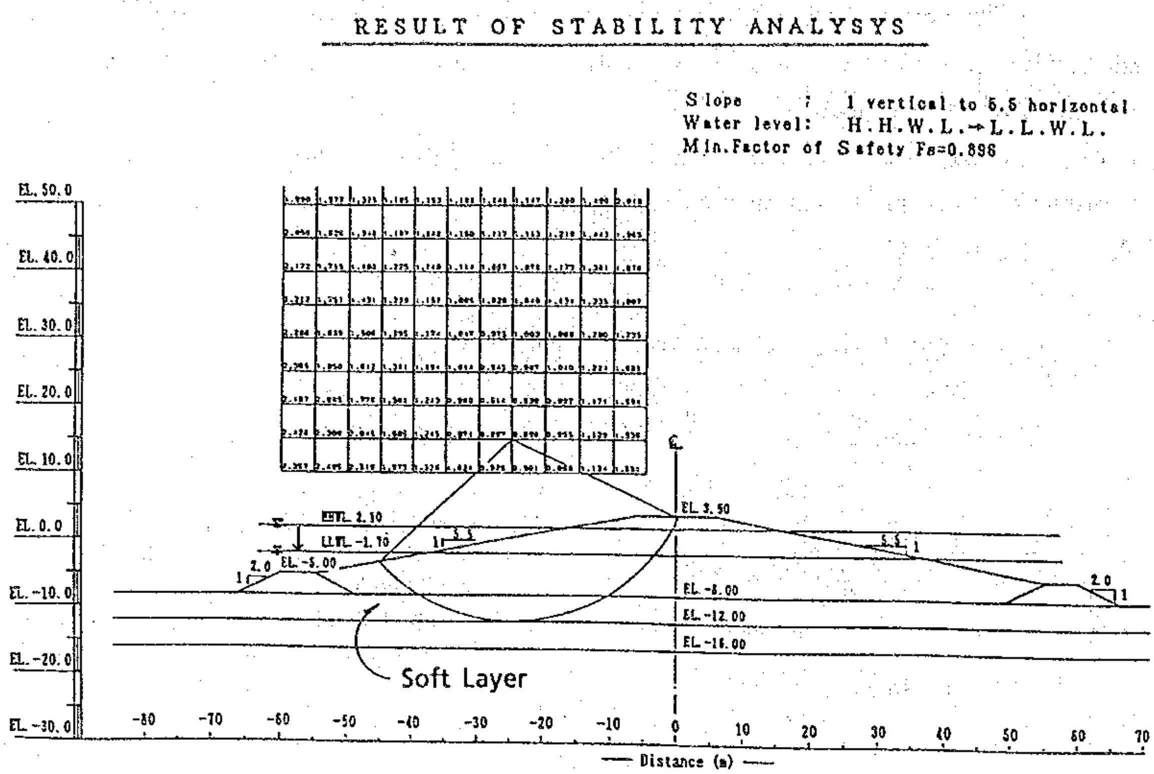
FIGURE 6-2 STABILITY ANALYSIS OF RAPID DRAWDOWN IN WATER LEVEL
(CASE OF UNIMPROVED SOFT LAYERS)



The soft layers found in the dam foundation are considered necessary to be improved, taking into consideration the fact that settlement after embankment will continue for about 29 years after completion of the construction works and there may be a danger of heavy slip failure occurrence through the aforementioned soft layers.

6.3.3 Design of Riverbed Foundation

1) General

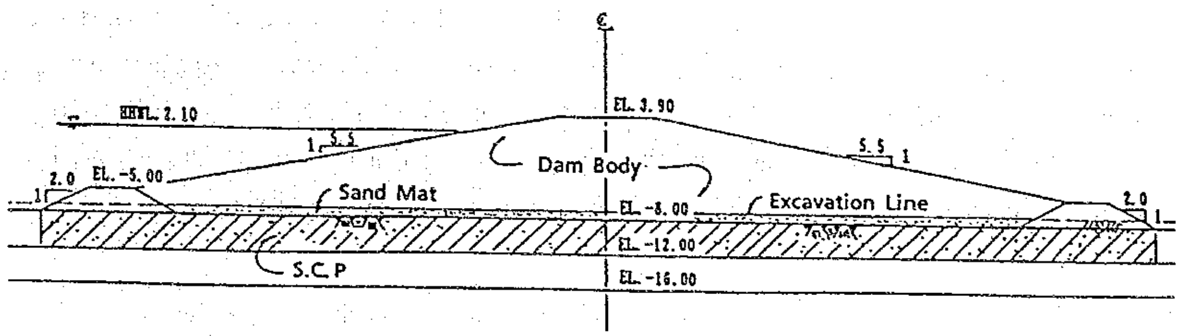
The improvement of the soft foundation at the riverbed aims at increasing stability through strengthening resistance to slip as well as decreasing residual settlement through acceleration of consolidation settlement. In this case, the replacement method and sand compaction pile method are considered, and the soil improvement method shall be determined through the comparative study on the above two methods.

For reference, the replacement method is that soft layers shall be excavated to be eliminated for backfilling with sufficient quality sandy materials taken from borrow area.

2) Sand Compaction Pile Method

The soft foundation layers around the riverbed can be improved with sand compaction piles before implementation of the embankment work of the closure dam.

FIGURE 6-3 SKETCH OF IMPROVEMENT WORKS BY SAND COMPACTION PILE METHOD



Sand compaction piles, in considering underwater construction, shall be placed with diameters as large as 2000 mm and casing diameter of 1500 mm. The pile intervals shall be determined by using the following Barron's equation. (Refer to Appendix 6. 1. 2)

After determining the pile intervals, the stability analysis shall be made with the slip circle slice method as the composite ground.

$$U(Th) = 1 - \exp\left(-\frac{8Th}{F(n)}\right)$$

$$F(n) = \frac{n^2}{n^2 - 1} \ell_n n - \frac{3n^2 - 1}{4n^2}$$

$$n = de/dw$$

$$Tn = (Cv/de^2)\, t$$

Where: U(Th); Consolidation degree for time factor

Th; Time coefficient for consolidation degree

de; Circular conversion of water collecting capacity in diameter per pile (cm)

dw; Diameter of sand compaction pile (200 cm)

Cv; Consolidation coefficient in horizontal direction (cm^2/day)

t; Time factor for necessary consolidation degree (day)

Drilling intervals shall be determined so that the consolidation degree can reach more than 80 percent for about one-and-a-half years from starting to completing of the works. The consolidation factor shall take the following value in considering the fact that the consolidation degree (settlement speed) will slow down when the replacement ratio exceeds about 20 percent.

$$Cv/Cvo = 0.2$$
$$Cv = 0.2 \times Cvo$$
$$= 0.2 \times 6 \times 10^{-3}\ cm^2/min$$
$$= 1.2 \times 10^{-3}\ cm^2/min = 1.73\ cm^2/day$$

Where: Cv; Consolidation coefficient for consolidation analysis

Cvo; Consolidation coefficient obtained from soil tests ($6\times10^{-3} cm^2/min$)

As a result of the analysis, the relationship among pile drilling intervals, consolidation degree and replacement ratio can be shown as follows, and the pile interval shall be taken as 2.4 m when consolidation degree exceeds 80 percent.

TABLE 6-2 PILE INTERVALS AND CONSOLIDATION DEGREE

Pile Intervals (%)	Consolidation Degree (%)	Replacement Ratio (%)
2.6	66.7	46.4
2.5	76.1	50.2
2.4	83.9	54.5

The stability analysis by slip circle slice method is made with the design values after soil improvement by sand compaction piles method. The design values required are shown in Table 6-3.

TABLE 6-3 DESIGN VALUES FOR STABILITY ANALYSIS

Zone		Density			Shear Strength	
		$\gamma t\ (t/m^3)$ *1	$\gamma sat\ (t/m^3)$ *2	$\gamma sub\ (t/m^3)$ *3	C (tf/m_3) *4	ϕ (°) *5
Earthfill Zone		1.50	1.80	0.80	0	25
Rockfill Zone		1.80	2.20	1.20	0	35
Soft Layer	Unimproved Ground	1.55	1.55	0.55	Cu=1.5(P≦7.5 tf/m^3)*6 Cu=1.5+0.2(P-7.5)U (P>7.5tf/m^2)	0
	Sand Compa-ction Gound	1.80	2.00	1.00	0	30
	Composite Ground	1.69	1.80	0.80	0.45 Cu	17.6
Intermediate Layer		1.98	1.98	0.98	6.5	0
Foundation Layer		2.07	2.07	1.07	21.7	0

*1 Wet density *2 Saturated density *3 Submerged density *4 Cohesion
*5 Friction angle *6 P : Effective load of objective ground
U : Consolidation degree of objective ground

The results of the stability analysis conducted are shown below.

TABLE 6-4 RESULTS OF STABILITY ANALYSIS (AFTER SOIL IMPROVEMENT BY SAND COMPACTION PILE METHOD)

Case	Water Level	Calculation		
		Safety Factor		Allowable Safety Factors
Case 1	Constant W.L. (H.H.W.L.)	2.074	>	1.20
Case 2	〃 W.L. (L.L.W.L.)	1.978	>	1.20
Case 3	Drawdown W.L. (H.H.W.L.) → (L.L.W.L.)	1.120	>	1.10

As shown in the above table, the allowable safety factors can be satisfied in a number of cases.

3) Determination of River Bed Improvement Method

Economic comparison between the replacement method and sand compaction pile method shows the following results:

TABLE 6-5 COMPARISON OF CONSTRUCTION COST BETWEEN REPLACEMENT METHOD AND SAND COMPACTION PILE METHOD

Work Item	Unit Price (฿)	Replacement Method		Sand Compaction Pile Method	
		Quantity	Total	Quantity	Total
1. Foundation Excavation	80	845.0 m^3	67,600	138.0 m^3	11,040
2. Embankment					
2.1 Riprap	820	100.4 m^3	82,328	100.4 m^3	82,328
2.2 Embank. with	120	1132.1 m^3	135,852	667.1 m^3	80,052
Borrow Materials	700	266.0 m^3	186,200	66.0 m^3	46,200
2.3 Embankment with Rock Materials					
3. Sand Compaction Pile	250	-	-	101.0 m^3	25,250
Works	2,100	-	-	292.6 m^3	614,460
3.1 Sand Mat					
3.2 Sand Compaction Pile (underwater construction)					
Construction Cost (unit price per meter in direction along the dam axis)			471,980		859,330

As shown in the above table, the replacement method is more economical in terms of unit cost per meter in direction along the dam axis than the sand compaction pile method by about ฿387,000.

Comparative study of the two methods illustrates that the replacement method is easier in construction work, shorter in construction period, lower in cost, etc. than the sand compaction pile method. Under these conditions, the riverbed improvement shall be executed by the replacement method.

6. 3. 4 Design of Abutment Foundation

1) Outline

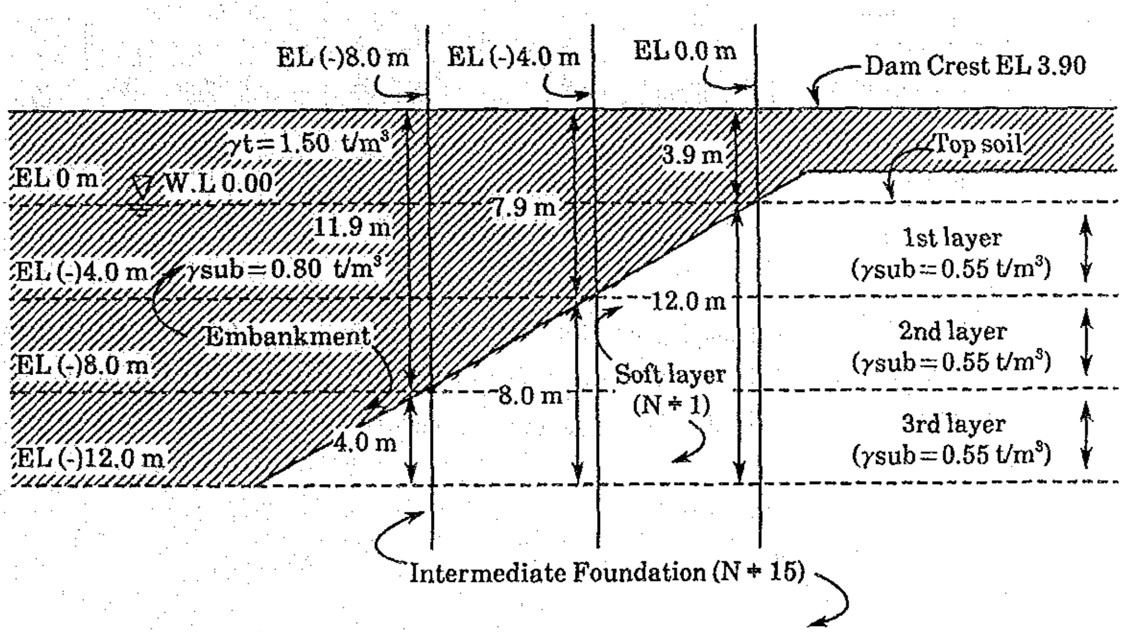
As mentioned in paragraph 6. 1 on topography and geology, the soft layers distribute from the right abutment to riverbed foundation at about EL (-)12 m at the lowest and in the left abutment foundaton at EL (-)8.0 to EL (-)10.0 m at the lowest. In the case where the closure dam is constructed over such a soft foundation, stability of the dam body cannot be ensured as described in 6. 3. 2 on the study of the soft layers of the dam foundation, and improvement is essential. For the soft layers of the dam foundation, the soft layers are to be totally eliminated for the river bed, but the total replacement is difficult for the abutment of the both banks. Since the closure dam is to be construction on those soft layers, the sand compaction pile method shall be adopted to improve the unfavorable soft foundation. (Refer to Appendix 6. 1. 3)

2) Determination of the Improvement Extent for Soft Foundation

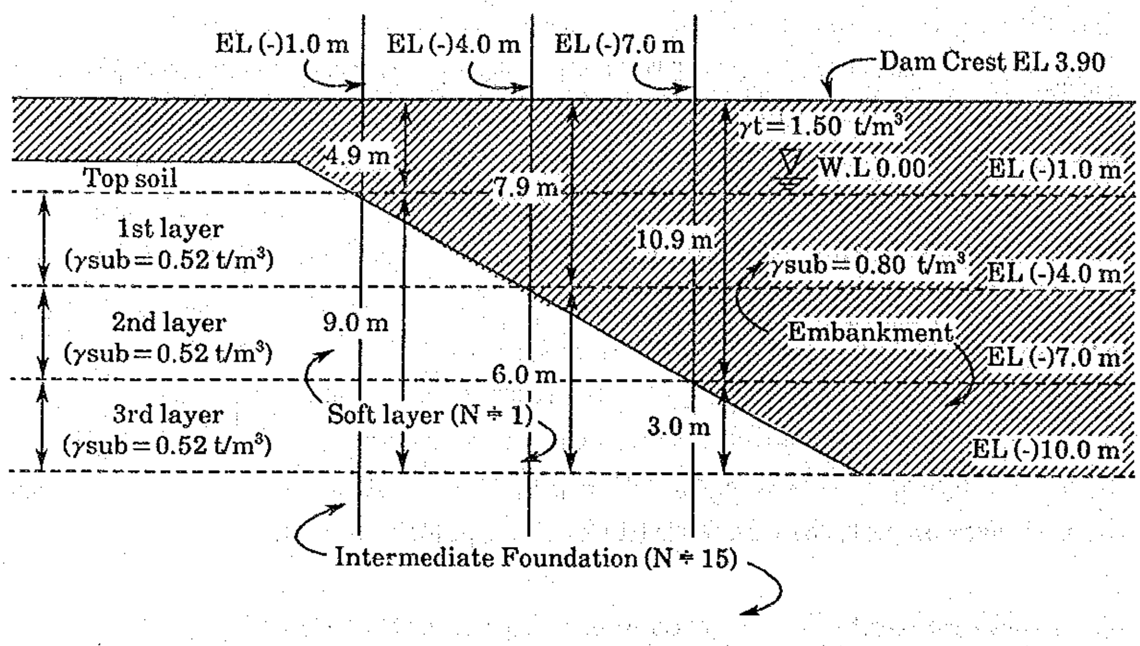
For determining the extent of the improvement for soft foundation, stability analysis is made in conditions of the dam foundation by EL 0 m, EL (-)4.0 m and EL (-)8.0 m at the right abutment, and EL (-)1.0 m, EL (-)4.0 m and EL (-)7.0 m at the left abutment, respectively, as shown in Figure 6 - 4.

FIGURE 6 - 4 PROFIEL OF ABUTMENT FOUNDATION AT THE CLOSURE DAM

(RIGHT ABUTMENT)



(LEFT ABUTMENT)



The design vales of the soft layers found in the both abutment areas are shown in the following table.

TABLE 6 - 6 DESIGN VALUES OF THE STABILITY ANALYSIS FOR THE ABUTMENT FOUNDATION

Position		Density			Shear Strength	
		γt (t/m³) *1	γsat (t/m³) *2	γsub (t/m³) *3	C (tf/m²) *4	ø (°) *5
Soft Layer	Right Abutment	1.55	1.55	0.55	Cu=1.5(P≦7.5 tf/m³) *6 Cu=1.5+0.2(P-7.5)U (P>7.5 tf/m³)	0
	Left Abutment	1.52	1.52	0.52		0

*1 Wet density *2 Saturated density *3 Submerged density *4 Cohesion
*5 Friction angle *6 P : Effective load of objective ground
U : Consolidation degree of objective ground

For further references, the design values for the intermediate layers and the foundation layers for the dam embankment foundation shall be the same as shown in Table 6 - 3. The results of the stability analysis are shown in table 6-7.

TABLE 6-7 RESULT OF STABILITY ANALYSIS FOR UNIMPROVED LAYERS

<RIGHT ABUTMENT>

*1 Profile for Analysis	Stability Analysis by Slip Circle Method					Consolidation (Settlement)	
	Case	Water Level *2	Safety Factor		Allowable Safety Factor	Total Consolidation (cm)	Time Required to Reach U80 (year)
I	Case 1	Constant W.L. (H.H.W.L.)	1.498	>	1.20	50.9	28.8
	Case 2	〃 W.L. (L.L.W.L.)	1.117	<	1.20		
	Case 3	Drawdown W.L. (H.H.W.L. → L.L.W.L.)	0.896	<	1.10		
II	Case 1	Constant W.L. (H.H.W.L.)	1.410	>	1.20	89.9	115.1
	Case 2	〃 W.L. (L.L.W.L.)	1.024	<	1.20		
	Case 3	Drawdown W.L. (H.H.W.L. → L.L.W.L.)	0.872	<	1.10		
III	Case 1	Constant W.L. (H.H.W.L.)	1.901	>	1.20	94.8	258.9
	Case 2	〃 W.L. (L.L.W.L.)	1.460	>	1.20		
	Case 3	Drawdown W.L. (H.H.W.L. → L.L.W.L.)	1.314	>	1.10		

*1 Profile for analysis I: Foundation excavation elevation EL (-)8.0 m
Profile for analysis II: Foundation excavation elevation EL (-)4.0 m
Profile for analysis III: Foundation excavation elevation EL (-)0.0 m
*2 H.H.W.L. 2.10 m L.L.W.L. (-)1.70 m

<LEFT ABUTMENT>

*1 Profile for Analysis	Stability Analysis by Slip Circle Method					Consolidation (Settlement)	
	Case	Water Level	Safety Factor		Allowable Safety Factor	Total Consolidation (cm)	Time Required to Reach U80 (year)
I	Case 1	Constant W.L. (H.H.W.L.)	1.618	>	1.20	30.7	16.2
	Case 2	〃 W.L. (L.L.W.L.)	1.228	>	1.20		
	Case 3	Drawdown W.L. (H.H.W.L. → L.L.W.L.)	0.953	<	1.10		
II	Case 1	Constant W.L. (H.H.W.L.)	1.526	>	1.20	44.1	64.7
	Case 2	〃 W.L. (L.L.W.L.)	1.115	<	1.20		
	Case 3	Drawdown W.L. (H.H.W.L. → L.L.W.L.)	0.931	<	1.10		
III	Case 1	Constant W.L. (H.H.W.L.)	2.074	>	1.20	44.5	145.6
	Case 2	〃 W.L. (L.L.W.L.)	1.601	>	1.20		
	Case 3	Drawdown W.L. (H.H.W.L. → L.L.W.L.)	1.416	>	1.10		

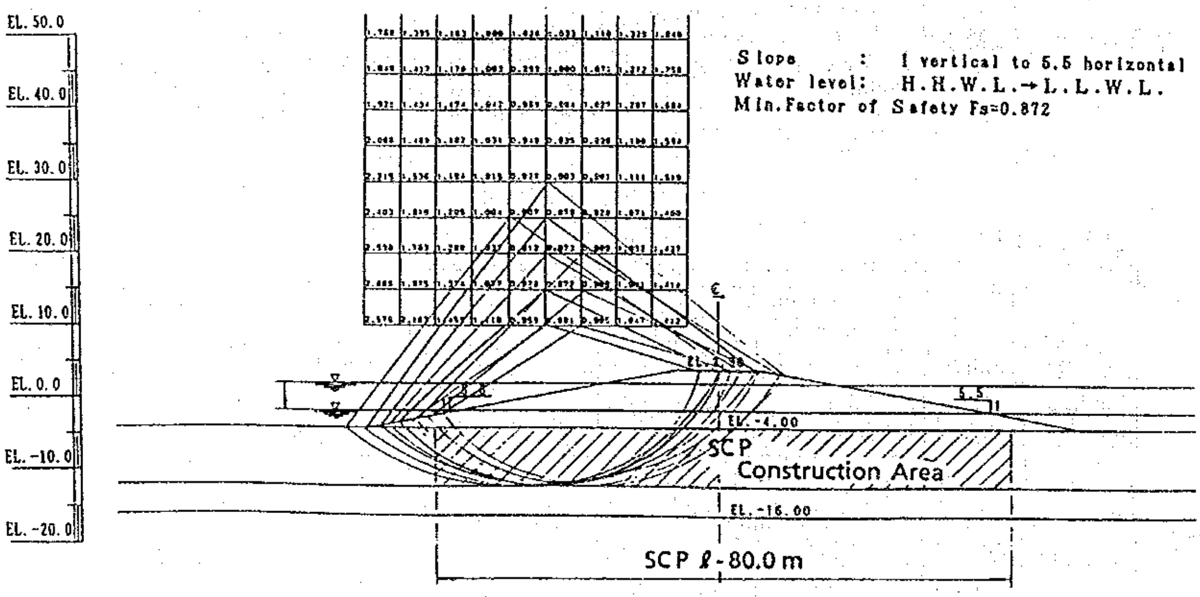
*1 Profile for analysis I: Foundation excavation elevation EL (-)7.0 m
Profile for analysis II: Foundation excavation elevation EL (-)4.0 m
Profile for analysis III: Foundation excavation elevation EL (-)1.0 m

As clearly learned from Table 6 - 7, when the elevation dam foundation is higher than EL (-)2.0 m : or when the dam height is lower than 5.9 m, the dam embankment stability can be ensured even in conditions where the soft foundation will not be improved or will remain intact.

