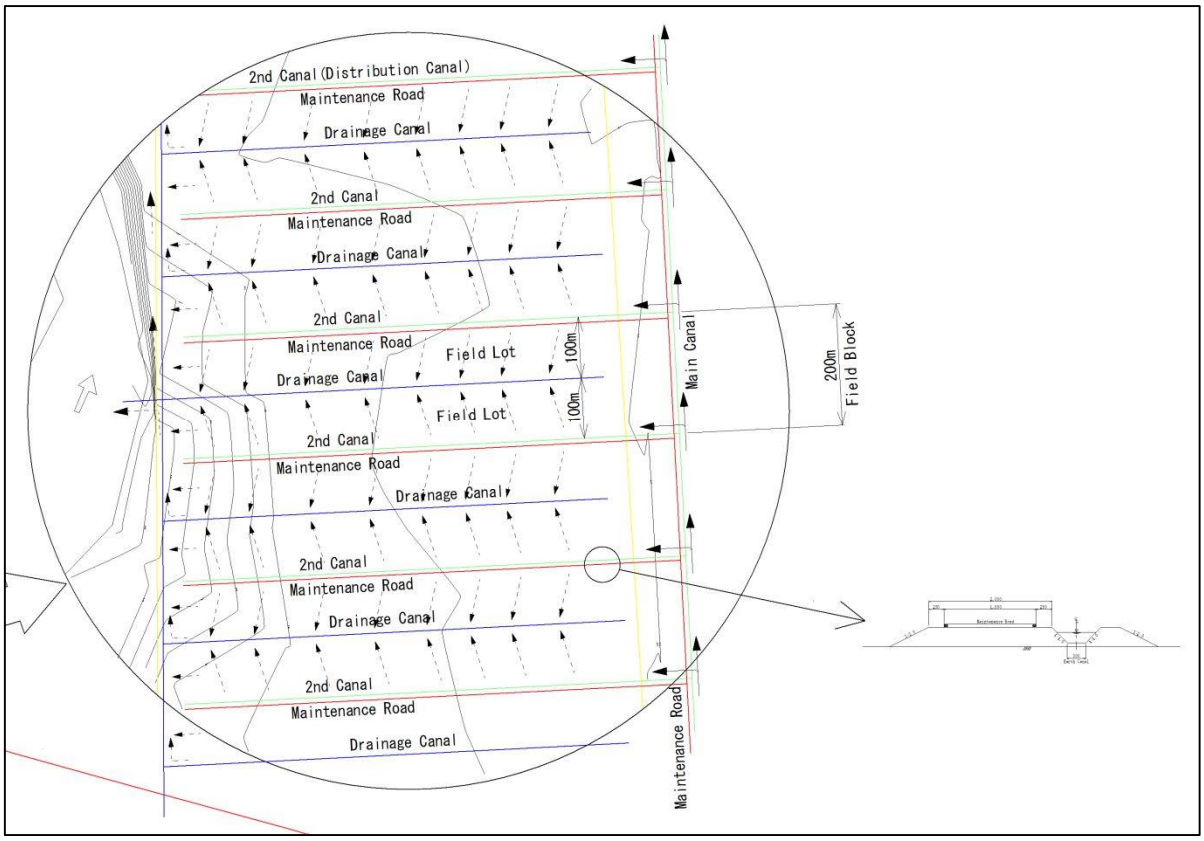


Figure 8.4.5 Secondary Canal and Drainage in Command Area

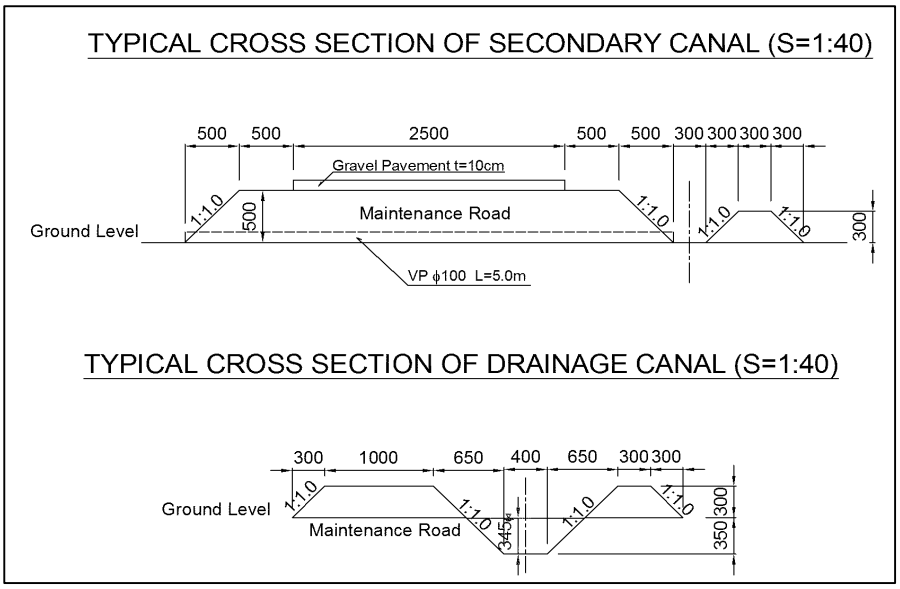


Figure 8.4.6 Typical Cross Section of Secondary Canal and Drainage

(3) Main drainage canal

Main drainage canal, which has a function for gathering the drainage from command area, is located at the west side of command area and along the flood protection dike shown in the Figure 8.4.7

On the other hand, another main drainage canal is required to protect the command area against the outflow from the east side catchment area out of the command area. However, the range and size of catchment area is unclear as well as the current flow direction at the site. The study of main drainage canal for catchment area is required in the future design stage.

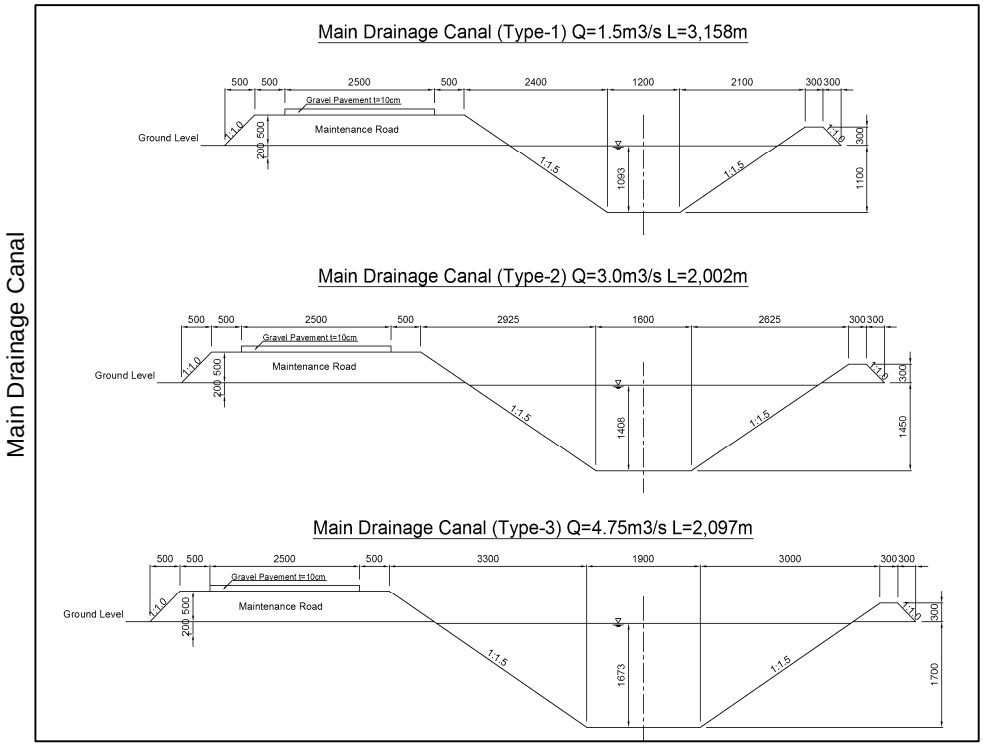


Figure 8.4.7 Typical Cross Section of Main Drainage Canal

(4) Examination method of canal capacity

Main irrigation canal is designed as the concrete lining canal. Secondary canal and Drainage are designed as the earth canal. The size of the cross section is planned by the volume of the required water with Manning formula.

Table 8.4.2 Calculation of Irrigation Canal Section

Items		Main Irrigation Canal		Secondary Canal
		Type-1	Type-2	
Design discharge	Q (m^3/s)	0.53	0.70	0.022
Width of canal bed	B (m)	0.70	0.80	0.30
Water depth	d (m)	0.679	0.746	0.14
Bank slope	1:N	1.0	1.0	1.0
Cross-sectional area of flow	A (m)	0.936	1.153	0.062
Wetted perimeter	P (m)	2.621	2.910	0.696
Hydraulic mean depth	R (m)	0.357	0.396	0.089
Coefficient of roughness	n	0.015	0.015	0.025
Canal bed slope	I (%)	0.0286	0.0286	0.20
Mean velocity	V (m/s)	0.567	0.608	0.357
Velocity head	hv (m)	0.016	0.019	0.006
Free board	Fb (m)	0.171	0.204	0.16
Height of canal	H	0.85	0.95	0.30

Table 8.4.3 Calculation of Drainage Section

Items		Drainage	Main Drainage		
			Type-1	Type-2	Type-3
Design discharge	Q (m^3/s)	0.15	1.50	3.00	4.75
Width of canal bed	B (m)	0.40	1.20	1.60	1.90
Water depth	d (m)	0.345	1.093	1.408	1.673
Bank slope	1:N	1.0	1.5	1.5	1.5
Cross-sectional area of flow	A (m)	0.257	3.104	5.226	7.377
Wetted perimeter	P (m)	1.376	5.141	6.677	7.932
Hydraulic mean depth	R (m)	0.187	0.604	0.783	0.930
Coefficient of roughness	n	0.025	0.025	0.025	0.025
Canal bed slope	I (%)	0.20	0.0286	0.0286	0.0286
Mean velocity	V (m/s)	0.585	0.483	0.574	0.644
Velocity head	hv (m)	0.017	0.012	0.017	0.021
Free board	Fb (m)	0.255	0.207	0.192	0.227
Height of canal	H	0.60	1.30	1.60	1.90

Typical canal sections are shown in the Figure 8.4.4, Figure 8.4.6 and Figure 8.4.7 respectively.

(5) Recommendation

The route of main canal in the survey work is located in the undulating land, particularly the section between the dam and the upstream of command area. As shown the canal profiles of Figure 8.2.2, the route of main canal in the survey work numerous earthworks for embankment are required in whole section. It is recommended that these routes shall be reviewed to reduce the amount of earthworks, save the construction cost and shorten the constriction term in the future design stage.

8.5 Flood Protection Dike

(1) Flood protection dike

Flood protection dike shall be constructed around command area to protect the farmland from flood of Nile River. Height of dikeôs crest shall be decided by considering flood water level which was confirmed at site investigation conducted by RSS-TT. The gradient of River Jur is supposed one to

fifty thousand (1/5,000) by topographic survey, and the gradient of dike shall be same as River Jur.

