2. HYDROLOGICAL AND HYDRAULIC ANALYSIS

2.1 Design Criteria

Bridge: Design water level is 100-year return period water level + 2.0m freeboard (minimum) up to the bottom of bridge girders, in reference to Japanese "Government ordinance for structural standards for river administration facilities".

Motorway Alignment: The elevation at the bottom of sub base level is to be above the 100-year return period of high water level.

Protection of Road Embankment: It is provided for inundated areas except reaches where flow velocity is low. The elevation of protection level is 1.0m above 100-year return period flood level.

2.2 Hydrological Analysis

Hydrological analysis was carried out to estimate the design discharges of streams at motorway crossing points which are required to estimate the hydraulic design outputs at bridges and also water levels. The corresponding catchment area of stream was measured using topographic maps or/and referring the data from nearby gauging stations.

In this section, the discharge around three bridges are re-examined by discharge data which is collected in chapter 4.

2.2.1 Kanchpur Bridge

There is no existing river plan at Kanchpur Bridge and Lahkya river, hence the discharge value for Kanchpur Bridge is estimeted in this study by using recently collected reference data.

There are two water level and discharge measuring station, Demra at Lahkya river and Demra at Balu river which is maintained by BWBD. The discharge at Kanchpur Bridge is sum of discharge of Lahkya and Balu river.

100-year return period discharge at Demra(Lahkya) and Demra(Balu) is estimated according to Japanese Government's technical standard shown in Table 2.2.2 and Table 2.2.3, and the 100-year return period discharge at Kanchpur Bridge is 3480 [m3/s] , shown in Table 2.2.1 and Figure 2.2.1.

Table 2.2.1 100-year return period discharge at Kanchpur Bridge

	Demra(Lahyka) [m3/s]	Demra(Balu) [m3/s]	Kanchpur Bridge [m3/s]
100-year discharge	2596	884	3480

Table 2.2.2 Occurrence Probability for Discharge at Demra(Lahkya) St.

	Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	Ishihara Takase	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM
Return Period in year 2	1705	1776	1772	—	1893	1879	—	—	—	—	—	—	—
3	1891	1953	2019	—	2066	2056	—	—	—	—	—	—	—
5	2125	2151	2311	—	2208	2209	—	—	—	—	—	—	—
10	2443	2399	2703	—	2333	2351	—	—	—	—	—	—	—
20	2761	2638	3106	—	2415	2452	—	—	—	—	—	—	—
30	2947	2775	3349	—	2450	2497	—	—	—	—	—	—	—
50	3182	2946	3665	—	2485	2545	—	—	—	—	—	—	—
80	3397	3103	3965	—	2511	2581	—	—	—	—	—	—	—
100	3500	3177	4112	—	2521	2596	—	—	—	—	—	—	—
150	3686	3312	4383	—	2536	2620	—	—	—	—	—	—	—
200	3818	3407	4581	—	2546	2635	—	—	—	—	—	—	—
400	4136	3637	5072	—	2564	2665	—	—	—	—	—	—	—
SLSC(99%)	0.099	0.066	0.084	—	0.038	0.038	—	—	—	—	—	—	—
Error of Estimation	224	181	266	—	238	216	—	—	—	—	—	—	—

Source: Estimated by the study team according to Japanese Gorvernment technical standard

Table 2.2.3 Occurrence Probability for Discharge at Demra(Balu) St

	Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	Ishihara Takase	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM
Return Period in year 2	337	363	360	378	392	—	—	—	380	—	—	—	—
3	406	429	455	446	460	—	—	—	445	—	—	—	—
5	493	503	571	515	520	—	—	—	511	—	—	—	—
10	611	595	734	592	577	—	—	—	585	—	—	—	—
20	730	684	906	657	616	—	—	—	649	—	—	—	—
30	799	735	1012	691	634	—	—	—	684	—	—	—	—
50	886	798	1153	731	652	—	—	—	725	—	—	—	—
80	966	856	1288	764	665	—	—	—	761	—	—	—	—
100	1004	884	1355	779	671	—	—	—	778	—	—	—	—
150	1073	934	1479	804	680	—	—	—	807	—	—	—	—
200	1122	970	1571	821	685	—	—	—	828	—	—	—	—
400	1240	1055	1801	859	695	—	—	—	875	—	—	—	—
SLSC(99%)	0.068	0.052	0.072	0.061	0.086	—	—	—	0.058	—	—	—	—
Error of Estimation	203	167	479	279	642	—	—	—	78	—	—	—	—

Source: Estimated by the study team according to Japanese Gorvernment technical standard

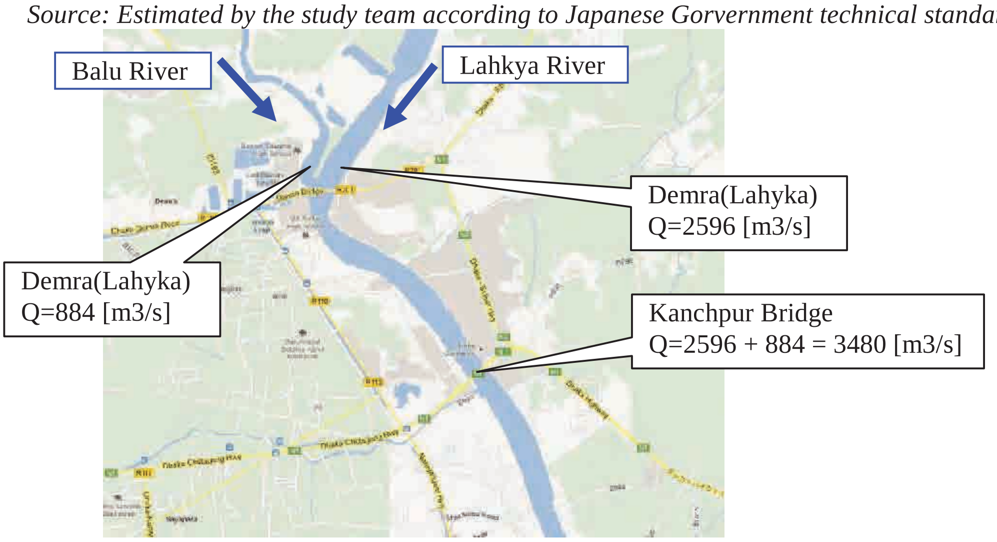
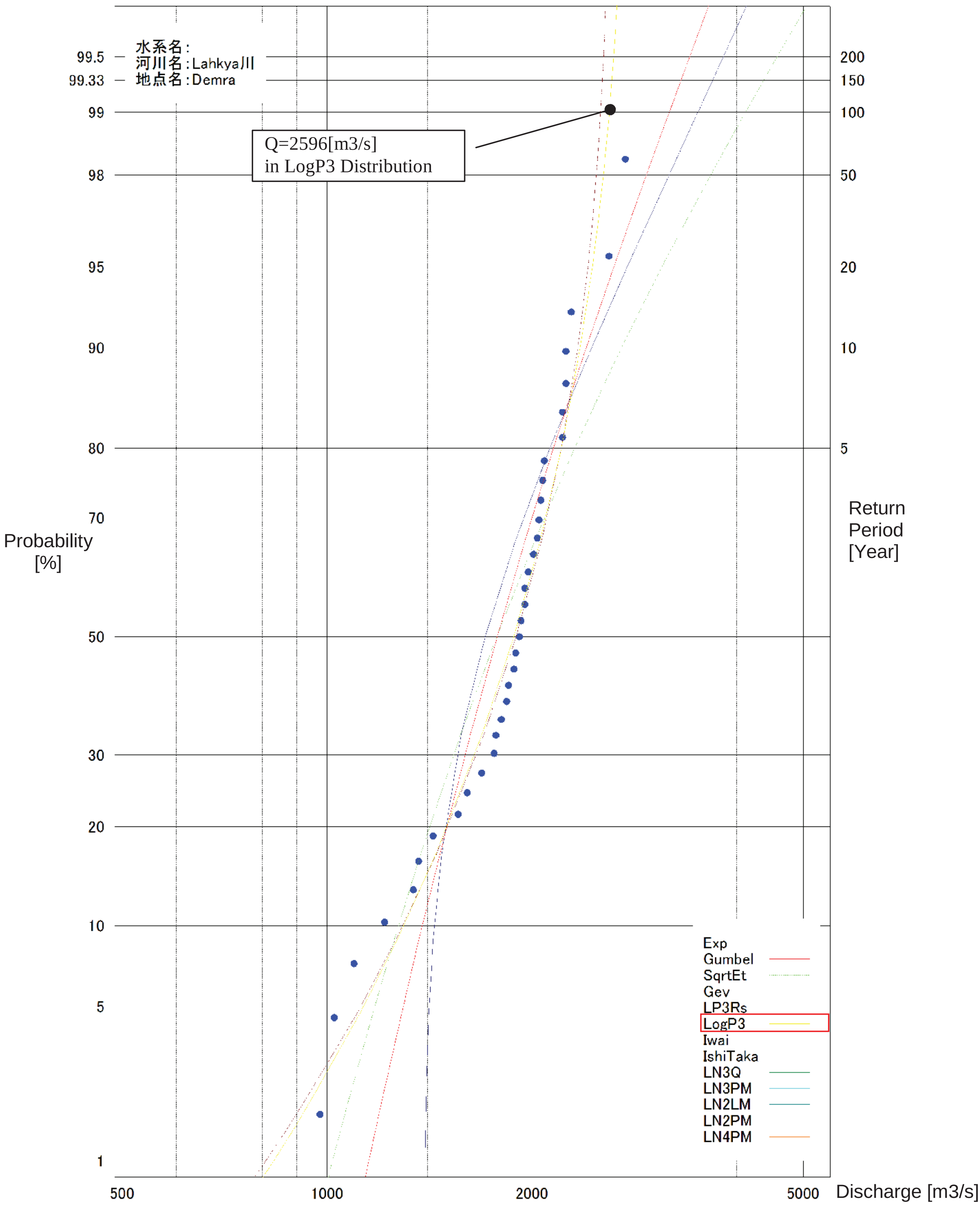
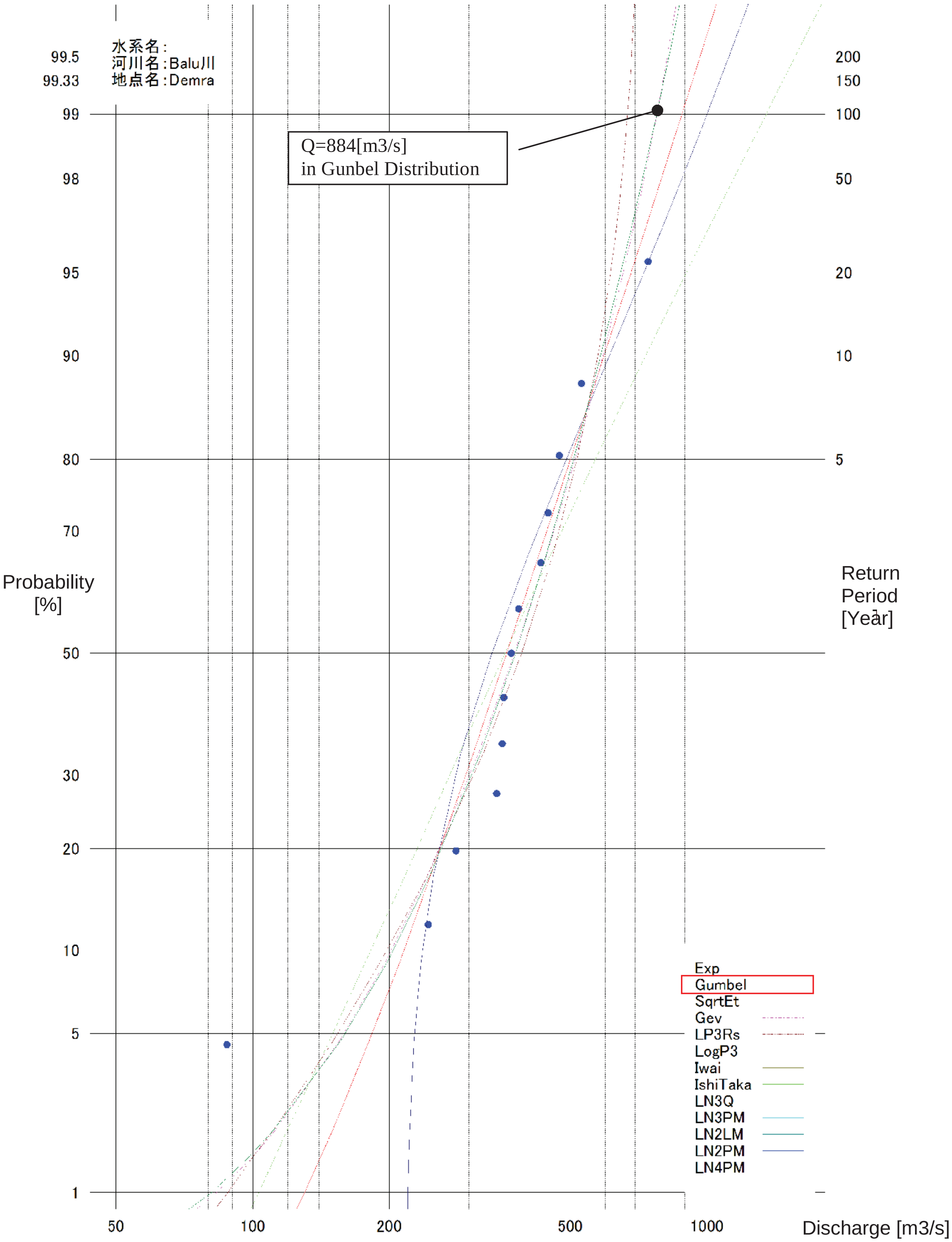


Figure 2.2.1 Discharge measuring station map around Kanchpur Bridge



Source: Estimated by the study team according to Japanese Gorvernment technical standard

Figure 2.2.2 Frequency Curve for Design Discharge (W=1/100) at Demra(Lahkya) St.



Source: Estimated by the study team according to Japanese Gorvernment technical standard

Figure 2.2.3 Frequency Curve for Design Discharge (W=1/100) at Demra(Balu) St.

2.2.2 Meghna & Gumti Bridge

The design discharge should be determined by the maximum number considering the former plan discharge and latast discharge data.

In upper Meghna river, there is only one discharge measuring station at Bhairab Bazar which is maintained by BWBD. Hence, the discharge is estimated according to the ”Feasibility study on Meghna, Gumti Bridges construction project - final report (1985), JICA”. In this report, discharge at Bhairab Bazar is estimated at first, then discharge at Meghna and Gumti Bridge is estimated by considering the flow distribution to main channel and branch of Meguna river and rest of catchment area after Bhairab Bazar Station.

100-year return period discharge at Bhairab Bazar Station is estimated by three method in Table 2.2.4, the maximum discharge is 23700[m3/s] in 1985's JICA Report.

100-year return period discharge at Bridge is estimated below, relationship between discharge and catchment area, discharge distribution is shown in Figure 2.2.5.

- 100 year return period discharge of Meghna Bridge Q= 15,200m^3/sec.
- 100 year return period discharge of Gumti Bridge Q= 12,400m^3/sec.

Table 2.2.4 100-year return period discharge at Bhairab Bazar

	Discharge at Bhirab Bazar [m3/s]	Remarks
1985 JICA report	**23,700**	Adaption in this research
1992 FAP9B	20,300	
Estimated using by collected data	22,848	See Table 2.2.5 and Figure 2.2.4

Table 2.2.5 Occurrence Probability for Discharge at Bhairab Bazar (Estimated)

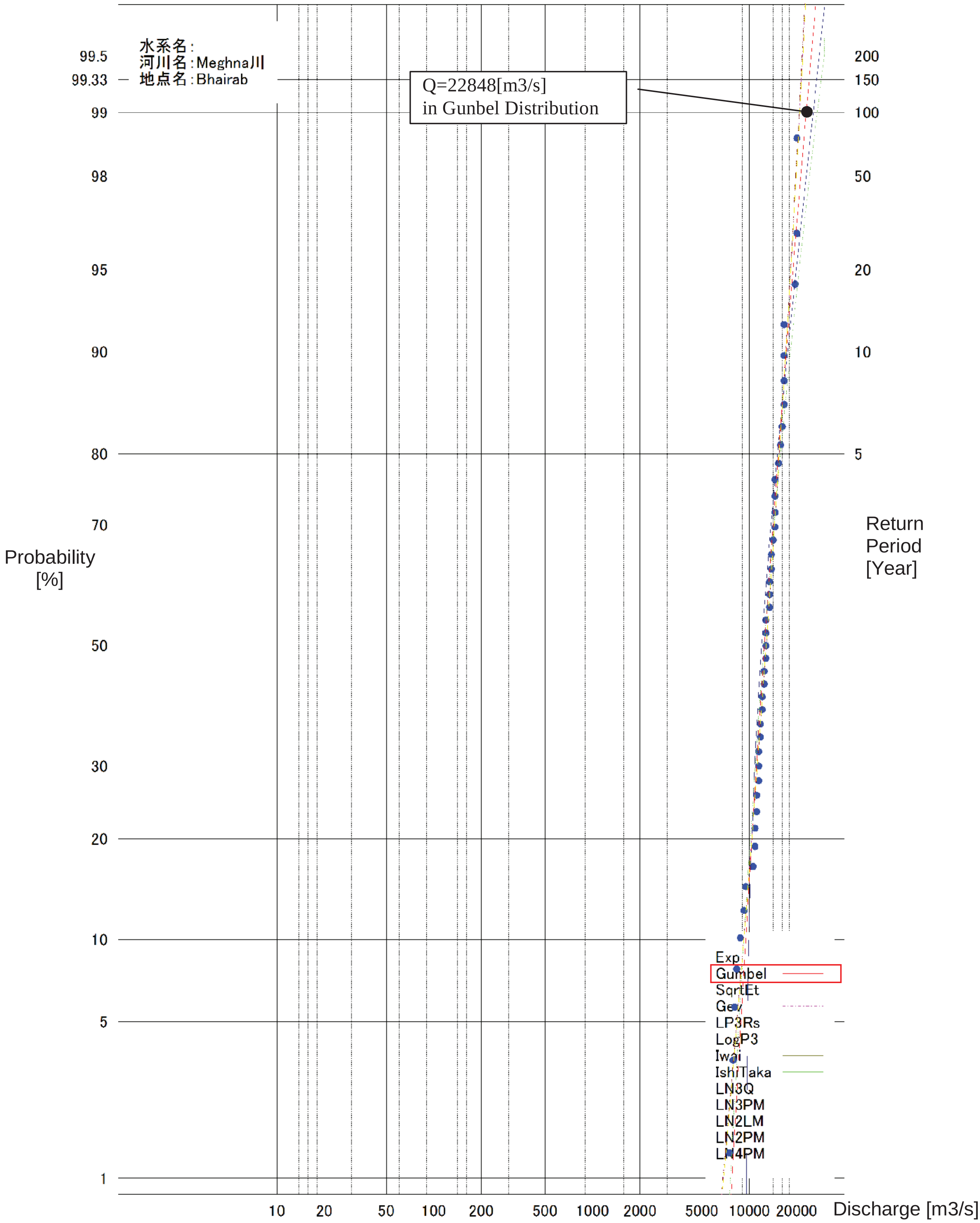
		Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	Ishihara Takase	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM
Return Period in year	2	11888	12417	12348	12715	12771	12739	–	–	–	–	–	–	–
	3	13273	13738	13892	14072	14111	14080	–	–	–	–	–	–	–
	5	15017	15209	15709	15448	15445	15429	–	–	–	–	–	–	–
	10	17385	17058	18136	16994	16924	16943	–	–	–	–	–	–	–
	20	19753	18832	20615	18307	18179	18246	–	–	–	–	–	–	–
	30	21138	19852	22107	18994	18843	18941	–	–	–	–	–	–	–
	50	22882	21128	24040	19789	19621	19763	–	–	–	–	–	–	–
	80	24488	22295	25875	20459	20291	20477	–	–	–	–	–	–	–
	100	25250	22848	26766	20758	20596	20803	–	–	–	–	–	–	–
	150	26635	23851	28419	21274	21129	21378	–	–	–	–	–	–	–
	200	27618	24562	29618	21619	21494	21773	–	–	–	–	–	–	–
	400	29985	26273	30000	22384	22330	22685	–	–	–	–	–	–	–
SLSC(99%)		0.069	0.037	0.053	0.033	0.028	0.028	–	–	–	–	–	–	–
Error of Estimation		1617	1349	1694	1723	1359	1587	–	–	–	–	–	–	–

Source: Estimated by the study team according to Japanese Gorvernment technical standard

Table 2.2.6 Catchment Area of the Meghna River

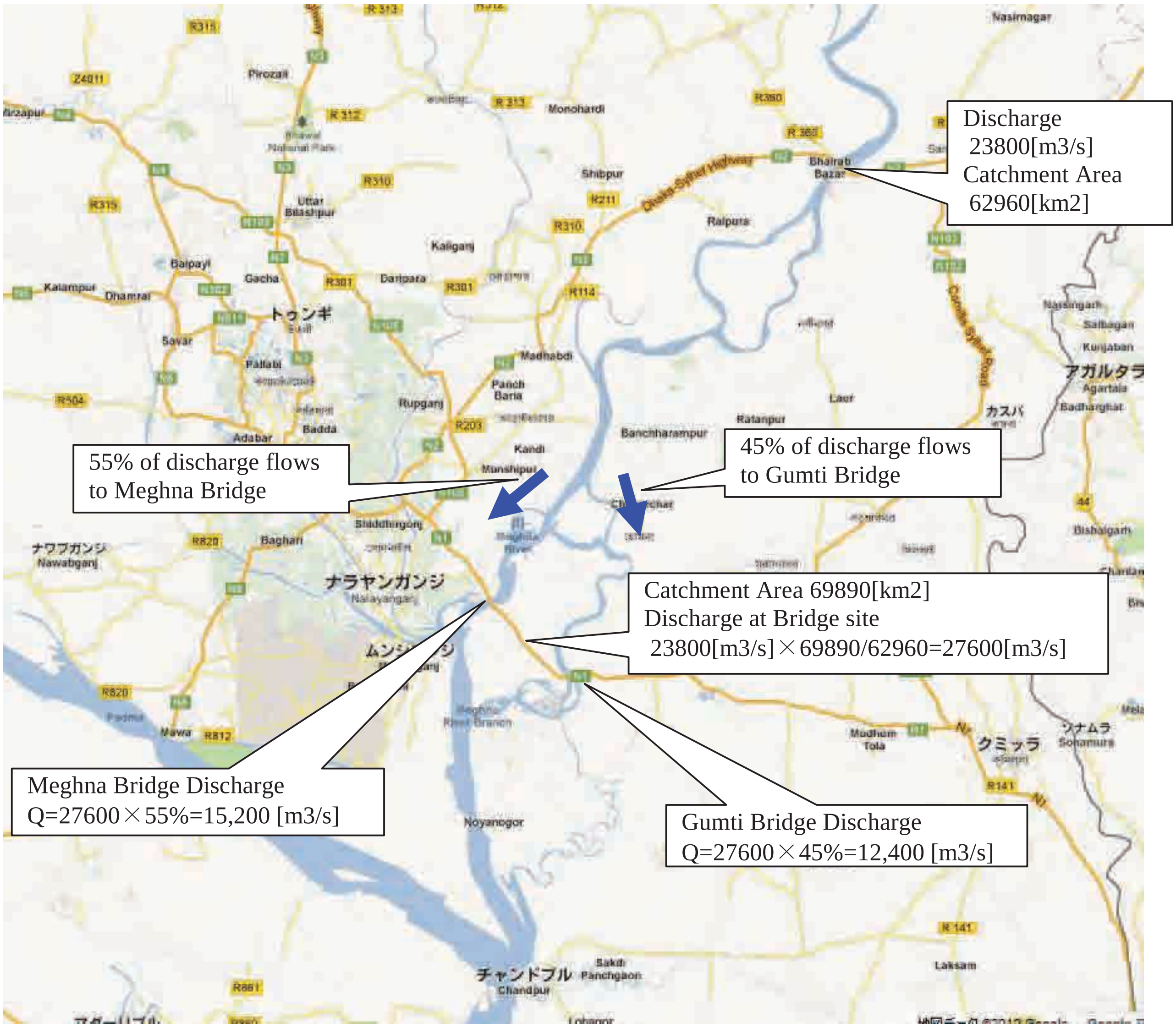
	Outside of Bangladesh[km2]	Inside of Bangladesh[km2]	Total [km2]
Catchment Area at Bhairab Bazar St.	41,390	21,570	62,960
Rest of Catchment Area Between Bridge Site And Bhairab Bazar St.	2,760	4,170	6,930
Catchment Area at Bridge Sites	44,150	25,740	6,9890

Source: 1985's JICA report



Source: Estimated by the study team according to Japanese Gorvernment technical standard

Figure 2.2.4 Frequency Curve for Design Discharge (W=1/100) at Bhairab Bazar St.



Source: Estimated by the study team according to1985's JICA report

Figure 2.2.5 Relationship Between 100-year period Discharge and Catchment Area

2.3 High-Water Level Calculation

2.3.1 Method

Hydraulic design was carried out to obtain the design outputs at the three bridges using Nays2D on i-Ric software platform developed by Professor Yasuyuki SHIMIZU of Hokkaido University(Japan). Nays2D is free software, which is capable of calculating unsteady horizontal two-dimensional river flows and riverbed variation / lateral erosion. The software can be downloaded from website: http:// http://i-ric.org/en/

Water surface profiles are computed from horizontal two-dimentional lattice by solving the 2d-unsteady equation of motion. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion coefficients. Nays2D requires inputs for boundary conditions of upstream discharge and either downstream water level.

The following procedure was adopted in the modelling.

- River profile is set up in the model using the river cross-sections taken at upstream and downstream. Cross section data is used (will be updated by using new survey results)

- Channel roughness “Manning’s n” is adopted according to the bed material diameter d=0.167[mm]. Manning's n value for d=0.167[mm] is n=0.020 according to Japanese Gorvernment's Technical Standard, that nunber is applied for main river and flood plain.

- The upstream boundary condition is applied for 100-year return period discharge for each bridges.

- The downstream boundary condition is applied for 100-year return period watar level for each bridges which is estimated according to Japanese Gorvernment's Technical Standard, shown in Table 2.3.2 to Table 2.3.4 and Figure 2.3.2 to Figure 2.3.4.

The boundary conditon for numerical model simulation is are summarized in Table 2.3.1. Water Level measured at BWDB's station is transformed from PWD.m to R.L.m by relationship shown in Figure 2.3.1.

