CHAPTER 3

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CHAPTER 3 CONTENS OF THE PROJECT

3.1. Basic Concept of the Project

3.1.1. Objectives of the Sindhuli Road Construction Project

The objectives of the Sindhuli Road Construction Project are as follows:

- To ensure further national security and further economic development through the utilization of the project road as an alternative trunk way, a “second back bone", which connects Kathmandu and the frontier to India via Terai Plain.
- To reduce the travel distance/time of the traffic between the Kathmandu Valley and Eastern Terai Plain, especially for the traffic conveying agricultural products.
- To upgrade and stimulate social and economic activities in the remote hill areas of the Central Development Region, particularly in the Sindhuli, Ramechhap and Kavrepalanchok Districts, and, consequently, to fulfill the basic human needs of the villagers living in the areas.

The Sindhuli Road Construction Project has been made a priority project by HMG/N. The Department of Roads had therefore–scheduled in its Twenty years plan to complete the entire section of the road within the 10th Five Year Plan period.

3.1.2. Objective of the Project

The Project (Urgent Rehabilitation of the Sindhuli Road Section IV) aims to restore the damage of the Project Road caused by the heavy rain during July 2002 to achieve the objectives of the Sindhuli Road Construction Project stated in Chapter 3.1.1.

3.1.3. Description of the Project

(1) Components of the Project

The Project (Urgent Rehabilitation of Sindhuli Road Section IV) will cover the following sites.

- Damaged sites from the recent disaster along Section IV Phase 2 Project and portions of road section that remained incomplete because of budgetary issues.
- The portion of Section IV Phase 1 Project which was completed and handed over to DOR but susceptible to obstruction of traffic flow due to the expansion of damages caused by the recent disaster and incomplete sites due to technical and budgetary

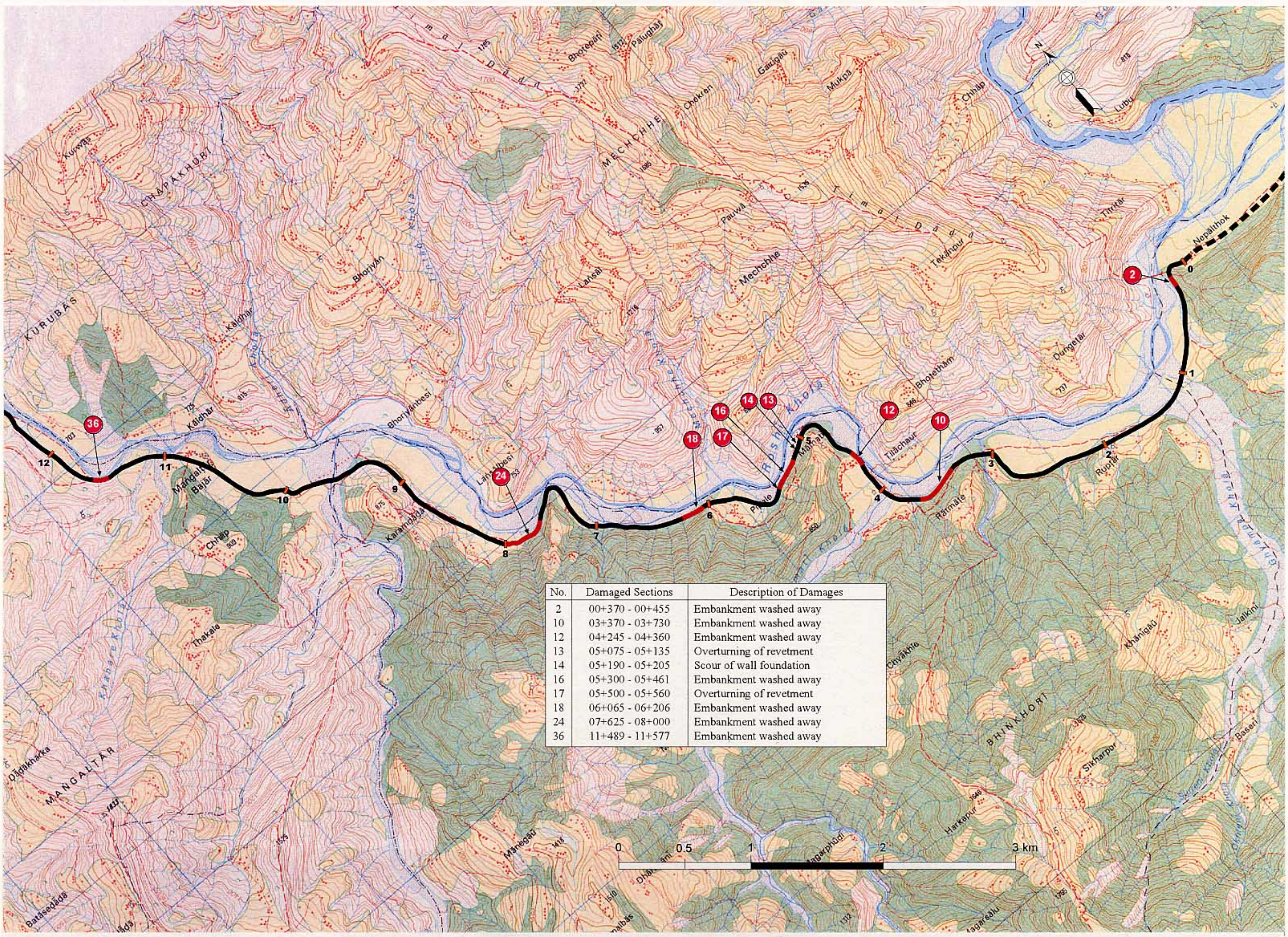
reasons from the DOR side.

