# Chapter 1　Background of the Project

# Chapter 1 Background of the Project

## 1-1 Background and Outline of the Request

Ministry of Water Resources and Irrigation of the Arab Republic of Egypt (hereinafter referred to as "Egypt") intends to improve agricultural productivity and increase farmer's income by replacing overage regulators and irrigation facilities to modern system that contributes to effective use of water resources and ensuring the balance between demand and supply by appropriate water management.

By the request of the Government of Egypt, the Government of Japan has supported the development of Bahr Yusef Irrigation Canal since 1990 and reported development study for the whole irrigation canal in the report of "Feasibility Study for Rehabilitation and Improvement of Delivery Water System on Bahar Yusef Canal" in 1992. Based on the report, the government of Egypt requested Japan's Grant Aid "The Project for Rehabilitation and Improvement of Bahr Yusef Canal" for the rehabilitation of the Lahoun Regulator and it was implemented under Japan's Grant Aid scheme in 1997. In succession, "The Project for Rehabilitation and Improvement for Mazoura Regulator of Bahr Yusef Canal" was implemented for Mazoura Regulator located at the upstream of the Lahoun Regulator and it was completed in 2002.

This Grant Aid Scheme was requested by the government of Egypt to practice appropriate water management and to supply irrigation water to beneficial area stably, by replacing Sakoula Regulator, which is located in the Bahr Yusef Irrigation Canal and remarkably decrepit, and introducing overflow-type gate which works more efficiently to regulate the water level and flow rate. Contents of the request are as follows;

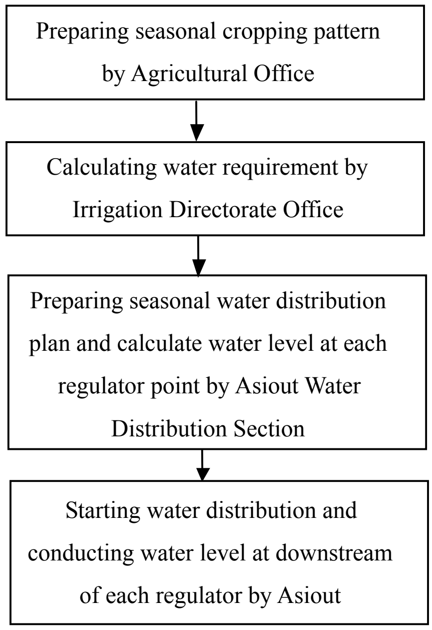
- Replacement the decrepit brick regulating body
- Change the manually-operated gates to electric-driven steel gates
- Construction of a control house to accommodate equipment that receives water control information
- Construction of maintenance bridge

Irrigation area of Bahr Yusef Canal is 320,000 ha and it equals 11% of total farm area of 2,900,000 ha in Egypt. Annual quantity of intake water from the Nile River is 4.5 billions $m^3$ and it equals 8% of 55.5 billions $m^3$ per year as the water right acquired by the Nile Agreement and it shows the canal as a important basic agricultural infrastructure. The population of Minia governorate, which has most of beneficiary area of Sakoula Regulator, accounts for about 30% of 4 governorates which Bahar Yusef Canal across. Therefore, distributing irrigation water to this area stably is considerable to contribute to improve agricultural production and to secure society of Egypt.

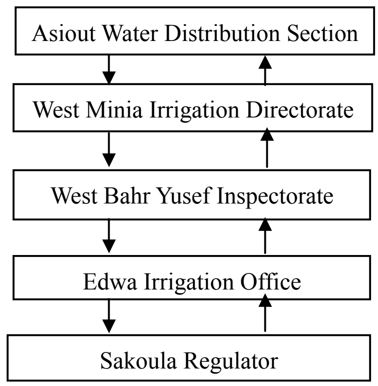
## 1-2 Present Condition of Project Site

**Problems in Farming Practices Due to Improper Water Management**

**(1) Status of Water Management in Bahr Yusef Irrigation System**




The Bahr Yusef Irrigation Canal has five regulators including an intake regulator at the head; namely Dairout. Water distribution management of the entire canal system is operated by controlling the downstream water level of each regulator. In other words, discharge distribution in the total system is controlled by setting water level at the downstream of each regulator. Water level is set up by the Asiout Water Distribution Section under the command of Asiout Irrigation Directorate located at 170km upstream of the Sakoula Regulator. The Water Distribution Section compiles and calculates the required water volume for irrigation in the downstream command area of each regulator based on the information of cropping patterns prepared by the district agriculture office at each governorate. Furthermore, they convert discharge into the water level and inform the converted water levels to every irrigation directorates (e.g. West Minia Irrigation Directorate for the Sakoula Regulator).




Meanwhile, the irrigation office deals with the daily gate operation of each regulator (e.g. Edwa Irrigation Office deals Sakoula Regulator) mainly maintaining the downstream water level of the regulator set up by the higher-level organization such Inspectorate, Directorate offices and so on, without any attentive management of water level upstream of the regulator. Thus, at five(5) regulators, which undertake and play important roles on management of irrigation system, actual condition is that control of upstream water level of the regulator which is the most important function for water intake to branch canals, has been left unconsidered because attention is given only on the downstream water level.

**(2) Improper Water Management caused by the Consideration of Upstream Water Level**

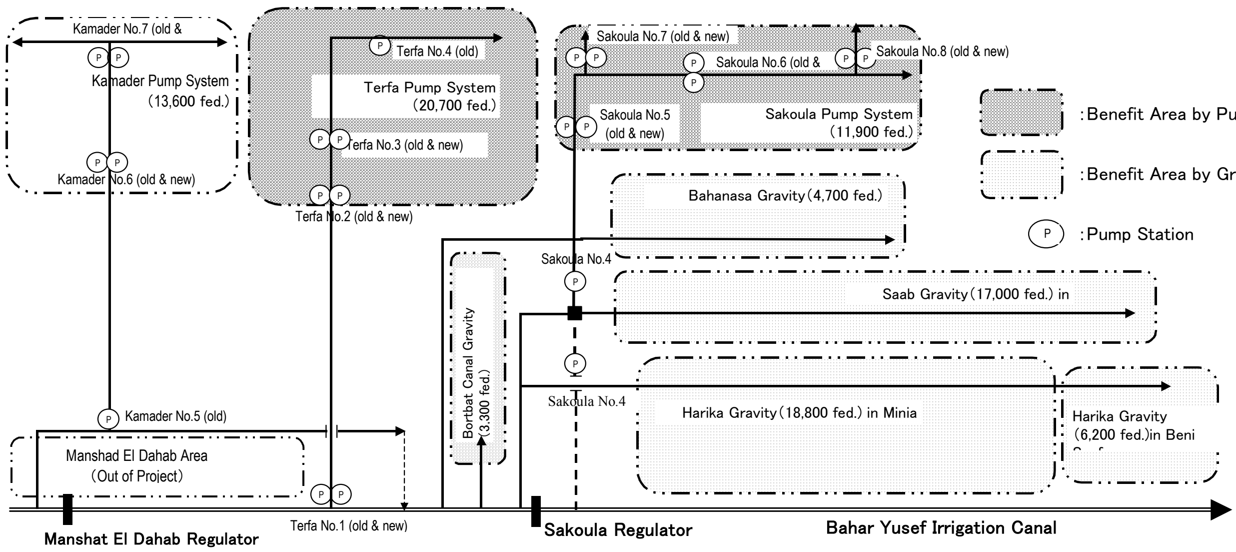
In Bahr Yusef Irrigation Canal, irrigation water diverted from each regulator and distributed to surrounding farmland through branch canals and secondary canals by the following two manners in general.

① Water supply to branch and secondary canals by gravity→irrigation to the end farmland using low lift pumps.

② Delivery of water to branch and secondary canals through Pump stations→irrigation to the end farmland by gravity or using low lift pumps.

As shown in the following figure, two kinds of water supply mentioned above are also intermingled in irrigation method in the command area of the Sakoula Regulator.

**Figure 1-2.1 Beneficial Area of Sakoula Regulator**




In the total command area of the Sakoula Regulator, 32,600 feddan (13,700 ha) is irrigated by pump intake. However, due to unstable upstream water level of the regulator, required suction water level can not be obtained to secure pumping volume as designed and forces to excess pump operation time.

There is 50,000 feddan (21,000 ha) of beneficial area irrigated by the gravity intake, such as the Harika canal, however, based on the study results of water sufficiency in the beneficial area between water requirement and diverted water volume, it was revealed that there was 5,639,000 $m^3$ for summer crops and 3,517,000 $m^3$ for winter crops of shortage of irrigation water. And there is 32,600 feddan (13,700 ha) of pump irrigation area. However, because the water level of upstream of the regulator is not stable, the stable intake water level for design pumping up quantity is not ensured, and discharge to the branch canal is unstable and the pump is forced to over work.

**Table 1-2.1 Excess and Deficiency of Water Quantity Required for Crops and Actual Irrigation Water Amount**

(Unit : 1,000$m^3$)

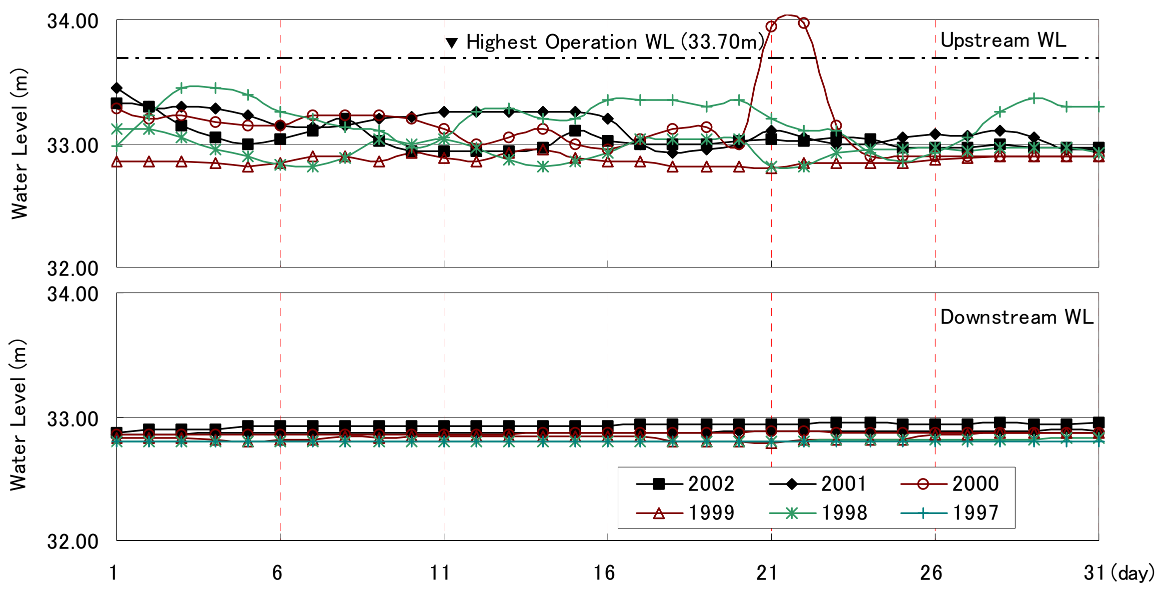
| Name of Canal | Items | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total | Total without Jan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bahanasa | Requirement | 1,199 | 1,439 | 2,105 | 1,882 | 1,697 | 2,953 | 3,925 | 2,623 | 897 | 575 | 748 | 1,111 | 21,155 | 19,955 |
| | Intake Water | 387 | 1,439 | 2,105 | 1,882 | 1,697 | 2,953 | 3,925 | 2,623 | 897 | 575 | 748 | 1,111 | 20,342 | 19,955 |
| | Deficit | -812 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -812 | 0 |
| | Ditto (%) | -67.7% | | | | | | | | | | | | -0.04 | 0.00 |
| Harika | Requirement | 6,379 | 7,656 | 11,198 | 10,011 | 9,027 | 15,708 | 20,875 | 13,951 | 4,773 | 3,057 | 3,979 | 5,910 | 112,524 | 106,146 |
| | Intake Water | 2,058 | 7,479 | 10,561 | 10,011 | 8,856 | 15,708 | 18,655 | 13,951 | 4,773 | 3,057 | 3,979 | 5,910 | 104,998 | 102,940 |
| | Deficit | -4,321 | -177 | -637 | 0 | -171 | 0 | -2,220 | 0 | 0 | 0 | 0 | 0 | -7,527 | -3,206 |
| | Ditto (%) | -67.7% | -2.3% | -5.7% | | -1.9% | | -10.6% | | | | | | -6.7% | -3.0% |
| Saab | Requirement | 4,337 | 5,206 | 7,615 | 6,808 | 6,138 | 10,681 | 14,195 | 9,487 | 3,246 | 2,079 | 2,705 | 4,019 | 76,516 | 72,179 |
| | Intake Water | 0 | 4,029 | 6,470 | 6,808 | 5,669 | 10,681 | 11,916 | 9,357 | 2,875 | 1,911 | 2,670 | 3,843 | 66,229 | 66,229 |
| | Deficit | -4,337 | -1,177 | -1,145 | 0 | -469 | 0 | -2,279 | -130 | -371 | -168 | -35 | -176 | -10,287 | -5,950 |
| | Ditto (%) | -100.0% | -22.6% | -15.0% | | -7.6% | | -16.1% | -1.4% | -11.4% | -8.1% | -1.3% | -4.4% | -13.4% | -8.2% |

* Average water deficit in Harika and Saab canals on July is about 13% of requirement.

The below table indicates that the inflow to branch canals varies as influenced by unstable water level at upstream of the Regulator, which causes the water shortage in intake quantity for irrigation. It is clear that the water level at upstream of the Sakoula Regulator fluctuates whereas the water level at downstream is kept almost constant from the record of water level at up/downstream of the regulator as shown below figure. The fluctuation of water level caused by leakage from gates and so on, is amplified by fluctuation of intake quantities by branch canals. It is assumed that the fluctuation of discharge at the Regulator compels operators to control the downstream water level by a complicated operation system with deteriorated gates.

**Figure 1-2.2 Up/Downstream Water Level in Sakoula Regulator for Past 6 Years（July）**

Source: West Minia Irrigation Directorate




In summarizing problems of water management in the existing Sakoula Regulator, water level at upstream of the Regulator is not stable due to leakage from the Regulator through the damaged gate body and it makes difficult, 1)to supply stable water to the tail reach of canals in the gravity irrigation area, 2)to maintain the suction water level at Pump stations. In addition, it is tried to control the water level at downstream of the Regulator informed by the higher-level organization, precise control of water level by operating gates takes longer time and amplifies amount of waste discharge during the gate operation, and helps in falling the water level at upstream. In fact, from the very beginning priority should be given to maintain the stable water level in the upstream in order to avoid influences on farming activities. Therefore, it is essential to maintain the stable water level in the upstream of the gate and to control flow-rate to the downstream of the Regulator for a better water management.

# Chapter 2 Contents of the Project

# Chapter 2 Contents of the Project

## 2-1 Basic Concept of the Project

**(1) National Development Plan and Project Target**

The government of Egypt prepareded "the Forth Five Years Development Plan" in 1997 mainly aiming stable self-sustenance in food. The Plan states 13 items of target such as to promote effective use of existing farmland, recovering productivity of farmland, providing agricultural extension services to farmers, rehabilitating and improving decrepit irrigation facilities, increasing agricultural water by reusing and so on.

Then, MWRI formulated "Water Policy to 2017" in order to contribute the above Plan to pursuit, in special, effective use of water resources by implementing rehabilitation and improvement projects. The Project will be performed in accordance with the above Plan and Water Policy.

There is 50,000 feddan (21,000 ha) of gravity irrigation area and 32,600 feddan (13,700 ha) of pump irrigation area located upstream of the Sakoula Regulator. 1)Based on the result of study, it was conformed that in the gravity irrigation area the summer crops encountered a water shortage of 11.5 % (water shortage for field) in July, and in February, for winter crops the shortage was 9.5%. Together, the shortage volume was about 9,156,000 $m^3$ (5,639,000 $m^3$ for summer crops, 3,517,000 $m^3$ for winter crops). 2)In the pump irrigation area, design intake water level can not be ensured and causes shortage of pump water supply. Under such situation, to supply required irrigation water the running time of pump has increased.

Among the problems of water management in the existing Sakoula Regulator, water level at upstream of the Regulator is not stable due 1)to leakage from the Regulator through the damaged gate body and 2)to waste discharge during manual gate operation for controlling downstream water level.

Therefore, this Project aims supplying irrigation water to the beneficial area stably by practicing proper water management by replacing overage existing Sakoula Regulator with electric powered driven overflow-type gates under the Japan's Grant Aid Scheme.

**(2) Outline of the Project**

① Replacement of Body of Existing Sakola Regulator and Gates

For the purpose of stopping leakage from the Sakoula Regulator through the body and gates, the Regulator shall be reconstructed with electric powered driven overflow-type gates. This type makes delicate-regulation of water level at upstream possible and flow-rate control at the Regulator smooth and easy by available correspondence between small and large discharges better than underflow-type in order to stable the water level at upstream of the Regulator. Japan's Grant Aid Scheme, therefore, offers funds for supplying irrigation water to the beneficial area stably by replacing over-aged existing Sakoula Regulator to modern regulator with electric powered driven overflow-type gates.

② Control House

To regulate water level and flow-rate accurately by the mentioned overflow-type gates, maintenance equipment and facilities such as gate control panel, electric facilities and emergency generator are necessary. Also, storage facility to protect these from bad weather like sand storms shall be provided. To maintenance the regulator body, gate and the above equipments, an operation and maintenance office that can correct operation data shall be installed. Furthermore, a water management office that plays a sub-system of flow-rate control management and unitary water management system in the whole Bahr Yusef Irrigation Canal in future and the place for training of technology transfer is required. By the above reason, a control house shall be constructed.

③ Maintenance Bridge

Sakoula Regulator is located at the center of Sakoula town in Minia governorate and about 180 km south from Cairo. The Sakoula town and vicinity area are scattered along both side of Bahr Yusef Irrigation Canal. The maintenance bridge of Sakoula Regulator lies in the center of the flow of local people and agricultural products, and it plays an important role in the daily local traffic. Based on the investigation of traffic at the Basic Design Study, the wheel traffic, which is related with the distribution including the crops, such as trucks, small trucks, tractors and carriages are about 1,100 cars/day. Moreover, the comings and goings including motorbikes and bicycles are about 9,500 people/day. And, an open market is hold around Sakoula Regulator every Sunday, the existing bridge is very crowed whole the day by people and wheels from the outskirts. Thus, maintenance bridge plays an important role for not only the distribution and comings and goings but the daily transportation.

However, the width of existing maintenance bridge is only 4 m and vehicles have to follow one way traffic only, and it is crowded with both vehicles and passersby. The type of the bridge is a brick arch structure, surface brick is broken off and large vehicles are prohibited to pass according to load limit. Therefore, this maintenance bridge is planned to be improved to suit present condition of traffic and transportation of agricultural products and to contribute to improvement of the circumstances of flow to the market in the beneficial area of the Project.

**(3) Outline of the Project Facilities**

Outline of the Project facilities are shown in following table;

**Table 2-1.1 Outline of Replacement of Sakoula Regulator**

| | |
|---|---|
| 1. Design discharge / Design water level | ･Max. discharge: 193.64 $m^3$/sec ･Highest control water level (upstream): 33.70m<br>･Min. discharge: 39.76 $m^3$/sec ･Lowest control water level (downstream):30.28m |
| 2. Regulator body | ･Reinforced concrete |
| 3. Gate drive system | ･Electric wire rope winch ･Upper gate: 1.5kW, Lower gate: 5.5kW |
| 4. Gate span | ･Width 8.0m × height 5.8m × 4 spans ･Gate sill elevation: 28.0m |
| 5. Gate type | ･Over flow type gate ･Slide type double leaf roller gate<br>･3 Edges with rubber seals at upstream ･Operation speed: more than 0.3m/min<br>･Height of upper leaf: 2.8m, Height of lower leaf: 3.0m |
| 6. Apron | ･Length of upstream apron: 6.0m ･Elevation of upstream apron surface: 27.55m<br>･Length of middle and downstream apron: 27.0m<br>･Elevation of downstream apron surface: 27.50m |
| 7. Canal bed protection | ･Concrete block ･Length of downstream protection: 44.0m, Width :38.0m |
| 8. Closure dike | ･Steel sheet pile type III and IV: L=9.0～12.5m<br>･Riprap slope protection: Total length 133.0m |
| 9. Slope protection | ･Steel sheet pile type III and IV: L=9.0～12.5m<br>･Riprap slope protection: Total length 157.0m |
| 10. Maintenance bridge | ･Reinforced concrete T-beam ･Length of bridge: 40.0m<br>･Design load: 60 ton ･One side single lane, Total width: 12.8m |
| 11. Control house | ･One-story, RC structure and block wall ･Floor area: 78.0$m^2$<br>･Remote control room, Storage, Kitchen, Toilet, Emergency generator room, etc. |
| 12. Control panel (Remote control/ Local control) | ･Upper and lower gate operation button ･Accumulative release discharge meter<br>･Buzzer stop button ･Recorder for water level, gate opening & discharge<br>･Lump test button ･Emergency stop button<br>･Upper and lower gate opening indicator ･Local telecommunication<br>･Upstream and downstream water level gauge |
| 13. Emergency generator | 50kVA, 380V/220V 1 unit (1.3m × 2.63m × 1.0m) |
| 14. Spare gate (Stop log gate) | ･Spare gate of Lahoun Regulator shall be used. |

## 2-2 Basic Design of the Requested Japanese Assistance

### 2-2-1 Design Policy

#### 2-1-1-1 Basic Policy

The basic policies considered in the design are as follows;

1) To built irrigation system enabling to distribute water to gravity area through branch canals and to be stable intake level of pump stations.
2) To introduce overflow-type gates for making water level and flow-rate control easy and precise.
3) To equip facilities to enable unitary water management among Lahoun, Mazoura and Sakoula Regulators in considering with using water resources effectively.
4) To construct control house for storing gate operation facilities, which enable monitoring water level and flow-rate for 24 hours to be able to practice proper water management decrease the amount of waste discharge.
5) To make local staff of West Minia Irrigation Directorate and the West Bahr Yusef Inspectorate offices to have

operation and maintenance by themselves with adopting On-the-Job-Training.

6) To provide space for a stand-by generator to enable to operate even during power failure,.
7) To prepare construction plan and schedule in considering with the nature and topographical conditions in Sakoula Regulator.

### 2-2-1-2 Natural Condition

**(1) Consideration of High Temperature**

① Mixture and Casting of Concrete

The highest mean temperature in summer (from May to September) occurs in July which is around 36.7℃. However, the maximum temperature may reach up to 45℃ or even more therefore, following counter measures should be taken into consideration;

1) Lowering the temperature of the concrete when mixing
2) Placing concrete when the temperature is relatively low

② Securing Insulation and Ventilation

Provision of adequate insulation and ventilation should be taken into consideration while planning the control house.

**(2) Consideration of Strong Wind and Drifted Sand**

From April through July and September, the wind velocity exceeds 7 to 16 knots (3.6 to 8.2 m/sec) a day in every two days. Especially from April to July, the wind carries drifted sand (so called "Khamaseen"). Thus, dustproof measures should be taken into consideration in the planning of the control house.

**(3) Consideration of Topography**

On the right bank of Sakoula Regulator, there is an island with a dimension of around 20m by 500m. This island separates the lock located on the right bank. This island is suitable for storage facility and/or warehouses during the construction stage.

**(4) Design High Water Level**

Through the water level analysis, the maximum water levels of 100 year return period for both up and down streams of the regulator have been worked out. After adding some margins and rounding them off, the water levels may be expressed as follows;

1) Upstream Design Highest High Water Level (U.H.H.W.L) :34.13+0.17= 34.30 m
2) Downstream Design Highest High Water Level (D.H.H.W.L) :33.73+0.10= 34.20 m

## 2-2-1-3 Geology and Soil Mechanics

### (1) Geological Structure

According to "GEOTECHNICAL INVESTIGATION REPORT" prepared for this project, the geology around Sakoula Regulator consists of back filling soil layer up to EL 31m from excavation work for existing Sakoula Regulator and Navigation locks, and Nile deposits. Nile deposit is divided into upper clay layer above EL28m and lower sand layers below EL28m. Geological structure around Sakoula Regulator is tabulated below;

**Table 2-2-1.1 Geological and Geotechnical Structure around Sakoula Regulator**

| Geologic unit | | Soil unit | Bottom elevation (EL. M) | Bottom depth from surface (m) | N-value | Uniaxial compressive strength (kgf/cm$^2$、(N/mm$^2$)) | Modulus of elasticity (kgf/cm$^2$、(N/mm$^2$)) | Hydraulic conductivity (cm/sec) |
|---|---|---|---|---|---|---|---|---|
| Bank | | Clay with bricks | 31.2～31.3 | 4.0 | 9～24 | 0.77～3.52 (0.075 ～ 0.35) | 27.2 (2.67) | |
| Nile deposits (Clay layer) | | Clay | 27.4～27.5 | 7.7～7.8 | 5～26 | 0.82～2.44 (0.082 ～ 0.24) | 22.3 (2.19) | |
| Nile deposits (Sand layer) | Upper | Sand with silt | 20.6～25.2 | 10.0～14.6 | > 50、29 ～ 30 at BH1 up to 10m | | 75.2～76.7 (7.37 ～ 7.52) | $5.54 \times 10^{-5}$ ～ $1.57 \times 10^{-4}$ |
| Nile deposits (Sand layer) | Upper | Silty sand | 21.7 (BH1 only) | 13.6 (BH1 only) | > 50 | | 157.6 (15.5) | $2.18 \times 10^{-5}$ |
| Nile deposits (Sand layer) | Upper | Sand | 16.6～17.2 | 18.0～18.6 | > 50 | | 176.7 (17.3) | $2.07 \times 10^{-5}$ |
| Nile deposits (Sand layer) | Middle | Sand with silt | 11.2～12.6 | 22.6～24.0 | > 50 | | | |
| Nile deposits (Sand layer) | Lower | Sand | less than 5.2～7.2 | 28.0 ～ more than 30.0 | > 50 | | | |
| Nile deposits (Sand layer) | Lower | Sand with silt | less than 5.2 | more than 30 | > 50 | | | |

### (2) Soil Mechanics

Design condition of soil (clay layer in Nile deposits: EL.27.4m～31.2m) is presented below having the reference of "GEOTECHNICAL INVESTIGATION REPORT" prepared for this project.

① Unit Weight

Unit weight of soil is decided from the unit weight of clay, which is 1.78～1.86t/m$^3$ under natural condition as presented below.

- Dried unit weight： 1.6 t/m$^3$
- Wet unit weight： 1.8 t/m$^3$
- Submerged unit weight： 2.0 t/m$^3$

② Internal Friction Angle

N-values of clay layer ranges from 5 to 26, therefore internal friction angle is decided from following equation.

