I.5 River Water Scheme : River Pumping Station in the RNR-RC in Bajo

I.5.1 Summary of Facility Plan

(1) General Conditions

In Bhutan, the surface water exploitation is considered to be the most important measure for the developing the water resources, and various surface water exploitation projects have been conducted so far. However, some of those projects have not implemented successfully especially in case of pumping scheme because of intrusion of sediment loads into the pumping equipment as well as the inlet structure. Such sediment intrusion results in frictional damages of impellers of the pumping equipment as well as obstruction to the water flow in pipes and canals. A high cost is necessary for removing such sediments load piled in and in front of the pumping station. In this connection, it is considered to be quite important and worth to develop and propose such type of pumping station which can overcome the above pumping troubles.

The river pumping station for the irrigation water to the farm in RNR-RC in Bajo was constructed in the flat yard beside the Chang Chhu to pump up the river water to the existing RNR-RC irrigation facilities. In Bhutan, there are other rivers having the similar topographic conditions to the planned site. The similar type of pumping station may be constructed in those other areas in the future. The structure and materials to be applied to this pumping station, therefore, should be those which are commonly available in the market of the country.

(2) Proposed Component of the System

The irrigation system of the RNR-RC farm yards are illustrated in Fig. I.5.1 and general pumping system plan was proposed as shown in Fig. I.5.2. The construction of the experimental facilities for RNR-RC farm yards includes the following items :

- construction of slide type pumping station, and
- connection of delivery pipe to the 1st. stage storage tank.

In determining the dimensions and sizes of facilities, it is that the pumping station to be constructed should be of the structure which can solve the above troubles and should function together with the existing irrigation system in the farm yard.

A slide type of pumping station is, therefore, applied for the construction to solve the above mentioned problem considering the following items :

- The difference of water level of Chang Chhu river between dry season and rainy season varies between 4 to 5 m and the difference in suction head of the pump between these two seasons are very big. For minimizing the suction head losses, the pump should be moved on the inclined steel rail depending on the water level.

- In order to prevent the entry of sediment load directly from the river bed to the suction pipe and the pumping system and to avoid the frictional damages of the impellers, a floating type suction pipe was designed.

- Since the construction equipment and materials required for the under water construction is not available in Bhutan, the facilities were designed in such a way that the construction should be carried out with the land construction equipment.

The pump units are not fixed on the ground since the pump units are moved on the inclined steel rail using the hand winch in accordance with the fluctuation of river water level. The suction hose is flexible and the suction strainer is floated in the river.

As for the pumping operation, a simple alternative calculation was carried out to work out the most appropriate pumping operation in the RNR-RC farm yards as shown in the Data Book (IV). As a result, the pumping operation presented in Fig. I.5.3 was proposed to attain the balanced operation utilizing the available facilities to the maximum extent.

(3) Design Conditions

The following conditions were considered in designing the River Pumping Station in the RNR-RC Farm.

1) Design Capacity

The design capacity is 62 l/sec with 10.5 hours per day (82 l/sec with 8 hours per day) of pumping operation for the proposed irrigation area of 12 hectares.

2) River Water Level and Pump Installation Level

a) River water level
- H.W.L (High Water Level) : TP 1,199 m
- L.W.L (Low Water Level) : TP 1,194 m

b) Pump installation level : TP 1,196 m ~ 1,200 m

c) Suction water level : TP 1,194 m ~ 1,198 m

d) Farm pond top of pipe level
- Discharge water level : TP 1,218 m

3) Number of Pumps

Two pump units are determined in consideration of the cropping pattern, seasonal water requirement and meteorological conditions.

4) Total Pump Head

The total pump head is determined as 34 m by adding pipeline losses to actual head with the following conditions;

- Actual head : 25 m
- Pipeline losses : 9 m
- Pipeline length : 270 m
- Pipe : 200 mm, PVC

(4) Principal Features of Facility

The principal features of the constructed facilities are summarized below, and the general plan and layout plan of the proposed facility are shown in Figures I.5.4 ~6.

1) Intake Pumping Unit

a) Intake Pump (2 Sets)
- Type : Single suction volute pump
- Capacity : 1.88 m^3/min/unit
- Total head : 34 m

b) Motor for Intake Pump (2 Sets)
- Type : Totally enclosed, square cage
- Output : 18.5 kW
- No. of poles : 4 P
- Voltage : 415 V

c) Slide Base (2 Sets)
- Material : Mild steel

d) Valves (2 Sets)
- Foot valve : 150 mm
- Sluice valve : 125 mm
- Non-return valve : 125 mm

e) Suction piping (2 Sets)
- Flexible pipe : 150 mm
- Connecting pipe : 150 mm x 125 mm

f) Delivery piping (2 Sets)
- Flexible pipe : 125 mm
- Connecting pipe : 100 mm x 125 mm
- Header pipe : 200 mm / 200 mm / 125 mm / 125 mm

g) Pump Control Panel (1 Set)
- Type : Outdoor, self-standing
- Starting method : Star-delta
- Power source : 415 V, 50 Hz

2) Concrete Base for Pump Sliding

- Concrete base : 13.4 (L) x 5.8 (B) x 0.5 (T) m
- Slide steel rail : 2 Sets
- Hand winch : 2 Sets

3) Revetment

- Gabion work : 60 (L) x 15 (B) m

I.5.2 Monitoring Works for River water Scheme

The river water of the Chang Chhu river is lifted up by the pumping station which is constructed as one of the experimental facilities. The pumping station is located in the RNR-RC in Bajo beside the Chang Chhu river and the irrigation water is supplied through the existing irrigation system.

(1) Purpose of Monitoring

Some trial constructions have been made in other irrigation projects by MOA, but unfortunately most of them failed due to difficulty in desilting works caused by the high amount of sediment load contained in the river water stream. As a pioneer method to solve this problem, a movable type of pump unit is proposed for the pumping station. Based on the results of monitoring, if this method is evaluated to be suitable to solve the above mentioned problem, this method can be applied to the other irrigation projects in Bhutan, which may also be suffering from same type of problem.

In this context, the purpose of monitoring is to examine and confirm the technical feasibility, applicability and suitability of the slide type pumping station.

(2) Monitoring Work

Monitoring work of slide type of pumping station was carried out from July 12 to end of August in 1995. The monitoring work was divided into two categories, one is monitoring of pump setting before and after pump operation and other is monitoring of pumping facilities. The main monitoring items are enumerated below;

- Monitoring of pump setting before and after pump operation
  - Required time for setting the pump before and after pump operation at various river water levels and at extreme flood conditions
  - Required time for filling up water into suction pipe before pump operation

- Monitoring of pumping facilities
  - Suction capacity of pump for each position of the pump and pipe length

- Conditions of flexible suction hose and floating unit

1). Monitoring of pump setting before and after pump operation

The civil structure of the pumping station was designed considering present hydrological conditions, especially the sudden flood condition of the river and the easy operation of the pump. At various river water levels, the pump unit should be fixed at the most suitable position for the effective suction and operation of the pump. Besides, the pump unit should be shifted to the top of the dike when heavy flooding occurs in the river. It is therefore proposed to observe the time required for sliding the pump before and after operation, and for shifting the suction hose from one position to the other. The layout of pumping position is shown in Fig.I.5.7 and the following items were observed:

- Variation of river water level in the Chang Chhu river
- Position of pump unit and the time required for sliding the pump unit on the inclined steel rail
- Position of float unit which includes suction hoses, foot valves and the floats and the time required for moving the float unit
- Any difficulty in positioning of pump unit and the float unit

a) Required time of pump setting at various river water levels

The time required for setting the pump unit and the float unit was monitored and the results of monitoring for each position are shown in Fig. I.5.8.

- Required time of pump setting

During the monitoring work, the pump was slided downwards from position P1 to P2, and position P1 to P3. Similarly, the pump was slided upwards from position P2 to P1, and position P3 to P1.
One supervisor and 5~6 supporting staff were involved in carrying out these works, and the time required for monitoring is shown in Fig. I.5.8.

The time required for sliding down the pump from position P1 to P2 was 10~25 minutes and from P1 to P3 was 10~35 minutes. similarly for sliding up the pump, the time required were 15~25 minutes and 15~30 minutes from position P2 to P1 and P3 to P1 respectively.

The reasons for the time consumption are enumerated below ;

- Weight of pump is 500 kg/unit and sliding of the pump is a heavy task.
- The weight of pump is not suitable for sliding operation,
- and therefore, the sliding should be done carefully.
- Since check valve for water hammer was placed on one side of pump, the pump is not in a well balanced position.
- Space of rail was relatively narrower for the sliding operation.
- It is relatively difficult to adjust both rails to fix the bolt between the rail and the pump stand to attain a stable and balanced position of
- the pump.
- Slope of concrete base was deep.

b) Required time of float setting

Corresponding to the sliding of the pump, the float unit which weighs 200 kg/unit was lifted up and down by 6~7 supporting staff.

The time required for lifting down the float from top of dike to the river water level was 10 to 35 minutes. Similarly the time required was 10 to 60 minutes for lifting up the float from the river water level to top of dike.

The reasons for time consumption are enumerated below ;

- The weight of floating unit is 200 kg/unit and there is no equipment for lifting operation. Furthermore, it is relatively difficult to lift the flange joint made of iron and connects the floats and the pipe.
- Weight of flexible hose is heavy in proportion to pipe length.
- Frame of float was made of iron, which weighs 60 kg/unit.
- There is no foothold in concrete base and Gabion

The total time required for setting up the pump unit and the float unit was 1~1.5 hours and 5~6 supporting staff are necessary for carrying out these works, considering the heavy weight of these units. Especially during sudden flooding conditions, the operators should be readily available to carry out these operations, in order to prevent the pump from submergence by the high river water level.

c) Required time for filling up water into suction pipe before pump operation

Before carrying out the pumping operation, it is necessary to fill up the suction pipe and the time required varies according to the pipe length as shown in Fig. I.5.8. The time required for filling up water into suction pipe for each pipe length was observed.

The observation was carried out for two times, one before pumping and the second after doing the pumping for half a day and then stopping it for 3 hours time. The time required for the second operation was measured in order to find out the leakage from the suction hose and part of joint.

- Required time for 1st operation

  The time required for filling up water was 20~30 minutes for all the pipe lengths, however, these operations were carried out by the operator who was inexperienced in this type of work, and this work can be completed in 10 minutes time after experiencing these type of works.

- Required time for 2nd operation

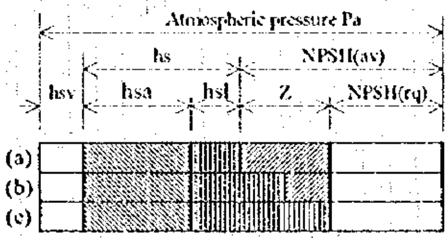
  Since the hose was already filled up with water through the pumping and there was no leakage for most of the pipe lengths, almost no time was required for filling up water for the 2nd operation. However as shown in Fig. I.5.8., some pipe lengths such as 6m and 8m length required 10-30 minutes times to fill up the water which was mainly due to leakage of water from the flexible hose caused by insufficiency tightening of flange joint during the first operation and this problem was improved after each operation.

2) Monitoring for pumping facility

a) Suction capacity of the pump

The cost of pump normally varies in accordance with its suction capacity. The suction capacity depends on two factors which includes the topographic conditions and the design conditions such as shape of bladed wheel, output of motor etc.. Suction head is the head difference between the atmospheric pressure and the pressure at the pump center. The pump capacity must be considered based on the topographic conditions, since the pump should comply with the existing conditions.

Suction capacity of pump includes Net Positive Suction Head Requirement and Net Positive Suction head Available .



where:

Pa = Atmospheric pressure (m)
hsv = Saturated vapor head (m)
hsa = Static suction head (m)
hsl = Loses suction side (m)
Z = Excess head (m)
hs = Suction head
= hsa +hsl
N.P.S.H(rq) = Required N.P.S.H
N.P.S.H(av)=Available N.P.S.H

Relationship between N.P.S.H(rq) and N.P.S.H(av) is summarized below :
N.P.S.H(rq) is the sum total of various losses caused in the course from the suction port of the pump until the water enters the impeller and is decided automatically when the flow rate of the individual pump is decided. Consequently, the excess head Z is expressed by the equation.

$$Z = Pa-Hsp-Hsa-NPSH(rq)$$
$$=NPSH(av)-NPSH(rq)$$

Cavitation occurs when Z of the above equation becomes 0, and the above equation becomes as follows as in case of (c) in the above chart.

$$NPSH(av)=NPSH(rq)$$

Therefore, it is necessary to consider the excess head of Z=1.0 m or more. The value NPSH(av) is subject to the external conditions such as the atmospheric pressure, liquid temperature, conditions of piping liquid, etc. While, NPSH(rq) depends on the design of the pump itself.

As mentioned above, the suction capacity of the pump consists of atmospheric pressure, static suction head and losses in the suction side and these losses and the suction capacity of the pump were monitored in this Study.

b) Conditions of flexible suction hose

The condition of flexible suction hose was observed to decide on the efficiency of the pumping operation. Monitoring was carried out on two items.

- Coefficient of head loss of flexible hose
- Coefficient of flow rate

The result of monitoring is shown in Fig. I.5.9. The coefficient of head loss (f) is random in between 0 to 2.5, irrespective of pipe length. However coefficient of flow rate (C) is observed to increase in proportion to pipe length. Coefficient of flow rate depends on the pipe material. The longer pipe is considered to be more stable than the shorter one. Considering the easy operation, head loss and flow rate, an optimum flexible pipe length of 6.0 m was chosen. The coefficient of flow rate (C) for the 6m length is 70.

c) Suction capacity of the pump for each position and pipe length

Relationship between N.P.S.H(rq) and N.P.S.H(av) in this monitoring is shown in Table.I.5.1 and Fig. I.5.10 (1/10~10/10). Accordingly, setting point of pump must be decided to prevent cavitation since the suction capacity of pump varies depending on the static suction head.

The excess head of the pumping facility is designed as 1.0m.

Atmospheric pressure is calculated using the following formula and atmospheric pressure at each altitude is shown below.

$$P=760x(1.0-0.0065h/288)^{5.256}$$

where P is the Atmospheric pressure (m)

Relationship between Altitude and Atmospheric pressure

Altitude (m)	0	500	1000	1500	2000
Head (m)	10.33	9.74	9.16	8.61	8.10
Mercurial column (mm)	760	716	674	634	596

RNR-RC where the pumping facility is installed, is located at an altitude of 1200m and the atmospheric pressure is calculated as 8.94m using the above formula.

Suction capacity was monitored for each position of the pump and pipe length. Results of monitoring are shown in Fig. I.5.10. In these figures, the solid line represents Net Positive Suction Head (req) and dotted line represents Net Positive Suction Head (av). An excess head of 1.0 m which accounts for the external conditions such as temperature of water etc. was deducted from the Net Positive Suction Head (av). Net Positive Suction Head (av) mentioned below represents the value of Net Positive Suction Head (av) after deducting 1.0m.

- Position P1

  Pipe lengths of 6.00m and 8.00m were used for monitoring and the elevation of pump center at position P1 is 1200.58m. The pipe was placed straight along the concrete base slope and no bending part was observed. The static suction head varied between 3.50~4.30m and the discharge ratio was observed as 125~140%, and the operation point was observed to be at the intersection of the two curves. It means that the values of N.P.S.H(rq) and N.P.S.H (av) are almost the same except for the excess head of 1.0m. If the discharge rate increases, cavitation will occur in the pump. Therefore while operating the pump at P1 position, the discharge of the pump shall be controlled by using the valve in order to prevent cavitation.

- Position P2

  Pipe lengths of 4.00m, 6.00m and 8.00m were used for monitoring and the elevation of pump center at position P2 is E.L.1199.59m, and the static water level is 1m lower than P1 position.

  As shown in Fig. I.5.10, there is a difference of 0.5m to 1.0m between N.P.S.H(rq) curve and N.P.S.H(av) curve. Discharge ratio is 130~140% and the head loss of P1 and P2 position is observed to be the same. Therefore this excess head of 0.5~1.0m, was attained by the difference of static water head between positions P1 and P2. Head losses observed were 1.00~1.90m using 4.00m and 6.00m pipe, and 1.50~2.50m using 8.00m pipe. The high head loss at the 8.00m pipe length was mainly due to the bending of the suction hose caused by its length.

- Position P3

  Pipe lengths of 2.00m, 4.00m, 6.00m and 8.00m were used. An excess head of 0.50~2.00m was observed similar to position P2, and this excess head was attained by reducing static water head. However, in case of 8.00m pipe, the head loss was high, and the values of N.P.S.H(rq) and N.P.S.H(av) are same.

  Based on the results of monitoring work, P2 position is recommended for setting the pump considering the following aspects :

-It is desirable to keep a static suction head of 2.00~3.50m considering head loss and cavitation.
-It is better to keep the pump at an upper position in order to prevent it from the rising of water level during sudden flooding situations.

A pipe length of 6.00m length is recommended considering the following reasons :

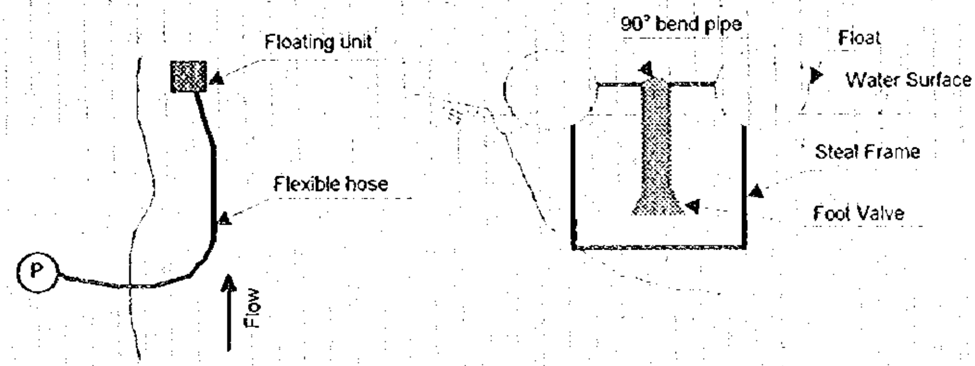
- A certain pipe length is needed, since this pumping facility will be utilized for the low water level during dry season.
- Head loss was observed to be same for the pipe lengths of 6.00m or less at each position of the pump.

During the monitoring work, the suction capacity was not observed for the changes in the inlet valve to control the discharge rate. However, the discharge ratio of the pump is desired to be 130% or less.

Especially while operating 1 unit of pump, the valve must be controlled to prevent the cavitation, since the head loss is lower for one unit than 2 units and the design discharge is high.

3) Conditions of Flexible Suction Hose and Floating Unit

The floating unit consists of steal frame, float, foot valve and 90° bend pipe, and connecting at the tail end of the flexible suction hose. This floating unit is connected only with wire, and it has been always moved with river flow. However,the following unit was designed to prevent the unit from touching the river bed.



FLEXIBLE SUCTION HOSE AND FLOATING UNIT

The foot valve is inside the steal frame and the depth to the bottom is always kept in the optimum condition for sucking the water. From the results of monitoring, even if the tail end of flexible suction hose moves near the river edge, any kind of problem does not take place during the pumping operation.

I.5.3 Evaluation and Recommendation

(1) Evaluation of System

Slide type of pumping station was designed in order to prevent the sediment loads and to reduce the cost of the facilities. During the monitoring period, sediment loads were observed on the concrete base below the river water level. However, the sediment loads did not obstruct the flow of water or the intake of the facilities and the removal of sediment loads was carried out easily using a scoop.

At first, the suction pipe and the float were placed directly into the river stream and then a steel frame was attached to the float so that the intake would not be affected by the river flow. Besides, monitoring was also carried out by placing the suction pipe over the concrete base and directly into the river. When the suction pipe was laid uniformly over the concrete base the head loss was low, whereas the head loss was high when it is placed into the river because of the bending of the suction pipe.

The construction of the pumping facilities which include concrete base and gabion are also easier, compared to large scale submergible construction and large scale excavation which are necessary for the direct pumping from the river water.

The results of the monitoring work can be summarized as follows :

- The total time required for setting up the pump unit and the float unit was 1~1.5 hours and 5~6 supporting staff are necessary for carrying out these works.
- The total time required for filling up water into the suction pipe before the pumping operation was 20-30 minutes. However, this time shall be reduced to 10 minutes after operator is experienced in this work for a few times.
- Among the three pumping positions of P1, P2 and P3; P2 position is recommended for setting up the pump, since a static suction head of 2.00~3.50m is desirable considering head loss and cavitation.
- Considering the easy operation, head loss and flow rate, an optimum flexible pipe length of 6.0 m was chosen. This pipe length is also optimum for pumping during low water level in the dry season. The coefficient of flow rate (C) for the 6m length is 70.
- During dry season 2 units of pump shall be operated since the water requirement is high and during the wet season, one unit is considered as sufficient. When one unit of pump is operated the discharge rate is high and therefore the valve shall be controlled to reduce the discharge rate.

Based on the results of the Study, the following inferences shall be made :

The slide type pumping facility was found to be suitable, considering the difference in river water levels at various seasons. Most of the rivers of Bhutan have a V - shape and one side of the river has mountainous landscape. Therefore, the pumping facility has to be placed on the other side of the river at a stable location. Considering all the above factors, the slide type pumping facility was chosen in this Study.

By using slide type pump, it is possible to slide the pump to various positions, and accordingly the suction head shall also be varied. Through the monitoring work, the maximum suction head of the monitoring facility was found to be 3.5m, and this facility is considered to be suitable for the river water levels at all seasons including the lowest water level in the dry season.

During this Study, a pump was planned to be installed at the mid level by the Ministry of Agriculture of the Government of Bhutan. However, since the capacity of the pump was not suitable, only the slide type of monitoring pump was monitored during this Study. Since the construction of pipe line was done during the monitoring survey in the rainy season, the pumping was carried out using one pump. As discussed already, the discharge ratio of the pump is higher than 130%, when the pumping was carried out using one pump. Therefore, while using one pump, the inlet valve should be controlled so that the discharge ratio will not exceed 130%.

When the existing pump is installed by the Ministry of Agriculture, the proposed pumping operation shall be referred to Data Book (IV). Since the size of the 1st. stage tank is small, the operation of the two pumps using the existing pump will be irregular. Among the 5 cases, case 3 shall be chosen, where a new pump should be purchased. In future, considering the wet and dry seasons, and the safety factor, two pumps are considered to be suitable for the area.

Considering the maintenance of the facilities, Volute Pump is considered to be more suitable, and by using slide type pump and the float, maintenance required shall be minimum. The existing equipment and facilities are enough to do the construction and maintenance of the pumping facilities. Besides, the monitoring sheet of the pumping facility shall also include the maintenance items, which shall be used to find out the performance and problems of the pumping facility.

The slide type of pumping facility requires construction of the inclined structure which is easier and cheaper than constructing big structures. Besides, the inlet unit including the float is immersed directly into the river and hence the pumping of water is considered as certain. In Bhutan where the river water level change is extreme in between wet and dry seasons, the slide type of pumping facility shall be considered to be more suitable.

(2) Recommendation of the Future Plan

Based on the results of monitoring of the slide type pumping station, the following recommendations are made :

Since the slide type pumping station was installed using the equipments, which are applied in existing pumping facilities, it is not necessary to introduce new techniques for operation and maintenance. Besides, since structure of concrete base has an inclined structure due to sliding pump unit, it was possible to do smooth construction and the problem of sediment loads can be solved. However, when a sudden flood occurs, it is relatively difficult to slide the pump unit from a determined point to the top of the dike. The slide type of pumping facilities shall be applied considering river improvement, river planning and landscape. Since the pumping facilities such as gabion are designed in accordance with the landscape, a small amount of construction is considered as sufficient.

On the whole, the slide type pumping station shall be used for the water resources development in Bhutan with some small modifications which will suit to the pump location.

The following items are recommended in the future planning of the slide type pumping station.

1) Location of pumping station

Setting of the pumping station is the most critical, which must be decided based on the sudden flooding conditions. The factors to be considered in selecting the suitable location for the pumping station are desirable as follows. However, in Bhutan, most of the rivers have V type shape, and accordingly the pumping facilities must be placed on the other side. Consequently, location of the pumping station must be decided to suit with the river conditions as much as possible to withdraw river water at all seasons. Slide type pump shall be used with a suction pipe of suitable length with the following considerations :

- There should be no fear of the problems of the river water fluctuation.
- Curve point in the river should not be selected for the pumping station.
- The pumping station must be placed at a mild slope of the river.
- The pumping station must be placed in the side of the water route of the river,
- The pumping station must be planned considering river improvement plan.

2) Pumping facility

Considering the pumping during wet and dry seasons and the safety factor, two pumps are considered to be more suitable. Considering the maintenance, volute pump shall be chosen. The pump and the pump capacity shall be decided considering the following factors :

- Command Area
- Demand Discharge
- Total pump head
- Actual pump head
- Weight of pump

While applying the slide type pumping station, weight of the pump should be considered for easy operation during sudden flood. Besides, the weight of the pump to be selected shall be comparatively small and correspondingly the pump capacity shall also become smaller. However, a pump of optimum size and suitable capacity should be decided based on the command area to be irrigated

and the pump type to be applied is classified into motor engine pump and diesel engine pump.
A diesel engine pump shall be installed easily with a cheaper amount and the weight is also low. However, the design capacity of the pump is not exact comparing with the motor engine pump. While the motor engine pump has an exactly designed capacity, weight of pump is heavy. Therefore, it is necessary to select the type of pump type considering purpose of system, site conditions and design discharge.

a) Diesel engine pump

The diesel engine pump would be applied easily at the desired location, where the revetment will be constructed.

Outline of specification of diesel engine pump is enumerated below :

- Volume of discharge : 0.90 m^3/min
- Total head : 30 m
- Weight of pump : 30~45 kg

While using diesel engine pump, it can be set at any desired location. It is not needed to decide the pump capacity based on the value of N.P.S.H(rq).

b) Motor Engine Pump

Motor engine pump with a pumping station shall be planned for large scale pumping facility. Since a diesel engine pump is not sufficient for this facility, rail and sliding concrete base should be constructed.

3) Structure of concrete base and Gabion

Since the slide type of pumping facilities must be made corresponding to the shape of gabion, these facilities shall be constructed as a part of revetment for river improvement and planning.
While using the diesel engine pump, the concrete base shall be placed on the gabion which is easier from the view point of economy and construction. And in case applying motor engine pump, a terrace type excavation shall be made and the concrete shall be filled over the terrace considering technical method in Bhutan.

Structure of concrete base is recommended as follows :

- Shape of concrete base must not affect the river flow.
- Cut off of concrete base must be placed to prevent erosion of bank.
- The gabion and the concrete base shall be placed in the same slope as the landscape.
- Slope of the concrete base and gabion shall be less than 1:2 considering volume of concrete, excavation and sliding operation.