(2) Project Sites

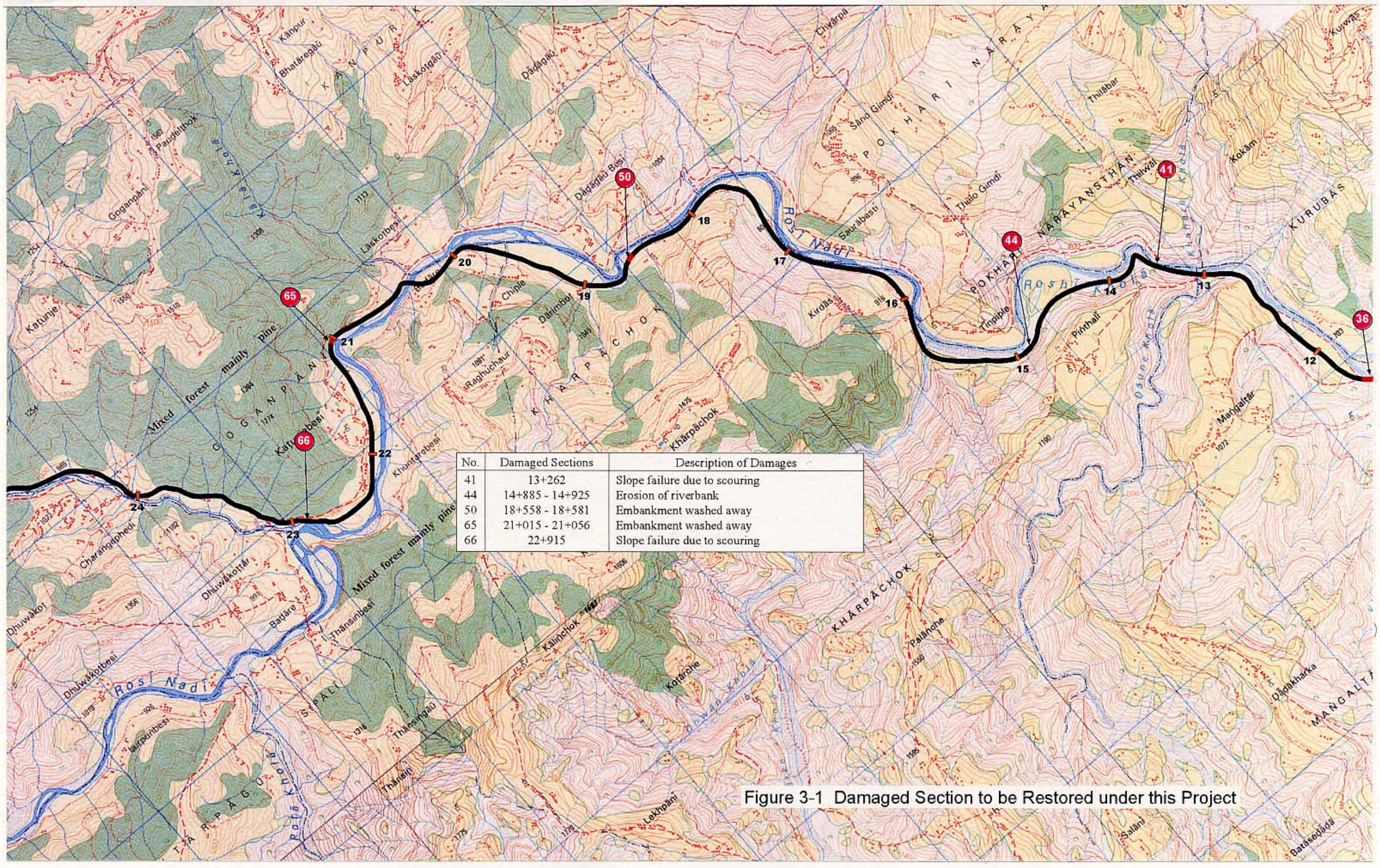
The damaged sections selected by the criteria mentioned above and to be restored under the Project are listed in Table 3-1 and shown in Figure 3-1 .

Table 3-1 Damaged sections to be restored under this project

No.	Damaged section	Length(m)	Description
2	00+370—00+455	85	Embankment washed away
10	03+370—03+730	360	Embankment washed away
12	04+245—04+360	115	Embankment washed away
13	05+075—05+135	60	Overturning of revetment
14	05+190—05+205	15	Scour of wall foundation
16	05+300—05+461	161	Embankment washed away
17	05+500—05+560	60	Overturning of revetment
18	06+065—06+206	141	Embankment washed away
24	07+625—08+000	375	Embankment washed away
36	11+489—11+577	88	Embankment washed away
41	13+262	—	Slope failure due to scouring
44	14+885—14+925	—	Erosion of riverbank
50	18+558—18+581	23	Embankment washed away
65	21+015—21+056	41	Embankment washed away
66	22+915	—	Slope failure due to scouring



