CHAPTER V NO.7 PUMPING STATION AND DELIVERY PRESSURED PIPELINES

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5.1 Location of No. 7 Pumping Station

5.1.1 Topography

The location of the pumping station was decided in consideration of topography and route the conveyance canal, designed water surface, economical feasibility, environmental impacts and field survey of the site. The main considerations for selection of the pumping station are shown below:

- To minimize the length of pipeline that require a high construction cost for reducing the project cost.
- To select the place with a comparatively large acreage as the site for the pumping station and related facilities such as sand settling basin, sub-station, residential houses for O/M, etc.
- To select the flat place, less impact of drifting sand dune and natural vegetation which may indicate stable environmental condition.
- To select the place with suitable ground surface elevation for smooth connection with upstream conveyance canal.
- To select the place with high accessibility to existing highway for easy maintenance

Based on the considerations mentioned above, results of field survey and comparative study of alternatives, the final selection of the site for pumping station was decided as indicated below.

- Location: 30° 59' 29" N, 33° 19' 43" E
- Elevation: approximately EL.13.4 m
- Station: KM 108.855 (BP. + 22.355 km)

The reasons of finally selecting No.7 pumping station site were as follows;

- Required area for the site of No.7 pumping station including sand settling basin was 15 hectares (width : 300 m × length : 500 m). There was a comparatively large acreage around the point of KM 108.855 (BP. + 22.355km).
- In order to minimize the length of pipeline, end point with the ground elevation of approx. 92 meters from the beginning point which elevation should be almost 13.4 m in consideration of the pumping house elevation.
- The pump house should be kept approx. 50 m from the drifting sand dune.
- The length of the pumping station to national highway was approx. 5.0 km.

5.1.2 Hydraulic Conditions of Pumping Station

Major purposes of water supply to the project area are irrigation with seasonal fluctuation and constant industrial supply. According to the revised project development plan, water demand projection of Stage I and Stage II can be summarized as follows ;

Table 5.1-1 Water Demand Projection

Month	Stage I Irrigation	Stage I Industry	Stage I Total	Stage II Irrigation	Stage II Industry	Stage II Total	Grand Total
Jan.	10.74	2.96	13.70	6.32	2.82	9.14	22.84
Feb.	12.69	2.96	15.65	7.46	2.82	10.28	25.93
Mar.	14.40	2.96	17.36	8.47	2.82	11.29	28.65
Apr.	12.42	2.96	15.38	7.30	2.82	10.12	25.50
May	11.95	2.96	14.91	7.03	2.82	9.85	24.76
Jun.	20.00	2.96	22.96	11.76	2.82	14.58	37.54
Jul.	**29.52**	**2.96**	**32.48**	**17.36**	**2.82**	**20.18**	**52.66**
Aug.	24.63	2.96	27.59	14.49	2.82	17.31	44.90
Sep.	12.42	2.96	15.38	7.30	2.82	10.12	25.50
Oct.	5.61	2.96	8.57	3.30	2.82	6.12	14.69
Nov.	5.13	2.96	8.09	3.02	2.82	5.84	13.93
Dec.	8.79	2.96	11.75	5.17	2.82	7.99	19.74
Average	**14.02**	**2.96**	**16.98**	**8.25**	**2.82**	**11.07**	**28.05**

Hydraulic conditions in the case of 3 units operation for Stage I and additional 2 units operation for Stage II are preliminary described as below :

Table 5.1-2 Design Water Level and Discharge of Pumping Station (7 units case)

Hydraulic Condition	Unit	After Completion of Stage I	After Completion of Stage II	
			Stage I Pumps	Stage II Pumps
No. of pump operation unit	Unit	3	3	2
No. of standby unit	Unit	1	1	1
Average discharge per one unit	cu.m/sec	10.827	10.827	10.827
Suction water level -High suction water level -Design suction water level -Low suction water level	m	 9.90 9.90 8.80	 10.70 9.90 8.80	
Discharge water level -Design discharge water level -Low discharge water level	m	 92.90 92.50	 92.90 92.50	 92.90 92.60
Lifting Head -Design static lifting head -Design total lifting head	m	 83.00 99.60 (= 100.0)	 83.00 99.60 (= 100.0)	 83.00 99.60 (= 100.0)

5.1.3 Flow Chart of Pump Design

Process of basic design of pump equipment as well as pumping station shall be followed the manners indicated Figure 5.1-1.

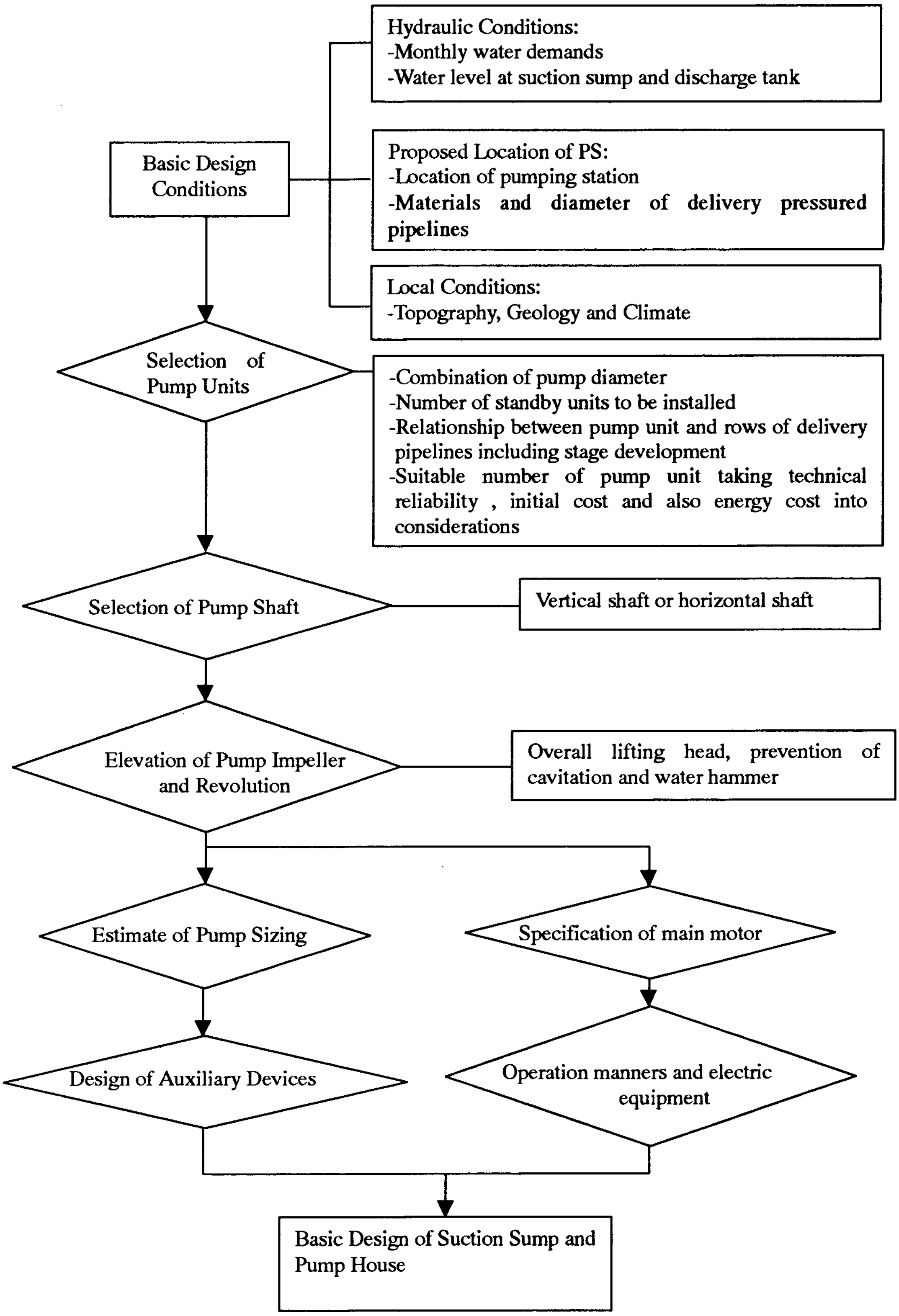


Figure 5.1-1 Flow Chart of Pumping Station Designing

5.2 Optimum Numbers of Pump Units

5.2.1 Technical Assessment

(1) Concepts of study on the optimum numbers of pump unit

Pump design practices in the Egyptian country (Mechanical and Electrical Department : MED) for the purpose of irrigation water supply are the oriented supply system, alternative operation of pump units, availability of spare parts for respective pump units. Standby unit of pump is basically one unit by each 4 units of operating pump plants. Exceeding 5 units (up to 8 units) of operating pump plants, one additional standby unit of pump shall be provided.

(2) Considerable alternatives of the pump units

Considerable alternatives of pump units in accordance with MED practices above mentioned can be tabulated as following table.

Table 5.2-1 Pump Unit Alternatives

Description	Case-1	Case-2	Case-3	Case-4	Case-5	Case-6	Case-7
1.Number of pump unit							
1.1 Stage I							
-Operating No.	3	3	4	5	5	6	6
-Standby No.	1	1	1	2	2	2	2
-Subtotal	4	4	5	7	7	8	8
1.2 Stage II							
-Operating No.	1	2	2	2	3	3	4
-Standby No.	0	1	1	0	0	1	1
-Sub-total	1	3	3	2	3	4	5
1.3 Total units							
-Operating	4	5	6	7	8	9	10
-Standby	1	2	2	2	2	3	3
-Total	5	7	8	9	10	12	13
2.Design discharge							
2.1 Unit discharge per unit (cu.m/sec/unit)	13.165	10.827	8.777	7.523	6.583	5.852	5.414
2.2 Total discharge (cu.m/sec)							
-Completion of stage I	39.495	32.481	35.108	37.615	32.915	35.112	32.484
(percentage to the plan)	(121.6)	(100.0)	(108.1)	(115.8)	(101.3)	(108.1)	(100.0)
-Completion of stage II	52.660	54.135	52.662	52.661	52.664	52.668	54.140
(percentage to the plan)	(100.0)	(102.8)	(100.0)	(100.0)	(100.0)	(100.0)	(102.8)

Note : The figures in parenthesis indicate percentage to the proposed design (peak) discharge.

(3) Technical comparison

Major technical points to be discussed for selecting suitable number of pumping plans are as follows:

a) To control pump operation smoothly for oriented supply system taking seasonal fluctuation of water requirement into account.
b) To satisfy spare part exchangeability of each pump unit
c) To keep well balance water supply between Stage I and Stage II development.
d) To consider technical reliability of whole pumping systems.
e) To select most economical alternatives taking into consideration of initial investment cost, pumping plant efficiency and energy cost.

Preliminary comparison of each alternatives from technical view point can be summarized as follows :

Table 5.2-2 Technical comparison

Key parameter	Case-1	Case-2	Case-3	Case-4	Case-5	Case-6	Case-7
1.Smooth operation for Seasonal fluctuation	2.0	2.0	2.3	1.7	2.3	2.3	2.0
2.Exchangeability of spare parts	2.0	2.0	2.0	2.0	2.0	2.0	2.0
3.Balanced water supply for stage I and stage II	1.0	3.0	2.0	1.5	3.0	2.0	3.0
4.Technical reliability of the systems	2.0	2.0	2.0	2.0	2.0	2.0	2.0
5.Overall technical justification	**7.0**	**9.0**	**7.3**	**7.2**	**9.3**	**8.3**	**9.0**
6.Order	**7**	**2**	**4**	**6**	**1**	**4**	**2**

Note : The figures in the table are "3" for suitable, "2" for moderate and "1" for inadequate.

Evaluation of criteria for the item 1 are done based on the below point considering ratio of minimum water demand (November) and the peak month (July) of that values, such as 25% for Stage I, 29% for Stage II and 26% for overall completion stage as indicated in the Table 5.2-1. Results of evaluation are tabulated as follows:

Table 5.2-3 Smooth operation factor for seasonal fluctuation

Key parameter	Case-1	Case-2	Case-3	Case-4	Case-5	Case-6	Case-7
1. Stage I	2	2	3	1	1	2	2
2. Stage II	1	2	2	2	3	3	2
3. Overall	3	2	2	2	3	2	2
4. Average	2.0	2.0	2.3	1.7	2.3	2.3	2.0

Balance of water supply between Stage I and Stage II can be evaluated from Table 5.2-1

Average figures of Stage I and II	Point
100.0 – 102.0	3.0
102.1 – 105.0	2.0
105.1 – 110.0	1.5
over 110.1	1.0

5.2.2 Economical Assessment

Estimated cost of civil construction works include representatively cost of excavation and reinforcement concrete. The former cost includes excavation , backfill and cost of replacing soil and cost of excavation which is about 8 LE per cu.m. The latter cost is about 500 LE per cu.m. as the cost of reinforcement concrete including concrete, reinforcement bar, concrete forms and temporary works. Average cost of pump house (building) is about 2,800 LE per sq.m. All cost for civil works and building referred to unit price of contract for No.6 pumping station in the North Sinai area.

On the other hand, cost of mechanical and electrical equipment was estimated by consultant experience and quotation base.

Preliminary cost for each cases are summarized as following table.

Table 5.2-4 Economic cost comparison Unit : million pounds

Cost parameter	Case-1	Case-2	Case-3	Case-4	Case-5	Case-6	Case-7
1.Initial cost							
-Civil construction cost	11.09	15.78	14.79	16.66	17.29	19.35	18.34
-Building cost	5.60	6.44	6.72	7.00	7.56	7.56	7.56
-Sub-total(a)	16.69	22.22	21.51	23.66	24.85	26.91	25.90
-Equipment cost(b)	167.09	184.18	181.95	176.15	176.65	181.42	183.40
-Total cost	183.78	206.40	203.46	199.81	201.50	208.33	209.30
2.Conversion to ann cost							
-Civil cost: (a)x0.06340	1.06	1.41	1.36	1.50	1.58	1.71	1 .64
-Equip.cost: (b)x0.07830	13.08	14.42	14.25	13.79	13.83	14.21	14.36
-Total	14.14	15.83	15.61	15.29	15.41	15.92	16.00
3.Operation cost							
-Energy consum.(mkwh)	293.5	275.5	282.3	288.2	277.2	282.4	275.9
-Energy. Cost(0.2 le/kwh)	58.70	55.09	56.46	57.65	55.45	56.48	55.17
4.Overall annual cost							
Item2 +item3	**72.84**	**70.92**	**72.07**	**72.94**	**70.86**	**72.40**	**71.17**
(percentage to lowest)	**(103)**	**(100)**	**(102)**	**(103)**	**(100)**	**(102)**	**(100)**
5.Order	**5**	**2**	**4**	**7**	**1**	**6**	**3**

5.2.3 Comprehensive Evaluation

Comprehensive evaluation of each options from technical and economical points of view can be summarized as following table. The weighted average of both technical and economical points will be assumed 30 % for former and 70 % for latter, respectively.

Table 5.2-5 Comprehensive evaluation of each options

Parameter	Case-1	Case-2	Case-3	Case-4	Case-5	Case-6	Case-7
1.Technical point							
1.1.Points	7.0	9.0	7.3	7.2	9.3	8.3	9.0
1.2.Percentage to max.	0.753	0.968	0.785	0.774	1.000	0.892	0.968
1.3.Weighted points	**0.226**	**0.290**	**0.236**	**0.232**	**0.300**	**0.268**	**0.290**
2.Economical point							
2.1.Points	103	100	102	103	100	102	100
2.2.Percentage to min. investment	0.97	1.00	0.98	0.97	1.00	0.98	1.00
2.3.Weighted points	**0.679**	**0.700**	**0.686**	**0.679**	**0.700**	**0.686**	**0.700**
3.Total weighted point	**0.905**	**0.990**	**0.922**	**0.911**	**1.000**	**0.954**	**0.990**
4. Order	**6**	**2**	**5**	**7**	**1**	**4**	**2**

Note : The figures of Technical Points referred to Table 5.2-2, and the figures of Economic Points referred to Table 5.2-4, respectively.

As the final conclusion, most suitable number of the pump to be installed should be Case-2, such as four (4) units including one standby unit for Stage I and three(3) units also including one standby unit for Stage II, considering ratio of design discharge for Stage I and Stage II, relationship between number of pump unit, row numbers of pipeline installation and simple operation manners, even through Case-7 is, which pump units are 13 in total including 3 standby units with slightly lower efficiency of pumps, the same level of Case-2.

Table5.2-6 Numbers of Pump Unit

	Operating	Standby	Total	Remarks
Stage I	3	1	4	10.827cu.m/sec/unit
Stage II	2	1	3	
Total	5	2	7	

5.3 Selection of pump type

5.3.1 General Description

Based on the design discharge and given conditions of conveyance canal stated in previous section, the pump type can be decided. Figure 5.3-1 indicates a general guide for selecting the large scale pump best suited to meet various head and capacity requirements. However, in selecting the type of best pump suited to a particular situation, economics of plant construction, efficiency of the units, and operation and maintenance costs should be considered.

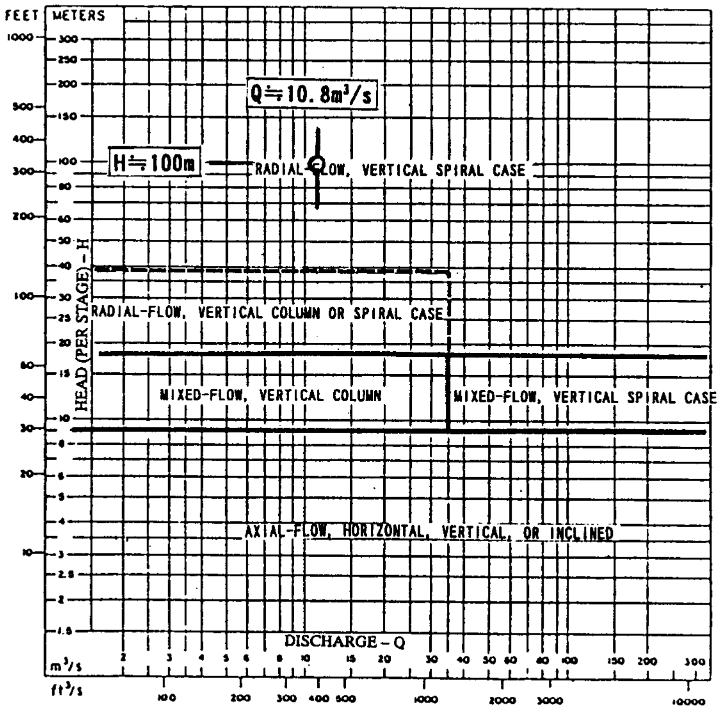


Figure 5.3-1 Large Pump Type Selection Guide
(Bibliography : The USBR Engineering Monograph No. 40)

Following items, in general, shall be studied for design of suitable pumps type based on given conditions.

- Selection of pump types : Centrifugal (radial flow) pump by Figure 5.3-1.
- Determination of pump shaft types : Vertical type by Figure 5.3-1, and shaft arrangement.
- Determination of pump floor types: Concrete embedded casing, suction elbow type because of large capacity pump.
- Determination of No. of pumps : 4 units in Stage I and 3 units in Stage II based on capacity for water demand.(one stand-by unit is including in each stage)
- Selection of prime mover and power transmissions : Direct-connected electrical

motor in economical power cost.

- Selection of operation control methods : Manual operation from electric room or machine side, and one man control /on-off control (preset value control) or automatic control (feedback control, preset value control) from field control room.
- Basic layout of pumping facilities : Arrangement of main and auxiliary equipment is shown in later section.

5.3.2 Shaft Arrangement

Horizontal centrifugal pumps are set on a pump floor above maximum water surface elevation to prevent possible flooding of the motors. Each pump is equipped with a flared suction tube extending down into the suction sump. Vertical centrifugal pumps usually have intake tubes and elbows leading from the plant suction sump to the pump. The pump casing is set below normal water surface and may be set on a pump floor or, in the case of large units, embedded in concrete.

Comparison of horizontal and vertical centrifugal pump is shown in Table 5.3-1. MED practices of electric motor installation are to be above maximum water level on the pump house. Therefore, shaft arrangement of the project shall be vertical type.