Table 2.3.1 Boundary Condition for Hydraulic Analysis at Each Bridge (100-Year Return Period)

Bridge Site	Discharge (m3/s)			Water Level					
	Measured Station		Upstream Discharge [m3/s]	Measured Station	[PWD.m]	[MSL.m]	Bed slope	Distance from station [m]	Downstream Water Level [MSL.m]
Kanchpur	Demra(Lahkya)	2596	3,480	Demra(Lahkya)	7.47	7.01	0.0001	4,180	6.59
	Demra(Balu)	884							
Meghna	Bhirab bazar	23700	15,200	Meghna Ferryghat	6.98	6.52	0.0001	1,332	6.39
Gumti			12,400	Daudkandi	7.36	6.90	0.0001	900	6.81

Source: Estimated by the study team according to Japanese Government technical standard

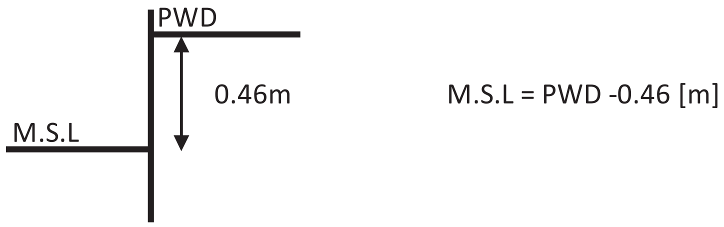


Figure 2.3.1 Relationship between BWDB's PWD.m and M.S.L.m

Table 2.3.2 Occurrence Probability for Water Level at Meghna Ferryghat St. (unit:PWD.m)

		Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	Ishihara Takase	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM
Return Period in year	2	5478	5549	5544	5551	—	5546	—	5546	5545	5547	—	—	—
	3	5664	5727	5718	5729	—	5724	—	5721	5721	5722	—	—	—
	5	5898	5924	5914	5926	—	5923	—	5916	5919	5918	—	—	—
	10	6216	6172	6165	6172	—	6171	—	6162	6167	6163	—	—	—
	20	6534	6410	6410	6407	—	6406	—	6399	6407	6398	—	—	—
	30	6720	6547	6554	6542	—	6542	—	6535	6545	6533	—	—	—
	50	6954	6719	6735	6709	—	6710	—	6706	6719	6702	—	—	—
	80	7170	6875	6903	6862	—	6865	—	6864	6880	6859	—	—	—
	100	7272	6949	6984	6934	—	6939	—	6939	6956	6933	—	—	—
	150	7458	7084	7131	7064	—	7073	—	7077	7096	7068	—	—	—
	200	7590	7180	7236	7156	—	7168	—	7175	7196	7165	—	—	—
	400	7907	7409	7492	7378	—	7399	—	7413	7440	7400	—	—	—
SLSC(99%)		0.046	0.030	0.029	0.030	—	0.030	—	0.029	0.028	0.028	—	—	—
Error of Estimation		284	239	215	391	—	285	—	266	304	265	—	—	—

Source: Estimated by the study team according to Japanese Gorvernment technical standard

Table 2.3.3 Occurrence Probability for Water Level at Daudkandi St. (unit:PWD.m)

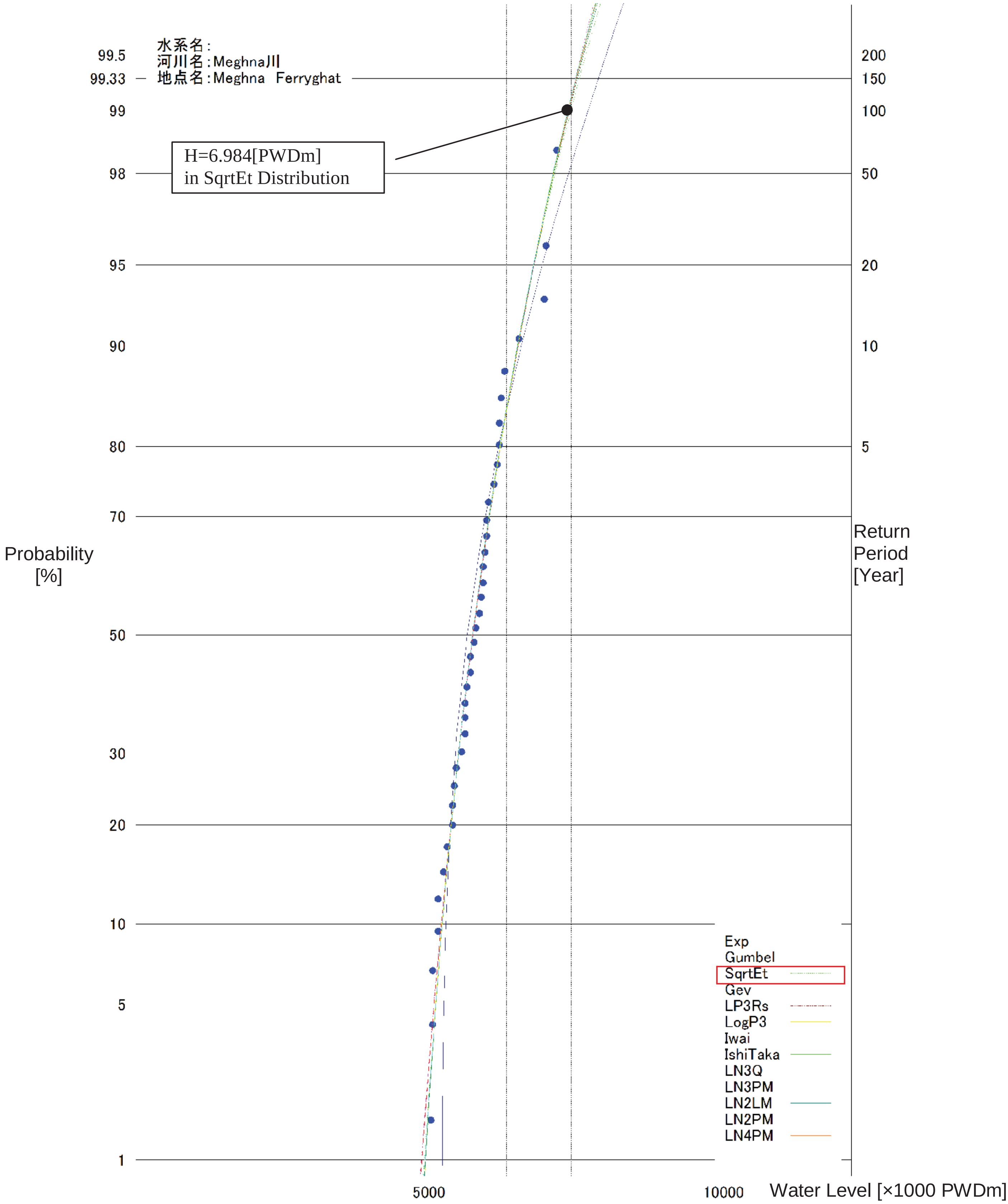
		Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	Ishihara Takase	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM
Return Period in year	2	5360	5456	5459	5500	—	—	5520	5512	5530	5512	5524	5524	—
	3	5612	5697	5731	5747	—	—	5760	5752	5766	5753	5765	5763	—
	5	5930	5964	6042	6001	—	—	6000	5996	5998	5996	6004	6001	—
	10	6361	6301	6444	6293	—	—	6270	6273	6255	6273	6272	6267	—
	20	6792	6624	6841	6547	—	—	6503	6516	6474	6515	6501	6495	—
	30	7044	6810	7074	6682	—	—	6628	6647	6590	6646	6624	6617	—
	50	7361	7042	7371	6841	—	—	6778	6804	6728	6802	6770	6762	—
	80	7654	7254	7649	6977	—	—	6908	6942	6847	6939	6897	6888	—
	100	7792	7355	7782	7039	—	—	6968	7006	6901	7003	6955	6945	—
	150	8045	7538	8026	7146	—	—	7074	7119	6997	7115	7058	7048	—
	200	8223	7667	8201	7218	—	—	7147	7198	7063	7194	7129	7118	—
	400	8655	7979	8630	7381	—	—	7318	7382	7216	7376	7294	7282	—
SLSC(99%)		0.068	0.036	0.046	0.029	—	—	0.024	0.024	0.026	0.024	0.024	0.025	—
Error of Estimation		288	241	331	290	—	—	186	205	197	203	214	200	—

Source: Estimated by the study team according to Japanese Gorvernment technical standard

Table 2.3.4 Occurrence Probability for Water Level at Demra(Lahkya) St (unit:PWD.m)

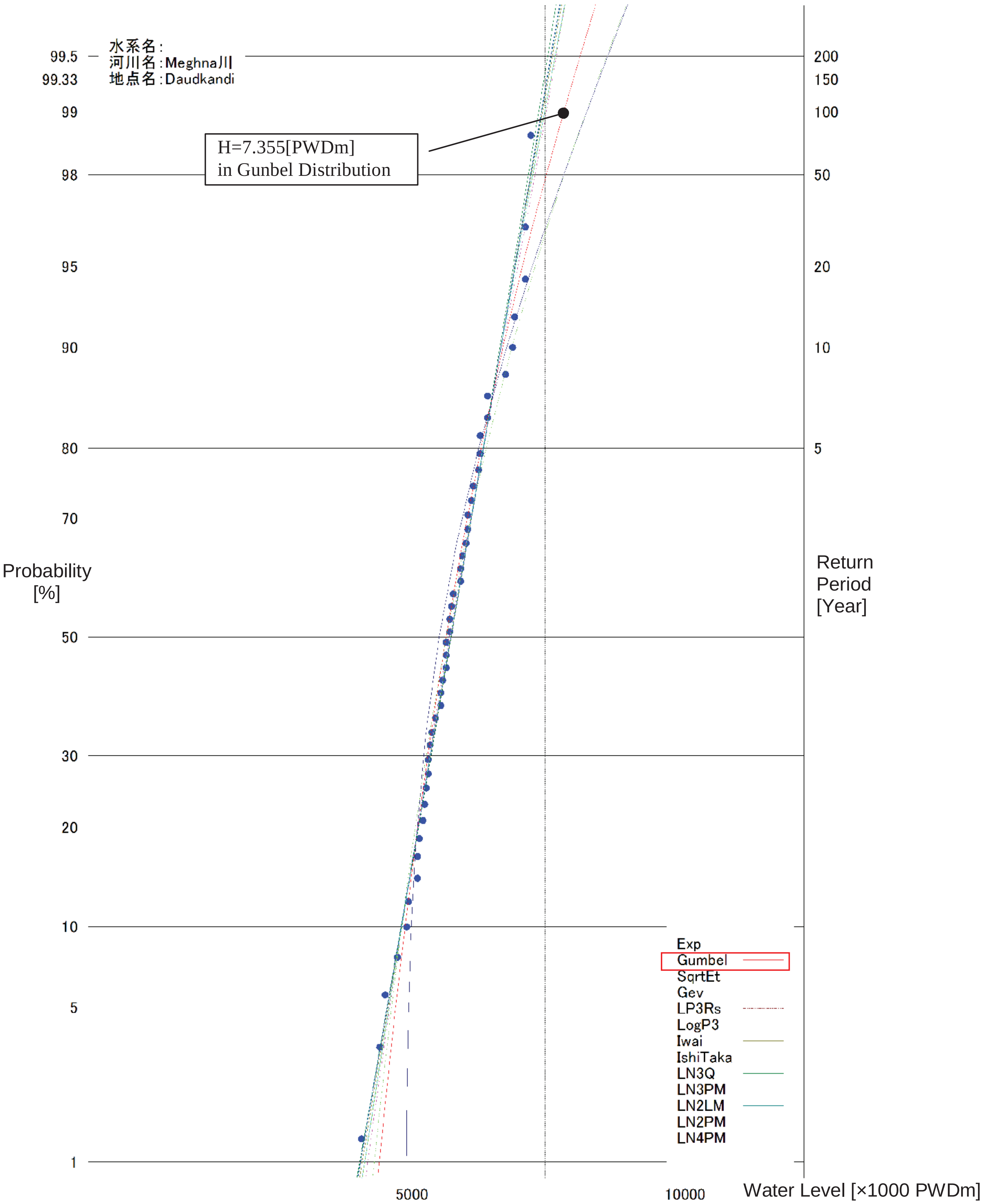
		Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	Ishihara Takase	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM
Return Period in year	2	5663	5745	5740	5761	—	5757	5765	5755	5766	5757	—	—	—
	3	5877	5949	5947	5968	—	5962	5969	5959	5968	5961	—	—	—
	5	6146	6176	6181	6191	—	6185	6188	6180	6182	6182	—	—	—
	10	6512	6461	6482	6460	—	6455	6450	6450	6439	6450	—	—	—
	20	6878	6735	6777	6707	—	6706	6691	6702	6675	6700	—	—	—
	30	7091	6893	6950	6844	—	6848	6826	6844	6806	6841	—	—	—
	50	7361	7090	7169	7010	—	7023	6992	7021	6967	7016	—	—	—
	80	7609	7270	7372	7158	—	7182	7141	7181	7113	7174	—	—	—
	100	7727	7356	7469	7227	—	7257	7211	7257	7181	7249	—	—	—
	150	7940	7511	7647	7349	—	7392	7338	7394	7303	7384	—	—	—
	200	8092	7620	7774	7434	—	7488	7427	7491	7390	7479	—	—	—
	400	8458	7885	8085	7632	—	7718	7640	7724	7596	7709	—	—	—
SLSC(99%)		0.052	0.028	0.029	0.030	—	0.028	0.026	0.026	0.027	0.026	—	—	—
Error of Estimation		291	244	237	390	—	290	399	274	276	271	—	—	—

Source: Estimated by the study team according to Japanese Gorvernment technical standard



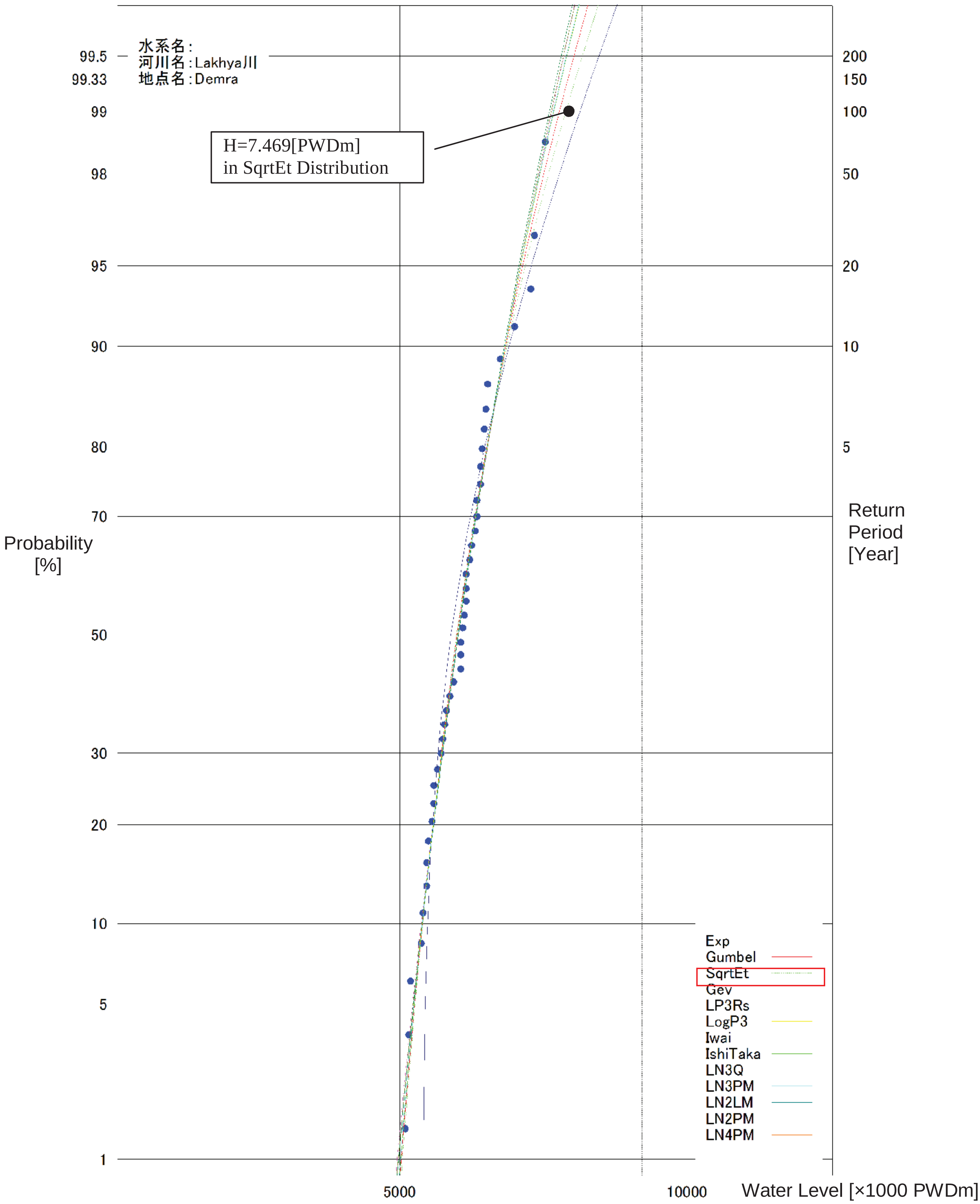
Source: Estimated by the study team according to Japanese Gorvernment technical standard

Figure 2.3.2 Frequency Curve for Design Water Level (W=1/100) at Meghna Ferryghat St.



Source: Estimated by the study team according to Japanese Gorvernment technical standard

Figure 2.3.3 Frequency Curve for Design Water Level (W=1/100) at Daudkandi St.



Source: Estimated by the study team according to Japanese Gorvernment technical standard

Figure 2.3.4 Frequency Curve for Design Water Level (W=1/100) at Demra(Lahkya) St.

2.3.2 Numerical Simulation Results in 100-year return period condition

To estimate scour around new bridge pier, hydraulic values in 100-year return period flood is calculated by Nays2D software for each bridges.

(1) Kanchpur Bridge

The hydraulic value of numerical analysis results at bridge center line in 100-year return period discharge is shown in Table 2.3.5, and cross section bed profile, water level, current velocity and water depth at same line is shown in Figure 2.3.5.

Contour map of bed elevation, current velocity, water depth, and water surface level in 100-year return period flood in this model is shown in *Source: Estimated by the study team*
Figure 2.3.6 and *Source: Estimated by the study team*

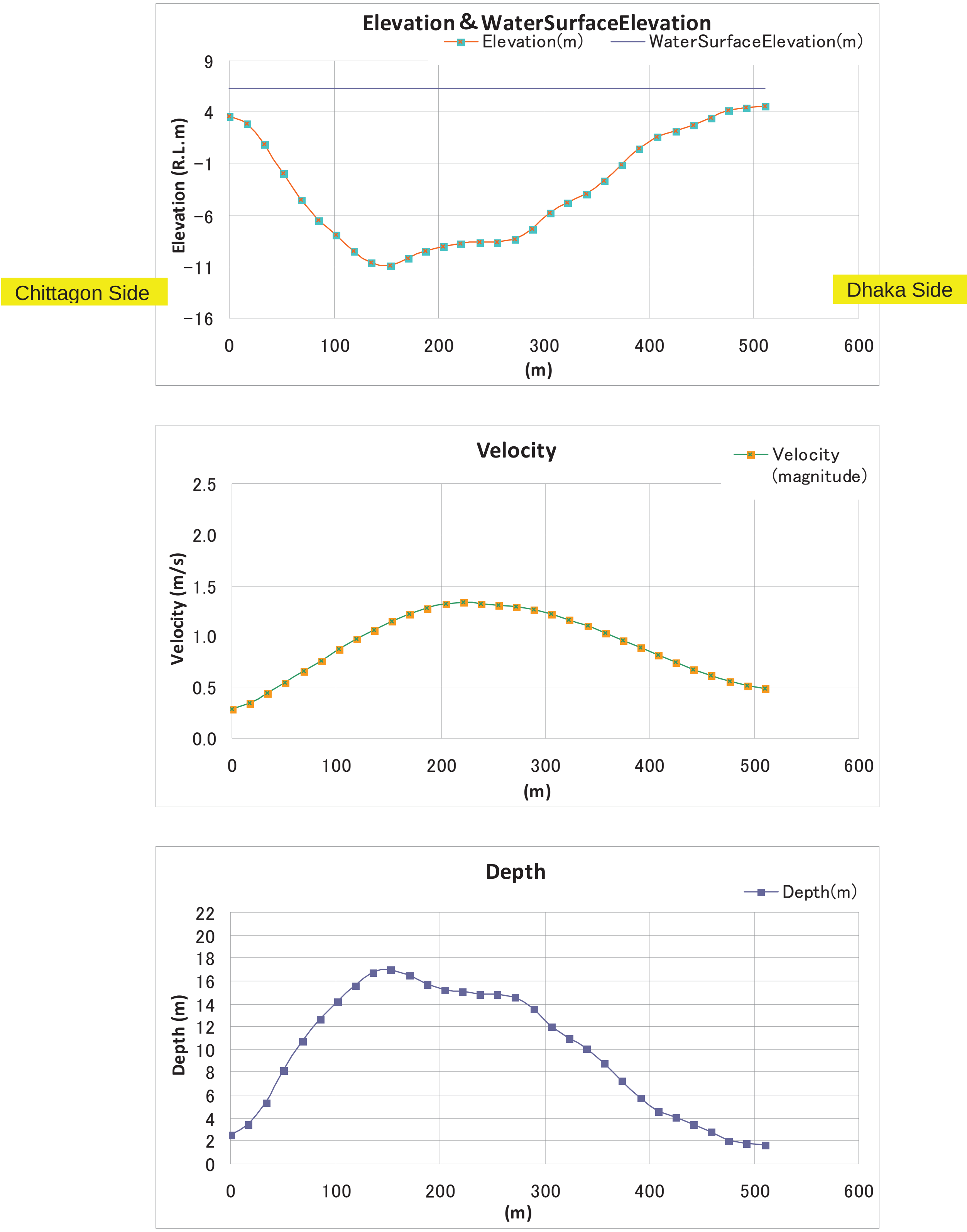
Figure 2.3.7.

The hydraulic value shown in Table 2.3.5 will be used to estimate the local scouring around each pier at Kanchpur Bridge.

Table 2.3.5 Numerical Analysis Result in 100-year return period at Kanchpur Bridge

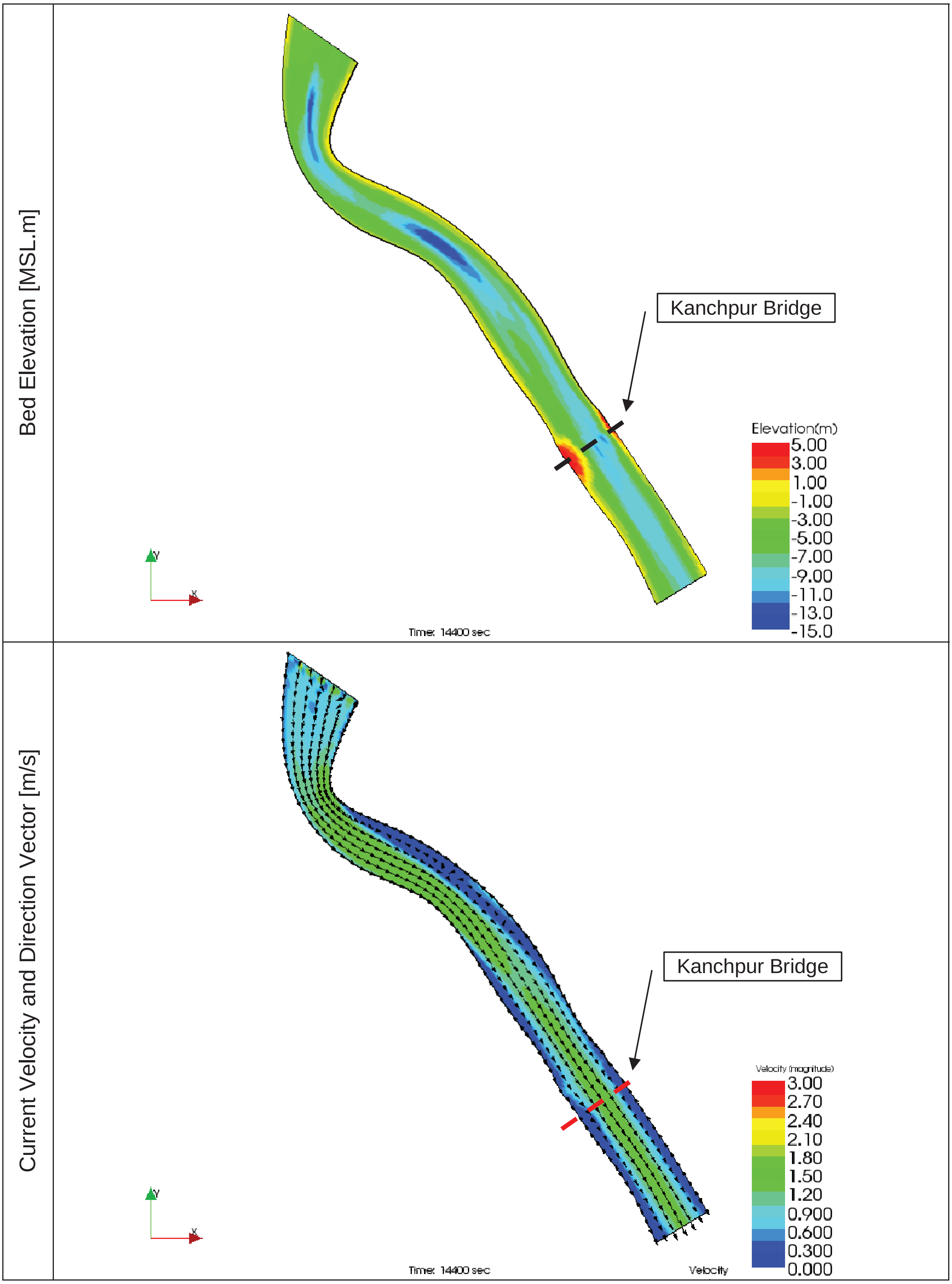
Pier No	Water Depth [MSL.m]	Bed Elevation [MSL.m]	Water Elevation [MSL.m]	Current Velocity [m/s]
A1	1.65	4.60	6.25	0.49
P1	2.76	3.49	6.25	0.62
P2	5.76	0.48	6.24	0.89
P3	12.04	-5.80	6.24	1.22
P4	14.90	-8.66	6.23	1.33
P5	16.44	-10.20	6.24	1.23
P6	12.67	-6.42	6.25	0.77
P7	2.61	3.65	6.26	0.28
A2	2.61	3.65	6.26	0.28

Source: Estimated by the study team



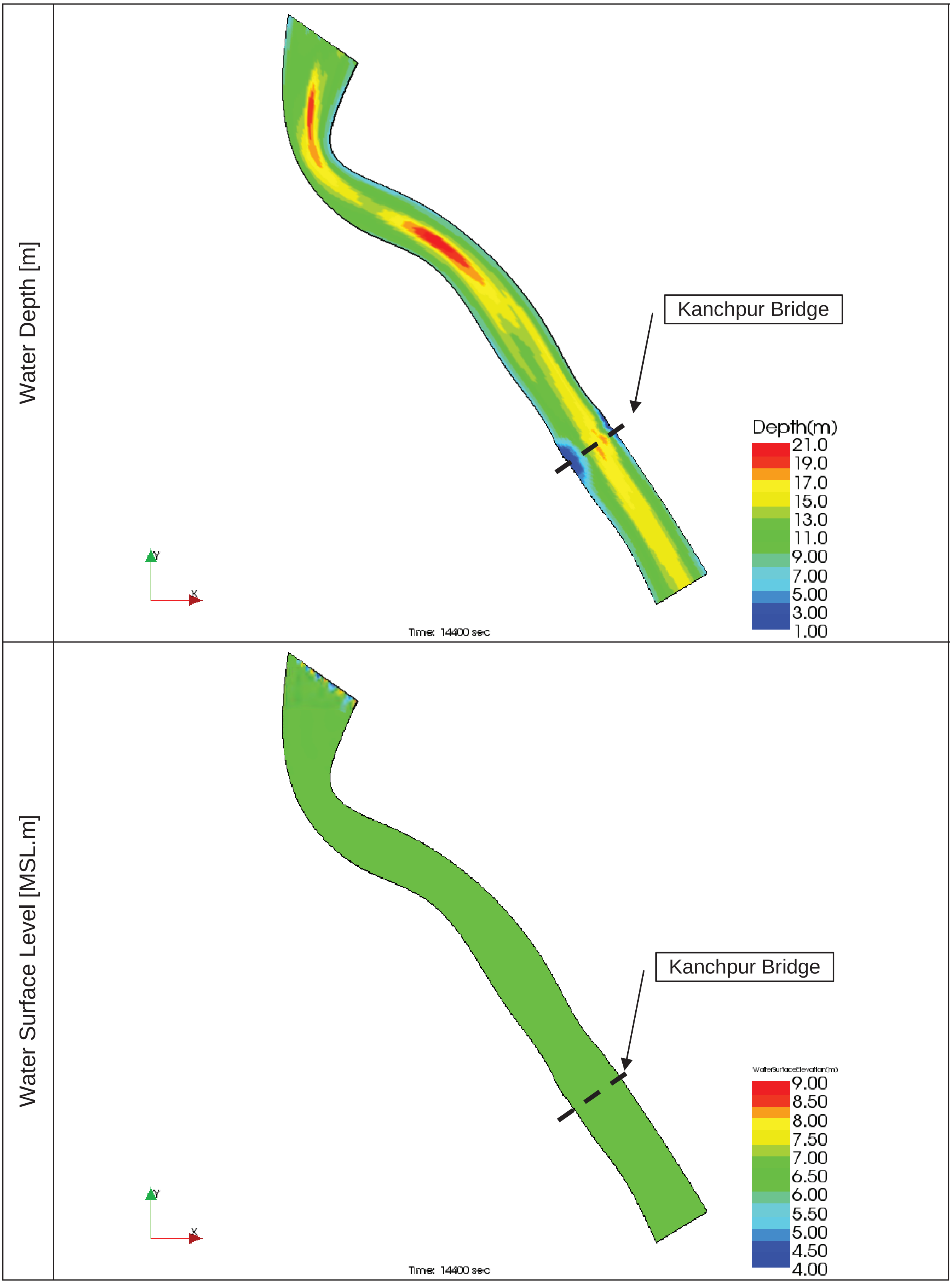
Source: Estimated by the study team

Figure 2.3.5 Numerical Analysis Result along Bridge Axis at Kanchpur Bridge (100-year)



Source: Estimated by the study team

Figure 2.3.6 Bed Elevation and Current Velocity Contour around Kanchpur Bridge (100-year)



Source: Estimated by the study team

Figure 2.3.7 Water Depth and Water Surface Level around Kanchpur Bridge (100-year)

(2) Meghna Bridge

The hydraulic value of numerical analysis results at bridge center line in 100-year return period discharge is shown in Table 2.3.6, and cross section bed profile, water level, current velocity and water depth at same line is shown in Figure 2.3.8.

