4.6.5 Water Source

(1) Hydrological and morphological data of Padma River

The Ganges River drains the southern slope of the Himalayas. After breaking through the Indian shield, the Ganges swings to the east along recent multiple faults between the Rajmahal Hills and the Dinajpur Shield. The river enters Bangladesh at Godagari and is called Padma. Before meeting with the Jamuna, the river travels about 2,600km, draining about 990,400km^2 of which about 38,880km^2 lies within Bangladesh. The average longitudinal slope of water surface of the Ganges（Padma） River is about 5/100,000. Size of bed materials decreases in the downstream. At the Harding Bridge, the average diameter is about 0.15mm.

The river planform is in between meandering and braiding, and varies temporally and spatially. Sweeping of the meandering bends and formation of a braided belt is limited within the active corridor of the river. This corridor is bounded by cohesive materials or man-made constructions that are resistant to erosion. Materials within these boundaries of the active corridor consist of loosely packed sand and silt, and are highly susceptible to erosion.

Hydrological and morphological data of Padma River has been corrected by BWDB at Harding Bridge and crossing line of RMG-13 shown in the Figure I-4-6-4.

Figure I-4-6-4 Bheramara site and Padma River

Figure I-4-6-5 shows the water level at Harding Bridge between 1976 and 2006.

In generally, the Padma River starts rising at the-end of June and attains its peak level in August or September, with a corresponding increase in its sediment load in the period. After mid November, water level in the Padma River becomes lower, and naturally very little sediment is borne by the river during the season.

Water levels of Padma River at Hardinge Bridge are following;

LLWL = EL+4.22 m
LWL = EL+5.47 m*
MWL = EL+8.74 m*
HWL = EL+13.63 m*
HHWL = EL+15.19 m
(*: average between 1976 and 2006)

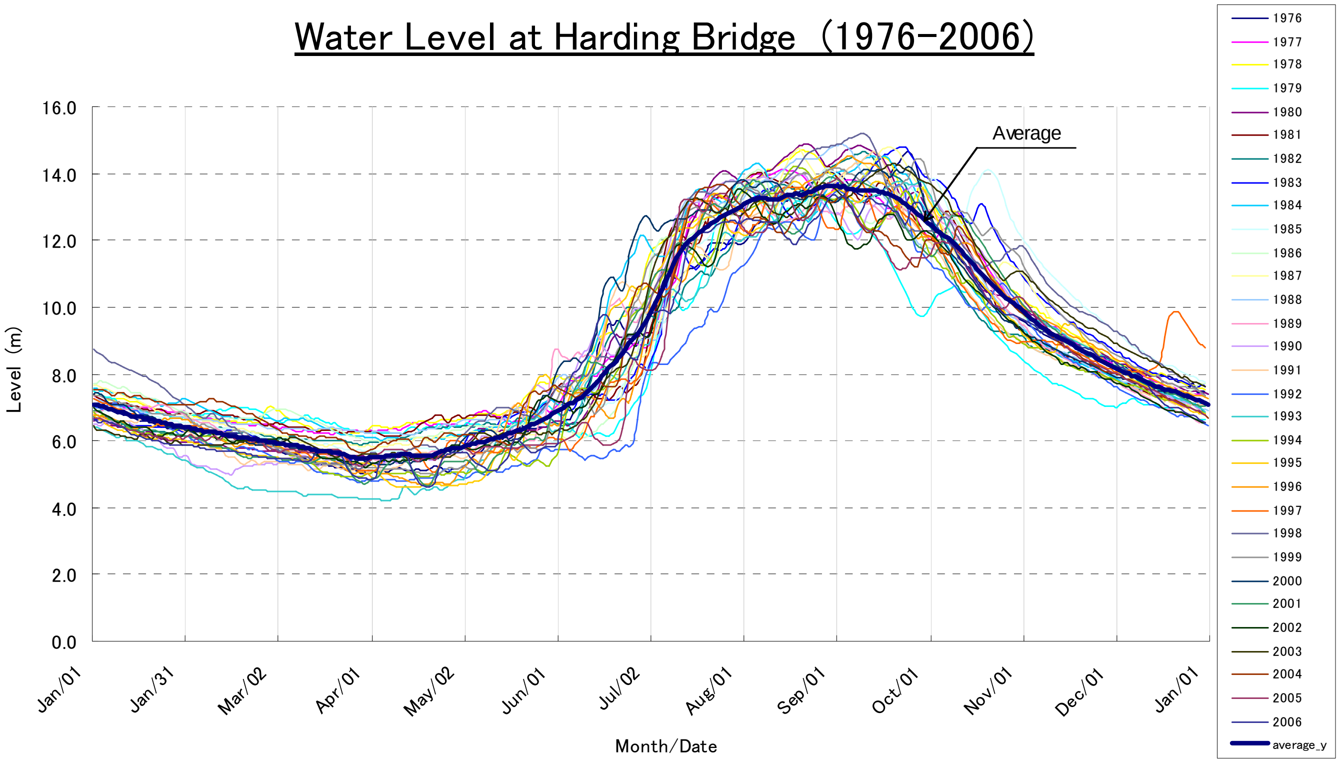


Figure I-4-6-5 Water level at Hardinge Bridge

Figure I-4-6-6 and Figure I-4-6-7 show the monthly variation of minimum discharge at Hardinge Bridge. Minimum discharge of Padma River at Hardinge Bridge as follows:

Minimum discharge : Qmin=183m^3/sec (Mar. 1997)
Averaged minimum discharge : Qmin=709m^3/sec (Apr.)