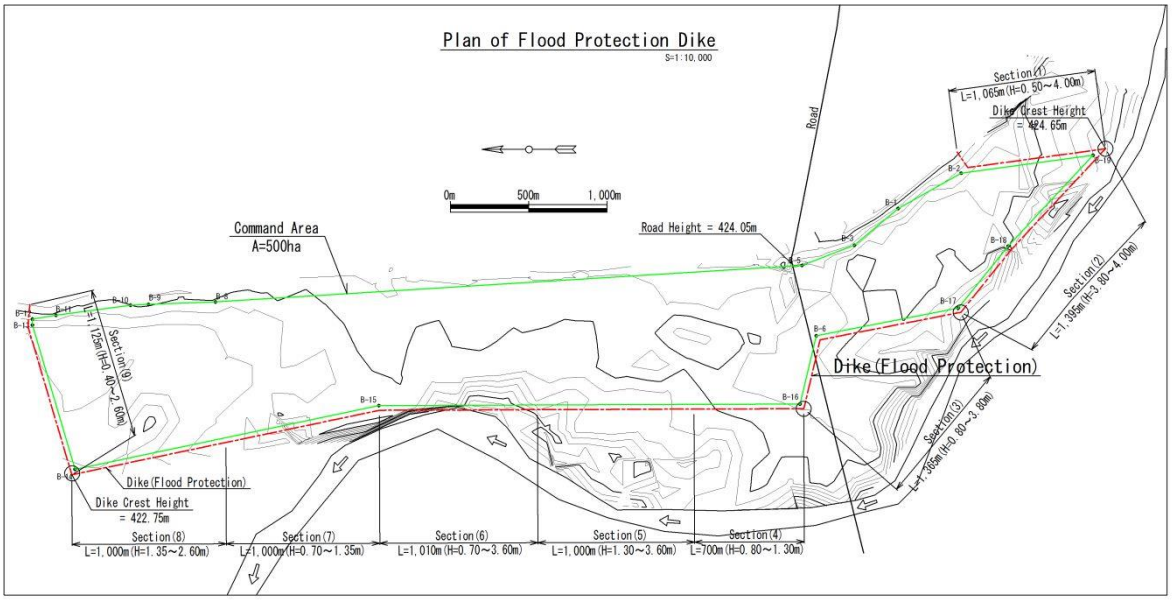


Figure 8.5.1 Location Map

Total length of flood protection dike is 9.66 km, and dike is divided into 9 sections. Height of dike is calculated in each section as shown in the Table 8.5.1.

Table 8.5.1 Plan of Flood Protection Dike

	Distance	Crest Height		Crest Width	Height			Dike Width		
		Upper	Lower		Minimum	Minimum	Average	Minimum	Minimum	Average
Section(1)	1,065 m	424.65 m	424.65 m	2.00 m	0.50 m	4.00 m	2.25 m	3.75 m	16.00 m	9.88 m
Section(2)	1,395 m	424.65 m	424.30 m	2.00 m	3.80 m	4.00 m	3.90 m	15.30 m	16.00 m	15.65 m
Section(3)	1,365 m	424.30 m	423.95 m	2.00 m	0.80 m	3.80 m	2.30 m	4.80 m	15.30 m	10.05 m
Section(4)	700 m	423.95 m	423.77 m	2.00 m	0.80 m	1.30 m	1.05 m	4.80 m	6.55 m	5.68 m
Section(5)	1,000 m	423.77 m	423.52 m	2.00 m	1.30 m	3.60 m	2.45 m	6.55 m	14.60 m	10.58 m
Section(6)	1,010 m	423.52 m	423.26 m	2.00 m	0.70 m	3.60 m	2.15 m	4.45 m	14.60 m	9.53 m
Section(7)	1,000 m	423.26 m	423.01 m	2.00 m	0.70 m	1.35 m	1.03 m	4.45 m	6.73 m	5.61 m
Section(8)	1,000 m	423.01 m	422.75 m	2.00 m	1.35 m	2.60 m	1.98 m	6.73 m	11.10 m	8.93 m
Section(9)	1,125 m	422.75 m	422.75 m	2.00 m	0.40 m	2.60 m	1.50 m	3.40 m	11.10 m	7.25 m
Total	**9,660 m**									

Dike sections are shown in the Figure 8.5.1.

(2) Recommendation

It is recommended that the flood water level should be observed continuously, and the height of dike crest should be re-examined.

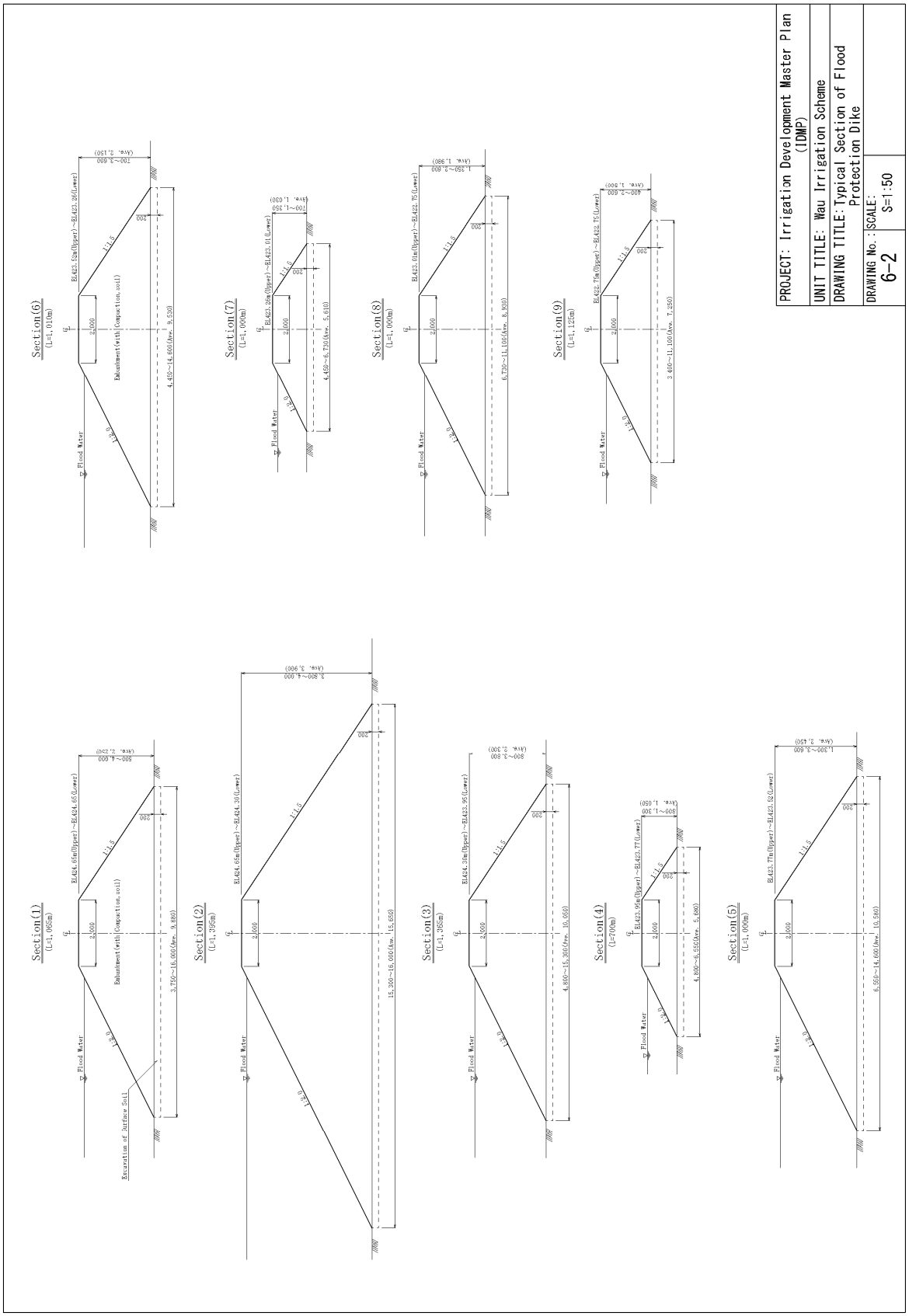


Figure 8.5.2 Cross Section of Dike

CHAPTER 9 OPERATION AND MAINTENANCE PLAN

9.1 Establishment of Scheme Management Office

Establishment of the scheme management office is quite effective since all resources relating to the scheme management are placed in one place. Therefore, it is recommended to establish Irrigation Scheme Management Office at each irrigation site.

For dam irrigation scheme, it is recommended to assign a senior dam engineer to maintain its operational function properly. Under the senior dam engineer, several support specialists are required in accordance with scale of the scheme. In large scale dam irrigation scheme, ideally 5 kinds of special fields are needed, that include electric engineer, dam operation engineer, service technician, sparker (if radio station is installed), and small craft pilot (if necessary)[4].

Major product in the Wau Irrigation Scheme is rice. However, it is reported that rice production has not yet started in the Wau area, and the rice production must start from seed production and distribution. Therefore, agronomist in charge of seed multiplication is required in the scheme management office. In addition, post harvest facilities including rice mill and storage are not found around the Wau Irrigation Scheme. It is recommended that, therefore, just like Awail Irrigation Scheme, the Scheme Management Office install rice mill facility and provide milling service for one of income generating activities. Also, provision of machinery services including land preparation, ploughing and harvesting, for example, can be an income gene4rating activity of the Scheme.

Following table shows ideal management structure of the scheme management office in the Wau Irrigation Scheme.

Table 9.1.1 Management Structure of Wau Rice Irrigation Scheme

Department	Functions and Responsibilities	Required Staff	Proposed No.
1. Admin.	• Overall management of the scheme • Coordination among stakeholders	Manager (Irrigation/Dam Eng.)	1
		Deputy Manager (Electromechanical Eng.)	1
	• Marketing • Procurement • Assets tracking • Keeping books of accounts for scheme operations • Irrigation fee collection • Administration of salaries, wages and other disbursements	Senior Accountant	1
		Cooperative Officer	1
		Asst. Accountant	1
		Asst. Cooperative Officer	1
		Tariff Collector	2
		Messenger/Guard/Driver	6
2. Irrigation/Dam O&M	• Annual planning and monitoring of dam/ pump operations, water distribution, etc. • Maintenance of dam/pump facilities, distribution network, etc. • Hydromet data recording, monitoring and reporting	Senior Irri./Dam Eng. (Dams, Pumps, Canals, etc)	1
		Electromechanical Eng.	1
		Planning and Budgeting Officer	1
		Asst. Irrigation/Dam Eng.	1
		Asst. Planning/Budgeting Officer	1
	• Opening, closure and maintenance of water control and distribution gates • Supervision of canals maintenance • Safeguarding of supplies and the facilities	Irrigation Technician	2
		Pump operator	2
		Irrigation Water Controller (Gate Keeper)	2
		Facilities' Guards	4
3. Farm Level	• Seed multiplication, observation trials for	Senior Agronomist	1

[4] ñManagement Standard of Land Improvement Facilities (Dam)ò, MOAFF-Japan, June 1993

Department	Functions and Responsibilities	Required Staff	Proposed No.
O&M	new rice varieties • Annual planning and monitoring of cropping plan and water requirement • Extension of irrigated agriculture • On-farm water management planning and supervision	Agronomist	1
		Agricultural Engineer	1
		Asst. Agricultural Engineer	1
	• Provision of outreach services to farmers • On-farm water management among farmers • Supervision of distribution and field canals maintenance	Extension Worker	2
		Tractor Operator	1
		Asst. Tractor Operator	1
4. Processing O&M	• Collection, drying, milling of rice • Storing rice with proper pesticide control	Rice mill operator	1
		Asst. Rice mill operator	1
Total			39

To perform above management function, followings are ideal equipment and machineries at the scheme management office.