- Average N-value :  N = 15
- Internal friction angle :  $\phi = \sqrt{15 \times N} + 15 = \sqrt{15 \times 15} + 15 = 30^\circ$

③ Cohesion of soil

Uniaxial compression strengths of clay layer show q = 0.82～2.44 kgf/cm$^2$, and its cohesion is derived from the following equation. As derived cohesion values are very small, cohesion shall not be considered in design.

- Cohesion :  C = 1 / 2 * q = 0.41～1.22 kgf/cm$^2$
  ≒ 0 kgf/cm2

### 2-2-1-4 Socio-economic Condition

**(1) Law and Order Situation**

In the prefectures namely, Minia, Asiout, Sohag, Qena (except Luxor), and Aswan (except Aswan city and Abu Simbel city) located in the Middle and Upper Reaches of the Nile, Islamic Fundamentalists have their bases somewhere in this region. Therefore, foreigners won't be able to move by themselves without police guard because of law and order situation. This constraint should be taken into consideration for the construction planning.

**(2) Respect for Religious Belief**

The majority of people are Muslims, however, there are many independent villages of Koptic in and around the city of Asiout and there are also some villages in Minia governorate. Therefore, religion and religious holidays should be taken into consideration for establishing construction schedule and recruiting labor forces.

**(3) Secure Present Function of Regulator**

Bahr Yusef Canal is the only one water source in and around the Project area therefore, intake for irrigation water shall be secured during the construction.

**(4) Maintain Appurtenant Function of Regulator**

One of the appurtenant functions of Sakoula Regulator is to maintain the passage for people, horses and donkeys, and vehicles. Since the nearest bridges are located far a way at around 6.5 km upstream of Bahr Yusef Canal and at around 20 km downstream of the Canal, the traffic passage function of the regulator, which connects the beneficial area (west side of Bahr Yusef Canal) and market areas on the east side of canal, such as the town of Maghaghah and Bani Mazar is very important. Therefore, this function should be maintained during and even after the construction.

**(5) Relevant Activities around the Regulator**

Along the Bahr Yusef Canal it is crowded with residential houses including 5 to 6 stories building. Thus any open space in and around the regulator area is very precious for the residents. Riverbanks are used for dish/cloth-washing spots. The island is utilized as a multi-purpose public space for drying crops, washing, trimming space for donkey, grazing area for cows, horses and so on. In addition, the bridge area of Regulator is used as market on every Sunday, and it is very crowded with retailers, customers, carts and vehicles. After the construction, the area i.e. both sides and intermediate bank of canal shall be advised to make use of the site as recreational spot.

**(6) Detour Road During Construction**

As tradition, Sunday market will be held on the detour road during the construction stage and traffic congestion will be expected. Therefore, such circumstances should be taken into consideration in the construction planning.

## 2-2-1-5 Plan for Agriculture and Irrigation Development

The beneficial area of the Sakoula Regulator consists of two types of irrigation system, i.e. the old land and reclaimed area. As the old land area is irrigated by the gravity flow system, the facilities for such irrigation is mainly performed by the intake gates for diverting water from the Bahr Yusef Canal and secondary canals to convey water to the service area. At present, the old land area is chronically suffered from insufficient water supply due to unstable water level at the upstream of Sakoula Regulator. After rehabilitation of the Sakoula Regulator, the water shortage problem in the old land will be solved by stably maintaining required water level at the upstream of the regulator through the proper operation of the new gates. In addition, the existing irrigation canals such as secondary, tertiary and end canals will be kept in proper condition based on the field survey results. From the hydraulic analysis, it has been found that the canals have enough capacity to carry the required amount of irrigation water if the intake water level is maintained appropriately.

In case of reclaimed area the pump irrigation system is applied. Water from the Bahr Yusef Canal is diverted by the intake pump and discharged into the service area through the secondary canals and boosting pumps. These pump irrigation systems will work well when upstream water level of the Sakoula Regulator is maintained appropriately to realize the required suction water level and stable discharge of the pumps. The existing irrigation canals in the pump irrigation are also in proper condition and considered to have enough capacity same as the gravity system.

It is believed that the rehabilitation of the irrigation facilities other than that of the Sakoula Regulator will not be required urgently because it is expected remarkable improvement which would be achieved by maintaining stable water level in the Bahr Yusef Canal and assurance of sufficient discharge by the rehabilitation of Sakoula Regulator.

Moreover, the traditional irrigation manners prevailing in the beneficial area such as crop rotation, cropping patterns and rotational irrigation inherited from old times with occasional improvement, should be followed without any change.

However, it is anticipated that the sufficient effectiveness of the rehabilitation of the Sakoula Regulator can not be achieved without securing the proper maintenance of the important irrigation facilities such as pump equipment which are main facilities for irrigation because, the existing pump facilities are seriously deteriorated and functioning at low capacity. To cope with these conditions, the Egyptian government intends to rehabilitate and improve the pump and canal system simultaneously in accordance with the MED improvement plan. In addition, for further effectiveness of the project, the implementation of the Mesqa Improvement project which is expected to bring the high efficiency in water consumption and contribute to the effective use of precious water should be introduced as soon as possible.

## 2-2-1-6 Bahr Yusef Irrigation Canal

**(1) Design Discharge**

The design discharge of the Bahr Yusef Canal which has been recommended in the Feasibility Study, are as shown in Figure 2-2-1.1. The design discharge of Sakoula Regulator is described below.

- Design Maximum Discharge（July） : $Q_{max}$ = 193.64$m^3$/sec
- Design Minimum Discharge（October） : $Q_{min}$ = 39.76$m^3$/sec

**(2) Design Water Level**

The standard cross-section and design profile of Bahr Yusef Canal which has been proposed in the Feasibility Study are as shown in Figure 2-2-1.1 and 2-2-1.2.

The design water levels are presented below;

- Extraordinary High Water Level (upstream) : U.H.H.W.L. 34.30m
- High Water Level (upstream) : U.H.W.L. 34.10m
- Highest Control Water Level (upstream) : Max. U.W.L. 33.70m
- Extraordinary High Water Level (downstream) : D.H.H.W.L. 34.20m
- Highest Control Water Level (downstream) : Max. D.W.L. 32.87m
- Lowest Control Water Level (downstream) : Min. D.W.L. 30.28m

1) Highest Control Water Level (Max. U.W.L. 33.70m) at upstream is the water level obtained at the Maximum Design Discharge at upstream of Sakoula Regulator（$Q_{max}$ = 209.82$m^3$/sec）. Minimum Design Discharge at upstream of the regulator（$Q_{min}$ = 42.43$m^3$/sec）at which upstream intakes are able to obtain the required discharge is defined as the same water level.
2) Highest Control Water Level (Max. D.W.L. 32.87m) at downstream is the water level obtained at the Maximum Design Discharge at downstream of Sakoula Regulator ($Q_{max}$ = 195.26$m^3$/sec), and Lowest Control Water Level (Min. D.W.L. 30.28m) is the water level at Minimum Design Discharge at upstream of the regulator（$Q_{min}$ = 44.05$m^3$/sec）.
3) Extraordinary High Water Level (U.H.H.W.L. 34.30m) at upstream is the Highest Water Level with 100-year probability.
4) The fore-passed Highest Water Level is 34.17m, therefore the Extraordinary High Water Level at downstream is described as D.H.H.W.L.34.20m.

### (3) Criteria for Hydraulic Calculation

Mean velocity formula will be used for calculating canal discharge, and hydraulic gradient will be derived using Manning's formula as shown below.

$Q = A \cdot V$

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

A : Flow area ($m^2$)

V : Mean velocity (m/sec)

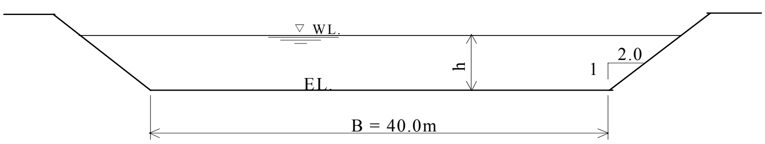
Manning's formula : $V = 1/n \cdot R^{2/3} \cdot I^{1/2}$

n : Coefficient of roughness, concrete : n = 0.015, others : n = 0.030

R : Hydraulic radius (m)

I : Hydraulic gradient

**Figure 2-2-1.1 Standard Cross-section of Bahr Yusef Canal**

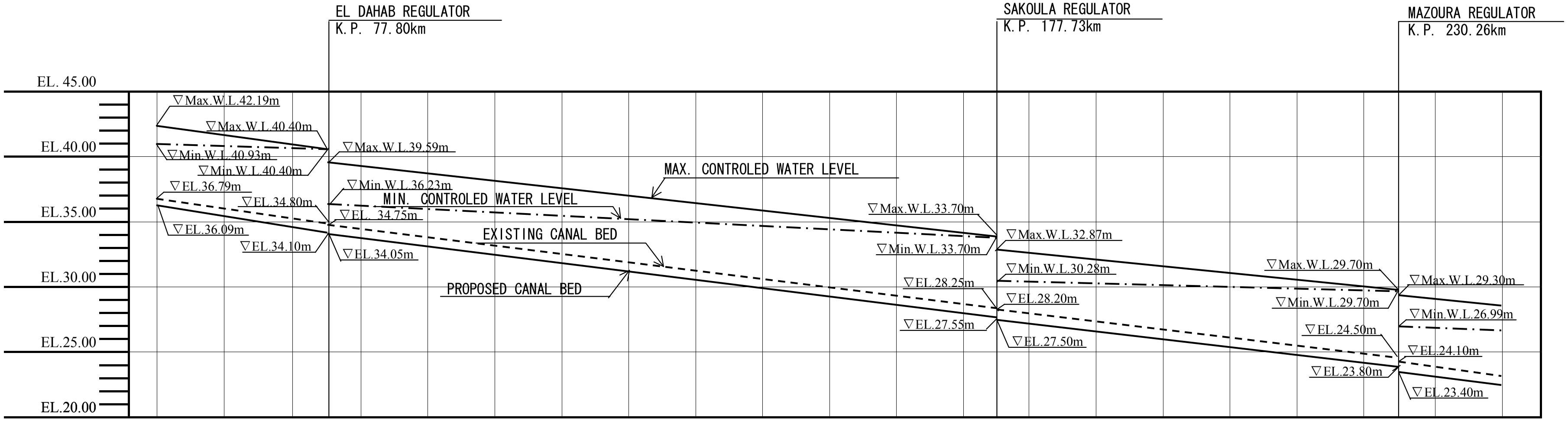



| Description | Symbol | unit | at Upstream Section | | at Downstream Section | |
|---|---|---|---|---|---|---|
| | | | Max. Discharge | Min. Discharge | Max. Discharge | Min. Discharge |
| Design Discharge | Q | $m^3$/s | 193.64 | 39.76 | 193.64 | 39.76 |
| Water Level | WL | m | 33.70 | 33.70 | 32.87 | 30.28 |
| Bottom Elevation | EL | m | 27.55 | 27.55 | 27.50 | 27.50 |
| Water Depth | h | m | 6.15 | 6.15 | 5.37 | 2.78 |
| Bottom Width | B | m | 40.00 | 40.00 | 40.00 | 40.00 |
| Flow Area | A | $m^2$ | 321.65 | 321.65 | 272.47 | 126.66 |
| Wetted Perimeter | P | m | 67.50 | 67.50 | 64.02 | 52.43 |
| Hydraulic Radius | R | m | 4.765 | 4.765 | 4.256 | 2.416 |
| Velocity | V | m/s | 0.60 | 0.12 | 0.71 | 0.31 |
| Roughness Coefficient | n | | 0.030 | 0.030 | 0.030 | 0.030 |
| Hydraulic Gradient | I | | 0.0000404 | 0.0000016 | 0.0000658 | 0.0000267 |
| Required Free Board | $F_b$ | m | 0.58 | 0.56 | 0.54 | 0.39 |
| Sidebank Height | H | m | 6.70 | 6.70 | 5.90 | 3.20 |

Manning' Formula: $Q = A \times 1/n \times R^{2/3} \times I^{1/2}$,

Free Board: $F_b = 0.05\ h + 1.0\ hv + (0.20 \text{ to } 0.30)$

# Figure 2-2-1.2 Profile of Bahr Yusef Canal




| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROPOSED MAX. CONTROLED WATER LEVEL | 42.19 | 42.19 | 42.19 | 40.40 / 39.59 | 39.45 | 38.86 | 38.27 | 37.68 | 37.10 | 36.51 | 35.92 | 35.33 | 34.74 | 34.16 | 33.70 / 32.87 | 32.73 | 32.13 | 31.53 | 30.92 | 30.32 | 29.72 | 29.70 / 29.30 | 28.85 | 28.39 |
| ABOVE GRADIENT | Ib = 6.44cm/km (1/15,500) | | | | Ib = 5.88cm/km (1/17,000) | | | | | | | | | | | Ib = 6.02cm/km (1/16,600) | | | | | | | Ib = 4.62cm/km (1/21,600) | |
| PROPOSED MIN. CONTROLED WATER LEVEL | 40.93 | 40.59 | 40.78 | 40.40 / 36.23 | 36.17 | 35.67 | 35.67 | 35.42 | 35.16 | 34.91 | 34.66 | 34.41 | 34.15 | 33.90 | 33.70 / 30.28 | 30.26 | 30.14 | 30.03 | 29.92 | 29.81 | 29.70 | 29.70 / 26.99 | 26.93 | 26.86 |
| ABOVE GRADIENT | Ib = 1.89cm/km (1/52,800) | | | | Ib = 2.53cm/km (1/39,600) | | | | | | | | | | | Ib = 1.10cm/km (1/90,800) | | | | | | | Ib = 0.67cm/km (1/149,000) | |
| EXISTING CANAL BOTTOM ELEVATION | 36.09 | 35.37 | 35.37 | 34.10 / 34.05 | 33.91 | 33.26 | 32.61 | 31.96 | 31.31 | 30.66 | 30.01 | 29.36 | 28.71 | 28.06 | 27.55 / 27.50 | 27.34 | 26.64 | 25.93 | 25.23 | 24.52 | 23.82 | 23.80 / 23.40 | 22.91 | 22.41 |
| ABOVE GRADIENT | Ib = 7.15cm/km (1/14,000) | | | | Ib = 6.5cm/km (1/15,400) | | | | | | | | | | | Ib = 7.0cm/km (1/14,300) | | | | | | | Ib = 5.0cm/km (1/20,000) | |
| PRESENT CANAL BOTTOM ELEVATION | 36.79 | 36.07 | 35.36 | 34.80 / 34.75 | 34.61 | 33.96 | 33.31 | 32.66 | 32.01 | 31.36 | 30.71 | 30.06 | 29.41 | 28.76 | 28.25 / 28.20 | 28.04 | 27.34 | 26.63 | 25.93 | 25.22 | 24.52 | 24.50 / 24.10 | 23.61 | 23.11 |
| ABOVE GRADIENT | Io = 7.15cm/km (1/14,000) | | | | Io = 6.5cm/km (1/15,400) | | | | | | | | | | | Io = 7.0cm/km (1/14,300) | | | | | | | Io = 5.0cm/km (1/20,000) | |
| ACCUM. DISTANCE (m) | 50,000 | 60,000 | 70,000 | 77,800 | 80,000 | 90,000 | 100,000 | 110,000 | 120,000 | 130,000 | 140,000 | 150,000 | 160,000 | 170,000 | 177,730 | 180,000 | 190,000 | 200,000 | 210,000 | 220,000 | 230,000 | 230,260 | 240,000 | 250,000 |
| STATION | 50.0 | 60.0 | 70.0 | 77.8 | 80.0 | 90.0 | 100.0 | 110.0 | 120.0 | 130.0 | 140.0 | 150.0 | 160.0 | 170.0 | 177.73 | 180.0 | 190.0 | 200.0 | 210.0 | 220.0 | 230.0 | 230.26 | 240.0 | 250.0 |

### 2-2-1-7 Rehabilitation of Sakoula Regulator

**(1) Rehabilitation Method**

Sakoula Regulator was constructed in 1902, which means almost 100 years has been past since its construction. The Regulator body was made from bricks, according to the laboratory tests the strength of brick itself and its joints have decreased by 87 % and 21 % respectively compared with their initial strength. It is in a danger of collapse because some bricks were already fallen down from decrepit regulator body. Therefore, urgent rehabilitation is desired.

The gates of existing Sakoula Regulator are double leaf wheel type gates operated manually by means of movable chain-hoists. As the number of the gates are many, efficient gate operation is not possible resulting in hindering modern water management. Therefore, it is planed to totally rehabilitate the body and gates of Sakoula Regulator.

**(2) Location of Sakoula Regulator**

In 1992, four alternative locations were reviewed in the Feasibility Study for Rehabilitation and Improvement of Water Delivery System in Bahr Yusef Canal. Alternative S-1 was adopted（refer to Figure 2-2-1.3 and 2-2-1.4）on the basis of the following two reasons. First, the advantage of non obstruction to the function of lock. Second, the advantage of carrying out construction work in dry condition.

However after Basic Design Study, the Irrigation Department expressed their favor of removing the existing regulator and the reconstruction at the existing site from the view point of difficulty in acquisition of agricultural land and construction of the access road. The local residents are eager to have rehabilitation of decrepit maintenance bridge (Refer to Alternative S-5). The planned construction site of S-1 is located in private agricultural land at present, so it is expected that the negotiation for expropriation may take longer period because the width of existing maintenance bridge is narrow with four meter, and traffic restriction has been enforced on the bridge.

The method of construction work within the canal such as diversion work, coffering work, and dewatering work will be possible to adopt according to the result of construction of Mazoura Regulator. In S-5, right bank side of existing regulator is planned to be demolished and reconstructed considering the canal flow and operation and maintenance of existing regulator. Also, the total width of the roadway on the maintenance bridge will be widen to 12.8 meters in accordance with specification required for main local road, and which has a straight alignment same as present..

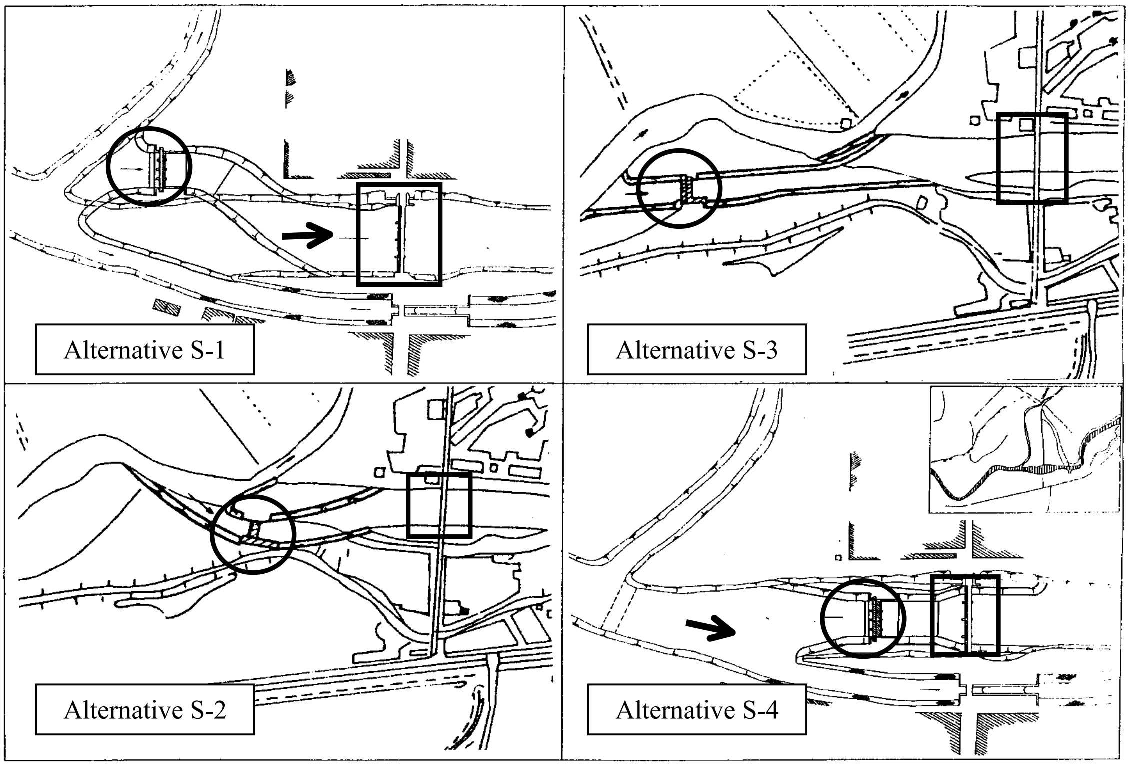
In this basic design, alignment of canal, expropriation of land, construction plan (diversion work, coffering work, and dewatering work), alignment of existing road, and economical effect in relation to alternative S-1 which had been examined in the Feasibility Study (construction under dry condition) and alternative S-5 in the application (construction within the canal) are planed to examine (Refer to Table 2-2-2.1).

**(3) Width of the Regulator**

The width of the existing regulator is 88 meters. It was constructed 60 years before the completion of the Aswan High Dam. The flow condition of the Bahr Yusef Canal has been changed drastically as the flood control function for

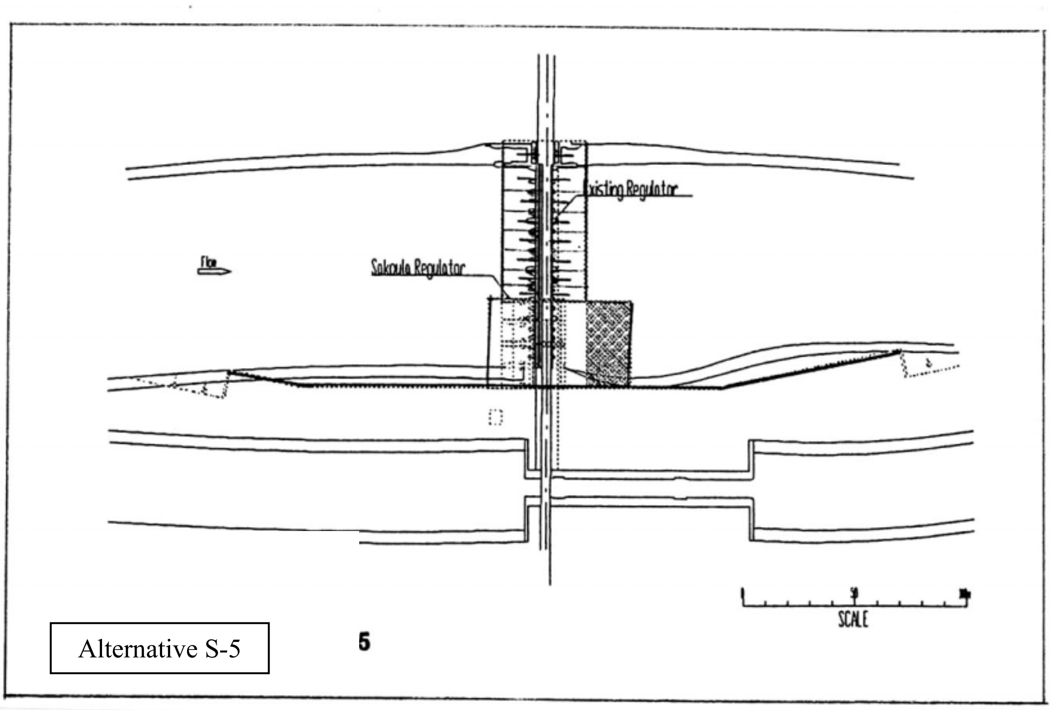
Nile River is ceased. Therefore, the cross-section of flow area at the Regulator and size of facilities are planed to decide in accordance with the Design Maximum Discharge ($Q_{max} = 193.64 m^3/sec$).

**Figure 2-2-1.3 Comparison of Location of Sakoula Regulator in the Feasibility Study**




○designed location □existing location

**Figure 2-2-1.4 Comparison of Location of Sakoula Regulator in the Application**



**(4) Design Criteria**

Referring to the design of load, reinforced concrete, regulator and canal, the design criteria of Egypt are adopted in this basic design. However, the rehabilitation should be fit with the design criteria of Canal, Headwork, Pump, and Fill Dam for Land Improvement Project Standard of Japan, Specifications for Highway bridges of Japan, and Hydraulic Gate and Penstock Standard of Japan. If any difference between the design criteria of Japan and Egypt, the latter will get the priority.

**(5) Structure of Regulator Body**

The design criteria used in the Lahoun and the Mazoura Regulator were based on the criteria of Headwork for Land Improvement Project Standard of Japan. According to the design standards of Egypt, the design seismic forces are estimated as one-third of Japanese standard, because earthquake is rare in Egypt compared to Japan. On the other hand, allowable stress increases by 50 percent at the time of earthquakes, therefore seismic forces shall not be considered in this basic design. Following structures are supposed to have application of such design policy.

1) Pier and its apron
2) Main gate
3) Steel sheet pile and concrete retaining wall
4) Maintenance bridge
5) Control house

For design of upper part structure of piers, Flat slab type and T-beam slab type are compared. The comparison of construction method between cast-insitu and pre-cast concrete. is also examined.

**(6) Existing Navigation Lock**

At present, the existing navigation lock attached to the Sakoula Regulator is managed by Irrigation Department and owned by the governor of Minia Prefecture. The function of navigation lock was ceased, but barges loaded with construction equipment will pass through the navigation lock during annual maintenance of dredging in the Bahr Yusef Canal. And to obtain the permission to remove the navigation lock from the Governor is envisaged to be very difficult from the experience during the construction of Mazoura Regulator. Therefore, the navigation lock will beremained intact.

## 2-2-1-8 Gate Operation, Water level and Discharge Control

**(1) Driving System of Gates**

The gates shall be operated easily and efficiently taking into account the stable distribution of irrigation water to beneficial area at upstream and reduction of waste discharge. Comparing manpower drine and electric powered drive gate, operation time in case of manpower drive is very long and gate operation is not smooth, however electric -powered drive has an economical advantage. (As referred to Table 2-2-1.2) In Egypt, driving system of main regulators gates has been changed from manpower to electric powered drive type taking into consideration of the future effective management. Therefore, electric powwrd driven is adopted for gate driving system. Also emergency generators will be installed in case of power failure.