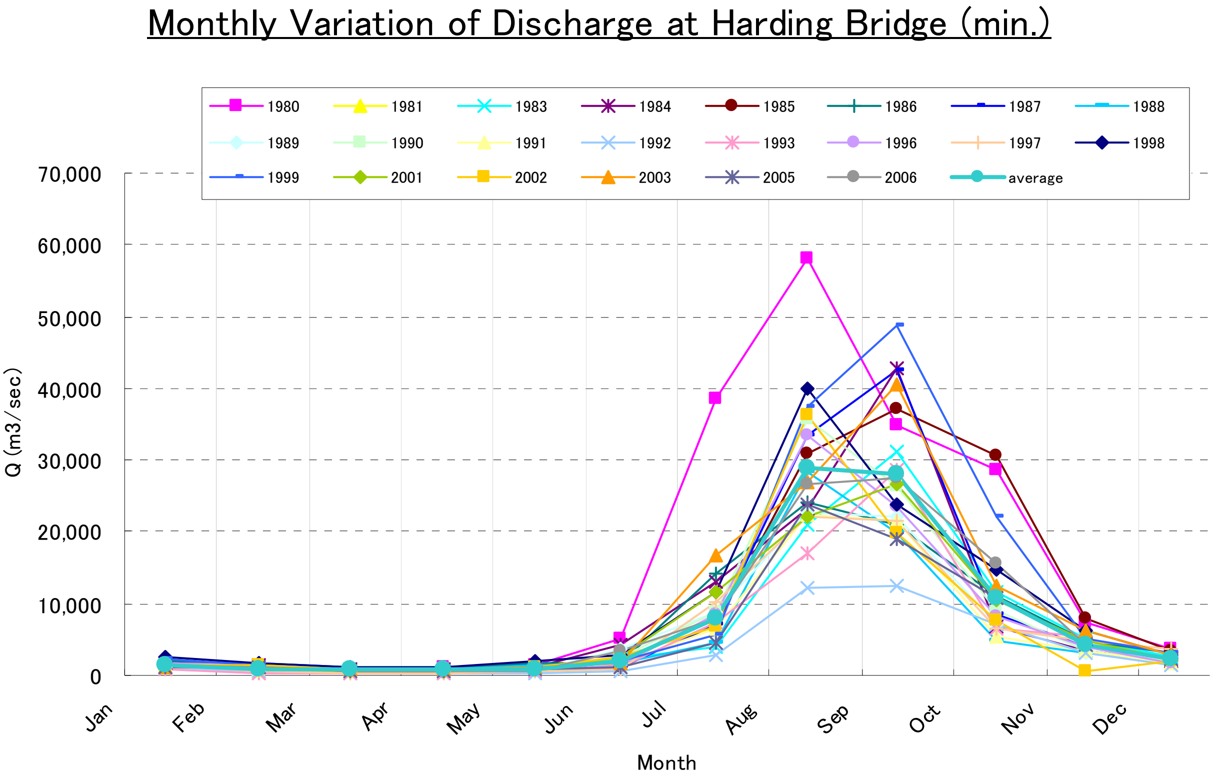


Figure I-4-6-6 Monthly variation of minimum discharge at Hardinge Bridge

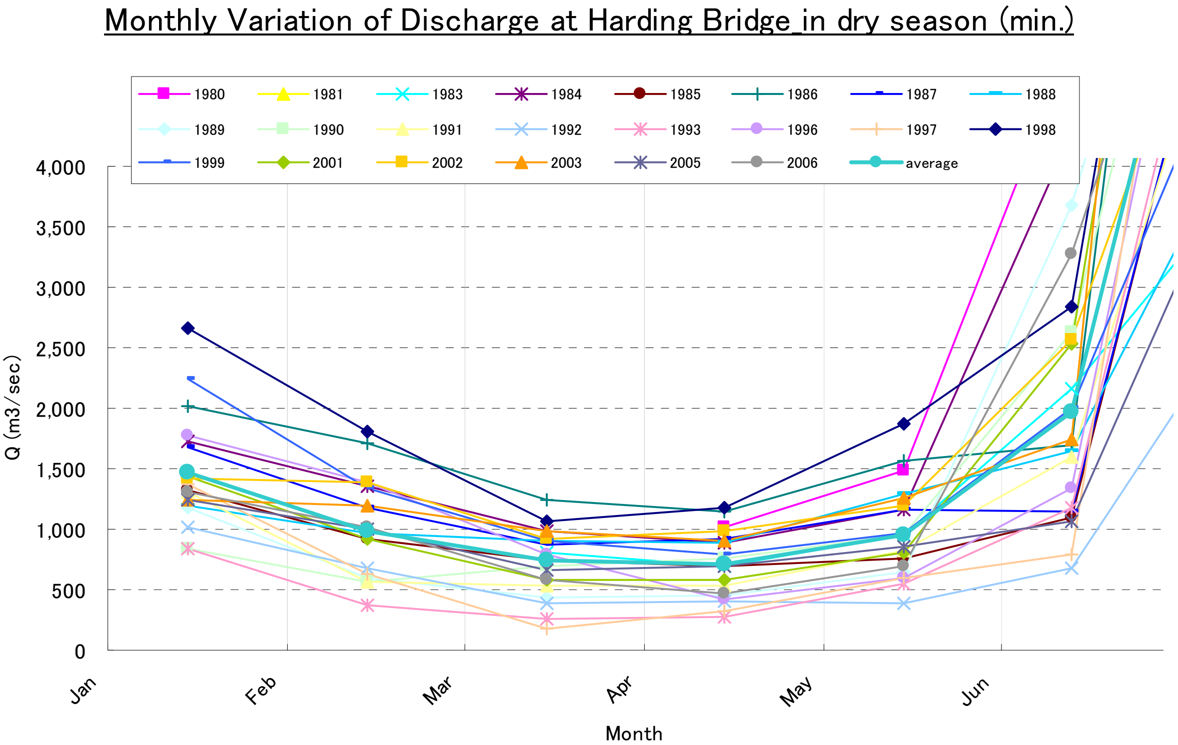


Figure I-4-6-7 Monthly variation of minimum discharge at Hardinge Bridge in dry season

Figure I-4-6-8 shows the velocity at Hardinge Bridge. Velocity of Padma River at Hardinge Bridge in 2007 is following;

Maximum velocity : V_{max}=3.62m/sec
Minimum velocity : V_{min}=0.32m/sec

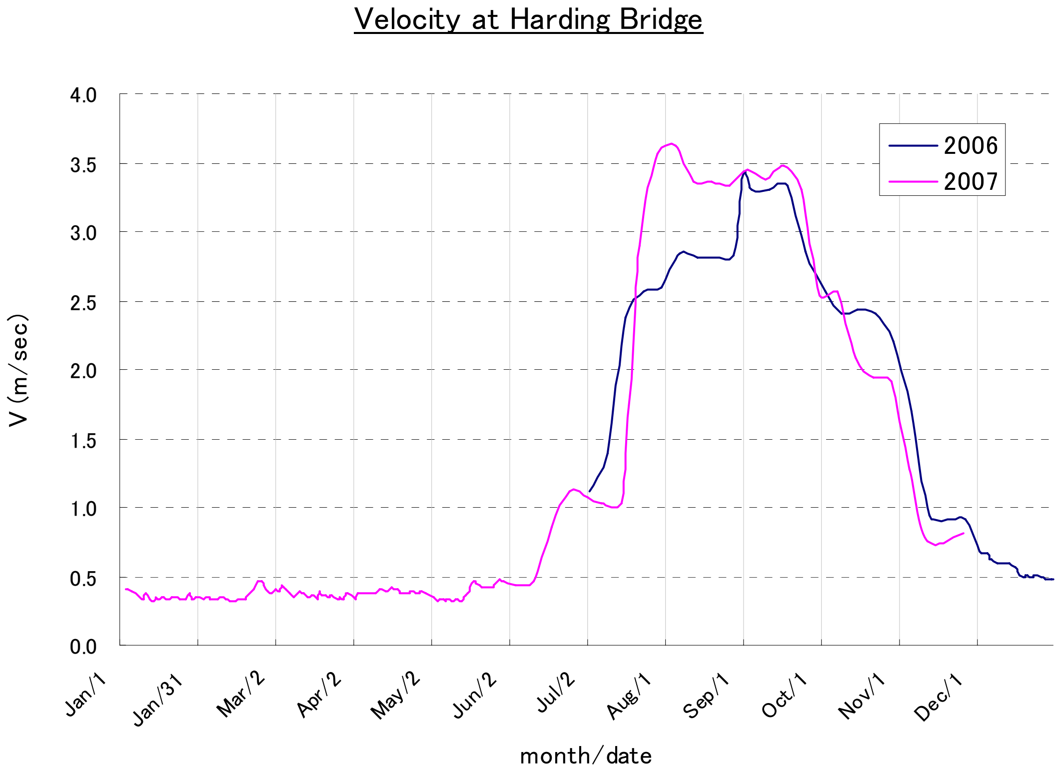


Figure I-4-6-8 Velocity at Hardinge Bridge

Figure I-4-6-9 shows the bed elevation of Padma River at cross section of RMG-13. The bed elevation has been measured almost once a year during dry season.

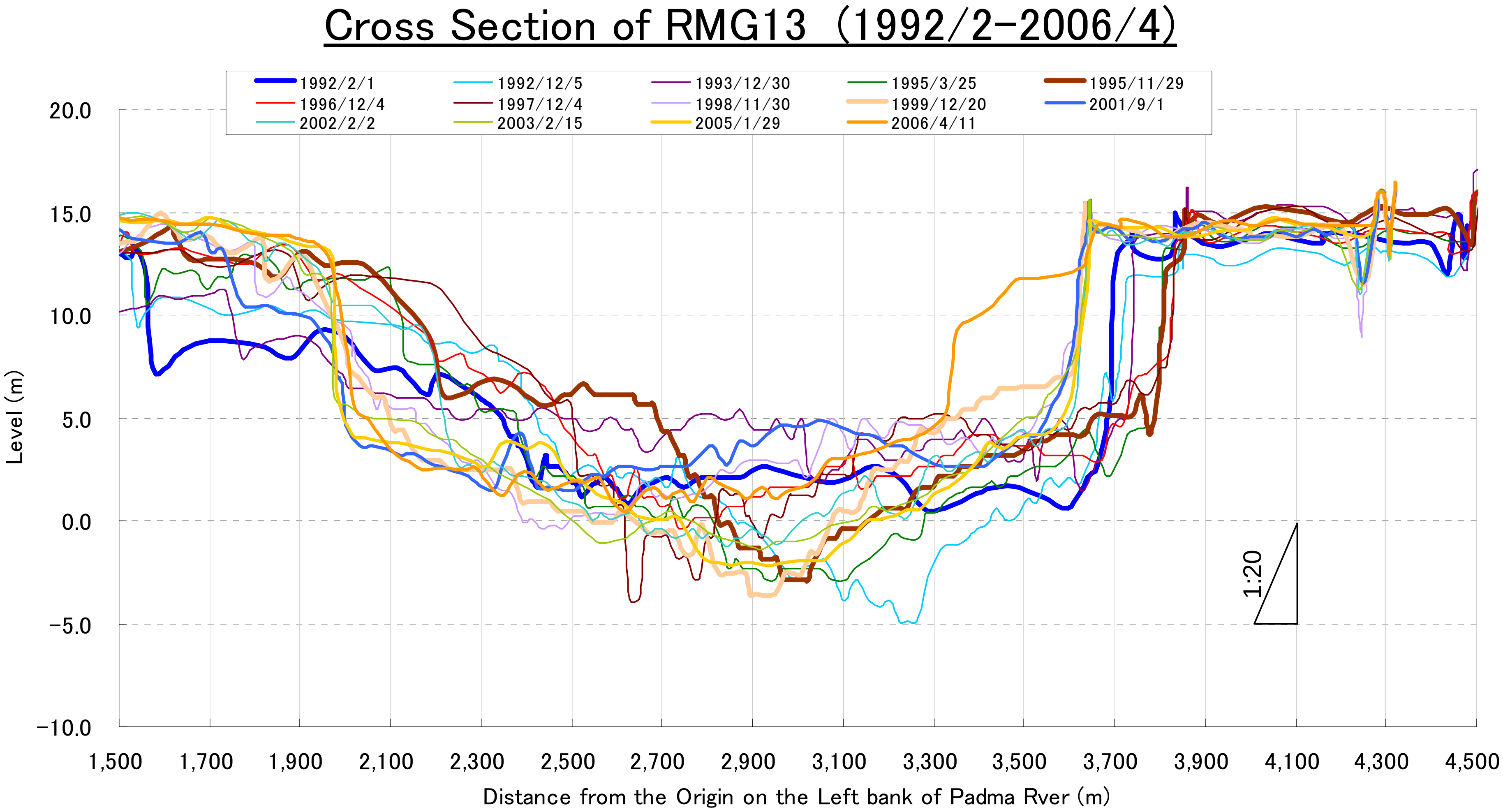


Figure I-4-6-9 Bed elevation of Padma River at cross section RMG-13

(2) Ground water Investigation

Ground water may be pumped up to secure the makeup water for the cooling tower, therefore, in order to obtain information on the baseline situation of aquifer condition present in the site area and assess any impact on the existing wells by long-term constant pumping, ground water investigation/study was conducted.

1) ground water investigation

Groundwater investigation with a set of one 100m pump well and twelve 100m observation wells was conducted.