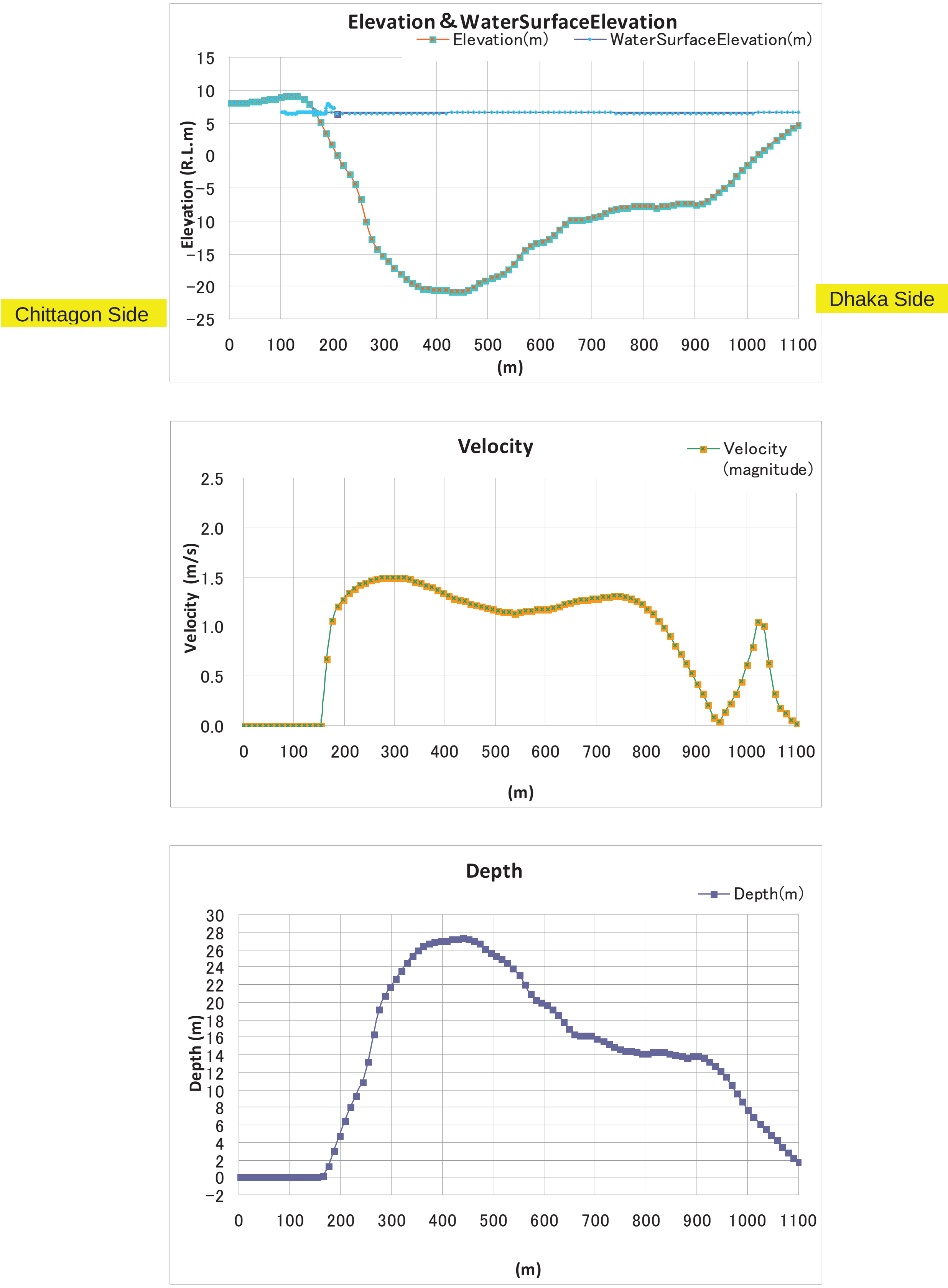
Contour map of bed elevation, current velocity, water depth, and water surface level in 100-year return period flood in this model is shown in Figure 2.3.9 and Figure 2.3.10.

The hydraulic value shown in Table 2.3.6 will be used to estimate the local scouring around each pier at Meghna Bridge.

Table 2.3.6 Numerical Analysis Result in 100-year return period at Meghna Bridge

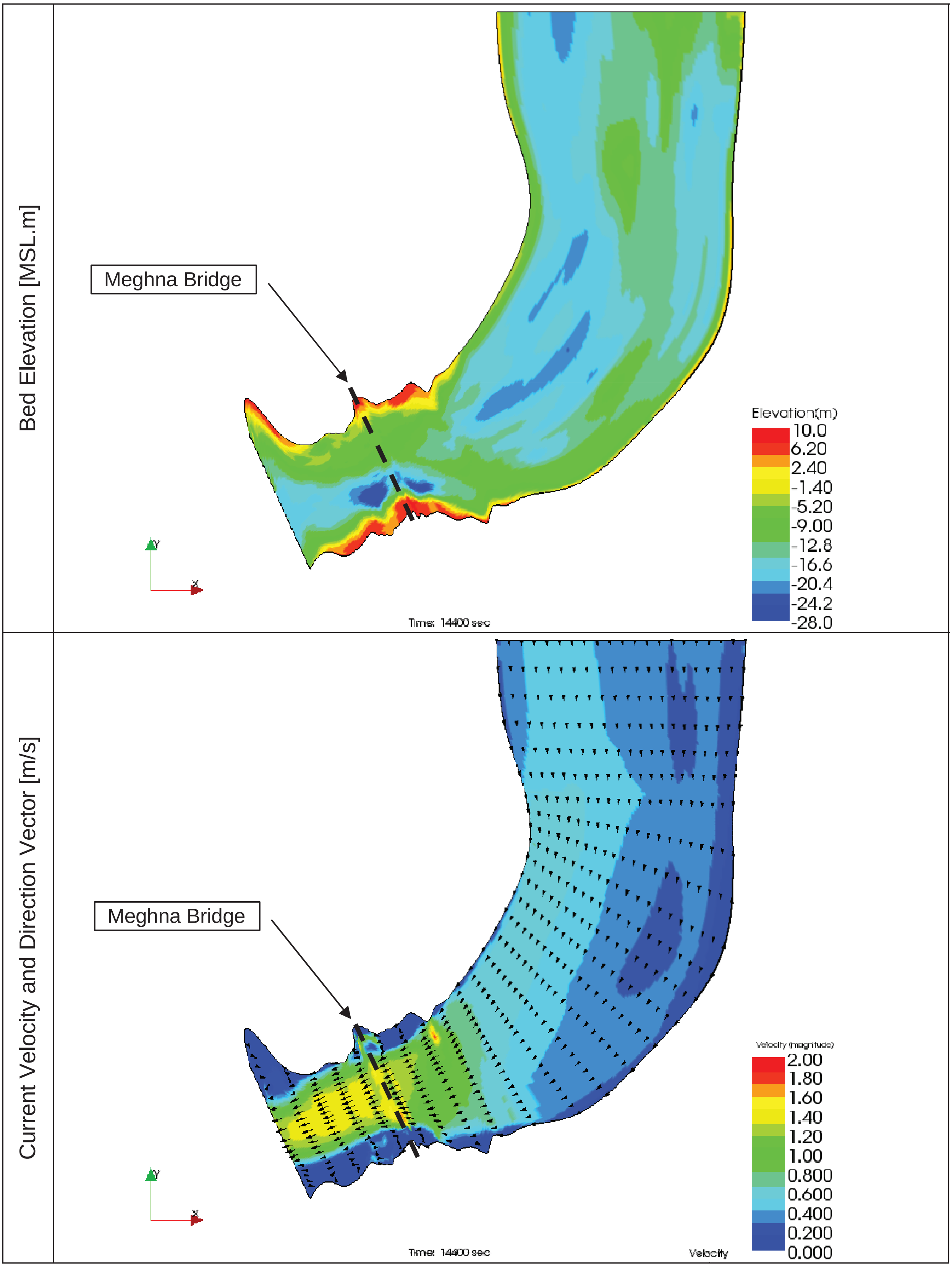
Pier No	Water Depth [MSL.m]	Bed Elevation [MSL.m]	Water Elevation [MSL.m]	Current Velocity [m/s]
A1	1.80	4.69	6.50	0.02
P1	2.87	3.62	6.50	0.13
P2	4.86	1.63	6.49	0.62
P3	7.78	-1.33	6.46	0.61
P4	13.91	-7.45	6.45	0.42
P5	14.27	-7.81	6.47	1.13
P6	15.23	-8.76	6.48	1.30
P7	18.54	-12.05	6.48	1.21
P8	23.89	-17.40	6.49	1.14
P9	27.23	-20.76	6.48	1.23
P10	25.97	-19.51	6.46	1.44
P11	16.41	-9.95	6.46	1.47
P12	1.36	5.11	6.48	1.07
A2	0.00	9.13	9.13	0.00

Source: Estimated by the study team



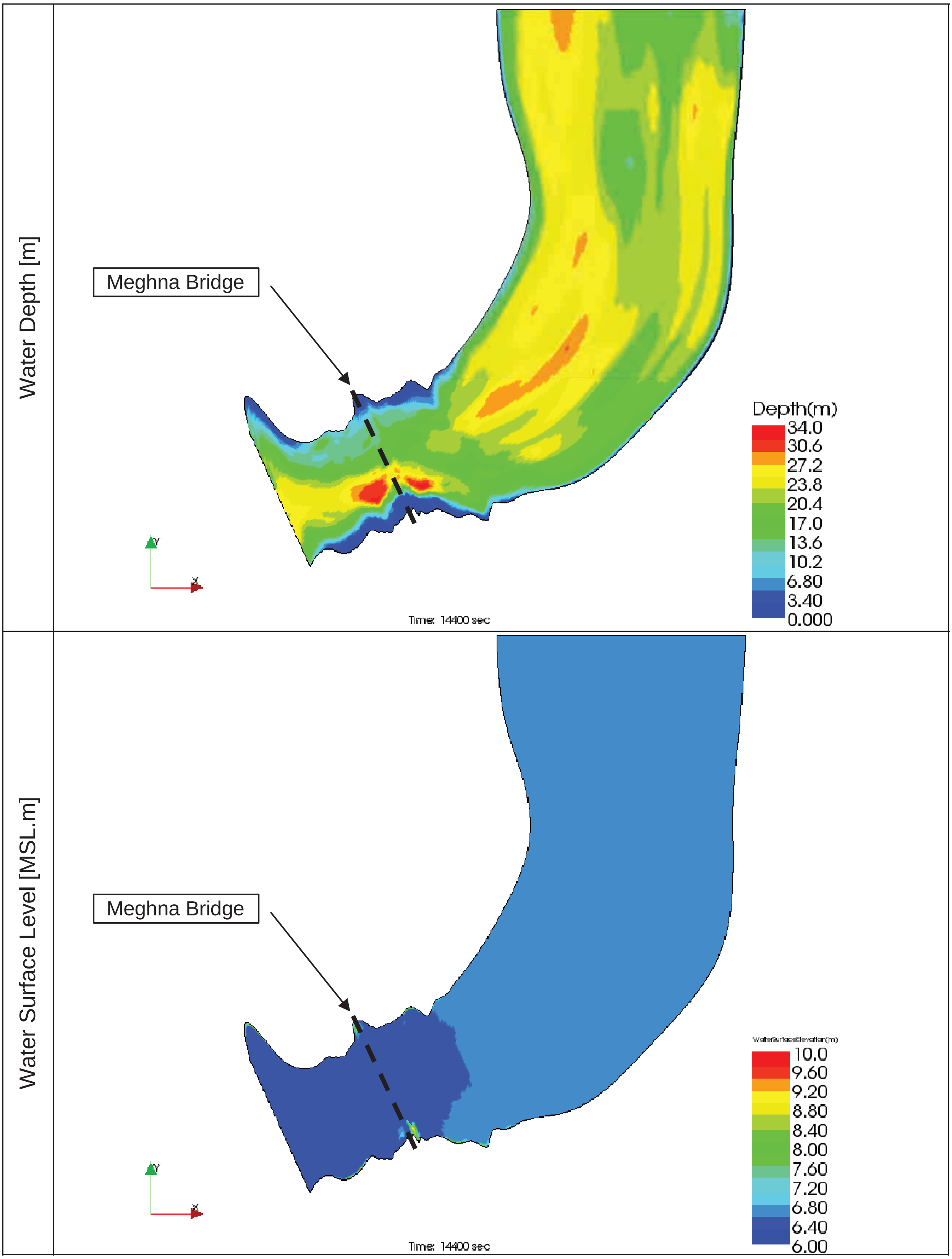
Source: Estimated by the study team

Figure 2.3.8 Numerical Analysis Result along Bridge Axis at Meghna Bridge (100-year)



Source: Estimated by the study team

Figure 2.3.9 Bed Elevation and Current Velocity Contour around Meghna Bridge (100-year)



Source: Estimated by the study team

Figure 2.3.10 Water Depth and Water Surface Level around Meghna Bridge (100-year)

(3) Gumti Bridge

The hydraulic value of numerical analysis results at bridge center line in 100-year return period discharge is shown in Table 2.3.7, and cross section bed profile, water level, current velocity and water depth at same line is shown in Figure 2.3.11.

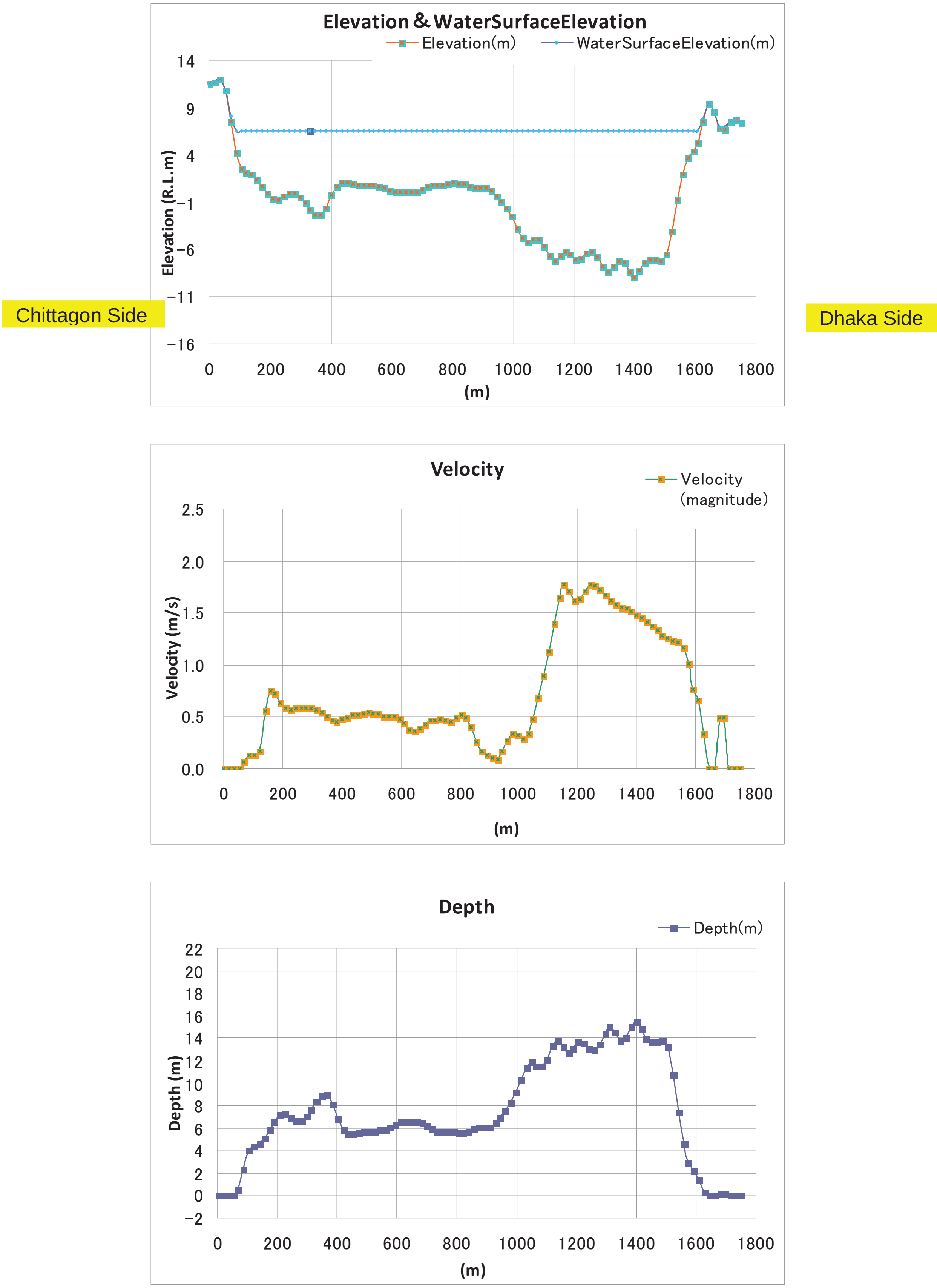
Contour map of bed elevation, current velocity, water depth, and water surface level in 100-year return period flood in this model is shown in Figure 2.3.12 and Figure 2.3.13.

The hydraulic value shown in Table 2.3.7 will be used to estimate the local scouring around each pier at Gumti Bridge.

Table 2.3.7 Numerical Analysis Result in 100-year return period at Gumti Bridge

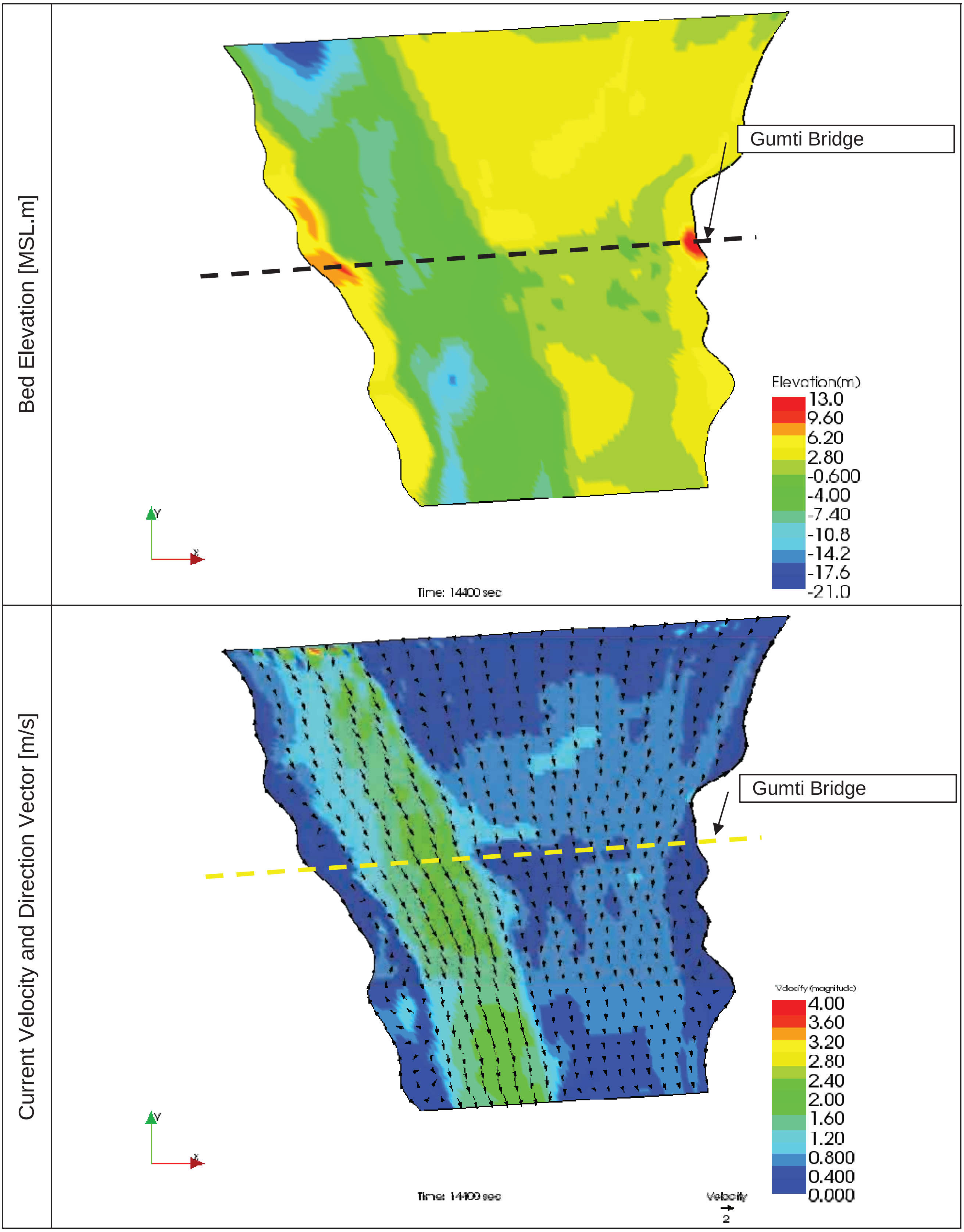
Pier No	Water Depth [MSL.m]	Bed Elevation [MSL.m]	Water Elevation [MSL.m]	Current Velocity [m/s]
A1	0.21	6.81	7.02	0.49
P1	2.94	3.64	6.58	1.01
P2	13.81	-7.22	6.59	1.29
P3	15.54	-8.94	6.60	1.48
P4	14.99	-8.39	6.60	1.62
P5	13.57	-6.97	6.60	1.71
P6	13.86	-7.28	6.58	1.65
P7	11.81	-5.23	6.58	0.48
P8	7.55	-0.96	6.59	0.27
P9	6.05	0.54	6.60	0.17
P10	5.68	0.91	6.59	0.49
P11	6.23	0.35	6.59	0.46
P12	6.50	0.08	6.59	0.43
P13	5.73	0.85	6.58	0.54
P14	8.19	-1.61	6.57	0.46
P15	6.70	-0.14	6.57	0.59
P16	5.17	1.38	6.56	0.75
A2	2.29	4.26	6.55	0.13

Source: Estimated by the study team



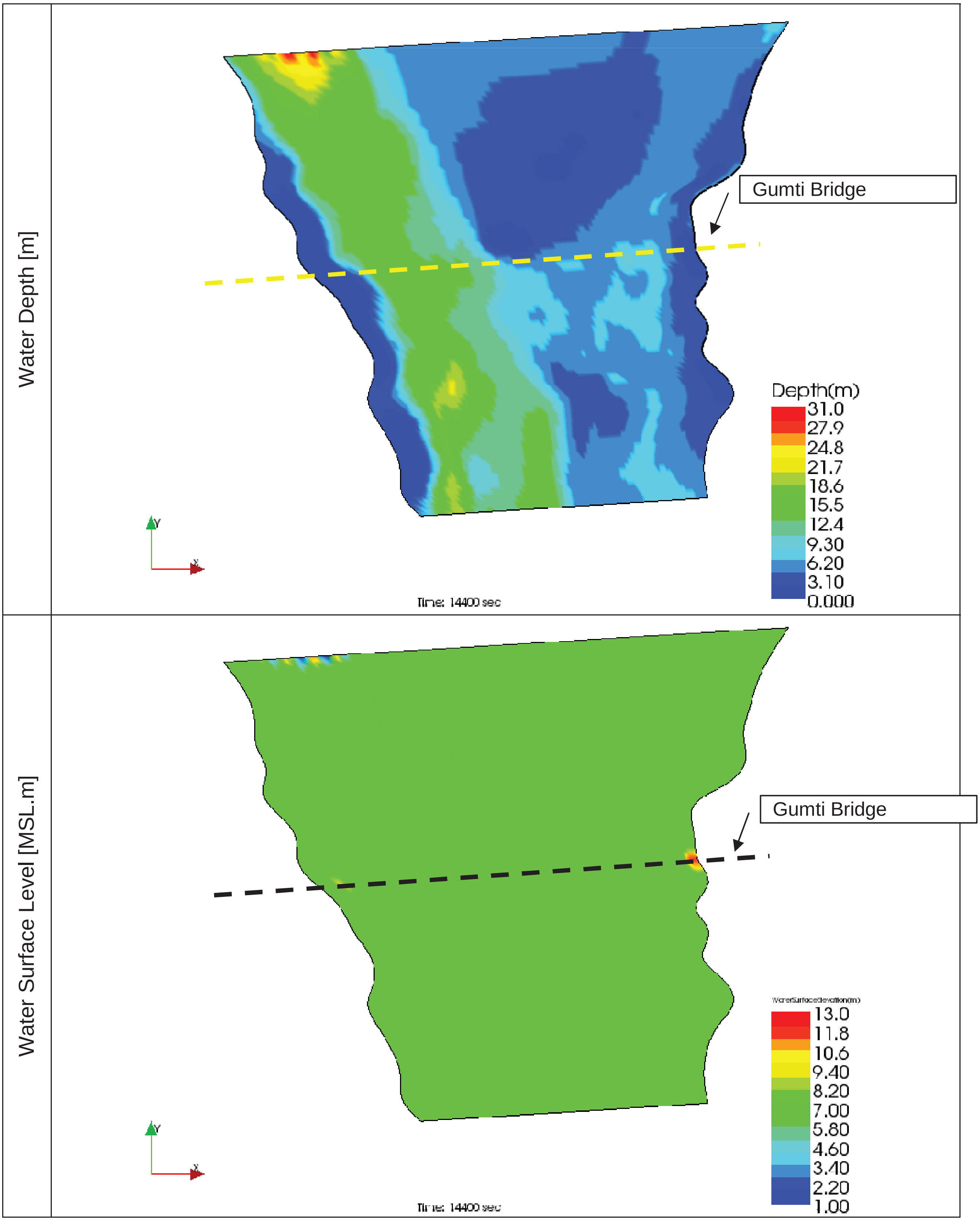
Source: Estimated by the study team

Figure 2.3.11 Numerical Analysis Result along Bridge Axis at Gumti Bridge (100-year)



Source: Estimated by the study team

Figure 2.3.12 Bed Elevation and Current Velocity Contour around Gumti Bridge (100-year)



Source: Estimated by the study team

Figure 2.3.13 Water Depth and Water Surface Level around Gumti Bridge (100-year)

2.3.3 Design Water Level

Based on the water level and discharge data collected from BWDB for the three rivers (Lahkya, Meghna and Gumti), the design parameters required to express the river flow and water level are calculated, which are summarized in Table 2.3.8.

