# 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 the Rejaf East 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 Rejaf East 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 Rejaf East Irrigation Scheme are summarized in Table 5.1.1.

**Table 5.1.1 Key Directorate of MEDIWR in 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 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) | Construction, rehabilitation, maintenance and operation of power plant and grid. |
| | 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 Rejaf East 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 Rejaf East Irrigation Scheme. At the planning stage, MAFCRD is required to develop water demand plan for crops related 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 Rejef East 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. |

| Organization | Stakeholders | Key Functions in Irrigation Development |
|---|---|---|
| | 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 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 |

| Organization | Stakeholders | Key Functions in Irrigation Development |
|---|---|---|
| | | 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 (LG) | County Department of Agriculture, Livestock, Fisheries and Forestry (CDALFF) | 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. |
| 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 Rejaf East 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)<br>- 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 Rejaf East 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 Rejaf East Irrigation Scheme development project.

**Table 5.3.1 Roles and Responsibilities of 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<br>・Financing<br>・Implementation<br>・M&E | ・Coordination<br>・M&E | ・Coordination<br>・M&E | ・Contribution<br>・Coordination<br>・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 Rejaf East 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 PLANNING

## 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)

The command area in Rejaf East is owned by three (3) communities namely; Guduge, Migiri and Mogoro. Therefore, beneficiaries the farmers in future irrigation scheme are expected to be mainly the members from those three (3) communities. Hence, their potentiality and intension should be taken into consideration for the plan.

According to the socio economic survey, the farmers in the communities allocate large area to vegetable cultivation and their irrigated farmland/HH was the largest among the three (3) sites. Above all, the farmers in Rejaf East seem to be more familiar with irrigated farming, and also relatively experienced in using agro-chemicals or agricultural machinery use rather than other two (2) sites. The farmers in Rejaf East seem to be eager to produce vegetables as a mean of cash generation and lots kind of vegetables are cultivated.

Accordingly, the share of vegetables counts up to more than half of all requested crops. (See Table

6.2.1 below)Overall, Maize and Ground nut has been the most chosen crops by interviewees. Among the vegetables, Okra and Jewôs mallow ranked at the highest followed by Tomato and Egg plant.

**Table 6.2.1 Requested Crops**

| Crop | Percentage of Answers |
|---|---|
| Maze | 9.9 |
| Sorghum | 4.9 |
| Cassava | 4.9 |
| Common Beans | 7.4 |
| Ground nut | 9.9 |
| Cowpea | 3.7 |
| Sesame | 3.7 |
| Sugarcane | 3.7 |
| Vegetables | 51.9 |
| Tomato | (11.1) |
| Okra | (12.3) |
| Jew's mallow | (12.3) |
| Amaranthus | (4.9) |
| Egg plant | (9.9) |
| Other vegetables | (1.2) |

Source: IDMP TT (Socio-economic survey, 2015)
* The questionnaire allowed multiple answers to the interviewee
* Parenthesized numbers show the breakdown of vegetables.

In addition, there is much promising potential in vegetable cultivation in Rejaf East, because the area is very near from the markets in Juba, only five (5) to six (6) km away, with high accessibility to the place with high demand of food crops.

As same as other two (2) sites, natural condition should be considered to make the plan realizable. The above crops highly requested from the farmers were examined from the aspect of heat temperature tolerance and its suitable soil type (Soil in the command area ranges mainly from Sandy to Sandy Loam).As results, no crops above have been excluded. There is no crucial obstacle regarding soil condition like acidity of soil etc. Actually, sandy to sandy loam is generally suitable for vegetable production. However, one point should be considered is that there is damp area near from the river. Drainage management should be applied in such area.

With the considerations above, Maize, Ground nut, Okra, Jewôs mallow, Tomato and Egg plant have been selected as representative of the farming plan.

Figure 6.2.1 shows the planned cropping pattern with project for Rejaf East.

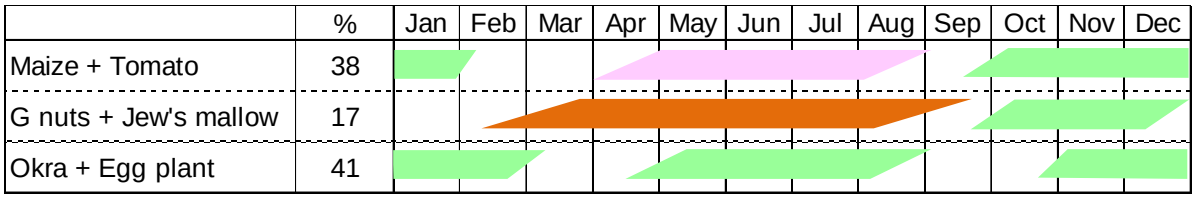



**Figure 6.2.1 Planned Cropping Pattern**

# 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. 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.

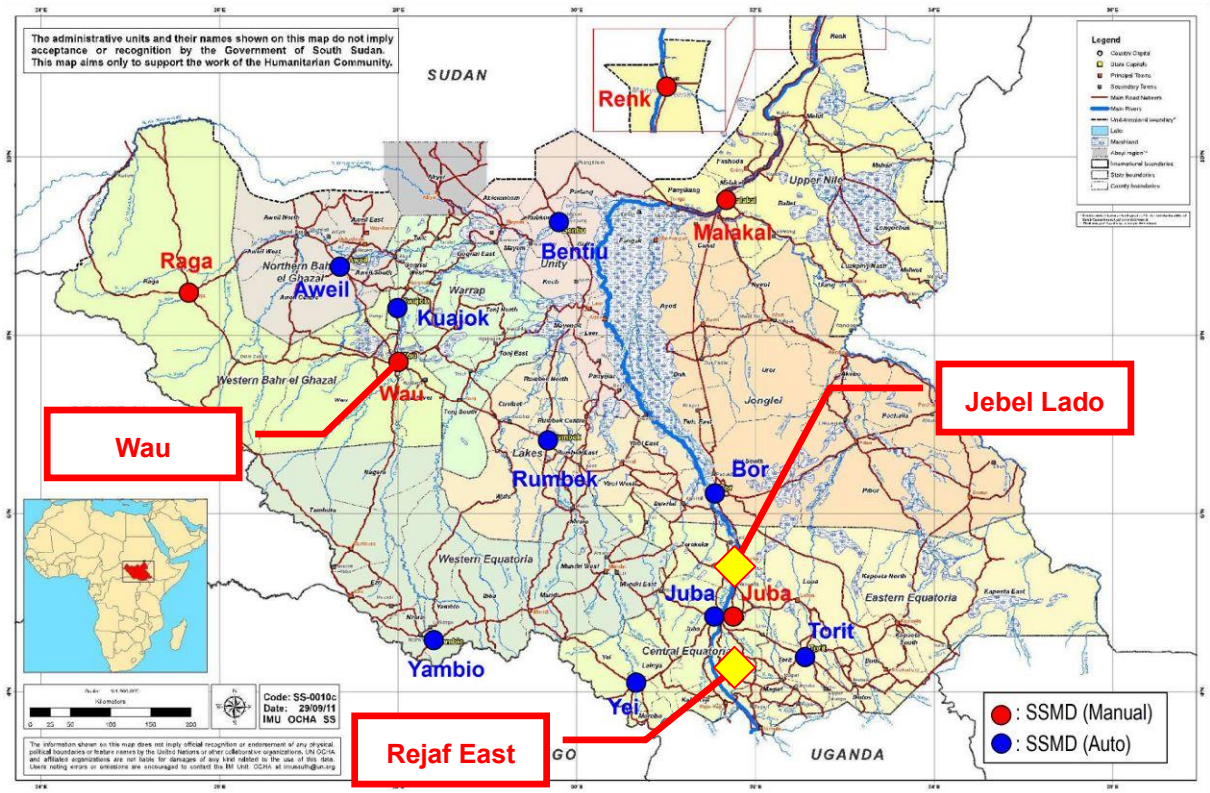



**Figure 7.1.1 Meteorological Stations in South Sudan**

**Table 7.1.1 Meteorological Stations for Necessary Climate Data**

| Priority Project Site | Climate Data | Meteorological Station | Remarks |
|---|---|---|---|
| Wau | Temperarure, Rainfall | Wau | |
| | Relative Humidity,<br>Wind Speed | Kauajok | No data in Wau meteorological station |
| Jebel Lado | Temperarure, Rainfall<br>Relative Humidity<br>Wind Speed | Juba | The nearest meteorological station |
| Rejaf East | Temperarure, Rainfall<br>Relative Humidity<br>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 Juba station is given in Table 7.1.2 and Figure 7.1.2.

**Table 7.1.2 Mean Monthly Rainfall at Juba**

| Meteorological Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Juba (mm) | 4.4 | 11.8 | 41.7 | 105.6 | 149.2 | 116.1 | 134.0 | 136.7 | 112.4 | 112.6 | 42.9 | 9.8 | 977 |

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

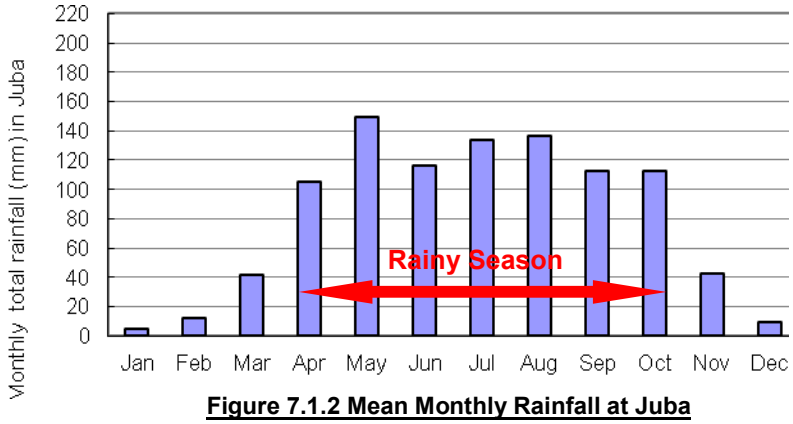



**Figure 7.1.2 Mean Monthly Rainfall at Juba**

### (3) Temperature

The temperature in Wau and Juba 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 7.1.5, Figure 7.1.3).

**Table 7.1.3 Monthly Mean Max and Min Temperature at Juba**

| Item | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Min Temp (°C) | 20.0 | 22.5 | 24.4 | 23.7 | 22.7 | 21.8 | 21.1 | 21.3 | 21.1 | 21.4 | 20.9 | 20.6 | 21.8 |
| Max Temp (°C) | 36.6 | 38.1 | 37.2 | 35.6 | 33.1 | 31.3 | 31.2 | 30.6 | 32.7 | 33.3 | 34.0 | 35.2 | 34.1 |

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

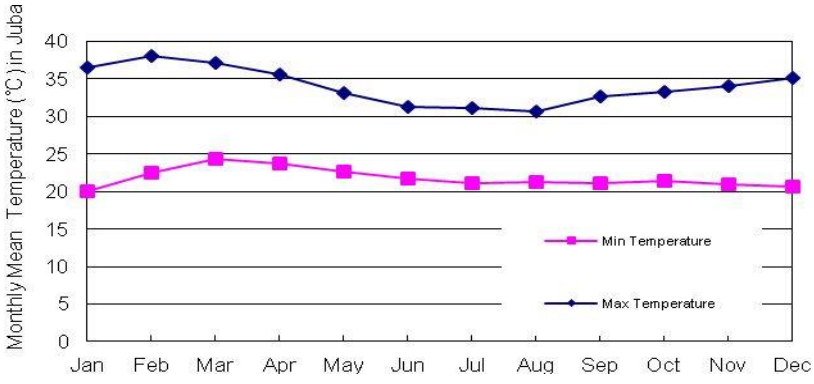



**Figure 3.1.3 Mean Monthly Max and Min Temperature at Juba**

### (4) Sunshine hours

Average sunshine hour is given in Table 7.1.6 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 63% for Juba. At Juba, it has 35 % in February, and has 82% in August. 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 Juba**

| Meteorological Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Juba (%) | 37 | 35 | 42 | 62 | 73 | 78 | 78 | 82 | 79 | 76 | 63 | 52 | 63 |

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

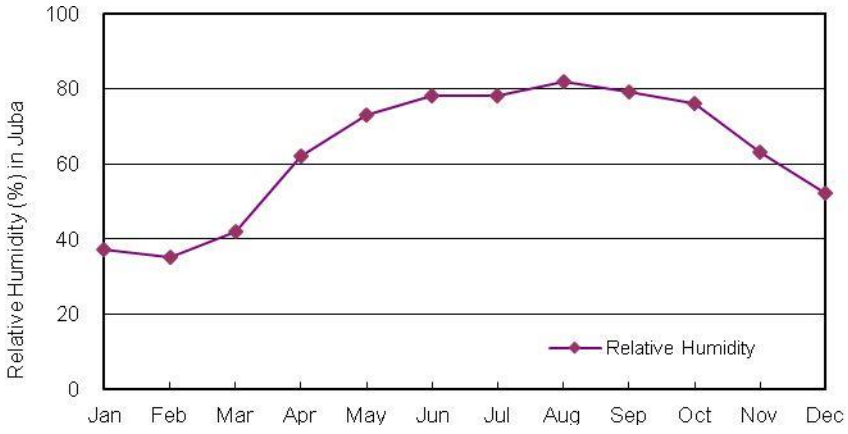



**Figure 7.1.4 Mean Monthly Relative Humidity at Juba**

### (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 Juba**

| Meteorological Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Juba (km/day) | 112 | 130 | 156 | 216 | 156 | 104 | 95 | 95 | 95 | 112 | 112 | 121 | 125.3 |

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

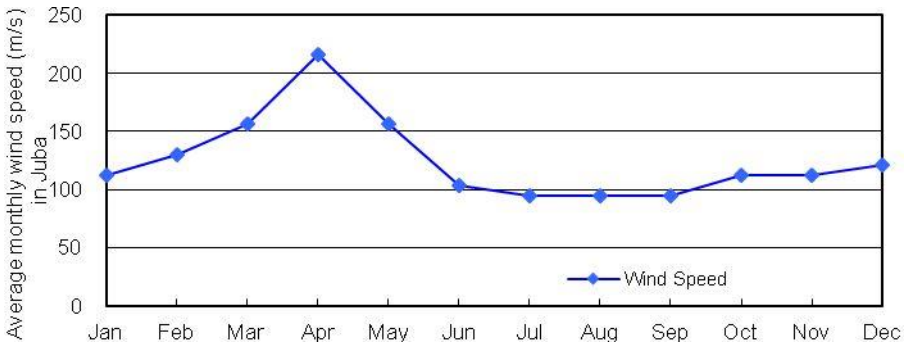



**Figure 7.1.5 Mean Monthly Wind Speed at Juba**

### (7) Summary of the necessary climate and weather data

Priority Project : Jebel Lado, Rejaf East
Station : Juba
Altitude :462m, Latitude : 5° 4'N, Longitude : 31° 40'E

**Table 7.1.7 Summary of the Climate Data at Juba**

| Item | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Average Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Min Temp (°C) | 20.0 | 22.5 | 24.4 | 23.7 | 22.7 | 21.8 | 21.1 | 21.3 | 21.1 | 21.4 | 20.9 | 20.6 | 21.8 |
| Max Temp (°C) | 36.6 | 38.1 | 37.2 | 35.6 | 33.1 | 31.3 | 31.2 | 30.6 | 32.7 | 33.3 | 34.0 | 35.2 | 34.1 |
| Humidity (%) | 37 | 35 | 42 | 62 | 73 | 78 | 78 | 82 | 79 | 76 | 63 | 52 | 63 |
| Wind (km/day) | 112 | 130 | 156 | 216 | 156 | 104 | 95 | 95 | 95 | 112 | 112 | 121 | 125.3 |
| Sunshine (hours) | 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 |
| Rainfall (mm) | 4.4 | 11.8 | 41.7 | 105.6 | 149.2 | 116.1 | 134.0 | 136.7 | 112.4 | 112.6 | 42.9 | 9.8 | 977 |

## 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 Rejaf East Farmlands is shown in Table 7.1.8.

**Table 7.1.8 Cropping Plan**

| Project site | Rainy season | Dry season |
|---|---|---|
| Rejaf East | Maize, ground nuts, okra | Vegetable (Egg plant/ tomato/ Jewŝs 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 Water Requirement

To estimate the crop water requirements, guidelines were developed and published by FAOñFAO Irrigation and Drainage Paper No. 24, Crop water requirementsò.

### 7.2.1 Reference Evapo-transpiration (ETo)

**(1) Estimation methods**

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 3.1.9. 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 Juba 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) in Jebel Lado and Rejaf East Estimated by Penman-Monteith**

| Particulars | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Min Temperature (°C) | 20.0 | 22.5 | 24.4 | 23.7 | 22.7 | 21.8 | 21.1 | 21.3 | 21.1 | 21.4 | 20.9 | 20.6 |
| Max Temperature (°C) | 36.6 | 38.1 | 37.2 | 35.6 | 33.1 | 31.3 | 31.2 | 30.6 | 32.7 | 33.3 | 34.0 | 35.2 |
| Relative Humidity (%) | 37 | 35 | 42 | 62 | 73 | 78 | 78 | 82 | 79 | 76 | 63 | 52 |
| Wind speed (km/day) | 112 | 130 | 156 | 216 | 156 | 104 | 95 | 95 | 95 | 112 | 112 | 121 |
| Sunshine (hours) | 11.8 | 11.9 | 12.0 | 12.2 | 12.3 | 12.4 | 12.3 | 12.3 | 12.1 | 12.0 | 11.9 | 11.8 |
| Radiation (MJ/m2/day) | 25.7 | 27.1 | 28.1 | 28.2 | 27.3 | 26.7 | 26.8 | 27.8 | 28.0 | 27.3 | 26.0 | 25.2 |
| ETo (mm/day) | 5.84 | 6.64 | 7.20 | 7.08 | 5.96 | 5.35 | 5.30 | 5.39 | 5.66 | 5.67 | 5.56 | 5.66 |

Source: JICA Team based on meteorological data recorded at Juba 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 follows 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.

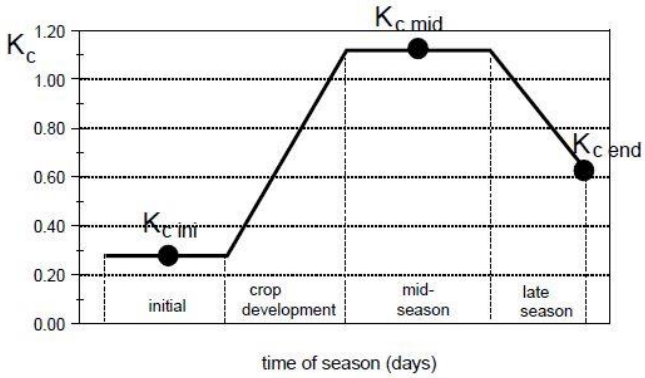



**Figure 7.2.1 Crop Coefficient Curve**

**Table 7.2.3 Crop Coefficient by Each Crop**

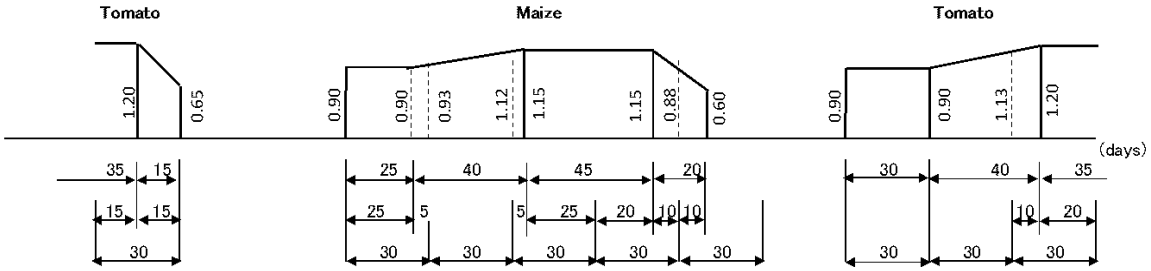
| Crop | Kc ini | Kc mid | Kc end |
|---|---|---|---|
| Maize | 0.90 | 1.15 | 0.60 |
| Egg plant/ okra | 0.90 | 1.05 | 0.85 |
| Tomato | 0.90 | 1.20 | 0.65 |
| Jewôs mallow* | 0.90 | 1.10 | 1.10 |
| Ground nuts | 0.90 | 1.05 | 0.60 |

Note: Kc of Jewôs mallow is applied Kc of celory.

## Rejaf East: Crop Coefficient (Kc)

**Crop-1**

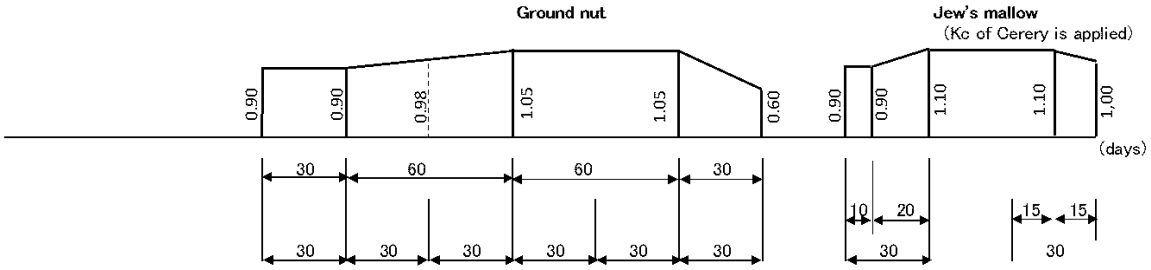
| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kc | 1.06 | 0.00 | 0.00 | 0.90 | 1.03 | 1.15 | 1.11 | 0.25 | 0.00 | 0.90 | 1.02 | 1.19 |




| | | | |
|---|---|---|---|
| Jan | Kc= (1.20*15+ (1.20+0.65)/2*15)/30 = 1.06 | Jul | Kc= (1.15*20+ (1.15+0.88)/2*10)/30 = 1.11 |
| Feb | Kc= 0 | Aug | Kc= (0.88+0.60)/2*10/30 = 0.25 |
| Mar | Kc= 0 | Sep | Kc= 0 |
| Apr | Kc= (0.90*25+ (0.90+0.93)/2*5)/30 = 0.90 | Oct | Kc= 0.90 |
| May | Kc= (0.93+1.12)/2*30/30 = 1.03 | Nov | Kc= (0.90+1.13)/2*30/30 = 1.02 |
| Jun | Kc= ((1.12+1.15)/2*5 + 1.15*25)/30 = 1.15 | Dec | Kc= ((1.13+1.20)/2*10 + 1.20*20)/30 = 1.19 |

**Crop-2**

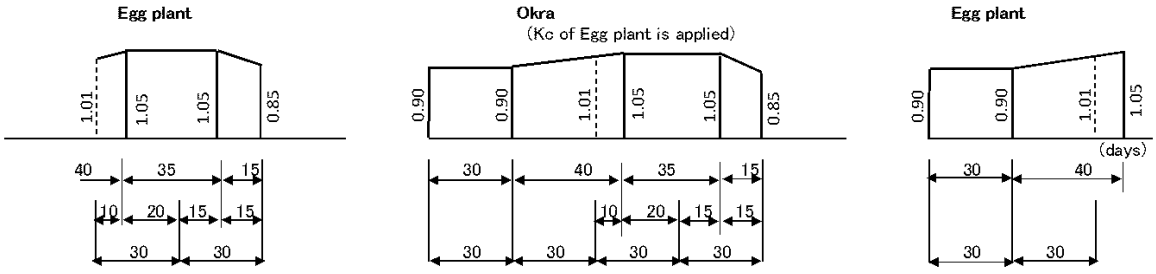
| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kc | 0.00 | 0.00 | 0.90 | 0.94 | 1.02 | 1.05 | 1.05 | 0.83 | 0.00 | 0.97 | 1.10 | 1.08 |




| | | | |
|---|---|---|---|
| Jan | Kc= 0 | Jul | Kc= 1.05 |
| Feb | Kc= 0 | Aug | Kc= (1.05+0.60)/2*30/30 = 0.83 |
| Mar | Kc= 0.90 | Sep | Kc= 0 |
| Apr | Kc= (0.90+0.98)/2*30/30 = 0.94 | Oct | Kc= (0.90*10+ (0.90+1.10)/2*20)/30 = 0.97 |
| May | Kc= (0.98+1.05)/2*30/30 = 1.02 | Nov | Kc= 1.10 |
| Jun | Kc= 1.05 | Dec | Kc= (1.10*15+ (1.10+1.00)/2*15)/30 = 1.08 |

**Crop-3** Banana : P.66, FAO No.24

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kc | 0.45 | 0.50 | 0.60 | 0.70 | 0.85 | 1.00 | 1.10 | 1.10 | 0.90 | 0.80 | 0.80 | 0.95 |




| | | | |
|---|---|---|---|
| Jan | Kc= ((1.01+1.05)/2*10+1.05*20)/30 = 1.04 | Jul | Kc= ((1.01+1.05)/2*10+1.05*20)/30 = 1.04 |
| Feb | Kc= (1.05*15+(1.05+0.85)/2*15)/30 = 1.00 | Aug | Kc= (1.05*15+(1.05+0.85)/2*15)/30 = 1.00 |
| Mar | Kc= 0 | Sep | Kc= 0 |
| Apr | Kc= 0 | Oct | Kc= 0 |
| May | Kc= 0.90 | Nov | Kc= 0.90 |
| Jun | Kc= (0.90+1.01)/2*30/30 = 0.96 | Dec | Kc= (0.90+1.01)/2*30/30 = 0.96 |

**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.

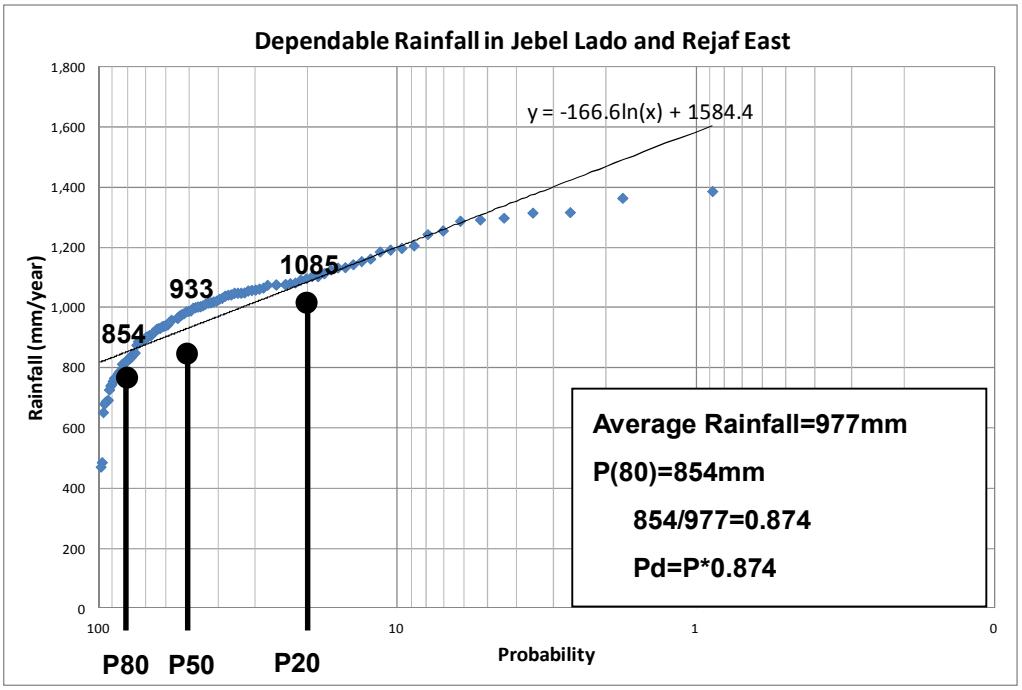



**Figure 7.3.1 Dependable Rainfall at Juba**

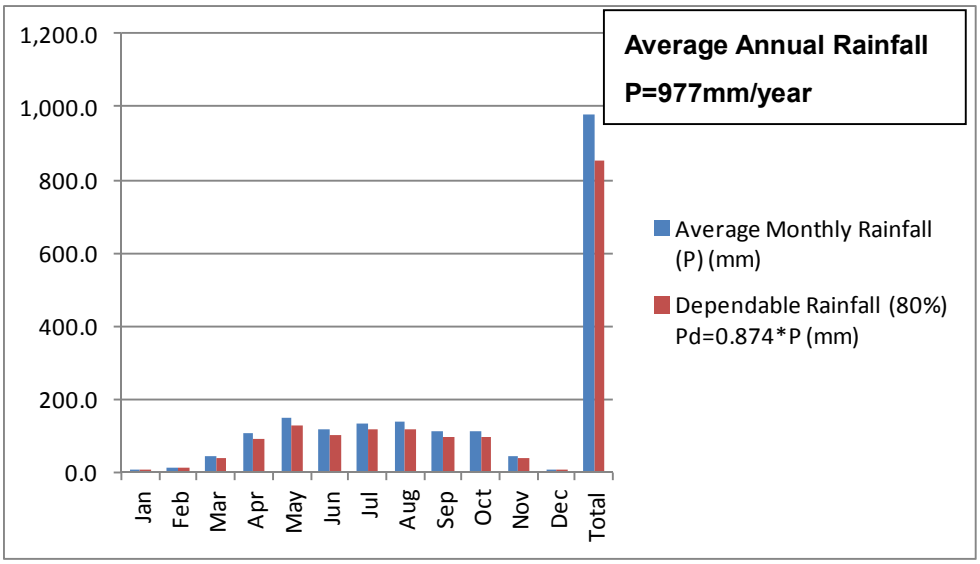



**Figure 7.2.4 Effective Rainfall at Juba**

**(2) Estimation of the effective fainfall**

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 Rejaf East scheme is shown in Table 7.3.3.

### 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.

### 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

The calculated NIR (ETcrop1, ETcrop2 and ETcrop3) for Rejaf East scheme is shown in Table 7.3.3.

### 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 Rejaf East scheme most of the soil water balance parameters 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 is 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 requirements/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, 0.60 for the field application efficiency in Jebel Lado and Rejaf East scheme, whereby the project irrigation efficiency comes to 0.49 for Jebel Lado and Rejaf East. Furrow irrigation methods are adopted in the farmlands because of the gentle terrain and soil feature of loam.

**Table 7.3.1 Irrigation Efficiencies for Jebel Lado and Rejaf East**

| Efficiency | E | Remarks |
|---|---|---|
| Conveyance Efficiency (Ec) | 0.90 | Continuous supply |
| Field Cancel Efficiency (Eb) | 0.90 | Blocks larger than 20 ha |
| Field Application Efficiency (Ea) | 0.60 | Referred to the case of furrow irrigation |
| Project Irrigation Efficiency | 0.49 | 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

Like in the case of Jebel Lado, the overall efficiency for Rejaf East Scheme = 0.9*0.9*0.6 = 0.49

### 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)/0.49

C.F = 1/8.64 = 0.1157

Hence q = CIR ((C.F) l/s/ha)/0.49

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

**(2) Calculated water requirement**

Table 7.3.2 and Table 7.3.3 show the calculation of water requirement by month in Rejaf East.

**Table 7.3.2 Rejaf East Scheme Irrigation Water Requirements**

| | |
|---|---|
| 1. Site | Rejaf East |
| 2. Command Area | 960 ha |
| 3. Planting ratio | 0.96 |
| 4. Planting area | 922 ha |
| 3. Water Source | River |
| 3. Irrigation Facility | Pump |
| 4. Irrigation Water Requirement | Pump 1.32 $m^3/s$<br>q= 1.430 l/s/ha |

## Table 7.3.3 Calculation of Irrigation Water Requirements per Month for Rejaf East Scheme

Water Requirement: Rejaf East (A=960ha)

| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Dry Season | | | Rainy Season | | | | | | | Dry Season | | |
| (1) ETcrop | | | | | | | | | | | | | | |
| Min Temperature | (°C) | 20.0 | 22.5 | 24.4 | 23.7 | 22.7 | 21.8 | 21.1 | 21.3 | 21.1 | 21.4 | 20.9 | 20.6 | 21.8 |
| Max Temperature | (°C) | 36.6 | 38.1 | 37.2 | 35.6 | 33.1 | 31.3 | 31.2 | 30.6 | 32.7 | 33.3 | 34.0 | 35.2 | 34.1 |
| Relative Humidity | (%) | 37 | 35 | 42 | 62 | 73 | 78 | 78 | 82 | 79 | 76 | 63 | 52 | 63.1 |
| Wind speed | (km/day) | 112 | 130 | 156 | 216 | 156 | 104 | 95 | 95 | 95 | 112 | 112 | 121 | 125.3 |
| Sunshine | (hours) | 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 |
| Radiation | (MJ/m2/day) | 25.7 | 27.1 | 28.1 | 28.2 | 27.3 | 26.7 | 26.8 | 27.8 | 28.0 | 27.3 | 26.0 | 25.2 | 27.0 |
| ETo | (mm/day) | 5.84 | 6.64 | 7.20 | 7.08 | 5.96 | 5.35 | 5.30 | 5.39 | 5.66 | 5.67 | 5.56 | 5.66 | CropWar8.0 |
| Crop 1 | | Vegetable | | | Maize | Maize | Maize | Maize | | | Vegetable | Vegetable | Vegetable | Tomato |
| Crop 2 | | | | Ground Nuts | | Ground Nuts | | Ground Nuts | | | | | Vegetable | Jew's mallow |
| Crop 3 | | Vegetable | Vegetable | | | Vegetable | Vegetable | Vegetable | Vegetable | | | Vegetable | Vegetable | Okra/Egg plant |
| Crop coeffient 1 | Kc1 | 1.06 | 0.00 | 0.00 | 0.90 | 1.03 | 1.15 | 1.11 | 0.25 | 0.00 | 0.90 | 1.02 | 1.19 | |
| Crop coeffient 2 | Kc2 | 0.00 | 0.00 | 0.90 | 0.94 | 1.02 | 1.05 | 1.05 | 0.00 | 0.00 | 0.97 | 1.10 | 1.08 | |
| Crop coeffient 3 | Kc3 | 1.04 | 1.00 | 0.00 | 0.00 | 0.90 | 0.96 | 1.04 | 1.00 | 0.00 | 0.00 | 0.90 | 0.96 | |
| Etcrop 1 ($ET_o$ x Kc1) | (mm/day) | 6.19 | 0.00 | 0.00 | 6.37 | 6.14 | 6.15 | 5.88 | 1.35 | 0.00 | 5.10 | 5.67 | 6.74 | |
| Etcrop 2 ($ET_o$ x Kc2) | (mm/day) | 0.00 | 0.00 | 6.48 | 6.66 | 6.08 | 5.62 | 5.57 | 0.00 | 0.00 | 5.50 | 6.12 | 6.11 | |
| Etcrop 3 ($ET_o$ x Kc3) | (mm/day) | 6.07 | 6.64 | 0.00 | 0.00 | 5.36 | 5.14 | 5.51 | 5.39 | 0.00 | 0.00 | 5.00 | 5.43 | |
| | | | | | | | | | | | | | | |
| (2) Effective Rainfall (Pe) | | | | | | | | | | | | | | |
| Monthly Mean Rainfall | (mm/month) | 4.4 | 11.8 | 41.7 | 105.6 | 149.2 | 116.1 | 134.0 | 136.7 | 112.4 | 112.6 | 42.9 | 9.8 | 977.2 |
| Dependable Rainfall (80%) | (mm/month) | 3.8 | 10.3 | 36.5 | 92.3 | 130.5 | 101.5 | 117.2 | 119.5 | 98.3 | 98.5 | 37.5 | 8.6 | 854.5 |
| Effective Rainfall (ER) | (mm/month) | 0.0 | 0.0 | 12.0 | 50.0 | 80.0 | 57.0 | 70.0 | 72.0 | 55.0 | 55.0 | 13.0 | 0.0 | 464.0 |
| Effective Rainfall (ER) | (mm/day) | 0.0 | 0.0 | 0.4 | 1.7 | 2.7 | 1.9 | 2.3 | 2.4 | 1.8 | 1.8 | 0.4 | 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) | 6.19 | 0.00 | 0.00 | 4.67 | 3.44 | 4.25 | 3.58 | 0.00 | 0.00 | 3.30 | 5.27 | 6.74 | |
| Etcrop 2 | (mm/day) | 0.00 | 0.00 | 6.08 | 4.96 | 3.38 | 3.72 | 3.27 | 0.00 | 0.00 | 3.70 | 5.72 | 6.11 | |
| Etcrop 3 | (mm/day) | 6.07 | 6.64 | 0.00 | 0.00 | 2.66 | 3.24 | 3.21 | 2.99 | 0.00 | 0.00 | 4.60 | 5.43 | |
| | | | | | | | | | | | | | | |
| (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 |
| Field Application Efficiency | Ea | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | Furrow |
| Total Irrigation Efficiency | Ep | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | |
| | | | | | | | | | | | | | | |
| (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) | 1.46 | 0.00 | 0.00 | 1.10 | 0.81 | 1.00 | 0.85 | 0.00 | 0.00 | 0.78 | 1.24 | 1.59 | |
| Crop 2 | (l/s/ha) | 0.00 | 0.00 | 1.44 | 1.17 | 0.80 | 0.88 | 0.77 | 0.00 | 0.00 | 0.87 | 1.35 | 1.44 | |
| Crop 3 | (l/s/ha) | 1.43 | 1.57 | 0.00 | 0.00 | 0.63 | 0.77 | 0.76 | 0.71 | 0.00 | 0.00 | 1.09 | 1.28 | |
| | | | | | | | | | | | | | | |
| (9) Command Area | | | | | | | | | | | | | | |
| Crop 1 | (ha) | 365 | 365 | 365 | 365 | 365 | 365 | 365 | 365 | 365 | 365 | 365 | 365 | |
| Crop 2 | (ha) | 163 | 163 | 163 | 163 | 163 | 163 | 163 | 163 | 163 | 163 | 163 | 163 | |
| Crop 3 | (ha) | 394 | 394 | 394 | 394 | 394 | 394 | 394 | 394 | 394 | 394 | 394 | 394 | Command Area |
| Total | (ha) | 922 | 922 | 922 | 922 | 922 | 922 | 922 | 922 | 922 | 922 | 922 | 922 | A= 960 ha |
| | | | | | | | | | | | | | | Planting Ratio 96% |
| (10) Water Requirement for Pump | | | | | | | | | | | | | | |
| Crop 1 | (m3/s/Crop1) | 0.53 | 0.00 | 0.00 | 0.40 | 0.30 | 0.36 | 0.31 | 0.00 | 0.00 | 0.28 | 0.45 | 0.58 | |
| Crop 2 | (m3/s/Crop2) | 0.00 | 0.00 | 0.24 | 0.19 | 0.13 | 0.14 | 0.13 | 0.00 | 0.00 | 0.14 | 0.22 | 0.24 | |
| Crop 3 | (m3/s/Crop3) | 0.56 | 0.62 | 0.00 | 0.00 | 0.25 | 0.30 | 0.30 | 0.28 | 0.00 | 0.00 | 0.43 | 0.50 | |
| Total | (m3/s/Total) | 1.10 | 0.62 | 0.24 | 0.59 | 0.67 | 0.81 | 0.73 | 0.28 | 0.00 | 0.43 | 1.10 | 1.32 | |
| | | | | | | | | | | | | | | |
| (11) Water Requirement for Dam | (m3/month/Total) | 2,839,422 | 1,601,732 | 609,141 | 1,535,045 | 1,747,049 | 2,103,377 | 1,904,809 | 724,350 | 0 | 1,105,561 | 2,855,596 | 3,418,454 | 20,444,535 |
| | | | | | | | | Required Pump Discharge | | | | 1.32 | (m3/s) | |
| | | | | | | | | Annual Water Requirement | | | | 20,444,535 | (m3/year) | |

# CHAPTER 8 FACILITY PLAN AND DESIGN

## 8.1 General

### 8.1.1 Outline of Main Facilities

Main facilities planed in Rejaf East shemea are as follows,

- Command area: A=960ha
- Pump station: 4 place
- Main Irrigation Canal: riverside L= 2.4km, hillside L=5.6km
- Irrigation and Drainage Facilities in command area: 1 L.S
  Secondary canal, Tertiary canal, Feeder canal, Drainage, Road, Road crossing, Distribution gate, Water measurement facilities, etc.

Pump station is planned by each community because of the difficulty of consensus among three (3) communities. Pump facility are operated through the year for farming, withdrawing from Bahr el Jebel.

### 8.1.2 Command Area

Command area is located from the right bank of Bahr el Jebel toward the hillside of almost 2km distance. The terrain between riverside and Rejaf Road is flat of ground level about EL.450m, and many small irrigation farms are scattered along the river. The area of more EL.452m is featured as undulate hillside. The land gradient shows around 2.0% toward the west from the east.

Also the terrain of hillside is complicated, and many bushes, trees and grasses dominate in the site. Pump station site has some big trees. In the pipe line and canal line, the conditions are almost same as the command area.

Pump station site is located beside Bahr el Jebel. The land is almost bare and some trees are shown. In the pipe line and canal line, there are community road among some small communities, bushes and trees etc. along the line.

In addition, on the route of the pipeline No.1, the additional pump station called No.1-H is planned near the Rejaf road to convey the irrigation water to the hillside farms in the view of the reduce the total head of pump and the economic efficiency.

- To reduce the total head of pump contributes to save the engine power,
- To reduce the discharge in the pipeline contributes to make the pipe diameter to small size, and
- To raise the economic efficiency due to the above matters.

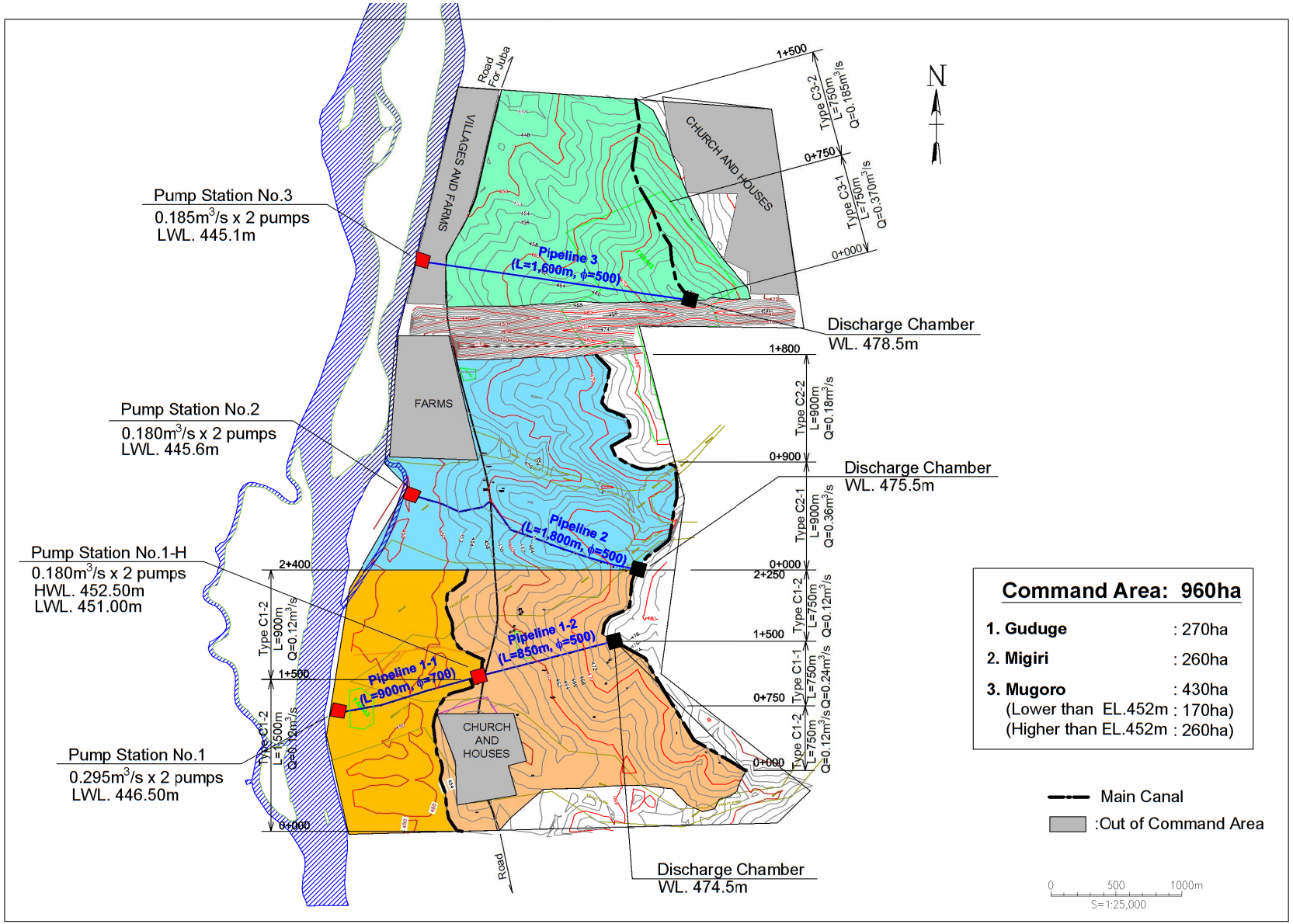



**Figure 8.1.1 Location Map**

## 8.2 Pump Station

### 8.2.1 Location and River Water Level

#### (1) River water level

The pump stations are located at the right of Bahr el Jebel. The water level measured in the survey work at the pump station on 3rd June 2015 is shown in the Table 8.2.1 and Figure 8.2.1. According to the water level record at Juba gauge station which is comparatively near to the pump station, the range of water level fluctuation is observed among 2.04m water depth as shown in the Figure 8.2.1.

Low Water Level (LWL) required in pump design of Bahr el Jebel is assumed at the about 0.5m lower down the river observed water level, and High Water Level (HWL) also assumed at the plus 2.0m with LWL.

**Table 8.2.1 Water Level of Bahr el Jebel at Pump Station Locationl**

| Pump Station Number | River Water Level Observed (WL.m) | Design Low Water Level (LWL.m) | Design High Water Level (HWL.m) |
|---|---|---|---|
| No.1 | 446.96 | 446.50 | 448.50 |
| No.2 | 446.06 | 445.60 | 447.60 |
| No.3 | 445.59 | 445.10 | 447.10 |

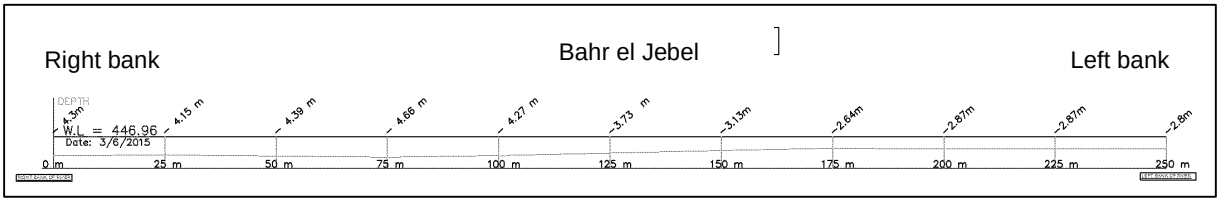



**Figure 8.2.1 River Cross Section at Pump Station No.1**

### 8.2.2 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. According to the ñDesign Pump Facilities Technical Document (Japan)ò, the pump diameter (ű) is determined as follows based on the pump capacity.

Pump station No.1: 0.295$m^3$/s (unit capacity) × 2 set = 0.59 $m^3$/s, ű350mm
Pump station No.1-H: 0.180$m^3$/s (unit capacity) × 2 set = 0.36 $m^3$/s, ű300mm
Pump station No.2: 0.180$m^3$/s (unit capacity) × 2 set = 0.36 $m^3$/s, ű300mm
Pump station No.3: 0.185$m^3$/s (unit capacity) × 2 set = 0.37 $m^3$/s, ű300mm

**Table 8.2.2 Water Requirement ($m^3/s$)**

| Pump Station Number | Farm Area (ha) | Plannting Ratio | Irrigable Area (ha) | Water Requirement (m3/s) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
| Station No.1 | 170 | 0.96 | 163 | 0.49 | 0.28 | 0.11 | 0.26 | 0.30 | 0.36 | 0.33 | 0.13 | 0.00 | 0.19 | 0.49 | 0.59 |
| Station No.1-H | 260 | 0.96 | 250 | 0.30 | 0.17 | 0.06 | 0.16 | 0.18 | 0.22 | 0.20 | 0.08 | 0.00 | 0.12 | 0.30 | 0.36 |
| Station No.2 | 260 | 0.96 | 250 | 0.30 | 0.17 | 0.06 | 0.16 | 0.18 | 0.22 | 0.20 | 0.08 | 0.00 | 0.12 | 0.30 | 0.36 |
| Station No.3 | 270 | 0.96 | 259 | 0.31 | 0.17 | 0.07 | 0.17 | 0.19 | 0.23 | 0.21 | 0.08 | 0.00 | 0.12 | 0.31 | 0.37 |

### (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 8.2.3 Total Head of Pump**

| Items | Unit | No.1 | No.1-H | No.2 | No.3 |
|---|---|---|---|---|---|
| Pump Capacity per Unit | Q ($m^3/s$) | 0.295 | 0.18 | 0.18 | 0.185 |
| Design outlet Water level | DWL (m) | 452.50 | 475.00 | 475.50 | 478.50 |
| Design Intake Water Level | LWL (m) | 446.50 | 451.50 | 445.60 | 445.10 |
| Actual head | Ha (m) | 6.00 | 23.50 | 29.90 | 33.40 |
| Total Head Loss | (m) | 7.4 | 11.07 | 20.01 | 19.08 |
| Total Head | (m) | 13.40 | 34.57 | 49.91 | 52.48 |
| Design Total Head | H (m) | 14.00 | 35.00 | 50.00 | 53.00 |

### (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 and diesel engine output are calculated in the Table 8.2.4.

**Table 8.2.4 Diesel Engine Output**

| Pump Station | Power Shaft Power (kw) | Diesel Engine Output (kw) |
|---|---|---|
| Station No.1 | 49.3 | 57 |
| Station No.1-H | 79.0 | 91 |
| Station No.2 | 112.8 | 130 |
| Station No.3 | 122.9 | 141 |

## 8.2.3 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 8.2.2.

### (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

Pump station No.1 and No.2: According to the log of boring PB-01 and PB-02, the geological condition is shown the medium dense and it is not suitable for the spread foundation. It is

recommended to adopt the pile foundation in future design stage through the additional geological investigation for clarifying the very dense layer.