Table 5.3-1 Comparison Table for Pump Shaft Arrangement

Shaft arrangement / Item	Vertical shaft	Horizontal shaft
Area to be used for pump unit	Narrow space is required than horizontal shaft type	Wide space is required than vertical shaft type
Filling water of pump	Filling water equipment (Vacuum pump etc.) is not necessary	Filling water equipment (Vacuum pump etc.) is necessary
Suction performance of pump (NPSH)	Good: High speed pump can be adopted due to positive NPSH ava.	No Good: Low speed pump than vertical shaft type will be adopted due to negative NPSH ava.
Readiness for Starting of pump unit	Easier than horizontal shaft type	Complicate than vertical shaft type
Readiness for operation / maintenance	Pump internal checking is complicate. However, reliability is very high due to less number of auxiliary equipment	Pump internal checking is easy. However, reliability is less than vertical shaft type due to many number of auxiliary equipment.
Manufacturing	In case of large vertical pump the casing will be manufactured by steel plate and embedded in concrete.	So large horizontal pump is not common in the world due to the difficulty of casting of pump casing.
Vibration	Since the pump rotating parts can be suspended vertically, no fatigue strength analyses is required.	In case of so large horizontal pump, the shaft deflection due to own rotating parts weight will cause the fatigue limit somehow.
Pump efficiency	Approx. 91 percent	Approx. 1 percent less than vertical shaft type due to low specific speed and scale effect (smaller than vertical one on impeller size)
Decision	Applied Applicable	Not Applicable

5.3.3 Cavitation

Since pumps are often operated at a point other than the design point because of the difference in water level between the inside and outside or depending on the number of pumps operated, suction specific speed should be found from the maximum capacity (%) in the pump operation range in Figure 5.4-4. If ratio of maximum capacity and planned one is large, pump design point will be shifted to large capacity side within a range which pump efficiency is not affected so that civil work cost for construction of pumping station can be saved.

General consideration of preventing cavitation methods are summarized in the Table 5.3-2, and detailed discussion will be made in section 5.4.2 of the report.

Table 5.3-2 Cavitation Prevention Method

Method	Vertical pump	Horizontal pump
Pump setting position (Suction head)	Impeller center can be lowered and made adequate suction head.	Impeller center can not be lowered, if dose not allowed to lower the motor position under the suction sump high water level.
Pump speed	Most economical pump speed can be decided considering pump station construction cost.	If the motor position can not be lowered, pump speed must be lowered. And the pump size will be larger.
Suction pipe	Adequate suction pipe size can be designed to minimize friction loss since the suction head can take smaller than horizontal pump.	Uneconomical suction pipe size will be used to reduce friction loss if the suction head is forced to keep high.

5.3.4 Water Hammer

When pumps used in a long delivery is suddenly stopped by power failure or mechanical failure, rapid pressure changes occur in the pressured pipeline. This phenomenon is referred to as water hammer because of the hammering sound which often accompanies the phenomena.

Preventive measures against water hammer in the pump facility should be taken.

The main discharge valve of the pump, which is operated at the specified time for pump operation and a predetermined time to prevent water hammer should be provided. The bi-plane type butterfly valve can be operated with hydraulic servomotor and counterweight which starts to close immediately and automatically by mean of the weight preset on adjusting closing speed when it detect an emergency situation by a solenoid cluth.

Countermeasures of water hammer for delivery pressured pipelines will be discussed in later section.

There are no difference method for prevention water hammer in the large pump except above mentioned procedure.

5.3.5 Overall Economy and Conclusion

In comparison of vertical and horizontal pump, following items will be effect in view stand of the economical judgement.

1. Pump size : There is restriction for adoption of the large horizontal pump in manufacturing and vibration program so that number of the horizontal pump will increase than one of the vertical pump.
2. Manufacturing : There is limitations for casting of the large horizontal pump casing due to the foundry capacity so that the number of the pump shall be increased and reflects to increase the pump cost. On the other hand, the vertical pump casing can be manufactured by the steel plate, and be no limitation in size on manufacturing.
3. Pump cost : The vertical pump casing is embedded in the concrete so that it weight will be smaller than one of the horizontal pump to be placed on the floor, and be low cost..
4. Construction cost of pump station: The horizontal pump requires the large space than the vertical pump.
5. Motor setting position : If the motor is kept the above suction sump maximum water level, cavitation will be caused. And if the motor is set below the water level, there is a risk that the motor will be immerse in the water.

From the above mentioned reason, the vertical shaft type pump was finally selected for the Project.

5.4 Basic Design of Pump Equipment

5.4.1 Design Conditions and Standards

(1) General

The pump units shall be selected in a system where appreciable change in total head will occur, and under all weather conditions including sever wind driven dust and indirect sunlight with ambient temperature of 45 ℃.

The ground elevation of pumping plant will be at 13.4 meter above sea level.

(2) Hydraulic Conditions

(a)Suction Sump

- High water level elevation:	10.7 m
- Design water level elevation:	9.9 m
- Low water level elevation (full unit operation):	9.7 m
- Lowest water level elevation (one unit operation):	8.8 m

(b)Discharge Tank

- Design water level elevation: 92.9 m
- Low water level elevation (one unit operation):
  - Pumps for Stage I 92.5 m
  - Pumps for Stage II 92.6 m

(c)Static Head

- Design static head (full unit operation): 83.0 m (= 92.9 – 9.9)
- Minimum static head (full unit operation): 82.2 m (= 92.9 – 10.7)
- Maximum static head (full unit operation): 83.2 m (= 92.9 – 9.7)
- Static head at lowest low water level (one unit operation) *:
  - Pumps for Stage I 83.7 m (= 92.5 – 8.8)
  - Pumps for Stage II 83.8 m (= 92.6 – 8.8)

* In case of one unit operation, low water level elevation in suction sump is limited to 8.8 m. (in November)

(d)Hydraulic Losses

At Stage I construction, the plant configuration will consist of four pump units including one stand-by. And at Stage II construction, three pump units including one stand-by are installed.

Each stages pump units are manifolded into one discharge header connected to the discharge lines, which has a length of approximately 9.4km with the following hydraulic losses;

- Pumps for Stage I
  - One pump operating (approximate flow 10.827 m^3/sec) : h_l = 3.5 m
  - Three pump operating (rated total flow 32.48 m^3/sec) : h_l = 16.6 m
- Pumps for Stage II
  - One pump operating (approximate flow 10.827 m^3/sec) : h_l = 5.6 m
  - Two pumps operating (approximate flow 21.65 m^3/sec) : h_l = 16.6 m

(e) Total Pumping Head

- Pumps for Stage I
  - Maximum (three units operating): 99.8 m (= 83.2+16.6)≒100 m
  - Design (three units operating): 99.6 m (=83.0+ 16.6)
  - Minimum (one unit operation): 87.2 m (=83.7+3.5)≒87 m
- Pumps for Stage II
  - Maximum (tow units operating): 99.8 m (= 83.2+16.6)≒100 m
  - Design (tow units operating): 99.6 m (=83.0+ 16.6)
  - Minimum (one unit operation): 89.4 m (=83.8+5.6) ≒89 m

5.4.2 Basic Design of Main Pump

For a given head Hn and capacity Qn, pump design point in most economical should be decided considering the head range that pump must operate within.

(1) Determination of Pump speed

Since the best efficiency of the centrifugal pump for rated capacity of 10.827 m^3/s ranges between 40 to 65 m-m^3/s of the pump specific speed as shown Figure 5.4-1 , n_s = 40 were selected in considering the head range which pump must operate within. In widely ranged pump operation in head, lower specific speed pump of 40 is likely than one of 65 because it have more gently smooth efficiency curve as shown in Figure 5.4-2.

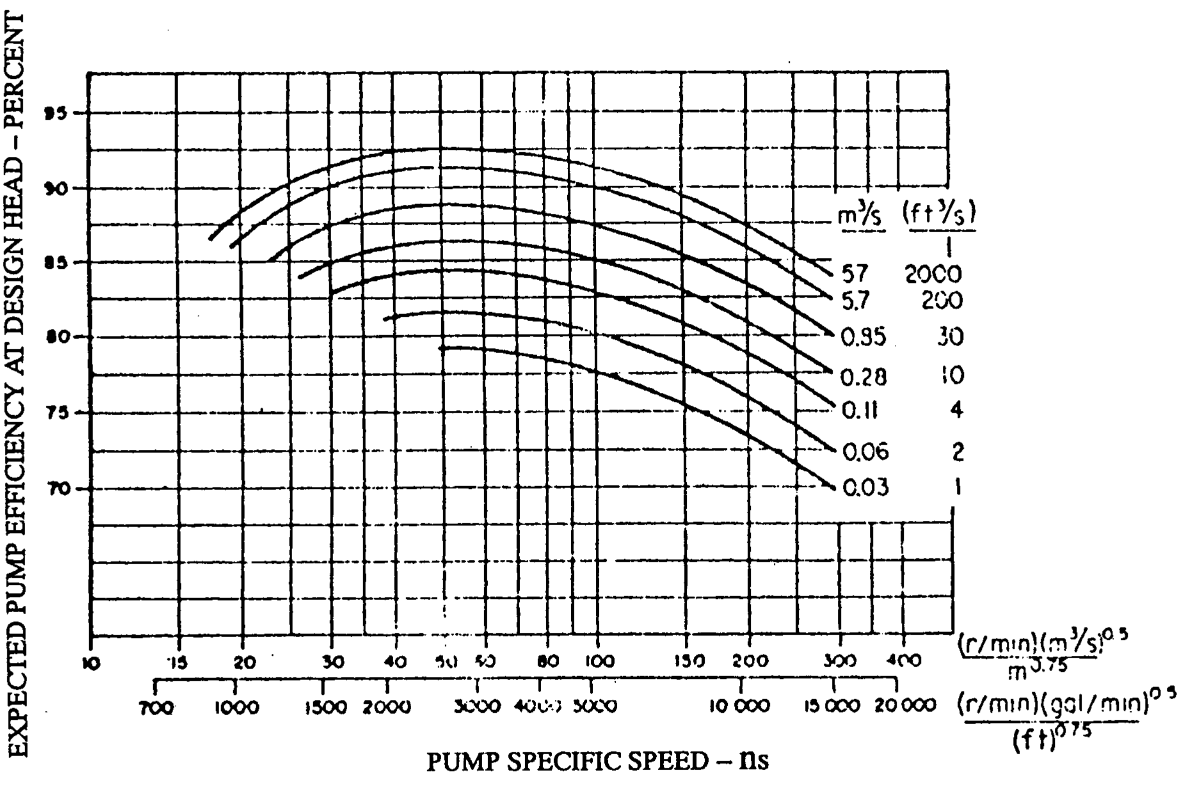


Figure 5.4-1 Expected Pump Efficiency Versus Specific Speeds

(Bibliography : The USBR Engineering Monograph No. 40)

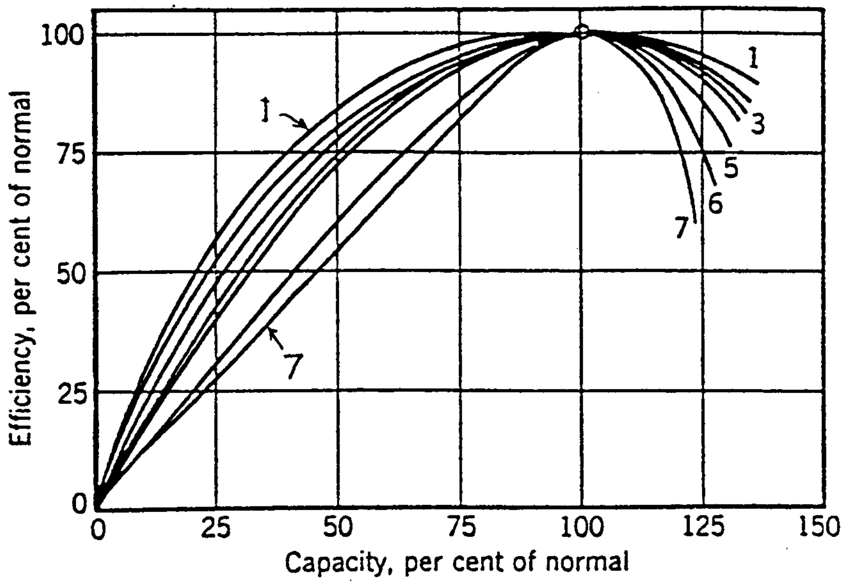


Figure 5.4-2 Efficiency Curves for Different Specific Speeds.
(Bibliography : Stepanoff, A.J., " Centrifugal and Axial Flow pumps,"2d ed.)

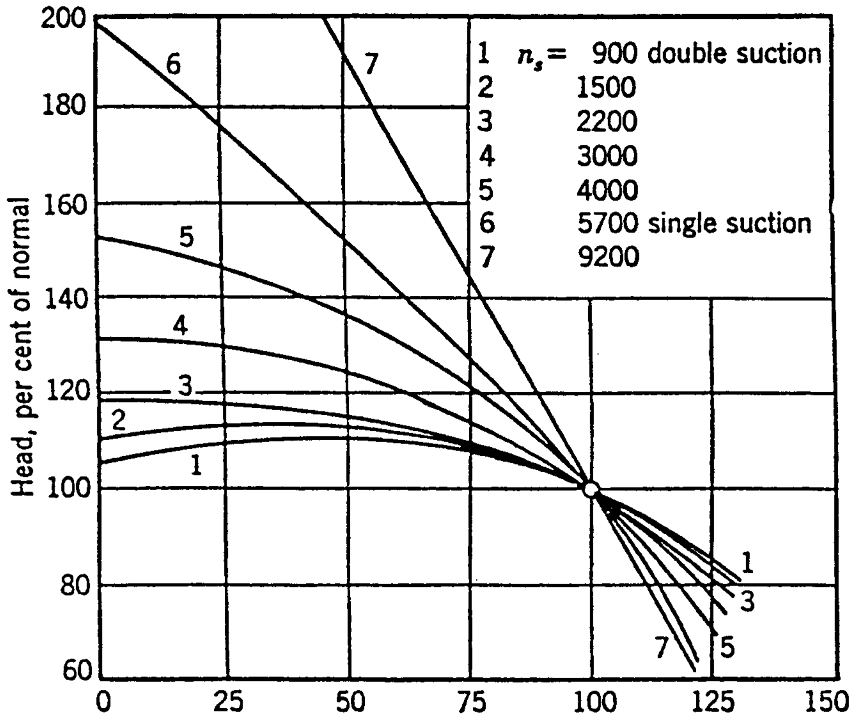


Figure 5.4-3 Head-capacity Curves for Several Specific Speeds
Unit of specific speed is in (r/min) (gal/min $)^{0.5}$ / (ft) $^{0.75}$
(Bibliography : Stepanoff, A.J., " Centrifugal and Axial Flow pumps,"2d ed.)

Therefore, the pump speed is ;

$N= N_s H^{3/4} / Q^{1/2}= 310 \times 99.6^{0.75} / 649.62^{0.5} = 383$ r/ min

Using a multiple of two pole, the closest 50 Hz synchronous speed to 383 r/min is ;

N = 120 x (frequency)/ (number of poles) =120 x50 /16 = 375 r /min

Where,

Ns =Specific speed (40 r/min-m-m^3/s =310 r/min-m-m^3/min)

H = Rated total head (99.6 m)

Q = Rated capacity = (10.827 m^3/sec=649.62 m^3 /min)

(2) Determination of Pump submergence

To determine pump installation level and speed, the influence of cavitation should be checked.

Cavitation terms conditions within the pump where, owing to a local pressure drop, cavities filled with water vapor are formed; these cavities collapse as soon as vapor bubbles reach region of higher pressure on their way through the pump. As a result of the study and accumulated experience, pumps now operate at higher speeds and are safer against cavitation damage such as vibration, noise, drop in efficiency, impeller vane pitting and corrosion fatigue of metals.

The experimental relationship between the impeller eye velocity at cut-off capacity and the suction pressure gives a satisfactory means for predicting cavitation for low specific speed pumps. Thoma's cavitation constant σ be defined as;

$\sigma = H_{svo} / H=$ constant

Where,

H_{svo}: Required NPSH (m)

H_{sv} : Available NPSH ($H_s + P_a - P_v - h_l - 0.5 \geqq H_{svo}$) (m)

P_a : Atmospheric pressure (m)

H_s : Suction static head (m)

P_v : Saturated vapor pressure (m)

h_l : Head loss in suction pipe (m)

H : Total head (m)

0.5: Allowance (m)

Suction condition of pumps in respect to cavitation can be expressed by a criterion known as suction specific speed and defined as;

$S=N\,Q^{1/2}/ H_{svo}^{3/4}$

Where,

S: Suction specific speed (1,400 m-m^3/min. constant for volute pumps)

Q: Capacity at design point (${m^3}$/min)

N: Pump rotational speed (r/min)

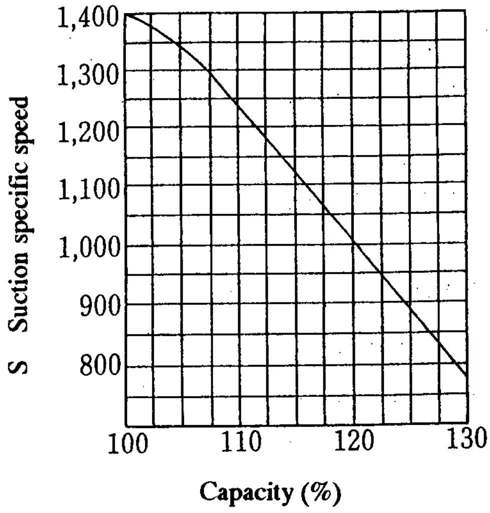


Figure 5.4-4 Suction Specific Speed of a Volute Pump

The submergence of the unit can be found using the pump speed as follows ;

$Hs \geqq H_{svo} - Pa + Pv + h_l + 0.5 = (N\ Q_d^{1/2} / S)^{4/3} - 10.33 + 0.33 + 0.3 + 0.5$

$= (375 \times 714^{0.5} / 1{,}240)^{1.333} - 9.2 = 7.0$ m

Where,

Hs : Suction head (m)

Q_d : Capacity at design point (11.9 m^3/sec = 714 m^3/min)

S : Suction specific speed at 110% design point capacity (1,240 m-m^3 / min-r/min)

h_l : Head loss in suction pipe (0.3m)

Therefore, the pump impeller were set at elevation 1.6 m which deducted suction head (Hs) 7.0 m from lowest suction water level (LSWL 8.60m.) at the mouth of suction pipe.

As for determination of capacity at design point , It were decided by try and error method considering pump operation range within. And, since capacity Qd of 11.9 m^3/sec were decided as best efficiency point of the pump, design head can be calculated using laws of pump scaling as follows;

$(Hd / Hn)^{1/2} = (Qd / Qn)^{1/3}$

$Hd = Hn (Qd / Qn)^{2/3} = 99.6 \times (10.827 / 11.9)^{0.666} = 93.5$ m

Where,

Qn : Rated capacity (10.827 m^3/sec)

Hn : Rated head (99.6 m)

(3) Determination of pump specific speed

Pump specific speed Ns for best efficiency condition under pump speed of 375 r/min is calculated as follows ;

$Ns = N\,Q_d^{1/2} / H_d^{3/4} = 375 \times 11.9^{0.5} / 93.5^{0.75} = 43.0$ m-m^3/s-r/min (333 m-m^3/min-r/min)

5.4.3 Determination of Optimum Pump Dimensions

The pump dimensions were determined based on dimensions estimated by using following three different methods and experience.

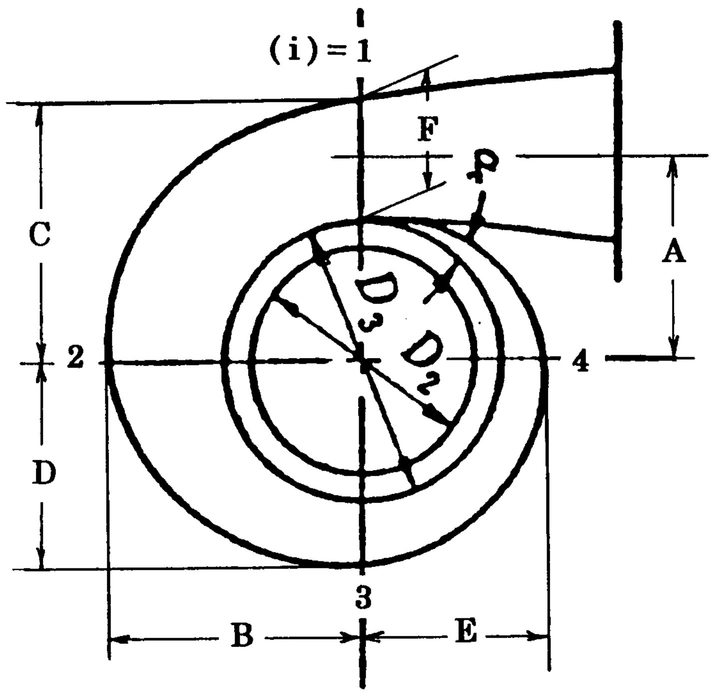


Figure 5.4-5 Spiral Case Dimensions

(1) Analytical method

Once the capacity, total head and speed have been determined, the approximate dimensions of the impeller, which determines the main pump's principal dimensions, can be determined from Figure 5.4-6.

(a)Impeller discharge diameter D_2

For estimating D_2, determine the speed constant Ku using Ns = 43.0 m-m^3/s-r/min (333 m-m^3/min-r/min).