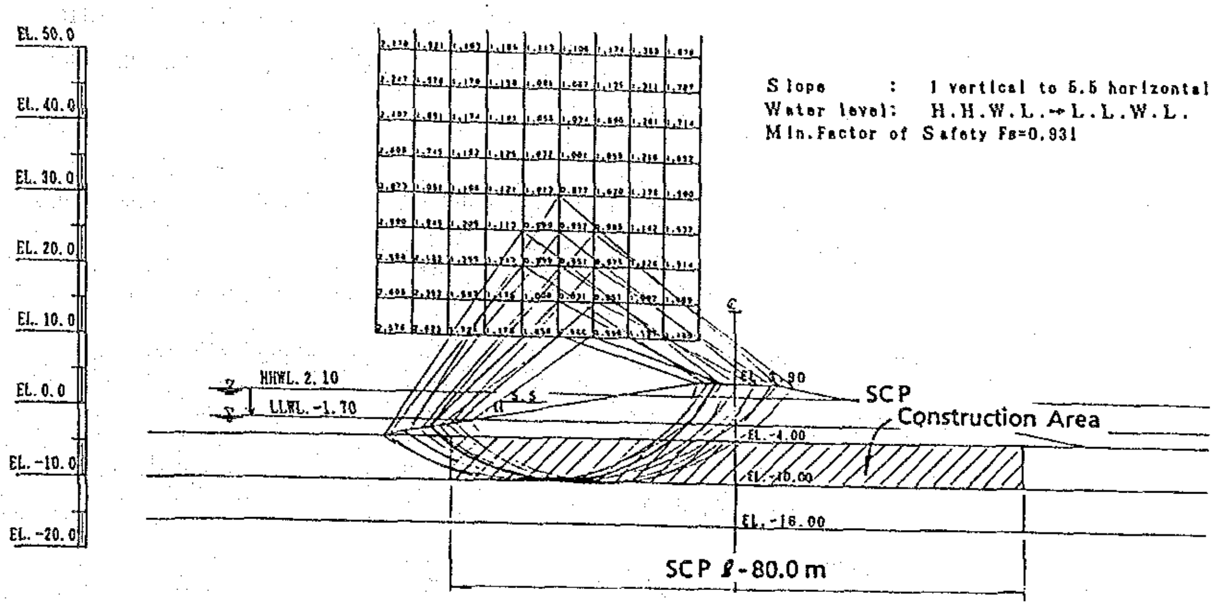
Under such conditions, the extent of improvement of the soft foundation in profile of the closure dam is determined as the deeper part by EL (-)2.0 m of the foundation, while the one in cross section is determined to an extent 40 m in each direction, both up-and-downstream sides, from the center of dam, in taking into account the passing line of the reasonable slip circle slice below the necessary safety factor as shown in Figure 6 - 5.

FIGURE 6 - 5 RESULT OF STABILITY ANALYSIS IN UNIMPROVED FOUNDATION

<RIGHT ABUTMENT>



<LEFT ABUTMENT>



3) Design of Sand Compaction Piles

The sand compaction piles proposed shall be 400 mm by casing diameter and 700 mm by sand formed pile diameter. The studies of pile intervals are made as to the each analyzed section II in Figure 6 - 4, where the elevation of the both abutments foundation are at EL (-)4.0 m.

First of all, pile drilling intervals shall be roughly determined so that the consolidation degree can reach more than 80 percent for about one year from starting to completing of the works.

In this connection, the consolidation speed will not slow down when the replacement ratio is less than 15 percent, on the other hand, its will slow down the value of about 80 percent when the replacement ratio is about 20 percent. Because of this, the consolidation coefficient is taken as Cv = 4.8 × 10^{-3} cm^2/min (=6.0 × 10^{-3} cm^2/min × 0.8) in the right abutment foundation and 6.0 × 10^{-3} cm^2/min in the left abutment foundation, respectively.

* Cv = 6.0 × $10^{-3}$$cm^2$/min; the value is obtained from the results of soil mechanical test.

As a results of the analysis, the relationship among pile drilling intervals, consolidation degree and replacement ratio are shown in Table 6-8, and the pile intervals should be 1.5 m or less at the right abutment foundation and 1.6 m or less at the left abutment foundation, respectively, in which case consolidation degree will exceed 80 percent.

TABLE 6 - 8 PILE INTERVALS AND CONSOLIDATION DEGREE FOR THE ABUTMENT FOUNDATION

	Pile Interval (m)	Consolidation Degree (%)	Replacement Ratio (%)
Right Abutment Found.	1.7	70.5	13.3
	1.6	78.2	15.0
	1.5	86.1	17.1
	1.4	92.6	19.6
Left Abutment Found.	1.8	71.1	11.8
	1.7	78.2	13.3
	1.6	85.1	15.0

The ground after implementation of the sand compaction pile works, shall be treated as composite ground, and the results of the stability analysis made by the slip circle slice method are shown as follows in taking the replacement ratio by 15.0 percent, 17.1 percent and 19.6 percent, respectively.

Replacement Ratio	Right Abutment Found	Left Abutment Found
0%	Fs = 0.872	Fs = 0.931
15.0%	Fs = 1.061	Fs = 1.102
17.1%	Fs = 1.083	-
19.6%	Fs = 1.104	-

As shown in the above table, the allowable safety factors can be satisfied on the condition that the replacement ratio are adopted by 19.6 percent (pile interval 1.4 m in square position) at the right abutment foundation and 15.0 percent (pile interval 1.6 m) at the left abutment foundation, respectively.

On the basis of the above results, the specifications of the sand compaction piles are determined as follows.

<RIGHT ABUTMENT FOUNDATION>

Conditions for execution of the Piling works :	Land implementation (ground elevation by EL 1.50 m)
Pile diameter :	Sand pile diameter by 700 mm (casing diameter by 400 mm)
Pile intervals :	1.4 m in square position
Replacement ratio :	19.6 percent
Extent for implementation:	Up to 40 m each for up-and-downsteam from dam axis (total length 80 m)
	Elevation of the excavation line: EL. (-)2.0 to (-)12.0 m
	Depth of construction: Up to EL.(-)12.0 m

<LEFT ABUTMENT FOUNDATION>

Conditions for execution of the Piling works :	Land implementation (ground elevation by EL 1.50 m)
Pile diameter :	Sand pile diameter by 700 mm (casing diameter by 400 mm)
Pile intervals :	1.6 m in square position
Replacement ratio :	15.0 percent
Extent for implementation:	Up to 40 m each for up-and-downsteam from dam axis (total length 80 m)
	Elevation of the excavation line: EL. (-)2.0 to (-)10.0 m
	Depth of construction: Up to EL.(-)10.0 m

6. 4 Design of Dam Embankment

1) Outline

The construction of the closure dam, which will be constructed as work on the water, desirably required sandy embankment materials including low content of fine particle materials. That is because:

- Sandy embankment materials facilitate the necessary bearing capacity in a short time after embankment works are finished.

- Sandy materials can be consolidated within a short time with little settlement

- Sandy materials bring a low level of river water pollution during construction works.

As the embankment materials for proposed closure dam, the borrow materials are available at the site around Ban Lum Maha Chai, about 35 km northeast of the construction site, and are deemed to have sufficiently qualified soil features.

On the other hand, clayey materials will become available through excavating a great deal of materials from the diversion canal site. Excavation of the diversion canal shall begin from the portion between the diversion and road bridge in dry excavation, and the rest shall be dredged by dredger boat. The total amount of dry excavation will be about 1.06 million cubic meters, approximately 230 thousand cubic meters of which are to be excavated from the layers deeper than EL (-) 8.0 m which can be appropriated as embankment materials to the closure dam. Even if, however, the total amount of the dry excavation materials can be used for embankment, the lots for O and M buildings and embankment for roads and closure dam body cannot be filled with these materials, which will inevitable use the borrow materials as embankment. In this case, the clayey materials to be excavated at the diversion canal site shall be used for embankment of the building lots and roads, while the sandy borrow materials for engagement of the closure dam body.

This paragraph discusses suitability of the sandy borrow materials and the clayey excavated materials for the embankment of the closure dam. (Refer to Appendix 6. 2. 1 and 6. 2. 2)

2) Study on Sandy Borrow Materials

The specific gravity of the borrow materials is in the range from 2.62 to 2.70, in consisting of sand from 58 to 90 percent, silt from 6 to 33 percent, and clay 6 to 11 percent. The materials can be classified as sandy materials in SM by the Unified Soil Classification System. The materials can be used as embankment materials in applying the embankment section as shown in Figure 6 - 1.

The settlement of the embankment with the proposed borrow materials can be estimated at 48 cm in total by the method that the dam embankment shall be divided into 8 layers for estimating the consolidation settlement of each layer to obtain the total. Since sandy materials, however, is comparatively large in consolidation coefficient, more than half of settlement action will be over during the embankment construction, and it is judged that the residual settlement will not give any adverse effects to the embankment.

Study of stability analysis to the slip failure of the embankment shall be carried out by slip circle slice method. The design values of the embankment and foundation are shown in Table 6 - 3, and the stability analysis results are shown in the following table.

TABLE 6 - 9 RESULTS OF STABILITY ANALYSIS FOR EMBANKMENTS WITH BORROW MATERIALS

Case	Water Level	Safety Factor		Allowable Safety Factors
Case 1	Constant W.L. (H.H.W.L.)	2.074	>	1.20
Case 2	〃 (L.L.W.L.)	2.076	>	1.20
Case 3	Drawdown W.L. (H.H.W.L. → L.L.W.L.)	1.120	>	1.10

As clarified in the above table, the safety factors are more than the allowable safety factor in every case. And the proposed dam body is safe from slip failure.

3) Study on Excavated Clayey Materials

The clayey materials to be excavated to a depth of 8.0 m at the canal site are judged unsuitable as embankment materials in considering that these materials will decrease remarkably in strength in heavy disturbance by excavation because of their characteristic features with Wf = 50 - 100 percent in natural water contents, IC < 0 in consistency index, IL > 3.0 in liquidity index, etc. On the other hand, there is a possibility that the material, found below 8.0 m can be used as embankment materials for the dam in view of their highly stable materials because of having features in Wf = 30 percent, IC = 0.5 - 1.5, IL < 1.0, etc. The excavated materials, however, will settle heavily during and after construction works to give adverse effects to the dam body, owing to clayey ones and using in submerged works.

In the case of using excavated materials from the diversion canal as an embankment for the closure dam, since the soft layers at the foundation are clayey similar to the embankment materials in cohesion with almost the same strength as the embankment materials, a thick surface softened mud layer about one meter shall be eliminated by excavation, while the soft layers found at EL (-)8.0 to (-)12 m shall remain intact. And the total settlement shall be calculated to obtain a total settlement of about 160 cm, which comprises about 110 cm in the embankment portion and about 50 cm in the soft layers of the dam foundation.

The time required for this consolidation is shown as follows.

TABLE 6-10 TIME FOR CONSOLIDATION

Single Drainage Condition (In case where sand mat is not provided on the soft layer)	Consolidation Degree 100 % - 351 year 〃 80 % - 199 year
Double Drainage Condition (In case where a 2.0 m thick sand mat is provided on the soft layer)	Consolidation Degree 100 % - 51 year 〃 80 % - 29 year

As a result of the above study when the materials excavated at the diversion canal site are used as embankment material for the closure dam, it will take as long as 29 years to complete the settlement of more than 160 cm in total and for consolidation degree to reach 80 percent with double drainage system provided. It is, consequently, considered unsuitable for the excavated materials at the diversion canal site to be used for embankment of the closure dam.

For further references, the stability analysis for slip failure reveals that the embankment slopes for both the up-and-downstream sides will have to be as gentle as 1 : 10 in stability when the excavated materials are used for dam body embankment.

4) Determination of Embankment Materials for Dam Body

As learned from the above studies and analyses, it will become evident that the sandy borrow materials will be superior in consolidation factors to the silty and clayey excavated materials for the embankment of the closure dam. In the Project, since the amount of materials to be excavated at the diversion canal site cannot completely cover the whole requirements of the projects, use of the borrow materials cannot be avoided in meeting the requirements, and for the dam embankment which requires higher embankment to play a vitally important role in the Project, the borrow materials must be adopted.

However, it should be considered that the excavated materials from the diversion canal are to be used for the embankment of the closure dam, if the properties of the excavated materials accomplish the requirements due to construction period, site situation, construction cost, etc.

CHAPTER 7. DESIGN OF ROAD AND ROAD BRIDGE

7.1 Road

7.1.1 Route Alignment

In the Basic Design Report, the proposed road will be in alignment with the starting point at the existing road on the left bank so as to cross over the Bang Pakong river through the proposed closure dam embankment after making a detour of the residential area of Chuknua village. The road shall cross the diversion canal at a place downstream of the diversion dam, where the road bridge shall be constructed about 200 m downstream from the diversion dam so as to reduce the influence from released water through the dam gates.

The alignment of the proposed road shall take the route which will link with the existing road on the right bank via the proposed road bridge.

The distance between the starting point and IP_1 is as short as 178.0 m, and the crossing angle is 62°13'16". Consequently, the radius for the necessary curve will be 200 m.

And the design speed for the portion of about 300 m from Sta. 0 to Sta. + 300 shall be 60 km/hr, while that for the other portions will be 80 km/hr.

There is no need to widen the road width at the road curve because the proposed road radius is more than 200 m, and no transition portion for speed reduction shall be provided.

7.1.2 Profile Alignment

The road design criteria of the Highway Department, Thailand, stipulates that the profile slope of the class 4 road with design speed 60 - 80 km/hr is 4 percent at the maximum in flat or very gentle topography. In other respects, since there is no drainage provided in this road, the minimum profile slope of the road should be flat.

The design road elevation at the respective point is show as:

① At the starting point by Sta. 0, the elevation shall be EL.2.26 m, level with the elevation of the existing road.

② For the portion of the closure dam (Sta. 0 + 920 - Sta. 1 + 200), the road elevation shall be EL.4.20 m, level with the dam crest elevation.

③ In the area for the O/M buildings (Sta. 2 + 160 - Sta. 2 + 440), the road elevation shall be EL.3.90 m, level with the crest elevation of the diversion canal embankment.

④ For the road bridge (Sta. 2 + 620 - Sta. 2 + 880), the road elevation shall be EL.5.20 m, level with the surface elevation of the road bridge, and

⑤ For other portions, the road elevation shall be EL.2.50 m in adding 0.1 m to the maximum water level of Max. W.L.2.40 m.

The maximum vertical slope shall be 2.250 percent, and at its transitional point, the vertical curve shall be determined at more than 1,400 m in radius for design speed 60 km/hr and more than 3,000 m in radius for design speed 80 km/hr so as to mitigate the shock given by the movement of vehicles and secure visual distance. The designed vertical curve radius is in the range from 3,560 m to 33,300 m.

7.1.3 Cross-sectional Alignment

As a result of consultative discussions with RID, the road width has been decided as follows:

① The ordinary part of the road shall have a width of 9.0 m with two lanes.

② The crest of the closure dam shall be of 12.0 m including two lanes together with shoulder protection.

③ In the area for the O/M buildings, the road shall have 28.0 m including 6 lanes and pedestrian walks, and

④ In the bridge portion, the road shall be 12.0 m in width including two lanes and pedestrian walks.

According to the criteria of the Highway Department, the cross-sectional slope shall be 3.5 percent.

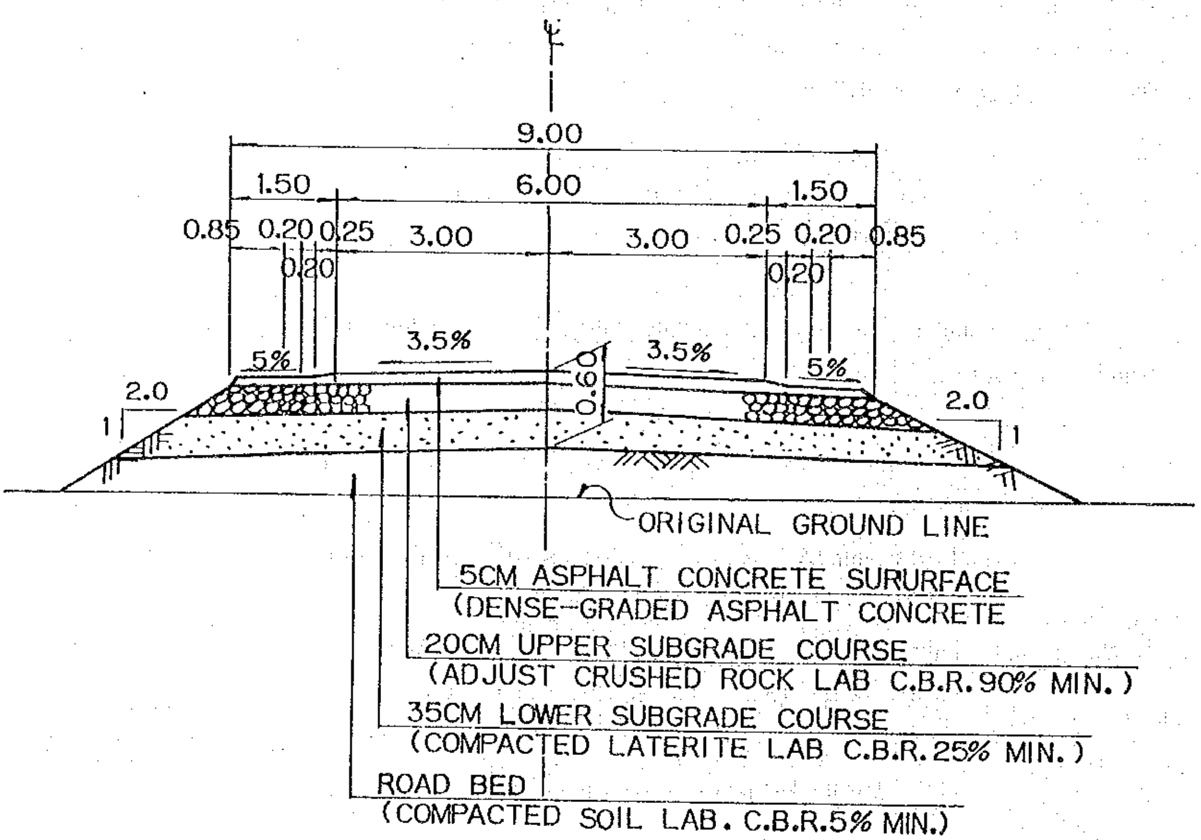
On the other hand, for the curve with 200 m radius shall have a one-sided slope of 8.0 percent, while that with 500 m radius by 6.0 percent slope in proportion to the design speed, respectively. Average illumination intensity by 15 ℓx, and O & M rate by 0.65.

The embankment slope shall be 1:2.0 based on the same criteria.

7. 1. 4 Pavement Works

In the daily traffic conditions of 100 to 250 vehicles of larger size and the design C.B.R. by 3 percent, the design pavement will be composed of 5 cm of surface layer, 20 cm of upper course, 35 cm of basic course to make a total pavement to 60 cm in thickness. (Refer to Appendix 7. 1. 4)

FIGURE 7 - 1 TYPICAL CROSS SECTION OF ROAD



7.1.5 Lighting Facilities for Road

The road lighting facilities are designed in such conditions as; standard brightness by 0.5 cd/m^2 average illumination density by 15 ℓx and conservation rate by 0.65.

The lighting for the general parts of the road with width of 9.0 m shall be made with equipment of 10 m elevated high voltage sodium lamps of NH150F (light flux: 13,000 ℓm , life time; 12,000 hr power supply; 175 watt.) provided at 35 m intervals on one side of the road.