Pump station No.3: According to the log of boring PB-03, the geological condition are shown the loose dense of the 3m depth and it is not suitable for the spread foundation. It is recommended to adopt the replacement foundation that remove away the loose soil and back fill by the suitable soil with the adequate compaction manner.

Pump station No.1-H: According to the log of boring RB-01 near the pump station but the distance of about 1km far, the geological condition are shown the high dense and it is suitable for the spread foundation. However, it is recommended to carry out the additional geological investigation for clarifying the geological conditions at the site.

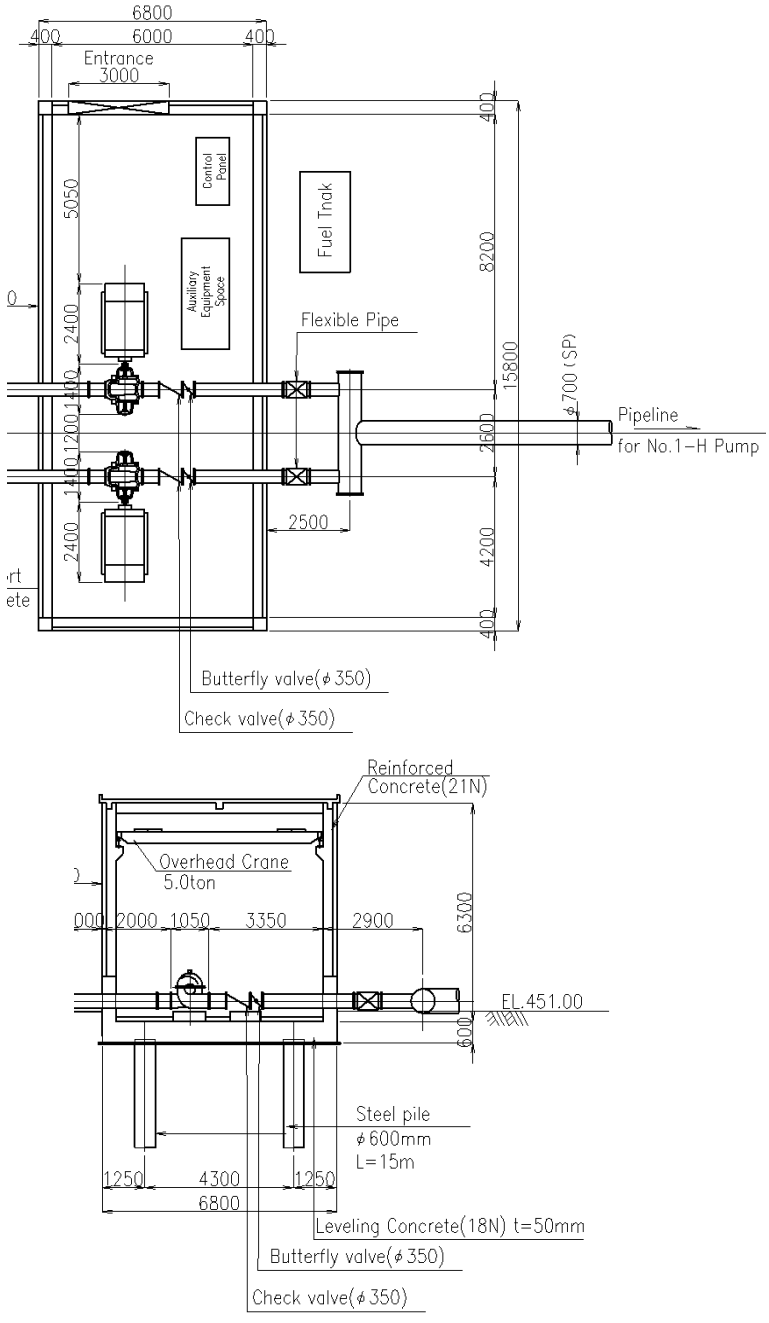



**Figure 8.2.2 Plan and Section of Pump Station Building**

### 8.2.4 Riverbank Protection

#### (1) Installation range

Due to the possible erosion by river flow, however, the suction pipe embedded underground might be exposed and the safety of the pipe could be endangered with the trashes/drifts clinched. This requires the riverbank protection works for attaining sustainable operation of the pump station. The extent of the riverbank protection shall cover 20 m each of both upstream and downstream directions from the centre of suction pipe.

#### (2) Structure type

The structure of mortar masonry retaining wall by using natural stones shall be adopted for the protection works, considering the gentle slope of 1:2.0, safety against the effect of water flow, availability of required materials, other viewpoints including landscape evaluation, economy and easiness in construction etc.

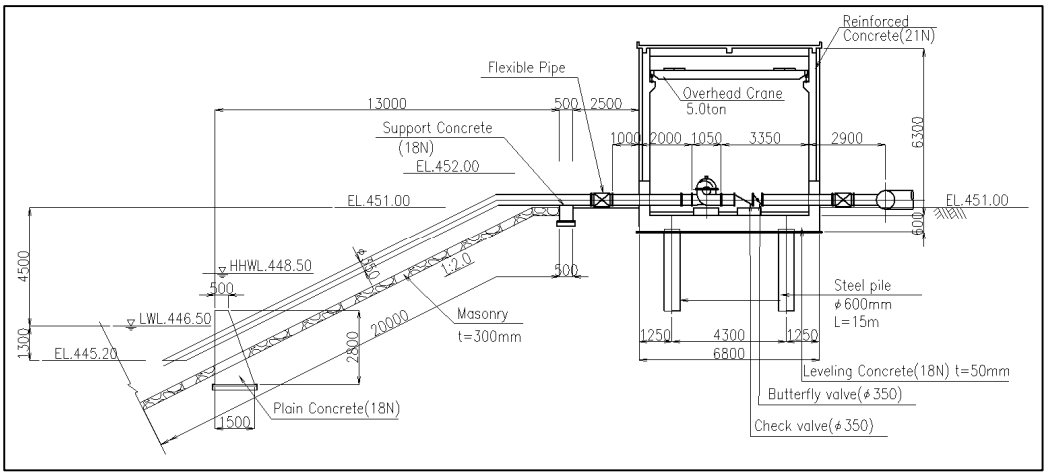



**Figure 8.2.3 Plan and Section of Pump Station Building (Profile)**

### 8.2.5 Storage for Pump Station No.1-H

Storage structure is required to store and convey the irrigation water for the hillside farms at the outlet of pipeline in the vicinity of Rejaf road. The capacity of storage (V) is determined at more than 650m$^3$ to ensure the half an hour volume of the pump No.1-H capacity 0.36m$^3$/s of 2 set. The structure type shall be of firm reinforced concrete or masonry with mortal to avoid the water leakage.

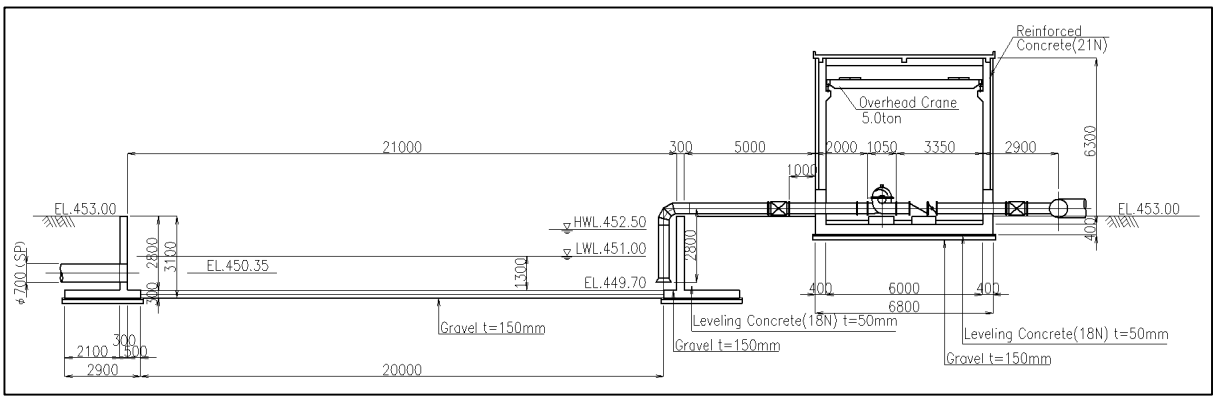



**Figure 8.2.4 Storage**

### 8.2.6 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 500mm diameter in case of the pipeline No.2, No3 and No.1-H.. 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.

**Table 8.2.5 Pipeline Dimensions**

| Pipeline Number | Diameter (mm) | Section Area ($m^2$) | Discharge ($m^3$/s) | Velocity (m/s) |
|---|---|---|---|---|
| Station No.1 | 700 | 0.385 | 0.59 | 1.53 |
| Station No.1-H | 500 | 0.196 | 0.36 | 1.83 |
| Station No.2 | 500 | 0.196 | 0.36 | 1.83 |
| Station No.3 | 500 | 0.196 | 0.37 | 1.88 |

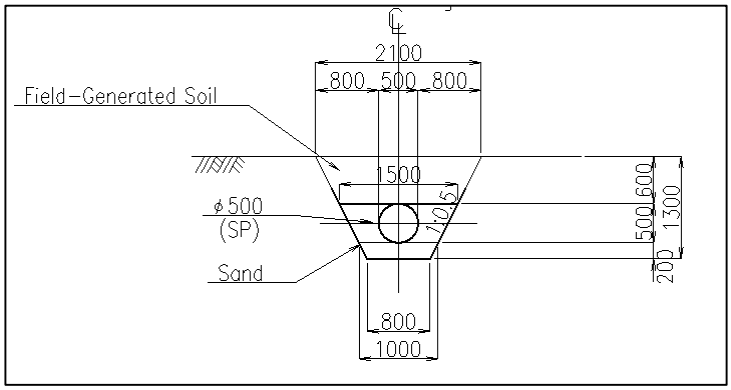



**Figure 8.2.5 Typical Section of Pipeline No.1**

#### (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.

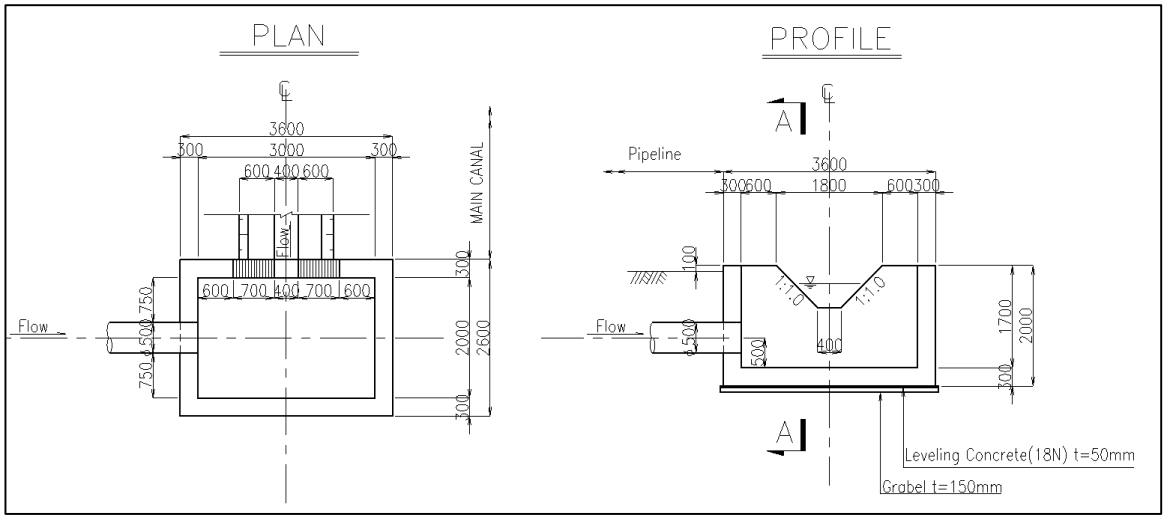



**Figure 8.2.6 Discharge Chamber (reference)**

## 8.3 Main Canal

### 8.3.1 Location

Main canal shall be planned to conduct the irrigation water from the discharge chamber at the end of pipeline to the command area. Main canals are planned at both riverside and hillside, which are flat and undulate respectively. Because of the difficulty of consensus among the communities, Main canals are planned by each community show in the Figure 8.1.1.

The station number, length, and design discharge of each section is shown in the Table 8.3.1.

**Table 8.3.1 Main Canal**

| Type | Length (m) | Design Discharge (m3/s) | Remarks |
|---|---|---|---|
| Area of Pump Station No.1 & No.1-H | 2.400 | | |
| C1-1 | 750 | 0.24 | |
| C1-2 | 3,900 | 0.12 | |
| Area of Pump Station No.2 | 1.800 | | |
| C2-1 | 900 | 0.36 | |
| C2-2 | 900 | 0.18 | |
| Area of Pump Station No.3 | 1.500 | | |
| C3-1 | 750 | 0.37 | |
| C3-2 | 750 | 0.185 | |

### 8.3.2 Examination Method of Canal Capacity

Main canal is designed of the plain concrete lining, considering hydraulic characteristics, conveyance efficiency, durability, and maintenance. The size of the cross section is planned by the volume of the required water with Manning formula

**Table 8.3.2 Calculation of Main Canal Section**

| Items | | C1-1 | C1-2 | C2-1 | C2-2 | C3-1 | C3-2 |
|---|---|---|---|---|---|---|---|
| Design discharge | Q ($m^3$/s) | 0.24 | 0.12 | 0.36 | 0.18 | 0.37 | 0.185 |
| Width of canal bed | B (m) | 0.40 | 0.30 | 0.50 | 0.40 | 0.40 | 0.30 |
| Water depth | d (m) | 0.403 | 0.313 | 0.457 | 0.348 | 0.384 | 0.299 |
| Bank slope | 1:N | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Cross-sectional area of flow | A (m) | 0.324 | 0.192 | 0.437 | 0.260 | 0.301 | 0.1796 |
| Wetted perimeter | P (m) | 1.540 | 1.185 | 1.793 | 1.384 | 1.486 | 1.146 |
| Hydraulic mean depth | R (m) | 0.210 | 0.162 | 0.244 | 0.188 | 0.203 | 0.156 |
| Coefficient of roughness | n | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| Canal bed slope | I (%) | 0.10 | 0.10 | 0.10 | 0.10 | 0.286 | 0.286 |
| Mean velocity | V (m/s) | 0.746 | 0.626 | 0.823 | 0.691 | 1.229 | 1.034 |
| Velocity head | hv (m) | 0.028 | 0.020 | 0.035 | 0.024 | 0.077 | 0.055 |
| Free board | Fb (m) | 0.196 | 0.187 | 0.193 | 0.152 | 0.216 | 0.201 |
| Height of canal | H | 0.60 | 0.50 | 0.65 | 0.50 | 0.60 | 0.50 |

Canal section is shown in the Figure 8.3.1.

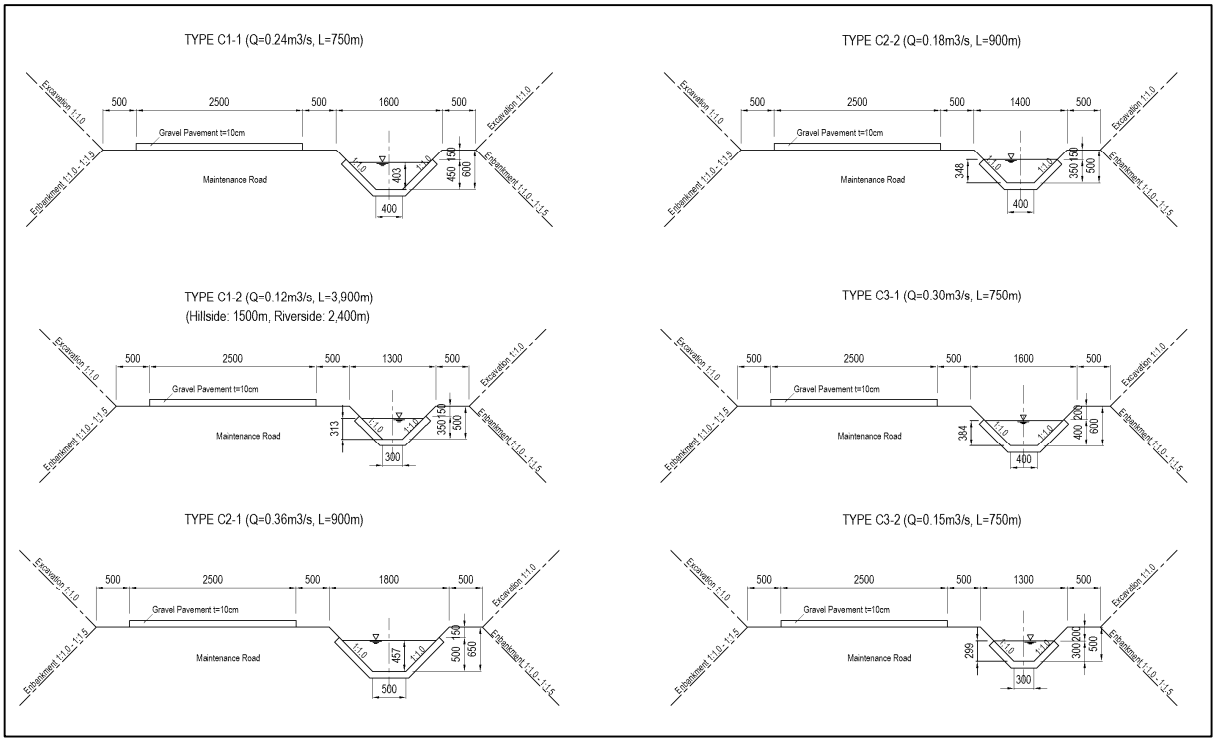



**Figure 8.3.1 Typical Cross Section of Main Canal**

## 8.4 Irrigation and Drainage System in Farmlands

### 8.4.1 Outline of Command Area

The command area is comprised of three (3) communities and the pump station is panned by each community. The terrain between riverside and Rejaf Road is flat of ground level about EL.450m, and many small irrigation farms are scattered along the river. The area of more than EL.452m is featured as undulate hillside. The land gradient shows around 2.0% toward the west from the east.

The major facilities such as the secondary canal, drainage and road are generally arranged from hillside toward riverside. The tertiary canal is planned to branch off from the secondary canal, also the feeder canal is planned to branch off from the tertiary canal for the distributing the irrigation water to the furrows. The canal is made of the earth because of a small size.

The drainage is allocated between the both secondary canals. The surplus water from tertiary canal and farm flows down to the drainage. The drainage is planned to be the earth canal.

The road used for farming and maintenance for facilities shall be planned along the secondary canal and tertiary canal. The road crossing is placed at the crossing point between the canal and road.

The length of furrow from 40m to 100m is assumed based on the soil survey results conducted in command area and Table 8.4.1 shown below. That survey results that the soil classification is mainly sandy loam or loam.

**Table 8.4.1 Example of Maximum Furrow Length of Different Soil**

| Soil | Root zone depth (m) | One-time irrigation volume (mm) | Maximum furrow length (m) |
|---|---|---|---|
| Sandy soil | 40 | 16 | 4 |
| Volcanic ash soil | 40 | 44 | 29 |
| Sandy loam | 40 | 34 | 36 |
| Loam | 40 | 38 | 99 |
| Clay | 40 | 44 | 121 |

Note: Furrow inclination is 10%
Source: Engineering Manual for Irrigation & Drainage, Upland Irrigation (1990), the Japanese Institute of Irrigation and Drainage

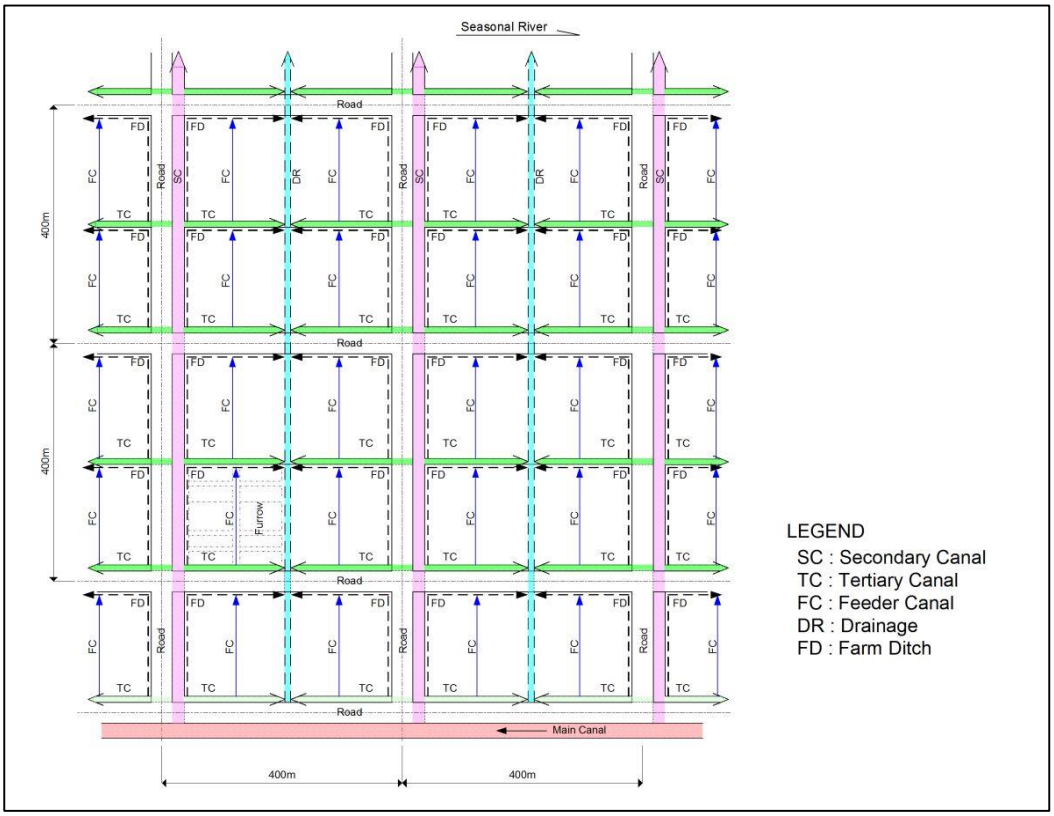



**Figure 8.4.1 Layout of Irrigation and Drainage Facilities in Command Area**

## 8.4.2 Design Discharge of Canal and Drainage

### (1) Irrigation canal

Unit water requirement was estimated at 1.43 l/s/ha, depending on the calculation of water requirement.

- Secondary canal: Q= 0.12$m^3$/s (=0.00143×averagely 80ha)
- Tertiary canal and Feeder canal: Q= 0.023$m^3$/s (=0.00143×16ha)

### (2) Drainage

Unit area drainage discharge was estimated at 0.045m3/s/ha, depending on the calculation of runoff discharge...

- Drainage : Q= 3.78$m^3$/s (=0.045× averagely 84ha)
- Farm ditch: Q= 0.090$m^3$/s (=0.045×averagely 2ha)

## 8.4.3 Examination Method of Canal Capacity

All of canals in the command area are designed of the earth canal, considering the economical reason. 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 and Farm Ditch**

| Items | | Secondary canal | Tertiary canal | Feeder canal | Farm ditch |
|---|---|---|---|---|---|
| Design discharge | Q ($m^3$/s) | 0.12 | 0.023 | 0.023 | 0.090 |
| Width of canal bed | B (m) | 0.30 | 0.30 | 0.30 | 0.30 |
| Water depth | d (m) | 0.270 | 0.174 | 0.092 | 0.182 |
| Bank slope | 1:N | 1.0 | 1.0 | 1.0 | 1.0 |
| Cross-sectional area of flow | A (m) | 0.154 | 0.082 | 0.036 | 0.088 |
| Wetted perimeter | P (m) | 1.064 | 0.792 | 0.560 | 0.815 |
| Hydraulic mean depth | R (m) | 0.145 | 0.104 | 0.064 | 0.108 |
| Coefficient of roughness | n | 0.025 | 0.025 | 0.025 | 0.025 |
| Canal bed slope | I (%) | 0.50 | 0.10 | 1.0 | 1.0 |
| Mean velocity | V (m/s) | 0.780 | 0.279 | 0.642 | 0.907 |
| Velocity head | hv (m) | 0.031 | 0.004 | 0.021 | 0.042 |
| Free board | Fb (m) | 0.180 | 0.126 | 0.203 | 0.168 |
| Height of canal | H (m) | 0.45 | 0.30 | 0.30 | 0.35 |

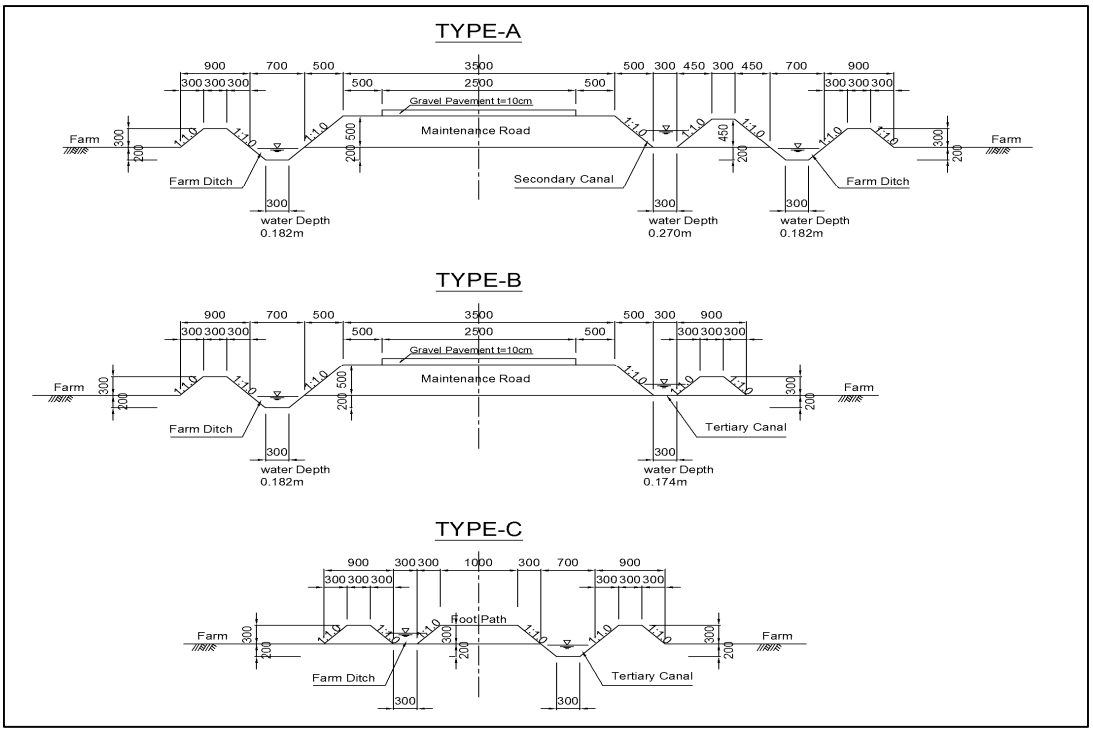



**Figure 8.4.2 Typical Cross Section of Irrigation and Drainage Facilities in Command Area**

### 8.4.4 Relative Structures

In general the relative structures such as diversion gate, drop, water measurement facilities, cross culvert and siphon etc. are required in the canal system if necessary. They shall be designed considered the canal system and the terrain around canal in the future design stage.

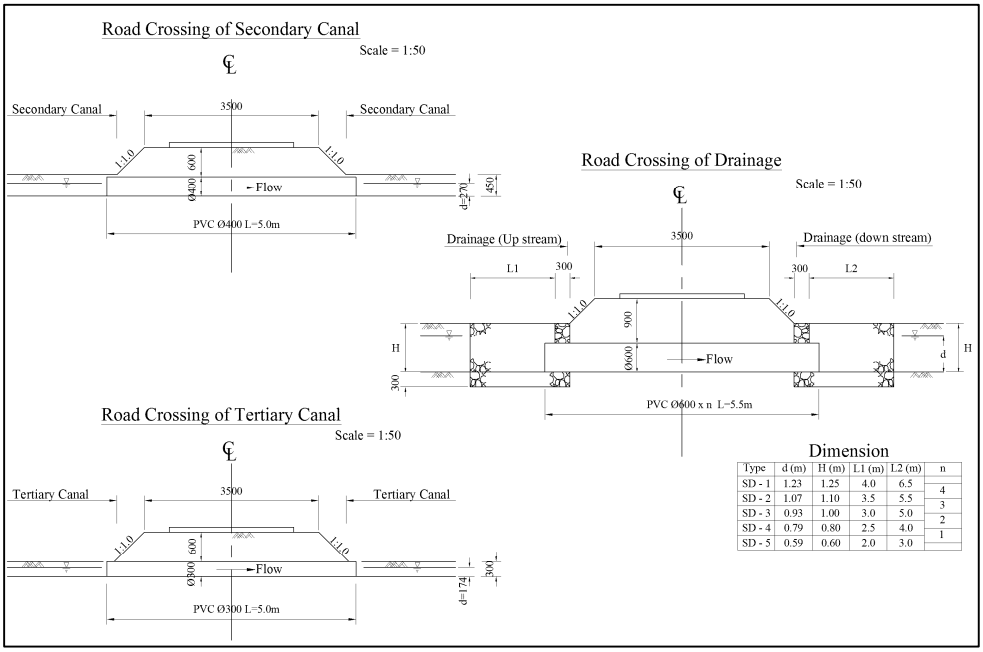



**Figure 8.4.3 Typical Cross Section of Road Crossing in Command Area**

### 8.4.5 Recommendation

#### (1) Investigation for intake rate

In the future design stage, more investigation is required to carry out the design of upland. For example, the intake rate is very important factor to make a plan of irrigation system. The intake rate is the rate for irrigation water or rainwater infiltration into soil under the specific conditions, and generally measurement in term of mm/hr. As an index of water permeability in unsaturated soil, it is an important factor to be considered in deciding the irrigation method and the appropriate irrigation intensity for upland irrigation. The intake rate is measured either by the cylinder intake rate or by the furrow intake rate, depending on the purpose of the measurement. For furrow irrigation, the intake rate is measured by the furrow intake rate.

#### (2) Drainage arrangement plan

It is necessary to investigate and survey the existing drainage routes and system in the site through the interview to the villagers and the site investigation, before planning the drainage arrangement. After that, the irrigation canal arrangement would be planned on the map.

# 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.

Irrigation method in Jebel Lado and Rejaf East is pump irrigation. Pump irrigation scheme also required a senior pump engineer to maintain its operational function properly. Under the senior pump engineer, several support specialists are required in accordance with scale of the scheme. For example, assignment of electric engineer and service technician are necessary. Following table shows ideal management structure of pump irrigation scheme.

**Table 9.1.1 Management Structure of Rejaf East Irrigation Scheme**

| Department | Functions and Responsibilities | Required Staff | Proposed No. |
|---|---|---|---|
| 1. Admin. | • Overall management of the scheme<br>• Coordination among stakeholders | Manager (Irrigation/Dam Eng.) | 1 |
| | | Deputy Manager (Electromechanical Eng.) | 1 |
| | • Marketing<br>• Procurement<br>• Assets tracking<br>• Keeping books of accounts for scheme operations<br>• Irrigation fee collection<br>• 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.<br>• Maintenance of dam/pump facilities, distribution network, etc.<br>• Hydromet data recording, monitoring and reporting | Senior Irri./Dam Eng. (Dams, Pumps, Canals, etc) | 1 |
| | | Electromechanical Eng. | 1 |
| | | Planning and Bugeting Officer | 1 |
| | | Asst. Irrigation/Dam Eng. | 1 |
| | | Asst. Planning/Budgeting Officer | 1 |
| | • Opening, closure and maintenance of water control and distribution gates<br>• Supervision of canals maintenance<br>• Safeguarding of supplies and the facilities | Irrigation Technician | 2 |
| | | Pump operator | 2 |
| | | Irrigation Water Controller (Gate Keeper) | 2 |
| | | Facilities' Guards | 4 |
| 3. Farm Level O&M | • Seed multiplication, observation trials for new rice varieties<br>• Annual planning and monitoring of cropping plan and water requirement<br>• Extension of irrigated agriculture<br>• On-farm water management planning and supervision | Senior Agronomist | 1 |
| | | Agronomist | 1 |
| | | Agricultural Engineer | 1 |
| | | Asst. Agricultural Engineer | 1 |
| | • Provision of outreach services to farmers<br>• On-farm water management among farmers<br>• 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<br>• Storing rice with proper pesticide control | Rice mill operator | 0 |
| | | Asst. Rice mill operator | 0 |
| Total | | | 37 |

For operation and maintenance purpose, following equipment and machineries are needed.

**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<br>· Amphibious excavator, Backhoe, Bulldozer, Dump track |
| 3. Agricultural Extension | · PC for planning and data management purpose<br>· Motorbike for extension purpose (2) |
| 4. Farm Operation | · Tractor (5), Harvester (3) |
| 5. O&M | · Working machines (Lathe Machine, Welding Machine, Power Drill, Power Saw, Generator, Portable Generator, etc.) |

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 Central Equatoria 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)<br>· Based on the report from SMO, taking necessary measure to repair or rehabilitate the irrigation system (MEDIWR)<br>· Assign relevant officials to SMO (MEDIWR, MAFCRD) |
| 2. Central Equatoria State Juba County, Rejaf Payam Office | · Assign relevant officials to SMO<br>· Supervising and support SMOs activities<br>· Coordination among and mobilization of communities |
| 3. Rejaf East Irrigation Scheme Management Office (SMO) | · Coordinate and facilitate the formation and activities of WUA<br>· O&M of main irrigation facilities (pump station, main and secondary canal, intake gate until on-farm)<br>· Provision of tractor service<br>· Provision of seeds and other inputs if any<br>· Collection of irrigation service fee and tractor service fee |
| 4. WUA | · On-farm level operation and maintenance<br>· Payment of irrigation service fee<br>· Selling of products |

## 9.2 Operation Plan

### (1) 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.

### (2) 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 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 and develop pump 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[1].

- 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

[1] SEAGA Sector Guideline, FAO, 1998

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 tailend 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 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 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 Rejaf East 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 |
|---|---|
| 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 |

**(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 Rejaf East 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<br>- cleaning silt at flow measuring devices<br>- removal of floating debris<br>- minor repair of canal and structures<br>- greasing or oiling of bearing, gates, and other metal structures | - On-farm: WUA/Community<br>- Main facilities: Scheme Management Office |
| Periodical Maintenance | Works to be done at a certain interval. | - strengthening of banks and structures<br>- Removal solid deposition & silt<br>- grass cutting of embankment & canal banks<br>- repair of damaged structures /a<br>- repair of damaged equipment /b<br>- painting of structures<br>- checking of tightness of bolts, nuts, inside valves, & accessories at pump station | - On-farm: WUA/Community<br>- 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<br>- On-farm: WUA/Community |

Note: a/ Diagnosis of damaged structures (e.g. gate) 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 Rejaf East 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 | 626,472 |
| Pump Operation | 4,100,600 |
| Equipment and Machineries (fuel, lubricant, etc.) | 89,500 |
| Normal Maintenance Cost of Irrigation Facilities | 73,200 |
| Depreciation Cost /a | |
| Project Facilities | 3,168,100 |
| Equipment and Machineries | 640,200 |
| Total Costs | 8,698,072 |

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 Rejaf East 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 the 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 Rejaf East Irrigation Scheme. Following table shows estimated ATP of the scheme.

**Table 9.4.2 Annual O&M Cost**

| Planned Crops /a | Net Income /b (SSP/ha) | Affordability Rate (%) | ATP (SSP/ha) | ATP (SSP/feddan) |
|---|---|---|---|---|
| Maize | 4,699 | 3 % | 140 | 60 |
| Vegetables | 265,470 | 3 % | 7,960 | 3,340 |
| Groundnuts | 4,466 | 3 % | 130 | 50 |

Note: a/ Vegetable is represented by tomato.
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 for ISF estimation. 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 are excluded from the fixed charge estimation since 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.
- As for the variable part, in this analysis, it includes personnel expenses, pump operation fee, equipment and machinery operation costs, and normal maintenance cost of irrigation facilities. This part was divided by proportion of water consumption volume of each crop, and then divided by planted area of each crop, so that ISF rate of each crop can be obtained.
- Minimum farm lot size is set as 1 acre.

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

Fixed Charge (Member Fee) = Dem ÷ Nl

Where: Dem = Depreciation cost of equipment and machineries

Nl = Number of farming lot

$$\text{Variable Charge } (ISF_{C1}) = O\&M \times \frac{VC1}{\Sigma VC1_{\sim 3}} \div A_{C1}$$

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. However, since ATPs of maize and groundnuts are too low, ISFs of these crops are further adjusted to provide incentive to shift cash crop production. 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 Rejaf East 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) |
| Maize | 2,381 | 140 | 140 | 695 | 17 days |
| Vegetables | 4,524 | 7,960 | 4,524 | | |
| Groundnuts | 3,571 | 130 | 130 | | |

**(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 SSP236/acre in the Rejaf East Irrigation Scheme, which could be converted to 12 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 pump station, canals, and on-farm structures.

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

- Revenue includes ISF, membersô fee and tractor service fee, whereas expenditure includes annual O&M cost and depreciation of equipment, machineries and the project facilities.
- 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.

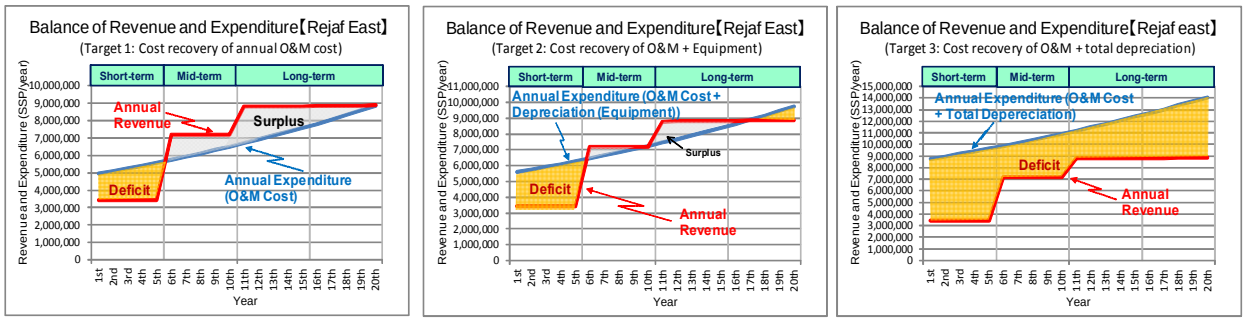



**Figure 9.4.1 Balance of Revenue and Expenditure**

- As 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. However, under the condition, even the target 1 cannot be achieved due to mainly high O&M cost particularly pump operation cost. To achieve the target 1, it is necessary to increase ISF collection rate, including 70% in the short-term, 80% in the mid-term and 100% in the long-term. In addition, in the long-term, ATP have to be increased to 8% to achieve cost recovery target of the target 1.

- 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 invents.

- 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 Rejaf East 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 farmersô financial 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 suitable 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 6th year. Accumulated amount of the surplus will be 5,425 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. 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 | Labour, 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 Rejaf East is shown in Table 10.2.1.

Out of the total project cost, 44% for pump station and facilities in farmlands direct construction cost occupies large part of the total cost.

**Table 10.2.1 Project Cost**

| No. | Work Description | Unit | Quantity | Price (million US$) | Rate (%) |
|---|---|---|---|---|---|
| 1. | Direct Construction Cost | | | | |
| 1-1 | Pump Station | L.S. | 1 | 4.4 | 19.1 |
| 1-2 | Pipeline Work | L.S. | 1 | 2.5 | 10.9 |
| 1-3 | Main Irrigation Canal | L.S. | 1 | 1.4 | 6.1 |
| 1-4 | Facilities in Farmlands | L.S. | 1 | 5.7 | 24.8 |
| | Sub-total (A) | | | 14.0 | 60.9 |
| 2. | Overhead (B=A*45%) | L.S. | 1 | 6.3 | 27.4 |
| | C=A+B | L.S. | 1 | 20.3 | 88.3 |
| 3. | Administration (D=C*4%) | L.S. | 1 | 0.7 | 3.1 |
| 4. | Consultant Fee (E=C*5%) | L.S. | 1 | 1.0 | 4.3 |
| 5. | Physical Contingency (F=C*5%) | L.S. | 1 | 1.0 | 4.3 |
| | Total | | | 23.0 | 100.0 |
| | Command Area A=960ha | | | 24,000 US$/ha | |

# CHAPTER 11 IMPLEMENTATION PLAN

## 11.1 Conditions of Construction

### (1) Rainfall

Rainy season in Rejaf East seems to be from April to October in general. The earthworks are strongly influenced by rainfall. Therefore, the construction at the site might be intermitted in the vicinity of July.

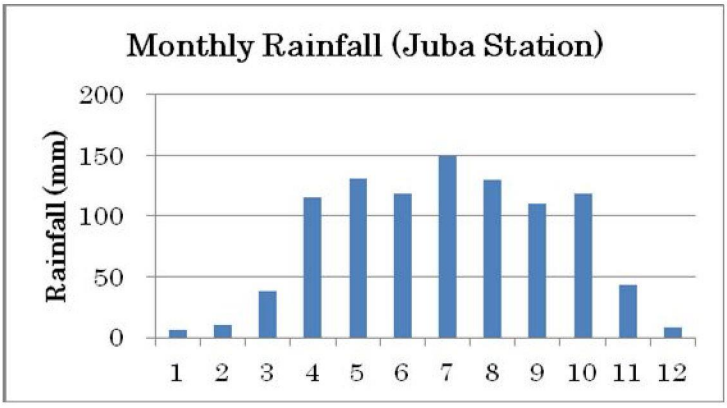



**Figure 11.1.1 Monthly Rainfall (Juba Station)**

### (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 to 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 should be achieved by 3rd year, considering their high priority and the earlier effective benefit.

**Table 11.2.1 Implementation Schedule**

| Work Description | Project Cost | Quantity | Year | | |
|---|---|---|---|---|---|
| | | | 1st | 2nd | 3rd |
| Pump Station | 7.2 | Investigation, Detail Design, Procurement: Pump etc. Construction (4 stations) | | | |
| Pipeline | 4.0 | Investigation, Detail Design, Procurement: Steel Pipe SPϕ700/ϕ500, L=5.15km | | | |
| Main Irrigation Canal | 2.3 | Investigation, Detail Design, Main Canal L=7.95km | | | |
| Facilities in Farmlands | 9.5 | Investigation, Detail Design, Canal & Drainage A=960ha | | | |
| total | 23.0 | (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 preliminarily taken for one of the priority projects in Rejaf East 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<br>Local communities<br>State / County government<br><br>Ministry of Wildlife Conservation and Tourism, Wildlife officials | Community profile, local economy, wildlife, flood records<br>Current plan, program, project, etc., flood records, wildlife<br>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 project was evaluated compared with ñzero optionò. Evaluation was judged through scoring method on each following evaluation item.

**Table 12.3.1 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 the table below (details are given in Appendix 5):

**Table 12.3.2 Summary of Scoring and Ranking**

| Evaluation Items | Alternative A | Zero Option |
|---|---|---|
| Natural Environment | 2.7 | 3.0 |
| Social Environment | 2.3 | 3.0 |
| Economy, development | 4.5 | 3.0 |
| **Total Score** | **9.5** | **9.0** |
| **Rank** | **1** | **2** |

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 project site is located in the peri-urban of Juba city, therefore land use potential is high. This area is attractive for investment and land development for housing, commercial zone, possible future industrial development, etc.

**2) Proposed project**

Components of the alternative A are pump station, canal and pipeline, and command area. The proposed command area occupies large land, approximately 1,220 ha. Major impacts will be caused by land occupation. Certain community houses, social facilities exist along the road passing north to south. Some of areas in / around the project site have been invested by private sectors. Those complicated situation can raise conflict among communities and private sectors.

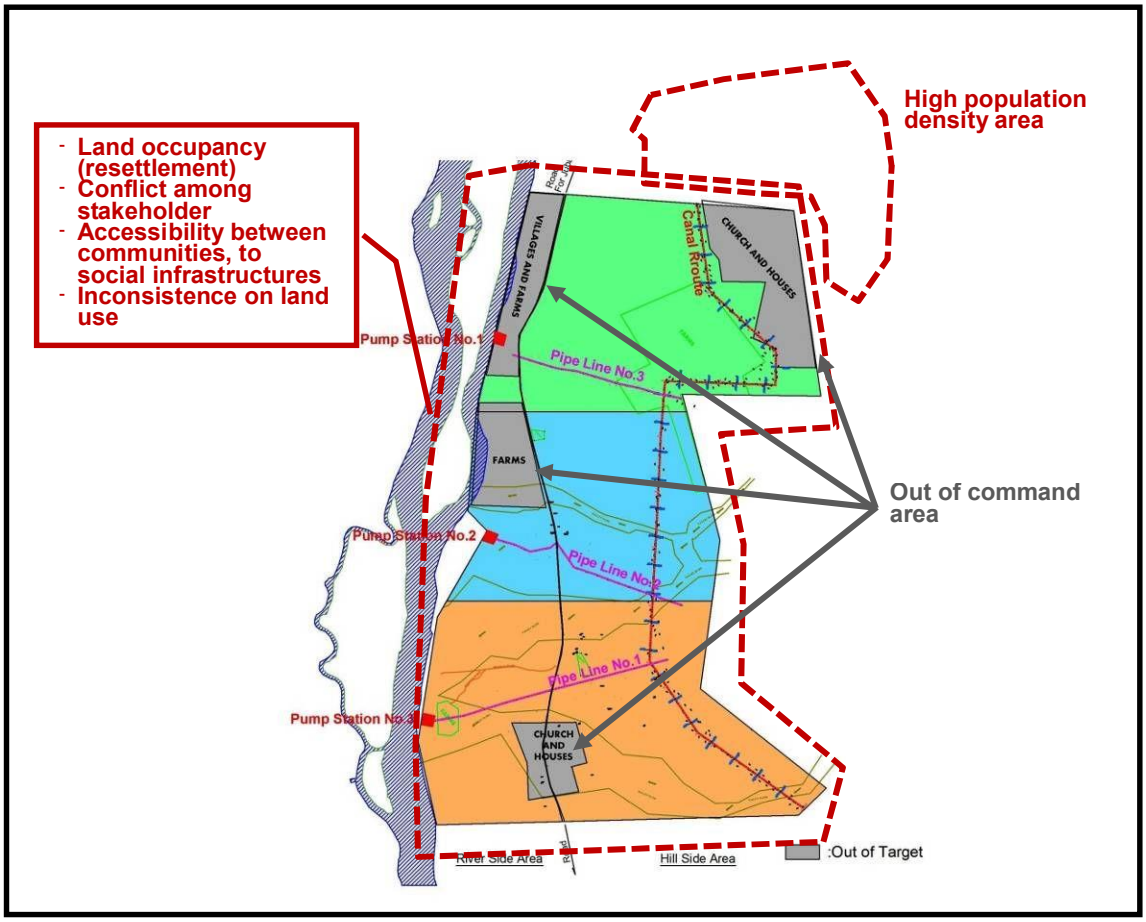
However there is large potential to generate cash income by the project because the project site is located adjacent Juba city. On the other hand, the project can increase agricultural land, and encourage agricultural production.

**3) Results**

Based on the above evaluation, the proposed project is suggestible. Demand on increasing of agricultural production, which contributes to economic development, is quite attractive in spite of complicated land hold condition. For smooth implementation of the project, sufficient consensus building among stakeholder is important.