Circumferential speed at impeller discharge diameter D_2 is calculated from the equation;

$U_2 = Ku\ (2gHd)^{0.5} = 1.11 \times (2 \times 9.8 \times 93.5)^{0.5} = 47.52$ m/s

and

$D_2 = 60\ U_2/\pi N = 60 \times 47.52/(\pi \times 375) = 2.420$ m

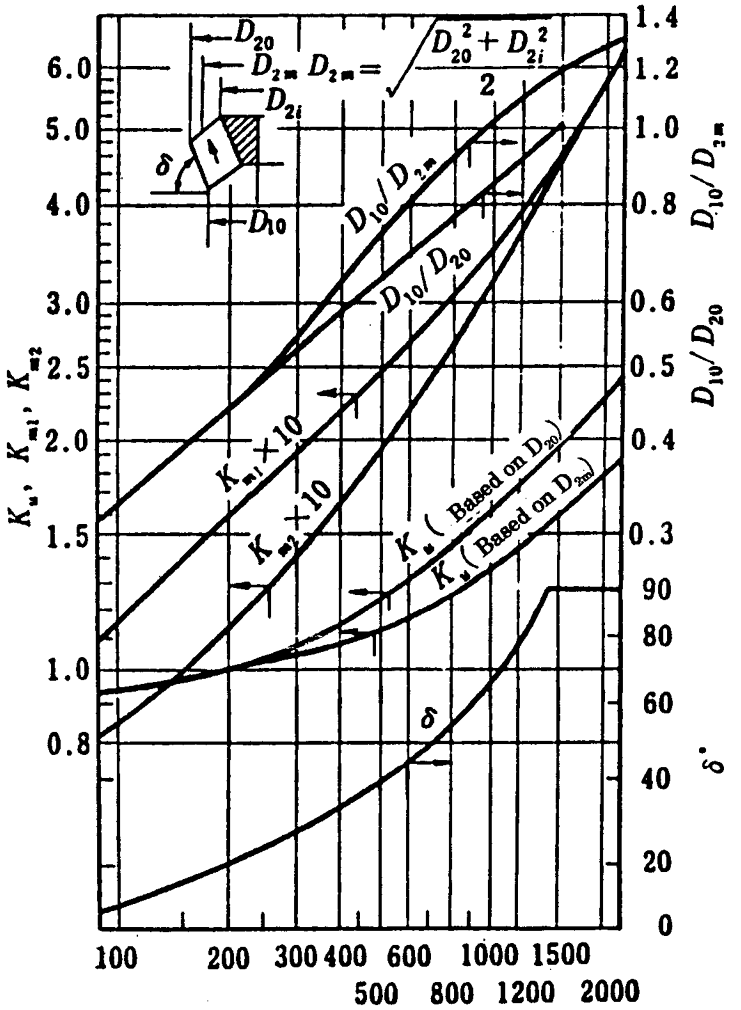


Figure 5.4-6 Impeller Constants

(Bibliography : The Japan Society of Mechanical Engineers' Handbook "Fluid Machinery", 1976 : Original Stepanoff, A.J., " Centrifugal and Axial Flow pumps,"2d ed)

(b)Impeller inlet diameter D_1

For estimating D_1, determine the Ratio D_1/D_2 from the curve in Figure 5.4-6 using Ns = 43.0 m-m³/s-r/min (333 m-m³/min-r/min).

$D_1/D_2 = 0.55$

Therefore,

$D_1 = 0.55 \times 2.420 = 1.331$ m

Therefore,

D_1 =0.55 x 2.420=1.331 m

(c)Pump casing dimensions

Spiral case dimensions can be approximated analytically by using Stepanoff's volute velocity equation.

(i)Volute area

For estimating V, determine K_v from the curve in Figure 5.4-7 using Ns = 43.0 m-m^3/s-r/min (333 m-m^3/min-r/min).

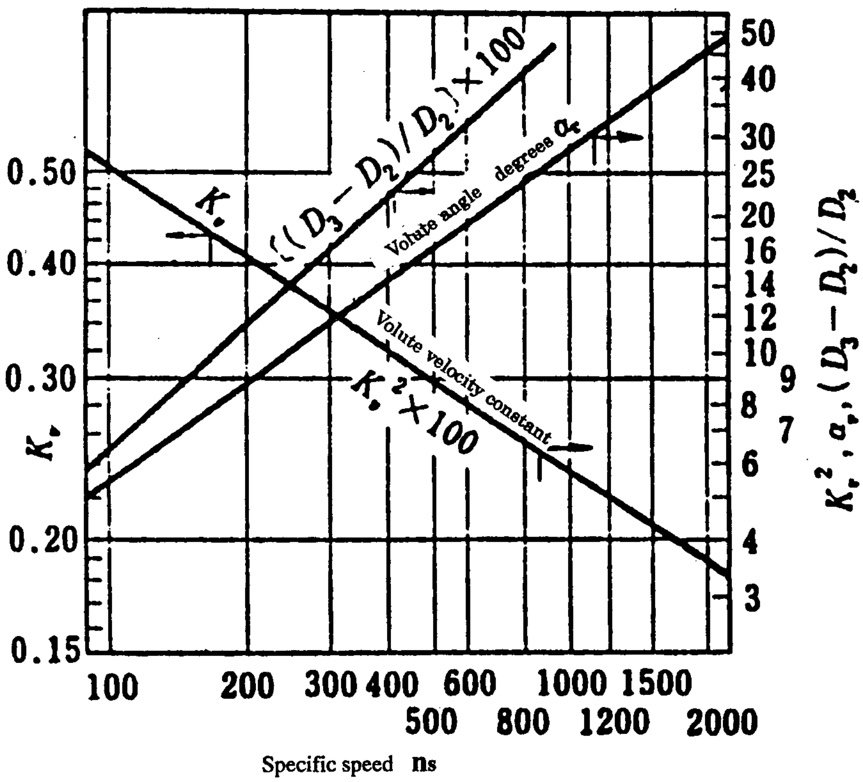


Figure 5.4-7 Volute Constants

(Bibliography : The Japan Society of Mechanical Engineers' Handbook Fluid Machinery", 1976 : Original Stepanoff, A.J., " Centrifugal and Axial Flow pumps,"2d ed)

$V = K_v (2 g Hd)^{0.5} = 0.332 \times (2 \times 9.8 \times 93.5)^{0.5} = 14.2$ m/s

Where,

V : Velocity in the spiral case (m/s)

K_v: Experimental design constant

$= 1.15 (Ns)^{-0.33} = 1.15 \times 43.0^{-0.33} = 0.332$

g : Acceleration of gravity = 9.8 m/s^2

Hd : Design Head = 93.5 m

Assuming V is constant and Q increases in direct proportion to the angular distance from cut water (the wall dividing the initial section and the discharge nozzle portion of the casing) .

The spiral case diameter d can be approximated at various location (i) from the equation of continuity ;

$d_{(i)} = (Q_{(i)} / 0.785\ V)^{0.5} \times 10^3$

Therefore,

$d_B = \{ 11.9 / (0.785 \times 14.2)\}^{0.5} \times 10^3 = 1{,}033$ mm

$d_C = \{(11.9 \times 270 /360) /(0.785 \times 14.2)\}^{0.5} \times 10^3 = 895$ mm

$d_D = \{(11.9 \times 180 /360) /(0.785 \times 14.2) \}^{0.5} \times 10^3 = 731$ mm

$d_E = \{(11.9 \times 90 /360) /(0.785 \times 14.2) \}^{0.5} \times 10^3 = 517$ mm

(ii)Base circle diameter

The diameter of the base circle D_3 can be found from Figure 5.4-7 as follows ;

$(D_3 - D_2) / D_2 = 0.19$

Therefore,

$D_3 = 1.19\ D_2 \times 10^3 = 1.19 \times 2.420 \times 10^3 = 2{,}880$ mm

(iii)Spiral casing dimensions (Refer to Figure 5.4-5)

$A = (D_3 + d_B) / 2 = (2{,}880 + 1{,}033) / 2 = 1{,}957$ mm

$B = (D_3 / 2) + d_B = (2{,}880 / 2) + 1{,}033 = 2{,}473$ mm

$C = ((D_3 / 2) + d_C = (2{,}880 / 2) + 895 = 2{,}335$ mm

$D = (D_3 / 2) + d_D = (2{,}880 / 2) + 731 = 2{,}171$ mm

$E = (D_3 / 2) + d_E = (2{,}880 / 2) + 517 = 1{,}957$ mm

$F = d_B = 1{,}033$ mm

(2) Empirical method

Dimensions of the impeller can be found by the following equations.

(a)Impeller inlet diameter D_1

$D_1 = 550\,\alpha\ Hd^{0.5} / N = 550 \times 87.6 \times 93.5^{0.5} / 375 = 1{,}242$ mm

Where,

α : speed ratio factor

$= 810 (Ns / 1{,}000)^{0.707} = 810 \times (43.0 / 1{,}000)^{0.707} = 87.6$

(b)Impeller discharge diameter D_2

$D_2 = 84{,}600\ Ku\ Hd^{0.5} / N = 84{,}600 \times 1.09 \times 93.5^{0.5} / 375 = 2{,}378$ mm

Where,

Ku : Speed constant

$= 0.82 + (6.4\ Ns / 10^3) - 3.3 (Ns / 10^3)^2 = 0.82 + 6.4 \times 43.0 / 10^3$

$- 3.3 \times (43.0 / 10^3)^2 = 1.09$

(c)Pump casing dimensions

Using estimated impeller discharge diameter D_2 and Pump specific speed Ns, spiral casing dimensions can be found by Figure 5.4-8.

Following shows pump dimensions. (Refer to Figure 5.4-5)

$A = 0.87\ D_2 = 0.87 \times 2{,}378 = 2{,}069$ mm

$B = 1.13\ D_2 = 1.13 \times 2{,}378 = 2{,}687$ mm

$C = 1.03\ D_2 = 1.03 \times 2{,}378 = 2{,}449$ mm

$D = 0.94\ D_2 = 0.94 \times 2{,}378 = 2{,}235$ mm

$E = 0.87\ D_2 = 0.87 \times 2{,}378 = 2{,}069$ mm

$F = 0.22 \times 2\ D_2 = 0.22 \times 2 \times 2{,}378 = 1{,}046$ mm

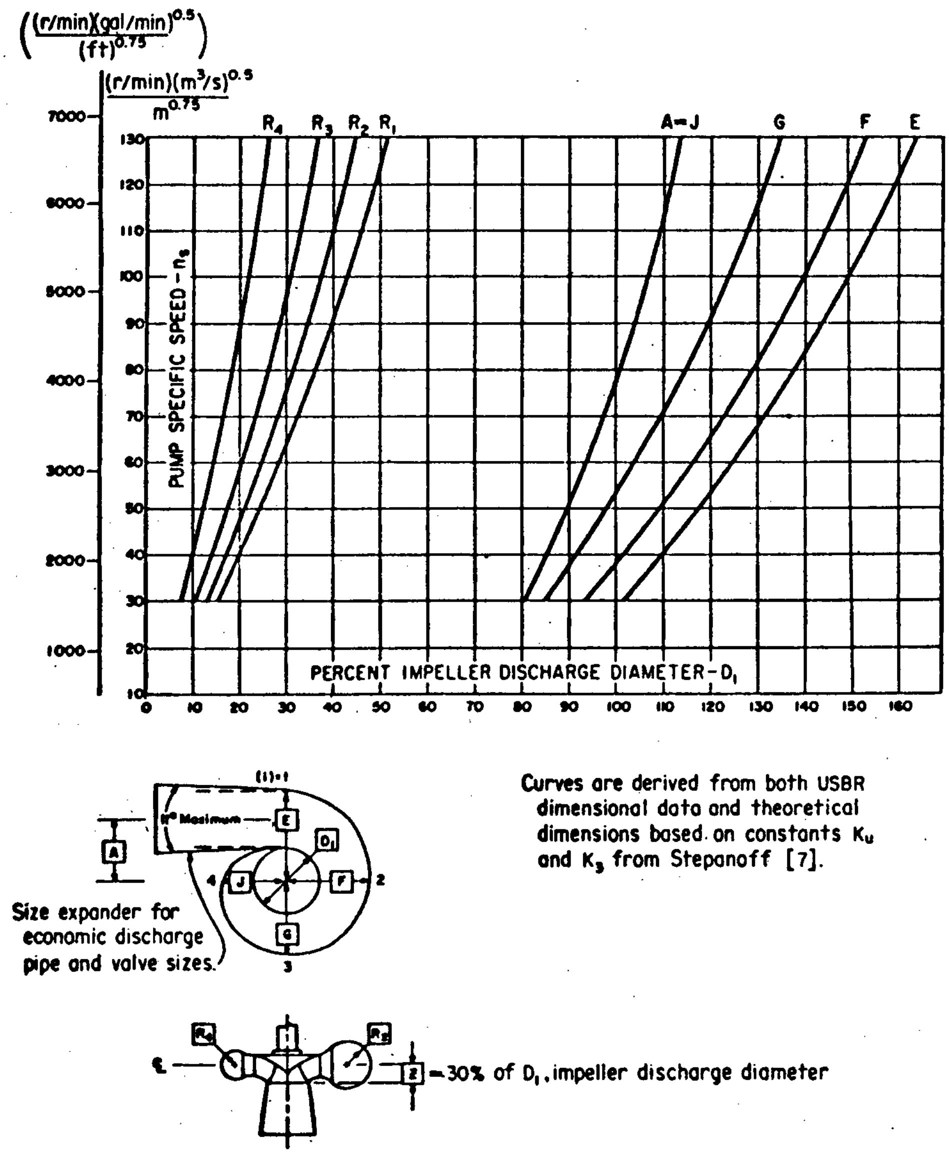


Figure 5.4-8 Approximate Spiral Case Dimensions

(Bibliography : The USBR Engineering Monograph No. 40) (d)Selection of the pump dimensions

As a result of study, largest dimension, in principle, was selected considering the followings.

The physical over-all dimensions of the pump casing are determined by the size of the volute areas (spiral casing dimension F) and the diameter of the base circle D_3 (determined by the physical limitations of the maximum impeller diameter, almost discharge diameter D_2) and the selection of these elements is governed by theoretical considerations but their actual values have been established experimentally for best hydraulic performance. It is unnecessary to combine largest F and D_3 in study because of that pump characteristic designed is different.

Following Table 5.4-1 shows the pump dimensions studied.

Table 5.4-1 Pump Dimension

Item	I	II	
Description	Analytical method by using Stepanoff 's volute velocity equation	Empirical method by using USBR Engineering monograph No.40	Pump casing dimension selected
Impeller inlet diameter D1	1.33 m	1.24 m	1.4 m
Impeller discharge diameter D2	2.42 m	2.38 m	2.5 m
Spiral case dimensions A	1.96 m	2.07 m	2.1 m
Spiral case dimensions B	2.47 m	2.69 m	2.7 m
Spiral case dimensions C	2.34 m	2.45 m	2.5 m
Spiral case dimensions D	2.17 m	2.24 m	2 3 m
Spiral case dimensions E	1.96 m	2.07 m	2.1 m
Spiral case dimensions F	1.03 m	1.05 m	1.1 m

Note 1: Detailed dimensions of suction sump and pumping station were discussed in section 5.6.2 and 5.6.3.

Note 2: Refer to Figure 5.4-5.

5.4.4 Appurtenant Devices

(1) Bulkhead gate (suction sump)

(a)Type and functions

One set of vertical lift bulkhead gate shall be used to close the suction pipe of the pump for inspection and maintenance purposes, and are constructed so that the closing member is completely removed from the water passageway when the gate is full open. The gate will be selected the fixed roller gate which the operating member moves on wheels or rollers to engage with the sealing element, and shall be capable of raising at 2.4 meters of the pressure difference between up and down stream sides of the gate after the suction pipe has been refilled by using unwatering valves in the pump station, also will be lowered under balanced head condition.

(b)Structural general

The fixed roller gate consists primarily of a skin plate supported by horizontal beams which in turn are supported by vertical girders at the sides. Continuous roller trains are mounted around the vertical girders and transmit the load to tracks in the face of the structure. Frames consist of tracks and seal seats mounted on structural beams, and guides. These frames are erected in blockouts in the concrete face and are aligned by anchor bolts embedded in the original pour. After alignment the blockouts are filled in with concrete.

(2) Screen

The trash screen shall be designed to install at 75° inclined angle for mechanical raking and be constructed from steel bar 9 mm thickness and the width which held in accurate spacing with spacers to give a maximum clearance of 50 mm between bars. The effective clearance of the trash screen is usually determined on basis the of pump type, impeller passage area, and the type and quantity of trash.

Meanwhile, the guard scream shall be designed to install at 60° inclined angle and to give a maximum clearance of 100 mm between bars.

(3) Trash rake

The trash car type rake shall be used since the amount of trash is small and the water velocity is low.

(4) Gantry crane

Gantry crane shall be used to serve all the bulkhead gates in chamber at suction side and have a hoist of lifting capacity 1.25 times of the maximum expected load required to lift the bulkhead gate. The gantry crane shall have two speeds, normal and inching in the three directions, which be controlled longitudinal, traverse and hoisting motion.

(5) Overhead traveling crane

The overhead travelling crane shall be provided in station for serving the area of the main pump units, valves and station auxiliaries for unloading and loading, and installing and maintaining of the equipment. It shall be electrically operated cab controlled type and be complete with main traverse girders, cab, main and auxiliary hoists, shafting, gearing, complete electrical equipment and necessary components for proper and efficient operation of the crane. The capable of lifting weights shall be of 25% above the weight of the heaviest parts.

(6) Unwatering facilities

Pumping stations with vertical centrifugal pumps, and those in which the pumps are below maximum intake water surface elevation are ordinarily provided with facilities for unwatering any leakage of water flow into the sump pit from either inside or outside the pump station and suction pipe. These facilities consist of the bulkhead gate, or stop logs, dewatering valves and a sump with permanently installed the pumps. The sump pumps shall be enough capacity for unwatering the sump pit or the unit from the sump pit in the pumping station to the suction sump.

(7) Cooling water supply system

Cooling water is supplied to the cooler and bearings of motors, pump bearings, intermediate shaft bearings and pump shaft ground packing. The cooling water is taken from the discharge pipe by a motor operated valve individually and then must be passed through the strainer and cyclone separator. The system will also be provided a pressure reducing valve, a safety valve and flow relays with necessary pipes and valves.

5.4.5 Header Pipe Hydraulics

The header pipes shall be designed and constructed with the following objectives:

- To achieve smooth uniform flow into the header by providing gradual expansion for the connecting pipe.
- To minimize the water head loss.
- To minimize the forces due to internal flow in the header.

Diameter of the header pipe is designed to keep flow speed within 1 m/s considering the above, and decided as follow;

- Header pipe : 3,800 mm

Each discharge pipes and delivery pipes are provided flared pipe to match the header pipe and diameter of the pipe is as follows ;

- Discharge pipe : 1,500 mm
- Delivery pipe : 2,400 mm

Conceptual layout of the header pipe is illustrated in Figure 5.4-9.

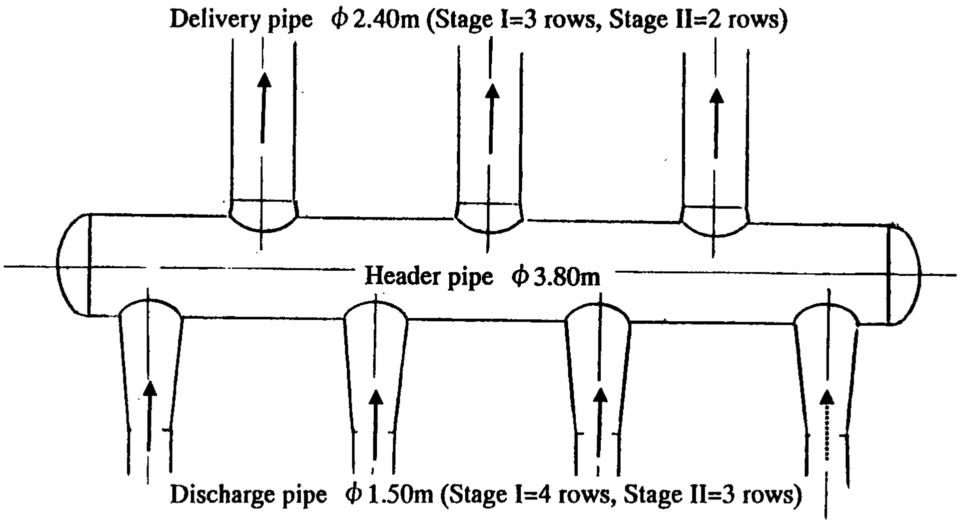


Figure 5.4-9 Outline of Header Pipes

5.4.6 Optimum Sizing of Equipment and Pump Station

As discussed in the previous sections, such as design standard and selection of pump type, and hydraulic conditions, the preliminary layout of pump equipment can be summarized the following Table 5.4-2.