No.	Damaged Sections	Description of Damages
2	00+370 - 00+455	Embankment washed away
10	03+370 - 03+730	Embankment washed away
12	04+245 - 04+360	Embankment washed away
13	05+075 - 05+135	Overturning of revetment
14	05+190 - 05+205	Scour of wall foundation
16	05+300 - 05+461	Embankment washed away
17	05+500 - 05+560	Overturning of revetment
18	06+065 - 06+206	Embankment washed away
24	07+625 - 08+000	Embankment washed away
36	11+489 - 11+577	Embankment washed away



No.	Damaged Sections	Description of Damages
41	13+262	Slope failure due to scouring
44	14+885 - 14+925	Erosion of riverbank
50	18+558 - 18+581	Embankment washed away
65	21+015 - 21+056	Embankment washed away
66	22+915	Slope failure due to scouring

Figure 3-1 Damaged Section to be Restored under this Project

3.2. Basic Design of the Requested Japanese Assistance

3.2.1. Assumed Causes of the Failures

(1) Comparison between Original Design Consideration of Section IV and situation after this Flood

The original design concept of Section IV and its situation after this flood by incessant rain in July, 2002 are summarize in Table 3-2

Table 3-2 Comparison between Original design and situation after this flood

Item		Original design	This flood
H.W.L and Precipitation	Diurnal precipitation	—	3 days: 312 mm(21~23rd, July) Return Period: 50 years
	Discharge of Roshi river	774～1,080m3/s Return Period: 50 years	No data (Closing of observatory)
	Consideration	Since observed data are not available, it is impossible to compare between B/D concept and this flood directly. However, it is presumed that flood level of July 20, 2002 was approximately equal to the original design H.W.L according to flood mark and calculation result in this study.	
Design Criteria for Revetment Structures	Top level of wall structures	H.W.L. + 1.2m	Standard section will not be overtopped.
	Freeboard	Standard section： = (Analyzed value,0～0.8m) Bend section： = (Analyzed value,0～0.8m) + (value added at Bend section only)	Standard section： Water level was below designed H.W.L. Bend section： No overflow at section where radius of curvature is small. (Overflow occurred at 4 locations. Extent of damages at 2 locations is severe.)
	Estimated Max Scouring depth	Standard section :1.0m Bend section: 1.5m	Damages by scouring were immense only at bend Section
	Embedded depth	= (Lowest riverbed) – (2.0～2.5 m)	Damages by scouring were immense only at bend Section
	Foot protection	3t concrete blocks installed at bend section.	Washed away partially
	Consideration	In the original plan, design criteria were adopted from Japanese standards considering characteristics of Roshi River. However, huge debris flow from tributary and long lasting rainfall caused large scale unexpected scouring.	

Item		Original design	This flood
Maintenance Policy	Scale of Maintenance	It is assumed that DOR can sustain maintenance works using grant equipment.	Long continuous damages of road at six locations were occurred.
	Maintenance Works	DOR will sustain maintenance works, such as removal of Debris, Concrete pavement at Causeway, Gabions, Retaining walls and DBSD	Huge embankment and revetment structures were washed away by flood.
	Consideration	Maintenance requirement of damages on 20 July 2002 at several locations is beyond the capacity of DOR. Particularly the damages between STA.0 and STA. 8 are of large scale.	

(2) Classification of Damages along river

The types of damages in road structures along Roshi-river can be classified as follows:

- Type-A： Erosion of road surface by surface water
- Type-B： Scouring (can be further classified into following 4 types)
    - B-1： Crack and/or settlement of road surface
    - B-2： Depression of road surface
    - B-3： Overturning of revetment
    - B-4： Washing away of embankment
- Type-C： Washing away by overflow
- Type-D： Destruction of revetment due to excessive hydraulic pressure
- Type-E： Settlement of backfilling
- Damage of gabion box, concrete pavement, approach road and deposition of Debris at causeways

Figure 3-2 through Figure 3-4 show illustrations and photos of the different types of damages mentioned above.