Table 9.1.2 Ideal Equipment and Machineries at Scheme Management Office

Function	Equipment and Machineries
1. Administration	・ PC for accounting and financial management purpose
2. Irrigation Engineering	・ PC for planning and data management purpose ・ Motor Grader, Backhoe Loader, Wheel Loaders, Dump track
3. Agricultural Extension	・ PC for planning and data management purpose ・ Motorbike for extension purpose (2)
4. Farm Operation	・ Tractor (3), Attachment (plough, harrow, levelers, sprayer, fertilizer distributor, trailer), Harvester (3)
5. O&M	・ Working machines (Lathe Machine, Welding Machine, Power Drill, Power Saw, Generator, Portable Generator, etc.)
6. Rice Mill	・ Rice miller, Thresher, Dryer, Warehouse

MEDIWR takes an initiative to organize the Irrigation Scheme Management Office. However, the Scheme Management Office cannot be managed by officials from MEDIWR alone, and collaboration with relevant stakeholders especially MAFCRD and Western Bahr el Ghazal state government are inevitable. At the time of design work (detail design stage of the irrigation development planning), it is recommended to establish the management office through intensive discussion on function of the management office, demarcation of responsibility, staff allocation, and budget allocation. Also, it is important to discuss the demarcation with WUA. Ideal demarcation among stakeholders is as follows;

Table 9.1.3 Ideal Demarcations among Stakeholders

Stakeholders	Demarcation
1. National Government	・ Taking initiative to establish SMO (MEDIWR) ・ Based on the report from SMO, taking necessary measure to repair or rehabilitate the irrigation system (MEDIWR) ・ Assign relevant officials to SMO (MEDIWR, MAFCRD)
2. Western Bahr el Ghazal State Government, Jur River County, Roc Roc Dong Payam Office	・ Assign relevant officials to SMO ・ Supervising and support SMOôs activities ・ Coordination among and mobilization of communities
3. Wau Irrigation Scheme Management Office (SMO)	・ Coordinate and facilitate the formation and activities of WUA ・ O&M of main irrigation facilities (dam, pump station, main and secondary canal, intake gate until on-farm) ・ Provision of tractor service and milling service ・ Provision of seeds and other inputs if any ・ Collection of irrigation service fee, tractor service fee and milling service fee
4. WUA	・ On-farm level operation and maintenance ・ Payment of irrigation service fee ・ Selling of products

9.2 Operation Plan

(1) Dam operation rule

Before starting annual dam operation, it is necessary to establish basic operation rule of proposed Wau Irrigation Dam. Basically, the dam operation must consider two (2) aspects which are opposed to each other. The first is to promote effective discharge to meet water requirement in the downstream area. However, the promotion of effective discharge results in reduction in water storage in Wau Irrigation Dam. The second is to address a potential water shortage, which requires putting restraints on water discharge from Wau Irrigation Dam. To meet these requirements, it is necessary to set storage target by month or by season. However, for this purpose, accurate river flow data of Jur River and rainfall in catchment area are required.

It is also necessary to make a dam operation role based on the objective of the dam. For example, on one hand, if the main objective of the dam is to supply supplemental water to peak cropping season, it is necessary to store water by the time of the peak season. On the other hand, if the main objective of dam is to supply irrigation water during dry season, it is necessary to store water until peak level by the end of rainy season. In case of Wau Irrigation Dam, main objective is to supply water for dry season, and the latter is the necessary measure to be taken.

In addition, it is necessary to establish the operation rule under the flood warning condition. Under the situation, dam operator has to collect meteorological data promptly and forecast inflow to dam reservoir. Then, if the dam has spillway gate, the operator has to make decision whether it is necessary to discharge stored water from dam. For this purpose, it is necessary to establish flood warning system involving stakeholders including local government, police station, and residents in downstream areas.

(2) Water distribution plan

Operation plan includes basic operation plan at feasibility planning stage, and annual operation plan after implementation of the project. Objective of the basic operation plan is to establish basic method of operation, such as selection of water distribution method and order of the water distribution among upstream/downstream or large-/small-scale farmers. Typical water distribution methods are summarized in Table 9.2.1 Responsible organizations at this stage are the scheme management officials from MEDIWR and MAFCRD, and collaboration between both organizations and communities is necessary.

Table 9.2.1 Typical Water Distribution Method in Open Canal Scheme

Method	Description
Flow Sharing (Proportional Delivery) Method	Every farm receives an equal share of the canal discharge. The structure that is suitable for this method of water distribution is the proportional division box. The flow over each weir is proportional to the width of the crest, provided that these crests have the same height and shape. This method does not need any action by farmers or operators for regulating the flow of irritation water to the farms.
Time Sharing (Rotation) Method	Every farm receives the full canal discharge. The distribution of an irrigation delivery to one farm must be chosen in a way that both meets the irrigation water needs of the crops and is convenient to the farmers. With this method, there is no need for a flow division structure. It may be convenient to have structures with allow either closure or passage of the full canal flow. The method does require action from operators or farmers to direct the canal flow to the farm that is schedule to receive irrigation water.

Source: Irrigation Scheme Operation and Maintenance, Irrigation Water Management Training Manual No.10, FAO1996.

(3) Annual operation plan

The annual operation plan includes preparation of cropping calendar, estimation of expected water demand and supply, and irrigation facility operation planning. After irrigation system being constructed, MAFCRD takes responsibility on developing annual clopping calendar, which in turn utilized in estimation of crop water requirement or water demand. Then, water distribution plan (including operation plan of Wau Irrigation Dam) is developed by MEDIWR, based on water distribution method, irrigation water availability, and management capacity of gate operator. Basic process of the water management is as follows;

1) The scheme management officials from MAFCRD, in collaboration with farmers, develop cropping calendar and crop water requirement. Then the scheme management officials estimate seasonal water demand of command area
2) Based on the request from the water users, the scheme management officials from MEDIWR decide water volume at intake facility or dam site and develop pump operation plan or dam operation plan
3) Based on the above plan, in-charge of water control makes schedule of water distribution including gate operation plan
4) The above water distribution plan should be informed to all over the operators at main and branch as well as terminal canals thoroughly.

According to FAOôs guideline for irrigation development, the planning of irrigation schedules should take into consideration the following issues[5].

- Irrigation schedules must be simple, in particular in irrigation schemes where many farmers are involved. It will often be necessary to discuss with the farmers the various alternatives and come to an agreement which best satisfies all parties involved. Important to guarantee is that in these discussions all groups of farmers, small and large, head-end and tail-end, women and men, are properly represented.

- On-demand water delivery ensures the farmers an adequate and timely water supply, in cases where water is not a limiting factor. On-demand rotation is often convenient for them in terms of flexibly planning their work. A disadvantage might be that influential irrigators can better defend their interests than vulnerable or female irrigators, whose ódemand may not be heardô. Especially during peak periods such as land preparation or transplanting, less influential farmers, notably women farmers, could have problems to secure their water turn.

- A scheduled water delivery or rotation system has the advantage that it guarantees a regular supply of water to each plot, although timing might be less convenient and quantity not always adequate, especially in the tail-end of the scheme. If possible a design that plans for night irrigation should be avoided, as especially for women it might not be socially acceptable or dangerous to go out at night for their irrigation turn. During planning meetings with the farmers these issues need to be discussed, and a decision reached on what type of water delivery suits everyone best.

- In a scheduled rotation system it is crucial for all groups of farmers to have access to information regarding the timing of their water turn. Women may have less access to this information than

[5] SEAGA Sector Guideline, FAO, 1998

men. Not having access to the right information results in sometimes losing all, or part, of their water share.

Table 9.2.2 shows a typical operation activities and their responsible organization;

Table 9.2.2 Typical Operation Activities and Responsible Organizations

Planning	Activity	Details	Timing	Responsible Organization
Basic Operation Planning (before construction)	Establishment of basic method of operation	Whether to adopt Flow Sharing (proportional delivery) Method or Time Sharing (rotation) Method. How to coordinate the intention of large-scale farmers and small-scale farmers, upstream farmers and downstream farmers.	at the F/S stage, design work stage, at the start of every season or every two seasons	MEDIWR/ MAFCRD
Annual Irrigation Planning (after construction)	Preparation of cropping calendar	Develop cropping calendar by season (dry and rainy season), per month, taking into consideration of pattern of planting (gradual increase in planting season and gradual decrease in harvesting season)	at the start of every season or every two seasons	Scheme Management Office (MAFCRD)
	Estimation of expected water demand and supply	Estimation of crop water requirement, based on cropping calendar. Water demand is estimated by considering effective rainfall, runoff, evaporation, transpiration, percolation, and conveyance loss.	at the start of every season or every two seasons	Scheme Management Office (MAFCRD)
	Irrigation scheduling and facility operation planning	Water distribution plan (including dam operation and pump operation plans) is developed based on water distribution method, irrigation water availability, and management capacity of gate operator.	at the start of every season or every two seasons	Scheme Management Office (MEDIWR)

9.3 Maintenance Plan

(1) Maintenance method

Division of role in maintenance work is a key for successful and sustainable operation of irrigation system. Maintenance plan have to be developed based on clear commitment of all stakeholders, in addition to financial and human resources, and technical capacity of them. At the time of maintenance planning, technical and financial capabilities of stakeholders have to be discussed. In this regard, it is necessary to identify required maintenance works of each irrigation facilities.

For pump stations, followings are necessary operation and maintenance activities.

- Specification sheets, operation & maintenance manuals, spare parts list, operation records and so on should always be available for the daily inspection and maintenance. To prolong the equipment life, the operation records should be described in accordance with the checking items (suction pressure, discharge pressure, current, voltage, operation hour, vibration, noise, etc).
- Spare parts, packing, oil and grease should be kept.
- Inspection shall be made before operation for related facilities as well as pump equipment in order to maintain fitness and stability among equipment, intake and discharge pipes, discharge reservoir, canal, etc.

Following table shows major structure of the Wau Irrigation Scheme. The required maintenance works vary from structure to structure as follows.

Table 9.3.1 Typical Maintenance Activities of Irrigation Facilities

Irrigation Facilities	Maintenance Activities
Dams and Reservoirs	Removal of waterweeds, Removal of foreign materials, Lubrication (oiling or greasing) of gates, Anticorrosion treatment (painting) of gates, Monitoring of water quality, Survey and removal if possible solid deposition (silt and stones), Monitoring of dam embankment and catchment area (watershed condition, water pollution, land slide, inflow of debris flow, etc.)
Pump Station	Inspection of deterioration of bearing grease and bearing surfaces, Changing and/or addition of bearing grease, Checking of vibration and noise, Changing of packing, Disassemble inspection, checking of tightness of bolts and nuts, checking of abnormal parts and inside valves, checking of accessories, cleaning
Irrigation Network (lined canals = main canal)	Removal of silt and solid deposition, Repair of damaged joints, slabs and lining concrete with cracks, Weed control at joints and on surface of slabs
Irrigation Network (unlined canals = in-field distribution canal)	Removal of silt, Cutting and removal of earth weeds and waterweeds on wetted parts of canal slopes, and floating waterweeds, Plugging small holes and replacement of porous soils to prevent seepage, Rebuilding of eroded banks
Head gates, check dates and other structures	Removal of silt and obstructions, Lubrication (oiling and greasing) of gates, Anticorrosion treatment (painting) of mechanical elements
Drainage Network	Removal of silt and solid deposition, Weed control in the canal section, Repair and shaping of canal section
Farm Road	Refilling of holes on road surface, Grading road surface, Repair of road shoulders eroded, De-silting and repair of side ditches and culverts, Provision of additional pavement materials for paved roads
Flood Dikes, Bunds in the Fields	Refilling of holes on dike surface, Grading dike surface, Repair of shoulders of eroded embankment, Compaction and re- building, Weed control

(2) Maintenance activities and responsible organizations

Maintenance works consist of routine maintenance, periodical maintenance and emergency maintenance works. The routine maintenance is a day-to-day maintenance work including cleaning silt at flow measuring devices, removal of floating debris, minor repair of canal and structures and greasing or oiling of gates of facilities. WUA should actively participate in this activity at least for on-farm level structure.

Periodical maintenance is works to be done at a certain interval, after harvest season or before planting season for example. Basically, WUA bear a responsibility for on-farm level maintenance, whereas the Wau Irrigation Scheme Management Office are obligated to main facilities such as intake facilities, main and second canals, and gate structures. Emergency maintenance is an emergency works at the time of natural disasters which causes damages on irrigation structures. This type of maintenance requires large investment for long term and/or large scale of replacement, and main responsible organization should be the National Government (MEDIWR) except on-farm level structures.