Table 2.3.8 Design Water Level at Bridge Center Line

Design parameter		Kanchpur Bridge			Meghna Bridge			Gumti Bridge		
Design discharge (m3/sec)		3,480			15,200			12,400		
Water Level	point	Demra(Lahkya)		Bridge CL	Meghna Ferryghat		Bridge CL	Daudkandi		Bridge CL
	unit	PWD	M.S.L	M.S.L	PWD	M.S.L	M.S.L	PWD	M.S.L	M.S.L
	Design W.L (1/100)	7.36	6.90	6.57	6.98	6.52	6.49	7.36	6.90	6.91
	H.H.W.L	7.11	6.65	6.33	6.76	6.30	6.27	6.77	6.31	6.32
	S.H.W.L	5.07	4.61	4.29	3.50	3.04	3.01	4.40	3.94	3.95
	S.H.W.L	5.82	5.36	5.04	5.50	5.04	5.01	5.55	5.09	5.10
	L.L.W.L	0.48	0.02	-0.30	0.20	-0.26	-0.29	0.22	-0.24	-0.23

H.H.W.L	Highest high water level	Highest of annual highest water level in observation period
S.H.W.L	Smallest high water level	Lowest of annual highest water level in observation period
S.H.W.L	Standard high water level	Mean of annual highest water level in observaition period
L.L.W.L	Lowest low water level	Lowest watar level in observation period

It is noted that the available water level data collected for the last 50 years for Meghna and Gumti River along with that collected for the last 40 years for Lahkya(Sitalakhya) River are taken as reference data for water level calculations.

- The water level data collected from BWDB is expressed in PWD units which are converted to MSL units by deducting 0.46m. The water level data along the bridge axis expressed in MSL units is used for the present project.
- In Table 2.3.8, four categories of water level data are shown using MSL units. Among them, Mean High Water Level (M.H.W.L) that corresponds to the mean of annual highest water level in an observation period shall be used as the base for water surface elevation which is termed Standard High Water Level (S.H.W.L).
- Design water level with a 100 year return period corresponds to the design discharge shown in the table.

2.4 Estimation of Scour at Bridges

2.4.1 Basic concept

Scouring at bridge occurs due to the erosive action of flowing water, excavating and carrying away materials from the riverbed and its banks. Scour process is cyclic in nature which makes complicated to determine the magnitude of scour. Scour can be deepest near the peak of a flood; however, it is hardly visible since scour holes refill with sediment during receding stage of flood. In general, several floods may be needed to attain maximum scour under typical flow conditions at bridge crossings.

2.4.2 Methodology of scour computation

In designing the bridge substructure, it is very important to evaluate the scour potential at piers and abutments, careful study of the site, specific subsurface information. Total scour at a bridge crossing is comprised of three components.

- Long-term Aggradations and Degradations,
- Local scour

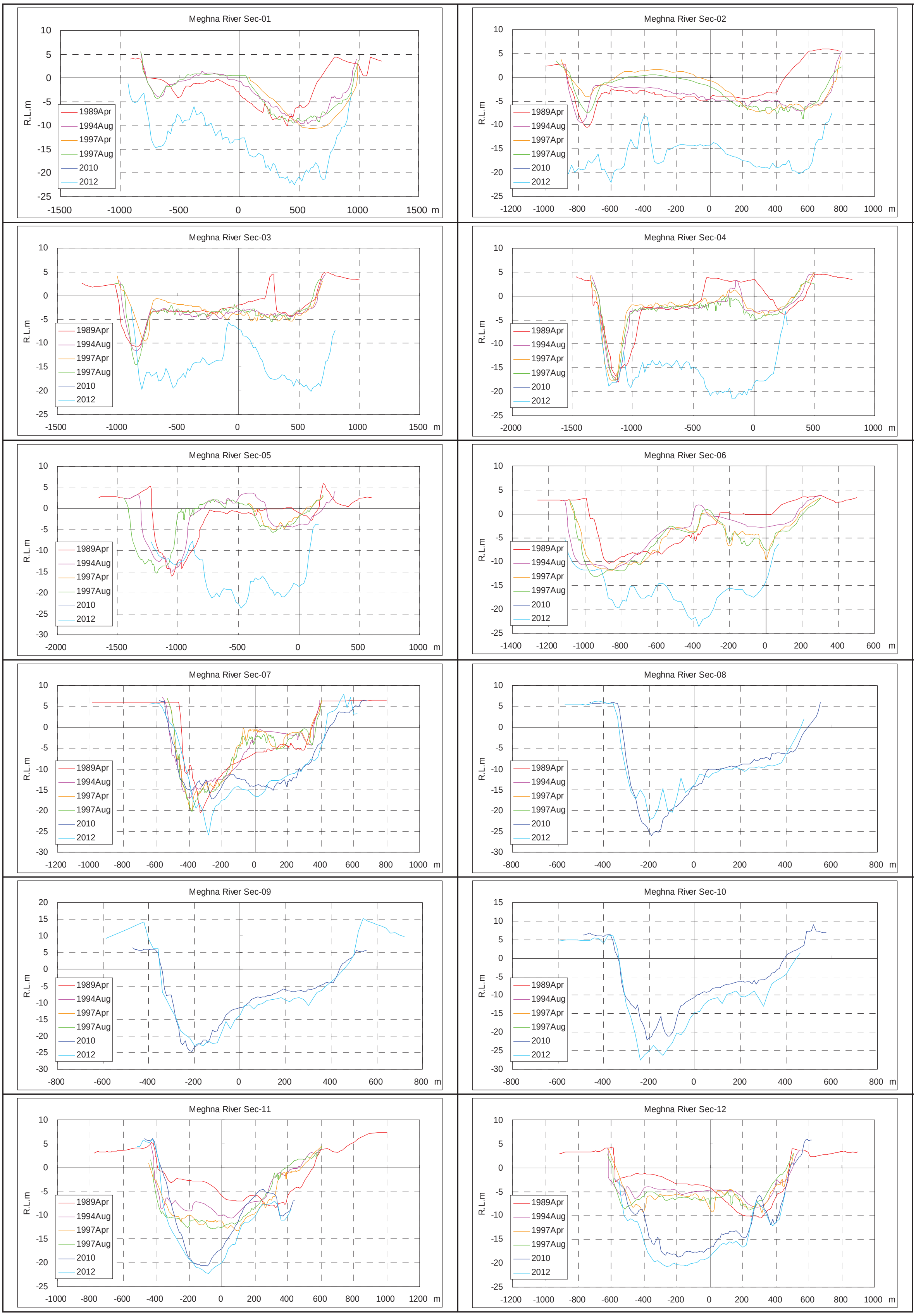
2.4.3 Long-term Aggradations and Degradations

Aggradation and degradation are changes of streambed elevation in long-term due to natural or man-induced causes which can affect the streambed. Aggradation involves the deposition of material eroded by the stream or water shedding from upstream of the bridge and degradation involves the lowering of the streambed due to the lack of sediment supply from upstream. Basically, it is to be evaluated independently from the hydraulic model. Generally, streams are considered to be stable and balance of sediment transport, if the configuration is not changed in long-term.

The historical change of cross section around Meghna Bridge is shown in Figure 2.4.1, which indicate that river bed height is widely declined between 1989 to 2012. It seems that river bed degradation is little for long range around Meghna Bridge by BWDB's regularly cross section survey shown in Figure 2.4.2, then it is supposed that reason of degradation is not change of natural circumstance like discharge, sediment transport.

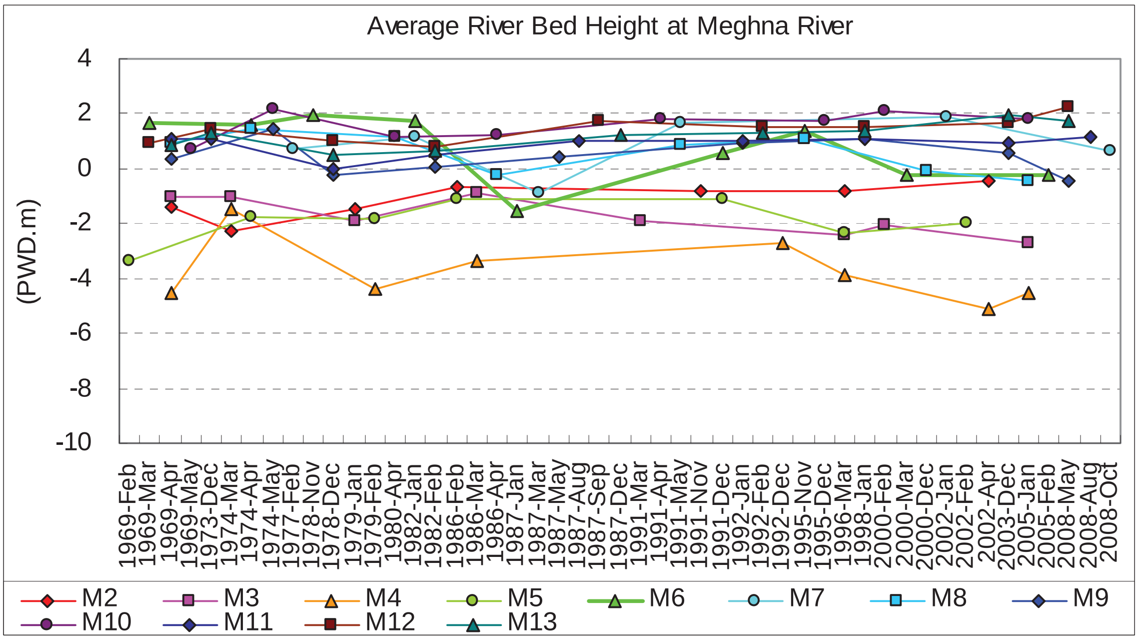
It is reported that illegal dredging is carried out in Bangladesh and it causes social problems, and it is known that dredging was carried out around Meghna Bridge by interview at RHD.

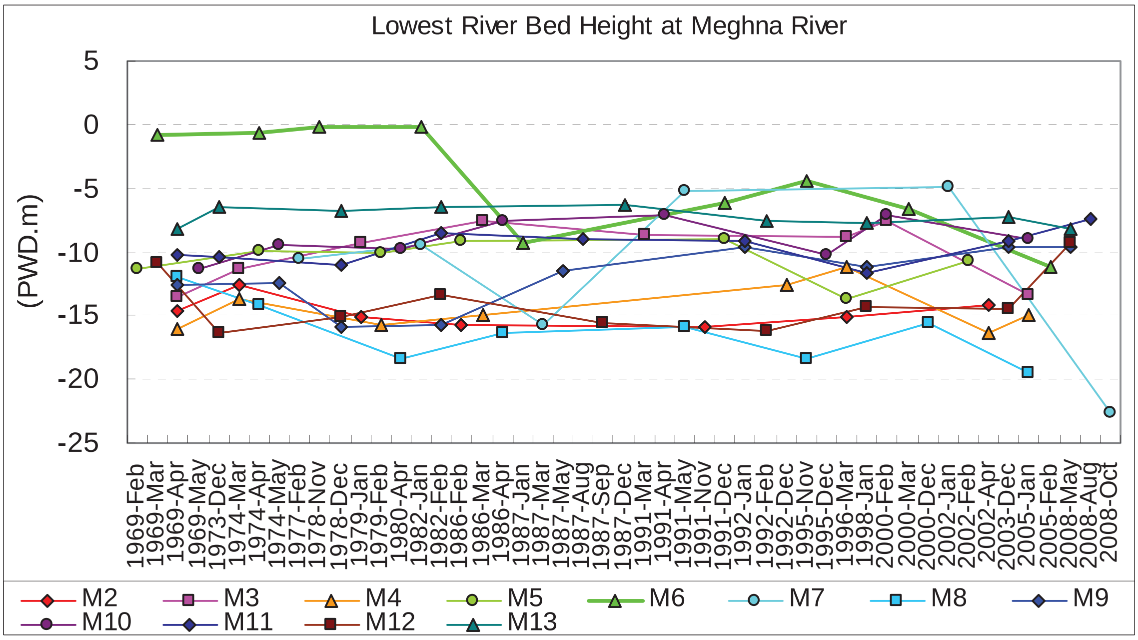
It is difficult to define the reason of degradation, but it seems that illegal dredging is one of the affective impact, hence it supposed that it should be keeping bed height around bridge.



Source: Made by the study team

Figure 2.4.1 Histrical Change of Cross Section Profile around Meghna Bridge





Source :Edited BWDB observation data by JICA Team

Figure 2.4.2 Average and Longitudinal River Bed Height at Meghna River

DHAKA MONDAY JUNE 11, 2012

The Daily Star

SECOND EDITION

Your Right to Know

QUICK RENTALS' IMPACT
Losses of state enterprises double to Tk 16,880 crore

MY DREAM
A programme showcases talent of differently abled Chinese artistes

REGIME ON 'LAST LEGS'
Abdel Basset says as Syrian Nat'l Council elects him new leader

Fresh tax on mobile calls

Govt mulls surcharge on cellphone users to create 'energy fund'

A syndicate illegally extracts silt from the Meghna in Narayanganj, causing land erosion nearby. A mobile court yesterday confiscated three dredgers and sentenced one person to three month's in jail in this connection.

PHOTO: PALASH KHAN

No hope of top leaders' release

BNP's Dhaka rally today

Fresh agitation likely as party's 90-day deadline for restoring

Bus, launch service stalled

Arrests ahead of rally

DIATRIBES AGAINST PROF SAYEED

Sangsad regrets

Unparliamentary words to be expunged

Figure 2.4.3 Report about illigally dredging on newspaper

	
Dredging machine on a boat near Gumti Br.	Unload area at Kanchpur bridge

Figure 2.4.4 Dredging around the Bridge

2.4.4 Local Scour

(1) Overall

Local scour at piers or abutments is due to the removal of bed material as a result of formation of vortices known as the horseshoe vortex and wake vortex at their base. The horseshoe vortex results from the pileup of water on the upstream surface due to the obstruction and subsequent acceleration of the flow around the nose of the pier or abutment. The action of the vortex removes bed material around the base of the obstruction. In addition, to the horseshoe vortex around the base of a pier, there are vertical vortices downstream of the pier called the wake vortex. Both the horseshoe and wake vortices remove material from the pier base region. The intensity of wake vortices diminishes rapidly as the distance of the downstream of the pier increases. As a result, there is often deposition of material immediately downstream of a long pier.

Factors which affect the magnitude of local scour depth at piers and abutments are;

- Velocity of the approach flow,
- Depth of flow,
- Width of the pier,
- Discharge intercepted by the abutment and returned to the main channel at the abutment,
- Length of the pier if skewed to flow,
- Size and gradation of bed material,
- Angle of attack of the approach flow to a pier or abutment,
- Shape of a pier or abutment,
- Bed configuration, and
- Ice formation or jams and debris.

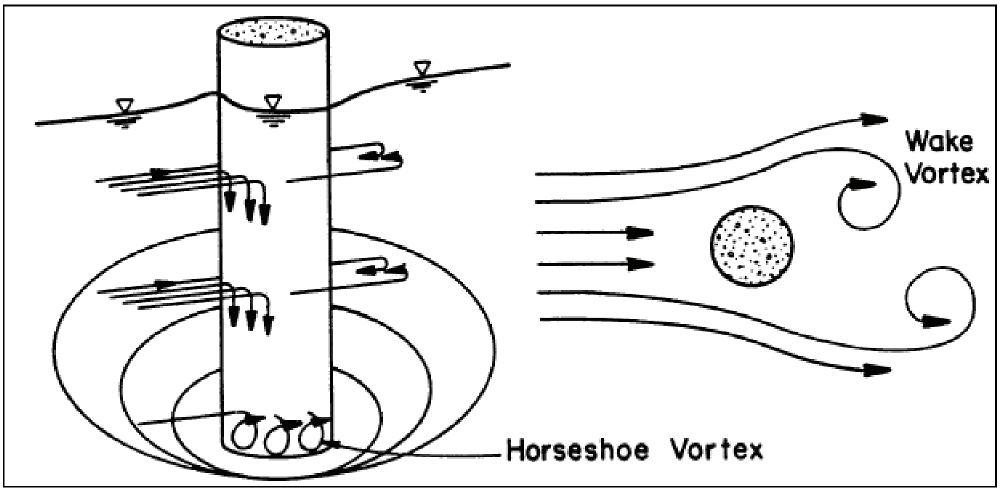


Figure 2.4.5 Schematic representation of scour at a pier

(2) Method

To predict scouring around pier, it is important to recognize bed condition in flood time. Scouring is caused by unbalance of river bed material transport, which is classified three type below. If there are no bed material transport around pier, no scouring is occured. When sediment transport around pier is more than transport from upstream, then scouring is caused around pier (Clear water scour). And the bed material around pier and upstream pier is moved (Dynamic balance Condition) , it is difficult to predict the scouring around pier because bed material move with morphing bed topography and cause sand wave like dune, ripple, flat bed and antidune.

The water depth of Meghna and Kanchpur river is very deep, as maximum 20 – 30 m height, and bed material diameter is very small (d50 is about 0.1 – 0.2 mm, fine sand), then non-dimension shear stress (τ *) which is the index of bed material transportation will be large, and the bed condition seems to be in dynamic balance.

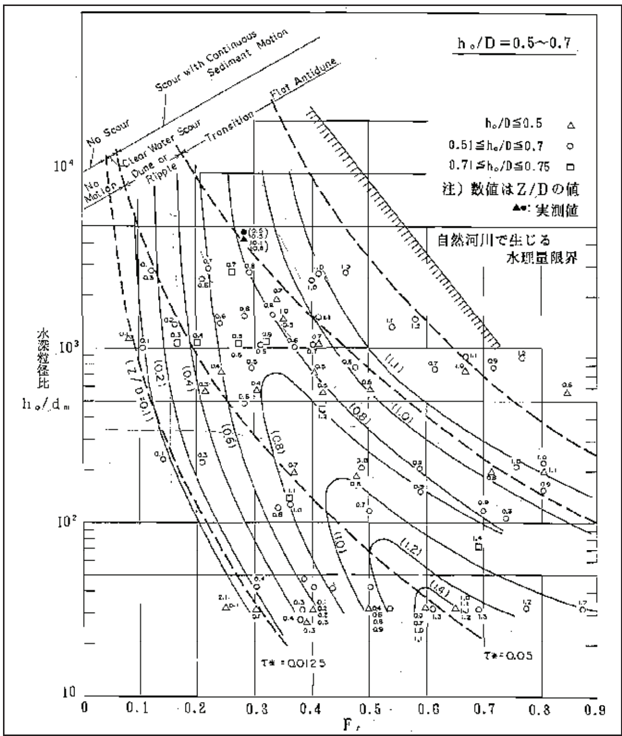
1. $Q_{So} = Q_{si} = 0$: No Scour

2. $Q_{So} > Q_{si} = 0$: Clear water scour (Static balance Condition)

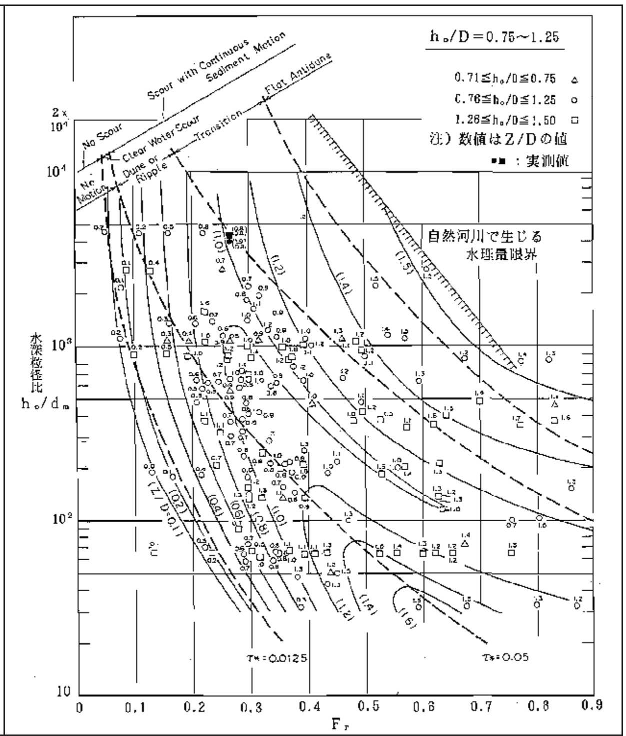
3. $Q_{So} > Q_{si} > 0$: Scour with continuous sediment motion (Dynamic Balance Condition)

where:
Q_{So} = Bed material transport around pier
Q_{si} = Bed material transport from upstream of pier

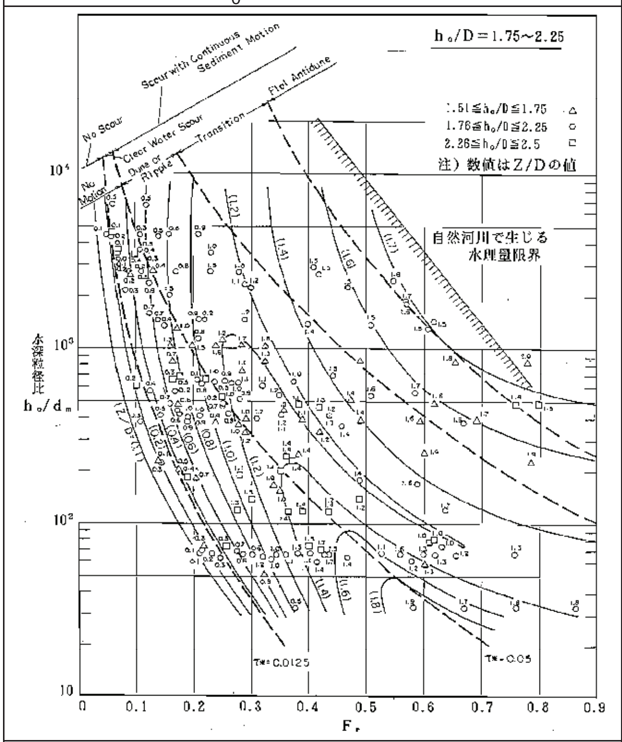
In this study, a method for predict scouring based on Japanese Public Work Research Institute (PWRI) is recommended to determine pier scour, both live-bed and clear-water pier scour as given in Japanese Government's technical standard. The method predicts maximum pier scour depths with hydraulic value calculated with Nays2D and charts shown in Figure 2.4.6.



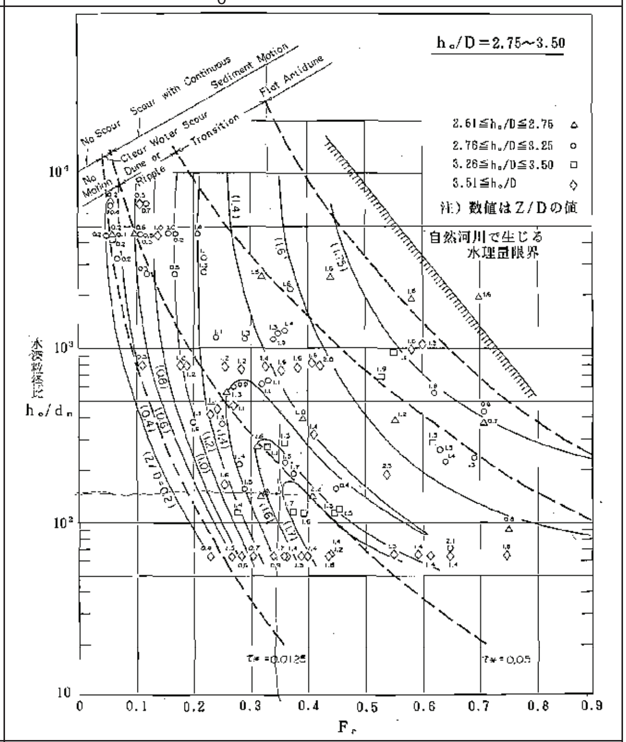
h_0/D = 0.5 to 0.7



h_0/D = 0.75 to 1.25



h_0/D = 1.75 to 2.25



h_0/D = 2.75 to 3.5

Source:Technical Guideline by PWRI of JAPAN[4]

Figure 2.4.6 Chart for Scour Depth(Z/D) Estimation

[4] *Problem of Bridge Pier from Flood Control, Public Works Research Institute of Japan, Nov 1993*

2.4.5 Scour Estimation Results

Results of scour computations by Japanese PWRI method are shown in Table 2.4.1 to Table 2.4.3 which is calculated with "Separated " and "Merged" situation. Lowest bed height with scouring around pier is calculated from latest bed height surveyed in this study work.

On the other hand, there are many equations for estimating the scouring depth, and adaptability of these equations is not checked for river in Bangladesh, then velocity and bed height measurement around bridge axis line will be carried out in the rainy season to check the scouring and adaptability of method. After the measurement, It will be decided scouring depth and width to be applying by engineering judgement.