Table 5.4-2 Principal Items for Major Equipment

Principal items \ Planing	Stage I	Stage II
1) Main Pump		
a) Type	Vertical shaft Single suction Centrifugal	Vertical shaft Single suction Centrifugal
b) Number of set (stand-by)	3 + (1)	2 + (1)
c) Suction/Discharge bore (mm)	1,900 / 1,500	1,900 / 1,500
d) Capacity (cu.m/sec)	10.827	10.827
e) Total head (m)	99.6	99.6
f) Revolution (r/min)	375	375
2) Main Motor		
a) Type	Vertical shaft Synchronous Totally enclosed with CACW cooler	Vertical shaft Synchronous Totally enclosed with CACW cooler
b) Out put (kW)	13,000	13, 000
c) Voltage (kV) x Frequency (Hz)	11 x 50	11 x 50
d) No of pole (Revolution・rpm)	16 (375)	16 (375)
e) Insulation class	F	F
f) Starting method	Auto-Transformer	Auto-Transformer
3) Main Discharge Valve		
a) Type	Hydraulic operated bi-plane valve	Hydraulic operated bi-plane valve
b) Number of set	4	3
c) Diameter (mm)	1,500	1,500
4) Main Isolating Valve		
a) Type	Electrical operated bi-plane valve	Electrical operated bi-plane valve
b) Number of set	4	3
c) Diameter (mm)	1,500	1,500
5) Pipeline isolating Valve		
a) Type	Electrical operated bi-plane valve	Electrical operated bi-plane valve
b) Number of set	3	2
c) Diameter (mm)	2,400	2,400
6) Overhead Traveling Crane		
a) Type	Electrical operated overhead	Electrical operated overhead
b) Number of set	1	1
c) Lifting capacity (ton)	100	100
d) Span (m)	Approx.18.5	Approx.18.5
e) Traveling distance (m)	Approx.65	Approx.56
7) Bulkhead Gate		
a) Type	Roller gate	Roller gate
b) Number of gate	1	1
c) width(m)	5.5	5.5
8) Trash Rack		
a) Type	Trash car on the rail	Trash car on the rail
b) Cannel width (m)	5.5	5.5
c) Operating method	manual / semi auto	manual / semi auto

5.5 Basic Design of Electrical Equipment

5.5.1 Design Conditions and Standards

Overall design conditions and standards for the electrical equipment shall be as described in Clause 3.4.4 in Chapter III Design Conditions and Standards.
However, specific conditions and standards for major equipment shall be described in this Clause.

5.5.2 Basic Design of Main Motors

The main electric motors shall be a vertical solid shaft brushless excitation salient pole type synchronous motor with starting cage winding. The motors shall be designed for indoor use and the enclosure shall be totally enclosed of the water-cooler heat exchanger type.
The motors shall require a 10% margin at the design point on the loading curve. The locked rotor current values at rated volts and frequency of the motors shall not exceed 600% of full load current.
The motors shall be synchronized to operate together, their rated exciting current being maintained, under running conditions at rated load with a variation in the voltage or the frequency up to the following:

- Plus or minus 10% of rated voltage, with rated frequency
- Plus or minus 5% of rated frequency, with rated voltage
- A combined variation in voltage and frequency of 10% (sum of absolute values) of the rated values, provided the frequency variation does not exceed plus or minus 5% of rated frequency.

Insulation of the armature and field windings of the motors shall be use Class F, and temperature rise shall be limited to Class B.

Motors shall be provided with stator winding temperature detectors, which shall consist of six resistance type temperature detectors (RTD), or two RTD per phase, embedded in the stator windings. The RTD shall be PT-100 resistance type having a resistance of 100 ohm at 0°C. RTD shall be provided with surge protecting devices in the terminal box.

The motors shall be provided with thrust bearing and upper and lower guide bearings in accordance with manufacturer's requirement for the motor application. The thrust and guide bearings shall be provided with RTD's (one (1) each) and with a vibration detector on the thrust bearing.
Each motor shall be provided with anti-condensation space heaters with IP 55 terminal box to prevent condensation in the windings or oil reservoirs when the motor is shut down for long periods.
The protection system for the main pumps units shall be designed taking the sequential

interrelations into consideration. Protection system shall be as shown in the following table.

Table 5.5-1 Table of Protection System

Abnormal condition	Pump Stop	Main Motor C.B Trip	Alarm/ Indication
(1) Major Fault			
a. Pump			
Low Water Level (Suction Well)	O	O	O
Guide Bearing	O	O	O
High Temp	O	O	O
Low Oil Level (Guide Bearing)	O	O	O
b. Motor			
Over Current / Over Load	O	O	O
Phase Fault / Reverse Phase	O	O	O
Out of step-detecting	O	O	O
Differential	O	O	O
Field Current Fault	O	O	O
Electric System Fault (under voltage of DC Power Source)	O	O	O
Bearing High Temp. (Thrust/Guide)	O	O	O
(2) Minor Fault			
a. Pump			
Starting failure	–	–	O
High/Low Pressure (Pump Impeller)	–	–	O
Vibration on Guide Bearing	–	–	O
Low Cooling Water Flow	–	–	O
b. Motor			
High Stator winding temp.	–	–	O
High cooling water temp.	–	–	O
Low cooling water flow	–	–	O
Aux. machine fault	–	–	O

A one-line diagram of the synchronous motor is shown in Figure 5.5-1 (for Stage I and Stage II).

The power supply system to the main pump units and pump auxiliaries/common auxiliaries motors are shown in Drawing BE-01, BE-02 and BE-03 (for Stage I) and Drawing BE-04, BE-05 and BE-06 (for Stage II).

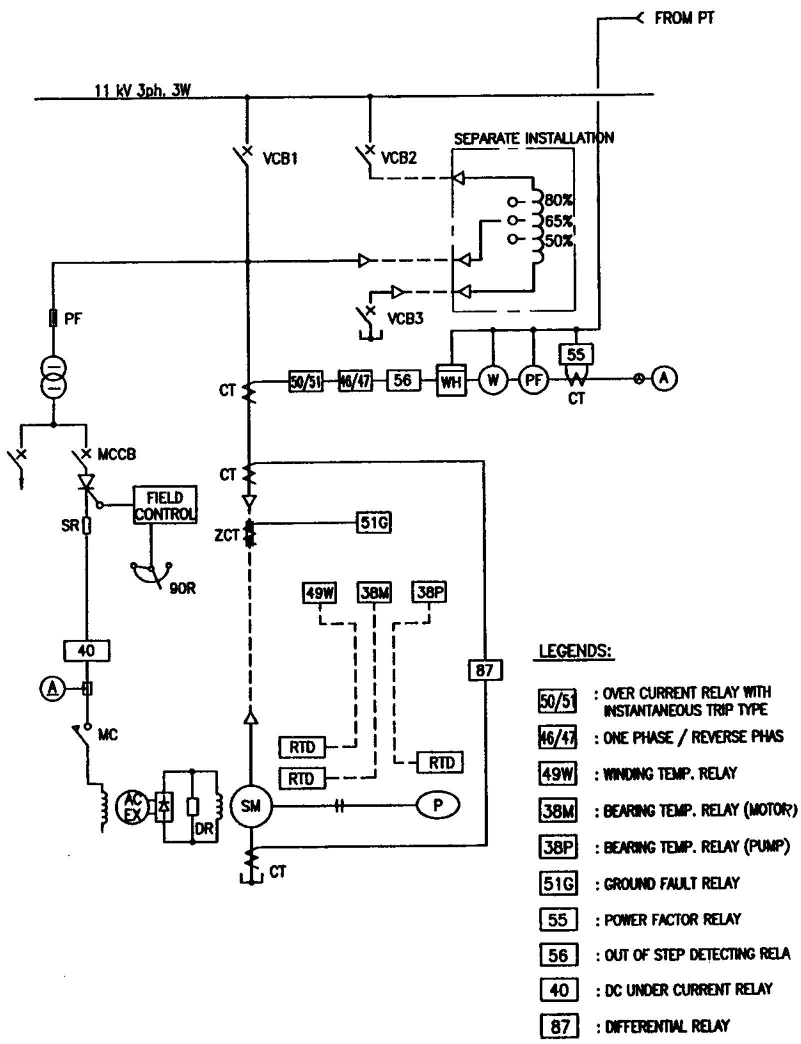


Figure 5.5-1 One – Line Diagram of Synchronous Motor (Typical)

5.5.3 Starting Equipment of Main Motors and Motor Exciting Panel

(1) Starting Equipment

The MED and JICA team discussed the starting system of the main pump motor based on the recommended plan and comparison table of motor starting systems provided by the Team.

From a technical and economical point of view, the Kondorfer starting system shall be used for the main pump motors this was agreed by MED.

There are many types of starting systems for various size motors. The detailed comparative study is as fallow:

- Line start
- Star-Delta start
- Reactor start
- Compensator start
- Auto-transformer (Kondorfer) start
- Variable voltage variable frequency (VVVF-Thyristor control system) start

The line start system is used for small size motors and the star-delta and reactor start systems are used for middle size motor. The expected size of main motor in this project may be 13MW. Consequently the Compensator systems, Kondorfer system or VVVF system are appropriate. However, VVVF system is difficult to maintain and the cost is much higher than that of the other two systems so the VVVF system is not recommended.

A comparison of these two of starting systems is shown below. Although both the Compensator and Kondorfer starting systems have almost the same start characteristics, the Kondorfer starting system was selected, because the Compensator starting system produces a large in-rush current when the reduced voltage start transfers to line voltage.

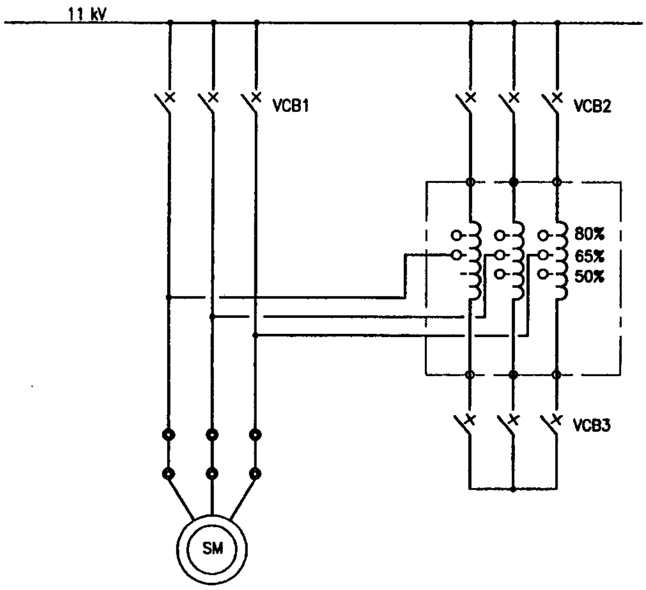
Table 5.5-2 Comparison for Alternative Motor Starting Systems

Items	Starting System	
	Compensator	Kondorfer
Affect on power supply source	Large	Smaller than Compensator system
Starting time	Short	Short
Starting equipment	1-Auto-transformer 1-Circuit breaker	1-Auto-transformer 2-Circuit breaker
Reliability	High	High
Terminal voltage (V) (Ratio)	Tap : 80%, 65%, 50% V : 0.8, 0.65, 0.50	Tap : 80%, 65%, 50% V : 0.8, 0.65, 0.50
Starting torque (Ts) (Ratio)	Tap : 80%, 65%, 50% Ts : 0.64, 0.42, 0.25	Tap : 80%, 65%, 50% Ts : 0.64, 0.42, 0.25
Starting Current (Is) (Ratio)	Tap : 80%, 65%, 50% Is : 0.64, 0.42, 0.25	Tap : 80%, 65%, 50% Is : 0.64, 0.42, 0.25
Cost (Ratio)	0.9	1.0

The electrical circuit for the Kondorfer starting method is shown in Figure 5.5-2 (for Stage I and Stage II). The principal of the Kondorfer starting method is as follows:

	C.B Activity	Function of Kondorfer Unit
Step-1	VCB2/VCB3 – on VCB1- off	as starting transformer.
Step-2	VCB2 – on VCB3/VCB1 – off	as reactor
Step-3	VCB1 – on VCB2/VCB3 – off	Unit to be released from main circuit. Motor put into normal running.

Usually the Kondorfer unit shall be provided with starting taps of 50, 65 and 80% of line voltage, and selection of the starting tap depends on the starting torque and the time required for the pump unit. Each main motor shall have its own individual Kondorfer unit.



CIRCUIT BREAKER ACTIVITY			
STEP	1	2	3
VCB1	OFF	OFF	ON
VCB2	ON	ON	OFF
VCB3	ON	OFF	OFF

Figure 5.5-2 Diagram of Kondorfer Starting Method (Typical)

(2) Exciting Panel

The main motor exciting panel shall consist of static thyristor exciter circuit, power factory relay, pull out relay, and accessories all mounted on metal frames, complete with all electrical connections and completely enclosed within sheet metal housings.

The motor exciter panel shall be of the following type and ratings:

- Type : Indoor, self-supported, metal-enclosed type
- Rated voltage : 380V AC, 3-phase, 4-wires
- Rated insulation voltage : 600V AC

- Rated frequency : 50Hz
- Power frequency withstands voltage : 2.5KV r.m.s

All equipment, materials and fabrication shall conform to the latest applicable IEC 439, 473, 521 and 541 standards or equivalent. The motor exciter panel shall be fabricated from flat rolled steel panel, reinforced where necessary, in such manner that the complete structure is rigid. The panel shall be fabricated from not less than 2mm thick steel sheets.

The outline of the brushless excitation system is as follows:

The brushless excitation system shall consist of AC exciter and silicone rectifier. The equipment shall be mounted on the shaft of the main motor. The AC exciter is the revolving-armature type. The field poles mounted on the stator are excited by a static-exciting device this means very small power capacity will be required. Generated AC power in the revolving armature windings will be rectified by the silicone rectifiers and then it is fed to the field windings of the main motor. Therefore, the excitation system has no sliding or energized parts, thereby making both the main motor and AC exciter a completely brushless construction.

5.5.4 Medium and Low Voltage Switchgear

(1) Medium voltage switchgear

All switchgear together with the control and relay boards shall be of the totally enclosed type. The switchgear shall be metal-clad with IP42 protection for enclosure and compartments. Cubicles shall be vermin proof and insect proof. Each switchgear shall be arranged for MV cable and Control cable entry at the bottom of the panel. The switchgear earthing common bar hall be have a minimum section of 150mm^2.

The metal thickness shall not be less than 2.0mm for structural members and 1.6mm for side panel and doors.

Each switchgear shall be equipped with a space heater for prevent moisture within the switchgear. The heater shall be thermostatically on-off controlled.

The circuit breaker operating mechanism shall be motor spring stored-energy operated and shall be electrically and mechanically trip-free.

In order to afford security for operation and/or maintenance staff, and to ensure the correct operation, mechanical and electrical interlocking devices shall be provided to prevent mal-operation of circuit breaker.

In addition to the above interlocking requirements, padlocking facilities shall be provided for the selector mechanisms on circuit breakers, at "Disconnected" and "Service" positions.

All switchgear shall be designed and manufactured in accordance with IEC56, IEC298, IEC632 and IEC694.

(2) Low voltage switchgear

The low voltage switchgear shall be totally enclosed IP42, completely dust proof and assembled in a steel housing. The equipment shall comprise the busbars, circuit breakers, switches, etc., necessary for the power supply to the main pump unit, auxiliaries and commonly used equipment.

The low voltage switchgear shall employ air circuit breaker (ACB) for the incoming transformer feeders and molded case circuit breaker (MCCB) for the outgoing circuit to the downstream switchboard.

Low voltage switchgear and motor control centers (MCC) shall be constructed on a modular basis allowing for each extension and modification as required.

Low voltage feeder circuit shall be provided with over current and earth fault protection either as separate protection or as an integral protection in the case of MCCB's.

Each motor starter unit of the MCC shall be provided with a circuit breaker, control transformer, magnetic starter and protection. The starter shall be the normal means of stopping and starting the motor. Each unit shall be contained in an individual compartment having a front access door.

Layout plan of the medium and low voltage switchgear is shown on the Drawing DS-08 (for Stage I) and Drawing DS-14 (for Stage II).

5.5.5 Appurtenant Equipment

(1) DC Power Supply Equipment

The DC power supply equipment is used for switchgear control, instrumentation, protection and alarm circuits, emergency lighting, etc., independently of the main power system.

The DC power supply system shall consist of:

- Lead-acid batteries with adequate capacity for supplying the continuous DC load and emergency DC load.

- Battery chargers capable of supplying the DC load and maintaining the batteries fully charged.
- D.C. distribution panel

  Branch circuit breaker handles shall be accessible from the front of the cubicle without the necessity of opening the hinged panel.

The maximum and minimum battery voltages are based on 2.3V per cell for charge equalization and 2.0V per cell end of load cycle discharge voltage, respectively, using lead acid type. The batteries shall be rated for 10 hours discharge rate.

The battery chargers shall normally float charge the batteries and shall also supply the D.C. load. The battery chargers shall equalize the batteries when needed. They shall also be capable of recharging their respective batteries to 80% capacity in 10 hours at the end of the battery discharge load cycle while supplying the load of their respective batteries.

Battery charger shall be a full wave silicone controlled rectifier type with fully automatic controls or thyristor controls.
Input power sources for the battery charger shall be of 3-phase, 380 volts, 50Hz and output of the DC equipment shall be of 110 volts DC.

The battery charger and distribution panel shall be a floor mounted, free standing cubicle. The batteries shall be mounted on a steel rack and installed in a cubicle. The cubicle shall be constructed of heavy gauge steel, suitably braced, vermin-proof, with a degree of protection equal to indoor IP 31 to IEC or equivalent.

5.5.6 Main Pump Units Operation

(1) Starting Conditions

The starting conditions for main pumps and motors are as follows:

(a)For Pumps

- Higher than the prescribed water level in the suction well
- Greater than the prescribed water pressure in the water-supply to the stuffing box and the bearing
- Greater than the prescribed oil level at the oil reservoir of the guide bearing
- Greater than the prescribed cooling water flow from the heat exchanger of the bearing (Intermediate and guide bearing)
- Greater than the prescribed water flow for the pump shaft seal water
- Closing position of discharge valve
- The other pumps are not in a starting condition
- No operation for the protection relays of the pump (Refer to item (2) protection

system)

(b)For Motors

- Greater than the prescribed oil level at the oil reservoir of the bearing
- Greater than the prescribed cooling water flow from the heat exchanger of the bearing (Thrust, upper guide and lower guide bearing)
- Greater than the prescribed water pressure for the bearing
- Greater than the prescribed cooling water flow from the cooler of the motor
- No operation for the protection relays of the motors (Refer to item (2) Protection system)
- 11KV power "ON"

(2) Protection Systems

The main pump units and related equipment shall be equipped with the following protection systems.

Table 5.5-3 Protection Systems

		Abnormal condition
Major Fault	Pump	(1) Low water level in the suction well (2) High temperature at the following bearings a. Inter mediate guide bearing b. Pump guide bearing (3) Low oil level at the pump guide bearing
	Motor	(4) Over current / over load (5) Phase fault / reverse phase (6) Out of step-detecting (7) Differential (8) Field current fault (9) Major electric system fault (Under voltage, DC control source off etc.) (10)High temperature at the following a. The thrust bearing b. The upper and lower guide bearings
Minor Fault	Pump	(1) Starting failure (2) High/Low pressure above the pump impeller (3) High cooling water temperature at the inlet / outlet of the bearing oil heat exchanger (4) Vibration on guide bearing (5) Low cooling water flow on the following a. The heat exchanger of the bearing b. The pump shaft seal water
	Motor	(6) High stator winding temperature (7) High cooling water temperature at the following a. The cooler of the motor b. The inlet / outlet of the bearing oil heat exchanger (8)Low cooling water flow from the cooler of the motor (9)An auxiliary machine fault (over load, etc.) (10)Minor electric system fault

Note 1: In case of major fault, the main pump shall be automatically stopped.

Note 2: In case of minor fault, the operator shall check the fault and determine whether or not to stop the main pump.

(3) Main Pump Operation Procedure

The operation of the main pump units shall be in accordance with the outline procedure shown in the Figure 5.5-3.