## 12.4 Current Environmental and Social Aspects

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

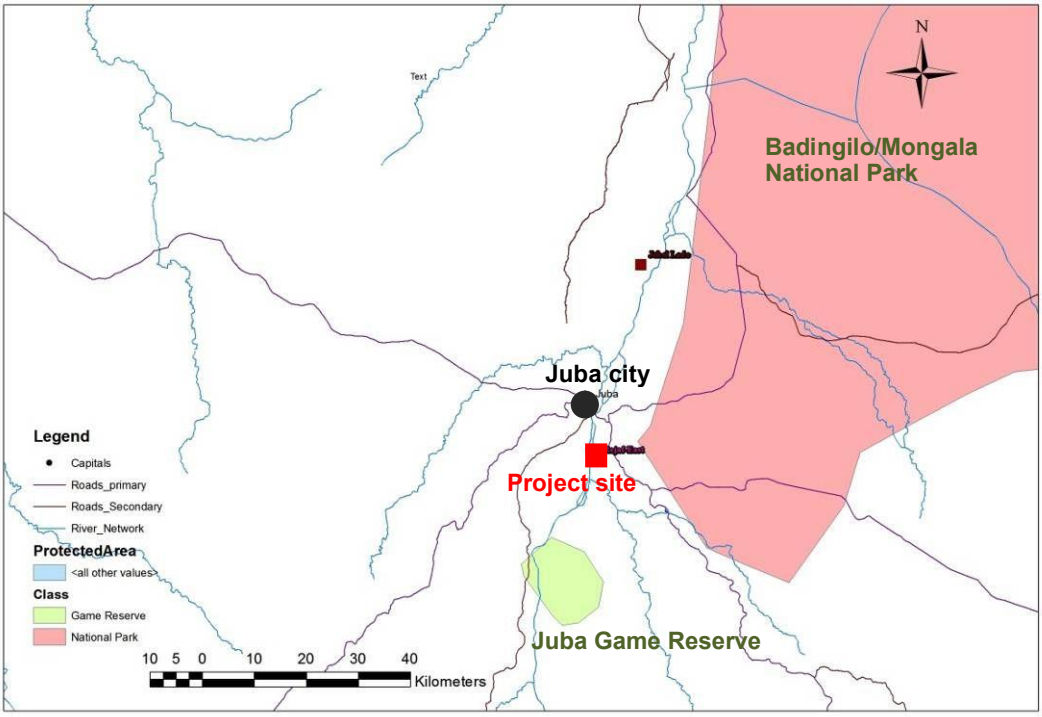



Source: IDMP-TT

**Figure 12.4.1 Overview of Possible Impacts**

### (1) Natural environmental aspects

The project site, as shown in Figure 12.4.2, is located close to Badingilo / Mongala National Park and near Juba Game Reserve. Yet details study about wildlife habitats, feeding sites, migration corridors, etc. has not been taken, critical areas for wildlife conservation is not expected because the project site is located in peri-urban of Juba city, and population dense area exists eastern-north side of the project site.




Source: Ministry of Environment

**Figure 12.4.2 Location of Designated Areas for Wildlife Conservation**

The project site is only less than 10 km far from Juba city. The proposed command area is located from right bank of the White Nile River toward the hillside of around 2 km distance. The terrain between riverside and Rejaf Road is flat. Land cover characterizes bushes, grassland and tree plantation dominated.

Water flow of the White Nile River is estimated 37,210 MCM/year, and annual rainfall is around 1,000 mm. It is, therefore, concluded that plenty of water can be used for irrigation. Amount of pumped water is quite small compared with the river flow. On the other hand, kinds of tracks of stream were observed as shown in Figure 12.4.3.

According to the communities, rain water flushes along the seasonal streams in rainy season. Design of command area, land levelling work, and drainage network and flood control as well must be considered to avoid stagnation of water flow.

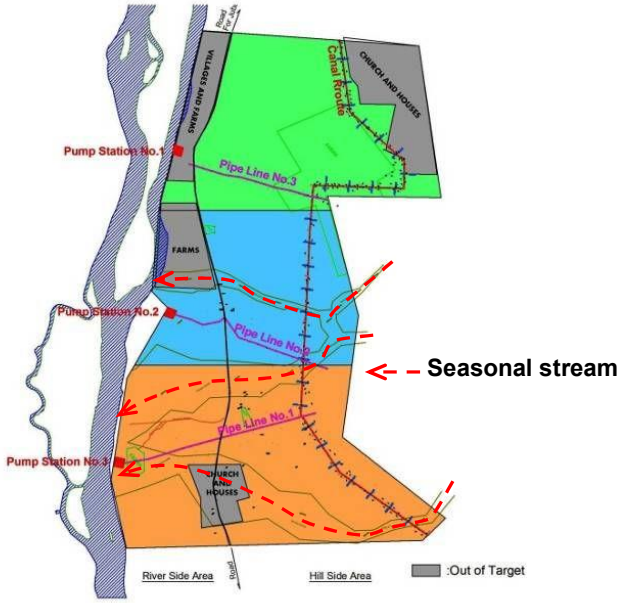



**Figure 12.4.3 Tracks of Seasonal Stream**

**(2) Social environmental aspects**

The project site is located close to Juba city, high demand on food supply is expected due to its large population. Certain private agricultural development have been implemented or planned in / around project site according to the communities. Chinese farmland has been operated near northern side of the project site. Rejaf East is expected to raise a potential on investment for not only

agriculture but also housing, commercial zone, etc. Consistency and harmonization with those plans will be key issue for project implementation.

The project site is tenured under three communities, namely Guduge, Migiri and Mogoro. Dominant livelihood of those communities is farming and fishery, but certain people work in Juba for side businesses.

Community has experienced irrigated agriculture, and small scale of pump irrigation facilities exist along the White Nile River. It, therefore, is expected for the community to easily adopt a new irrigation system introduced by the project.

Small scale of farmlands and residential areas are dotted in the terrain between right bank of the river and the Rejaf Road. A church is built in the southern part belonging to Mugoro Community, certain dense area and buildings are observed around the church. A school is under re-construction. According to the communities, they were caught in battles under the past civil war. Therefore many grave yards are scattered in the project site.

Floods occurred near the river bank, but have rarely spread in the proposed command area. No historical / cultural heritage was confirmed, while certain number of trees and stones, which are for traditional ceremonies, are scattered.

School

Community house

Grave yard

Tree for traditional

Source: The IDMP -RSS

**Figure 12.4.4 Facilities in the Project Site**

## 12.5 Evaluation of the Impact

### (1) Overall evaluation

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

(1) Land possession, resettlement (negative impact);
(2) Living and livelihood (negative / positive impact);
(3) Local economy (positive impact);

(4) Land use (negative impact), and
(3) Local conflict (negative impact).

The most considerable impacts will be caused by land possession. The project site is tenured under the three communities; however some of areas are invested by private sectors. There are many community farmland dotted in the western side and along Rejaf Road, private as well as public farmlands (called ñprison farmò) are also operated. Considerable number of land owner ship is issued without documented records. Due to close location from Juba city, land potential is quite high, it was informed that private housing had been progressed. It is possible to raise demand of land development because of close location to Juba city. Those situations cause complicated land holding. Careful consideration, therefore, is important.

It is expected to raise agricultural production by the project which can benefit to the communities. Also demand on construction materials, tools / equipment, job opportunity may give positive impacts to the communities in terms of improvement of living condition and livelihood. On the other hand, existing agricultural activities as well as community houses, social infrastructures, etc. must be obstructed by the project construction works. It can lead decrease of their income and raise conflict among communities and other vested interests. Proper compensation plan as well as resettlement plan will be required.

Most of the communities are farmer with side jobs, so decree of benefits may vary depending how much they concentrate with farming. Therefore fair allocation of benefit and proper compensation 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 | D | -C | -B | Construction works may generate turbid water, e.g., but it can be controlled by moderate measures. Storage of oil, hazardous waste must be properly managed.<br>Use of pesticide and fertilizers need proper rules. |
| | Waste | -C | -C | -C | Construction waste will be considerable. |
| | Soil/Sediment Contamination | D | -C | -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 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 | -C | -C | +C | No proper studies have been conducted, therefore level of impacts are not identified. |

| Environmental Items | | Pre-construction | Construction | Operation | Summary of Impact |
|---|---|---|---|---|---|
| | | | | | It may be less possibility of endangered / rare species because the site is close to high population area. |
| | Hydrology | -C | -C | D | Due to topographic feature, possible floods may expand near river side; most of the command area will be rarely affected. On the other hand, seasonal stream should not be blocked. |
| | Topography and Geology | D | D | D | No certain impacts are anticipated. |
| | Subsidence / Erosion | D | -C | D | Risk of erosion during construction phase can be controlled by proper and moderate measures. |
| | Global Warming | D | D | -C | No impact on global warming is anticipated. |
| | Landscape | D | D | D | There is no activity to affect landscape. |
| Social Environment | Resettlement | -B | -B | D | Project site is potential on population increasing and urbanization because it is adjacent to Juba city. |
| | Living and Livelihood | -B | -B | +B | Land occupancies in command area may affect existing communityes living condition, livelihood as well. While recruitment and job opportunity are 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 | -C | D | D | A church is observed in the southern area under Mugoro Community. |
| | Land Use | -C | -B | -B | Due to close location from Juba city, land use potential is high. Consistency and harmonization with land use plan / development is important to be considered. Those situations 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 | Improper allocation of project benefit, inconsistency with other development / plan can raise conflict. |
| | Water Use / Right | -C | -C | -C | Use of water newly provided by irrigation shall need a rule to mitigate conflict. |
| | Social Infrastructure / Services | -C | -C | D | Local grave yards are scattered in the project site. |
| | Infectious Diseases | D | D | D | Mosquito bleeding in water area (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. The command area occupies large land. Considerable parts of the project site have been used for community farmlands,

private farmlands as well. Residential zones have spread in the project site.

- Land holding is complicated. Therefore careful consensus building, a study to identify condition of land use and land title, and proper plans for resettlement / compensation are important.
- It is expected to improve communityôs livelihood, local economy through increase of agricultural production. On the other hand, obstruction on existing land use, agricultural works by project construction can lead social conflict. In addition, careful consideration with other further projects related to land use / land possession is important.
- 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:

- Further study in order to identify land use, location of community houses and other facilities is required.
- Existing or further planned land development, investment shall be investigated.
- Though impacts on ecosystem are expected small, this condition 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.
- Fare allocation of the project benefit among stakeholders is important. In the same manner, adequate compensation plan must be given in order to avoid social conflict.
- 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<br>- Site survey on location of possible sensitive zones against air pollution such as residential area, school zone, etc. | - Possible affected areas especially sensitive zone<br>- Selection of environmentally friendly equipment with proper maintenance |
| Water pollution | - Measure of current water quality<br>- Examine of possible pollution sources by the project | - Possible water pollution source and affected area<br>- Farming plan in terms of use of chemicals |
| Waste | - Investigation of possible disposal site for construction waste<br>- Estimation approximate waste volume | - Location of possible disposal site<br>- Types of waste<br>- Procedure / rules of storage and disposal of waste |

| Survey Items | Possible Methods | Points to be surveyed |
|---|---|---|
| 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<br>- Site survey on possible sensitive zones against noise / vibration such as residential area, school zone, etc. | - Possible affected areas especially sensitive zone<br>- Selection of environmentally friendly equipment with proper maintenance<br>- Pump operation schedule |
| Ecosystem | - Interview with local communities<br>- Direct observation on wildlife habitats, migration, etc.<br>- Trap survey | - Wild life corridor<br>- Wildlife habitats<br>- Forest, plantation, e.g. |
| Hydrology | - Historical records of floods<br>- Site reconnaissance on water body condition | - Condition of water body in rainy season<br>- Historical records of floods |
| Subsidence / erosion | - Historical records of subsidence / erosion | - Location of possible erosion site |
| Resettlement | - Survey on land use, land status, land ownership, etc.<br>- Estimation of land and asset price<br>- Public consultation for consensus building | - Number and location of houses / facilities likely to be relocated<br>- Agreement on the project<br>- Resettlement plan |
| Living and livelihood | - Investigation of community living condition and livelihood<br>- Interview with communities | - Existing land use, development plans<br>- Possible job opportunities by the project in both construction and operation phases |
| Local economy | - Investigation of local economic profile<br>- Investigation of future plans, developments, investments | - Possible materials, equipment for the project<br>- Possibility of procurement in local |
| Land use | - Survey on land use, land status, land ownership<br>- Investigation of land use plan<br>- Public consultation | - Land map describing houses, facilities, land use, etc.<br>- Existing and/or further land use plan |
| Local conflict | - Investigation of job profile, income level and sources<br>- Public consultation | - Community profile, job profile<br>- Consensus building among communities<br>- Compensation plan |
| Water use / right | - Investigation of water use / right<br>- Public consultation | - Status of water use, legal status on water right<br>- Consensus building among communities |
| Social infrastructures / services | - Site survey on location of social infrastructures<br>- Interview with local communities, etc. | - Location of infrastructure<br>- Location of grave yards<br>- Existing and/or further infrastructure development plan |

# CHAPTER 13 PROJECT EVALUATION

## 13.1 Outline of the Project Area

The irrigation development project in Jebel Lado located in CE will serve water to totaling 960 ha of target field. The project will develop the present unused land and the existing farmland into large farming fields with irrigation. The project will furnish the infrastructures to introduce a irrigated agriculture, leading to increase farming income for the farmer beneficiaries. Following are the outline of the site.

Outline of Project (Rejaf East):

| | |
|---|---|
| Location: | Just southeast of Juba City |
| Project area: | 960 ha |
| Land Holding: | Ave. 1.8 ha/household (6.0 members/household) |

## 13.2 Farming Plan

### (1) Cropping pattern

Around the site in Rejaf East, major crops are maize and sorghum, and vegetables are grown as cash crops, such as okra. The crops to be grown in the project area will be represented by maize, tomato, groundnut, jewsô mallow, okra and eggplant. In the project, the cropping intensity is expected to increase by the improvement of farming conditions, compared to the current cropping intensity. Considering the situation of existing areas, whose cropping intensity is estimated around 80 %, the intensity in the project is assumed to be 192 %.

### (2) Irrigation system

Irrigation water is taken from the Nile by pumps and transported through pipelines. The pumped water is sent to high places and will be delivered to each field by gravity.

## 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 Labor 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. | Description | Unit | Financial Price (SSP) | Conversion Factor | Economic Price (SSP) | Remarks |
|---|---|---|---|---|---|---|
| **A.** | **Agriculture Product** | | | | | |
| | - Maize | kg | 3.70 | - | 3.05 | Estimated by import parity price |
| | - Sorghum | kg | 4.20 | - | 3.44 | - do - |
| | - Cassava | kg | 5.00 | - | 3.94 | - do - |
| | - Common bean | kg | 4.60 | - | 3.89 | - do - |
| | - Groundnut | kg | 3.90 | - | 3.20 | - do - |
| | - Sesame | kg | 4.80 | - | 3.92 | - do - |
| | - Okra | kg | 9.10 | - | 7.04 | - do - |
| | - Tomato | kg | 4.30 | - | 3.41 | - do - |
| | - Jew's mallow | kg | 4.50 | 0.90 | 4.05 | |
| | - Eggplant | kg | 11.10 | - | 8.55 | Estimated by import parity price |
| | | | | | | |
| **B.** | **Farm Input** | | | | | |
| **1** | **Conventional Seed** | | | | | |
| | - Maize | kg | 11.90 | 0.90 | 10.71 | |
| | - Sorghum | kg | 7.00 | 0.90 | 6.30 | |
| | - Cassava | kg | 10.00 | 0.90 | 9.00 | |
| | - Common bean | kg | 11.00 | 0.90 | 9.90 | |
| | - Groundnut | kg | 17.50 | 0.90 | 15.75 | |
| | - Sesame | kg | 12.40 | 0.90 | 11.16 | |
| | - Okra | fed | 125.40 | 0.90 | 112.86 | |
| | | | | | | |
| **2** | **Improved Seed** | | | | | |
| | - Maize | kg | 14.00 | 0.90 | 12.60 | |
| | - Tomato | kg | 500.00 | 0.90 | 450.00 | |
| | - Groundnut | kg | 16.00 | 0.90 | 14.40 | |
| | - Jew's mallow | kg | 200.00 | 0.90 | 180.00 | |
| | - Okra | kg | 500.00 | 0.90 | 450.00 | |
| | - Eggplant | kg | 534.00 | 0.90 | 480.60 | |
| | | | | | | |
| **3** | **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 | |
| | | | | | | |
| **4** | **Agro Chemical** | | | | | |
| | - Pesticdes (insecticide) | lit | 85.00 | 0.90 | 76.50 | |
| | - Fungicide | lit | 107.00 | 0.90 | 96.30 | |
| | - Agro-chemicals, Okra | fed | 128.00 | 0.90 | 115.20 | |
| | | | | | | |
| **5** | **Labor** | | | | | |
| | - Family Labor | m*d | 50.0 | 0.45 | 22.5 | |
| | - Hired Labor | m*d | 50.0 | 0.45 | 22.5 | |
| | | | | | | |
| **6** | **Equipment** | | | | | |
| | - Tractor rental | ha | 476.19 | 0.90 | 428.57 | |
| | - Sprayer | ha | 100.00 | 0.90 | 90.00 | |
| | - Transportation | time | 22.20 | 0.90 | 19.98 | |
| | | | | | | |
| **7** | **Others** | | | | | |
| | - Sack / Box | piece | 7.50 | 0.90 | 6.75 | |
| | | | | | | |

Source: Agriculture and Socioeconomic Survey, 2015

## 13.4 Project Cost

### (1) Project cost at financial price

The project cost of Rejaf East at financial price is estimated 23 million US$ or 24 thousand US$/ha. Next table summarizes the project cost at financial price.

**Table 13.4.1 Summary of Project Cost at Financial Price**

| Item | US$/ha | Ha | Total (,000US$) |
|---|---|---|---|
| 1. Direct Construction Cost | 14,602 | 960 | 14,018 |
| 2. Indirect Construction Cost | 6,571 | | 6,308 |
| Sub-total | 21,173 | | 20,326 |
| 3. Administration (4%) | 847 | | 813 |
| 4. Consultant Fee (5%) | 1,058 | | 1,016 |
| 5. Physical Contingency (5%) | 1,058 | | 1,016 |
| Total | 24,136 | | 23,171 |

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 labor, unskilled labor, 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 was, then, estimated at 20 million US$ or 21 thousand US$ per ha. Next table shows the estimation of the project cost at economic price.

**Table 13.4.2 Estimation of Project Cost 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 | | |
| | 14,018 | CF×% | 0.600 | 0.090 | 0.090 | 0.090 | 0.000 | 0.870 | 12,196 |
| Indirect Construction Cost | | % | 60.0 | 10.0 | 20.0 | 10.0 | 0.0 | | |
| | 6,308 | CF×% | 0.600 | 0.090 | 0.090 | 0.090 | 0.000 | 0.870 | 5,488 |
| Administration | | % | 60.0 | 10.0 | 20.0 | 10.0 | 0.0 | | |
| | 813 | CF×% | 0.600 | 0.090 | 0.090 | 0.090 | 0.000 | 0.870 | 707 |
| Consultant Fee | | % | 60.0 | 35.0 | 5.0 | 0.0 | 0.0 | | |
| | 1,016 | CF×% | 0.600 | 0.315 | 0.023 | 0.000 | 0.000 | 0.938 | 953 |
| Physical Contingency | | % | 60.0 | 10.0 | 20.0 | 10.0 | 0.0 | | |
| | 1,016 | CF×% | 0.600 | 0.090 | 0.090 | 0.090 | 0.000 | 0.870 | 884 |
| Total | 23,171 | | | | | | | | **20,228** |

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 labor value), the net incremental incomes were calculated. Next table is the summary of the net incremental income. Total net incremental income was estimated at 16,076 thousand US$ or 16,746 US$/ha.

**Table 13.5.1 Summary of Net Incremental Income at Financial Price**

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

| Crop | Without Project | | | | | With Project | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area | Gross output | Production cost | Net Benefit | | Area | Gross output | Production cost | Net Benefit | | Increment | |
| | (ha) ① | (000US$) ② | (000US$) ③ | (000US$) ④=②－③ | (US$/ha) ⑤=④/① | (ha) ⑥ | (000US$) ⑦ | (000US$) ⑧ | (000US$) ⑨=⑦－⑧ | (US$/ha) ⑩=⑨/⑥ | (000US$) ⑪=⑨－④ | (US$/ha) ⑫=⑪/⑥or① |
| Maize | 34.54 | 29.07 | 82.73 | -53.66 | -1,554 | 364.80 | 1,372.64 | 1,550.71 | -178.07 | -488 | -124.41 | -341 |
| Sorghum | 11.33 | 14.26 | 33.54 | -19.28 | -1,702 | - | - | - | - | - | 19.28 | 1,702 |
| Cassava | 5.72 | 15.17 | 16.75 | -1.58 | -276 | - | - | - | - | - | 1.58 | 276 |
| Common bean | 1.98 | 1.08 | 8.79 | -7.71 | -3,896 | - | - | - | - | - | 7.71 | 3,896 |
| Groundnut | 11.00 | 11.42 | 39.19 | -27.78 | -2,525 | 163.20 | 655.90 | 768.58 | -112.68 | -690 | -84.90 | -520 |
| Sesame | 0.33 | 0.26 | 0.82 | -0.56 | -1,704 | - | - | - | - | - | 0.56 | 1,704 |
| Okra | 22.44 | 75.66 | 53.88 | 21.78 | 971 | 393.60 | 3,642.47 | 2,513.70 | 1,128.76 | 2,868 | 1,106.98 | 2,812 |
| Tomato | - | - | - | - | - | 364.80 | 5,849.17 | 2,856.57 | 2,992.60 | 8,203 | 2,992.60 | 8,203 |
| Jew's mallow | - | - | - | - | - | 163.20 | 1,127.74 | 872.12 | 255.62 | 1,566 | 255.62 | 1,566 |
| Eggplant | - | - | - | - | - | 393.60 | 14,661.93 | 2,760.67 | 11,901.26 | 30,237 | 11,901.26 | 30,237 |
| Total | 87.34 | 146.91 | 235.70 | -88.79 | -92 | 1,843.20 | 27,309.84 | 11,322.35 | 15,987.49 | 16,654 | **16,076.29** | **16,746** |

Source: IDMP-TT

### (3) Project benefits at economic price

Project benefits at financial price were converted into the ones at economic prices, using conversion factors and import party prices as it has been mentioned. For economic analysis, incremental benefit (count family labor as cost) also will be 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 at economic price. Total incremental benefit was estimated at 5,348 thousand US$ or 2,061 US$/ha.

**Table 13.5.2 Summary of Economic Incremental Benefits**

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

| Crop | Without Project | | | | | With Project | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area | Gross output | Production cost | Net Benefit | | Area | Gross output | Production cost | Net Benefit | | Increment | |
| | (ha) ① | (000US$) ② | (000US$) ③ | (000US$) ④=②－③ | (US$/ha) ⑤=④/① | (ha) ⑥ | (000US$) ⑦ | (000US$) ⑧ | (000US$) ⑨=⑦－⑧ | (US$/ha) ⑩=⑨/⑥ | (000US$) ⑪=⑨－④ | (US$/ha) ⑫=⑪/⑥or① |
| Maize | 34.54 | 23.96 | 28.44 | -4.48 | -130 | 364.80 | 1,131.50 | 849.55 | 281.95 | 773 | 286.43 | 785 |
| Sorghum | 11.33 | 11.68 | 11.17 | 0.51 | 45 | - | - | - | - | - | -0.51 | -45 |
| Cassava | 5.72 | 11.96 | 5.95 | 6.01 | 1,050 | - | - | - | - | - | -6.01 | -1,050 |
| Common bean | 1.98 | 0.91 | 2.90 | -1.99 | -1,003 | - | - | - | - | - | 1.99 | 1,003 |
| Groundnut | 11.00 | 9.37 | 13.70 | -4.33 | -394 | 163.20 | 538.17 | 412.04 | 126.13 | 773 | 130.47 | 799 |
| Sesame | 0.33 | 0.21 | 0.28 | -0.07 | -218 | - | - | - | - | - | 0.07 | 218 |
| Okra | 22.44 | 58.53 | 20.79 | 37.75 | 1,682 | 393.60 | 2,817.91 | 1,541.04 | 1,276.87 | 3,244 | 1,239.12 | 3,148 |
| Tomato | - | - | - | - | - | 364.80 | 4,638.52 | 1,618.72 | 3,019.80 | 8,278 | 3,019.80 | 8,278 |
| Jew's mallow | - | - | - | - | - | 163.20 | 1,014.97 | 523.77 | 491.19 | 3,010 | 491.19 | 3,010 |
| Eggplant | - | - | - | - | - | 393.60 | 11,293.65 | 1,849.25 | 9,444.40 | 23,995 | 9,444.40 | 23,995 |
| Total | 87.34 | 116.62 | 83.22 | 33.40 | 35 | 1,843.20 | 21,434.72 | 6,794.38 | 14,640.34 | 15,250 | **14,606.94** | **15,216** |

Source: IDMP-TT

## 13.6 Project Evaluation

### (1) Cash flows of cost and benefit

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 1,511 thousand US$/year.

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 60 %, 70 %, 80 % and 90 % of the full benefit will be achieved in the first, the second, the third and the fourth year respectively.

### (2) Financial analysis

With the costs and benefits at financial price, here we apply financial internal rate of return (FIRR) and financial net present value (FNPV) and cost-benefit ratio (B/C) for examining the efficiency of the investment. To estimate FNPV, 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 and FNPV and B/C are calculated at 36.8 %, 85,454 thousand US$ and 2.92 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 was calculated at 38.0 %. 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 94,807 thousand US$. The B/C discounted at 7.5 % was 3.18.

# CHAPTER 14 CONCLUSION AND RECOMMENDATIONS

Project evaluation shows that the project is economically feasible and also financially viable. In terms of the selection of crops, the most profitable crop among the planned crops is eggplant. It seems that eggplant cultivation has high demand in the market and can take high yield as well as tomato. However, the farmerôs selling price per kg of eggplant is more than double of tomato. Tomato is also considered to be a good introducing crop though it is not so high profit, compared to eggplant.

Beneficiary farmers in Rejaf East can bring their produce easily to market in Juba: however, there is hard competition with imports from neighboring countries. Staple and quasi-staple crops, such as maize, groundnut, etc., are not proper crops in agriculture in suburban areas since they can be produced in other wider areas more efficiently and conveyed to town markets. But small amount of those production are necessary for self/ community consumption.

# APPENDIX - 1

# FACILITY PLAN AND DESIGN

# CHAPTER 1 GENERAL

## 1.1 Outline of Main Facilities

Main facilities planed in Rejaf East shemea are as follows,

- Command area: A=960ha
- Pump station: 4 place
- Main Irrigation Canal: riverside L= 2.4km, hillside L=5.6km
- Irrigation and Drainage Facilities iin command area: 1 L.S

  Secondary canal, Tertiary canal, Feeder canal, Drainage, Road, Road crossing,

  Distribution gate, Water measurement facilities, etc.

Pump station is planned by each community because of the difficulty of consensus among three (3) communities. Pump facility are operated through the year for farming, withdrawing from Bahr el Jebel.

## 1.2 Command Area

Command area is located from the right bank of Bahr el Jebel toward the hillside of almost 2km distance. The terrain between riverside and Rajaf Road is flat of ground level about EL.450m, and many small irrigation farms are scattered along the river. The area of more EL.452m is featured as undulate hillside. The land gradient shows around 2.0% toward the west from the east.

Also the terrain of hillside is complicated, and many bushes, trees and grasses dominate in the site. Pump station site has some big trees. In the pipe line and canal line, the conditions are almost same as the command area.

Pump station site is located beside Bahr el Jebel. The land is almost bare and some trees are shown. In the pipe line and canal line, there are community road among some small communities, bushes and trees etc. along the line.

In addition, on the route of the pipeline No.1, the additional pump station called No.1-H is planned near the Rajaf road to convey the irrigation water to the hillside farms in the view of the reduce the total head of pump and the economic efficiency.

- To reduce the total head of pump contributes to save the engine power,
- To reduce the discharge in the pipeline contributes to make the pipe diameter to small size, and
- To raise the economic efficiency due to the above matters.

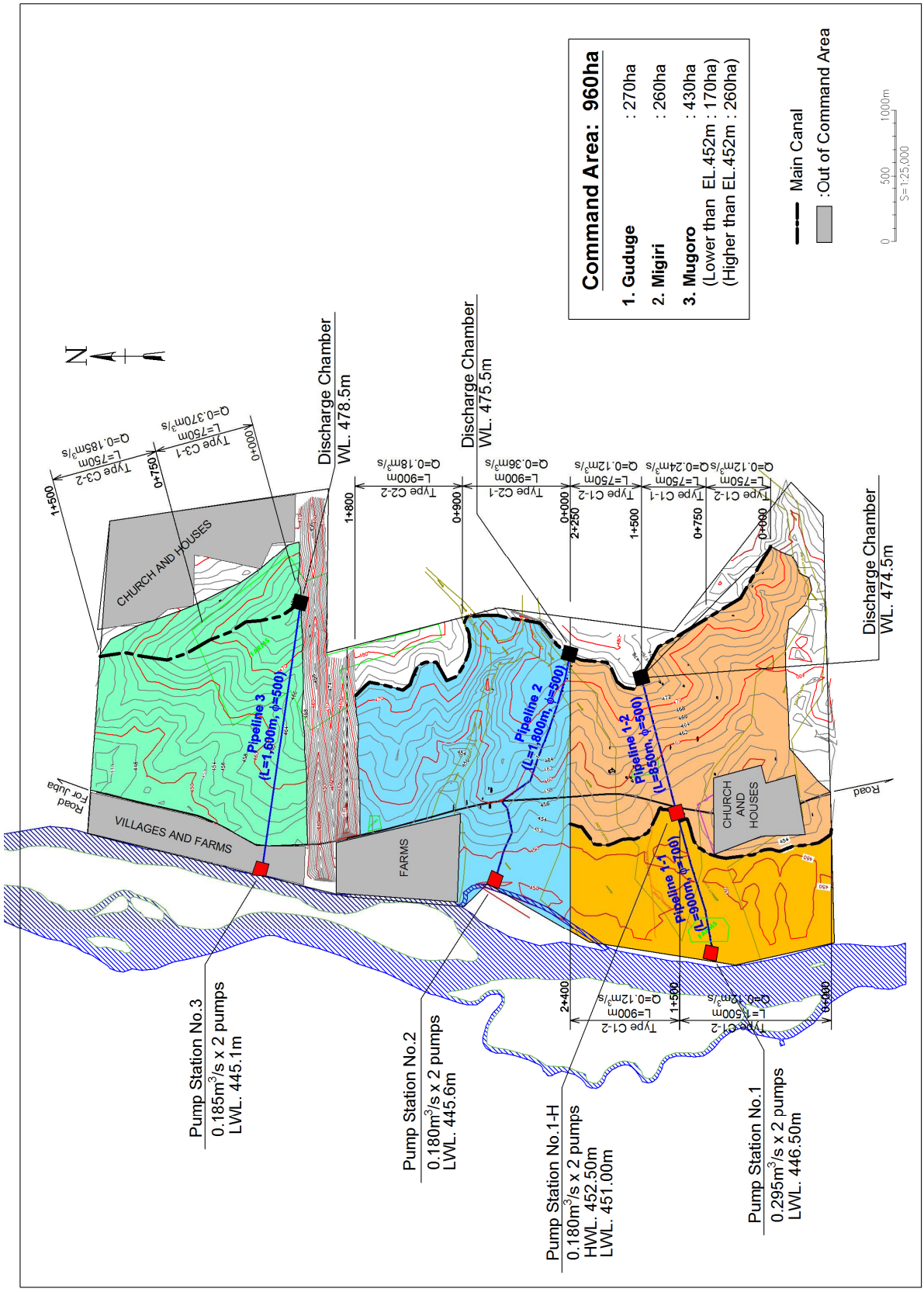



**Figure 1.1.1 Scheme Layout**

# CHAPTER 2 PUMP STATION

## 2.1 Location and River Water Level

### (1) River Water Level

The pump stations are located at the right of Bahr el Jebel. The water level measured in the survey work at the pump station on 3rd June 2015 is shown in the Table 2.1.1 and Figure 2.1.1. According to the water level record at Juba gauge station which is comparatively near to the pump station, the range of water level fluctuation is observed among 2.04m water depth as shown in the Figure 2.1.2.

Low Water Level (LWL) required in pump design of Bahr el Jebel is assumed at the about 0.5m lower down the river observed water level, and High Water Level (HWL) also assumed at the plus 2.0m with LWL.

**Table 2.1.1 Water Level of Bahr el Jebel at Pump Station locationl**

| Pump Station Number | River Water Level Observed (WL.m) | Design Low Water Level (LWL.m) | Design High Water Level (HWL.m) |
|---|---|---|---|
| No.1 | 446.96 | 446.50 | 448.50 |
| No.2 | 446.06 | 445.60 | 447.60 |
| No.3 | 445.59 | 445.10 | 447.10 |

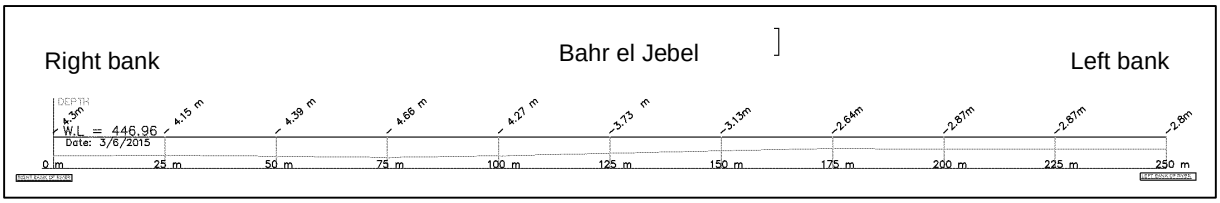



**Figure 2.1.1 River Cross Section at Pump Station No.1**

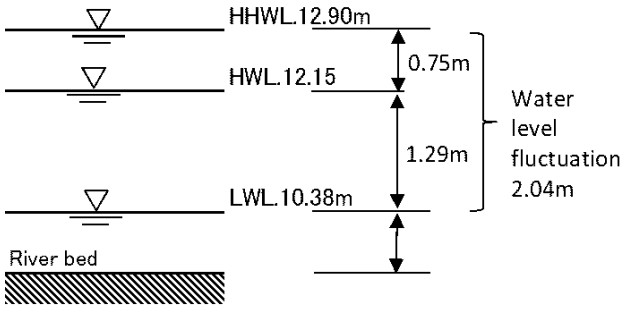
### (2) Pump Station at Hillside

Pump station No.1 is planned to irrigate the low riverside farms and convey the irrigation water to the hillside farms. In particular on the route of the pipeline No.1, the additional pump station called No.1-H is planned near the Rajaf road to convey the irrigation water to the hillside farms in the view of the reduce the total head of pump and the economic efficiency.

- To reduce the total head of pump contributes to save the engine power,
- To reduce the discharge in the pipeline contributes to make the pipe diameter to small size, and
- To raise the economic efficiency due to the above matters.

**Juba Gage Station:**

| No. | Year | Depth Annual Min. (LWL.m) | Depth Annual Max. (HWL.m) | Remarks |
|---|---|---|---|---|
| 1 | 2007 | 11.00 | 12.90 | 1st (HHWL) |
| 2 | 2008 | 11.26 | 12.46 | |
| 3 | 2009 | 10.91 | 11.34 | |
| 4 | 2010 | 10.89 | 11.59 | |
| 5 | 2011 | 10.24 | 12.44 | |
| | Mean | **10.86** | **12.15** | **difference 1.29 m** |




**Juba (2011) Monthly Water Lebel**

| Month | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Water Lebel | 11.24 | 11.11 | 10.49 | 10.89 | 10.99 | 10.91 | 10.97 | 11.33 | 11.59 | 11.55 | 11.93 | 11.53 |

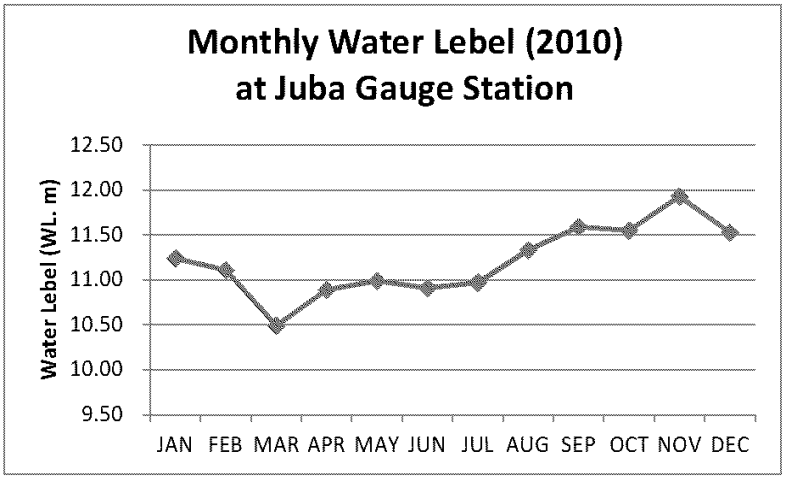



**Figure 2.1.2 Juba Gauge Station**

## 2.2 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.

As for the discharge control by pumps, the most simple, common and effective manner by the numbers of pumps run shall be employed. The manner has been practiced for a considerable period with which much fluctuating monthly water demands can be managed by adjusting the operation hours of pumps in addition to the control on the number of units run. In this case, the more the number of pumps, with higher efficiency the pumps can be operated to meet the fluctuating demands. However, this is not always the effective case due to the larger requirement of land space for the station and further causing more complicated piping works leading to higher construction cost as well as land acquisition cost.

Therefore the two (2) same capacity pumps are planned to provide at the site. According to the ñDesign Pump Facilities Technical Document (Japan)ò, the pump diameter ( $\phi$ ) is determined as follows based on the pump capacity.

Pump station No.1: 0.295$m^3$/s (unit capacity) × 2 set = 0.59 $m^3$/s, $\phi$ 350mm
Pump station No.1-H: 0.180$m^3$/s (unit capacity) × 2 set = 0.36 $m^3$/s, $\phi$ 300mm
Pump station No.2: 0.180$m^3$/s (unit capacity) × 2 set = 0.36 $m^3$/s, $\phi$ 300mm
Pump station No.3: 0.185$m^3$/s (unit capacity) × 2 set = 0.37 $m^3$/s, $\phi$ 300mm

**Table 2.2.1 Water Requirement ($m^3$/s)**

| Pump Station Number | Farm Area (ha) | Plannting Ratio | Irrigable Area (ha) | Water Requirement (m3/s) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
| Station No.1 | 170 | 0.96 | 163 | 0.49 | 0.28 | 0.11 | 0.26 | 0.30 | 0.36 | 0.33 | 0.13 | 0.00 | 0.19 | 0.49 | 0.59 |
| Station No.1-H | 260 | 0.96 | 250 | 0.30 | 0.17 | 0.06 | 0.16 | 0.18 | 0.22 | 0.20 | 0.08 | 0.00 | 0.12 | 0.30 | 0.36 |
| Station No.2 | 260 | 0.96 | 250 | 0.30 | 0.17 | 0.06 | 0.16 | 0.18 | 0.22 | 0.20 | 0.08 | 0.00 | 0.12 | 0.30 | 0.36 |
| Station No.3 | 270 | 0.96 | 259 | 0.31 | 0.17 | 0.07 | 0.17 | 0.19 | 0.23 | 0.21 | 0.08 | 0.00 | 0.12 | 0.31 | 0.37 |

### (2) Total head of pump

#### 1) Designed water level for pump (Suction and discharge)

The suction water level for pump is determined based on the water levels of Bahr el Jebel. The pump operation is planned throughout the year in accordance with farming plan, and the planned suction water level shall be fixed based on the record of lowest water level at the site. On the other hand, the planned pump discharge level is to be fixed with the high water level in the irrigation canal which is obtained from the site survey result.

#### 2) Actual head

The actual head is given as the difference between the discharge water level and the suction water

level and calculated as in the followings.

Calculation of actual head

Ha = DWL ï LWL

Where, Ha : Actual head (m)
DWL : Discharge water level (m)
LWL : Suction water level (m)

**3) Calculation of total head**

The total head is obtained by adding various losses in pipes to the actual head and calculated by using the following formula.

Calculation formula for the total head

$H = Ha + H1 = (DWL-LWL) + hf + fn \cdot V^2/2g$

Where, H : Total head (m)
Ha : Actual head
H1 : Total head loss (m)
DWL : Discharge water level (m)
LWL : Suction water level (m)
hf : Friction head loss of pipes (m)
fn : Coefficient of various friction loss
V : Velocity (m/s)
G : Gravity acceleration ($m/s^2$) = 9.8 ($m/s^2$)

Friction Loss Calculation of the pipe aligned in the pump station by Darcy・Weisbach

$h_f = \lambda \cdot (L/D) \cdot V^2/2g$ ・・・・・・・・・・・・ Darcy・Weisbach formula

$\lambda$ : Coefficient of friction ; normal steal pipe
$\lambda = \{0.0144+9.5/(1000 \cdot \sqrt{V})\} \cdot 1.5$
L : Length of pipe (suction & discharge) (m)
D : Pipe Diameter corresponding to Pipe Length L (m)

Friction Loss Calculation of the pipe aligned at outside of the pump station by Hazen・Williams

$h_f = 10.666 \cdot \{Q^{1.85}/(C^{1.85} \cdot D^{4.87})\} \cdot L$ ・・・・Hazen・Williams

Q : discharge ($m^3/s$)
C : Velocity Coefficient; Steal Pipe (No Coating) C=100
D : Diameter (m)
L : Length of Pipeline (m)

The calculation results of pipe losses around the pump and the total head are as shown in the Table 2.2.2.

**(3) Rating point of pumps**

The rating point for planning of pump is to be fixed in a way that the designed discharge will flow by the maximum pump lift within the actual pump operation range.

**Table 2.2.3 Rating point of pumps**

| Pump Station | Planned Discharge of Pump (m3/s/unit) | Planned Total Head (m) |
|---|---|---|
| Station No.1 | 0.295 | 14.0 |
| Station No.1-H | 0.180 | 35.0 |
| Station No.2 | 0.180 | 50.0 |
| Station No.3 | 0.185 | 53.0 |

**(4) Number of revolution, installation position and design point of pumps**

For the pump facilities, in future design stage, the examination is necessary to design the facilities to be operated safely against the possible cavitation in any range of pump running through analyzing varieties of pump installation positions, number of revolutions and design points in all cases.

## Table 2.2.2 Pipe losses and total head of each station

| Site | | Unit | Pump Station | | | | Remarks |
|---|---|---|---|---|---|---|---|
| | | | No.1 | No.1-H | No.2 | No.3 | |
| Pump capacity | | ($m^3$/s) | 0.59 | 0.36 | 0.36 | 0.37 | provided with 2 pumps |
| 1.Actual head (ha) | Design intake water level | LWL(m) | 446.5 | 451.5 | 445.6 | 445.1 | |
| | Design outlet water level | DWL(m) | 452.5 | 475.0 | 475.5 | 478.5 | |
| | Actual head (ha) | (m) | 6.00 | 23.50 | 29.90 | 33.40 | |
| 2.Friction head loss | | | | | | | |
| (1)Suction pipe | Q | ($m^3$/s) | 0.295 | 0.180 | 0.180 | 0.185 | per pump |
| | Pipe | | Steel | Steel | Steel | Steel | |
| | Diameter(D) | (mm) | 350 | 300 | 300 | 300 | |
| | Length(L) | (m) | 12.0 | 30.0 | 30.0 | 30.0 | |
| | Flow coefficient(C) | | 100 | 100 | 100 | 100 | |
| | Water velocity(V) | (m/s) | 3.07 | 2.55 | 2.55 | 2.62 | $V=Q/(\pi/4\cdot(D/1000)^2)$, $0.3m/s \leqq V \leqq 2.0m/s$ |
| | Friction head loss(fs) | (m) | 0.44 | 0.94 | 0.94 | 0.99 | $hf=10.67\cdot(Q^{1.85}\cdot C^{-1.85}\cdot D^{-4.87})\cdot L$ |
| (2)Delivery pipe1 | Q | ($m^3$/s) | 0.295 | 0.180 | 0.180 | 0.185 | |
| | Pipe | | Steel | Steel | Steel | Steel | |
| | Diameter(D) | (mm) | 350 | 300 | 300 | 300 | |
| | Length(L) | (m) | 7.0 | 10.0 | 10.0 | 10.0 | |
| | Flow coefficient(C) | | 100 | 100 | 100 | 100 | |
| | Water velocity(V) | (m/s) | 3.07 | 2.55 | 2.55 | 2.62 | |
| | Friction head loss(fs) | (m) | 0.26 | 0.31 | 0.31 | 0.33 | $hf=10.67\cdot(Q^{1.85}\cdot C^{-1.85}\cdot D^{-4.87})\cdot L$ |
| (3)Delivery pipe2 | Q | ($m^3$/s) | 0.590 | 0.360 | 0.360 | 0.370 | |
| | Pipe | | Steel | Steel | Steel | Steel | |
| | Diameter(D) | (mm) | 700 | 500 | 500 | 500 | |
| | Length(L) | (m) | 900.0 | 850.0 | 1800.0 | 1600.0 | |
| | Flow coefficient(C) | | 100 | 100 | 100 | 100 | |
| | Water velocity(V) | (m/s) | 1.53 | 1.83 | 1.83 | 1.88 | $V=Q/(\pi/4\cdot(D/1000)^2)$, $0.3m/s \leqq V \leqq 2.0m/s$ |
| | Friction head loss(fs) | (m) | 4.10 | 7.99 | 16.93 | 15.83 | $hf=10.67\cdot(Q^{1.85}\cdot C^{-1.85}\cdot D^{-4.87})\cdot L$ |
| (4)Total Friction loss | | (m) | 4.80 | 9.24 | 18.18 | 17.15 | |
| 3.Partial head loss | | | | | | | |
| (1)Check valve | | (Nos.) | 2 | 2 | 2 | 2 | |
| | Diameter(D) | (mm) | 350 | 300 | 300 | 300 | |
| | Water velocity(V) | (m/s) | 3.07 | 2.55 | 2.55 | 2.62 | |
| | Coefficient of valve loss(fcv) | | 0.96 | 0.90 | 0.90 | 0.90 | |
| | Check valve loss(hcv) | (m) | 0.92 | 0.60 | 0.60 | 0.63 | $hcv=fcv\cdot V^2/2g$ |
| (2)Sluice valve | | (Nos.) | 2 | 2 | 2 | 2 | |
| | Diameter(D) | (mm) | 350 | 300 | 300 | 300 | |
| | Water velocity(V) | (m/s) | 3.07 | 2.55 | 2.55 | 2.62 | |
| | Coefficient of valve loss(fsv) | | 0.44 | 0.33 | 0.33 | 0.33 | |
| | Sluice valve loss(hsv) | (m) | 0.42 | 0.22 | 0.22 | 0.23 | $hsv=fsv\cdot V^2/2g$ |
| (3)90°elbow | | (Nos.) | 2 | 2 | 2 | 2 | |
| | Diameter(D) | (mm) | 350 | 300 | 300 | 300 | |
| | Water velocity(V) | (m/s) | 3.07 | 2.55 | 2.55 | 2.62 | |
| | Coefficient of elbow loss(fbe) | | 1.10 | 1.10 | 1.10 | 1.10 | |
| | 90°elbow loss(hbe) | (m) | 1.06 | 0.73 | 0.73 | 0.77 | $hbe=fbe\cdot V^2/2g$ |
| (4)T Interflow | | (Nos.) | 1 | 1 | 1 | 1 | |
| | Diameter(D) | (mm) | 700 | 600 | 500 | 600 | |
| | Water velocity(V) | (m/s) | 1.53 | 1.83 | 1.83 | 1.88 | |
| | Coefficient of elbow loss(f13) | | 0.65 | 0.65 | 0.65 | 0.65 | |
| | T Interflow loss(hbe) | (m) | 0.08 | 0.11 | 0.11 | 0.12 | $h13=f13\cdot V^2/2g$ |
| (5)Remnant head | Diameter(D) | (mm) | 700 | 500 | 500 | 500 | |
| | Water velocity(V) | (m/s) | 1.53 | 1.83 | 1.83 | 1.88 | |
| | Coefficient of head loss(fo) | | 1.00 | 1.00 | 1.00 | 1.00 | |
| | Remnant velocity head(Lo) | (m) | 0.12 | 0.17 | 0.17 | 0.18 | |
| (6)Total parcial los | Particial head loss(Lp) | (m) | 2.60 | 1.83 | 1.83 | 1.93 | |
| 4.Head loss(hf) | Total | (m) | 7.40 | 11.07 | 20.01 | 19.08 | |
| 5.Total head(H) | H=ha+hf | (m) | 13.40 | 34.57 | 49.91 | 52.48 | |
| 6.Design total head(H) | | (m) | 14.00 | 35.00 | 50.00 | 53.00 | |

**(5) 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 can be calculated with the following formula.

Formula for Pump Shaft Power

$L = 0.163 \cdot Q \cdot H \cdot ɔ/(ɖ/100)$

L: Pump shaft power (kW)
Q: Discharge ($m^3$/min)
H: Total head (m)
ɔ : Unit weight of water; 1.0 (kgf/l)
ɖ : Pump efficiency (%); 78 % at design point for centrifugal pump

The planned diesel engine output is estimated with the following, where, the power transfer efficiency and allowance are added on the basic pump shaft power.