APPENDIX I
TABLES

Table. I.2.1 Pumping up Discharge at Deep Well

May						June						July						August					
Date	S m^3/day	P m^3/day	T m^3/day	Sun hrs/day	Rain mm	Date	S m^3/day	P m^3/day	T m^3/day	Sun hrs/day	Rain mm	Date	S m^3/day	P m^3/day	T m^3/day	Sun hrs/day	Rain mm	Date	S m^3/day	P m^3/day	T m^3/day	Sun hrs/day	Rain mm
5/1	9.20	0.19	9.39	7.60	0.0	6/1	2.73	0.37	3.10	2.30	0.0	7/1	8.84	0.13	8.98	0.57	3.5	8/1	2.34	0.91	3.25	3.30	1.5
5/2	10.00	0.82	10.82	5.50	0.0	6/2	2.63	1.79	4.41	3.60	0.0	7/2	0.00	0.26	0.26	0.00	8.3	8/2	11.33	0.95	12.28	7.50	0.2
5/3	0.24	0.28	0.53	6.70	0.1	6/3	-	-	-	-	0.0	7/3	0.00	0.29	0.29	0.10	3.5	8/3	0.22	0.41	0.63	1.30	0.0
5/4	13.00	0.14	13.13	9.00	0.0	6/4	-	-	-	-	0.0	7/4	1.39	1.93	3.32	1.00	18.1	8/4	0.29	0.18	0.47	1.50	4.6
5/5	-	-	-	8.30	0.0	6/5	8.98	2.81	11.79	5.50	0.0	7/5	0.00	0.18	0.18	0.00	29.1	8/5	12.05	0.09	12.14	8.30	0.0
5/6	-	-	-	6.40	0.0	6/6	-	-	-	-	0.0	7/6	0.00	0.20	0.20	0.00	1.9	8/6	13.71	0.17	13.88	7.20	0.0
5/7	-	-	-	2.60	1.5	6/7	8.06	2.37	10.43	3.30	5.0	7/7	0.11	0.18	0.29	0.43	1.0	8/7	6.73	0.61	7.34	5.10	0.0
5/8	13.37	0.16	13.53	8.60	6.1	6/8	11.43	0.55	11.98	7.30	0.0	7/8	9.59	0.03	9.62	9.00	4.5	8/8	5.57	2.64	8.21	4.50	6.8
5/9	14.42	0.14	14.56	9.40	0.0	6/9	13.78	0.06	13.85	9.70	0.0	7/9	2.27	0.73	3.01	1.30	5.5	8/9	10.47	0.55	11.02	6.90	4.5
5/10	14.58	0.18	14.76	10.20	0.0	6/10	-	-	-	-	0.0	7/10	0.11	0.31	0.42	1.90	2.0	8/10	8.62	1.52	10.14	6.30	0.0
5/11	13.58	0.09	13.67	9.00	0.0	6/11	-	-	-	-	0.0	7/11	0.00	3.22	3.22	6.00	2.5	8/11	3.12	6.65	9.77	12.00	4.0
5/12	9.38	0.22	9.60	-	0.0	6/12	-	-	-	0.10	7.8	7/12	9.88	0.00	9.88	7.00	0.0	8/12	0.36	0.79	1.15	0.40	0.0
5/13	9.86	0.28	10.14	-	0.0	6/13	0.00	0.21	0.21	0.90	10.0	7/13	4.42	1.52	5.94	4.20	1.8	8/13	0.00	0.47	0.47	0.00	2.6
5/14	-	-	-	-	0.0	6/14	0.00	0.20	0.20	0.10	20.0	7/14	8.39	0.08	8.47	7.70	5.9	8/14	0.54	0.88	1.42	1.40	23.4
5/15	6.41	0.38	6.79	-	0.0	6/15	0.00	0.22	0.22	0.70	15.0	7/15	3.73	0.28	4.01	6.25	5.6	8/15	1.61	0.96	2.56	4.30	29.3
5/16	-	-	-	-	0.0	6/16	0.00	0.22	0.22	2.40	2.0	7/16	13.75	0.14	13.89	6.00	0.3	8/16	1.09	1.20	2.29	2.20	1.6
5/17	-	-	-	-	0.0	6/17	-	-	-	0.00	2.0	7/17	7.03	0.67	7.70	6.60	0.0	8/17	3.03	1.93	4.96	4.40	0.0
5/18	5.29	0.15	5.44	-	0.0	6/18	-	-	-	-	0.0	7/18	4.71	3.86	8.57	3.60	11.0	8/18	7.60	0.64	8.24	7.20	1.4
5/19	8.76	0.74	9.49	-	0.0	6/19	0.00	0.20	0.20	0.40	5.0	7/19	0.00	0.22	0.22	0.00	3.8	8/19	11.50	0.14	11.64	8.20	0.0
5/20	-	-	-	-	0.0	6/20	0.43	0.14	0.57	2.20	15.0	7/20	5.94	0.35	6.29	5.80	16.0	8/20	8.03	0.57	8.60	4.40	0.0
5/21	-	-	-	-	0.0	6/21	2.85	0.24	3.09	2.90	0.0	7/21	4.09	0.68	4.77	6.40	1.8	8/21	5.13	0.37	5.50	5.30	0.0
5/22	-	-	-	5.30	0.0	6/22	0.14	0.20	0.34	1.20	0.0	7/22	0.91	0.27	1.18	2.20	0.6	8/22	10.77	0.45	11.22	9.30	4.4
5/23	7.61	0.04	7.65	7.00	0.0	6/23	-	-	-	0.30	6.1	7/23	9.28	0.10	9.38	6.40	0.0	8/23	10.61	0.11	10.72	8.30	1.0
5/24	9.67	0.00	9.67	8.90	0.0	6/24	0.00	0.14	0.14	0.00	7.6	7/24	0.08	0.16	0.23	1.20	8.7	8/24	9.79	0.23	10.02	7.20	0.0
5/25	10.74	0.69	11.43	6.50	0.0	6/25	-	-	-	7.30	6.2	7/25	12.02	0.82	12.84	6.40	0.0	8/25	0.23	0.33	0.56	2.40	0.0
5/26	-	-	-	8.20	0.0	6/26	12.89	0.44	13.33	8.00	0.0	7/26	6.86	2.83	9.70	8.20	0.2	8/26	0.22	0.37	0.59	1.30	1.6
5/27	0.00	0.20	0.20	3.30	0.0	6/27	5.18	0.92	6.10	3.60	0.0	7/27	0.06	0.24	0.30	0.50	0.0	8/27	13.54	0.05	13.59	7.20	0.0
5/28	-	-	-	-	0.0	6/28	0.00	2.69	2.69	-	0.0	7/28	7.10	6.15	13.25	5.10	6.7	8/28	0.47	0.40	0.87	2.30	2.5
5/29	0.00	0.16	0.16	1.70	12.0	6/29	0.00	0.25	0.25	0.40	0.0	7/29	12.35	0.24	12.59	7.50	0.0	8/29	0.20	0.30	0.50	0.20	22.6
5/30	-	-	-	4.30	2.0	6/30	0.30	0.31	0.61	1.20	1.2	7/30	3.43	0.29	3.72	1.50	0.0	8/30	12.14	0.07	12.21	8.20	0.0
5/31	-	-	-	-	0.0							7/31	8.93	1.92	10.85	5.20	12.2	8/31	13.25	0.11	13.36	9.30	0.0
Max	14.58	0.82	14.76	10.2	12.0	Max	13.78	2.81	13.85	9.70	20.0	Max	13.75	6.15	13.89	9.00	29.1	Max	13.71	6.65	13.88	12.00	29.3
Min	0.00	0.00	0.16	1.7	0.0	Min	0.00	0.06	0.14	0.00	0.0	Min	0.00	0.00	0.18	0.00	0.0	Min	0.00	0.05	0.47	0.00	0.0
Ave	8.67	0.27	8.94	6.8	0.7	Ave	3.47	0.72	4.18	2.76	3.4	Ave	4.69	0.91	5.60	3.81	5.0	Ave	5.95	0.81	6.76	5.08	3.6
Total	156.12	4.83	160.94	128.50	21.70	Total	69.39	14.30	83.70	63.40	102.9	Total	136.34	26.34	162.68	112.85	154.5	Total	171.30	24.93	196.23	148.10	112.0

S : Solar, P : Public, T : Total, Sun : Sunshine, Rain : Rainfall

Table. I.4.1 The Data of Contineous Pumping Test

Date 20/5/95 Time 8:15 Weather (Fine, Cloud, Rain, Snow)

a) Water Level at Chang Chhu	8.36 m	b) Water Level at Well	8.38 m
c)-1 Cumulative flow mater at Start	202 m³	d)-1 Water Temp.	19 °c
c)-2 Cumulative flow mater at end	887 m³	d)-2 Temperature	19 °c

e) Continuous pumping test				f) Recovery water level test				
Time (hr)	(min)	e)-1 Pump up level (gauge height)	e)-2 Drawdown	Time (hr)	(min)	f)-1 Recovery level (gauge height)	f)-2 Fluctuation level	f)-3 Draw up
	0	8.38 m	m		0	6.73 m	m	m
	1	8.28 m	0.10 m		1	6.77 m	0.04 m	0.04 m
	2	8.27 m	0.01 m		2	6.79 m	0.02 m	0.06 m
	3	8.26 m	0.01 m		3	6.82 m	0.03 m	0.09 m
	4	8.23 m	0.03 m		4	6.85 m	0.03 m	0.12 m
	5	8.20 m	0.03 m		5	6.87 m	0.02 m	0.14 m
	6	8.16 m	0.04 m		6	6.89 m	0.02 m	0.16 m
	7	8.14 m	0.02 m		7	6.91 m	0.02 m	0.18 m
	8	8.10 m	0.04 m		8	6.94 m	0.03 m	0.21 m
	9	8.06 m	0.04 m		9	6.96 m	0.02 m	0.23 m
	11	8.02 m	0.04 m		11	7.00 m	0.04 m	0.27 m
	13	7.99 m	0.03 m		13	7.05 m	0.05 m	0.32 m
	15	7.90 m	0.09 m		15	7.09 m	0.04 m	0.36 m
	18	7.83 m	0.07 m		18	7.14 m	0.05 m	0.41 m
	21	7.74 m	0.09 m		21	7.20 m	0.06 m	0.47 m
	24	7.70 m	0.04 m		24	7.25 m	0.05 m	0.52 m
	27	7.64 m	0.06 m		27	7.30 m	0.05 m	0.57 m
	30	7.59 m	0.05 m		30	7.35 m	0.05 m	0.62 m
	35	7.50 m	0.09 m		35	7.42 m	0.07 m	0.69 m
	40	7.44 m	0.06 m		40	7.48 m	0.06 m	0.75 m
	45	7.38 m	0.06 m		45	7.52 m	0.04 m	0.79 m
	50	7.32 m	0.06 m		50	7.60 m	0.08 m	0.87 m
	55	7.38 m	-0.06 m		55	7.64 m	0.04 m	0.91 m
1 hr	60	7.24 m	0.14 m	1 hr	60	7.69 m	0.05 m	0.96 m
	70	7.16 m	0.08 m		70	7.76 m	0.07 m	1.03 m
	80	7.10 m	0.06 m		80	7.83 m	0.07 m	1.10 m
	90	7.06 m	0.04 m		90	7.88 m	0.05 m	1.15 m
	100	7.01 m	0.05 m		100	7.93 m	0.05 m	1.20 m
	110	6.98 m	0.03 m		110	7.96 m	0.03 m	1.23 m
2 hr	120	6.96 m	0.02 m	2 hr	120	8.00 m	0.04 m	1.27 m
	135	6.92 m	0.04 m		135	8.04 m	0.04 m	1.31 m
	150	6.89 m	0.03 m		150	8.08 m	0.04 m	1.35 m
	165	6.86 m	0.03 m		165	8.10 m	0.02 m	1.37 m
3 hr	180	6.85 m	0.01 m	3 hr	180	8.12 m	0.02 m	1.39 m
	195	6.84 m	0.01 m		195	8.14 m	0.02 m	1.41 m
	210	6.82 m	0.02 m		210	8.16 m	0.02 m	1.43 m
	225	6.81 m	0.01 m		225	8.17 m	0.01 m	1.44 m
4 hr	240	6.80 m	0.01 m	4 hr	240	8.18 m	0.01 m	1.45 m
	260	6.79 m	0.01 m		260	8.20 m	0.02 m	1.47 m
	280	6.78 m	0.01 m		280	8.21 m	0.01 m	1.48 m
5 hr	300	6.77 m	0.01 m	5 hr	300	8.22 m	0.01 m	1.49 m
	320	6.77 m	0.00 m		320	8.23 m	0.01 m	1.50 m
	340	6.77 m	0.00 m		340	8.24 m	0.01 m	1.51 m
6 hr	360	6.77 m	0.00 m	6 hr	360	8.24 m	0.00 m	1.51 m
7 hr	420	6.76 m	0.01 m	7 hr	420	8.26 m	0.02 m	1.53 m
8 hr	480	6.76 m	0.00 m	8 hr	480	8.26 m	0.00 m	1.53 m
9 hr	540	6.74 m	0.02 m	9 hr	540	8.28 m	0.02 m	1.55 m
10 hr	600	6.74 m	0.00 m	10 hr	600	8.28 m	0.00 m	1.55 m
11 hr	660	6.73 m	0.01 m	11 hr	660	8.29 m	0.01 m	1.56 m
12 hr	720	6.73 m	0.00 m	12 hr	720	8.29 m	0.00 m	1.56 m

Table. I.4.2 Function of Well

N \ u	$N \times 10^{-15}$	$N \times 10^{-14}$	$N \times 10^{-13}$	$N \times 10^{-12}$	$N \times 10^{-11}$	$N \times 10^{-10}$	$N \times 10^{-9}$	$N \times 10^{-8}$	$N \times 10^{-7}$	$N \times 10^{-6}$	$N \times 10^{-5}$	$N \times 10^{-4}$	$N \times 10^{-3}$	$N \times 10^{-2}$	$N \times 10^{-1}$	N
1.0	33.96	31.66	29.36	27.05	24.75	22.45	20.15	17.84	15.54	13.24	10.94	8.63	6.33	4.04	1.82	0.220000
1.1	33.87	31.56	29.26	26.96	24.66	22.35	20.05	17.75	15.45	13.14	10.84	8.54	6.24	3.94	1.74	0.190000
1.2	33.78	31.48	29.17	26.87	24.57	22.27	19.96	17.66	15.36	13.06	10.75	8.45	6.15	3.86	1.66	0.160000
1.3	33.70	31.40	29.09	26.79	24.49	22.19	19.88	17.58	15.28	12.98	10.67	8.37	6.07	3.78	1.59	0.140000
1.4	33.63	31.32	29.02	26.72	24.41	22.11	19.81	17.51	15.20	12.90	10.60	8.30	6.00	3.71	1.52	0.120000
1.5	33.56	31.25	28.95	26.65	24.35	22.04	19.74	17.44	15.14	12.83	10.53	8.23	5.93	3.64	1.46	0.100000
1.6	33.49	31.19	28.89	26.58	24.28	21.98	19.68	17.37	15.07	12.77	10.47	8.16	5.86	3.57	1.41	0.090000
1.7	33.43	31.13	28.83	26.52	24.22	21.92	19.62	17.31	15.01	12.71	10.41	8.10	5.80	3.51	1.36	0.074000
1.8	33.37	31.07	28.77	26.47	24.16	21.86	19.56	17.26	14.95	12.65	10.35	8.05	5.74	3.46	1.31	0.065000
1.9	33.32	31.02	28.71	26.41	24.11	21.81	19.50	17.20	14.90	12.60	10.29	7.99	5.69	3.41	1.26	0.056000
2.0	33.27	30.97	28.66	26.36	24.06	21.76	19.45	17.15	14.85	12.55	10.24	7.94	5.64	3.35	1.22	0.049000
2.1	33.22	30.92	28.61	26.31	24.01	21.71	19.40	17.10	14.80	12.50	10.19	7.89	5.59	3.31	1.18	0.043000
2.2	33.17	30.87	28.57	26.27	23.96	21.66	19.36	17.06	14.75	12.45	10.15	7.84	5.54	3.26	1.15	0.037000
2.3	33.13	30.83	28.52	26.22	23.92	21.62	19.31	17.01	14.71	12.41	10.10	7.80	5.50	3.22	1.11	0.033000
2.4	33.09	30.78	28.48	26.18	23.88	21.57	19.27	16.97	14.67	12.36	10.06	7.76	5.46	3.18	1.08	0.028000
2.5	33.05	30.74	28.44	26.14	23.83	21.53	19.23	16.93	14.62	12.32	10.02	7.72	5.42	3.14	1.04	0.025000
2.6	33.01	30.70	28.40	26.09	23.80	21.49	19.19	16.89	14.59	12.28	9.98	7.68	5.38	3.10	1.01	0.022000
2.7	32.97	30.67	28.36	26.06	23.76	21.46	19.15	16.85	14.55	12.25	9.94	7.64	5.34	3.06	0.98	0.019000
2.8	32.93	30.63	28.33	26.02	23.72	21.42	19.12	16.81	14.51	12.21	9.91	7.60	5.30	3.03	0.96	0.017000
2.9	32.90	30.59	28.29	25.99	23.69	21.38	19.08	16.78	14.48	12.17	9.87	7.57	5.27	2.99	0.93	0.015000
3.0	32.86	30.56	28.26	25.96	23.65	21.35	19.05	16.74	14.44	12.14	9.84	7.53	5.23	2.96	0.91	0.013000
3.1	32.83	30.53	28.23	25.92	23.62	21.31	19.01	16.71	14.41	12.11	9.80	7.50	5.20	2.93	0.88	0.011000
3.2	32.80	30.50	28.19	25.89	23.59	21.29	18.98	16.68	14.38	12.08	9.77	7.47	5.17	2.90	0.86	0.010000
3.3	32.77	30.47	28.16	25.86	23.56	21.25	18.95	16.65	14.35	12.04	9.74	7.44	5.14	2.87	0.84	0.008900
3.4	32.74	30.44	28.13	25.83	23.53	21.22	18.92	16.62	14.32	12.01	9.71	7.41	5.11	2.84	0.81	0.007900
3.5	32.71	30.41	28.10	25.80	23.50	21.20	18.89	16.59	14.29	11.99	9.68	7.38	5.08	2.81	0.79	0.007000
3.6	32.68	30.38	28.08	25.77	23.47	21.17	18.86	16.56	14.26	11.96	9.65	7.35	5.05	2.78	0.77	0.006200
3.7	32.65	30.35	28.05	25.75	23.44	21.14	18.84	16.54	14.23	11.93	9.63	7.33	5.03	2.76	0.76	0.005400
3.8	32.63	30.32	28.02	25.72	23.42	21.11	18.81	16.51	14.21	11.90	9.60	7.30	5.00	2.73	0.74	0.004800
3.9	32.60	30.30	28.00	25.69	23.39	21.09	18.79	16.48	14.18	11.88	9.57	7.27	4.97	2.71	0.72	0.004300
4.0	32.58	30.27	27.97	25.67	23.36	21.06	18.76	16.46	14.15	11.85	9.55	7.25	4.95	2.68	0.70	0.003800
4.1	32.55	30.25	27.95	25.64	23.34	21.04	18.74	16.43	14.13	11.83	9.52	7.22	4.92	2.66	0.69	0.003300
4.2	32.53	30.22	27.92	25.62	23.32	21.01	18.71	16.41	14.11	11.80	9.50	7.20	4.90	2.63	0.67	0.003000
4.3	32.50	30.20	27.90	25.60	23.29	20.99	18.69	16.38	14.08	11.79	9.48	7.17	4.88	2.61	0.65	0.002600
4.4	32.48	30.17	27.87	25.57	23.27	20.97	18.66	16.36	14.06	11.76	9.45	7.15	4.85	2.59	0.64	0.002300
4.5	32.46	30.15	27.85	25.55	23.25	20.95	18.64	16.34	14.04	11.73	9.43	7.13	4.83	2.57	0.63	0.002100
4.6	32.44	30.13	27.83	25.53	23.23	20.92	18.62	16.32	14.01	11.71	9.41	7.11	4.81	2.55	0.61	0.001800
4.7	32.41	30.11	27.81	25.51	23.21	20.90	18.60	16.30	13.99	11.69	9.39	7.09	4.79	2.53	0.60	0.001600
4.8	32.39	30.09	27.79	25.49	23.18	20.88	18.58	16.27	13.97	11.67	9.37	7.07	4.77	2.51	0.58	0.001500
4.9	32.37	30.07	27.77	25.46	23.16	20.85	18.56	16.25	13.95	11.65	9.35	7.04	4.75	2.49	0.57	0.001300
5.0	32.35	30.05	27.75	25.44	23.14	20.84	18.54	16.23	13.93	11.63	9.33	7.02	4.73	2.47	0.56	0.001100
5.1	32.33	30.03	27.73	25.42	23.12	20.82	18.52	16.21	13.91	11.61	9.31	7.01	4.71	2.45	0.55	0.001000
5.2	32.31	30.01	27.71	25.41	23.10	20.80	18.50	16.19	13.89	11.59	9.29	6.99	4.69	2.43	0.54	0.000900
5.3	32.29	29.99	27.69	25.39	23.08	20.78	18.48	16.18	13.87	11.57	9.27	6.96	4.67	2.41	0.53	0.000810
5.4	32.28	29.97	27.67	25.37	23.06	20.76	18.46	16.16	13.85	11.55	9.25	6.95	4.65	2.39	0.51	0.000720
5.5	32.26	29.95	27.65	25.35	23.05	20.74	18.44	16.14	13.84	11.53	9.23	6.93	4.63	2.38	0.50	0.000640
5.6	32.24	29.94	27.63	25.33	23.03	20.73	18.42	16.12	13.82	11.52	9.21	6.91	4.61	2.36	0.49	0.000570
5.7	32.22	29.92	27.62	25.31	23.01	20.71	18.41	16.10	13.80	11.50	9.20	6.89	4.60	2.34	0.48	0.000510
5.8	32.20	29.90	27.59	25.30	22.99	20.69	18.39	16.09	13.78	11.48	9.18	6.88	4.58	2.33	0.47	0.000450
5.9	32.19	29.88	27.58	25.28	22.98	20.67	18.37	16.07	13.77	11.46	9.16	6.86	4.56	2.31	0.46	0.000400
6.0	32.17	29.87	27.56	25.26	22.96	20.66	18.35	16.05	13.75	11.45	9.14	6.84	4.54	2.30	0.45	0.000360
6.1	32.15	29.85	27.55	25.25	22.94	20.64	18.34	16.04	13.74	11.43	9.13	6.83	4.53	2.28	0.45	0.000320
6.2	32.14	29.83	27.53	25.23	22.93	20.62	18.32	16.02	13.72	11.41	9.11	6.81	4.51	2.26	0.44	0.000290
6.3	32.12	29.82	27.52	25.21	22.91	20.61	18.31	16.00	13.70	11.40	9.10	6.79	4.50	2.25	0.43	0.000260
6.4	32.11	29.80	27.50	25.20	22.89	20.59	18.29	15.99	13.68	11.38	9.08	6.78	4.48	2.23	0.42	0.000230
6.5	32.09	29.79	27.48	25.18	22.88	20.58	18.27	15.97	13.67	11.37	9.06	6.76	4.47	2.22	0.41	0.000200
6.6	32.07	29.77	27.47	25.17	22.86	20.56	18.26	15.96	13.65	11.35	9.05	6.75	4.45	2.21	0.40	0.000180
6.7	32.06	29.76	27.45	25.15	22.85	20.55	18.24	15.94	13.64	11.34	9.03	6.73	4.44	2.19	0.40	0.000160
6.8	32.04	29.74	27.44	25.14	22.83	20.53	18.23	15.93	13.62	11.32	9.02	6.72	4.42	2.18	0.39	0.000140
6.9	32.03	29.73	27.42	25.12	22.82	20.52	18.21	15.91	13.61	11.31	9.00	6.70	4.41	2.16	0.38	0.000130
7.0	32.02	29.71	27.41	25.11	22.81	20.50	18.20	15.90	13.60	11.29	8.99	6.69	4.39	2.15	0.37	0.000120
7.1	32.00	29.70	27.40	25.09	22.79	20.49	18.19	15.88	13.58	11.28	8.98	6.67	4.38	2.14	0.37	0.000100
7.2	31.99	29.68	27.38	25.08	22.78	20.47	18.17	15.87	13.57	11.26	8.96	6.66	4.36	2.12	0.36	0.000092
7.3	31.97	29.67	27.37	25.07	22.76	20.46	18.16	15.86	13.55	11.25	8.95	6.65	4.35	2.11	0.35	0.000082
7.4	31.96	29.66	27.35	25.05	22.75	20.45	18.14	15.84	13.54	11.24	8.93	6.63	4.34	2.10	0.35	0.000074
7.5	31.95	29.64	27.34	25.04	22.74	20.43	18.13	15.83	13.53	11.22	8.92	6.62	4.32	2.09	0.34	0.000066
7.6	31.93	29.63	27.33	25.03	22.72	20.42	18.12	15.82	13.51	11.21	8.91	6.61	4.31	2.07	0.33	0.000059
7.7	31.92	29.62	27.32	25.01	22.71	20.41	18.10	15.80	13.50	11.20	8.89	6.59	4.30	2.06	0.33	0.000053
7.8	31.91	29.60	27.30	25.00	22.70	20.39	18.09	15.79	13.49	11.18	8.88	6.58	4.28	2.05	0.32	0.000047
7.9	31.89	29.59	27.29	24.99	22.68	20.38	18.08	15.78	13.47	11.17	8.87	6.57	4.27	2.04	0.32	0.000042
8.0	31.88	29.58	27.28	24.97	22.67	20.37	18.07	15.76	13.46	11.16	8.86	6.55	4.26	2.03	0.31	0.000038
8.1	31.87	29.57	27.26	24.96	22.66	20.36	18.05	15.75	13.45	11.15	8.84	6.54	4.25	2.02	0.31	0.000034
8.2	31.86	29.55	27.25	24.95	22.65	20.34	18.04	15.74	13.44	11.13	8.83	6.53	4.23	2.00	0.30	0.000030
8.3	31.85	29.54	27.24	24.94	22.64	20.33	18.03	15.73	13.42	11.12	8.82	6.52	4.22	1.99	0.29	0.000027
8.4	31.83	29.53	27.23	24.93	22.62	20.32	18.02	15.72	13.41	11.11	8.81	6.51	4.21	1.98	0.29	0.000024
8.5	31.82	29.52	27.22	24.91	22.61	20.31	18.01	15.70	13.40	11.10	8.80	6.49	4.20	1.97	0.28	0.000022
8.6	31.81	29.51	27.20	24.90	22.60	20.30	17.99	15.69	13.39	11.09	8.78	6.48	4.19	1.96	0.28	0.000019
8.7	31.80	29.50	27.19	24.89	22.59	20.29	17.98	15.68	13.38	11.08	8.77	6.47	4.18	1.95	0.27	0.000017
8.8	31.79	29.48	27.18	24.88	22.58	20.27	17.97	15.67	13.37	11.06	8.76	6.46	4.16	1.94	0.27	0.000016
8.9	31.78	29.47	27.17	24.87	22.57	20.26	17.96	15.66	13.35	11.05	8.75	6.45	4.15	1.93	0.26	0.000014
9.0	31.76	29.46	27.16	24.86	22.55	20.25	17.95	15.65	13.34	11.04	8.74	6.44	4.14	1.92	0.26	0.000012
9.1	31.75	29.45	27.15	24.85	22.54	20.24	17.94	15.64	13.33	11.03	8.73	6.43	4.13	1.91	0.26	0.000011
9.2	31.74	29.44	27.14	24.83	22.53	20.23	17.93	15.62	13.32	11.02	8.72	6.41	4.12	1.90	0.25	0.000010
9.3	31.73	29.43	27.13	24.82	22.52	20.22	17.92	15.61	13.31	11.01	8.71	6.40	4.11	1.89	0.25	0.000009
9.4	31.72	29.42	27.12	24.81	22.51	20.21	17.91	15.60	13.30	11.00	8.70	6.39	4.10	1.88	0.24	0.000008
9.5	31.71	29.41	27.11	24.80	22.50	20.20	17.89	15.59	13.29	10.99	8.68	6.38	4.09	1.87	0.24	0.000007
9.6	31.70	29.40	27.09	24.79	22.49	20.19	17.88	15.58	13.28	10.98	8.67	6.37	4.08	1.86	0.23	0.000006
9.7	31.69	29.39	27.08	24.78	22.48	20.18	17.87	15.57	13.27	10.97	8.66	6.36	4.07	1.85	0.23	0.000006
9.8	31.68	29.38	27.07	24.77	22.47	20.17	17.86	15.56	13.26	10.96	8.65	6.35	4.06	1.84	0.23	0.000005
9.9	31.67	29.37	27.06	24.76	22.46	20.16	17.85	15.55	13.25	10.95	8.64	6.34	4.05	1.83	0.22	0.000005

Table. I.4.3 Well Capacity by Size

Case. R= 3.50 m																						
Drawdown s	s (m)	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00	2.10	2.20	2.30	2.40	2.50
Radioous of Well	r_o (m)	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
Used time	t (sec)	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800
Coefficient of Transmission	T (m^2/sec)	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3
Coeffiient of Storage	S	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1
Function	u	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3
of Well	Wu	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69
Capacity of discharge	Q (m^3/sec)	0.002	0.003	0.003	0.004	0.004	0.005	0.005	0.006	0.006	0.007	0.007	0.008	0.008	0.009	0.009	0.010	0.010	0.011	0.011	0.011	0.012
Remark																						

Case. R= 2.00 m																						
Drawdown s	s (m)	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00	2.10	2.20	2.30	2.40	2.50
Radioous of Well	r_o (m)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Used time	t (sec)	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800
Coefficient of Transmission	T (m^2/sec)	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3
Coeffiient of Storage	S	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1
Function	u	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4	6.4E-4
of Well	Wu	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78
Capacity of discharge	Q (m^3/sec)	0.002	0.002	0.002	0.003	0.004	0.004	0.004	0.005	0.005	0.006	0.006	0.006	0.007	0.007	0.008	0.008	0.008	0.009	0.009	0.010	0.010
Remark																						

Case. R= 1.00 m																						
Drawdown s	s (m)	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00	2.10	2.20	2.30	2.40	2.50
Radioous of Well	r_o (m)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Used time	t (sec)	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800	28800
Coefficient of Transmission	T (m^2/sec)	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3	2.2E-3
Coeffiient of Storage	S	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1	1.6E-1
Function	u	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4	1.6E-4
of Well	Wu	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16	8.16
Capacity of discharge	Q (m^3/sec)	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.006	0.007	0.007	0.007	0.008	0.008	0.008
Remark																						