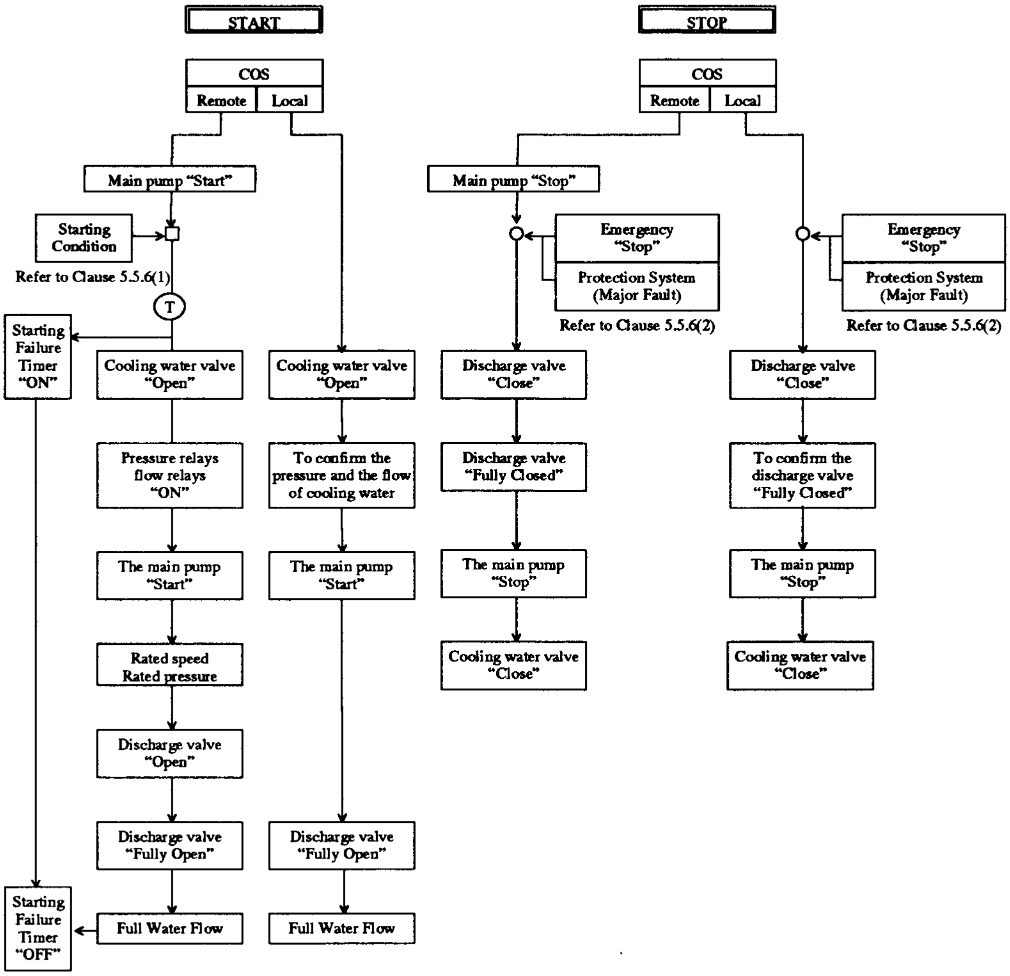


Figure 5.5-3 Block Diagram for the Start or Stop of the Main Pump

5.6 Basic Design of Pumping Station

5.6.1 Background of Construction Method and Layout of No.7 Pumping Station

(1) Construction method alternatives by the stage development

As discussed previous section, design discharges (peak demand in July) of Stage I and Stage II are 32.48 cu.m/sec and 20.18 cu.m/sec respectively. Distribution of number of pump units including standby for each stages are four (4) units for Stage I and three (3) units for Stage II.

Following three alternatives can be considered in order to find suitable and reliable construction method of pumping station and installation of pump plants. Illustration of the three alternatives is shown in Figure 5.6-1.

- Alternative A : One construction stage of pumping station (civil works and building) but separate installation of pump equipment (four units for Stage I and three units for Stage II) and delivery pressured pipelines (three rows for Stage I and two rows for Stage II)

- Alternative B : Two construction stage of pumping station (Stage I and Stage II respectively) and installation of pump equipment and delivery pressured pipeline, same manner of alternative A as mentioned above, but one unit function of pumping system after completion of Stage II development.

- Alternative C : Completely separate construction of pumping station and installation of pump equipment and delivery pressured pipelines for Stage I and Stage II, respectively.

(2) Technical comparison of the alternative plans

(a) General Technical Comparison

The following components shall be considered for technical comparison of construction method of No7. Pumping station.

- Sizing of suction sump and pump house including repairing space
- Space of gallery, ducts and stair
- Reliability of foundation treatment of pumping station
- Demolish and replacement works
- Travelling crane installation
- Workability of second stage construction works
- Convenience of operation and maintenance
- Negative benefits for advanced initial investment
- Government intention

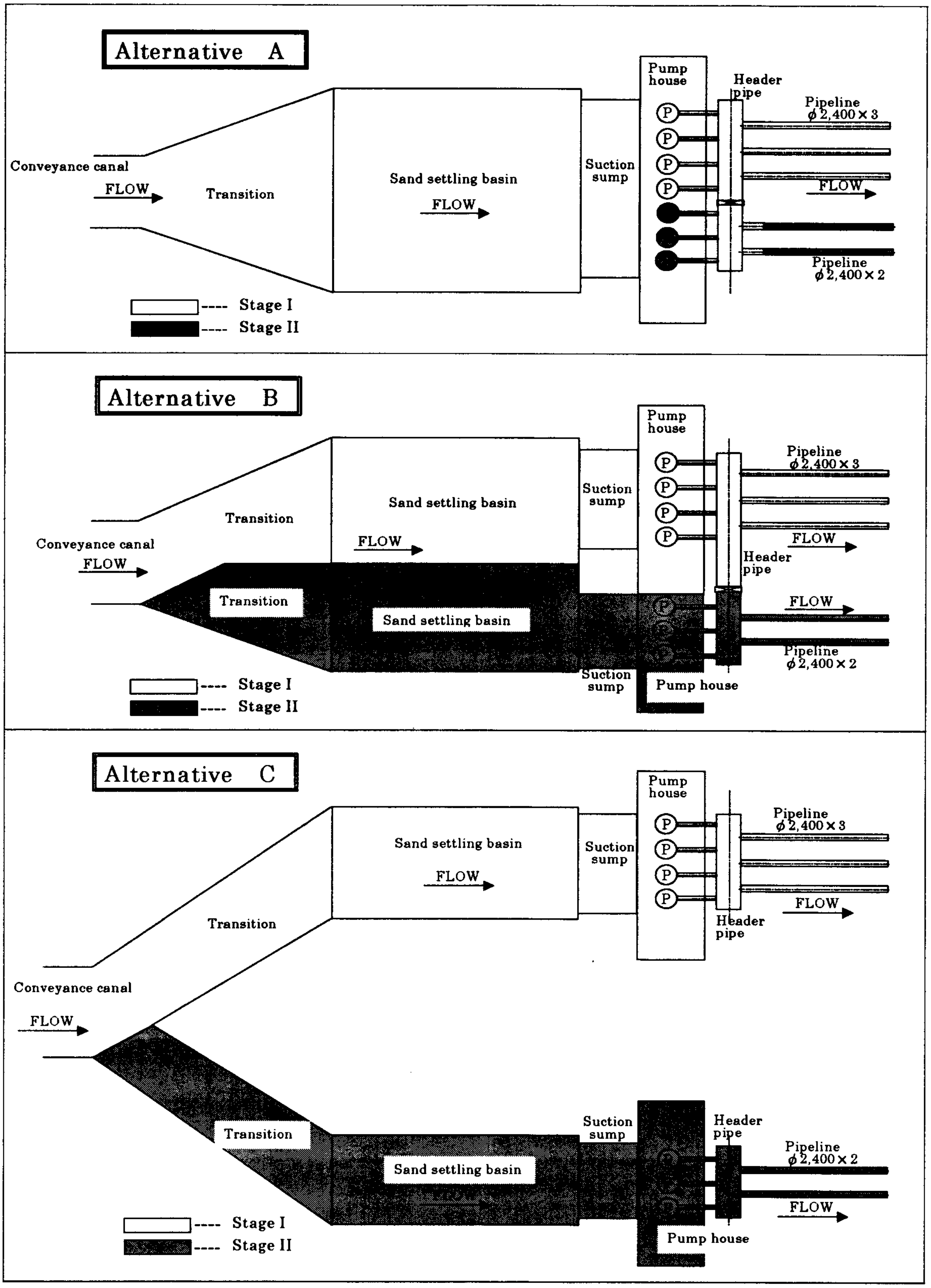


Figure 5.6-1 Construction Method for No. 7 Pumping Station

(b) Technical Comparison

Simple comparison of technical factor is tabulated in Table 5.6-1.

Table 5.6-1 Technical comparison

Component	Alternative A	Alternative B	Alternative C
1.Sizing of suction sump/building	3.0	2.0	1.0
2.Space of gallery and stairs	2.0	1.5	1.5
3.Reliability of foundation treatment	3.0	2.0	3.0
4.Demolish and replacement works	2.5	1.0	2.0
5.Travelling crane installation	2.0	2.0	1.5
6.Workability of 2nd stage construction	3.0	2.0	2.5
7.Convenience of operation/maintenance	3.0	3.0	1.0
8.Negative benefits for advanced invest	1.0	3.0	3.0
9.Overall points	**19.5**	**16.5**	**15.5**
10.Order	**1**	**2**	**3**

Note: The figuers in the table are "3" for suitable,"2" for moderate and "1" for inadequate.

(c) Particular technical consideration of Alternative B

Alternative B is combined construction methods of No.7 Pumping station as one unit function of the facilities after completion of the second stage construction works. Suction sump and building work of second stage shall be constructed beside the existing facilities, which was constructed at the first stage and under operating conditions of existing pumping plants.

The construction methods of second stage pumping station and its countermeasures to decrease impact against the existing pumping station should be considered paying special attentions as mentioned below, illustrations for this are shown below figures.

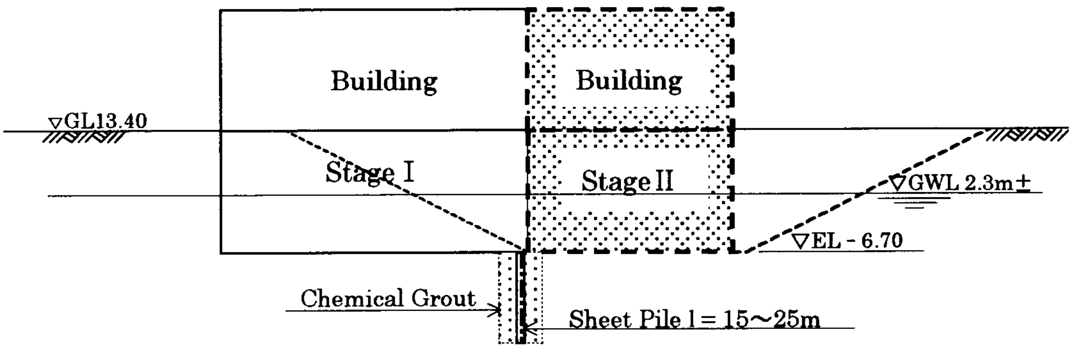


Figure 5.6-2 Cross Section of Countermeasures for Existing Pumping Station

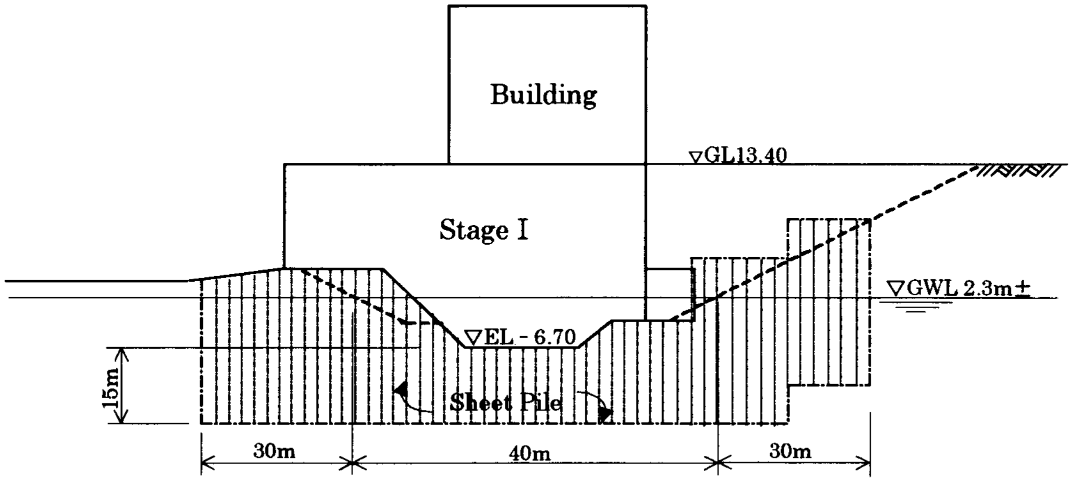


Figure 5.6-3 Profile of Countermeasures for Existing Pumping Station

Impact to the existing pumping station (Stage I) after excavation works by beside of the facilities was completed, are i) loosing the foundation of existing facilities after draining out groundwater, ii) occurring piping phenomenon of base soil under the existing pumping station due to high groundwater level (about (+) 2.3 m) compare to the deepest surface of excavation (approximately (-) 6.70m).

Countermeasures against unforeseeable impact as mentioned above are provision of steel sheet piling in order to prevent piping phenomenon and to keep appropriate creep length. In case of sand layer of the foundation, creep ratio of Bligh's formula will be 3, therefore, the proposed sheet pile length of vertical and horizontal directions are around 15 m and 25 m, respectively. Piling method of sheet pile shall be applied water jet technology because foundation of the construction site is rather hard sand layer with more than 50 of penetration values N. During sheet piling works of first stage foundation treatment, looseness of foundation soil vicinity of sheet piled might be happened by water jet piling. These loosed foundation soil should be improved by chemical grout method in order to avoid future differential settlement of the foundation as much as possible.

Facilities constructed by the Stage I and Stage II period shall be independent structures connecting with expansion joint in order to prevent differential settlement between two facilities and crack of concrete. Therefore, high technologies will be required for these construction works and more than six months of construction period including sheet piling will be required compared to the ordinary methods.

(d) Other Issues

Walls of the existing station shall be demolished and cable ducts, gallery and passages shall be connected carefully for common use of travelling crane and related equipment after second stage concrete placing was completed.

Differential settlement of foundation for the existing pumping station may be happened during the second stage construction period due to draw down of groundwater level by well points dewatering method, even though the piling work was provided in the first stage of construction period.
Installation and/or re-installation of mechanical and electrical equipment will be required more frequent than the other alternatives during operation of the existing pumping station. In addition to this, the cost of such works will be increased compared to other alternatives.

(3) Economic comparison

Differences of the cost for each alternatives are mainly based on the repairing area of pump house, re-excavation and/or additional excavation work of suction sump, extension and/or replacement of electric equipment and cables, additional installation of travelling crane, etc. Preliminary cost for each alternatives is tabulated as follows ;

Table 5.6-2 Economic Comparison Unit : 1,000 LE

Cost Item	Alternative A	Alternative B	Alternative C
1.Civil works			
-Earth works (excavation)	984	1,192	1,432
-Concrete works	14,800	15,550	17,000
-Chemical grouting	0	6,700	0
-Sub-total	15,784	23,442	18,432
2.Building works	6,440	7,560	9,240
3.Equipment supply/installation			
-Mechanical equipment	130,010	136,510	146,510
-Electrical equipment	54,170	56,878	59,587
-Sub-total	184,180	193,388	206,097
4. Total cost	206,404	224,390	233,769
5. Order	1 (100)	2 (109)	3 (113)

(4) Overall evaluation and conclusion

From the figure of Table 5.6-1 and 5.6-2, overall weighted points can be summarized as follows ;

Table 5.6-3 Overall Evaluation of Three Alternatives

Comparative Parameter	Alternative A	Alternative B	Alternative C
1.Technical evaluation			
(1) Technical points	19.5	16.5	15.5
(2) Percentage to min. point	1.00	0.85	0.79
(3) Weighted points	0.300	0.255	0.237
2.Economical evaluation			
(1) Investment points	100	109	113
(2) Percentage to min. point	1.00	0.92	0.88
(3) Weighted points	0.700	0.644	0.616
3.Overall weighted points	1.000	0.899	0.853
4. Order	1	2	3

Government policy on the project development plan is Stage Development divided into "Two Stages" and implementation of the project for Stage I and Stage II will be conducted separately with keeping adequate interval (minimum 5 years).

In case of less than five years interval of implementation period between Stage I and Stage II, Alternative A is best plan compared to other alternatives.

In case that the interval is more than 5 years, it should be considered Alternative B and/or Alternative C. However, the results of geological investigation at the proposed site, groundwater level is very high as 2.3 m MSL. So Alternative B is required high technology for the construction work as discussed previously.

Government of Egypt has decided to challenge involvement of private sector for the development of irrigation schemes as well as post project management.

Finally, the Project Steering Committee (PSC) was concluded to adopt Alternative C through long time discussion among the high officials concerned, even the cost slightly higher than Alternative A and B.

(5) Layout of Pumping Station

Pumping station on Stage I will be located at the northern part of site. And pumping station on Stage II will be located at the southern part of site. Distance between Stage I station and Stage II station should keep 50 meters to prevent in suffering by construction of pumping station on Stage II. The area of substation and residential building will be located at hill which is found the northeastern part of the site.

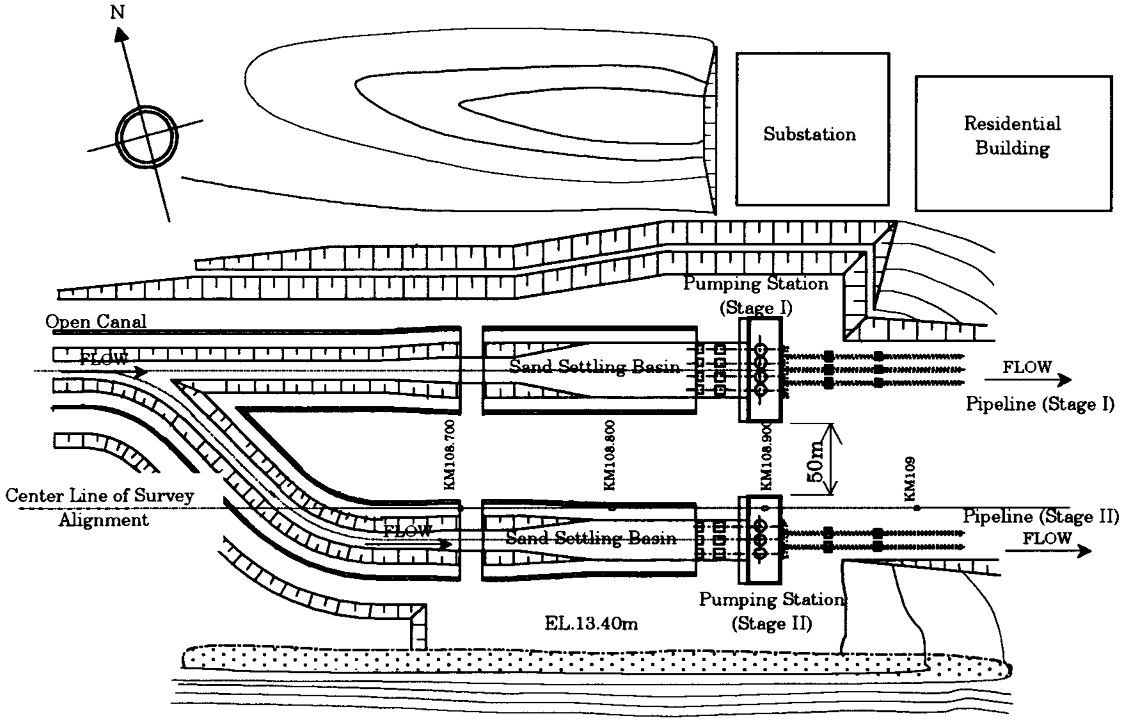


Figure 5.6-4 Preliminary Layout Plan of No.7 Pumping Station

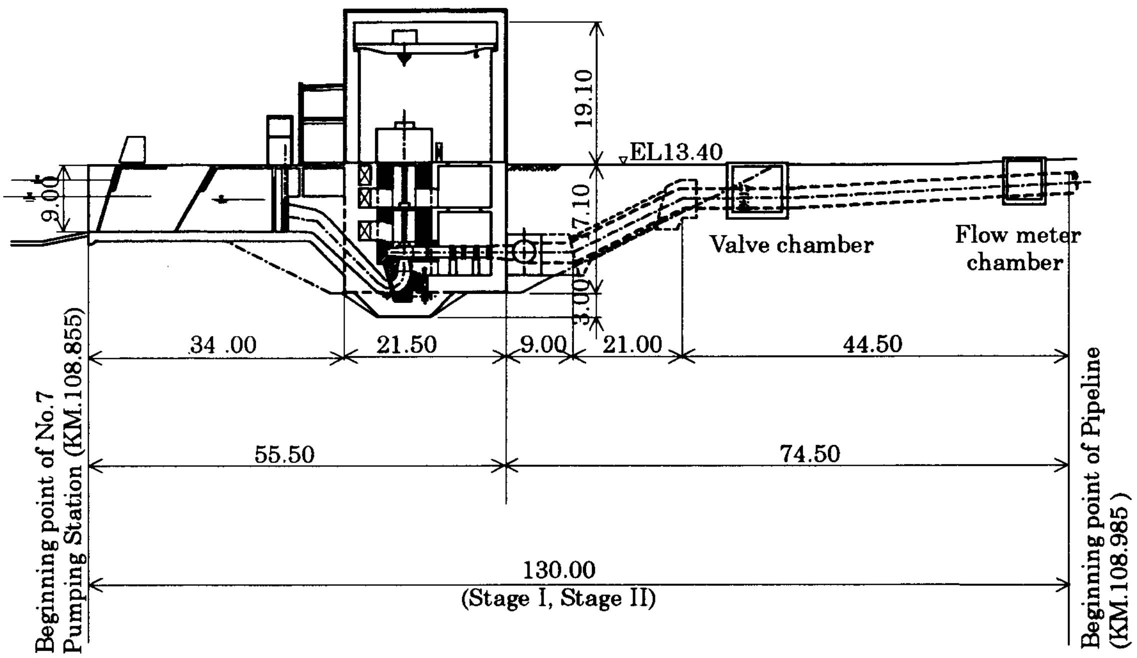


Figure 5.6-5 Longitudinal Profile of No.7 Pumping Station

5.6.2 Hydraulic Design of the Pumping Station

(1) Condition for Hydraulic Design of the Suction Sump

The water level and the major dimensions required for the design of the suction sump are shown in Table 5.6-4. The design suction water level is decided by subtracting the loss head of the screen from the water level of the sand settling basin. The loss head of the screen is estimated at 0.2 m on the condition that movable mechanical trash racks are provided.