**Table 2-2-1.2 Comparison of Gate Drive System of Sakoula Regulator**

| Drive system | Manpower drive | | Electric powered drive | |
|---|---|---|---|---|
| Size | ･span : 3.0m x height : 3.0m x 22gates | － | ･span：8.0m x height：3.0m x 8gates | － |
| Operation force | ･up to 10kgf（100N） | △ | ･no limit | ◎ |
| Operation speed | ･approx. 3 cm/min (operation force 40kgf) | × | ･approx. 30cm/min | ◎ |
| Operation time | ･3.9 hr./gate<br>･85.8 hr./22 gates | × | ･23min./gete<br>･1.5hr./4 gates | ◎ |
| Regulative function of water level and discharge | ･Operation speed is slower,<br>･Regulative function is inferior | △ | ･Operation speed is faster,<br>･Regulative function is superior | ◎ |
| Construction cost of gates and piers<br>（million LE） | ･Gates： 20.6<br>･Piers： 5.6<br>･Total： 26.2<br>（1.003） | ○ | ･Gate： 23.5<br>･Piers： 2.6<br>･Total： 651<br>（1.000） | ○ |
| Annual operation and maintenance cost<br>（thousand LE/year） | ･Personnel cost： 75.8<br>･Operation cost： 5.8<br>･O & M cost： 81.6<br>（1.207） | △ | ･Personnel cost： 60.6<br>･Operation cost： 6.9<br>･O & M cost： 67.5<br>（1.000） | ○ |
| Comprehensive evaluation | × | | ◎ | |

**(2) Gate Type**

According to the necessity to practice integrated water management in all three regulators as mentioned above, the gate type should be selected. The gate types are classified as follows.

① Classification by with or without overflow

1) Overflow type :Roller gate, Slide gate, Flap gate and Rubber gate

2) None-overflow type :Roller gate, Slide gate and radial gate

② Classification by structure of gate body

1) Single leaf gate :Single leaf roller gate, Radial gate, Slide gate, Flap gate and Rubber gate

2) Double leaf gate :Slide type double leaf roller gate, Stackable type double leaf roller gate and Roller gate with flap

From the view point of gate operation and water level/discharge operation, the gate type should be selected for this Project.

**(3) Control of Water Level and Discharge**

Existing Sakoula Regulator was constructed about 100 years ago. In those days, there were no alternative of gate types, but only non-overflow type gate should be adopted and downstream level was controlled through under flow. Now a days, various type of gates are selective as above mentioned. Selection of gates will be made from the view point of gate operation and water level/discharge operation. Following 3 types of gate are selected for the comparison.

①"Underflow release by non-overflow gate",

②" Underflow release below lower gate by overflow gate" and,

③"Overflow release above upper gate by overflow gate"

The released discharge from Sakoula Regulator would be the range between 39.76$m^3$/sec (in October) to 193.64$m^3$/sec (in July). Due to this wide range, discharge release pattern becomes very complicated and require accurate discharge control. “Overflow release above upper gate by over flow gate” has better function than “underflow release below lower gate by over flow gate” in maintaining a stable supply of discharge and water level.

(A sample of discharge release)

1) Case 1: “Underflow release below lower gate” (opening height of gate: a = 0.10m)

$$Q = C_c \cdot B \cdot a \cdot \sqrt{2g(h_1 - C_c \cdot a)}$$
$$= 0.61 \times 8.00 \times 0.10 \times \sqrt{2 \times 9.8 (6.10 - 0.61 \times 0.10)}$$
$$= 5.31 m^3/sec$$ (equivalent to 13.4% of minimum discharge of 39.76$m^3$/sec)

2) Case 2: “Overflow release above upper gate” (opening height of gate: a = 0.10m)

$$Q = C_r \cdot B \cdot H^{3/2}$$
$$= 1.94 \times 6.50 \times 0.10^{3/2}$$
$$= 0.40 m^3/sec$$ (equivalent to 1.0% of minimum discharge of 39.76$m^3$/sec)

As a result of comparison among three(3) types of gates as mentioned above, "Overflow release on upper gate by overflow gate" was adopted considering the following reasons. (Detail of comparison: Refer to Table 2-2-1.3)

① Delicate-regulation of water level at upstream is possible.

② Water level at downstream is smoothly controlled due to flexible corresponding between small and large discharges

③ If the overflow water depth is decided, the released discharge can be estimated. Therefore, the measurement of discharge to be released to the downstream would be easier.

In addition to the above items described in ① to ③,

④ In the future, integrated water management among Sakoula and the other two regulators rehabilitated by Japan’s Grant Aid shall be required.

**Table 2-2-1.3 Comparison of Control Method of Water Level and Discharge**

| Gate type | Weight | Non-overflow type gate | | Overflow type gate | | | |
|---|---|---|---|---|---|---|---|
| Release type | (%) | Underflow | | Underflow | | Overflow | |
| Structure of gate | — | ・This type gates had been introduced long time ago.<br>・Structure of gate leaf is simple comparatively.<br>(Single leaf gate) | | ・This type gates had been introduced since the 1960th.<br>・Structure of gate leaf is simple comparatively.<br>(Single leaf gate) | | ・This type gates had been introduced since the 1970th.<br>・Structure of gate leaf is more complicated .<br>(Double leaves gate) | |
| Height of gate | — | Gate crest：EL. 34.20m<br>Gate sill： EL. 28.00m<br>Height： 6.20m | | Gate crest：EL. 33.80m<br>Gate sill： EL. 28.00m<br>Height： 5.80m | | Gate crest：EL. 33.80m<br>Gate sill： EL. 28.00m<br>Height： 5.80m | |
| Maximum release discharge | — | ・456.64$m^3$/s > 193.64$m^3$/s | Eval. | ・456.64$m^3$/s > 193.64$m^3$/s | Eval. | ・194.64$m^3$/s > 193.64$m^3$/s | Eval. |
| Regulative function of water level | 20 | ・Delicate regulated water level is impossible due to occur vibration during small opening height of gate.<br>・Delicate regulated water level is impossible due to large discharge by unit opening height of gate.<br>・The keeping of upstream water level is difficult. | 10 | ・Delicate regulated water level is impossible due to occur vibration during small opening height of gate.<br>・Delicate regulated water level is impossible due to large discharge by unit opening height of gate.<br>・The keeping of upstream water level is difficult. | 10 | ・Delicate regulated water level is possible due to not occur vibration during small opening height of gate.<br>・Delicate regulated water level is possible due to small discharge by unit opening height of gate.<br>・The keeping of upstream water level is easy. | 20 |
| Regulative function of discharge | 20 | ・The precisions of discharge regulating are approx. 12.4% to 13.4% during minimum discharge.<br>・The discharge regulating within 5% of operation loss in irrigation plan is impossible.<br>・Delicate discharge regulating is impossible due to large discharge by unit opening height of gate. | 10 | ・The precisions of discharge regulating are approx. 12.4% to 13.4% during minimum discharge.<br>・The discharge regulating within 5% of operation loss in irrigation plan is impossible.<br>・Delicate discharge regulating is impossible due to large discharge by unit opening height of gate. | 10 | ・The precisions of discharge regulating are approx. 1.0% to 4.4% during minimum discharge.<br>・The discharge regulating within 5% of operation loss in irrigation plan is possible.<br>・Delicate discharge regulating is possible due to small discharge by unit opening height of gate. | 20 |
| Gate operation | 15 | ・24 hours watching shall be required due to non-overflow type gate.<br>・Gate operation shall be more frequency due to not delicate regulating of water level and discharge.<br>・The gate operation is easy due to only underflow release. | 8 | ・Watching by instrument shall be possible due to overflow type gate.<br>・Gate operation shall be more frequency due to not delicate regulating of water level and discharge.<br>・The gate operation is easy due to only underflow release. | 12 | ・Watching by instrument shall be possible due to overflow type gate.<br>・Gate operation shall be less frequency due to delicate regulating of water level and discharge.<br>・The gate operation is complicated comparatively due to underflow and overflow release. | 8 |
| O/M of gate and regulator | 15 | ・The trouble of gate structure and operation is a little due to single leaf and simple structure.<br>・O/M cost of gates shall be higher due to operation loads is large.<br>・Difficult to treat trash.<br>・There is danger that occur to scour canal-bed at downstream. | 8 | ・The trouble of gate structure and operation is a little due to single leaf and simple structure.<br>・O/M cost of gates shall be higher due to operation loads is large.<br>・Difficult to treat trash.<br>・There is danger that occur to scour canal-bed at downstream. | 8 | ・There is a little danger that occur to trouble of gate structure and operation due to double leaves and complicated structure.<br>・O/M cost of gates shall be lower due to operation loads is small.<br>・Easy to treat trash.<br>・There is no danger that occur to scour canal-bed at downstream. | 12 |
| Economical efficiency (regard non-overflow as 100) | 30 | ・Height of gates is higher than overflow type, and the cost is relatively expensive than underflow release by overflow gate. (1.00) | 28 | ・Height of gates is able to designed lower than non-overflow type, and the cost is also cheep. (0.93) | 30 | ・The gates are double leaf type, cost is relatively expensive than non-overflow type.(1.30) | 21 |
| Comprehensive evaluation | 100 | | 64 | | 70 | | 81 |

Note) 1) The gate crest of overflow type is Maximum Control Water Level at upstream (Max. U.W.L. 33.70m) + freeboard（0.10m）= EL. 33.80m (height：5.80m).
2) The gate crest of non-overflow type is High Water Level at upstream（U.H.W.L. 34.10m）+ freeboard（0.10m）= EL. 34.20m（height：6.20m）.
3) The freeboard of gates is depended on the criteria of Headwork for Land Improvement Project Standard of Japan.

At present, Sakoula Regulator is operated by means of controlling the water level due to absence of flow measurement instrument. It is anticipated that in the future reclaimed land area will be increased and water demand also will be increased accordingly. And the water level control method is supposed to change to discharge control method in order to integrate water management, which will help for achieving an appropriate water management of Bahr Yusef Canal. Installation of water level gauges at up/downstream of the Regulator shall be planned, and also a calculation method for computing discharge from the openings of gates shall be established.

**(4) Gate Type**

In "Over flow release on upper gate by overflow-gate", two overflow-type of gates will be recommended for the Sakoula Regulator as follows;

① Double leaf roller gate (slide-type)

② Roller gate with flap

① Double Leaf Roller Gate (slide-type)

Double leaf roller gates (slide-type) are widely used for the gates project in the river and canal because gate structure is more simple and it is reliable in water-tightness. Compared with Roller with flap, advantages of this type of gates are to enable effective water level and discharge control by operating the upper leaf, while keeping the lower leaf closed. In case of having large differences in the water levels between up-and downstream, overflow from the upper leaf will bring a dissipation effect.

② Roller Gate with Flap

From the reason of gate structure, the height of flap gate should be limited to 1.9m in other words they should be one third of the total height of the gate of 5.8m. In this case, the discharge capacity of flap gates would be approximately 140m$^3$/sec by overflow from the upper gates and less than 193.64m$^3$/sec of the maximum discharge.

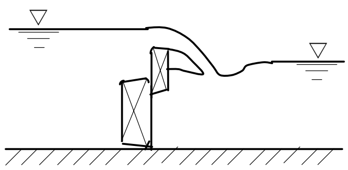
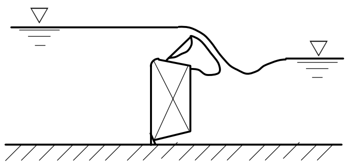
Therefore, double leaf roller gates of slide-type shall be employed for the Sakoula Regulator considering the flowing reasons (Refer to Table 2-2-1.4).

1) In this project, the water level and discharge control are required to be maintained very precisely.
2) Although the cost of double leaf roller gates will be higher than the roller gates with flaps however, the control of water level and discharge can be maintained with extreme preciseness.
3) The capacity of overflow from the upper gate is 193.64m$^3$/sec of the maximum discharge.
4) Floating objects can easily be disposed by overflow water release.

**(5) Spare Gate (Stop logs gate)**

Spare Gate will be needed to stop the flowing water from upper side of the regulator, for recoating and repair of main gate. It may be worthy to consider to use the spare gate of Lahoun Regulator, which had been rehabilitated already, and it is recommended that the main gates are recoated at a frequency of once in ten years. In this connection, cooperation of Beni Suef Irrigation Directorate is indispensable because they are in charge of Lahoun Regulator.

**Table 2-2-1.4 Comparative Table of Overflow Type Gates**

| Type / Description | Weight (%) | Double Leaf Roller Gate (Slide-type) | | Roller Gate with Flap | |
|---|---|---|---|---|---|
| Sketch of Section | – |  | |  | |
| Control System | – | - Upper gates are operated up and downward with overflow water release system during small discharge.<br>- Lower roller gates are operated up and downward with underflow water release system during big discharge. | | - Flap gate is operated falling backward and raising up with overflow water release system during small discharge.<br>- Lower roller gate is operated up and downward with underflow water release system during big discharge. | |
| Control Capacity | 20 | - Maximum discharge is more than 193.64m$^3$/sec by the overflow. | 20 | - Maximum discharge is 132.10m$^3$/sec and less than 193.64m3/sec by the overflow.<br>- Lower gates shall be operated with the underflow during more than 132.10m$^3$/sec | 10 |
| Control Precision | 20 | - Downstream discharge control under small opening height is easy due to overflow water.<br>- Delicate discharge control is easy due to overflow water release. | 20 | - Downstream discharge control under small opening height is easy due to overflow water.<br>- Delicate discharge control is hard due to underflow water release during more than 132.10m$^3$/sec. | 10 |
| Operation & Maintenance for Gates | 10 | - Upper and Lower gates shall be separated structures, since this type gates are structurally simple and easy maintenance. | 10 | - Flap gates are installed at the top of lower roller gates by hinge. The troubles are easy occurred at the hinge. The maintenance of this type gate is hard. | 7 |
| Pier Scale | 5 | - Pier length shall be longed due to complex structure of track rail.<br>- The top slab of pier shall be large scale due to many numbers of hoisting device. | 2 | - Downstream discharge control under small opening height is easy due to overflow water.<br>- Delicate discharge control is easy due to overflow water release. | 4 |
| Energy Dissipating at Downstream | 5 | - Downstream discharge control under small opening height is easy due to overflow water.<br>- Delicate discharge control is easy due to overflow water release. | 5 | - Downstream discharge control under small opening height is easy due to overflow water.<br>- Delicate discharge control is easy due to overflow water release. | 3 |
| Gate Seal | 5 | - Downstream discharge control under small opening height is easy due to overflow water.<br>- Delicate discharge control is easy due to overflow water release. | 2 | - Downstream discharge control under small opening height is easy due to overflow water.<br>- Delicate discharge control is easy due to overflow water release. | 5 |
| Disposing of Flowing Objectives | 5 | - Downstream discharge control under small opening height is easy due to overflow water.<br>- Delicate discharge control is easy due to overflow water release. | 5 | - Downstream discharge control under small opening height is easy due to overflow water.<br>- Delicate discharge control is easy due to overflow water release. | 3 |
| Practice | 5 | - Downstream discharge control under small opening height is easy due to overflow water.<br>- Delicate discharge control is easy due to overflow water release. | 5 | - Downstream discharge control under small opening height is easy due to overflow water.<br>- Delicate discharge control is easy due to overflow water release. | 3 |
| Economically | 15 | - Downstream discharge control under small opening height is easy due to overflow water.<br>- Delicate discharge control is easy due to overflow water release. | 13 | - Downstream discharge control under small opening height is easy due to overflow water.<br>- Delicate discharge control is easy due to overflow water release. | 15 |
| Operation Cost | 10 | - Delicate control of water level and discharge can be easy.<br>- Normal water level and discharge shall | 10 | - Delicate control of water level and discharge can be easy.<br>- Normal water level and discharge | 8 |

| | | | | | |
|---|---|---|---|---|---|
| | | be controlled by only operation of upper leaf gate. O/M cost shall be cheap due to small hoisting load.<br>- Flowing objectives are easy disposed by overflow water release. | | shall be controlled by only operation of upper leaf gate. O/M cost shall be cheap due to small hoisting load.<br>- Pier length can be shorted due to simple structure of track rail.<br>- Flowing objectives are easy disposed by overflow water release. | |
| General Evaluation | 100 | | 92 | | 68 |

### 2-2-1-9 Control House

**(1) Necessity of a Control Room**

Control house will be used as the office for operation and maintenance as described below;

① Regulator Operation Office: Office for Gate Operation

1) Operation facility for precise control of water level and flow-rate

Precise control of water level and flow-rate is required for Sakoula Regulator keeping an uniformity with other 2 Regulators. By adopting conventional way of “down stream water level control” it is difficult to control flow-rate due to difficulty in measuring the water quantity. New regulator shall control flow-rate accurately by measuring the amount that will over flow the upper gate. Therefore, gates shall be operated electrically and controlling devices should be observed 24 hours by 2 shifts of operators and reported to administrator as before. A remote control room shall be installed in the control house to realize this way of operation.

2) House for equipment and materials

i) Remote control room

Remote control panel should be equipped with a flow meter (micro computer) which will calculate flow-rate from water levels of upper and down stream and gate opening ratio. It is recommended that the remote control panel shall be installed indoors in order to avoid sand storm and heat.

ii) All time observation by personnel

Sakoula Regulator shall be watched 24 hours by 2 shifts of gate operators and reported to administrator as before. Remote control panel, electrical equipment, kitchen and toilet shall be installed indoors to safeguard the electrical and control equipment all time.

iii) Space for materials and equipment

Separate space for equipment, data and information for operation and maintenance, and spare parts of gate facilities shall be made in the control house.

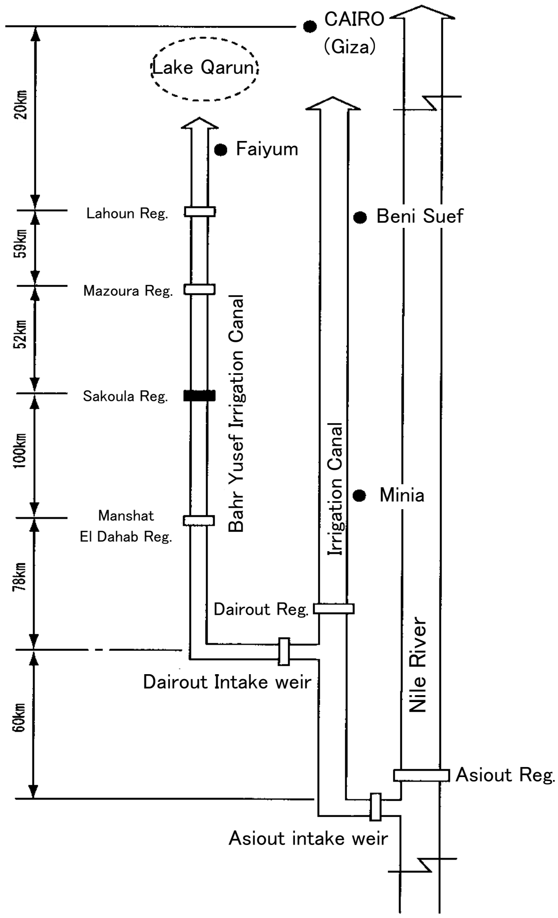
iv) House for emergency generator

The gates of Sakoula Regulator will be operated by electric power, therefore, emergency generators shall be installed in the control house in case of any power failure.

② Role of Equipment Maintenance Management Office

Although it is necessary to carry out maintenance check daily and monthly for good management of the equipment, it is recommended that all findings should be recorded every day and maintained orderly. Chief gate operator who is also the resident administrator shall carry out daily checking, but monthly checking shall be carried out by the mechanic dispatched from West Minia Irrigation Directorate. Control House shall be used as a maintenance office checking gate indicator, gate opening speed, water stop rubber, conditions of nuts and so on.

**Figure 2-2-1.5 Regulator Location Map**




**(2) Bahr Yusef Irrigaiton System in the Future**

Bahr Yusef Irrigation system consists of five(5) regulators as listed below;

1) Lahoun Regulator (Rehabilitated by Japan's Grant Aid)
2) Mazoura Regulator (Rehabilitated by Japan's Grant Aid)
3) Sakoula Regulator (Requested Japanese Assistance)
4) Manshat El Dahab Reguloator
5) Dairout Regulator

① Unitary Water Management System

For Bahr Yusef Irrigation Canal, about 230m$^3$/sec water is withdrawn at the Dairout Regulator at Ibrahimia Canal borne from the Nile River and supply irrigation water for a beneficial area of 320,000 ha scattered from upper to lower side of the irrigation canal through four regulators.

It would be necessary to establish a water management network by setting Dairout Regulator as a key station and other four regulators as sub-system stations while Dairout Regulator is main station for overall Bahr Yusef Irrigation Canal. Ultimate water distribution plan will be decided based on the result of verification of the sufficient amount of water distributed for irrigation in Bahr Yusef Irrigation system covering the end farmland under the control of five regulators (station at sub irrigation system). And the flow-rate management in each sub system will be brought under one water management network.

② Role of Sub-system Stations in the Unitary Water Management

As it is recommended above that an unitary water management system will be established and maintained, the Control house of each regulator has to be shouldered some responsibilities as a management office for sub-system. The responsibilities would be as follows;

1) To collect and accumulate date of required irrigation water to branch canals and farmland through each regulator.

2) To record water levels of upstream and management of flow-rate to down stream by gate operation.

3) To serve as a sub-system management office of water management system covering 320,000ha of beneficial area.

③ Role as a Water Management Office

| Month | day | Mazoura | Watrer requirement at Lahoun | | | | | at Giza | |
|---|---|---|---|---|---|---|---|---|---|
| | | Discharge | A Canal | B Canal | C Pump S. | D Pump S. | Total | ・・・・ | ・・・・ |
| August | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| | 4 | | | | | | | | |
| | 5 | | | | | | | | |
| | 6 | | | | | | | | |
| | 7 | | | | | | | | |
| | 8 | | | | | | | | |
| | ・ | | | | | | | | |
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| | ・ | | | | | | | | |

When Sakoula Regulator is improved and unitary water management of three(3) regulators is started, it will be required to calculate monthly water amount based on cropping pattern and the amount of intake for each canal and pumping station. Accordingly release of the amount of discharge to downstream along with the amount of intake water at upstream (actual amount of irrigation water) has to be decided. In doing this, excess and shortage in each regulator and records of discharge at three(3) regulators should be taken into consideration. The Control house can be used for these works, which will record as shown in the above chart as an example. The daily discharge records should be tabulated so that it will be easy to grasp the amount of intake water for agricultural land and discharge flow to downstream by three(3) regulators.

④ A Place for Technology Transfer

Control house should be used as a place for technical instruction on gate operation, maintenance of facilities and flow-rate managemen. Implementation of technical transfer at the regulator site can also be undertaken.

**(3) The Structure of the Control House**

The Control house is designed as one-stored, RC piers and block wall structure from following reasons;

1) The remote control room is located in Bahr Yusef Canal side in order to operate with confirming situations at up/downstream.
2) Generators are installed at downstream of the canal side.
3) The Control house is planed to one-stored, RC piers and block wall structure.

**(4) Operation from the Remote Operation Panel and Indications**

Operation from the remote operation panel is mentioned below;

1) Operation of upper gates
   Water level control at up/downstream is operated by means of overflow release. The operation buttons are installed both remote control panel and local control pane on the slab of gate pier l.
2) Operation of lower gates
   In case of full gate opening of lower leaf at extraordinary time, lower leaf is operated from remote control panel and control panel on the slab of gate pier. Therefore, the operation buttons are installed both remote

operation room and local control cabinet on the slab of gate pier.

3) Opening height of upper and lower gates

Opening height of upper and lower gates is indicated by both analog and digital display on remote control panel.  Both displays are indicated on local control panel as well.

4) Water Level at Up/downstream

Indication of water level is shown by analog display at gates and by digital at remote operation panel.

5) Discharge and Accumulative Discharge

Discharge and Accumulative Discharge are displayed only on remote operation panel by digital.

6) Recording of Water Level, Gate Opening and Discharge

Water level, gate opening and release discharge are self-recorded on paper at remote operation panel.

7) Communicate System

Telephone system shall be established as communication between remote operation room and the local control cabinet.

**(5) Configuration of Operation Panel**

① Remote Operation Panel

Configuration of remote operation panel is shown in below;

1) Upper gate operation button（No.1 to No.4 gates）
2) Lower gate operation button（No.1 to No.4 gates）
3) Buzzer stop button
4) Lump test button
5) Upper gate opening indicator（digital display, No.1 to No.4）
6) Upper gate opening indicator（analog display, No.1 to No.4）
7) Lower gate opening indicator（digital display, No.1 to No.4）
8) Lower gate opening indicator（analog display, No.1 to No.4）
9) Upstream water level gauge（digital display）
10) Lower water level gauge（digital display）
11) Release discharge meter（digital display）
12) Accumulative release discharge meter（digital display）
13) Recorder of water level, gate opening and release discharge
14) Emergency stop button
15) Local telecommunication

② Local Operation Panel

Configuration of local operation panel is shown as follow.

1) Upper gate operation button（No.1 to No.4 gate）
2) Lower gate operation button（No.1 to No.4 gate）

3) Upper gate opening indicator（digital display, No.1 to No.4）
4) Upper gate opening indicator（analog display, No.1 to No.4）
5) Lower gate opening indicator（digital display, No.1 to No.4）
6) Lower gate opening indicator（analog display, No.1 to No.4）
7) Upstream water level gauge（digital display）
8) Lower water level gauge（digital display）
9) Voltage indicator（analog display）
10) Ampere meter（analog display, No.1 to No.4）
11) Operation location selection button
12) Operation mode button
13) Buzzer stop button
14) Lump test button
15) Emergency stop button
16) Reset button
17) Local telecommunication

## 2-2-1-10 Maintenance Bridge

**(1) Width of Maintenance Bridge**

The width of the attached bridge is decided as below by following reasons;

Total width 12.80m（vehicles width : 3.0m x 2 + horse cart and bikeway width : 2.0m x 2 + sidewalk width : 1.0m x 2 + curb width：0.4m x 2）

［Design criteria of Egypt］

1) According to the plan of the Road Department, the attached bridge is one of four main local road（national road class, design wheel loads : 60 ton）which connect Asiout-Cairo desert road（Route 2）and Cairo-Aswan agricultural road（Route 1.
2) The width of maintenance bridge on main local road is decided to 12.0m.

［Experience in Egypt］

3) The total width of maintenance bridge of Minia Regulator that is repaired by the local irrigation office in West Minia is 12.8m.

4) The total width of attached bridge both of Lahoun and Mazoula Regulators are 12.5 to12.8m.