Formula for diesel engine output

$P = L \cdot (1+A)/ɖt$

P : Planned diesel engine output (kW)
L : Pump shaft power (kW)
A : Allowance (0.15 for the case of diesel engine)
ɖt : Transfer efficiency (Fixed at 1.0 as direct jointing is applied)

As the power source, diesel engine shall be adopted and standard type is planned in view of the compatibility. The diesel engine capacities is calculated as follows.

**Table 2.2.4 Pump Efficiency of Centrifugal Pump**

| Pump Station | Power Shaft Power (kw) | Diesel Engine Output (kw) |
|---|---|---|
| Station No.1 | 49.3 | 57 |
| Station No.1-H | 79.0 | 91 |
| Station No.2 | 112.8 | 130 |
| Station No.3 | 122.9 | 141 |

**Table 2.2.5 Pump Efficiency of Centrifugal Pump**

| Discharge ($m^3$/min) | Diameter (mm) | Specific Speed (Ns) | | | |
|---|---|---|---|---|---|
| | | 160 | 250 | 400 | 630 |
| 4.0 | 200 | 0.710 | 0.720 | 0.720 | 0.710 |
| 6.3 | 250 | 0.740 | 0.750 | 0.750 | 0.740 |
| 10 | 300 | 0.770 | 0.780 | 0.780 | 0.770 |
| 16 | 350 | 0.810 | 0.820 | 0.820 | 0.810 |
| 20 | 400 | 0.815 | 0.825 | 0.825 | 0.815 |

| | | | | | |
|---|---|---|---|---|---|
| 25 | 450 | 0.825 | 0.835 | 0.835 | 0.825 |
| 32 | 500 | 0.830 | 0.840 | 0.840 | 0.830 |
| 40 | 600 | 0.840 | 0.850 | 0.850 | 0.840 |
| 63 | 700 | 0.850 | 0.860 | 0.860 | 0.850 |
| 85 | 800 | 0.855 | 0.865 | 0.865 | 0.855 |
| 100 | 900 | 0.860 | 0.870 | 0.870 | 0.860 |
| 130 | 1000 | 0.860 | 0.870 | 0.870 | 0.860 |
| 160 | 1200 | 0.865 | 0.875 | 0.875 | 0.865 |

Source: Design Pump Facilities Technical Document (Japan)

**(6) Valves around the pump**

**1) Sluice valve on discharge side**

At the time of starting the pump operation, there will be an inhalation of air as caused by the vacuum pump running. To shut this air, a valve is necessary to be provided.

**2) Check valve**

In case of main pump shut-down in a condition the discharge valve opened due to the sudden power cut etc, a check valve is needed on the discharge side to stop the pumped water to counter to pump equipment.

**2.3 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.

The style of the building is in general to be determined in consideration of the kinds and types of pump and in connection with the suction sump. Water level fluctuation in the River Jur is quite large and therefore the building is planned as a single-floor type located at the basement at the level where pump operation can be made without cavitation even with the low water level.

**(2) Pump room**

The plan of pump room shall be decided mainly by the alignment of pumps. The alignment shall be considered in a way that pumps may satisfy various hydraulic conditions required by pump operation and also attention be paid on daily operation, inspection and maintenance to be made easily and safely.

Under the subject project, double-suction pump is to be introduced and the linear alignment shall be adopted where hydraulic condition is the best without having eccentric flow. In the case of linear alignment, the length of building becomes a little longer in the right angle direction to the pumped water flow, however, there is no problem in the required land lot for construction. The length between beams of the pump room shall be calculated by adding the suction and discharge pipe lengths on the dimensions of the space between each of flange face, assuming that such major equipment as pumps,

valves, enginew and etc be hanged vertically by the overhead crane. While the length of building (Right angle direction to the flow) shall be determined so that the required space for effective O&M works could be secured around the pumps and motors under the concept of safety first. Further, the height of the building may be determined taking into consideration the height of hanging required for installation as well as O&M works for the equipment in the pump room.

Based on the considerations as above, the plan and section of pump station building are planned as shown in the Figure 2.3.1.

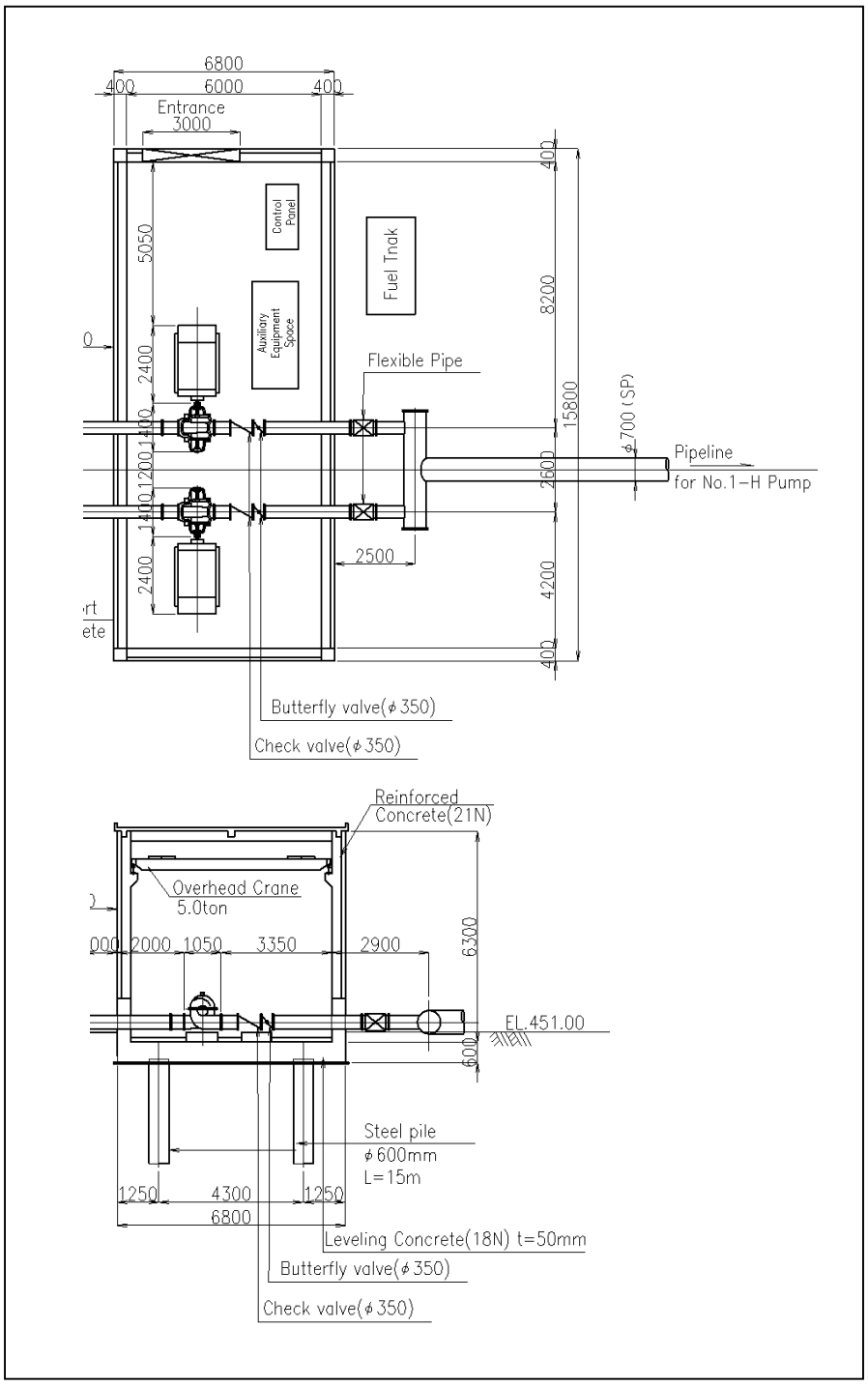



**Figure 2.3.1 Plan and Section of Pump Station Building**

**(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**

As the types of foundation works for pump station building, there are spread foundation, pile foundation and caisson foundation and the selection shall be made on considerations on the ground condition, characteristics of the upper structure, construction period as well as the economic aspect. Generally, the spread foundation is adopted for the case of about 2 m depth to the bearing stratum and the pile foundation for the depth longer than 5 m.

For reference, the log of boring at pump station is shown in the Figure 2.3.2, Figure 2.3.3, Figure 2.3.4 and Figure 2.3.5.

Pump station No.1 and No.2: According to the log of boring PB-01 and PB-02, the geological condition are shown the medium dense and it is not suitable for the spread foundation. It is recommended to adopt the pile foundation in future design stage through the additional geological investigation for clarifying the very dense layer.

Pump station No.3: According to the log of boring PB-03, the geological condition are shown the loose dense of the 3m depth and it is not suitable for the spread foundation. It is recommended to adopt the replacement foundation that remove away the loose soil and back fill by the suitable soil with the adequate compaction manner.

Pump station No.1-H: According to the log of boring RB-01 near the pump station but the distance of about 1km far, the geological condition are shown the high dense and it is suitable for the spread foundation. However, it is recommended to carry out the additional geological investigation for clarifying the geological conditions at the site.

Drilling equipiment Rotary drilling Mobile B 30 Coordinate 4-45'-24''N & 31- 36'-02''E
Drilling method: Rotary Core
Drilling Date 2nd - 3rd of June/2015
BH diameter(mm) 115 Logged by T.T.A
BH ID PB 01 G.W.L. 6.5mts b.g.s.

| depth(m) | Legend | description of Strata | SPT N | SPT N' (corrected) | bearing value(kN/m2) |
|---|---|---|---|---|---|
| 0 – 1.5 | SAND | Loose dark brown slightly silty slightly clayey SAND (SW) | 8 | 22 | 200 |
| 2 – 2.5 | SAND | Medium dense dark brown silty SAND (SM) | 23 | 34 | 250 |
| 3 – 3.5 | Clayey SAND | Stiff Dark grey silty clayey SAND (SC) | 9 | 17 | 150 |
| 4 – 4.5 | Clayey SILT | Stiff dark grey sandy clayey SILT (MC) | 8 | 11 | 100 |
| 5 – 5.5 | Silty SAND | Firm dark grey Clayey silty SAND (SM) | 6 | 8 | 90 |
| 6 – 6.5 | Silty SAND | Loose grey silty SAND (SM) | 9 | 10 | 95 |
| 7 – 7.5 | Silty SAND | Stiff Dark gray clayey silty SAND (SM) | 11 | 15 | 150 |
| 8 – 8.5 | GNEISS | Dark grey slight to moderately weathered & jointed GNEISS | | refusal | 10000 |
| 9 – 9.5 | | | | | |
| 10 | | | | | |

Project Irrigation Development Master Plan (IDMP): Rejaf-East Geological Survey & Soil Mechanical Investigati
Consultant SANYU Consultants Inc
Contractor Amare & Families Consulting Engineers (SS) Co Ltd

**Figure 2.3.2 Log of Boring (PB-01) at pump station No.1**

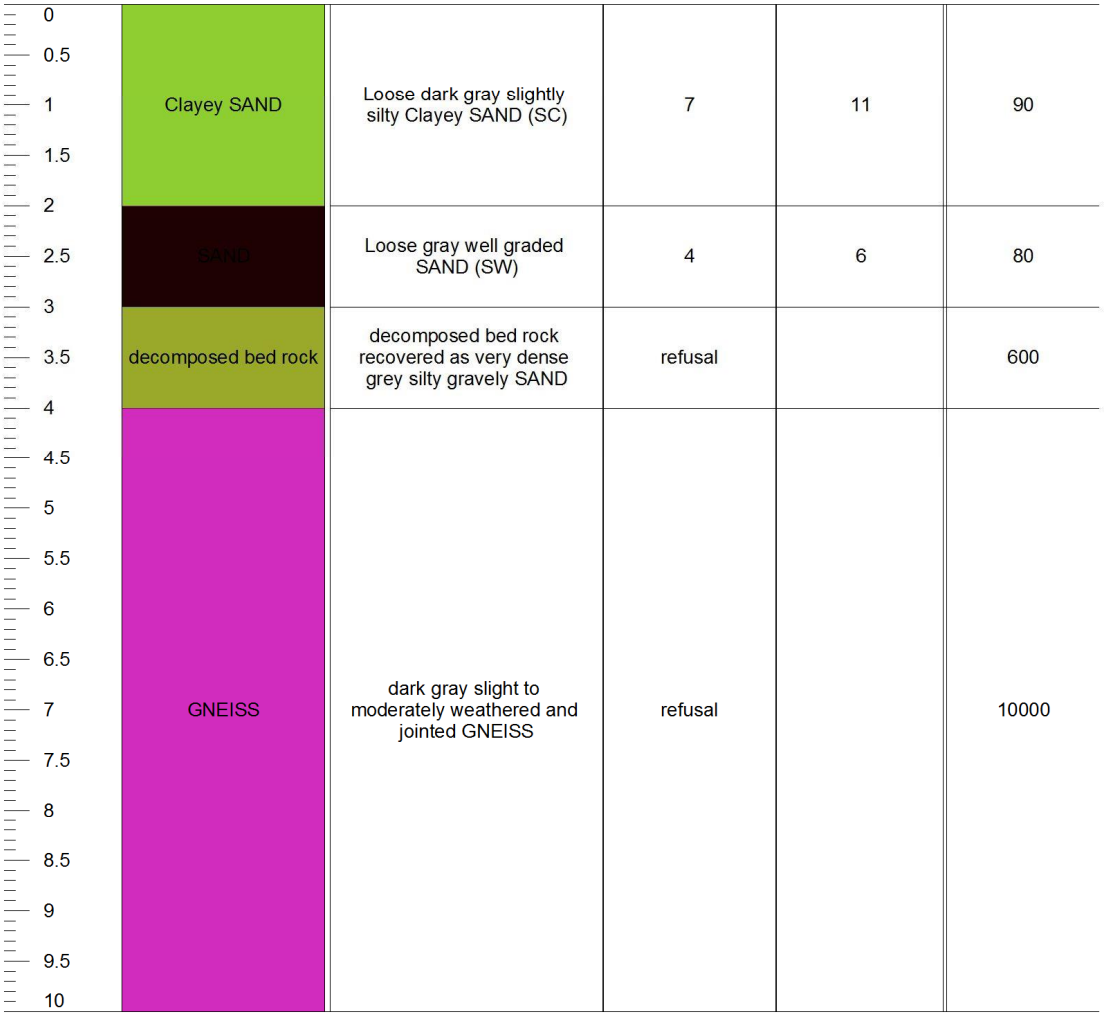
| | |
|---|---|
| Project | Irrigation Development Master Plan (IDMP): Rejaf-East Geological Survey & Soil Mechanical Investiga |
| Consultant | SANYU Consultants Inc |
| Contractor | Amare & Families Consulting Engineers (SS) Co Ltd |

| depth(m) | Legend | description of Strata | SPT N | SPT N'(corrected) | bear. value (kN/m2) |
|---|---|---|---|---|---|
| 0 – 1.5 | clayey SILT | Firm grey sandy Clayey SILT (MC) | 8 | 12 | 110 |
| 2 – 2.5 | Clayey SAND | Loose gray silty clayey SAND (SC) | 9 | 13 | 95 |
| 3 – 3.5 | SAND | Medium dense gray well graded SAND (SW) | 18 | 25 | 220 |
| 4 – 4.5 | SAND | Loose gray poorly graded SAND (SP) | 4 | 5 | 70 |
| 5 – 5.5 | SAND | Medium dense gray well graded SAND (SW) | 14 | 14 | 150 |
| 6 – 6.5 | SAND | Medium dense gray well graded SAND (SW) | 21 | 19 | 160 |
| 7 – 7.5 | SAND | Medium dense gray well graded SAND (SW) | 23 | 17 | 160 |
| 8 – 10 | GNEISS | dark&grey slightly weathered &jointed GNEISS | | | 10000 |

| | | | | | |
|---|---|---|---|---|---|
| Drilling equipiment | Rotary drilling Mobile B 30 | | Coordinate | 4 - 46 - 03N &31-36-18E | |
| Drilling method | Rotary Core Drilling | Date | 4th of June/2015 | | |
| BH diameter(mm) | 115 | Logged by | T.T.A | | |
| BH ID PB02 | G.W.L. | 6.5mts b.g.s. | | | |

**Figure 2.3.3 Log of Boring (PB-02) at pump station No.2**

Coordinate 4-47-01N & 31-36-22E
Date 5th of June/2015
Logged by T.T.A
G.W.L. 1.2m.b.g.s.




Project Irrigation Development Master Plan (IDMP): Rejaf-East Geological Survey & Soil Mechanical InvestigationWorks Drilling equipiment Rotary drilling M
Drilling method Rotary Core Drilling
Consultant SANYU Consultants Inc BH diameter(mm) 115
BH ID PB03
Contractor Amare & Families Consulting Engineers (SS) Co Ltd

**Figure 2.3.4 Log of Boring (PB-03) at pump station No.3**

Project Irrigation Development Master Plan (IDMP): Rejaf-East Geological Survey & Soil Mechanical InvestigationWorks Drilling equipiment Rotary drilling M
Drilling method Rotary Core Drilling
Consultant SANYU Consultants Inc BH diameter(mm) 115
BH ID RB01
Contractor Amare & Families Consulting Engineers (SS) Co Ltd

| depth(m) | Legend | description of strata | SPT N | SPT N'(corrected) | bear.value(kN/m2 |
|---|---|---|---|---|---|
| 0 – 0.4 – 0.8 – 1.2 – 1.6 – 2 | SAND | Dense gray well graded SAND (SW) | 44 | 50 | 400 |
| 2 – 2.4 – 2.8 | Well graded SAND | Medium dense gray well graded SAND (SW) | 22 | 33 | 300 |
| 3.2 – 3.6 | Gravely SAND | Very dense grey slightly silty gravely SAND | canceled (due to refusal) | | 600 |
| 4 – 4.4 – 4.8 | GEISS | dark grey moderately weathered & jointed / sheared GNEISS | canceled (due to refusal) | | 10000 |
| 5.2 | | | | | |

Coordinate 4-45-56N & 31-36-40E
Date 6th of June/2015
Logged by T.T.A
G.W.L. Not encountered

**Figure 2.3.5 Log of Boring (RB-01) near pump station No.1-H**

## 2.4 Riverbank Protection

### (1) Installation range

For the river bank of Bahr el Jebel, there is no protection works provided in general, and there can be seen some parts eroded by the river flow with higher velocity during the floods. The pump station sites are located on the gentle curve line river bank but not on the water colliding river bank. Due to the possible erosion by river flow, however, the suction pipe embedded underground might be exposed and the safety of the pipe could be endangered with the trashes/drifts clinched. This requires the riverbank protection works for attaining sustainable operation of the pump station. The extent of the riverbank protection shall cover 20 m each of both upstream and downstream directions from the center of suction pipe considering the position of suction pipe embedded. Also for connecting the riverbank protection with the present bank, 2 m width space shall be secured.

### (2) Structure type

The structure of mortar masonry retaining wall by using natural stones shall be adopted for the protection works, considering the gentle slope of 1:2.0, safety against the effect of water flow, availability of required materials, other viewpoints including landscape evaluation, economy and easiness in construction etc. For the connecting work with the present riverbank and protection work for embankment slope, gabion works with high flexibility shall be adopted.

### (3) Foundation

In order to average the variable velocity distributions during the suction, it is necessary to secure sufficient space for the head of suction pipe. Also, it is preferable to provide structures to fix the suction pipe so as to protect the suction pipe with considerable length exposed from various actions/effects by the river flow. In view of the above considerations, retaining wall of plain concrete which will satisfy the both requirements as discussed shall be provided for the foundation portion for the riverbank protection works around the suction pipe.

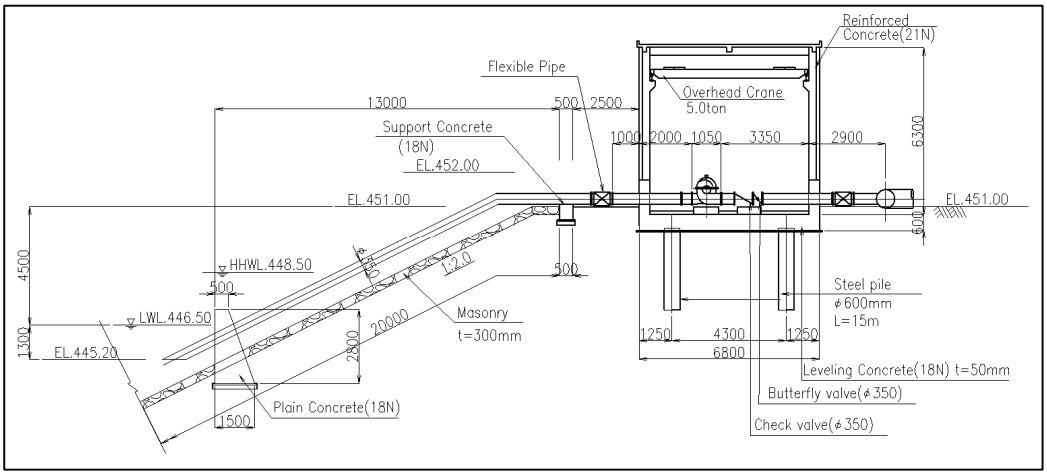



**Figure 2.4.1 Plan and Section of Pump Station Building (Profile)**

## 2.5 Storage for Pump Station No.1-H

### (1) Required Capacity of Storage

Storage structure is required to store and convey the irrigation water for the hillside farms at the outlet of pipeline in the vicinity of Rajaf road. The capacity of storage (V) is determined at more than 650$m^3$ to ensure the half an hour volume of the pump No.1-H capacity 0.36$m^3$/s of 2 set.

$$V = 0.36m^3/s \times 30min \times 60 = 648m^3$$

### (2) Design Water Level

High Water Level (HWL) is determined at 452.50m based on the existing ground level at the site. Also Low Water Level (LWL) is assumed at 451.00m, considering the effective water depth of 1.5m.

In case of the effective water depth of 1.5m, the length of one side is determined at 21m. Therefore, the capacity results to 662m3 finally, and it is satisfied with the required capacity.

### (3) Structure Type

The structure type shall be of firm reinforced concrete or masonry with mortal to avoid the water leakage.

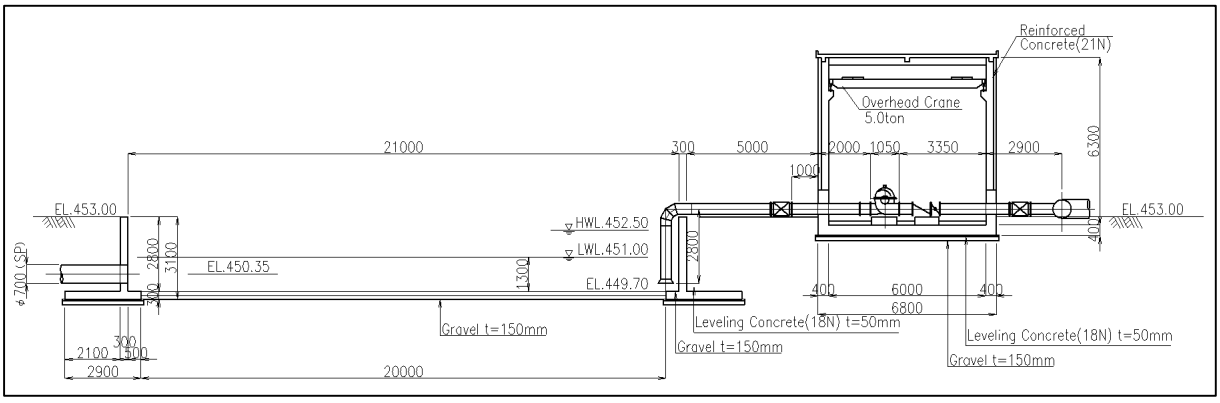



**Figure 2.6.2 Storage**

## 2.6 Pipeline

### 2.6.1 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 500mm diameter in case of the pipeline No.2, No3 and No.1-H. 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.

**Table 2.6.1 Pipeline Dimensions**

| Pipeline Number | Diameter (mm) | Section Area ($m^2$) | Discharge ($m^3/s$) | Velocity (m/s) |
|---|---|---|---|---|
| Station No.1 | 700 | 0.385 | 0.59 | 1.53 |
| Station No.1-H | 500 | 0.196 | 0.360 | 1.83 |
| Station No.2 | 500 | 0.196 | 0.360 | 1.83 |
| Station No.3 | 500 | 0.196 | 0.37 | 1.88 |

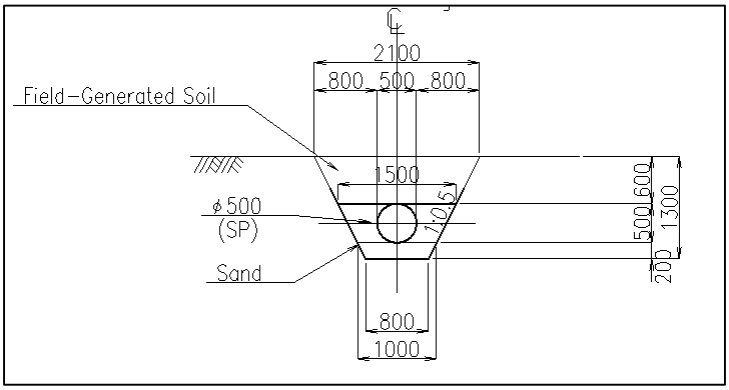



**Figure 2.6.1Typical Section of Pipeline No.1**

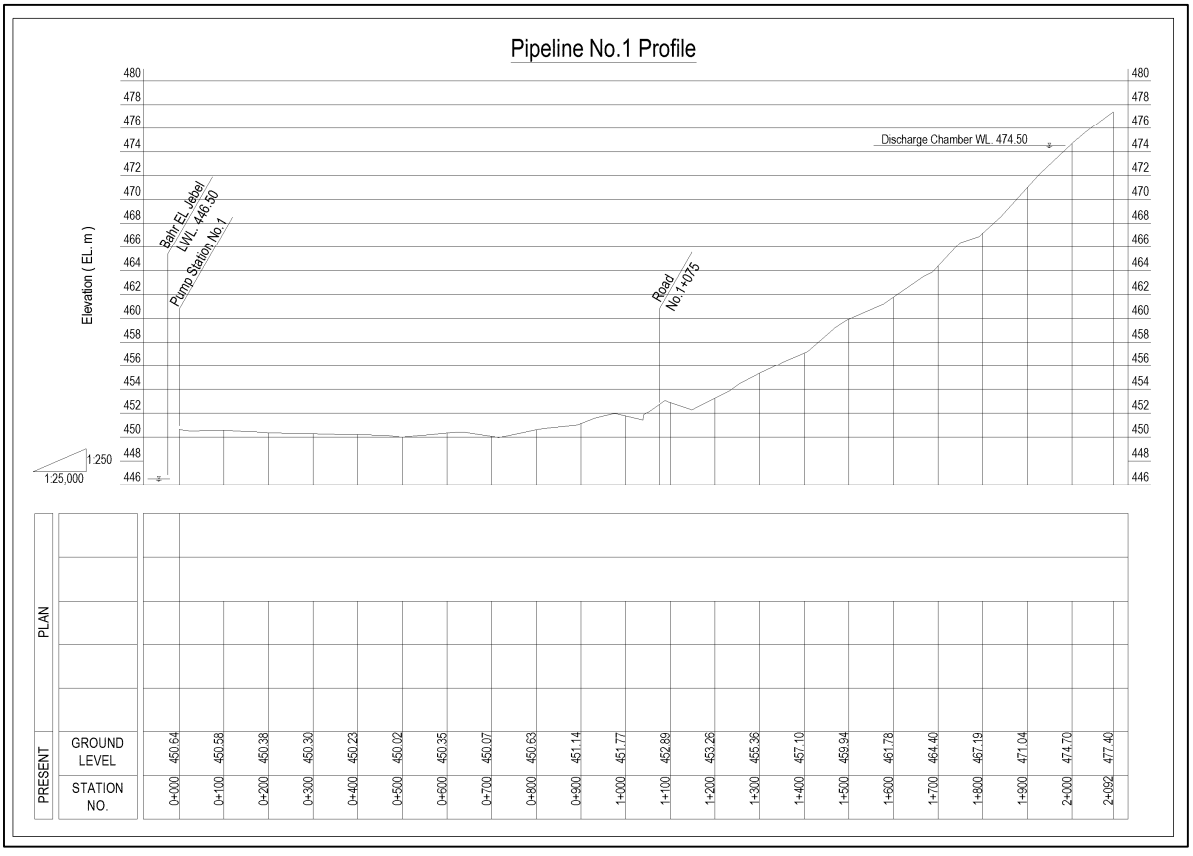



**Figure 2.6.2 Profile of Pipeline No.1**

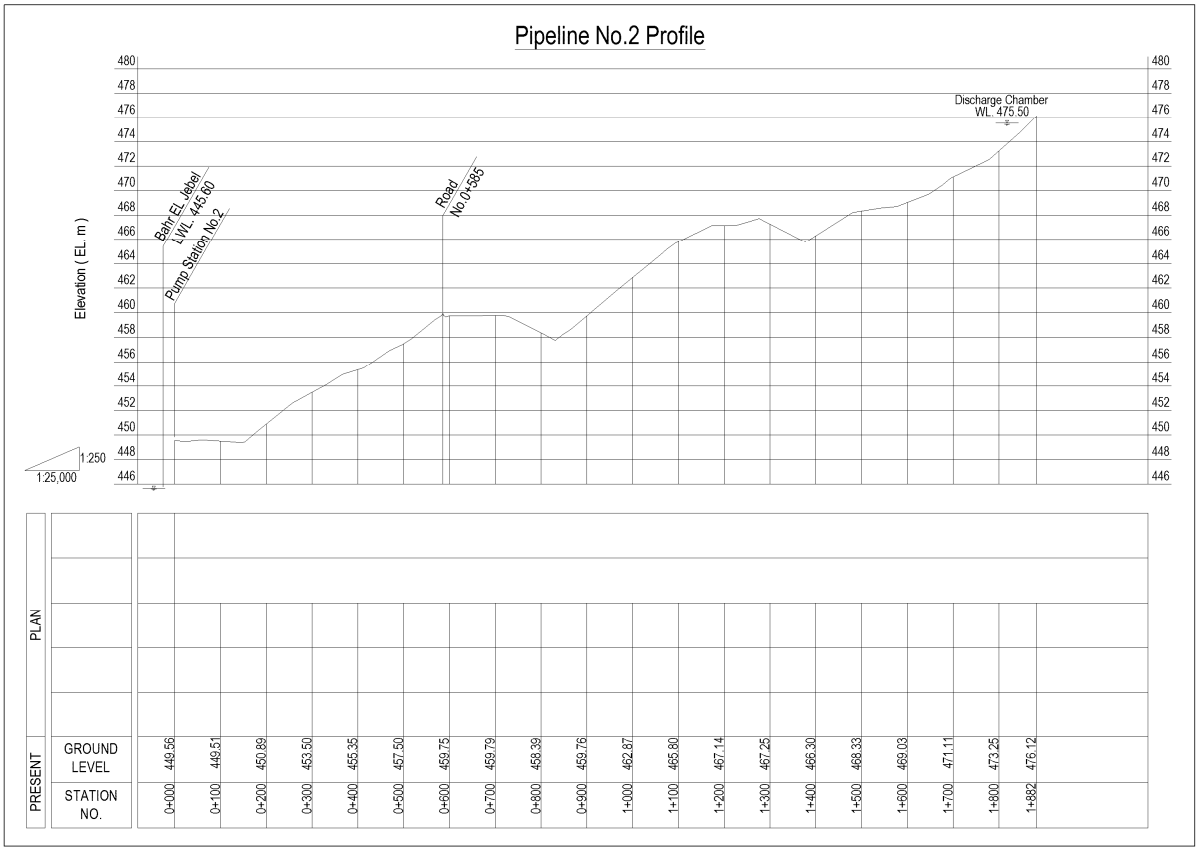



**Figure 2.6.3 Profile of Pipeline No.2**

Pipeline No.3 Profile

The pipeline No.3 profile was made a survey in accordance with the Technical Specification of the Contract. However, it was clarified that the surveyed route was not appropriate for the pipeline route because of the vicinity of the deep valley after checking the survey profile. Therefore, it is necessary to survey the new route of pipeline No.3 in the future design stage.

### 2.6.2 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.

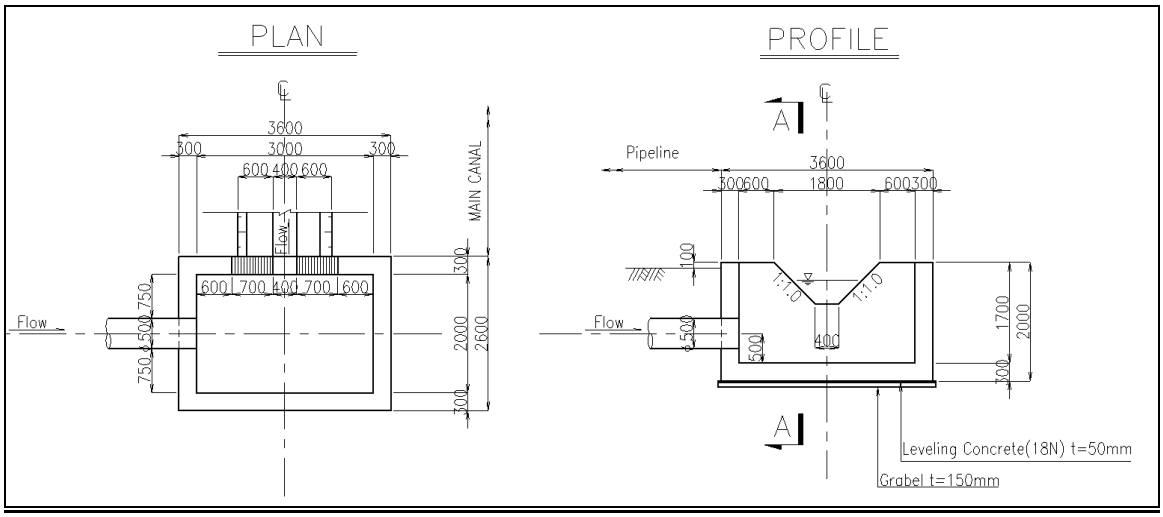



**Figure 2.6.2 Discharge Chamber (reference)**

# CHAPTER 3 MAIN CANAL

## 3.1 Location

Main canal shall be planned to conduct the irrigation water from the discharge chamber at the end of pipeline to the command area. Main canals are planned at both riverside and hillside, which are flat and undulate respectively. Because of the difficulty of consensus among the communities, Main canals are planned by each community show in the Table 3.1.1.

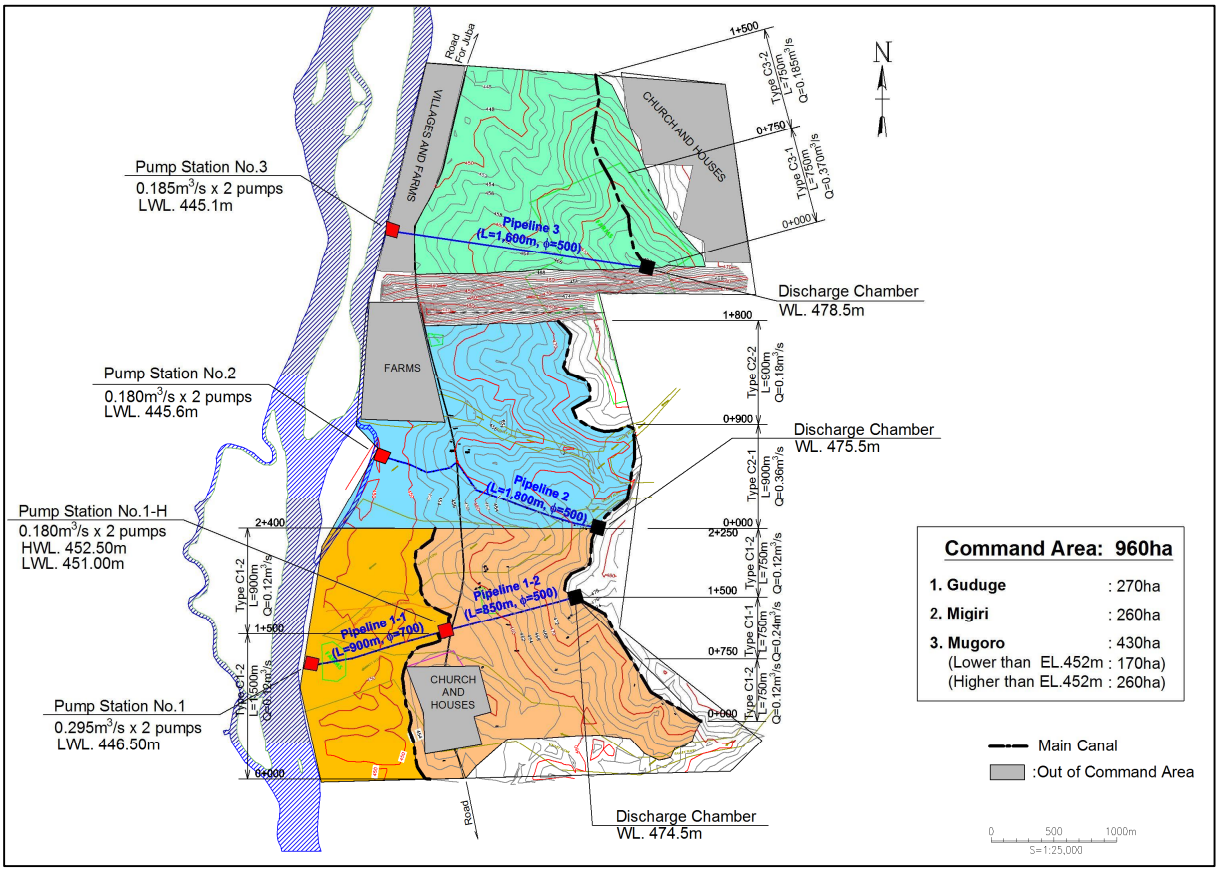



**Figure 3.1.1 Scheme layout**

The station number, length, and design discharge of each section is shown in the Table 3.1.1

**Table 3.1.1 Main canal**

| Type | Length (m) | Design Discharge (m3/s) | Remarks |
|---|---|---|---|
| Area of Pump Station No.1 & No.1-H | 2.400 | | |
| C1-1 | 750 | 0.24 | |
| C1-2 | 3,900 | 0.12 | |
| Area of Pump Station No.2 | 1.800 | | |
| C2-1 | 900 | 0.36 | |
| C2-2 | 900 | 0.18 | |
| Area of Pump Station No.3 | 1.500 | | |
| C3-1 | 750 | 0.37 | |
| C3-2 | 750 | 0.185 | |

### 3.2 Design Discharge

Unit water requirement was estimated at 1.43 l/s/ha, depending on the calculation of the water requirement.

Design discharge is estimated by the method that the unit water requirement multiples the subject area.

$Q = q \times A \times p$

Where, Q: Design irrigation discharge ($m^3/s$)

q: Unit water requirement (0.00143 $m^3/s/ha$)

A: Subject area (ha)

p: Planting Ratio (96%)

Design discharge of main canal is determined based on the water requirement of pump station irrigable area.

**Table 3.2.1 Design Discharge for Main canal**

| Type | Area (ha) | Planting Ratio | Unit W.R. (m3/s/ha) | Design Discharge (m3/s) |
|---|---|---|---|---|
| Area of Pump Station No.1 | 430 | | | 0.59 |
| Lower than EL.452m | 170 | 0.96 | 0.00143 | 0.23 |
| Hillside (No.1-H) | 260 | 0.96 | 0.00143 | 0.36 |
| Area of Pump Station No.2 | 260 | 0.96 | 0.00143 | 0.36 |
| Area of Pump Station No.3 | 270 | 0.96 | 0.00143 | 0.37 |
| Total | 960 | | | |

### 3.3 Examination Method of Canal Capacity

Main canal is designed of the plain concrete lining, considering hydraulic characteristics, conveyance efficiency, durability, and maintenance. The required function of canal is to convey the irrigation water properly with the required water level and water volume supplied from the pump station. The volume of the required water is determined based on the irrigation area or each irrigation blocks as divided by the regulator. The size of the cross section is planned by the volume of the required water with Manning formula as follows.

$Q = A \cdot V$

where, Q : Discharge ($m^3/sec$)

A : Flow Area ($m^2$)

V : Average flow velocity (m/sec);

Manningôs formula : $V = 1/n \cdot R^{2/3} \cdot I^{1/2}$

n : Roughness coefficient, for concrete lining canals : n = 0.015

R : Hydraulic radius (m)

I : Hydraulic gradient

Therefore the examination method for the canal capacity will apply the followings.

・Firstly, calculate the required water volume for the each irrigation block at schemes

・Secondly, examine the required size of the cross section to discharge for the above water volume

As for the detail method in examining the size of the existing canal section and required size of the canal section, it will be carried out as follows.

1. The canal bed slope, bank slope and bed width are estimated for each section of canal, then the target cross section is selected from each irrigation blocks
2. The clearance of the water level is decided by referring Japanese Design book in which the following calculation formula is shown, and the clearance should be higher than the calculated figure.

$Fb = 0.05d + \beta \cdot hv + hw$

Fb : clearance (m)

d : depth of the design discharge

hv : velocity head (m)

β : conversion coefficient from velocity head to static head. (generally it is 0.5～1.0)

hw : clearance for the waving of water surface. (generally it is 0.10～0.15cm)

**Table 3.3.1 Calculation of Main Canal Section**

| Items | | C1-1 | C1-2 | C2-1 | C2-2 | C3-1 | C3-2 |
|---|---|---|---|---|---|---|---|
| Design discharge | Q ($m^3$/s) | 0.24 | 0.12 | 0.36 | 0.18 | 0.37 | 0.185 |
| Width of canal bed | B (m) | 0.40 | 0.30 | 0.50 | 0.40 | 0.40 | 0.30 |
| Water depth | d (m) | 0.403 | 0.313 | 0.457 | 0.348 | 0.384 | 0.299 |
| Bank slope | 1:N | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Cross-sectional area of flow | A (m) | 0.324 | 0.192 | 0.437 | 0.260 | 0.301 | 0.1796 |
| Wetted perimeter | P (m) | 1.540 | 1.185 | 1.793 | 1.384 | 1.486 | 1.146 |
| Hydraulic mean depth | R (m) | 0.210 | 0.162 | 0.244 | 0.188 | 0.203 | 0.156 |
| Coefficient of roughness | n | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
| Canal bed slope | I (%) | 0.10 | 0.10 | 0.10 | 0.10 | 0.286 | 0.286 |
| Mean velocity | V (m/s) | 0.746 | 0.626 | 0.823 | 0.691 | 1.229 | 1.034 |
| Velocity head | hv (m) | 0.028 | 0.020 | 0.035 | 0.024 | 0.077 | 0.055 |
| Free board | Fb (m) | 0.196 | 0.187 | 0.193 | 0.152 | 0.216 | 0.201 |
| Height of canal | H | 0.60 | 0.50 | 0.65 | 0.50 | 0.60 | 0.50 |

Canal section is shown in the Figure 3.3.1.

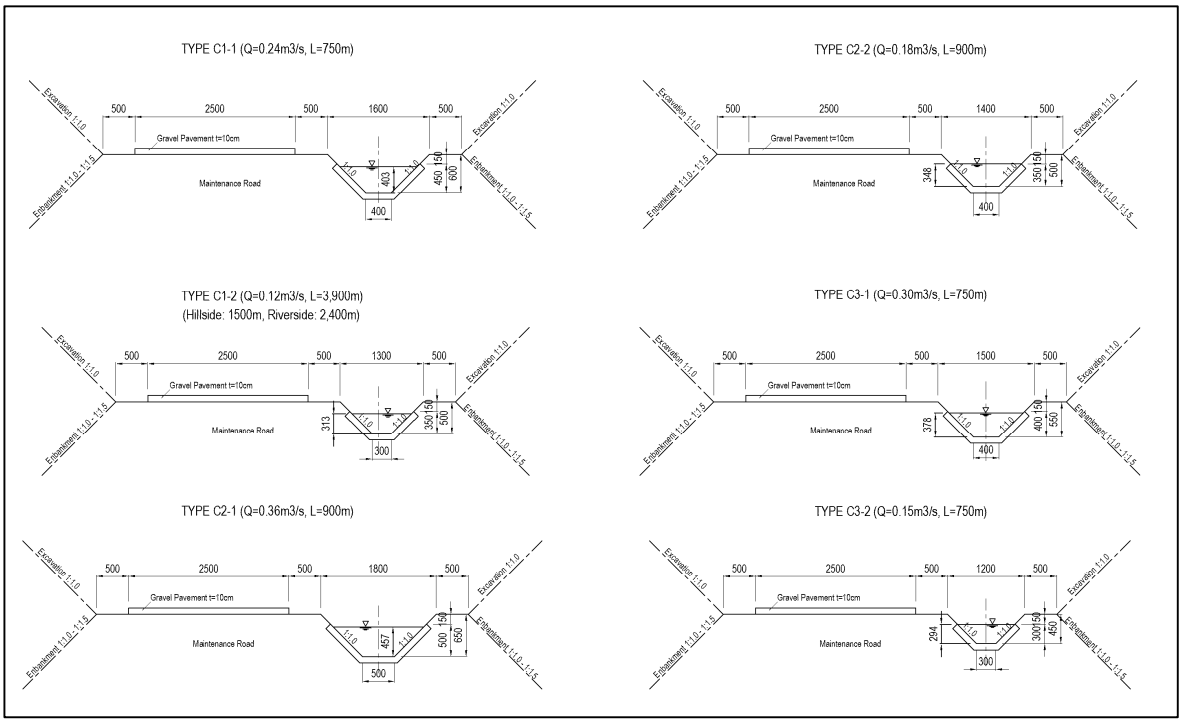



**Figure 3.3.3 Typical Cross section of Main Canal**

## 3.4 Relative structures

In general the relative structures such as diversion gate, canal spillway, drop, water measurement facilities, cross culvert and siphon etc. are required in the canal system if necessary. They shall be designed considered the canal system and the terrain around canal in the future design stage.

**Reference: Minimum / Maximum allowable velocity**

For reference, the Canal works guideline published in Japan shows the minimum / maximum allowable velocity as follows. It is recommended to take a caution for them in canal design.

### 6.1.1 Minimum allowable velocity

(1) Object discharge

Object discharges in studying the minimum allowable velocity are as shown in Table 6.1.1.

Table 6.1.1 Object discharges in studying the minimum allowable velocity

| Type of canal | Object discharges |
|---|---|
| Irrigation canal | Most frequent discharge (the discharge which occurs most times in the pentad mean discharge unit through out the water conveyance period of the canal) |
| Drainage canal | Discharge to study the low water revetment, etc. (1-year or 2-year probability discharge) |

(2) Minimum allowable velocity

It is appropriate that the minimum allowable velocity would not be below the velocity under the object discharge flow condition. However, when the velocity is below the minimum allowable velocity out of necessity, the structure and management system that are capable of maintaining drainage function of the canal shall be provided.

Also, the minimum allowable flow velocities shall follow values provided in Table 6.1.2.

Table 6.1.2 Minimum allowable flow velocities

| Condition of canal | Minimum allowable velocity |
|---|---|
| Canal where concerns regarding deposition of floating sediment do exist. | 0.45 - 0.90 m/s |
| Canal where concerns regarding overgrowth of water weed do exist. | 0.70 m/s |

Note: The minimum allowable velocity shall be determined by the grain size of floating sediment.

### 6.1.2 Maximum allowable velocity

(1) Object discharge

Object discharges in studying the maximum allowable velocity are as shown in Table 6.1.3.

Table 6.1.3 Object discharges in studying the maximum allowable velocity

| Type of canal | Object discharges |
|---|---|
| Irrigation canal | Planned maximum flow discharge |
| Drainage canal | Discharge to study the low water revetment, etc. (1-year or 2-year probability discharge)<br>185-day water discharge or firm drainage discharge during irrigation season |

(2) Maximum allowable velocity

The maximum allowable velocity involves uncertainties because it significantly varies depending on the material constituting the canal. Therefore, judgments have to be exercised based on experiences and other case examples. Based on materials and thickness of the members of the canal and the inside surface of the canal structure, those values shown in Table 6.1.4 are considered as approximate limiting values.