Following table shows ideal demarcation of each stakeholder in maintenance works.

Table 9.3.2 Typical Maintenance Activities and Responsible Organizations

Maintenance Level	Description	Activities	Responsible Organization
Routine Maintenance	Day-to-day maintenance work.	- removal of earth weeds and waterweeds - cleaning silt at flow measuring devices - removal of floating debris - minor repair of canal and structures - greasing or oiling of bearing, gates, and other metal structures	- On-farm: WUA/Community - Main facilities: Scheme Management Office

Maintenance Level	Description	Activities	Responsible Organization
Periodical Maintenance	Works to be done at a certain interval.	- strengthening of banks and structures - Removal solid deposition & silt - grass cutting of embankment & canal banks - repair of damaged structures /a - repair of damaged equipment /b - painting of structures - checking of tightness of bolts, nuts, inside valves, & accessories at pump station	- On-farm: WUA/Community - Main facilities: Scheme Management Office
Emergency Maintenance /a	Emergency work	- repair of damaged structure caused by unforeseen disasters, including floods, heavy rainfall, earthquake, theft, etc.	- Main facilities: Scheme Management Office/ County/ State/National - On-farm: WUA/Community

Note: a/ Diagnosis of damaged structures (e.g. dam embankment, gate, etc.) is outsourced to engineering firms.
b/ Maintenance of equipment (pump, electric supply, etc.) are outsourced to suppliers and manufacturer.

9.4 Financial Management of Irrigation Scheme

(1) Cost recovery through irrigation service fee

Whether an irrigation system is operated and maintained by a government agency or private organization, it always requires budget to undertake O&M activities. It needs budget for; 1) the services rendered by people in the delivery and distribution of irrigation water, 2) the normal maintenance of irrigation facilities and structures, and 3) the periodic and emergency repair of irrigation facilities and structures. Therefore, generating budget for these O&M activities is one of major function of the Scheme Management Office.

It is an important issue that, to which extent, the irrigation service fee (ISF) should cover costs of irrigation management, so called cost recovery principle. The costs to be discussed in the ISF estimation of the Wau Irrigation Scheme are shown in table below.

Table 9.4.1 Annual O&M Cost

Cost Items	Amount (SSP/year)
Annual Operation and Maintenance Cost	
Personnel Expenses	665,430
Pump Operation	250,000
Equipment and Machineries (fuel, lubricant, etc.)	91,100
Normal Maintenance Cost of Irrigation Facilities	181,600
Depreciation Cost /a	
Project Facilities	5,629,500
Equipment and Machineries	626,500
Total Costs	7,444,130

Note: a/ Straight line method is adopted to estimate depreciation cost.

Even though cost recovery is a basic principle of ISF introduction, it is recommended to start at a lower level upon its introduction. The main focus at this stage is to let farmers develop the healthy habit of paying ISF regularly for the supply service of irrigation water, and enjoy timely and sufficient volume of water for crop production. Thereafter, the consumers, upon recognizing that irrigation water is indispensable in their farming, will be more open to a higher ISF level and the next round of increases can be made to meet the cost recovery requirement.

Therefore, it is recommended to take step-wise targets for financial management of the Wau Irrigation Scheme to materialize sustainable operation and management of the scheme.

- Short-term target is to make farmers familiarize irrigation farming and develop the healthy habit of paying ISF regularly for the irrigation water supply
- Mid-term target is to materialize cost recovery of annual O&M costs including personnel expenses, pump operation fee, equipment and machinery operation costs, and normal maintenance cost of irrigation facilities
- Long-term target is to accumulate earning retention for periodic and emergency repair of irrigation facilities and structures

(2) Affordability to Pay (ATP)

The level of the ISF is a sensitive issue in managing an irrigation scheme. If the level of ISF is too low, it would be impossible to mobilize adequate fund for regular operation and maintenance of the scheme, which in turn result in poor service delivery of the scheme. In contrast, if the ISF level is too high for farmers, price of products will increase due to high production cost, and farmers may lose incentive to participate in management of the irrigation scheme.

Therefore, it is quite important to set up a reasonable level of ISF to ensure management of the irrigation scheme. To identify the reasonable level of ISF, the planner sometime conducts interview survey to farmers for grasping their willingness-to-pay (WTP) and affordability-to-pay (ATP). Usually, WTP is estimated based on the socio-economic survey, and the survey was conducted in the course of IDMP formulation. However, since most farmers had no idea for systematic provision of irrigation water, it was difficult to obtain proper reply to estimate WTP. Therefore, in this ISF estimation, ATP was figured out to obtain proper level of ISF.

In water sector, ATP is usually estimated at 3 to 5% of disposable income. By following the precedent, the lowest figure of 3% was applied in this analysis, and ATP was estimated based on net income of planned crops in the Wau Irrigation Scheme. Following table shows estimated ATP of the scheme.

Table 9.4.2 Annual O&M Cost of Wau Irrigation Scheme

Planned Crops /a	Net Income /b (SSP/ha)	Affordability Rate (%)	ATP (SSP/ha)	ATP (SSP/feddan)
Rice	8,234	3 %	250	110
Leaf Vegetables	5,393	3 %	160	70
Fruits Vegetables	62,579	3 %	1,880	790

Note: a/ Leaf vegetable is represented by Jew's mallow and fruits vegetable is represented by water melon.
b/ Family labour is excluded from net income of planned crops.

(3) Pricing method for the ISF

There are two (2) major practical pricing methods, namely area-based pricing and volumetric pricing. The area-based pricing is a fixed charge based on the area irrigated or supposed to be irrigated. They are often calculated by dividing the total area irrigated into the O&M costs of providing irrigation water, which basically follows the average cost pricing principle. While the volumetric pricing method is estimated and charged in accordance with amount of water delivered.

Further, the volumetric pricing method can be divided into two (2) methods, including block pricing and two-parts pricing. The block pricing involves varying the water price when water use for a set time period exceeds a set volume. If high water charges are a concern, an increasing block charge can be used. Whereas the two-part pricing is a combination of volumetric pricing and a fixed admission charge. The volumetric part can be based on marginal cost, which encourages less water use, while the fixed part can be used to make up any deficits and ensure a certain revenue flow regardless of how much water is available and delivered.

In this analysis, the area-based pricing method is adopted. The O&M costs composed of fixed parts and variable parts. The former is depreciation costs which are constant during economic life of the equipments, machineries and facilities, whereas the latter is changeable in accordance of irrigation scheme management. Followings are assumption of the ISF estimation.

- Depreciation cost of project facilities (infrastructure components) are excluded from the fixed charge estimation since the investment cost of the project facilities are too heavy for farmers to shoulder, and can be regarded as the national governmentôs property.
- On the other hand, equipment and machineries, including tractors and its attachments, can be regarded as properties of the irrigation management office since their economic life are relatively short, and should be reinvested by the users.
- However, among the depreciation costs of equipment and machineries, the cost for milling equipment is excluded from the ISF estimation. The milling equipment must be amortized by other revenue, namely milling service fee from its users.
- In this analysis, the area-based pricing method is adopted. The O&M costs composed of fixed parts and variable parts. The former is depreciation costs which are constant during economic life of the equipments, machineries and facilities, whereas the latter is changeable in accordance of irrigation scheme management. Followings are assumption of the ISF estimation.
- Minimum farm lot size is set as 1 acre.

Based on the above assumptions, following formulas are applied to obtain ISF of the Wau Irrigation Scheme.

Fixed Charge (Member Fee) = Dem ÷ Nl

Where: Dem = Depreciation cost of equipment and machineries

Nl = Number of farming lot

$$\text{Variable Charge } (ISF_{C1}) = O\&M \times \frac{VC1}{\Sigma VC1\sim3} \div A_{C1}$$

Where: ISF_{C1} = ISF of Crop1

O&M = Annual O&M costs

$VC_{1\sim3}$ = Total volume of water consumption of crops

A_{C1} = Cropped area of Crop1

Based on the above formula, fixed charge as a member fee, and variable charge as an ISF were estimated. Then, on one hand, the estimated ISF was adjusted by ATP to obtain payable and practical level of ISF. On the other hand, member fee is not adjusted by ATP, but can be paid by in kind. Following table shows proposed ISF and membersôfee in the Wau Irrigation Scheme.

Table 9.4.3 Proposed ISF and Members' Fee

Crop	ISF			Members Fee	
	Estimated ISF (SSP/ha)	ATP (SSP/ha)	Adjusted ISF (SSP/ha)	Members' Fee (SSP/ha)	In Kind (=Labour in Days)
Rice	1,190	250	250	1,074	27 days
Leaf Vegetables	1,190	160	160		
Fruits Vegetables	1,190	1,880	1,190		

(4) Collection method for the ISF

There are two key steps in cost recovery; the first is to design a pricing mechanism that covers the appropriate costs, and the second is to achieve high collection rates through effective water management. Collecting ISF from farmers is crucial in many developing countries since most farmers are poor. Followings are ideal method for collecting ISF and membersô fee.

- Farmers have to inform their cropping plan of the season, before starting the crop season. WUA will compile each farmerôs plan and submit to the Scheme Management Office. Then the Office will issue ISF bill to each farmers through WUA. SMS billing system through mobile phone is more effective since most people nowadays use mobile phone.
- ISF and membersô fee is collected after harvesting crops when farmers can obtain cash income from their farm products. Payment methods include cash, bank transmission, check, and in kind. Farmer should pay at the Scheme Management Office after harvest of the season.
- Membersô fee can be paid by in kind and is estimated at SSP410/acre in the Wau Irrigation Scheme, which could be converted to 11 days of labour work. ISF can also be paid by in kind, but it is recommended to collect ISF in cash since it is equal to or less than the ATP.
- Penalty clause must be clearly stated in statute, and properly be executed.
- Introduction of an incentive measure to ISF collectors is effective. Each collector should have own jurisdiction and those who mark the highest ISF collection rate of the year will be commented by managers of the Scheme.
- Privatization of billing and ISF collection (PPP) is also effective. Traditional chief or local authority would be involved with a certain incentives.

(5) Cash flow analysis to set management target

To see the balance of revenue and expenditure and assure the sustainability of the irrigation scheme management, cash flow statement of the scheme management office is effective. The cash flow statements show the movement of the scheme management officeôs revenue and expenditure during a certain period. Cash inflow comes from daily operation of the scheme management office, including the collected ISF and other revenue such as membersô fee and penalty fee, whereas cash outflow includes regular operation and maintenance expenditures. Cash flow analysis will help the scheme management office to set relevant ISF to cover O&M costs of irrigation management, and help the office foresee potential deficit which would be the subsidy from the national or state government.

In the short-term, it could be happed that the revenue of the scheme management office cannot cover all O&M costs and the office heavily depends on subsidy from the national government, since farmers are still poor and cannot pay higher ISF. However, in the mid-term, it is better to increase ISF rates in

accordance with growing farmerôs income so that the revenue can cover normal O&M expenditure of the scheme. In the long-term, it is important to accumulate the earning retention for periodic and emergency repair of irrigation facilities and structures.

To see the degree of cost recovery based on the proposed ISF rate, three targets were set up in the cash flow analysis as follows;

- Target 1: Cost recovery of the annual O&M cost, which includes personnel expenses, pump operation fee, equipment and machinery operation costs, and normal maintenance cost of irrigation facilities.
- Target 2: Cost recovery of the annual O&M cost and a part of depreciation cost (equipment and machineries cost)
- Target 3: Cost recovery of the annual O&M cost and the total depreciation cost, including equipment and machineries cost, and project facilities such as dam, pump station, canals, and on-farm structures.

Then, before starting the cash flow analysis, followings assumptions were established.