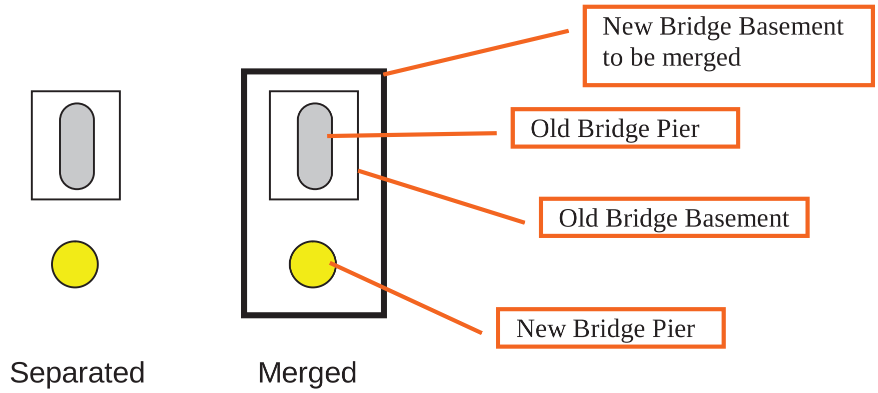
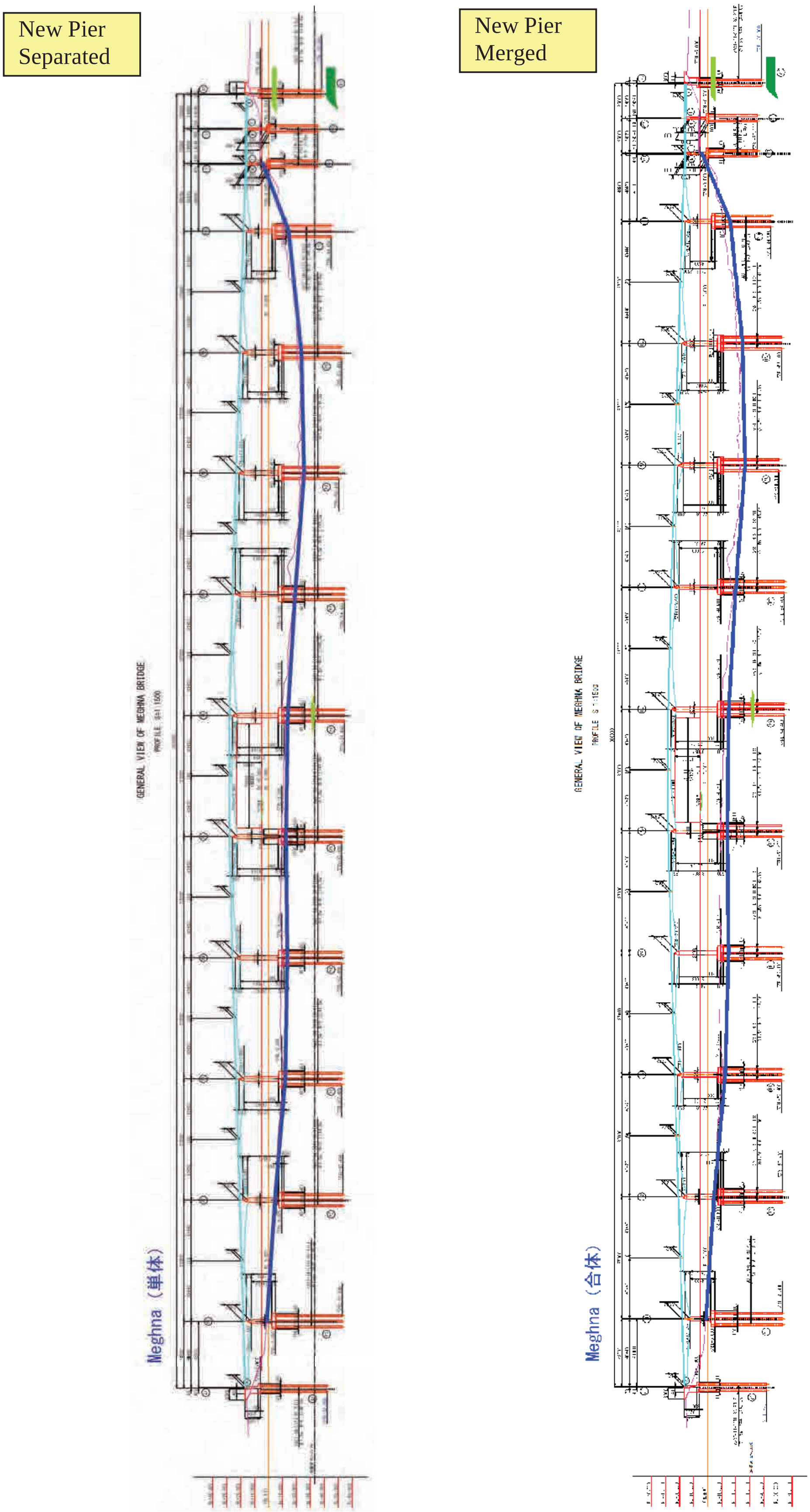


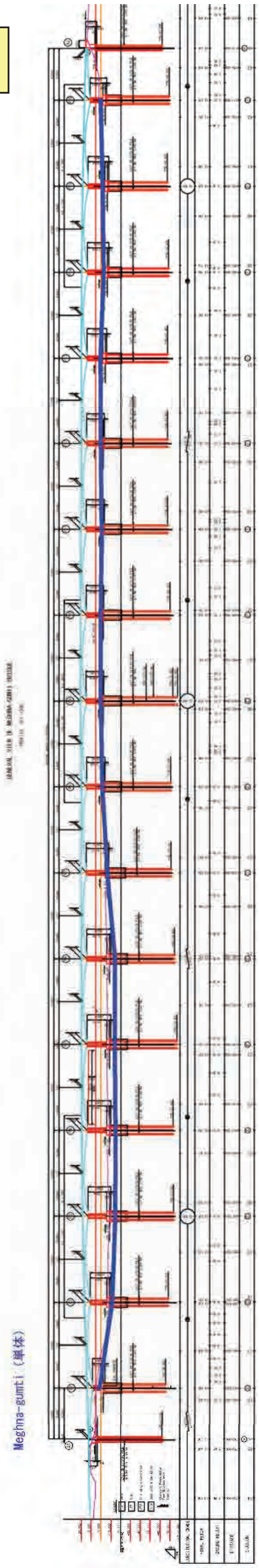
Figure 2.4.7 Bridge size for Local Scour estimation



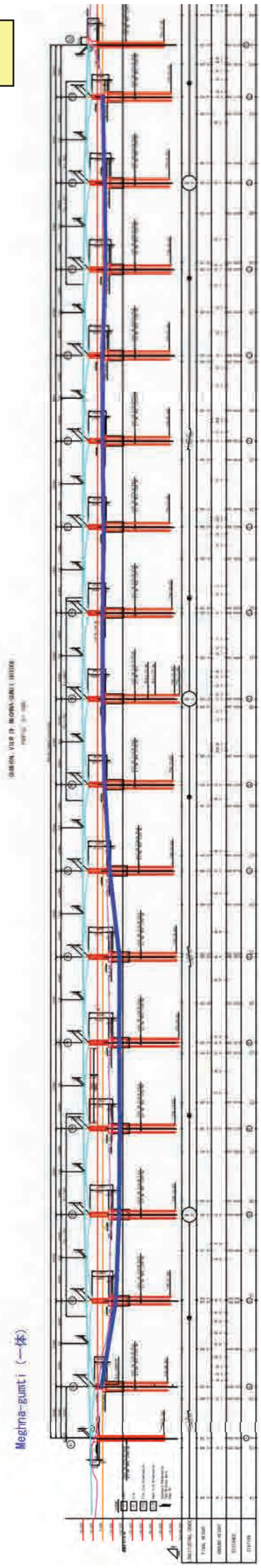
Source: Estimated by the study team

Figure 2.4.8 Estimated Bed Profile with Local Scouring at Meghna Bridge

New Pier Separated

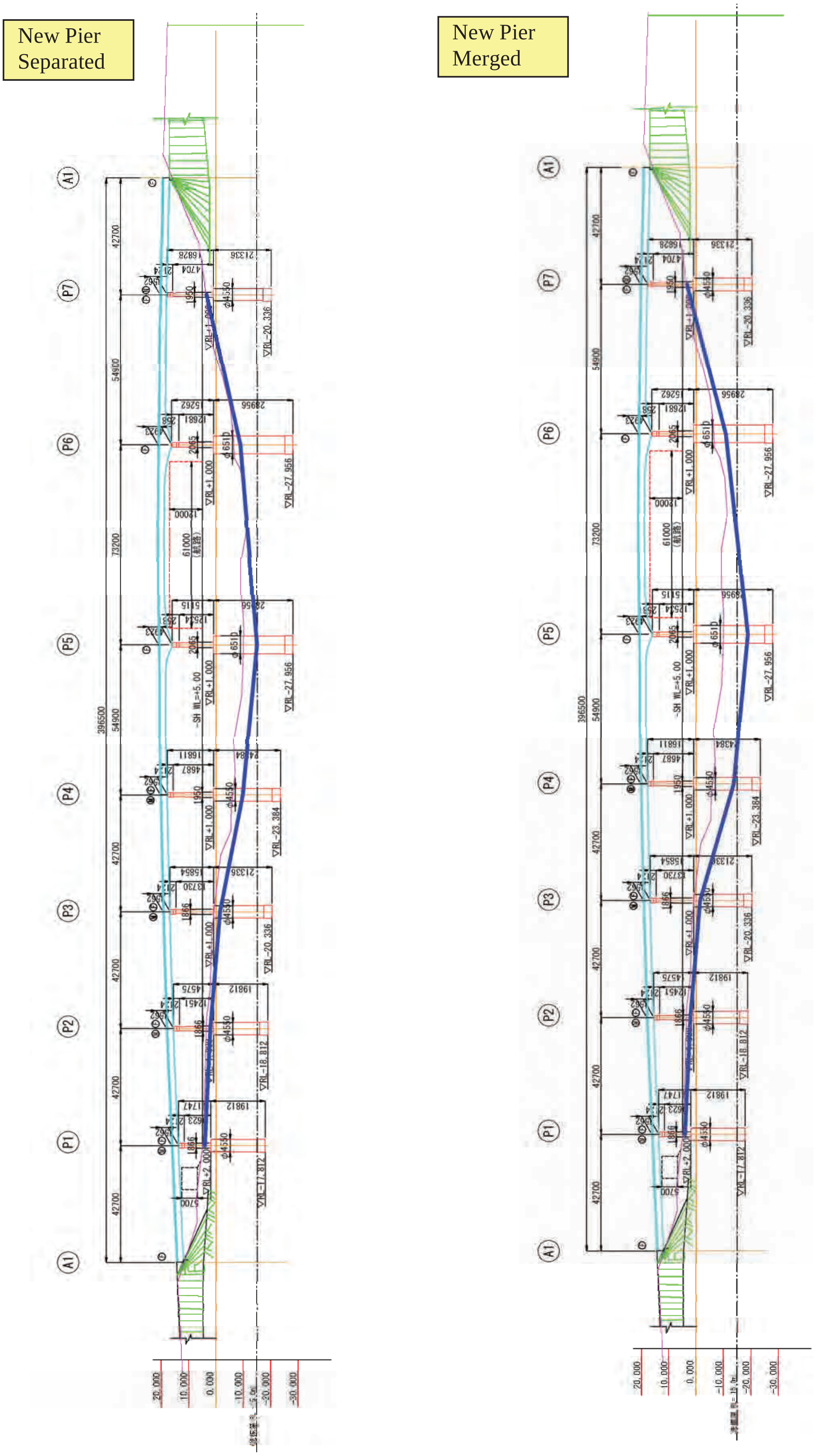


New Pier Merged



Source: Estimated by the study team

Figure 2.4.9 Estimated Bed Profile with Local Scouring at Gumti Bridge



Source: Estimated by the study team

Figure 2.4.10 Estimated Bed Profile with Local Scouring at Gumti Bridge

Table 2.4.1 Local Scour in 100-Year Return Period Flood at Kanchpur Bridge

Existing and New Piers Separated

Pier No.			P1	P2	P3	P4	P5	P6	P7	Reference
Pier Width		m	1.89	1.89	1.89	1.95	2.07	2.07	1.95	
Foundation Width		m	4.55	4.55	4.55	4.55	6.15	6.15	4.55	
Foundation Exposed / Coveried by Present bed condition			covered	covered	covered	exposed	exposed	exposed	covered	
Pier Width (foundation width included)	D	m	1.89	1.89	1.89	4.55	6.15	6.15	1.95	
Water Level in 100-year return period flood		MSL.m	6.25	6.24	6.24	6.23	6.24	6.25	6.26	From Hydraulic Analysis
Bed Elevation at Pier Position		MSL.m	2.78	4.00	0.87	-6.04	-9.09	-6.36	3.65	Surveyed in this study
Water Depth	h0	m	3.47	2.24	5.36	12.27	15.33	12.61	2.61	
Current Velocity	V	m/s	0.62	0.89	1.22	1.33	1.23	0.77	0.28	From Hydraulic Analysis
Froude Number	Fr	-	0.11	0.19	0.17	0.12	0.10	0.07	0.06	
Bed Material Diameter dm	dm	mm	0.167	0.167	0.167	0.167	0.167	0.167	0.167	
Z/D		-	0.42	0.80	1.20	0.80	0.80	0.40	0.10	Read from Diagram
h0/D		-	1.84	1.19	2.84	2.70	2.49	2.05	1.34	
h0/dm		-	20774	13436	32123	73473	91807	75516	15606	
Estimated Scour Depth	Z	m	0.79	1.51	2.26	3.64	4.92	2.46	0.20	
Estimated Scour Width from Pier Edge	R	m	1.70	3.24	4.85	7.81	10.55	5.28	0.42	
Estimated Bed Level after Scouring		MSL.m	1.99	2.49	-1.39	-9.68	-14.01	-8.82	3.46	

Existing and New Piers Merged

Pier No.			P1	P2	P3	P4	P5	P6	P7	Reference
Pier Width		m	1.89	1.89	1.89	1.95	2.07	2.07	1.95	
Foundation Width		m	9.55	9.55	9.55	9.55	11.15	11.15	9.55	
Foundation Exposed / Coveried by Present bed condition			covered	covered	covered	exposed	exposed	exposed	covered	
Pier Width (foundation width included)	D	m	1.89	1.89	1.89	9.55	11.15	11.15	1.95	
Water Level in 100-year return period flood		MSL.m	6.25	6.24	6.24	6.23	6.24	6.25	6.26	From Hydraulic Analysis
Bed Elevation at Pier Position		MSL.m	2.78	4.00	0.87	-6.04	-9.09	-6.36	3.65	Surveyed in this study
Water Depth	h0	m	3.47	2.24	5.36	12.27	15.33	12.61	2.61	
Current Velocity	V	m/s	0.62	0.89	1.22	1.33	1.23	0.77	0.28	From Hydraulic Analysis
Froude Number	Fr	-	0.11	0.19	0.17	0.12	0.10	0.07	0.06	
Bed Material Diameter dm	dm	mm	0.167	0.167	0.167	0.167	0.167	0.167	0.167	
Z/D		-	0.42	0.80	1.20	0.80	0.80	0.40	0.10	Read from Diagram
h0/D		-	1.84	1.19	2.84	1.28	1.38	1.13	1.34	
h0/dm		-	20774	13436	32123	73473	91807	75516	15606	
Estimated Scour Depth	Z	m	0.79	1.51	2.26	7.64	8.92	4.46	0.20	
Estimated Scour Width from Pier Edge	R	m	1.70	3.24	4.85	16.38	19.13	9.56	0.42	
Estimated Bed Level after Scouring		MSL.m	1.99	2.49	-1.39	-13.68	-18.01	-10.82	3.46	

Source: Estimated by the study team

Table 2.4.2 Local Scour in 100-Year Return Period Flood at Meghna Bridge

Existing and New Piers Separated

Pier No.			P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	Reference
Pier Width		m	2.70	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	2.70	1.50	1.50	
Foundation Width		m	11.20	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.20	7.20	7.20	
Foundation Exposed / Coveried by Present bed condition			Covered	Covered	Exposed	Exposed	Exposed	Exposed	Exposed	Exposed	Exposed	Exposed	Covered	Covered	
Pier Width (foundation width included)	D	m	2.70	3.20	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.20	1.50	1.50	
Water Level in 100-year return period flood		MSL.m	6.49	6.44	6.46	6.47	6.48	6.49	6.48	6.47	6.45	6.47	6.48	8.64	From Hydraulic Analysis
Bed Elevation at Pier Position		MSL.m	2.78	-4.56	-10.78	-9.83	-8.94	-10.78	-16.63	-22.80	-20.60	-10.48	5.68	6.16	Surveyed in this study
Water Depth	h0	m	3.71	11.01	17.24	16.30	15.42	17.27	23.12	29.27	27.05	16.94	0.80	0.20	
Current Velocity	V	m/s	0.32	0.13	0.72	1.28	1.28	1.17	1.17	1.32	1.49	1.39	1.07	0.00	From Hydraulic Analysis
Froude Number	Fr	-	0.05	0.01	0.06	0.10	0.10	0.09	0.08	0.08	0.09	0.11	0.38	0.00	
Bed Material Diameter dm	dm	mm	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	
Z/D		-	0.10	0.01	0.10	0.30	0.30	0.25	0.20	0.20	0.25	0.35	1.05	#N/A	Read from PWRI Diagram
h0/D		-	1.37	3.44	1.45	1.37	1.29	1.45	1.94	2.46	2.27	1.51	0.53	0.13	
h0/dm		-	22229	65920	103216	97593	92315	103420	138424	175289	162005	101458	4770	1198	
Estimated Scour Depth	Z	m	0.27	0.03	1.19	3.57	3.57	2.98	2.38	2.38	2.98	3.92	1.58	#N/A	
Estimated Scour Width from Pier Edge	R	m	0.58	0.07	2.55	7.66	7.66	6.39	5.11	5.11	6.39	8.41	3.38	#N/A	
Estimated Bed Level after Scouring		MSL.m	2.51	-4.60	-11.97	-13.40	-12.51	-13.76	-19.01	-25.19	-23.58	-14.40	4.11	#N/A	

Existing and New Piers Merged

Pier No.			P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	Reference
Pier Width		m	2.70	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	2.70	1.50	1.50	
Foundation Width		m	16.20	16.91	16.91	16.91	16.91	16.91	16.91	16.91	16.91	16.20	12.20	12.20	
Foundation Exposed / Coveried by Present bed condition			Covered	Covered	Exposed	Exposed	Exposed	Exposed	Exposed	Exposed	Exposed	Exposed	Covered	Covered	
Pier Width (foundation width included)	D	m	2.70	3.20	16.91	16.91	16.91	16.91	16.91	16.91	16.91	16.20	1.50	1.50	
Water Level in 100-year return period flood		MSL.m	6.49	6.44	6.46	6.47	6.48	6.49	6.48	6.47	6.45	6.47	6.48	8.64	From Hydraulic Analysis
Bed Elevation at Pier Position		MSL.m	2.78	-4.56	-10.78	-9.83	-8.94	-10.78	-16.63	-22.80	-20.60	-10.48	5.68	6.16	Surveyed in this study
Water Depth	h0	m	3.71	11.01	17.24	16.30	15.42	17.27	23.12	29.27	27.05	16.94	0.80	0.20	
Current Velocity	V	m/s	0.32	0.13	0.72	1.28	1.28	1.17	1.17	1.32	1.49	1.39	1.07	0.00	From Hydraulic Analysis
Froude Number	Fr	-	0.05	0.01	0.06	0.10	0.10	0.09	0.08	0.08	0.09	0.11	0.38	0.00	
Bed Material Diameter dm	dm	mm	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	
Z/D		-	0.10	0.01	0.10	0.30	0.30	0.25	0.20	0.20	0.25	0.35	1.05	#N/A	Read from PWRI Diagram
h0/D		-	1.37	3.44	1.02	0.96	0.91	1.02	1.37	1.73	1.60	1.05	0.53	0.13	
h0/dm		-	22229	65920	103216	97593	92315	103420	138424	175289	162005	101458	4770	1198	
Estimated Scour Depth	Z	m	0.27	0.03	1.69	5.07	5.07	4.23	3.38	3.38	4.23	5.67	1.58	#N/A	
Estimated Scour Width from Pier Edge	R	m	0.58	0.07	3.63	10.88	10.88	9.07	7.25	7.25	9.07	12.16	3.38	#N/A	
Estimated Bed Level after Scouring		MSL.m	2.51	-4.60	-12.47	-14.90	-14.01	-15.01	-20.01	-26.19	-24.83	-16.15	4.11	#N/A	

Source: Estimated by the study team

Table 2.4.3 Local Scour in 100-Year Return Period Flood at Gumti Bridge

Existing and New Piers Separated

Pier No.			P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	Reference
Pier Width		m	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	
Foundation Width		m	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	
Foundation Exposed / Coveried by Present bed condition			covered	exposed	exposed	exposed	exposed	exposed	exposed	exposed	covered	covered	covered	covered	covered	covered	covered	covered	
Pier Width (foundation width included)	D	m	4.90	11.41	11.41	11.41	11.41	11.41	11.41	11.41	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	
Water Level in 100-year return period flood		MSL.m	6.58	6.59	6.60	6.60	6.60	6.58	6.58	6.59	6.60	6.59	6.59	6.59	6.58	6.57	6.57	6.56	From Hydraulic Analysis
Bed Elevation at Pier Position		MSL.m	2.78	-7.32	-9.87	-9.34	-7.91	-8.01	-5.86	-1.02	0.33	0.58	-0.20	0.58	1.21	-2.36	-1.06	2.09	Surveyed in this study
Water Depth	h0	m	3.80	13.91	16.47	15.94	14.51	14.59	12.44	7.61	6.27	6.02	6.79	6.01	5.37	8.93	7.62	4.46	
Current Velocity	V	m/s	1.01	1.29	1.48	1.62	1.71	1.65	0.48	0.27	0.17	0.49	0.46	0.43	0.54	0.46	0.59	0.75	From Hydraulic Analysis
Froude Number	Fr	-	0.17	0.11	0.12	0.13	0.14	0.14	0.04	0.03	0.02	0.06	0.06	0.06	0.07	0.05	0.07	0.11	
Bed Material Diameter dm	dm	mm	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	
Z/D		-	0.73	0.35	0.40	0.47	0.53	0.53	0.06	0.04	0.02	0.10	0.10	0.10	0.15	0.08	0.15	0.35	Read from Diagram
h0/D		-	0.78	1.22	1.44	1.40	1.27	1.28	1.09	0.67	1.28	1.23	1.39	1.23	1.10	1.82	1.56	0.91	
h0/dm		-	22754	83275	98601	95432	86865	87388	74479	45546	37545	36028	40668	36011	32162	53488	45651	26729	
Estimated Scour Depth	Z	m	3.58	3.99	4.57	5.36	6.05	6.05	0.68	0.46	0.10	0.49	0.49	0.49	0.74	0.39	0.74	1.72	
Estimated Scour Width from Pier Edge	R	m	7.67	8.57	9.79	11.50	12.97	12.97	1.47	0.98	0.21	1.05	1.05	1.05	1.58	0.84	1.58	3.68	
Estimated Bed Level after Scouring		MSL.m	-0.80	-11.32	-14.44	-14.70	-13.96	-14.06	-6.54	-1.47	0.23	0.08	-0.69	0.08	0.48	-2.75	-1.79	0.38	

Existing and New Piers Merged

Pier No.			P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	Reference
Pier Width		m	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	
Foundation Width		m	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	
Foundation Exposed / Coveried by Present bed condition			covered	exposed	exposed	exposed	exposed	exposed	exposed	exposed	covered	covered	covered	covered	covered	covered	covered	covered	
Pier Width (foundation width included)	D	m	4.90	16.41	16.41	16.41	16.41	16.41	16.41	16.41	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	
Water Level in 100-year return period flood		MSL.m	6.58	6.59	6.60	6.60	6.60	6.58	6.58	6.59	6.60	6.59	6.59	6.59	6.58	6.57	6.57	6.56	From Hydraulic Analysis
Bed Elevation at Pier Position		MSL.m	2.78	-7.32	-9.87	-9.34	-7.91	-8.01	-5.86	-1.02	0.33	0.58	-0.20	0.58	1.21	-2.36	-1.06	2.09	Surveyed in this study
Water Depth	h0	m	3.80	13.91	16.47	15.94	14.51	14.59	12.44	7.61	6.27	6.02	6.79	6.01	5.37	8.93	7.62	4.46	
Current Velocity	V	m/s	1.01	1.29	1.48	1.62	1.71	1.65	0.48	0.27	0.17	0.49	0.46	0.43	0.54	0.46	0.59	0.75	From Hydraulic Analysis
Froude Number	Fr	-	0.17	0.11	0.12	0.13	0.14	0.14	0.04	0.03	0.02	0.06	0.06	0.06	0.07	0.05	0.07	0.11	
Bed Material Diameter dm	dm	mm	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	
Z/D		-	0.73	0.35	0.40	0.47	0.53	0.53	0.06	0.04	0.02	0.10	0.10	0.10	0.15	0.08	0.15	0.35	Read from Diagram
h0/D		-	0.78	0.85	1.00	0.97	0.88	0.89	0.76	0.46	1.28	1.23	1.39	1.23	1.10	1.82	1.56	0.91	
h0/dm		-	22754	83275	98601	95432	86865	87388	74479	45546	37545	36028	40668	36011	32162	53488	45651	26729	
Estimated Scour Depth	Z	m	3.58	5.74	6.57	7.71	8.70	8.70	0.98	0.66	0.10	0.49	0.49	0.49	0.74	0.39	0.74	1.72	
Estimated Scour Width from Pier Edge	R	m	7.67	12.32	14.08	16.54	18.66	18.66	2.11	1.41	0.21	1.05	1.05	1.05	1.58	0.84	1.58	3.68	
Estimated Bed Level after Scouring		MSL.m	-0.80	-13.07	-16.44	-17.05	-16.61	-16.71	-6.84	-1.67	0.23	0.08	-0.69	0.08	0.48	-2.75	-1.79	0.38	

Source: Estimated by the study team

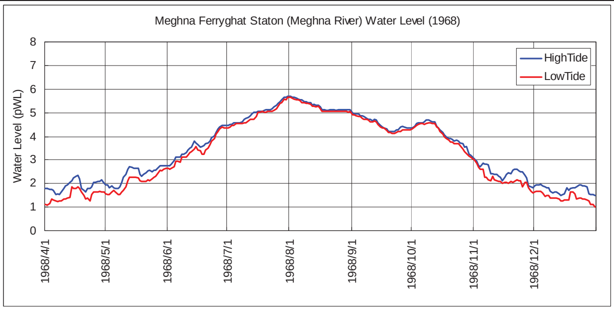
2.4.6 Scour Countermeasures

It is recommended that highway bridges should be structurally designed taking into account the estimated potential scour at the bridges, piers and abutments. The potential scour is estimated for both contraction and local scour based on HEC-18. In addition, the allowance for long term degradation is also provided where necessary referring to the river profile and its cross sections.

In this study, the SPSP method will be adopted for pier protection, so countermeasures against scouring will not be needed.

Furthermore, the Bangladesh Army will carry out emergency protection work around Meghna Bridge, which suffers from deep scouring and degradation. After the Army's work, bed height around Meghna Bridge will be the same height as when the bridge was constructed, then the existing bridge will be stable for a while until the new bridge will be constructed.