Groundwater investigation includes the following physical works:

- Test drilling and analysis
- Drilling, installation and development of pumping well and observation wells
- Geo-electrical logging of borehole
- Recording of pumping test (continuous pumping test of 72 hours duration and recovery)
- Evaluating results

Pump/Observation wells layout is shown in the Figure I-4-6-10.

Figure I-4-6-10 Pump/Observation wells layout

Aquifer of the site area was determined by sieve analysis of drilled samples from pumping well and observation wells and also electrical logging.
Test pump capacity is max. 2.0 ft^3/sec (=3.40m^3/min=204m^3/hr) and actual discharge of pumping well was 159.0 – 163.3 m^3/hr. Information of hydrostratigraphic units are shown in Table I-4-6-2.

Table I-4-6-2 Information of hydrostratigraphic units

Well ID	Depth of upper aquitard below GL (m)	Depth of upper part of aquifer below GL (m)	Depth of main part of aquifer below GL (m)	Total depth of boring below GL(m)	Height of well casing above GL (m)	Total depth of well below GL(m)	Depth of screen below GL (m)	Discharge
PW-01	6.09	36.58	not defined	92.68	0.46	86.91	42.71–85.39	**159.00-163.30** (m^3/h)
TTW/ OW-01	12.19	36.58	not defined	100.00	0.305	83.84	79.27–82.32	36 l/s
OW-02	9.14	42.68	not defined	100.00	0.305	84.15	79.58–82.63	36 l/s
OW-03	6.09	30.48	not defined	100.61	0.305	50.00	45.43–48.48	32 l/s
OW-04	6.09	48.78	not defined	101.22	0.305	77.75	73.18–76.23	37 l/s
OW-05	3.04	27.43	not defined	100.61	0.305	83.84	79.27–82.32	36 l/s
OW-06	12.19	36.58	not defined	100.00	0.305	76.22	71.65–74.70	36 l/s
OW-07	6.09	42.68	not defined	100.61	0.305	76.83	71.65–74.70	31 l/s
OW-08	6.09	36.58	not defined	100.61	0.305	77.75	73.18–76.23	32 l/s
OW-09	6.09	24.39	not defined	100.00	0.305	76.22	71.65–74.70	36 l/s
OW-10	6.09	42.68	not defined	100.61	0.305	74.70	70.13–73.18	37 l/s
OW-11	6.09	36.58	not defined	100.00	0.305	79.27	74.70–77.75	35 l/s
OW-12	6.09	42.68	not defined	100.00	0.305	79.88	75.31–78.36	38 l/s

Longitudinal cross sections of aquifer both S-N and W-E direction are shown in the Figure I-4-6-11, 12.
The cross sections reveal two hydrostratigraphic units up to the drilling depth of approximately 100m. The upper aquitard is the top unit, which is composed of clay, silty clay and sandy clay. The thickness of this unit is approximately 6.5m of average (3m-12m). The aquifer unit lies below the upper aquitard and continues up to the drilling depth. The upper part of the aquifer unit is composed of finer sand fractions up to the depth of approximately 40m of average (25m-55m). The main part comprises interlayer of medium to fine sand and fine to medium sand with occasional coarse sand up to the depth of approximately 90m of average (80m-more than 100m) and gravel at the bottom part.
If an aquifer has beds of clay or silt within or next to it the lowered water pressure in the sand and gravel causes slow drainage of water from the clay and silt beds. The reduced water pressure causes a loss of support for the clay and silt beds. Because these beds are compressible, they compact (become thinner), and the effects are seen as a lowering of the land surface. However, geologically, the area is a point bar of a very big world's prominent

meandering river the Ganges. The well known meandering river model of Allen (1970) is taught in sedimentology. The Allen's sedimentary facies model shows that point bar sequence of meandering river comprises a fining upward sequence. At the bottom gravels are deposited, then gradually coarse sand, medium sand, fine sand, and very fine sands are deposited. Clay layer is only deposited on the surface. The cross sections show the above typical meandering river model sedimentation. Therefore, it is very unlikely that significant land subsidence will occur due to slight lowering of groundwater table at the site area.

Pump well design is shown in the Figure I-4-6-13. Pumping test result (drawdown record of both pumping well and observation wells) is shown in the Figure I-4-6-14.

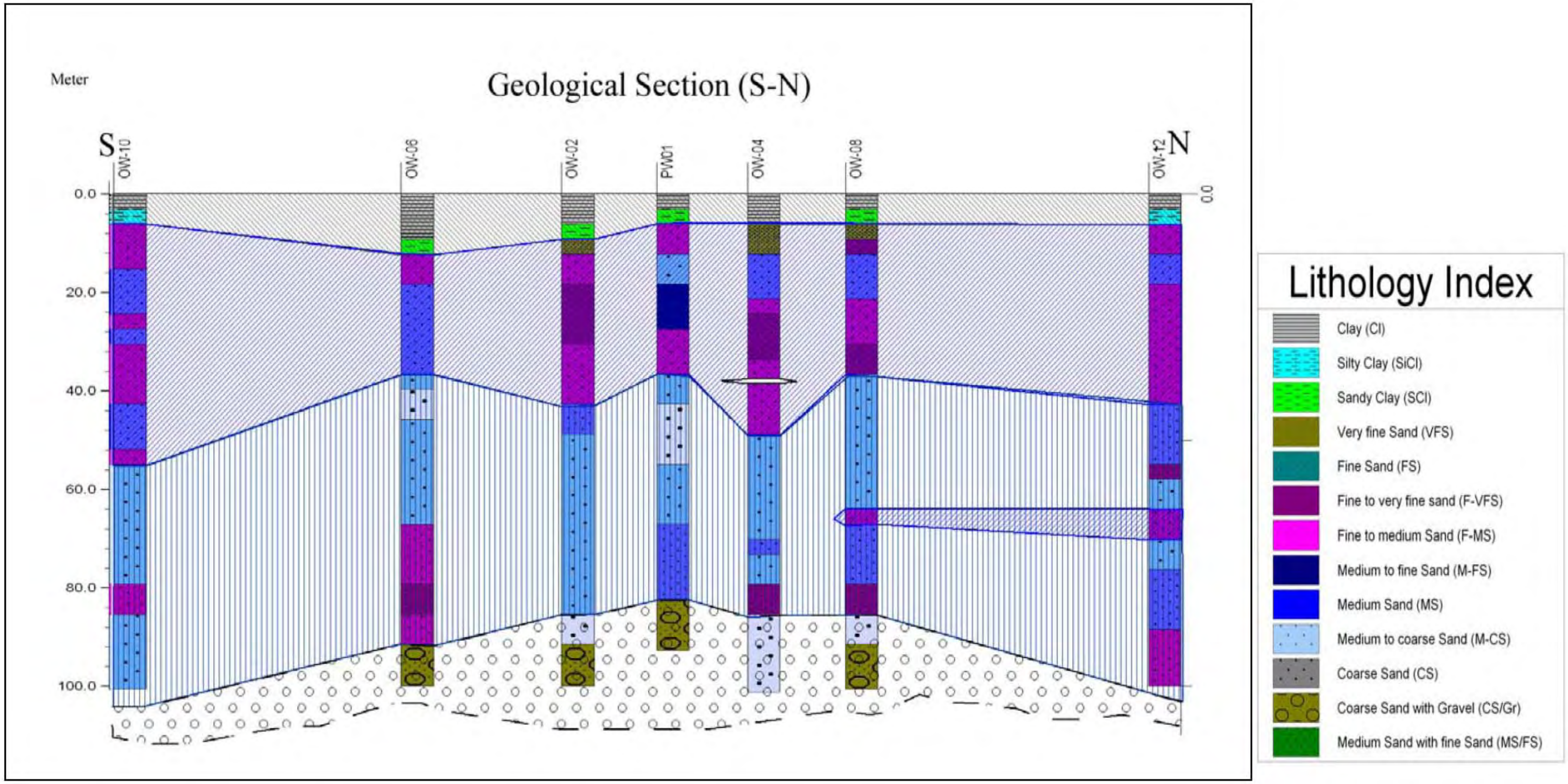


Figure I-4-6-11 Longitudinal cross section (S-N)