- Revenue includes ISF, membersô fee, tractor service fee and milling service fee, whereas expenditure includes annual O&M cost and depreciation of equipment, machineries and the project facilities. The milling fee of rice is estimated based of the volume of rice to be milled by farmers.
- Price escalation is taken into consideration in the cash flow analysis. By taking linear regression of consumer index for four years (2011-2015), price escalation rate of 1.67%/annum for general consumption goods and 3.34% for fuel and electricity is estimated.
- ISF collection rate is lower at the beginning of irrigation service provision, but will increase after 5 years, and 10 years on the ground of incentive measures to the collectors and penalty measures to the farmers. As a default setting, ISF collection rate is set as 60% in the short-term, 70% in the mid-term and 80% in the long-term.
- Cropping area will change in short-term, mid-term, and long-term. According to the socio-economic survey conducted by the IDMP-TT at the project site, most farmers want to plant cereal crops for food security reason. However, it can be reasonably assumed that as farmer experiences irrigated agriculture more, they recognizes potential of irrigation farming and tend to increase cash crop production more.
- ISF is estimated based on the ATP of planted crops. In the short-term, minimum rate of 3% is applied in due consideration of farmersô financial capacity. However, as farmers become more familiar with irrigation farming and obtain more income from the farming, the ATP will be increase. In the mid-term and the long-term, the ATP of 5% is adopted.

Based on the above assumptions, cash flow analysis was conducted. The major findings of the cash flow analysis are as follows, and the results are shown in Appendix 4.

- Among three targets, only Target 1 could show positive result in the mid-term and the long-tem operation period, and other two targets were far from the cost recovery. It means the cost recovery of the annual O&M is achievable, whereas the cost recovery of depreciation costs is quite difficult in this scheme.

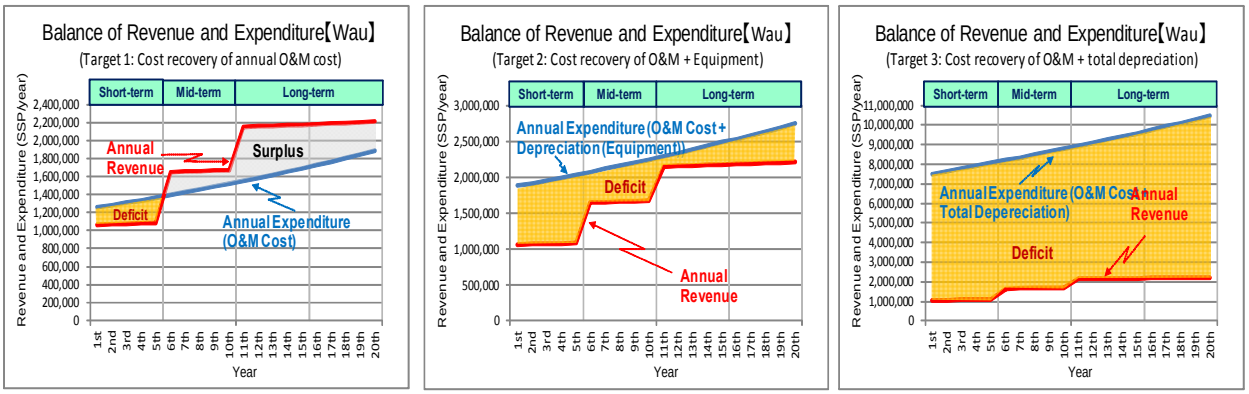


Figure 9.4.1 Balance of Revenue and Expenditure

- As for the Target 1, in the short-term, in other words, during the first 5 years, the balance of annual O&M cost and revenue is ñminusò. The deficit must be compensated by the national government as a subsidy. However, in the mid-term and the long-term, the balance will become ñplusò, meaning the Scheme Management Office can start accumulation of the earning retention to cover a part of depreciation costs after 6th year of its operation.

- As for the Target 1, the balance of revenue and expenditure cannot be ñplusò during the short-term period. To overcome this situation, there are two possible ways for the scheme management, including increase in ISF rate, or increase in ISF collection rate. Among the alternatives, increase in ISF is not better solution since farmers are still poor at the beginning of irrigation water provision. Rather, making efforts to increase ISF collection rate is realistic. However, even if ISF collection rate becomes 100%, the balance at the short-term period is still ñminusò due to mainly high project cost, O&M costs, and low revenues.

- Result of the cash flow analysis indicated that the Scheme Management Office can achieve the target 1, and can manage at least annual O&M cost under the proposed ISF level. Also, the Scheme Management Office can obtain a surplus from the 6th year, which can be the internal revenue fund for covering a part of depreciation costs or unexpected events.

- However, the office cannot manage depreciation costs in full including amortization of equipment, machineries, and project structures, since the initial investment costs is quite high. Therefore, government support as a subsidy to cover the depreciation costs is necessary for reinvestment of the Wau Irrigation Scheme.

(6) Recommendation

The cost recovery principle must be adapted in the irrigation scheme management, and its revenue should be their services including provision of irrigation water supply, tractor service, and others. However, as result of cash flow analysis indicated, it is not easy to recover depreciation cost. Therefore, it is recommended that financial target will be cost recovery of annual operation costs of the scheme. The annual O&M cost includes personnel expenditure, pump operation cost, equipment and machinery operation cost, and regular maintenance cost of the scheme.

For this purpose, proposed ISF level is considered reasonable and proper. The proposed ISF estimated in the analysis is set in low level at the first 5 years in due consideration of farmersôfinancial capacity. However, it should be increased from 6th year when farmer beneficiaries become familiar with irrigation farming, and will be ready enough for paying higher ISF. Also, form the mid-term operation,

it is necessary to advice farmers to shift more capital intensive farming, from current cereal crop production to more profitable crops through applying adequate farm inputs including high quality seeds, fertilizers and pesticides.

On the other hand, to materialize sustainable financial management of the scheme, administrative efforts and engineering efforts are necessary. If farmers could satisfied to the irrigation service from the Scheme Management Office, farmers will show their satisfaction through continuous payment of the ISF, which result in increase in revenue of the scheme. Therefore, the Office should provide demand oriented or used friendly services including input service, farming technology extension, post harvest services, and off-farm training for example, in addition to the regular supply of irrigation water.

If the financial target of the scheme is set to recover annual operation and maintenance costs, the Scheme Management Office can acquire surplus from 6^{th} year. Accumulated amount of the surplus will be 5,678 thousand SSP by the end of the long-term period, after 20 years from the project completion. It is recommended that the surplus will be retained in the account of the scheme so that the scheme can reinvest a part of equipment and machinery costs needed, or can address unexpected event in the future.

CHAPTER 10 COST ESTIMATE

The project costs are estimated at USD as of June 2015. The unit price is set up on the basis of the actual construction orders done by MEDIWR.

10.1 Conditions for Cost Estimate

Table 10.1.1 presents the conditions for cost estimate.

Table 10.1.1 Conditions for Estimate

Items	Contents and Conditions
a) Direct Construction cost	Labor, materials, machinery, etc. and including pump and relative facilities, etc
b) Indirection construction cost	45% of the above a), as overhead cost
c) Administration	4% of the above a)
d) Consultant Fee	5% of the above a)
e) Physical Contingency	5% of the above a)

10.2 Project Cost

Project cost of Wau Rice scheme is shown in Table 10.2.1.

Out of the total project cost, 33% for the dam direct construction occupies large part of the total cost.

Table 10.2.1 Project Cost

No.	Work Description	Unit	Quantity	Price (million US$)	Rate (%)
1.	Direct Construction Cost				
1-1	Dam	L.S.	1	21.1	31.53
1-2	Pump Station	L.S.	1	1.4	2.1
1-3	Irrigation Canal	L.S.	1	9.1	13.6
1-4	Drainage Canal	L.S.	1	2.4	3.4
1-5	Flood Protection Dike	L.S.	1	6.5	9.7
	Sub-total (A)			40.4	60.3
2.	Overhead (B=A*45%)	L.S.	1	18.2	27.2
	C=A+B	L.S.	1	58.6	87.5
3.	Administration (D=C*4%)	L.S.	1	2.4	3.5
4.	Consultant Fee (E=C*5%)	L.S.	1	3.0	4.5
5.	Physical Contingency (F=C*5%)	L.S.	1	3.0	4.5
	Total			67.0	100.0
	Command Area A=500ha			134,000 US$/ha	

CHAPTER 11 IMPLEMENTATION PLAN

11.1 Conditions of Construction

(1) Rainfall

Rainy season in Wau seems to be from May to October in general. The earthworks are strongly influenced by rainfall. Therefore, the construction at the site is assumed to be intermitted from July and September.

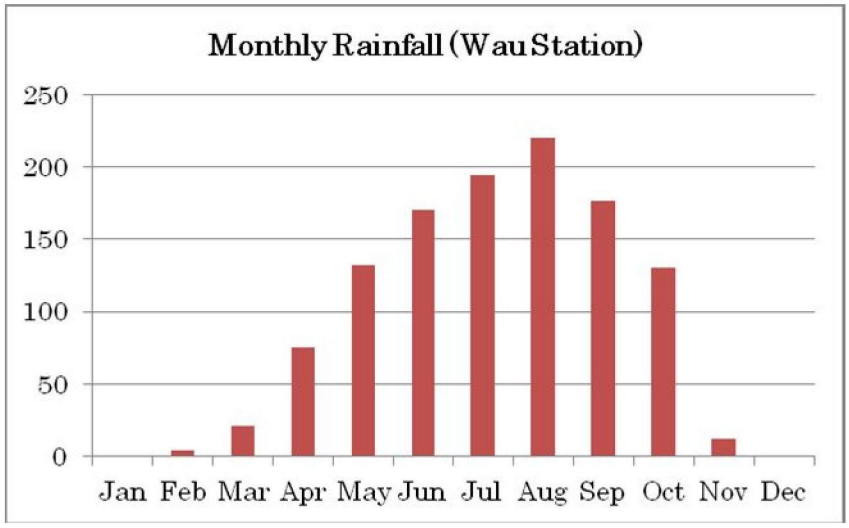


Figure 11.1.1 Monthly Rainfall (Wau Station)

(2) Land acquisition and collaboration with relative agencies

Land acquisition shall be finished by the beginning of construction. MEDIWR shall prepare the budget for the land acquisition and proceed the procedure. Moreover MEDIWR shall proceed to collaborate with the relative agencies.

11.2 Implementation Schedule

It is proposed that all of the construction works except for the dam should be achieved by 3rd year, considering their high priority and the earlier effective benefit.

Flood protection dike would be constructed in parallel with Main drainage canal and implemented by 2nd year, considering the following canal and drainage works in the command area implemented at 3rd year. Dam construction would be commenced from 3rd year and implemented by 5th year.

Table 11.2.1 Implementation Schedule

Work Description	Project Cost	Quantity	Year				
			1st	2nd	3rd	4th	5th
Dam	34.9	Investigation, Detail Design, Embank 256,000m^3, Spillway Concrete 15,700m^3					
Pump Station	2.3	Investigation, Detail Design, Procurement: Pump etc. Construction					
Irrigation Canal	15.0	Investigation, Detail Design, Main Canal L=13.3km, Canal & Drainage A=500ha					
Drainage Canal	4.0	Investigation, Detail Design, Main Drainage L=7.3km, Excavation 54,000m^3					
Flood Protection Dike	10.8	Investigation, Detail Design, Main Drainage L=7.3km, Embankment 134,000m^3					
total	67.0	(million US$)					

CHAPTER 12 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

12.1 Purposes

The irrigation development master plan (IDMP) has selected three priority projects in Wau, Jebel Lado and Rejaf East. Those projects are expected to contribute to agricultural improvement in the RSS; while it is also important to avoid and/or mitigate any environmental and social impacts.