Table 6.1.4 Maximum allowable velocity

| Type of material | Velocity (m/s) | Classification | Velocity (m/s) |
|---|---|---|---|
| Sandy soil | 0.45 | Thick concrete (approximately 18 cm) | 3.00 |
| Sandy loam | 0.60 | Thin concrete (approximately 10 cm) | 1.50 |
| Loam | 0.70 | Asphalt | 1.00 |
| Clayey loam | 0.90 | Block cavity wall (buttress pier less than 30 cm) | 1.50 |
| Clay | 1.00 | Block cavity wall (buttress pier 30 cm or larger) | 2.00 |
| Sandy clay | 1.20 | Block mortar masonry | 2.50 |
| Soft rock | 2.00 | Reinforced concrete pipe | 3.00 |
| Semi-hard rock | 2.50 | Steel pipe, ductile cast iron pipe | 5.00 |
| | | Petrochemical products group (polyvinyl chloride pipe, reinforced plastic composite tube) | 5.00 |
| Hard rock | 3.00 | Reinforced concrete secondary product canal (excluding fence culvert) | 3.00 |

Notes:
1. The maximum allowable velocity is a value determined mainly by structural durability of the material of the canal structure against scour and wear. Specifically when a velocity close to the maximum allowable velocity value is used, it is necessary to study the hydraulic stability (especially regarding waves, water level rise at the cross section transition point, air entrapment in pipes, etc.).
2. Maximum allowable velocities for structures such as wasteways/spillways that are part of the canal and convey temporary flows shall be equal to or less than 1.5 times of values listed in the table above.
3. In cases of drainage canals, the value equal to or less than 1.5 times of values in this table shall be applied to discharges (1-year or 2-year probability discharge) to study the low water revetment. However, such value shall not also exceed values in this table at the time of 185-day water discharge or firm drainage discharge during irrigation season. Additionally, this table is not applicable to cases where appropriate erosion protections such as bed protection, etc., are provided for the subject facility in areas such as chutes, steep slope drainage canals, etc., or where structural members are reinforced by means such as increasing concrete thickness or reinforcing bars, or where the drainage canal is as large as a river. In such cases, the maximum allowable flow velocities shall be determined by referring to the structure and topography/geology of the subject canal as well as similar case examples.
4. The maximum allowable flow velocities for cast-in place concrete structures whose member thickness is 13 cm or larger shall be 3.0 m/s or less.
   Also, values of thick concrete or thin concrete in the above table may be applied to the maximum allowable flow velocities for plain concrete structures and for thickness between 10 cm and 18 cm, the value may be determined by proportional distribution.
5. In case of increasing the covering thickness, according to the standard of the U.S. Reclamation Bureau, regarding structures where the velocity exceeds 3.0 m/s, the structural durability can be secured by adding 1.5 cm of covering thickness to the value shown in Table 7.8.34, and by increasing the thickness by 1.5 cm every time the velocity is increased by 3.0 m/s.

# CHAPTER 4 IRRIGATION AND DRAINAGE SYSTEM IN FARMLANDS

## 4.1 Outline of Command Area

The command area is comprised of three (3) communities and the pump station is panned by each community. The terrain between riverside and Rajaf Road is flat of ground level about EL.450m, and many small irrigation farms are scattered along the river. The area of more than EL.452m is featured as undulate hillside. The land gradient shows around 2.0% toward the west from the east.

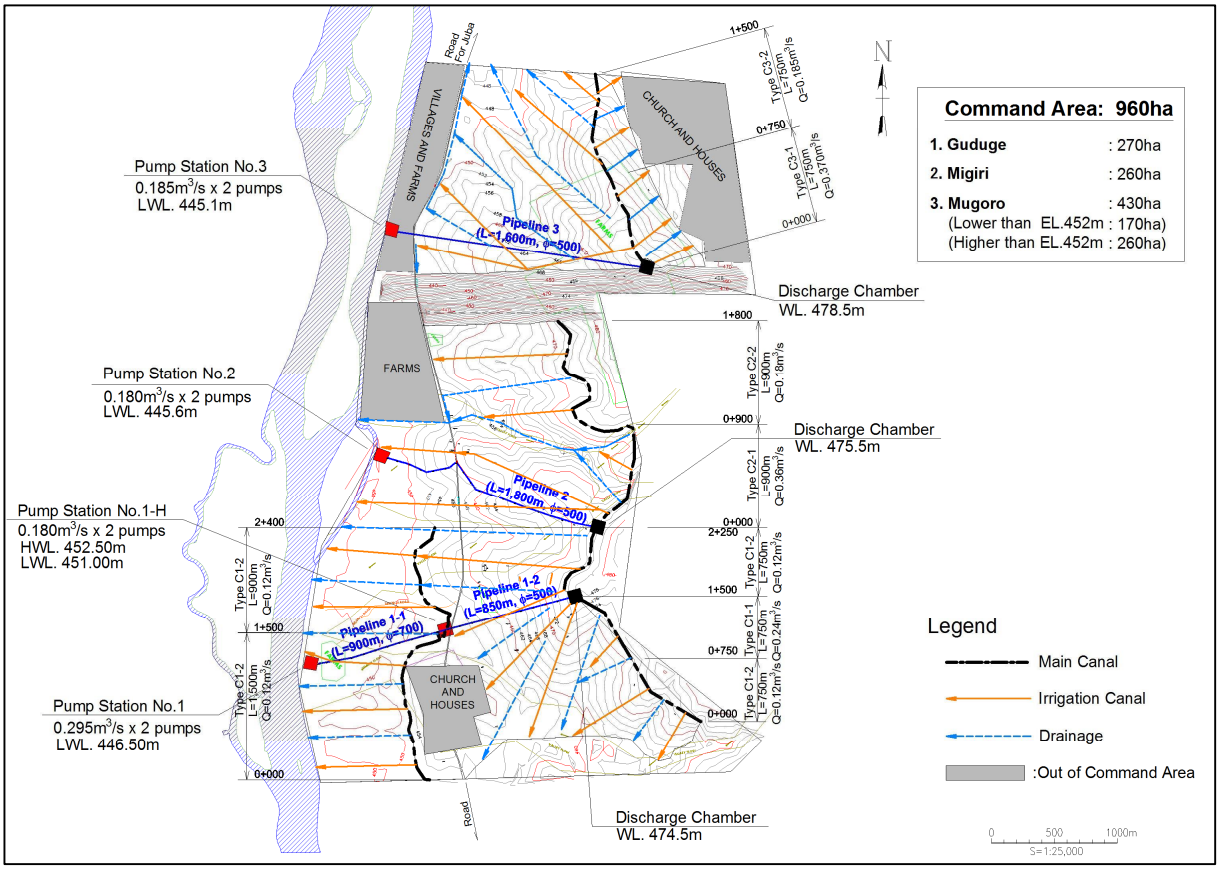



**Figure 4.1.1 Scheme Layout**

The major facilities such as the secondary canal, drainage and road are generally arranged from hillside toward riverside. The tertiary canal is planned to branch off from the secondary canal, also the feeder canal is planned to branch off from the tertiary canal for the distributing the irrigation water to the furrows. The canal is made of the earth because of a small size.

The drainage is allocated between the both secondary canals. The surplus water from tertiary canal and farm flows down to the drainage. The drainage is planned to be the earth canal.

The road used for farming and maintenance for facilities shall be planned along the secondary canal and tertiary canal. The road crossing is placed at the crossing point between the canal and road.

The length of furrow from 40m to 100m is assumed based on the soil survey results conducted in command area and Table 4.1.1 shown below. That survey results that the soil classification is mainly sandy loam or loam.

**Table 4.1.1 Example of Maximum Furrow Length of Different Soil**

| Soil | Root zone depth (m) | One-time irrigation volume (mm) | Maximum furrow length (m) |
|---|---|---|---|
| Sandy soil | 40 | 16 | 4 |
| Volcanic ash soil | 40 | 44 | 29 |
| Sandy loam | 40 | 34 | 36 |
| Loam | 40 | 38 | 99 |
| Clay | 40 | 44 | 121 |

Note: Furrow inclination is 10%

Source: Engineering Manual for Irrigation & Drainage, Upland Irrigation (1990), The Japanese Institute of Irrigation and Drainage

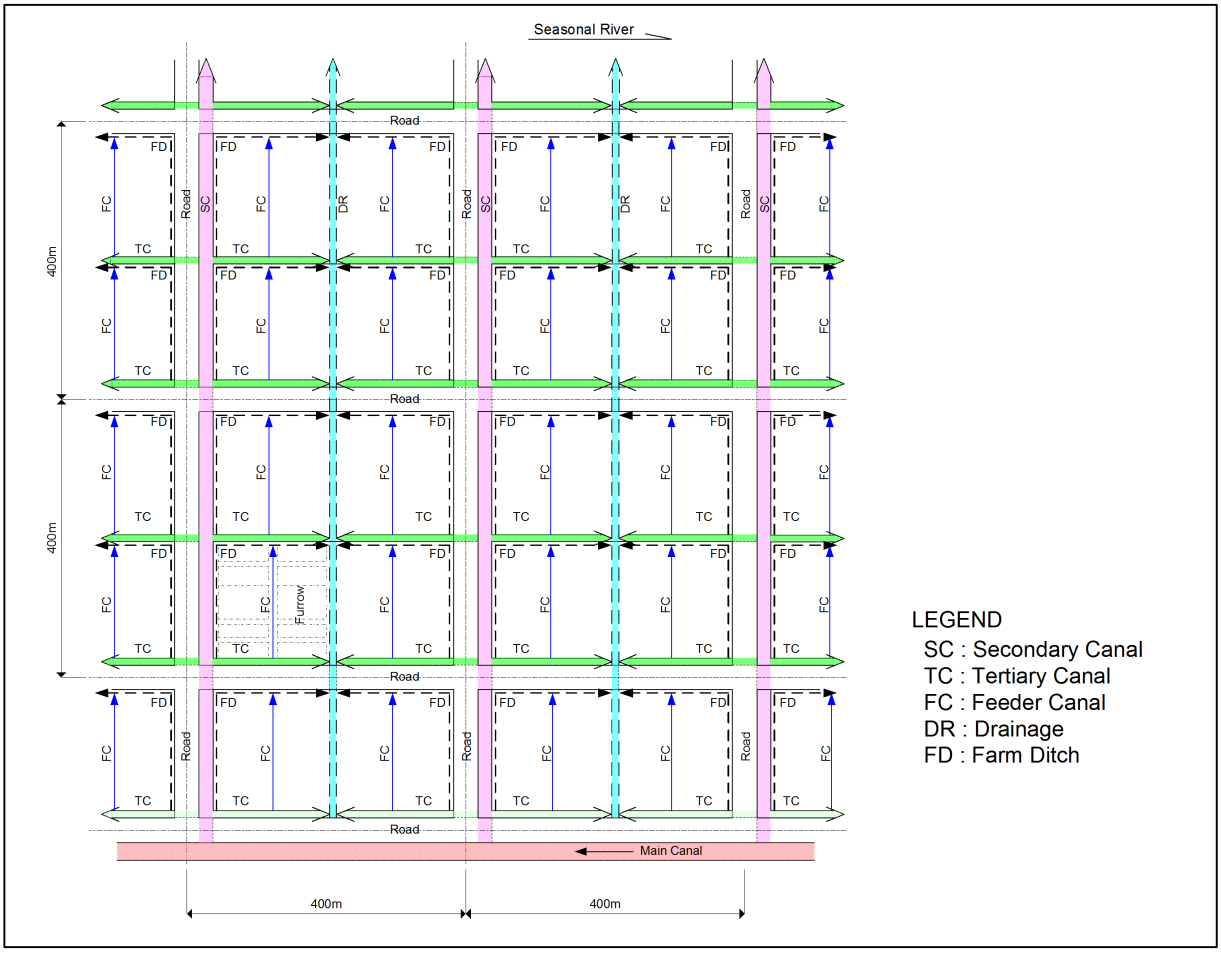



**Figure 4.1.2 Layout of Irrigation and drainage Facilities in Command Area**

## 4.2 Design Discharge of Canal and Drainage

### 4.2.1 Irrigation Canal

Unit water requirement was estimated at 1.43 l/s/ha (0.00143$m^3$/s/ha), depending on the calculation of water requirement.

Design discharge is estimated by the method that the unit water requirement multiples the subject area.

$Q = q \times A$

Where, Q: Design irrigation discharge ($m^3$/s)

q: Unit water requirement (0.00143 $m^3$/s/ha)

A: Subject area (ha)

- Secondary canal: Q= 0.12$m^3$/s (=0.00143 × averagely 80ha)
- Tertiary canal and Feeder canal: Q= 0.023$m^3$/s (=0.00143 × 16ha)

### 4.2.2 Drainage

Unit area drainage discharge was estimated at 0.045m3/s/ha, depending on the calculation results as below.

Return period T=5 year: outflow Q= 60.4$m^3$/s (catchment area A= 13.3$km^2$)

Unit area drainage discharge: q= Q/A = 4.5 $m^3$/s/$km^2$ = 0.045$m^3$/s/ha

Design discharge is estimated by the method that the unit water requirement multiples the subject area.

$Q = q \times A$

Where, Q: Design drainage discharge ($m^3$/s)

q: Unit area drainage discharge (0.0095 $m^3$/s/ha)

A: Subject area (ha)

- Drainage : Q= 3.78$m^3$/s (=0.045 × averagely 84ha)
- Farm ditch: Q= 0.090$m^3$/s (=0.045 × averagely 2ha)

<u>Unit area drainage discharge (5 year return period)</u>

・Rainfall intension

$$r_t = \frac{R_{24}}{24} \cdot \left(\frac{24}{t}\right)^{2/3} \quad \cdots\cdots \text{Mononobe equation}$$

$r_t$ : Average effective rainfall intensity in $t$ time (mm/hr) = $r_e$

$R_{24}$ : 24 hours rainfall (94.4 mm for 5 year return period)

$t$ : Rain fall duration or period of flood concentration (= 1 hr)

$$r_t = \frac{R_{24}}{24} \cdot \left(\frac{24}{t}\right)^{2/3} = \frac{94.4}{24} \cdot \left(\frac{24}{1}\right)^{2/3} = 32.7$$

Rational formula

$$Q_p = \frac{1}{3.6} \cdot r_e \cdot A$$

where: $Q_p$: peak flood discharge ($m^3/s$)

A: catchment area (13.3 $km^2$) → 1330ha

$r_e$: average effective rainfall intensive in the catchment within the lag time of flood (32.7 mm/hr) $r_e = f_p \cdot r_t = 0.5 \times r_t$

$$Q_p = \frac{1}{3.6} \times 0.5 \times 32.7 \times 13.3 = 60.4(m^3/s)$$

Therefore, Unit area drainage discharge: q= 60.4$m^3$/s / 1330ha = 0.045 $m^3$/s/ha

**Table 4.2.1 Annual Maximum Rainfall in Juba**

| Year | (mm) | Year | (mm) | Year | (mm) | Year | (mm) |
|---|---|---|---|---|---|---|---|
| 1970 | 66.7 | 1981 | 66.5 | 1992 | 52.0 | 2003 | missing |
| 1971 | 86.7 | 1982 | 131.8 | 1993 | 115.0 | 2004 | missing |
| 1972 | 46.4 | 1983 | 71.7 | 1994 | 106.5 | 2005 | 68.0 |
| 1973 | 64.0 | 1984 | 81.0 | 1995 | 55.0 | 2006 | 95.0 |
| 1974 | 68.5 | 1985 | 87.9 | 1996 | 70.0 | 2007 | 73.5 |
| 1975 | 88.3 | 1986 | 67.5 | 1997 | 75.5 | 2008 | 62.0 |
| 1976 | 83.9 | 1987 | 80.0 | 1998 | 59.0 | 2009 | 67.2 |
| 1977 | 41.0 | 1988 | 137.5 | 1999 | 119.5 | 2010 | 60.0 |
| 1978 | 82.9 | 1989 | 74.5 | 2000 | 66.8 | 2011 | 73.0 |
| 1979 | 107.0 | 1990 | 111.5 | 2001 | 61.2 | - | - |
| 1980 | 68.2 | 1991 | 51.5 | 2002 | 76.0 | - | - |

**Table 4.2.2 Return Period Probability**

| Return Period T Year | ζ | 1/a・ζ | Average Y+1/a・ζ | X+b | Return Period Probability (m3/s) X |
|---|---|---|---|---|---|
| 2 | 0 | 0 | 1.7718 | 59.1326 | 74.4 |
| 5 | 0.5951 | 0.12644 | 1.8983 | 79.1167 | 94.4 |
| 10 | 0.9062 | 0.19254 | 1.9643 | 92.1229 | 107.4 |
| 20 | 1.1631 | 0.24710 | 2.0189 | 104.4552 | 119.7 |
| 30 | 1.2967 | 0.27551 | 2.0473 | 111.5160 | 126.8 |
| 50 | 1.4520 | 0.30851 | 2.0803 | 120.3189 | 135.6 |
| 100 | 1.6450 | 0.34951 | 2.1213 | 132.2333 | 147.5 |
| 200 | 1.8215 | 0.38702 | 2.1588 | 144.1590 | 159.5 |
| 500 | 2.0350 | 0.43238 | 2.2042 | 160.0310 | 175.3 |
| 1000 | 2.1850 | 0.46425 | 2.2361 | 172.2165 | 187.5 |

## 4.3 Examination Method of Canal Capacity

All of canals in the command area are designed of the earth canal, considering the economical reason. The required function of canal is to convey the irrigation water properly with the required water level and water volume supplied from the pump station. The volume of the required water is determined based on the irrigation area or each irrigation blocks as divided by the regulator. The size of the cross section is planned by the volume of the required water with Manning formula as follows.

$Q = A \cdot V$

where, Q : Discharge ($m^3$/sec)
A : Flow Area ($m^2$)
V : Average flow velocity (m/sec); Manningôs formula : $V = 1/n \cdot R^{2/3} \cdot I^{1/2}$
n : Roughness coefficient, for concrete lining canals : n = 0.015
and for earth canals : n = 0.025
R : Hydraulic radius (m)
I : Hydraulic gradient

Therefore the examination method for the canal capacity will apply the followings.

・Firstly, calculate the required water volume for the each irrigation block at schemes
・Secondly, examine the required size of the cross section to discharge for the above water volume

As for the detail method in examining the size of the existing canal section and required size of the canal section, it will be carried out as follows.

1. The canal bed slope, bank slope and bed width are estimated for each section of canal, then the target cross section is selected from each irrigation blocks
2. The clearance of the water level is decided by referring Japanese Design book in which the following calculation formula is shown, and the clearance should be higher than the calculated figure.

$Fb = 0.05d + \beta \cdot hv + hw$

Fb : clearance (m)
d : depth of the design discharge
hv : velocity head (m)
β : conversion coefficient from velocity head to static head. (generally it is 0.5～1.0)
hw : clearance for the waving of water surface. (generally it is 0.10～0.15cm)

**Table 4.3.1 Calculation of Irrigation Canal Section and Farm ditch**

| Items | | Secondary canal | Tertiary canal | Feeder canal | Farm ditch |
|---|---|---|---|---|---|
| Design discharge | Q ($m^3$/s) | 0.12 | 0.023 | 0.023 | 0.090 |
| Width of canal bed | B (m) | 0.30 | 0.30 | 0.30 | 0.30 |
| Water depth | d (m) | 0.270 | 0.174 | 0.092 | 0.182 |
| Bank slope | 1:N | 1.0 | 1.0 | 1.0 | 1.0 |
| Cross-sectional area of flow | A (m) | 0.154 | 0.082 | 0.036 | 0.088 |
| Wetted perimeter | P (m) | 1.064 | 0.792 | 0.560 | 0.815 |
| Hydraulic mean depth | R (m) | 0.145 | 0.104 | 0.064 | 0.108 |
| Coefficient of roughness | n | 0.025 | 0.025 | 0.025 | 0.025 |
| Canal bed slope | I (%) | 0.50 | 0.10 | 1.0 | 1.0 |
| Mean velocity | V (m/s) | 0.780 | 0.279 | 0.642 | 0.907 |
| Velocity head | hv (m) | 0.031 | 0.004 | 0.021 | 0.042 |
| Free board | Fb (m) | 0.180 | 0.126 | 0.203 | 0.168 |
| Height of canal | H (m) | 0.45 | 0.30 | 0.30 | 0.35 |

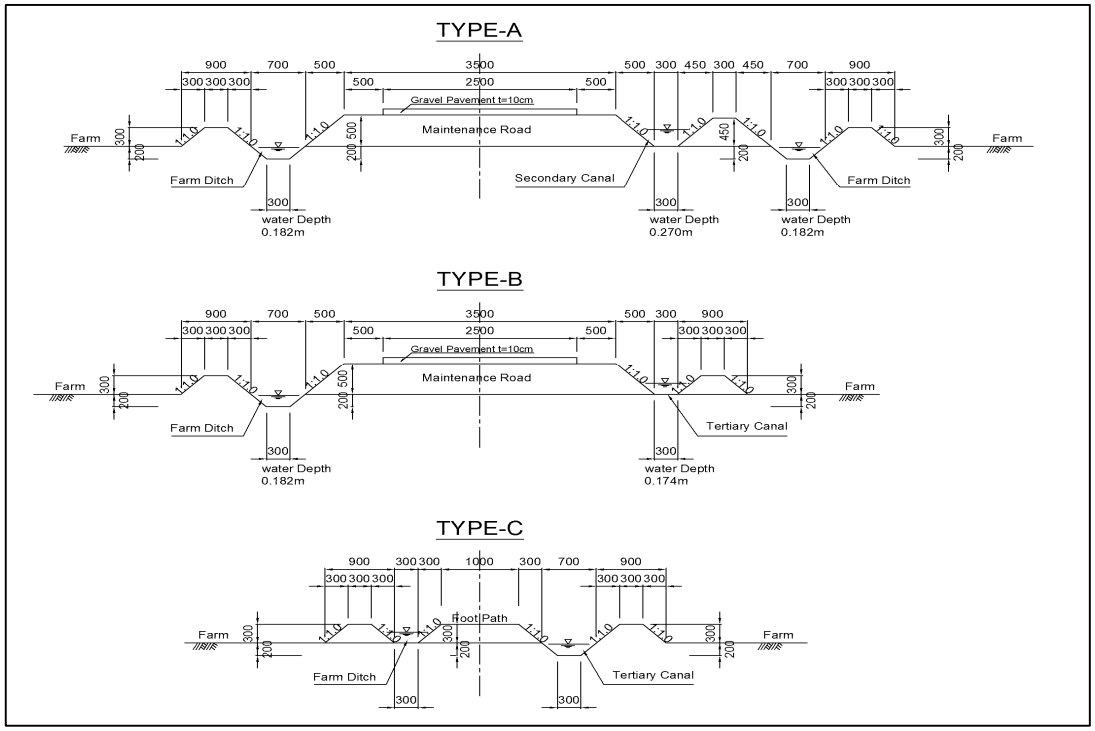



**Figure 4.2.1 Typical Cross section of Irrigation and drainage Facilities in Command Area**

## 4.4 Furrow Irrigation methods

Surface irrigation methods are in general classified to four (4) methods. In this Jebel Lado area, the furrow irrigation methods are adequate depending on the conditions of the terrain and soil characteristic.

Surface Irrigation Methods

1) Furrow irrigation methods

The method irrigates plant roots by water permeated from the side of the furrow. Supply channels are arranged at certain intervals between the moderately sloped furrow, and cause a fixed amount of water to flow. Water is retained for the minimum necessary time to secure water depth downstream to supply sufficient water to the roots, while upstream where water is retained for

an excessive time, water penetration loss to the deeper layer cannot be avoided. The irrigation efficiency is influenced by geographical features, intake rate, furrow length, and discharge amount. To make a uniform slope of a furrow, construction is required.

2) Border irrigation methods

The field is divided into bands by low boundary ridges, and sloped to cause water to flow as a thin laminar flow. The deep layer penetration loss and irrigation efficiency are similar to those of the furrow irrigation method. Compared with the furrow irrigation method, it requires less labor force; whereas it requires greater amount of water and as the limitation factor is the slope, land levelling over a wider area is indispensable. It is often used for irrigation pasture land.

3) Contour ditch irrigation methods

A ditch to introduce water is prepared with a slope of 1/1000 along the contour line, and water is supplied from the turnout provided at the ditch. The method is applicable even on relatively irregular land, but the irrigation efficiency is low.

4) Basin irrigation methods

According to this method, farm land will be flatten and enclosed by ridges. The irrigation water will be conveyed through canals or pipelines to irrigate the farm land intermittently.

### 4.5 Relative structures

In general the relative structures such as diversion gate, drop, water measurement facilities, cross culvert and siphon etc. are required in the canal system if necessary. They shall be designed considered the canal system and the terrain around canal in the future design stage.

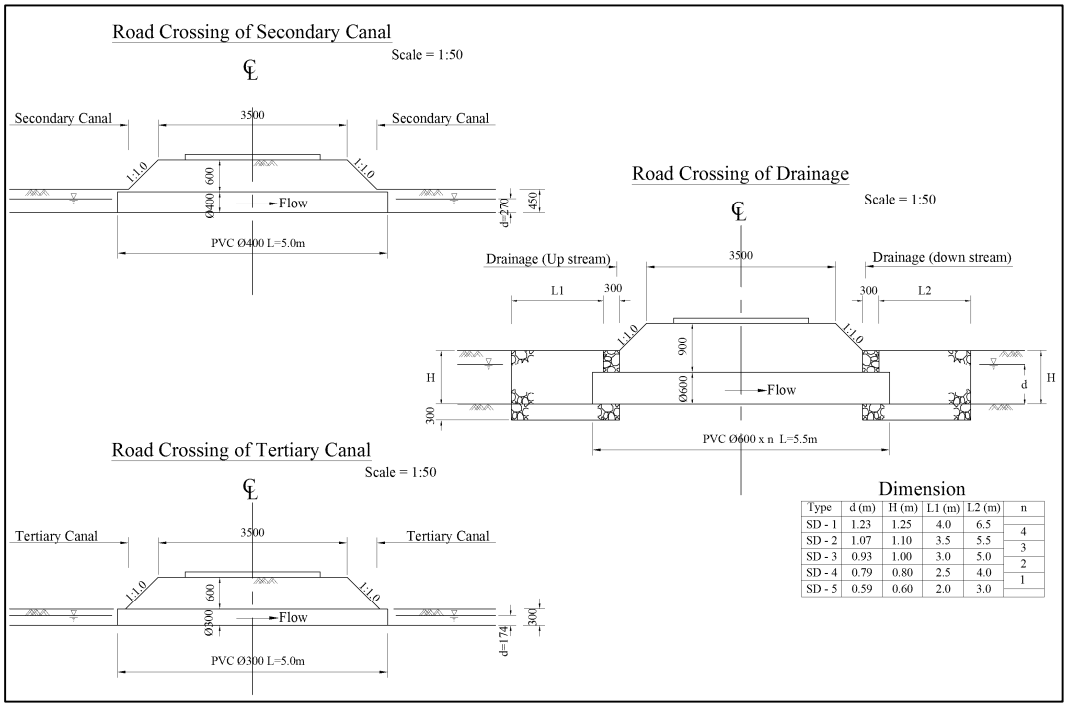



**Figure 9.3 Typical Cross section of Road Crossing in Command Area**

### 4.6 Recommendation

(1) Investigation for Intake Rate

In the future design stage, more investigation is required to carry out the design of upland. For example, the intake rate is very important factor to make a plan of irrigation system. The intake rate is the rate for irrigation water or rainwater infiltration into soil under the specific conditions, and generally measurement in term of mm/hr. As an index of water permeability in unsaturated soil, it is an important factor to be considered in deciding the irrigation method and the appropriate irrigation intensity for upland irrigation. The intake rate is measured either by the cylinder intake rate or by the furrow intake rate, depending on the purpose of the measurement. For furrow irrigation, the intake rate is measured by the furrow intake rate.

(2) Drainage Arrangement Plan

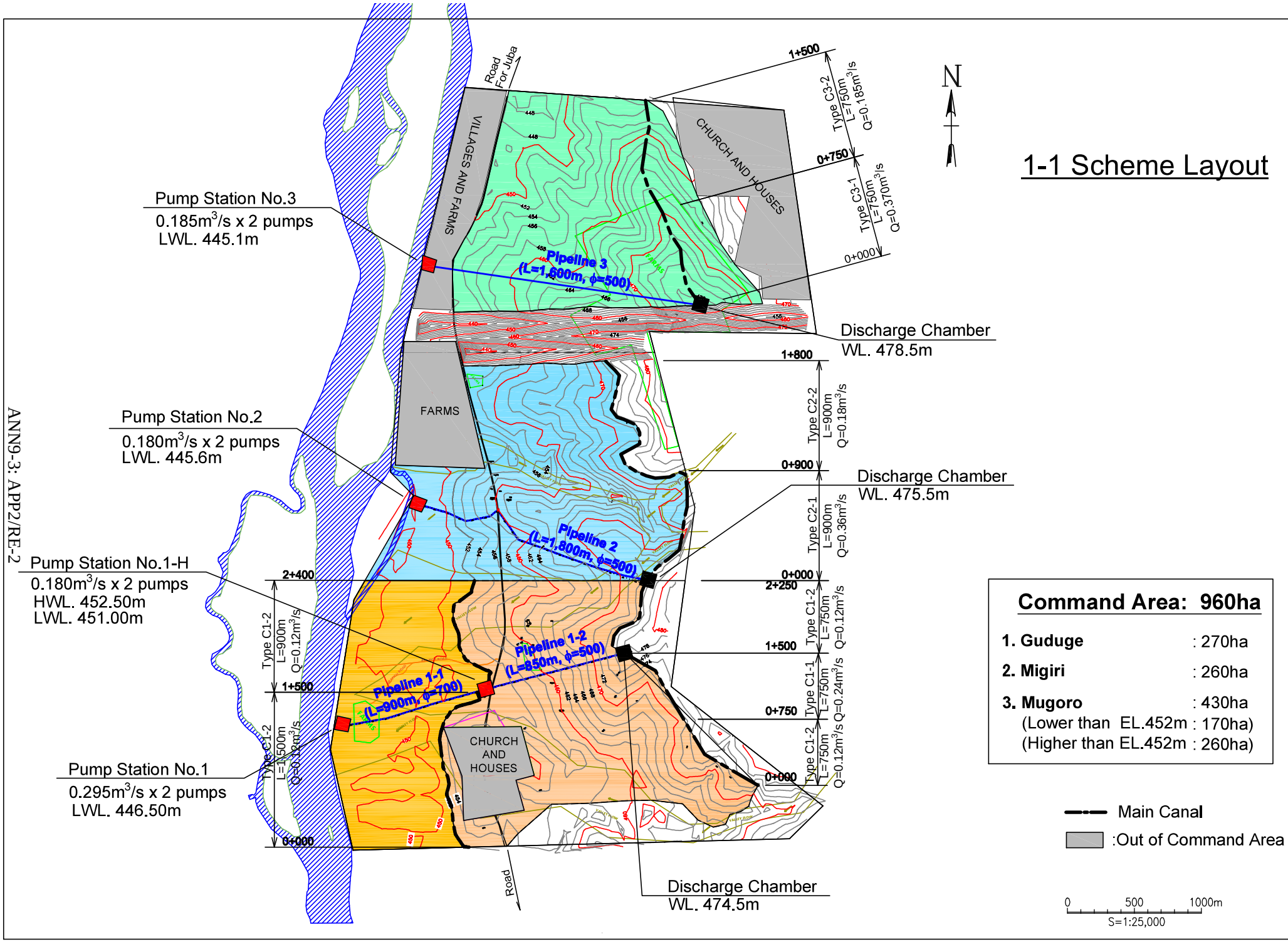
It is necessary to investigate and survey the existing drainage routes and system in the site through the interview to the villagers and the site investigation, before planning the drainage arrangement. After that, the irrigation canal arrangement would be planned on the map.

# APPENDIX - 2

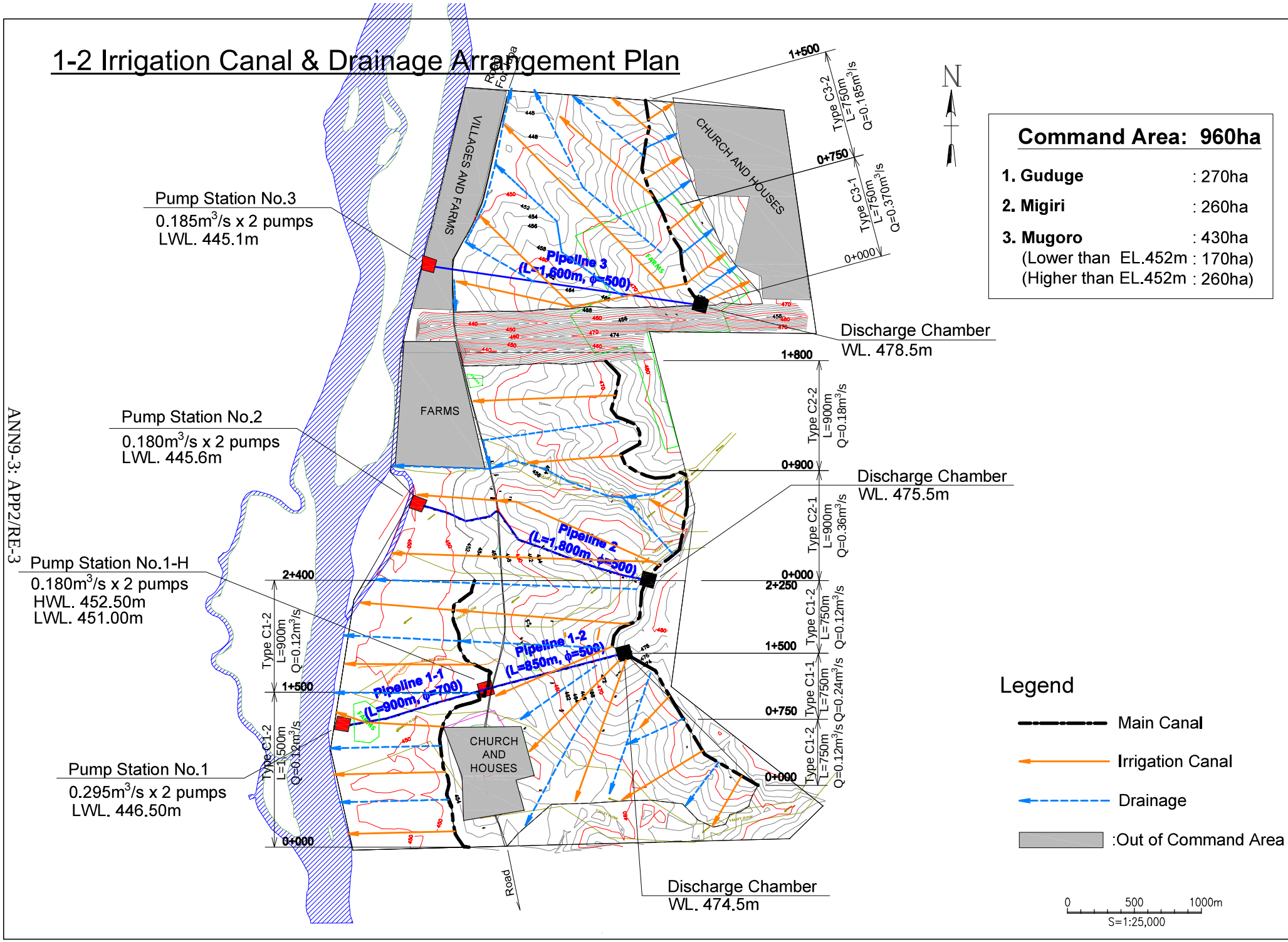
# DRAWINGS

# List of Drawings: Rejaf East Irrigation Scheme

| No. | Name of Drawing | Sheet |
|---|---|---|
| **1. Irrigation Plan** | | |
| 1-1 | Scheme Layout | 1 |
| 1-2 | Irrigation Canal and Drainage Arrangement Plan | 1 |
| **2. Pump Station** | | |
| 2-1 | No.1 Pump Staion | 1 |
| 2-2 | No.1-H Pump Staion | 1 |
| 2-3 | No.2 Pump Staion | 1 |
| 2-4 | No.3 Pump Staion | 1 |
| 2-5 | Discharge Chamber | 1 |
| **3. Pipeline** | | |
| 3-1 | Pipelime No.1Profile | 1 |
| 3-2 | Pipelime No.2 Profile | 1 |
| 3-3 | Pipelime No.3 Profile | 1 |
| **4. Main Irrigation Canal** | | |
| 4-1 | Typical Cross Section of Main Canal | 1 |
| | Total | 11 |


1-1 Scheme Layout
ANN9-3: APP2/RE-2
N
Road For Juba
VILLAGES AND FARMS
CHURCH AND HOUSES
FARMS
CHURCH AND HOUSES
Road
Pump Station No.3
0.185m3/s x 2 pumps
LWL. 445.1m
Pump Station No.2
0.180m3/s x 2 pumps
LWL. 445.6m
Pump Station No.1-H
0.180m3/s x 2 pumps
HWL. 452.50m
LWL. 451.00m
Pump Station No.1
0.295m3/s x 2 pumps
LWL. 446.50m
Pipeline 3
(L=1,600m, ϕ=500)
Pipeline 2
(L=1,800m, ϕ=500)
Pipeline 1-2
(L=850m, ϕ=500)
Pipeline 1-1
(L=900m, ϕ=700)
Discharge Chamber
WL. 478.5m
Discharge Chamber
WL. 475.5m
Discharge Chamber
WL. 474.5m
1+500
Type C3-2
L=750m
Q=0.185m3/s
0+750
Type C3-1
L=750m
Q=0.370m3/s
0+000
1+800
Type C2-2
L=900m
Q=0.18m3/s
0+900
Type C2-1
L=900m
Q=0.36m3/s
0+000
2+400
Type C1-2
L=900m
Q=0.12m3/s
1+500
Type C1-2
L=1,500m
Q=0.12m3/s
0+000
2+250
Type C1-2
L=750m
Q=0.12m3/s
1+500
Type C1-1
L=750m
Q=0.24m3/s
0+750
Type C1-2
L=750m
Q=0.12m3/s
0+000
Command Area: 960ha
1. Guduge : 270ha
2. Migiri : 260ha
3. Mugoro : 430ha
(Lower than EL.452m : 170ha)
(Higher than EL.452m : 260ha)
Main Canal
:Out of Command Area
0 500 1000m
S=1:25,000

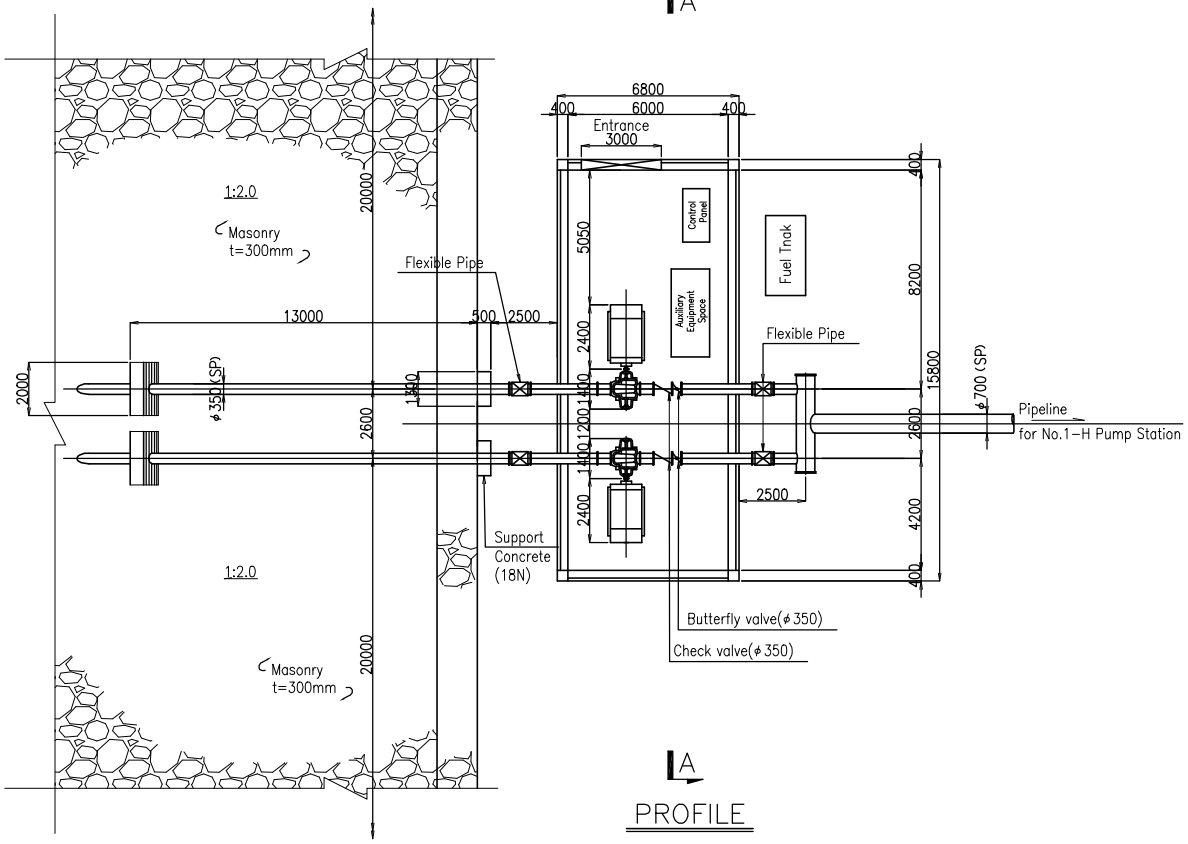
# 1-2 Irrigation Canal & Drainage Arrangement Plan