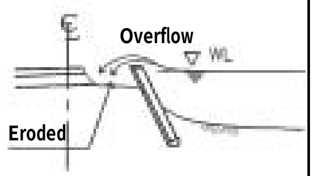
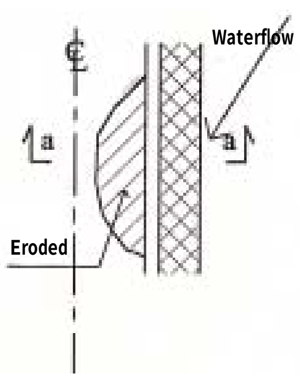
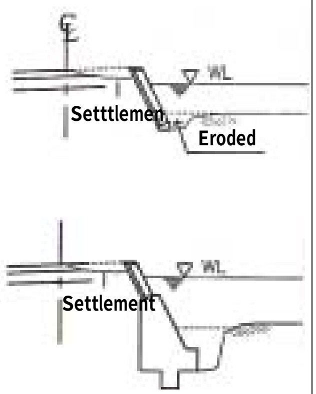
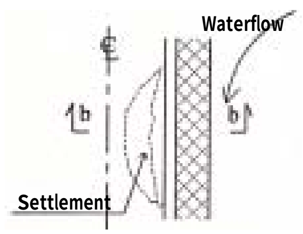
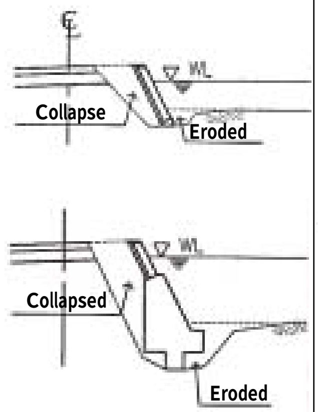
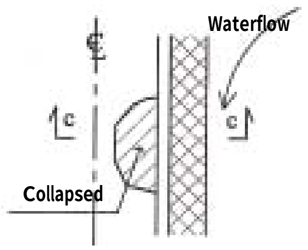
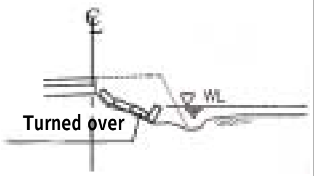
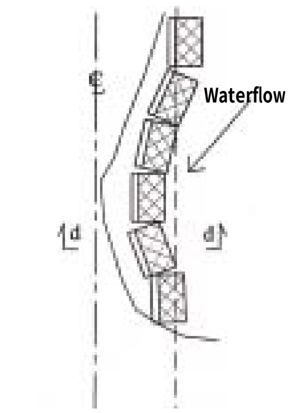
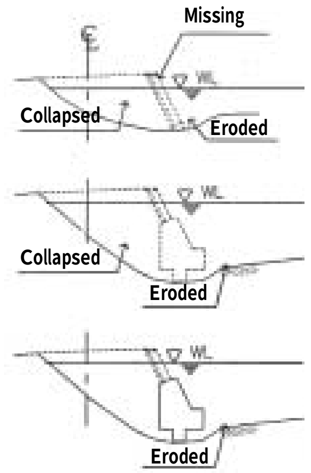
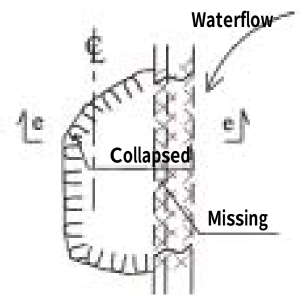
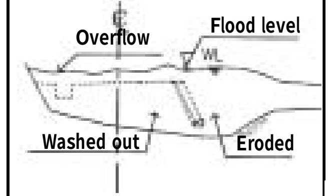
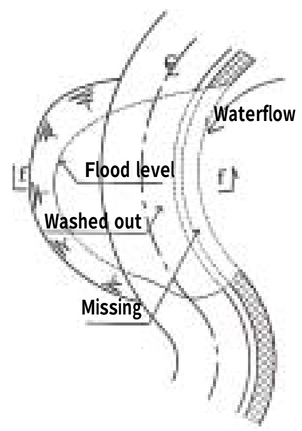
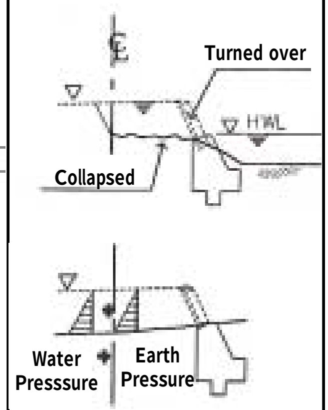
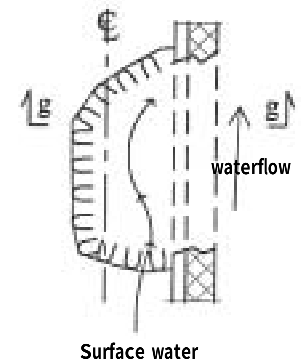
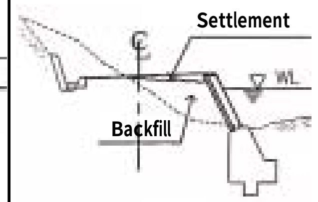
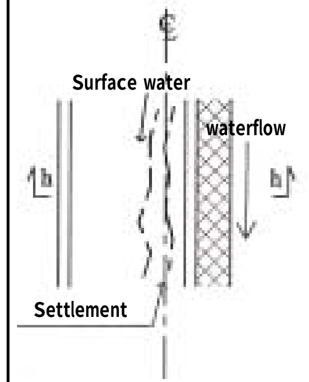
Descriptions	Type- A	Type- B				Type- C	Type- D	Type- E
		B-1	B-2	B-3	B-4			
	Erosion of road surface by surface water	Scouring: Crack and/or settlement of road surface	Scouring: Depression of road surface	Scouring: Overturning of revetment	Scouring: Washing away the embankment	Washing away by overflow	Destruction of revetment by hydraulic pressure by water	Settlement of backfilling
Images of Destruction	**Cross section**  **Plan** 	**Cross section**  **Plan** 	**Cross section**  **Plan** 	**Cross section**  **Plan** 	**Cross section**  **Plan** 	**Cross section**  **Plan** 	**Cross section**  **Plan** 	**Cross section**  **Plan** 
Photos	Photo- 1	Photo- 2	Photo- 3	Photo- 4	Photo- 5	Photo- 6	Photo- 7	Photo- 8

Figure 3-2 Types of Damages

	＜Photo 1＞ Type A: Erosion of road surface by surface water
	＜Photo 2＞ Type B-1: Scouring Crack and/or settlement on road surface
	＜Photo 3＞ Type B-2: Scouring Depression of road surface
	＜Photo 4＞ Type B-3: Scouring Overturning of revetment

Figure 3-3 Types of Damages (Photo 1/2)

＜Photo 5＞ Type B-4:

Scouring
Washing away of embankment

＜Photo 6＞
Type C

Washing away due to overflow

＜Photo 7＞ Type D:

Destruction of revetment due to excessive hydraulic pressure

＜Photo 8＞Type E:

Settlement of backfilling

Figure 3-4 Types of Damages (Photo 2/2)

(3) Assumed Causes of the Failures

Based on the evidence described in Chapter 2.3.2, it can be concluded that the damages during July 2002 Flood were caused by the complicated and unanticipated hydrological mechanism and heavy rain lasting three days. This justification is supported by the evidence that there are no damage as shown in photo 9, and that the flood levels were also within the estimated high water level in the river sections where the flow was normal.