［Design criteria in Japan/current traffic condition］

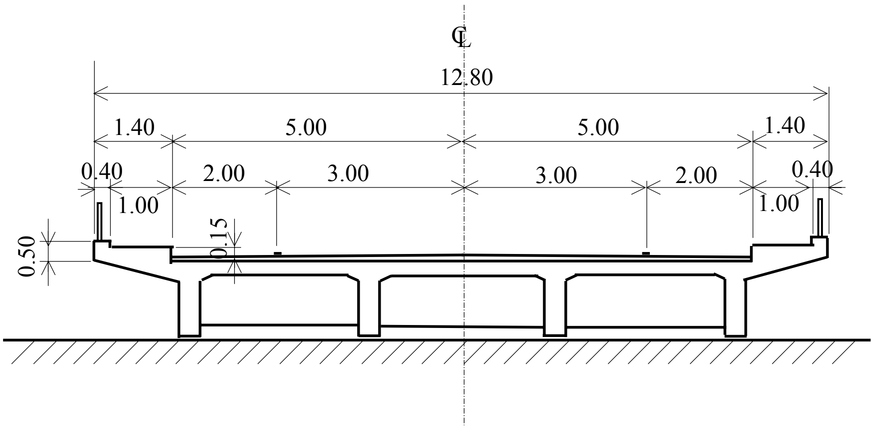
5) Designed traffic volume of wheels is 2,000, therefore roadway width is decided on : 3.0m x 2 lines = 6.0m. (refer to the criteria of Firm Road for Land Improvement Project Standard of Japan )
6) Designed traffic volume of bike and cart is 5,000, cart and bikeway width is decided as 2.0m x 2 lines = 4.0m (refer to the Road Structural Law of Japan).
7) Designed pedestrian volume is 8,100, and sidewalk width：1.0m x 2 lines = 2.0m (refer to the Road Structural

Law of Japan).

［Construction and maintenance］

8) Track crane is used for installation and repair of gates. Its turning radius is 4.5m, so required total width is 10.0m.

**Figure 2-2-1.6 Standard Cross-Section of Maintenance Bridge**




**(2) Beam Type of Maintenance Bridge and Implementation**

The basic policy of the maintenance bridge is mentioned below;

1) The design of the bridge is based on the Specifications for Highway bridges of Japan.
2) Beam spans is 8.0m and numbers of span are 4, same as regulator gate span.
3) From the aspect of economical efficiency, 4-span continual beam type has an advance. However, 2-span continual beam type are adopted, considering bridge length (40.0m) and structural problem (thermal variation).
4) If the beam spans are 10m, the profile of beams shall be adopted reinforced concrete T-beam that is time-proven in Japan.
5) Beams of the attached bridge shall be constructed as cast-in concrete because required height of steel support is relatively short (7.5m) and construction shall be executed in coffering area.

## 2-2-1-11 Conditions of Construction and Equipment

In Egypt there are many small local contractors, and also big contractors who have experiences in large size of project with higher standard of technique. They have ability to execute general civil construction works and building construction works. According to the research on the construction projects of regulator and barrage executed in Egypt, they need the construction period of 3 to 5 years for those projects in general. Since the construction period of this project is expected to be a few years, proper method of construction and procurement arrangement shall be planned in order to complete the project in the required period.

Concerning the cofferdam construction for the regulator and barrage projects, the contractors in Egypt has experience of the construction under the scheme of joint venture with foreign contractors. A few contractors in Egypt could execute the same construction alone. Therefore in general, the foreign contractor's guidance is required because they have less experience to manage schedule control, quality control and safety control in total including control of the work at field level.

Concerning labor workforce, in the vicinity of Sakoula, it is possible to recruit general workers, but it is difficult to recruit skilled workers. The skilled workers such as carpenter, re-bar workers and plasterer etc. and also general workers required at the peak time of construction are planed to recruit from Minia City and Cairo City.

## 2-2-1-12 Procurement of Gate

As the result of study, large size slide type double leaf roller gates are planned to adopt in this project. Most of large size gate constructed in Egypt were designed and manufactured in the third countries or Japan because of following reasons;

① Large size gate

In Egypt there is no maker which is able to design and fabricate such large size water gate which require complicate function and high grade of accuracy. Usually for large water gate project, slide type double leaf roller gate have been imported from Japan and radial type of gate have been imported from third country.

In the recent project, it is planed to produce large size of radial gate by having engineering and technical supports in design and fabrication from the third country, however no result recorded

Slide type double leaf roller gates are not popularly employed in third country, where radial type of gates are popular, on the other hand in Japan, slide type double leaf roller gate are popularly employed for the water gate in head works project, and which design standard are well established and which have been constructed in many projects.

② Gates and electrical equipment

Gate lifting devise and electrical equipment which are used to be designed and fabricated together with aforesaid large size water gate shall be required to have united function guaranteed with gate equipment, therefore which are also imported together with gate equipment from Japan or third country and which have not been designed and fabricated in Egypt as well.

Therefore, the proposed slide type double leaf roller gates, its subsidiary equipment and electrical equipment in this project shall be planed to procure from Japan where design standard for slide type double leaf roller gate are well established and which have been employed in many projects in Japan.

## 2-2-1-13 Procurement of Other Equipment

### (1) Steel Sheet Pile and Large Type-H Shape Steel

Generally the procurement of steel sheet pile and large size H section steel materials are made from Japan and the third country and the place of procurement are planed to determine based on the result in comparing the quality, delivery time, and cost.

In Egypt, general purpose steel material such as re-bar, steel plate, small size steel section member are produced in accordance with international standard, however steel sheet pile and large size H-section steel are not produced in Egypt and imported from Japan and third country. Those steel materials are used to be procured and owned by the local contractors and special subcontractors for foundation construction for their own use purpose when they undertake the project. Those materials are not well circulated in the market in quantity wise and variety wise of specification, therefore procurement of big quantity of materials are planed to make through importation every time on required, comparing the quality, delivery time, and cost, those materials are planed to import from Japan.

Refer to Table 2-2-1.5 Comparison of procurement on steel sheet pile (for temporary use) and 2-2-1.6 Comparison of procurement on steel sheet pile (for permanent use).

## Table 2-2-1.5 Comparison of Procurement on Steel Sheet Pile (For temporary use)

| | Procurement from Japan | | | | | | Procurement from Third Country | | Procurement from Egypt | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Purchase + Selling in Japan | | Purchase + Selling in Egypt | | Lease | | Purchase + Selling in Egypt | | Purchase + Selling in Egypt | | Lease | |
| Condition | Purchased in Japan and transported to Egypt. Sold in Japan after use. | | Purchased in Japan and transported to Egypt. Sold in Egypt after use. | | Leased in Japan and transported to Egypt. Returned after use to lease company in Japan. | | Imported from the Third Country and sold in Egypt after use. | | Purchased and sold after use in Egypt. | | Leased and returned after use in Egypt. | |
| Standard | ・Type IV<br>・W=400mm<br>・190.25kg/m・wall width 1m<br>・composite section modulus: 2270cm3/wall width 1m | | | | | | ・TYPE PU20<br>・W=600mm<br>・140.5kg/m・wall width1m<br>・composite section modulus: 2532cm3/wall width1m | | ・TYPE PU20<br>・W=600mm<br>・140.5kg/m・wall width1m<br>・composite section modulus: 2532cm3/wall width1m | | | |
| Delivery time | Enough stock, easy arrangement for export, timely delivery on schedule as required. | ○ | Enough stock, easy arrangement for export, timely delivery on schedule as required. | ○ | Enough stock, easy arrangement for export, timely delivery on schedule as required.. | ○ | A risk on non delivery on time arising from the process of order and manufacturing in case of shortage of stock in the market of Third Country. | △ | Uncertain delivery time because there are not enough stocks in the market and need process of order, manufacturing and import when required. | × | Uncertain delivery time because lease market with rich stock does not exist in Egypt and order, manufacturing and import is required. | × |
| Technical Performance | Thicker thickness , big stiffness and better workability in handling. | ○ | Thicker thickness , big stiffness and better workability in handling. | ○ | Thicker thickness , big stiffness and better workability in handling. | ○ | Possibility of transformation due to less thinness and inferior stiffness of member. | △ | Possibility of transformation due to less thinness and inferior stiffness of member. | △ | Possibility of transformation due to less thinness and inferior stiffness of member.. | △ |
| Cost | 20,100 yen/m・wall width 1m | ○ | 23,180 yen/m・wall width 1m | △ | 20,600 yen/m ・ wall width 1m | ○ | 28,700 yen/m ・ wall width 1m | × | 30,900 yen/m・wall width 1m | × | 30,700 yen/m・wall width 1m | × |
| Evaluation | Better technical performance, timely delivery, most economical. | | Better technical performance, timely delivery , economical. | | Better technical performance, timely delivery , economical.. | | Uncertain delivery time, costly | | Uncertain delivery time, costly | | No ordinary lease market, costly | |
| | ◎ | | △ | | ○ | | × | | × | | × | |

**Table 2-2-1.6 Comparison of Procurement on Steel Sheet Pile (For permanent use)**

| | Procurement from Japan | | Procurement from Third Country | | Procurement from Egypt | |
|---|---|---|---|---|---|---|
| Standard | ・Type IV<br>・W=400mm<br>・190.25kg/m・wall width 1m<br>・ composite section modulus: 2270 cm3/wall width 1m | | ・TYPE PU20<br>・W=600mm<br>・140.5kg/m・wall width 1m<br>・ composite section modulus: 2532 cm3/wall width 1m | | ・TYPE PU20<br>・W=600mm<br>・140.5kg/m・wall width 1m<br>・ composite section modulus: 2532 cm3/wall width 1m | |
| Delivery time | Enough stock, easy arrangement for export, timely delivery on schedule as required. | ○ | A risk on delivery time arising from process of order and manufacturing due to shortage of stock for large quantity in the Third Country. | △ | Uncertain delivery time because of needs of process of order, manufacturing and import due to large quantity required and shortage of stock in the market. | × |
| Technical performance | Thicker thickness and better stiffness of member. | ○ | Thinner thickness of member and inferior in durability for permanent use. | × | Thinner thickness and inferior in durability for permanent facility. | × |
| Cost | 21,800 yen/m・wall width 1m | ○ | 22,300 yen/ m・wall width 1m | △ | 24,500 yen/ m・wall width 1m | × |
| Evaluation | Better technical performance, timely delivery , economical. | | Inferior in technical performance, uncertain delivery time | | Inferior in technical performance, uncertain delivery time. | |
| | ○ | | △ | | × | |

**(2) General Construction Materials**

In Egypt, cement, reinforcing bar, general building materials, light steel products, fittings, ventilation and lighting equipment, electric wire, piping materials and so on are available. In this project, most of them are planed to transport from Cairo City.

Coarse aggregates for concrete are planed to procure from Dashulte. Stone materials are planed to procure from Minia and fine aggregates from the quarry site in $6^{th}$ October City near Cairo City. Refer to Appendix 6B-1 Location map of Material Source Supply.

**(3) Construction Machinery**

In Egypt, most of general purpose construction equipment such as back hoe, bulldozer, truck, crane and so on are available. Most of those equipment are owned by local contractors and some of those equipment are available in rental market. However those equipment are not properly maintained which used to cause inferior in safety and low work efficiency. Since it is difficult to procure construction equipment from Sakoula area, the construction equipment are planed to procure from Cairo city and transported to the site.

Some construction equipment which are not well circulated in the market, which are not certainly available in Egypt and which are used for important works in critical work path in the schedule, are planed to procure from Japan. Refer to Table 2-2-1.7 Import plan: Construction materials, Construction machinery and Equipment and materials

**(4) Scaffold, Support, Form**

For the temporary construction material of form works, since most of local contractors are used to employ wooden scaffold supports and wooden boards for form, wooden materials are available in Egypt. Some big contractors are used to employ steel frame scaffolds and supports and plywood for form works, but those materials for temporary works have been procured and imported to meet the requirements in each project undertaken by those contractors. Since they don't have rental market supplying various kind of scaffolds and supports sufficiently, sizable quantity of those materials are planed to procure and import when required. Refer to Table 2-2-1.7 Import Plan: Construction Materials, Construction Machinery, Equipment and Materials

**Table 2-2-1.7 Import Plan: Construction Materials, Construction Machinery, Equipment and Materials**

| Category | Item | Place of Procurement | | | Notes | Critical work activity related |
|---|---|---|---|---|---|---|
| | | Local | Japan | The 3rd Country | | |
| Construction Materials | H section steel | | ○ | | more than 250mm | Temporary work (Temporary bridge) |
| | Steel sheet pile | | ○ | | TypeⅣ, Type Ⅴ | Temporary work (Cofferdam) |
| | Deck plate | | ○ | | | Temporary work (Temporary bridge) |
| | Tie-rod | | ○ | | | Temporary work (Cofferdam) |
| | Prefabricated frame scaffold | | ○ | | | Regulator structure work |
| | Scaffold pipe and scaffold board | | ○ | | | Regulator structure work |
| | Form panel fixing member | | ○ | | | Regulator structure work |
| | Bridge shoe, Expansion joint | | ○ | | | |
| | Step | | ○ | | | |
| Equipment and Materials | Gate equipment | | ○ | | | Gate mechanical equipment |
| | Electrical facilities for gate (i.e. Receiving and distribution of power and control system) | | ○ | | | Gate electrical equipment |
| Construction Machinery | Vibro-hammer | | ○ | | 40kw, 60kw, 90kw including generator | Temporary Works, (Cofferdam) |
| | Water jet | | ○ | | Pump pressure 150kg/cm$^2$ with generator | Temporary Works (Cofferdam) |
| | Soil improvement equipment | | ○ | | CJG (Boring and Grouting machine) | Temporary Works, (Cofferdam) |
| | Generator | | ○ | | 150,200kVA (for steel sheet pile) | Temporary Works, (Cofferdam) |
| | Concrete plant | | ○ | | 45m$^3$/hr | Regulator structure work |

## 2-2-1-14 Construction Plan and Method

**(1) Basic Policy of Construction**

The proposed new Regulator with 4 gates are planed to locate at the same position of the existing Regulator (total length of 88m) and to construct after demolishing 53m length of existing regulator at the right bank side. Main structure of the regulator is planed to construct under dry condition inside the cofferdam. The 8 nos. of existing gates to be used for water regulation purpose are examined to accommodate the flow of 193 $m^3$ of design maximum discharge in capacity.

After the completion of new Regulator and diverting the flow of Bahr Yusef Canal water to the Regulator, the closure dam is planed to construct by closing the canal with sheet pile at up and down steam of remaining existing gate structure at the left bank side.

Upper structure and pier structure of existing Regulator which would disturb the construction of buttress wall for tie rods under the closure dam are planed to demolish and lower part (pier, bottom slab) are planed to leave as it is. Back fill materials around the remaining regulator structure in the closure dam embankment are planed to compact well by manpower. Suitable materials are planed to use for embankment for the closure dam.

.New Regulator structure is planed to construct under dry condition inside the cofferdam. The cut-off wall function and stability of cofferdam are planed to examine in the detail design and careful supervision shall be required during construction stage.

**(2) Earth Works**

After de-watering inside the cofferdam closure, existing regulator structure is planed to demolish by giant breaker. Demolished materials are planed to dispose to designated dumping area. Excavation works are planed execute by back hoe and bulldozer and loading to dump truck and suitable soil material are plan to stock in the temporary stock yard for the use of backfill works. Unsuitable soil materials are planed to dispose to designated disposal area where is located in the desert area, 10km away from the site. (Refer to Basic Design Drawing DWG-16 Temporary Facility Plan and Appendix 6B-2 Borrow and Disposal Area)

Excavation up to 6m below water are planed to execute by 0.7$m^3$ class back hoe and for the deeper by the clamshell type of excavator. Embankment below road structure in the closure dam are planed to fill with suitable sandy soil material and compacted sufficiently with roller and rammer. Soil arrangement schedule of this project is shown in Appendix 6B-3 Soil Arrangement Schedule.

**(3) Demolishing Existing Structures**

Giant breaker attached to back hoe which is usually employed for the excavation of soft rock in Egypt are planed to use for demolishing existing structure.

**(4) Concrete Works**

Strength and quantity of concrete for the project are shown in Table 2-2-1.8.

**Table 2-2-1.8 Strength and Quantity of Concrete**

| Portion to be used | Design strength ($kgf/cm^2$) | Quantity ($m^3$) |
|---|---|---|
| Reinforced concrete | 210 | 6,900 |
| Plain concrete | 180 | 460 |
| Leveling g concrete | 180 | 240 |
| Total | | 7,600 |

**(5) Concrete Plant**

There is no concrete production plant near the site. Nearest plant is located in Minia city, owned by a local contractor with capacity of $30m^3$/hr. However, it is not suitable for the use because it takes about two hours for transportation. Therefore the concrete plant are planed to set up at the temporary yard inside the site, because 7,600 $m^3$ of concrete have to be placed in about 6 months, a large quantity of concrete are produced and supplied continuously keeping stable quality and it is important for the temperature of concrete to be controlled in the hot season.

Capacity $45m^3$/hr of concrete plant is planed considering that planned maximum daily placing quantity is $300m^3$. Waste water arising from the plant are planed not to drain directly to irrigation canal which is planed to treat in permeation type disposal pond so that it doesn't cause water pollution.

**(6) Surface Finishing of Structures**

There are two kinds of surface finishing method for the regulator structures in Egypt generally. One is fair finish method executed for Lahoun and Mazoura Regulators and Esna New regulator, and the other is stone pitching method used for most of old regulators and two new regulators now under construction in delta area. As a result of comparison study, considering construction time required and cost, fair finish method are planed to use for this project.

Concerning form works, wooden plank forms are generally used in Egypt which surface finishing with form joints is inferior in quality for fair finish surface texture. Surface treated plywood is planed to use for this project. It is inferior in form work skill in Egypt on accurate alignment and verticalness of form fixing, and on smooth and straight concrete joint surface, therefore the superior skill are planed to introduce from Japan.

**(7) Placing Concrete**

Concrete placing block arrangement are planed properly considering structural stress, construction joint, impermeability and capacity of plants in mixing and placing concrete. For the countermeasure required for mass concreting and concreting under hot climate with maximum temperature of 45 degrees, it is planed as following countermeasure.

1) To use water reducing agent to reduce heat of hydration
2) To keep cement in the shade.
3) To cover cement silo with heat cutting sheet.

4) To cover aggregate at stockyard with roof.

5) To use low temperature well water for mixing water.

6) To cover water tank with heat cutting sheet.

7) To shorten the time from mixing to placing as possible.

8) To keep the place of concreting in the shade.

9) To spray water on forms and reinforcing bars before placing concrete

10) To place concrete for major structures at the time of low temperature.

Mixed concrete at the concrete plant are planed to transport with agitator cars and place with concrete pump car or crane.

**(8) Pre-cast Method**

Concerning construction method of girder of attached bridge and top slab of pier, as a result of comparison study on pre-cast method and cast in-site method, the cast in-site method are planed to adopt because of economical and easier construction. The result of study is shown in Table 2-2-1.9.

**Table 2-2-1.9 Comparison of Method for Construction of Top Slab**

| | Cast in-site method | | Pre-cast method | |
|---|---|---|---|---|
| Method | To provide support from bottom slab. Conventional way of form works, re-bar work and concrete placing. | | To make pre-cast girder at the temporary yard. Members to be transported by truck and installed by crane. | |
| Period | Comparatively longer. About 3.0 month. | × | Shorter. About 2.5 month | ○ |
| Construction difficulty | Comparatively easier due to conventional way. | ○ | Special skill are required because of handling heavier weight members with big crane at height. | × |
| Cost | 0.3 million yen cheaper than pre-cast method. | ○ | Costly. | △ |
| Evaluation | This activity is not critical path. Easy and economical. | | Special skill are required and difficult. Costly. | |
| | ○ | | × | |

**(9) Installation of Gates**

Proposed gates are planed to transport in the complete shape of single leaf by sea and land. It is planed to assemble the parts only with bolts but without any welding work at site. For the assembling and erection of gates leaves, it is planed to use the platform occupying apron slab, additional temporary deck installed and attached bridge, and to use cranes for erection. For the gate erection, it is planed to employ 160 ton capacity of truck crane. Electric power required for gate installation works and test operation are planed to use public power supply through permanent transformer, which is to be supplied for the project.

**(10) Bank Protection Works**

Bank protection planed at the upstream and downstream of closure dam, and the both side of the canal, are planed to use steel sheet pile wall to tie with the buttress wall by tie-rod.

**(11) Bed Protection Works**

Cross blocks and rubbles on the canal bed are planed to execute before removing double steel sheet pile cofferdam. Stone materials are planed to obtain from a quarry site near Minia city.

**(12) Building Works**

Foundation of building are planed to use cast in-site concrete pile ( $\phi$ 800mm, L=7.5m). Bearing capacity will be confirmed by loading test. Structure of building is planed to use reinforced concrete for beam, column and slab, and concrete blocks for wall. Finishing works of tiles for the floor, emulsion and acrylic paint for the wall, cement board for the ceiling and asphalt water proof for the roof are designed.

## 2-2-1-15 Temporary Works

**(1) Temporary Diversion Road and Temporary Bridge**

Maintenance bridge on existing regulator is used for a road bridge along the local main road which is one of few roads crossing the canal in this area. During construction of new regulator including cofferdam closure work in the canal and demolishing work of existing regulator structure and existing maintenance bridge, the existing bridge become un-usable. Therefore, a temporary bridge and temporary detour road is planned to be constructed at the upstream of the regulator for general traffic (for man and horse, and vehicles) and transportation of construction materials and construction equipment during construction period.

The temporary bridge is planned to be separate use from site temporary access road for construction purpose in order to keep general traffic in safe. Location and structure of temporary bridge are planned not to disturb canal water flow. Span of pier of bridge is designed as long as possible considering practicable construction method. The length of the temporary bridge is planned to be the same width as existing canal.

The width of existing maintenance bridge is now narrow with 4 m width, and vehicles are not able to pass each other and have to wait for each other in case. The width of temporary diversion detour road and temporary bridge are planned to have enough width for dual passing for general vehicles and additional construction vehicles and for man and horse. IIP agreed to construct temporary diversion detour road and temporary bridge for the traffic. Weekly markets are open along the local main road and on the existing regulator but it is agreed to shift to another place during the construction period for safety.

The location of temporary diversion detour road and temporary bridge are shown in Basic Design Drawing DWG -16 Temporary Facility Plan. The temporary bridge is planned to be located upstream of existing regulator in order to have enough construction area for cofferdam construction and its length 100m and span of pier 6.0m. Temporary bridge width is planned to be 8m and lane arrangement with travel way for general vehicle 2.75m, for construction vehicle 3.00m, then total 5.75m, sidewalk (1.15m + 0.3m = 1.45m), curb and handrail (04x2 = 0.8m). The design load is planned to apply with T-25 traffic load and maximum load of crawler crane, which occur on extracting piles of temporary bridge.

**(2) Closing of Existing Canal**

The new regulator is planed to construct at the right side bank of existing regulator. Canal water flow is planed to control by the existing 8 gates at the left side bank of the existing regulator. Half of canal is planed to close with cofferdam and the new regulator is planed to construct under dry condition inside the cofferdam. (Refer to Basic Design Drawing DWG-16)

① Design Condition of Cofferdam

1) Height of cofferdam has been determined considering free board 0.5m on the second maximum water level in past 10 years.

| | | |
|---|---|---|
| Height of cofferdam at up stream | : EL+ 34.00ｍ＋0.50ｍ | = EL+ 34.50ｍ |
| Height of cofferdam at down stream | : EL+ 33.10ｍ＋0.50ｍ | = EL+ 33.60ｍ |
| Design water level at up stream | : EL+ 34.00, at down stream：EL+ 33.10ｍ | |
| Existing canal bottom elevation | : EL+ 28.40ｍ | |

Elevation of excavation for bottom slab of regulator：EL+ 25.70ｍ

2) Expected canal closing period：15 months

Double steel sheet pile with deep well for de-watering method is planed to adopt after comparing for the cofferdam with soil embankment method and single steel sheet pile with embankment method, and for the de-watering with shallow sump method, and deep well with shallow sump method.

Double steel sheet pile method with deep well method is the safest and the most economical because of following reasons; ① It is suitable for deeper water depth like this project. ② Width of the closure is 7 or 8m and occupying area in the canal is narrowest. ③ It is more possible to ensure cutting off water function and to avoid risks of boiling by steel sheet pile in the sand layer of comparatively large coefficient of permeability at site. ④ It is possible to work in the dry condition and secure the bearing capacity of foundation during bedding work. ⑤ There are projects adopting same method in delta area and it was also adopted in the construction of Lahoun and Mazoura regulators. It is most reliable and economical method.