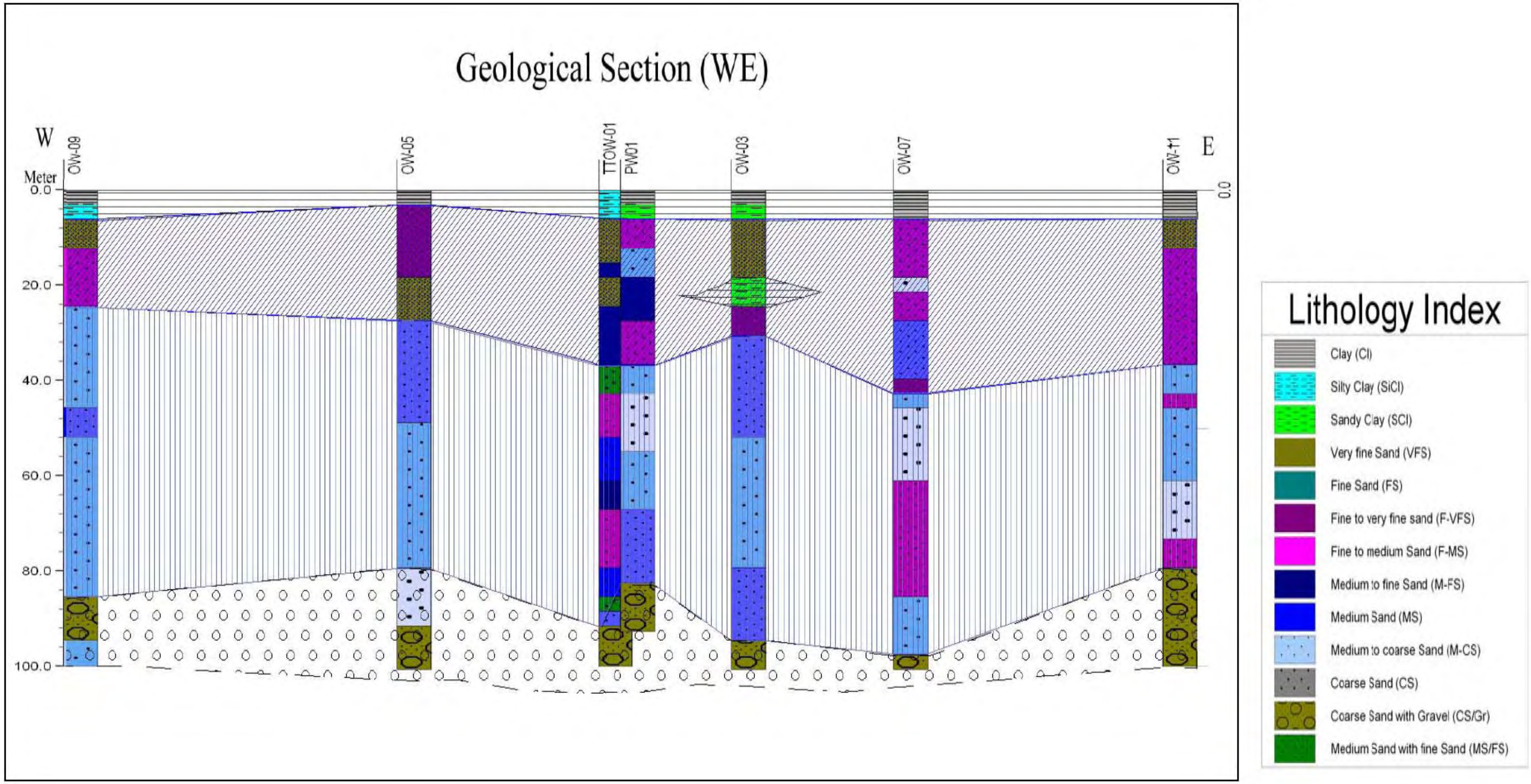
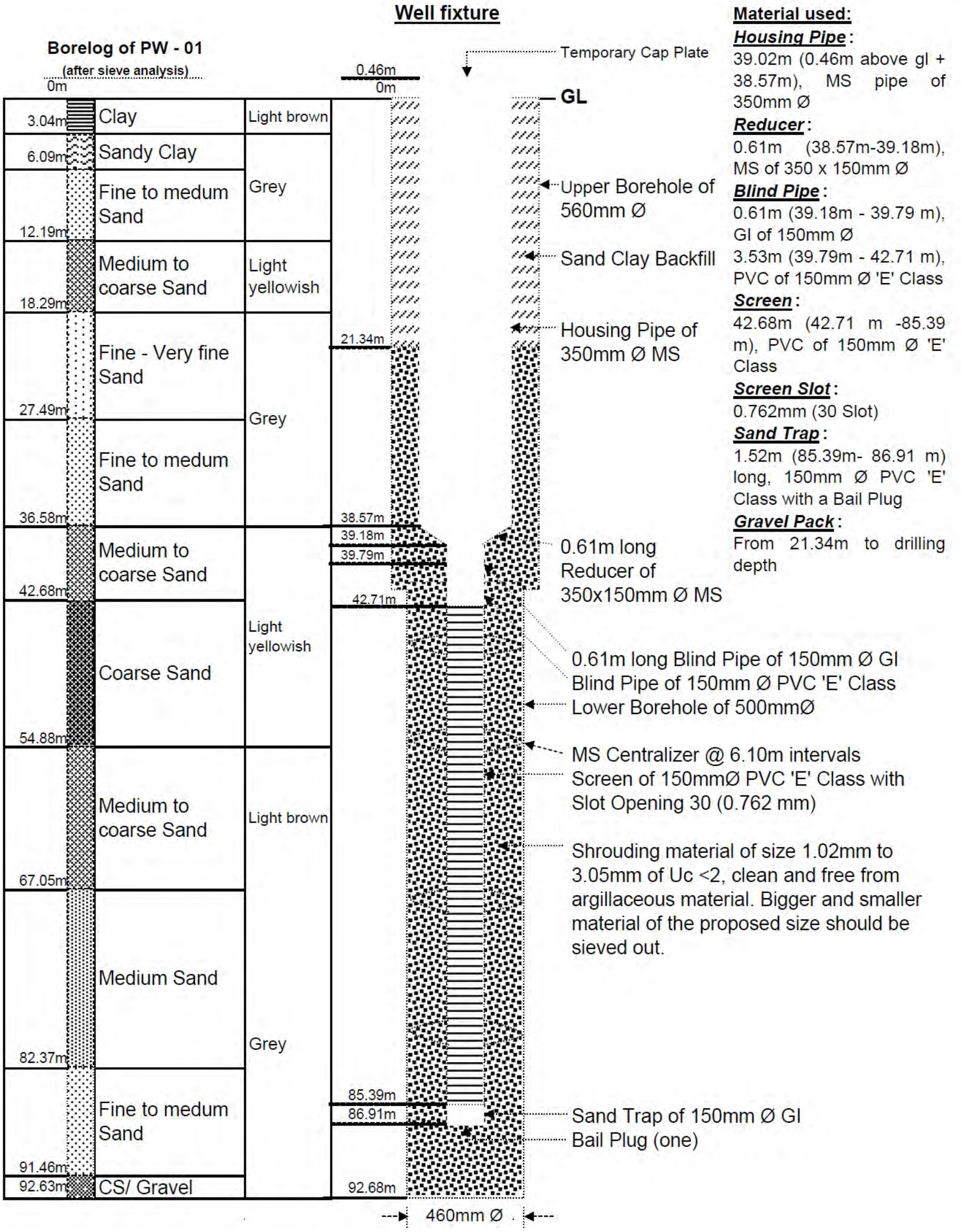


Figure I-4-6-12 Longitudinal cross section (W-E)

PUMPING WELL (PW-01)

Work: Drilling & well fixture installation of Pumping Well (PW-01) of 350x150 mm dia., shrouded
Project: Bheramara 450 MW Combined Cycle Power Plant, Bheramara, Kushtia
Location: E89^{0}01'00.5? N24^{0}02'59.4? (inside-'Site-A' and beside canal of GK Project)
Drilling completion: 24 August to 09 September 2008
Well installation: 09 September to 10 September 2008



3.04m	Clay	Light brown
6.09m	Sandy Clay	Grey
12.19m	Fine to medum Sand	
18.29m	Medium to coarse Sand	Light yellowish
27.49m	Fine - Very fine Sand	Grey
36.58m	Fine to medum Sand	
42.68m	Medium to coarse Sand	Light yellowish
54.88m	Coarse Sand	
67.05m	Medium to coarse Sand	Light brown
82.37m	Medium Sand	Grey
91.46m	Fine to medum Sand	
92.63m	CS/ Gravel	

Material used:

***Housing Pipe*:** 39.02m (0.46m above gl + 38.57m), MS pipe of 350mm Ø

***Reducer*:** 0.61m (38.57m-39.18m), MS of 350 x 150mm Ø

***Blind Pipe*:** 0.61m (39.18m - 39.79 m), GI of 150mm Ø 3.53m (39.79m - 42.71 m), PVC of 150mm Ø 'E' Class

***Screen*:** 42.68m (42.71 m -85.39 m), PVC of 150mm Ø 'E' Class

***Screen Slot*:** 0.762mm (30 Slot)

***Sand Trap*:** 1.52m (85.39m- 86.91 m) long, 150mm Ø PVC 'E' Class with a Bail Plug

***Gravel Pack*:** From 21.34m to drilling depth

Figure I-4-6-13 Pump well design

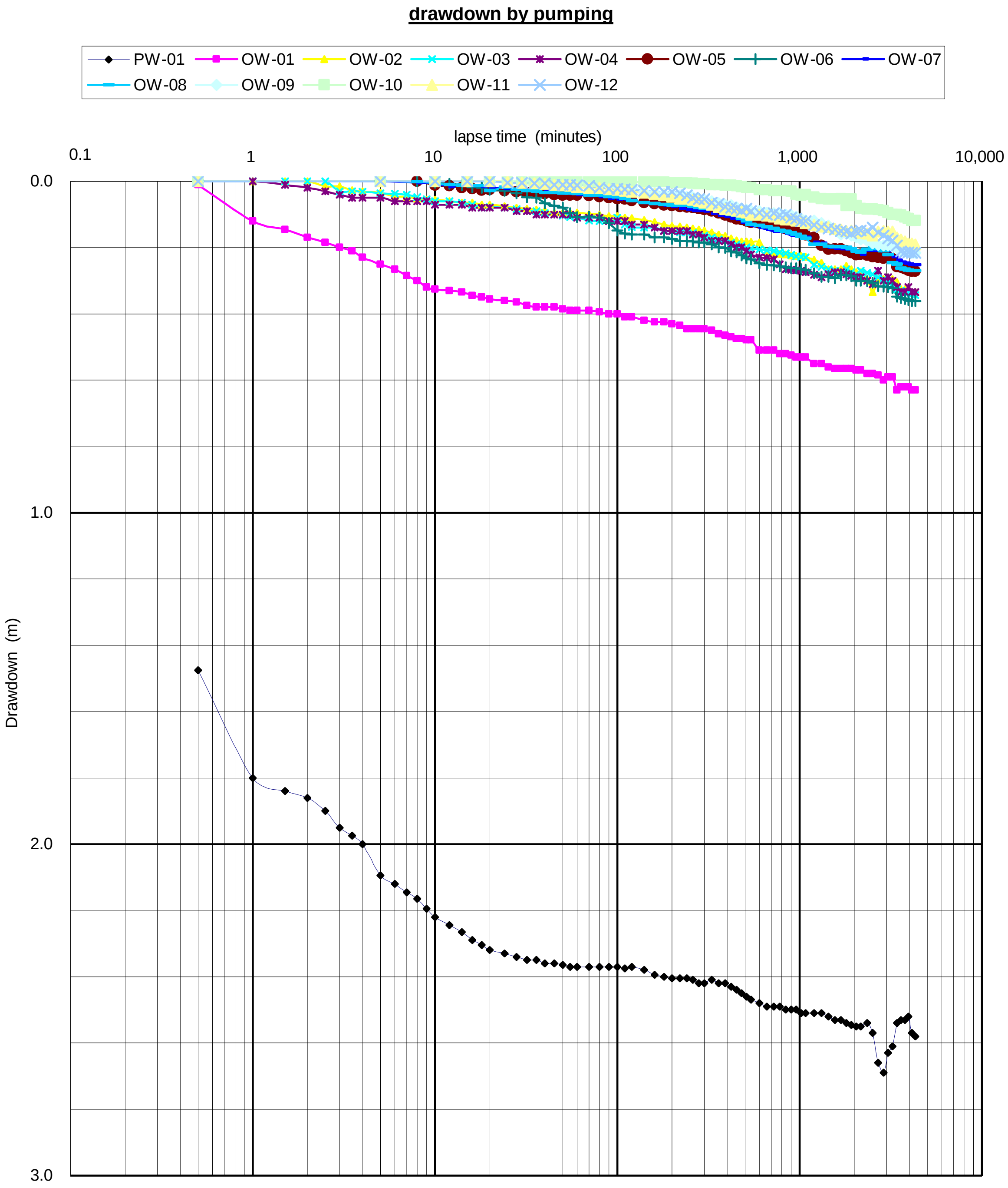


Figure I-4-6-14 Pumping test result

Hydrogeological constant of aquifer (hydraulic conductivity(K), transmissivity(T), storativity(S)) was determined from the analysis of pumping test data.

Equation for confined aquifer:

Theis (1935) derived a solution for unsteady flow to a fully penetrating well in a confined aquifer. The solution assumes a line source for the pumped well and therefore neglects wellbore storage.

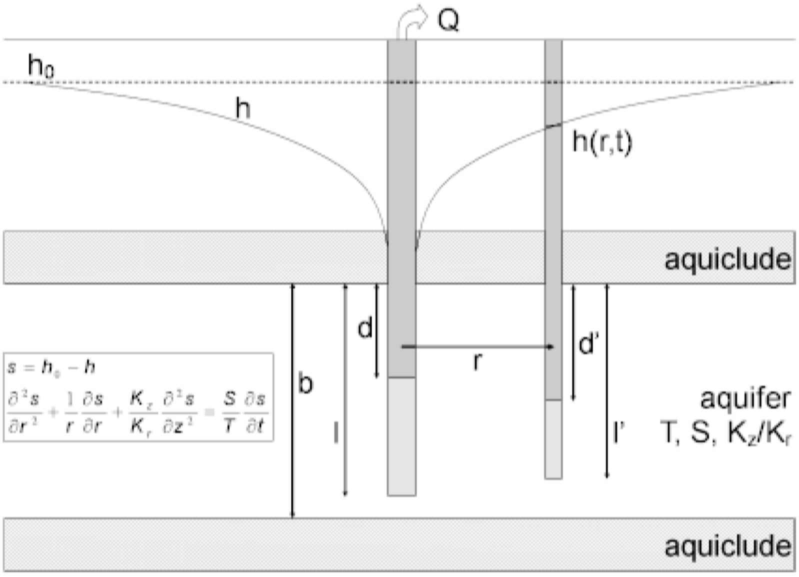


Figure I-4-6-15 Confined aquifer

The equation is:

$$s = \frac{Q}{4\pi T}\int_u^{\infty}\frac{e^{-y}}{y}dy$$

$$u = \frac{r^2 S}{4Tt}$$

$$s_D = \frac{4\pi T}{Q}s$$

$$t_D = \frac{Tt}{r^2 S}$$

where

Q is pumping rate [L3/T]
r is radial distance [L]
s is drawdown [L]
S is storativity [dimensionless]
t is time [T]
T is transmissivity [L2/T]

Equation for unconfined aquifer

Neuman (1972, 1974) derived an analytical solution for unsteady flow to a fully or partially penetrating well in a homogeneous, anisotropic unconfined aquifer with delayed gravity response. The Neuman model assumes instantaneous drainage at the water table. Neuman (1974) derived an analytical solution for unsteady flow to a partially penetrating well in an unconfined aquifer with delayed gravity response.

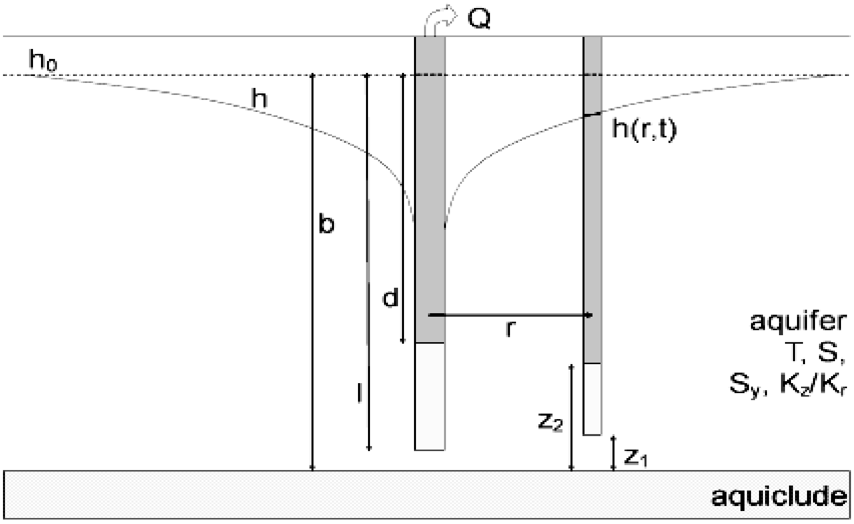


Figure I-4-6-16 Unconfined aquifer

The equation is:

$$s = \frac{Q}{4\pi T}\int_0^\infty 4yJ_0(y\sqrt{\beta})\left[u_0(y)+\sum_{n=1}^\infty u_n(y)\right]dy$$

$$\beta = \frac{r^2K_z}{b^2K_r}$$

$$\sigma = \frac{S}{S_y}$$

$$t_s = \frac{Tt}{Sr^2}$$

$$s_D = \frac{4\pi T}{Q}s$$

where

b is aquifer thickness [L]
Kr is radial hydraulic conductivity [L/T]
Kz is vertical hydraulic conductivity [L/T]
Q is pumping rate [L3/T]
r is radial distance [L]
s is drawdown [L]
S is storativity [dimensionless]
Sy is specific yield [dimensionless]
t is time [T]
T is transmissivity [L2/T]

Table I-4-6-3 summarizes the aquifer properties determined from the analysis of pumping test data of all observation wells using Theis confined type curve matching method, and Table I-4-6-4 summarizes the aquifer properties determined from the analysis of pumping test data of all observation wells using Neumann curve matching technique.

Table I-4-6-3 Aquifer properties (Theis method)

Observation Well	**T (m^2/d)**	**S**	**K (m/d)**
OW-1	6063	0.001	60.6
OW-2	7509	0.007	75.1
OW-3	7509	0.006	75.1
OW-4	8537	0.004	85.4
OW-5	6894	0.007	68.9
OW-6	3058	0.004	30.6
OW-7	6894	0.007	68.9
OW-8	7195	0.019	72.0
OW-9	4495	0.009	45.0
OW-10	5110	0.028	51.1
OW-11	5810	0.006	58.1
OW-12	6063	0.007	60.6

Table I-4-6-4 Aquifer properties (Neumann method)

Obs. Well	**Early**				**Late**				**Average**		
	T (m^2/d)	**S**	**Kh (m/d)**	**Kv (m/d)**	**T (m^2/d)**	**Sy**	**Kh (m/d)**	**Kv (m/d)**	**T (m^2/d)**	**Kh (m/d)**	**Kv (m/d)**
OW-1	2498	0.008	25.0	8.7	2498	0.40	25.0	8.66	2498	25.0	8.7
OW-2	4929	0.005	0.0	8.9	3168	0.16	31.7	5.73	4049	15.9	7.3
OW-3	4929	0.003	49.3	7.2	3168	0.14	31.7	4.62	4049	40.5	5.9
OW-4	4605	0.003	46.1	9.0	3391	0.12	33.9	6.63	3998	40.0	7.8
OW-5	5275	0.004	52.8	7.7	4302	0.04	43.0	6.24	4789	47.9	7.0
OW-6	3755	0.003	37.6	9.2	4019	0.02	40.2	0.10	3887	38.9	4.7
OW-7	4451	0.004	44.5	4.3	4605	0.02	46.1	4.44	4528	45.3	4.4
OW-8	7667	0.011	76.7	3.5	4929	0.04	49.3	2.26	6298	63.0	2.9
OW-9	2333	0.005	23.3	6.1	4451	0.02	44.5	1.17	3392	33.9	3.6
OW-10	5275	0.022	52.8	1.2	5099	0.04	51.0	1.11	5187	51.9	1.1
OW-11	6692	0.005	66.9	4.1	4764	0.02	47.6	2.92	5728	57.3	3.5
OW-12	5841	0.005	58.4	1.7	4302	0.02	43.0	1.23	5072	50.7	1.4

The average transmissivity of the aquifer estimated by the Theis method and Neumann methods are 6,261m^2/d and 4,456 m^2/d, respectively. It could be mentioned here that the bottom of the aquifer has not been encountered in the project site during drilling. The effective thickness of the aquifer is presumably much more greater and transmissivity for the full thickness of the aquifer may exceed 10,000 m^2/d. Howard Humphre (1984) estimated transmissivities of KT-2 (Amguri, Meherpur, Kushtia) and KT-6 (Darmaehali, Gangi, Kushtia) which are 9,800 m^2/d and 5,700 m^2/d, respectively.