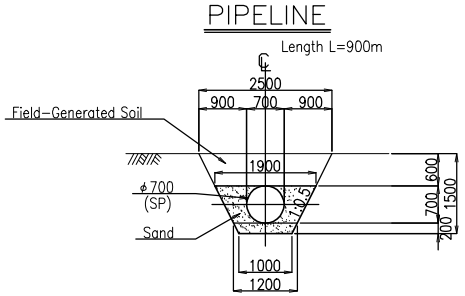

ANN9-3: APP2/RE-3

# 2-1 NO.1 PUMP STATION

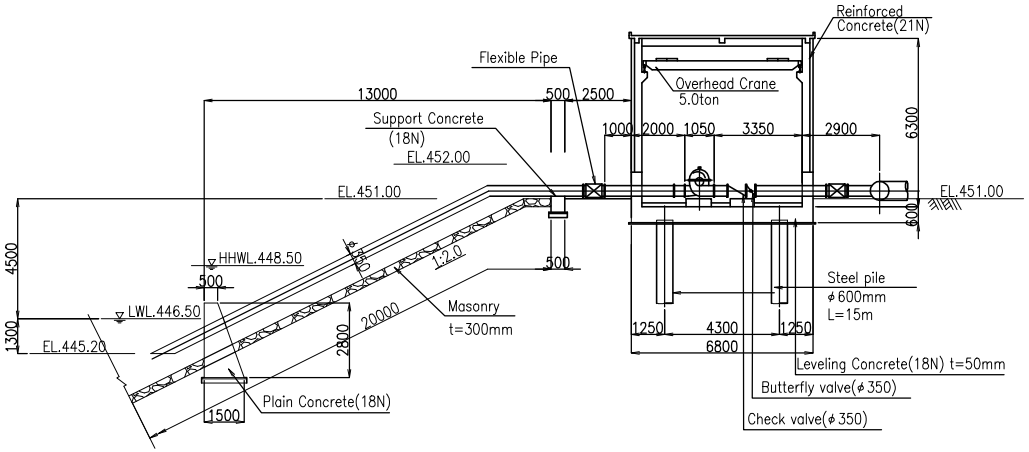
## PLAN



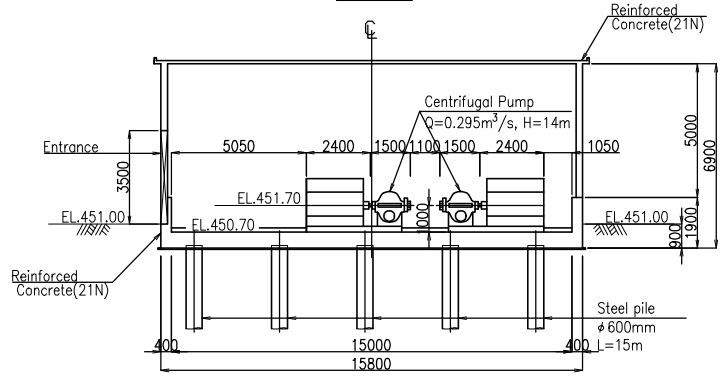

## PIPELINE

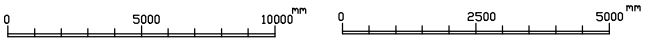



## PROFILE




## A-A

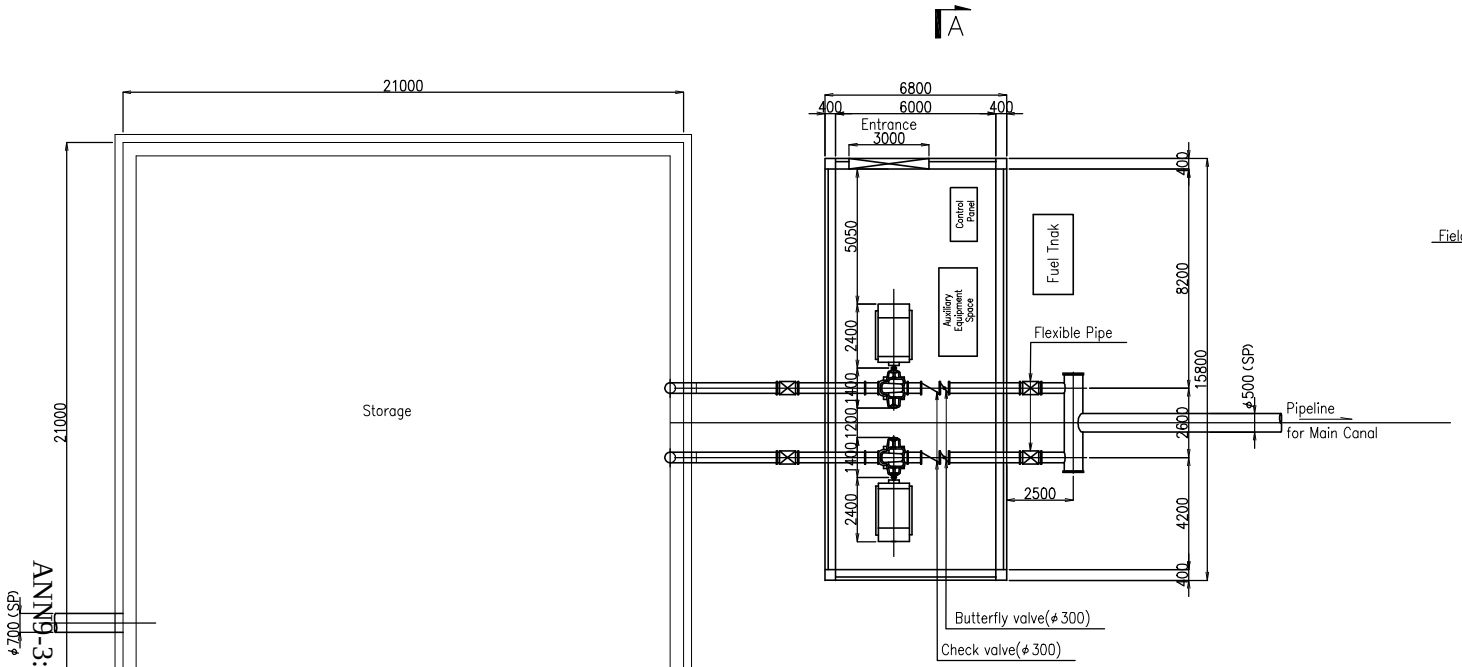


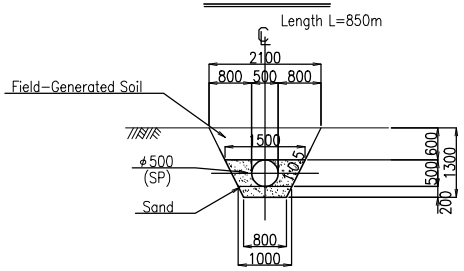

ANN9-3: APP2/RE-4

ANNEX-3: APP2/RE-5

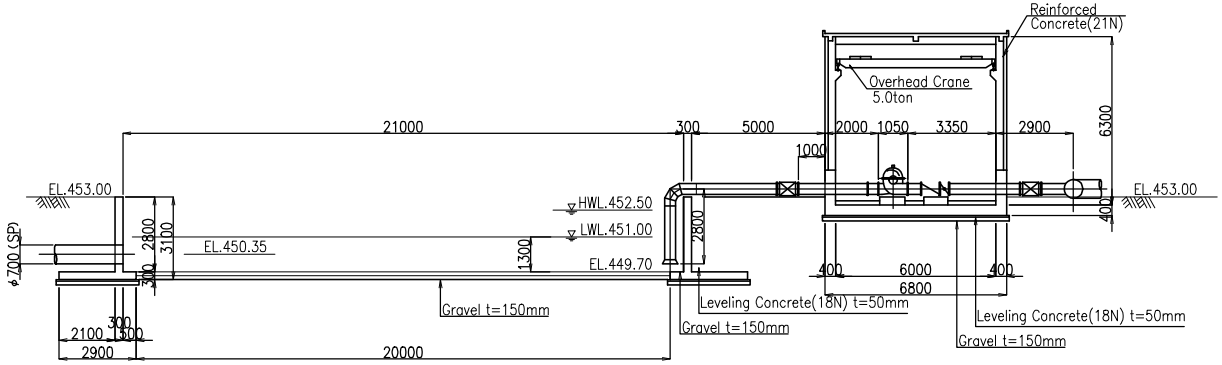
# PLAN 2-2 NO.1-H PUMP STATION



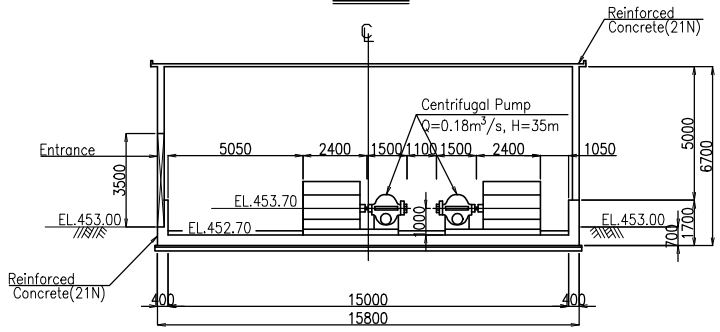

## PIPELINE

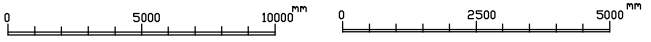



## PROFILE




## A-A

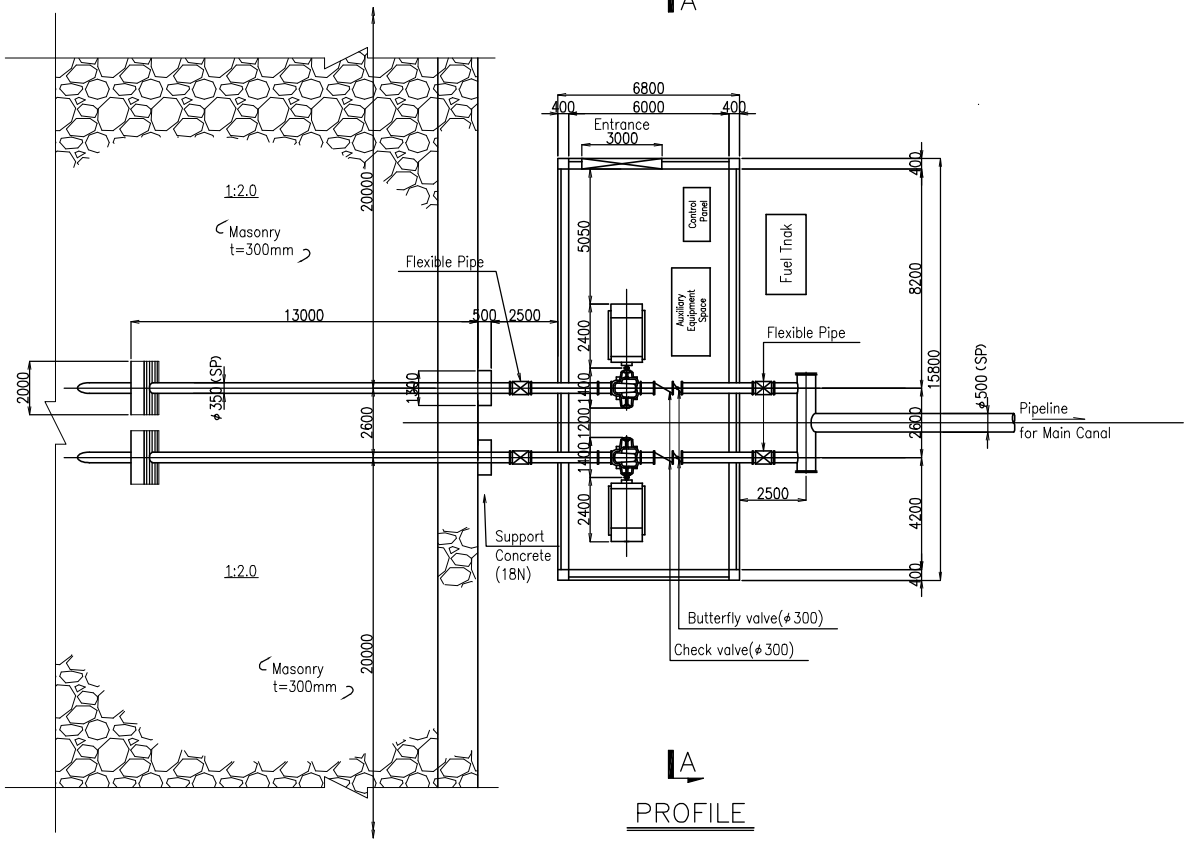


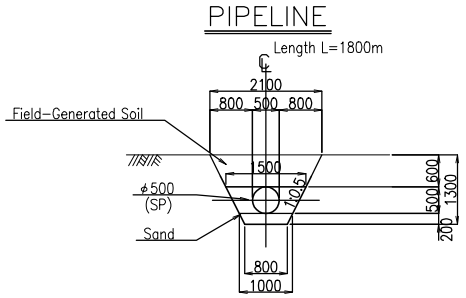
# 2-3 NO.2 PUMP STATION

ANN9-3: APP2/RE-6

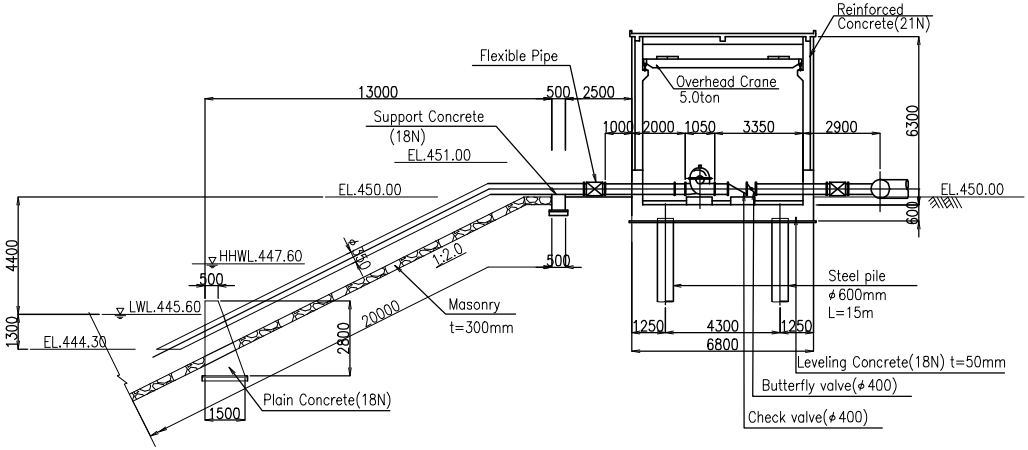
## PLAN



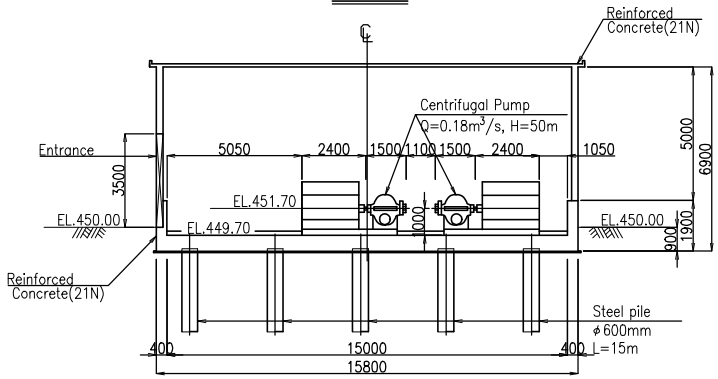

## PIPELINE

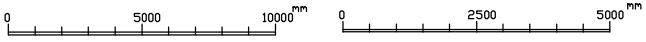



## PROFILE



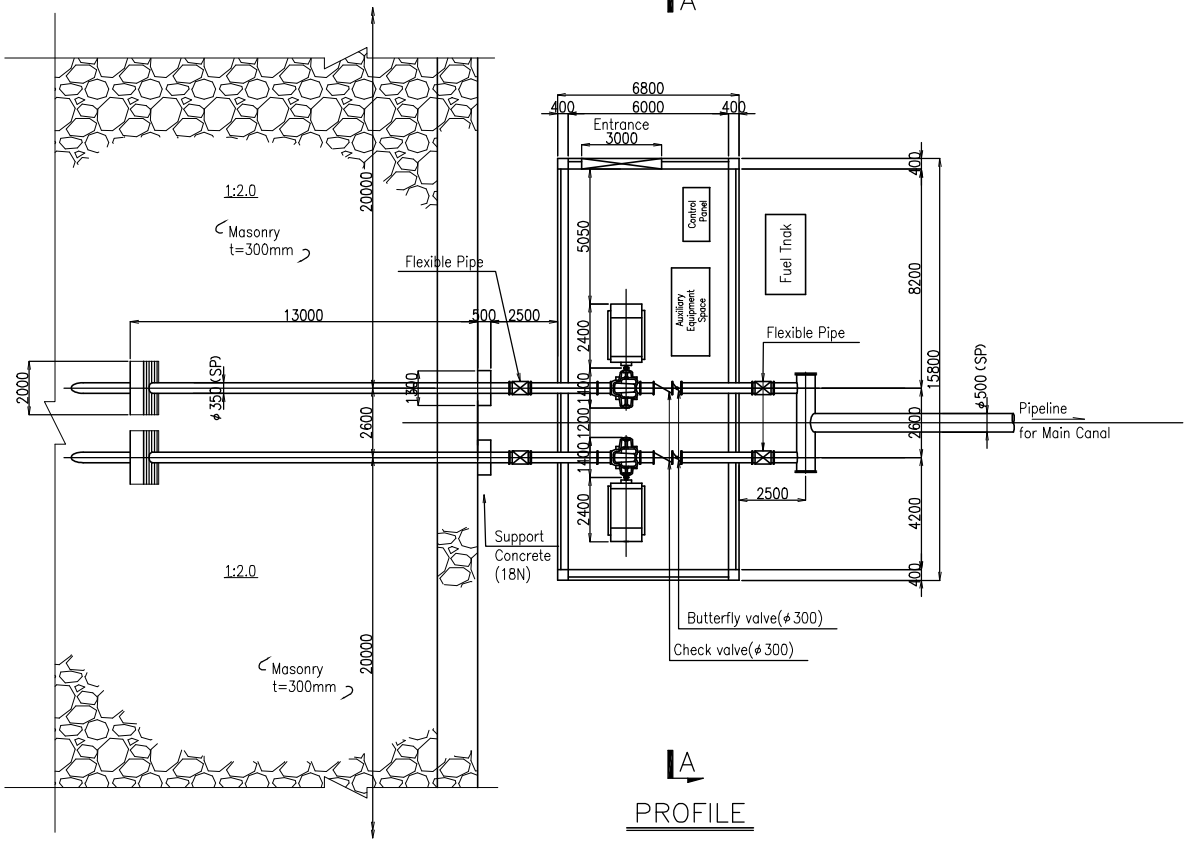

## A—A



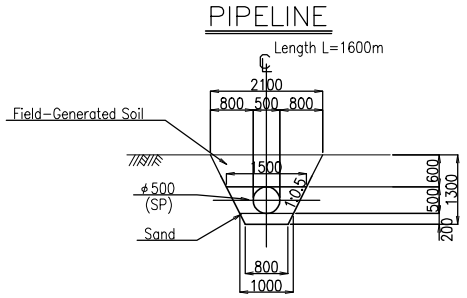



# 2-4 NO.3 PUMP STATION

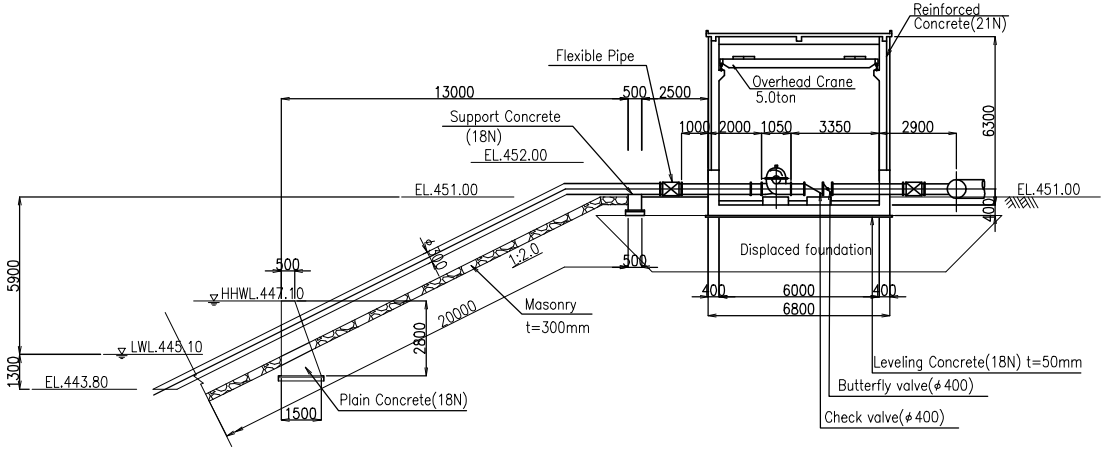
## PLAN



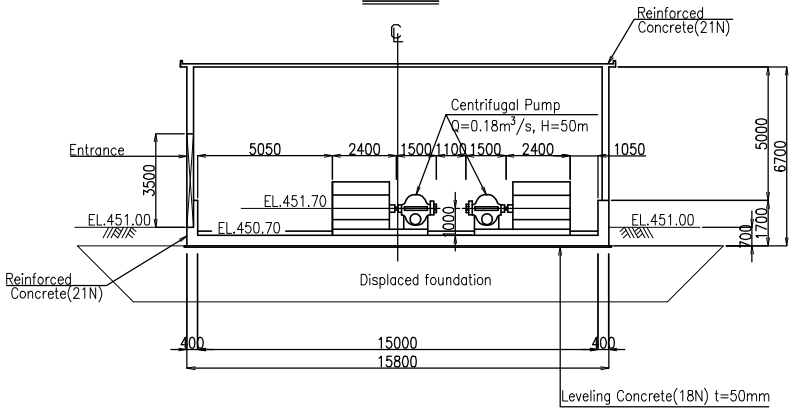

## PIPELINE

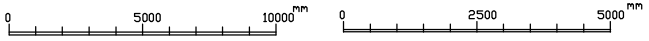



## PROFILE




## A-A



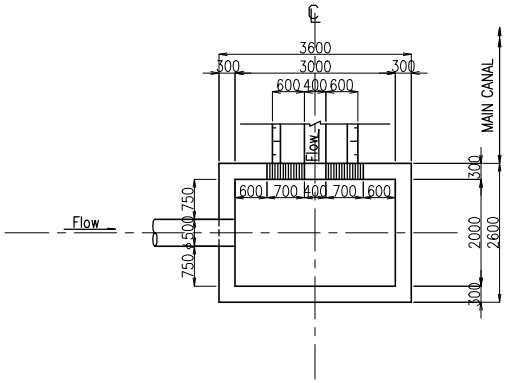




ANN9-3: APP2/RE-7

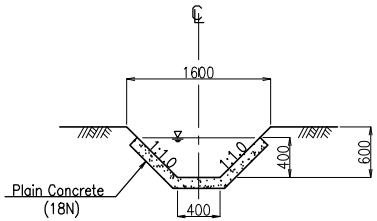
# 2-5 DISCHARGE CHAMBER



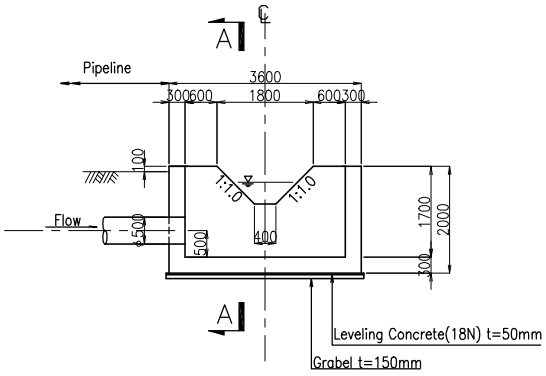
## PLAN



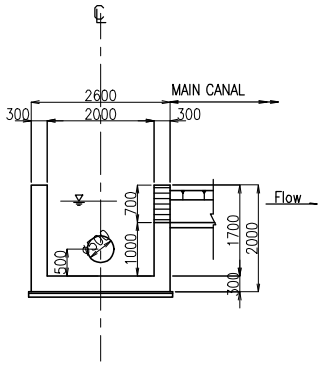

## CANAL

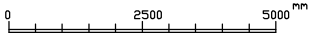



## PROFILE

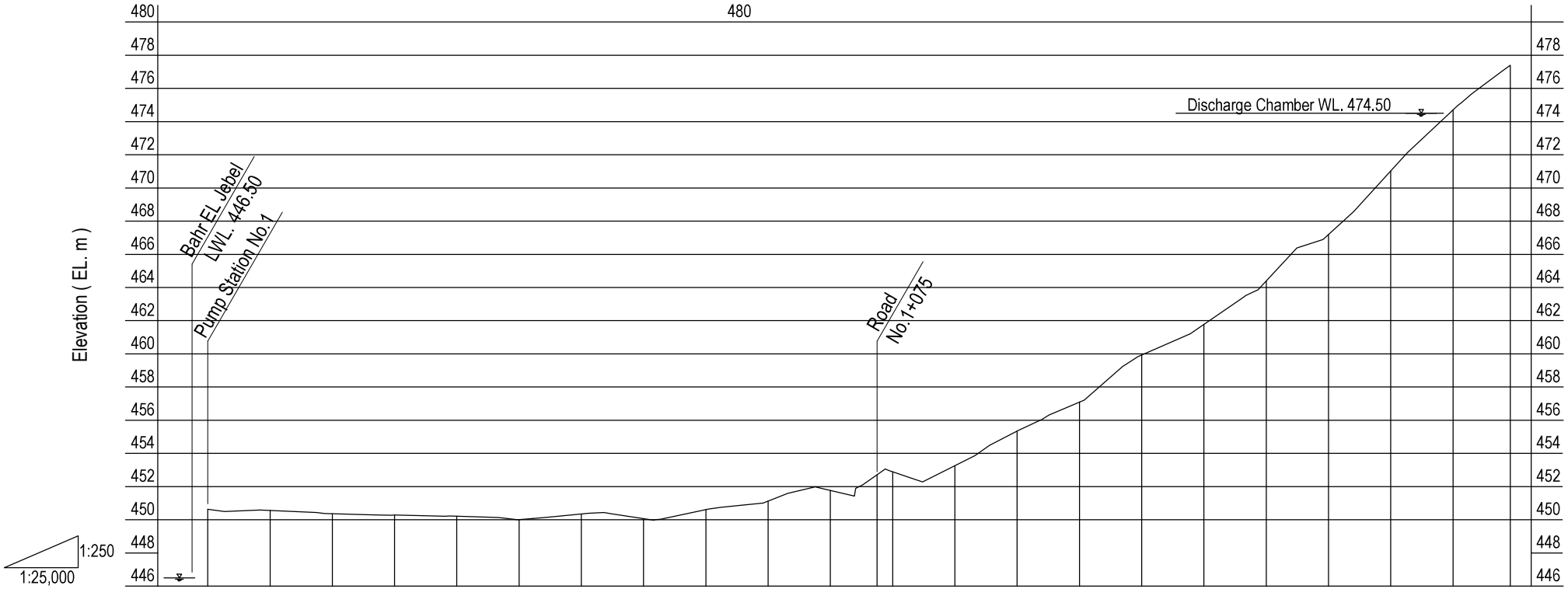



## A–A



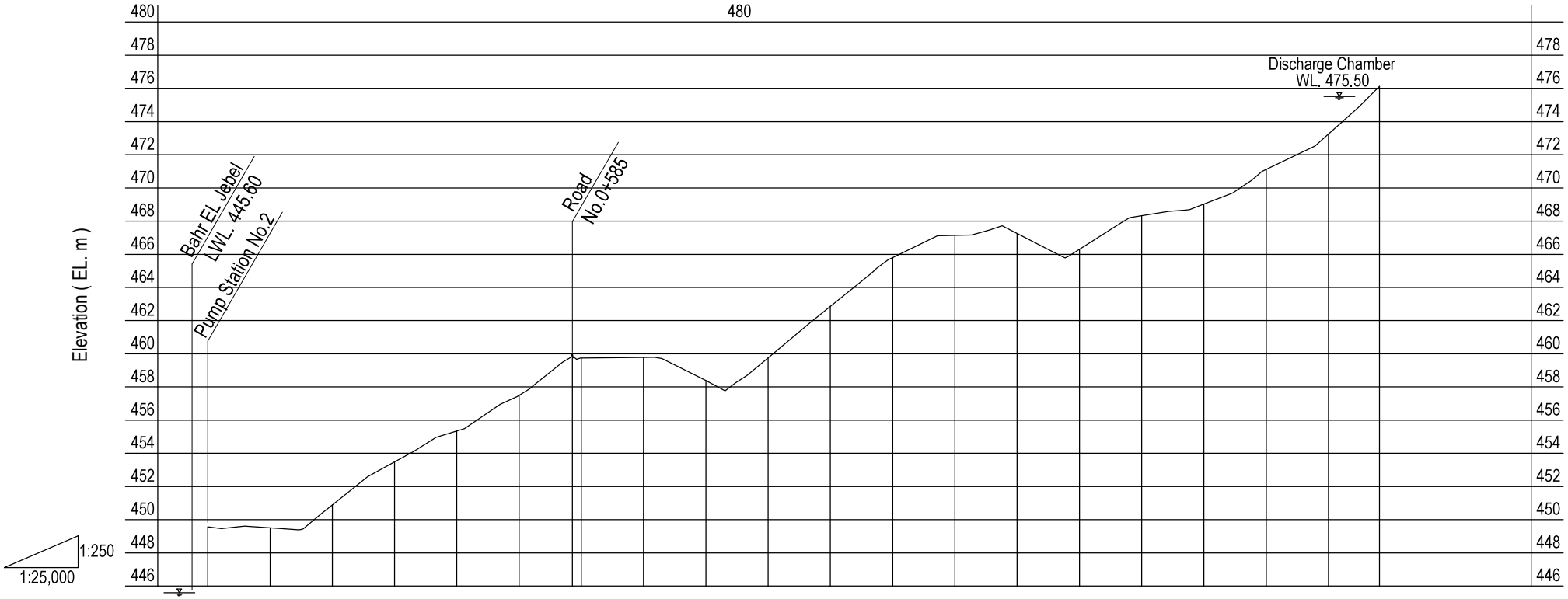
# 3-1 Pipeline No.1 Profile




ANN9-3: APP2/RE-9

| | | 0+000 | 0+100 | 0+200 | 0+300 | 0+400 | 0+500 | 0+600 | 0+700 | 0+800 | 0+900 | 1+000 | 1+100 | 1+200 | 1+300 | 1+400 | 1+500 | 1+600 | 1+700 | 1+800 | 1+900 | 2+000 | 2+092 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PLAN | | | | | | | | | | | | | | | | | | | | | | | |
| PRESENT | GROUND LEVEL | 450.64 | 450.58 | 450.38 | 450.30 | 450.23 | 450.02 | 450.35 | 450.07 | 450.63 | 451.14 | 451.77 | 452.89 | 453.26 | 455.36 | 457.10 | 459.94 | 461.78 | 464.40 | 467.19 | 471.04 | 474.70 | 477.40 |
| | STATION NO. | | | | | | | | | | | | | | | | | | | | | | |

# 3–2 Pipeline No.2 Profile




ANN9-3: APP2/RE-10

| | | 0+000 | 0+100 | 0+200 | 0+300 | 0+400 | 0+500 | 0+600 | 0+700 | 0+800 | 0+900 | 1+000 | 1+100 | 1+200 | 1+300 | 1+400 | 1+500 | 1+600 | 1+700 | 1+800 | 1+882 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRESENT | STATION NO. | 0+000 | 0+100 | 0+200 | 0+300 | 0+400 | 0+500 | 0+600 | 0+700 | 0+800 | 0+900 | 1+000 | 1+100 | 1+200 | 1+300 | 1+400 | 1+500 | 1+600 | 1+700 | 1+800 | 1+882 |
| | GROUND LEVEL | 449.56 | 449.51 | 450.89 | 453.50 | 455.35 | 457.50 | 459.75 | 459.79 | 458.39 | 459.76 | 462.87 | 465.80 | 467.14 | 467.25 | 466.30 | 468.33 | 469.03 | 471.11 | 473.25 | 476.12 |
| PLAN | | | | | | | | | | | | | | | | | | | | | |

# 3-3 Pipeline No.3

ANN9-3: APP2/RE-11

This Profile surveyed in June (Contract) is different from the route of desined pipline.

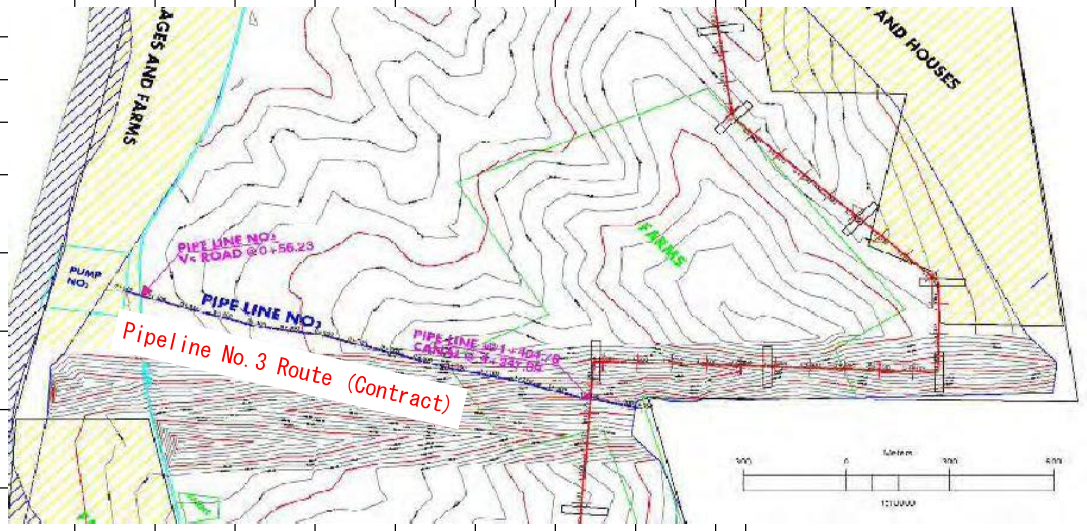
Elevation ( EL. m )

480 478 476 474 472 470 468 466 464 462 460 458 456 454 452 450 448 446

Road No.0+050

1:250

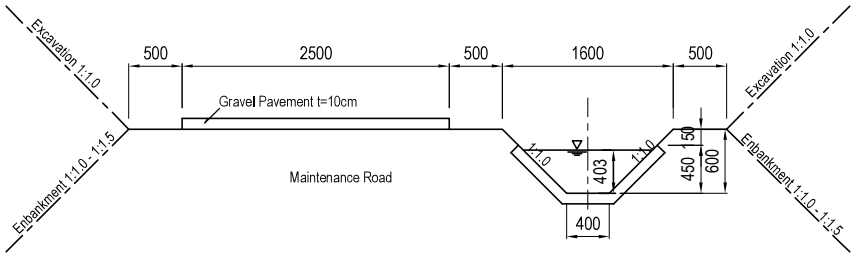
1:25,000



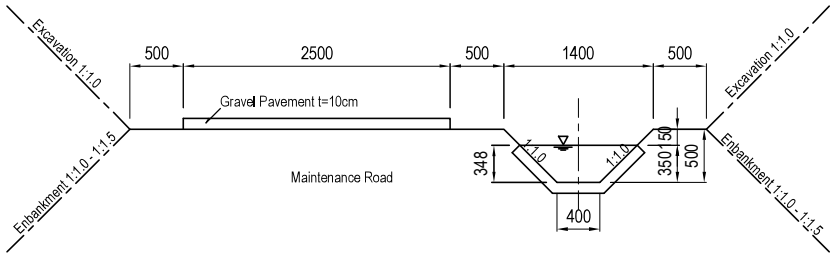

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRESENT | STATION NO. | 0+000 | 0+100 | 0+200 | 0+300 | 0+400 | 0+500 | 0+600 | 0+700 | 0+800 | 0+900 | 1+000 | 1+100 | 1+200 | 1+300 | 1+400 | 1+500 | 1+558 |
| | GROUND LEVEL | 451.98 | 452.34 | 453.94 | 456.43 | 458.09 | 458.94 | 461.01 | 463.46 | 463.77 | 460.95 | 458.39 | 456.00 | 460.83 | 466.38 | 470.92 | 473.66 | 473.14 |
| PLAN | | | | | | | | | | | | | | | | | | | |

# 4–1 Typical Cross Section

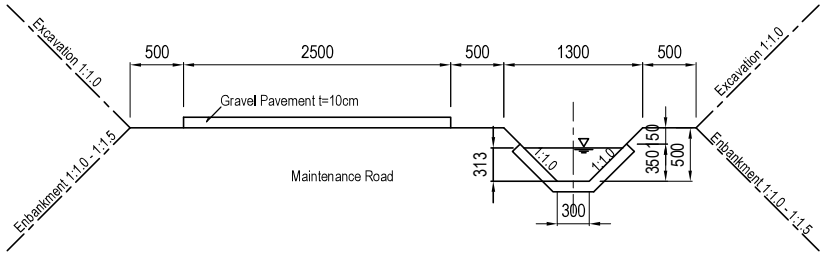
TYPE C1-1 (Q=0.24m3/s, L=750m)



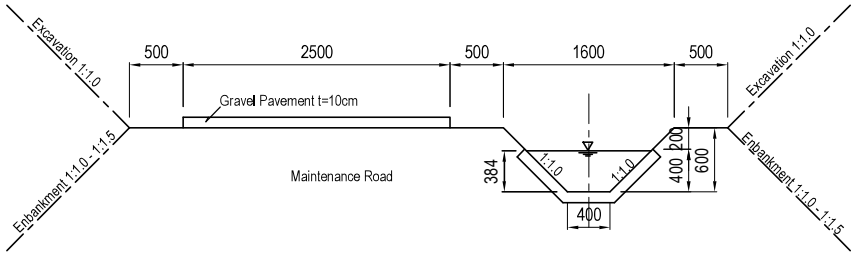

TYPE C2-2 (Q=0.18m3/s, L=900m)



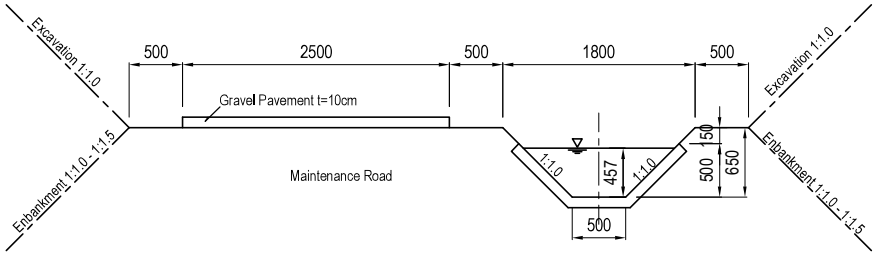

TYPE C1-2 (Q=0.12m3/s, L=3,900m)
(Hillside: 1500m, Riverside: 2,400m)



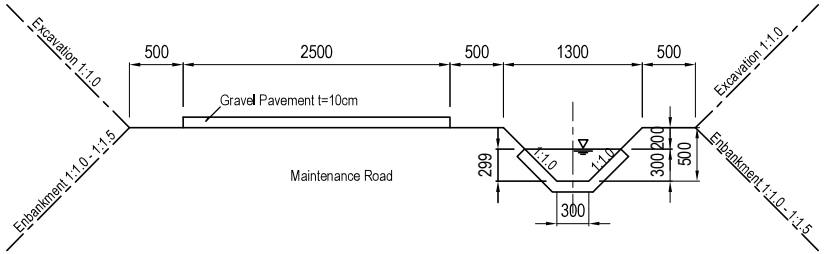

TYPE C3-1 (Q=0.30m3/s, L=750m)




TYPE C2-1 (Q=0.36m3/s, L=900m)




TYPE C3-2 (Q=0.15m3/s, L=750m)




ANN9-3: APP2/RE-12

# APPENDIX - 3

# PROJECT INVESTMENT COST

### 3.1 Project Investment Cost

## Rejaf East Irrigation Scheme

**Project Cost 23 million US$**

| No. | Work Description | Unit | Quantity | Price (1000 US$) | Total (1000 US$) |
|---|---|---|---|---|---|
| **1. Works** | | | | | |
| 1-1. | Pump Station | LS. | 1 | 4,418 | 4,418 |
| 1-2. | Pipeline Work | LS. | 1 | 2,450 | 2,450 |
| 1-3. | Main Irrigation Canal | LS. | 1 | 1,390 | 1,390 |
| 1-4. | Facilities in Command Area | ha | 960 | 6.0 | 5,760 |
| | | | | **Total** | 14,018 |
| | **Direct Construction Cost (A)** | | | | **14,018** |
| | **Indirect Construction Cost (B = A * 45%)** | | | | **6,308** |
| | | **C = A + B** | | | **20,326** |
| | **Adminiostration (D = C * 4%)** | | | | **813** |
| | **Consultant Fee (E = C * 5%)** | | | | **1,016** |
| | **Physical Contingency (F = C * 5%)** | | | | **1,016** |
| | **Grand Total Cost (F = C + D + E)** | | | | **23,171** |
| | | | | | **23,000** |
| | | | | | **(*1000 US$)** |
| | | | | FC. (60%) | **13,800** |
| | | | | LC. (40%) | **9,200** |
| | | | | | **(*1000 US$)** |
| | | ha | 23 million US$ / 960ha = | | **24,000** |
| | | | | | **(US$)** |

### 3.2 Pumping Station & Pipeline Works

## Rejaf-East Irrigation Scheme

**Pump Statoin & Pipeline Works 6.9 million US$**

| No. | Work Description | Unit | Quantity | Price (1000 US$) | Total (1000 US$) |
|---|---|---|---|---|---|
| No.1 Pump Station (Mugoro) | | | | | |
| 1. | Pump Building | LS. | 1 | 309 | 309 |
| 2. | Pump Equipment | LS. | 1 | 784 | 784 |
| 3. | Slop Protectioon | LS. | 1 | 44 | 44 |
| 4. | Pipelin Work ( $\phi$ 700, L=900m) | LS. | 1 | 507 | 507 |
| | | | | Sub-total | 1,644 |
| **No.1-H Pump Station (Mugoro)** | | | | | |
| 1. | Pump Building | LS. | 1 | 305 | 305 |
| 2. | Pump Equipment | LS. | 1 | 669 | 669 |
| 3. | Storage | LS. | 1 | 152 | 152 |
| 4. | Pipelin Work ( $\phi$ 500, L=850m) | LS. | 1 | 377 | 377 |
| 5. | Discharge Chamber | LS. | 1 | 18 | 18 |
| | | | | Sub-total | 1,521 |
| **No.2 Pump Station (Migiri)** | | | | | |
| 1. | Pump Building | LS. | 1 | 309 | 309 |
| 2. | Pump Equipment | LS. | 1 | 724 | 724 |
| 3. | Slop Protectioon | LS. | 1 | 44 | 44 |
| 4. | Pipelin Work ( $\phi$ 500, L=1800m) | LS. | 1 | 799 | 799 |
| 5. | Discharge Chamber | LS. | 1 | 18 | 18 |
| | | | | Sub-total | 1,894 |
| **No.3 Pump Station (Guduge)** | | | | | |
| 1. | Pump Building | LS. | 1 | 314 | 314 |
| 2. | Pump Equipment | LS. | 1 | 719 | 720 |
| 3. | Slop Protectioon | LS. | 1 | 44 | 44 |
| 4. | Pipelin Work ( $\phi$ 500, L=1600m) | LS. | 1 | 713 | 713 |
| 5. | Discharge Chamber | LS. | 1 | 18 | 18 |
| | | | | Sub-total | 1,809 |
| | | | | | |
| | | | | **Total** | **6,868** |
| | | | | | |
| | | | | Pump Station | 4,418 |
| | | | | Pipeline Work | 2,450 |

### 3.2 (1) Pump No.1 Station and Pipeline Works

## Rejaf East Irrigation Scheme

**No.1 Pump Statoin & Pipeline Works 1.6 million US$**

| No. | Work Description | Unit | Quantity | Unit Price (US$) | Total (US$) |
|---|---|---|---|---|---|
| **1. No.1 Pump Station Work** | | | | | |
| **1-1.** | **Pump Building(No.1)** | | | | |
| 1-1-1. | Common Excavation | m3 | 368 | 10.0 | 3,675 |
| 1-1-2. | Leveling Concrete | m3 | 6 | 350.0 | 1,960 |
| 1-1-3. | Backfill | m3 | 265 | 11.0 | 2,918 |
| 1-1-4. | Building | m2 | 107 | 2,800.0 | 300,832 |
| | | | | Sub total | 309,385 |
| **1-2.** | **Pump Eqipment** | | | | |
| 1-2-1 | Pump Facilities (Pump, Engne & Auxiliary equipment) | nos | 2 | 250,000.0 | 500,000 |
| 1-2-2. | Pipe(SP, ű350) | m | 49 | 240.0 | 11,683 |
| 1-2-3. | Control Panel | nos | 1 | 86,500.0 | 86,500 |
| 1-2-4. | Overhead Crane(5ton) | nos | 1 | 77,900.0 | 77,900 |
| 1-2-5. | Butterfly valve(ű350) | nos | 2 | 15,000.0 | 30,000 |
| 1-2-6. | Check valve(ű350) | nos | 2 | 13,000.0 | 26,000 |
| 1-2-7. | Flexible tube(ű350) | nos | 4 | 3,800.0 | 15,200 |
| 1-2-8. | Steel pile(ű600, L=15m) | nos | 10 | 3,600.0 | 36,000 |
| | | | | Sub total | 783,283 |
| **1-3.** | **Slope protection** | | | | |
| 1-3-1. | Masonry | m3 | 256 | 140.0 | 35,784 |
| 1-3-2. | Support Concrete (18N) | m3 | 12 | 350.0 | 4,193 |
| 1-3-3. | Leveling Concrete | m3 | 1 | 350.0 | 350 |
| 1-3-4. | Gravel | m3 | 1 | 50.0 | 72 |
| 1-2-5. | Temporary Works (River Close) 10% of above sum | L.S | 1 | | 4,000 |
| | | | | Sub total | 44,399 |
| **2. Pipeline Work** | | | | | |
| **2-1.** | **Pipeline(φ700)** | | | | |
| 2-1-1. | Common Excavation | m3 | 2,363 | 10.0 | 23,625 |
| 2-1-2. | Sand(under) | m3 | 198 | 24.0 | 4,752 |
| 2-1-3. | Sand(around) | m3 | 630 | 24.0 | 15,128 |
| 2-1-4. | Backfill | m3 | 1,188 | 11.0 | 13,068 |
| 2-1-5. | Pipe(SP, ű700) | m | 900 | 500.0 | 450,000 |
| | | | | Sub total | 506,573 |
| | | | | | |
| | | | **Direct cost** | **Total** | **1,643,640** |
| | | | | | |
| | | | **Pump Station** | | **1,137,067** |
| | | | **Pipeline** | | **506,573** |

# Quantity Calculation

Irrigation Scheme : Scheme
Item of Work : Pump Station Work



| Item | Calculation | | Quantity | Unit | Remark |
|---|---|---|---|---|---|
| **1. Pump Station Work** | | | | | |
| **1-1. Pump Building(No.1)** | | | | | |
| 1-1-1. Common Excavation | 1/2*(7.80*16.80+9.20*18.20)*0.60+(7.00*16.00*0.20) | = 111.94 | | | |
| | 20.00*(20.00+2.60+20.00)*0.3 | = 255.60 | | | |
| | | 367.54 | 367.54 | m3 | |

Irrigation Scheme : Scheme
Item of Work : Pump Station Work



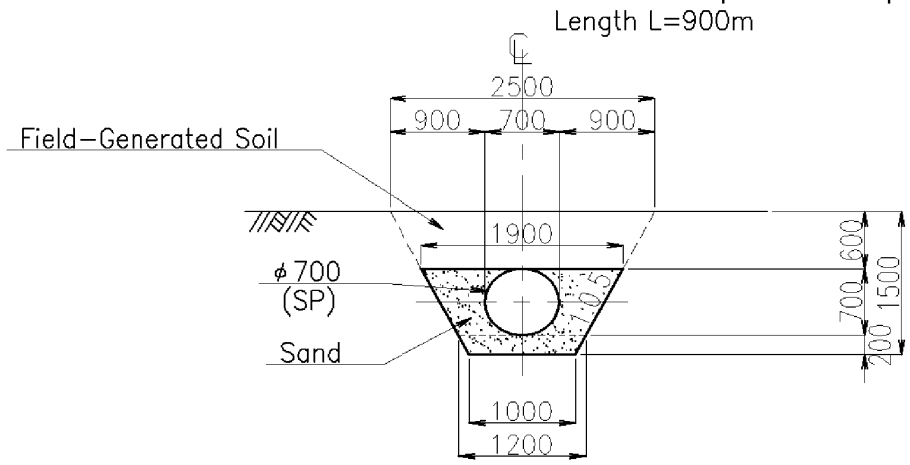
| Item | Calculation | | | Quantity | Unit | Remark |
|---|---|---|---|---|---|---|
| 1-1-2. Leveling Concrete | 7.00*16.00*0.05 | = | | 5.60 | m3 | |
| 1-1-3. Backfill | 367.54-5.60-(6.80*15.80*0.90) | = | | 265.24 | m3 | |
| 1-1-4. Building | 6.80*15.80 | = | | 107.44 | m2 | |
| **1-2. Pump Equipment** | | | | | | |
| 1-2-1 Pump Facilities (Pump, Engne & Auxiliary equipment) | | | | 2.00 | nos | |
| 1-2-2. Pipe(SP, $\phi$ 350) | 2*(13.64+3.55+3.00+0.60+3.55) | = | | 48.68 | m | φ350、SP |
| 1-2-3. Control Panel | | | | 1.00 | nos | |
| 1-2-4. Overhead Crane(5ton) | | | | 1.00 | nos | |
| 1-2-5. Butterfly valve(φ350) | | | | 2.00 | nos | |
| 1-2-6. Check valve(φ350) | | | | 2.00 | nos | |
| 1-2-7. Flexible tube(φ350) | | | | 4.00 | nos | |
| 1-2-8. Steel pile( $\phi$ 600, L=15m) | 2*5 | | | 10.00 | nos | |
| **1-3. Slope protection** | | | | | | |
| 1-3-1. Masonry | 20.00*(20.00+2.6+20.00)*0.30 | | | 255.60 | m3 | |
| 1-3-2. Support Concrete (18N) | 2*{1/2*(0.50+1.50)*2.80*2.00} | = | 11.20 | | | |
| | 2*(0.50*0.60*1.30) | = | 0.78 | | | |
| | | | 11.98 | 11.98 | m3 | |
| 1-3-3. Leveling Concrete | 2*(1.70*2.20*0.05+0.70*1.50*0.05) | = | | 0.48 | m3 | |
| 1-3-4. Gravel | 2*(1.70*2.20*0.15+0.70*1.50*0.15) | = | | 1.44 | m3 | |

# Quantity Calculation

Irrigation Scheme : Scheme
Item of Work : Pipeline Work



| Item | Calculation | | Quantity | Unit | Remark |
|---|---|---|---|---|---|
| **2. Pipeline Work** | | | | | |
| **2-1. Pipeline(φ700)** | | | | | |
| 2-1-1. Common Excavation | 1/2*(2.50+1.00)*1.50*900.00 | = | 2,362.50 | m3 | |
| 2-1-2. Sand(under) | 1/2*(1.20+1.00)*0.20*900.00 | = | 198.00 | m3 | |
| 2-1-3. Sand(around) | {1/2*(1.90+1.20)*0.70-0.70^2* π /4}*900.00 | = | 630.32 | m3 | |
| 2-1-4. Backfill | 1/2*(2.50+1.90)*0.60*900.00 | = | 1,188.00 | m3 | |
| 2-1-5. Pipe(SP, φ 700) | | = | 900.00 | m | |



### 3.2 (2) Pump No.1-H Station and Pipeline Works

## Rejaf East Irrigation Scheme

**No.1-H Pump Statoin & Pipeline Works** **1.5** **million US$**

| No. | Work Description | Unit | Quantity | Unit Price (US$) | Total (US$) |
|---|---|---|---|---|---|
| **1. No.1-H Pump Station Work** | | | | | |
| **1-1.** | **Pump Building(No.1-H)** | | | | |
| 1-1-1. | Common Excavation | m3 | 127 | 10.0 | 1,269 |
| 1-1-2. | Leveling Concrete | m3 | 6 | 350.0 | 1,960 |
| 1-1-3. | Gravel | m3 | 17 | 50.0 | 840 |
| 1-1-4. | Backfill | m3 | 29 | 11.0 | 322 |
| 1-1-5. | Building | m2 | 107 | 2,800.0 | 300,832 |
| | | | | Sub total | 305,223 |
| **1-2.** | **Pump Eqipment** | | | | |
| 1-2-1. | Pump Facilities (Pump, Engne & Auxiliary equipment) | nos | 2 | 220,000.0 | 440,000 |
| 1-2-2. | Pipe(SP, ű300) | m | 26 | 220.0 | 5,764 |
| 1-2-3. | Control Panel | nos | 1 | 86,500.0 | 86,500 |
| 1-2-4. | Overhead Crane(5ton) | nos | 1 | 77,900.0 | 77,900 |
| 1-2-5. | Butterfly valve(ű300) | nos | 2 | 13,000.0 | 26,000 |
| 1-2-6. | Check valve(ű300) | nos | 2 | 10,000.0 | 20,000 |
| 1-2-7. | Flexible tube(ű300) | nos | 4 | 3,100.0 | 12,400 |
| | | | | Sub total | 668,564 |
| **1-3.** | **Storage** | | | | |
| 1-3-1. | Common Excavation | m3 | 3,418 | 10.0 | 34,182 |
| 1-3-2. | Leveling Concrete | m3 | 11 | 350.0 | 3,903 |
| 1-3-3. | Gravel | m3 | 93 | 50.0 | 4,673 |
| 1-3-4. | Backfill | m3 | 1,652 | 11.0 | 18,177 |
| 1-3-5. | Reinforced Concrete | m3 | 206 | 440.0 | 90,596 |
| | | | | Sub total | 151,531 |
| **2. Pipeline Work** | | | | | |
| **2-1.** | **Pipeline(φ500)** | | | | |
| 2-1-1. | Common Excavation | m3 | 1,602 | 10.0 | 16,023 |
| 2-1-2. | Sand(under) | m3 | 153 | 21.2 | 3,244 |
| 2-1-3. | Sand(around) | m3 | 364 | 21.2 | 7,726 |
| 2-1-4. | Backfill | m3 | 918 | 11.0 | 10,098 |
| 2-1-5. | Pipe(SP, ű500) | m | 850 | 400.0 | 340,000 |
| | | | | Sub total | 377,091 |
| **2-2.** | **Discharge Chamber** | | | | |
| 2-2-1. | Common Excavation | m3 | 375 | 10.0 | 3,751 |
| 2-2-2. | Leveling Concrete | m3 | 1 | 350.0 | 448 |
| 2-2-3. | Gravel | m3 | 4 | 50.0 | 192 |
| 2-2-4. | Backfill | m3 | 243 | 11.0 | 2,676 |
| 2-2-5. | Reinforced Concrete | m3 | 26 | 440.0 | 11,238 |
| | | | | Sub total | 18,305 |
| | | | | | |
| | | | **Direct cost** | **Total** | **1,520,714** |
| | | | | | |
| | | | **Pump Station** | | **618,745** |
| | | | **Pipeline** | | **901,969** |

# Quantity Calculation

Irrigation Scheme : Scheme
Item of Work : Pump Station Work



| Item | Calculation | | Quantity | Unit | Remark |
|---|---|---|---|---|---|
| **1. Pump Station Work** | | | | | |
| **1-1. Pump Building(No.1-H)** | | | | | |
| 1-1-1. Common Excavation | 1/2*(7.80*16.80+9.20*18.20)*0.70+(7.00*16.00*0.20) | = 126.87 | | | |
| | | 126.87 | 126.87 | m3 | |