(Refer to Table 2-2-1.10 Comparison of method for Temporary cofferdam and Table 2-2-1.11 Comparison of method for de-watering works)

## Table 2-2-1.10 Comparison of Method for Temporary Cofferdam

○ : superior △ : a little inferior × : inferior

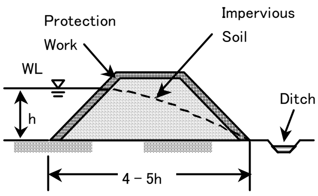
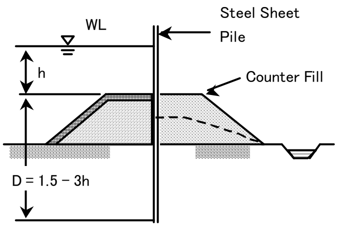
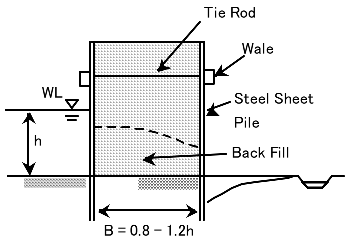
| Method | Soil Embankment | | Single steel sheet pile and embankment | | Double steel sheet pile | |
|---|---|---|---|---|---|---|
| Cross Section |  | |  | |  | |
| Application | ・Suitable for shallow depth (about 3m) and short period.<br>・In case of 7m depth, largest width of closure embankment (about 5 times of depth = 35m). Not applicable because not ensuring enough space for existing 8 gates operation during the construction. | × | ・Suitable for small closure for about 5m depth.<br>・in case of 3m height of counter fill, width is required 10m at the top, 5 times of height = 25m at bottom. Not applicable because not ensuring enough space for existing 8 gates operation during the construction is impossible. | × | ・Suitable for depth up to 10m and long period construction.<br>・Width of closure is about 8m (about 1.2 times of depth). It is possible to ensure enough space for existing 8 gates operation during the construction.<br>・This method is adopted in the construction of Mazoura regulator and barrages under construction in delta area. | ○ |
| Safety | ・Big risks of boiling.<br>・Frequent maintenance for revetment. | × | ・Inferior function of cutting off water due to single steel sheet pile.<br>・Risk of boiling.<br>・Maintenance for revetment is required. | △ | ・Smaller risk of boiling.<br>・More superior than single steel sheet pile in cutting off water function.<br>・Better in stability.<br>・Safer for water flowing. | ○ |
| Environmental impact | ・Bigger impact on water pollution in the canal. | × | ・some impact on water quality in the canal. | △ | ・Temporarily impact on water pollution in the canal. No impact after completion of cofferdam. | ○ |
| Workability | ・Difficult in obtaining large quantity of impermeable soil.<br>・Revetment work is required. | × | ・Temporary platform is required for the construction.<br>・Revetment work is required. | △ | ・By adopting advance sand filling method inside the closure, working platform can be prepared easily.<br>・Various work and skilled work required. | △ |
| Construction time | ・Shorter | ○ | ・Average | ○ | ・comparatively longer | △ |
| Cost | ・Rather costly comparing to double steel sheet pile.(about 5.6 million yen/10m) | △ | ・Rather costly comparing to double steel sheet pile (about 5.2 million yen/10m) | △ | ・Rather economical comparing to another method. (about 5.0 million yen/10m) | ○ |
| Evaluation | ・Not applicable because not ensuring enough space for existing 8 gates operation during the construction. | × | ・Not applicable because not ensuring enough space for existing 8 gates operation during the construction. | × | ・It is possible to ensure the space for existing 8 gates during the construction.<br>・This method is used generally in similar work as closing work and reliable. | ○ |

**Table 2-2-1.11 Comparison of Method for De-watering Works**

○ : superior △ : a little inferior × : inferior

| Method | Shallow Sump | | Deep Well | | Deep well with Shallow Sump | |
|---|---|---|---|---|---|---|
| System | To install shallow sump and de-water with pump simultaneously following excavation works. | | To lower the water level by deep well before commencement of excavation. | | To de-water up to bedding level by deep well and to de-water by shallow sump pump during bedding works.. | |
| Workability ・Stability | ・Bigger risk of boiling.<br>・Difficult in maintaining dry condition on excavation bed.<br>・Easy to have damage on foundation and reduce bearing capacity.<br>・Require frequent re-setting of pump and ump. | × | ・Smaller risk of boiling.<br>・Efficient excavation work.<br>・Ensuring bearing capacity of foundation.<br>・Adopted in the Construction of Mazoura regulator and barrages project in delta area. Generally this method adopted in many project.<br>・The water load on back of steel sheet pile is reduced and the closure get stable. | ○ | ・Risk of boiling is reduced.<br>・Easy to damage on foundation and reduce bearing capacity<br>・The water load on back of steel sheet pile is reduced and the closure get stable. | △ |
| Construction Period | ・Lower efficiency in excavation because of constant wet condition and requiring supplementary works of de-watering.<br>・Longer period. | × | ・It takes one month to install deep well.<br>・Efficiency of excavation is improved<br>・Shorter period. | ○ | ・Efficiency of excavation become lower on bedding works.<br>・Longer period. | △ |
| Cost | Rather costly (about 41million yen) | △ | Rather economical (about 40 million yen) | ○ | Rather costly (about 41 million yen) | △ |
| Evaluation | Lower efficiency of excavation work. Bigger risks of boiling. | | Reliable. Advantage in securing construction period. Economical. | | Longer construction period. | |
| | × | | ○ | | △ | |

Width of cofferdam, depth of excavation, water level and type of steel sheet pile are shown in attached Basic Design Drawing DWG-16, 17.

For the method of construction of double steel sheet pile, there are pontoon method, advance embankment method and block piling method. The advance embankment method, which was used in construction of Mazoura regulator and which is most adequate method considering difficulty in procurement of suitable type of pontoon with economical cost, construction period, safety and cost of pontoon. Comparison of method is shown in Table 2-2-1.12 Comparison of method for double steel sheet pile works.

**Table 2-2-1.12 Comparison of Method for Double Steel Sheet Pile Works**

○ : superior △ : a little inferior × : inferior

| Method | Pontoon | | Advance Embankment | | Block Piling | |
|---|---|---|---|---|---|---|
| Working platform | Sheet piles are driven on the pontoon and tie rods are installed in the water and then sand filling inside the closure is executed. | | To prepare embank platform before piling. To fill inside of the closure with the embankment materials outside of closure. | | To drive sheet piles in a block and back fill inside the block every 8m length block (the partition of steel sheet pile is required) | |
| Environmental Influence | ・Less impact on water pollution. | ○ | ・Minimizing measure for water pollution is required. | △ | ・Less impact on water pollution. | △ |
| Workability | ・Piling work on a pontoon in the flowing water requires skilled work. Less experience. Lower work efficiency<br>・Difficult in procurement due to less availability of required type of pontoon for mobilization in assembling and disassembling .<br>・Require safety measures for on the water works. | × | ・Better work efficiency due to on land work. | ○ | ・Lower work efficiency due to back fill works in every block and it is critical procedure in work schedule. | △ |
| Construction Period | ・Lower work efficiency on pontoon.<br>・Longer, need 3.0 months | × | ・Shorter, need 2.5 months. | ○ | ・Longer, need 4.0 months | △ |
| Cost | 2 million yen higher cost than advance embankment method. | × | Most economical. | ○ | 3 million yen higher cost than advance embankment method. | × |
| Evaluation | Longer construction period and higher cost. | | Shorter construction period and lower cost. Minimizing measure for water pollution is required. | | Longer construction period and higher cost. | |
| | × | | ○ | | × | |

Combination use of vibro-hammer and water-jet are planed to use for piling of steel sheet pile in accordance with the Cost estimation standard of Ministry of Land, Infrastructure and Transport, which combination method is suitable for the ground condition having N-value exceeding 50.

② Special Closure Work Crossing Existing Regulator Base

At the base section with 30m length of existing regulator where proposed cofferdam is planed to cross, it is impossible to drive sheet piles by vibro-hammer through the base of existing regulator. In the construction of Mazoura regulator, cofferdam wall was constructed by installing double steel sheet pile on the base and soil improvement cut-off wall by column jet grout under the base.

As a result of comparison of method on the method of breaking the base and piling (breaking the base of regulator and piling) and the method of soil improvement under the base (double steel sheet pile on the base and soil improvement under the base), method of soil improvement under the base is planed to adopt in this project, which has less impact to the existing regulator structure and was adopted in the construction of Mazoura Regulator. (Refer to Table 2-2-1.13 Comparison of method closing work crossing existing regulator)

For soil improvement method, there are single packer method, double packer method and triple packer method. Triple packer method (Column jet grout method) are planed to adopt, which are suitable for the ground condition having N-value exceeding 50.

**Table 2-2-1.13 Comparison of Method Closing work Crossing Existing Regulator**

| | Breaking existing base structure and sheet piling | | Soil improvement under existing base structure and install sheet pile | |
|---|---|---|---|---|
| Method | Breaking the base of existing regulator base structure by special breaker and l sheet piling. | | Installing steel sheet pile cofferdam on the base of existing regulator and constructing cut-off wall by soil improvement treatment under the base of existing regulator. | |
| Workability | ・Better function of water cut off by steel sheet pile.<br>・Big mobilization of machinery is required.<br>・Cause vibration impact to existing regulator structure.<br>・Require blocking measure for eater flow through piers.<br>・Need safety measures for work under the water. | × | ・Confirmation survey for cut off function is required.<br>・Special machinery is required.<br>・In Mazoura, same method was applied<br>・Less impact to existing regulator structure. | ○ |
| Construction period | Need about 2 months | × | Need about 1.5 month | ○ |
| Cost | About 13.7 million yen | △ | About 13.1 million yen | ○ |
| Evaluation | Need mitigating measure for vibration impact on existing regulator and need blocking water flow through piers. Longer construction period. Costly. | | Less impact to existing regulator structure. Many application of this method are recorded for the projects requiring soil improvement. Shorter construction period. | |
| | × | | ○ | |

③ Structure of Temporay Closure Work at Right Side Bank

Right side bank of cofferdam is the access front to mobilize construction materials and equipment for regulator structure works and canal bed protection works. Single sheet pile wall type cofferdam are planed to adopt considering accessbility required and cost.

**(3) Diversion of Existing Utilities**

On the existing regulator, 150mm diameter of water supply pipe, street light, telephone line and telemeter are installed. Those utilities are planed to divert and to maintain in use during the construction. After completion of the works, they are planed to restore on the proposed road on the closure dam and attached bridge of new regulator.

**(4) Temporary Yard**

Location of temporary yard and temporary facility plan including following facilities are shown in Basic Design Drawing DWG-16.

| | | |
|---|---|---|
| 1) | Warehouse | 200m$^2$ |
| 2) | Cement storage house | 70m$^2$ |
| 3) | Shed (form, re-bars) | 150m$^2$ |
| 4) | Toilet・Shower | 3m$^2$ |
| 5) | Concrete plant | 550m$^2$ |
| 6) | Aggregate storage yard | 200m$^2$ |
| 7) | Form・Re-bar stock yard | 300m$^2$ |
| 8) | Steel products stock yard | 900m$^2$ |
| 9) | General materials stock yard | 300m$^2$ |
| 10) | Soil stock yard | 3,000m$^2$ |
| 11) | Labors' camp | 260m$^2$ |
| 12) | Temporary road（width 8ｍ） | |

Intermediate bank between the canal and navigation lock, and the land along the left side bank of the canal are planed to use for the project as temporary yard which are to be prepared by the implementation agency of Egypt. Since residential houses are built along both side of the canal and space of the Intermediate bank and the land at left side bank along the canal is not enough for temporary yard purpose, it was discussed with implementation agency of Egypt and planed to use the canal space of navigation lock by back filling inside temporarily, and further the idea of renting the neighboring land has been examined. As a result of examination, the area back filled in the canal space of navigation lock are planed to use for concrete plant and form and re-bar material stock and neighboring land are planed to rent for another purpose of materials and equipment. (Refer to Table 2-2-1.14 Comparison of plans for temporary facility yard and Appendix 6B-4 Temporary Yard Plan and Electric Power Plan)

The area back filled in the canal space and the land area rented are planed to be 3,000 ㎡ and 4,500 ㎡ respectively considering cost and work efficiency. The soil materials back filled in the canal space are planed to remove eventually and dispose to designated dumping area or re-use for the embankment at left side bank of down stream along the canal.

**Table 2-2-1.14 Comparison of Plans for Temporary Facility Yard**

| | A: Back filling inside navigation lock canal | | B: Back filling inside navigation lock canal and additional rental land out of site | |
|---|---|---|---|---|
| Area required | 8,400 $m^2$ | | 8,400 $m^2$ | |
| ・Concrete Plant | 3,200 $m^2$ at navigation lock | | 3,200 $m^2$ at navigation lock | |
| ・Form and Re-bar processing and stock yard | 1,300 $m^2$ at navigation lock | | 1,300 $m^2$ at navigation lock<br>Those materials are planed to stock within the site considering the case of stocking out of the site which cause difficulty in construction progress and scheduling. | |
| ・Steel products, Gate equipment, Temporary materials | 3,000 $m^2$ navigation lock | | 3,000 $m^2$<br>Those materials are planed to keep out of the site which will not cause difficulty in construction progress and scheduling. | |
| ・Labors' camp | 900 $m^2$<br>At open land in the Site(left bank side) | | 900 $m^2$<br>At open land in the Site(left bank side) | |
| Construction and schedule control. | Easy to manage | ○ | Rather difficult manage | △ |
| Cost | Quite costly.<br>About 79 million yen | × | Economical.<br>About 31 million yen | ○ |
| Evaluation | × | | ○ | |

The land for temporary yard is planed to level the surface and cover with gravel. Temporary fence and gate are planed to construct along the boundary of temporary yard for the safety to third party and for the security. Guard house are planed to construct at the gate. A few large trees in the intermediate bank are planed to preserve as requested by the implementation agency of Egypt.

**(5) Site Office and Accommodation for the Project**

For the office of the Consultant, site office of the Contractor and accommodation are planed to rent private houses neighboring to the site. A liaison office are planed to locate in Cairo City for the arrangement of procurement and transportation of materials and equipment in Egypt, transportation of imported materials and equipment from the port to the site, and recruiting and administration of workers affair for the project. Consultant's residence is planed to locate in Minia City so as to keep close coordination with the implementation agency of Egypt and other authorities concerned.

**(6) Controlling Water Pollution and Contamination**

Following countermeasure is planed to take;

1) For contamination with filling soil during the construction of advance embankment for steel sheet piling work: Slope of embankment are planed to protect with sand bag.
2) For the soil contaminated in the water de-watered from inside the cofferdam: Settling basin are planed to

construct.

3) For oils and fats from construction machinery: Oil fence are planed to install.

4) For waste water from concrete plant: Treatment basin are planed to construct.

5) For sanitary water from camp and office: Septic tank are planed to install and dispose waste periodically.

**(7) Electric Power Supply Facilities for Construction**

It is planed to receive the power from existing 11KV high voltage power lines which are running near the proposed regulator. The line is available at the right bank of the upstream, 220m away from the regulator.

During construction stage, it is planned to receive the power from the existing 11KV high voltage power lines connecting to temporary transformer installed near the concrete plant. A transformer is planned to be installed near control house as permanent receiving facility after opening to receive power. (Refer to 6B-4 Temporary Yard Plan and Electric Power Plan)

Considering power break occurring in 1 to 2 times a months in this area, the generator are planed to use for de-water pump for deep-well, where the site is supposed to have serious damage in case of failure of power, and machinery which are used in limited period during construction period such as sheet piling. Electricity required for such machinery which are used constantly in all the construction period is planned to be purchased from public power supply, and for the back up in case of power failure, a reserve generator is planned to be provided.

**(8) Transportation Plan**

① Transportation from Japan and third country

After unloading and customs clearance at Alexandria Port, the materials and equipment for the project are planned to be transported by truck or trailer to the site via Cairo. It is planned estimating 4 weeks for marine transportation and 4 weeks for unloading, customs clearance at the port and inland transportation to the site.

② Inland Transportation in Egypt

Materials and equipment procured in Egypt are planned to transport from Cairo City and Minia City and its suburb by truck or trailer on the land. There are some narrow intersections along local road near the site but it is possible for those vehicles to pass by controlling traffic. Main access roads to the site are planned to take the desert road going from north to south along the west side of Nile River and the farm road along the Nile River.

Concerning the transportation, marine transportation (up to Alexandria) and inland transportation after landing is planned to be executed by Japanese side. However, it is agreed that Government of Egypt shoulders expense for inland transportation of materials and equipment for permanent works among imported ones.

## 2-2-1-16 Participation of Local Contractor

### (1) Technical Capacity of Contractors in Egypt

Technical capacity of contractors in Egypt is comparatively high. They have enough skill to execute concrete works, foundation works etc. to the satisfactory under the management of Japanese contractor. This is the project to construct new regulator on the same location of existing regulator which are including demolish of existing regulator structure and construction of large scale of cofferdam in the canal.

It is planed for Japanese contractors to conduct the project with local contractors in Egypt, who could participate the project as the subcontractor and the supplier of labor, construction materials and construction equipment under the supervision of Japanese contractor and complete the project as planed.

### (2) Utilization of Construction Equipment Available in Egypt

In Egypt, general purpose construction equipment are available, however there are less demand for special purpose equipment in the market and also less stocks in the market (i.e. less stocks in local contractors and rental company). In Egypt, majority of leasing equipment are available from local contractors' s own equipment and generally expensive. Even general purpose construction equipment are available, some type of equipment are not properly maintained which used to cause disturbance to the quality for the works and to construction schedule, therefore those equipment are planed to procure from Japan or third country.

### (3) Labor Workforce in Egypt

Technical standard and quality of skilled worker for the construction in Egypt is comparatively high. Recently it is getting easier to obtain capable engineer and skilled worker because they have experienced through the civil and building construction projects executed. Sakoula regulator is located in the isolated area, 220km away from Cairo city, therefore it is expected to face difficulty in obtaining construction engineer and skilled worker in the region and probably to recruit them in Cairo city and Minia city area. General workers and security guards from the farming area nearby are expected to employ.

## 2-2-1-17 Operation and Maintenance of the Facilities

Maintenance policy of the facilities is shown as follows;

1) Sakoula Regulator, which will be improved is maintained by West Minia Irrigation Directorate and West Bahr Yusef Inspectorate office, which is affiliated with it as present condition.
2) Although maintenance of the facilities should be planned that the government of Egypt itself can carry out, technical instruction for long term will be implemented about operation of discharge management by introduction overflow type electric gate in order to master operation skills completely.
3) There are three pump station systems in beneficial area covering Sakoula Regulator and they delivery water to beneficial irrigation area, though maintenance expense won't be included the amount of cost from the following reasons that ①Project aim is renewal of Sakoula Regulator, ②Maintenance of pump is under the jurisdiction of Mechanical and Electrical Department (MED).

## 2-2-1-18 Ability on Operation and Maintenance of Executing Agency

**(1) Ability on Maintenance of Executing Agency**

Specification and Gate operation of Sakoula Regulator which will be improved is equivalent with Lahoun (Rehabilitated in 1997) and Mazoura Regulator (Rehabilitated in 2002), which were already completed by Grant Aid, therefore, it will be considered that Beni Suef Irrigation Directorate which manage completed Regulators has know-how for maintenance of the these gate. However, On the Job Training (OJT) should be implemented about operation and maintenance of the gate so that Egypt will be maintenance in detail of it at the time of handing facilities. However, West Minia Irrigation Directorate controls Sakoula Regulator and it is deferent from other completed regulators, which controlled by Beni Suef Irrigation Directorate, thereby it is essential to cooperate with Beni Suef Irrigation Directorate.

**(2) Acceptance of Gate Operator**

It will be proposed to employ Gate Operator who has the graduation qualification of Technical Secondary School to Egypt. In Egypt, it will progress to Secondary School through a Preparatory School (three years) after the graduation from an Elementary School (six years), after that it is divided Ordinal School to proceed to University and Technical School to get a job. There are about 20 numbers of Technical schools in Minia governorate and about 65% of the graduate from a Preparatory School progress to the Technical School, so it will be not difficult to find those who fulfilled condition.

## 2-2-1-19 Project Schedule

For the project schedule, it is planed to examine the scale of the project and actual record on construction schedule, and study the timing of E/N, detail design, tendering and construction period. Further it is planed to compare the schedule based on A and B national loan scheme. (Refer to Appendix 6B-5 Comparison schedule of A and B national loan scheme)

## 2-2-2 Basic Design

## 2-2-2-1 Sakoula Regulator

### (1) Location of Sakoula Regulator

In this basic design, alignment of canal, expropriation of land, construction plan (diversion work, coffering work, and dewatering work), alignment of existing road, and economical effect were examined about Alternative S-1 which had been examined in the feasibility study (construction under dry condition) and Alternative S-5 in the Application (construction inside the canal). As a result of examination, S-5 requested in the Application (construction within the canal) is adopted as shown in Table 2-2-2.1

**Table 2-2-2.1 Comparison of Sakoula Regulator Location**

| Description | | Alternative S-1:(F/S) (construction under dry condition) | | Alternative S-5：(Application) (construction inside the canal) | |
|---|---|---|---|---|---|
| Location | | Agricultural land on right bank | | On centerline of existing regulator | |
| Coffering | | Strut type | | Double steel sheet pile with tie-rod | |
| Attached Bridge | | Total width：12.80m,<br>Length：40.0m | | Total width：12.80m,<br>Length：40.0m | |
| Expropriation | | 12,000m$^2$ | | 0m$^2$ | |
| Temporary Bridge | | 0m | | 100m | |
| Earthwork direct cost 〈million LE〉 | Earthworks for diversion canal | 4.12 | | 0.64 | |
| | Temporary works | 5.09 | | 6.34 | |
| | Demolition works | 0 | | 0.76 | |
| | Retaining wall by sheet pile | 1.40 | | 3.09 | |
| | Revetment by slope pavement | 0.44 | | 0.44 | |
| | Riprap works | 0.92 | | 0.92 | |
| | Regulator body works | 4.13 | | 4.13 | |
| | Building works | 0.64 | | 0.64 | |
| | Attached works | 0.64 | | 0.64 | |
| | Appurtenant works | 3.29 | | 0.84 | |
| | **Subtotal** | **20.67** | | **18.44** | |
| Expropriation cost （million LE） | Expropriation cost | 0.20 | | 0 | |
| | **Subtotal** | **0.20** | | **0** | |
| Project cost （million LE） | Total | **20.87**<br>(1.13) | △ | **18.44**<br>(1.00) | ○ |
| Construction period （month） | Temporary work | 5 | | 5 | |
| | Permanent work | 10 | | 10 | |
| | Removal, coffering | 8 | | 5 | |
| | Total | **23** | | **20** | |
| Alignment of canal | | ・Hydraulic alignment is not smooth. | △ | ・Hydraulic alignment is smooth. | ○ |
| Alignment of road | | ・Road alignment is not straight. | △ | ・Road alignment is straight. | ○ |
| Expropriation of land and compensation for crops | | ・Expropriation of land and compensation are required. | △ | ・Expropriation and compensation are not required. | ○ |
| Effects on existing regulator during construction. | | ・No effect for existing regulator. | ○ | ・Existing structures are affected by vibration. | △ |
| Attached bridge & Temporary bridge | | ・Existing bridge is used for temporary bridge. | ○ | ・Temporary bridge is required. | △ |
| Diversion canal | | ・Diversion canal is not required. | ○ | ・A part of existing regulator is used for diversion. | △ |
| Coffer dam and dewatering during construction | | ・Coffer dam is not need, and dewatering is a little. | ○ | ・Coffer dam is necessary, and dewatering is quite amount.. | △ |
| Economical efficiency | | ・Construction cost is expensive, and the period is long. | △ | ・Construction cost is cheap, and the period is short | ○ |
| Comprehensive evaluation | | △ | | ○ | |

**(2) Cross Section of Flow Area**

As far as design maximum discharge is able to be released to downstream, less flow area of cross section is economical and advantageous. Meanwhile, if flow velocity is too fast, it must be cared about scouring earth canal. The soil forming the canal around Sakoula Regulator comprises from sand with silt to clay, for which allowable velocity is 1.00 to 1.20m/sec (refer to the design criteria of Canal for Land Improvement Project Standard of Japan). The velocity at up/downstream become 0.6 to 0.7m/sec, and the velocity around the regulator shall be designed to be below allowable maximum velocity in order not to cause discontinuity of velocity.

To prevent the sand sediments under gates, the velocity around gates are planed to be 1.5 to 2.0 times more than the velocity at up/downstream (refer to the criteria of Canal for Land Improvement Project Standard of Japan). The velocity at up/downstream is 0.6 to 0.7m/sec, and the total width of regulator is designed as the planned velocity at gate is about 1.2m/sec.

① (Total width of regulator) = (Maximum Design Discharge) ÷ (velocity at gates) ÷ (water depth at gates)

where, Design discharge : 193.64$m^3$/sec

Velocity at gates : 1.15m/sec

Water depth at gates : Max. U.W.L. 32.87m − EL. 27.50m ≒ 5.40m

② (Total width of regulator) = 193.64$m^3$/sec ÷1.15m/sec ÷ 5.40m

= 31.2m ≒ 32.0m

Total width of regulator is defined as 32.0m, which is equated to the designed width in the Feasibility Study for Rehabilitation and Improvement of Delivery Water System on Bahr Yusef Canal.

On the assumption that total width of regulator is 32.0m and gates are fully opened, the water level at upstream of regulator on releasing Design Maximum Discharge is EL. 32.925m which does not exceed the Highest Control Water Level : Max. U.W.L. 33.70m (refer to Figure 2-2-2.1 and Table 2-2-2.2).

**Figure 2-2-2.1 Hydraulic Profile at Design Maximum Discharge**

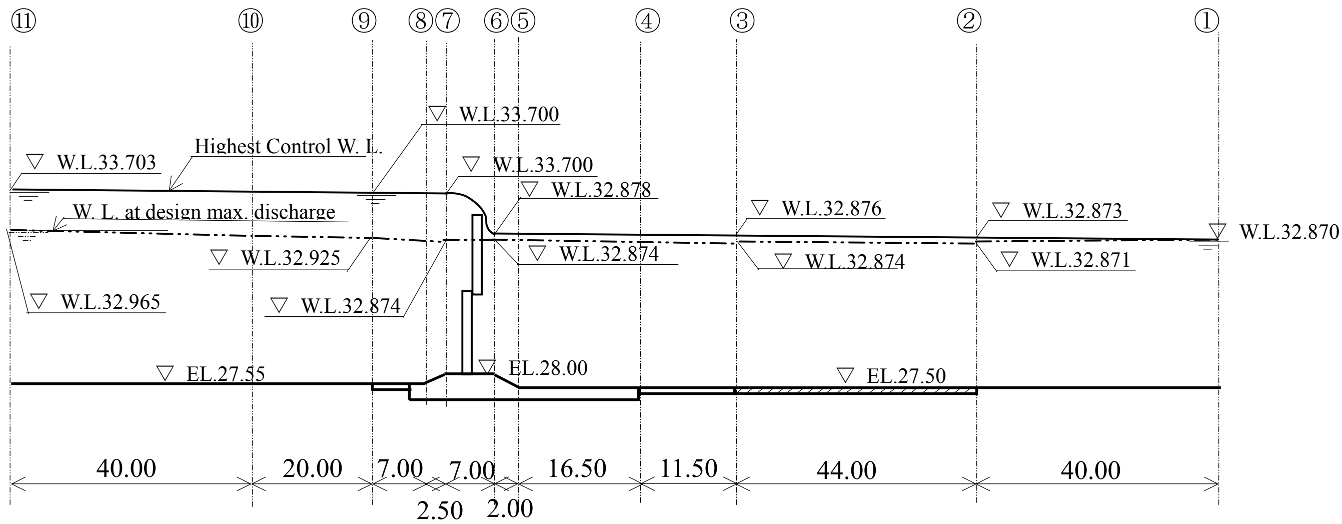


**Table 2-2-2.2 Hydraulic Conditions at Design Maximum Discharge (Sill-up height: 0.45m)**

| Description | Symbol | Unit | Point ① | Point ② | Point ③ | Point ④ | Point ⑤ | Point ⑥ | Point ⑦ | Point ⑧ | Point ⑨ | Point ⑩ | Point ⑪ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Design Max. Discharge | Q | $m^3$/sec | 193 640 | 193 640 | 193 640 | 193.640 | 193.640 | 193 640 | 193.640 | 193.640 | 193.640 | 193.640 | 193 640 |
| Design Highest Control W. L. | Max. W.L. | m | 32.870 | 32.873 | 32.876 | 32.876 | 32.877 | 32.878 | 33 700 | 33 700 | 33 700 | 33 701 | 33 703 |
| Elevation of canal | EL. | m | 27.500 | 27.500 | 27.500 | 27.500 | 27.500 | 28.000 | 28.000 | 27.550 | 27.550 | 27.550 | 27.550 |
| Width of canal | B | m | 40.000 | 38.000 | 38.000 | 32.000 | 32.000 | 32.000 | 32.000 | 32.000 | 38.000 | 38.000 | 40 000 |
| Distance | L | m | 0 000 | 40.000 | 44 000 | 11.500 | 16.500 | 2.000 | 7 000 | 2.500 | 7 000 | 20.000 | 40 000 |
| Water depth | D | m | 5.370 | 5.371 | 5.374 | 5.372 | 5.373 | 4 874 | 4.874 | 5.345 | 5.375 | 5 410 | 5 415 |
| Flow area of cross section | A | $m^2$ | 272.474 | 261.798 | 204.222 | 171.896 | 171.939 | 155.953 | 155.980 | 171.025 | 204.232 | 264 115 | 275.236 |
| Wetted perimeter | P | m | 64 015 | 62.020 | 48.749 | 64.230 | 64.239 | 61.241 | 61.246 | 64.067 | 70.247 | 62.194 | 64.216 |
| Hydraulic mean depth | R | m | 4.256 | 4.221 | 4.189 | 2.676 | 2.677 | 2.547 | 2.547 | 2.669 | 2.907 | 4.247 | 4.286 |
| Velocity | V | m/sec | 0 711 | 0 740 | 0.948 | 1.126 | 1.126 | 1.242 | 1.241 | 1.132 | 0.948 | 0 733 | 0 704 |
| Velocity head | hv | m | 0 026 | 0 028 | 0 046 | 0 065 | 0.065 | 0 079 | 0 079 | 0 065 | 0 046 | 0 027 | 0.025 |
| Coefficient of roughness | n | - | 0 030 | 0 030 | 0.018 | 0 018 | 0 018 | 0 018 | 0 018 | 0.018 | 0 018 | 0 030 | 0 030 |
| Surface slope | I | - | 0 0000659 | 0 0000722 | 0 0000431 | 0 0001107 | 0 0001106 | 0 0001436 | 0.0001436 | 0 0001122 | 0 0000702 | 0.0000703 | 0 0000640 |
| Max. W L. after construction | W.L. | m | 32.870 | 32.871 | 32.874 | 32.872 | 32.873 | 32.874 | 32.874 | 32.895 | 32.925 | 32.960 | 32.965 |
| EL. of energy line | Eng | m | 32.896 | 32.899 | 32.920 | 32.936 | 32.938 | 32.952 | 32.953 | 32.960 | 32.970 | 32.987 | 32.990 |
| Friction head loss | hf | m | 0 000 | 0 003 | 0 003 | 0 000 | 0 002 | 0 000 | 0 001 | 0 000 | 0.001 | 0 001 | 0 003 |
| Head loss by change of cross-section | he | m | 0.000 | 0 000 | 0 018 | 0.000 | 0 000 | 0 014 | 0 000 | 0 007 | 0 010 | 0 000 | 0 000 |
| Head loss by pier | hp | m | 0.000 | 0 000 | 0 000 | 0 016 | 0 000 | 0 000 | 0 000 | 0 000 | 0 000 | 0 016 | 0 000 |
| Check of EL. of energy line | Eng. C | m | 32.896 | 32.896 | 32.899 | 32.920 | 32.936 | 32.938 | 32.952 | 32.953 | 32.960 | 32.970 | 32.987 |

### (3) Elevations of Principal Part of Regulator

① Control Water Level

As a result of the field survey, the controlled water level of Sakoula Regulator is designed as follow.