3. WATER LEVEL DATA NEAR BRIDGE



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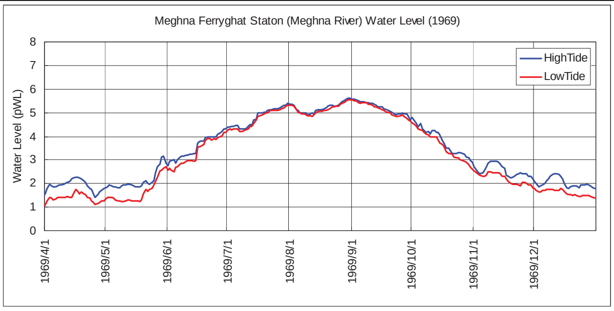

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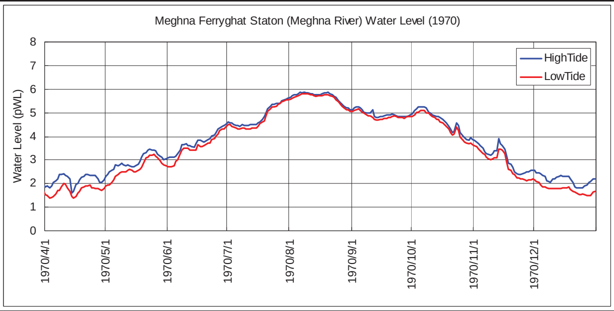

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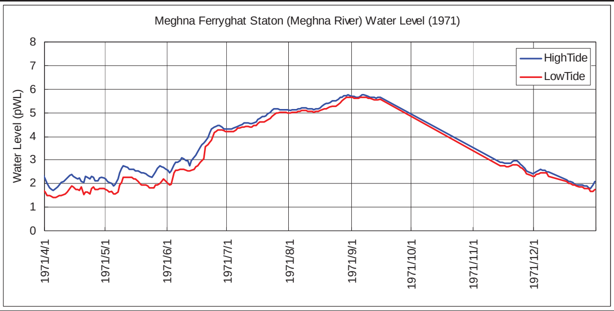

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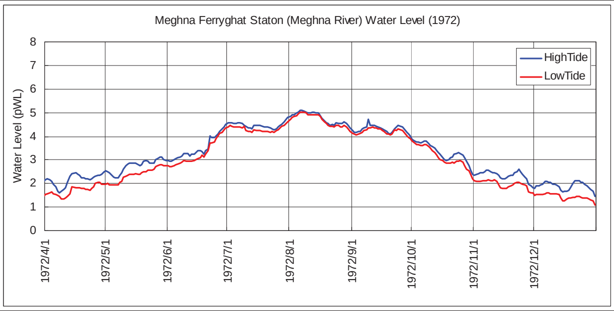

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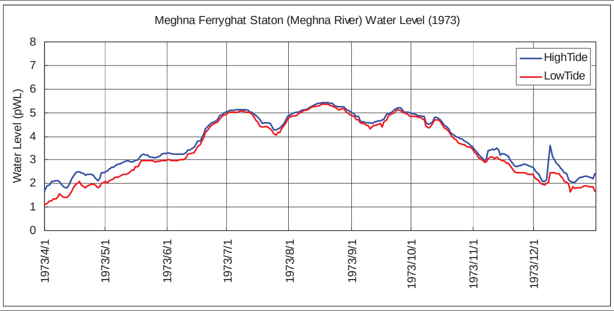

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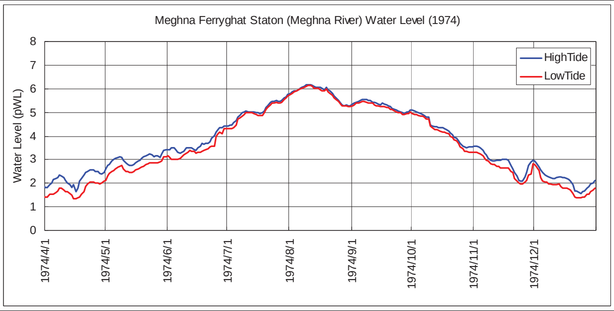

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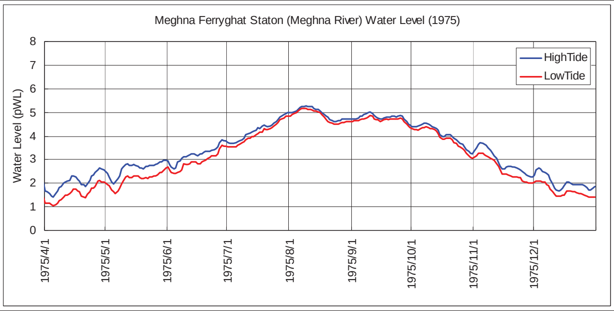

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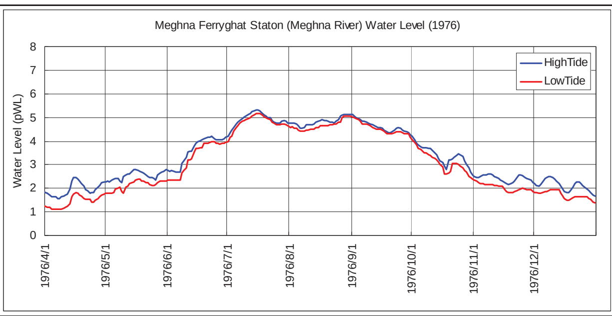

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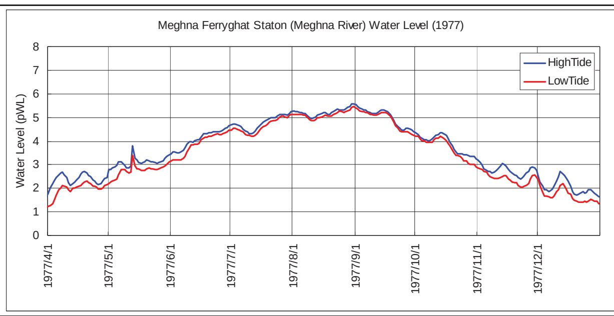
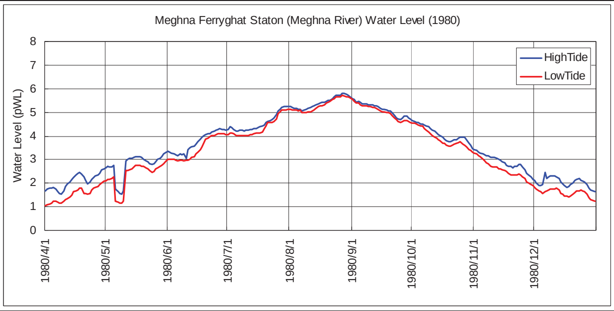


1977

Figure 11(1) Daily Water Level at Meghna Ferryghat St (1/5)

1978

1979



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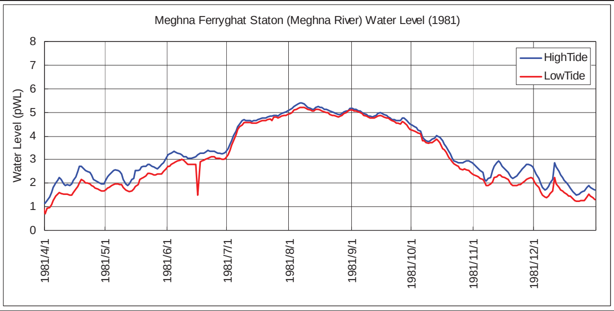

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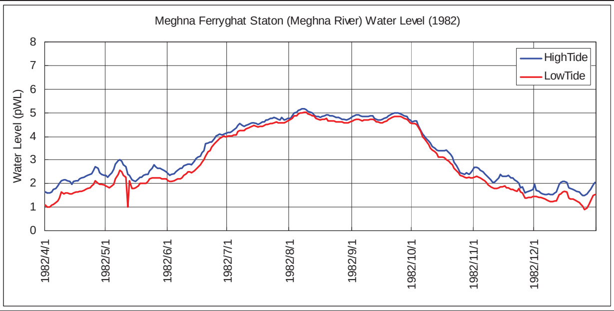

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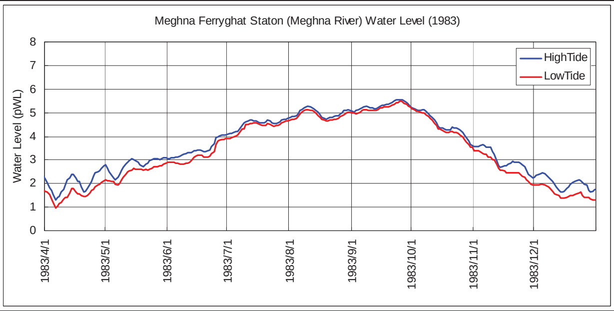

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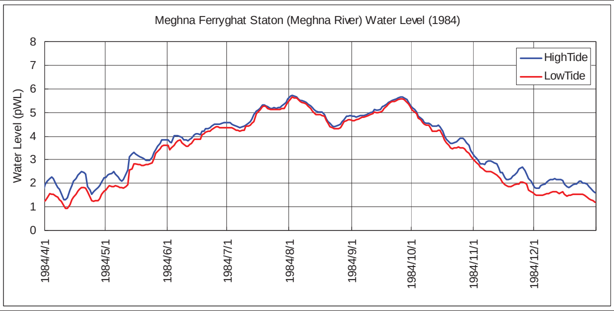

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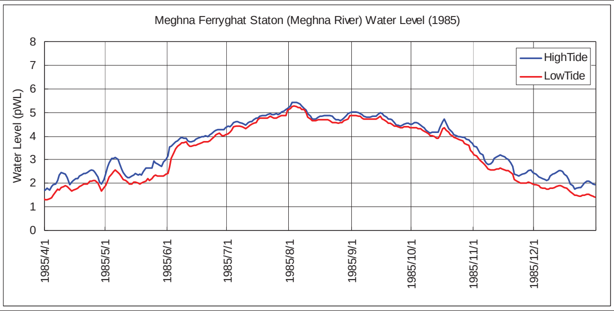

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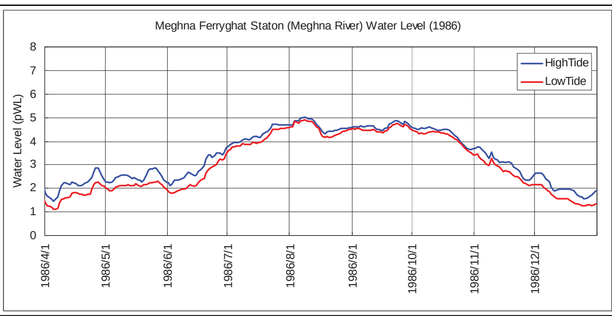

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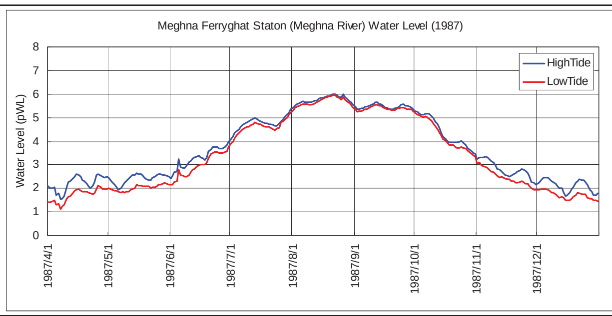

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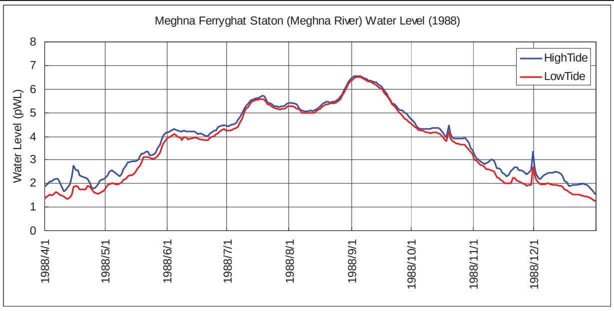
Figure 11(2) Daily Water Level at Meghna Ferryghat St (2/5)



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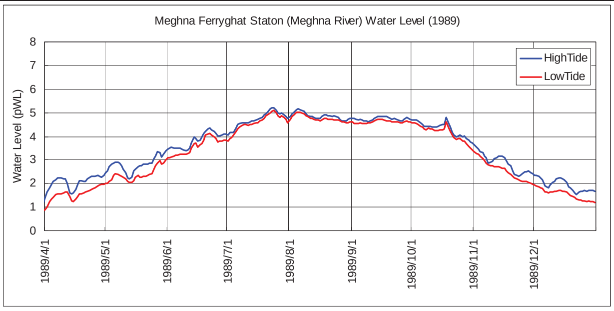

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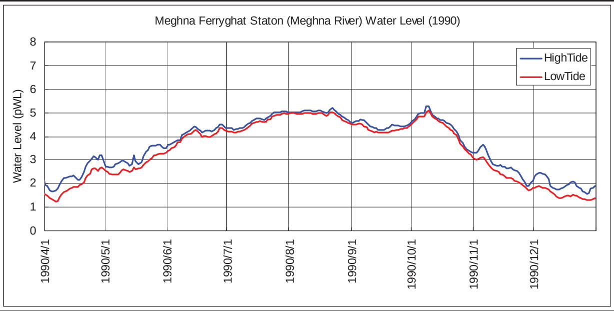

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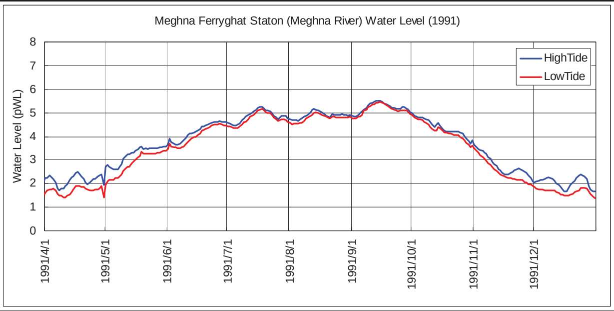

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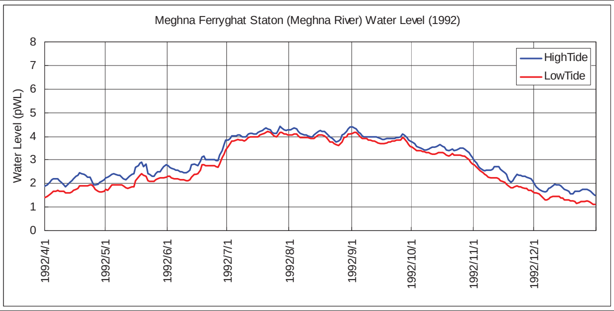

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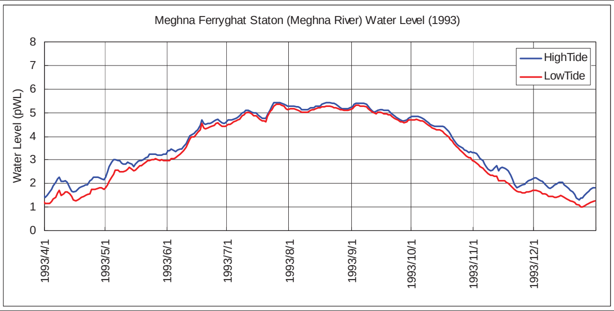

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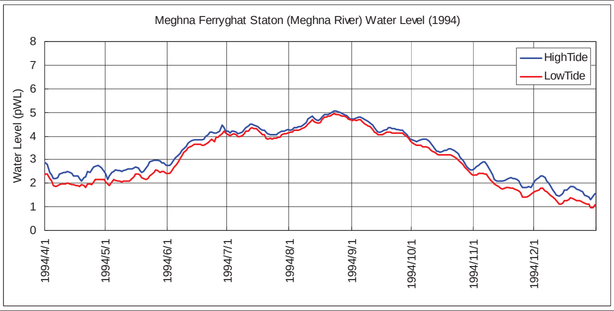

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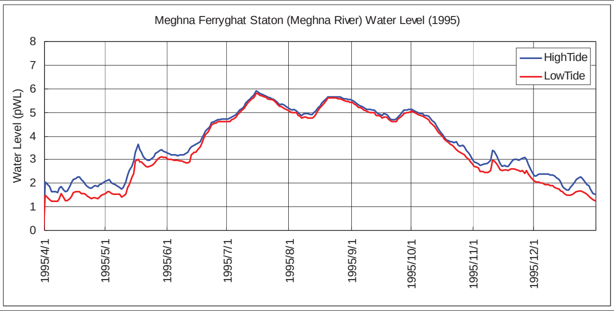

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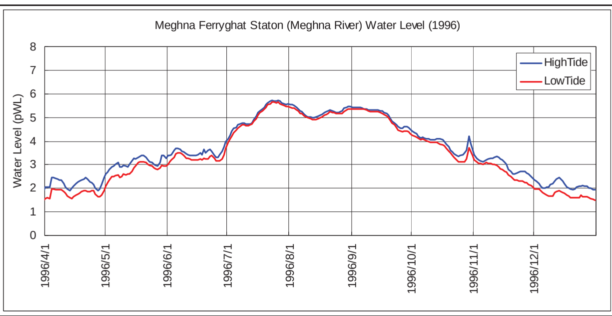

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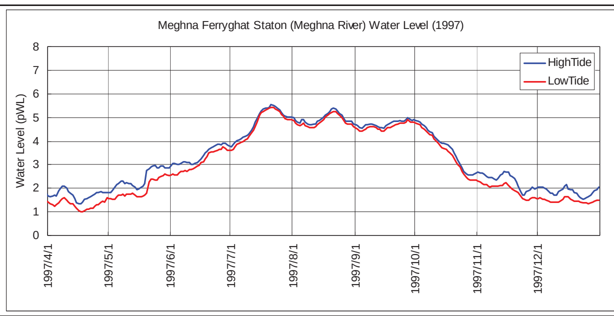
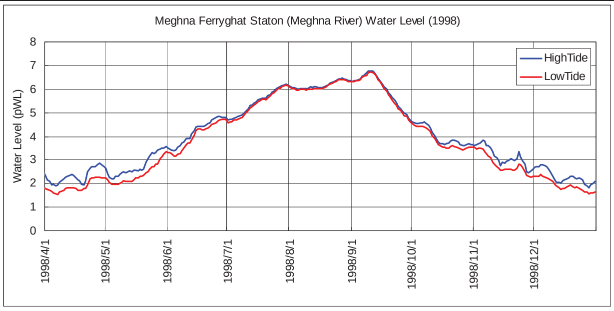


1997

Figure 11(3) Daily Water Level at Meghna Ferryghat St (3/5)



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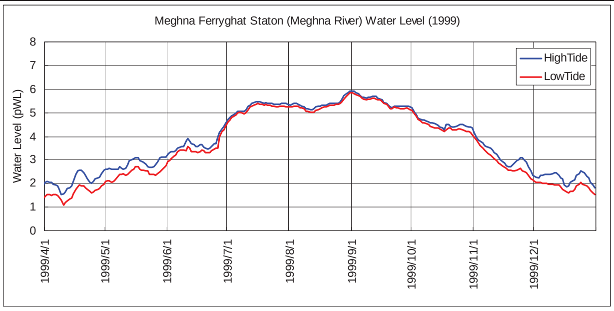

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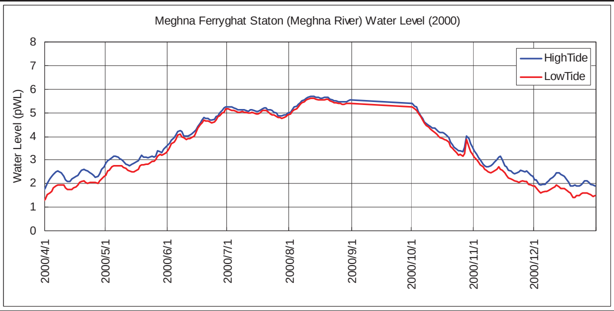

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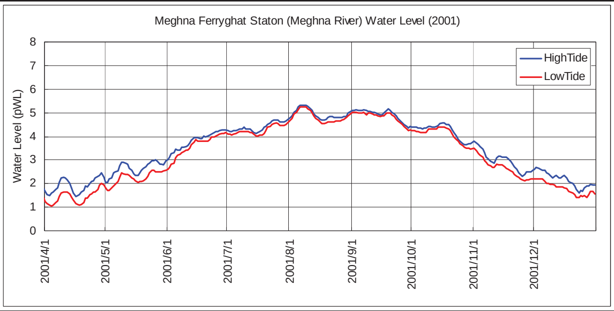

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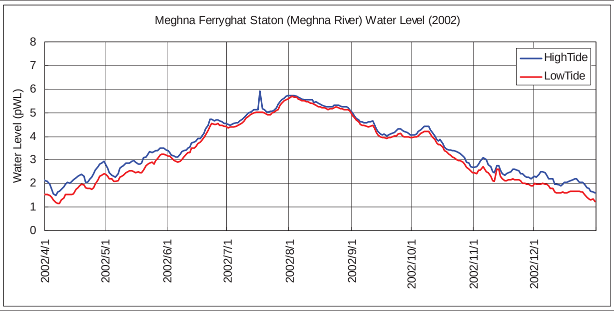

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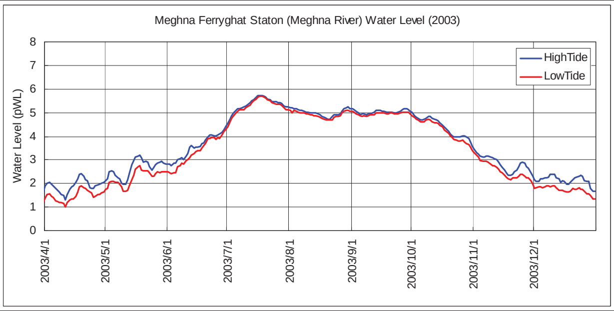

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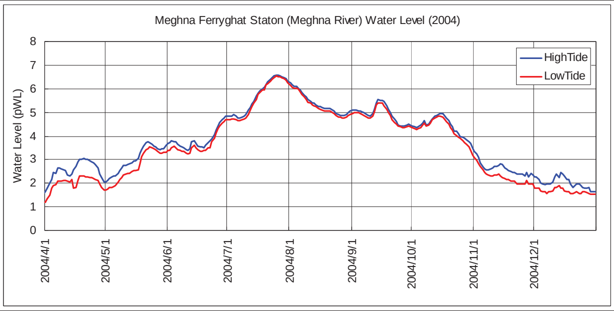

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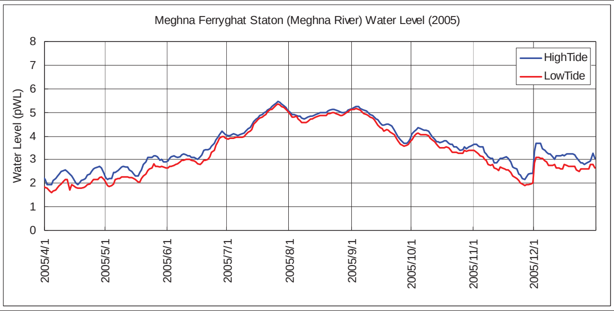

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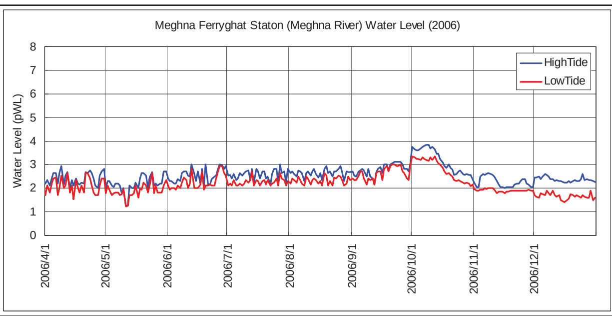

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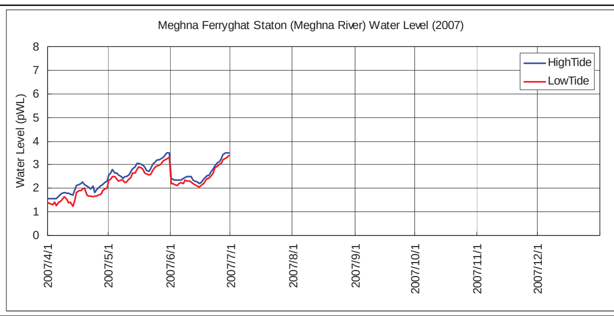
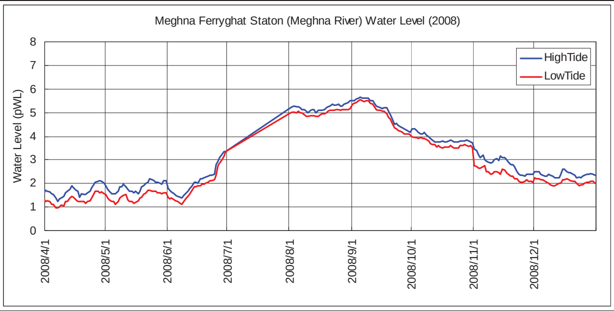
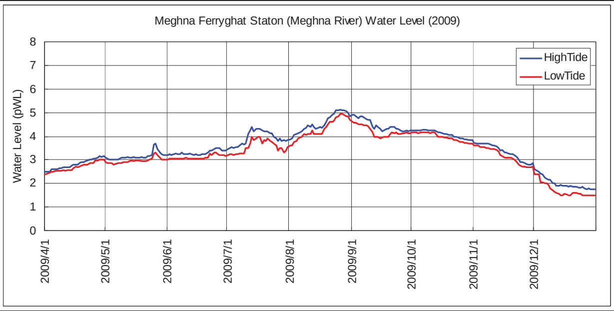


2007

Figure 11(4) Daily Water Level at Meghna Ferryghat St (4/5)



2008



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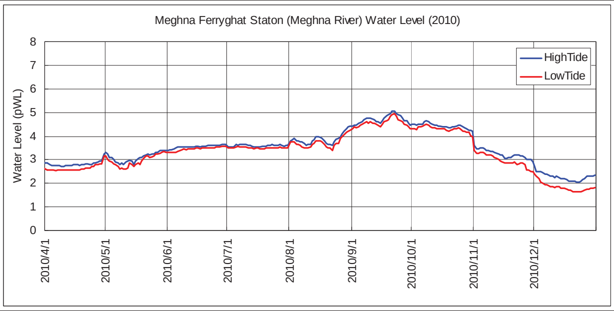
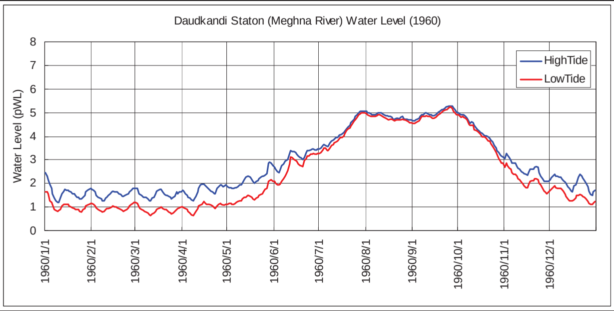


2010

2011

Figure 11(5) Daily Water Level at Meghna Ferryghat St (5/5)