Table 5.6-4 Condition for Hydraulic Design of Suction Sump

	Stage I	Stage II
1) Water Level		
a) At Intake of Suction Sump		
- Highest high water level	(HHWL11.94m)	HHWL11.94m
- High water level	HWL 9.90m	HWL 10.70m
- Design water level	NWL 9.90m	NWL 9.90m
- Lowest water level	LWL 8.80m	LWL 8.80m
b) Head loss of screen	0.20m	0.20m
c) At Mouth of Suction Pipe		
- Design suction water level	NSWL 9.70m	NSWL 9.70m
- Lowest suction water level	LSWL 8.60m	LSWL 8.60m
2) Main Pump		
a) Number of Pump unit	3 units and 1 standby unit Total 4 units	2 units and 1 standby unit Total 3 units
b) Suction / Discharge bore	1,900mm / 1,500mm	1,900mm / 1,500mm
c) Designed Discharge	10.827 m^3/sec/unit	10.827 m^3/sec/unit
d) Total Discharge	32.481 m^3/sec	21.654 m^3/sec

Note: Highest high water level is the water level which at the time overflowing crest of spillway.

(2) Shape and Size of the Suction Sump

Study on the shape and size of suction sump shall be considered carefully considering prevention of air-entraining vortexes or submerged vortexes and water surface turbulence, hydraulic and operation conditions.

The following adverse effects on the pump and its facilities may be brought.

- Generation of vibration and noise.
- Suction of air, causing pump performance to deteriorate or pump failure.
- Generation of unstable swirling flows at the impeller entrance, resulting in lock of discharge or motor overload due to excessive discharge.
- Impeller erosion and submerged bearing wear.
- Entrained air in pumped water, causing vibration, surging, and air hammer in water supply pipes.

The following process must be checked to determine the dimension and shape of the suction sump.

- In generally velocity at mouth of suction pipe is approx. 0.50 m/sec or less in order to prevent intrusion of sand soil into suction sump.
- The dimensions of the mouth of suction pipe shall be designed in consideration of the design velocity of approx. 0.50 m/sec.
- The minimum seal height shall be 0.50m for designing of sill elevation.
- The width of suction sump shall be designed based on size and shape of suction pipes and pump equipment.

(a) Dimension of the Mouth of Suction Pipe

As vertical shaft single suction centrifugal pumps are adopted for the No.7 Pumping station, the impeller of the pumps shall be set at elevation EL 1.60 m for the safety against cavitation. Therefor, the deepest elevation of the pump suction pipe is decided at EL(-)3.90 m from the a pump casing and a diameter of the pipe, and the depth from the lowest suction water level to the pump suction pipe is as deep as 12.5 m. The closed type suction method with bend suction pipe is adopted to ensure the stable hydraulic flow and to reduce the construction cost. (Refer to Figure 5.6-7)

The dimension of the mouth of the suction pipe so decided as to give the suction velocity about 0.5 m/sec. The downstream part of the suction pipe is connected to the pump suction pipe (ϕ1,900 mm). Although a square or a circle shape of suction pipe is suitable from the point of hydraulic and easy construction, the rectangular of 5.50 m x 3.70 m with length and breadth ratio 1:1.5 is adopted from an economic point to avoid the deep bottom of the mouth of suction pipe. A bell mouthed profile (R=0.30 m) is adopted for the hydraulic advantage.

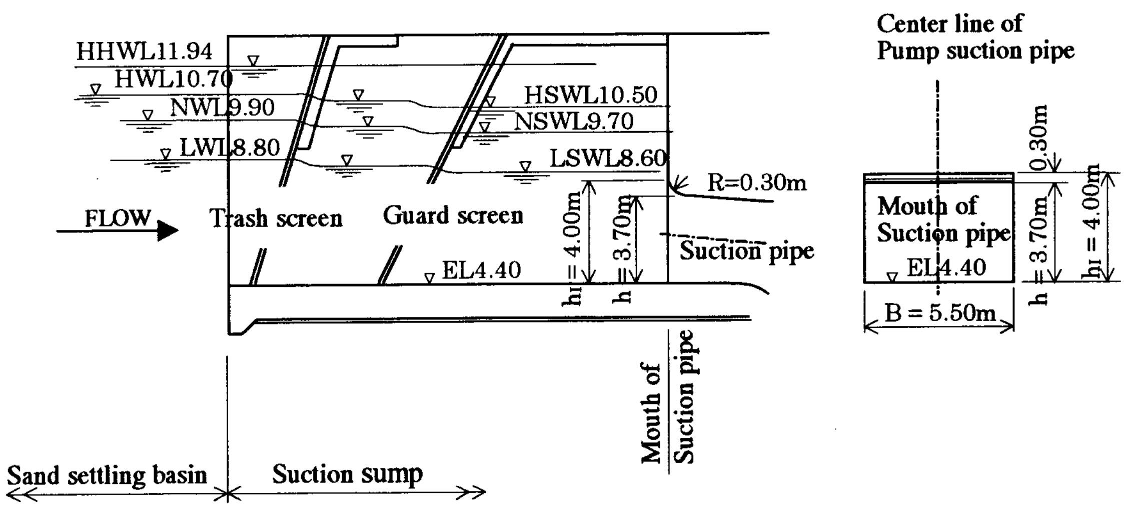


Figure 5.6-6 Dimension of Mouth of Suction Pipe (Stage I & Stage II)

The inflow velocity of the mouth of the suction pipe is given below;

$v = 10.827 / (5.50 \times 4.00) = 0.492 \fallingdotseq 0.50$ m/sec

The bottom elevation of the mouth of the suction pipe is set at EL 4.40 m (LSWL8.60-0.50-3.70) to give minimum 0.50 m depth from the lowest suction water level. The cross sectional area of the suction pipe shall be decreased from the mouth to the pump suction pipe to minimize the head loss by changing constantly the velocity.

(b) The length of Suction Sump

The length of the suction sump is decided in consideration of the necessary lengths for the trash racks, the maintenance bulkhead gates, a control room, offices, auxiliary substation room, etc.

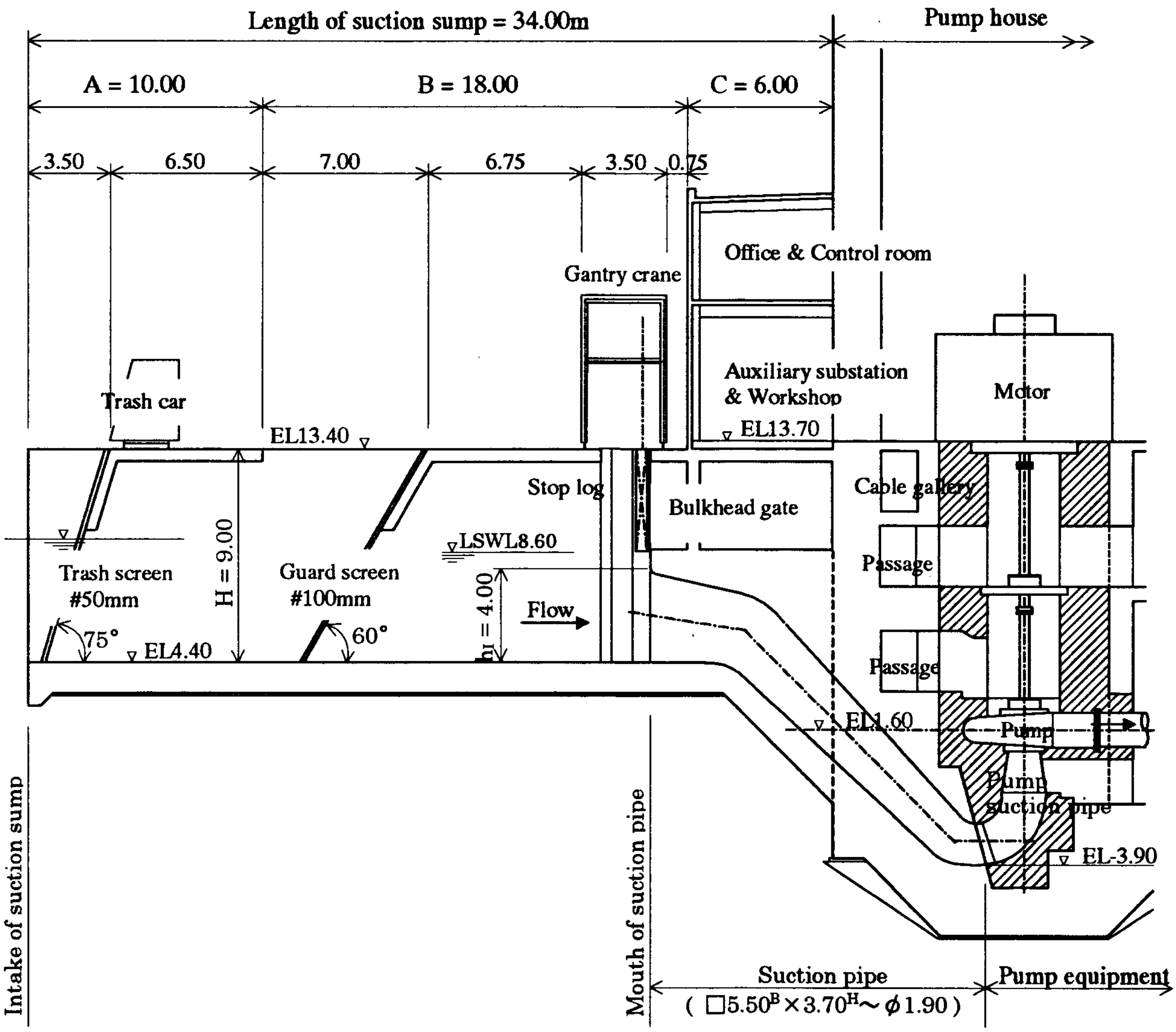


Figure 5.6-7 Length of Suction Sump (Stage I & Stage II)

As illustrated in Figure 5.6-7, the space for the trash screen and the car rack A=10.00 m, the space for the guard screen and the gantry crane to lift up the gates and stop logs B=18.00 m, and the space for the control house and offices C = 6.00 m give the total length of suction sump (A+B+C=) 34.00 m.

(c) The width of Suction Sump

The width of the suction sump is decided by the number and interval of the pumps, and width of the suction intake and the width of side wall. As illustrate in Figure 5.6-8, the number of pump units (Stage I = 4 units), the interval of erection (9.00 m), the width of the suction intake (5.50 m) and the width of side wall give the total width 35.50 m (Stage I).

As same as Stage I, the width of the suction sump of Stage II (3 units) will be 26.50 m.

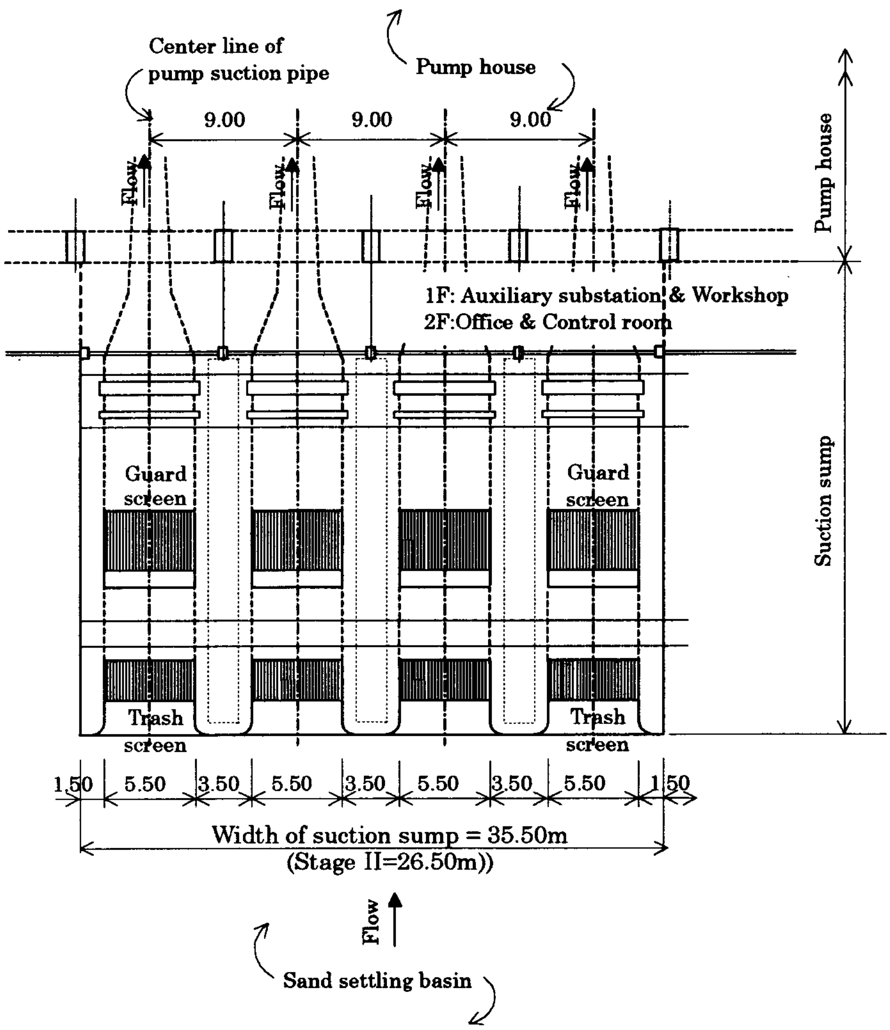


Figure 5.6-8 Width of Suction Sump (Stage I & Stage II)

5.6.3 Basic Design of the Pumping Station

(1) Suction Sump

(a) The elevation of the Platform of the Suction Sump

The elevation of the platform of the suction sump (Stage I & Stage II) is decided at the same level of 13.40 m as the designed ground surface (approx. original ground surface level).

(b) Appurtenant Facilities of Suction Sump

The following appurtenant facilities of suction sump shall be provided for the protection of pumps and the operation & maintenance. (Stage I & Stage II)

(i) Trash Screen and Guard Screen

Trash screens are provided in order to avoid the damage to the pump. Opening of the trash screen is designed at 50 mm in meeting with the size of the pumps. Collected trash from the screen is planned by the trash car for dumping. Meanwhile, opening of the guard screen is designed at 100mm.

(ii) Gate and Stop Logs

The bulkhead gate and one set of stop logs for emergency are provided at the mouth of the suction sump for maintenance and inspection. The bulkhead gate and stop logs are placed in due location.

(iii) Gantry Crane

One set of gantry crane is installed for the erection and dismantlement of the gate and the stop logs.

(2) Dimension of Pump House

As discussed in Section 5.4 Basic Design of Pump Equipment, basic dimension of pump was examined by three methods. The following dimensions of pump house are decided based on the basic dimension.

(a) Width of Pump House

The width of the pump house consists of following A and B. (Refer to Figure 5.6-9)

A : pump unit pitch = 9.0 m

Pump unit pitch is decided by motor maximum dimension 7.20m plus 1.80m of passage width between motors.

B : space of maintenance area = 20.0 m

Necessary space of service area is depend on occupied area of pump and motor parts overhauled such as motor rotor, pump casing cover, impeller, shafts and truck to board these parts considering traveling crane working area. (Refer to Figure 5.6-10)

Therefore the width of the pump house will be 67.0 m (Stage I = 9.0×3 + 20.0×2) and 58.0 m (Stage II = 9.0×2 + 20.0×2).

(b) Length of Pump House

The length of the pump house consists of C, D, E, F & G. (Refer to Figure 5.6-11)

C : width of valve gallery = 7.0 m

D : 1st. embedded concrete wall thickness = 1.0 m

E : block out of pump house = max. dimension of pump casing plus installation working area=7.0 m

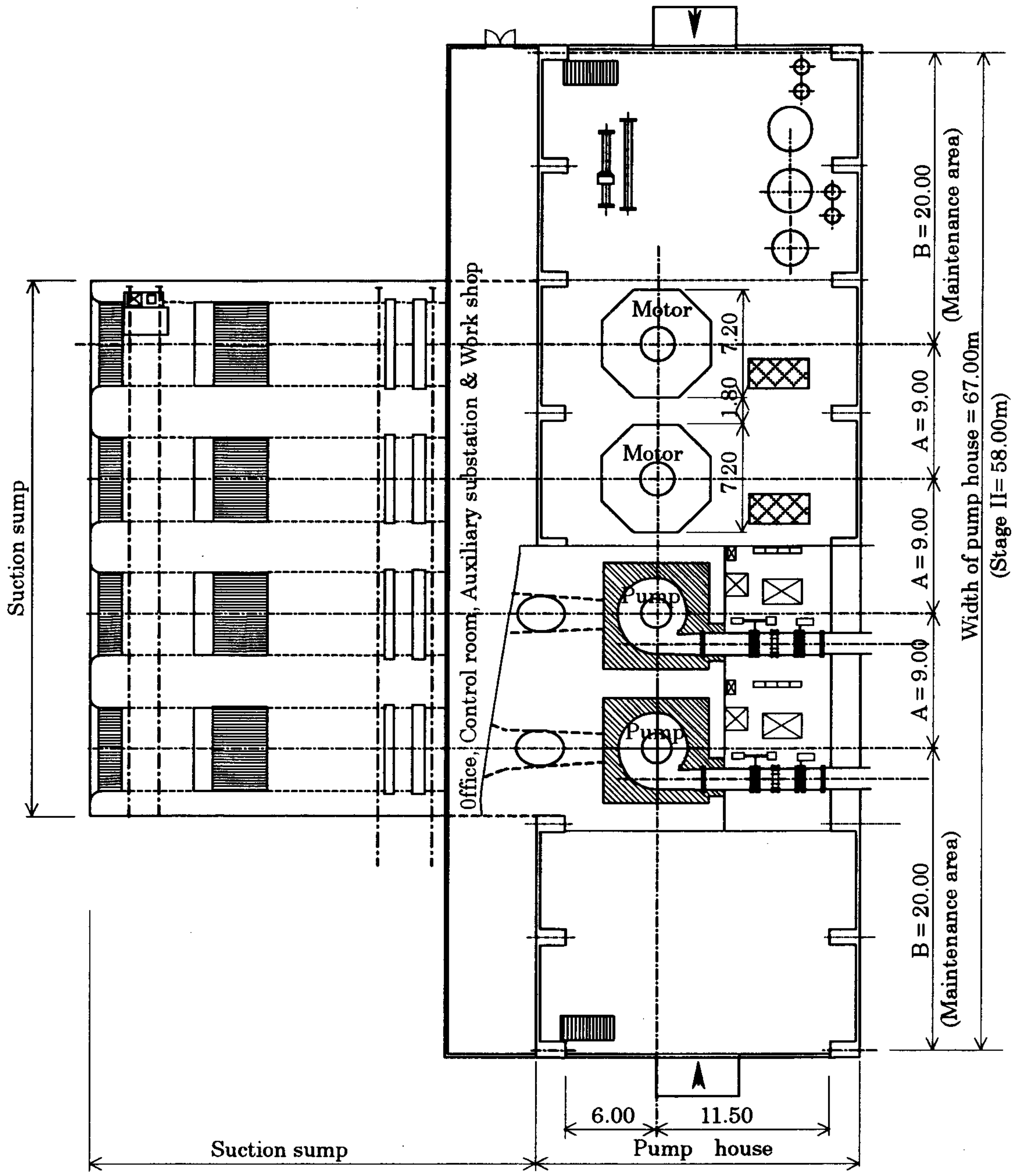


Figure 5.6-9 Width of Pump House (Stage I Stage II)

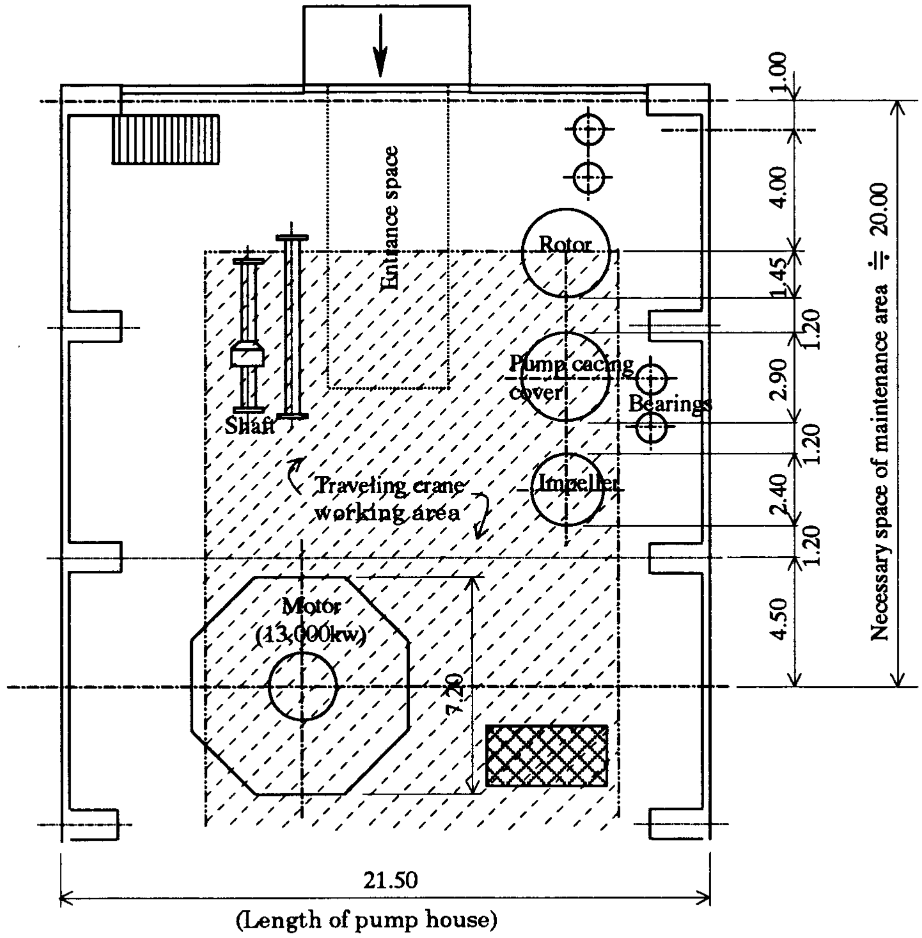


Figure 5.6-10 Necessary Space of Maintenance Area (Stage I & Stage II)

F : passage = 1.5 m

G : wall thickness or column depth of pump house = 2.0 m

Therefore the length of pump house both Stage I and Stage II will be 21.5 m (= 7.0 + 1.0 ×2 + 7.0 + 1.5 +2.0×2).