The lighting for the 28 m-wide road in the area of the O/M buildings shall be made with 10 m-elevated high-voltage sodium lamps of NH150F provided at intervals of 30 m on the both sides of the road. (Refer to Appendix 7. 1. 5)

7.1.6 Road Crossing Structure

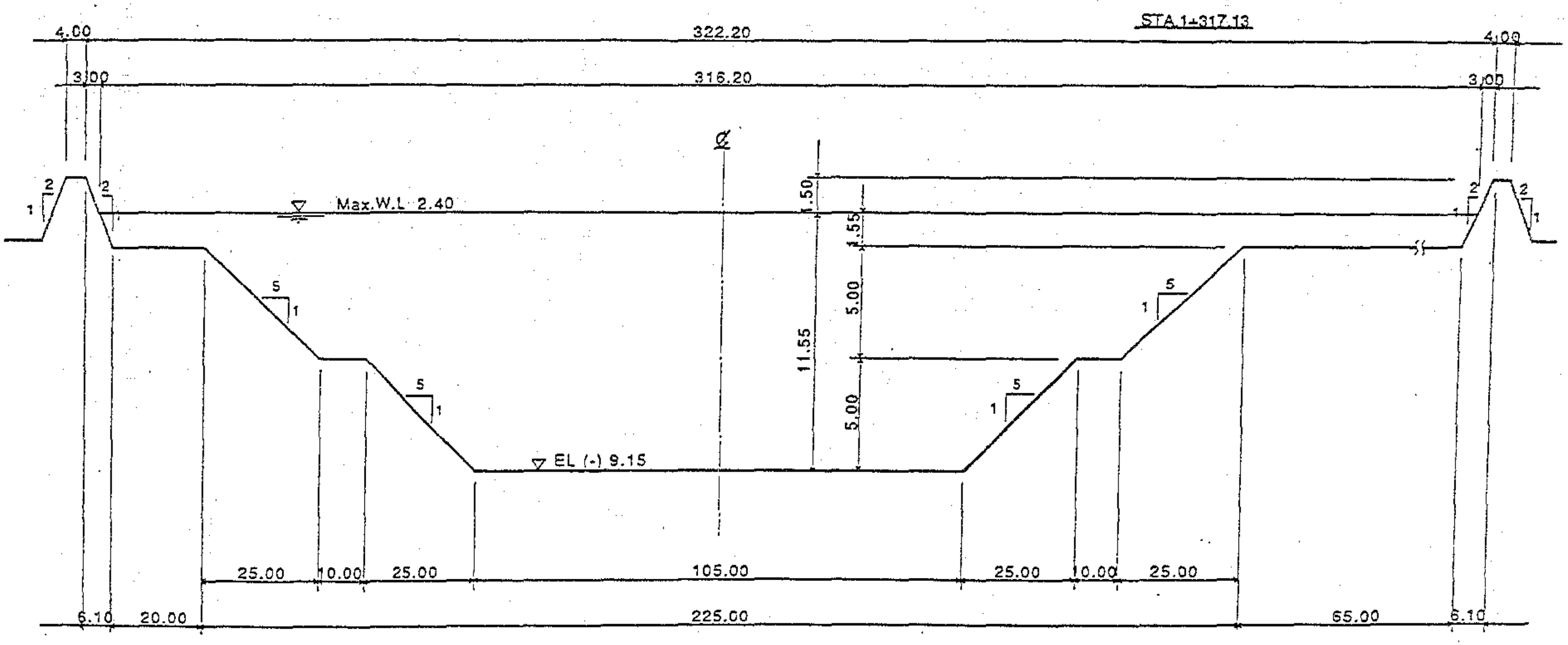
Pipe culverts for water conveyance shall be adopted for road crossing the existing canals and in the area of the O/M buildings. The size of the pipe culverts shall be determined through consideration of the cross-sections of the existing canals. The pipe culverts at Sta. 0 + 10 and Sta. 2 + 365, shall be of concrete-made double pipes with 1,000 mm dia. according to the criteria of the Highway Department, and other crossing structures shall be concrete-made single pipes with diameters in the range of 600 to 1,000 mm.

7.2 Road Bridge

7.2.1 Basic Design Conditions

1)	Road class	: Class 4 by design criteria of the Highway Department in Thailand
2)	Design speed	: 80 km/hr
3)	Design traffic	: 300 to 1000 vehicles/day
4)	Bridge class	: Class 1 (TL - 20)
5)	Bridge length	: 226.85 meters
6)	Bridge construction	: For vehicle 2 lanes × 4.0 m = 8.0 m
		For shoulder 2 × 0.5 m = 1.0 m
		For Side-walk 2 × 1.50 m = 3.0 m
		Total width 12.0 m
7)	Route alignment	: straight
8)	Inclined angle	: 90 degrees
9)	Pavement	: Asphalt pavement with 6.0 cm thickness for vehicles lanes.
10)	Cross slope	: 3.5 % for vehicles lane
11)	Longitudinal slope	: Level
12)	Special load	: Lighting facilities
13)	River planning	
	River name	: Bang Pakong river
	Location of bridge	: Sta. 1 + 317.3
	Design flood discharge	: $Q = 1600\ m^3/s$
	Maximum water level	Max. W. L. 2.40 m
	Design crest dike elevation:	EL. 3.90 m
	Design river bed elevation :	EL. (-) 9.15 m
	Design river bed slope	: I = 1/4,000
	Design cross section	: as Figure 7-2

FIGURE 7-2 DESIGN CROSS SECTION OF DIVERSION CANAL

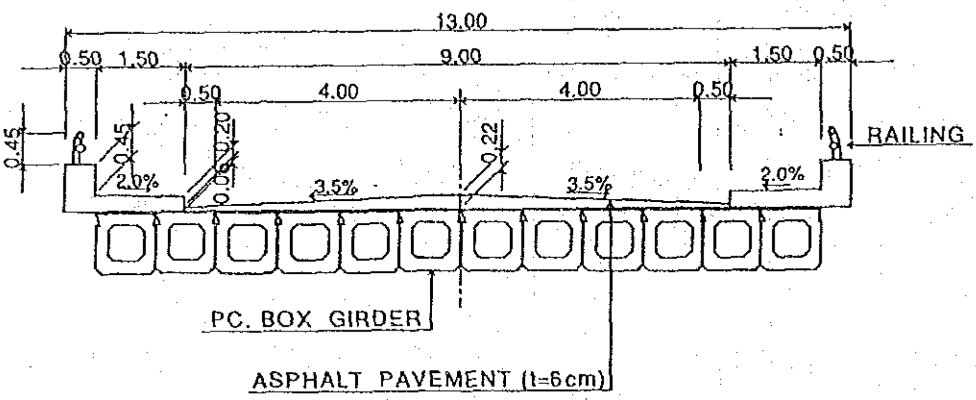


7. 2. 2 Alignment Plan

1) Cross Alignment

The cross alignment of the road bridge will be the same as that of the road as shown in Figure 7-3.

FIGURE 7-3 TYPICAL CROSS SECTION OF ROAD BRIDGE



2) Longitudinal Alignment

The longitudinal alignment of the proposed road bridge will be level. The road bridge surface elevation will be EL.5.20 meters allowing for the fact that the beam seat elevation should be kept at more than EL.3.90 meters, which is the dike elevation.

Bridge surface elevation = Design dike elevation + Beam height + Pavement thickness
= EL. 3.90 m + 1.00 m + 0.22 m
= EL. 5.12 m ≒ EL. 5.20 m

7. 2. 3 Bridge Length

The bridge length will be determined by taking into account the fact that the river cross section must have the ability to cope with the flow of design flood discharge of Q = 1,600m^3/s at the maximum water level (Max. W. L. 2.40

m) in making the abutments front surface (EL. 0.85 m) contact the berm shoulder. The following equation should be applied to obtain the bridge length.

$$
\begin{aligned}
\text{Bridge length} &= \text{River width} + 2 \times \text{Beam seat width} \\
&= 225\text{ m} + 2 \times 0.80\text{ m} \\
&= 226.60\text{ m} \fallingdotseq 226.85\text{ m}
\end{aligned}
$$

7.2.4 Type of Superstructure and Span

The type of superstructure and span length should be determined taking into consideration economy, ease of construction and of O and M works, along with a comprehensive and comparative study of the following seven (7) types and their respective span lengths.

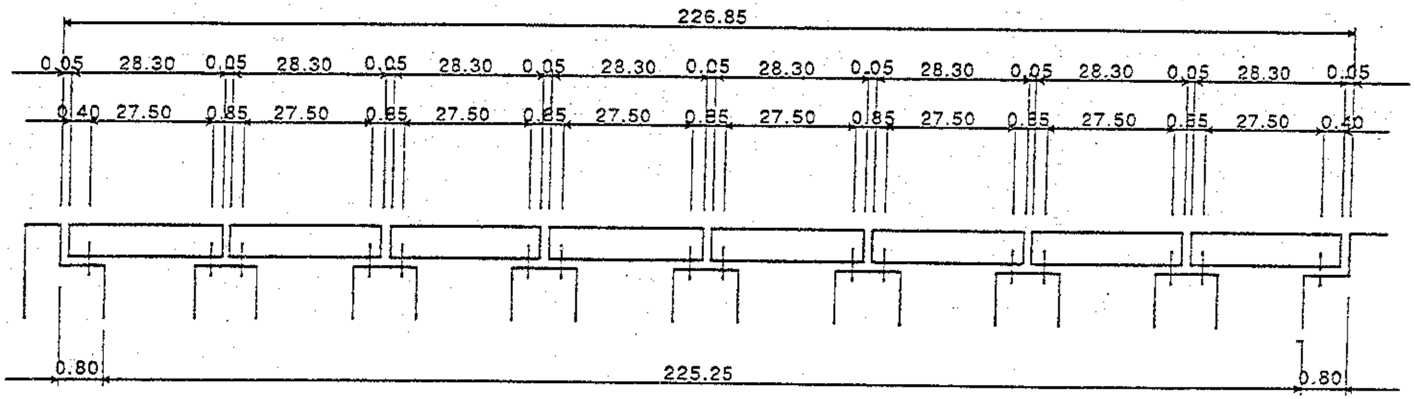
Superstructure	Span	Name of Case
P.C. I - Section Girder	8 spans	A - 1
	9 spans	A - 2
P.C. Hollow Box Girder	7 spans	B - 1
	8 spans	B - 2
	9 spans	B - 3
Steel Simple Composite Girder	5 spans	C - 1
	6 spans	C - 2

The most suitable type of superstructure and the related span length is determined to be Case B-2 (Hollow Box P.C. bridge : 27.5 m × 8 span) in view of the results of a comparative study on economy, merits and demerits of construction and O and M works as shown in Table 7-1.

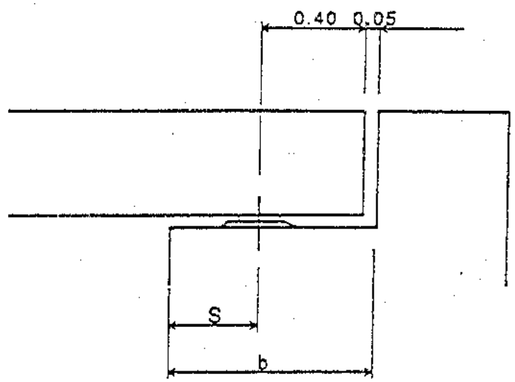
TABLE 7-1 COMPARISON OF SUPERSTRUCTURE TYPE AND SPAN

Scheme	Type of Superstructure	Span	Economy	Specific Features	Overall Appraisal
A-1	Prestressed Concrete Bridge Girder I-Section	27.5 m × 8	137%	- Dead load reaction is largest - O and M works are not required - Economically, initial cost is largest - No need for bent method and easy in construction	△
A-2		24.5 m × 9	141%		△
B-1	Prestressed Concrete Hollow Box Girder	31.6 m × 7	104%	- O and M works are not required - Most economical - No need for bent method and easy in construction	△
B-2		27.5 m × 8	100%		◎
B-3		24.5 m × 9	101%		○
C-1	Simple Composite Steel Girder	44.7 m × 5	118%	- Dead load reaction is least - Bent method is required and high technique is necessary in construction	△
C-2		37.2 m × 6	113%		△

FIGURE 7-4 ELEVATION OF ROAD BRIDGE



Elevation of Road Bridge



S = 20 + 0.5×l
= 20 + 0.5×27.50
= 34cm → 35.0cm

b = 0.35 + 0.40 + 0.05 = 0.80 m

Detail of Girder Seat

7. 2. 5 Infrastructure

1) Abutment

The abutments shall be designed with common inverted T-shape type because of having a height of 6.3 m on the pile foundation.

2) Piers

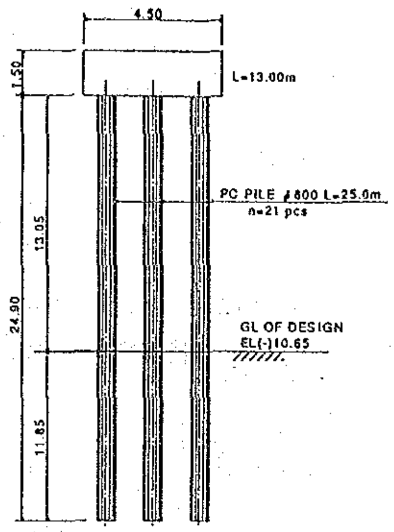
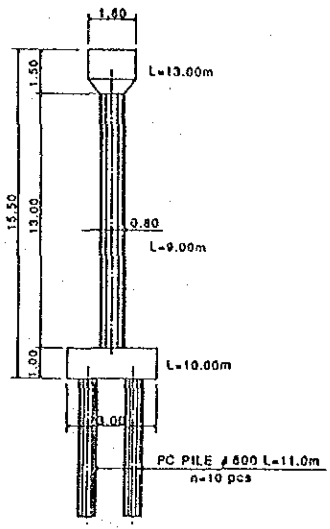
There are two types of piers as ① pile bent type and ② inverted T-shape ellipse type, and the proposed piers shall be of ② inverted T-shape ellipse type as the result of the comparative study of economy and hydraulical advantages, and table 7-2 shows the results.

7. 2. 6 Design of Superstructure

1) Design Conditions

a)	Type	:	Post-tension simple hollow type
b)	Live load	:	TL-2D
c)	Shock coefficient	:	L-Load $i = 10/(25 + L)$
			T - Load $i = 20/(50 + L)$
d)	Bridge length	:	226.85 m
e)	Girder length	:	28.30 m
f)	Span length	:	27.50 m
g)	Width	:	9.0 m (vehicle) + 1.5 m × 2 (side - walk) + 0.5 m × 2 (shoulder) = 13.0 m
h)	Angles	:	90°

TABLE 7-2 COMPARISON OF INFRASTRUCTURE BY TYPES

	① Pile Bent Type	② Inverted T-Shape Type
Figure		
Economy	102%	100%
Others	° To cause scouring around piers. ° Driftwood and trash catch by the piers, and the obstacles due to the flood flow can be occurred. ° Construction supervisions are required so that the piles have coupler. ° To be caused wear at coupler parts.	° Stability structure against driftwood. ° Dry-works are possible, and no problem for construction.

i) Material Quality and Allowable Stress

① Concrete

Descriptions	Main Beam
° Design standard stress	400 kg/cm^2
° Allowable bending compressive stress	180 〃
° Allowable bending tension stress	-15 〃
° Allowable average shear stress	5.5 〃

② P. C Steel

Descriptions	Main Girder
° Kind	SWPR 7A 12T 12.4
° Tension stress	17,500 kg/cm²
° Allowable tension stress	
(Design load)	10,500
(After introduction)	12,250

2) Determination of Main Girder Section

The main beam section can be shown as follows in taking into consideration bending stress, construction works, P.C steel, etc.

- ° Web thickness .... Min. 200 mm
- ° Bottom slab thickness .... Min. 150 mm
- ° Crest slab thickness .... 250 mm as bending stress of main girder

3) Intersectional Force (at max. girder : G_2 and G_{11} Girder)

Descriptions	Bending Moment	Shearing Force
° Main girder dead load	154.64 t-m	22.96
° Cast-in-situ load	26.00	3.78
° Bridge surface load	59.99	8.73
° Line load	50.03	7.28
° Crowd load	8.36	1.22
° Total dead load	240.63	35.47
° Total live load	58.37	8.50
Total	299.00	43.97

4) Calculation of Pre-stress

- ° Specifications of P.C. steel : SWPR7A 12T 12.4 × 6 pieces
- ° Pre-stress after introduction: $\sigma pt = 9{,}270 \text{ kg/cm}^2 < 12{,}250 \text{ kg/cm}^2$
- ° Pre-stress effective coefficient: $\eta = 0.762$
- ° Designed stress of P.C. Steel: $\sigma p = 7{,}526 \text{ kg/cm}^2 < 10{,}500 \text{ kg/cm}^2$

5) Compound Stress Analysis

The maximum stress at the beam with maximum load can be shown as follows.

	Upper end (kg/cm^2)	Lower end (kg/cm^2)
° After introduction	Min. 18.9 > - 15.0	175.9 < 180.0
° Designed load	137.2 < 180.0	Min. 128 > - 15.0

6) Shearing Stress Analysis

Designed average shearing stress

$$\tau m = 3.9 \text{ kg/cm}^2 < 5.5 \text{ kg/cm}^2$$

7) Deflection Analysis

Deflection : 1/1,388 < 1/500

7. 2. 7 Stability and Structural Calculation for Infrastructure

The structures as infrastructure of the road bridge are of the following two types as follows, and the stability analysis and structural calculation have been made for these structures.

- ° Inverted T-shape type abutment A1
- ° Inverted T-shape type pier P1, P2, P3

1) Stability Calculation

a) General Figure

The general figures of both the abutment and pier in the inverted T-shape type are shown as follows.

Figure of Inverted T-Shape Abutment

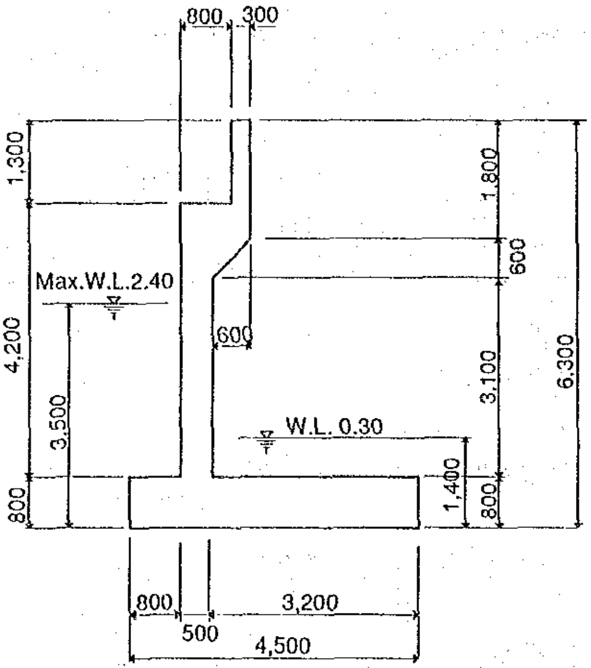
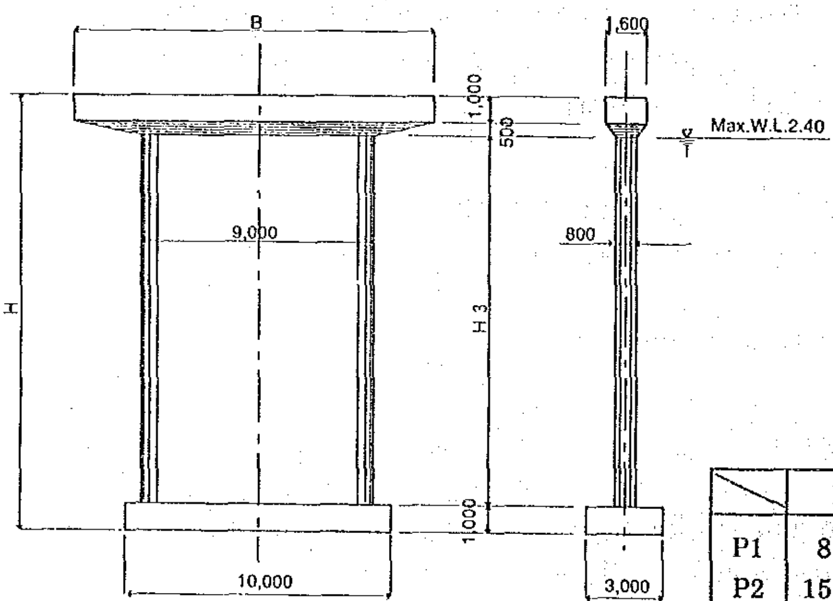


Figure of Inverted T-Shape Pier



	H	B
P1	8,000	14,000
P2	15,500	16,000
P3	15,500	14,000

b) Water Level

The water level study has been made as follows for stability analysis.

	Flood	Back side of abutment
Abutment	Max. W.L. 2.40 m	W.L. 0.30
Pier	〃	-

c) Case Studies for Stability Analysis

The following three cases have been taken up for stability analysis as follows:

Case	Condition	Abutment	Pier
Case 1	Low water level	Bridge Center dir.	Thalweg
Case 2	Flood	〃	〃
Case 3	Construction	〃	Bridge Center dir.

d) Results of Stability Calculation

The results of stability calculation for the infrastructural works, are shown in Table 7-3. The abutment has been designed so as to secure the safety factor against overturning during construction work. The width of footing slab has been designed in consideration of the foundation works and figure of columns.

e) Structural Calculation

The abutment thickness of the footing slab is designed at 0.80 m in view of the abutment height and foundation pile structure. The wall thickness of the abutment is designed at 0.50 m for a required thickness of 0.40 m and a coverage over reinforcement of 0.10 m.

The thickness of the pier columns will be 0.80 m and the thickness of the footing slabs will be 1.00 m based on the maximum pier height of 15.50 m. The results of the designed reinforcement and stress analysis can be shown in Appendix 7.2.8.

TABLE 7-3 RESULT OF STABILITY ANALYSIS FOR INFRASTRUCTURE

Type			Vertical Force	Horizontal Force	Moment	Against Sliding		Against Overturning		Soil Reaction	
			ΣV	ΣH	ΣM	Factor of safety		E	B/6	Q1	Q2
			(t)	(t)	(t·m)	Fs	Fsa	(m)	(m)	(t/m^2)	(t/m^2)
ABUT A−1		Case 1	1218.32	184.84	2138.84	3.55	> 1.5	0.49	< 0.75	34.56	7.10
		Case 2	1075.05	152.73	1802.92	3.73	> 1.5	0.58	< 0.75	32.42	4.34
		Case 3	724.86	−	1090.05	−	> 1.5	0.75	< 0.75	24.78	0
PIER	P1	Case 1	1360.55	14.00	147.00	58.31	> 1.5	0.11	< 3.33	48.29	42.41
		Case 2	1214.18	14.00	147.00	52.04	> 1.5	0.12	< 3.33	43.41	37.53
		Case 3	718.68	−	900.02	−	> 1.5	0.25	< 0.50	35.93	11.98
	P2,P3	Case 1	1453.56	14.00	217.00	62.30	> 1.5	0.15	< 3.33	52.79	44.11
		Case 2	1263.62	14.00	217.00	54.16	> 1.5	0.17	< 3.33	46.46	37.78
		Case 3	803.46	−	1027.15	−	> 1.5	0.22	< 0.50	38.56	15.00

7.2.8 Design of Foundation Works

1) Load Conditions

The maximum vertical and horizontal loads to the abutment and piers are shown in the following table.