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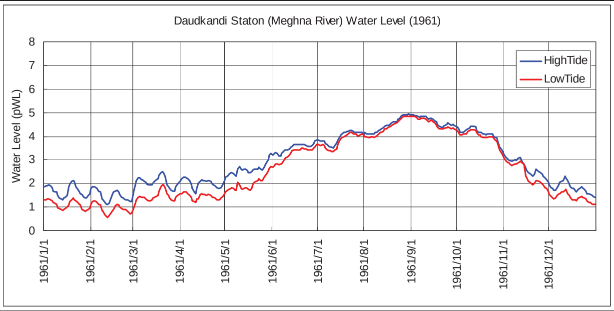
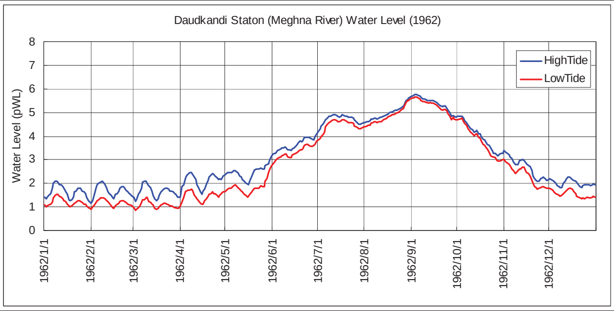
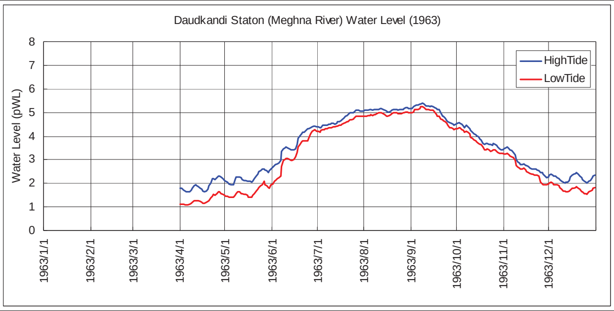


1961



1962



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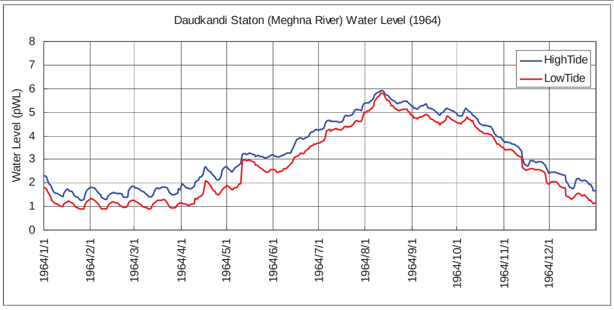

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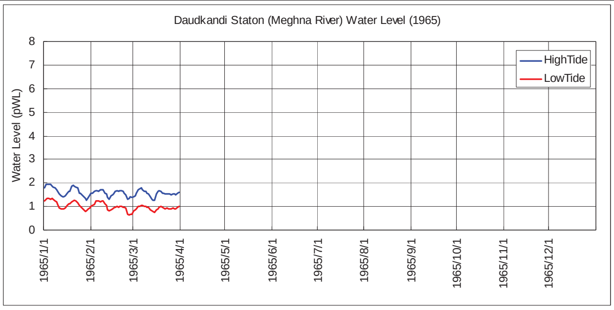

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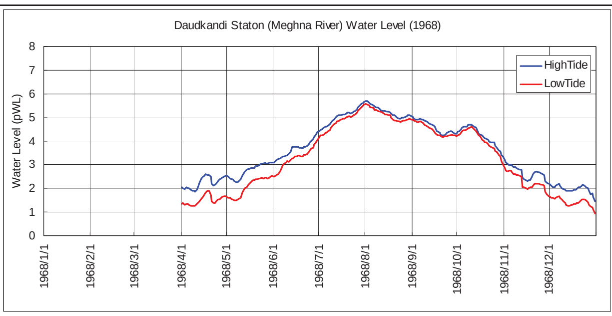

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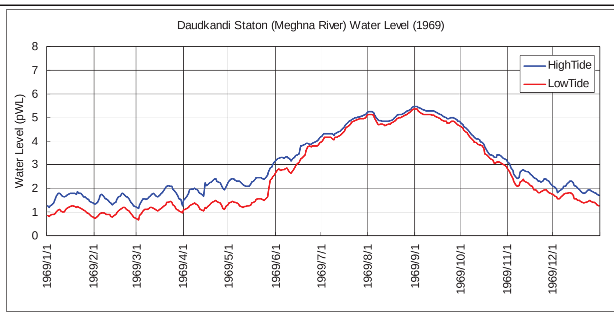


1967

1968

1969

Figure 12(1) Daily Water Level at Daudkandi St (1/6)

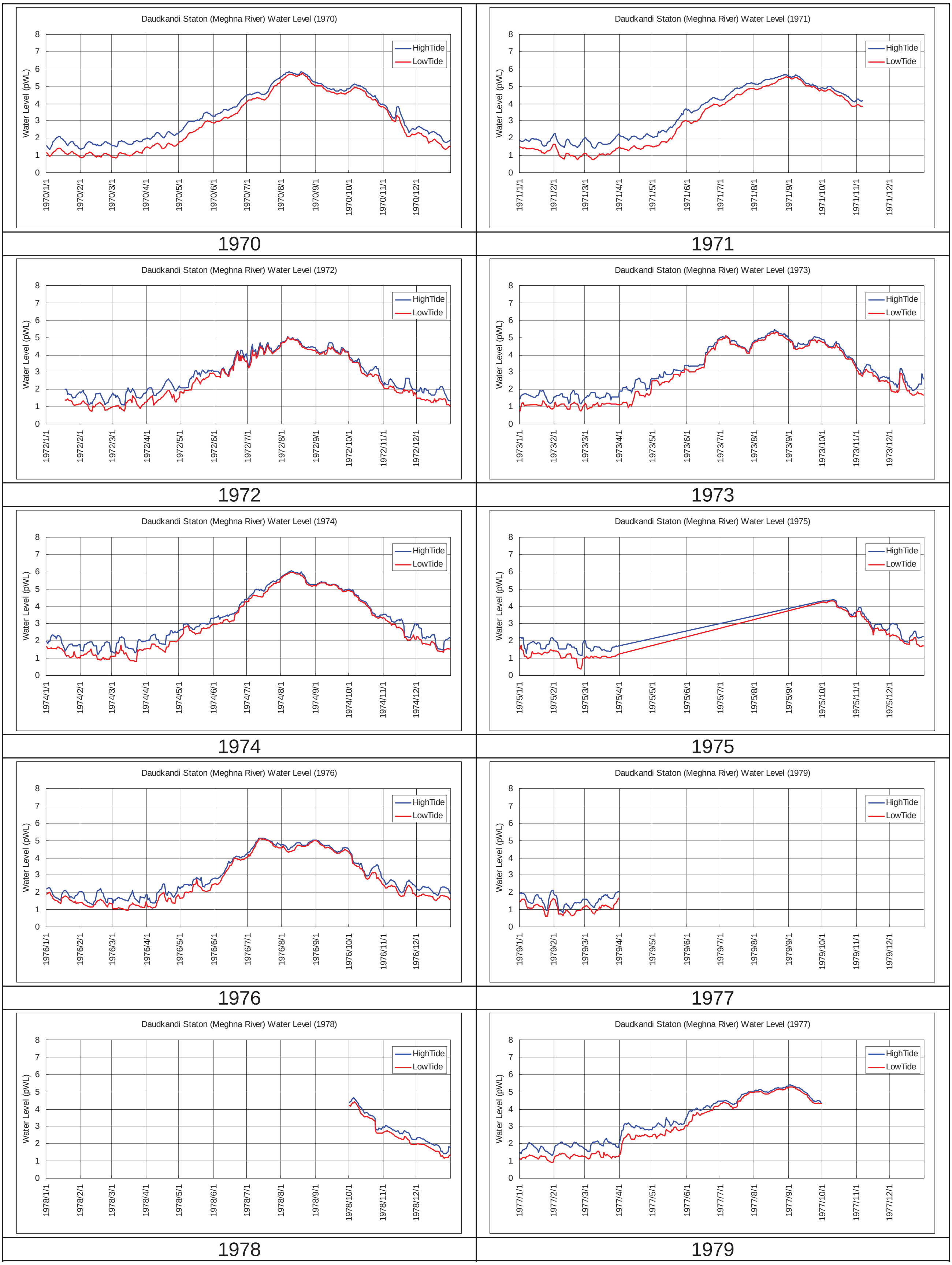
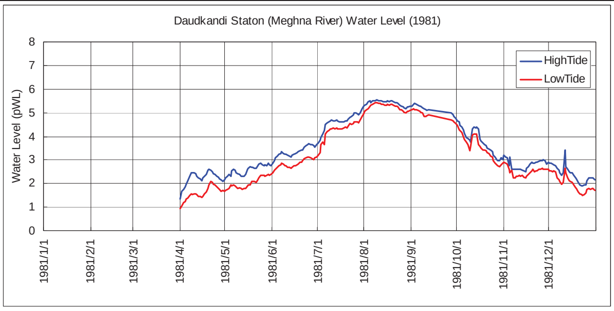


Figure 12(2) Daily Water Level at Daudkandi St (2/6)

1980



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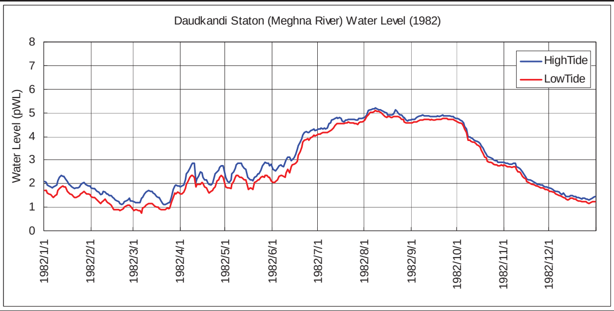

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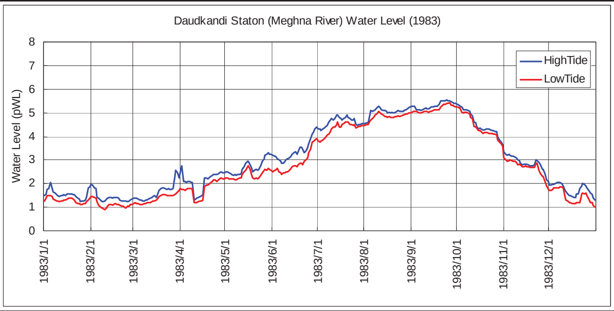

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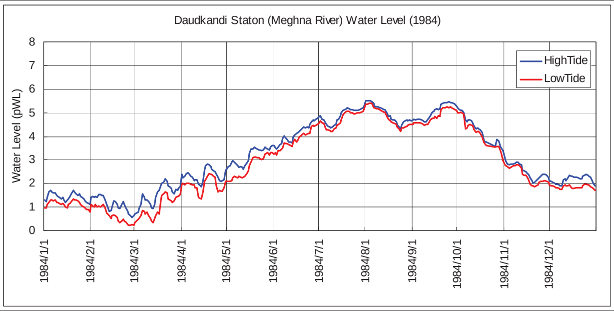

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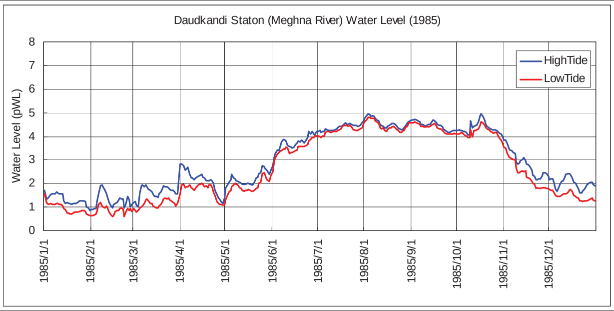

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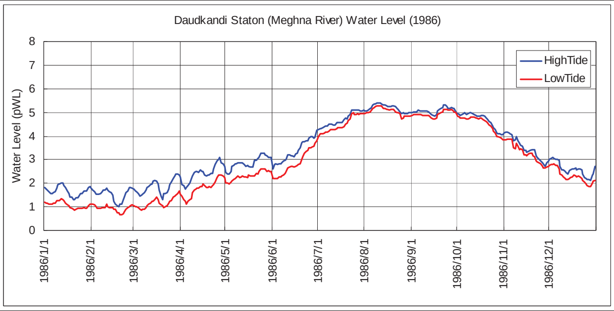

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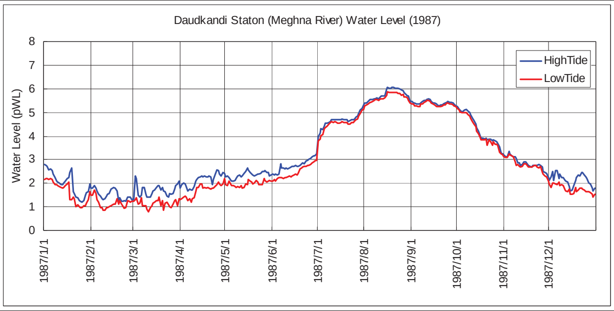

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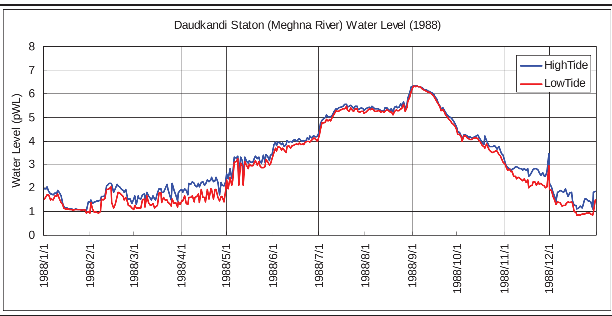

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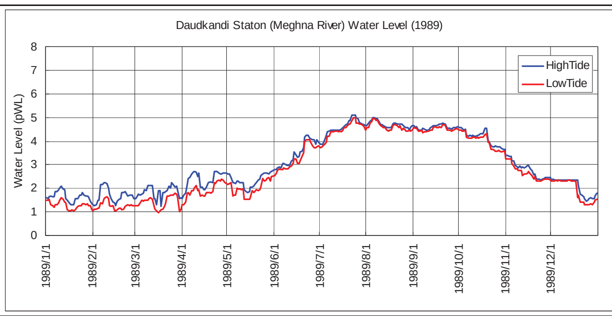
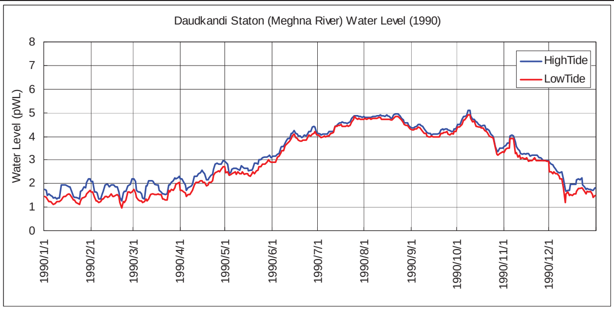


1989

Figure 12 (3) Daily Water Level at Daudkandi St (3/6)



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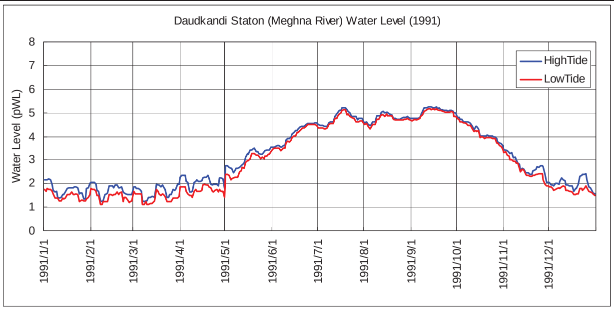

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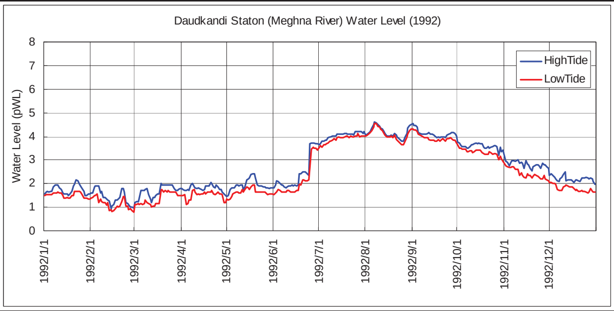

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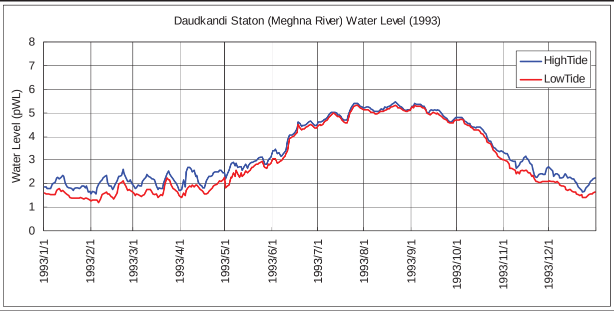

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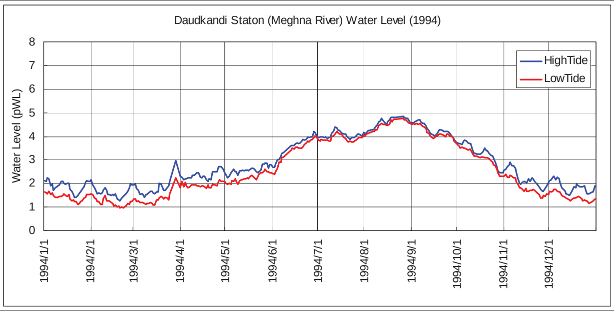

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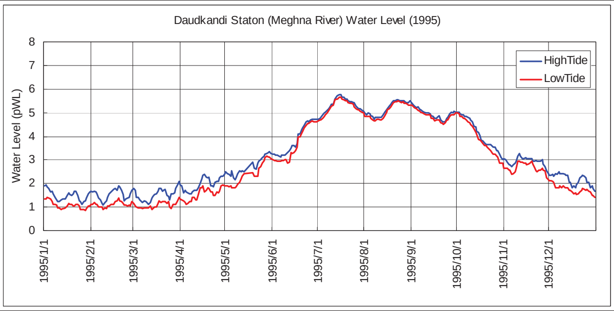

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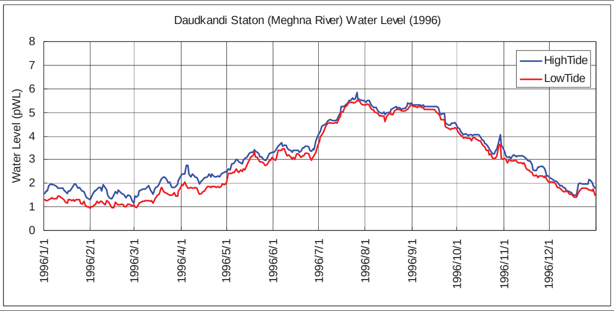

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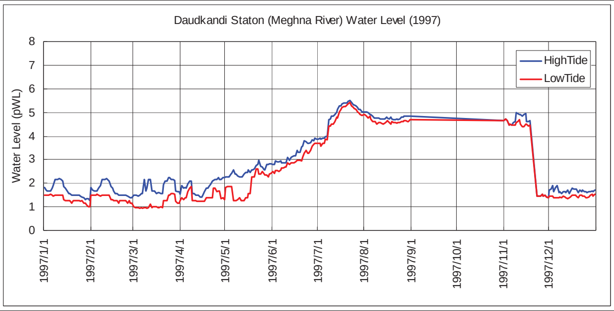

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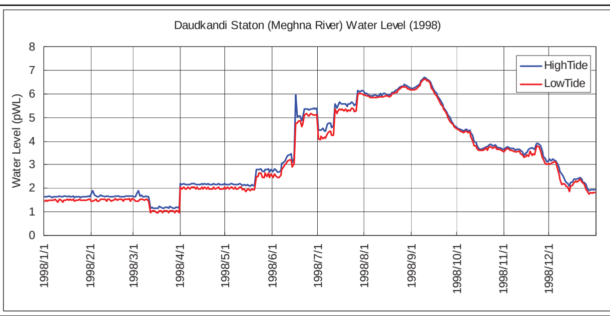

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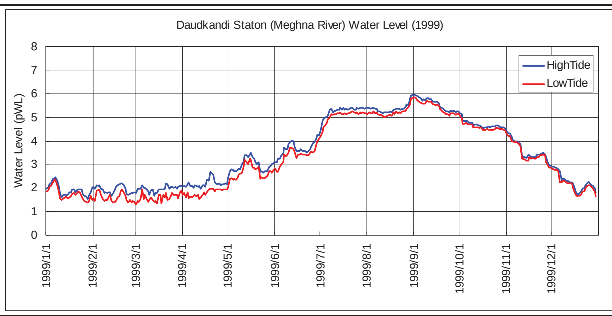
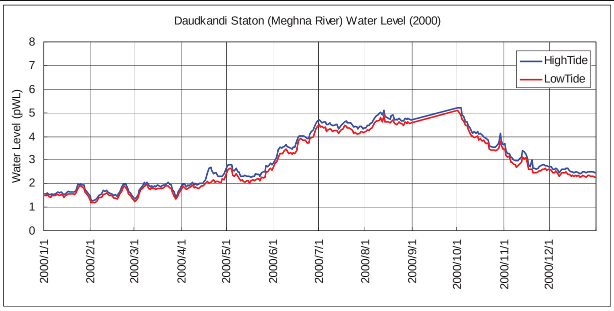


1999

Figure 12 (4) Daily Water Level at Daudkandi St (4/6)



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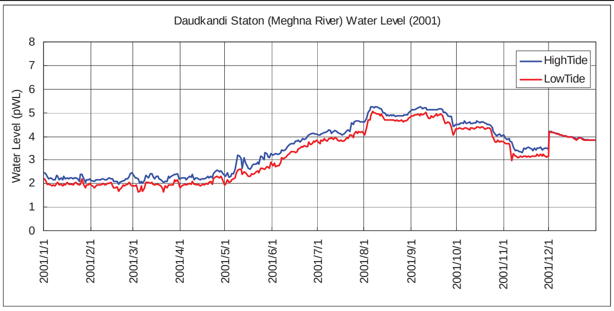

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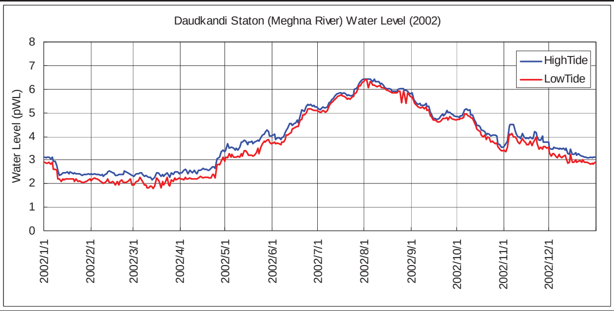

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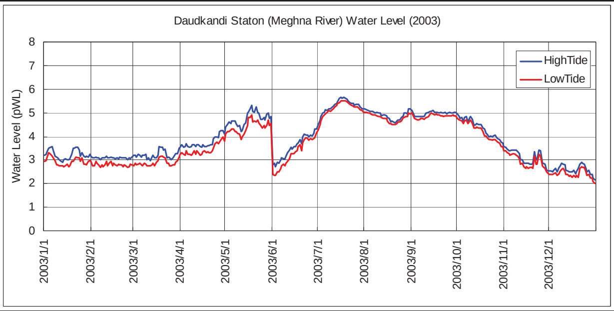

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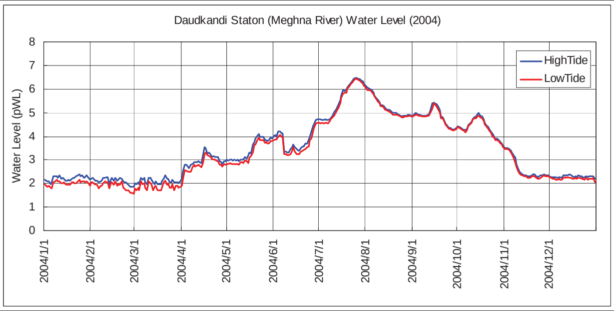

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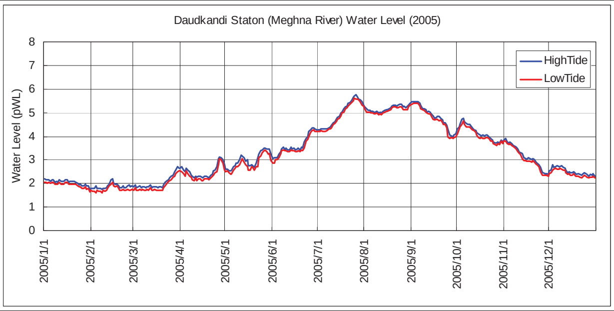

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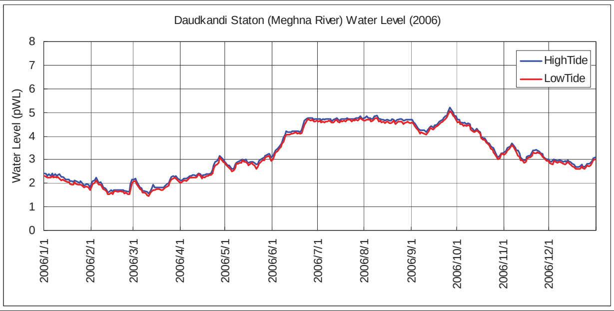

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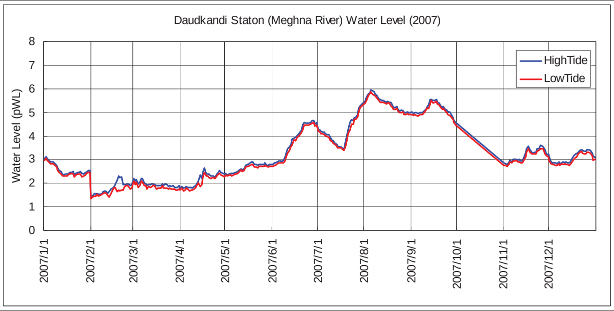

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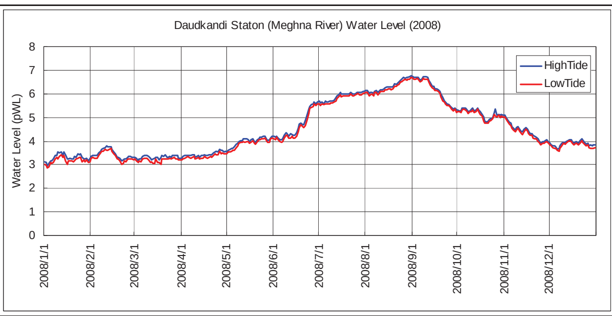

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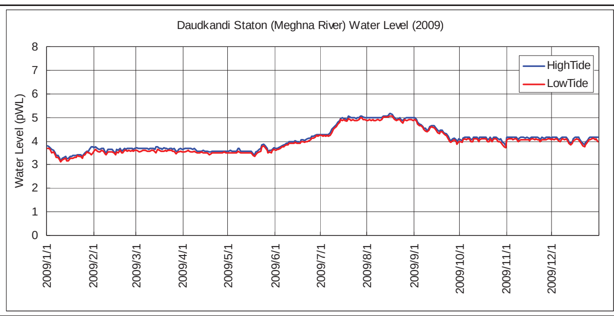
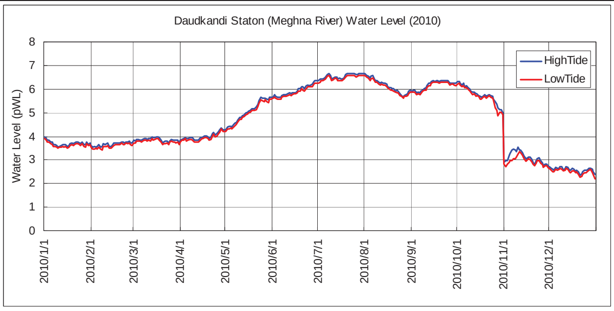
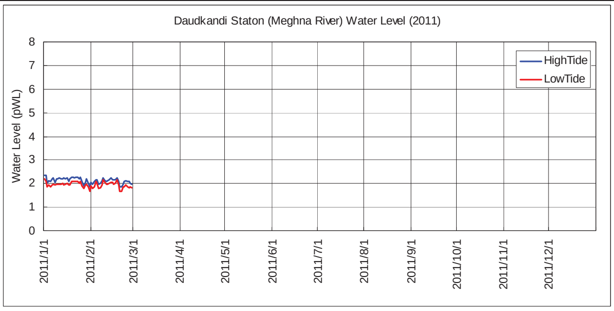