The hydraulic conductivity of unconsolidated fine sand ranges from $2x10^{-7}$ to $2x10^{-4}$ m/s and that of gravel ranges from $3x10^{-4}$ to $3x10^{-2}$ m/s (Domenico and Schwartz 1990). In the project area the average horizontal hydraulic conductivity (Kh) of the aquifer is found to be 42.5 m/d ($\approx 5\times10^{-4}$ m/s). This value is acceptable because this value is well within the range of fine sand to gravel by which the aquifer is composed.

Reference groundwater table of Well No. KTA-7, which is at the west side of the office of the Executive Engineer, O&M (Pump Station) Division of BWDB. (About 3km away from G.K. Pump Station), and Padma River water table are shown in the Figure I-4-6-17. This figure shows that river water level and ground level are well related.

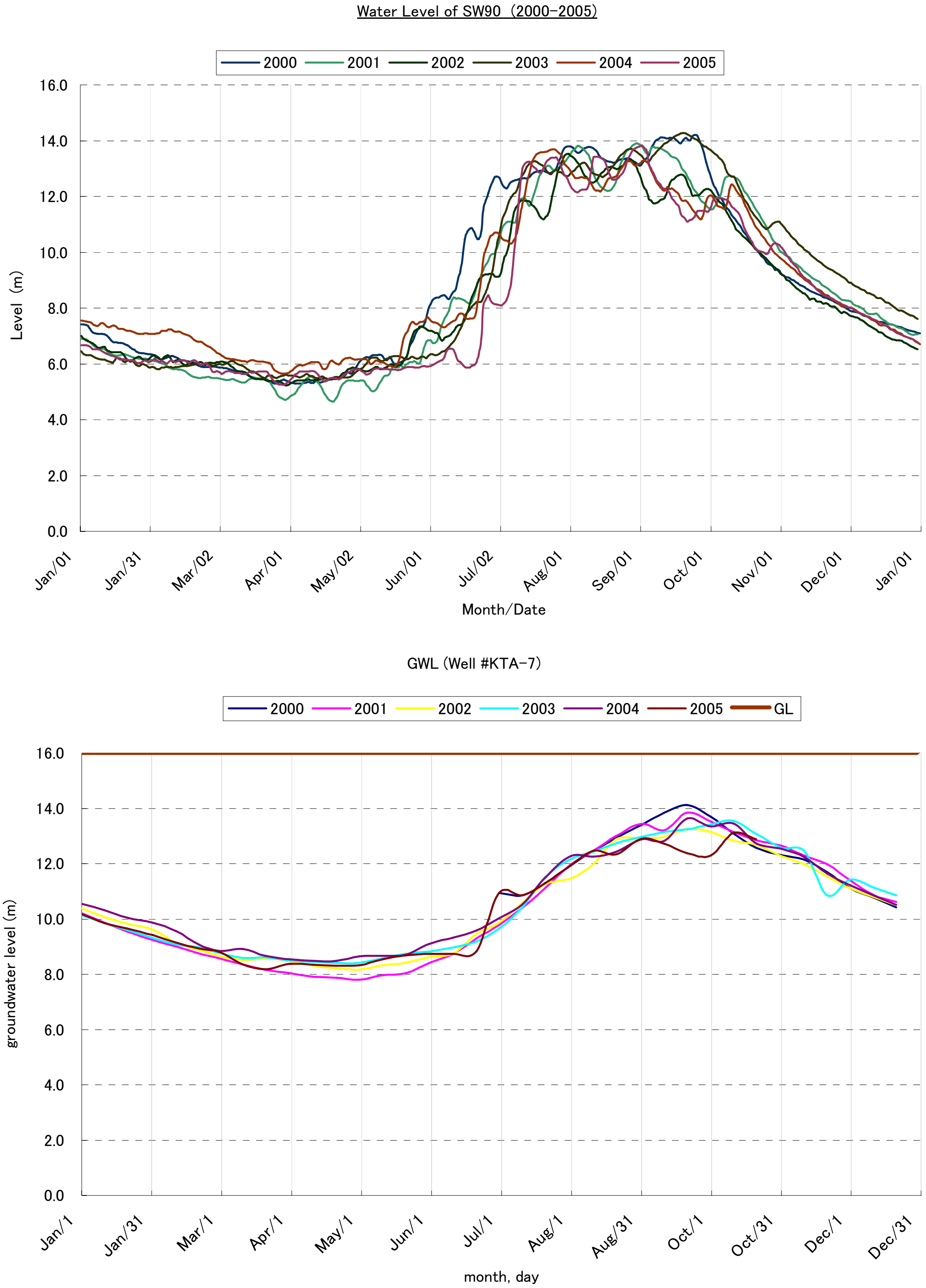


Figure I-4-6-17 Groundwater table of Well No. KTA-7 and Padma River water level

Water table contour maps for both dry and wet season have been drawn for the site area based on the water level monitoring data of observation wells including KTA-7.

In the dry season (April or May) water level elevation reaches to the minimum. Figure I-4-6-18 gives the water table contour map of minimum elevation. The lowest elevation of water level generally occurs in wells nearer to the river.

In the wet season (August or September) groundwater level reaches to its maximum. Figure I-4-6-19 shows the water table contour map of maximum elevation. The highest elevation of water table generally occurs in areas nearer to the river. This indicates that the aquifer is well connected with river.

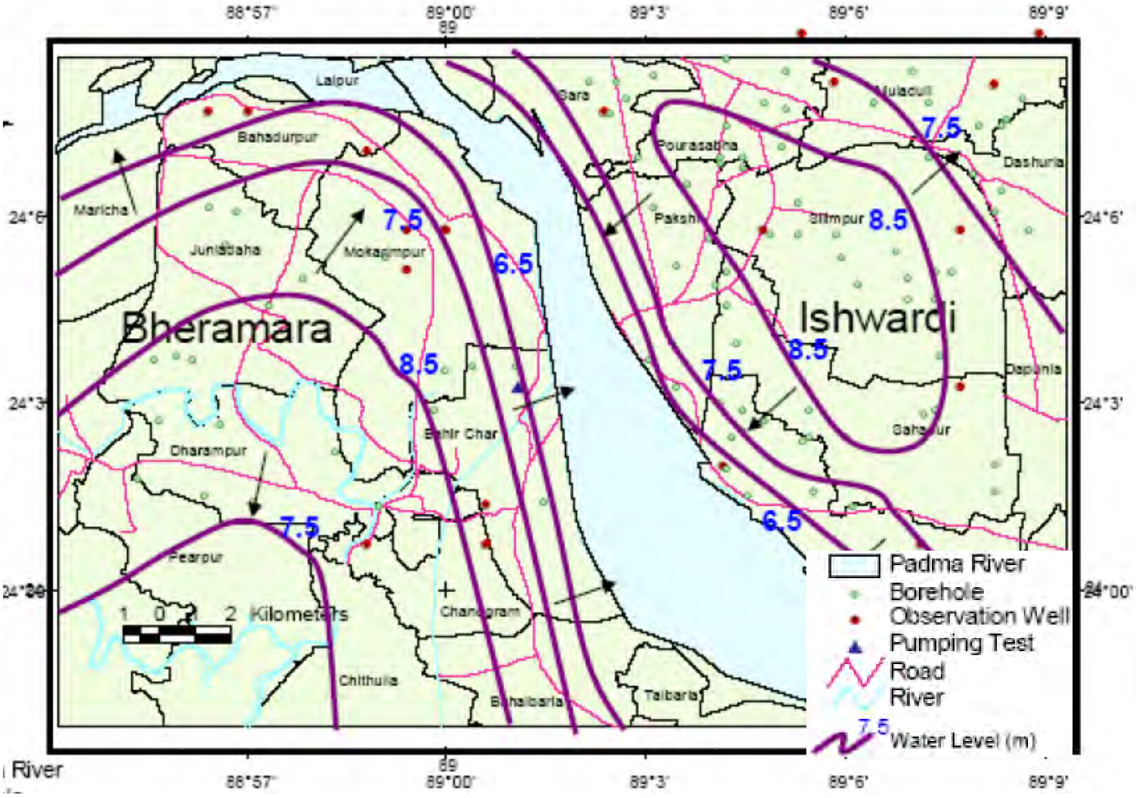


Figure I-4-6-18 Groundwater table contour map of minimum elevation (dry season)