	Direction	Ver. Force V (t)	Hor. Force H (t)	Ecc. Distance e (m)	Moment M (t-m)
Abutment	Center	1,218	185	0.49	597
Pier P1	Thalweg	1,361	14	0.11	150
Pier P2, P3	Thalweg	1,454	14	0.15	218

2) Study on Foundation Construction Method

The allowable bearing capacity of the ground can be estimated by load conditions bearing on each structure of the proposed infrastructure and the results are shown in the following table.

The direct foundation construction method cannot be adopted for these foundation works of abutments and piers because the load working thereupon will be larger than the allowable bearing capacity. The pile foundation method, therefore, shall be adopted to the foundation works for the infrastructure.

	Ultimate bear. Capacity Vu (t)	Safety Factor Fs	Allowable Bear. Capacity Va (t)	Ver. Force V (t)
Abutment	386	3	129	< 1,218
Pier P1	352	3	117	< 1,361
Pier P2, P3	1,134	3	378	< 1,454

3) Determination of Pile Length

The pile tips for foundation works shall be inserted into the clayey layers with N-values of more than 20 to the depth at last by the diameter of the piles in those layers.

The pile length for the abutment shall be designed by L = 21.0 m and that for the piers by L = 10.0 m to 15.0 m. (Refer to Figure 7 - 5)

4) Study on Proposed Pile Types

Steel piles are selected for the abutment foundation works because the abutment's horizontal force is larger than the vertical force. The piles specified by SKK Standard 400 shall be used in taking into consideration the fact that the foundation is considerably weak with N-values in a range from 0 to 1. And the economic comparison has resulted in the fact that the foundation piles for the abutment should be steel piles of SKK 400 with a diameter of 450 mm and thickness of 9.0 mm. And PC piles shall be used in this case because the piers will have smaller horizontal force than the vertical force.

Finally, it was decided that the steel piles to be used for the works should be PC piles by TIS standard in a diameter of 500 mm.

5) Study of Pile Arrangement

The results of the calculation for the pile foundation works are shown in Table 7-4.

The piles for the abutment foundation are specifically defined as SKK 400 steel piles with diameter 450 mm and thickness of 9.0 mm in view of reliable stress and displacement of pile head, and the necessary quantity is obtained as 32 sets of 11 units, and 10 sets plus 11 sets.

For the vertical bearing force, the TIS standard PC piles with diameter of 500 mm and quantity of 12 sets of 6 sets × 2 rows for the P_1 pier and 16 sets of 8 sets × 2 rows for the P_2 and P_3 piers. (Refer to Figure 7-6)

FIGURE 7-5 LENGTH OF FOUNDATION PILES

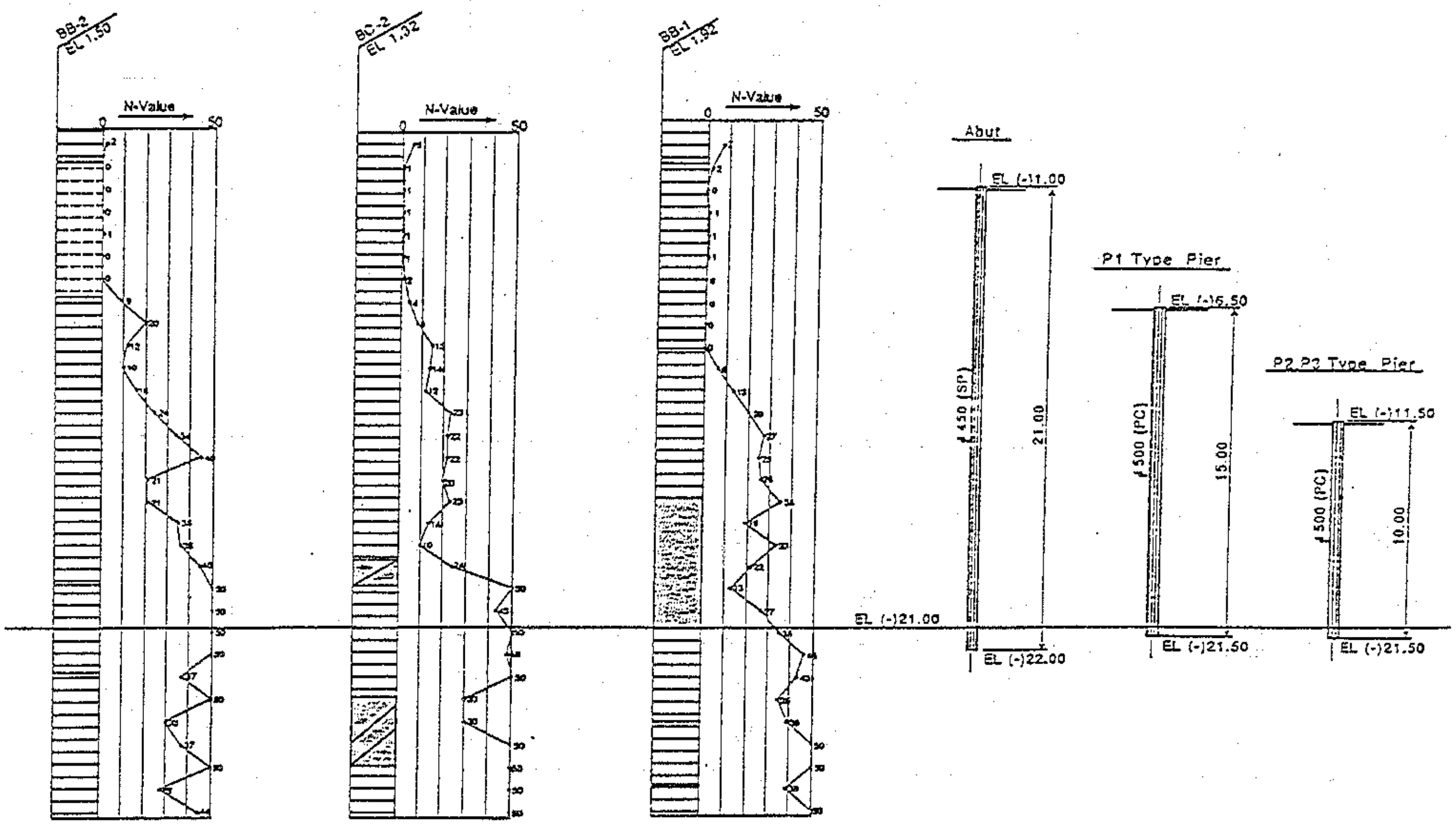
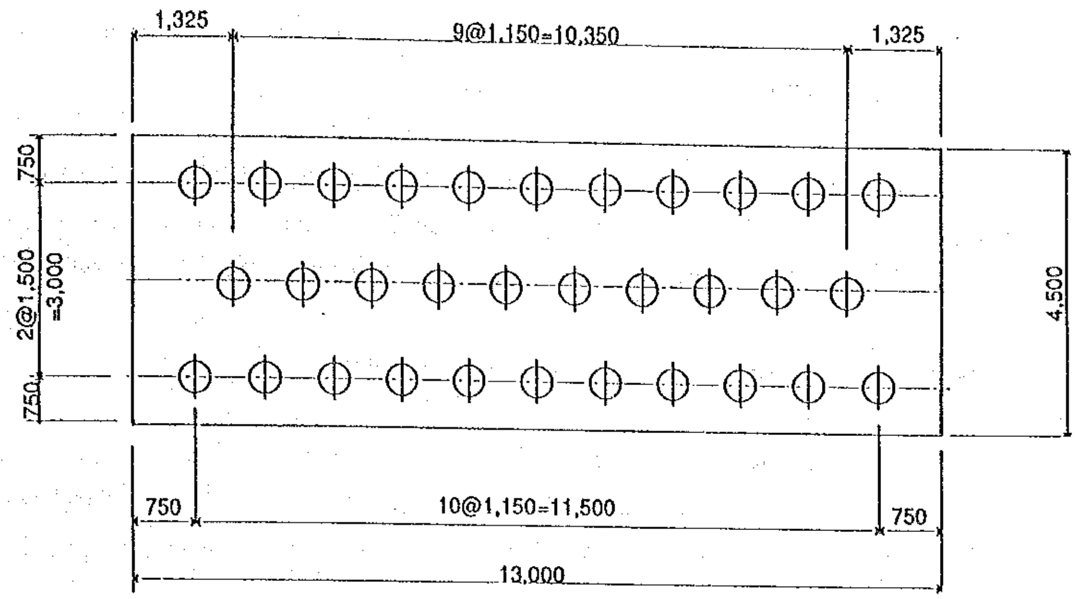


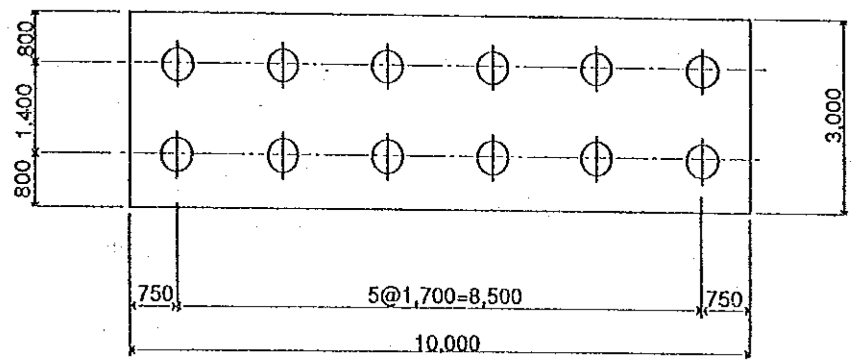
TABLE 7-4 RESULTS OF FOUNDATION PILES ANALYSIS FOR INFRASTRUCTURE

Type	Cace	Number of Piles	Vertical Load		Horizontal load		Compressive Stress		Tensile Stress		Horizontal Displacement	
		(pcs.)	V (t/pcs.)	Va (t/pcs.)	H (t/pcs.)	Ha (t/pcs.)	σ (kg/cm^2)	σa (kg/cm^2)	σ (kg/cm^2)	σa (kg/cm^2)	δ (cm)	δa (cm)
ABUT	A1	32	65	< 110	5.8	< 7.3	1314	< 1400	622	< 1400	1.40	< 1.5
PIRE	P1	12	121	< 128	1.2	< 21.0	146	< 170	0	< 0	0.10	< 1.5
	P2,P3	16	98	< 99	0.9	< 108.9	130	< 170	0	< 0	0.02	< 1.5

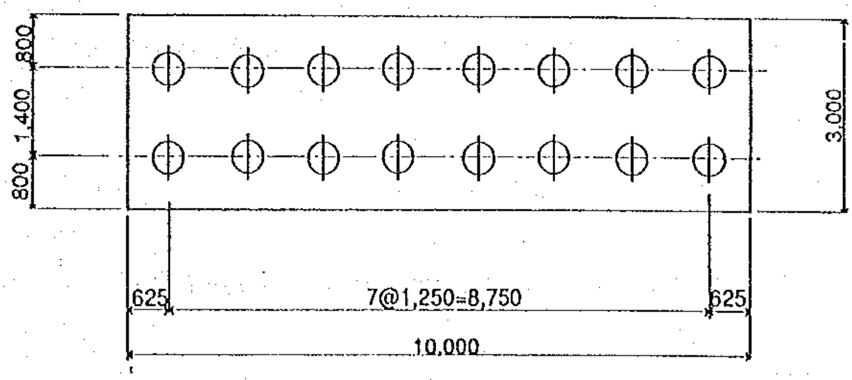
FIGURE 7-6 ARRANGEMENT OF INFRASTRUCTURE



Pile of Abutment



Pile of P1 type Pier



Pile of P2 and P3 Type Piers

CHAPTER 8. DESIGN OF PUMPING STATION

8. 1 Location of Pumping Station

The location of the proposed pumping station has been selected to be about 2.3 km upstream from the proposed diversion canal on the left bank of the Bang Pakong River, taking into consideration the following conditions :

i) Easy connection to the main canal and at a short distance ;

ii) Little expectation of suspended sand and organic particles settlement after completion of the project works and the possibility of flushing floating weeds growing in the river away during the wet season ; and

iii) No problems of noise pollution and troubles in relation to the river water control.

(refer to Appendix 8. 1)

8. 2 Pumping Facilities

1) Basic Conditions

a) Pumping Water Discharge and Operation Hours

The pumping capacity of the proposed facilities was designed to be Q = 16.00 m^3/s equivalent to the maximum diversion water requirement for 20 years from 1968 to 1987, operating the pump for 24 hours a day (refer to Appendix 8. 2).

b) Water Levels at Suction and Delivery Sides

The designed suction water level shall be determined to be EL. (-) 1.60 m in the pump suction water level (P. S. W. L.) and EL. (-) 1.90 in the min. suction water level (Min. S. W. L.) based on the min. reservoir water level in the Bang Pakong Reservoir (Min. O. L.) of EL. (-) 1.30 m.

The design delivery water level shall be determined by the pump delivery water level (P. D. W. L.) of EL. (+) 3.80 m based on the plan of the main canal (refer to Appendix 8. 2).

2) Number of Pump Units and Pump Bore

The proposed number of pump units is four (4), each with the same capacity, taking into consideration the following conditions, without standby units.

i) High applicability for water discharge variations ;
ii) Lightening of damage due to machine trouble, etc. ;
iii) Spare parts' interchangeability ; and
iv) Economy.

The pump bore shall be of 1,350 mm, considering a delivery water discharge per unit of 4.00 m^3/s (16.00 $m^3/s/4$) (refer to Appendix 8. 2).

3) Type of Pump

The vertical shaft-type mixed flow pump shall be adopted, as a result of examination on the pump suction performance, which will not inflict any harmful cavitation in the extent of expected pump operation (refer to Appendix 8. 2).

4) Pump Head

The actual static head (Ha) of the pumps at the design point shall be Ha = 5.40 m which is the difference between the designed suction and discharge water levels. By adding the above head and the head losses due to pipe friction etc. the total pump head (H) can be obtained as follows :

Pump by motor	H = 6.10 m
Pump by engine	H = 6.20 m

(refer to Appendix 8. 2).

5) Main Pipes and Valves

The main pump and the discharge reservoir are connected by the steel pipe involving a discharge valve and non-return valve for each set of pump unit.

Pump Bore	Main Pipe	Discharge Valve	Non-return Valve
ø 1,350 mm	ø 1,350 mm ~ ø 1,650 mm (Steel Pipe)	ø 1,350 mm (Butterfly Valve)	ø 1,650 mm (Flap Valve)

6) Overhead Crane

An overhead crane shall be used for the installation of the pumping equipment and overhaul inspections of the equipment necessary for the operations and maintenance.

The type and capacity of the crane shall be determined according to the type and capacity of the pumps.

For the proposed pumping station, since the pumps are of vertical shaft-type mixed flow pump with a bore of 1,350 mm and 5.9 m in the pump column length, the overhead traveling crane with the capacity of 20 tons shall be applied.

8. 3 Prime Mover

1) Type of Prime Mover

As prime movers for the proposed pumps, electric motors shall be adopted for three (3) units out of a total of four (4) units and the remains shall be diesel engine, taking into careful consideration conditions of pump operation, power supply, advantages in economy, etc. (refer to Appendix 8. 3).

2) Output of Prime Movers

The output of the prime movers shall be as follows, taking into account the discharge capacity and total head (refer to Appendix 8. 3).

Output of motors	P_M = 350 kw
Output of diesel engine	P_E = 500 ps

3) Power Transmission Equipment

A right-angle bevel gear reducer shall be used for the power transmission of the prime movers. Its speed reduction ratios are as follows :

i) Motor (6 p, 1,000 rpm)

1,000 rpm : approx. 250 rpm ≑ 4 : 1

ii) Diesel engine (1,000 rpm)

1,000 rpm : approx. 250 rpm ≑ 4 : 1

4) Cooling System

The cooling system for the diesel engine shall be of an in-pipe cooling type because of the following reasons :

i) There is no need to supply a vloume of clean water and long-term operation is possible ; and

ii) Operation is highly reliable and maintenance is easy because a small units of the related equipment are required.

8. 4 Intake Canal and Intake

1) Intake Canal

The functions of stilling basin shall be given to the intake canal with a total length of 50.0 m to protect the related pumping facilities. And the sill elevation of the entrance shall be EL. (-) 2.70 m so as to reduce a quantity of sediment entering from the Bang Pakong River as much as possible (refer to Appendix 8. 5).

2) Intake

a) Sill Elevation

The sill elevation of the intake shall be EL. (-) 3.50 m so as to reduce the inflow velocity to less than 0.50 m/s at the front of the trashrack (refer to Appendix 8. 5).

b) Width and Elevation of Concrete Plank

There shall be working space for trash removal and a traffic way provided with a width of W_1 = 4.00 m and W_2 = 5.00 m, respectively. The plank elevation for trash removal shall be EL. 2.00 m for keeping sufficient working space, while that of the traffic way shall be EL. 4.00 m, taking into account the flood water level of Max. W. L. 2.50 m (refer to Appendix 8. 5).

c) Space between Bars for Trashrack

At the entrance of the intake, the steel bars shall be provided with effective space of 50 mm in consideration of a main pump bore of 1,350 mm (refer to Appendix 8. 5).

8.5 Suction Sump

1) Water Depth in Suction Sump

The water depth in suction sump shall be 3.65 m based on the water depth necessary for submergence of the ø1,350 mm pumps, etc. And consequently, the sill elevation of the sump shall be EL. (-) 5.55 m, which is 3.65 m lower than the Min. S. W. L. of EL. (-) 1.90 m (refer to Appendix 8. 6).

2) Dimensions of Suction Sump

The intake water way for each suction sump at the deepest bottom floor shall extend a distance of 5.00 m which is bigger than value of three (3) times pump bore (D) (≧ 3 D) and a distance of 1.50 m up to the partition wall toward the upstream and downstream of pump axis, respectively.

The total length of the sump shall be 16.00 m, which are eventually required for the installation spaces of pumping facilities.

The total width of sump shall be 19.90 m, considering the number of required pump units and the necessary wall depth (refer to Appendix 8. 6).

3) Floor Elevation

a) Prime Mover Installation Floor

The floor elevation for installing movers shall be determined at EL. 4.00 m taking into prudent consideration the prime movers in safety from a flood water level of Max. W. L. 2.50 m, and the finished floor elevation shall be EL. 4.30 m including cinder-concrete depth (refer to Appendix 8. 6).

b) Pump Installation Floor

The floor elevation for pump installation shall be EL. 1.70 m, which is a little higher than the ordinary flood water level with a probability of 1/10 year, anticipating wet floors due to leakage water in case of a lower elevation floor, although possibly low floor elevation will decrease the costs for pump equipment and construction.

For further information, water tightness shall be given to the pump base. The in-plant drainage facilities are provided in paying attention to the design maximum flood water level of W. L. 2.50 m (refer to Appendix 8. 6).

8. 6 Pump House

1) Dimensions of Pump Room

The length of the pump room shall be 15.00 m in total, necessary for installation of the diesel driven pump unit (refer to Appendix 8. 7).

2) Width of Pump House

The total width of the pump house shall be 30.50 m in consideration of the three (3) factors, such as pump installation floor width, material entrance floor width and electricity room width (refer to Appendix 8. 7).

3) Height of Pump House

a) Pump Room

The height of the pump room including material entrance floor shall be determined, considering hoisting height for the main pump, necessary clearance for crane installation and depth of main beam. In this pumping station, the definite clearance shall be 11.00 m above the ground elevation of EL. 4.00 m at the pumping station site (refer to Appendix 8. 7).

b) Electricity Room

Clearance between floor surface and bottom of the beam shall be 3.00 m as effective height, and the total height including the office room in the second storey shall be 7.50 m above the ground surface (refer to Appendix 8. 7).

4) Building Structure

Beams, columns and floors shall be constructed of reinforced concrete, while walls are with concrete blocks. The beams of the pump house shall be made of iron frames, because of having such a long span as 15.0 m.

8. 7 Discharge Reservoir

1) Water Depth in Discharge Reservoir

The water depth in the discharge reservoir shall be more than 2.05 m for the delivery pipe mouth to be sufficiently submerged. The bottom slab surface elevation of the discharge reservoir, consequently, shall be EL. (-) 0.80 m, which is lower than 2.05 m below the Min. D. W. L. of EL. 1.39 m (refer to Appendix 8. 8).

2) Plan of Discharge Reservoir

The width of the discharge reservoir shall be 18.30 m in total net inside measurement based on the spacing of pump installation. The total length shall be 43.5 m including the connecting section (transition) with the main canal (refer to Appendix 8. 8).

8. 8 Structural Calculation of Suction Sump

Structural calculation of the suction sump shall be made, in principle, by box type rahmen structure with four (4) sides composed of upper plate, bottom plate, side wall and/or separation wall, except hydraulic pressure walls and earth pressure walls at the back of the pump units which shall be designed as a four (4) sides fixed plate.

In this paragraph, the results of two (2) calculations are shown for prime mover installation section and pump installation section of the suction sump.

1) Dead Loads

Reinforced concrete weight	:	2.4 t/m^3
Plain concrete weight	:	2.2 t/m^3

2) Active Loads

Diesel engine	500 ps	:	5.49 t × 1.3 = 7.14 t/unit
Motor	350 kw	:	2.40 t × 1.3 = 3.12 t/unit
Main pump w/ reduction gear		:	34.76 t/unit
Uniform loads		:	prime mover's floor 0.50 t/m^2
			pump floor 0.30 t/m^2
			outside embankment 1.00 t/m^2

3) Building Loads

The axial force acting to the building columns shall be taken into consideration.