(c) Height of Pump House (Building)

The height of pump house consists of H, I, J & K. (Refer to Figure 6.7-10)

H : height of motor with exciter removed = 5.3 m

I : height of rotor = 6.0 m

J : space of lifting gear = 2.1 m

K : distance between highest level of crane hock to ceiling = 5.4 m

Therefore the height of pump house both Stage I and Stage II will be 18.8 m (= 5.3 + 6.0 + 2.1 + 5.4).

(d) Depth of Pump House

The depth of pump house consists of L, & M. (Refer to Figure 5.6-11)

L : depth between motor floor and pump impeller = EL13.70-EL1.60 = 12. 1m

The elevation of motor floor will be decided elevation 13.7 m, higher than 0.3 m from around the ground elevation of the pumping station of 13.4 m.

Installated elevation of pump impeller will be decided by the study on the cavitation. It's elevation is 1.6 m of which deducted suction head Hs =7.0 m from lowest suction water level LSWL 8.6m at the mouth of suction pipe. (Refer to Section 5.4.2 Basic Design of Main Pump)

M : depth between pump impeller and bottom of block out of pump house = 6.5 m

This depth consists of dimension of pump casing from impeller and necessary space to install pump suction pipe. (5.5 + 1.0 = 6.5 m)

Therefore, the depth of pump house both Stage I and Stage II will be 18.6 m. (= 12.1 + 6.5)

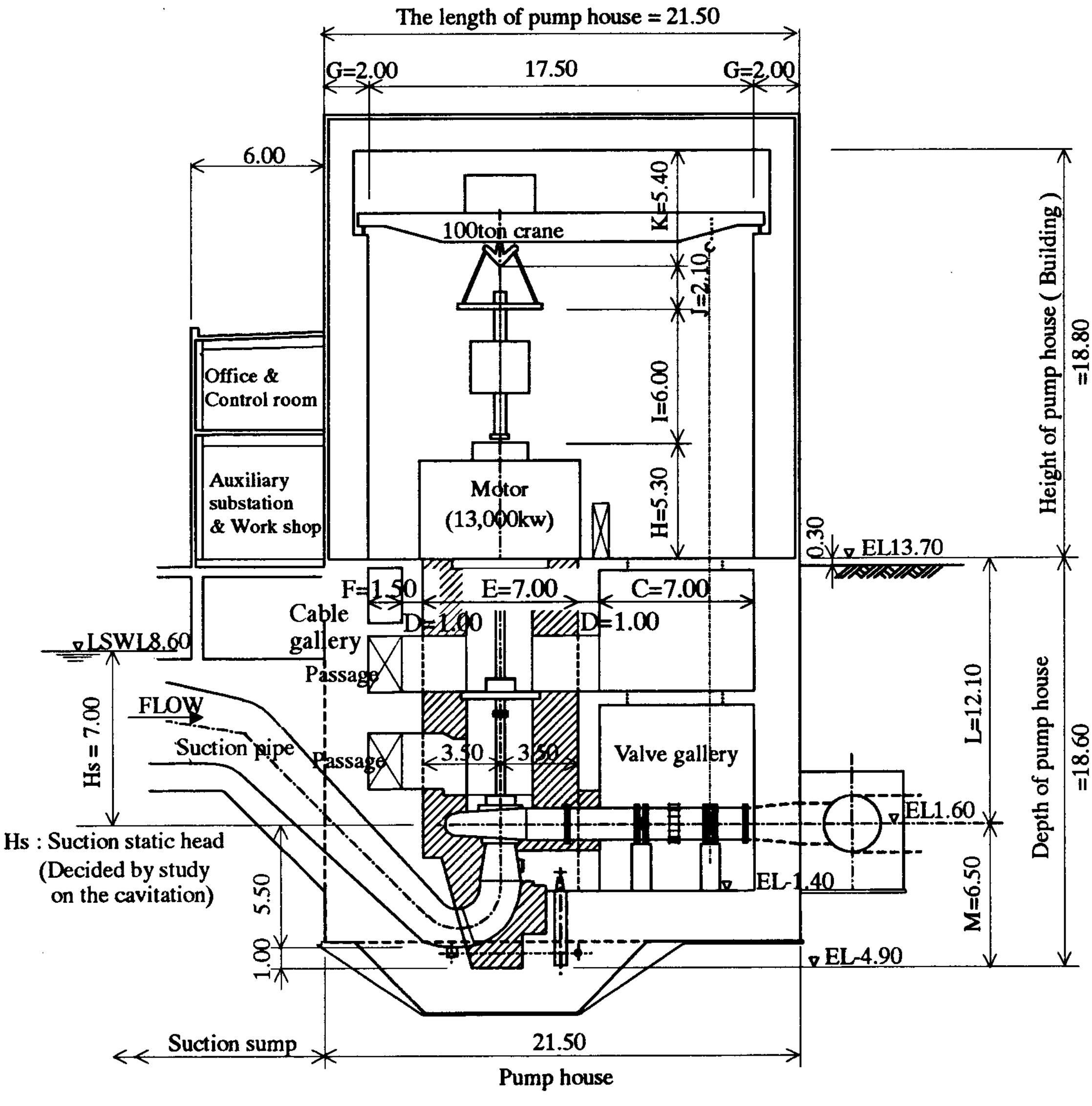


Figure 5.6-11 Width, Height and Depth of Pump House (Stage I & Stage II)

(e) Location of Auxiliary Equipment

The location of auxiliary equipment which is necessary for operating main pump, will be under the maintenance area, showing in Figure 5.6-12.

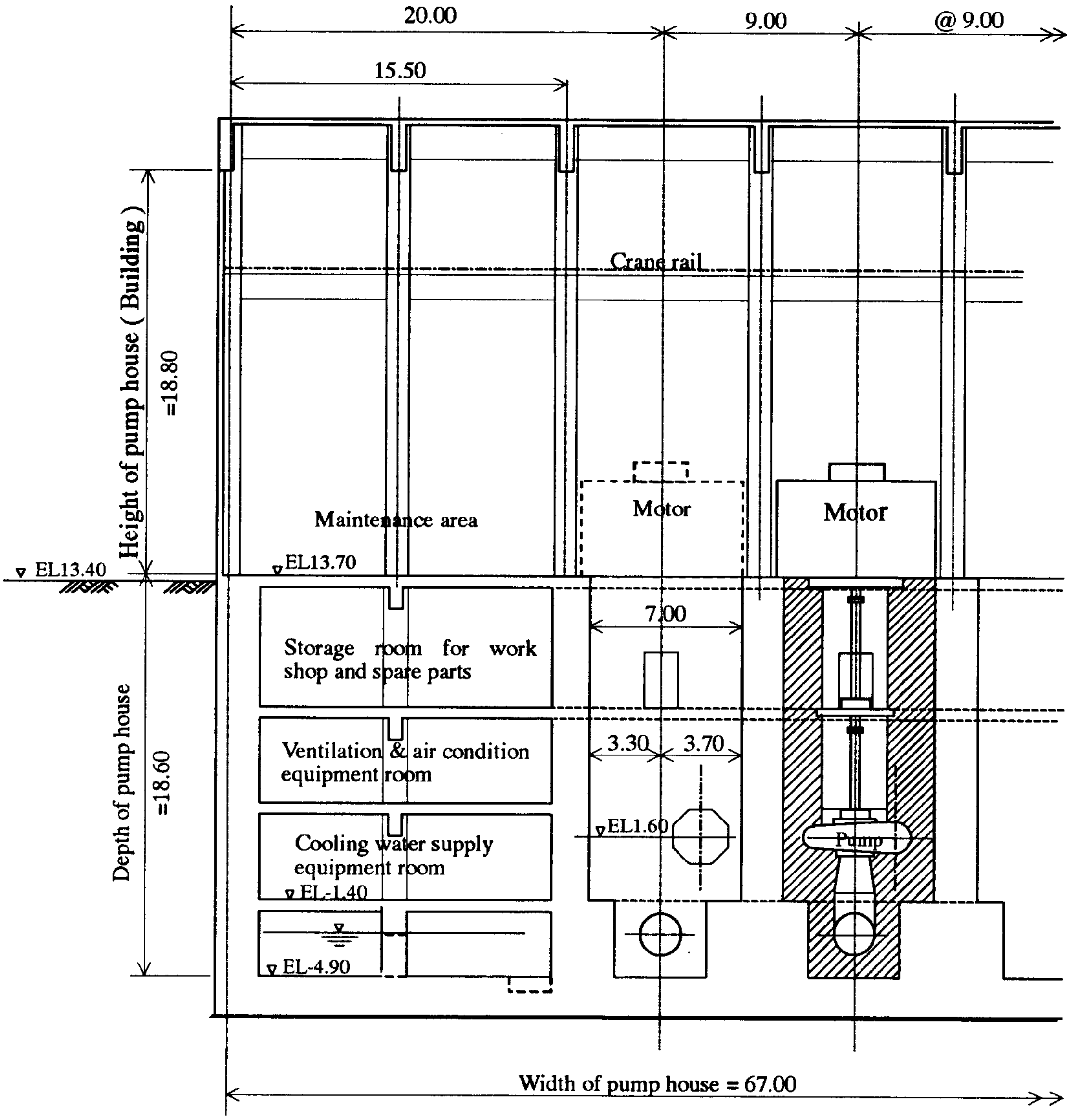


Figure 5.6-12 Location of Auxiliary Equipment (Stage I & Stage II)

(3) Layout of Pumping Station

Basic design drawings of No.7 pumping station for Stage I and Stage II were illustrated in the Drawing No. BC-01 to BC-07.

5.6.4 Foundation Treatment

This section will describe the outline of the foundation treatment of the pumping station based on the results of the bore hole drilling survey.

(1) Sub-surface Condition of Pumping Station

Ten bore holes with depth of 40 m were drilled in and around the site of the pumping station. Most of the bore holes give the similar character of sub-surface condition. The geological log at the pumping house is shown in Figure 5.6-14. The foundation is consist of fine-medium sand partly with thin silty clay. The sub-surface condition is judged favorable for the foundation of pumping station with N value of standard penetration test more than 50.

(2) Examination of Bearing Capacity

The design of the foundation with stability analysis will be made in the detailed design stage, the bearing capacity of the foundation will be estimated by the modified Terzaghi equation.

Long term allowable bearing capacity

$$q_a = \frac{1}{3} \cdot \left(\alpha \cdot C \cdot N_c + \beta \cdot \gamma_1 \cdot B \cdot N_\gamma + \gamma_2 \cdot D_f \cdot N_q\right) \quad (\text{tf/m}^2)$$

Short term allowable bearing capacity

$$q_a = \frac{2}{3} \cdot \left(\alpha \cdot C \cdot N_c + \beta \cdot \gamma_1 \cdot B \cdot N_\gamma + \frac{1}{2} \cdot \gamma_2 \cdot D_f \cdot N_q\right) \quad (\text{tf/m}^2)$$

where q_a : allowable bearing capacity (tf/m^2)

C : cohesion of ground below foundation load surface (tf/m^2)

γ_1 : unit weight of ground below foundation load surface (tf/m^3) When it is below groundwater level, use the submerged unit weight.

γ_2 : average unit weight of ground above foundation load surface (tf/m^3). When it is below groundwater level, use the submerged unit weight

α, β : shape factor

N_c, N_γ, N_q : coefficient of bearing capacity, which is a function of angle of internal friction

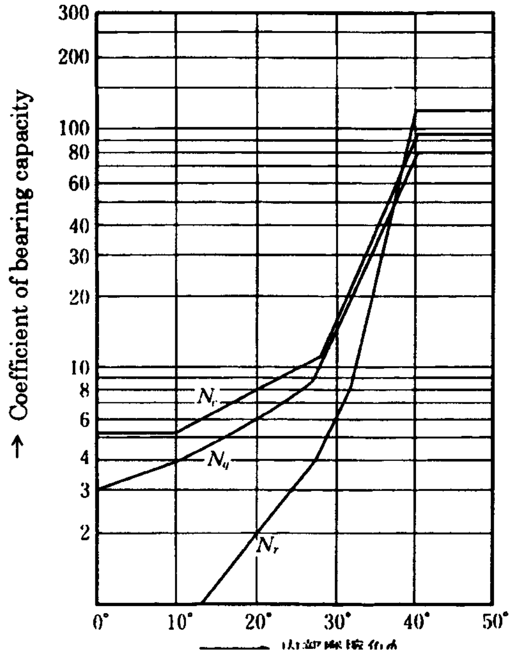
D_f : depth from deepest ground surface adjacent to foundation to foundation load surface (m)

B : minimum width of foundation load surface. In case of circular shape, use diameter (m).

Table 5.6- 5 Shape Factor

Shape of Foundation / Shape Factor	Continuous	Square	Rectangle	Circle
α	1.0	1.3	$1.0+0.3\frac{B}{L}$	1.3
β	0.5	0.4	$0.5-0.1\frac{B}{L}$	0.3

Note; B: Length of short side of rectangle
L: Length of long side of rectangle



→ Angle of internal friction ϕ

Figure 5.6- 13 Coefficient of bearing capacity

Angle of internal friction can be estimated by Dunhum equation ($\phi = \sqrt{12N}$ +15~25). N value shows 50 at Figure 5.6-14. Then Angle of internal friction is estimated at the range from 39 to 49° . Therefore, 35° is adopted as respective Angle of internal friction at the site. Calculated long term allowable bearing capacity of the Pumping Station is as following table.

Table 5.6- 6 Long term bearing capacity of Pumping Station

	B (m)	L (m)	α	β	C (tf/m^2)	N_c	N_γ	N_q	γ_1 (tf/m^2)	γ_2 (tf/m^2)	D_f (m)	q_a (tf/m^2)
Stage I	21.50	52.50	1.12	0.46	0	35	25	30	1.0	1.0	6.60	148
Stage II	21.50	43.50	1.15	0.45	0	35	25	30	1.0	1.0	6.60	146

(3) Selection of Foundation Treatment Method

The bottom of the pumping station is the type of flat foundation and the unit load is estimated at 35 tf/m^2. Whereas the bearing capacity of the foundation is estimated at more than 100 tf/m^2 from the result of the bore hole survey. Spread foundation is adopted for the pumping station. During the construction, poor plain concrete shall be placed when excavated below the design elevation of the foundation.

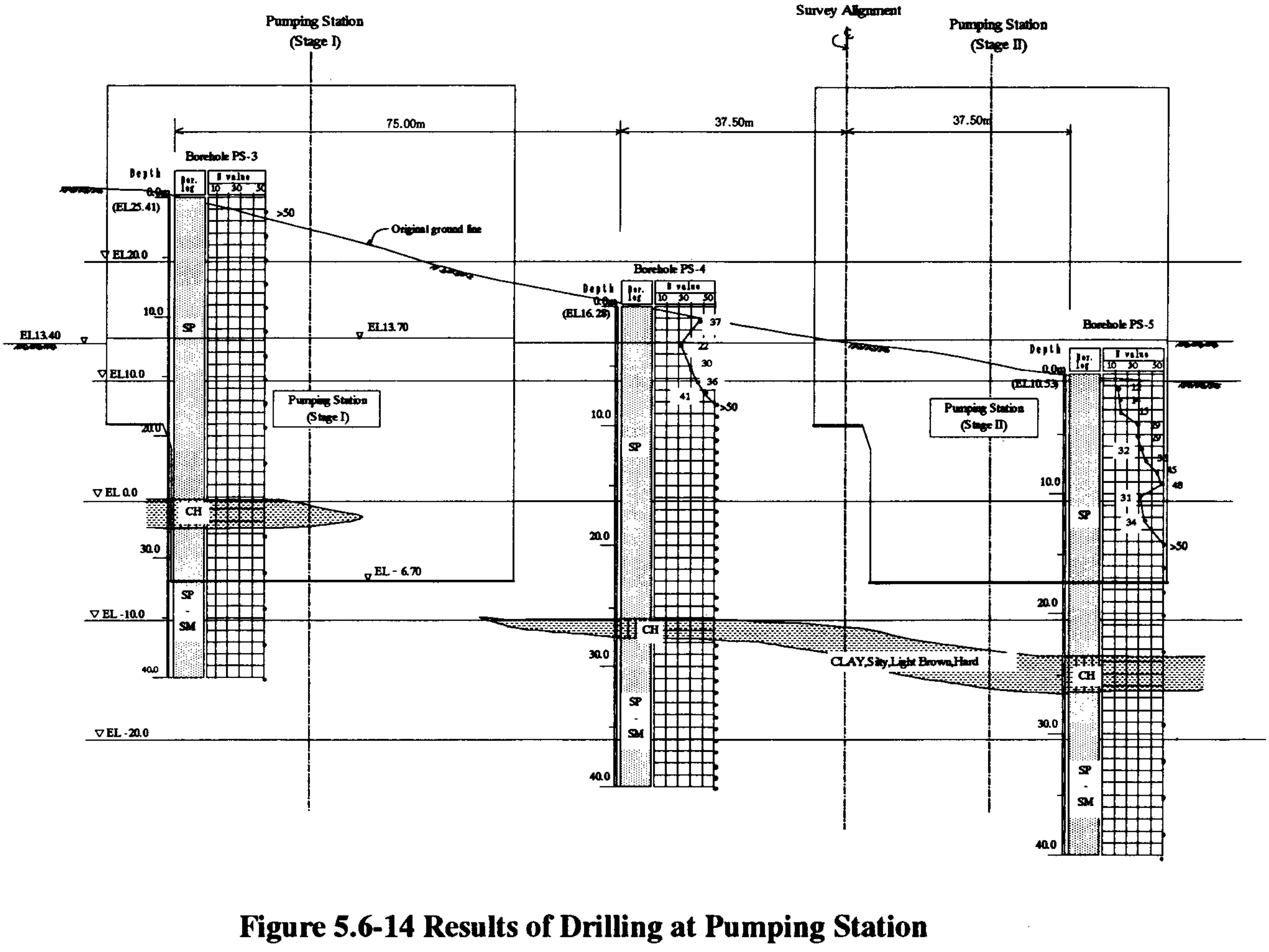


Figure 5.6-14 Results of Drilling at Pumping Station

5.6.5 Basic Design of Sand Settling Basin

(1) Necessity and Location of Sand Settling Basin

The sand blown into the conveyance canal will flow to downstream if the transport capacity of the conveyance canal is larger than the critical friction force. However, the sand will settle where the transport capacity is less than the critical friction force and the sedimentation will occur and blockade the flow area of the conveyance canal. A sand settling basin shall be provided at the upstream of such a section with potential sedimentation.