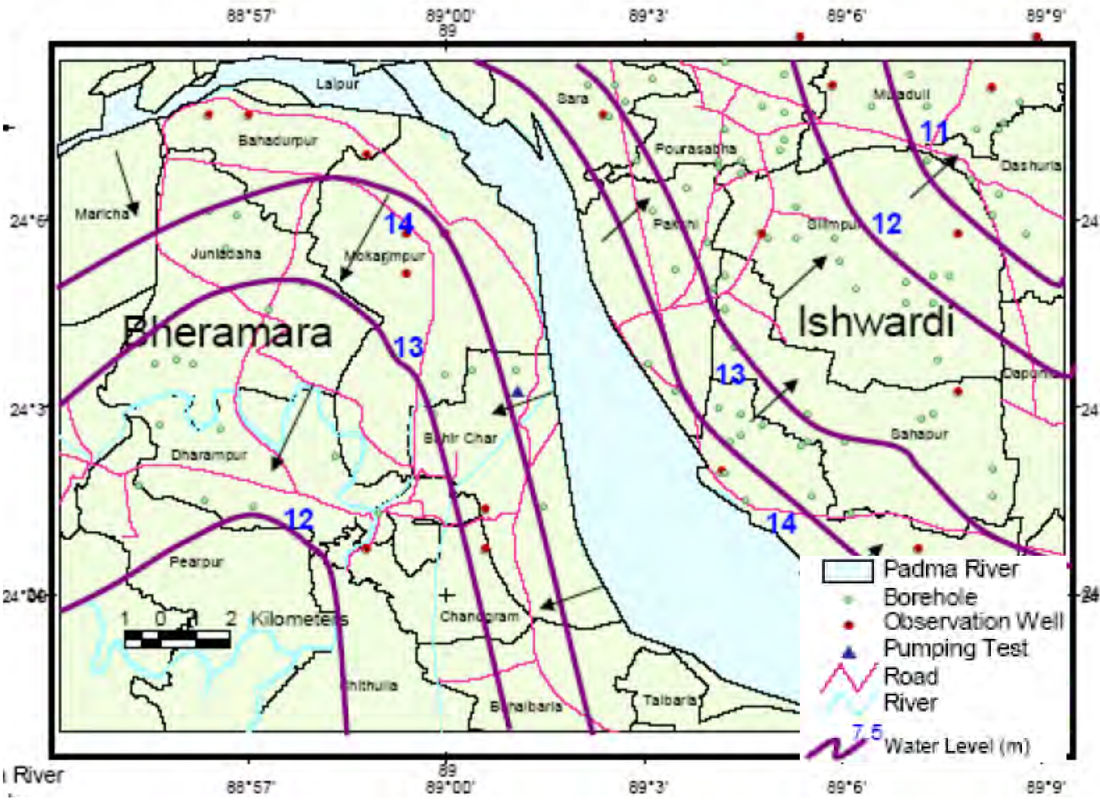


Figure I-4-6-19 Groundwater table contour map of maximum elevation (wet season)

2) existing tubewell survey

Existing tubewell survey was conducted in Bahirchar union.

Following three (3) types of tubewells are running in the union.

- Hand tubewell (HTWs) :
  approx. 0.3*l*/s (0.02m^3/m) of discharge rate, 8-16m of depth and for domestic potable water
- Shallow tubewell (STWs) :
  approx. 15*l*/s (0.9m^3/m) of discharge rate, 40-50m of depth and for irrigation
- Deep tubewell (DTWs) :
  approx. 160m^3/m of discharge rate, 90-100m of depth and for irrigation

HTWs could not suction more than one atmospheric pressure (10m water height) in principle and could operate only in suction limit of approximately 7.5m. Figure I-4-6-17 shows that groundwater table in dry season almost reaches the suction limit of hand tubewell. However, No HTWs which could not suction in dry season was found by this survey.

The result of existing tubewell survey in Bahirchar union is shown in Table I-4-6-5 and tubewell survey map of Bahirchar union is shown in Figure I-4-6-20.

Table I-4-6-5 Result of existing tubewell survey

J.L. No.	Geo code	Locality	Area (km^2)	House Hold (nos)	Population (2001) (head)	HTWs (nos)	STWs (nos)	DTWs (nos)	Water Bodies (nos)
30	**213**	**Chak Bheramara**	**0.81**	**196**	**929**	**151**	**4**	**1**	**11**
165	**307**	**Char Mokarimpur**	**4.04**	**122**	**492**	**79**	**9**		**13**
168	**331**	**Char Ruppur**	**1.28**	**28**	**346**	**18**	**6**		**17**
29	**355**	**Damukdia**	**2.97**	**647**	**3,095**	**415**	**8**	**2**	**12**
		Char Damukdia		181	936	173	3	1	4
		Purba Damukdia		365	1,705	166	3		5
		Paschim Damukdia		101	454	76	2	1	3
166	**902**	**Pashchim Bahirchar**	**12.88**	**3,412**	**16,889**	**2,077**	**5**	**5**	**53**
		Powerhouse Coloney		175	767	28			1
		Bara Dag		279	1,420	277	1	1	4
		68 Para		141	694	109		1	3
		Moslempur		444	2,218	153	1		3
		Munshi Para		241	1,174	185			4
		Sholadag Dakshinpara		552	2,716	437	1		8
		Sholadag		551	2,712	274			9
		Paschim Bahirchar		856	4,334	456	2		13
		Pumphouse Coloney		70	353	112		3	6
		Bengal Para		103	501	46			2

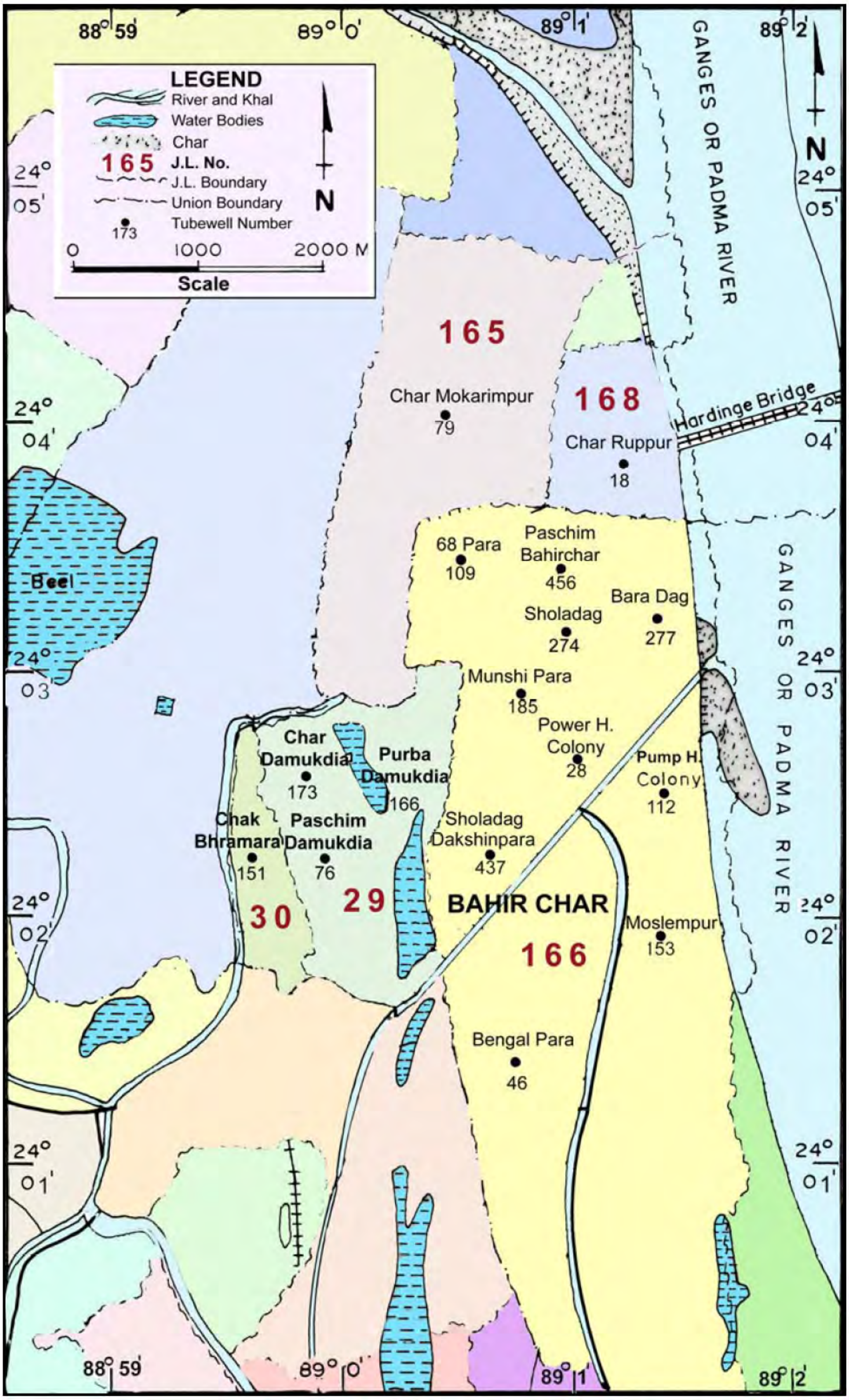


Figure I-4-6-20 Tubewell survey map

3) ground water study

The objective of this study is to assess the potentiality of the aquifer system of Bheramara Upazila and surrounding areas to provide a continuous supply of 1,300m^3/hr for makeup water for the cooling tower. Groundwater models are generally used to determine the potentiality of development of any aquifer. They are representation of a real system or processes that approximately simulates the relevant excitation-response relation of the real world system and offer a quantitative evaluation of groundwater resources through a correct mathematical and physical framework (Bear and Bachmat 1991). The basis for modeling three dimensional groundwater flow forms the integrated modeling package MODFLOW. This is a generalized tool with comprehensive applicability range usable to accommodate the hydrological conditions can be visualized in cross-section or plan view at any time during the development of the model or displaying of the results.