Table. I.5.1 Condition of the Suction Capacity

Position	Pipe length	Date	Suction Gage	Static head	Discharge Q	Ratio (%)	Head Loss (m)	pipe	N.P.S.H. (rq)	N.P.S.H. (ave)	Balance	Remark
P1	6.00	18-Jul -1	5.0	3.217	2.56	136%	1.783	0.809	2.032	2.471	0.439	
		-2	5.0	3.277	2.47	131%	1.723	0.816	1.894	2.492	0.598	
		27-Jul -1	5.1	3.617	2.60	138%	1.483	0.476	2.101	2.361	0.260	
		-2	5.1	3.787	2.39	127%	1.313	0.462	1.797	2.409	0.612	
	8.00	13-Jul -2	5.5	3.777	2.43	129%	1.723	0.843	1.845	2.000	0.155	
		14-Jul -1	5.5	4.277	2.37	126%	1.223	0.386	1.776	2.023	0.247	
		24-Jul -1	5.2	3.457	2.63	140%	1.743	0.714	2.136	2.264	0.128	
		-2	5.2	3.577	2.39	127%	1.623	0.774	1.784	2.319	0.535	
		28-Aug	5.5	4.277	2.41	128%	1.223	0.360	1.818	2.005	0.187	
P2	4.00	29-Jul -1	4.5	2.692	2.67	142%	1.808	0.746	2.241	2.944	0.703	
		-2	4.5	3.592	2.42	129%	0.908	0.034	1.826	3.002	1.175	
		8-Aug -1	4.0	2.492	2.54	135%	1.508	0.549	1.980	3.476	1.495	
		-2	4.0	2.512	2.61	139%	1.488	0.472	2.126	3.420	1.293	
	6.00	19-Jul -1	4.5	2.092	2.57	137%	2.408	1.427	2.036	2.979	0.942	
		-2	4.5	2.292	2.44	130%	2.208	1.320	1.851	3.007	1.156	
		26-Jul -1	4.5	2.592	2.47	132%	1.908	0.997	1.897	3.000	1.104	
		-2	4.5	2.732	2.45	130%	1.768	0.872	1.872	3.005	1.133	
		19-Aug -1	4.5	2.992	2.66	141%	1.508	0.457	2.206	2.947	0.741	
		-2	4.5	2.992	2.45	131%	1.508	0.611	1.872	2.995	1.122	
		21-Aug -2	4.5	2.992	1.97	105%	1.508	0.928	1.453	3.079	1.626	
	8.00	12-Jul -1	4.0	2.242	2.61	139%	1.758	0.748	2.103	3.470	1.367	
		21-Jul -1	4.5	2.052	2.51	134%	2.448	1.508	1.947	2.991	1.044	
		-2	4.5	2.232	2.61	139%	2.268	1.252	2.107	2.968	0.861	
		5-Aug -1	4.8	3.192	2.58	137%	1.608	0.619	2.062	2.666	0.604	
		-2	5.0	3.492	2.55	136%	1.508	0.537	2.009	2.459	0.450	
		11-Aug -2	4.5	3.092	2.67	142%	1.408	0.349	2.211	2.945	0.733	
		-2	4.5	3.192	2.69	143%	1.308	0.234	2.249	2.940	0.691	
P3	0.00	15-Jul -1	2.2	0.648	2.69	143%	1.552	0.738	2.248	5.250	3.002	
	2.00	1-Aug -1	3.0	1.228	2.61	139%	1.772	0.760	2.104	4.459	2.355	
		2-Aug -1	3.0	1.248	2.38	127%	1.752	0.908	1.781	4.511	2.730	
		-2	3.0	1.748	2.55	136%	1.252	0.281	2.009	4.459	2.450	
		10-Aug -1	4.0	2.348	2.56	136%	1.652	0.677	2.032	3.458	1.426	
		31-Aug -1	4.0	1.948	2.62	140%	2.052	1.028	2.132	3.443	1.311	
	4.00	28-Jul -1	3.5	1.548	2.38	127%	1.952	1.108	1.781	4.011	2.230	
		-2	3.5	1.848	2.46	131%	1.652	0.753	1.874	3.994	2.120	
		7-Aug -1	4.0	2.548	2.56	136%	1.452	0.479	2.010	3.471	1.461	
		-2	4.0	2.648	2.65	141%	1.352	0.307	2.174	3.436	1.262	
		24-Aug -1	4.5	2.248	3.09	165%	2.252	0.832	Not applicable	-	-	
		-2	4.5	2.148	1.83	98%	2.352	1.848	1.391	3.102	1.712	
		30-Aug -1	3.5	2.048	2.31	123%	1.452	0.659	1.703	4.014	2.311	
		-2	4.0	2.248	2.54	135%	1.752	0.794	1.980	3.463	1.483	
	6.00	15-Jul -2	3.4	1.188	2.50	133%	2.212	1.282	1.925	4.094	2.170	
		17-Jul -1	3.6	1.348	2.58	137%	2.252	1.262	2.062	3.876	1.814	
		25-Jul -1	3.5	1.688	2.44	130%	1.812	0.928	1.848	4.018	2.170	
		-2	3.5	1.848	2.54	135%	1.652	0.688	2.004	3.984	1.980	
		22-Aug -2	4.5	2.248	2.41	128%	2.252	1.387	1.819	2.979	1.160	
		25-Aug -1	5.0	2.148	2.54	135%	2.852	1.894	1.980	2.476	0.496	
		26-Aug -2	4.5	2.248	2.69	143%	2.252	1.172	2.280	2.913	0.632	
	8.00	22-Jul -1	3.2	1.228	2.36	126%	1.972	1.138	1.762	4.314	2.552	
		-2	3.2	1.448	2.55	136%	1.752	0.782	2.008	4.272	2.264	
		9-Aug -1	5.0	2.448	2.67	142%	2.552	1.490	2.240	2.444	0.204	
		-2	5.0	2.448	2.78	148%	2.552	1.403	Not applicable	-	-	
		15-Aug -1	4.5	2.548	2.66	142%	1.952	0.896	2.209	2.946	0.737	
		-2	5.0	2.648	2.72	145%	2.352	1.249	Not applicable	-	-	
		23-Aug -1	4.5	2.448	2.81	150%	2.052	0.876	Not applicable	-	-	
		-2	4.5	2.448	2.76	147%	2.052	0.918	Not applicable	-	-	

APPENDIX I
FIGURES

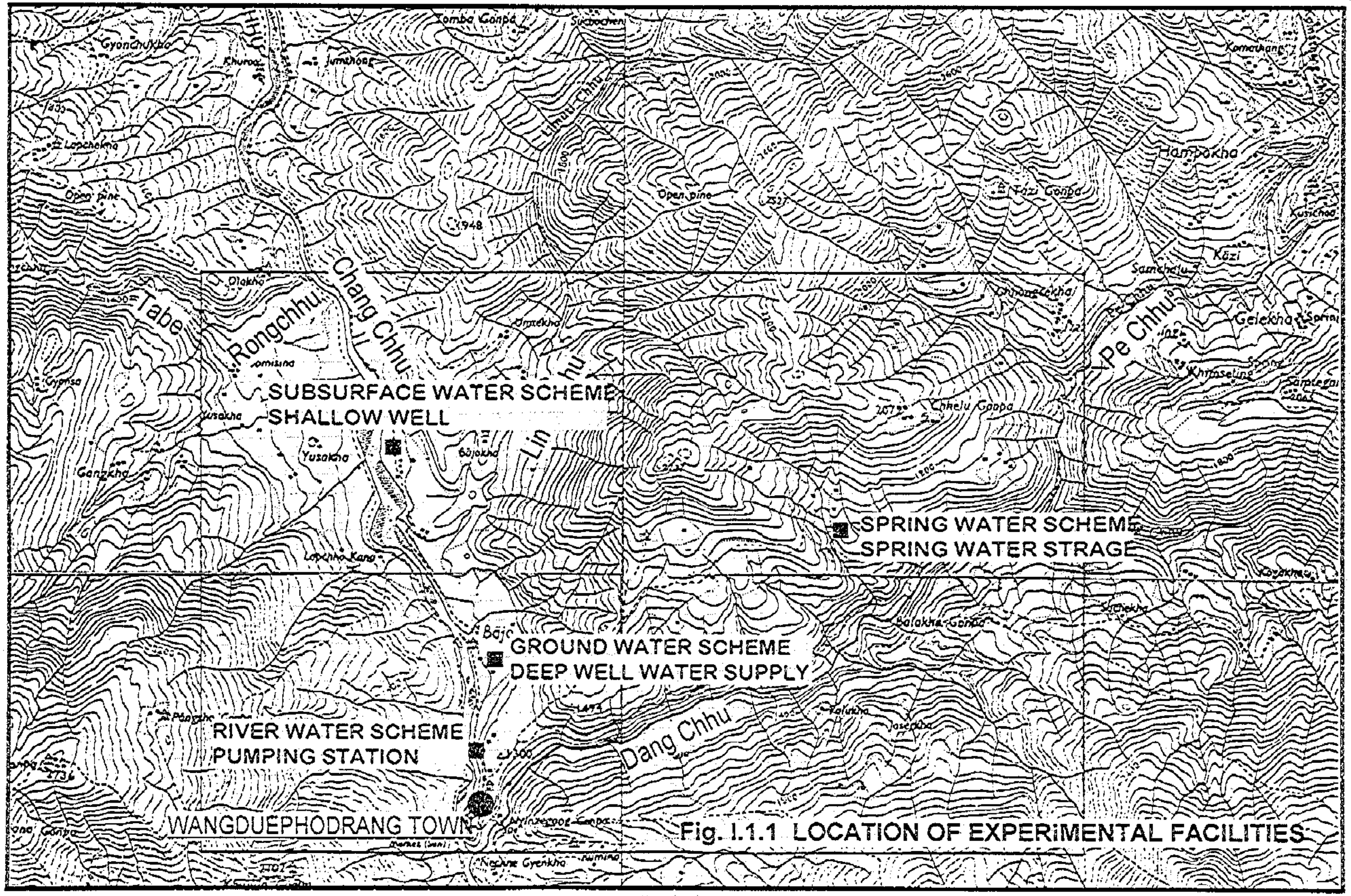


Fig. I.1.1 LOCATION OF EXPERIMENTAL FACILITIES

SCHEME	Groundwater Scheme	Spring Water Scheme	Subsurface Water Scheme	River Water Scheme
FACILITY	SOLAR POWER SYSTEM	WATER TAP AND STORAGE TANK	SHALLOW WELL	SLIDE TYPE PUMPING SYSTEM
PURPOSE OF MONITORING	To examine technical feasibility, performance and applicability of the solar power system.	To measure the volume of spring water which saved by installing water tap at the outlet of the pipe.	To examine and confirm the technical feasibility, applicability and suitability in applying the shallow well in the area.	- To confirm and examine technical feasibility, applicability of the slide type pumping station in the area including operation and management aspects. - To confirm overall performance of irrigation water management with pumping system.
MONITORING ITEMS	*Effects of Solar Power System* - Operation hours with solar and electric power systems. - Volume of water lifted up with solar and electric power systems. *Other Reference Records* - Meteorological records - Maintenance records	*Effects of Water Tap* - Volume of spring water saved by installing water tap - Purpose of using water	*Basic Hydrological Condition of Well* - Basic data on hydrological conditions of shallow well (Pumping Tests) *Relation between Subsurface and River Water* - River and well water levels *Other Reference Records* - Meteorological records - Maintenance records - Purpose of using water	*Performance of Slide Type Pump* - Variation of river water level - Position of pump units - Discharge and operation hours of pumping units - Suction and discharge pressure - River water temperature *Performance of Floating Suction* - Position of suction hoses - Damage and difficulties in positioning hoses *Water Management* - Water levels in primary and secondary tank - Operation of 2nd. stage pump *Other Reference Records* - Meteorological records - Operation and maintenance records