Dhulikel direction seen fromSta.13+800

Nepalthok direction seen from Sta.16+700

Photo 9 No Damaged Section

A typical example of the simulated sequences of failure process of revetment based on a preliminary 2.5 dimension riverbed fluctuation analysis at the section between STA. 3+370 and STA. 3+730 as shown in Figure 3-5 through to Figure 3-8 and described below. The foundation of the revetment was set at 3 meter below the riverbed with foot protection blocks. The structures were designed for a 5.5 m/s of flow velocity.

- Just after the occurrence of the flood, the velocity and water depths are within the design conditions.
- After 24 hours of the continuous flood, maximum velocity is 5.7m/sec and maximum water depth is 5.0m almost equivalent to design level.
- After 48 hours of the continuous flood, maximum velocity and maximum water depth reached 6m/sec and 6.9m respectively. At this point, the revetment is very vulnerable to being washed away. It was observed that the actual failure of structures at the site only started after 48 hours from the beginning of the flood event justifying the results of the analysis.
- After 72 hours from the beginning of the flood, maximum velocity reaches 6.9m/sec and maximum water depth is 8.8m.

The preliminary 2.5 dimension riverbed fluctuation thus justifies the assumption that the July 2002 event was a hydrologically unforeseen case, caused by the heavy rainfall lasting over a three day period.

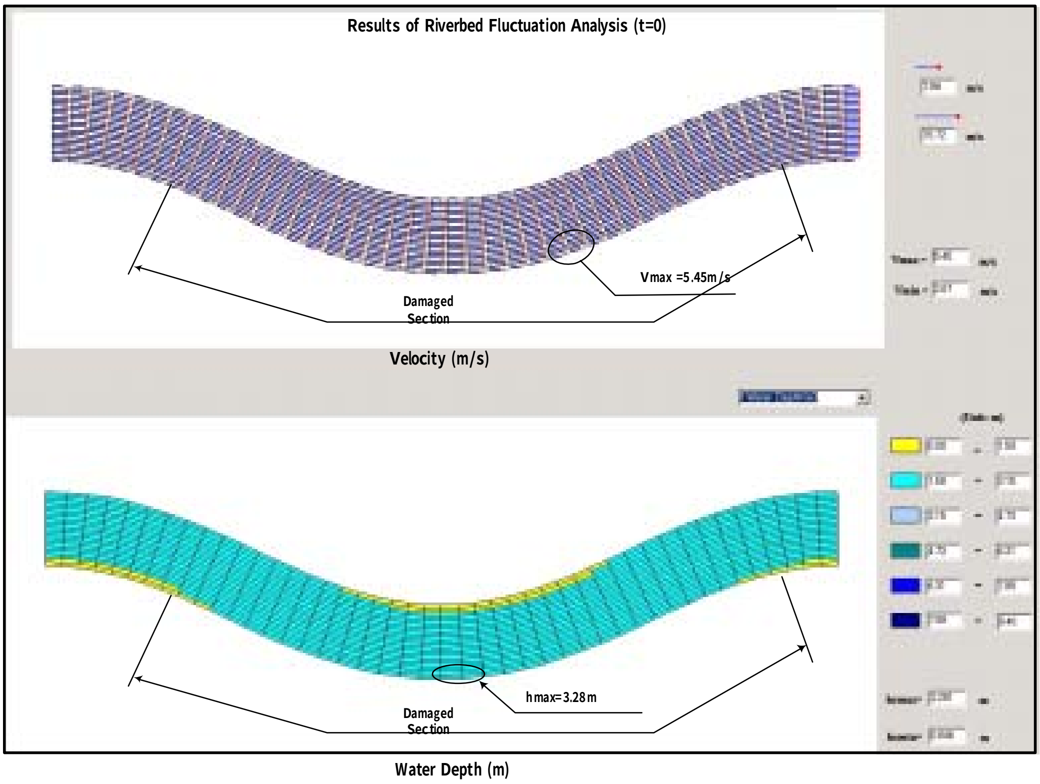


Figure 3-5 2.5 dimension riverbed fluctuation analysis (at beginning)