Irrigation Scheme : Scheme
Item of Work : Pump Station Work



| Item | Calculation | | Quantity | Unit | Remark |
|---|---|---|---|---|---|
| 1-1-2. Leveling Concrete | 7.00*16.00*0.05 | = | 5.60 | m3 | |
| 1-1-3. Gravel | 7.00*16.00*0.15 | = | 16.80 | m3 | |
| 1-1-4. Backfill | 126.87-5.60-16.80-(6.80*15.80*0.70) | = | 29.26 | m3 | |
| 1-1-5. Building | 6.80*15.80 | = | 107.44 | m2 | |
| **1-2. Pump Building(No.1-H)** | | | | | |
| 1-2-1. Pump Facilities (Pump, Engne & Auxiliary equipment) | | | 2.00 | nos | |
| 1-2-2. Pipe(SP, $\phi$ 300) | 2*(3.30+3.50+3.00+0.60+2.70) | = | 26.20 | m | φ300、SP |
| 1-2-3. Control Panel | | | 1.00 | nos | |
| 1-2-4. Overhead Crane(5ton) | | | 1.00 | nos | |
| 1-2-5. Butterfly valve( $\phi$ 300) | | | 2.00 | nos | |
| 1-2-6. Check valve(φ300) | | | 2.00 | nos | |
| 1-2-7. Flexible tube(φ300) | | | 4.00 | nos | |
| **1-3. Storage** | | | | | |
| 1-3-1. Common Excavation | 1/2*(34.00*34.00+26.8*26.80)*3.60+(24.80*24.80-19.80*19.80)*0.20 | | 3,418.23 | m3 | |
| 1-3-2. Leveling Concrete | (24.80*24.80-19.80*19.80)*0.05 | = | 11.15 | m3 | |
| 1-3-3. Gravel | (24.80*24.80-19.80*19.80)*0.15+20.00*20.00*0.15 | = | 93.45 | m3 | |
| 1-3-4. Backfill | 3,418.23-11.15-93.45-205.90-(21.00*21.00*3.30) | = | 1,652.43 | m3 | |

Irrigation Scheme : Scheme
Item of Work : Pump Station Work



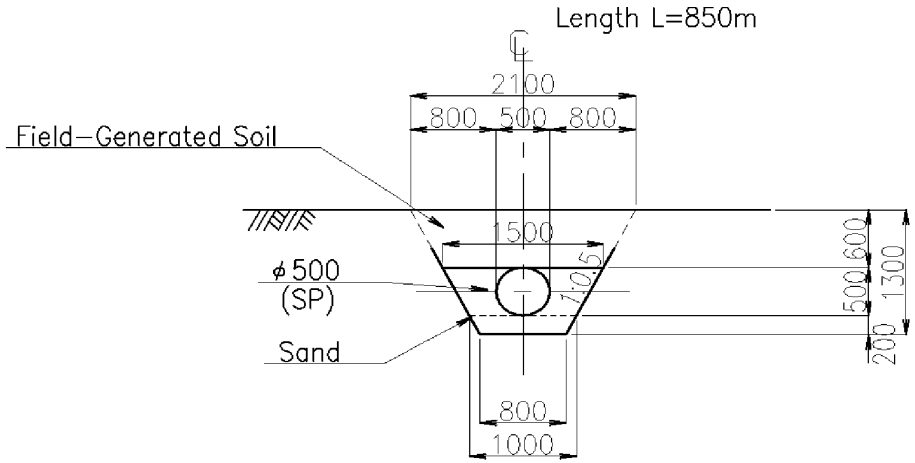
| Item | Calculation | | | Quantity | Unit | Remark |
|---|---|---|---|---|---|---|
| 1-3-5. Reinforced Concrete | Base 1 | (24.60*24.60-20.00*20.00)*0.30 | = 61.55 | | | |
| | Base 2 | 20.00*20.00*0.15 | = 60.00 | | | |
| | Wall 1 | 2*21.00*0.30*3.30 | = 41.58 | | | |
| | Wall 2 | 2*21.60*0.30*3.30 | = 42.77 | | | |
| | | | 205.90 | 205.90 | m3 | |

# Quantity Calculation

Irrigation Scheme : Scheme
Item of Work : Pipeline Work



| Item | Calculation | Quantity | Unit | Remark |
|---|---|---|---|---|
| **2. Pipeline Work** | | | | |
| **2-1. Pipeline(φ500)** | | | | |
| 2-1-1. Common Excavation | 1/2*(2.10+0.80)*1.30*850.00 = | 1,602.25 | m3 | |
| 2-1-2. Sand(under) | 1/2*(1.00+0.80)*0.20*850.00 = | 153.00 | m3 | |
| 2-1-3. Sand(around) | {1/2*(1.50+1.00)*0.50-0.50^2* π /4}*850.00 = | 364.44 | m3 | |
| 2-1-4. Backfill | 1/2*(2.10+1.50)*0.60*850.00 = | 918.00 | m3 | |
| 2-1-5. Pipe(SP, φ 500) | = | 850.00 | m | |



# Quantity Calculation

Irrigation Scheme : Scheme
Item of Work : Discharge Chamber Work



| Item | Calculation | | | Quantity | Unit | Remark |
|---|---|---|---|---|---|---|
| **2. Discharge Chamber Work** | | | | | | |
| **2-2. Discharge Chamber** | | | | | | |
| 2-2-1. Common Excavation | 1/2*((7.30*4.90)+(14.4*12.0))*3.55+(6.3*3.9*0.20) | | = | 375.13 | m3 | |
| 2-2-2. Leveling Concrete | 6.4*4.0*0.05 | | = | 1.28 | m3 | |
| 2-2-3. Gravel | 6.4*4.0*0.15 | | = | 3.84 | m3 | |
| 2-2-4. Backfill | 375.13-7.3*4.9*3.55-6.3*3.9*0.2 | | = | 243.23 | m3 | |
| 2-2-5. Reinforced Concrete | Base | 6.6*3.9*0.35 | = | 9.01 | | |
| | Wall 1 | 3.9*3.0*0.35*2 | = | 8.19 | | |
| | Wall 2 | 5.6*3.0*0.35*2 | = | 11.76 | | |
| | South c | -1.0*1.25 | = | -1.25 | | |
| | North c | -0.9*1.15 | = | -1.04 | | |
| | Pipe | -1/4*3.14*1.2^2 | = | -1.13 | | |
| | | | | 25.54 | 25.54 | m3 |

### 3.2 (3) Pump No.2 Station and Pipeline Works

## Rejaf East Irrigation Scheme

**No.2 Pump Statoin & Pipeline Works 1.9 million US$**

| No. | Work Description | Unit | Quantity | Unit Price (US$) | Total (US$) |
|---|---|---|---|---|---|
| **1. No.2 Pump Station Work** | | | | | |
| **1-1.** | **Pump Building(No.2)** | | | | |
| 1-1-1. | Common Excavation | m3 | 368 | 10.0 | 3,675 |
| 1-1-2. | Leveling Concrete | m3 | 6 | 350.0 | 1,960 |
| 1-1-3. | Backfill | m3 | 265 | 11.0 | 2,918 |
| 1-1-4. | Building | m2 | 107 | 2,800.0 | 300,832 |
| | | | | Sub total | 309,385 |
| **1-2.** | **Pump Equipment** | | | | |
| 1-2-1. | Pump Facilities (Pump, Engne & Auxiliary equipment) | nos | 2 | 220,000.0 | 440,000 |
| 1-2-2. | Pipe(SP, ű300) | m | 50 | 240.0 | 12,055 |
| 1-2-3. | Control Panel | nos | 1 | 86,500.0 | 86,500 |
| 1-2-4. | Overhead Crane(5ton) | nos | 1 | 77,900.0 | 77,900 |
| 1-2-5. | Butterfly valve(ű350) | nos | 2 | 15,000.0 | 30,000 |
| 1-2-6. | Check valve(ű350) | nos | 2 | 13,000.0 | 26,000 |
| 1-2-7. | Flexible tube(ű350) | nos | 4 | 3,800.0 | 15,200 |
| 1-2-8. | Steel pile(ű600, L=15m) | nos | 10 | 3,600.0 | 36,000 |
| | | | | Sub total | 723,655 |
| **1-3.** | **Slope protection** | | | | |
| 1-3-1. | Masonry | m3 | 256 | 140.0 | 35,784 |
| 1-3-2. | Support Concrete (18N) | m3 | 12 | 350.0 | 4,193 |
| 1-3-3. | Leveling Concrete | m3 | 1 | 350.0 | 350 |
| 1-3-4. | Gravel | m3 | 1 | 50.0 | 72 |
| 1-2-5. | Temporary Works (River Close) 10% of above sum | L.S | 1 | | 4,000 |
| | | | | Sub total | 44,399 |
| **2. Pipeline Work** | | | | | |
| **2-1.** | **Pipeline(φ500)** | | | | |
| 2-1-1. | Common Excavation | m3 | 3,393 | 10.0 | 33,930 |
| 2-1-2. | Sand(under) | m3 | 324 | 21.2 | 6,869 |
| 2-1-3. | Sand(around) | m3 | 772 | 21.2 | 16,361 |
| 2-1-4. | Backfill | m3 | 1,944 | 11.0 | 21,384 |
| 2-1-5. | Pipe(SP, ű500) | m | 1,800 | 400.0 | 720,000 |
| | | | | Sub total | 798,544 |
| **2-2.** | **Discharge Chamber** | | | | |
| 2-2-1. | Common Excavation | m3 | 375 | 10.00 | 3,751 |
| 2-2-2. | Leveling Concrete | m3 | 1 | 140.0 | 179 |
| 2-2-3. | Gravel | m3 | 4 | 50.00 | 192 |
| 2-2-4. | Backfill | m3 | 243 | 11.00 | 2,676 |
| 2-2-5. | Reinforced Concrete | m3 | 26 | 440.00 | 11,238 |
| | | | | Sub total | 18,036 |
| | | | | | |
| | | | **Direct cost** | **Total** | **1,894,019** |
| | | | **Pump Station** | | **1,077,439** |
| | | | **Pipeline** | | **816,580** |

# Quantity Calculation

Irrigation Scheme : Scheme

Item of Work : Pump Station Work



| Item | Calculation | Quantity | Unit | Remark |
|---|---|---|---|---|
| **1. Pump Station Work** | | | | |
| **1-1. Pump Building(No.2)** | | | | |
| 1-1-1. Common Excavation | 1/2*(7.80*16.80+9.20*18.20)*0.60+(7.00*16.00*0.20) = 111.94<br>20.00*(20.00+2.60+20.00)*0.30 = 255.60<br>367.54 | 367.54 | m3 | |

Irrigation Scheme : Scheme
Item of Work : Pump Station Work

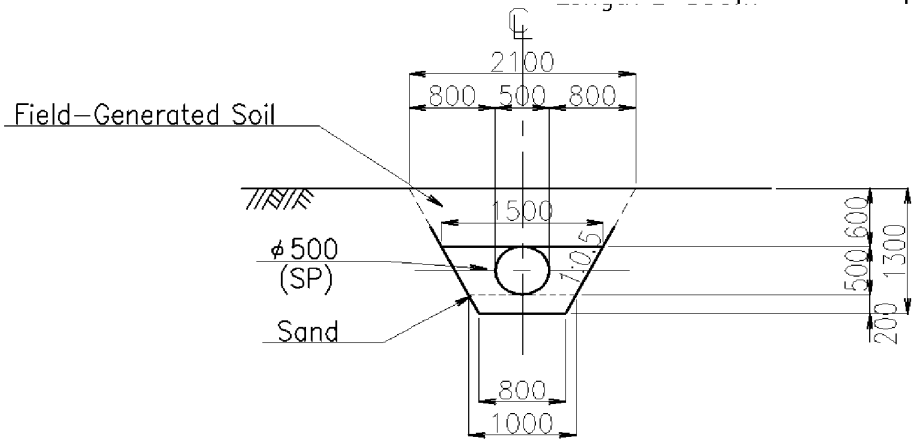


| Item | Calculation | | Quantity | Unit | Remark |
|---|---|---|---|---|---|
| 1-1-2. Leveling Concrete | 7.00*16.00*0.05 | = | 5.60 | m3 | |
| 1-1-3. Backfill | 367.54-5.60-(6.80*15.80*0.90) | = | 265.24 | m3 | |
| 1-1-4. Building | 6.80*15.80 | = | 107.44 | m2 | |
| **1-2. Pump Equipment** | | | | | |
| 1-2-1. Pump Facilities (Pump, Engne & Auxiliary equipment) | | | 2.00 | nos | |
| 1-2-2. Pipe(SP, $\phi$ 300) | 2*(15.876+1.70+3.25+0.60+3.69) | = | 50.23 | m | φ350、SP |
| 1-2-3. Control Panel | | | 1.00 | nos | |
| 1-2-4. Overhead Crane(5ton) | | | 1.00 | nos | |
| 1-2-5. Butterfly valve(φ350) | | | 2.00 | nos | |
| 1-2-6. Check valve(φ350) | | | 2.00 | nos | |
| 1-2-7. Flexible tube(φ350) | | | 4.00 | nos | |
| 1-2-8. Steel pile( $\phi$ 600, L=15m) | 2*5 | | 10.00 | nos | |
| **1-3. Slope protection** | | | | | |
| 1-3-1. Masonry | 20.00*(20.00+2.60+20.00)*0.30 | | 255.60 | m3 | |
| 1-3-2. Support Concrete (18N) | 2*{1/2*(0.50+1.50)*2.80*2.00} | = 11.20 | | | |
| | 2*(0.50*0.60*1.30) | = 0.78 | | | |
| | | 11.98 | 11.98 | m3 | |
| 1-3-3. Leveling Concrete | 2*(1.70*2.20*0.05+0.70*1.50*0.05) | = | 0.48 | m3 | |
| 1-3-4. Gravel | 2*(1.70*2.20*0.15+0.70*1.50*0.15) | = | 1.44 | m3 | |

# Quantity Calculation

Irrigation Scheme : Scheme
Item of Work : Pipeline Work



| Item | Calculation | | Quantity | Unit | Remark |
|---|---|---|---|---|---|
| **2. Pipeline Work** | | | | | |
| **2-1. Pipeline(φ500)** | | | | | |
| 2-1-1. Common Excavation | 1/2*(2.10+0.80)*1.30*1800.00 | = | 3,393.00 | m3 | |
| |  | | | | |
| 2-1-2. Sand(under) | 1/2*(1.00+0.80)*0.20*1800.00 | = | 324.00 | m3 | |
| 2-1-3. Sand(around) | {1/2*(1.50+1.00)*0.50-0.50^2* π /4}*1800.00 | = | 771.75 | m3 | |
| 2-1-4. Backfill | 1/2*(2.10+1.50)*0.60*1800.00 | = | 1,944.00 | m3 | |
| 2-1-5. Pipe(SP, φ 500) | | = | 1,800.00 | m | |

# Quantity Calculation

Irrigation Scheme : Scheme
Item of Work : Discharge Chamber Work



| Item | Calculation | | | Quantity | Unit | Remark |
|---|---|---|---|---|---|---|
| **2-2. Discharge Chamber** | | | | | | |
| 2-2-1. Common Excavation | 1/2*((7.30*4.90)+(14.4*12.0))*3.55+(6.3*3.9*0.20) | = | | 375.13 | m3 | |
| 2-2-2. Leveling Concrete | 6.4*4.0*0.05 | = | | 1.28 | m3 | |
| 2-2-3. Gravel | 6.4*4.0*0.15 | = | | 3.84 | m3 | |
| 2-2-4. Backfill | 375.13-7.3*4.9*3.55-6.3*3.9*0.2 | = | | 243.23 | m3 | |
| 2-2-5. Reinforced Concrete | Base 6.6*3.9*0.35 | = | 9.01 | | | |
| | Wall 1 3.9*3.0*0.35*2 | = | 8.19 | | | |
| | Wall 2 5.6*3.0*0.35*2 | = | 11.76 | | | |
| | South c -1.0*1.25 | = | -1.25 | | | |
| | North c -0.9*1.15 | = | -1.04 | | | |
| | Pipe -1/4*3.14*1.2^2 | = | -1.13 | | | |
| | | | 25.54 | 25.54 | m3 | |

### 3.2 (4) Pump No.3 Station and Pipeline Works

## Rejaf East Irrigation Scheme

**No.3 Pump Statoin & Pipeline Works 1.8 million US$**

| No. | Work Description | Unit | Quantity | Unit Price (US$) | Total (US$) |
|---|---|---|---|---|---|
| **1. No.3 Pump Station Work** | | | | | |
| **1-1.** | **Pump Building(No.3)** | | | | |
| 1-1-1. | Common Excavation | m3 | 903 | 10.0 | 9,029 |
| 1-1-2. | Leveling Concrete | m3 | 6 | 350.0 | 1,960 |
| 1-1-3. | Backfill | m3 | 216 | 11.0 | 2,377 |
| 1-1-4. | Building | m2 | 107 | 2,800.0 | 300,832 |
| | | | | Sub total | 314,198 |
| **1-2.** | **Pump Equipment** | | | | |
| 1-2-1. | Pump Facilities (Pump, Engne & Auxiliary equipment) | nos | 2 | 220,000.0 | 440,000 |
| 1-2-2. | Pipe(SP, ű300) | m | 55 | 240.0 | 13,234 |
| 1-2-3. | Control Panel | nos | 1 | 86,500.0 | 86,500 |
| 1-2-4. | Overhead Crane(5ton) | nos | 1 | 77,900.0 | 77,900 |
| 1-2-5. | Butterfly valve(ű350) | nos | 2 | 15,000.0 | 30,000 |
| 1-2-6. | Check valve(ű350) | nos | 2 | 13,000.0 | 26,000 |
| 1-2-7. | Flexible tube(ű350) | nos | 4 | 3,800.0 | 15,200 |
| 1-2-8. | Displaced foundation | m3 | 612 | 50.0 | 30,582 |
| | | | | Sub total | 719,416 |
| **1-3.** | **Slope protection** | | | | |
| 1-3-1. | Masonry | m3 | 256 | 140.0 | 35,784 |
| 1-3-2. | Support Concrete (18N) | m3 | 12 | 350.0 | 4,193 |
| 1-3-3. | Leveling Concrete | m3 | 1 | 350.0 | 350 |
| 1-3-4. | Gravel | m3 | 1 | 50.0 | 72 |
| 1-2-5. | Temporary Works (River Close) 10% of above sum | L.S | 1 | | 4,000 |
| | | | | Sub total | 44,399 |
| **2. Pipeline Work** | | | | | |
| **2-1.** | **Pipeline(φ500)** | | | | |
| 2-1-1. | Common Excavation | m3 | 3,016 | 10.0 | 30,160 |
| 2-1-2. | Sand(under) | m3 | 288 | 24.0 | 6,912 |
| 2-1-3. | Sand(around) | m3 | 686 | 24.0 | 16,464 |
| 2-1-4. | Backfill | m3 | 1,728 | 11.0 | 19,008 |
| 2-1-5. | Pipe(SP, ű500) | m | 1,600 | 400.0 | 640,000 |
| | | | | Sub total | 712,544 |
| **2-2.** | **Discharge Chamber** | | | | |
| 2-2-1. | Common Excavation | m3 | 375 | 10.00 | 3,751 |
| 2-2-2. | Leveling Concrete | m3 | 1 | 350.0 | 448 |
| 2-2-3. | Gravel | m3 | 4 | 50.00 | 192 |
| 2-2-4. | Backfill | m3 | 243 | 11.00 | 2,676 |
| 2-2-5. | Reinforced Concrete | m3 | 26 | 440.00 | 11,238 |
| | | | | Sub total | 18,305 |
| | | | | | |
| | | | **Direct cost** | **Total** | **1,808,862** |
| | | | **Pump Station** | | **1,078,013** |
| | | | **Pipeline** | | **730,849** |

# Quantity Calculation

Irrigation Scheme : Scheme
Item of Work : Pump Station Work



| Item | Calculation | | Quantity | Unit | Remark |
|---|---|---|---|---|---|
| **1. Pump Station Work** | | | | | |
| **1-1. Pump Building(No.3)** | | | | | |
| 1-1-1. Common Excavation | 1/2*(11.00*20.00+16.60*25.60)*2.80 | = 902.94 | 902.94 | m3 | |

Irrigation Scheme : Scheme
Item of Work : Pump Station Work

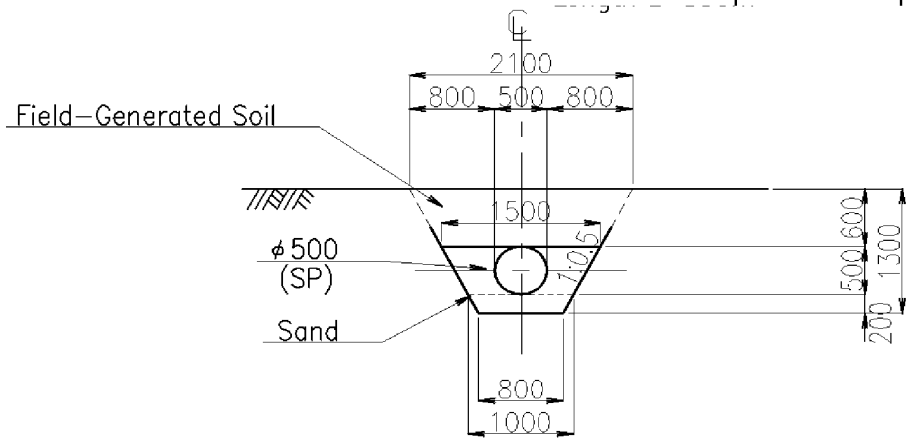


| Item | Calculation | | | Quantity | Unit | Remark |
|---|---|---|---|---|---|---|
| 1-1-2. Leveling Concrete | 7.00*16.00*0.05 | = | | 5.60 | m3 | |
| 1-1-3. Backfill | 902.94-(6.80*15.80*0.70)-611.63 | = | | 216.10 | m3 | |
| 1-1-4. Building | 6.80*15.80 | = | | 107.44 | m2 | |
| **1-2. Pump Equipment** | | | | | | |
| 1-2-1. Pump Facilities (Pump, Engne & Auxiliary equipment) | | | | 2.00 | nos | |
| 1-2-2. Pipe(SP, $\phi$ 300) | 2*(16.771+3.55+3.30+0.60+3.35) | = | | 55.14 | m | φ300、SP |
| 1-2-3. Control Panel | | | | 1.00 | nos | |
| 1-2-4. Overhead Crane(5ton) | | | | 1.00 | nos | |
| 1-2-5. Butterfly valve(φ350) | | | | 2.00 | nos | |
| 1-2-6. Check valve(φ350) | | | | 2.00 | nos | |
| 1-2-7. Flexible tube(φ350) | | | | 4.00 | nos | |
| 1-2-8. Displaced foundation | 1/2*(11.00*20.00+15.20*24.20)*2.10-(7.00*16.00*0.05) | | | 611.63 | m3 | |
| **1-3. Slope protection** | | | | | | |
| 1-3-1. Masonry | 20.00*(20.00+2.60+20.00)*0.30 | | | 255.60 | m3 | |
| 1-3-2. Support Concrete (18N) | 2*{1/2*(0.50+1.50)*2.80*2.00} | = | 11.20 | | | |
| | 2*(0.50*0.60*1.30) | = | 0.78 | | | |
| | | | 11.98 | 11.98 | m3 | |
| 1-3-3. Leveling Concrete | 2*(1.70*2.20*0.05+0.70*1.50*0.05) | = | | 0.48 | m3 | |
| 1-3-4. Gravel | 2*(1.70*2.20*0.15+0.70*1.50*0.15) | = | | 1.44 | m3 | |

# Quantity Calculation

Irrigation Scheme : Scheme
Item of Work : Pipeline Work



| Item | Calculation | | Quantity | Unit | Remark |
|---|---|---|---|---|---|
| **2. Pipeline Work** | | | | | |
| **2-1. Pipeline(φ500)** | | | | | |
| 2-1-1. Common Excavation | 1/2*(2.10+0.80)*1.30*1600.00 | = | 3,016.00 | m3 | |
| |  | | | | |
| 2-1-2. Sand(under) | 1/2*(1.00+0.80)*0.20*1600.00 | = | 288.00 | m3 | |
| 2-1-3. Sand(around) | {1/2*(1.50+1.00)*0.50-0.50^2* π /4}*1600.00 | = | 686.00 | m3 | |
| 2-1-4. Backfill | 1/2*(2.10+1.50)*0.60*1600.00 | = | 1,728.00 | m3 | |
| 2-1-5. Pipe(SP, φ500) | | = | 1,600.00 | m | |

# Quantity Calculation

Irrigation Scheme : Scheme
Item of Work : Discharge Chamber Work



| Item | Calculation | | | Quantity | Unit | Remark |
|---|---|---|---|---|---|---|
| **2-2. Discharge Chamber** | | | | | | |
| 2-2-1. Common Excavation | 1/2*((7.30*4.90)+(14.4*12.0))*3.55+(6.3*3.9*0.20) | = | | 375.13 | m3 | |
| 2-2-2. Leveling Concrete | 6.4*4.0*0.05 | = | | 1.28 | m3 | |
| 2-2-3. Gravel | 6.4*4.0*0.15 | = | | 3.84 | m3 | |
| 2-2-4. Backfill | 375.13-7.3*4.9*3.55-6.3*3.9*0.2 | = | | 243.23 | m3 | |
| 2-2-5. Reinforced Concrete | Base 6.6*3.9*0.35 | = | 9.01 | | | |
| | Wall 1 3.9*3.0*0.35*2 | = | 8.19 | | | |
| | Wall 2 5.6*3.0*0.35*2 | = | 11.76 | | | |
| | South c -1.0*1.25 | = | -1.25 | | | |
| | North c -0.9*1.15 | = | -1.04 | | | |
| | Pipe -1/4*3.14*1.2^2 | = | -1.13 | | | |
| | | | 25.54 | 25.54 | m3 | |

### 3.3 Main Irrigation Canal Works

## Rejaf East Irrigation Scheme

## Main Irrigation Canal Works 1.4 million US$

| No. | Work Description | Unit | Quantity | Unit Price (US$) | Total (US$) |
|---|---|---|---|---|---|
| **1. TYPE C1-1** | | | | | |
| **1-1. Preparatory Work** | | | | | |
| 1-1-1. | Site Clearing (Cutting & Clearing of Grass, Bushes) | ha | 0.5 | 11,900.0 | 5,950 |
| | *Average width of excavation x Canal length | | | **Sub total** | **5,950** |
| **1-2. Earth Work** | | | | | |
| 1-2-1. | Excavation of Surface Soil (200mm Depth) | m3 | 858 | 8.0 | 6,864 |
| 1-2-2. | Excavation for Common Soil | m3 | 265 | 10.0 | 2,650 |
| 1-2-3. | Spreading (Bulldozer) | m3 | 1,869 | 13.0 | 24,297 |
| 1-2-4. | Embankment with Compaction | m3 | 1,869 | 14.0 | 26,166 |
| 1-2-5. | Soil (Banking Material) | m3 | 1,604 | 7.6 | 12,190 |
| 1-2-6. | Hauling by Dump Truck (Banking Material) | m3 | 1,604 | 9.0 | 14,436 |
| 1-2-7. | Aggregate, Crushed, 2-4cm (Gravel Pavement) | m3 | 188 | 50.0 | 9,400 |
| 1-2-8. | Spreading of Aggregate (Bulldozer) | m3 | 188 | 13.0 | 2,444 |
| | | | | **Sub total** | **98,447** |
| **1-3. Canal Work (Main Canal)** | | | | | |
| 1-3-1. | Class 18 Concrete (include Form Work) | m3 | 132 | 350.0 | 46,200 |
| | | | | **Sub total** | **46,200** |
| **1-4. Canal Structure (Main Canal)** | | | | | |
| 1-4-1. | Turnout (Slide Gate, B=0.3m, H=0.3m) | unit | 4 | 220.0 | 880 |
| | | | | **Sub total** | **880** |
| | | | | **Total** | **151,477** |
| **2. TYPE C1-2** | | | | | |
| **2-1. Preparatory Work** | | | | | |
| 2-1-1. | Site Clearing (Cutting & Clearing of Grass, Bushes) | ha | 2.5 | 11,900.0 | 29,750 |
| | *Average width of excavation x Canal length | | | **Sub total** | **29,750** |
| **2-2. Earth Work** | | | | | |
| 2-2-1. | Excavation of Surface Soil (200mm Depth) | m3 | 4,150 | 8.0 | 33,200 |
| 2-2-2. | Excavation for Common Soil | m3 | 1,221 | 10.0 | 12,210 |
| 2-2-3. | Spreading (Bulldozer) | m3 | 7,566 | 13.0 | 98,358 |
| 2-2-4. | Embankment with Compaction | m3 | 7,566 | 14.0 | 105,924 |
| 2-2-5. | Soil (Banking Material) | m3 | 6,345 | 7.6 | 48,222 |
| 2-2-6. | Hauling by Dump Truck (Banking Material) | m3 | 6,345 | 9.0 | 57,105 |
| 2-2-7. | Aggregate, Crushed, 2-4cm (Gravel Pavement) | m3 | 975 | 50.0 | 48,750 |
| 2-2-8. | Spreading of Aggregate (Bulldozer) | m3 | 975 | 13.0 | 12,675 |
| | | | | **Sub total** | **416,444** |
| **2-3. Canal Work (Main Canal)** | | | | | |
| 2-3-1. | Class 18 Concrete (include Form Work) | m3 | 534 | 350.0 | 186,900 |
| | | | | **Sub total** | **186,900** |
| **2-4. Canal Structure (Main Canal)** | | | | | |
| 2-4-1. | Turnout (Slide Gate, B=0.3m, H=0.3m) | unit | 21 | 220.0 | 4,620 |
| | | | | **Sub total** | **4,620** |
| | | | | **Total** | **637,714** |

| | | | | | |
|---|---|---|---|---|---|
| **3. TYPE C2-1** | | | | | |
| **3-1. Preparatory Work** | | | | | |
| 3-1-1. | Site Clearing (Cutting & Clearing of Grass, Bushes) | ha | 0.7 | 11,900.0 | 8,330 |
| | *Average width of excavation x Canal length | | | **Sub total** | **8,330** |
| **3-2. Earth Work** | | | | | |
| 3-2-1. | Excavation of Surface Soil (200mm Depth) | m3 | 1,066 | 8.0 | 8,528 |
| 3-2-2. | Excavation for Common Soil | m3 | 354 | 10.0 | 3,540 |
| 3-2-3. | Spreading (Bulldozer) | m3 | 2,504 | 13.0 | 32,552 |
| 3-2-4. | Embankment with Compaction | m3 | 2,504 | 14.0 | 35,056 |
| 3-2-5. | Soil (Banking Material) | m3 | 2,150 | 7.6 | 16,340 |
| 3-2-6. | Hauling by Dump Truck (Banking Material) | m3 | 2,150 | 9.0 | 19,350 |
| 3-2-7. | Aggregate, Crushed, 2-4cm (Gravel Pavement) | m3 | 225 | 50.0 | 11,250 |
| 3-2-8. | Spreading of Aggregate (Bulldozer) | m3 | 225 | 13.0 | 2,925 |
| | | | | **Sub total** | **129,541** |
| **3-3. Canal Work (Main Canal)** | | | | | |
| 3-3-1. | Class 18 Concrete (include Form Work) | m3 | 180 | 350.0 | 63,000 |
| | | | | **Sub total** | **63,000** |
| **3-4. Canal Structure (Main Canal)** | | | | | |
| 3-4-1. | Turnout (Slide Gate, B=0.3m, H=0.3m) | unit | 5 | 220.0 | 1,100 |
| | | | | **Sub total** | **1,100** |
| | | | | **Total** | **201,971** |
| **4. TYPE C2-2** | | | | | |
| **4-1. Preparatory Work** | | | | | |
| 4-1-1. | Site Clearing (Cutting & Clearing of Grass, Bushes) | ha | 0.6 | 11,900.0 | 7,140 |
| | *Average width of excavation x Canal length | | | **Sub total** | **7,140** |
| **4-2. Earth Work** | | | | | |
| 4-2-1. | Excavation of Surface Soil (200mm Depth) | m3 | 958 | 8.0 | 7,664 |
| 4-2-2. | Excavation for Common Soil | m3 | 318 | 10.0 | 3,180 |
| 4-2-3. | Spreading (Bulldozer) | m3 | 1,746 | 13.0 | 22,698 |
| 4-2-4. | Embankment with Compaction | m3 | 1,746 | 14.0 | 24,444 |
| 4-2-5. | Soil (Banking Material) | m3 | 1,428 | 7.6 | 10,853 |
| 4-2-6. | Hauling by Dump Truck (Banking Material) | m3 | 1,428 | 9.0 | 12,852 |
| 4-2-7. | Aggregate, Crushed, 2-4cm (Gravel Pavement) | m3 | 225 | 50.0 | 11,250 |
| 4-2-8. | Spreading of Aggregate (Bulldozer) | m3 | 225 | 13.0 | 2,925 |
| | | | | **Sub total** | **95,866** |
| **4-3. Canal Work (Main Canal)** | | | | | |
| 4-3-1. | Class 18 Concrete (include Form Work) | m3 | 132 | 350.0 | 46,200 |
| | | | | **Sub total** | **46,200** |
| **4-4. Canal Structure (Main Canal)** | | | | | |
| 4-4-1. | Turnout (Slide Gate, B=0.3m, H=0.3m) | unit | 5 | 220.0 | 1,100 |
| | | | | **Sub total** | **1,100** |
| | | | | **Total** | **150,306** |
| **5. TYPE C3-1** | | | | | |
| **5-1. Preparatory Work** | | | | | |
| 5-1-1. | Site Clearing (Cutting & Clearing of Grass, Bushes) | ha | 0.5 | 11,900.0 | 5,950 |
| | *Average width of excavation x Canal length | | | **Sub total** | **5,950** |
| **5-2. Earth Work** | | | | | |
| 5-2-1. | Excavation of Surface Soil (200mm Depth) | m3 | 828 | 8.0 | 6,624 |
| 5-2-2. | Excavation for Common Soil | m3 | 265 | 10.0 | 2,650 |

| | | | | | |
|---|---|---|---|---|---|
| 5-2-3. | Spreading (Bulldozer) | m3 | 1,658 | 13.0 | 21,554 |
| 5-2-4. | Embankment with Compaction | m3 | 1,658 | 14.0 | 23,212 |
| 5-2-5. | Soil (Banking Material) | m3 | 1,393 | 7.6 | 10,587 |
| 5-2-6. | Hauling by Dump Truck (Banking Material) | m3 | 1,393 | 9.0 | 12,537 |
| 5-2-7. | Aggregate, Crushed, 2-4cm (Gravel Pavement) | m3 | 188 | 50.0 | 9,400 |
| 5-2-8. | Spreading of Aggregate (Bulldozer) | m3 | 188 | 13.0 | 2,444 |
| | | | | **Sub total** | **89,008** |
| **5-3. Canal Work (Main Canal)** | | | | | |
| 5-3-1. | Class 18 Concrete (include Form Work) | m3 | 121 | 350.0 | 42,350 |
| | | | | **Sub total** | **42,350** |
| **5-4. Canal Structure (Main Canal)** | | | | | |
| 5-4-1. | Turnout (Slide Gate, B=0.3m, H=0.3m) | unit | 4 | 220.0 | 880 |
| | | | | **Sub total** | **880** |
| | | | | **Total** | **138,188** |
| **6. TYPE C3-2** | | | | | |
| **6-1. Preparatory Work** | | | | | |
| 6-1-1. | Site Clearing (Cutting & Clearing of Grass, Bushes) | ha | 0.5 | 11,900.0 | 5,950 |
| | *Average width of excavation x Canal length | | | **Sub total** | **5,950** |
| **6-2. Earth Work** | | | | | |
| 6-2-1. | Excavation of Surface Soil (200mm Depth) | m3 | 768 | 8.0 | 6,144 |
| 6-2-2. | Excavation for Common Soil | m3 | 235 | 10.0 | 2,350 |
| 6-2-3. | Spreading (Bulldozer) | m3 | 1,259 | 13.0 | 16,367 |
| 6-2-4. | Embankment with Compaction | m3 | 1,259 | 14.0 | 17,626 |
| 6-2-5. | Soil (Banking Material) | m3 | 1,024 | 7.6 | 7,782 |
| 6-2-6. | Hauling by Dump Truck (Banking Material) | m3 | 1,024 | 9.0 | 9,216 |
| 6-2-7. | Aggregate, Crushed, 2-4cm (Gravel Pavement) | m3 | 188 | 50.0 | 9,400 |
| 6-2-8. | Spreading of Aggregate (Bulldozer) | m3 | 188 | 13.0 | 2,444 |
| | | | | **Sub total** | **71,329** |
| **6-3. Canal Work (Main Canal)** | | | | | |
| 6-3-1. | Class 18 Concrete (include Form Work) | m3 | 92 | 350.0 | 32,200 |
| | | | | **Sub total** | **32,200** |
| **6-4. Canal Structure (Main Canal)** | | | | | |
| 6-4-1. | Turnout (Slide Gate, B=0.3m, H=0.3m) | unit | 4 | 220.0 | 880 |
| | | | | **Sub total** | **880** |
| | | | | **Total** | **110,359** |
| | | | | | |
| | **Direct Construction Cost (A)** | | | | **1,390,015** |
| | | | | | **(US$)** |

Irrigation Facility: Main Canal:

| | | | |
|---|---|---|---|
| (1) Canal Length | Type C1-1= | 750.00 | m |
| (2) Canal Length | Type C1-2= | 3,900.00 | m |
| (3) Canal Length | Type C2-1= | 900.00 | m |
| (4) Canal Length | Type C2-2= | 900.00 | m |
| (5) Canal Length | Type C3-1= | 750.00 | |
| (6) Canal Length | Type C3-2= | 750.00 | |
| | **Total** | **7,950.00** | **m** |

# Quantity Calculation

Irrigation Scheme : Rejaf East Irrigation Scheme
Item of Work : Main Canal



| Item | Calculation | Quantity | Unit | Remark |
|---|---|---|---|---|
| **1. TYPE C1-1** | | | | |
| **1-1. Preparatory Work** | | | | |
| 1-1-1. Site Clearing | Width Length<br>6.9 x 750 / 10000 | **0.5** | **ha** | |
| **1-2. Earth Work** | | | | |
| 1-2-1. Stripping | Section(1) Section(2) Length<br>( 0.872 + 0.272 ) x 750 | **858** | **m3** | |
| 1-2-2. Excavation | Section Length<br>0.353 x 750 | **265** | **m3** | |
| 1-2-3. Embankment | Section(1) Section(2) Length<br>( 1.996 + 0.496 ) x 750 | **1,869** | **m3** | |
| 1-2-4. Gravel Pavement | Section Length<br>2.5 x 0.1 x 750 | **188** | **m3** | |
| **1-3. Canal Works** | | | | |
| 1-3-1. Concrete Lining | Section Length<br>0.176 x 750 | **132** | **m3** | |
| **2. TYPE C1-1** | | | | |
| **2-1. Preparatory Work** | | | | |
| 2-1-1. Site Clearing | Width Length<br>6.5 x 3900 / 10000 | **2.5** | **ha** | |
| **2-2. Earth Work** | | | | |
| 2-2-1. Stripping | Section(1) Section(2) Length<br>( 0.832 + 0.232 ) x 3900 | **4,150** | **m3** | |

Irrigation Scheme : Rejaf East Irrigation Scheme
Item of Work : Main Canal



| Item | Calculation | Quantity | Unit | Remark |
|---|---|---|---|---|
| 2-2-2. Excavation | Section Length<br>0.313 x 3900 | **1,221** | **m3** | |
| 2-2-3. Embankment | Section(1) Section(2) Length<br>( 1.57 + 0.37 ) x 3900 | **7,566** | **m3** | |
| 2-2-4. Gravel Pavement | Section Length<br>2.5 x 0.1 x 3900 | **975** | **m3** | |
| **2-3. Canal Works** | | | | |
| 2-3-1. Concrete Lining | Section Length<br>0.137 x 3900 | **534** | **m3** | |
| **3. TYPE C2-1** | | | | |
| **3-1. Preparatory Work** | | | | |
| 3-1-1. Site Clearing | Width Length<br>7.3 x 900 / 10000 | **0.7** | **ha** | |
| **3-2. Earth Work** | | | | |
| 3-2-1. Stripping | Section(1) Section(2) Length<br>( 0.892 + 0.292 ) x 900 | **1,066** | **m3** | |
| 3-2-2. Excavation | Section Length<br>0.393 x 900 | **354** | **m3** | |
| 3-2-3. Embankment | Section(1) Section(2) Length<br>( 2.216 + 0.566 ) x 900 | **2,504** | **m3** | |
| 3-2-4. Gravel Pavement | Section Length<br>2.5 x 0.1 x 900 | **225** | **m3** | |

Irrigation Scheme : Rejaf East Irrigation Scheme
Item of Work : Main Canal



| Item | Calculation | Quantity | Unit | Remark |
|---|---|---|---|---|
| **3-3. Canal Works** | | | | |
| 3-3-1. Concrete Lining | Section 0.2 x Length 900 | **180** | **m3** | |
| **4. TYPE C2-2** | | | | |
| **4-1. Preparatory Work** | | | | |
| 4-1-1. Site Clearing | Width 6.6 x Length 900 / 10000 | **0.6** | **ha** | |
| **4-2. Earth Work** | | | | |
| 4-2-1. Stripping | ( Section(1) 0.832 + Section(2) 0.232 ) x Length 900 | **958** | **m3** | |
| 4-2-2. Excavation | Section 0.353 x Length 900 | **318** | **m3** | |
| 4-2-3. Embankment | ( Section(1) 1.57 + Section(2) 0.37 ) x Length 900 | **1,746** | **m3** | |
| 4-2-4. Gravel Pavement | Section 2.5 x 0.1 x Length 900 | **225** | **m3** | |
| **4-3. Canal Works** | | | | |
| 4-3-1. Concrete Lining | Section 0.147 x Length 900 | **132** | **m3** | |
| **5. TYPE C3-1** | | | | |
| **5-1. Preparatory Work** | | | | |
| 5-1-1. Site Clearing | Width 6.8 x Length 750 / 10000 | **0.5** | **ha** | |

Irrigation Scheme : Rejaf East Irrigation Scheme
Item of Work : Main Canal



| Item | Calculation | Quantity | Unit | Remark |
|---|---|---|---|---|
| **5-2. Earth Work** | | | | |
| 5-2-1. Stripping | Section(1) Section(2) Length<br>( 0.852 + 0.252 ) x 750 | **828** | **m3** | |
| 5-2-2. Excavation | Section Length<br>0.353 x 750 | **265** | **m3** | |
| 5-2-3. Embankment | Section(1) Section(2) Length<br>( 1.78 + 0.43 ) x 750 | **1,658** | **m3** | |
| 5-2-4. Gravel Pavement | Section Length<br>2.5 x 0.1 x 750 | **188** | **m3** | |
| **5-3. Canal Works** | | | | |
| 5-3-1. Concrete Lining | Section Length<br>0.161 x 750 | **121** | **m3** | |
| **6. TYPE C3-2** | | | | |
| **6-1. Preparatory Work** | | | | |
| 6-1-1. Site Clearing | Width Length<br>6.3 x 750 / 10000 | **0.5** | **ha** | |
| **6-2. Earth Work** | | | | |
| 6-2-1. Stripping | Section(1) Section(2) Length<br>( 0.812 + 0.212 ) x 750 | **768** | **m3** | |
| 6-2-2. Excavation | Section Length<br>0.313 x 750 | **235** | **m3** | |
| 6-2-3. Embankment | Section(1) Section(2) Length<br>( 1.364 + 0.314 ) x 750 | **1,259** | **m3** | |

Irrigation Scheme : Rejaf East Irrigation Scheme
Item of Work : Main Canal



| Item | Calculation | Quantity | Unit | Remark |
|---|---|---|---|---|
| | Section Length | | | |
| 6-2-4. Gravel Pavement | 2.5 x 0.1 x 750 | **188** | **m3** | |
| **6-3. Canal Works** | | | | |
| | Section Length | | | |
| 6-3-1. Concrete Lining | 0.123 x 750 | **92** | **m3** | |

# APPENDIX - 4

# OPERATION AND MAINTENANCE PLAN COST

## 4.1 Unit Cost of Personnel Expenses (SSP/month)

| Department | Staffing and Specialization | Grade | Basic Pay (SSP per Month) | Average Pay (SSP per Month) | Accom. Allo. (SSP per Month) | Cost of Living Allo. (SSP per Month) | Respon. Allo. | Represen. Allo. (SSP per Month) | Job Specific (SSP per Month) | Gross Pay (SSP per Month) | Pension Contri. (5%of Gross) | Income Tax: 10% of (Gross-300-Pension) | Net Pay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Management staff | Manager (Irrigation/Dam Eng.) | 3 | 1,625/2,000 | 1,813 | 1,800 | 75 | 88 | 88 | 810 | 4,674 | 234 | 414 | 4,026 |
| | Deputy Manager (Electromechanical Eng.) | 4 | 1525/1714 | 1620 | 1200 | 75 | 75 | 75 | 730 | 3,775 | 189 | 329 | 3258 |
| | Senior Accountant | 7 | 1188/1388 | 1,288 | 630 | 63 | | | 650 | 2,631 | 132 | 220 | 2280 |
| | Assistant Accountant | 9 | 925/1125 | 1,025 | 630 | 50 | | | 450 | 2,155 | 108 | 175 | 1873 |
| | Cooperative/Marketing Officer | 8 | 1075/1200 | 1,138 | 630 | 50 | | | 580 | 2,398 | 120 | 198 | 2080 |
| | Asst. Cooperative/Marketing Officer | 9 | 925/1125 | 1,025 | 630 | 50 | | | 450 | 2,155 | 108 | 175 | 1873 |
| | Tariff Collector (Book-keeper) | 12 | 375/440 | 408 | 450 | 38 | | | 400 | 1,296 | 65 | 93 | 1138 |
| | Messenger/Guard/Driver | 13 | 313/378 | 346 | 450 | 38 | | | 390 | 1,224 | 61 | 86 | 1077 |
| 2. Irrigation/Dam Operations and Maintenance | Senior Irri./Dam Eng. (Dam/Pump) | 7 | 1188/1388 | 1,288 | 630 | 63 | | | 650 | 2,631 | 132 | 220 | 2280 |
| | Electro-mechanical Eng. | 8 | 1075/1200 | 1,138 | 630 | 50 | | | 580 | 2,398 | 120 | 198 | 2080 |
| | Planning and Bugeting Officer | 8 | 1075/1200 | 1,138 | 630 | 50 | | | 580 | 2,398 | 120 | 198 | 2080 |
| | Asst. Irrigation/Dam Eng. | 9 | 925/1125 | 1,025 | 630 | 50 | | | 450 | 2,155 | 108 | 175 | 1873 |
| | Asst. Planning and Bugeting Officer | 9 | 925/1125 | 1,025 | 630 | 50 | | | 450 | 2,155 | 108 | 175 | 1873 |
| | Irrigation Technician | 10 | 825/950 | 888 | 450 | 38 | | | 440 | 1,816 | 91 | 142 | 1582 |
| | Pump operator | 11 | 500/565 | 533 | 450 | 38 | | | 410 | 1,431 | 72 | 106 | 1254 |
| | Irrigation Water Control Gate Operator | 11 | 500/565 | 533 | 450 | 38 | | | 410 | 1,431 | 72 | 106 | 1254 |
| | Facilities' Guards | 11 | 500/565 | 533 | 450 | 38 | | | 410 | 1,431 | 72 | 106 | 1254 |
| 3. Farm Level Operations | Senior Agronomist | 7 | 1188/1388 | 1,288 | 630 | 63 | | | 650 | 2,631 | 132 | 220 | 2280 |
| | Agronomist | 8 | 1075/1200 | 1,138 | 630 | 50 | | | 580 | 2,398 | 120 | 198 | 2080 |
| | Agricultural Engineer | 8 | 1075/1200 | 1,138 | 630 | 50 | | | 580 | 2,398 | 120 | 198 | 2080 |
| | Asst. Agricultural Engineer | 9 | 925/1125 | 1,025 | 630 | 50 | | | 450 | 2,155 | 108 | 175 | 1873 |
| | Extension Worker | 10 | 825/950 | 888 | 450 | 38 | | | 440 | 1,816 | 91 | 142 | 1582 |
| | Tractor Operator | 11 | 500/565 | 533 | 450 | 38 | | | 410 | 1,431 | 72 | 106 | 1254 |
| | Asst. Tractor Operator | 13 | 313/378 | 346 | 450 | 38 | | | 390 | 1,224 | 61 | 86 | 1077 |
| 4. Processing Operations | Rice mill operator | 10 | 825/950 | 888 | 450 | 38 | | | 440 | 1,816 | 91 | 142 | 1582 |
| | Asst. Rice mill operator | 11 | 500/565 | 533 | 450 | 38 | | | 410 | 1,431 | 72 | 106 | 1254 |
| Total per month | | | | 24,540 | 16,140 | 1,257 | 163 | 163 | 13,190 | 55,453 | 2,773 | 4,488 | 48,192 |
| Total per year | | | | 294,474 | 193,680 | 15,084 | 1,956 | 1,956 | 158,280 | 665,430 | 33,272 | 53,856 | 578,303 |

## 4.2 Annual Personnel Expenses (SSP/year)

| Department | Required Staff and Specialization | Grade | Rejaf East Irrigation Scheme | |
|---|---|---|---|---|
| | | | Prposed Number of Staff | Salary Budget (Gross in SSP) |
| Management staff | Manager (Irrigation/Dam Eng.) | 3 | 1 | 4,674 |
| | Deputy Manager (Electromechanical Eng.) | 4 | 1 | 3,775 |
| | Senior Accountant | 7 | 1 | 2,631 |
| | Cooperative/Marketing Officer | 8 | 1 | 2,155 |
| | Assistant Accountant | 9 | 1 | 2,398 |
| | Asst. Cooperative/Marketing Officer | 9 | 1 | 2,155 |
| | Tariff Collector | 12 | 2 | 1,296 |
| | Messenger/Guard/Driver | 13 | 6 | 1,224 |
| Irrigation/Dam Operations and Maintenance | Senior Irri./Dam Eng, (Dam/Pump) | 7 | 1 | 2,631 |
| | Electromechanical Eng. | 8 | 1 | 2,398 |
| | Planning and Bugeting Officer | 8 | 1 | 2,398 |
| | Asst. Irrigation/Dam Eng. | 9 | 1 | 2,155 |
| | Asst. Planning and Bugeting Officer | 9 | 1 | 2,155 |
| | Irrigation Technician | 10 | 2 | 1,816 |
| | Pump operator | 11 | 2 | 1,431 |
| | Irrigation Water Control Gate Operator | 11 | 2 | 1,431 |
| | Facilities' Guards | 11 | 4 | 1,431 |
| Farm Level Operations | Senior Agronomist | 7 | 1 | 2,631 |
| | Agronomist | 8 | 1 | 2,398 |
| | Agricultural Engineer | 8 | 1 | 2,398 |
| | Asst. Agricultural Engineer | 9 | 1 | 2,155 |
| | Extension Worker | 10 | 2 | 1,816 |
| | Tractor Operator | 11 | 1 | 1,431 |
| | Asst. Tractor Operator | 13 | 1 | 1,224 |
| Processing Operations | Rice mill operator | 10 | 0 | 0 |
| | Asst. Rice mill operator | 11 | 0 | 0 |
| Total per month | | | 37 | 52,206 |
| Total per year | | | | 626,472 |

Note: W = Wau, JL = Jebel Lado and RE = Rejaf East

## 4.3 Equipment and Machinery Investment Cost

| Cost Item | Grade/Spec | Unit Cost (SSP/unit) /a | Depreciation Schedule /b | Depreciation Cost /c | Rejaf East Irrigation Scheme | |
|---|---|---|---|---|---|---|
| | | | | | Number | Cost (SSP/year) |
| Equipment/Machineries | | | | | | |
| Motor Grader | 220HP (John Deere) | 2,141,480 | 15 | 128,500 | 1 | 128,500 |
| Backhoe Loader | 422F (Caterpillar) | 953,304 | 15 | 57,200 | 1 | 57,200 |
| Wheel Loaders | 938H (Caterpillar) | 2,030,952 | 15 | 121,900 | 1 | 121,900 |
| Dump Truck | 6 × 4 18CUM (Caterpillar) | 863,500 | 15 | 51,800 | 1 | 51,800 |
| Motor Bike | | 10,000 | 10 | 900 | 2 | 1,800 |
| Tractor /d | 75HP, 4WD (John Deere) | 203,786 | 10 | 18,300 | 5 | 91,500 |
| Attachment (plough) | 3-disc (John Deere) | 27,632 | 10 | 2,500 | 5 | 12,500 |
| Attachment (harrow) | 20-disc manually operated (John | 43,175 | 10 | 3,900 | 5 | 19,500 |
| Attachment (levellers) | | 3,600 | 10 | 300 | 5 | 1,500 |
| Attachment (sprayer) | 400ml, 8M (John Deere) | 46,974 | 10 | 4,200 | 5 | 21,000 |
| Attachment (fertilizer distributor) | | 13,816 | 10 | 1,200 | 5 | 6,000 |
| Attachment (trailer) | 5 tonne (John Deere) | 58,718 | 10 | 5,300 | 5 | 26,500 |
| Combine Harvester | | 81,000 | 10 | 7,300 | 3 | 21,900 |
| Working machines (Workshop) | | | | | | |
| Pick-pu Track | Single Cabine (4DW) | 20,900 | 10 | 1,900 | 2 | 3,800 |
| Portable Generator | 240V Capacity | 112,545 | 8 | 12,700 | 2 | 25,400 |
| Nattery Charger | 72V Chapacity | 500 | 8 | 100 | 2 | 200 |
| Generator | Perkins Type 1500RPM 150 kVA (380-54\\415V) | 357,441 | 8 | 40,200 | 1 | 40,200 |
| Lathe Machine | Universal High Precision | 54,600 | 8 | 6,100 | 1 | 6,100 |
| Power Saw | | 6,400 | 5 | 1,200 | 1 | 1,200 |
| Welding Machine | Arc | 2,700 | 5 | 500 | 2 | 1,000 |
| Welding Machine | Acetylene Gas Welding | 1,800 | 5 | 300 | 2 | 600 |
| Power Drill | Portable Heavy Duty Hand Drill | 500 | 5 | 100 | 1 | 100 |
| Rice Mill | | | | | | |
| Rice Mill | 2.0t/hr | 409,500 | 15 | 24,600 | | |
| Grain Threshing Machine | Vicon Type 1 tonne/hr | 7,300 | 15 | 400 | | |
| Drying Machine | | 36,400 | 15 | 2,200 | | |
| Warehouse | | 41,000 | 15 | 2,500 | | |
| Total | | | | | 58 | 640,200 |

Note: a/ Price quotations are obtained from Lonagro South Sudan Ltd. (Jhon Deere), Ezentus (Catepillar), and Aweil Irrigation Rehabilitation Project.
b/ Depreciation schedule is quoted from water supply project in Sounth Asia.
c/ 10% of residual value is taken into account in estimation of depreciation cost.