Fig. I.1.2 MONITORING PURPOSES AND ITEMS

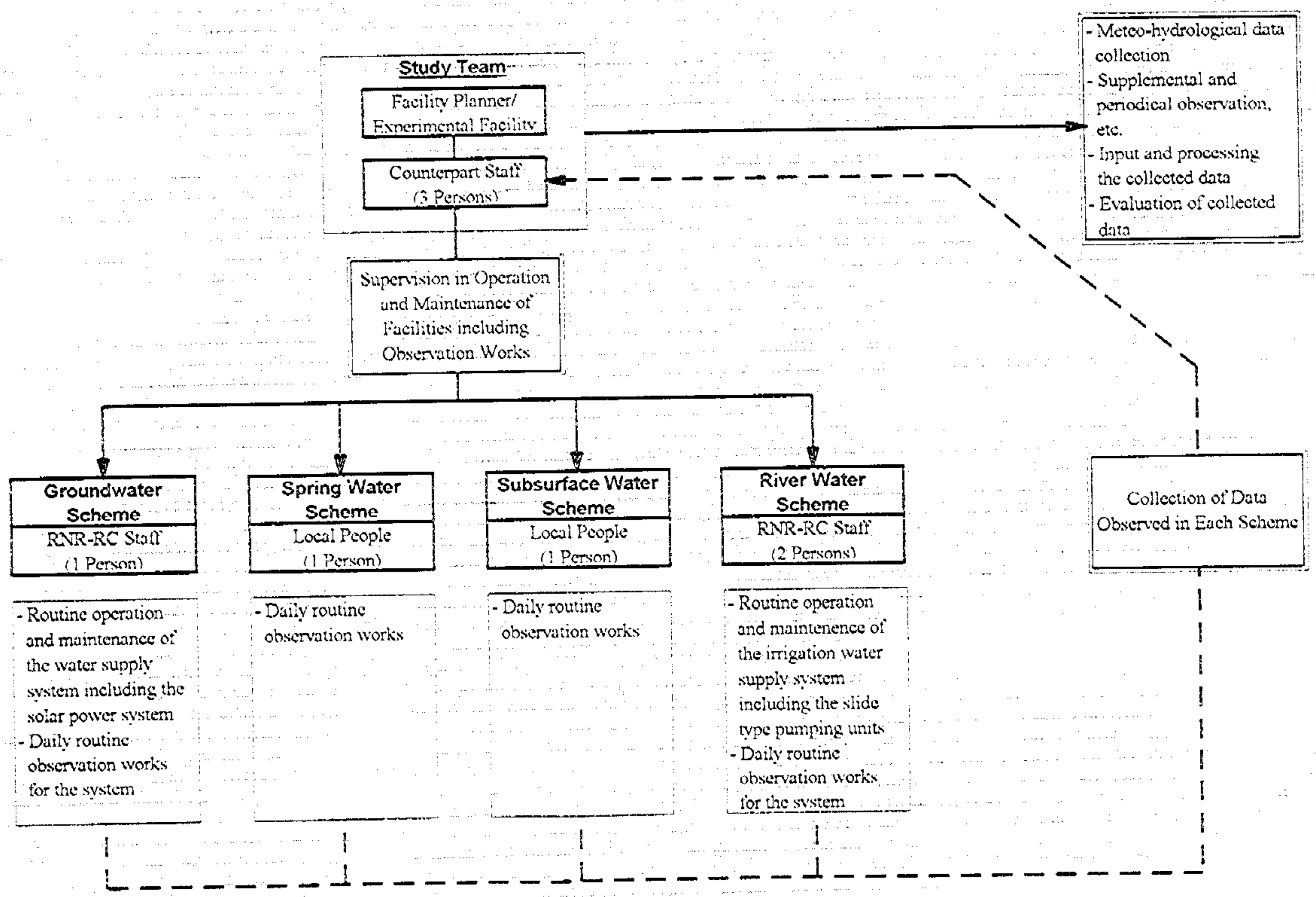


Fig. I.1.3 MONITORING FORMATION

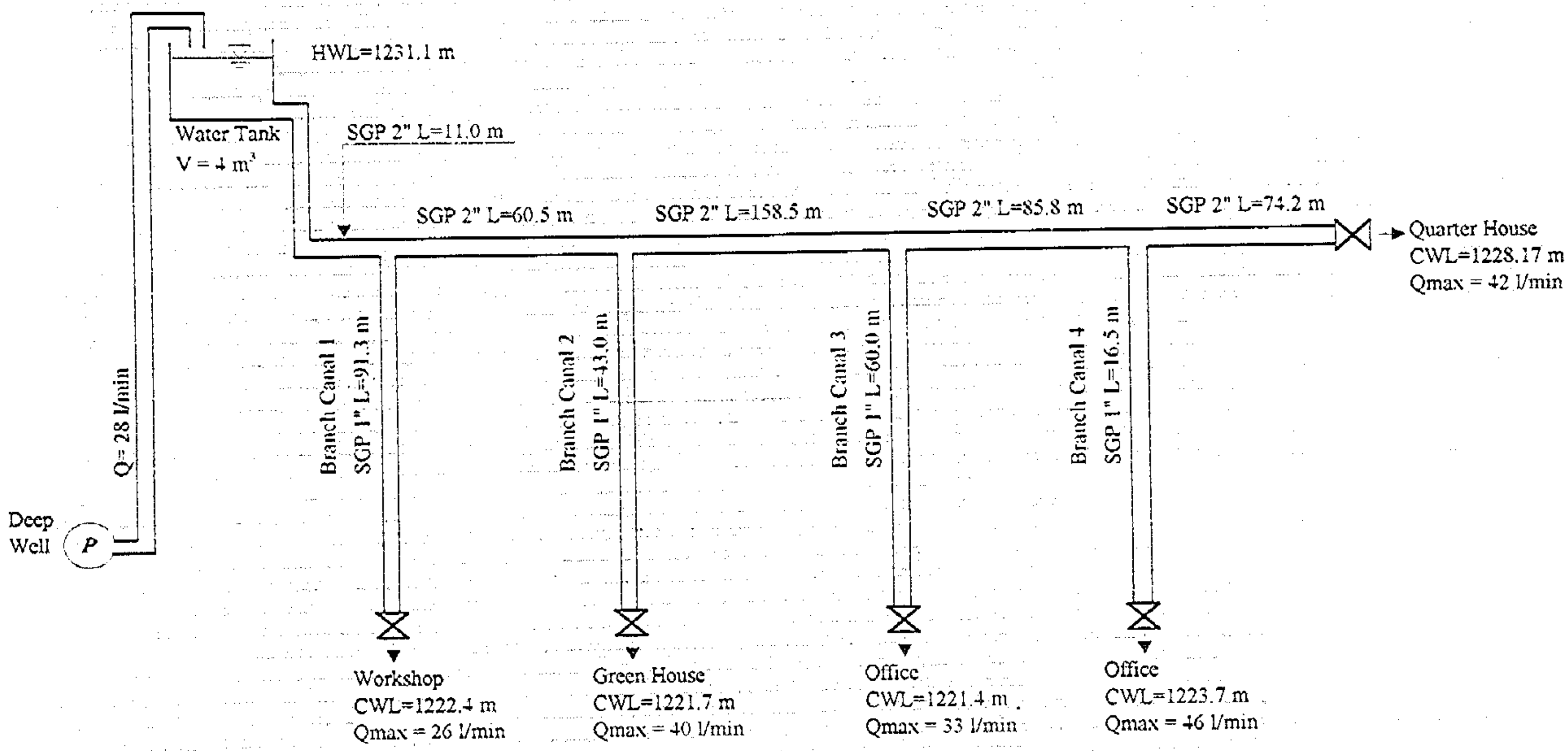


Fig. I.2.1 SCHEMATIC DIAGRAM OF GROUND WATER SCHEME

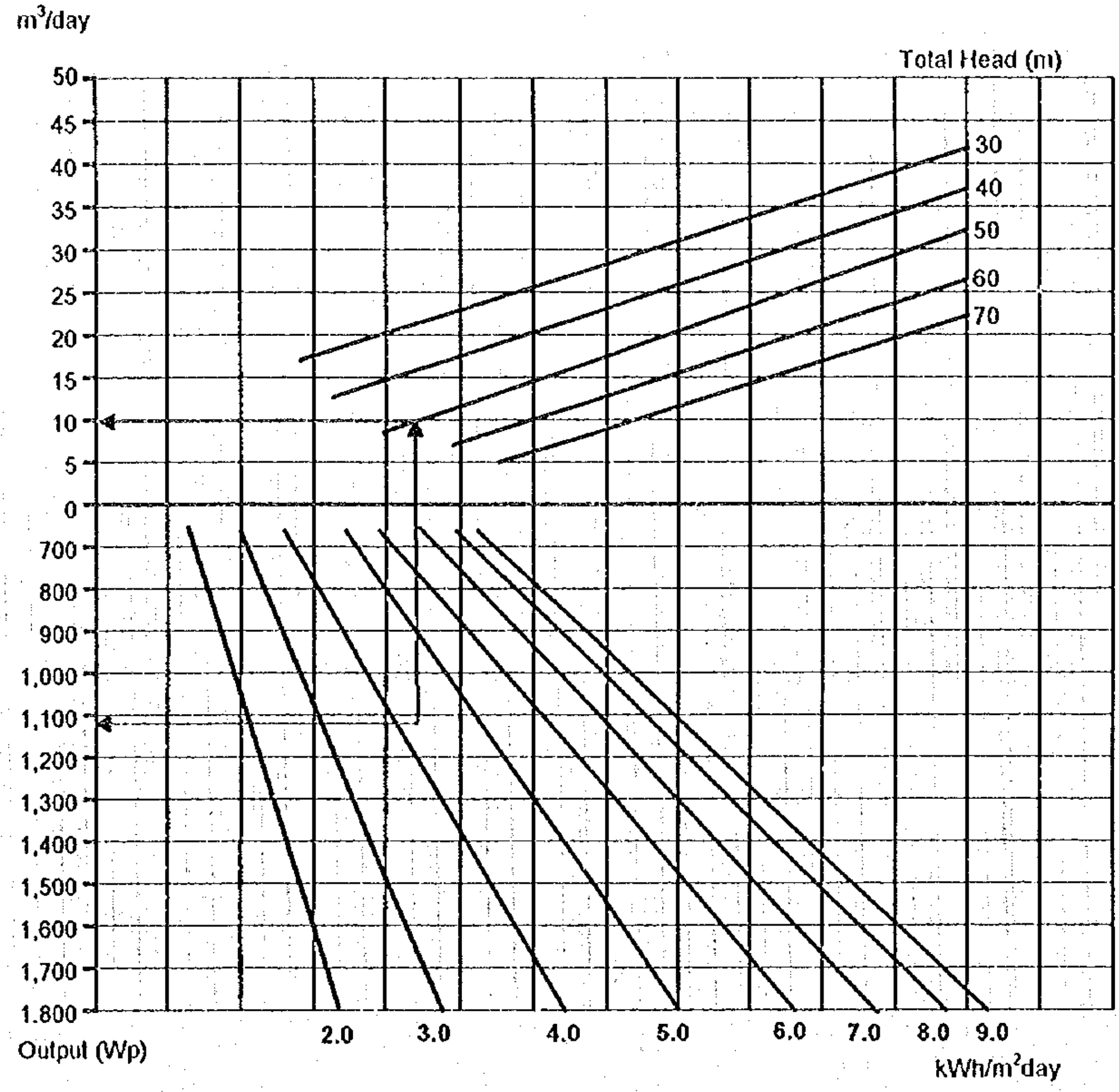


Fig. I.2.2 PERFORMANCE OF SOLAR SYSTEM

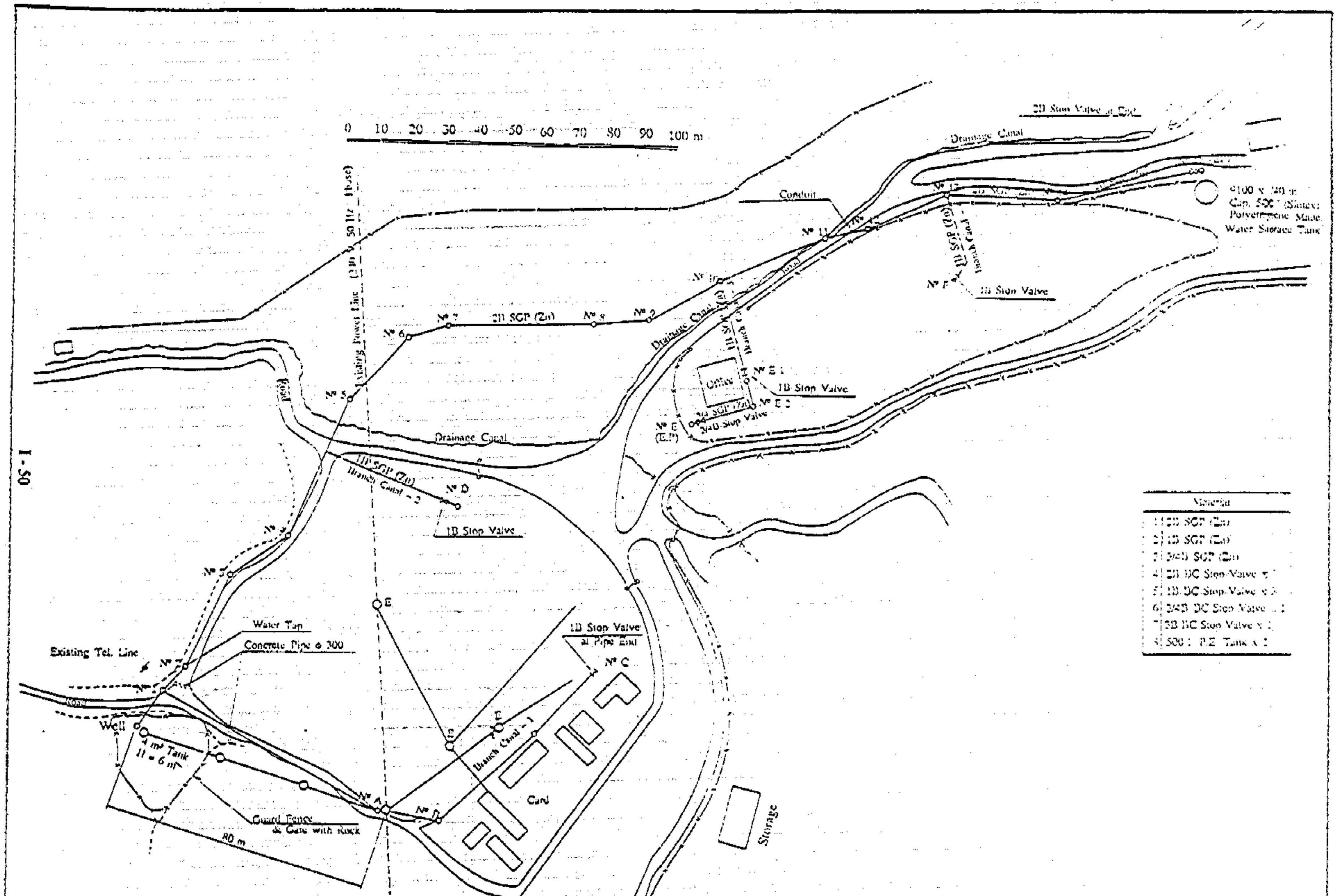


Fig. I.2.3 GENERAL PLAN AND DISTRIBUTION NETWORK, WATER SUPPLY FACILITY OF DEEP WELL

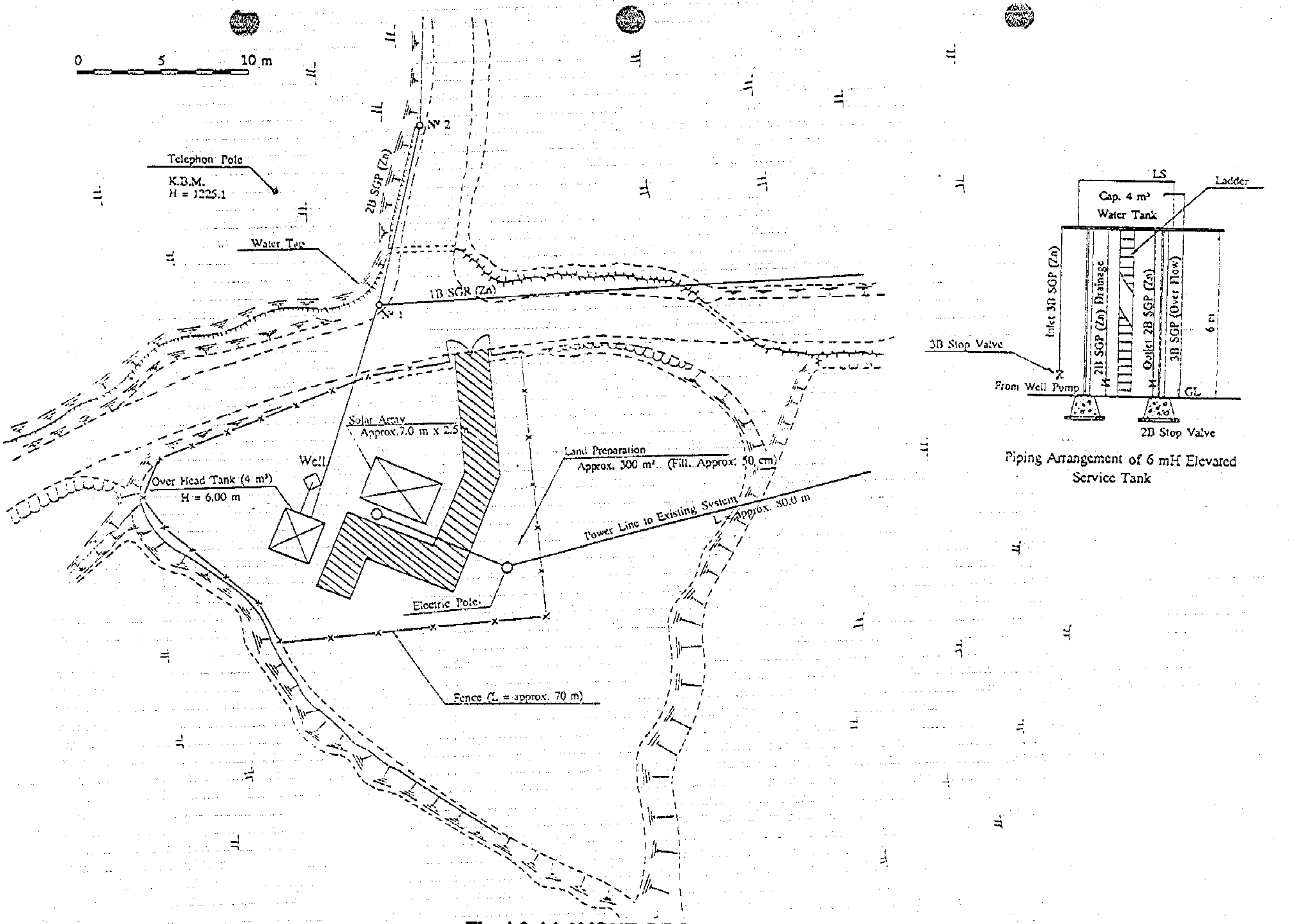


Fig. I.2.4 LAYOUT OF PUMPING STATION, WATER SUPPLY FACILITY OF DEEP WELL

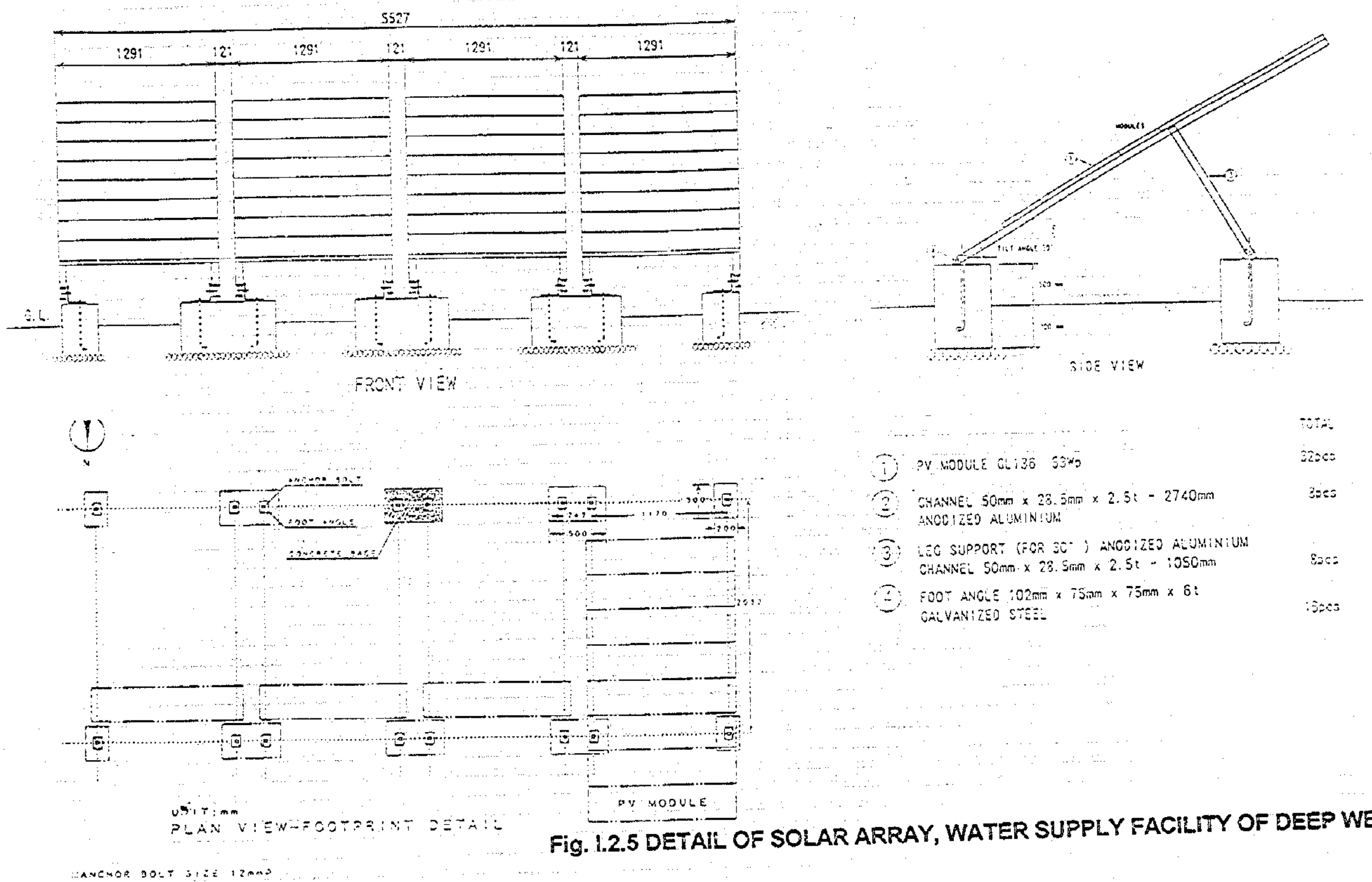
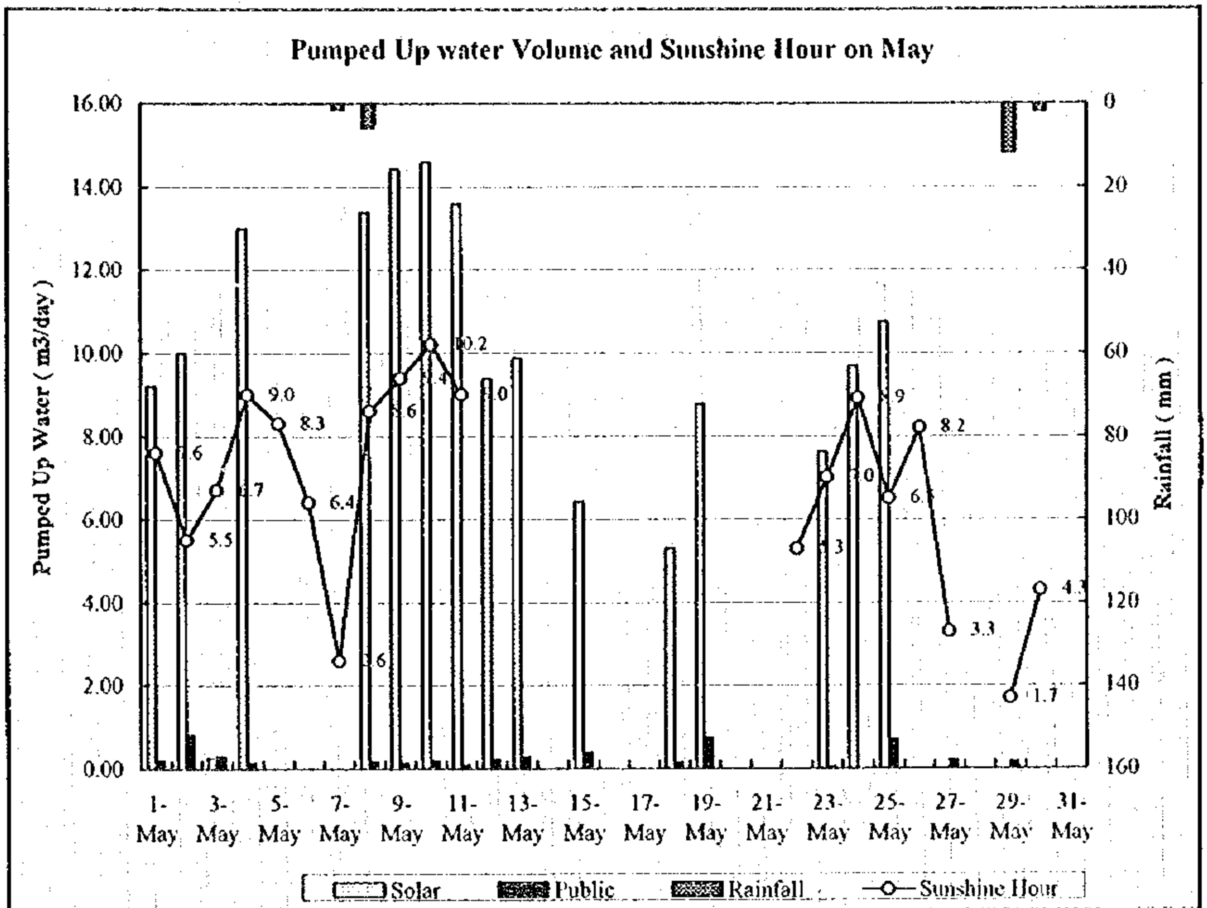


Fig. I.2.5 DETAIL OF SOLAR ARRAY, WATER SUPPLY FACILITY OF DEEP WELL



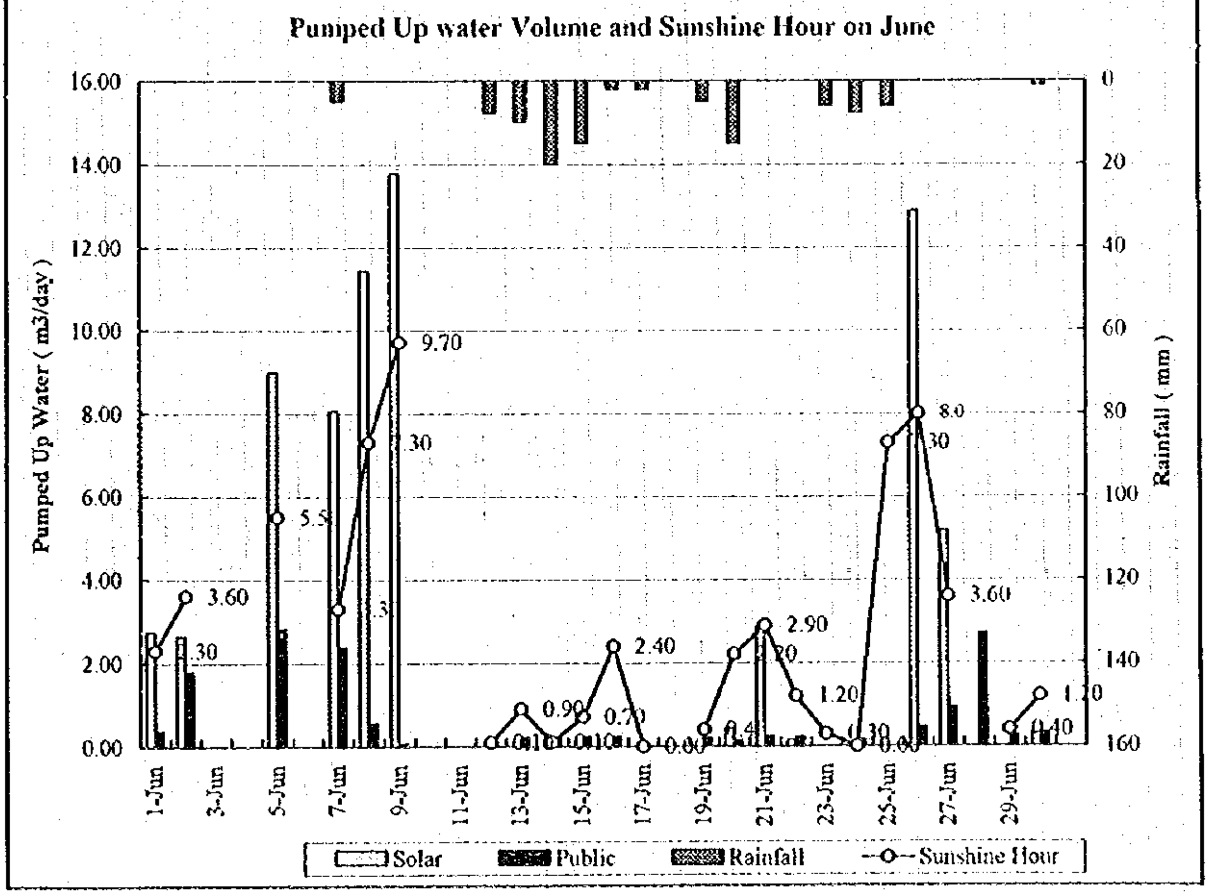


Fig. I.2.6 Daily Pumping up Discharge at Deep Well (1/2)

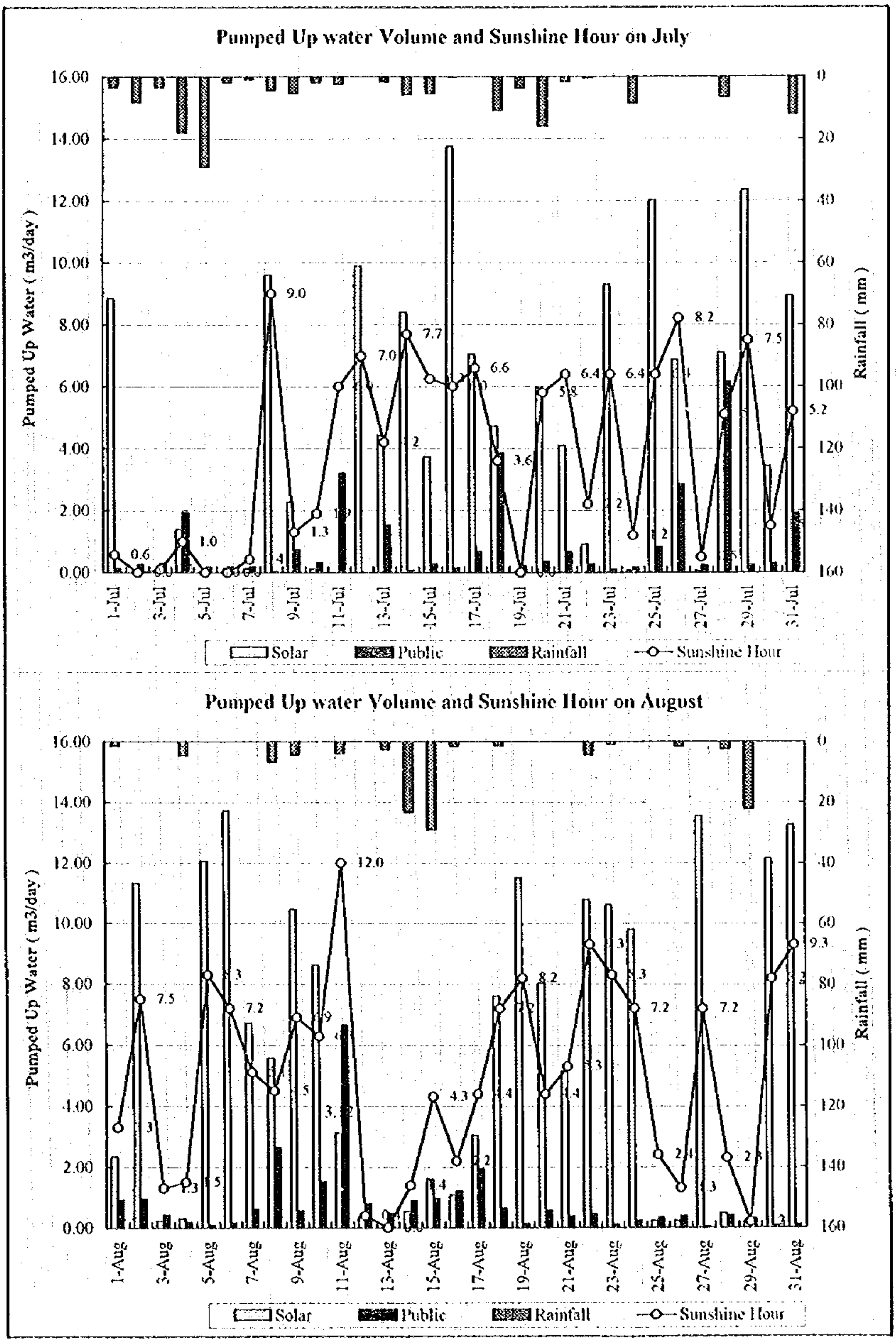


Fig. I.2.6 Daily Pumping up Discharge at Deep Well (2/2)

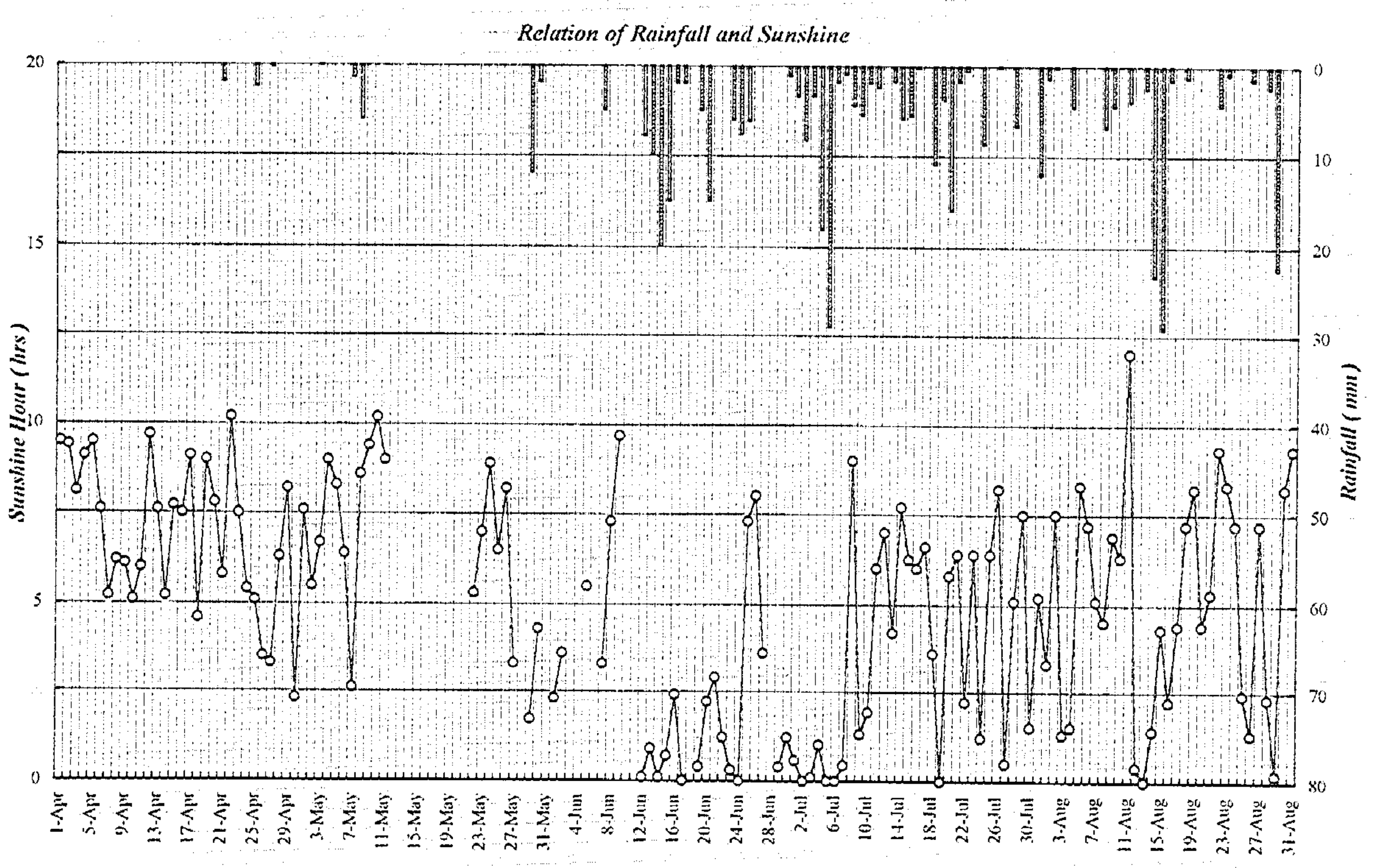
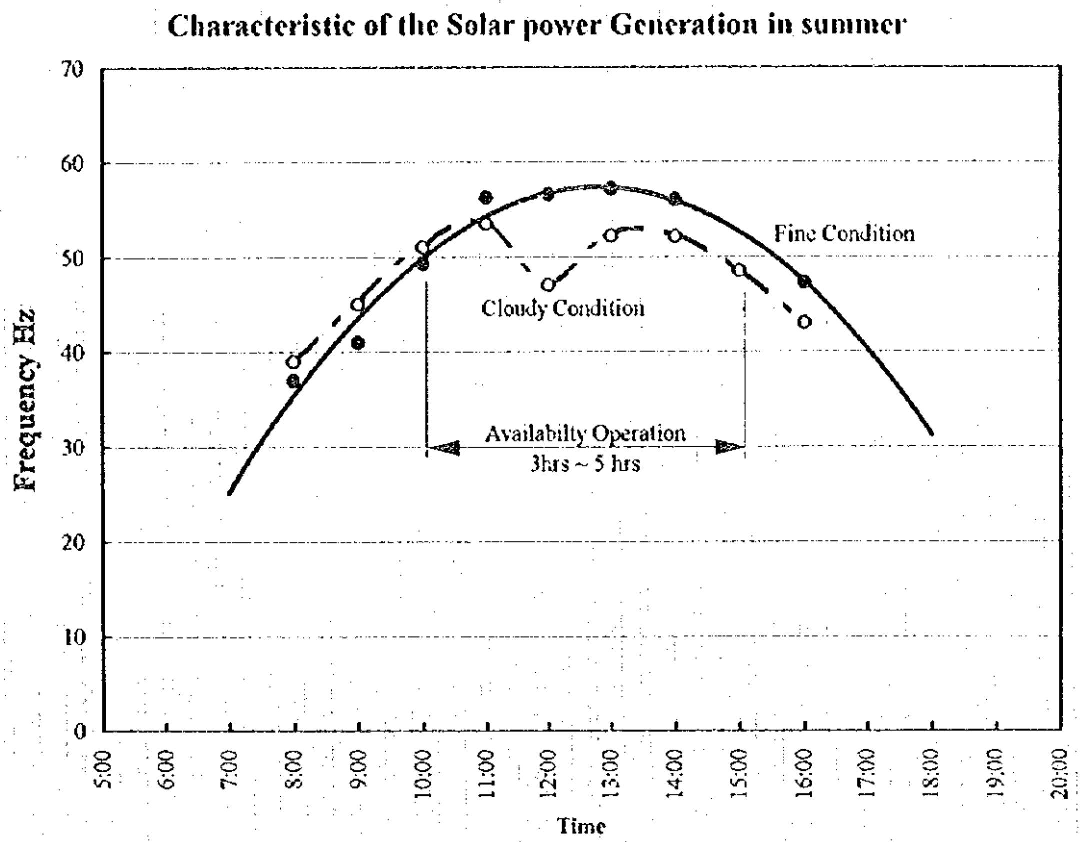