4) Earth Pressure

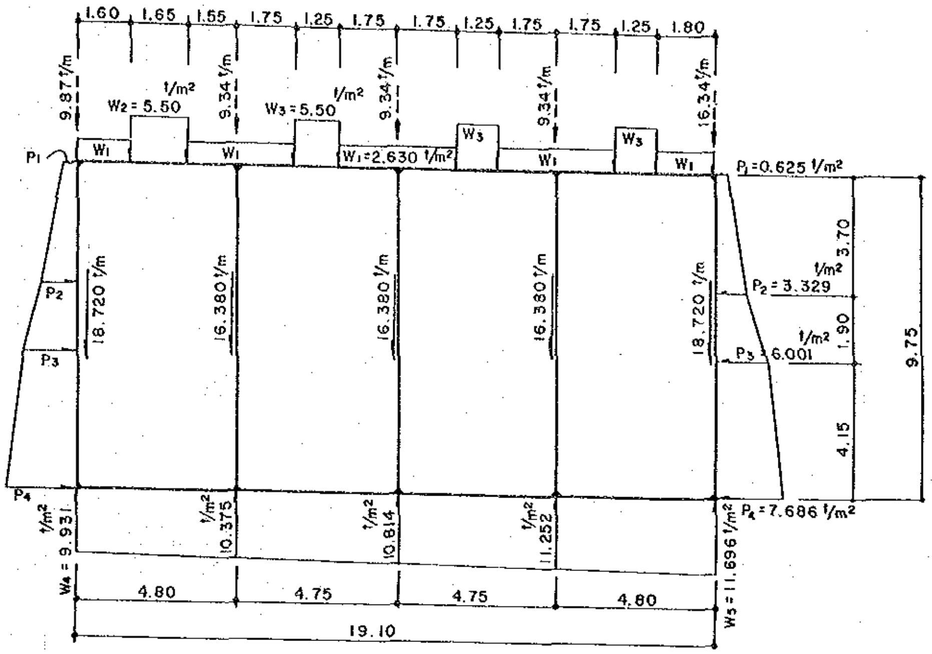
Internal friction angle	:	$\phi = 25°$	
Earth pressure coefficient	:	K = 0.461	
Earth weight	:	wetted earth	$\gamma_t = 1.8$ t/m^3
		saturated earth	$\gamma_{sub} = 2.0$ t/m^3

5) Water Level Conditions

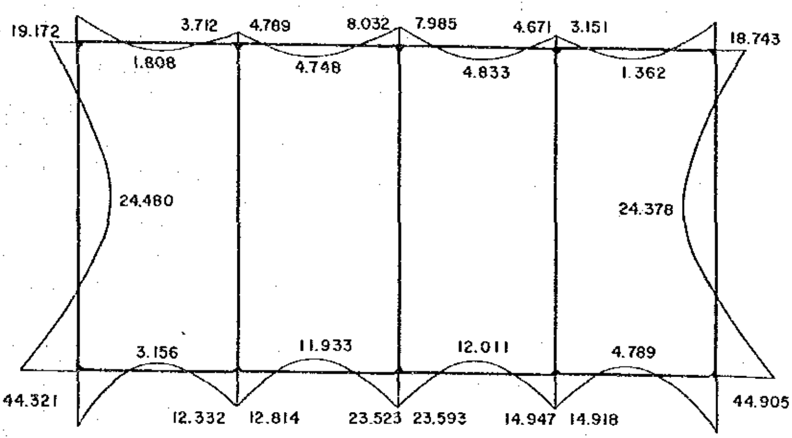
Water level in the sump	:	Min. S. W. L. (-) 1.90 m
Ground water level	:	G. W. L. 0.00 m

FIGURE 8-1 LOAD & SECTIONAL FORCE OF MOVER INSTALLATION SECTION

Loads Diagram



Bending Moment Diagram (t · m)



Shearing Force Diagram (t)

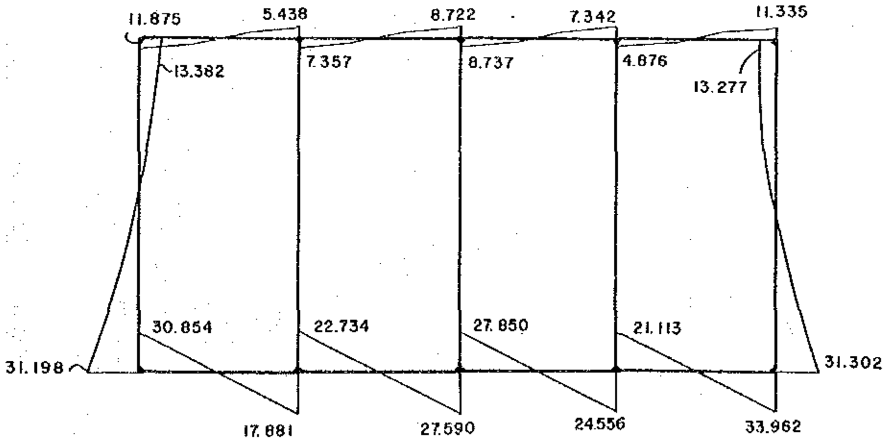


TABLE 8-1 (a) CALCULATION RESULTS FOR MOVER INSTALLATION SECTION (1/2)

Item			Upper Plate			Bottom Plate		
			End 1	Center	End 2	End 1	Center	End 2
Sectional Dimension	b	(cm)	100	100	100	100	100	100
	h	(〃)	60	60	60	100	100	100
	d	(〃)	52.5	52.5	52.5	85	90	85
Bending Moment	M	(t·m)	19.172	4.833	8.032	44.905	12.011	23.593
Axial Force	N	(t)	13.382	13.431	13.443	31.302	31.149	31.149
Shearing Force	S	(〃)	11.875	-	8.737	33.692	-	27.850
Reinforcing Bar Schedule	Diameter	(mm)	D20	D20	D20	D25+D28	D20	D25
	Spacing	(〃)	@125	@250	@250	@250	@250	@250
	Area of Bars	(cm^2)	25.12	12.56	12.56	44.28	12.56	19.64
k & j Ratios for R. C. Beam	k		0.265	0.916	0.196	0.275	0.154	0.193
	j		0.912	0.935	0.935	0.908	0.949	0.936
Stress	σc	(kg/cm^2)	66.6	31.1	43.8	61.9	41.4	52.9
	σs	(〃)	1,312	205	724	927	-	622
	τ	(〃)	2.5	-	1.8	4.4	-	3.5
Verification of Shear Stress	S'	(t)				* 24.054		
	τ'	(kg/cm^2)				3.1		
Allowable Stress	σca	(kg/cm^2)	94.5	94.5	94.5	94.5	94.5	94.5
	σsa	(〃)	1,400	1,400	1,400	1,400	1,400	1,400
	τa	(〃)	4.2	4.2	4.2	4.2	4.2	4.2

* The verifications is made at the point of h/2 from wall face.

TABLE 8-1 (b) CALCULATION RESULTS FOR MOVER INSTALLATION SECTION (2/2)

Item			Side Wall			Separation Wall		
			Upper Part	Center	Lower Part	Upper Part	Lower Part	
Sectional Dimension	b	(cm)	100	100	100	100	100	
	h	(〃)	80	80	80	70	70	
	d	(〃)	70	70	70	60	60	
Bending Moment	M	(t·m)	19.172	24.480	44.905	9.605	21.428	
Axial Force	N	(t)	11.875	21.235	30.055	-	16.380	
Shearing Force	S	(〃)	13.382	-	31.302	3.655	17.439	
Reinforcing Bar Schedule	Diameter	(mm)	D20	D16+D20	D25+D28	D20	D16+D20	
	Spacing	(〃)	@125	@250	@250	@250	@250	
	Area of Bars	(cm^2)	25.12	20.60	44.28	12.56	20.56	
k & j Ratios for R. C. Beam	k		0.234	0.215	0.298	0.185	0.230	
	j		0.922	0.928	0.901	0.938	0.923	
Stress	σc	(kg/cm^2)	42.9	63.1	82.0	29.0	66.9	
	σs	(〃)	930	1,274	1,253	1,283	1,444	
	τ	(〃)	2.1	-	5.0	0.6	3.1	
Verification of Shear Stress	S'	(t)			* 24.549			
	τ'	(kg/cm^2)			3.9			
Allowable Stress	σca	(kg/cm^2)	94.5	94.5	94.5	118.1	118.1	
	σsa	(〃)	1,400	1,400	1,400	1,750	1,750	
	τa	(〃)	4.2	4.2	4.2	5.2	5.2	

* The verifications is made at the point of h/2 from the slab face.

FIGURE 8-2 LOAD & SECTIONAL FORCE OF PUMP INSTALLATION SECTION

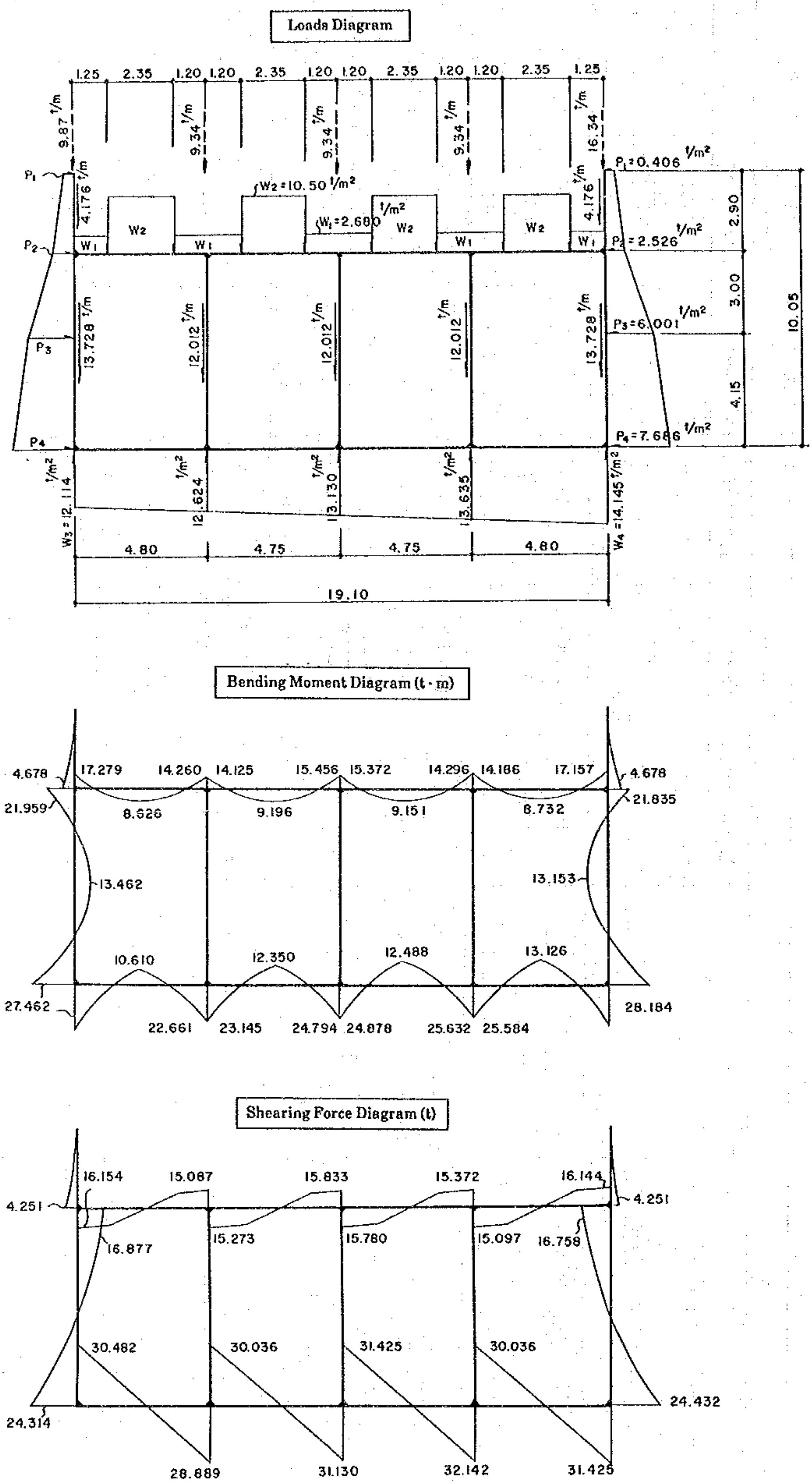


TABLE 8-2(a) CALCULATION RESULTS FOR PUMP INSTALLATION SECTION (1/2)

Item			Upper Plate			Bottom Plate		
			End 1	Center	End 2	End 1	Center	End 2
Sectional Dimension	b	(cm)	100	100	100	100	100	100
	h	(〃)	80	80	80	100	100	100
	d	(〃)	70	70	70	85	90	85
Bending Moment	M	(t·m)	17.279	9.196	15.456	28.184	13.126	25.632
Axial Force	N	(t)	21.128	21.041	21.041	24.433	24.433	24.424
Shearing Force	S	(〃)	16.154	-	15.833	31.425	-	32.142
Reinforcing Bar Schedule	Diameter	(mm)	D20	D20	D20	D25	D20	D25
	Spacing	(〃)	@125	@250	@125	@125	@250	@250
	Area of Bars	(cm^2)	25.12	12.56	25.12	39.28	12.56	39.28
k & j Ratios for R. C. Beam	k		0.234	0.172	0.234	0.261	0.154	0.261
	j		0.922	0.943	0.922	0.913	0.949	0.913
Stress	σc	(kg/cm^2)	44.6	39.0	41.1	42.6	38.8	40.0
	σs	(〃)	616	196	505	583	190	500
	τ	(〃)	2.5	-	2.5	4.0	-	4.1
Verification of Shear Stress	S'	(t)						
	τ'	(kg/cm^2)						
Allowable Stress	σca	(kg/cm^2)	94.5	94.5	94.5	94.5	94.5	94.5
	σsa	(〃)	1,400	1,400	1,400	1,400	1,400	1,400
	τa	(〃)	4.2	4.2	4.2	4.2	4.2	4.2

TABLE 8 - 2 (b) CALCULATION RESULTS FOR PUMP INSTALLATION SECTION (2/2)

Item			Side Wall			Separation Wall		
			Lower Part			Upper	Center	Lower Part
Sectional Dimension	b	(cm)	100			100	100	100
	h	(〃)	60			80	80	80
	d	(〃)	50			70	70	70
Bending Moment	M	(t · m)	4.678			21.959	13.462	28.184
Axial Force	N	(t)	4.176			20.330	27.194	34.048
Shearing Force	S	(〃)	4.251			16.877	-	24.432
Reinforcing Bar Schedule	Diameter	(mm)	D20			D20	D20	D25
	Spacing	(〃)	@250			@125	@250	@125
	Area of Bars	(cm^2)	12.56			25.12	12.56	39.28
k & j Ratios for R. C. Beam	k		0.200			0.234	0.172	0.284
	j		0.933			0.922	0.943	0.905
Stress	σc	(kg/cm^2)	23.6			53.0	54.3	61.0
	σs	(〃)	608			922	444	675
	τ	(〃)	0.9			2.6	-	3.9
Verification of Shear Stress	S'	(t)						
	τ'	(kg/cm^2)						
Allowable Stress	σca	(kg/cm^2)	94.5			94.5	94.5	94.5
	σsa	(〃)	1,400			1,400	1,400	1,400
	τa	(〃)	4.2			4.2	4.2	4.2

8. 9 Design for Foundation Works

1) Selection of Construction Method for Foundation Works

The foundation under the respective structure of the proposed pumping station is found as the soft ML layer with N-value of less than 4 and the comparatively favorable CL layer with N-value of over 15 at a depth of more than 4 m even in the shallowest (refer to Figure 8 - 3). Consequently, the pile foundation construction method shall be employed in the Project.

2) Determination of Pile Length

Pile tip shall stably penetrate the firmed layers to have sufficient bearing capacity for heavily loaded important structures.

In this Project, the pile tip shall be penetrate up to approximately EL. (-) 18.00 m for the foundations of such structures as Intake, Suction Sump, Discharge Reservoir, and Pump House as show in Figure 8-3, while the piling shall be made up to EL. (-) 14.0 m for the transitional sections with a light loading.

TABLE 8 - 3 PILE LENGTH FOR EACH WORKS

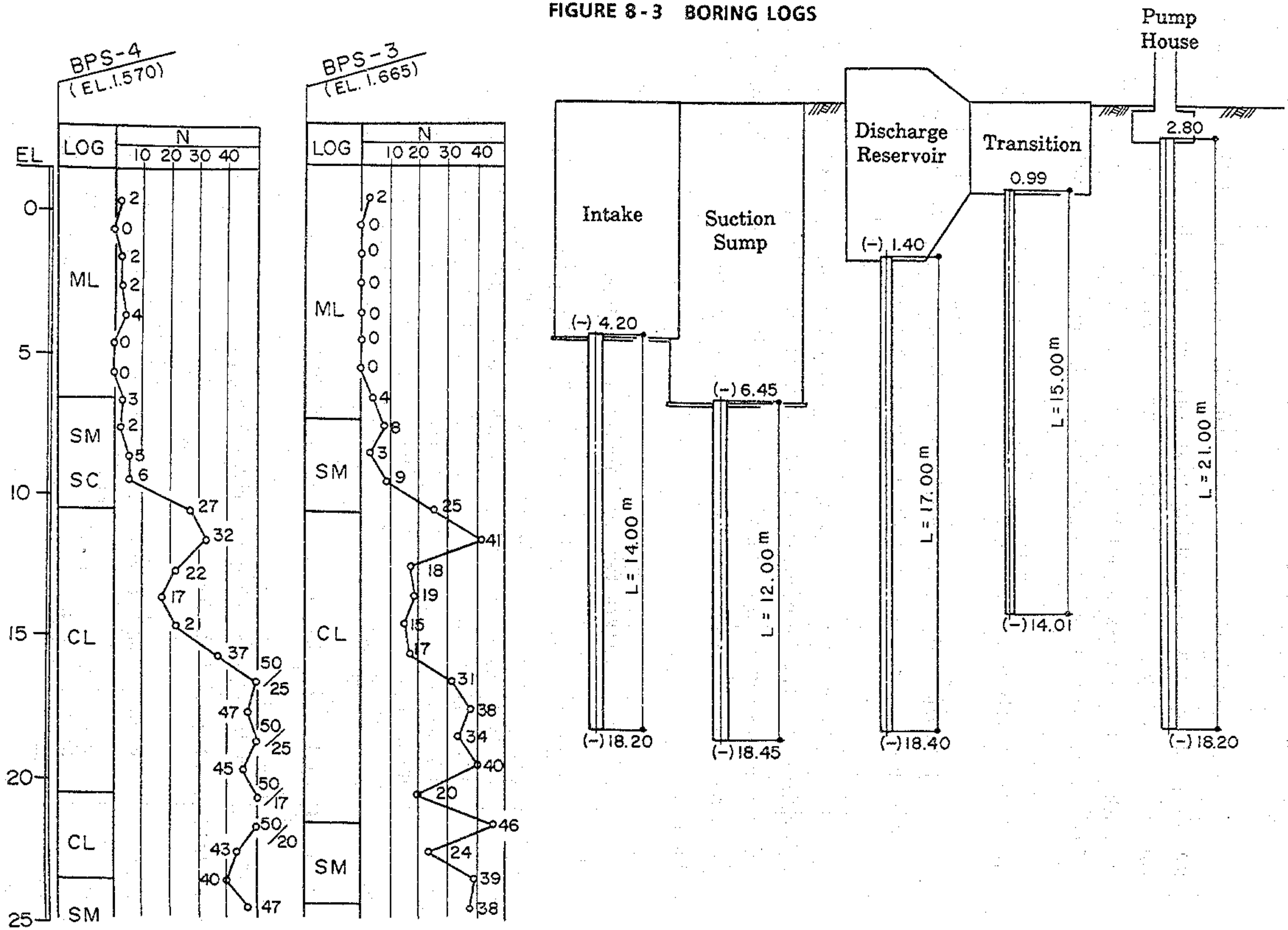
Works	EL. of Pile Head	EL. of Pile Tip	Pile Length
Intake	EL. (-) 4.20 m	EL. (-) 18.20 m	L = 14.00 m
Suction Sump	EL. (-) 6.45 m	EL. (-) 18.45 m	L = 12.00 m
Discharge Reservoir	EL. (-) 1.40 m	EL. (-) 18.40 m	L = 17.00 m
Pump House	EL. 2.80 m	EL. (-) 18.20 m	L = 21.00 m
Transitions	EL. 0.99 m	EL. (-) 14.01 m	L = 15.00 m

3) Calculation of Allowable Bearing Capacity for Pile in Vertical Direction

Allowable bearing capacity for pile in vertical direction (Ra) can be calculated by the following equation :

$$Ra = 1/3 \cdot (qd \cdot A + U \cdot \Sigma \ell \cdot f_i)$$

FIGURE 8-3 BORING LOGS



Where,

Ra	:	Allowable bearing capacity for pile in vertical direction (t/pile)
A	:	Sectional area of pile (m^2)
U	:	Circumference of pile (m)
ℓ_i	:	Thickness of layers for considering skin friction (m)
f_i	:	Max. skin frictional force (t/m^2)
qd	:	Ultimate bearing capacity per unit area supported by pile tip (t/m^2)

$\ell/D < 5.0$ qd = $(10 + 4\,\ell/D) \cdot N$ for $\ell/D < 5.0$

$\ell/D \geqq 5.0$ qd = 30 N for $\ell/D \geqq 5.0$

ℓ	:	Depth of pile penetrated into a bearing layer (m)
D	:	Pile diameter (m)
N	:	Design N-value at pile tip

a) The Pile Tip Locations at EL. (-) 18.20 m

$N = 33, \quad \ell = 2.3$ m

ℓ_i = EL. (-) 10.64 m – EL. (-) 18.20 ≒ 7.50 m

$f_i = N_i = 15\ (\leqq 15)$

Pile Dia. (mm)	qd	Bearing Capacity (t/pile)			Remarks
		qd · A	U · ℓi · fi	Ra	
ø 300	30 N	70.0	106.0	58.6	
ø 400	30 N	124.4	144.1	89.5	
ø 500	28.4 N	184.0	176.7	120.2	
ø 600	25.3 N	236.0	212.1	149.3	

b) Pile Tip Locations at EL. (-) 14.00 m

$N = 18, \ell/D \geqq 5.0$

ℓ_i = EL. (-) 10.64 m – EL. (-) 14.00 ≒ 3.30 m

$f_i = N_i = 15\ (\leqq 15)$

Pile Dia. (mm)	qd	Bearing Capacity (t/pile)			Remarks
		qd · A	U · ℓi · fi	Ra	
ø 300	30 N	38.2	46.7	28.3	
ø 400	30 N	67.9	62.2	43.3	
ø 500	30 N	106.0	77.8	61.2	
ø 600	30 N	152.7	93.3	82.0	

4) Determination of Pile Specifications

The specifications of the piles used for the respective foundations under the structures shall be determined by selecting the most economical ones among PC-piles (TIS 398-2524) based on the respective design loads.

a) Design Load

TABLE 8-4 DESIGN LOADS FOR RESPECTIVE WORKS

Works		Vert. Force V (t)	Horz. Force H (t)	Eccentr. Dist. e (m)	Moment M (t · m)
Intake	With Uplift	1,767	- 134	- 0.54	- 954
	Without Uplift	2,761	- 134	- 0.55	- 1,519
Suction Sump	With Uplift	3,990	- 519	0.01	40
	Without Uplift	5,470	- 519	0.01	55
Discharge Reservoir	With Uplift	1,797	-	- 1.08	- 1,941
	Without Uplift	1,986	-	- 1.31	- 2,602
Transition 1		675	-	- 0.17	- 115
Transition 2		553	-	- 0.38	- 210
Transition 3		324	-	- 0.65	- 211
Pump House Footing F_1		190	-	-	-
Pump House Footing F_2		90	-	-	-

Note: Horizontal force and eccentric distance are taken in the direction of the flow, taking positive sign towards the downstream.

b) Economic Comparison

Comparison of the respective foundation works for each structure is shown in Table 8-5.