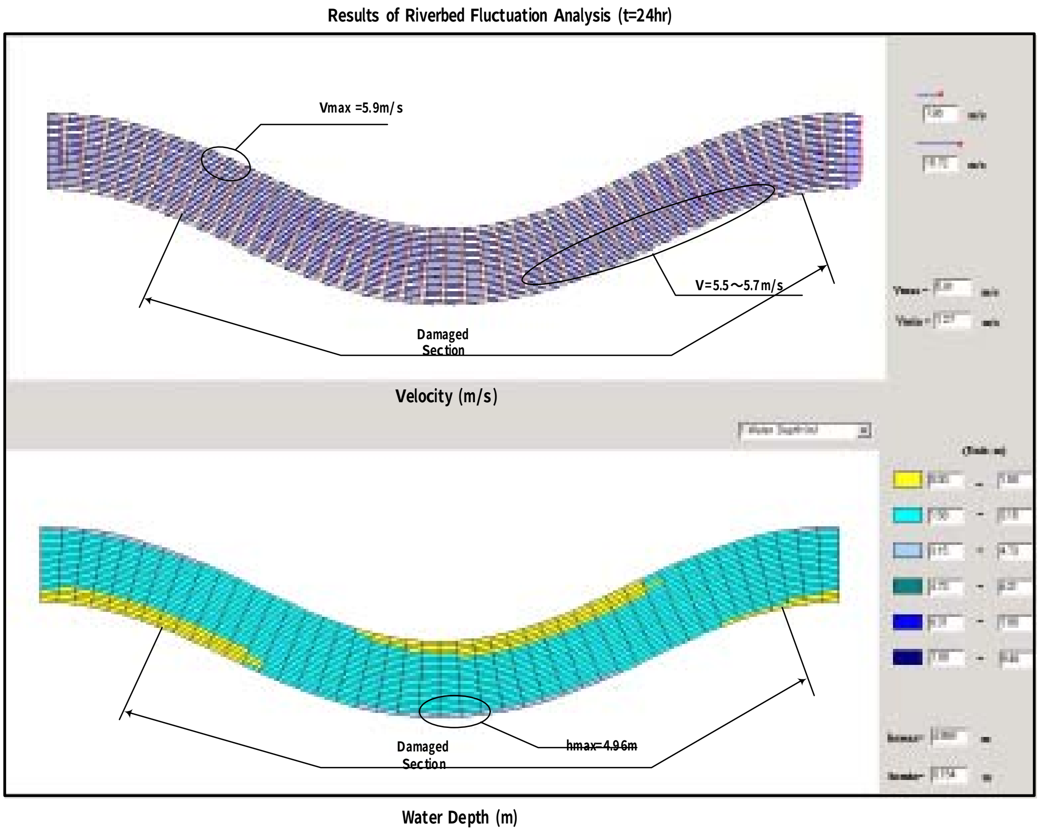


Figure 3-6 2.5 dimension riverbed fluctuation analysis (after 24hours)

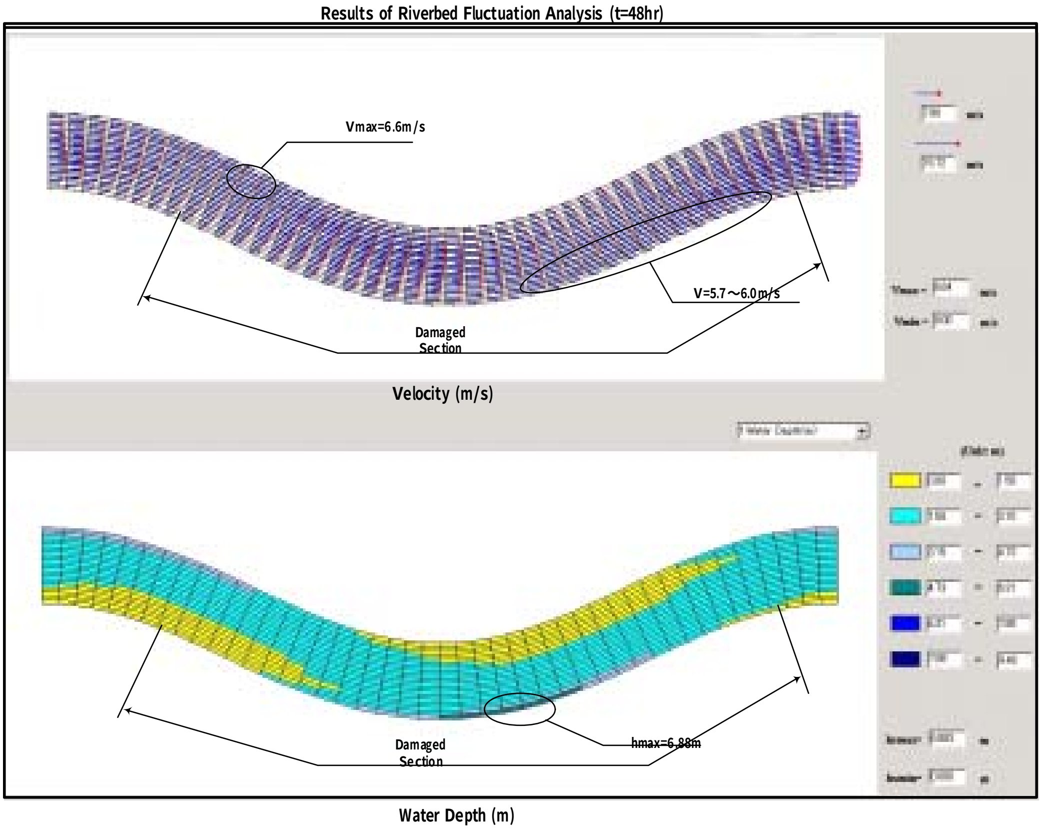


Figure 3-7 2.5 dimension riverbed fluctuation analysis (after 48hours)