Fig. I.2.7 Weather Conditions and Sunshine Hour



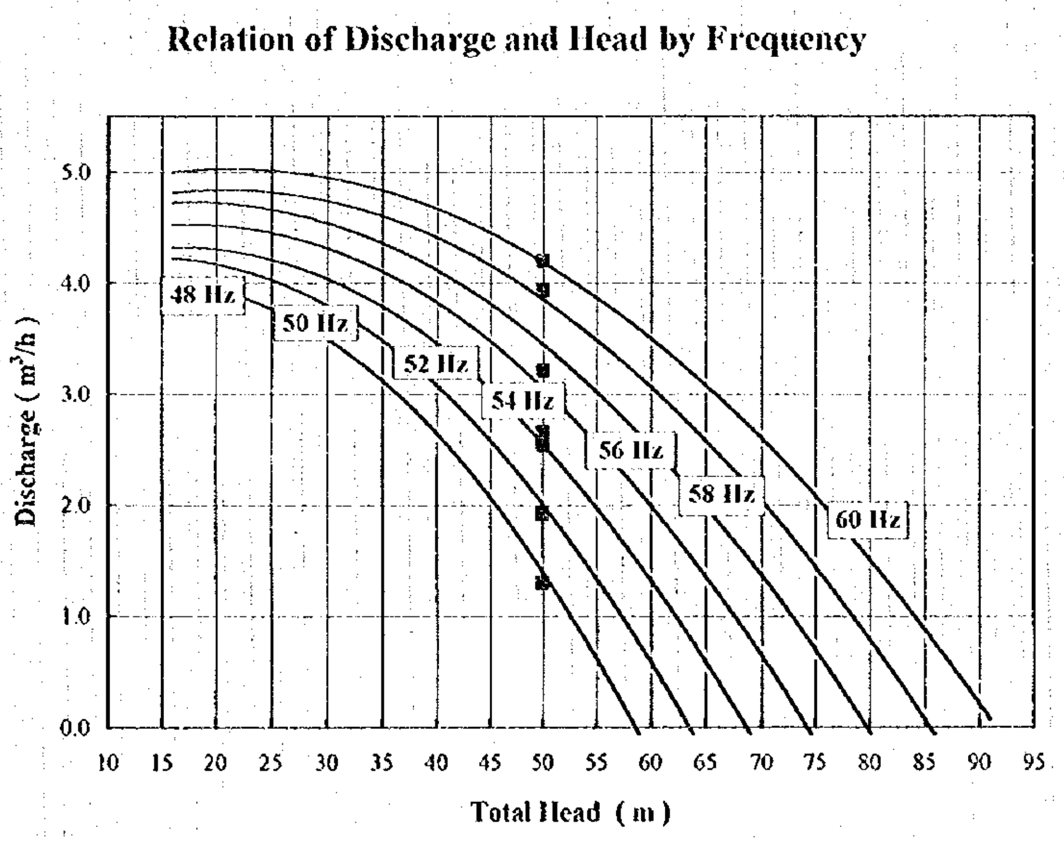


Fig. I.2.8 Condition of the Solar Power

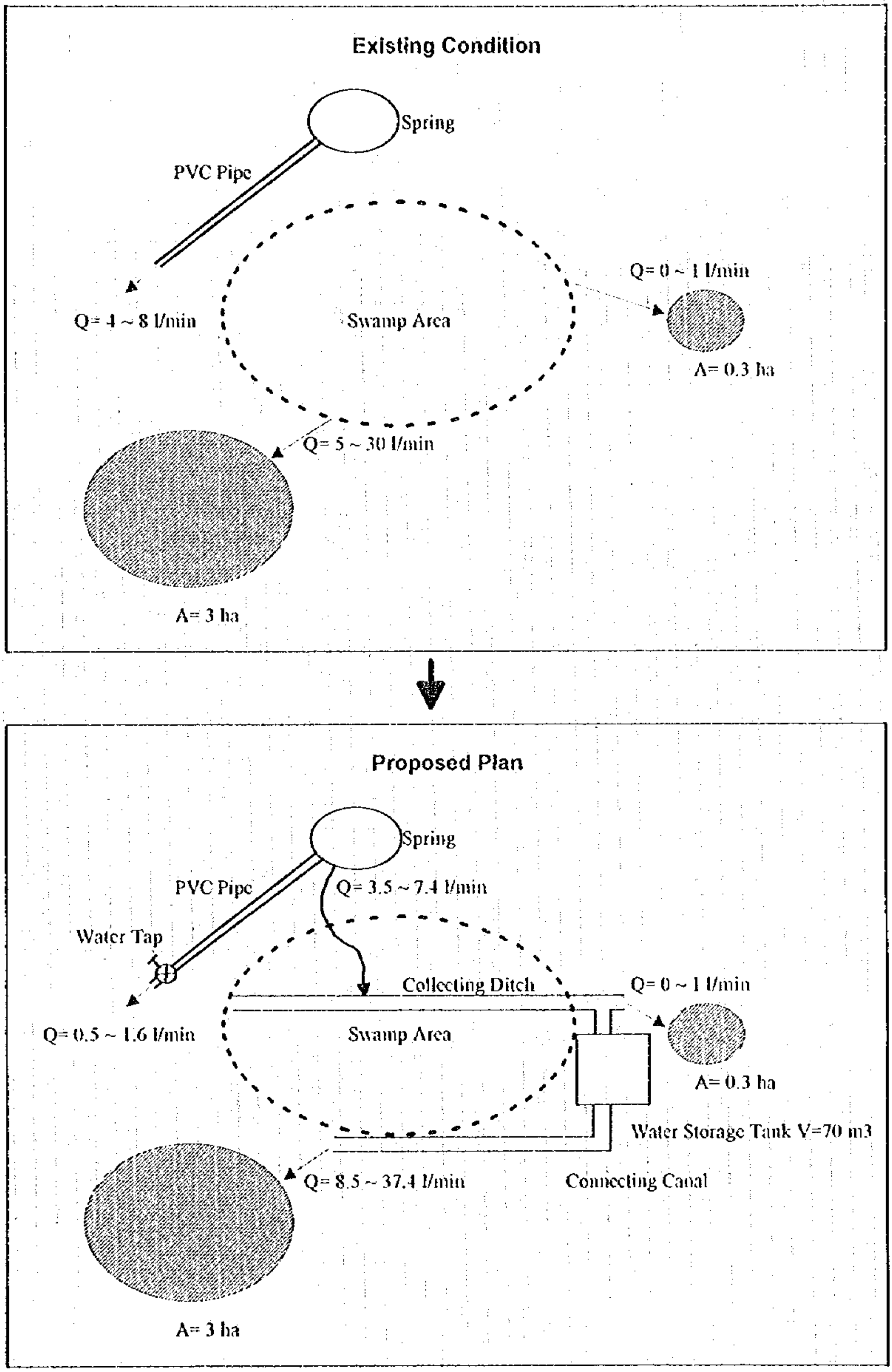


Fig. I.3.1 SCHEMATIC ILLUSTRATION OF SPRING WATER SCHEME IN PHANGYUL AREA

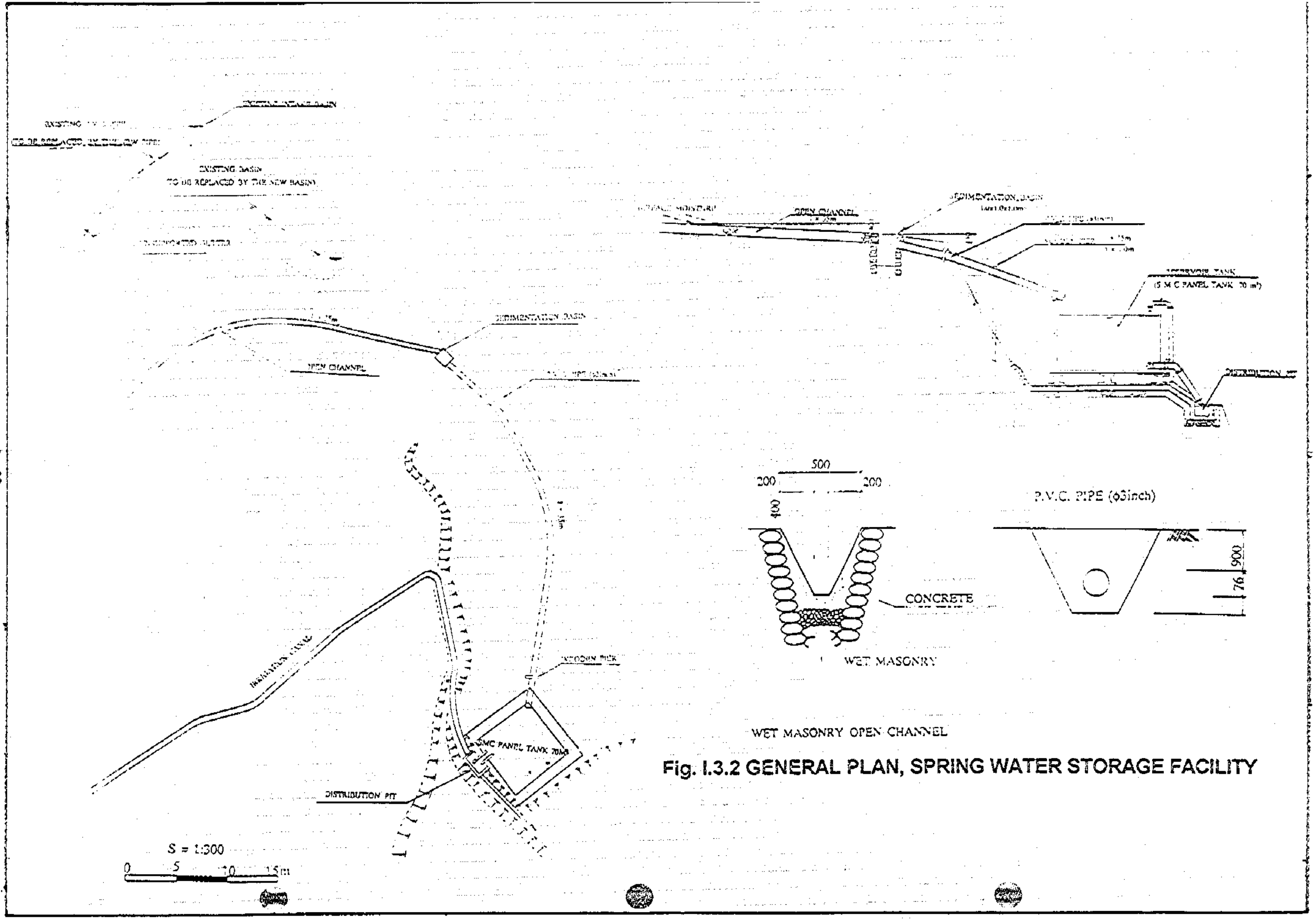


Fig. I.3.2 GENERAL PLAN, SPRING WATER STORAGE FACILITY

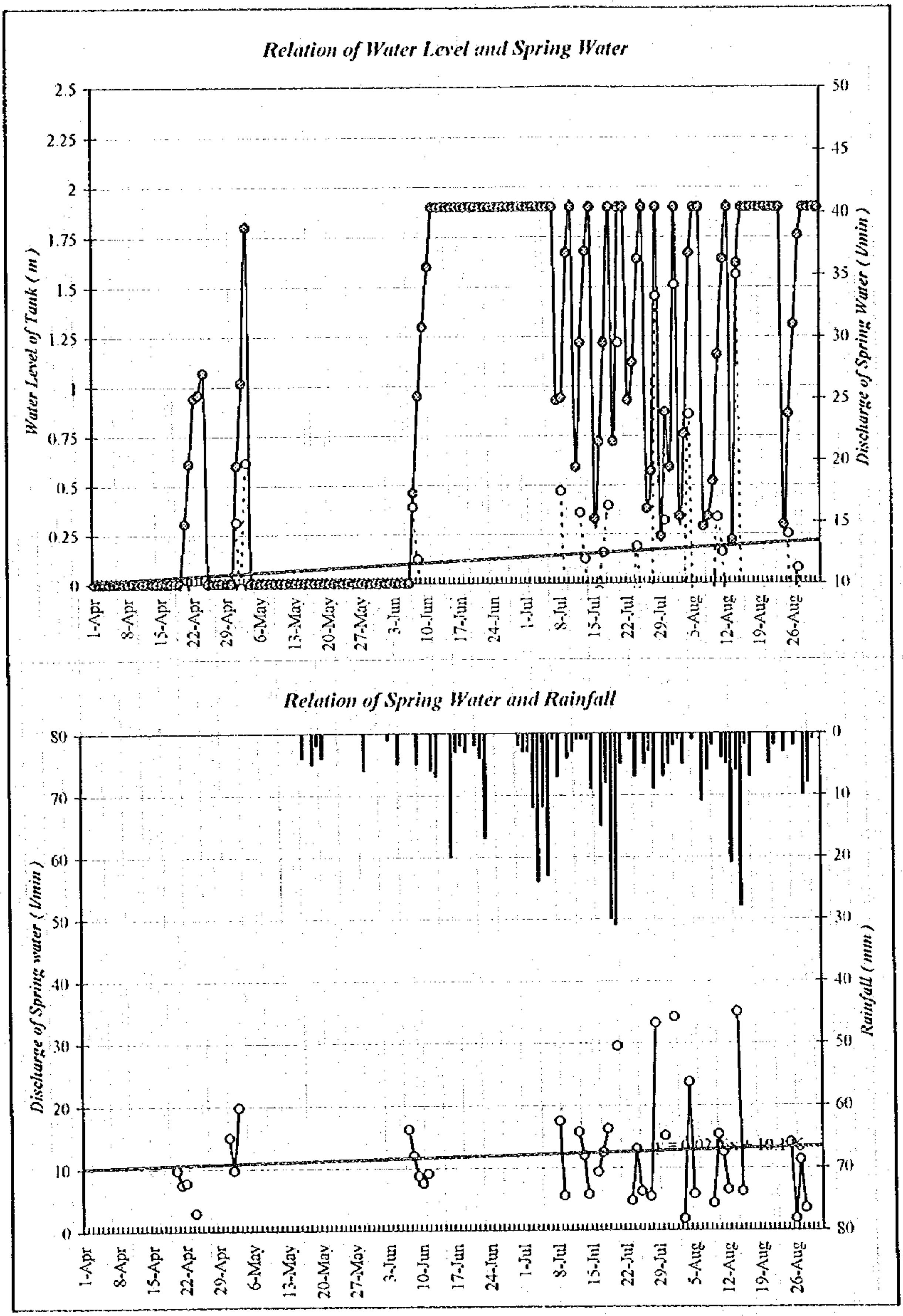


Fig. I.3.3 Water Level of the Storage Tank and Stored Water Volume

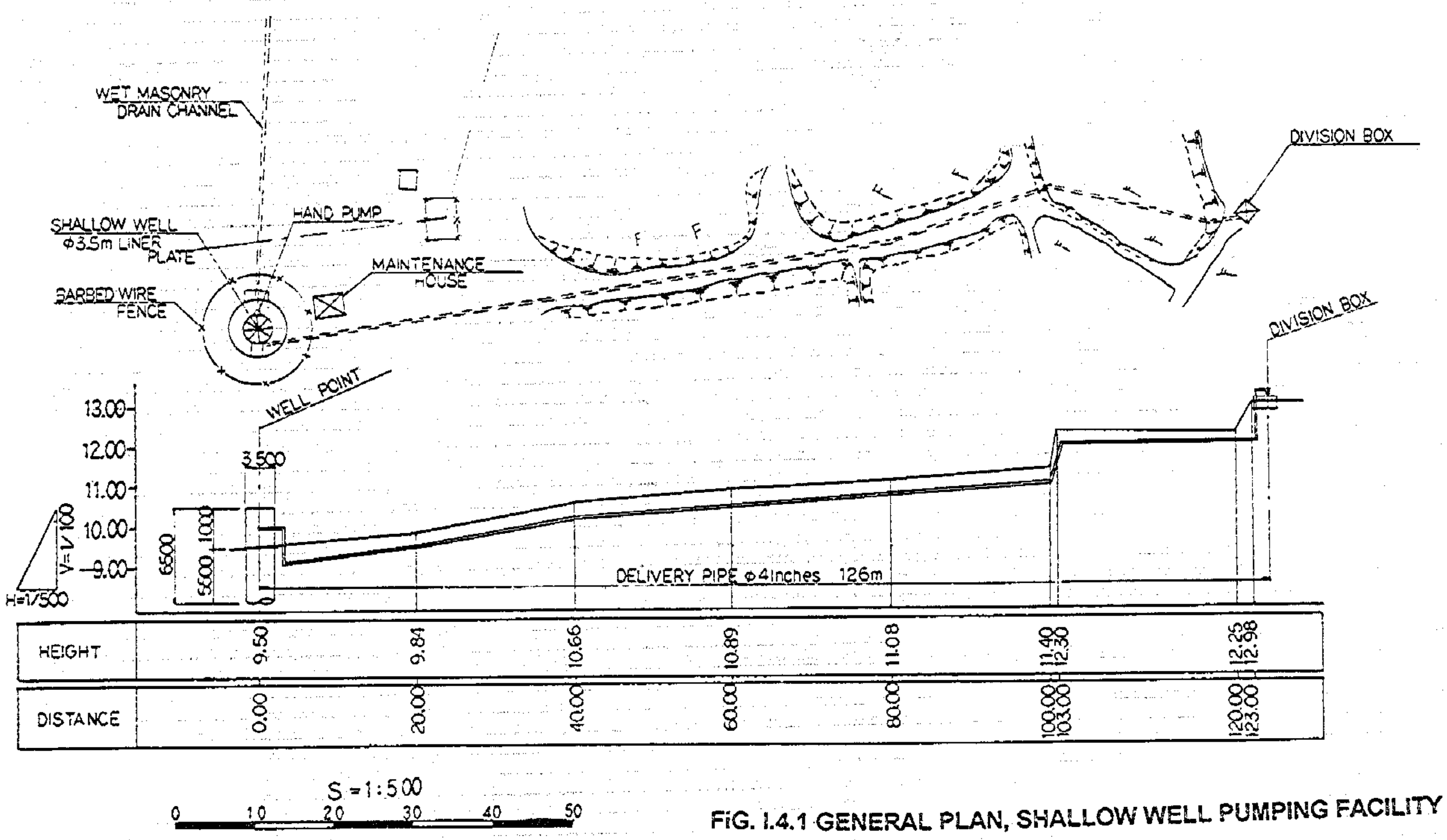
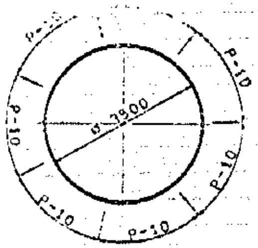
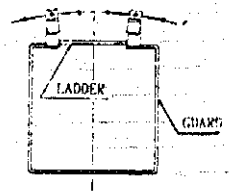


FIG. I.4.1 GENERAL PLAN, SHALLOW WELL PUMPING FACILITY

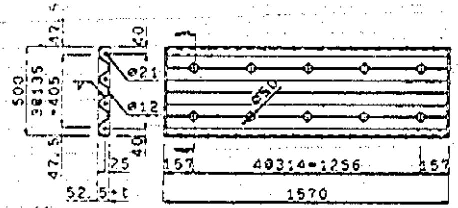
PLAN S=1/80



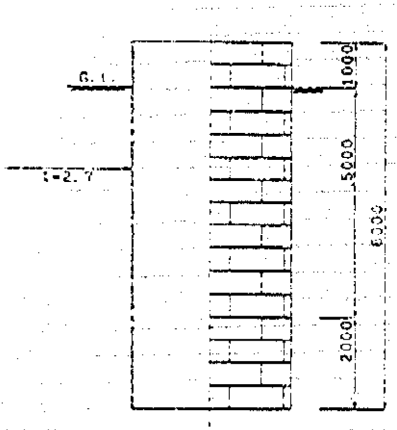
GUARD



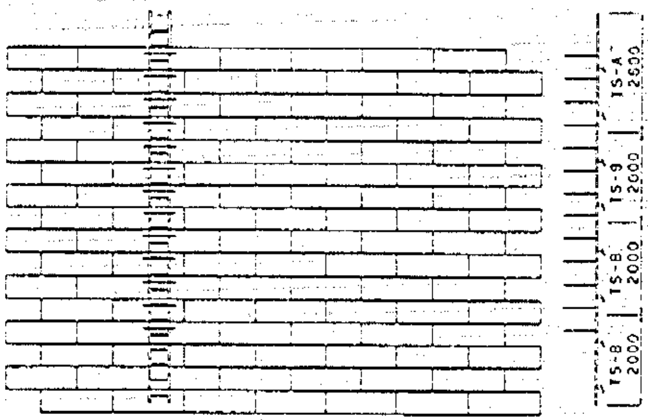
LINER PLATE S=1/20



SECTION S=1/80



MANUSCRIPT S=1/80



NAME	TYPE SPEC (mm)	UNIT WEIGHT (kg)	Q'TY	WEIGHT (kg)	REMARKS
LINER PLATE	P-10 t=2.7	27.1	84	2276.4	LANDING
LINER PLATE	P-10 t=2.7	27.1	28	758.8	LANDING
BOLT	M16X30(4.6)	0.137	1498	205.2	LANDING
		SUB TOTAL		3240.4	
TS-A LADDER	h:2500	27.0	1	27.0	LANDING
TS-B LADDER	h:2000	20.6	3	61.8	LANDING
		3.02	8	24.2	
		4.30	13	55.9	
BOLT	M16X45 (8.8)	0.158	84	13.3	LANDING
		SUB TOTAL		182.2	
TOTAL				3422.6 kg	

Fig. I.4.2 DETAIL OF LINER PLATE, SHALLOW WELL PUMPING FACILITY

04-LPW-0095

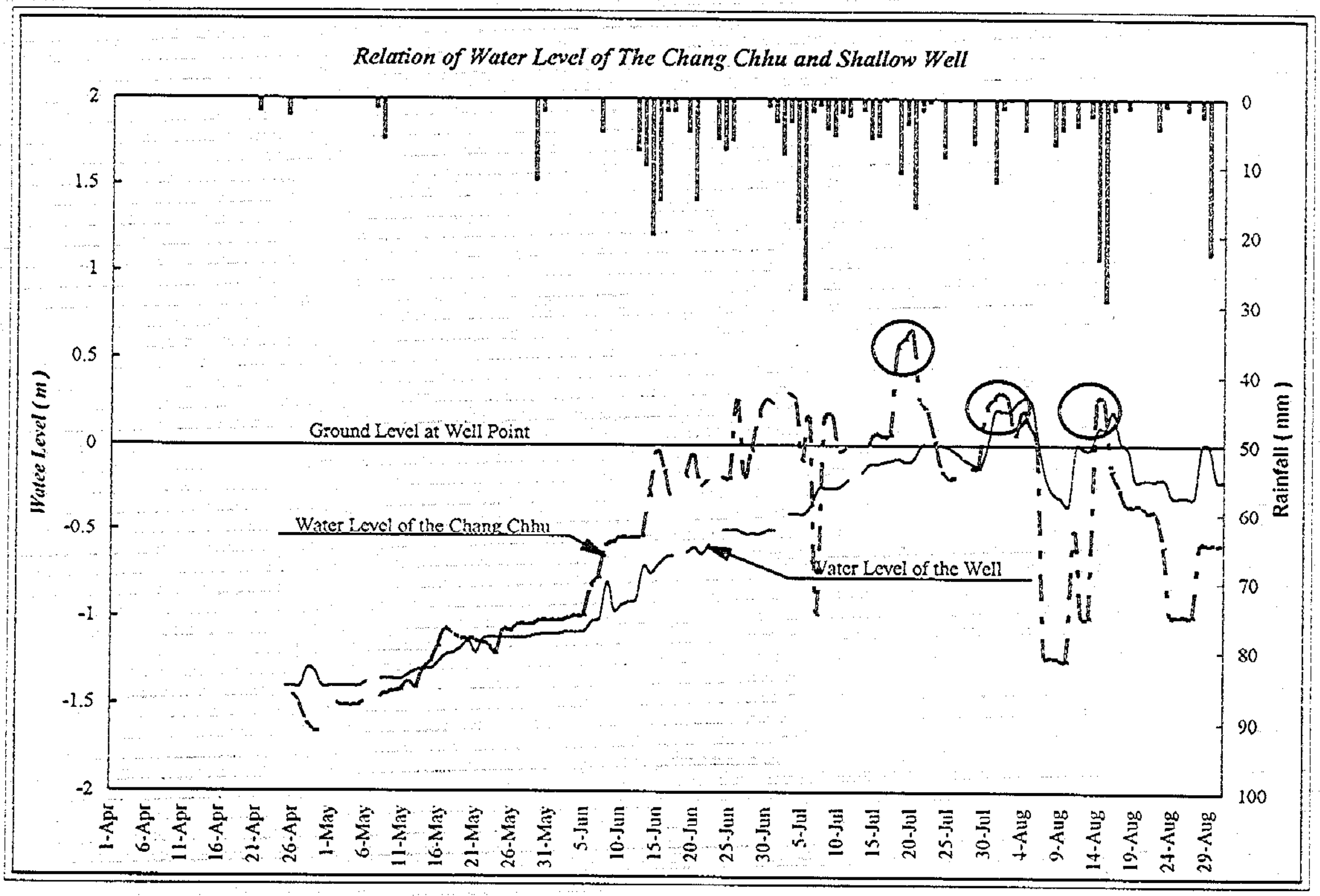


Fig. I.4.3 Water level of the Chang Chhu River and the Shallow Well (April to August ,1995)