TABLE 8-5 ECONOMIC COMPARISON OF FOUNDATION WORKS FOR EACH STRUCTURE

Structures	Pile Specification			Pile Arrangement	Const. Cost per Pile (B)	Const. Cost(B)	Cost Ratio
	Kinds	Dia.	Length				
Intake	PC Pile	ø 400mm	14.0 m	5×7+4×2=43	8,300	356,900	1.03
		ø 500mm		4×6+2×2=28	12,400	347,200	1.00
		ø 600mm		4×6+2×2=28	17,440	488,320	1.41
Suction Sump	PC Pile	ø 400mm	12.0 m	10×13=130	7,120	925,600	1.10
		ø 500mm		8×10=80	10,640	851,200	1.02
		ø 600mm		7×8=56	14,960	837,760	1.00
Discharge Reservoir	PC Pile	ø 300mm	17.0 m	6×7=42	6,570	275,940	1.00
		ø 400mm		5×6=30	10,080	302,400	1.10
		ø 500mm		4×6=24	15,060	361,440	1.31
Transition 1, 2, 3	PC Pile	ø 300mm	15.0 m	27+22+14=63	5,800	365,400	1.00
		ø 400mm		17+14+10=41	8,900	364,900	1.00
		ø 500mm		17+14+10=41	13,300	545,300	1.46
Pump House Footing F_1, F_2	PC Pile	ø 400mm	21.0 m	3×4+2×2=16	12,460	199,360	1.07
		ø 500mm		2×4+1×2=10	18,620	186,200	1.00
		ø 600mm		2×4+1×2=10	26,180	261,800	1.41

c) Determination of Pile Diameter

Determination of the pile diameter shall be made based on the economic comparison, in principle.

d) Pile Layout

The pile layout is illustrated in Figure 8-4.

5) Calculation Results for Foundation Works

Based on the aforesaid loading conditions and pile layout, the calculation was made as shown in Table 8-6. As a result of calculation on pile loading force, stress in pile, displacement at pile head, etc., all of those values are within allowable extent.

FIGURE 8-4(a) PILE LAYOUT (1/2)

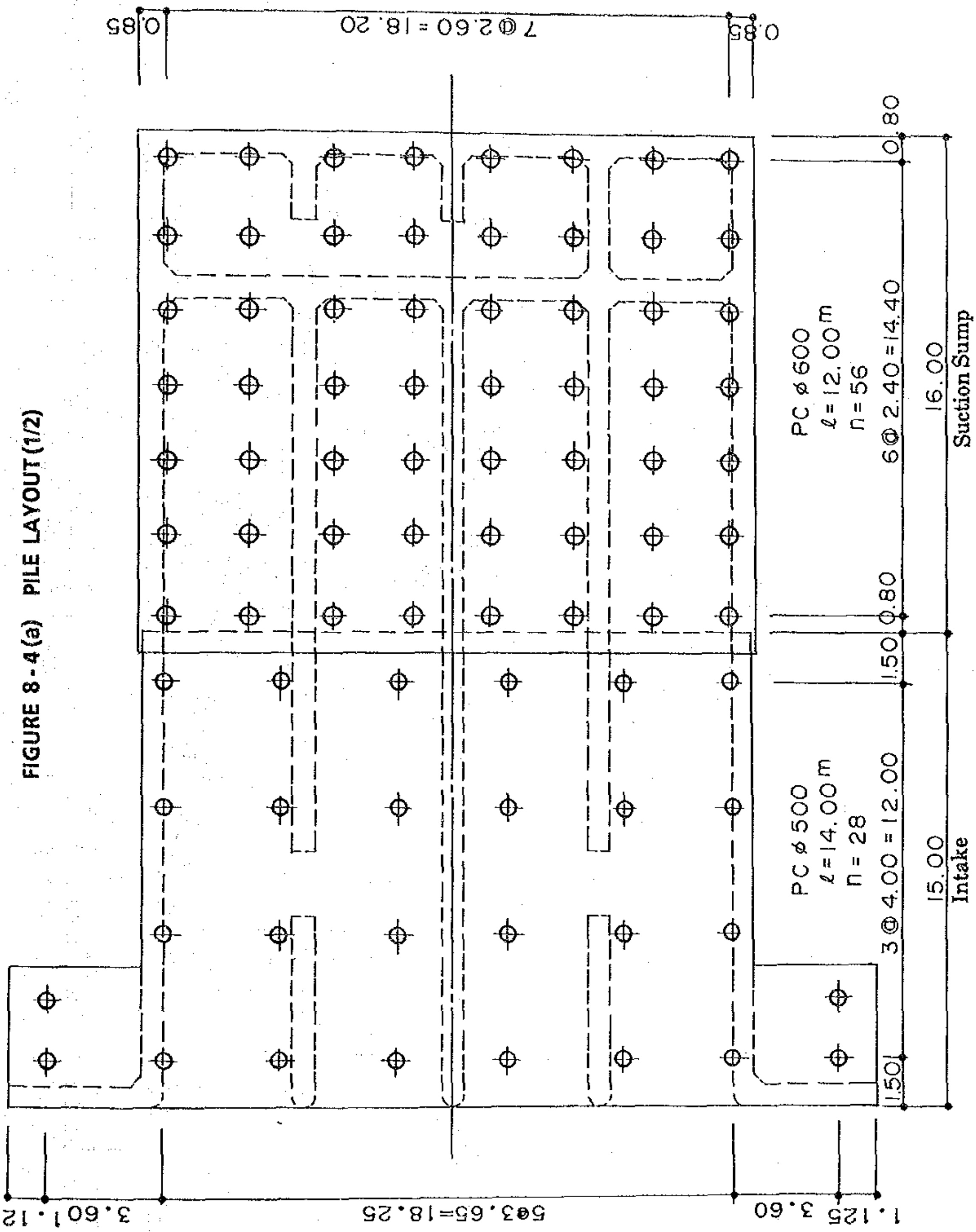


FIGURE 8-4 (b) PILE LAYOUT (2/2)

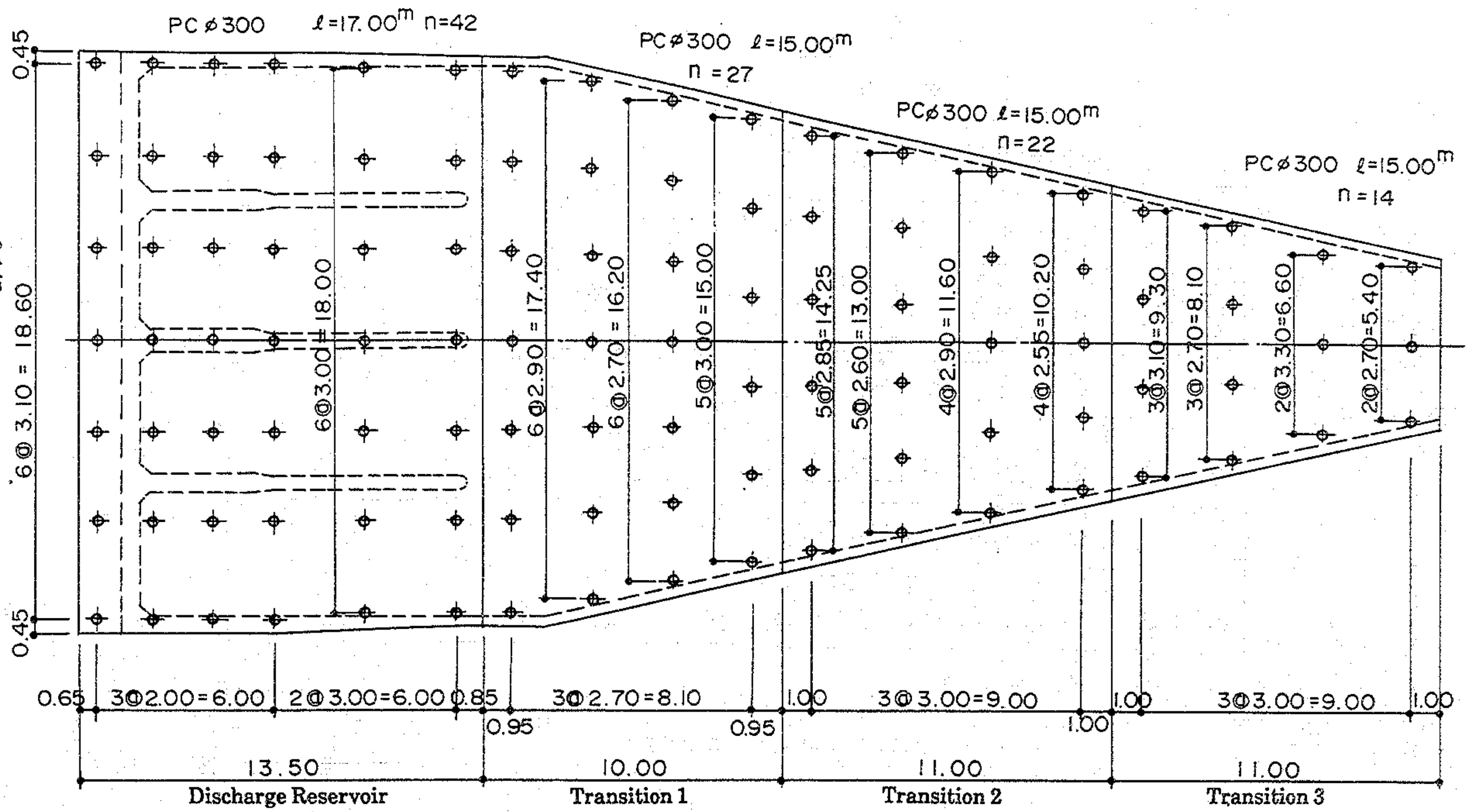


TABLE 8-6 CALCULATION RESULTS FOR FOUNDATION WORKS

Works		Pile Dia. (mm)	No. of Piles	Pile Loading Force (t)		Stress within Pile (kg/cm^2)				Displacement (cm)	
				Calcul'ed. Value	Allow. Value	Compaction Stress		Tensile Stress		Calcul'ed Value	Allow. Value
						Calcul'ed Value	Allow. Value	Calcul'ed Value	Allow. Value		
Intake	With Uplift	ø 500	28	64.3	≦ 120.2	167	≦ 225	0 (-18.4)	0	0.3	≦ 1.5
	Without Uplift			101.5	≦ 120.2	200	≦ 225	0 (-10.8)	0	0.3	≦ 1.5
Suction Sump	With Uplift	ø 600	56	75.3	≦ 149.3	168	≦ 225	0 (-37.5)	0	0.3	≦ 1.5
	Without Uplift			101.6	≦ 149.3	185	≦ 225	0 (-20.6)	0	0.3	≦ 1.5
Discharge Reservoir	With Uplift	ø 300	42	49.6	≦ 58.6	146	≦ 225	-		-	
	Without Uplift			58.4	≦ 58.6	166	≦ 225	-		-	
Transition	1	ø 300	27	25.2	≦ 28.3	93	≦ 225	-		-	
	2		22	26.1	≦ 28.3	95	≦ 225	-		-	
	3		14	25.0	≦ 28.3	93	≦ 225	-		-	
Pump House	F 1	ø 500	2	95	≦ 120.2	122	≦ 225	-		-	
	F 2		1	90	≦ 120.2	118	≦ 225	-		-	

Note :
1. Compression stress within pile $\sigma ca = 0.45 fc$
2. The values in parenthesis are tensile stress left pre-stress $\sigma_e = 40 kg/cm^2$ out of consideration

CHAPTER 9. DESIGN OF CONTROL SYSTEM

9.1 Objectives of Control System

A control system for the Bang Pakong Diversion Dam Project will be introduced for the proper operation of the Diversion Dam and Pumping Station. The use of this centralized control system, is expected to save control time and ensure the safety of the facilities and surroundings of the Diversion Dam. Another objective is the effective utilization of water resources and the fair distribution of the water.

The general plan of the control system is shown in Figure 9-1.

The Bang Pakong Diversion Dam Project includes the Diversion Dam, the Pumping Station, 8 water level gauges and 2 salinity instruments. The monitoring of Tha Lat Diversion Dam (existing), Rabom Dam (existing), Khlong Si Yat Dam and sea level gauge at the estuary will be added to the system according to the full plan of the Tha Lat River Basin Development Project.

9.2 Scope of the Control System and Control Level

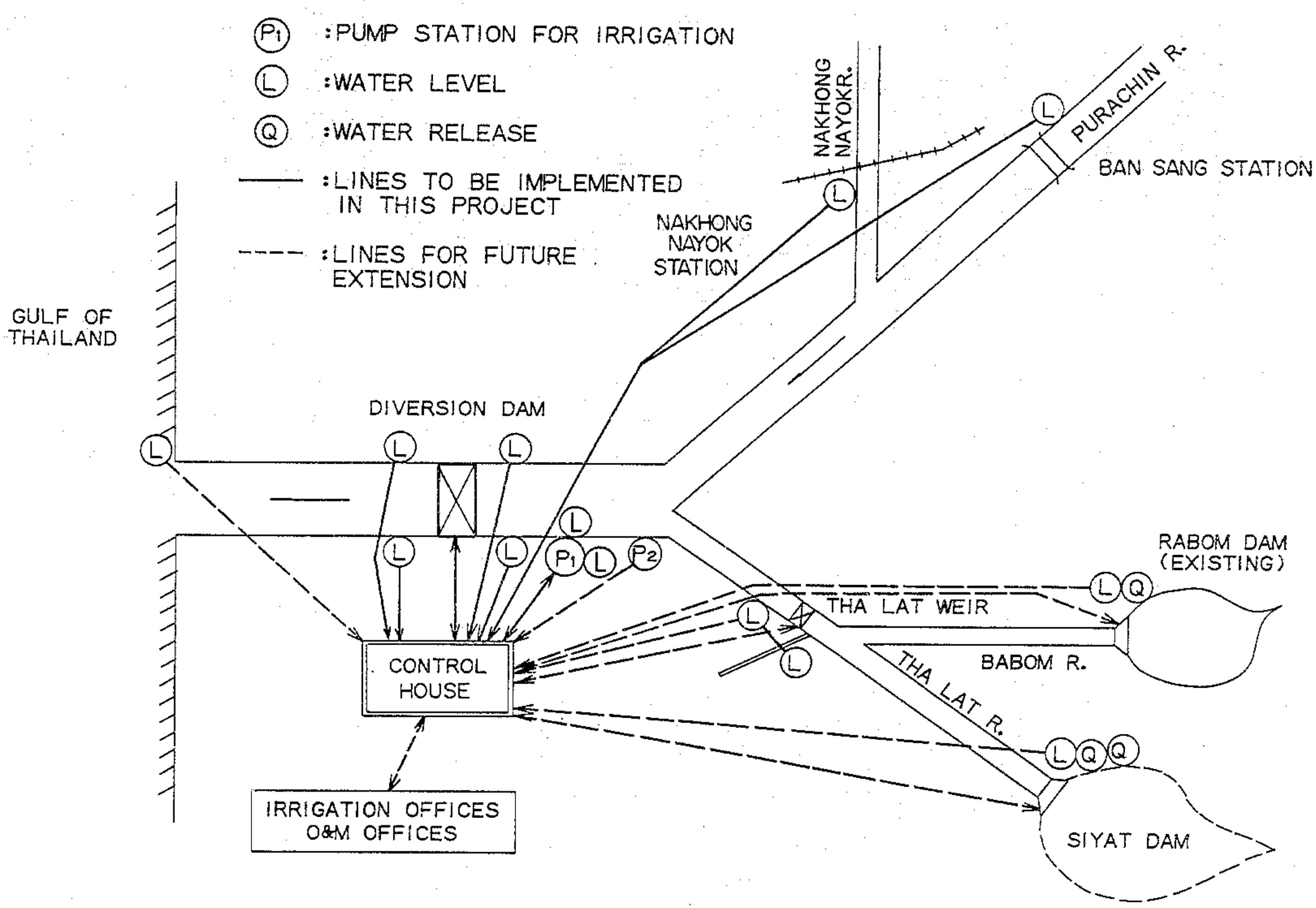
The control system should be simple to operate and maintain. Therefore, a centralized control and monitoring system should be adopted for the main system.

The control and monitoring system for Electrical Facilities is convenient for the operation and maintenance of the dispersed electrical facilities, such as the Hoist House, Substation of the Diversion Dam, Pumping Station and residential area on the O/M building site.

9.2.1 Scope of the Control System

The facilities for the centralized control and monitoring system are shown in Table 9-1. The reasons for this selection of facilities are shown below.

FIGURE 9-1 GENERAL PLAN OF CONTROL SYSTEM



1) Control of the Diversion Dam is possible by monitoring water levels downstream and upstream of the Diversion Dam and in the Prachin and the Nakhong Nayok rivers.

2) Both remote control and monitoring of the main facilities, that is the Diversion Dam and the Pumping Station, as possible.

TABLE 9 - 1 FACILITIES FOR CONTROL AND MONITORING

Name of Facilities	Monitoring	Control	Remarks
1. Diversion Dam	○	○	
2. Pumping Station ①	○	○	Irri. W. Supply, Fish, Others
3. Pumping Station ②	(○)		Industry
4. Upstream Water Level at Diversion Dam	○		2 Spots
5. Downstream Water Level at Diversion Dam	○		2 Spots
6. Ban Sang Station	○		1 Spot
7. Nakhong Nayok Station	○		1 Spot
8. Tide at Estuary	(○)		1 Spot
9. Salinity at Diversion Dam	○		2 Spots
10. Khlong Si Yat Dam	(○)		
11. Rabom Dam	(○)		
12. Tha Lat Diversion Dam	(○)		

Note: Facilities with ( ) are not included in Bang Pakong Diversion Dam Project

The following facilities are not included in this Project because the full plan of the Tha Lat River Basin Development Project including these facilities is not immediately necessary.

a) Tha Lat Diversion Dam(existing)
b) Rabom Dam (existing)
c) Khlong Si Yat Dam
d) Pumping Station ②, Tide at Estuary

9.2.2 Control Level

The control level of the Control House and other facilities is shown below.

1) Control House

a) Telemetry System

The following items will be operated by a telemetry system. But, online control using collected information is not included in this system.

Indication of collected information
Accumulation of -do-
Recording of -do-
Processing of -do-

b) Control and Monitoring of Electrical Facilities

The following items will be operated by this system.

On-Off tele-control of electrical facilities
Indication and monitoring of gauges

2) Ban Sang and Nakhon Nayok Station

Water levels of Ban Sang and Nakhon Nayok station will be transmitted to the Control House by radio (VHF).

3) Diversion Dam and Pumping Station

a) Telemetry System

Water levels will be transmitted to the Control House by communication circuit.

b) Control and Monitoring of Facilities

The following items will be operated by this system.

- Manual On-Off control of facilities
- Indication and monitoring of gauges

9.3 Outline of Control System

The control and Monitoring System for the Bang Pakong Diversion Dam Project shall be composed of the following six(6) sub-systems.

- Gate control and monitoring sub-system
- Pumping Station control and monitoring sub-system
- Substation control and monitoring sub-system
- Telemetry data acquisition sub-system
- ITV monitoring sub-system
- Information by paging sub-system

The outline of the control system is shown in Figure 9-2.