A guideline of environmental and social considerations for irrigation development (ESCID Guideline) has been developed in formulating the irrigation master plan. An IEE study was taken for one of the priority projects in Wau by using the ESCID Guideline.

The purposes of the IEE study are:

- To figure out current environmental and social aspects in the project site;
- To preliminarily assess the impacts likely affected by the priority projects;
- To indicate scope of works of an environmental impact assessment in the further process of feasibility study, e.g.

12.2 Methods

(1) Process of environmental and social considerations

According to the draft ESCID Guideline, the IEE is taken through the following main process.

1. Screening process: to identify whether or not further environmental and social considerations are necessary
2. Preliminary Survey: to find key environmental aspects
3. Scoping: to indicate highlighted impacts and the impact levels, and also to address the study method for a further study

(2) Methods for the preliminary survey

The preliminary survey was taken in the manner of hearing with local communities, government organization (county government, ministry, e.g.), visual observation, etc. The following table shows summary of the methods.

Table 12.2.1 Summary of Preliminary Survey Methods

Survey Methods	Target Items
Data collection	Protected wildlife,
Interview with Local communities County government Wau Univ., zoo, wildlife officials	Community profile, local economy, wildlife, flood records Current plan, program, project, etc., flood records, wildlife Wildlife
Visual observation	Landuse, wildlife, local economy, water use, etc.
Topographic and geographic survey (conducted under the IDMP)	Topographic and geographic condition

12.3 Evaluation of Alternatives

(1) Description of the alternatives

The three project designs listed in the following table were evaluated.

Table 12.3.1 Summary of Project Alternatives' Descriptions

	Alternative A	Alternative B	Zero option
Description	Combination of dam and pump irrigation	Year-round pump irrigation	No project
Command area Total area (ha) Crop pattern	500 ha Rice / Jew's mallow, Egg plant	Same as on the left	-
Dam site Reservoir area Reserve capacity Outlet discharge Operation time	1.8 km^2 (at F.W.L) 5,300,000 m^3 0.53 m^3/s Dry season	-	-
Pump station Number of pump Power source Operation time	2 Diesel Rainy season	2 Diesel Whole year	-
Canal / pipeline Irrigation canal Main Length Volume Secondary Length Drainage canal Main Length Secondary Length	 13.6 km 0.7 m^2/s 26.3 km 7.3 km 22.6 km	 10.9 km 0.7 m^2/s 26.3 km 7.3 km 22.6 km	-

Source: IDMP-TT

Evaluation was judged trough scoring method on each following evaluation item.

Table 12.3.2 Evaluation Methods (Evaluation Items)

Score	Evaluation Items
Natural Environment	Pollution (Air pollution, Water pollution, Waste, Soil/Sediment contamination, Noise and vibration, Odour, Global warming)
	Biodiversity (Protected areas, Ecosystem)
	Nature, disasters (Hydrology, Topography and geology, Subsidence / Erosion, Landscape)
Social Environment	Land occupies resettlement (Resettlement. Landuse)
	Social conflict (Vulnerable groups, Water use / Rights)
	Living condition (Living and livelihood, Local economy, Historical / Cultural heritage, Social infrastructure / Services, Infectious diseases)
Economy, development	Economy, development
	Consistency

(2) Results of comparison

The summary of score is shown in Table below (details are given in Appendix 5):

Table 12.3.3 Summary of Scoring and Ranking

Evaluation Items	Alternative A	Alternative B	Zero Option
Natural Environment	2.7	2.7	3.0
Social Environment	2.3	2.7	3.0
Economy, development	4.0	4.0	2.5
Total Score	**9.0**	**9.4**	**8.5**
Rank	**2**	**1**	**3**

Source: IDMP-TT

1) Zero option

It is, of course, not expected to generate any environmental and social impacts by zero option. On the other hand, food security and economic improvement are urgent challenges in the RSS; especially agricultural / irrigation development can have high potential on these matters. The priority projects are formulated based on the irrigation master plan; therefore it can be consistent with the RSS policies and directions.

2) Alternative A

The alternative A will occupy larger area than the alternative B, so the impact is not negligible. However, both proposed command area and dam site are far from protected areas such as national parks, game reserves. Though further detail study will be required; critical situation on wildlife conservation is not been expected. On the other hand, it was observed community houses scattered in the dam site; hence resettlement will be one of the considerable impacts.

3) Alternative B

Alternative B has an advantage to avoid land occupation by dam. Level of impact on wildlife conservation caused in the proposed of command area will be higher than dam site. That is why impact on wildlife conservation may be same level compared with alternative A.

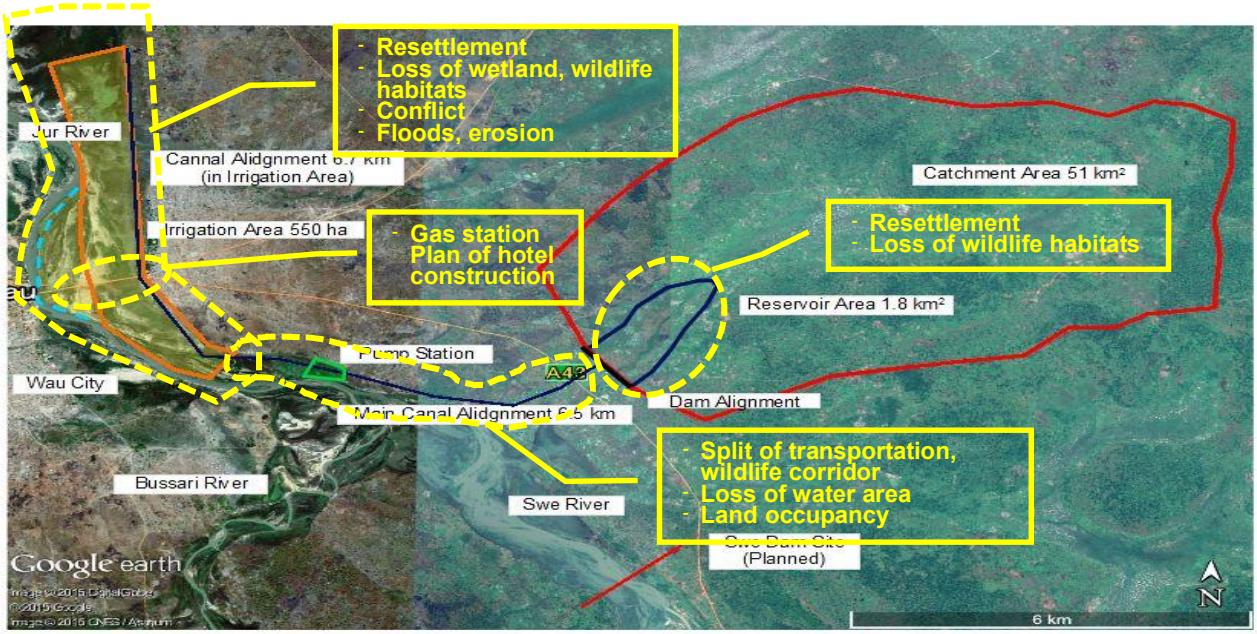
4) Results

Based on the above evaluation, both alternatives could be reasonable compared to zero option. And it was judged that alternative B was most suggestible because existing of dam site could raise more adverse impact on land occupation. Though further detail study is necessary to assess the impacts on resettlement and wildlife conservation, it is expected to avoid or mitigate those adverse impacts. On the other hand, positive impacts which contribute to economic improvements are considerable benefits.

By the way, alternative A can have more advantage from the viewpoint of sustainability according to an engineering side. Operation of pump station may require sophisticated maintenance, supported by manufacture may be necessary, also provision of spare parts and fuel consumption are costly. There have been many cases in the RSS that pump stations have been out of operation due to low quality of maintenance, lack of spare parts and fuel, etc.

12.4 Current Environmental and Social Aspects

Overview of possible adverse impacts is illustrated in the following map:

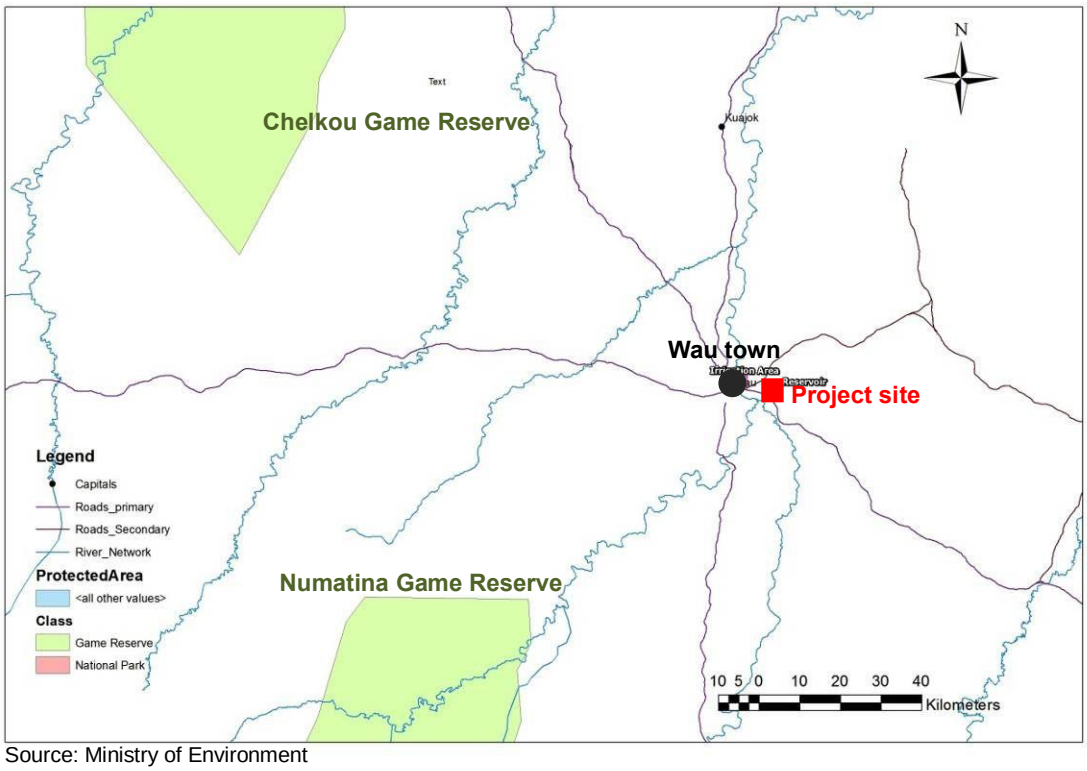


Source: IDMP-TT

Figure 12.4.1 Overview of Possible Impacts

(1) Natural environmental aspects

The project site, as shown in Figure 12.4.2, is located far from protected areas. Yet detail study to survey wildlife habitats, feeding sites, migration corridors, etc. have not been taken, critical areas for wildlife conservation have not been identified. The site mostly features savannah or bare land covered with bush, dotted forest. The forest is not primary, mostly planted by communities.



Source: Ministry of Environment

Figure 12.4.2 Location of Designated Areas of Wildlife Conservation

Typical wildlife likely observed in the project site is hippopotamus, crocodile, hyena, e.g. (see Figure

12.4.3). According to the communities, elephants, white rhinoceroses were occasionally found near the project site in past years. However they recently went out to other areas because of human pressures such as insecurity by past war, forest-cutting, grass-burning.

Hippopotamus

Crocodile*

Sparted Hyena*

Source: IDMP-TT
*: Pictures taken in Wau Animal Zoo

Figure 12.4.3 Typical Wildlife

The command area is located right bank of the Jur River, opposite side of Wau town. The land is almost flat and lies in flood plain. Dam site is located along a seasonal stream, flush flow occurs just after rain during rainy season according to the communities. Underground water aquifer lies around 3 ï 5m below the ground. The elevation in dam site is approximately 20m higher than the command area.