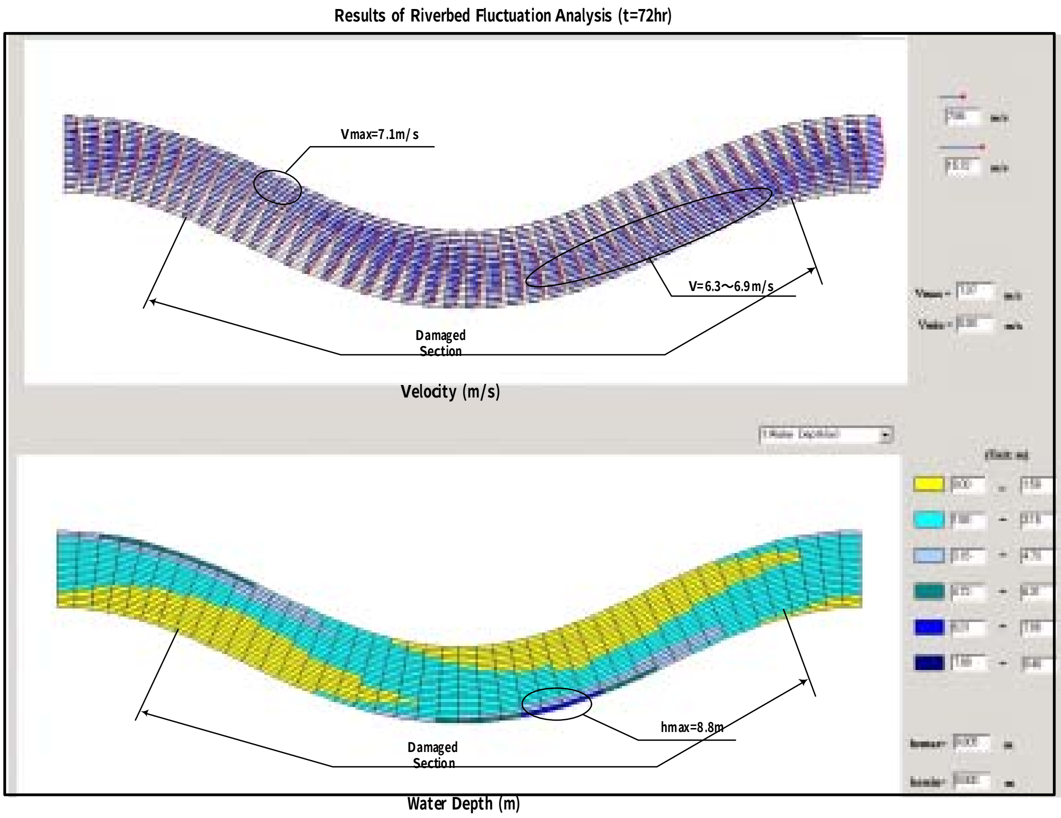


Figure 3-8 2.5 dimension riverbed fluctuation analysis (after 72hours)

3.2.2. Restoration Policy

(1) Design Consideration in the Original Plan

Design high water level was estimated by a hydrological analysis based on the flood record at Panauti Station in original plan. The 50-year return-period flood for Roshi River was applied for the analysis. The 3-days average precipitation over the Roshi River basin was estimated to be 312mm, which is equivalent to the 50-year return-period 3-days average precipitation. Therefore, it can be judged that the flood in July 2002 is almost equivalent to the design flood.

Since the observed flood water levels were below the design level and there had been no serious damage in the sections along the normal river condition, it can be judged that the original design conditions, such as the design high water level, the depth of revetment's foundation, etc. are based on adequate basis.

(2) Design Principles of Restoration Works

As described in Chapter 3.2.1, the main cause of the problem was the deposit of huge amounts of debris in the tributaries. The villagers had also reported that the same magnitudes of debris flow have occurred in about 20-year intervals in the past. The damage in the July 2002 flood was mainly caused by a complicated and unforeseen hydrological mechanism, triggered by heavy incessant rain lasting three days. The design of the Restoration Works should therefore be carried out using high water level and velocity of flood calculation based on the hydrological analysis from the July 2002 flood experience rather than the approaches used during the original design.

(3) Maximum Utilization of existing undamaged Structures

As the Project aims to only restore the damaged structures, the scope of works should be limited to restoration of the damaged portions only and not extend to reconstruct the existing structures under fine conditions.

The implementation of a new road profile will be limited to the washed away sections only. Double Bituminous Surface Treatment will then be applied to the road surfaces for achieve waterproofing of these sections.

3.2.3. Design Policy of Revetment Works

Based on the policies described in Clause3.2.2 and a 50-year return period flood, the basic design of restoration works will be carried out. The design will be done with consideration to the following hydrological conditions.

- Rise of flood water at bend sections
- Flood velocity and scouring depth
- Suction of backfill

(1) Design Criteria for Countermeasures against Rise of Flood Level at Bend

As a countermeasure against the rising of flood levels at curve sections, the vertical alignment shall be reviewed considering high water level estimated in the chapter.

1) Design Flood

50 years flood (Q50) estimated in this study is 25 % larger than that predicted during the previous study, for the following reasons;

- The data period considered during the previous design was from 1964 to 1985 whereas the major flood event occurred in July 2002.
- The methodologies of the estimation of the flood peak in this study and the previous study are different as explained in Chapter 2.3.1.
- The flood peak value estimated in this study has some allowances depending upon the selection of hyetograph.