## 4.4 Equipment and Machinery O&M Cost

| Cost Item | Grade/Spec | Unit Cost (SSP/unit) /a | O&M Cost (1% of Unit Cost) | Rejaf East Irrigation Scheme | |
|---|---|---|---|---|---|
| | | | | Number | Cost (SSP/year) |
| Equipment/Machineries | | | | | |
| Motor Grader | 150-160HP | 2,141,480 | 21,410 | 1 | 21,410 |
| Backhoe Loader | 90HP | 953,304 | 9,530 | 1 | 9,530 |
| Wheel Loaders | 80HP | 2,030,952 | 20,310 | 1 | 20,310 |
| Dump Truck | 160HP | 863,500 | 8,640 | 1 | 8,640 |
| Motor Bike | | 10,000 | 100 | 2 | 200 |
| Tractor /d | 75HP, 4WD | 203,786 | 2,040 | 5 | 10,200 |
| Attachment (plough) | 3-disc | 27,632 | 280 | 5 | 1,400 |
| Attachment (harrow) | 20-disc manually operated | 43,175 | 430 | 5 | 2,150 |
| Attachment (levellers) | | 3,600 | 40 | 5 | 200 |
| Attachment (sprayer) | 400ml, 8M | 46,974 | 470 | 5 | 2,350 |
| Attachment (fertilizer distributor) | | 13,816 | 140 | 5 | 700 |
| Attachment (trailer) | 5 tonne | 58,718 | 590 | 5 | 2,950 |
| Combine Harvester | | 81,000 | 810 | 3 | 2,430 |
| Working machines (Workshop) | | | | | |
| Pick-pu Track | Single Cabine (4DW) | 20,900 | 210 | 2 | 420 |
| Portable Generator | 240V Capacity | 112,545 | 1,130 | 2 | 2,260 |
| Battery Charger | 72V Chapacity | 500 | 10 | 2 | 20 |
| Generator | Perkins Type 1500RPM 150 kVA (380-54\\415V) | 357,441 | 3,570 | 1 | 3,570 |
| Lathe Machine | Universal High Precision | 54,600 | 550 | 1 | 550 |
| Power Saw | | 6,400 | 60 | 1 | 60 |
| Welding Machine | Arc | 2,700 | 30 | 2 | 60 |
| Welding Machine | Acetylene Gas Welding | 1,800 | 20 | 2 | 40 |
| Power Drill | Portable Heavy Duty Hand Drill | 500 | 10 | 1 | 10 |
| Rice Mill | | | | | |
| Rice Mill | 1.0-2.0t/hr | 409,500 | 4,100 | | |
| Grain Threshing Machine | Vicon Type 1 tonne/hr | 7,300 | 70 | | |
| Drying Machine | | 36,400 | 360 | | |
| Warehouse | | 41,000 | 410 | | |
| Total | | | | 58 | 89,460 |

Note: a/ Price quotations are obtained from Lonagro South Sudan Ltd. (Jhon Deere), Ezentus (Catepillar), and Aweil Irrigation Rehabilitation Project.
b/ Depreciation schedule is quoted from water supply project in Sounth Asia.
c/ 10% of residual value is taken into account in estimation of depreciation cost.

## 4.5 Water Tariff Estimation

| | Rejaf East Irrigation Scheme | |
|---|---|---|
| | Detail | SSP |
| A. Project Cost (SSP) | USD 25,000,000 | 73,214,286 |
| B. Depreciation Cost (SSP/year) | | 8,698,067 |
| Project Facility | 1,081,797 | 3,168,119 |
| Equipment and Machinary | | 640,200 |
| C. Annual O&M Cost (SSP/year) | | |
| Personnel Expenses | | 626,472 |
| Pump Operation | USD 1,400,206 | 4,100,602 |
| Equipment and Machinary (1% of Procurement Cost) | | 89,460 |
| Maintenance Cost (0.1% of Project Cost) | | 73,214 |
| Sub-total (Annual Operation Cost) | | 4,889,748 |
| D. Irrigable Area (ha) | | 922 |
| Annual O&M Cost per Irrigable Area (SSP/ha) | | 5,303 |
| Minimum Area for Feeding Family (ha/HH/year) /a | | 0.42 |
| Number of Lot for Distribution (1lot = 1feddan = 0.42ha) | | 2,195 |
| E. Water Consumption ($m^3$/season) | Total | 20,444,535 |
| Crop 1 | Maize | 3,555,312 |
| Crop 2 | Vegetables | 3,079,545 |
| Crop 3 | Groundnuts | 13,809,678 |
| F. Water Tariff Estimation | | |
| Area-based Pricing (SSP/lot, or SSP/feddan) | | SSP 2,230 fd |
| Volumetric Pricing 1 (SSP/$m^3$) | Total | SSP 0.24 m3 |
| Crop 1 | Maize | SSP 1.38 m3 |
| Crop 2 | Vegetables | SSP 1.59 m3 |
| Crop 3 | Groundnuts | SSP 0.35 m3 |
| Volumetric Pricing 2 (SSP/season/feddan) | | |
| Crop 1 | 869 ac | **SSP 1,000 fd** |
| Crop 2 | 388 ac | **SSP 1,900 fd** |
| Crop 3 | 2,195 ac | **SSP 1,500 fd** |
| Volumetric Pricing 2 (SSP/season/ha) | | |
| Crop 1 | 365 ha | SSP 2,300 ha |
| Crop 2 | 163 ha | SSP 4,500 ha |
| Crop 3 | 922 ha | SSP 3,600 ha |
| Member's Fee (SSP/lot) /b | | **SSP 695 /ha** |
| Member's Fee (In Kind = Labor Work in days) /c | | **17 days/year** |

Note: a/ Necessary area for feeding family members (7person/HH) by planting maize is estimated at 0.21ha. Planned yield of maize is 3t/ha.

b/ Members' fee is estimated by dividing number of lot into depreciation cost of equipment and machinary.

c/ In kind is equivalent to labor cost of SSP40/ha.

## 4.6 Affordability to Pay (ATP)

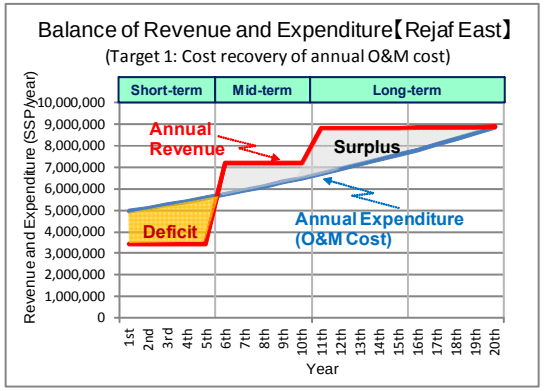
| Term | Crops | Net Income /a (SSP/ha) | Cropped Area (ha) | Total Net Income (SSP/ha) | Affordability Rate (%) | ATP (SSP/ha) | Estimated ISF (SSP/ha) | ISF Adjustd (SSP/ha) |
|---|---|---|---|---|---|---|---|---|
| Short-term | Maize | 4,699 | 346 | 1,625,854 | 3% | 140 | 2,381 | **140** |
| | Vegetable | 265,470 | 746 | 198,040,620 | 3% | 7,960 | 4,524 | **4,524** |
| | Groundnuts | 4,466 | 155 | 692,230 | 3% | 130 | 3,571 | **130** |
| | Weighted Average | 160,673 | 1,247 | 200,358,704 | 3% | 4,820 | 2,230 | 2,230 |
| <id-term | Maize | 4,699 | 0 | 0 | 5% | 230 | 2,381 | **230** |
| | Vegetable | 265,470 | 1,748 | 464,041,560 | 5% | 13,270 | 4,524 | **4,524** |
| | Groundnuts | 4,466 | 0 | 0 | 5% | 220 | 3,571 | **220** |
| | Weighted Average | 265,470 | 1,748 | 464,041,560 | 5% | 13,270 | 2,230 | 2,230 |
| Long-term | Maize | 4,699 | 0 | 0 | 8% | 380 | 2,381 | **380** |
| | Vegetable | 265,470 | 1,748 | 464,041,560 | 8% | 21,240 | 4,524 | **4,524** |
| | Groundnuts | 4,466 | 0 | 0 | 8% | 360 | 3,571 | **360** |
| | Weighted Average | 265,470 | 1,748 | 464,041,560 | 8% | 21,240 | 2,230 | 2,230 |

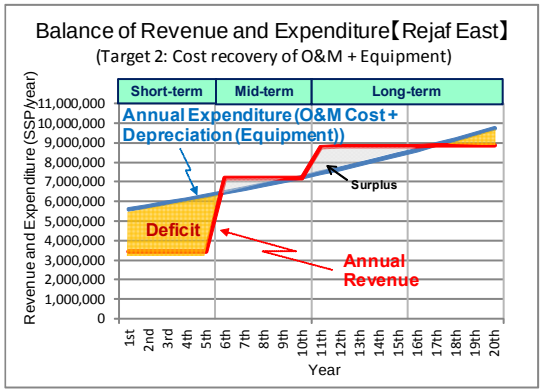
Note: a/ "Net income" is not cosidered in family labor cost.

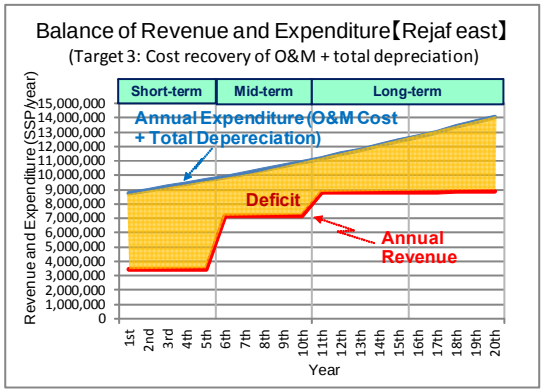
## 4.7 Cash Flow Analysis

| | Short-term | | | | | Mid-term | | | | | Long-term | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st Year | 2nd Year | 3rd Year | 4th Year | 5th Year | 6th Year | 7th Year | 8th Year | 9th Year | 10th Year | 11th Year | 12th Year | 13th Year | 14th Year | 15th Year | 16th Year | 17th Year | 18th Year | 19th Year | 20th Year |
| Revenue | | | | | | | | | | | | | | | | | | | | |
| Member Fee /a | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 | 640,940 |
| Irrigation Service Fee /b | 3,714,167 | 3,714,167 | 3,714,167 | 3,714,167 | 3,714,167 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 |
| ISF Collection Rate | 70% | 70% | 70% | 70% | 70% | 80% | 80% | 80% | 80% | 80% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Amount of ISF Collected | 2,599,917 | 2,599,917 | 2,599,917 | 2,599,917 | 2,599,917 | 6,326,095 | 6,326,095 | 6,326,095 | 6,326,095 | 6,326,095 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 | 7,907,619 |
| Tractor Service Fee /c | 174,800 | 180,638 | 186,672 | 192,906 | 199,350 | 206,008 | 212,888 | 219,999 | 227,347 | 234,940 | 242,787 | 250,896 | 259,276 | 267,936 | 276,885 | 286,133 | 295,690 | 305,566 | 315,772 | 326,319 |
| Sub-total | 3,415,657 | 3,421,495 | 3,427,528 | 3,433,763 | 3,440,206 | 7,173,043 | 7,179,924 | 7,187,034 | 7,194,382 | 7,201,976 | 8,791,346 | 8,799,455 | 8,807,835 | 8,816,495 | 8,825,444 | 8,834,692 | 8,844,249 | 8,854,125 | 8,864,331 | 8,874,878 |
| Expemditure | | | | | | | | | | | | | | | | | | | | |
| Annual O&M Cost (SSP/year) | | | | | | | | | | | | | | | | | | | | |
| Personnel Expenses | 679,500 | 690,848 | 702,385 | 714,115 | 726,040 | 738,165 | 750,493 | 763,026 | 775,768 | 788,724 | 801,895 | 815,287 | 828,902 | 842,745 | 856,819 | 871,128 | 885,676 | 900,466 | 915,504 | 930,793 |
| Pump Operation | 4,100,602 | 4,237,562 | 4,379,097 | 4,525,359 | 4,676,506 | 4,832,701 | 4,994,113 | 5,160,916 | 5,333,291 | 5,511,423 | 5,695,505 | 5,885,734 | 6,082,318 | 6,285,467 | 6,495,402 | 6,712,348 | 6,936,541 | 7,168,221 | 7,407,640 | 7,655,055 |
| Equipment and Machinary (1% of Procurement Cost) | 89,460 | 92,448 | 95,536 | 98,727 | 102,024 | 105,432 | 108,953 | 112,592 | 116,353 | 120,239 | 124,255 | 128,405 | 132,694 | 137,126 | 141,706 | 146,439 | 151,330 | 156,384 | 161,607 | 167,005 |
| Maintenance Cost (0.1% of Project Cost) | 73,214 | 74,437 | 75,680 | 76,944 | 78,229 | 79,535 | 80,864 | 82,214 | 83,587 | 84,983 | 86,402 | 87,845 | 89,312 | 90,803 | 92,320 | 93,862 | 95,429 | 97,023 | 98,643 | 100,290 |
| Sub-total | 4,942,776 | 5,095,295 | 5,252,697 | 5,415,144 | 5,582,799 | 5,755,833 | 5,934,422 | 6,118,748 | 6,308,999 | 6,505,368 | 6,708,057 | 6,917,271 | 7,133,226 | 7,356,142 | 7,586,246 | 7,823,776 | 8,068,975 | 8,322,095 | 8,583,394 | 8,853,144 |
| Depreciation Cost (SSP/year) | | | | | | | | | | | | | | | | | | | | |
| Project Facility | 3,168,119 | 3,221,026 | 3,274,818 | 3,329,507 | 3,385,110 | 3,441,641 | 3,499,116 | 3,557,552 | 3,616,963 | 3,677,366 | 3,738,778 | 3,801,216 | 3,864,696 | 3,929,236 | 3,994,855 | 4,061,569 | 4,129,397 | 4,198,358 | 4,268,470 | 4,339,754 |
| Equipment and Machinary | 640,200 | 650,891 | 661,761 | 672,813 | 684,049 | 695,472 | 707,087 | 718,895 | 730,900 | 743,107 | 755,516 | 768,134 | 780,961 | 794,003 | 807,263 | 820,745 | 834,451 | 848,386 | 862,554 | 876,959 |
| Sub-total | 3,808,319 | 3,871,918 | 3,936,579 | 4,002,320 | 4,069,158 | 4,137,113 | 4,206,203 | 4,276,447 | 4,347,863 | 4,420,473 | 4,494,295 | 4,569,349 | 4,645,657 | 4,723,240 | 4,802,118 | 4,882,313 | 4,963,848 | 5,046,744 | 5,131,025 | 5,216,713 |
| Annual O&M + Depreciation (Equipment) | 5,582,976 | 5,746,186 | 5,914,459 | 6,087,956 | 6,266,848 | 6,451,305 | 6,641,509 | 6,837,643 | 7,039,900 | 7,248,475 | 7,463,573 | 7,685,405 | 7,914,187 | 8,150,145 | 8,393,510 | 8,644,521 | 8,903,426 | 9,170,481 | 9,445,949 | 9,730,103 |
| Annual O&M + Depreciation (Total) | 8,751,095 | 8,967,213 | 9,189,276 | 9,417,463 | 9,651,957 | 9,892,946 | 10,140,625 | 10,395,195 | 10,656,862 | 10,925,841 | 11,202,351 | 11,486,621 | 11,778,883 | 12,079,381 | 12,388,364 | 12,706,090 | 13,032,823 | 13,368,839 | 13,714,419 | 14,069,857 |
| Balance /d | | | | | | | | | | | | | | | | | | | | |
| Target 1: Annual O&M Cost | -1,527,120 | -1,673,800 | -1,825,169 | -1,981,381 | -2,142,593 | 1,417,210 | 1,245,501 | 1,068,286 | 885,383 | 696,607 | 2,083,290 | 1,882,184 | 1,674,609 | 1,460,354 | 1,239,198 | 1,010,916 | 775,274 | 532,031 | 280,937 | 21,734 |
| Subsidy (SSP/year) | 1,527,120 | 1,673,800 | 1,825,169 | 1,981,381 | 2,142,593 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Subsidy (%) | 31% | 33% | 35% | 37% | 38% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Target 2: Annual O&M Cost + Deprecoation (Equipment) | -2,167,320 | -2,324,691 | -2,486,930 | -2,654,193 | -2,826,641 | 721,738 | 538,415 | 349,391 | 154,483 | -46,499 | 1,327,773 | 1,114,051 | 893,648 | 666,350 | 431,935 | 190,171 | -59,177 | -316,356 | -581,618 | -855,225 |
| Subsidy (SSP/year) | 2,167,320 | 2,324,691 | 2,486,930 | 2,654,193 | 2,826,641 | - | - | - | - | 46,499 | - | - | - | - | - | - | 59,177 | 316,356 | 581,618 | 855,225 |
| Subsidy (%) | 39% | 40% | 42% | 44% | 45% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 3% | 6% | 9% |
| Target 3: Annual O&M Cost + Deprecoation (Total) | -5,335,439 | -5,545,718 | -5,761,748 | -5,983,700 | -6,211,751 | -2,719,903 | -2,960,702 | -3,208,161 | -3,462,480 | -3,723,866 | -2,411,005 | -2,687,165 | -2,971,048 | -3,262,886 | -3,562,920 | -3,871,397 | -4,188,574 | -4,514,714 | -4,850,088 | -5,194,979 |
| Subsidy (SSP/year) | 5,335,439 | 5,545,718 | 5,761,748 | 5,983,700 | 6,211,751 | 2,719,903 | 2,960,702 | 3,208,161 | 3,462,480 | 3,723,866 | 2,411,005 | 2,687,165 | 2,971,048 | 3,262,886 | 3,562,920 | 3,871,397 | 4,188,574 | 4,514,714 | 4,850,088 | 5,194,979 |
| Subsidy (%) | 61% | 62% | 63% | 64% | 64% | 27% | 29% | 31% | 32% | 34% | 22% | 23% | 25% | 27% | 29% | 30% | 32% | 34% | 35% | 37% |

Note: a/ Member fee (fixed charge per year) is estimated by dividing procurment cost of equipment by number of lot (=1feddan). In Wau, milling facility is excluded from the procurment cost.
b/ Irrigation service fee (ISF) is estimated by dividing total water consumption volume by each crops' water consumption volume in a season.
c/ Unit price of tractor service fee is SSP200/feddan, quoted from Socio-economic Survey conducted by IDMP-TT in 2015.
d/ Balance is estimated to cover annual O&M cost by revenue of the scheme.



# APPENDIX - 5

# ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

## Evaluation Sheet for Alternatives

**Project Title: Irrigation Development in Rejaf East**

**Evaluation Method**

| | |
|---|---|
| Evaluation method | Evaluation criteria: 5: Exceptionally suitable, 4: Suitable, 3: Negligible/ Neutral<br>2: Not suggestible, 1: Suggest avoiding<br>Evaluation items<br>ñPollutionò includes: ñAir Pollution ò, ñWater Pollution ò, ñWasteò, ñSoil/Sediment Contaminationò,<br>ñNoise and Vibrationò, ñOdourò, ñGlobal Warmingò<br>ñBiodiversityò includes: ñProtected Areasò ñEcosystemò<br>ñNature, disastersò includes: ñHydrologyò, ñTopography and Geology ò, ñSubsidence / Erosionò,<br>, ñLandscapeò<br>ñLand occupies resettlementò includes: ñResettlementò. ñLand Useò<br>ñSocial conflictò includes: ñVulnerable Groupsò, ñWater Use / Rightsò<br>ñLiving conditionò includes: ñLiving and Livelihood ò, ñLocal Economy ò, ñHistorical / Cultural Heritageò<br>ñSocial Infrastructure / Servicesò, ñInfectious Diseasesò<br>ñEconomy, developmentò means: contribution to economic improvement in the RSS<br>ñConsistencyò means: consistency / harmonization with the RSS policies |

**Project Summary**

| | Alternative A | | Zero option |
|---|---|---|---|
| Project Summary | Pump irrigation | No project | |

**Evaluation**

| Valuation Items | | Alternative A | | Zero option |
|---|---|---|---|---|
| Natural Environment | **Average of a), b), c) ------- (1)** | **2.7** | | **3.0** |
| | a) Pollution | 3 3 | | |
| | b) Ecosystem | 2 3 | | |
| | c) Nature, disasters | 3 3 | | |
| | Reason | | | |
| Social Environment | **Average of a), b), c) ------- (2)** | **2.3** | | **3.0** |
| | a) Land occupies, resettlement | 2 3 | | |
| | b) Social conflict | 2 3 | | |
| | c) Living condition | 3 3 | | |
| | Reason | | | |
| Economy, development | **Average of a), b), c) ------- (3)** | **4.5** | | **3.0** |
| | a) Economy, development | 5 3 | | |
| | b) Consistency | 4 3 | | |
| | Reason | | | |

**Results**

| | Alternative A | Alternative B | Zero option |
|---|---|---|---|
| Total score (1) + (2) + (3) | **9.5 9.0** | | |
| Ranking | **1 2** | | |
| Overall | The project site has high land potential because of its location adjacent Juba city. It is expected to generate cash income by selling agricultural production. | | |

## Preliminary Scoping Check Sheet

**Project Title: Irrigation Development in Rejaf East**

Project Activity: Pre-construction
Land preparation

| Environmental Items | | Duration a) | Extent b) | Intensity c) | Cumulative d) | Reversible e) | Total Score (T) a)+b)+c)+d)+e) / Rank |
|---|---|---|---|---|---|---|---|
| | | Short: 1<br>Medium: 2<br>Long: 3 | Limited: 1<br>Medium: 2<br>Wide: 3 | Small/Negligible: 1<br>Medium: 2<br>Big: 3 | Non-Cumulative: 1<br><br>Cumulative: 3 | Reversible: 1<br><br>Irreversible: 3 | |
| | | Indication: no: no impact, +: positive -: negative<br>Rough indication for ranking: The score is rough value. Your judgement based on your experiences / knowledge will be reflected to the ranking.<br>-15 -12 \| -11 -7 \| -6 +6 \| +7 +11 \| +12 +15<br>-A \| -B or -C \| D or ±C \| +B or +C \| +A | | | | | |
| Pollution | Air Pollution | -1 | -1 | -1 | -1 | -1 | -5/D |
| | Water Pollution | no | no | no | no | no | D |
| | Waste | -1 | -2 | -1 | -1 | -1 | -6/-C |
| | Soil/Sediment Contamination | no | no | no | no | no | D |
| | Noise and Vibration | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Odor | no | no | no | no | no | D |
| Natural Environment | Protected Areas | no | no | no | no | no | D |
| | Ecosystem | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Hydrology | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Topography and Geology | no | no | no | no | no | D |
| | Subsidence / Erosion | no | no | no | no | no | D |
| | Global Warming | no | no | no | no | no | D |
| | Landscape | no | no | no | no | no | D |
| Social Environment | Resettlement | -3 | -1 | -2 | -1 | -3 | -10/-B |
| | Living and Livelihood | -2 | -1 | -2 | -1 | -1 | -7/-B |
| | Local Economy | no | no | no | no | no | D |
| | Historical / Cultural Heritage | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Land Use | -1 | -1 | -1 | -1 | -3 | -7/-C |
| | Vulnerable Groups | no | no | no | no | no | D |
| | Local Conflict | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Water Use / Right | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Social Infrastructure / Services | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Infectious Diseases | no | no | no | no | no | D |
| Remark | | The project site has been used for community farmland. Residential zone has spread.<br>Land potential is high because of its location adjacent Juba city. | | | | | |

## Preliminary Scoping Check Sheet

**Project Title: Irrigation Development in Rejaf East**

Project Activity: Construction

Construction of pump station

| Environmental Items | | Duration a) | Extent b) | Intensity c) | Cumulative d) | Reversible e) | Total Score (T) a)+b)+c)+d)+e) / Rank |
|---|---|---|---|---|---|---|---|
| | | Short: 1<br>Medium: 2<br>Long: 3 | Limited: 1<br>Medium: 2<br>Wide: 3 | Small/Negligible: 1<br>Medium: 2<br>Big: 3 | Non-Cumulative: 1<br><br>Cumulative: 3 | Reversible: 1<br><br>Irreversible: 3 | |
| | | Indication: no: no impact, +: positive -: negative<br>Rough indication for ranking: The score is rough value. Your judgement based on your experiences / knowledge will be reflected to the ranking.<br>-15 -12 \| -11 -7 \| -6 +6 \| +7 +11 \| +12 +15<br>-A \| -B or -C \| D or ±C \| +B or +C \| +A | | | | | |
| Pollution | Air Pollution | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Water Pollution | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Waste | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Soil/Sediment Contamination | no | no | no | no | no | D |
| | Noise and Vibration | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Odor | no | no | no | no | no | D |
| Natural Environment | Protected Areas | no | no | no | no | no | D |
| | Ecosystem | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Hydrology | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Topography and Geology | no | no | no | no | no | D |
| | Subsidence / Erosion | no | no | no | no | no | D |
| | Global Warming | no | no | no | no | no | D |
| | Landscape | no | no | no | no | no | D |
| Social Environment | Resettlement | no | no | no | no | no | D |
| | Living and Livelihood | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Local Economy | +1 | +1 | +1 | +1 | +1 | +5/+C |
| | Historical / Cultural Heritage | no | no | no | no | no | D |
| | Land Use | no | no | no | no | no | D |
| | Vulnerable Groups | no | no | no | no | no | D |
| | Local Conflict | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Water Use / Right | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Social Infrastructure / Services | no | no | no | no | no | D |
| | Infectious Diseases | no | no | no | no | no | D |
| Remark | | | | | | | |

## Preliminary Scoping Check Sheet

**Project Title: Irrigation Development in Rejaf East**

Project Activity: Construction

Installation of canal and pipe

| Environmental Items | | Duration a) | Extent b) | Intensity c) | Cumulative d) | Reversible e) | Total Score (T) a)+b)+c)+d)+e) / Rank |
|---|---|---|---|---|---|---|---|
| | | Short: 1<br>Medium: 2<br>Long: 3 | Limited: 1<br>Medium: 2<br>Wide: 3 | Small/Negligible: 1<br>Medium: 2<br>Big: 3 | Non-Cumulative: 1<br><br>Cumulative: 3 | Reversible: 1<br><br>Irreversible: 3 | |
| | | Indication: no: no impact, +: positive -: negative<br>Rough indication for ranking: The score is rough value. Your judgement based on your experiences / knowledge will be reflected to the ranking.<br>-15 -12 \| -11 -7 \| -6 +6 \| +7 +11 \| +12 +15<br>-A \| -B or -C \| D or ±C \| +B or +C \| +A | | | | | |
| Pollution | Air Pollution | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Water Pollution | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Waste | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Soil/Sediment Contamination | no | no | no | no | no | D |
| | Noise and Vibration | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Odor | no | no | no | no | no | D |
| Natural Environment | Protected Areas | no | no | no | no | no | D |
| | Ecosystem | -1 | -1 | -2 | -1 | -1 | -6/-C |
| | Hydrology | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Topography and Geology | no | no | no | no | no | D |
| | Subsidence / Erosion | no | no | no | no | no | D |
| | Global Warming | no | no | no | no | no | D |
| | Landscape | no | no | no | no | no | D |
| Social Environment | Resettlement | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Living and Livelihood | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Local Economy | +1 | +1 | +2 | +1 | +1 | +6/+C |
| | Historical / Cultural Heritage | no | no | no | no | no | D |
| | Land Use | no | no | no | no | no | D |
| | Vulnerable Groups | no | no | no | no | no | D |
| | Local Conflict | -2 | -1 | -2 | -1 | -1 | -7/-C |
| | Water Use / Right | no | no | no | no | no | D |
| | Social Infrastructure / Services | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Infectious Diseases | no | no | no | no | no | D |
| Remark | | | | | | | |

Preliminary Scoping Check Sheet

**Project Title: Irrigation Development in Rejaf East**

Project Activity: Construction

Land clearance and leveling in command area

| Environmental Items | | Duration a) | Extent b) | Intensity c) | Cumulative d) | Reversible e) | Total Score (T) a)+b)+c)+d)+e) / Rank |
|---|---|---|---|---|---|---|---|
| | | Short: 1<br>Medium: 2<br>Long: 3 | Limited: 1<br>Medium: 2<br>Wide: 3 | Small/Negligible: 1<br>Medium: 2<br>Big: 3 | Non-Cumulative: 1<br><br>Cumulative: 3 | Reversible: 1<br><br>Irreversible: 3 | |
| | | Indication: no: no impact, +: positive -: negative<br>Rough indication for ranking: The score is rough value. Your judgement based on your experiences / knowledge will be reflected to the ranking.<br>-15 -12 \| -11 -7 \| -6 +6 \| +7 +11 \| +12 +15<br>-A \| -B or -C \| D or ±C \| +B or +C \| +A | | | | | |
| Pollution | Air Pollution | -1 | -1 | -2 | -1 | -1 | -6/-C |
| | Water Pollution | -1 | -1 | -2 | -1 | -1 | -6/-C |
| | Waste | -1 | -1 | -2 | -1 | -1 | -6/-C |
| | Soil/Sediment Contamination | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Noise and Vibration | -1 | -1 | -2 | -1 | -1 | -6/-C |
| | Odor | no | no | no | no | no | D |
| Natural Environment | Protected Areas | no | no | no | no | no | D |
| | Ecosystem | -3 | -1 | -2 | -1 | -3 | -10/-C |
| | Hydrology | -1 | -1 | -2 | -1 | -1 | -6/-C |
| | Topography and Geology | no | no | no | no | no | D |
| | Subsidence / Erosion | -2 | -1 | -1 | -1 | - | -6/-C |
| | Global Warming | no | no | no | no | no | D |
| | Landscape | no | no | no | no | no | D |
| Social Environment | Resettlement | -2 | -1 | -2 | -1 | -1 | -7/-B |
| | Living and Livelihood | -2 | -1 | -2 | -1 | -1 | -7/-B |
| | Local Economy | +2 | +1 | +1 | +1 | +1 | +6/+B |
| | Historical / Cultural Heritage | no | no | no | no | no | D |
| | Land Use | -1 | -1 | -1 | -1 | -3 | -7/-B |
| | Vulnerable Groups | no | no | no | no | no | D |
| | Local Conflict | -2 | -1 | -2 | -1 | -1 | -7/-B |
| | Water Use / Right | -1 | -1 | -2 | -1 | -1 | -6/-C |
| | Social Infrastructure / Services | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Infectious Diseases | no | no | no | no | no | D |
| Remark | | Existing agricultural production can be obstructed by construction work. | | | | | |

## Preliminary Scoping Check Sheet

**Project Title: Irrigation Development in Rejaf East**

Project Activity: Operation and Maintenance

Operation of pump

| Environmental Items | | Duration a) | Extent b) | Intensity c) | Cumulative d) | Reversible e) | Total Score (T) a)+b)+c)+d)+e) / Rank |
|---|---|---|---|---|---|---|---|
| | | Short: 1 Medium: 2 Long: 3 | Limited: 1 Medium: 2 Wide: 3 | Small/Negligible: 1 Medium: 2 Big: 3 | Non-Cumulative: 1 Cumulative: 3 | Reversible: 1 Irreversible: 3 | |
| | | Indication: no: no impact, +: positive -: negative<br>Rough indication for ranking: The score is rough value. Your judgement based on your experiences / knowledge will be reflected to the ranking.<br>-15 -12 \| -11 -7 \| -6 +6 \| +7 +11 \| +12 +15<br>-A \| -B or -C \| D or ±C \| +B or +C \| +A | | | | | |
| Pollution | Air Pollution | -1 | -1 | -2 | -1 | -1 | -6/-C |
| | Water Pollution | -1 | -1 | -2 | -1 | -1 | -5/-C |
| | Waste | no | no | no | no | no | D |
| | Soil/Sediment Contamination | no | no | no | no | no | D |
| | Noise and Vibration | -1 | -1 | -2 | -1 | -1 | -6/-C |
| | Odor | no | no | no | no | no | D |
| Natural Environment | Protected Areas | no | no | no | no | no | D |
| | Ecosystem | no | no | no | no | no | D |
| | Hydrology | no | no | no | no | no | D |
| | Topography and Geology | no | no | no | no | no | D |
| | Subsidence / Erosion | no | no | no | no | no | D |
| | Global Warming | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Landscape | no | no | no | no | no | D |
| Social Environment | Resettlement | no | no | no | no | no | D |
| | Living and Livelihood | no | no | no | no | no | D |
| | Local Economy | no | no | no | no | no | D |
| | Historical / Cultural Heritage | no | no | no | no | no | D |
| | Land Use | no | no | no | no | no | D |
| | Vulnerable Groups | no | no | no | no | no | D |
| | Local Conflict | no | no | no | no | no | D |
| | Water Use / Right | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Social Infrastructure / Services | no | no | no | no | no | D |
| | Infectious Diseases | no | no | no | no | no | D |
| Remark | | | | | | | |

## Preliminary Scoping Check Sheet

**Project Title: Irrigation Development in Rejaf East**

Project Activity: Operation and Maintenance
Farming

| Environmental Items | | Duration a) | Extent b) | Intensity c) | Cumulative d) | Reversible e) | Total Score (T) a)+b)+c)+d)+e) / Rank |
|---|---|---|---|---|---|---|---|
| | | Short: 1<br>Medium: 2<br>Long: 3 | Limited: 1<br>Medium: 2<br>Wide: 3 | Small/Negligible: 1<br>Medium: 2<br>Big: 3 | Non-Cumulative: 1<br><br>Cumulative: 3 | Reversible: 1<br><br>Irreversible: 3 | |
| | | Indication: no: no impact, +: positive -: negative<br>Rough indication for ranking: The score is rough value. Your judgement based on your experiences / knowledge will be reflected to the ranking.<br>-15 -12 \| -11 -7 \| -6 +6 \| +7 +11 \| +12 +15<br>-A \| -B or -C \| D or ±C \| +B or +C \| +A | | | | | |
| Pollution | Air Pollution | no | no | no | no | no | D |
| | Water Pollution | -2 | -2 | -2 | -1 | -1 | -8/-B |
| | Waste | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Soil/Sediment Contamination | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Noise and Vibration | no | no | no | no | no | D |
| | Odor | no | no | no | no | no | D |
| Natural Environment | Protected Areas | no | no | no | no | no | D |
| | Ecosystem | +2 | +1 | +1 | +1 | +3 | +8/+C |
| | Hydrology | no | no | no | no | no | D |
| | Topography and Geology | no | no | no | no | no | D |
| | Subsidence / Erosion | no | no | no | no | no | D |
| | Global Warming | no | no | no | no | no | D |
| | Landscape | no | no | no | no | no | D |
| Social Environment | Resettlement | no | no | no | no | no | D |
| | Living and Livelihood | +3 | +1 | +2 | +1 | +3 | +10/+B |
| | Local Economy | +3 | +2 | +3 | +3 | +3 | +14/+A |
| | Historical / Cultural Heritage | no | no | no | no | no | D |
| | Land Use | -3 | -2 | -1 | -1 | -1 | -8/-B |
| | Vulnerable Groups | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Local Conflict | -2 | -1 | -2 | -3 | -1 | -9/-B |
| | Water Use / Right | -1 | -1 | -1 | -1 | -1 | -5/-C |
| | Social Infrastructure / Services | no | no | no | no | no | D |
| | Infectious Diseases | -1 | -1 | -1 | -1 | -1 | -5/-C |
| Remark | | Agricultural production can contribute to economic improvement.<br>Water / soil pollution may occur if pesticide, fertilize is not properly used. | | | | | |

# Scoping Matrix

**Project Title: Irrigation Development in Rejaf East**

| Environmental Parameters | | Pre-construction | | Construction | | | | | | | | | Operation & Maintenance | | | | Overall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Land preparation | | Construction of pump station | Installation of canals and pipe | Land clearance and levelling, in command area | | | | | | | Operation of pump | Farming | | | |
| Remark | | positive: +, negative: -<br>A: Significant impact is expected, B: Moderate impact is expected, C: Level of impact unknown, D: No / negligible impact is | | | | | | | | | | | | | | | |
| Pollution | Air Pollution | D | | -C | -C | -C | | | | | | | -C | D | | | -C |
| | Water Pollution | D | | -C | -C | -C | | | | | | | -C | -B | | | -C |
| | Waste | -C | | -C | -C | -C | | | | | | | D | -C | | | -C |
| | Soil/Sediment Contamination | D | | D | D | -C | | | | | | | D | -C | | | -C |
| | Noise and Vibration | -C | | -C | -C | -C | | | | | | | -C | D | | | -C |
| | Odour | D | | D | D | D | | | | | | | D | D | | | D |
| Natural Environment | Protected Areas | D | | D | D | D | | | | | | | D | D | | | D |
| | Ecosystem | -C | | -C | -C | -C | | | | | | | D | +C | | | -C |
| | Hydrology | -C | | -C | -C | -C | | | | | | | D | D | | | -C |
| | Topography and Geology | D | | D | D | D | | | | | | | D | D | | | D |

| Environmental Parameters | | Pre-construction | | Construction | | | | | | | | | Operation & Maintenance | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Land preparation | | Construction of pump station | Installation of canals and pipe | Land clearance and levelling, in command area | | | | | | | Operation of pump | Farming | | | Overall |
| Remark | | positive: +, negative: -<br>A: Significant impact is expected, B: Moderate impact is expected, C: Level of impact unknown, D: No / negligible impact is | | | | | | | | | | | | | | | |
| | Subsidence / Erosion | D | | D | D | -C | | | | | | | D | D | | | -C |
| | Global Warming | D | | D | D | D | | | | | | | -C | D | | | D |
| | Landscape | D | | D | D | D | | | | | | | D | D | | | D |

# Scoping Matrix

| Environmental Parameters | | Pre-construction | | Construction | | | | | | | | | Operation & Maintenance | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Land preparation | | Construction of pump station | Installation of canals and pipe | Land clearance and levelling, in command area | | | | | | | Operation of pump | Farming | | | Overall |
| Remark | | positive: +, negative: -<br>A: Significant impact is expected, B: Moderate impact is expected, C: Level of impact unknown, D: No / negligible impact is | | | | | | | | | | | | | | | |
| Social Environment | Resettlement | -B | | D | -C | -B | | | | | | | D | D | | | -B |
| | Living and Livelihood | -B | | -C | -C | -B | | | | | | | D | +B | | | +/-B |
| | Local Economy | D | | +C | +C | +B | | | | | | | D | +A | | | +A |
| | Historical / Cultural Heritage | -C | | D | D | D | | | | | | | D | D | | | D |
| | Land Use | -C | | D | D | -B | | | | | | | D | -B | | | -B |
| | Vulnerable Groups | D | | D | D | D | | | | | | | D | -C | | | D |
| | Local Conflict | -C | | -C | -C | -B | | | | | | | D | -B | | | -B |
| | Water Use / Right | -C | | -C | D | -C | | | | | | | -C | -C | | | -C |
| | Social Infrastructure / Services | -C | | D | -C | -C | | | | | | | D | D | | | -C |
| | Infectious Diseases | D | | D | D | D | | | | | | | D | -C | | | D |

# Outline of Scoping Results

**Project Title: Irrigation Development in Rejaf East**

| Type of Impact and Score | | Outline of Impact | Expected Mitigations | Study Items for EIA | Recommended Method |
|---|---|---|---|---|---|
| (1) Pollution | | | | | |
| Air pollution | -C | - Exhaust gas generated by construction works and operation of pump | - Use low-emission equipment with proper maintenance | - Air quality conditions<br>- Construction plan, pump operation plan | - Check of quality of construction equipment and pump in terms of prevention from exhaust gas<br>- Site survey on location of possible sensitive zones against air pollution such as residential area, school zone, etc. |
| Water pollution, Soil / sediment contamination | -C | - Turbid water from construction site<br>- Oil leakage<br>- Pesticide and fertilizers in farming | - Proper temporary drainage<br>- Storage of used oil<br>- Proper use of pesticide and fertilizers | - Water quality conditions<br>- Farming plan in terms of use of chemicals | - Measure of current water quality<br>- Examine of possible pollution sources by the project |
| Waste | -C | - Construction waste<br>- Agricultural waste | - Proper use of waste disposal site<br>- Proper waste storage<br>- Waste recycle, reuse and reduction | - Disposal site<br>- Waste type | - Investigation of possible disposal site for construction waste<br>- Estimation approximate waste volume |
| Noise | -C | - Construction noise by equipment, truck, e.g.<br>- Noise form generator during pump operation | - Noise barrier<br>- Select low-noise generator, equipment, truck, etc.<br>- Adjust construction time avoiding night time | - Noise measurement<br>- Sensitive zone | - Check of quality of construction equipment and pump in terms of prevention from noise / vibration<br>- Site survey on possible sensitive zones against noise / vibration such as residential area, school zone, etc. |
| (2) Natural Environment | | | | | |
| Ecosystem | -C | - Wildlife habitats, feeding / nurturing area. Possibility may be low because of location in peri-urban of Juba city<br>- Secondary forest, plantation | - Canal and pipeline route avoiding wildlife corridor | - Location of wildlife habitats, feeding / nurturing area<br>- Forest, plantation | - Interview with local communities<br>- Direct observation on wildlife habitats, migration, etc.<br>- Trap survey |
| Hydrology, Floods | -C | - Obstruction of water flow | - Proper design of command area<br>- Flood prevention | - River water flow<br>- Possible flood prone area | - Historical records of floods<br>- Condition of water body in rainy season |

| Type of Impact and Score | | Outline of Impact | Expected Mitigations | Study Items for EIA | Recommended Method |
|---|---|---|---|---|---|
| (3) Social Environment | | | | | |
| Resettlement | -B | - Land occupation<br>- Proposed command area is mostly bare land with low production. | - Agreement on resettlement with proper compensation plan | - Land use<br>- Public consultation<br>- Resettlement plan | - Survey on land use, land status, land ownership, etc.<br>- Estimation of land and asset price<br>- Public consultation for consensus building |
| Living and livelihood | +/- B | - Land occupation<br>- Job / business opportunity be construction works, farming<br>- Obstruction of existing activities during construction phase | - Public announcement, consensus building<br>- Priority recruitment to local community<br>- Income recovery plan, compensation plan | - Community and local job profile<br>- Public consultation | - Investigation of community living condition and livelihood<br>- Interview with communities |
| Local economy | +A | - Job / business opportunity be construction works, farming | - Priority procurement from local<br>- Proper farming plan to increase agricultural production | - Business profile in local<br>- Expected agricultural production by the project | - Investigation of local economic profile<br>- Investigation of future plans, developments, investments |
| Land use | -B | - Land occupancy<br>- Obstruction of existing business<br>- Inconsistence between other land use plans / projects | - Consensus building<br>- Encourage alternative improvement | - Existing and future land use plan<br>- Public consultation | - Survey on land use, land status, land ownership<br>- Investigation of land use plan<br>- Public consultation |
| Local Conflict | -B | - Gap of benefits among communities<br>- Inconsistence between other plans / projects | - Consensus building<br>- Income recovery plan<br>- Proper compensation | - Public consultation<br>- Compensation plan | - Investigation of job profile, income level and sources<br>- Public consultation |
| Water use / right | -C | - Increasing of water irrigated | - Consensus building<br>- Proper rules on fair water use | - Public consultation<br>- Legal status on water use / right | - Investigation of water use / right<br>- Public consultation |
| Social Infrastructure / Services | -C | - Scattered grave yards in the project site | - Proper design avoiding those facilities, relocation if possible and necessary | - Land use<br>- Mapping | - Site survey on location of social infrastructures<br>- Interview with local communities, etc. |