- Extraordinary High Water Level (upstream) : U.H.H.W.L. 34.30m
- High Water Level (upstream) : U.H.W.L. 34.10m
- Highest Control Water Level (upstream) : Max. U.W.L. 33.70m
- Extraordinary High Water Level (downstream) : D.H.H.W.L. 34.20m
- High Water Level (Downstream) : Max. D.W.L. 32.87m
- Highest Control Water Level (downstream) : Min. D.W.L. 30.28m

② Elevation of Apron

Elevation of canal at Sakoula regulator (77.73 km from the starting point of Bahr Yusef Canal) is EL.27.55m at upstream of the regulator and EL.27.50m at the downstream, in the design profile of the Canal. Accordingly, elevations of apron at up/downstream are decided in conformity with the designed elevation in the design profile of canal.

- Elevation of Apron (upstream) : EL.27.55m
- Elevation of Apron (downstream) : EL. 27.50m

③ Sill Elevation of Gates

Designed elevation of canal at Sakoula Regulator is EL. 27.55m at upstream of the regulator and EL. 27.50 m at the downstream. While, the existing elevation of canal bed is about EL.28.40m.

The designed elevation of canal bed is 0.85m lower than the existing elevation, and if gates sill elevation is designed in accordance with the designed elevation of canal, there should be cause difficulty in complete and safety gate operation due to sedimentation under gates. Therefore, gate sill elevation is designed 0.50m higher than the designed elevation of canal bed.

- Sill elevation of gate : EL. 28.00m

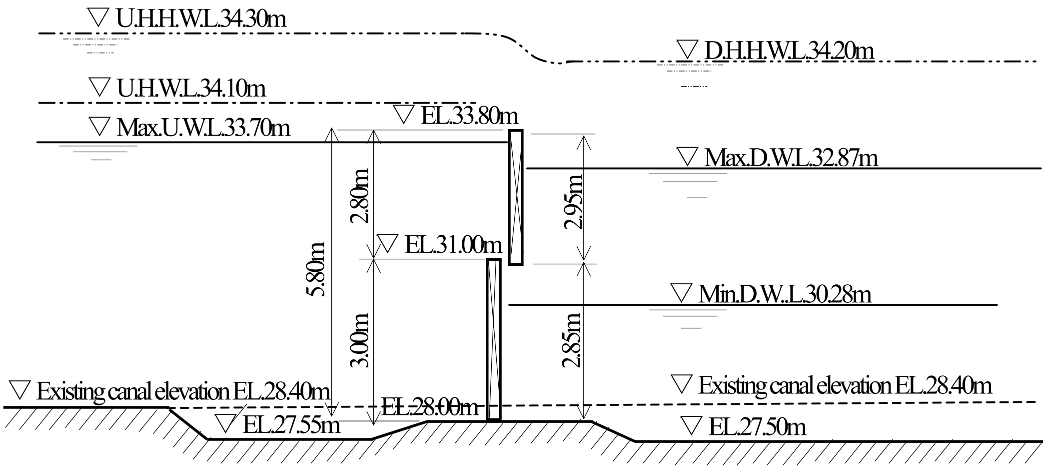
④ Elevation of Gate Crest and Height of Gate

The elevation of gate crest is designed to meet following two requirements.

1) The water level should include Freeboard : 0.10m added to Highest Control Water Level (upstream) : Max. U.W.L. 33.70m
2) Elevation of existing gates crest : EL. 33.70m should be met.

- Elevation of gate crest : = (Highest Control Water Level at upstream) + (freeboard)
  = Max. U.W.L. 33.70m + 0.10m
  = EL. 33.80m
- Height of gate : = (elevation of gate crest) − (gate sill elevation)
  = EL. 33.80m − EL. 28.00m
  = 5.80m

**Figure 2-2-2.2 Gate EL. and Height (1/2)**



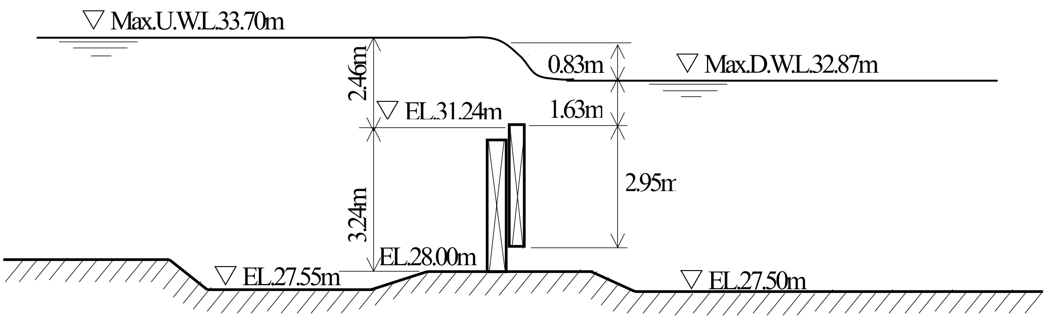

⑤ Elevation of Lower Gate Crest

Elevation of lower gate crest is designed to meet following requirements.

1) Elevation that maximum discharge is able to be released by overflow above upper gate.

To release maximum discharge ($Q_{max.}$ = 193.64m$^3$/sec) by overflow above upper leaf, following overflow depth is required.

**Figure 2-2-2.3 Gate EL. and Height (2/2)**




$h_2$ = 1.63m < 2/3・$h_1$ = 2/3 x 2.46 = 1.64m (perfect overflow)

$$Q_{max.} = C_r \cdot B \cdot H^{3/2}$$

$$C_r = 1.706 \frac{1+1.146 (W/h_1)}{1+1.250 (W/h_1)} \cdots\cdots\cdots\cdots ①$$

where, $2.5 < L/h_1 < 10$

$$C_r = 1.373 \frac{0.984+ (L/h_1)}{0.500+ (L/h_1)} \cdots\cdots\cdots\cdots ②$$

where, $0.3 < L/h_1 < 2.5$

Q ; Discharge (m$^3$/s)

H ; Overflow depth with velocity head (m),

$H = h_1 + h_v$ (velocity head) $= 2.46 + 0.00 = 2.46$m

$C_r$ ; Coefficient of discharge

B ; Width of regulator, B = (8.00 – 2 x 0.75) x 4 = 26.00m

L ; Length of regulator, L = 1.65m

W ; Height of regulator, W = 3.24m

$h_1$ ; Overflow depth, $h_1$ = WL.33.70 – EL.31.24 = 2.46m

*Velocity head ($h_v$) is not considerab

$L/h_1 = 1.65/2.46 = 0.671$,then

$C_r = 1.373 \times (0.984 + 1.65/2.46)/(0.500 + 1.65/2.46) = 1.940$

Q max. = 1.940 x 26.00 x 2.463/2 = 194.62$m^3$/sec ≒ 193.64$m^3$/sec

Elevation that maximum discharge at downstream is able to be released above upper leaf is ranged as below;

Elevation of lower gate crest : EL.31.00m～EL.31.24m

2) Elevation for safety height of gate in structural

To meet allowable deflection and allowable stress, the ratio of gate height to clear gate span, in case of roller gate must be within 1/10. Clear gate span of the regulator is 8.00m, height is required over 0.80m, therefore, the elevation of lower gate crest must be within following range.

・Elevation of lower gate crest：EL.31.00m～EL.32.90m

As a result of above examination, elevation of lower gate crest is designed as follow, in order to release the maximum discharge by overflow release above upper gate.

・Elevation of lower gate crest：EL.31.00m

3) Maximum discharge by overflow release above upper gate

To keep stable water release by overflow above upper gate, discharge flow should be critical overflow. Maximum discharge at critical overflow is designated as follows.

$h_2$ ; Water depth at downstream, $h_2 = 1.63\text{m} < 2/3 \cdot h_1 = 2/3 \times 2.46 = 1.64$m (critical overflow)

H ; Overflow head (m), $H = h_1 + h_v$ (velocity head) $= 2.49 + 0.00 = 2.49$m

W ; Height of regulator, W = 3.21m

$h_1$ ; Overflow water level, $h_1$ = WL.33.70 – EL.31.21 = 2.49m

$L/h_1 = 1.65/2.49 = 0.663$

$C_r = 1.373 \times (0.984 + 1.65/2.49)/(0.500 + 1.65/2.49) = 1.944$

$Q_{max.} = 1.944 \times 26.00 \times 2.49^{3/2} = 198.60 m^3/sec$

Maximum discharge by overflow release above upper gate is computed as 198.60$m^3$/sec.

⑥ Elevation of Gate Sill at hoisting gates up and Elevation of Beam Bottom of the Maintenance Bridge

Elevation of gate sill at hoisting gates up and elevation of beam bottom of the maintenance bridge are designed as the elevation of Extraordinary High Water Level at upstream adding freeboard.

- Extraordinary High Water Level (upstream)： U.H.H.W.L. 34.30m
- Freeboard： $Fb = 0.05\ d + hv + (0.20\sim0.30)$
  $= 0.05 \times 6.75 + 0.902/(2 \times 9.8) + (0.20\sim0.30)$
  $= 0.34 + 0.04 + (0.20\sim0.30)$
  $= 0.58m\sim0.68m$
  To stay on safe side, Fb is defined to 0.70m.
- Elevation of gate sill at hoisting gate up and elevation of beam bottom of the maintenance bridge：
  = U.H.H.W.L. 34.30m + 0.70m
  = EL. 35.00m

⑦ Crest Elevation of Closure Dike and Steel Sheet Pile Retaining Wall at Up/downstream

1) Crest elevation of closure dike

To secure height of shoe (0.05m), height of beam（1.50m）and height of mound for pavement (0.15m) from elevation of beam bottom of the maintenance bridge (EL. 35.00m), crest elevation of enclosing dike is decided as EL. 36.70m.

2) Crest elevation of steel sheet pile retaining wall at up/downstream

Crest elevation of steel sheet pile retaining wall at up/downstream are derived from addition of Ordinary Raising Water Level (High Water Level at upstream: U.H.W.L. 34.10m and Highest Control Water Level: Max. D.W.L. 32.87m) and freeboard of retaining wall (0.60m).

- Crest elevation of steel sheet pile retaining wall at upstream： EL. 34.70m
- Crest elevation of steel sheet pile retaining wall at downstream： EL. 33.50m

**(4) Gate Span**

Plural number of gates are designed to disperse risks. Construction cost of the civil works (only gate pier) and gate facility cost were examined based on the following five alternatives, ① span：16.0m x 2 gates, ② span : 10.7m x 3gates, ③ span : 8.0m x 4 gates, ④ span : 6.4m x 5 gates, and ⑤ span : 4.0m x 8 gates (refer to Table 2-2-2.3).

As a result of economical comparison, ③ span：8.0m x 4 gates becomes the cheapest plan.

In general, if number of gates is fewer, construction cost becomes cheaper. However, shell type gates must be adopted for alternative ① and ② from the respect of the ratio of height and span of gates. The gate facility cost of shell type become more expensive than that of Girder type. Therefore, Alternative ③ span：8.0m x 4 gates, which is the maximum span of Girder type, is adopted.

**Table 2-2-2.3 Comparison of Gate Span**

| | | Alternative ① | Alternative ② | Alternative ③ | Alternative ④ | Alternative ⑤ |
|---|---|---|---|---|---|---|
| Span x height of gates | | 16.0m×5.8m | 10.7m×5.8m | 8.0m×5.8m | 6.4m×5.8m | 4.0m×5.8m |
| Number of gates | | 2 gates | 3 gates | 4 gates | 5 gates | 8 gates |
| Gate type | | Double leaf roller gate (Slide type) | | | | |
| Hoisting device type | | Motor wire rope winch type (1M-2D) | Motor wire rope winch type (1M-2D) | Motor wire rope winch type (1M-2D) | Motor wire rope winch type (1M-2D) | Motor wire rope winch type (1M-2D) |
| Capacity of motor | Upper gate | 5.5kW × 2No. | 2.2kW × 3No. | 1.5kW × 4No. | 1.5kW × 5No. | 1.5kW × 8No. |
| | Lower gate | 11.0kW × 2No. | 7.5kW × 3No. | 5.5kW × 4No. | 3.7kW × 5No. | 1.5kW × 8No. |
| Approximate weight (ton) | Gate leaf | 97.0 | 61.0 | 43.0 | 36.0 | 25.0 |
| | Guide frame | 24.0 | 15.0 | 11.0 | 9.0 | 6.0 |
| | Hoisting device | 41.0 | 26.0 | 18.0 | 16.0 | 11.0 |
| | Subtotal (per one gate) | 162.0 | 102.0 | 72.0 | 61.0 | 42.0 |
| | Total | 324.0 | 306.0 | 288.0 | 305.0 | 336.0 |
| Construction cost (million LE) (From design to installation of gate) | | 26.5 | 25.0 | 23.5 | 25.1 | 27.6 |
| Earthwork Cost (million LE) | Number of piers | 3 units | 4 units | 5 units | 6 units | 9 units |
| | Width of pier | 2.4m | 2.2m | 2.0m | 2.0m | 2.0m |
| | Construction cost | 1.9 | 2.3 | 2.6 | 3.1 | 4.7 |
| Total construction cost (million LE), (Raito) | | 28.4 (1.086) | 27.3 (1.046) | 26.1 (1.000) | 28.2 (1.080) | 32.3 (1.237) |
| Order | | 4th | 2nd | 1st | 3rd | 5th |

**(5) Design of Regulator Body**

① Regulator Body Type

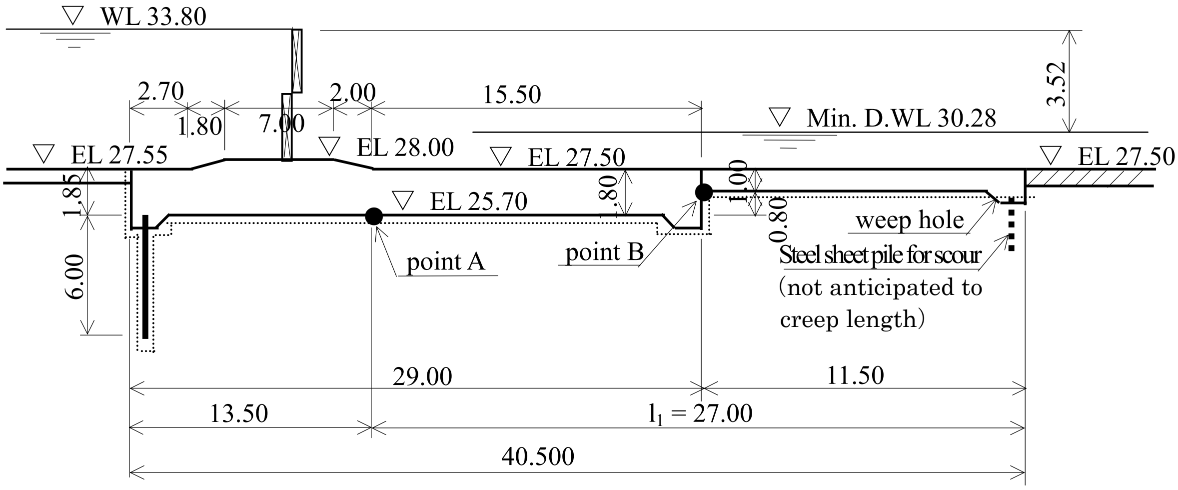
The Type of Regulator body is divided into Fixed type (constructed on bedrock) and Floating type (constructed on sediment and gravels depending on permeability of foundation). The type of Sakoula Regulator is designed on Floating type because geology at the regulator area is sand with silt.

② Design of Middle and Downstream Apron

1) Profile for design

Design of middle and downstream apron is made, based on following profile and in accordance with the design criteria of Headwork for Land Improvement Project Standard of Japan.

**Figure 2-2-2.4 Profile of Apron**




2) Length of middle and downstream of apron

Length of middle and downstream apron is designed from Blugh's formula (refer to the design criteria of Headwork for Land Improvement Project Standard of Japan, P 217).

$$l_1 = 0.9 \cdot C \sqrt{D_1} = 0.9 \times 15 \times \sqrt{3.52} = 25.33\text{m}$$

where, $l_1$ : Length of middle and downstream apron (m)

$D_1$ : Maximum head difference between up/downstream (m)

$D_1$ = EL 33.80m – Min. D.W.L. 30.28m = 3.52m

C : Coefficient of Blugh, (fine sand) C = 15

Length of middle and downstream apron is $l_1$ = 25.33m on calculation, $l_1$ = 27.00m is adopted as design length, considering the scale of the Regulator.

**Table 2-2-2.4 Coefficient for Bligh's Method and Lane's Method**

| Foundation | Blugh's C | Lane's weighted creep ratio C' | Adoption |
|---|---|---|---|
| Very fine sand and clay | 18 | 8.5 | |
| Fine sand | 15 | 7.0 | ○ |
| Medium sand | — | 6.0 | |
| Coarse sand | 12 | 5.0 | |
| Gravel | — | 4.0 | |
| Coarse gravel | — | 3.5 | |
| Gravel with sand | 9 | — | |
| Gravel with cobble stone and gravel | — | 3.0 | |
| Rocks with cobble stone and gravel | — | 2.5 | |
| Rocks with gravel and sand | 4～6 | — | |
| Soft clay | — | 3.0 | |
| Medium Clay | — | 2.0 | |
| Heavy Clay | — | 1.8 | |
| Hard Clay | — | 1.6 | |

3) Creep Length

a) Examination method

To prevent piping, a safe creep length along the foundation of regulator and retaining wall must be ensured. The creep length must be designed from the larger value calculated by ① Bligh's method and ② Lane's one (refer to the criteria of Headwork for Land Improvement Project Standard of Japan).

The purpose of steel sheet pile at the downstream apron end is prevention for scour, and weep holes shall be provided in the cutoff at the downstream apron end to reduce uplift pressure. Therefore, those steel sheet pile are not included for creep length design.

b) Examination of creep length

i) Bligh's method

$S \geqq C \cdot \Delta H = 15 \times 3.52 = 52.80\text{m} \leqq 55.15\text{m}$

where, S : Creep length measured along the foundation of regulator (m)

$S = 1.85 + 40.50 + 6.00 \times 2 + 0.80 = 55.15\text{m}$

C : Coefficient of Bligh, (fine sand) C = 15

⊿H : Maximum head difference at up/downstream, ⊿H = 3.52m

ii) Lane's method

$L \geqq C' \cdot \Delta H = 7.0 \times 3.52 = 24.64\text{m} \leqq 28.15\text{m}$

where, L : Weighted creep length (m), $L = \Sigma\, l_v + 1/3 \cdot \Sigma\, l_h$

$L = (1.85 + 6.00 \times 2 + 0.80) + 1/3 \times 40.50 = 28.15\text{m}$

C' : Lane's weighted creep coefficient, (fine sand) C' = 7.0

⊿H : Maximum head difference at up/downstream, ⊿H = 3.52m

As above, assumed design section in preceding profile is meeting to the computation result from both formulas and keeps safety for piping.

4) Thickness of middle and downstream apron

Thickness of middle and downstream apron is designed from a formula about the balance of uplift pressure （refer to the design criteria of Headwork for Land Improvement Project Standard of Japan）.

$t \geqq 4/3 \cdot (\Delta H - H_f) / (\gamma - 1)$

where, t : Thickness of apron at certain point（m）

⊿H : Maximum head difference at up/downstream, ⊿H = 3.52m

$H_f$ : Head loss of infiltrated flow at certain point （m）

$\gamma$ : Unit weight of reinforced concrete, $\gamma = 2.35$ $t_f/m^3$

4/3 : Safety factor

a) Middle apron : examination at point A

- Total creep length :

  $L = 1.85 + 40.50 + 6.00 \times 2 + 0.80 = 55.15m$
- Creep length to point A :

  $L_A = 1.85 + 13.50 + 6.00 \times 2 = 27.35m$
- Head loss of infiltrated flow to A point :

  $H_f = L_A/L \times \triangle H = 27.35/55.15 \times 3.52 = 1.75m$
- Thickness of middle apron :

  $t \geqq 4/3 \cdot (\triangle H - H_f) / (\gamma - 1)$

  $= 4/3 \times (3.52 - 1.75) / (2.35 - 1) = 1.75m$

Consequently, the thickness of middle apron at point A shall be 1.80m.

b) Downstream apron : examination at point B

- Creep length to point B :

  $L_B = 1.85 + 29.00 + 6.00 \times 2 = 42.85m$
- Head loss of infiltrated flow to point B :

  $H_f = L_A/L \times \triangle H = 42.85/55.15 \times 3.52 = 2.73m$
- Thickness of downstream apron :

  $t \geqq 4/3 \cdot (\triangle H - H_f) / (\gamma - 1)$

  $= 4/3 \times (3.52 - 2.73) / (2.35 - 1) = 0.78m$

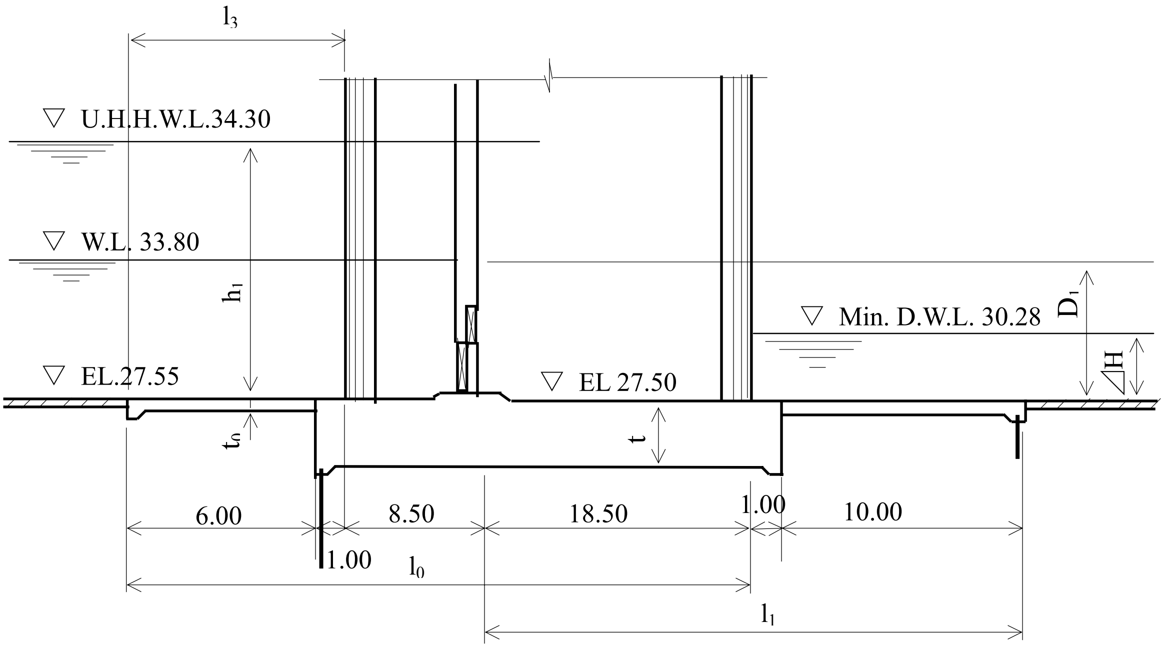
Thereafter, the thickness of downstream apron at point B shall be the minimum value, t = 1.00m.

③ Design of Upstream Apron

1) Length of upstream apron

Length of upstream apron shall be calculated in accordance with the description in P-216 in the design criteria of Headwork for Land Improvement Project Standard of Japan.

**Figure 2-2-2.5 Profile of upstream apron**




$l_o$ in above figure should be extended to over twice of the upstream water depth at designed high water level ($h_1$) and also $l_3$ should be over 3 times of the pier thickness, in order to operate as board crest weir and obtain the effect of roughness.

$l_o \geqq 2 \times h_1$ $h_1$ ; Design high water depth (＝ 6.75m)

$l_3 \geqq 3 \times B$ B ; Thickness of pier (＝ 2.00 m)

Length of upstream apron assumed to be 6.00m.