A modeling study has been conducted using MODFLOW model with some of the readily available data of the investigated area. Model geometry was prepared using borelogs of the study area. Aquifer properties were determined by analyzing the pumping test data as mentioned the above and was assigned to the aquifer layers. River boundary, recharge and evapotranspiration boundaries were set up using estimated values. Model calibration was also made using observation well data of well KTA 7. The preliminary model was then used to predict the water level and groundwater conditions after 20 years of pumping at a rate of 31,200m^3/day.

Modeled dry season (May) water table contour map of the study area after 20 years of pumping is shown in the Figure I-4-6-21. Modeled wet season (September) water table contour map of the study area after 20 years of pumping is shown in the Figure I-4-6-22.

Contour of the Figure I-4-6-21 and I-4-6-22 shows ground water level. In dry season (May), parallel contour along Padma River is going down toward the Padma River water level of EL+5.0m and contour in a concentric fashion is going down to less than EL+3.0m centering around the pumping point of the site. In wet season (September), parallel contour along Padma River is adversely going down from the Padma River water level of EL+12.0m and contour in a concentric fashion is going down to less than EL+9.5m centering on the pumping point of the site.

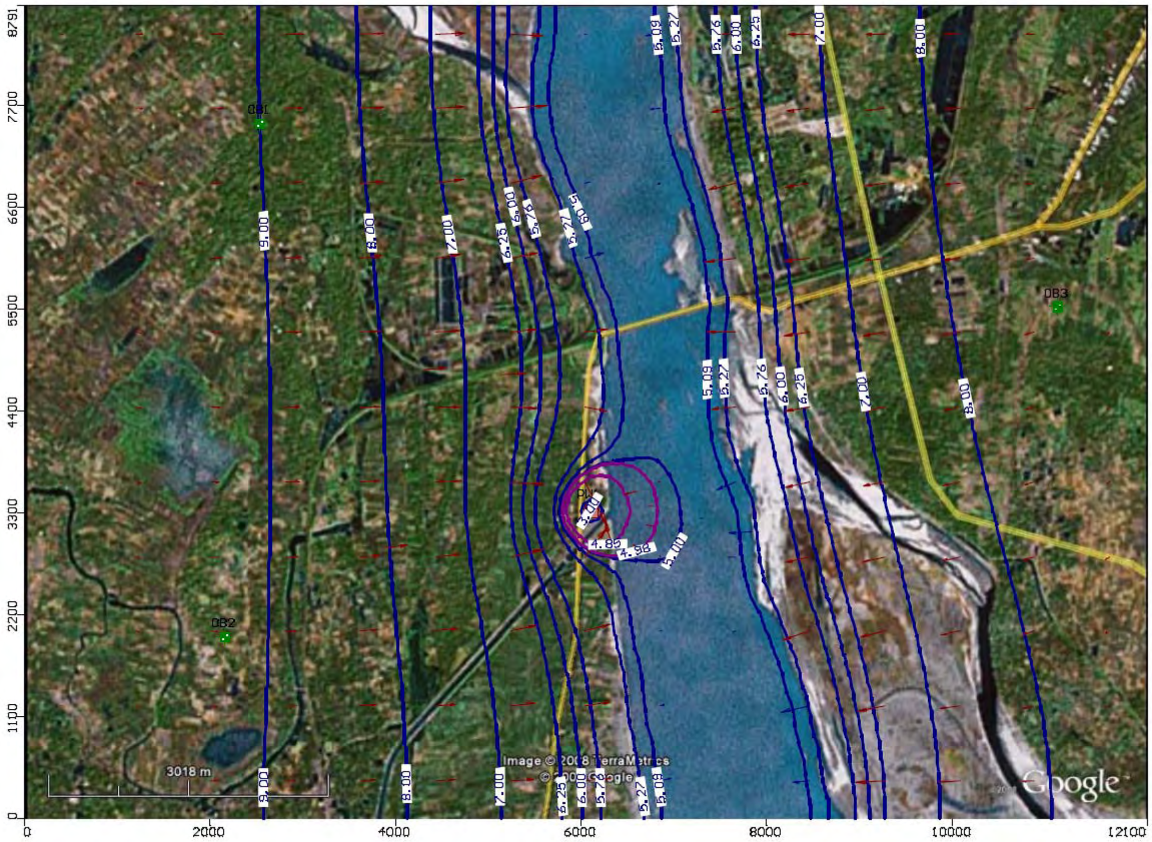


Figure I-4-6-21 Modeled dry season (May) water table contour map

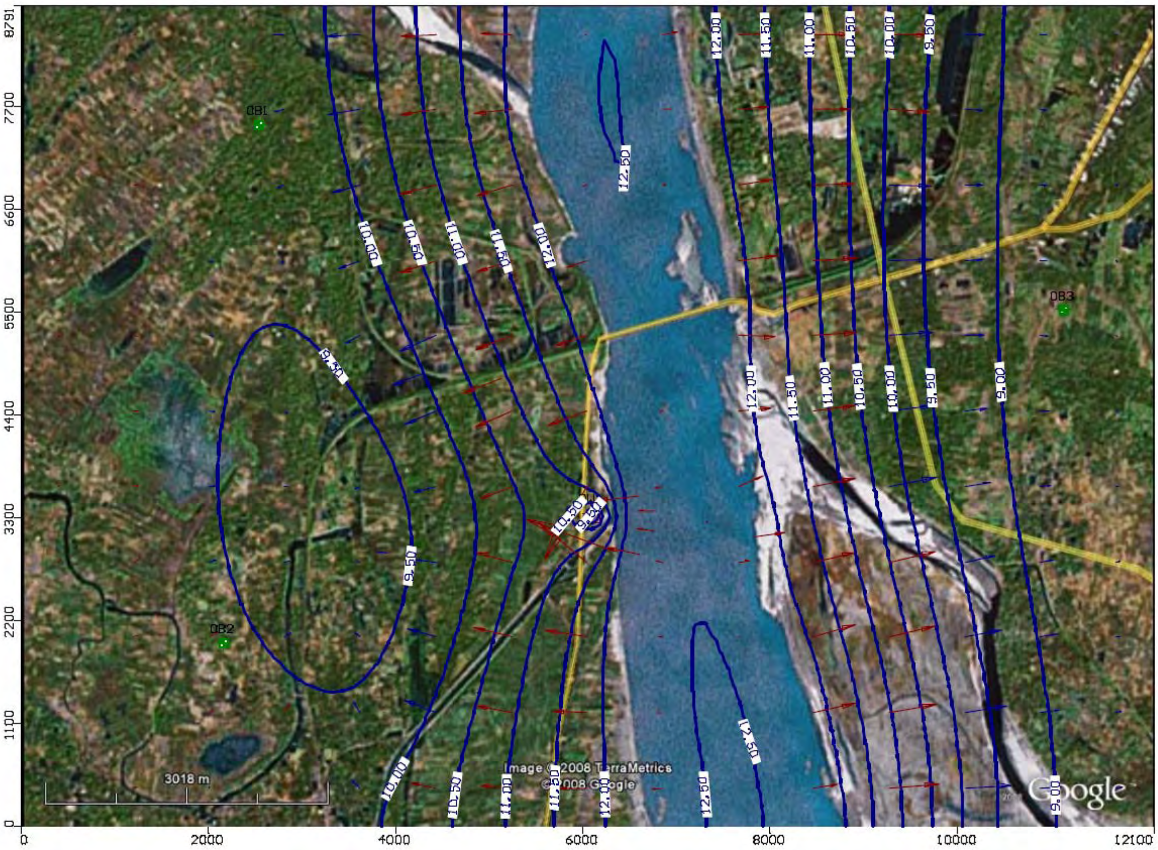


Figure I-4-6-22 Modeled wet season (September) water table contour map

4) findings from groundwater investigation

The preliminary study, which was done based on the invested hydraulical conditions of quifer, suggests that the natural aquifer condition in the study area may be suitable for supplying 31,200m^3/day (=1,300m^3/hr x 24hr/day) of required makeup water for the cooling tower continuously without massive lowering of groundwater table and environmental degradations. Padma River contributes significantly in recharging the aquifer in each year.

The deep well layout study to minimize any impact on existing tube wells and the ground water study based on the above optimum layout were described in Section 4.7.4 Selection of Cooling System (2) Study on Water Intake for Cooling Systems.

Finally, determination of hydraulical conditions of aquifer based on the groundwater investigation result and whole process of groundwater study including modeling, input data/condition and output were reviewed by an expert in field of groundwater hydrology (Ph. D.). The expert concluded that the above investigation and study could be acceptable.

Detailed result of the groundwater investigation/study is shown in the Attachment 2 of Groundwater investigation report and Attachment 3 of Groundwater study report.

4.6.6 Site Environment

Environmental conditions such as ambient temperature, humidity, rainfall, wind direction and wind speed are necessary data for designing of the power plant. In the Study, such data were corrected through document research and were described in Sub-section 7.1.2.

Furthermore, in the Study, present air quality, noise and water quality was measured and it was confirmed that present environmental condition satisfied the environmental standards. Details