Water flow of the Jur River is estimated approximately 5,200 MCM/year, amount of water discharged from the project site is quite small compared with the river flow.

(2) Social and environmental aspects

The project site is located near Wau town, approximately 1 km to the nearest point, it can be said that the site is in the Wau economic circle. The command area is located in Boma Panamet, while dam site is in Boma Kuanya; its population is around 3,000 each.

Since the command area lies in flood plain, there have been no permanent residences observed. This land, basically, is under government control. Some brick factories were observed in the preliminary survey. They are licenced to business in the area with annual permission. Approximately 70 persons are registered according to the Directorate of Industry and Mining. In addition, gas stations and a water supply facility are located, and constructions of hotels are planned according to the State Ministry of Physical Infrastructures. The dam site is located 9km from the command area, along the seasonal stream. According to the Jurchol community, several houses are built in the dam site.

Gas station

Community houses

Brick factory

		
Cattle grazing	Fishing in Jur river	Fruit tree

Source: IDMP-TT

Figure 12.4.4 Facilities and Activities in the Project Site

According to the community profile of Jurchol community, approximately 90% of community people are engaged in agriculture. Next, remittance shares around 20% of means of livelihood. Fishery sector occupies 10% of them. Most of community people engaged in fishery are also involved in agriculture. Kuom community in Boma Panamet also shows similar profile as Jurchol community, that is to say, the most dominant livelihood is agriculture. By the way, the command area is in the flood plain, agriculture is partly operated in rainy season only.

No historical / cultural heritage was confirmed, while some grave yards were observed around dam site and along the canal route.

12.5 Evaluation of the Impact

(1) Overall evaluation

According to the preliminary survey, major impacts can be described as follows:

(1) Change of hydrological feature (negative impact);
(2) Obstruction of ecosystem, wildlife (negative impact);
(3) Resettlement (negative impact);
(4) Living and livelihood, local economy (Positive impact) and
(5) Local conflict (negative impact).

The proposed command area will occupy a certain area in the river bank where is in flood plain. Change of water flow may cause floods, erosion, etc.

The most considerable impacts are caused by land possession. The river bank is important for watering place of wildlife, also this area must be feeding and nurturing place. Though the project site is far from the protected areas, certain endangered / rare / threatened species are possibly living in the project site (Actually Hippopotamuses were found in the Jur and Sue River).

Some communities have temporary used the river bank during dry season such as production of brick materials, cattle grazing. Change of land use may affect to those activities. Several houses were observed in the proposed dam site and along the canal route.

Demand on construction materials, tools / equipment, job opportunity may give positive impacts to local living condition and livelihood. Also improvement of agricultural production can contribute to local and national economic development. The communities can increase their income from farming, they will reduce demand to cut trees and/or hunt animals for selling. This situation may mitigate human pressure against consuming natural resources.

Mostly farmers can benefit from the project, while fishery activity, hunting, cattle grazing, brick factories can be affected. Therefore fair allocation of benefit and proper compensation, income recovery plan must be considered.

(2) Results of scoping

Results of scoping are summarised in Table 12.5.1.

Table 12.5.1 Results of Scoping

Environmental Items		Pre-construction	Construction	Operation	Summary of Impact
Pollution	Air Pollution	D	-C	-C	Construction works and operation of pump may generate exhaust gas; it can be controlled by moderate measures.
	Water Pollution	-C	-C	-B	Construction works may generate turbid water, etc., but it can be controlled by moderate measures. Storage of oil, hazardous waste must be properly managed. Use of pesticide and fertilizers need proper rules.
	Waste	-C	-C	-C	Construction waste will be considerable.
	Soil/Sediment Contamination	D	D	-C	Though polluted water can contaminate soil / sediment, it can be controlled by moderate measures.
	Noise and Vibration	-C	-C	-C	Construction works and operation of pump may generate noise, however its scale may not be significant, and it can be controlled by moderate measures.
	Odour	D	D	D	No certain odour is anticipated.
Natural Environment	Protected Areas	D	D	D	There are no protected areas adjacent the project site.
	Ecosystem	-B	-B	+C	No proper studies have been conducted, therefore level of impacts are not identified.
	Hydrology	-C	-B	-C	Existence of dam and operation of pump may change hydrological feature. Most possible impact is related to flood disaster by command area.
	Topography and Geology	D	D	-C	Dam site may change topographic feature.
	Subsidence / Erosion	-C	-B	D	Those risks will be possible on dam construction; however it can be mitigated by moderate measures.
	Global Warming	D	D	D	No impact on global warming is anticipated.
	Landscape	D	-C	+C	Change of topographic feature may change landscape.
Social Environment	Resettlement	-B	-C	D	Several houses are located in the proposed dam site and along the canal route according to the interview with communities.
	Living and Livelihood	-B	+C	+B	Land occupancies in command area and dam site may affect

Environmental Items		Pre-construction	Construction	Operation	Summary of Impact
					community's living condition, livelihood as well. While recruitment and job opportunity are one of the most expected benefits.
	Local Economy	D	+B	+A	Construction works require provision of material, tools /equipment, man power, etc. Agricultural production can raise local economy.
	Historical / Cultural Heritage	D	D	D	There is no historical / cultural heritage observed.
	Land Use	-B	-C	-B	Though impacts by change of land use are relatively small, the situation can lead social conflict among the communities.
	Vulnerable Groups	D	D	-C	Possible adverse impacts are child labour, unfair allocation of benefit, etc.
	Local Conflict	-C	-B	-B	Farmers are mostly given benefits, while fishery, hunting, cattle grazing, etc. must be limited.
	Water Use / Right	-B	-C	-C	The proposed command area occupies river side, it can limit water use.
	Social Infrastructure / Services	-C	-C	D	A school is located near the dam site. Local grave yards are possibly scattered in the project site.
	Infectious Diseases	D	D	D	Mosquito bleeding in water area (dam, canals, etc.) can be very limited.

+/-A: Significant positive/negative impact is expected.
+/-B: Positive/negative impact is expected to some extent.
+/-C: Extent of positive/negative impact is unknown (Examination is needed. Impacts may become clear as study progresses.)
D : No impact is expected.

12.6 Conclusions and Recommendations

(1) Conclusions

Conclusions are:

- The most significant impacts are related to land possession. Though the proposed command area is located in the river bank, and under government control, some temporary activities such as brick productions, cattle grazing are observed. A gas station has been operated, water supply facility is under construction, and construction of hotels is planned. While there are several houses observed near/in the proposed dam site and canal route. Resettlement and change of land use must be considerable impacts.
- Land possession can also affect ecosystem even though the project site is not located in/near protected areas. Important habitats of wildlife, especially endangered / rare / threatened species could not be denied.
- Hydrological feature especially caused by existence of the command area may raise possible risks on flooding and erosion.

- Pollutions related to air, water, noise, etc. can be controlled by moderate measures.
- The project is expected to effectively contribute to improvement of agricultural production.

(2) Recommendations

Recommendations are:

- Since certain tourism developments (construction of hotels) are planned, consistency and arrangement between those plans shall be investigated.
- Possible change of hydrological feature especially river water flow must be examined. And the project design shall be confirmed, or revised if necessary, based on the survey.
- Ecosystem in/around the project site has been hardly studied. Therefore appropriate scientific survey is recommended.
- Though workshops were conducted under the IDMP, public consultation with the communities is useful to know their opinions, concerns etc., in order to take consensus building among them, and to formulate adequate compensation plan.
- Most of the group who benefits from the project are farmers, on the other hand the people who are engaged in fishery, hunting, cattle grazing, manufactures could be less benefited. Adequate compensation must be given in order to avoid social conflict. In addition benefits from the project must be fairly allocated among the communities.
- Further certain environmental assessment will be required in a feasibility study, e.g. The following survey methods are recommendable:

Table 12.6.1 Recommended Survey Methods for Further Study

Survey Items	Possible Methods	Points to be surveyed
Air pollution	- Check of quality of construction equipment and pump in terms of prevention from exhaust gas - Site survey on location of possible sensitive zones against air pollution such as residential area, school zone, etc.	- Possible affected areas especially sensitive zone - Selection of environmentally friendly equipment with proper maintenance
Water pollution	- Measure of current water quality - Examine of possible pollution sources by the project	- Possible water pollution source and affected area - Farming plan in terms of use of pesticide, fertilizer, etc.
Waste	- Investigation of possible disposal site for construction waste - Estimation approximate waste volume	- Location of possible disposal site - Types of waste - Procedure / rules of storage and disposal of waste
Soil / sediment contamination	- Examine of possible water pollution sources by the project	- Same as ñwater pollutionò
Noise and vibration	- Check of quality of construction equipment and pump in terms of prevention from noise / vibration - Site survey on possible sensitive zones against noise / vibration such as residential area, school zone, etc.	- Possible affected areas especially sensitive zone - Selection of environmentally friendly equipment with proper maintenance - Pump operation schedule
Ecosystem	- Interview with local communities - Direct observation on wildlife habitats, migration, etc. - Trap survey	- Wild life corridor - Bird migratory - Forest, e.g.

Survey Items	Possible Methods	Points to be surveyed
Hydrology	- Historical records of floods - Measure of river flow - Simulation on change of river flow	- River water flow - Flood prevention plan in Wau town - Historical records of disasters
Topography and geology	- Underground water survey	- Condition of well water
Subsidence / erosion	- Historical records of subsidence / erosion - Simulation on erosion	- River water flow - Historical records of disasters
Landscape	- Interview with local people, e.g. about possible demand on sightseeing	- Possible sightseeing site
Resettlement	- Survey on land use, land status, land ownership, etc. - Estimation of land and asset price - Public consultation for consensus building	- Number and location of houses / facilities likely to be relocated - Agreement on the project - Resettlement plan
Living and livelihood	- Investigation of community living condition and livelihood - Interview with communities	- Possible job opportunities by the project in both construction and operation stages
Local economy	- Investigation of local economic profile - Investigation of future plans, developments, investments	- Possible materials, equipment for the project - Possibility of procurement in local
Land use	- Survey on land use, land status, land ownership - Investigation of land use plan - Public consultation	- Land map describing houses, facilities, land use, etc. - Existing and/or further land use plan
Local conflict	- Investigation of job profile, income level and sources - Public consultation	- Community profile, job profile - Consensus building among communities - Compensation plan
Water use / right	- Investigation of water use / right - Public consultation	- Status of water use, legal status on water right - Consensus building among communities
Social infrastructures / services	- Site survey on location of social infrastructures - Interview with local communities, etc.	- Location of infrastructure - Location of grave yards - Existing and/or further infrastructure development plan

CHAPTER 13 PROJECT EVALUATION

13.1 Outline of the Project Area

The irrigation development project in Wau located in WBEG will serve totalling 500 ha of target area. The project will develop the present unused land into large farming fields with irrigation and round-embankment. The project will furnish the infrastructures to introduce an irrigated agriculture, leading to increase farming income for the farmer beneficiaries. Following are the outline of the site.

Outline of Project (Wau):

Location:	Just East of Wau City
Project area:	500 ha
Land Holding:	Ave. 2.4 ha/household (8.0 members/household)

13.2 Farming Plan

(1) Cropping pattern

Around the site in Wau, major crops are maize, millet, sorghum and rice, and sesame and vegetables are grown as cash crops. The crops to be grown in the project area will be represented by rice, jewsô mallow and watermelon. With the project, the cropping intensity is expected to increase by the improvement of farming conditions. Considering the situation of existing areas, where the irrigation development project was implemented, the cropping intensity with project situation is assumed to be 200 %.

(2) Irrigation system

It is required to introduce a dam into the irrigation system to stabilize intake of water. Though the dam can reduce the operation cost of pumps, it needs huge amount of initial cost. Considering these conditions, the irrigation system is planned with 2 cases. Case 1 is pump irrigation without dam. Case 2 is pump irrigation with dam.