$l_o = 6.00 + 1.00 + 8.50 = 15.50 \text{ m} \geqq 2 \times 6.75 = 13.50 \text{ m}$ OK

$l_3 = 6.00 + 1.00 = 7.00 \text{ m} \geqq 3 \times 2.00 = 6.00 \text{ m}$ OK

Thereby, Length of upstream apron is designed on 6.00m.

2) Thickness of upstream apron

Thickness of upstream apron is defined as 1/2 to 2/3 of maximum thickness of downstream apron according to the design criteria of Headwork for Land Improvement Project Standard of Japan. Maximum thickness of downstream apron is 1.80m from said examination, and thickness of upstream should be ranged from 0.90 to

1.20m, therefore it is designed as 0.9m that is minimum thickness.

**(6) Gate Pier**

The structure of gate pier shall be designed considering smooth water release, safety for loads and gate operation.

① Height and Thickness of Gate Pier

1) Height of gate pier

Height of gate pier is designed from following formula in the design criteria of Headwork for Land Improvement Project Standard of Japan.

Crest elevation of gate pier = Extraordinary high water level + Freeboard① + Gate height + Freeboard② + Top plate thickness

where, Extraordinary high water level ;
Extraordinary high water level at upstream
U.H.H.W.L. 34.30m

Freeboard ① ; Freeboard of Bahr Yusef Canal, 0.70m

Gate height ; Gate height of lower leaf, 3.00m

Freeboard ② ; Current gate height (generally, the height is assumed that overflow depth : 3.1m+0.10 m )+ 1.00m, therefore, Freeboard ② is designed on 4.20m.

Top slab thickness ; 1.30m

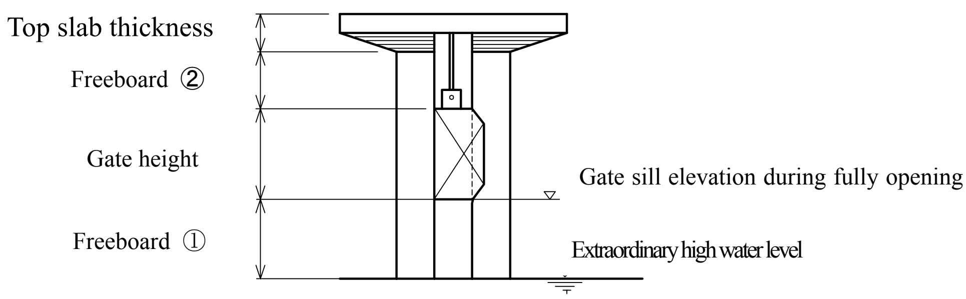



**Figure 2-2-2.6 Explanatory profile for crest elevation of pier**

Crest elevation of gate pier is calculated as follow.

U.H.H.W.L. 34.30m + 0.70m + 3.00m + 4.20m + 1.30m = EL. 43.50m

And crest elevation of gate pier is designed EL. 43.50m.

2) Thickness of gate pier

Thickness of gate pier is designed from following empirical equation in the criteria of Headwork for Land Improvement Project Standard of Japan.

$$t_p = 0.12\ (D_p + 0.2 \cdot B_t)\ \pm\ 0.25$$

where, $t_p$ ; Thickness of gate pier（m）

$D_p$ ; Height of gate pier（m）

$B_t$ ; Gate span（m）

$D_p$ = EL. 43.50m – EL. 27.50m = 16.00m、$B_t$ = 8.00m

$t_p = 0.12\ (16.00 + 0.2 \times 8.00)\ \pm\ 0.25 = 1.86\text{m} \sim 2.36\text{m}$

As above, thickness of gate pier is designed on 2.00m, and pier thickness of both ends is designed on 1.40m subtracting the thickness of gate groove.

3) Length of gate pier

Considering gate pier height, gate groove, disposition of hoisting device and width of attached bridge etc., length of gate pier is designed as 28.00m.

4) Space for hoisting device

To secure the space for installation of operating facility and works for check and repair etc., the hoisting device space is decided as 8.00m toward the canal direction, 40.8m toward regulator axial direction.

② Examination of Upper Part Structure of Gate Pier

Upper part structure of gate pier shall be designed taking account not only stability for external forces but working space for maintenance and check works. Items for maintenance and check at upper part of gate pier are tabulated below.

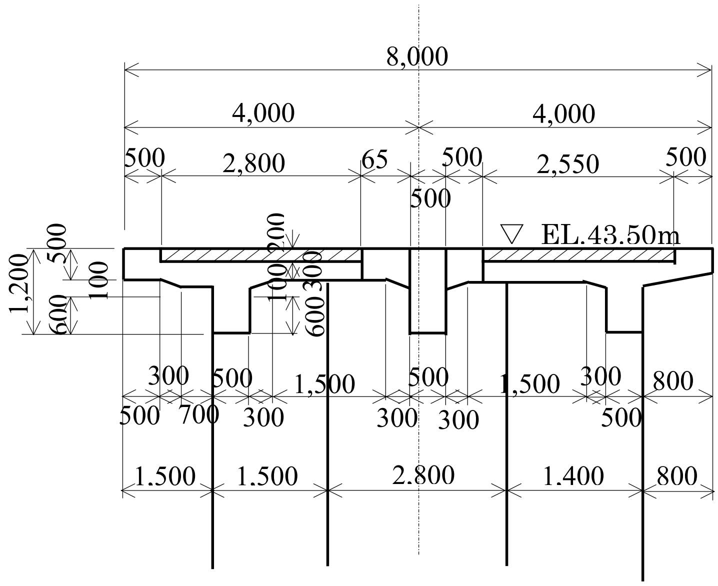
**Table 2-2-2.5 Item for Maintenance and Check at Middle and Upper Part of Gate Pier**

| Item | Contents | Attention Point |
|---|---|---|
| Rubber | Check, repair and replacement | ・Working space for adjustment, installation and disinstallation of rubber is ensured. |
| Roller | Lubrication, check, repair, and replacement | ・Easy to access to oil fill opening.<br>・Working space for check disinstallation of roller is ensured. |
| Operating facility | Lubrication, check and disinstallation | ・Easy to access to machinery room.<br>・Exit for equipment for check and repair is ensured and it is easy to carry out.<br>・Enough clearance around facility is ensured.<br>（Minimum clearance for worker' passage is 0.6m from the wall）.<br>・Enough clearance between hoist facility and ceiling is ensured （Minimum clearance is 1.5m）. |
| Painting | Check | — |

Workability of above maintenance works is depended on structure of upper part of gate pier.

Thickness of gate pier is $t_p$ = 2.00m, space for maintenance is endured enough, therefore, double pier structure is adopted.

**Figure 2-2-2.7 Profile of Upper Gate Pier of Sakoula Regulator**




**(7) Design Criteria for Structural Analysis of Regulator Body**

Structural analysis of regulator body is designed from allowable stress method. The design parameters for the calculation are shown in below.

① Allowable Stresses of Construction Material

The allowable stresses of construction materials, that are agreed upon and decided between IIS and the Basic Study Team, are summarized as follow.

1) Allowable stress of reinforced concrete

**Table 2-2-2.6 Allowable Stress of Reinforced Concrete**

| Allowable stress (kgf/cm$^2$) | | 28 days concrete strength (kgf/cm$^2$) | |
|---|---|---|---|
| | | 210 | 240 |
| Bending compressive stress | | 80 | 90 |
| Shear stress | Beams | 6 | 6.5 |
| | Slabs | 8 | 8.5 |
| Bond stress | Round bar | 6 | 7 |
| | Deformed bar | 8 | 9 |
| Bearing stress | | 55 | 60 |
| Structures to be applied | | Slabs, walls beams, columns and piers of main structures | Slabs of bridges |

Note: The modular ratio (modulus of elasticity of steel/modulus of elasticity of concrete) of 10 will be used for the design of the project facilities.

Source: Reinforced concrete design handbook established 2002 by Dr. Shaker El Behairy.

2) Allowable stress of plain concrete

**Table 2-2-2.7 Allowable Stress of Plain Concrete**

| Allowable stress ($kgf/cm^2$) | 28 days Concrete Strength ($kgf/cm^2$) | |
|---|---|---|
| | 120 | 180 |
| Bending compressive stress | 40 | 65 |
| Bending tensile stress | - | - |
| Bearing stress | 30 | 50 |
| Structures to be applied | Lane concrete | Plain concrete |

Source: Reinforced concrete design handbook established 2002 by Dr. Shaker El Behairy.

3) Allowable tensile stress of steel

- Deformed bar (Steel 52) $\sigma_{sa}$ = 1,800 $kgf/cm^2$
- Round bar (Steel 37) $\sigma_{sa}$ = 1,400 $kgf/cm^2$
- Structural steel (SS400) $\sigma_{sa}$ = 1,200 $kgf/cm^2$
- Steel sheet pile (SY295) $\sigma_{sa}$ = 1,400 $kgf/cm^2$

② Loads

1) Dead Load

Unit weight of each materials are as follows,

- Reinforced concrete $\gamma_c$ = 2.50 $tf/m^3$
- Plain concrete $\gamma_c$ = 2.35 $tf/m^3$
- Water $\gamma_w$ = 1.0 $tf/m^3$
- Dry soil $\gamma_e$ = 1.6 $tf/m^3$
- Wet soil $\gamma_e$ = 1.8 $tf/m^3$
- Saturated soil $\gamma_e$ = 2.0 $tf/m^3$
- Steel $\gamma_s$ = 7.85 $tf/m^3$

Source: the criteria of Headwork for Land Improvement Project Standard of Japan

2) Live loads

Structures on which heavy wheels pass over the side of the structure should be designed for the wheel loads, and other structures should be considered a crowd load of 300 $kg/m^2$.

3) Seismic loads

According to "The design of reinforced concrete COLUMNS (according to new Egyptian code concept 1990 established by structural design engineer Khalil Ibrahim Waked)", seismic load is as follow.

$$K_h = Z \cdot I \cdot K \cdot C \cdot S$$

where, $K_h$ : Seismic horizontal acceleration

Z : Correction coefficient for area, area 3: Z = 0.30

I : Correction coefficient for importance factor, bridge: I = 1.25

K : Correction coefficient for structure,

(Shear wall) or (Core), K = 1.333

C : Correction coefficient for natural vibration, that is calculated from following equation.

$C = 1/(15 \cdot \sqrt{T}) = 1/(15 \times \sqrt{0.395}) = 0.106$

T : Natural vibration of each foundation

$T = 0.09 \cdot H/\sqrt{b} = 0.09 \times 17.0 / \sqrt{15.0} = 0.395$

S : Correction coefficient for foundation,

normal soil: S = 1.15

$K_h = 0.30 \times 1.25 \times 0.106 \times 1.15 = 0.06$

Therefore, the seismic loads are not considered for the design of the project facilities. Especially, concrete structures under the ground like box culverts, it is not considered seismic loads. Liquefaction caused by earthquakes does not apply in the study area, because the moisture content of soil in the area is well below the danger point of 85%.

**(8) Foundation of Regulator Structure**

Elevation of existing apron sill is EL. 26.5m, which is about 1m below from the top of Nile deposit (sand), the basis elevation of structures after the rehabilitation is assumed to be EL. 26.0m. The two boring holes, which are started from EL. 35.0m, are drilled and also standard penetration test was conducted in the holes. At boring No.1, N-value between EL. 26.0m to EL. 25.0m is 30 and under EL. 25.0m is over 50. N-value at boring No.2 is over 50 through whole hole. Geology of both boring points is sand, which is not interbedded soft layers like clay, and it is suitable for foundation of structure. Therefore, spread foundation is adopted in this rehabilitation.

Bearing capacity of foundation, which N-value is 30 and 50, in case of spread foundation, is shown in Table 2-2-2.8. Required foundation reaction after rehabilitation is about $10tf/m^2$ ($0.10N/mm^2$), the foundation is evaluated that the foundation has enough bearing capacity.

**Table 2-2-2.8 Calculation of Allowable Bearing Capacity**

| Item | Foundation | | Remarks |
|---|---|---|---|
| | N-value is 50 (most part) | N-value is 30 (around BH No.1) | |
| Average N-value<br>Internal friction $\phi$<br>Coefficient of Form $\alpha$<br>Cohesion C $(tf/m^2)$<br>Coefficient of bearing capacity Nc | 50<br>42<br>1.3<br>0.0<br>95.7 | 30<br>36<br>1.3<br>0.0<br>42.2 | $\phi = \sqrt{15N}+15$ (the criteria of Headwork for Land Improvement Project Standard of Japan)<br>$\alpha$ ; square |
| Coefficient of Form $\beta$<br>Unit weight of soil $\gamma_1$ $(tf/m^3)$<br>Smallest width of foundation B(m)<br>Coefficient of bearing capacity Nr | 0.4<br>0.9<br>10.0<br>114.0 | 0.4<br>0.9<br>10.0<br>30.5 | $\beta$ ; square |
| Unit weight of soil $\gamma_2$ $(tf/m^3)$<br>Penetration Depth Df (m)<br>Coefficient of bearing capacity Nq | 0.8<br>0.0<br>83.2 | 0.8<br>0.0<br>29.0 | Df ; Penetration depth is neglected in the calculation, on the safety side. |
| Ultimate bearing capacity $(tf/m^2)$ | 410.4 | 109.8 | |
| Allowable bearing capacity $(tf/m^2)$ | 136.8 | 36.6 | |

Note) Terzagi's Formula is applied for calculating the bearing capacity

$$qa = 1/3 \times qu$$

$$qu = \alpha \cdot c \cdot Nc + \beta \cdot \gamma_1 \cdot B \cdot Nr + \gamma_2 \cdot Df \cdot Nq$$

where,
- qa : Allowable bearing capacity $(tf/m^2)$
- qu ; Ultimate bearing capacity $(tf/m^2)$
- C ; Cohesion of foundation $(tf/m^2)$
- $\gamma_1$ ; Unit soil weight under foundation $(tf/m^3)$ (Submerged unit weight is adopted for soils below water table)
- $\gamma_2$ ; Unit soil weight above foundation $(tf/m^3)$ (Submerged unit weight is adopted for soils below water table)
- $\alpha, \beta$ ; Coefficient of form
- Nc, Nr, Nq ; Coefficient of bearing capacity (Function of internal friction $\phi$)
- Df ; Depth of foundation from the lowest ground level near the foundation (m)
- B ; Smallest width of foundation(m)

**(9) Stability of Gate Pier**

① Design Conditions

1) Examination case on stability of pier

Following 6 cases will be examined on stability of pier.

Case ① ; Stability on flood time, gate-open and normal loads in flow direction.

Case ② ; Stability on low water, gate-closed, normal load, 0.30m-overflow above gates and 0.70m-sediment before gates in flow direction.

Case ③ ; Stability on no flow, gate-opened and normal load in flow direction.

Case ④ ; Stability on flood time, gate-opened and normal load in regulator axial direction.

Case ⑤ ; Stability on low water, gate-closed normal load, 0.30m-overflow above gates and 0.70m-sediment before gates in regulator axial direction.

Case ⑥ ; Stability on no flow, gate-opened and normal load in regulator axial direction.

2) Load conditions

The combination of loads in above cases is accordance with the load combination about the stability calculation for gate pier which is shown in Table 2-2-2.9. Seismic load is not considered.

**Table 2-2-2.9 Combination of Loads by Examination Case**

| Loads item \ Calculation case | | | Case ① | Case ② | Case ③ | Case ④ | Case ⑤ | Case ⑥ |
|---|---|---|---|---|---|---|---|---|
| Condition | Water level condition | | Flood | Low water | No flow | Flood | Low water | No flow |
| | Gate condition | | Open | Close | Open | Open | Close | Open |
| | Normal / quake | | Normal | Normal | Normal | Normal | Normal | Normal |
| | Direction | | Flow | Flow | Flow | Traverse | Traverse | Traverse |
| Vertical | $W_p$ | Pier weight | ○ | ○ | ○ | ○ | ○ | ○ |
| | Wt | Platform | ○ | ○ | ○ | ○ | ○ | ○ |
| | Wg | Gate | ○ | ○ | ○ | ○ | ○ | ○ |
| | Wm | Hoist | ○ | ○ | ○ | ○ | ○ | ○ |
| | Wb | Bridge | ○ | ○ | ○ | ○ | ○ | ○ |
| | Ww | Water | ○ | ○ | | ○ | ○ | |
| | U | Uplift | ○ | ○ | | ○ | ○ | |
| | We | Earth | | | | ○ | ○ | ○ |
| Horizontal load | $P_{w1}$ | Wind（Pier） | ○ | ○ | ○ | ○ | ○ | ○ |
| | $P_{w2}$ | Wind（Gate） | ○ | | ○ | | | |
| | $P_{w3}$ | Wind（bridge） | | ○ | | | | |
| | $P_{w4}$ | Wind（Platform） | ○ | ○ | ○ | | | |
| | $P_g$ | Static hydraulic pressure（Gate） | | ○ | | | | |
| | $P_p$ | Static hydraulic pressure（Pier） | ○ | ○ | | | | |
| | $P_{m1}$ | Dynamic hydraulic pressure（Gate） | | ○ | | | | |
| | $P_{m2}$ | Dynamic hydraulic pressure（Pier） | | ○ | | | | |
| | $P_{e1}$ | Sediment pressure | | ○ | | | | |
| | $P_{e2}$ | Earth pressure | | | | ○ | ○ | ○ |

3) Safety conditions

Safety conditions for examination of overturn, sliding and base load of gate pier are tabulated below.

| Examination | Allowable value on normal time |
|---|---|
| ① Overturn | e ≦ B/6 |
| ② Sliding | Fs ≧ 1.5 |
| ③ Base Load | Q ≦ Qa ($tf/m^2$) |

4) Result of stability calculation

Result of stability calculation for gate pier is shown in Table 2-2-2.10.

**Table 2-2-2.10 Result of Stability Calculation for Gate Pier**

| Item / Gate pier | Case | Normal/quake | Water level | Direction | Vertical force | Resistant moment | Horizontal force | turning moment | Sliding | | | Turning | | | Foundation capacity | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ΣV | ΣV・x | ΣH | ΣH・y | Safety Factor | | Required | Eccentric distance | | B/6 | Reaction ; $Q_1$ | Reaction ; $Q_2$ | Bearing capacity |
| | | | | | (tf) | (tf・m) | (tf) | (tf・m) | Fs | | Fsa | e (m) | | (m) | ($tf/m^2$) | ($tf/m^2$) | ($tf/m^2$) |
| Middle pier | ① | N | F | F | 3,745.69 | 53,037.51 | 43.84 | 717.65 | 47.04 | > | 1.5 | 0.86 | < | 4.92 | 6.80 | 9.69 | 36.60 |
| | ② | N | L | F | 3,781.46 | 51,483.10 | 285.64 | 1,819.06 | 7.30 | > | 1.5 | 1.13 | < | 4.92 | 6.41 | 10.24 | 36.60 |
| | ③ | N | N | F | 5,499.98 | 77,255.55 | 50.73 | 728.50 | 61.40 | > | 1.5 | 0.89 | < | 4.92 | 9.92 | 15.40 | 36.60 |
| | ④ | N | F | A | 3,745.69 | 31,485.46 | 1,101.50 | 4,535.13 | 1.87 | > | 1.5 | 0.61 | < | 2.57 | 5.77 | 9.36 | 36.60 |
| | ⑤ | N | L | A | 3,781.46 | 31,786.14 | 1,101.37 | 4,534.58 | 1.89 | > | 1.5 | 0.60 | < | 2.57 | 6.38 | 10.27 | 36.60 |
| | ⑥ | N | N | A | 5,499.98 | 46,231.65 | 1,101.37 | 4,534.58 | 2.83 | > | 1.5 | 0.17 | < | 2.57 | 11.30 | 12.91 | 36.60 |
| Side pier | ① | N | F | F | 2,289.87 | 32,035.80 | 46.01 | 713.72 | 27.39 | > | 1.5 | 0.90 | < | 4.92 | 6.34 | 9.18 | 36.60 |
| | ② | N | L | F | 2,299.12 | 30,739.77 | 196.16 | 1,337.53 | 6.45 | > | 1.5 | 1.28 | < | 4.92 | 5.76 | 9.82 | 36.60 |
| | ③ | N | N | F | 3,389.12 | 47,131.46 | 50.06 | 720.09 | 38.35 | > | 1.5 | 1.39 | < | 4.92 | 5.35 | 9.57 | 36.60 |
| | ④ | N | F | A | 2,289.87 | 11,449.35 | 0 | 0 | ∞ | > | 1.5 | 0.00 | < | 1.67 | 5.04 | 5.04 | 36.60 |
| | ⑤ | N | L | A | 2,299.12 | 11,495.60 | 0 | 0 | ∞ | > | 1.5 | 0.00 | < | 1.67 | 5.06 | 5.06 | 36.60 |
| | ⑥ | N | N | A | 3,389.12 | 16,945.60 | 0 | 0 | ∞ | > | 1.5 | 0.00 | < | 1.67 | 7.46 | 7.46 | 36.60 |

Abbrev. N: normal, Q: quake in “Normal/quake”

F: at flood, L: at low water level, N: at no flow in “Water level”

F: flow direction, A: regulator axial direction in “Direction”

**(10) Structural Analysis of Gate Pier**

In general, pier has enough length for loads to flow direction, structural analysis for gate pier is not necessary in flow direction. Reinforcement is arranged minimum reinforcement content, which is designed from examination in regulator axial direction, as additional bar. The most demanding load condition, which is gate-open and normal loads, is adopted for examination in regulator axial direction.

① Loads

Pier weight which is worked from bottom slab to upper part of pier, hoist weight, reaction of attached bridge and earth pressure are considered as load. And gate is assumed to be opened on the safe side.

② Stress calculation

Structure of gate pier is calculated on assumption that pier is a cantilever beam which is fixed by bottom slab. Axial load is excluded in the calculation of reinforcement, and examination at the end pier which is worked the most severe earth pressure is adopted. The result of the calculation is shown in below.

| | | | |
|---|---|---|---|
| 1) Section size ; | | 2) Arrangement plan ; | |
| Width : | b = 100.0 cm | Diameter : | D 25 mm |
| Section thickness : | h = 140.0 cm | Pitch : | @ 200 mm |
| Effective thickness : | d = 130.0 cm | Reinforcement content : | As = 23.87 $cm^2$ |
| 3) Bending moment ; | M = 47.52 $t_f \cdot m$ | | |
| 4) Sheering force ; | S = 43.81 $t_f$ | | |

5) Stress intensity ;

Concrete compressive stress : $\sigma_c$ = 68 $kg_f/cm^2$ < $\sigma_{ca}$ = 210 $kg_f/cm^2$

Tensile stress of reinforce : $\sigma_s$ = 1,750 $kg_f/cm^2$ < $\sigma_{sa}$ = 1,800 $kg_f/cm^2$

Sheering stress : $\tau$ = 3.5 $kg_f/cm^2$ < $\tau$ = 9.0 $kg_f/cm^2$

## 2-2-2-2 Protection for Bed and Retaining Wall

**(1) Rip-rap**

To prevent scour at downstream of regulator, the energy of high speed released water should be dissipated by friction of rip-rap sequentially, velocity at downstream of apron shall be equal to the velocity of continued canal.

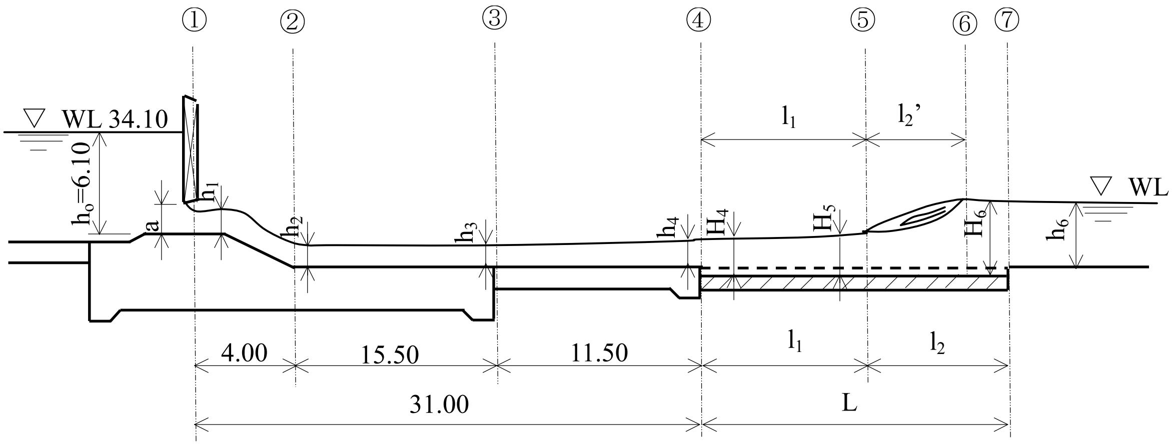
① Case A : Normal Loads and Underflow Release

1) Underflow release

Released water at Sakoula Regulator forms exposed jet flow when the canal depth at downstream is lower than the sub-critical flow side conjugate depth against the supercritical flow. When the head difference at up/downstream is the maximum before open gates, Sakoula Regulator faces the worst case.

This examination of rip-rap length is considered above hydraulic condition, and the length of exposed jet flow and hydraulic jump is also examined at gate opening each 0.50m from 0.50 to 6.10m.

**Figure 2-2-2.8 Examination of Rip-rap**




2) Result

The result of examination at underflow release is tabulated below.