9.3.1 Location and Function of the Control House

1) Location

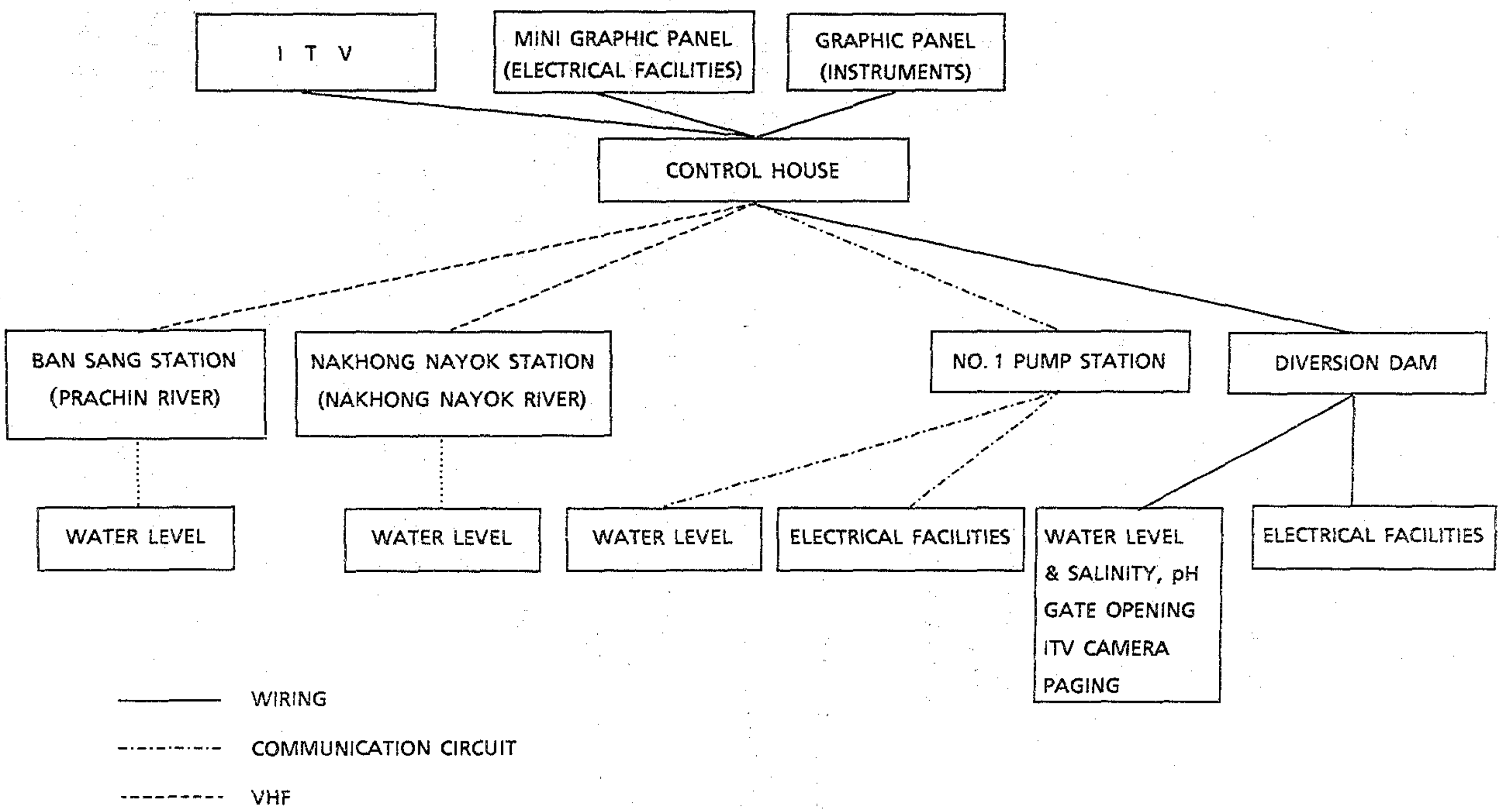
The Control House is located in one room of the control building, which is located on the left bank at the site of the Diversion Dam.

2) Function

The Control House is the supervisory room for the Diversion Dam, pumping station and all facilities of this Project. The main functions of this system are as follows.

- Monitoring of water levels and discharges
- Remote control of Diversion Dam, Pumping Station and other Electrical Facilities

FIGURE 9-2 OUTLINE OF SUPERVISORY SYSTEM



- Information processing
- Monitoring of Diversion Dam by ITV (Industrial T.V)
- Information by paging

Main instruments for this Control House are as follows.

- Central operation console
- Graphic panel
- Measuring and monitoring device
- Control and monitoring device
- Information processing device
- Alarming device
- ITV device
- Paging device

9.3.2 Composition

1) Graphic Panel for Measuring and Monitoring

- The graphic panel should be designed to include the full plan of the Tha Lat River Basin Development Project. For future alteration, the materials of the graphic panel should be of the mosaic type.

- Indication items on the graphic panel are as follows.

  - Water levels
  - Discharges from Diversion Dam and Pumping Station
  - Condition of regulating and flood gates
  - Condition of Pumps

2) Mini Graphic Panel for Electrical Facilities

- The condition of Substations and Electrical Facilities at the Diversion Dam, Pumping Station and residential area will be indicated on the graphic panel.
- The kind of indication will be the on-off condition of each load system.

9.3.3 Transmission Method and Information Circuit

The transmission method depends on the distance from the control house.

1) Distance between Control House and On-Site

- Ban Sang station (Prachin river) .... 35 km
- Nakhon Nayok station (Nakhon Nayok river) ... 30 km
- Pumping Station .... 7 km
- Diversion Dam .... 1 km

2) Transmission by Radio (VHF)

The next stations are far from the Control House, therefore, radio circuit (VHF 150 MHz band) will be adopted in this case.

- Ban Sang station
- Nakhong Nayok station

3) Transmission by Communication Circuit

The Pumping Station is 7 km from the Control House. It is therefore better to use a communication circuit between the Control House and the Pumping Station.

4) Transmission by Control Cable

Water level gauges and Electrical Facilities at the Diversion Dam site are less than 1 km away from the Control House. Therefore, control cables should be used for the route between the Control House and these facilities.

5) Radio Telephone System

Radio telephone system will be installed between Control House and sites. The frequency will be adopted 150 MHz band.

6) Monitoring and Paging

Each two monitoring cameras will be installed on the upstream and downstream sides of the Diversion Dam. Television pictures will be transmitted to the Control House by an ITV device. The angle of the monitoring cameras should be variable and a zooming device should be added because of the 170 m width of the Diversion Dam.

A paging device will be installed at each of the following places for announcements that are transmitted from the Control House.

- Upstream and downstream of the Diversion Dam
- Pumping Station
- Control House

9.3.4 Outline of Control System

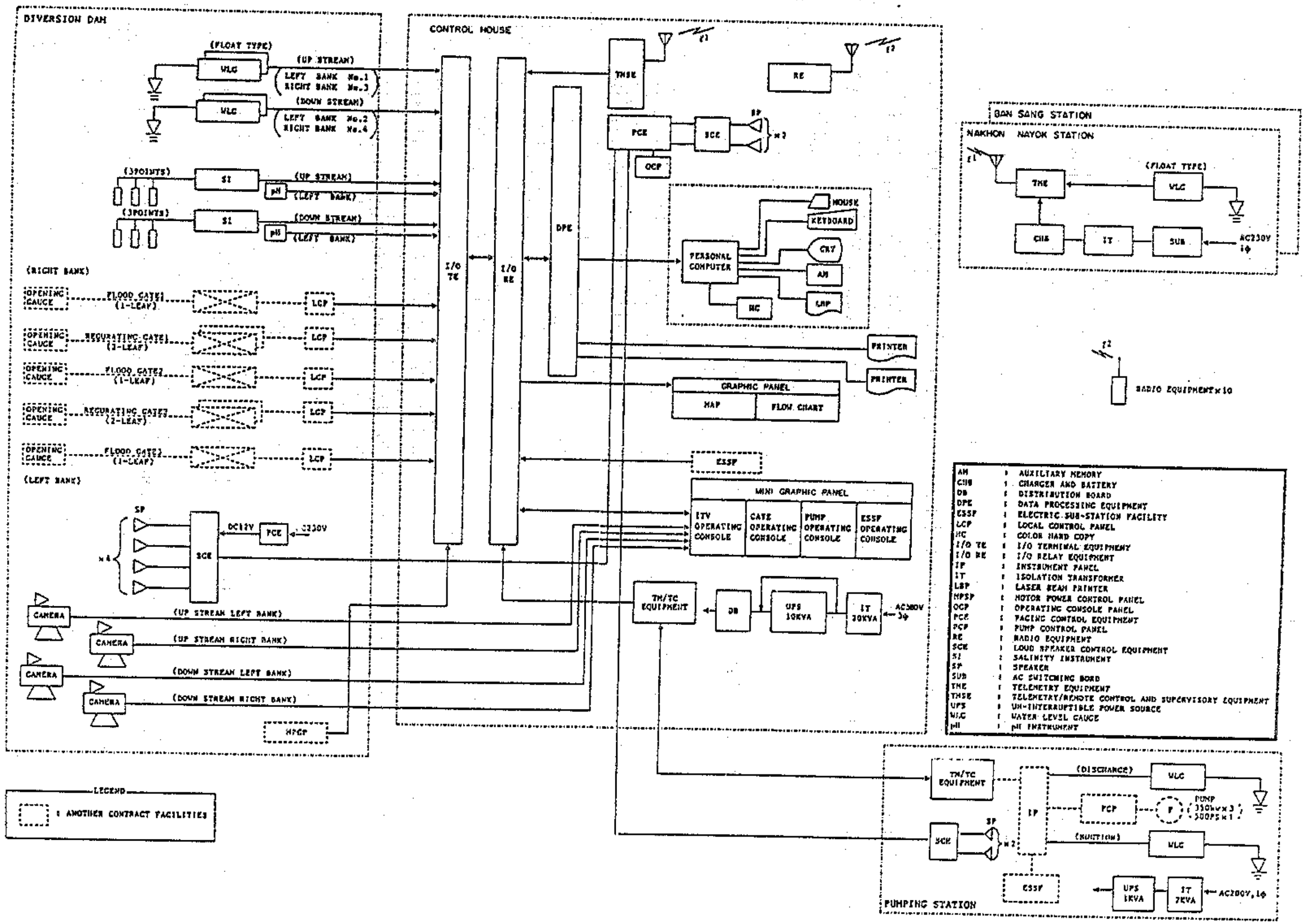
The outline of the control system is shown in Figure 9-3.

1) Scope of Centralized Monitoring System

a) Scope of Monitoring and Measuring System

Location	Measuring Items	Transmission Method
Ban Sang station	Water level ×1	VHF
Nakhon Nayok station	Water level ×1	VHF
Pumping Station	Water level ×2	Communication circuit
Diversion Dam	Water level ×4	-do-
-do-	Salinity instrument ×2	-do-
-do-	pH meter × 2	-do-
-do-	ITV camera ×4	Control cable
-do-	Condition of gates ×7	-do-

FIGURE 9 - 3 COMPOSITION OF CONTROL SYSTEM



b) Scope of Control and Monitoring System of Electrical Facilities

Location	Control & Monitoring items	Transmission method
Diversion Dam	Power unit	Control cable
-do-	Sub-station	-do-
-do-	Gate motor	-do-
-do-	Emergency power unit	-do-
Pumping Station	Power unit	Communication circuit
-do-	Sub-station	-do-
-do-	Pump motor	-do-
-do-	Emergency power unit	-do-

2) Function of Control and Monitoring System

a) Monitoring and Measuring

The purpose of monitoring and measuring is to collect, record and accumulate data. Discharge from the Diversion Dam and Pumping Station should be computed from the differences between water levels. (refer to Appendix 3.4)

b) Control and Monitoring of Electrical Facilities

The on-off controls of all devices and switches will be operated by this system. Also, voltage, electric current, power rate and power factor will be indicated, recorded and accumulated.

c) Alarm System

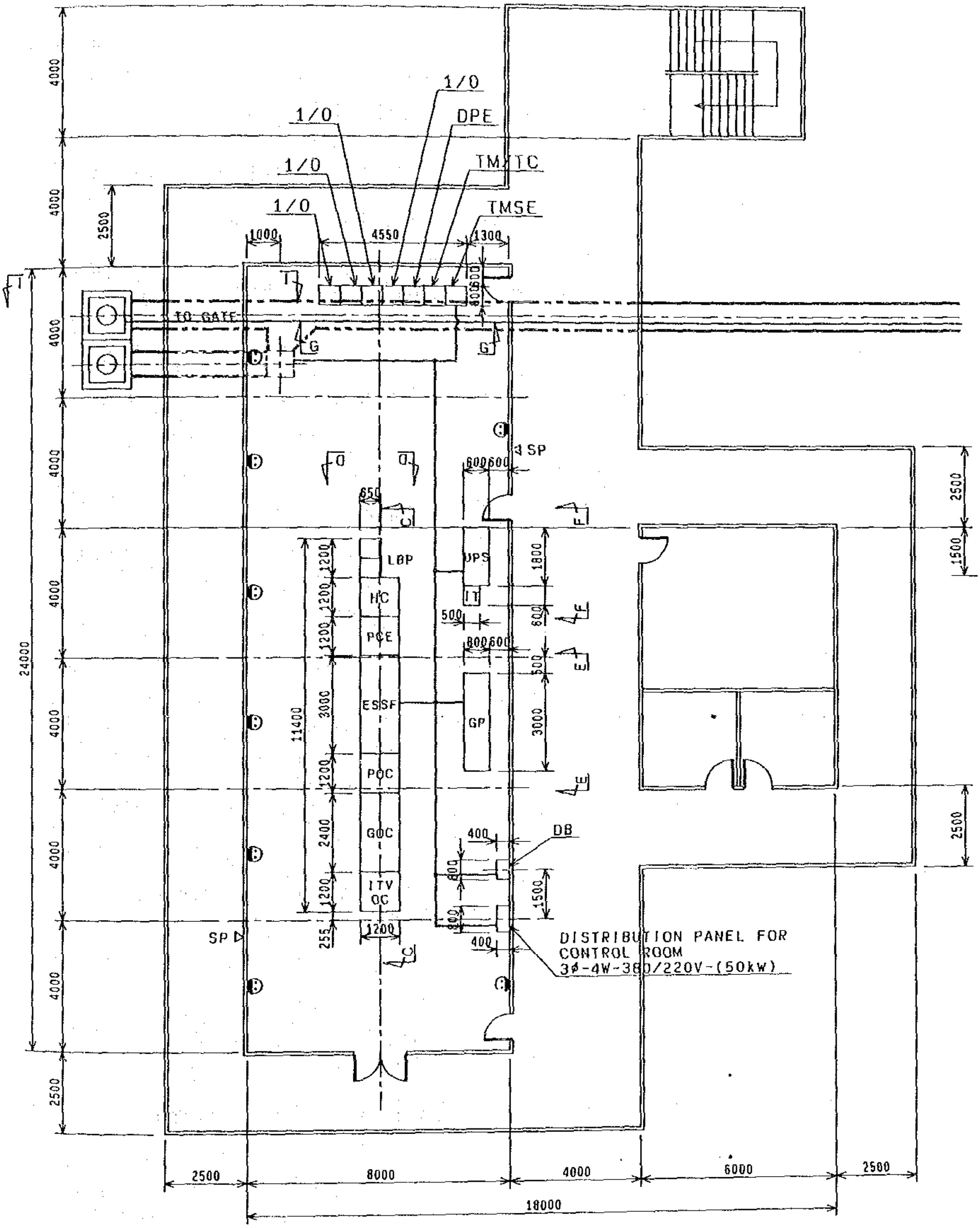
Warnings of an emergency including information on temperature and function of the control system, will be conveyed by indicators and buzzers.

3) Layout of Control House

The layout of the Control House is shown in Figure 9-4.

The Control House should be constructed with a free-type floor to enable wiring and future extension.

FIGURE 9-4 LAYOUT OF CONTROL HOUSE



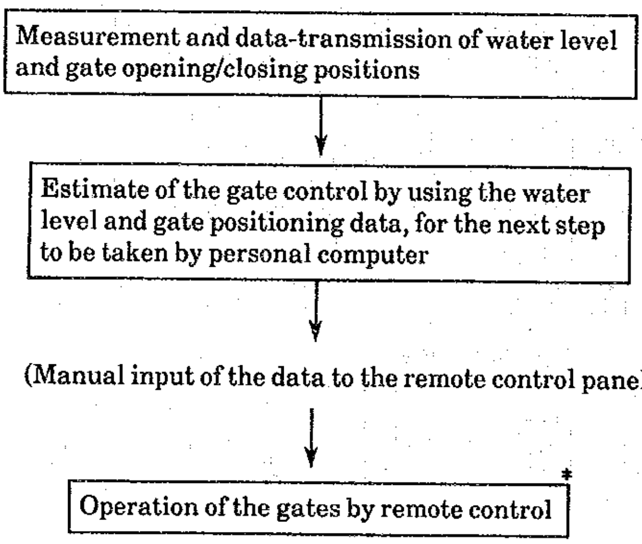
9.3.5 Gate Control

It may be possible to operate the tide protection gates by remote control depending on the results of the estimate of the degree of gate opening which in turn depends on the water level data.

There are three phases in the above-mentioned system. These phases are shown below.

1) Measuring data and data-transmission
2) Estimate of the gate opening and closing
3) Operation of the gates

Therefore, one manual input is provided in the system as shown below.



* The gate controlling will be operated by manual mode, and setting of the opening position will be set by manual control on the console desk.

The gate control mode shall be as follows.

- ON/OFF control
- Set point control for target opening position

Input data and output data for gate controlling shall be as follows.

1) Input Data

a) Gate opening for two(2) regulating gates
b) Gate opening for three(3) flood gates
c) Supervision items for three(3) flood gates and two(2) regulating gates
d) Salinity density of six(6) points at total of two(2) fixed sites.
e) pH value of two (2) fixed sites.
f) Salinity density of temporally site (Chachoengsao Bridge) by manual measurement

2) Output Data

The following are descriptions of output data.

a) Command signals for controlling regulating gates
b) Command signals for controlling flood gates
c) Output data for graphic panel

- 8 water levels including water levels at Pumping Station and upstream of Bang Pakong River
- Outflow data
- Inflow data
- Salinity density
- pH value
- The operation conditions of gates, open or close

d) Output data on the visual display equipment
e) Output data on gate operating console

- Gate opening
- Outflow data
- Inflow data
- Operation condition
- Equipment condition
- Hydrological condition

The following calculations shall be prepared for this system.

- Smooth processing for dam water levels
- Inflow calculation procedure
- Outflow calculation procedure
- Pumping discharge calculation procedure
- Detection the alarming water levels
- Target gate opening

9. 3. 6 Pumping Station Control and Monitoring Sub-System

The operation of the Pumping Station control and monitoring sub-system will be controlling and monitoring through use of the Pumping Station's input and output data.

1) Input Data

a) The operation conditions of the Pumping Station
b) Supervision items for Pumping Station
c) Suction water level
d) Discharge water level

2) Output Data

a) Command signals for Pumping Station
b) Output data for graphic panel

- 2 water levels
- Total discharge
- Operation condition
- Alarm

c) Output data on the visual display equipment
d) Output data on pump operating console

- Operation condition
- Alarms

The following calculations shall be prepared for this system.

- Smooth processing of suction water level and discharge water level
- The total discharge
- Detection the alarming water levels

3) Controlling

The pump controlling will be operated by manual mode.
The pump control mode shall be as follows.

- ON/OFF control

9.4 Composition of Instruments

9.4.1 Water Level Gauge

1) Location

a) Gauging Station for River

The purposes of the gauging stations for the river are as follows :

① Grasp of the fluctuations of the upstream's water levels.
② Monitoring of the alarming water levels (refer to Appendix 3.3).
③ Recording of water levels after the construction of the Diversion Dam.

Two water level gauging stations have been chosen after the site survey of the rivers. These stations profile are as follows.

Ban Sang Station	:	catchment area	9,260 km^2	(63%)
Nakhon Nayok Station	:	-do-	1,910 km^2	(13%)

Notes: the value of ( ) means the area's percentage of the total catchment area of the Diversion Dam of 14,729 km^2

Ban Sang station is just upstream of the existing water level gauging station (KGT. 22 Prachin river) that has been observed by RID using a staff gauge. This station is 35 km from the Diversion Dam.

There is no existing gauging station at the confluence with the Prachin river and the Nakhon Nayok river. Therefore, Nakhon Nayok station should be constructed at the crossing point between the railway and the Nakhon Nayok river. This new gauging station will be 30 km from the Diversion Dam. (refer to Appendix 9. 1)

b) Gauging Station for Diversion Dam and Pumping Station

Each two water level gauging stations should be constructed both upstream and downstream of the Diversion Dam, for the operation of the tide protection gates. In all, there needs to be four gauging stations at the Diversion Dam site.

Also, one gauging station should be constructed at both the suction sump and the discharge reservoir of the Pumping Station, for monitoring the pumping discharge. In all, there need to be two gauging stations at pumping station.

2) Type of Water Level Gauge

Floating-type water level gauges will be adopted for these stations because of their frequent use in the river. This type is available for long-term observation and maintenance.

9. 4. 2 Salinity Instrument and pH Instrument

1) Salinity Instrument

a) Location

Two salinity instruments will be installed both upstream and downstream of the left bank of the Diversion Dam. The upstream instrument will be used for monitoring water quality, and the downstream one will be used for the monitoring of salinity intrusion and operation of the tide protection gates.

Salinity at three depths should be monitored for each station. Each sensor shall be installed as follows, because of the water level condition of the Diversion Dam.

Upstream	:	EL.0.0 m, (-) 1.3 m, (-) 5.0 m (MSL)
Downstream	:	EL.(-)1.3 m, (-) 4.0 m, (-) 7.0 m (MSL)

b) Type of Salinity Instrument

The salinity instrument consists of a sensor for the water temperature and specific conductance.

Salinity is estimated from this specific conductance and water temperature shall be fed into the recorder.

2) pH Instrument

a) Location

pH is one of the basic water quality components. Therefore, the pH instrument shall be installed by the salinity instrument, upstream and downstream of the diversion dam.

The value of pH is estimated from hydrogen concentration.

pH	$>$	7	Alkaline
pH	$=$	7	Neutral
pH	$<$	7	Acid

Each sensor shall be installed as follows.

Upstream	:	EL.(-) 1.3 m (MSL)
Downstream	:	EL.(-) 1.3 m (MSL)

b) Type of pH Instrument

pH instrument consists of a sensor, cleaning unit control board and relay cable. The range of this instrument is 2 ~ 12 pH. Automatically, cleaning unit works for a sensor.

9. 4. 3 ITV Monitoring Sub-System

1) Purpose

ITV monitoring system is adopted for the safety and the reliability of gate control.

The purpose of the ITV monitoring system is as follows.

a) Confirmation of existence of boats and people near gates
b) Monitoring of outflow from gates
c) Monitoring of refuse and driftwood

2) Location

Upstream	:	On the left bank and right bank, 200 m upstream of Diversion Dam, 2 points
Downstream	:	On the road bridge, 200 m downstream of Diversion Dam, 2 points

Detailed selection of this location; refer to Appendix 9. 3.

3) Composition

The ITV monitoring system consists of two sets of cameras with auxiliary lamps installed at the downstream site of the Diversion Dam and at the upstream site of the Diversion Dam, two sets of monitor televisions are installed in the Control House. ITV camera and lens; refer to Appendix 9. 4.

The auxiliary lamps installed with camera will be prepare to provide the illuminous intensity sufficient to extend to the gate side. Fixed lamps shall be installed at the gate piers. (refer to Appendix 9. 5)

The remote control items on the ITV monitor console shall be as follows.