On the other hand, operation of pumps for sand mixed water will cause the abrasion of pump units which will induce the decrease of efficiency and the trouble. As the sand will blown into the conveyance canal of open canal section where the drifting sand dune is not prevailing, the sand settling basin shall be provided at immediate upstream of suction sump of No.7 Pumping station.

(a) Hydraulic Dimension of Open Canal and Box Culvert

The hydraulic dimensions of open canal and box culvert are shown in the following tables. The maximum discharge and the minimum discharge correspond to the discharge in July and November in the full-scale development.

Table 5.6-7 Hydraulic Dimensions of Open Canal

	Symbol	unit	Stage I		Stage II	
			Min. Discharge	Max. Discharge	Min. Discharge	Max. Discharge
Design Discharge	Q	m^3/s	8.09	32.48	13.93	52.66
Water Depth	H	M	1.17	2.55	1.60	3.31
Flow Area	A	m^2	16.78	43.61	24.32	61.63
Wetted Perimeter	P	m	17.23	23.40	19.16	26.80
Hydraulic Radius	R	m	0.974	1.864	1.269	2.300
Roughness Coefficient	1/n		55	55	55	55
Hydraulic Gradient	I		1 / 12,500	1 / 12,500	1 / 12,500	1 / 12,500
Velocity	V	m/s	0.484	0.745	0.577	0.857
Friction Velocity	U_*	cm/s	2.76	3.82	3.15	4.25
Critical Tractive Particle Size	d_c	mm	1.0	1.8	1.3	2.3
Max. Particle Size	d_{max}	mm	0.8	0.8	0.8	0.8
Required Friction Velocity	U_{*r}	cm/s	2.10	2.10	2.10	2.10
Safety Factor of Friction	F_f		1.31	1.82	1.50	2.02

Table 5.6-8 Hydraulic Dimensions of Box Culvert

	Symbol	unit	Stage I		Stage II	
			Min. Discharge	Max. Discharge	Min. Discharge	Max. Discharge
Design Discharge	Q	m^3/s	8.09	32.48	13.93	52.66
Water Depth	H	m	0.82	2.29	1.19	3.35
Flow Area	A	m^2	12.43	33.89	17.61	49.58
Wetted Perimeter	P	m	21.52	33.12	24.32	41.60
Hydraulic Radius	R	m	0.578	1.023	0.724	1.192
Roughness Coefficient	1/n		67	67	67	67
Hydraulic Gradient	I		1 / 5,000	1 / 5,000	1 / 5,000	1 / 5,000
Velocity	V	m/s	0.658	0.962	0.764	1.065
Friction Velocity	U_*	cm/s	3.37	4.48	3.77	4.83
Critical Tractive Particle Size	d_c	mm	1.4	2.5	1.8	2.9
Max. Particle Size	d_{max}	mm	0.8	0.8	0.8	0.8
Required Friction Velocity	U_{*r}	cm/s	2.10	2.10	2.10	2.10
Safety Factor of Friction	F_f		1.60	2.13	1.80	2.30

(b) Necessity and Location of Sand Settling Basin

The critical friction loss of the sand particle with maximum diameter 0.8 mm is 2.10 cm/sec, whereas the minimum transport capacity of the open canal or box culvert is 2.76 cm/sec. The sand blown into the open canal will flow to the No.7 Pump station through the open canal and the culvert. In order to avoid the pumping of the sand mixed water, the sand settling basin shall provided at the immediate upstream of the No.7 Pumping station.

(2) Basic Design of Sand Settling Basin

(a) Design Conditions

- Design Discharge: (Minimum, Average and Maximum design discharge are the pump capacity of 1, 2 or 3 and 3or 5 units, respectively.)

	Stage I	Stage II
Max. Discharge	32.48 m^3/sec.	21.15 m^3/sec.
Ave. Discharge	21.65 m^3/sec.	15.99 m^3/sec
Min. Discharge	10.83 m^3/sec	10.83 m^3/sec.

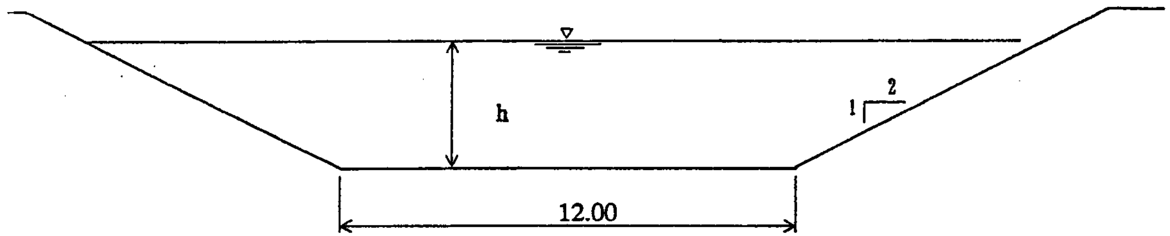
- Designed Elevation of the Canal Bottom at Beginning Point of the Sand Setting Basin : KM 108.48

Elevation of the Canal Bottom: EL. 7.42 m

- Design Water Level at Beginning Point of the Sand Setting Basin : KM 108.48

	Stage I	Stage II in total
Max. Discharge	HWL. 9.97 m	HWL. 10.78 m
Ave. Discharge	MWL. 9.46 m	MWL. 9.97 m
Min. Discharge	LWL. 8.81 m	LWL. 8.81 m

Table 5.6-9 Calculation of Water Depth of Uniform Flow in Open Canal



Dimension

STAGE I		
No. of Pump unit	unit	3
Design Discharge	m^3/s	32.48
STAGE II		
No. of Pump unit	unit	2
Design Discharge	m^3/s	20.18

	Symbol	unit	Case of Design Discharge		Case of Pump Operation				
			STAGE I	STAGE II	1 unit	2 units	3 units	4 units	5 units
Design Discharge	Q	m^3/s	32.48	52.66	10.83	21.65	32.48	43.31	54.14
Hydraulic Gradient	I		0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008
Roughness Coefficient	1/n		55	55	55	55	55	55	55
Assumed Water Depth	h'	m	2.55	3.31	1.39	2.04	2.55	2.98	3.36
Flow Area	A	m^2	43.61	61.63	20.54	32.80	43.61	53.52	62.90
Wetted Perimeter	P	m	23.40	26.80	18.22	21.12	23.40	25.33	27.03
Hydraulic Radius	R	m	1.864	2.300	1.127	1.553	1.864	2.113	2.327
	$R^{2/3}$		1.515	1.742	1.083	1.341	1.515	1.647	1.756
Velocity	V	m/s	0.745	0.857	0.533	0.660	0.745	0.810	0.864
Estimated Discharge	Q'	m^3/s	32.49	52.82	10.95	21.65	32.49	43.35	54.35
Friction Velocity	U_*	cm/s	3.82	4.25	2.97	3.49	3.82	4.07	4.27
Critical Tractive Particle Size	d_{max}	mm	1.8	2.3	1.1	1.5	1.8	2.1	2.3
Design Water Depth	h	m	2.55	3.31	1.39	2.04	2.55	2.98	3.36

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

Friction Velocity $U_* = (980 \times R \times 100 \times I)^{0.5}$

Iwagaki' Formula $dmax = (U^*/1.2)^2 \times 10/55.0$

- Particle Size of Settling Sediment in diameter:

Maximum Size	$d_{max.}$	= 0.8 mm
Average Size	$d_{ave.}$	= 0.5 mm
Minimum Size	$d_{min.}$	= 0.3 mm

(b) Design of Sand Settling Basin

In order to completely settle the sand sediment with diameter of 0.3 mm-0.8 mm, the design velocity of the sand settling basin is decided around 0.15 m/sec.

1) Width of sand settling basin

In consideration of the width of the suction sump of the pumping station, the width of the sand settling basin is decided at 36.0 m of Stage I and 23.5 m of Stage II, respectively.

In order to secure the flow even during the extrusion of sand from the sand settling basin, the basin shall be divided into two parts for only Stage I.

The method of division is in proportion to the number of pumps; 4 units which is to be erected in Stage I. And the width of the settling sub-basins in Stage I is decided at 18.00 m + 1.00 m +18.00 m = 37.0 m

2) Effective depth of sand settling basin

The bottom elevation of the sand settling basin is decided at EL.4.40 m as the same elevation of the suction sump of the pump station. In this case, the velocity in the sand settling basin should be as follows;

Table 5.6-10 Velocity in the Sand Settling Basin

Descriptions	Stage I : Discharge			Stage II : Discharge		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Design Discharge (m^3/s)	10.83	21.65	32.48	10.83	15.99	21.65
Width of Settling Basin (m)	36.00	36.00	36.00	23.50	23.50	23.50
Effective Water Depth (m)	4.40	5.05	5.56	4.40	5.56	6.37
Effective Flow Area (m^2)	158.40	181.80	200.16	103.40	130.66	149.70
Velocity of Flow (m/s)	0.068	0.119	0.163	0.104	0.122	0.144
Optimum Velocity (m/s)	Approx. 0.15	Approx. 0.15	Approx. 0.15	Approx. 0.15	Approx. 0.15	Approx. 0.15

3) Length of sand settling basin

It is planned that the sands with particle size 0.3 mm – 0.8 mm settle completely within the sand settling basin. The necessary length of the sand settling basin is given in the following equation;

$L = F \cdot H \cdot V / V_g$

Where, L : Required length of sand settling basin (m)

H : Effective water depth (m)

V : Velocity in sand settling basin (m/s)

V_g: Final speed of settling (m/s)

F : Safety factor of sand settling

Table 5.6-11 Required Length of the Sand Settling Basin

Descriptions	Stage I : Discharge			Stage II : Discharge		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Design Discharge (m^3/s)	10.83	21.65	32.48	10.83	15.99	21.65
Water Depth : H (m)	4.40	5.05	5.56	4.40	5.56	6.37
Velocity of Flow : V(m/s)	0.068	0.119	0.163	0.104	0.122	0.144
Final Speed : V_g (m/s)	0.022	0.022	0.022	0.022	0.022	0.022
Safety factor : F	2.0	2.0	2.0	2.0	2.0	2.0
Required length : L (m)	27.20	54.63	82.39	41.60	61.67	83.39

Therefor, the length of the sand settling basin is decided at 85.0 m.

4) Capacity of sand settling basin

The capacity of the sand settling basin shall be decided based on the volume of drift sand, the particle size distribution, the volume of sediment in the conveyance canal, the frequency of extrusion of sediment sand, etc.

Volume of drift sand in the open canal

Expected volume of sand would be estimated based on following observation, canal length and some assumptions.

- Deposited sand in the open canal is frequently observed on the one side of inclined wall and on the half-length of bed. (Hc=4.50m, SS=1:2.0, Lb=12.0/2=6.0 m)
- The proportion of deposited canal length is supposed 10 % in totally.
- Mean deposited thickness is measured 0.35m (0.5 to 0.2 m).
- Proposed open canal length is 14.6 km

Sedimentary volume in the canal

$Vo = (5.0^{0.5} \times 4.50+12.0/2) \times 0.35 \times 14{,}600 \times 10\ \% = 8{,}200$ cum./year

Volume to be deposited in the settling basin

Depend on particle size distribution test, mean percentage passing of d=0.3 mm is reported as 46 %.

No.1 Sample (Distance 72km) 56 %

No.2 Sample (Distance 72km) 36 %

No.3 Sample (Distance 72km) 47 %

Sedimentary volume in the basin

$V_1 = V_o \times (1-0.46) = 4{,}400$ cum./year

Design sedimentary depth of settling basin

- Removal of deposited sand — One time per year
- Effective length of basin — Le = 85.0 m
- Safety factor — F = 1.5

$d = V_1 / (WL) = 4{,}400 \times 1.5 / (59.5 \times 85.0) = 1.30\ m \Rightarrow 1.50\ m$

Design bed level of settling basin

Bed level = EL.4.40 m – 1.50m = EL.2.90 m

(c) Removal Method of Deposited Sand in Settling Basin

1) Dimensions and conditions of settling basin

Dimensions and conditions of settling basin are summarized as follows.

- Topographical condition

  Settling basin and pumping station are surrounded by hills or sand dune with elevation of EL.30 m approximately and designed ground level of this area is EL13.00 to13.40.
- Dimensions of settling basin mentioned above are as follows.

Stage	Design Volume	Width	Length	Sediment Height
Stage I	4,400 cu.m	18.0x2=36.0 m	85.0 m	1.4 m
Stage II	1,750 cu.m	23.5 m	85.0 m	0.9 m

- Elevation of bed levels and sedimentary depth are EL.2.90 and 1.4m, respectively.
- Excavator such as backhoe is operated for dredging work at completed open canal site.

2) Dredging method

Based on above condition, natural flushing method by gravity is impossible due to topographical condition Dredging by sand pump will require long pipeline and losses much water if dumped. Dredged soil shall be transported to somewhere in dried condition. Excavation method is divided into two ways, one is from on the ground and the other is in the basin work. The former will be carried out by dragline or clamshell and by sand pump. The latter will be done by tractor shovel and/or bulldozer in the settling basin. This method is best way considering of deposited volume, if request perfect removal of soil.

5.6.6 Basic Design of Pump Houses and Landscaping

The Alternative C has been adopted for the construction method of the No.7 Pumping Station where 4 pumps and 3 pumps are to be located in Stage I and Stage II pump houses respectively. Based on this staged construction method, two (2) pump house buildings of Stage I and Stage II are designed and the basic design drawings are prepared. Basic design of 2 Pump Houses has been proceeded according to the policies and concepts as stated in the Progress Report (2) in order to achieve the most practicable and efficient design for the buildings. The following policies are considered into the design:

- Materials shall be selected carefully with a view to their availability, durability, easy and/or free maintenance and simple construction.
- The building structure shall be designed based on reinforced concrete construction, as this is common practice locally. However, due to the size and span (21.5 m) of the pump house building which are much larger than the existing pump houses, the use of structural steel for the roof beams shall be considered in terms of technical, costs and construction.
- Facilities and space in the building shall be considered and planned in order to fulfil mechanical and electrical requirements, as well as operation and maintenance requirements.

(1) Building Design Concept:

i) The building provided for the Project shall essentially fulfil functional requirements for the pumping station equipment and provide easy operation and maintenance.

ii) Construction materials shall be selected taking into consideration of the severe climatic conditions of the regional atmosphere.

iii)The building architecture shall follow standard practice and care will be taken to provide safe conditions and to use durable materials.

iv) The building shall have a reasonable finishing standard in accordance with its functions.

(2) Scope of Works::

i) Basic design of Stage I and Stage II Pump Houses (above Ground Level). Detailed design is to be carried out only for Stage I Pump House building.

ii) Design of overhead crane (100 t) and the rails is to be undertaken by other disciplines, however the accurate size and loading data of the overhead crane are required for architectural and structural design of the building.

(3) Standards to be used:

Any authorized national or local standards and codes in Egypt will be considered in the design of the building. However, the internationally recognized codes and practices such as the following American standards:

- ACI American Concrete Institute
- ASTM American Society for Testing Materials

(4) Function and Layout Requirements

The purpose of the building and structure is :

i) To allow proper installation, operation and maintenance of all equipment required and,
ii) to allow reasonable working conditions for staff and workers in compliance with the laws and regulations in Egypt.

Floor plans, sections and elevations for the Pump Houses are defined in the drawings. Floor area breakdown of each room and the summary are shown in the drawing Nos. BB-01 and BB-08 for the Stage I and Stage II pump houses respectively. The following facilities and the area (in sq.m) are provided in the Stage I and Stage II pump house buildings:

	Stage I	Stage II
(a) Ground Floor:		
- Pump Room and Maintenance Area	1,440	1,247
- Auxiliary Substation	311	261
- Workshop & Storage	43	43
(Sub-total)	(1,794)	(1,551)
(b) First Floor:		
- Control Room	68	68
- Office	42	42
- Manager's Room	20	20
- Conference Room	36	-
- Rest Room	20	20
- Toilets	25	25
- Pantry	4	4
- Corridor & Stairs	91	78
(Sub-total)	(306)	(257)
Total:	2,100	1,808

(5) Physical requirements:

In order to avoid unreasonable heat accumulation in the building from natural sun-light, the following criteria is considered for the design of the building.

i) An adequate number of openings will be provided for natural ventilation.
ii) Insulation will be provided on the roof slab.
iii) Appropriate materials for the building enclosures will be used.

(6) Building Materials and Architectural Finishes:

(a) Building Materials

Building will be of reinforced concrete framing with masonry brick or block wall construction. Based on the existing pumping stations and where practical, the similar materials, proprietary products and architectural appearance shall be used in order to ensure satisfactory aesthetic design and the use of standard products and dimensions. Basic building materials will be proposed and designed based on the following criteria and considerations:

(i) Use of locally supplied materials as much as possible. Locally available materials will enable high efficiency and practicable construction which will result in lower cost.

(ii) Resistance to environmental conditions, i.e. temperature, wind, dust, moisture and sunlight.

(iii) Physical characteristics of materials: Strength, durability, easy maintenance and cleaning

(b) Architectural Finishes

The basic interior and external architectural finish for the Stage I and Stage II Pump Houses are defined on the Drawing Nos. BB-01and BB-08, respectively.

(i) External finishes:

- Roof: Water proofing with rigid insulation and covered with tiles.
- Wall: Brick wall construction and plastered and painted.

(ii) Floors:

- Unglazed ceramic tiles (150 mm x 150 mm or 200 mm x 200mm) for Pump Room and Auxiliary Substation and Control Room as well as Toilets and Pantry.
- Terrazzo tiles (250 mm x 250 mm) for administrative area such as Office, Manager's Room and Conference Room

(iii) Walls:

- Glazed ceramic tiles (150 mm x 150 mm) up to 2 m height from the finished floor level and paint for the remaining area above 2 m on plastered wall, for Pump Room, Auxiliary Substation, Control Room toilets and pantry.
- Paint on plastered masonry or RC structure walls for the remaining rooms.

(iv) Ceiling

- Generally paint on plastered RC structure.

(v) Doors and Windows:

- Main access door: Double swing steel door (partially glazed, approx. 4 m wide and 5 to 6 m high) with paint finish.
- All windows in the Pump Room and Auxiliary Substation area are aluminum framed bottom hinged windows. Windows will be located at 2 levels, i.e. 2 m above floor level and in the area between crane girder and the ceiling.

(vi) Miscellaneous steel and metal works:

- Handrail: Steel with oil paint.
- Ladder: Steel (caged) with oil paint
- Hatch: Steel checkered plate with oil paint.
- Down pipe: Cast iron pipe with oil paint.

(7) Landscaping

Design of landscaping related to the building shall be developed together with the total landscaping design taking the necessary irrigation systems into consideration.

(8) Building Services:

(a) Ventilation and air conditioning:

Rooms will be naturally ventilated by providing a sufficient number of openings. However mechanical ventilation will be considered for the rooms of Workshop/Storage and Toilets/Shower. No air conditioning is considered as defined in the finishing schedule on drawing Nos. BB-01 and BB-08. However split type or window type air conditioners can be installed to the room where Mechanical and Electrical equipment requires (to be defined and designated where lower temperature required for equipment operation).

(b) Lighting and building electrical services:

(i) Scope of Works:

Interior lighting system including convenient socket outlets within the building and exterior lighting for exterior plant area.

(ii) Design Policy:

The design for both the interior and exterior lighting shall maximize the use of energy efficient sources as appropriate for the area served.

(iii) Illumination levels:

Interior and exterior lighting systems will be designed based on the following minimum average illumination levels for each type of room:

	Illumination Levels (lx)
-Pump Room	150-200
-Switch Gear Room	150-200
-Office and Control Room	300
-Workshop	300
-Valve Gallery	150-200
-Exterior plant area/ perimeter road	10-15

(c) Plumbing and Drainage

(i) All plumbing works (drainage and water) will be designed in accordance with the rules and regulations of Egypt.

(ii) Plumbing work shall include provisions of all fixtures, equipment and appurtenances such as:

-Piping and auxiliary materials
-Plumbing fixtures and materials
-Equipment
-Valve and special items

(iii) Plumbing and drainage systems as described are within buildings or structures only

(d) Fire Protection and Fire Fighting

Fire extinguishers will be provided in the buildings. For every 100 m2 of floor area, there will be one fire extinguisher. A floor area of less than 100 m2 will have at least one fire extinguisher. Fire protection system will be designed in compliance with local standards and practices applicable to the facility.