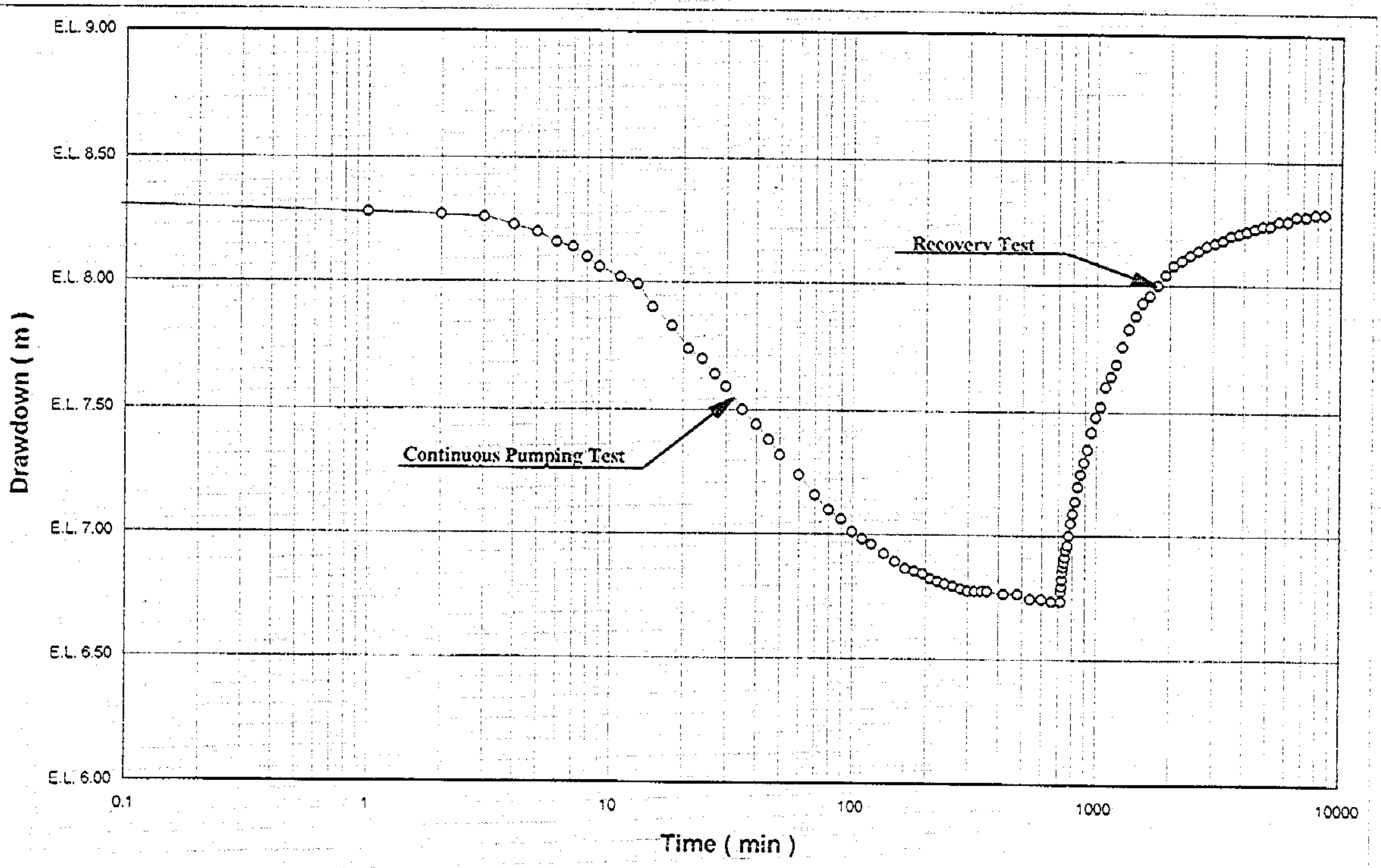


Fig. I.4.4 Result of the Pumping Tests

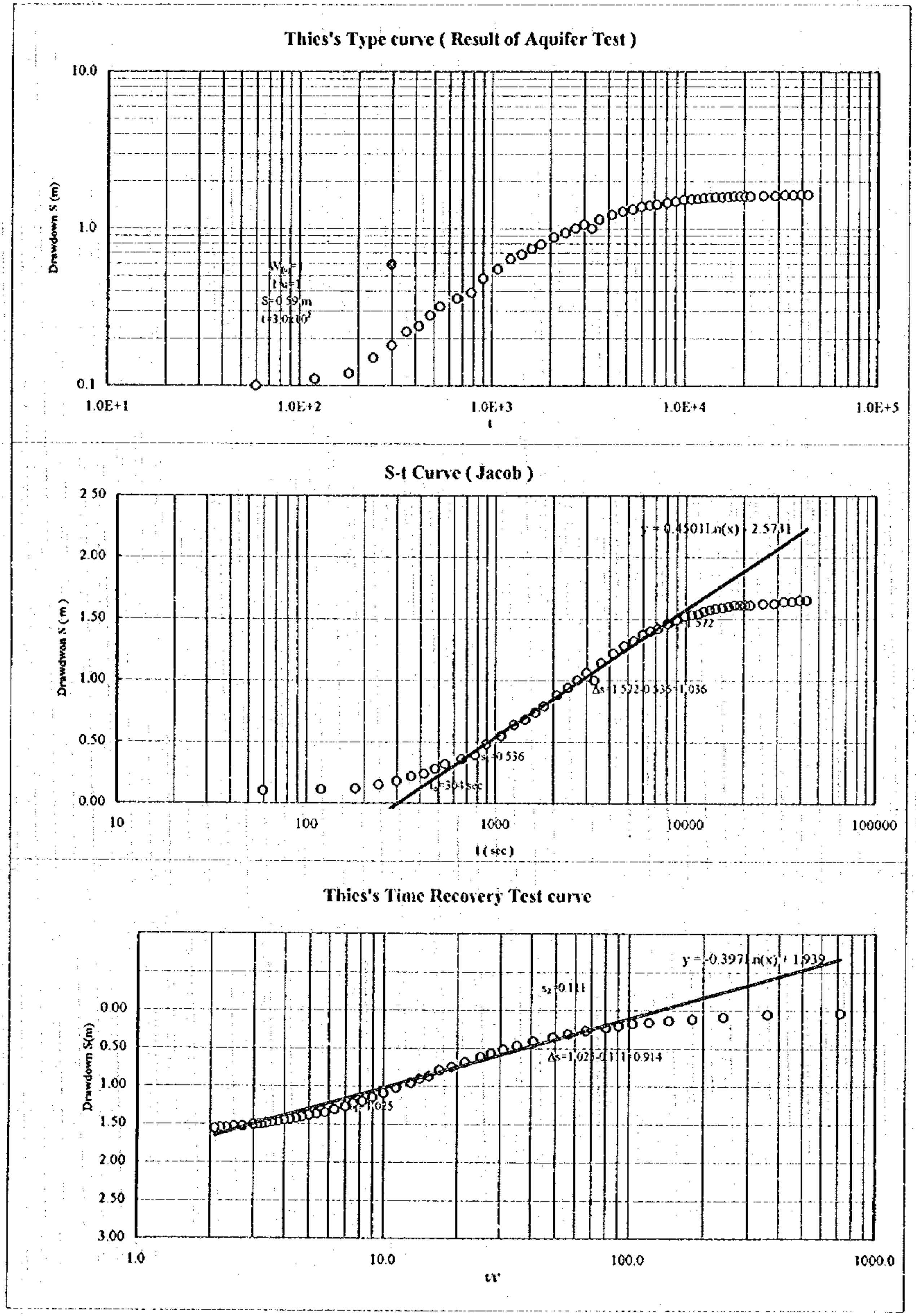


Fig. I.4.5 Analysis of the Methods

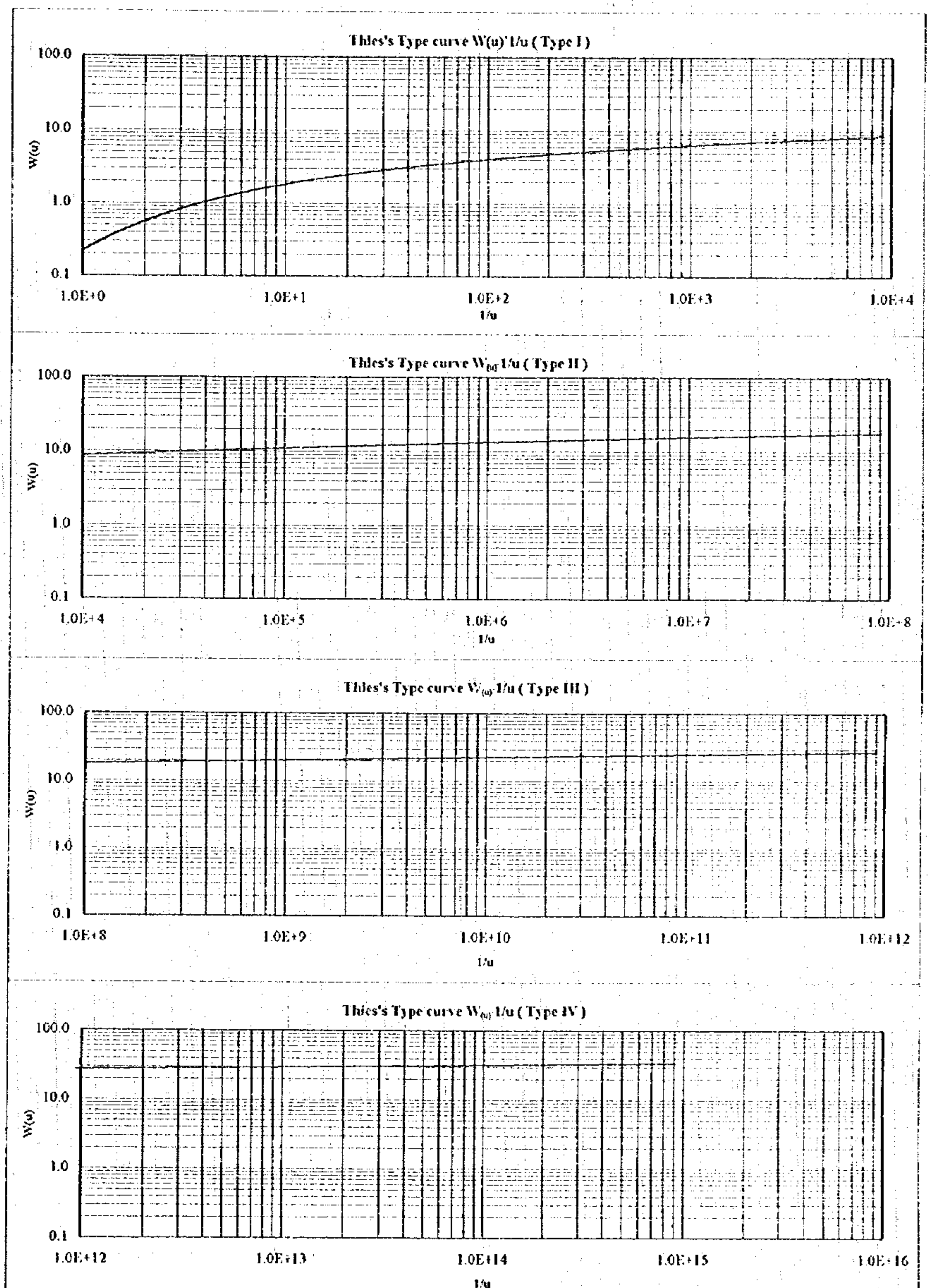


Fig. I.4.6 Function of Well

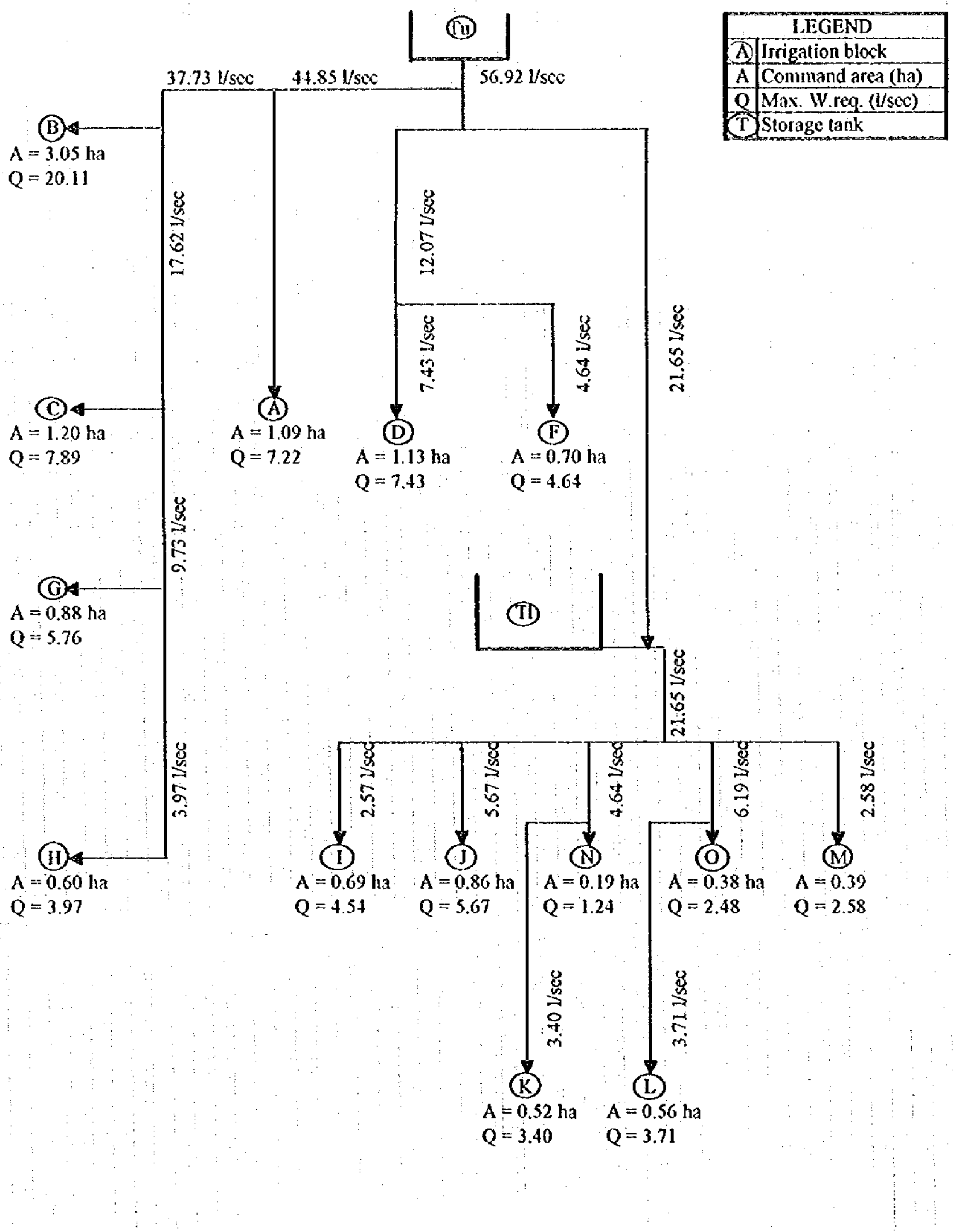


Fig. I.5.1 IRRIGATION PLAN AT RAR-RC

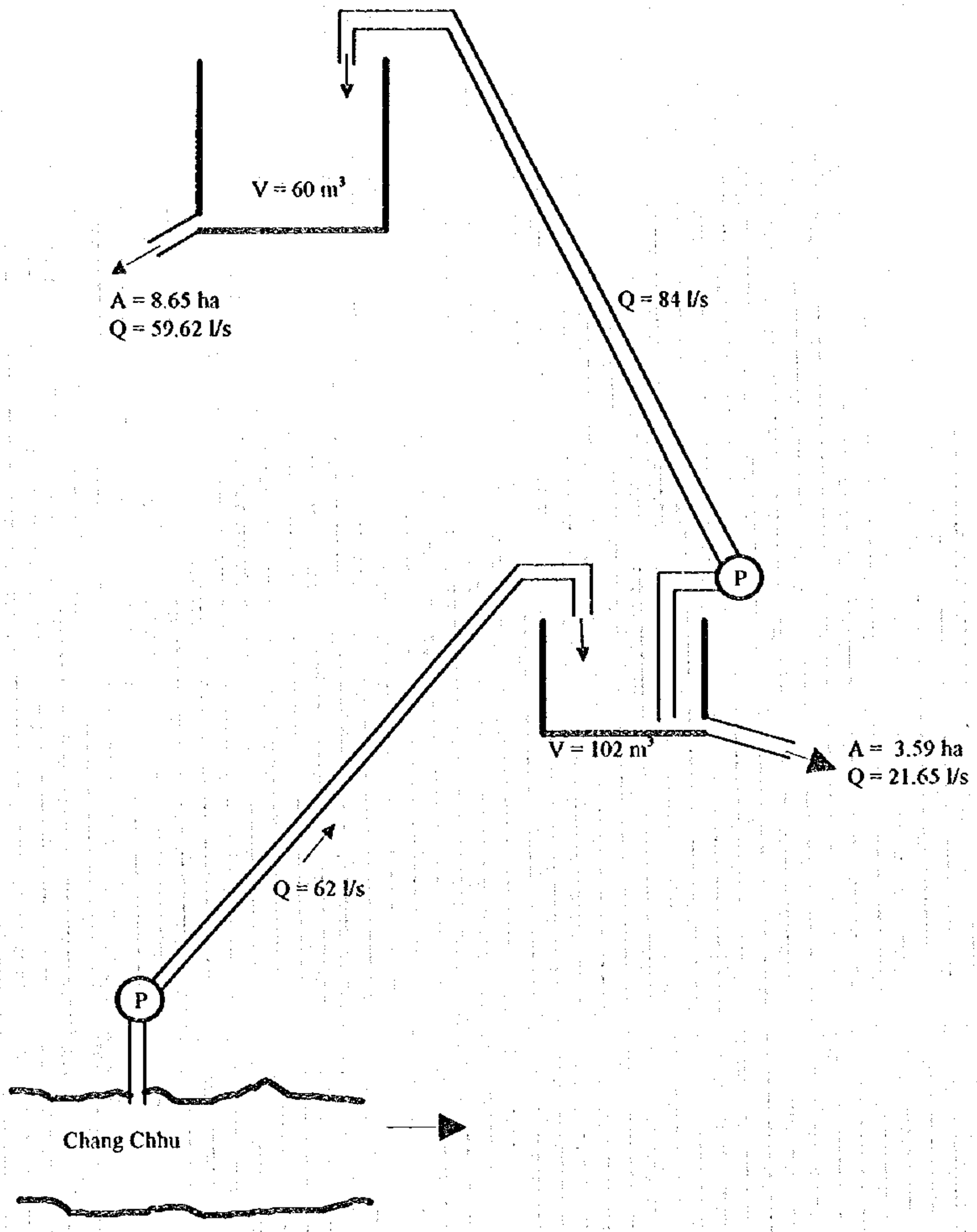
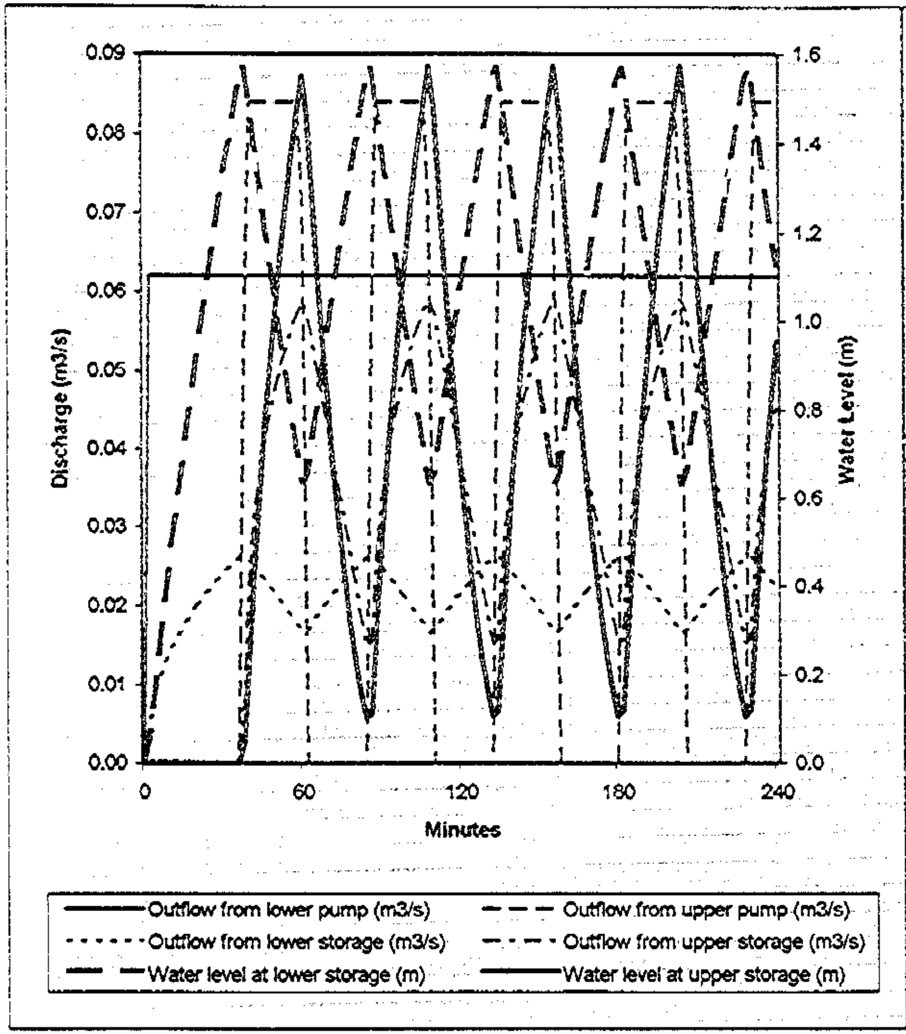
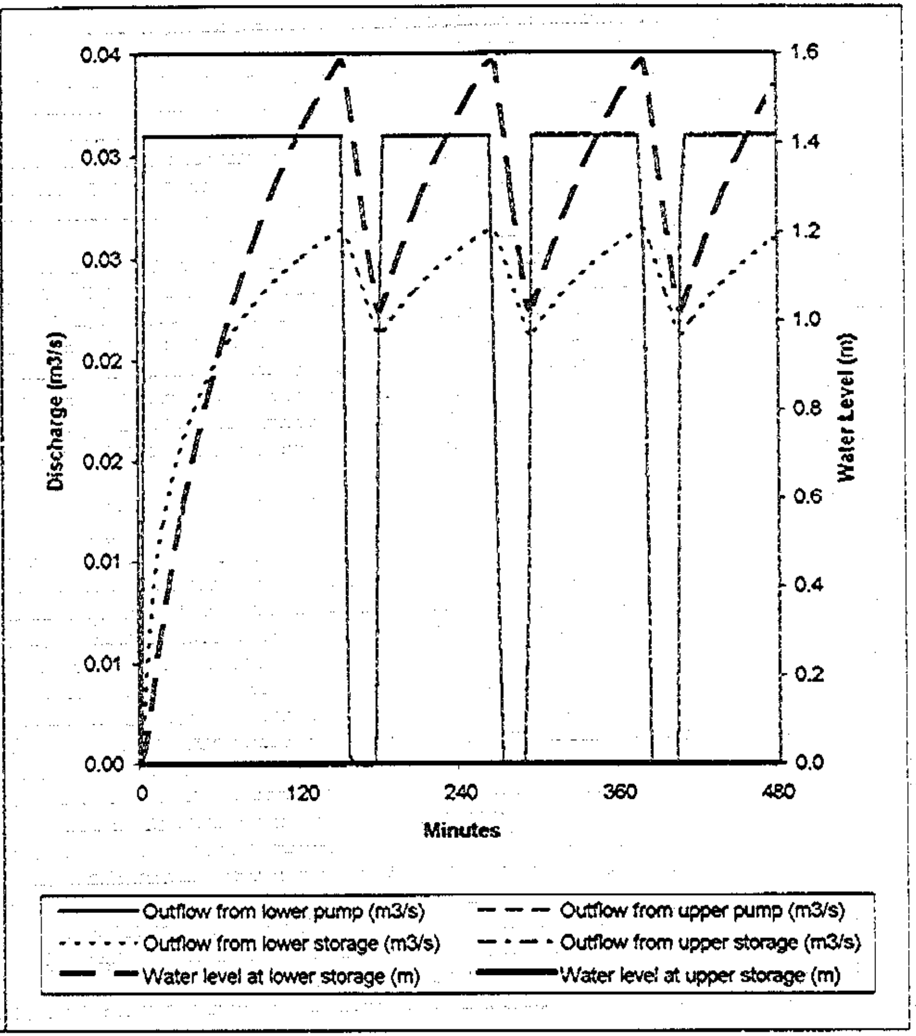