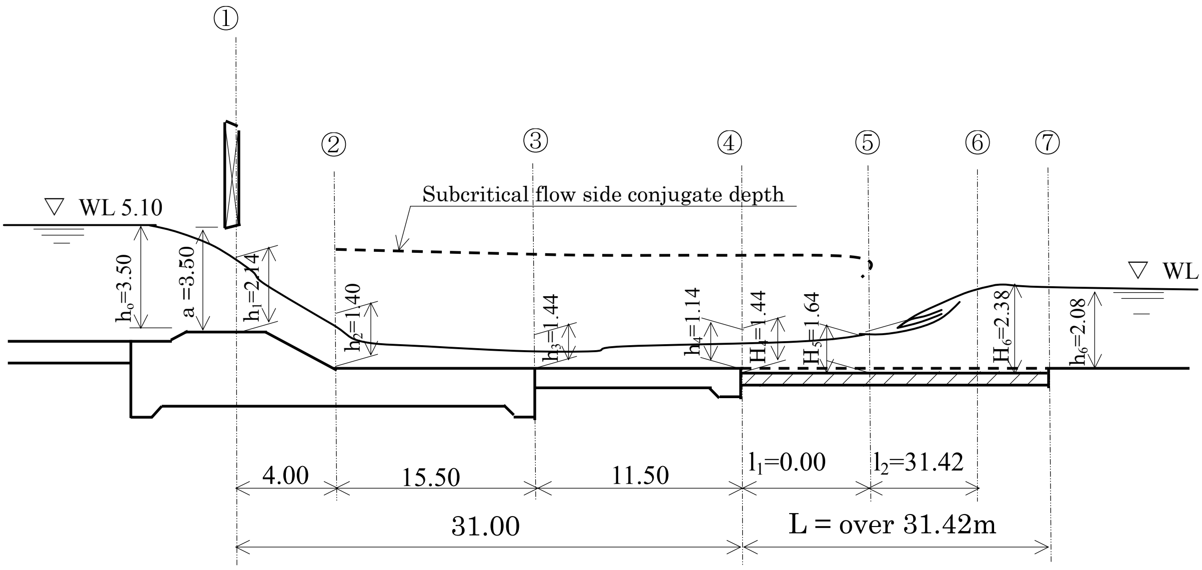
**Table 2-2-2.11 Result of Examination of Underflow Release**

| Opening height a (m) | Discharge Q ($m^3/s$) | Downstream Apron: Water depth $h_4$ (m) | Downstream Apron: Velocity $V_4$ (m/s) | Downstream Apron: Conjugate depth $H_{j5}$ (m) | Upstream end of rip-rap: Water depth $H_5$ (m) | Upstream end of rip-rap: Velocity $V_5$ (m/s) | Upstream end of rip-rap: Conjugate depth $H_{j5}$ (m) | Water depth of downstream $H_6$ (m/s) | Flow Condition | Length of hydraulic jump $l_2$ (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.50 | 26.00 | 0.311 | 7.96 | 1.857 | 0.611 | 4.05 | 1.158 | < 1.943 | Undular jump | 6.95 |
| 1.00 | 50.62 | 0.490 | 9.33 | 2.716 | 0.790 | 5.79 | 1.963 | < 2.733 | Perfect jump | 11.78 |
| 1.50 | 73.79 | 0.648 | 9.74 | 3.232 | 0.948 | 6.66 | 2.492 | < 3.333 | Perfect jump | 14.95 |
| 2.00 | 95.45 | 0.782 | 9.89 | 3.580 | 1.082 | 7.15 | 2.862 | < 3.822 | Perfect jump | 17.17 |
| 2.50 | 115.53 | 0.893 | 9.94 | 3.821 | 1.193 | 7.44 | - | < 4.232 | Perfect jump | 22.92 |
| 3.00 | 133.93 | 0.980 | 9.97 | 3.997 | 1.280 | 7.64 | - | < 4.580 | Perfect jump | 23.98 |
| 3.50 | 150.57 | 1.044 | 9.97 | 4.112 | 1.344 | 7.75 | - | < 4.877 | Perfect jump | 24.67 |
| 4.00 | 165.33 | 6.162 | 1.76 | - | 6.462 | 1.76 | - | < 5.128 | Subcritical flow | - |
| 4.50 | 178.08 | 6.179 | 1.78 | - | 6.479 | 1.78 | - | < 5.336 | Subcritical flow | - |
| 5.00 | 188.65 | 2.793 | 8.44 | 5.129 | 5.503 | 0.72 | - | < 5.203 | Undular jump | 30.77 |
| 5.50 | 196.87 | 2.900 | 8.49 | 5.237 | 5.630 | 0.73 | - | < 5.330 | Undular jump | 31.42 |
| 6.00 | 202.49 | 3.040 | 8.33 | 5.212 | 5.716 | 0.74 | - | < 5.416 | Undular jump | 31.27 |
| 6.10 | 203.27 | 3.060 | 8.30 | 5.208 | 5.727 | 0.74 | - | < 5.427 | Undular jump | 31.25 |

Accordingly, the required rip-rap length at underflow release is over L = 31.42m.

**Figure 2-2-2.9 Hydraulic Conditions at Underflow Release**

(Gate opening : a = 5.50m)




② Case B : Full Gate Opening

If all gates are full opened, the water level at downstream become higher than the critical depth at regulator crest, submerged overflow is generated. The length of rip-rap is designed 10 to 15 times of water depth under gates at the maximum discharge.

$L_r = L - l_a$

$L = (10 \sim 15) \times H = (10 \sim 15) \times 6.30 = 63.00 \sim 94.50$ m

where, $L_r$ : Length of rip-rap (m)

$L$ : Total length including length of apron ($l_a$) and length of rip-rap ($L_r$) (m)

$l_a$ : Length of downstream apron, $l_a$ = 29.30m

$H$ : Water depth under gates at maximum discharge (m)

H = U.H.H.W.L. 34.30m－EL. 28.00m = 6.30m

As above, the length of rip-rap is decided as follow.

$L_r = (63.00 \sim 94.50) - 29.30 = 33.70 \sim 65.20$m.

③ Case C : Empirical Equation

Length of rip-rap shall be examined from Bligh's equation.

$L_r = L - l_a$

$L = 0.67 \cdot C \cdot \sqrt{\Delta H \cdot q \cdot f}$

where, $L_r$ : Length of rip-rap (m)

$L$ : Total length including length of apron ($l_a$) and length of rip-rap ($L_r$) (m)

$l_a$ : Length of downstream apron, $l_a$ = 29.30m

$\triangle H$ : Maximum head difference at up/downstream (m)

$\triangle H$ = W.L. 34.10m－Min. D.W.L. 30.28m = 3.82m

q : Discharge per unit width at maximum discharge ($m^3$/sec/m)

q = 193.64 / (8.00 x 4) = 6.05 $m^3$/sec/m

$$L = 0.67 \times 15 \times \sqrt{3.82 \times 6.05 \times 1.5} = 72.47m$$

Length of rip-rap is decided on $L_r$ = 72.47－29.30 = 43.17m.

④ Decision of Length of Rip-rap

The result of each examination is shown in below.

| Case | Required length of rip-rap | Designed length of rip-rap |
|---|---|---|
| Case A : Underflow release | Over 31.42m | 44.00m |
| Case B : Full gate open | 33.70～65.20m | |
| Case C : Bligh's equation | 43.17m | |

Therefore, length of rip-rap is designed 44.00m.

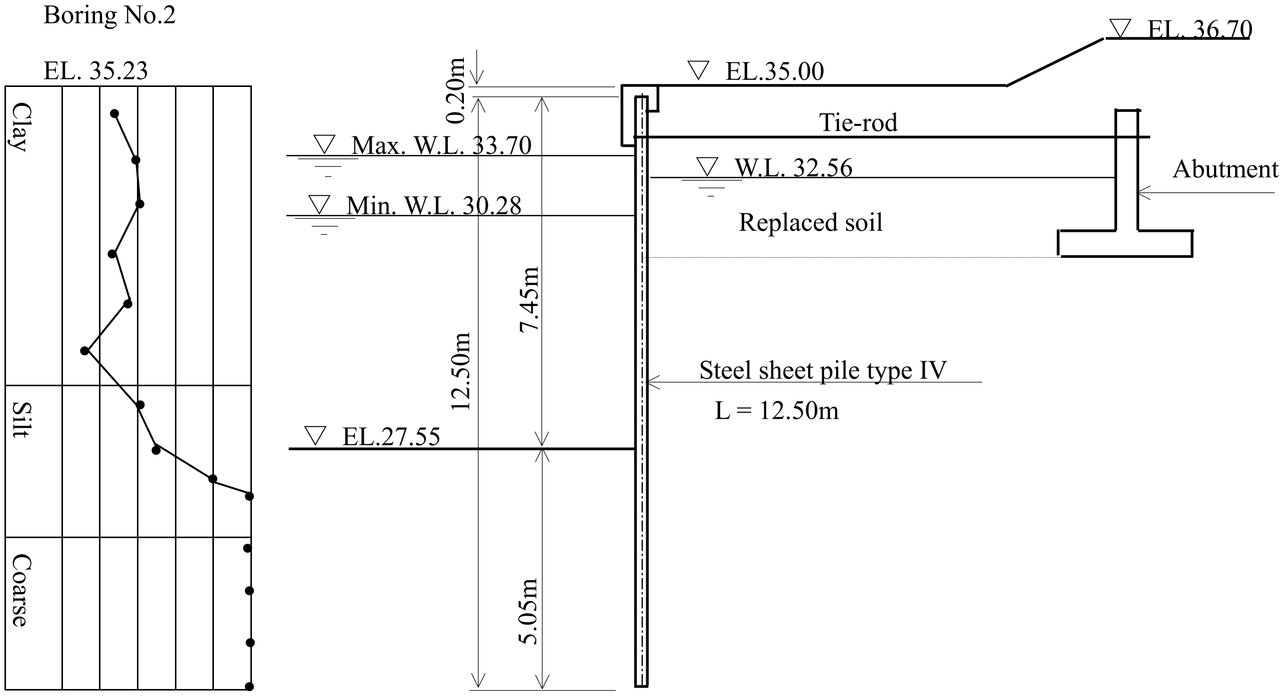
**(2) Retaining Wall**

① Retaining of Steel Sheet Pile

The steel sheet pile retaining wall is decided on tie-rod type taking account of shape of structures, condition of foundation and workability etc. External force to steel sheet pile is earth pressure, residual water pressure and overburden pressure of back of sheet pile.

The length of required penetration depth designed from the examination of balance of "Overturn moment" and "Residence moment" and examination of boiling is 5.03m and 4.00m respectively. IV type is adopted from the examination of the stress and the deflection, so the designed steel sheet pile is IV type, L = 12.50m.

**Figure 2-2-2.10 Examination of Steel Sheet Pile**




② Rip-rap (slop protection)

The slope of Bahr Yusef Canal is planned to 1:1.5, however, the slope around the regulator is designed 1:2.0 considering flow disturbance by the Regulator.

And, the required weight of rip-rap for slope (weight per a stone) is decided considering wave height, slope and masonry type. Hadson's equation is adopted to calculation (refer to Agricultural civil engineering handbook, p-430).

$$W = (\gamma_r \cdot H^3) / [K_d \{(\gamma_r / \gamma_w) - 1\}^3 \cot\alpha]$$

where, W : Weight of rip-rap on slope, (t)

$\gamma_r$ : Unit weight of riprap, $\gamma_r = 1.8tf/m^3$

$\gamma_w$ : Unit weight of water, $\gamma_w = 1.0tf/m^3$

$\alpha$ : Slope gradient, $\alpha = 1 : 2.0 = 26° 34'$

H : Wave height before slope, H = 0.50m

Kd : A constant dependent of material, Kd = 4.0

$$W = (2.65 \times 0.50^3) / [4.0 \times \{(1.8/1.0) - 1\}^3 \times \cot 26° 34']$$
$$= 0.331 / 4.096$$
$$= 0.081t = 81kg$$

Calibrating the weight into size of round boulder, the volume becomes 31,200cm$^3$ by applying a unit weight of 2.6 and diameter becomes 19.53cm by assuming sphere-shape.

$V = 4.189\ R^3$

where, V：Volume of stone (t)

R：Mean radius (cm)

Therefore, $R = (31{,}200 / 4.189)^{1/3} = 19.53$ cm. And mean diameter of stone for rip-rap is designed on 40cm（diameter : 30～50cm）.

③ Closure Dike

During construction, required water is released by existing gate on left bank side, canal flow is delivered and existing one shall be closed after completion of new regulator. The shore protection for the closure dike shall be examined with following three types.

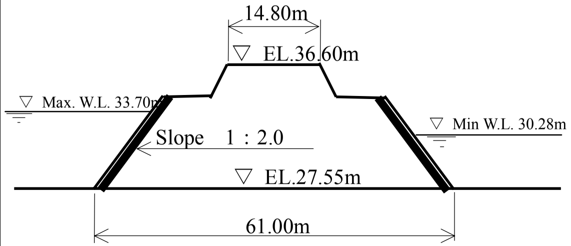
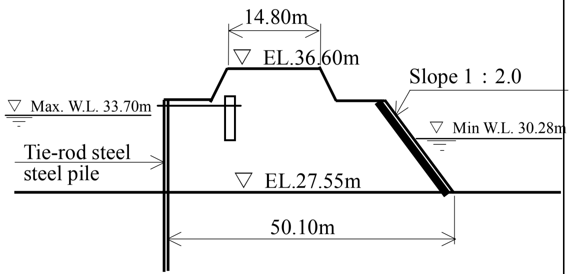
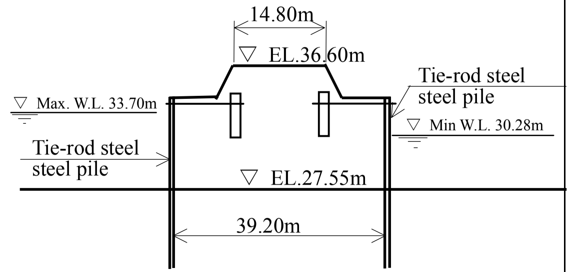
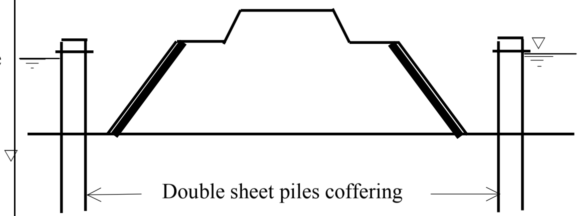
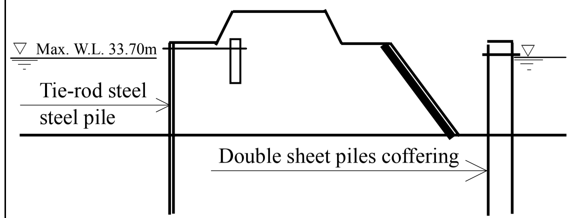
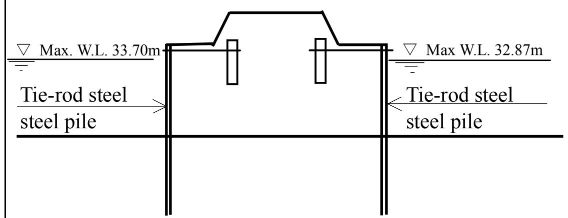
1) Rip-rap on both side of dike：Both slopes of dike are covered with rip-rap. The construction area for the dike shall be closed with double sheet pile coffering. A part of the existing regulator shall be demolished before backfilling and installation of rip-rap.

2) Steel sheet pile and rip-rap : Upstream shore of the dike shall be protected by the tie-rod type steel sheet piles which are used on temporary embankment. Downstream shore of the dike shall be protected by rip-rap. Canal flow is diverged after closing by tie-rod steel sheet piles and backfilling at upstream, and by double steel sheet pile at downstream. A part of the existing regulator shall be demolished before mentioned works.

3) Steel sheet pile on both side of dike：The both side of dike shall be protected by the tie-rod steel sheet piles which are used on the temporary embankment. Installation of sheet pile and diversion are carried out after banking for sheet piles works, and then abutment and tie-rod are installed. And existing regulator shall be demolished and backfill is executed.

As a result of the examination, the steel sheet pile on both side of dike, which is no need the coffer dam, are selected taking economic, construction period, workability and environmental impact as shown in Table 2-2-2.12.

**Table 2-2-2.12 Alternative Plan for Closure Dike Protection**

| Description | Plan 1: Riprap on Both Sides of Dike | Plan 2: Steel Sheet Pile on Upstream of Dike, Riprap on Downstream | Plan 3: Steel Sheet Piles on Both Sides of Dike |
|---|---|---|---|
| Structure |  |  |  |
| Temporary closure work |  |  |  |
| Direct construction cost | 8.8 million L.E. | 8.0 million L.E. | 6.0 million L.E. |
| Work period | 9.0 months | 7.5 months | 6.0 months |
| Safety and Workability | - Due to the height of riprap is 7.15m, it is unstable structurally.<br>- Double sheet piles are required for the construction of both sides. | - Due to the height of riprap at downstream is 6.00m, it is unstable structurally.<br>- Double sheet pile is required at downstream for banking work of closure dike. | - Tie-rod steel sheet pile has been used for long time.<br>- Tie-rod steel pile for temporary closure is reused, and double sheet piles are not need. |
| Evaluation | × | △ | ◎ |

### 2-2-2-3 Gate Section

**(1) Gate Type**

The overflow above upper gate type shall be selected due to able delicate water level and discharge control. In the overflow gate type, slide type double leaf roller gate is adopted due to release design maximum discharge of 193.64$m^3$/sec by overflow release.

**(2) Hoisting Device for Gates**

① Power unit

With regard to power unit of gate hoisting device, following prescript is in the hydraulic Gate and Penstock Standard of Japan.

Article 34 Gates have to be equipped power unit which is able to operate gates quickly, absolutely and easily at any time. The power unit should be electric in principle.

Also, there are following descriptions in the "Standard for Dam and Weir Equipment, 3-1-6 Power unit for operation machine".

1) Gates have to be equipped power unit that is able to open and close gates absolutely.
2) The power unit should be electric in principle.
3) Power unit for gate operation have to fulfill required output, torque that is suited to purpose of gates and time rating etc.

Meanwhile, buck-up power unit is defined in the "Gate and Penstock Standard of Japan".

Article 35: Gates that are need to operate for water release at flood, have to be equipped buck-up power unit for gate operation. Buck-up power unit have to be able to operate gates quickly, absolutely and easily when main power unit would be gone down.

And, there are following descriptions in the "Standard for Dam and Weir Equipment, 3-1-7 Buck-up power unit for operation machine".

1) Gates have to be equipped buck-up power unit in principle.
2) Buck-up power unit must have the capacity and structure that is able to operate gates quickly, absolutely and easily when main power unit would have troubles.
3) Buck-up power unit must be adopted the most suitable type considering importance of gate, condition of installation and maintenance system.

Based on these descriptions, power unit for hoisting device is employed low cost public electric power. Diesel generator is installed for buck-up power unit. Hand hoisting device is planned in preparation for accidents of electric system, however diesel generator is not suitable for long gate operation, therefore it is for water level adjustment at emergency and for fine adjustment at maintenance.

**(3) Design Specification of Gates**

Design specification of gates is as follow.

**Table 2-2-2.13 Design Specifications of Gates of Sakoula Regulator**

| Type | | Steel double leaf roller gate |
|---|---|---|
| Number of gate | | 4 gates |
| Clear span | | 8.00m |
| Gate height | | Upper leaf：2.80m + Lower leaf：3.00m<br>Total height：5.80m |
| Design water level | Front | U.H.W.L. 34.10m |
| | Rear | EL. 28.00m |
| Operation water level | Front | U.H.W.L. 34.10m |
| | Rear | EL. 28.00m |
| Control water level | Front | Max. U.W.L. 33.70m |
| | Rear | Min. D.W.L. 30.28m |
| Gate sill | | EL. 28.00m |
| Lifting height | | EL. 35.00m – EL. 28.00m = 7.00m |
| Water seal method | | Three way, rubber seal |
| Hoisting type | | Electric powered wire rope winding type （1M-2D） |
| Operation speed | | over 0.3m/min. |
| Control type | | Local and remote control |

## 2-2-2-4 Maintenance Bridge

**(1) Design Condition**

① Width of Maintenance Bridge

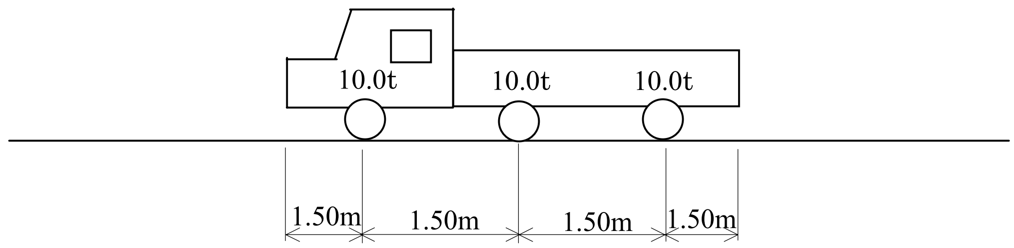
The width of the bridge is as follows,

| | | | |
|---|---|---|---|
| For vehicles： | 3.0m x 2 lines | = | 6.0m |
| For shoulder： | 2.0m x 2 | = | 4.0m |
| For side-walk： | 1.0m x 2 | = | 2.0m |
| For guardrail： | 0.4m x 2 | = | 0.8m |
| | Total width： | | 12.8m |

② Live Loads on the Bridge

Thanks to the discussion with ISS, the live load of maintenance bridge is decided on 60 ton is the standard load for a main local road, according to " Egyptian Code for Loading in Construction of Building, Roadway Bridge and Railway Bridge ". Above live load condition is shown in below.

**Figure 2-2-2.11 Live load condition at maintenance bridge**



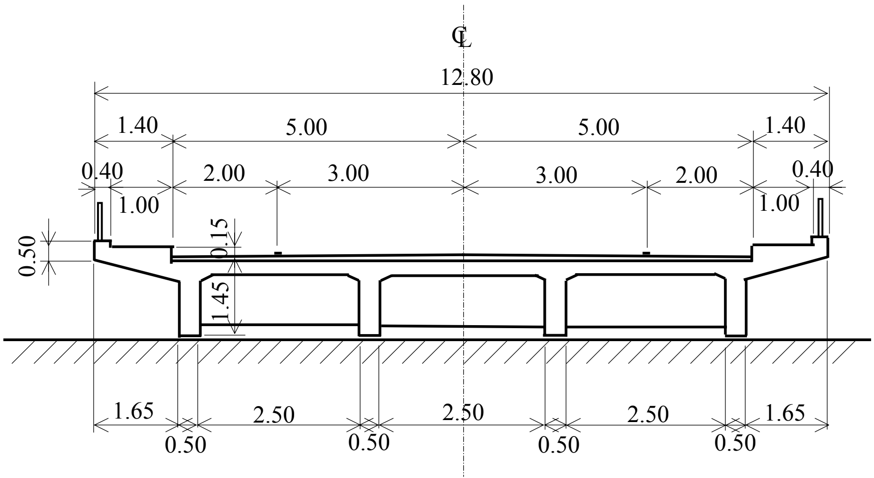

**(2) Maintenance Bridge Type**

The dimension of the maintenance bridge is span: 10.0m x width: 12.8m x 4 spans. The type of beams shall be adopted reinforced concrete T-beam which is time-proven in Japan

**(3) Standard Cross-section of Maintenance Bridge**

Standard cross-section of the maintenance bridge is decided as follow.

**Figure 2-2-2.12 Standard Cross-Section of Maintenance Bridge**




## 2-2-2-5 Control House

**(1) Design Condition**

① Component of Control House

The component of control house and space are designed as below.

**Table 2-2-2.14 Component and Space of Control House**

| Structure | Space |
|---|---|
| 1) Remote operation room | 6.0m x 6.0m (approx.) |
| 2) Emergency generator | 6.0m x 3.0m (approx.) |
| 3) Stock room | 5.0m x 4.0m (approx.) |
| 4) Kitchen and bathroom | 2.0m x 2.0m (approx.) |

**(2) Structure of Control House**

The control house is designed to one-stored, RC piers and block wall structure, which has been adopted for a long time. Cast-in reinforced concrete pile (diameter: 800mm x length: 7.50m) is employed for foundation works by reason that the foundation of the control house is Nile deposit (clay) which N-value is 7 to 21.

The structure of the control house is indicated in Basic Design Drawing DWG-8 and 9.

## 2-2-2-6 Control Panel

**(1) Remote control panel**

The configuration of remote control panel is shown in below.

**Table 2-2-2.15 Configuration of Remote Control Panel**

| Item | Specification | Remarks |
|---|---|---|
| 1) Upper gate operation button | Button for up, stop and down operation | For No.1～No.4 gate |
| 2) Lower gate operation button | Button for up, stop and down operation | For No.1～No.4 gate |
| 3) Buzzer stop button | | |
| 4) Lump test button | | |
| 5) Upper gate opening indicator | Digital display (unit：cm) | For No.1～No.4 gate |
| 6) Upper gate opening indicator | Analog display (unit：50 cm) | For No.1～No.4 gate |
| 7) Lower gate opening indicator | Digital display (unit：cm) | For No.1～No.4 gate |
| 8) Lower gate opening indicator | Analog display (unit：50 cm) | For No.1～No.4 gate |
| 9) Upstream water level gauge | Digital display (unit：cm) | |
| 10) Downstream water level gauge | Digital display (unit：cm) | |
| 11) Release discharge meter | Digital display (unit：$m^3$/sec) | Total of No.1～4 gate |
| 12) Accumulative release discharge meter | Digital display (unit：$m^3$/sec) | |
| 13) Recorder | For water level, gate opening & discharge | |
| 14) Emergency stop button | | |
| 15) Local telecommunication | | |

**(2) Local Control Panel**

If four local control panels are packed one cabinet, it would become oversize. Panels for No1 and No.2 are installed to one cabinet, and No.3 and No.4 are to another. The configuration of local control panel is shown in below;

**Table 2-2-2.16 Configuration of Local Control Panel**

| Item | Specification | Remarks |
|---|---|---|
| 1) Upper gate operation button | Button for up, stop and down operation | For No.1～No.4 gate |
| 2) Lower gate operation button | Button for up, stop and down operation | For No.1～No.4 gate |
| 3) Buzzer stop button | | |
| 4) Lump test button | | |
| 5) Upper gate opening indicator | Digital display (unit：cm) | For No.1～No.4 gate |
| 6) Upper gate opening indicator | Analog display (unit：50 cm) | For No.1～No.4 gate |
| 7) Lower gate opening indicator | Digital display (unit：cm) | For No.1～No.4 gate |
| 8) Lower gate opening indicator | Analog display (unit：50 cm) | For No.1～No.4 gate |
| 9) Upstream water level gauge | Analog display (unit：50 cm) | |
| 10) Downstream water level gauge | Analog display (unit：50 cm) | |
| 11) Voltage indicator | Analog display (unit：50 V) | |
| 12) Ampere meter | Analog display (unit：5 A) | For No.1～No.4 gate |
| 13) Operation location selection button | Choice between Local operation and Remote operation | |
| 14) Operation mode button | Choice between Normal and Emergency | |
| 15) Emergency stop button | | |
| 16) Reset button | | |
| 17) Local telecommunication | | |

## 2-2-2-7 Specification and Quantity of Miscellaneous Equipments

The specification and quantity of emergency generator and its engine are as follow;

**Table 2-2-2.17 Specification of Emergency Generator**

| Item | Specification & quantity | Remarks |
|---|---|---|
| 1) Type | Indoor Soundproof Type | |
| 2) No. of generator | 1 unit | |
| 3) Output rating | 65 kVA | |
| 4) No. of Phase | 3-phase, 4-wire system | |
| 5) Voltage | 380V/220V, 50Hz | |
| 6) Rated Speed | 1,500rpm | |
| 7) Power Factor | 0.8 (Lagging) | |
| 8) Voltage Regulation | within ± 1.5% | |
| 9) Dimensions | 1,300H x 2,630W x 1,000D | |