2009

Figure 12 (5) Daily Water Level at Daudkandi St (5/6)

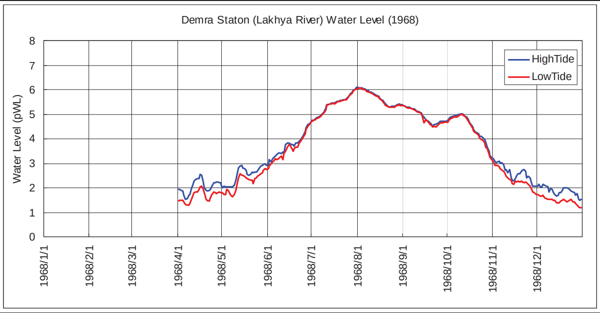


2010



2011

Figure 12 (6) Daily Water Level at Daudkandi St (6/6)



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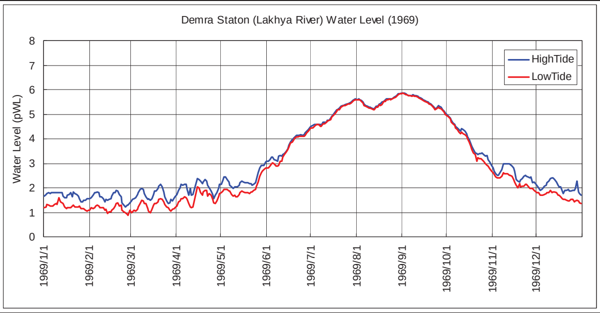

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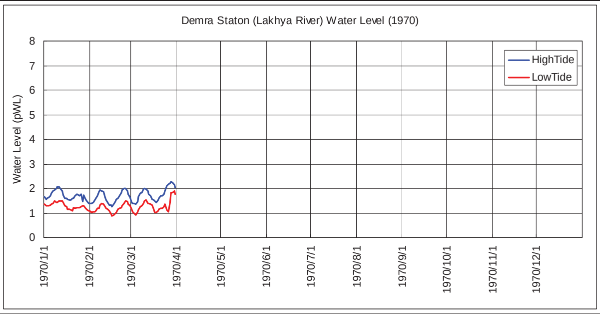

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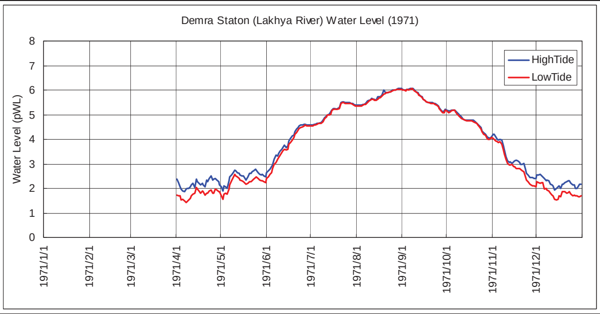

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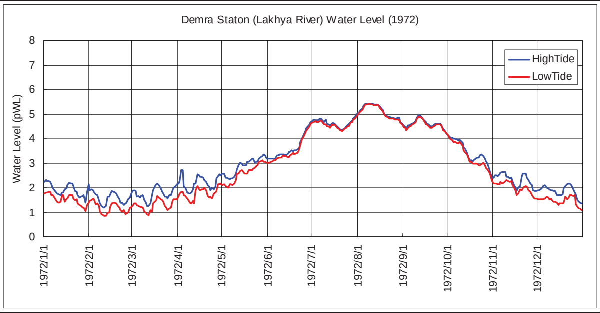

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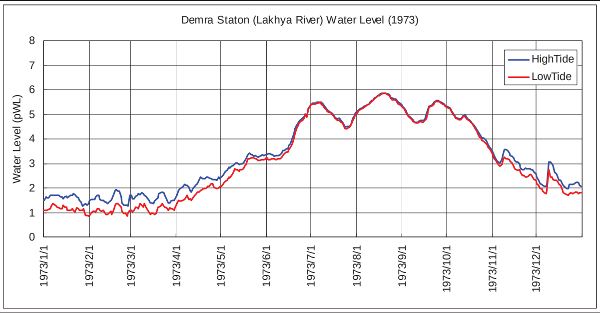

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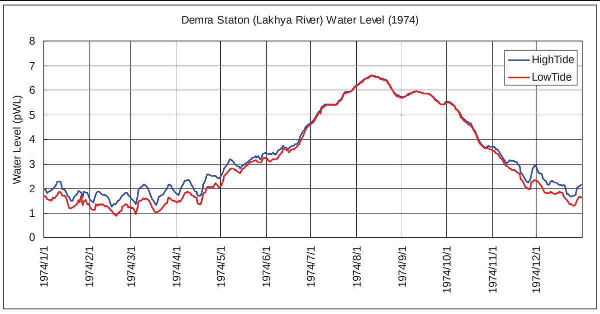

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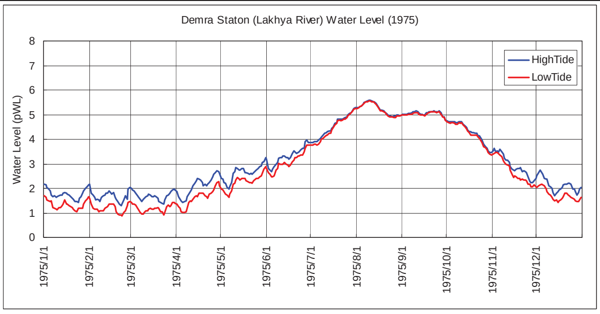

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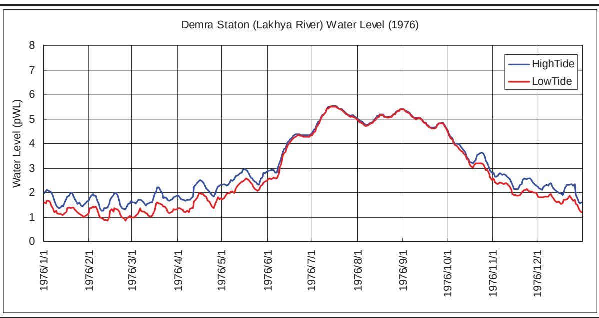

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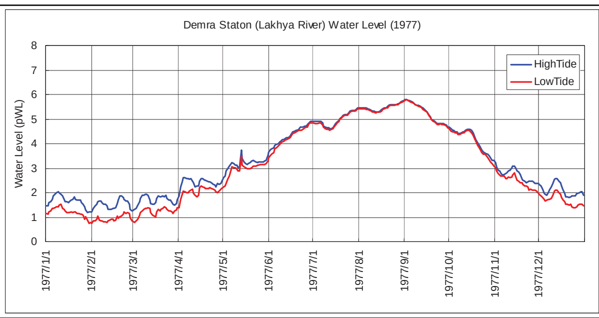
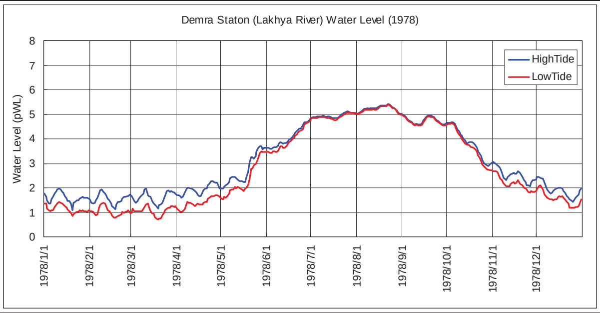


1977

Figure 13(1) Daily Water Level at Demra(Lahkya) St (1/5)



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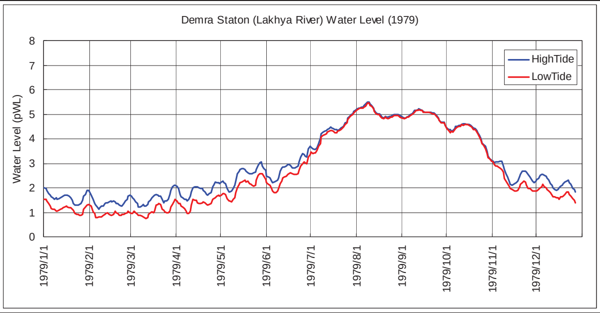

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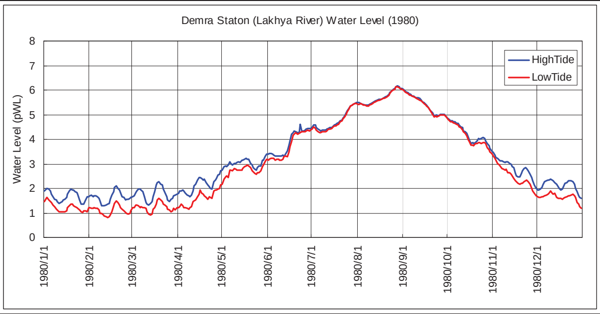

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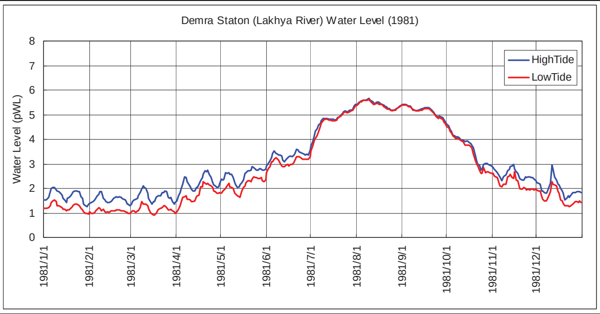

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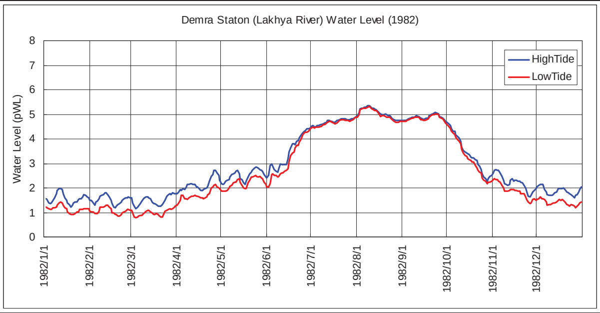

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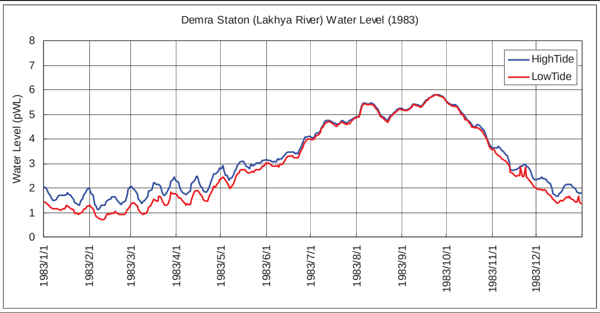

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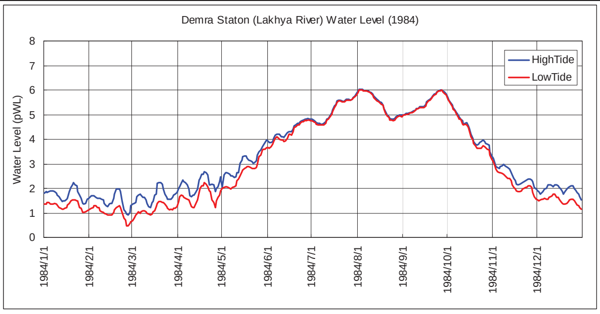

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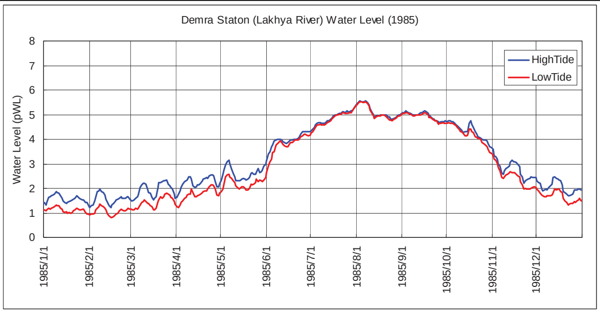

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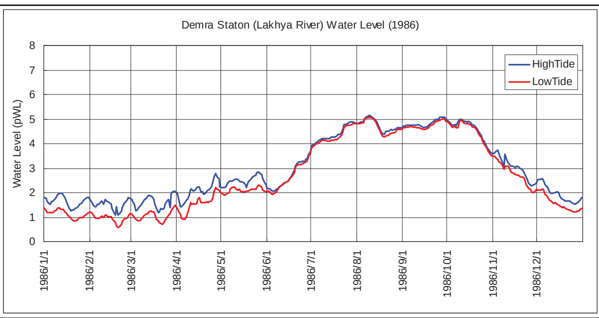
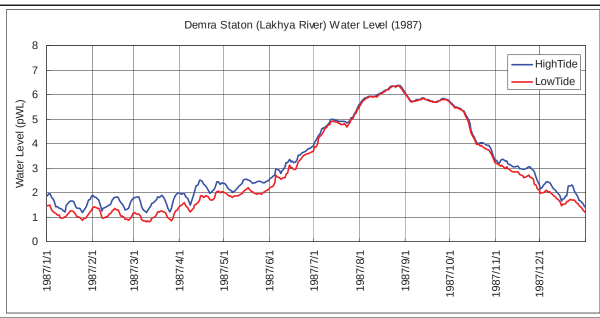
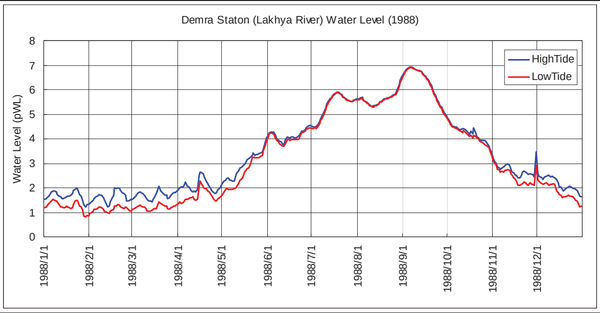


1986

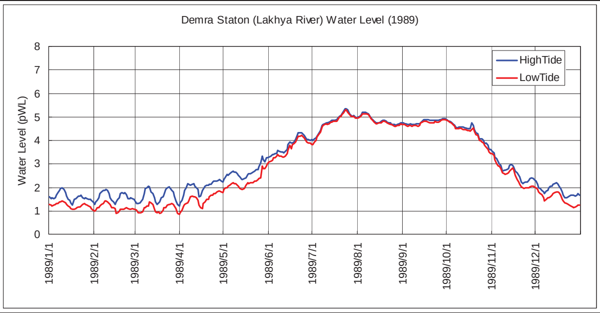


1987

Figure 13(2) Daily Water Level at Daudkandi St (2/5)



1988



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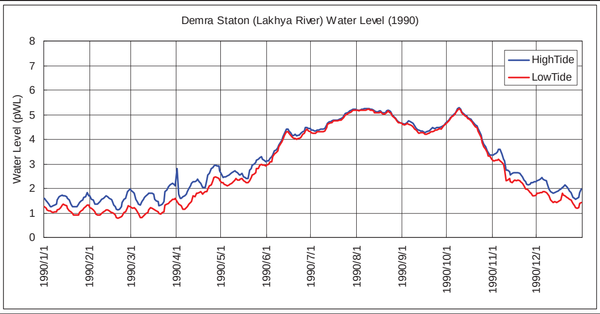

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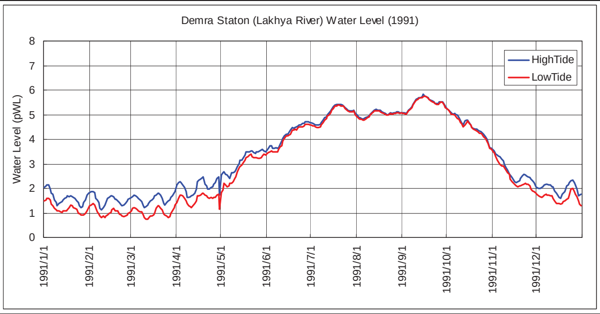

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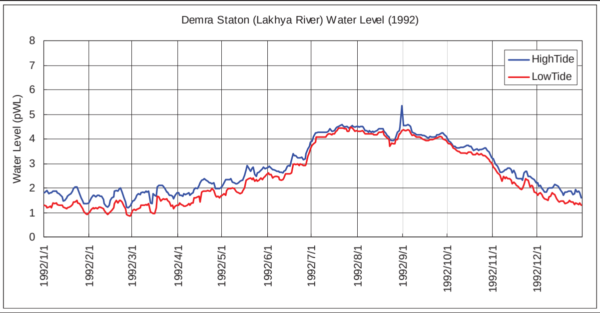

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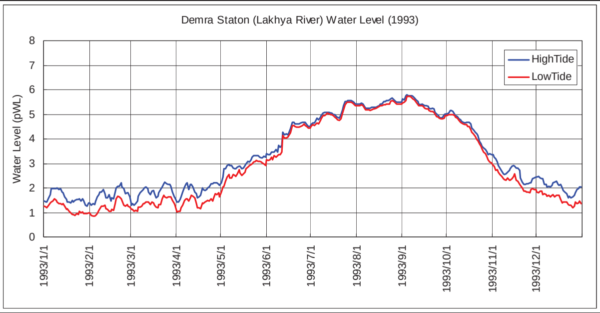

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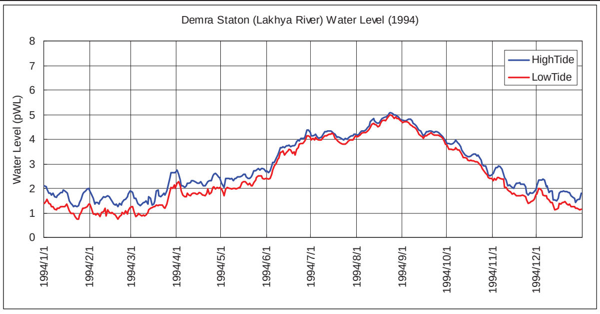

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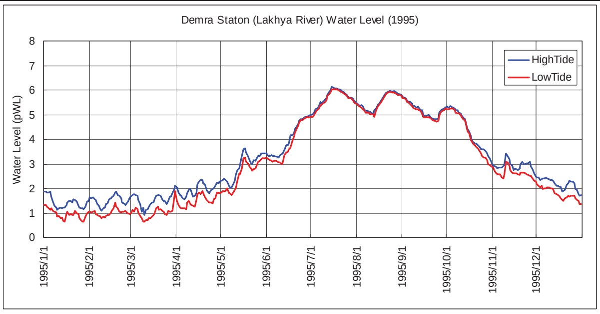
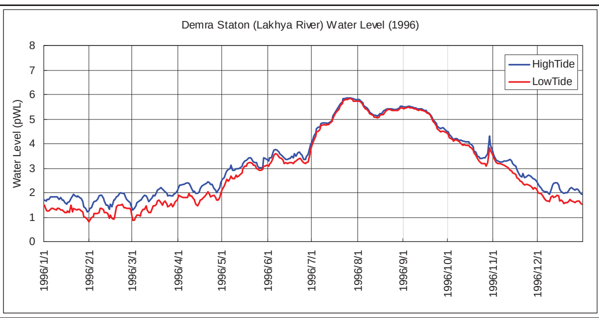


1995



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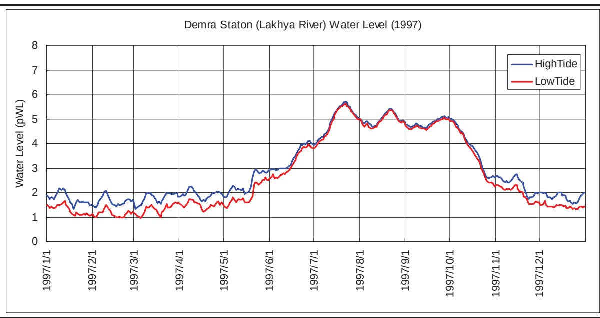


1997

Figure 13 (3) Daily Water Level at Daudkandi St (3/5)

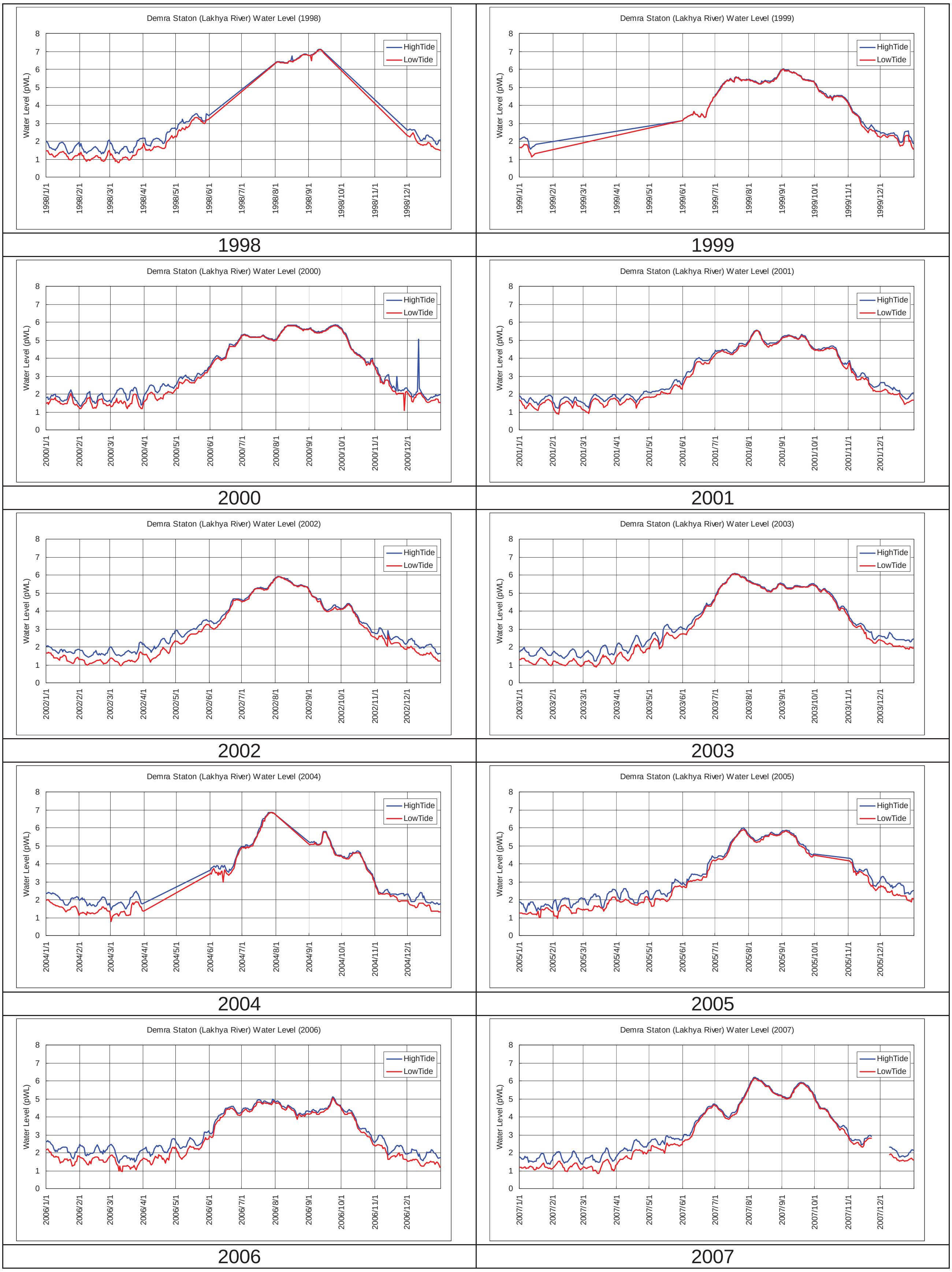
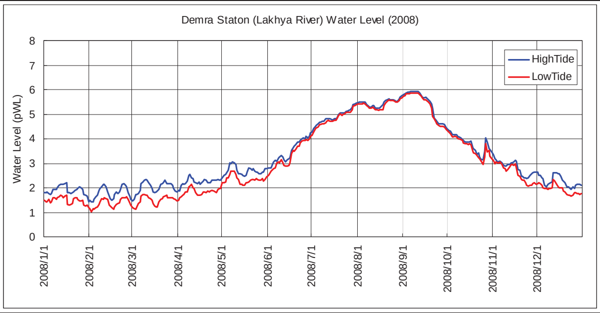
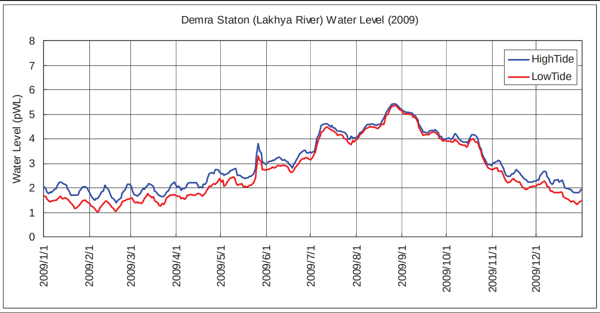


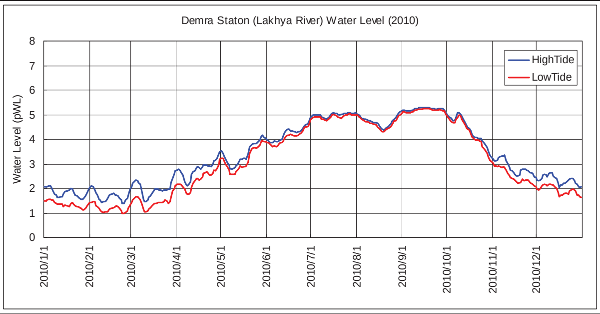
Figure 13 (4) Daily Water Level at Daudkandi St (4/5)



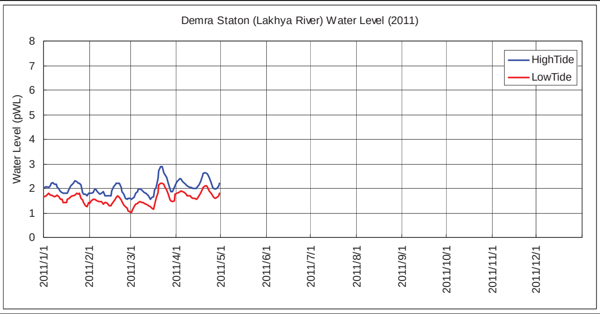
2008



2009



2010



2011

Figure 13 (5) Daily Water Level at Daudkandi St (5/5)