Fig. I.5.2 PROPOSED PUMPING SYSTEM AT RNR-RC



(1) Full Scale Operation after Installing Upper Pump



(2) Tentative Operation until Upper Pump is Installed

Fig. I.5.3 Proposed Pumping Operation in River Water Scheme

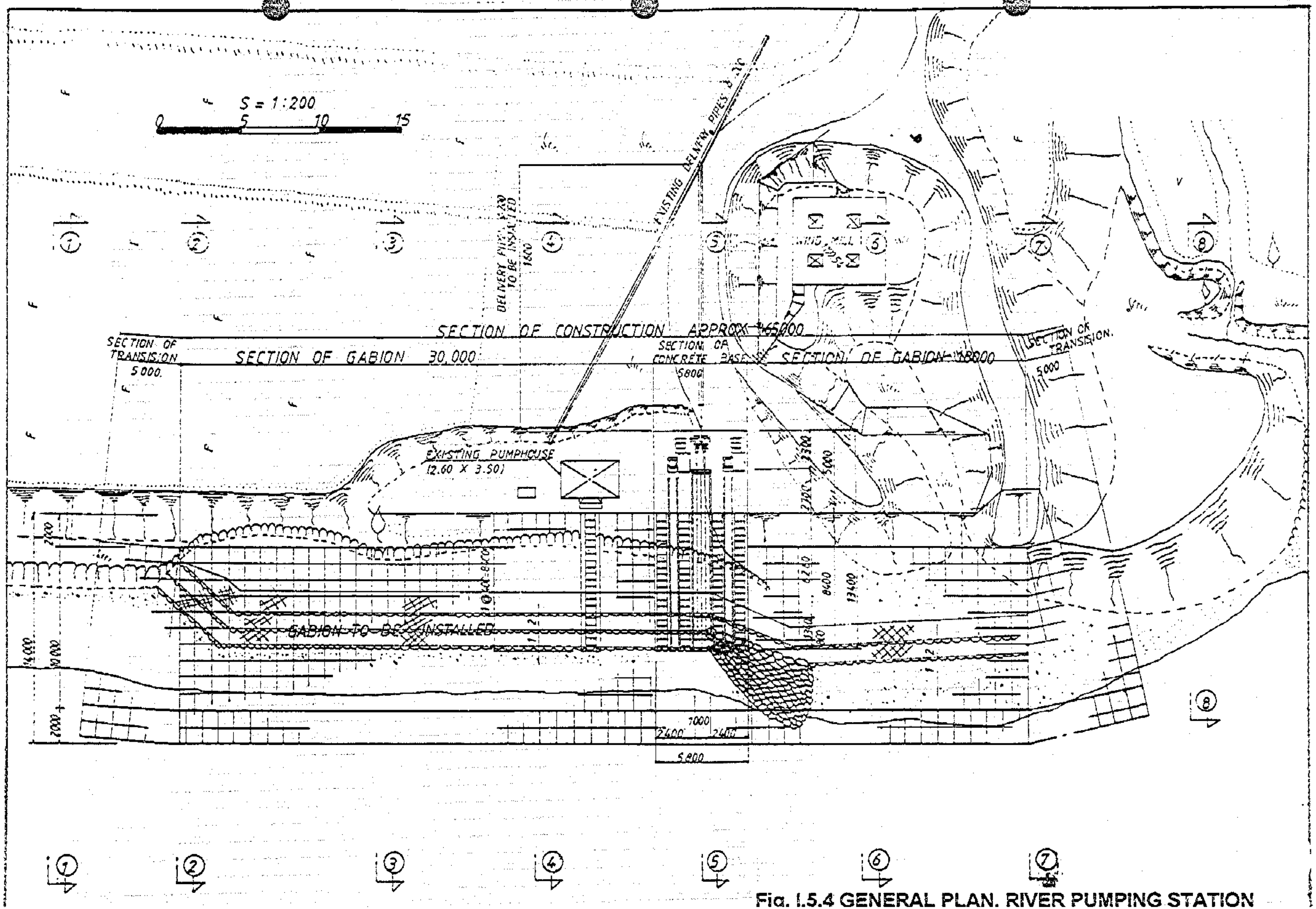


Fig. I.5.4 GENERAL PLAN. RIVER PUMPING STATION

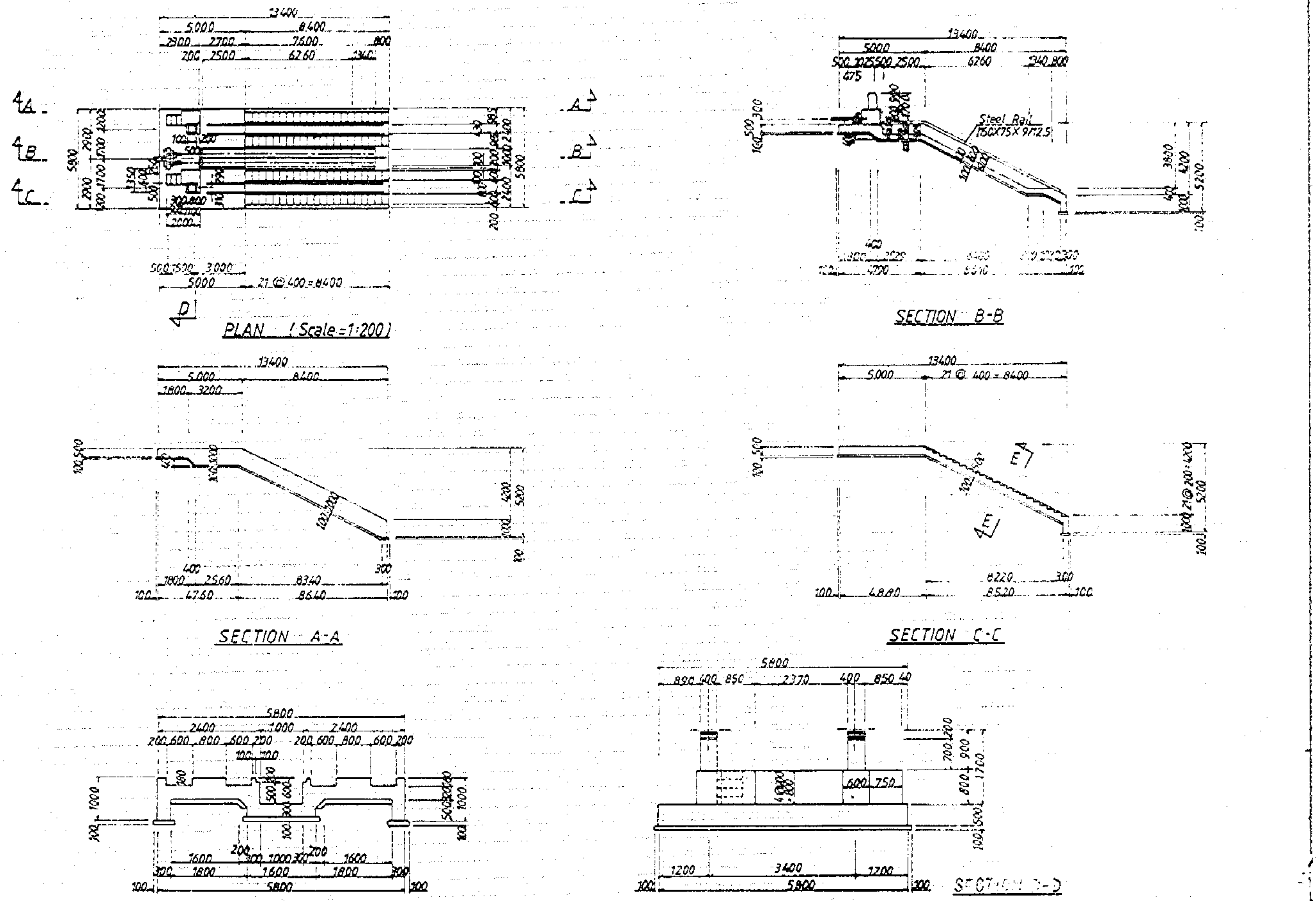


Fig. I.5.5 DETAIL OF CONCRETE BASE RIVER PUMPING STATION

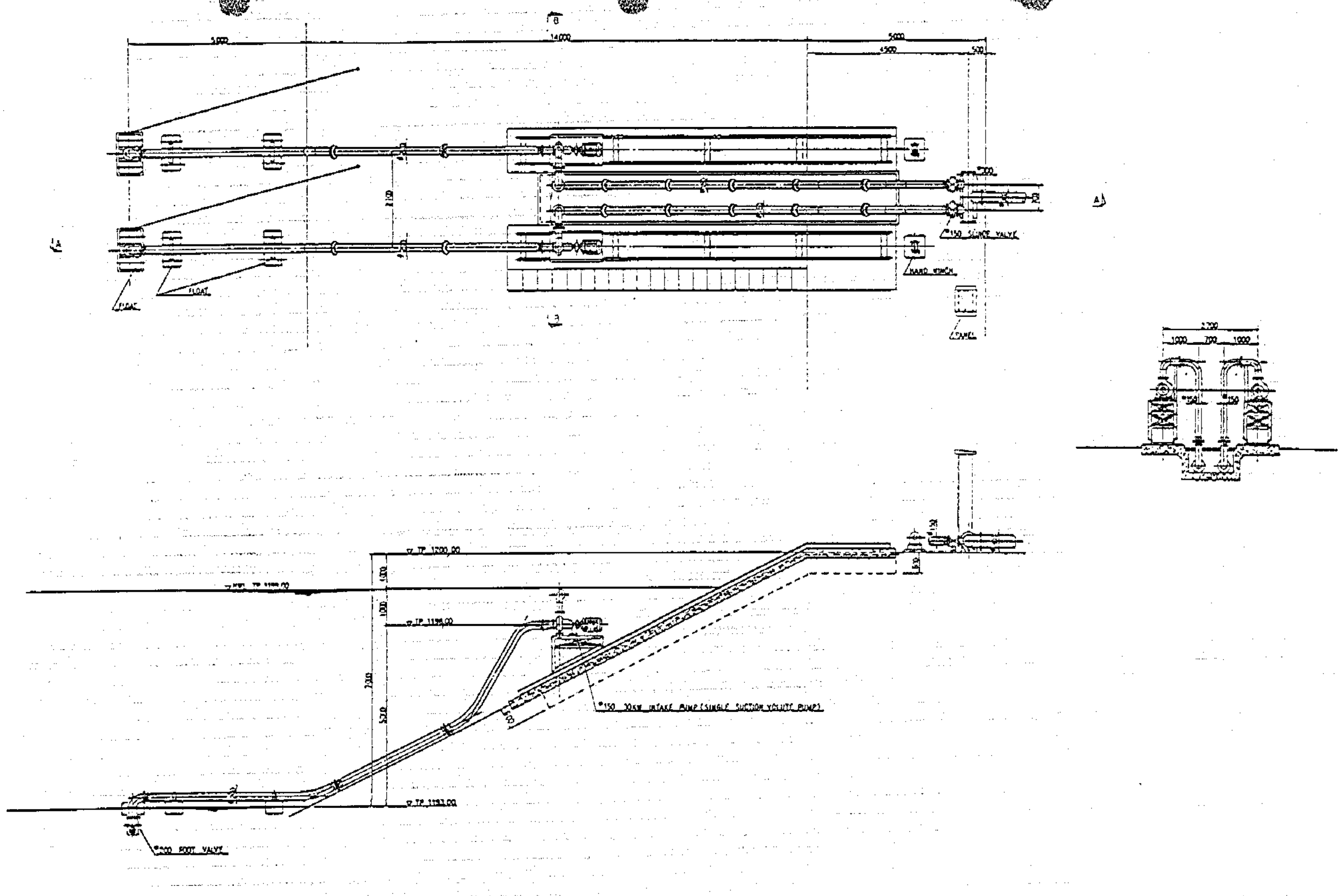


FIG. I.5.6 LAYOUT AND PLOFILE OF PUMPING STATION, RIVER WATER SCHEME

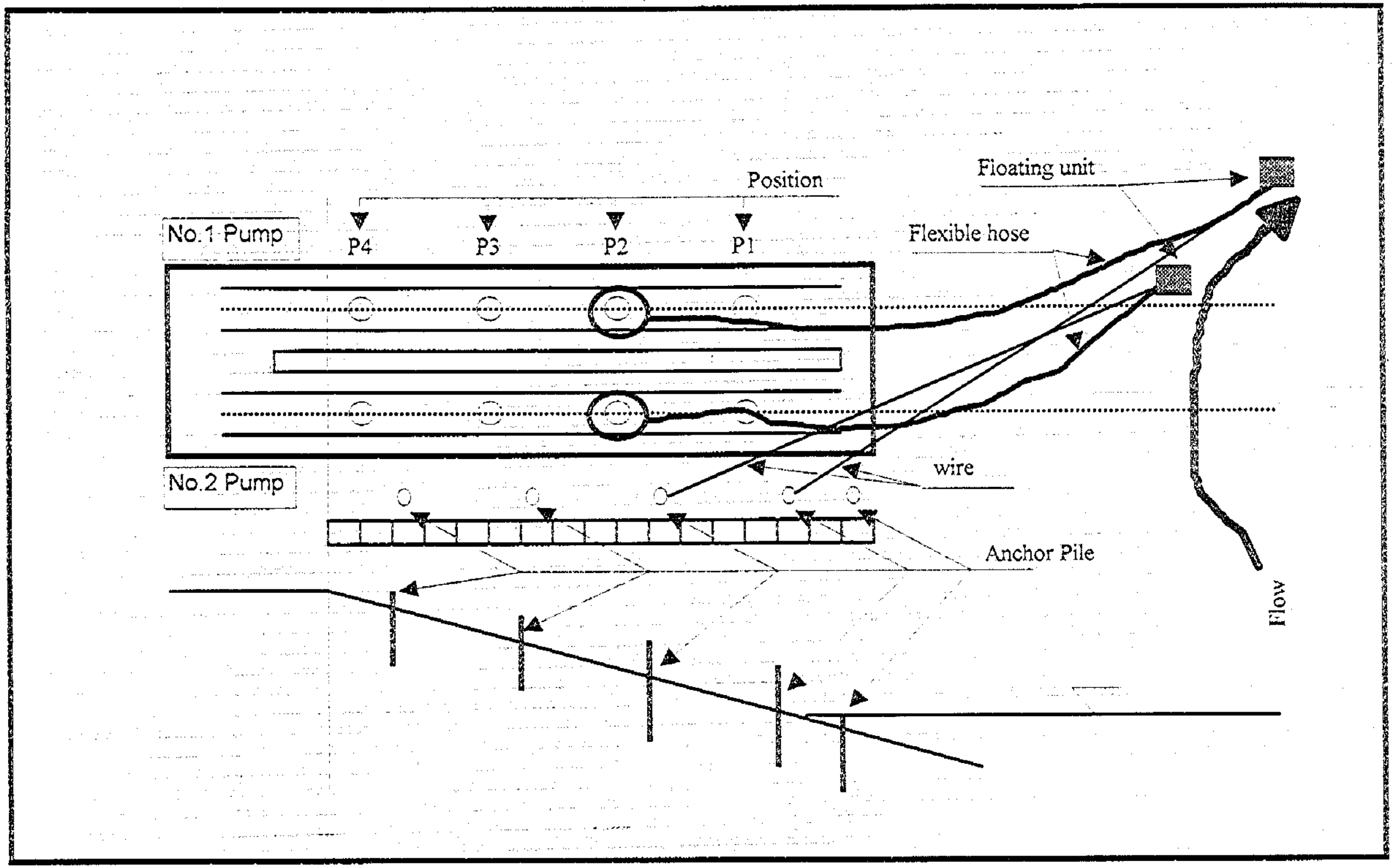


Fig. I.5.7 The Layout of Pumping Position

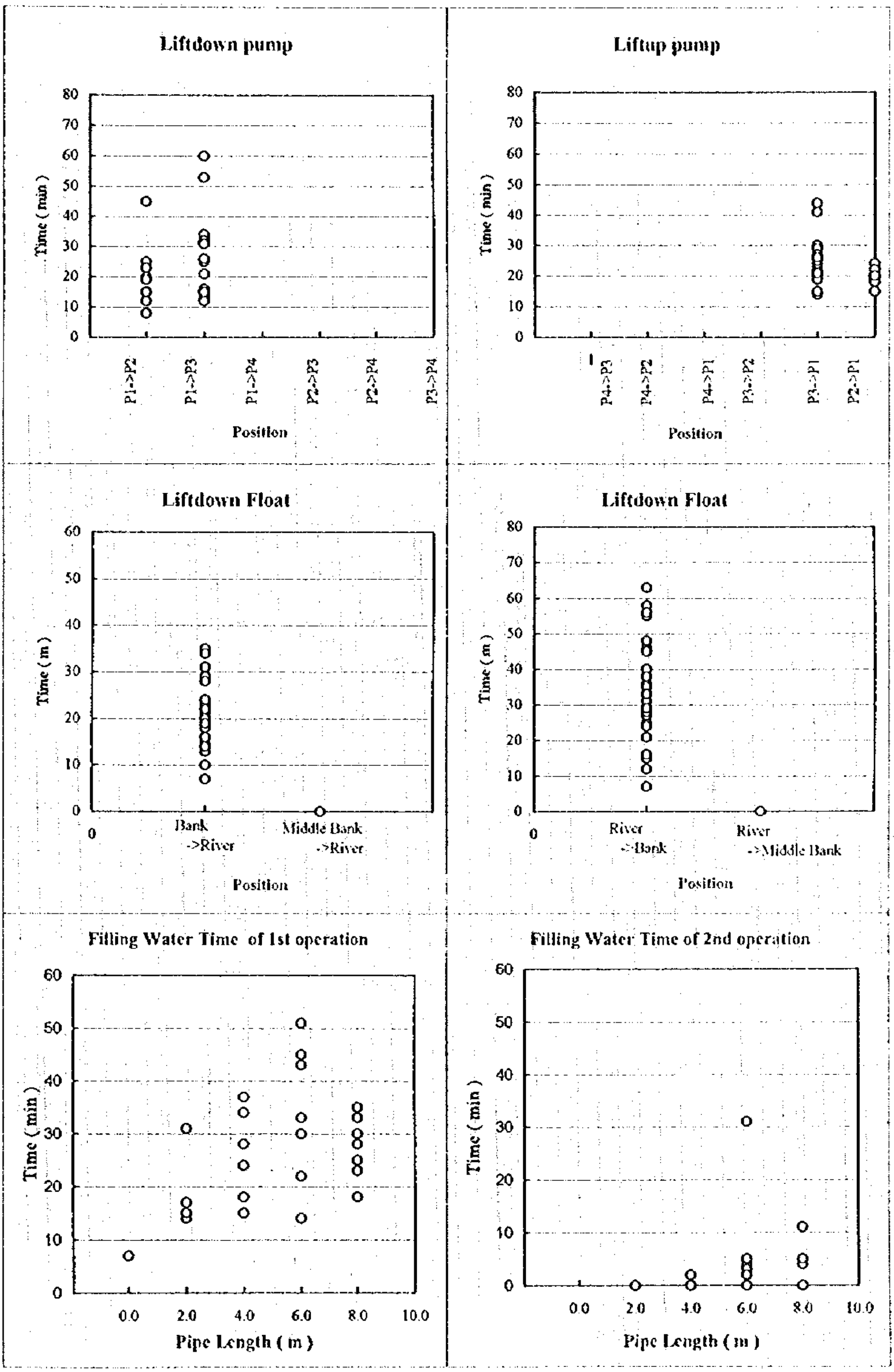
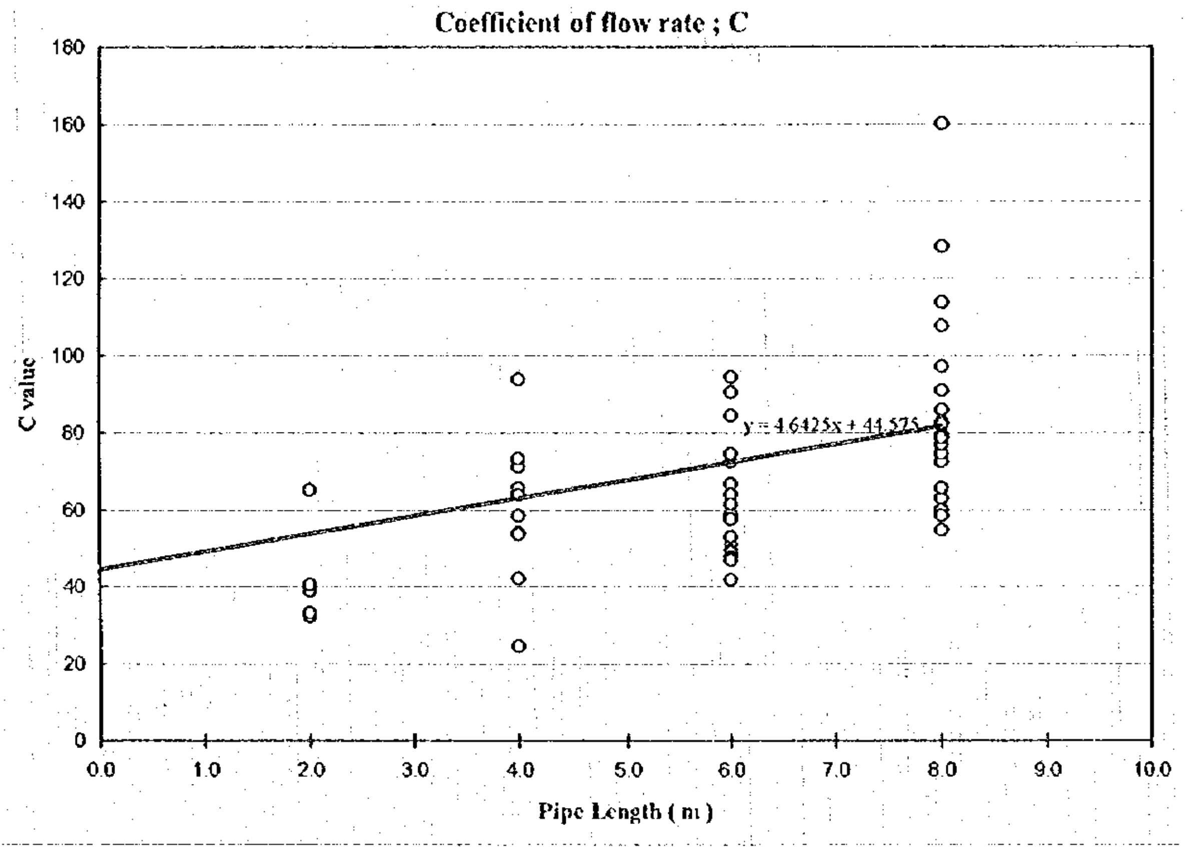


Fig. I.5.8 Required Time for Setting up



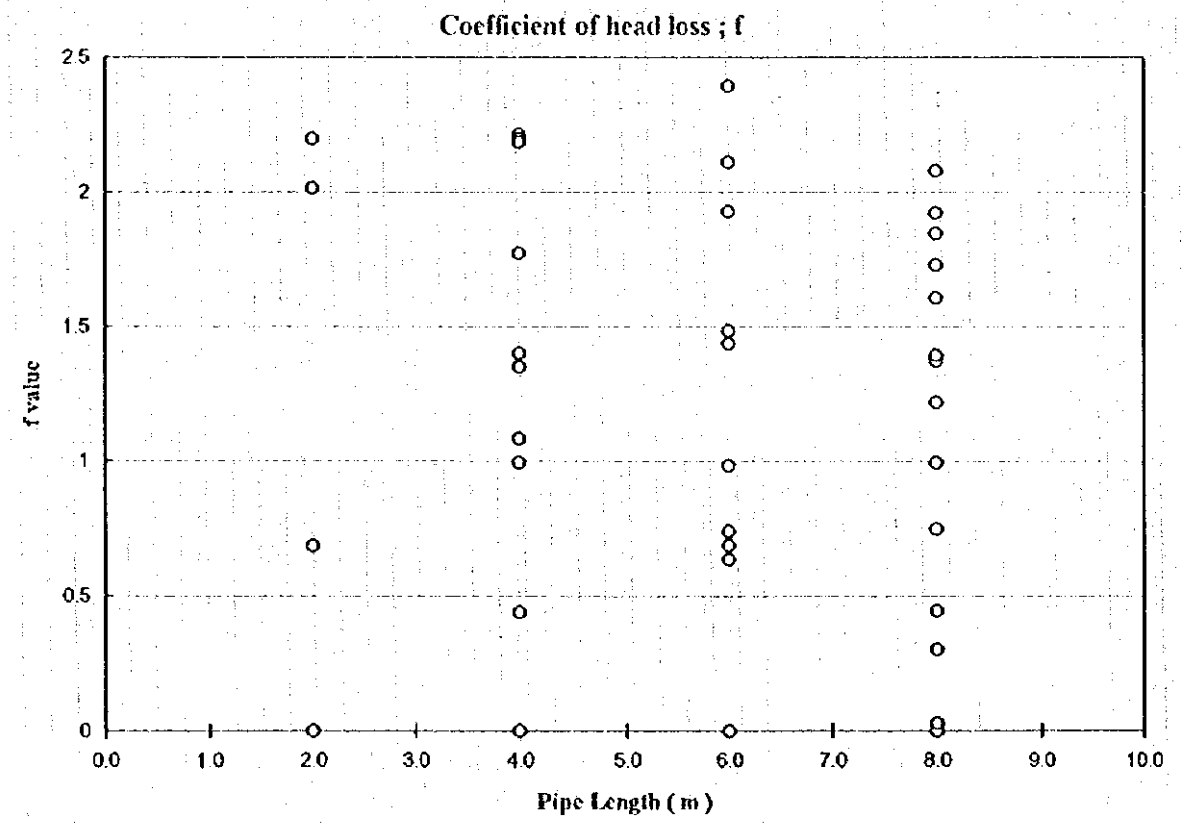


Fig. I.5.9 Condition of Flexible Pipe

Performance curve on position P1 and pipe length 6.00m

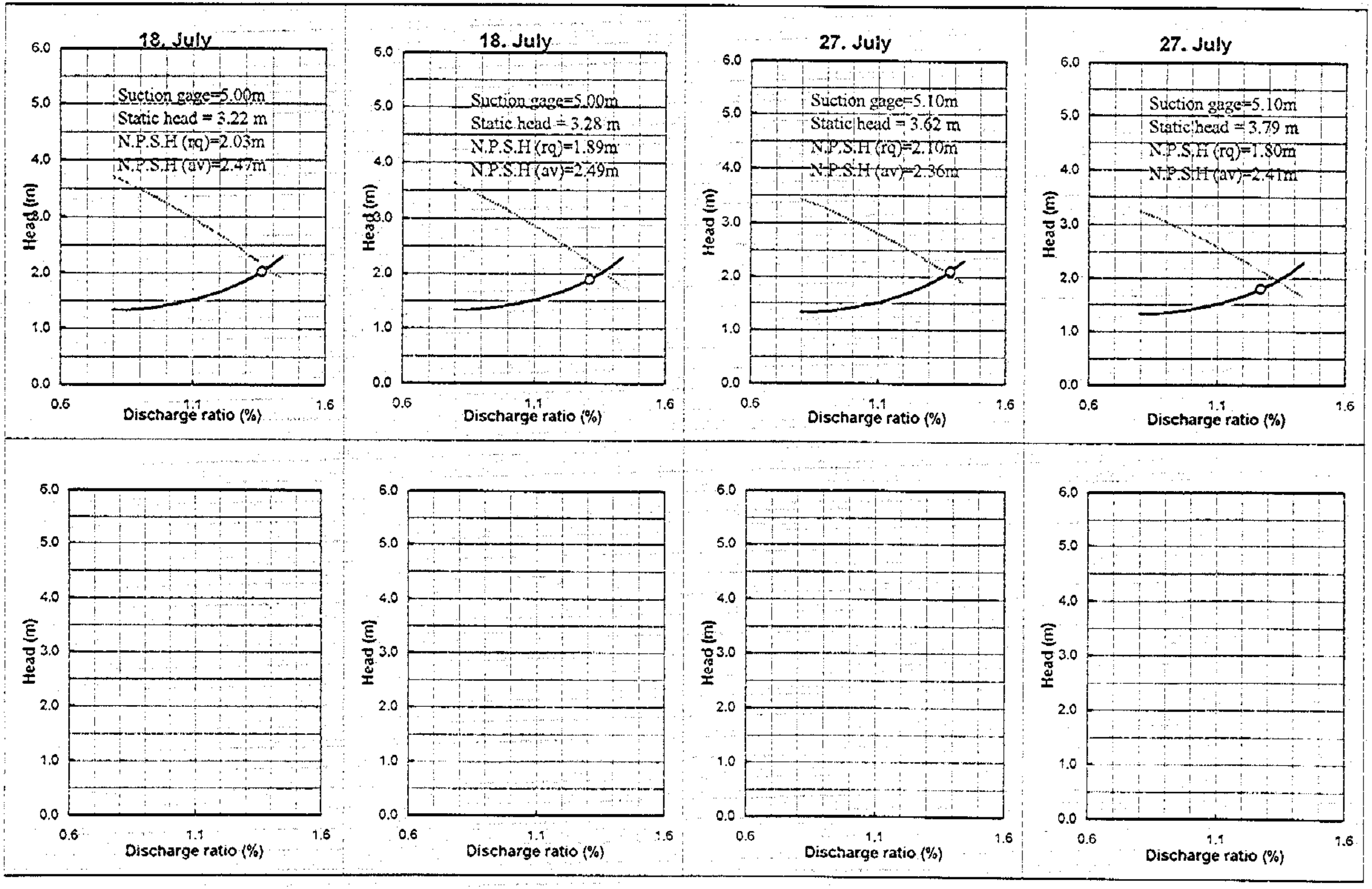


Fig. I.5.10 Performance Curve of N.P.S.H (1/10)

Performance curve on position P1 and pipe length 8.00m

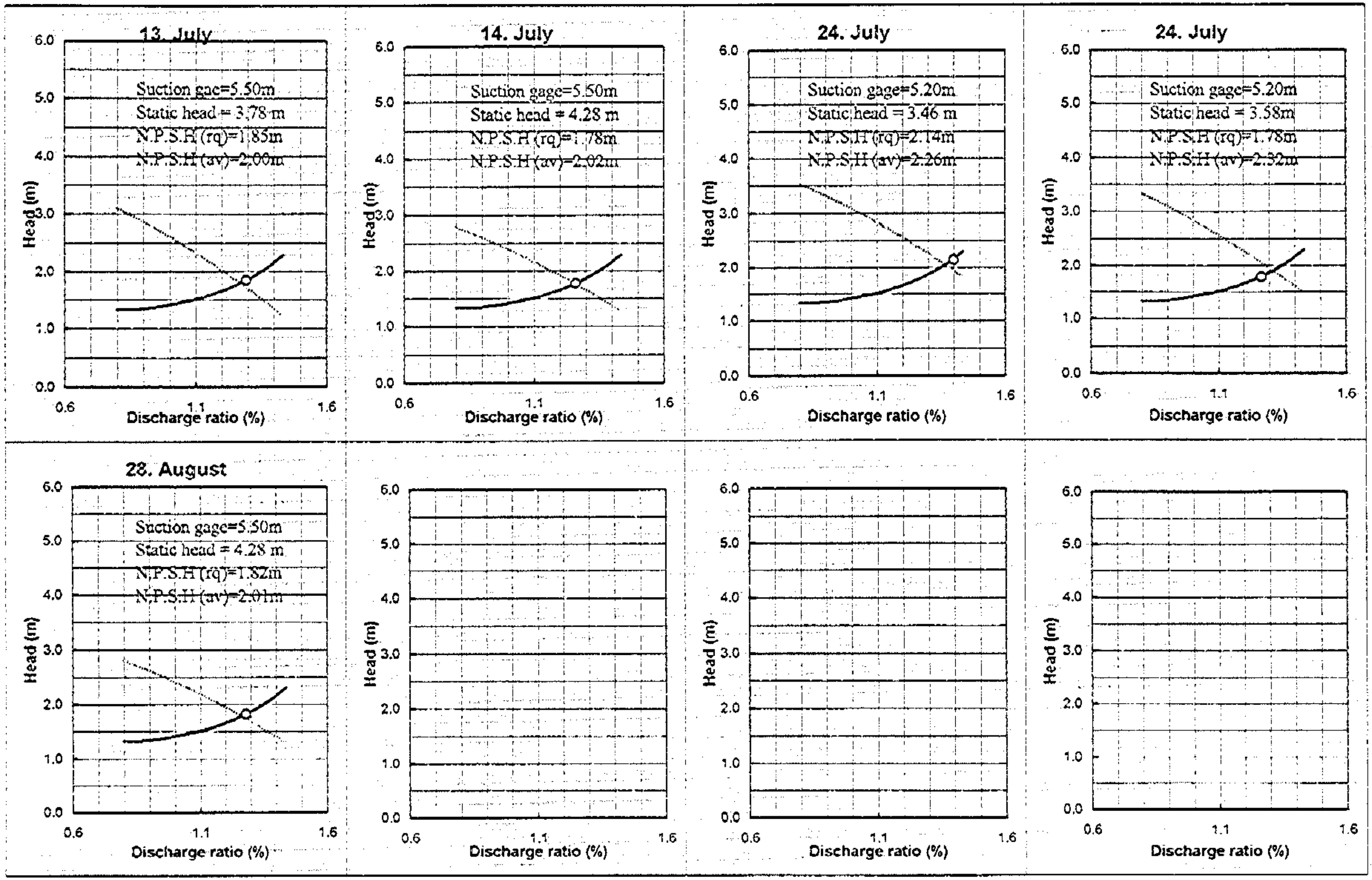


Fig. I.5.10 Performance Curve of N.P.S.H (2/10)

Performance curve on position P2 and pipe length 4.00m

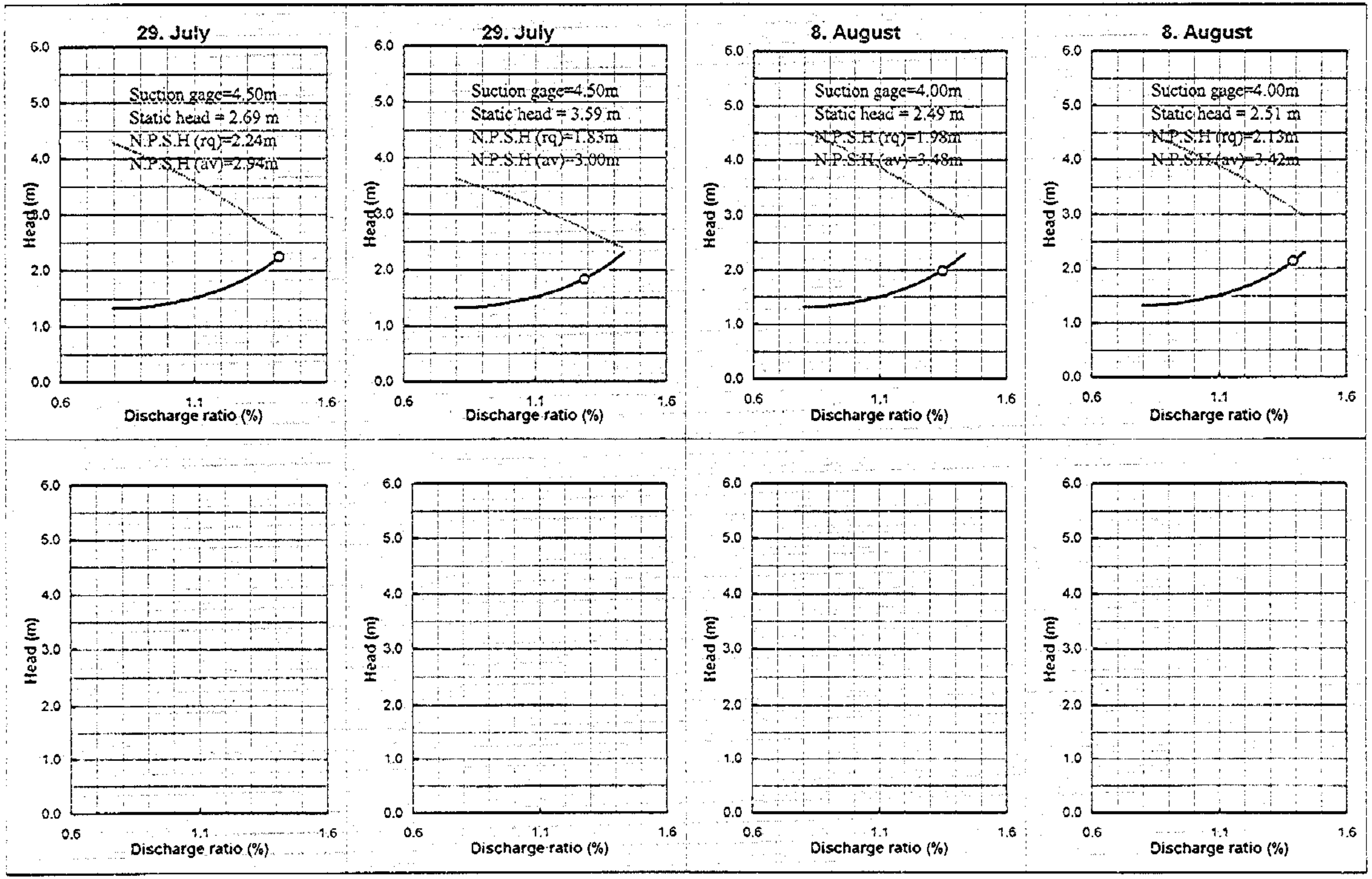


Fig. I.5.10 Performance Curve of N.P.S.H (3/10)

Performance curve on position P2 and pipe length 6.00m

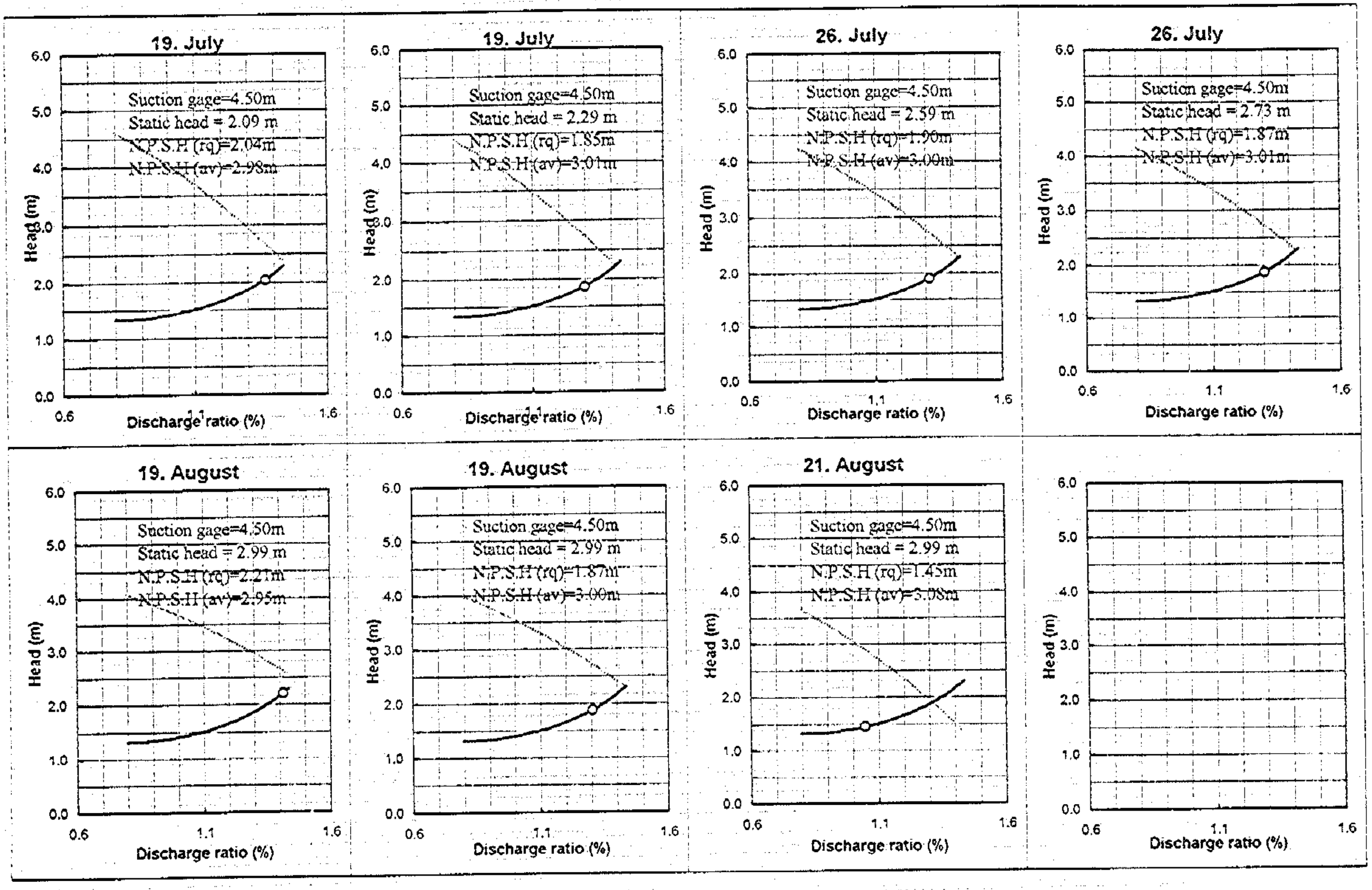


Fig. I.5.10 Performance Curve of N.P.S.H (4/10)

Performance curve on position P2 and pipe length 8.00m

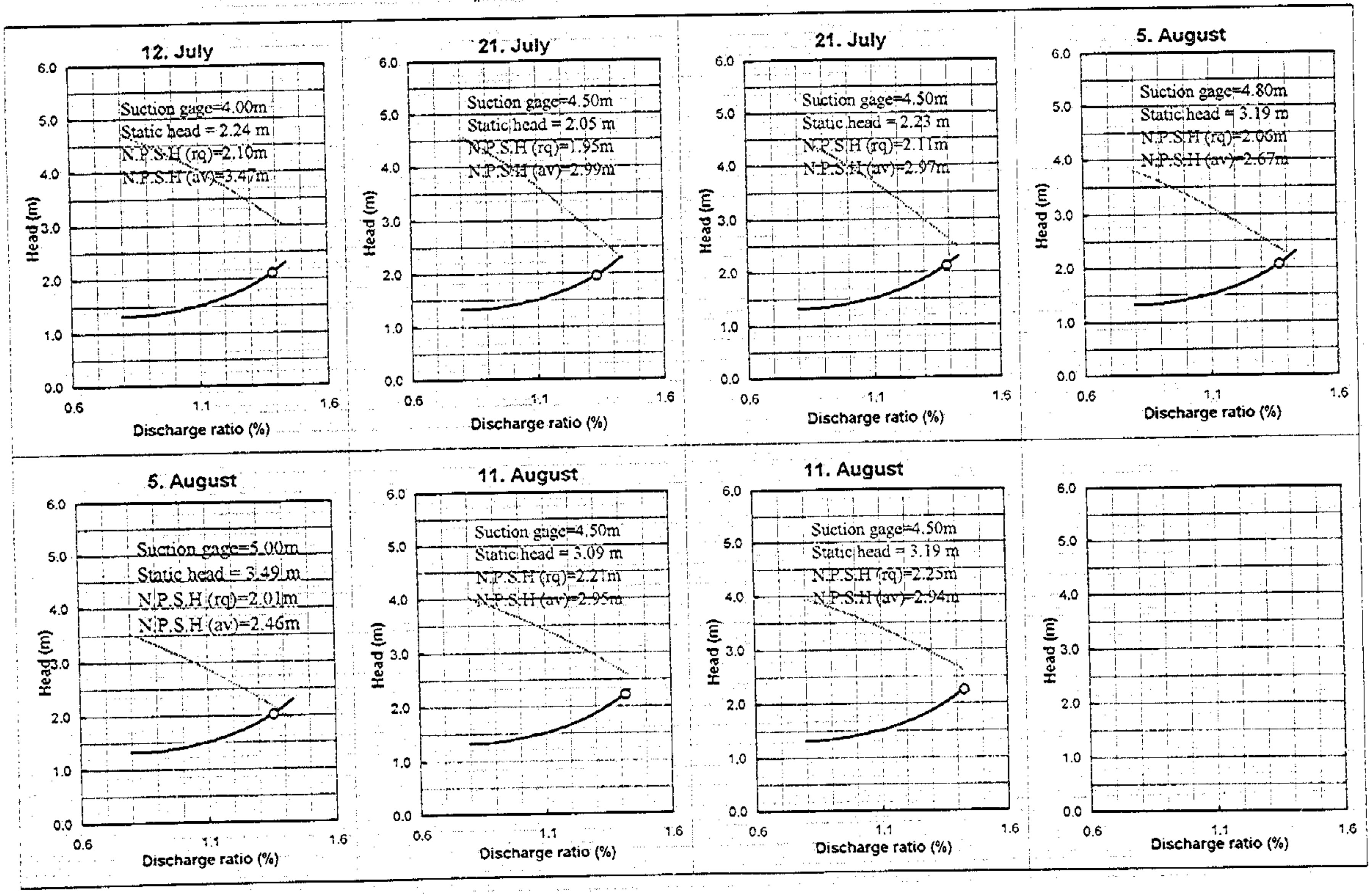


Fig. I.5.10 Performance Curve of N.P.S.H (5/10)