Case 1 and Case 2 will take same amount of water: namely, they can enjoy same benefit. The difference between Case 1 and Case 2 is the operation period of the pump. The duration of pump-up of water in Case 2 is only in May - September for paddy cultivation. Irrigation water in October - April can take from the river by gravity because of discharge from the dam.

13.3 Basic Assumptions for Economic Analysis

Upon conducting the economic analysis, following assumptions are set:

Financial prices of farming commodities are based on the results of Agriculture and Socioeconomic Survey in May 2015.

Financial prices are converted into economic prices using Standard Conversion Factor (SCF) of 0.90 and Labour Conversion Factor (LCF) of 0.45 (0.5 × SCF). Transfer payments are eliminated in converting economic price. Next table shows the summary of financial and economic prices.

Foreign exchange rate of 1 US$ = 2.95 SSP is applied, which is the current official exchange rate.

Cash flow analysis was conducted with 30 years since there is no significant replacement cost which will influence the economic efficiency and present value of cash flow. Values after 30 years will become very low as the influence in calculation is considered very little.

Table 13.3.1 Financial and Economic Price of Agricultural Produces/Inputs

No.	Item	Unit	Financial Price (SSP)	Conversion Factor	Economic Price (SSP)	Remarks
A.	**Agriculture Product**					
	- Rice	kg	8.40	-	6.84	Estimated by import parity price
	- Jew's mallow	kg	2.80	0.90	2.52	
	- Watermelon	kg	3.30	-	2.76	Estimated by import parity price
B.	**Farm Input**					
1	**Seed**					
	- Rice	kg	14.0	0.90	12.6	
	- Jew's mallow	kg	200.0	0.90	180.0	
	- Watermelon	ha	500.0	0.90	450.0	
2	**Fertilizer**					
	- DAP	kg	12.25	0.90	11.03	
	- Urea	kg	11.75	0.90	10.58	
	- CAN	kg	12.00	0.90	10.80	
	- NPK	kg	12.25	0.90	11.03	
	- Foliar (liquid)	lit	70.00	0.90	63.00	
3	**Agro Chemical**					
	- Pesticdes (insecticide)	lit	85.00	0.90	76.50	
	- Fungicide	lit	107.00	0.90	96.30	
4	**Labor**					
	- Family Labor	m*d	70.0	0.45	31.5	
	- Hired Labor	m*d	70.0	0.45	31.5	
5	**Equipment**					
	- Tractor rental	ha	476.19	0.90	428.57	
	- Sprayer	ha	100.00	0.90	90.00	
	- Threshing and milling	kg	1.21	0.90	1.09	
	- Transportation	time	22.20	0.90	19.98	
6	**Others**					
	- Sack / Box	piece	7.50	0.90	6.75	

13.4 Project Cost

(1) Project cost at financial price

The project cost of Case 1 at financial price is estimated 28 million US$ or 56 thousand US$/ha. Case 2 is estimated 62 million US$ or 124 thousand US$/ha. Next table summarizes the project cost at financial price.

Table 13.4.1 Summary of Project Cost at Financial Price

Item	Case 1		Case 2	
	US$/ha	Total of 500ha (,000US$)	US$/ha	Total of 500ha (,000US$)
1. Direct Construction Cost	38,660	19,330	80,776	40,388
2. Indirect Construction Cost	17,398	8,699	36,350	18,175
Sub-total	56,058	28,029	117,126	58,563
3. Administration (4%)	2,242	1,121	4,686	2,343
4. Consultant Fee (5%)	2,802	1,401	5,856	2,928
5. Physical Contingency (5%)	2,802	1,401	5,856	2,928
Total	63,904	31,952	133,524	66,762

Source: IDMP-TT

(2) Project cost at economic price

Project cost at financial price was categorized into foreign currency portion (F/C), local currency portion (L/C) and transfer payments such as taxes. Local currency portion was further divided into skilled labour, unskilled labour, and others. Relevant conversion factors (CF) were applied for respective categories of cost to estimate the project cost at economic price.

The project cost at economic price of Case 1 was, then, estimated at 28 million US$ or 56 thousand US$ per ha. The project cost at economic price of Case 2 was estimated at 58 million US$ or 117 thousand US$ per ha. Next tables show the estimation of the project costs at economic price.

Table 13.4.2 Estimation of Project Cost of Case 1 at Economic Price

Item	Financial Cost (,000US$) ①	CF	F/C 1.00 ②	L/C Skilled Labor 0.90 ③	L/C Unskilled Labor 0.45 ④	L/C Others (SCF) 0.90 ⑤	Tax 0.00 ⑥	Conversion Factor ⑦ Sum(②～⑥)	Economic Cost (,000US$) ⑧=①*⑦
Direct Construction Cost		%	60.0	10.0	20.0	10.0	0.0		
	19,330		0.600	0.090	0.090	0.090	0.000	0.870	16,817
Indirect Construction Cost		%	60.0	10.0	20.0	10.0	0.0		
	8,699	CF×%	0.600	0.090	0.090	0.090	0.000	0.870	7,568
Administration		%	60.0	10.0	20.0	10.0	0.0		
	1,121	CF×%	0.600	0.090	0.090	0.090	0.000	0.870	975
Consultant Fee		%	60.0	35.0	5.0	0.0	0.0		
	1,401	CF×%	0.600	0.315	0.023	0.000	0.000	0.938	1,313
Physical Contingency		%	60.0	10.0	20.0	10.0	0.0		
	1,401	CF×%	0.600	0.090	0.090	0.090	0.000	0.870	1,219
Total	31,952								**27,892**

Source: IDMP-TT

Table 13.4.3 Estimation of Project Cost of Case 2 at Economic Price

Item	Financial Cost (,000US$) ①	CF	F/C 1.00 ②	L/C Skilled Labor 0.90 ③	L/C Unskilled Labor 0.45 ④	L/C Others (SCF) 0.90 ⑤	Tax 0.00 ⑥	Conversion Factor ⑦ Sum(②～⑥)	Economic Cost (,000US$) ⑧=①*⑦
Direct Construction Cost	40,388	% CF×%	60.0 0.600	10.0 0.090	20.0 0.090	10.0 0.090	0.0 0.000	0.870	35,138
Indirect Construction Cost	18,175	% CF×%	60.0 0.600	10.0 0.090	20.0 0.090	10.0 0.090	0.0 0.000	0.870	15,812
Administration	2,343	% CF×%	60.0 0.600	10.0 0.090	20.0 0.090	10.0 0.090	0.0 0.000	0.870	2,038
Consultant Fee	2,928	% CF×%	60.0 0.600	35.0 0.315	5.0 0.023	0.0 0.000	0.0 0.000	0.938	2,745
Physical Contingency	2,928	% CF×%	60.0 0.600	10.0 0.090	20.0 0.090	10.0 0.090	0.0 0.000	0.870	2,547
Total	66,762								**58,280**

Source: IDMP-TT

13.5 Project Benefits

(1) Category of benefits

Though benefits with the project of the site Wau is the yield by new cultivation, the expected benefits compared with existing farming in surrounding area of the site will be as follows:

- Increase of crop yield by irrigation
- Increase of cropping intensity
- Reduction of farming cost by increasing farming efficiency

(2) Project benefits at financial price

Based on the estimations of net benefit (gross output ï production cost including family labour value) by crop, the net incremental benefits were calculated. Next table is the summary of the net incremental benefit. Total net incremental benefit was estimated at 5,319 thousand US$ or 10,637 US$/ha.

Table 13.5.1 Summary of Net Incremental Benefit at Financial Price

Net Bennefit: Gross output － Production cost including family labor value

Crop	Area (ha) ①	Gross output (000US$) ②	Production cost (000US$) ③	Net Benefit (000US$) ④=②－③	Net Benefit (US$/ha) ⑤=④/①
Rice	500	3,631	2,943	687	1,374
Jew's mallow	250	1,075	1,336	-261	-1,044
Watermeron	250	6,432	1,540	4,892	19,569
Total	1,000	11,138	5,819	**5,319**	**10,637**

Source: IDMP-TT

(3) Project benefits at economic price

Project benefits at financial price were converted into the ones at economic price, using conversion factors and import party prices as it has been mentioned. For economic analysis, incremental benefit (count family labour as cost) will be also considered since economic analysis stands on the viewpoint of the national economy to examine the efficiency of resources use in the country.

Next table shows the summary of farm benefit. Total incremental benefit was estimated at 5,206

thousand US$ or 10,411 US$/ha.

Table 13.5.2 Summary of Economic Incremental Benefits

Net Bennefit: Gross output － Production cost including family labor value

Crop	Area (ha) ①	Gross output (000US$) ②	Production cost (000US$) ③	Net Benefit (000US$) ④=②－③	Net Benefit (US$/ha) ⑤=④/①
Rice	500	2,956	2,053	903	1,807
Jew's mallow	250	967	875	92	369
Watermeron	250	5,380	1,169	4,210	16,841
Total	1,000	9,303	4,098	**5,206**	**10,411**

Source: IDMP-TT

13.6 Project Evaluation

(1) Cash flows of costs and benefits

Following is the proposed cash flow of investment (project cost) and the benefits accruing from the investment:

Investment (Project Cost):

Construction: Construction including survey, examination, etc. will be implemented in the first and second year.

O & M: Annual Operation and Maintenance (O&M) cost excluding the fuel of the pump is assumed 5 % of the total construction cost. The fuel cost of the pumping is estimated at 169 thousand US$/year for Case 1 and 85 thousand US$/year for Case2.

Replacement: The introduced suction pump has to be replaced in the 21st year after 20 years of service life. Other irrigation facilities have durability of more than 30 years.

Benefit:

Crop production: Benefit will start fully realizing three years after implementation of planned farming, namely from the fourth year of cultivation. It is assumed that 70 %, 80 % and 90 % of the full benefit will be achieved in the first, the second and the third year respectively.

(2) Financial analysis

With the costs and benefits at financial price, here we apply financial internal rate of return (FIRR), financial net present value (FNPV) and cost-benefit ratio (B/C) for examining the efficiency of the investment. To estimate FNPV and B/C, discount rate of 8.83 % was applied, which is average of short-term lending interest rates of commercial banks in January - March 2015.

Family labour in this analysis is counted as cost for we stand on the viewpoint of private enterprise (farm household as a firm), all the inputs should be counted as cost; namely, net incremental benefit will be applied for the analysis.

The FIRR, FNPV and B/C were calculated at 9.0 %, 591 thousand US$ and 1.01 respectively. The FIRR is over the interest rate of 8.83 %, the FNPV is over zero and the B/C is over 1.00. Therefore, it can be said the project is financially viable.

(3) Economic evaluation

With the economic costs and benefits estimated above, the Economic Internal Rate of Return (EIRR) is calculated. Cash flow is same with the one of the financial analysis. The EIRR of Case 1 was calculated at 10.7 %. Opportunity cost of capital in RSS is considered around 7.5 %, therefore, it can be said that the project is economically feasible. Economic net present value (ENPV) discounted at the rate of 7.5 % was calculated at 9,307 thousand US$. The B/C discounted at 7.5 % was 1.22.

On the other hand, the EIRR of Case 2 was calculated at 0.13 %. The ENPV of Case 2 discounted at the rate of 7.5 % was calculated at - 33,156 thousand US$. The B/C was 0.61.

CHAPTER 14 CONCLUSION AND RECOMMENDATIONS

Project evaluation of Case 1 shows that the project is economically feasible and also financially viable. Project evaluation of Case 2 shows that the project is not feasible economically due to the huge cost of the dam. However, the dam will stably provide large amount of water flow in the river. Therefore, we can expect some indirect effects to the project of Case 2, such as the increase of living water and water for animal/ fish. It is required to consider those effects from various viewpoints including food security.