- Power ON / OFF
- Zoom
- Tele. or wide mode change
- Focus
- Near or Far
- Wiper
- Defroster
- Light ON/OFF
- Direction control

9. 4. 4 Telemetry System and Graphic Panel

The telemetry system consists of the following three phases is shown in Figure 9-2.

Ban Sang and Nakhon Nayok station	radio wave (VHF)
Pumping Station	TM/TC
Diversion Dam area	control cables

1) Telemetry Telecontrol Equipment

a) Transmission system

- Communication system	:	duplex communication system
- Transmitting speed	:	200 bit/sec or more
- Transmission system	:	cyclic
- Correspondence method	:	1 : 1 method
- Communication system code configuration	:	Conforming to JIS 5104 or equivalent (high level data link control procedure frame configuration)

b) Power Supply : AC 220V ± 10%

c) Power consumption : 200VA or less

2) Graphic Panel

The Graphic Panel will feature digital displays and lamps for water levels, discharge, gate opening/closing and the condition of pumps.

The Mini Graphic Panel will indicate the condition of Electrical Facilities at the Diversion Dam and Pumping Station.

9.4.5 Radio Device

1) Radio Device (VHF)

A radio wave device will be adopted for the transmission of water levels of the Ban Sang and Nakhon Nayok station.

Transmission wavelength	150 MHz band
Transmission velocity	200 bit/sec
Transmission method	polling method
Linkage method	1 : 2, available to 1 : 7

According to the Tha Lat River Basin Development Project, monitoring stations will be increased in future. Therefore, it is economical to use the 1 : N polling method.

2) Telemetry Data Acquisition Sub-System

a) System Composition

Telemetering system to collect the necessary observation data for gate control and display system, consisting of the Control House, Nakhon Nayok station, and Ban Sang station.

b) Network of Telemetering System

Each gauging station shall be connected with the Control House by the frequency of 150 MHz band.

3) System Operation

a) The Control House shall collect water-level data by calling the gauging station.

b) Voice communication between the Control House and gauging station for maintenance use shall be possible in this system. Moreover, automatic calling shall take priority over voice communication.

4) System Function

The Control House shall transmit calling signal to the gauging stations, and shall collect the data from the gauging stations. The calling method shall be follows;

a) Automatic calling
b) Manual calling
c) Re-calling

5) Transmission System

a) Communication system : Half-duplex communication
b) Code format : NRZI format
c) Synchronous method : Asynchronous transmission
d) Modulation system : Sub-carrier frequency shift system
e) Communication rate : 200 bps
f) Error detecting method : 16-bit cyclic redundancy check
g) Code (frame) configuration: Based on JIS X5104
(High Level data Link Control procedures frame structure)

6) Antenna Tower

In consideration of the topographical map in the project area, the antenna height of each gauging stations is as follows.

- Ban Sang Station : H = 30 m
- Nakhon Nayok Station : H = 30 m
- Control House : H = 50 m

9.4.6 Control Device

This operation shall be controlled and monitored by the Electrical Facilities set up at the two sites;

One facility is at the Diversion Dam, and the other is at the Pumping Station. The monitored data from the Diversion Dam site and the Pumping Station, shall be displayed on Mini Graphic Panel and visual display equipment installed at the Control House. The Substation control mode shall be as follows.

- ON/OFF control for circuit breaker

Input and output data for this control is shown below.

1) Input Data

a) Voltage, current, power and power factor data
b) Supervision items for two Substations

2) Output Data

a) Command signals for Electrical Facilities
b) Output data for Mini Graphic Panel
    - Voltage, current, power and power factor data
    - The operation condition of Electrical Facilities
    - Alarm
c) Output data on the visual display equipment

9.5 Staff Organization

9.5.1 Staff Organization

A plan of operation and maintenance services is mainly executed upon operations of the Tide Protection Gate and the Pumping Station as well as the monitoring system and water conservation in the Bang Pakong river. For those services, a staff organization and its tasks are proposed to be divided into four divisions under a managing director.

Managing Director
- Administration and Accounting Division
- Electricity, Data-Transmission and Mechanical Division
- Agricultural Engineering Division
- Operation and Monitoring Division

This staff organization is proposed along with the operation and maintenance system under appointment of a managing director. Particularly the managing director, who is requested to manage as appropriate as possible overall management and engineering for the operation and maintenance services. The contents of their division task are proposed below.

9.5.2 Services in Division

1) Administration and Accounting Division

General services in the control house except for engineering tasks will be performed based on exchanging information between control house and external offices as per the regulation in RID. In the office, the accounting services for their expenditures will be settled and also the regulations in the RID.

2) Electricity, Data-Transmission and Mechanical Division

In the hardware component of the control and monitoring system, the equipment is mainly composed of electricity, wire and / or wireless telemeter as well as radio communication and mechanical devices. Those hardware parts should be maintained in normal condition without any trouble. For this purpose, this division will perform the maintenance services as constant interval as per the specifications of maintenance work.

3) Agricultural Engineering

For water operation and management, data collation, computation and recording are required. For execution service, an assistant engineer is proposed with a traming in agricultural engineering. The engineering services may not only analyse for hydrology and carry out data collation, but at the Pumping Station, assess the water supply operation programme regarding the water requirement on a daily and weekly basis in relation to the programme of pumping operations.

4) Monitoring and Operation

During the daily working in the Control House related to the operation and maintenance services, the mast as significant items are operation of the Tide Protection Gate and preparation the pumping operation routine under the monitoring on the runoff water in the river system of the overall basin. A suitable operation programme at the Bang Pakong Diversion Dam is proposed dividing into two routines one for wet and one for the dry season.

CHAPTER 10. DESIGN OF ELECTRICAL FACILITIES

10.1 Outline of Electrical Facilities

The Electrical Facilities, which supply electric power to every load required for the pumps and gates operation, are composed of an incoming line, substations and wiring to the project facilities, including the protective devices for electric circuits and a diesel-engine generator for emergency use. Layout of the project facilities and Electrical Facilities is shown in Figure 10-1. The major project facilities herein all Electrical Facilities to operate the Tide Protection Gates and Pumps. The power supply would be provided not only to the said major project facilities but also to the control facilities, such as water gauges, salinity instruments, loud-speakers, lighting for roads and gates, etc.

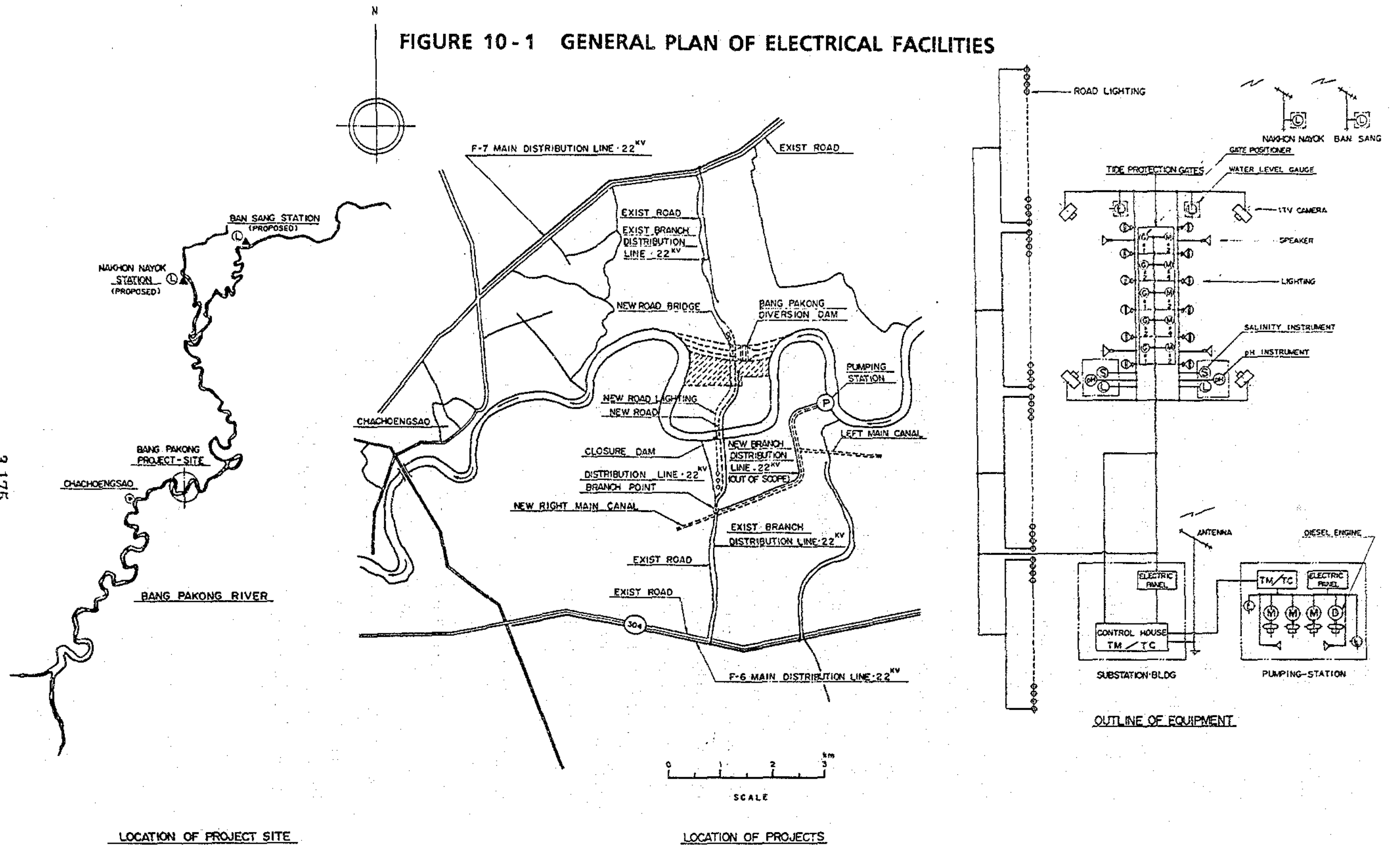
1) Incoming Distribution Line

Branch distribution line shall be branched off from the F-6 main distribution line on the left bank of the Bang Pakong river, and distribute the current to the Diversion Dam area and Pumping Station area from the beginning point of the new road. Incoming electrical works up to the terminal point near the Substation shall be done by PEA. The underground cable works from the pole of the terminal point to the Substation shall be included in the Project works.

2) Substations

Two (2) Substations are proposed, one at the Diversion Dam area and another in the Pumping Station area. Supply of electric power for the residences, which may be provided in the future, is excluded from the scope of the project works, because the power supply area is widely expanded and the electric power demand is only estimated. This future plan is expected to be studied by the RID.

FIGURE 10-1 GENERAL PLAN OF ELECTRICAL FACILITIES



3) Diversion Dam

The Diversion Dam is equipped with five gates, three for the flood gates, and two for the regulating gates. Each regulating gate consists of an upper gate and lower gate. Therefore, in terms of gate operation, seven (7) gates are provided. As each gate is operated by two (2) motors, a total number of motors is made up of fourteen (14) units.

4) Pumping Station

There are a total of 4 pumps in the pumping station. Those pumps are driven by electric motor and diesel engine; that is, 3 for 3 KV 350 KW motor and 1 for 500 ps diesel engine. Electric power, excluding the above, shall be supplied to the auxiliary equipment and lighting for the Pump House, the offices and the premises.

5) Lighting

To observe the tide protection gates by ITV cameras, the fixed type lighting fixtures shall be installed to supplement a quantity of light for each gate. The lighting for roads of a total distance of 3,160 m shall be performed by 112 lamps with 180 W for each and made up to 20 KW for the total load. The electric power shall be supplied by 380 V divided three (3) systems.

6) Control House

The Control House is located in the Diversion Dam area. The centralization control system shall be employed to monitor and control the operation of gates, pumps and all other equipment/instruments equipped for the Project including the Ban Sang and Nakhon Nayok stations in the upstream of the Diversion Dam. The electric power may be low in demand, since the electric currents supply for apparatus require only a small electric charge, such as the control devices and lighting units and air-conditioner in the Control House.

10. 2 Type of Load and Required Electric Power

1) Diversion Dam Area

Motor power (3ø - 50 Hz - 380 V) for the Diversion Dam is as follows

TABLE 10 - 1 MOTOR CAPACITIES FOR THE TIDE PROTECTION GATES

Gate		No. of Gate	Motor Capacity per one gate KW	Total Motor Capacity KW	Total KVA	Control Devices KVA	Grand Total
Flood gate		3	18.5 × 2 = 37	37 × 3 = 111	142	2 × 3 = 6	148
regulating gate	Upper	2	11 × 2 = 22	22 × 2 = 44	61	3 × 2 = 6	183
	Lower	2	22 × 2 = 44	44 × 2 = 88	116		
Total		7		243	319	12	331

TABLE 10 - 2 RATING CURRENT AND STARTING CURRENT OF MOTOR

Gate		Motor Capacity KW	Rating Current per one motor A	Starting Current per one motor A
Flood gate		18.5	36	180
regulating gate	Upper	11	23	107
	Lower	22	44	227

a) Basic Load and Operation Rules

Based on the values in Table 10-1 and Table 10-2, the basic loads of electric power are calculated as follows:

Rated basic load = (23.6 KVA × 2 + 15.1 KVA × 2 + 28.9 KVA × 2) + 12 KVA = 147 KVA

Starting basic load = (23.6 KVA × 2 + 15.1 KVA × 2 + 28.9 KVA × 5.2 × 2) + 12 KVA = ÷ 390 KVA

Then, according to the method of the above calculations for the basic starting load, the gate operation rules shall be set up for operating (starting) the first two (2) motors (23.6 KVA × 2 units) for the flood gate, the second two (2) motors (15.1 KVA × 2 units) for the upper leaf of regulating gate, followed by two (2) motors (28.9 KVA × 2 units) for lower leaf of regulating gate in sequence after the former motors enter into the normal operation condition.

The values of the above calculation are presented as the maximum loads for the operation of three (3) gates, one flood gate and each the of upper and lower leaves of the regulating gates. Within a range of the above load, therefore, these three (3) gates can operate in any sequence.

b) Miscellaneous Loads

TABLE 10-3 MISCELLANEOUS LOAD

No	Load	KW	Notes
1	Control house	50 + 40 = 90	lighting, etc. and control devices
2	Electricity house	30	lighting, fan, spares
3	Hoist houses	1 × 6 = 6	lighting for room
4	Lighting for gates	(0.4 × 4) × 10 = 16	4 lamps per gate, fixed lighting
5	ITV	2 + 0.5 = 2.5	U/S right bank, lighting, camera control
6	ITV	2 + 0.5 = 2.5	U/S left bank, do.
7	ITV	(2 + 0.5)×2 = 5.0	D/S left, right bank, do.
8	Water gauge stations	0.5 × 2 = 1	U/S, D/S right bank lighting
9	Water level and salinity observations stations	1 × 2 = 2	U/S, D/S left bank lighting & elec. source
			3.16 km long down stream side
10	Road lighting	0.18 × 112 ≒ 21	around control house & substation
11	Premises lighting	0.18 × 10 = 1.8	
	Total	≒ 178	

c) Control House, Laboratory and Dormitory

The power loads to these facilities (Table 10-4) are projected figures only, because the basic plan as well as construction program are as yet uncertain.

TABLE 10-4 PROJECTED LOADS FOR CONTROL HOUSE, ETC.

No.	Buildings	Area on drawings	Effective area	W/m²	Demand Factor	Total
1	Office	2,640 m²	1,850 m²	109	80 %	161 KW
2	Control house	-	-	-	-	-
3	Soil mach. laboratory	936	650	70	50	23
4	Warehouse	920	640	109	80	56
5	Tele-communications room	720	500	109	80	44
	sub-total	5,216	3,640			284
6	Lounge	900	630	109	80	55
7	Training center	2,752	1,930	70	50	68
8	Cafeteria	1,452	1,000	109	70	76
9	Cooking room	1,192	830	109	90	81
	sub-total	6,296	4,390			280
10	Dormitory	882	620	109	70	47
11	Ditto	882	620	109	70	47
	sub-total	1,764	1,240			94
	Total	13,276	9,270			658

Note : Value W/m^2 = 109 is quoted from "the mean value of office buildings in Tokyo" on data book of Tokyo Electric Power Co., 1975.

d) Residential Quarters and Households

Number of households in the residential quarters is shown in Table 10-5. In addition, there may be other facilities, like a canteen, in the quarters. However, only vague data regarding other facilities are available. Then, the power load to the residential quarters has not been included in the project facilities, as previously stated, expecting that this power supply will be implemented by the RID when the necessity arises.

TABLE 10-5 RESIDENTIAL QUARTERS AND HOUSEHOLD

Rank	Household
9	1
7 ~ 8	16
5 ~ 6	24
3 ~ 4	24
1 ~ 2	108
Laborer	228
Total	461

e) Max. Starting Power for Diversion Dam Area

TABLE 10-6 MAX. STARTING POWER FOR DIVERSION DAM AREA

No	Item	KVA
1	1 - Flood Gate, 1 - Upper and Lower Regulating Gate	390
2	Misc. load, refer to Table 10-3 (power factor = 80%)	210
3	Assumed load of control house etc., refer to Table 10-4	774
	Total	1,374

In accordance with the above table 10-6, the transformer capacity shall be 1500 KVA. If the power demand is increased to more than 1500 KVA in the future, it is expected that the RID will take the appropriate measures to cope with such increase.

2) Pumping Station Area

a) Load Capacity for Motors and Diesel Engine

TABLE 10-7 POWER FOR PUMPING STATION AND OPERATION RULES

No	Name	Type of motor	Capacity in operation
1	No. 1 Motor 350 KW	Cage type	(1) Starting = (350KW×2+350kw×3.9)/0.8
2	No. 2 do.	do.	= 2580 KVA
3	No. 3 do.	do.	(2) Rated ope. = (350KW × 3) /0.8 = 1310 KVA
4	No. 4 D. Engine 500 ps	-	(3) Auxiliary equip., lighting, etc = Approx. 100 KVA
	Total		(1) Starting time 2,680 KVA (2) Rated operations 1,410 KVA

Operation procedure is similar to the operations of the tide protection gates; that is, starting one by one, gradually.

b) Electric Power Required for Auxiliary Equipment Operation

Electric power of 25 KW is required for the operation of auxiliary equipment for the main pumps (refer to Table 10-8).

TABLE 10-8 LIST OF AUXILIARY PUMPS FOR MAIN PUMPS AND THE NUMBER OF UNITS

Name of Pumps	No. of Units	Remarks
Discharge valve	4	
Priming pump for gear	4	
Priming pump for diesel engine	1	
Air-compressor	2	1-standby
Gear pump for fuel supply	2	do.
In-plant drainage pump	2	do.
Pump for cooling system	2	do.

c) Other Load

Besides the loads of prime movers and motors for auxiliary equipment, the additional loads are estimated to be about 35 KW for an electric power source for control apparatus, power and lighting in the Pumping Station.

3) Emergency Generator and Load for Service Interruption

The emergency generator shall be placed in two sets, one for the Diversion Dam and the other for the Pumping Station, separately.

TABLE 10-9 LOADING CAPACITY OF EMERGENCY GENERATOR

No	Name	Capacity	Main Load	Other Load
1	Diversion Dam Area	270 KVA	28.9 KVA × 2	40 KVA
2	Pumping Station Area	60 KVA	Aux. equip. 12.5 KVA	17 KVA

a) In deciding the maximum load for the emergency generator of the diversion the following motors shall be used. Two (2) units of 22 KW and 2 units each of 11 KW and 18.5 KW. The gate operations should not be started at the same time. The main load for Pumping Station is auxiliaries equipments for D. Engine 500 ps.

b) Miscellaneous Loads are as Follows:

Diversion Dam .... Power sources for the Control House with of 20 KVA and lighting for security

Pumping Station .... Ceiling ventilation fan required for the diesel engine operation and the necessary lighting.

4) Condenser for Power Factor Improvement

Capacity of condenser for improvement of power factor is calculated on the basis of no-load loss of transformer and the loading capacity, as stated below:

Diversion Dam .... 360 KVA
Pumping Station .... 400 KVA
Where, power factor is 95%.

10.3 22 KV Incoming Distribution Line

Incoming distribution line shall be undertaken by P.E.A. in both materials supply and construction works but these costs are included in the Project costs. However, the PEA will undertake only the overhead distribution line. The underground cable from lead-in terminal to both Substations for Diversion Dam and Pumping Station including materials and construction are implemented by the Project.

1) Capacity of Branch Distribution Line

TABLE 10-10 PEA STANDARD

Material	Size (mm^2)	Current (A)		Capacity (MVA)	
		22 KV	33 KV	22 KV	33 KV
HAL	50	225	225	8.6	12.9
	95	340	340	12.9	19.4
	120	390	390	14.9	22.3
	185	520	520	19.8	29.7
	240	625	625	23.8	35.7
	400	855	855	32.6	48.9
	625	910	-	-	-

Size of the existing branch distribution line is 35 mm^2 in the sectional area. But this line shall be replaced with a line with a section area of 240 mm^2 for electric power supply. At present, loading power is assumed to be 6.3 MVA in the maximum. By adding this 6.3 MVA to 1.5 + 3.0 = 4.5 MVA required for the Project, a total of 10.8 MVA is obtained. This 10.8 MVA is only 45% of the power load of 23.8 MVA allowable for a sectional area of 240 mm^2 under 22 KV. Therefore, this size of cable will be out of the question in the electrical system.

2) Route of Branch Distribution Line

The route of the branch distribution line shall be determined as follows:

The branch distribution line shall branch off the F-6 main distribution line located along national road No. 304 and bifurcated at the 22 KV distribution line branch point as shown in Fig. 10-1. Then one line shall be provided with overhead wiring to the Substation for the Pumping Station along the new right main canal and another line shall be supplied with overhead wiring to the Substation for the Diversion Dam along the upstream side of the new road. Lengths of cable from the bifurcation point to the Diversion Dam and the Pumping Station are about 3 km and 4 km, respectively, and 7 km in total.

3) Signal Cable

In the project, the remote-control system shall be applied which will be able to control the major equipment of both the Diversion Dam and Pumping Station at the Control House.

Signal cable shall be wired on the 22 KV pole along the 22 KV distribution line from the Pumping Station to the Control House. These works are included in the Project works.