Performance curve on position P3 and pipe length 0.00m

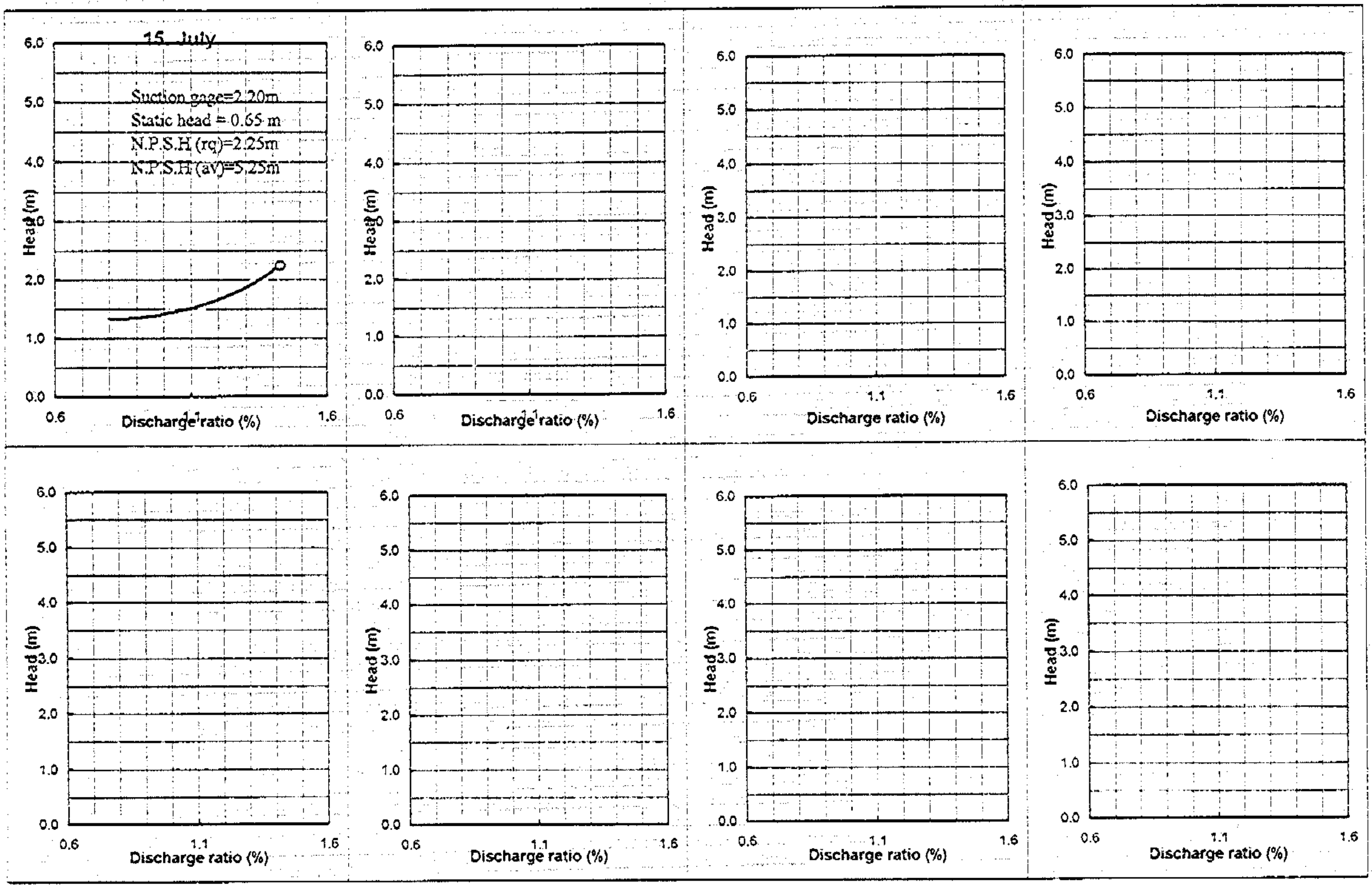


Fig. I.5.10 Performance Curve of N.P.S.H (6/10)

Performance curve on position P3 and pipe length 2.00m

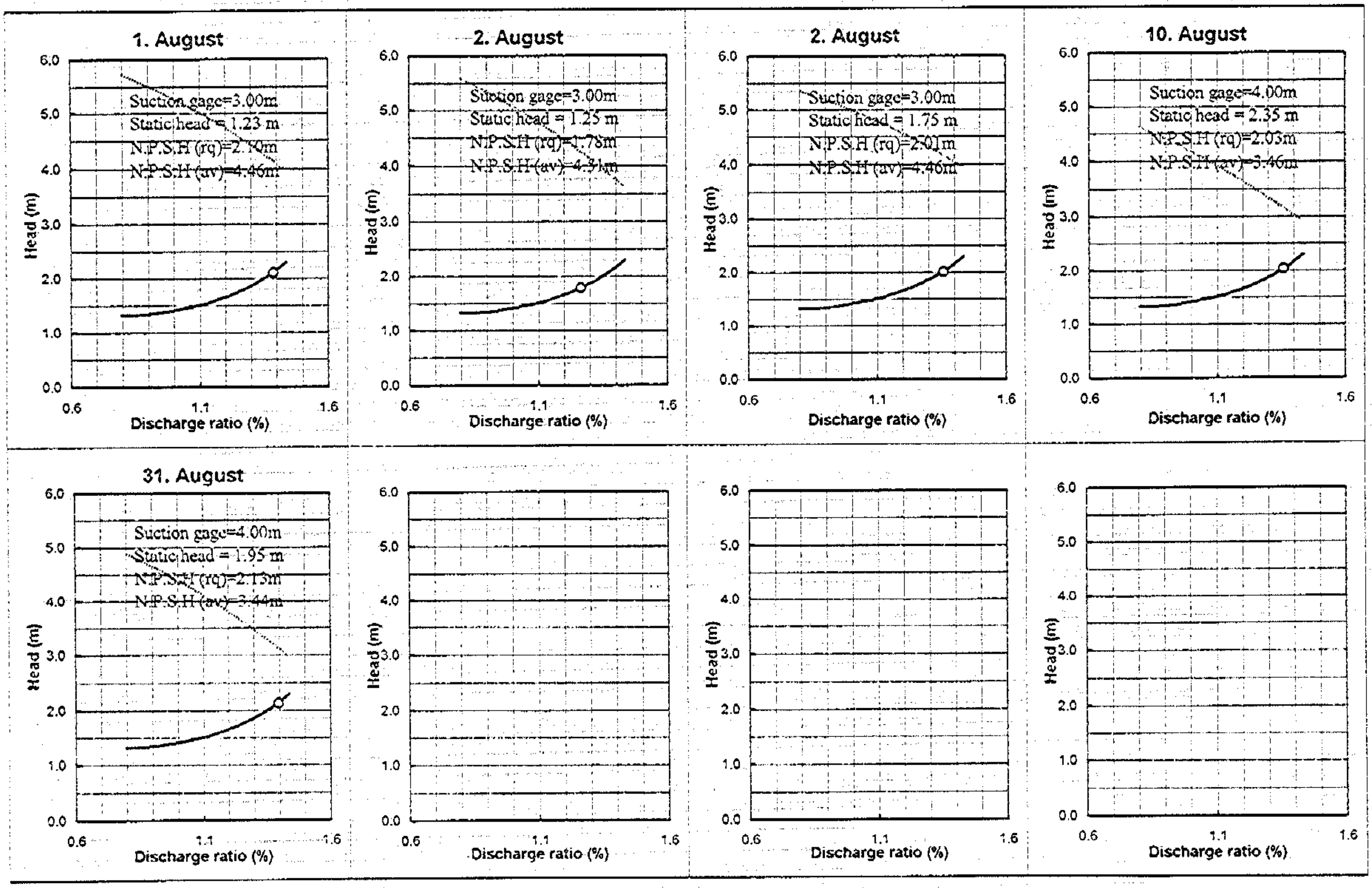


Fig. I.5.10 Performance Curve of N.P.S.H (7/10)

Performance curve on position P3 and pipe length 4.00m

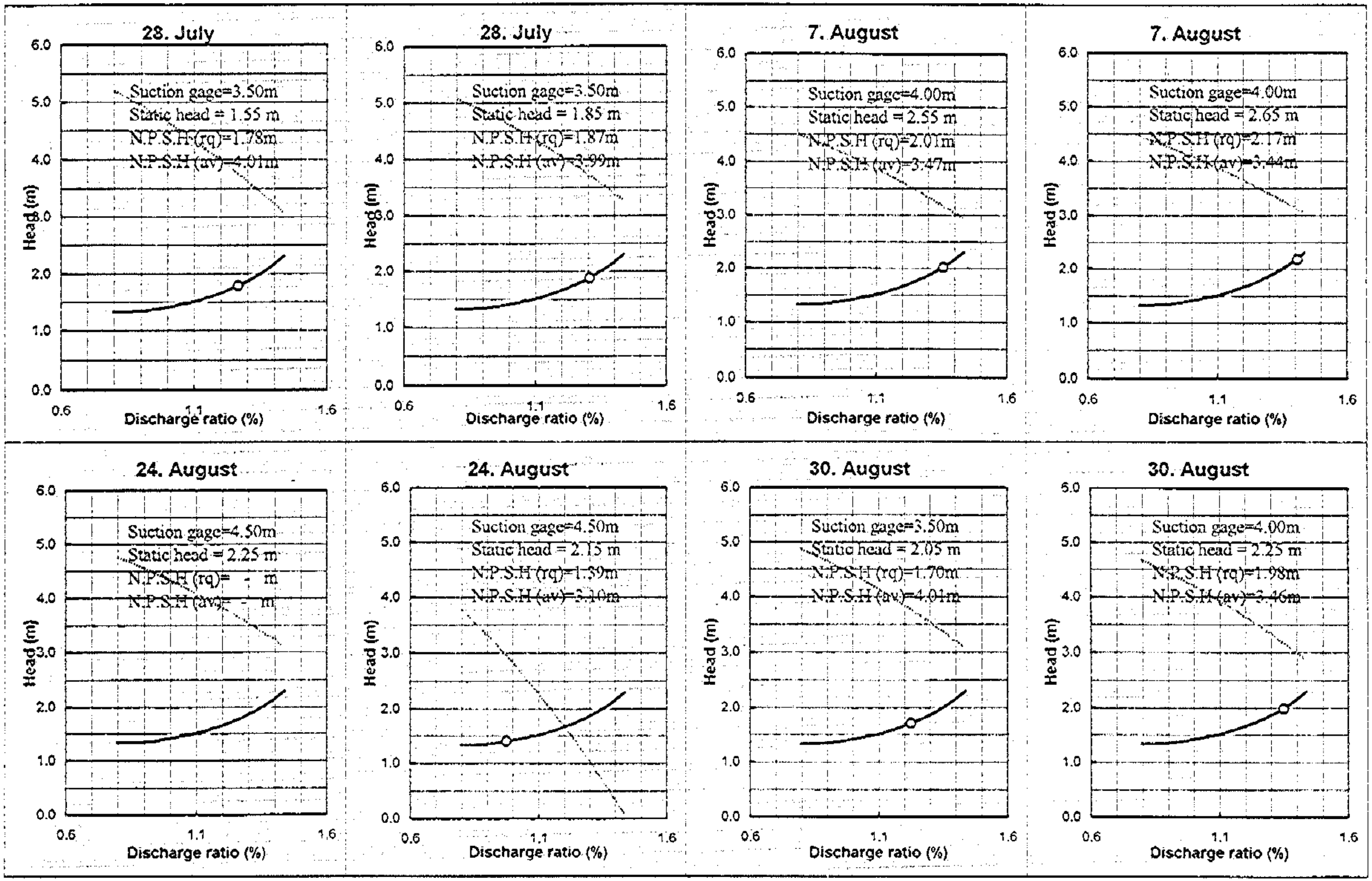


Fig. I.5.10 Performance Curve of N.P.S.H (8/10)

Performance curve on position P3 and pipe length 6.00m

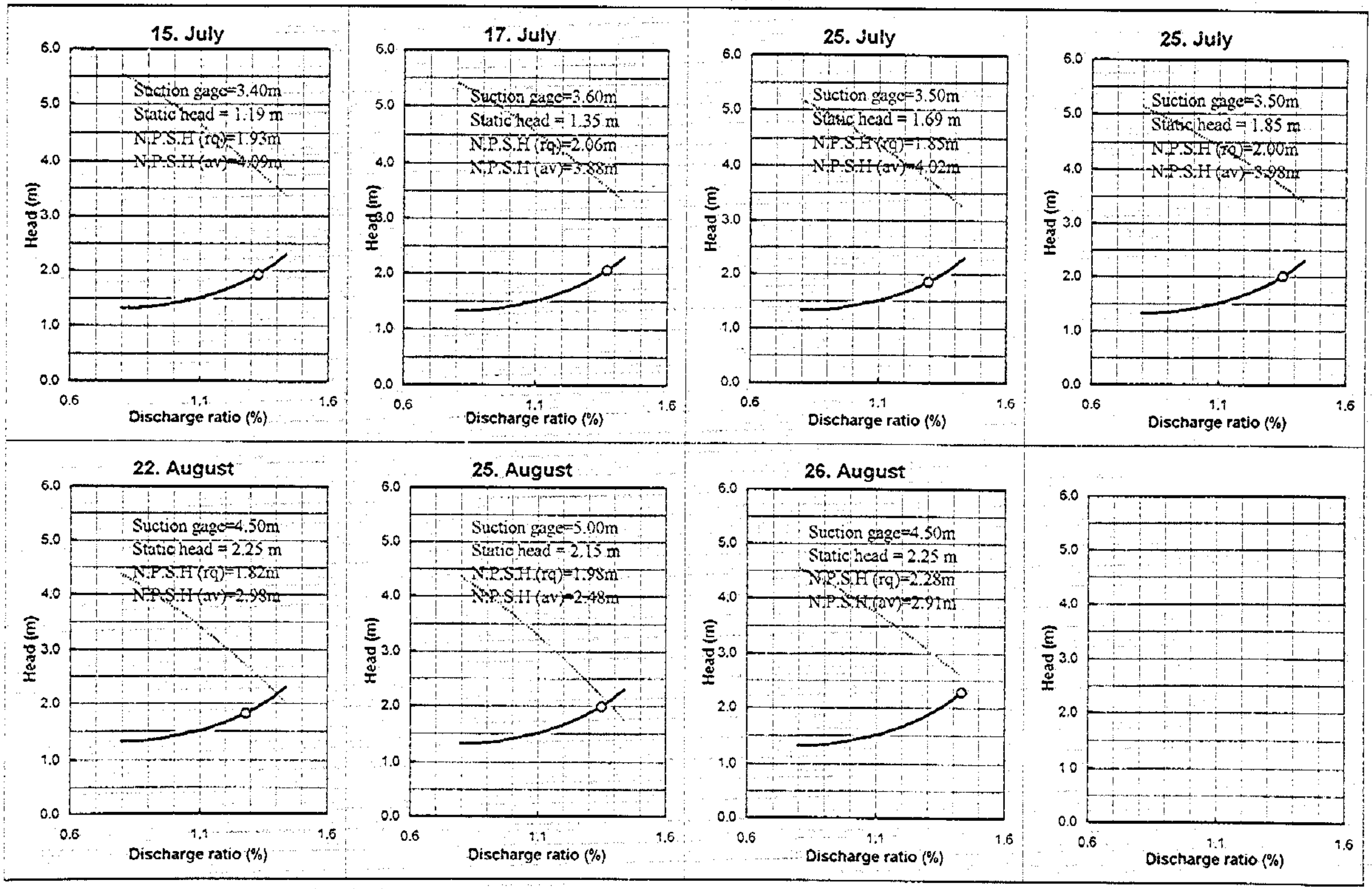


Fig. I.5.10 Performance Curve of N.P.S.H (9/10)

Performance curve on position P3 and pipe length 8.00m

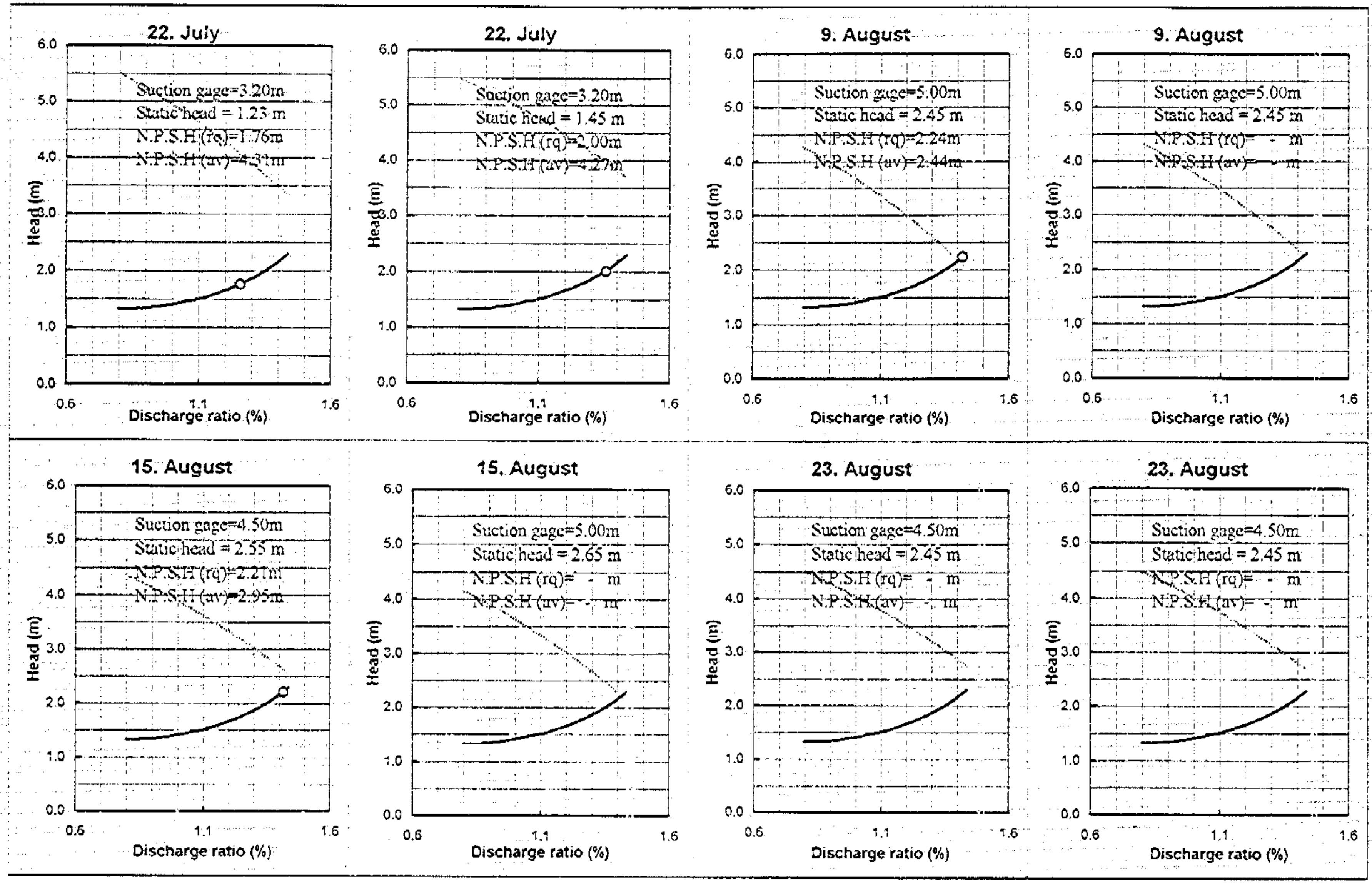


Fig. I.5.10 Performance Curve of N.P.S.H (10/10)

APPENDIX J
IMPLEMENTATION PLAN AND COST ESTIMATE

THE STUDY
ON
GROUNDWATER DEVELOPMENT
IN
WANGDUEPJODRANG DISTRICT OF BHUTAN

FINAL REPORT

VOLUME III: SUPPORTING REPORT

APPENDIX-J IMPLEMENTATION AND COST ESTIMATE

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APPENDIX-J IMPLEMENTATION AND COST ESTIMATE

J.1 Implementation Plan

J.1.1 General

The project implementation method is broadly classified into two (2) categories, such as Domestic Water Supply System and Irrigation Improvement Plan, based on the scale and the kind of the construction works involved. The Domestic Water Supply System is further sub-divided into Urban Water Supply System and Rural Water Supply System.

The construction work for the urban water supply system is to be executed by the contractor selected by international competitive tenders. It is required to use many imported materials and equipment for the construction work. The engineering services involve the detailed design work and supervision of the construction work is also necessary for such projects. The Urban Planning Section of PWD of MOC is responsible for the implementation of the project.

On the other hand, the construction work for the rural water supply system and irrigation improvement plan are to be performed under the direct management of the Government. The detailed survey is conducted by the Dzongkhag engineer. The design is transferred to the Head Quarters of Ministries for further detailed design and cost estimate. The procurement and delivery of the necessary materials are also controlled by Head Quarters of Ministries. The construction works are to be conducted under the supervision of the Dzongkhag engineer with the materials delivered at site. The common labors necessary for the construction works have to be prepared by the beneficiaries themselves. The participation of beneficiaries is very important to make the project successful.

J.1.2 Implementation Schedule

The implementation schedules for both of the Domestic Water Supply System and the Irrigation Improvement Plan are prepared based on the basic considerations for the Water Resources Development Plan as described in the Appendixes G and H.

Implementation schedules are divided into two stages, considering the basic conditions of the water resources development plan. Based on the physical year of the Five Year National Development Plans in the Bhutan, the following target years are set for the short term and long term plans.

- 2002 year for short term plan
- 2007 year for long term plan

(1) Urban Water Supply System

Considering the target year, the implementation schedule of the urban water supply systems for the Wangduephodrang town area is settled in Appendix G and is summarized as shown below;

Work Items	Year 1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Detailed Design and Administrative Arrangements	■	■									
Conveyance Pipeline			■								
Water Treatment and Distribution Station				■							
Distribution Networks and House Meters					■				■	■	

IMPLEMENTATION SHCEDULE OF URBAN WATER SUPPLY SYSTEM

The implementation period is set as 11 years in total taking into account of the first target year of 2002 and the final target year of 2007. The implementation period consists of 1 year for the administrative arrangement, 1 year for the detailed design, 5 years for the construction and 4 years for the adjustment. The target year for the construction is divided into 2 stages. The major construction works are to be completed in the first target year and the improvement works of distribution networks including the house pipeline connection and the house meters system are set to be completed in the final target year. During the administrative arrangement period, the preparations for project finance are to be performed. During the detailed design period, the detailed design work of conveyance facilities, treatment facility, distribution networks, and preparation of tender documents, etc. are to be executed. During the construction period, tendering, the construction works of the project facilities, procurement of operation and maintenance equipment, etc. are to be conducted.

(2) Rural Water Supply System

The implementation schedule of the rural water supply systems is described in Appendix G and is summarized as shown below;

Sub-area/Scheme	Type	Priority	Year 1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Lobeysa Sub-area		▶O											
New Scheme (A)	L-1	O-1									■		
New Scheme (C)	L-2	O-2										■	
Extension Scheme (B)	S-4	O-3										■	
Bajo Sub-area		▶O											
New Scheme (A)	B-1/S-1	O-1				■							
New Scheme (C)	B-2	O-3					■						
Additional Scheme	B-1	O-2					■						
Thangyul Sub-area		▶O											
New Scheme (A)	S-1	O-1	■										
New Scheme (B)	S-1	O-2		■									
New Scheme (C)	S-2	O-4			■								
Extension Scheme (A)	S-3	O-3		■									
Rubesya Sub-area		▶O											
New Scheme (A)	S-1	O-1						■					
New Scheme (C)	S-2	O-4								■			
Extension Scheme (A)	S-3	O-2							■				
Extension Scheme (B)	S-4	O-3								■			
Water Treatment Scheme	T-1	O-5									■		

IMPLEMENTATION SHCEDULE OF RURAL WATER SUPPLY SYSTEM

The implementation period of rural water supply system is also proposed as 11 years in total same with the urban water supply system based on the target year and the factors discussed in Appendix G. The construction works are to be conducted under the supervision of the Dzongkhag Engineer with the delivered materials. The procurement and delivery of the necessary materials are to be conducted by PHE/PWD of MOC.

(3) Irrigation Improvement Plan

The implementation schedule of the irrigation improvement plan is discussed in Appendix H. Based on the priority of the project, the implementation schedule is set considering the target year and total construction cost as shown below;

Proposed Implementation Schedule

Category of Land	Sub-Area	Name of Canal	Code	Priority	Year 1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Low Flat Area	Lobeysa	Upper Lobeysa	C1	(2)											
		Lower Lobeysa	C2	(3)											
	Bajo	Bajo	C9	(1)											
High Hilly Area	Phangyul	Phangyul	C10	(1)											
		Genkha	C15	(2)											
	Rubeysa	Nalakha	C18	(6)											
		Rutekha	C19	(3)											
		Maphekha	C20	(5)											
		Naykoyuwa	C21	(4)											
		Rumina	C22	(2)											
	Research the Optimum Diversification Crop														

All the required structures are to be completed in the short term plan period until the target year of 2002 and no construction work will be carried out there after during the long term plan period. Only the research work for applying optimum diversification crop is to be performed during the long term plan period until the target year of 2007.

J.2 Cost Estimate

J.2.1 Conditions of Cost Estimate

The project cost is estimated on the following conditions;

a. The price level used is as of July 1995.
b. The exchange rate used is US$ 1.00 = Nu. 30.85 = J.Yen 100.
c. The basic price such as labor wage, material cost and unit construction cost are based on the unit cost adopted in the Bhutan Schedule of Rate, PWD of MOC.
d. The price of materials includes transportation cost to the construction site.

The basic prices for cost estimation are Summarized as shown below;

(1) Labor Wage

(Unit : Nu)

	Items	Unit	Cost		Items	Unit	Cost
1	Labour	md	43.79	10	Electric Worker	md	65.75
2	Work Supervisor	md	90.00	11	Plant Operator	md	90.00
3	Carpenter	md	65.75	12	Driller	md	130.00
4	Head of Carpenter	md	74.43	13	Blaster	md	55.07
5	Mason Worker	md	55.07	14	Watchman	md	43.79
6	Head of Mason	md	65.75	15	Driver	md	65.00
7	Steel Worker	md	65.75	16	Welder	md	90.00
8	Machine Operator	md	90.00	17	Skilled Labour	md	90.00
9	Mechanic	md	76.43	18	Technician	md	90.00

(2) Material Cost

(Unit : Nu)

	Items	Unit	Cost		Items	Unit	Cost
1	Aggregate			12	HDP Strainer, D=90 mm	m	128.10
	(a) Sand	cum	203.22	13	HDP Pipe		
	(b) Gravel < 25 mm	cum	197.11		(a) D= 20 mm	m	24.90
	(c) Gravel < 50 mm	cum	153.63		(b) D = 30 mm	m	27.60
	(d) Rubble Stone	cum	121.40		(c) D= 50 mm	m	42.80
2	Lumber			14	Concrete Pipe		
	(a) Form Lumber	cum	415.50		(a) D = 900 mm	m	1,630.00
	(b) Plywood 1/2 & 4*8	sqm	142.25		(b) D= 1,000 mm	m	1,770.00
	(c) Timber	cum	4,206.03	15	PVC Pipe D = 8 inches	m	1,030.00
	(d) Timber beams	cum	3,760.15	16	PVC elbow, L=1.5 m	m	3,090.00
3	Reinforced Iron Bar	kg	14.63				
4	Nail, Bolt, Nut	kg	26.00	17	Steel Pipe (STPW, L=6 m)		
5	H-Beam	kg	87.75		100 mm	pc	3,300.00
6	Trash Rack	kg	39.50		300 mm	pc	16,453.00
7	Cement (1 bag = 50 kg)	bag	106.25	18	Corrugated Pipe (L= 1m)		
8	Fuel				400 mm, t=2 mm	pc	8,500.00
	(a) Gasoline	lit	17.89	19	Sluice Valve		
	(b) Diesel	lit	7.83		D = 75 mm	pc	975.85
9	Blasting				D = 200 mm	pc	1,331.50
	(a) Dynamite	kg	25.23		D= 300 mm	pc	2,110.00
	(b) Detonator	pc	1.86	20	Elbow		
10	Drilling				D = 75 mm	pc	140.00
	(a) Rod (for Sinker)	pc	45,000.00		D = 200 mm	pc	754.25
	(b) Bit (for Sinker)	pc	60,000.00		D = 300 mm	pc	815.75
11	GI Pipe			21	Air Valve D= 50 mm	pc	334.02
	(a) D= 15 mm	m	35.50	22	Mastic Filler	cum	875.90
	(b) D = 25 mm	m	49.60	23	Oil Paint	lit	99.64
	(c) D= 50 mm	m	117.60	24	Staff Gauge	m	196.00
	(d) D = 60 mm	m	176.10				
	(e) D = 80 mm	m	213.74				

(3) Construction Equipment

(Unit : 1000Nu)

	Items	Unit	Cost		Items	Unit	Cost
1	Bulldozer (21ton)	No.	11,087	5	Dump Truck (11 ton)	No.	3,844
2	Bulldozer (15ton)	No.	9,101	6	Truck crane (5 ton)	No.	4,651
3	Backhoe (0.6 m^3)	No.	5,776	7	Pickup (4WD)	No.	1,069
4	Backhoe (0.2 m^3)	No.	3,014	8	Self loader truck (3 ton)	No.	1,264

The project cost estimation is classified into two categories such as Domestic Water Supply Plan and Irrigation Improvement Plan. And the domestic water supply plan is further sub-divided into Urban Water Supply System and Rural Water Supply System.