The estimated flood peak values are therefore judged as realistic taking into account the considerations mentioned above. It is therefore recommended that the design of related structures is reviewed considering the modified Q50 (based on recent data) estimated in this study. However for undamaged portion of road stretches, the Original Design flood criteria are applicable. Table 3-3 illustrates the comparison of Q50 estimated by both methods at different locations of the Roshi River.

Table 3-3 Comparison of 1/50 Probable Flood Peak

Location	CA (km^2)	Original Design (m^3/s)	This Study (m^3/s)	Difference
Dapcha	400	774	977	26%
Narke	446	861	1,086	26%
Daune	465	899	1,130	26%
Bhyakure	503	972	1,213	25%
Mamuti	536	1,035	1,289	25%
Nepalthok	560	1,080	1,344	24%

2) High Flood Level (HFL) at river bend

The high flood level at bends will be adopted from whichever of following is greater:

- The water level calculated by non-uniform flow analysis plus additional rise in water level in river bend.
- High flood level during recent flood event.

i) Non-uniform Analysis

Boundary Condition

Since the flow condition of the river under study is supercritical, uniform water depth is assumed as upstream boundary condition.

Coefficient of Roughness

Table 3-4 shows the relationship between d_{60} and coefficient of roughness (n). Since the size of riverbed material ranges from 10mm to 43mm, a coefficient of roughness of 0.035 has been adopted.

Table 3-4 Relationship between d_{60} and coefficient of roughness

<table>
<tr><td colspan="2" rowspan="2">Riverbed material and d_{60}</td><td colspan="2">Coefficient of Roughness</td><td rowspan="2">Riverbed Condition</td></tr>
<tr><td>A</td><td>B</td></tr>
<tr><td colspan="2">Rock</td><td colspan="2">0.035～0.050</td><td rowspan="6">A: flatness without big Stone on the riverbed.
B: rugged with big Stone on the riverbed.</td></tr>
<tr><td rowspan="3">cobbled stone</td><td>d_{60}= 40cm to 60cm</td><td>0.037</td><td rowspan="3">0.042</td></tr>
<tr><td>d_{60}= 20cm ～40cm</td><td>0.037</td></tr>
<tr><td>d_{60} = 10cm ～20cm</td><td>0.037</td></tr>
<tr><td rowspan="2">coarse</td><td>d_{60} = 5cm ～10cm</td><td colspan="2">0.035</td></tr>
<tr><td>d_{60} = 2cm ～5cm</td><td>0.029</td><td>0.034</td></tr>
</table>

ii) Rise in Water Level at the Bend of the River

The rise in water level at the river bend is calculated from the following equation.

$$\Delta h = \frac{B \cdot U^2}{2 \cdot g \cdot r_c}$$

Where, Δh : Rise in water level at the outside of bend (m).

B : Width of river channel (m)

U : Average Velocity (m/s)

g : Gravitational acceleration (m/s2)

rc : Radius of Curvature of the river channel (m)

iii) Freeboard

According to the Japanese Criteria, the freeboard for discharge between 500 and 2000 m^3/s is 1.0m.

Due to the severe hydraulic condition around the river bend, a freeboard of 1.2m has will be adopted, which is 1 rank higher than the recommended 1.0 m freeboard for specified discharge, as per Japanese Criteria.

3) Results

The calculation results are listed in Table 3-5.

The adoption of new HFL should be determined considering site conditions of damaged road structures.

Table 3-5 Estimated High Water Level

River Cross Sec.No.	Road Sta. No.	h (m)	U (m/s)	B(m)	rc(m)	Δh (m)	h+Δh (m)	HFL on Jul.2002 (m)	Estimated H.W.L.
Sec-1	STA.0+350	555.380	4.99	80	1,000	0.102	555.482	-	555.482
Sec-2	STA.0+475	556.250	5.74	140	1,000	0.235	556.485	-	556.485
Sec-3	STA.0+750	560.280	3.56	200	1,000	0.129	560.409	-	560.409
Sec-4	STA.1+025	563.650	3.95	150	1,000	0.119	563.769	-	563.769
Sec-5	STA.1+275	566.400	3.84	140	1,000	0.105	566.505	-	566.505
Sec-6	STA.2+025	573.630	4.13	170	1,000	0.148	573.778	-	573.778
Sec-7	STA.2+475	579.570	3.34	140	0	0.000	579.570	-	579.570
Sec-8	STA.3+275	589.630	4.82	100	350	0.338	589.968	591.002	591.002
Sec-9	STA.3+525	592.770	5.25	100	350	0.402	593.172	594.766	594.766
Sec-10	STA.3+775	595.540	4.66	100	350	0.317	595.857	597.572	597.572
Sec-11	STA.4+100	598.320	5.37	100	400	0.368	598.688	-	598.688
Sec-12	STA.4+300	601.450	5.75	120	350	0.578	602.028	-	602.028
Sec-13	STA.4+700	607.420	4.79	140	0	0.000	607.420	-	607.420
Sec-14	STA.4+875	611.180	5.53	90	0	0.000	611.180	-	611.180
Sec-15	STA.5+050	613.590	5.15	90	0	0.000	613.590	-	613.590
Sec-16	STA.5+225	615.700	7.24	70	500	0.374	616.074	-	616.074
Sec-17	STA.5+350	619.060	4.70	70	500	0.158	619.218	-	619.218
Sec-18	STA.5+500	619.630	5.40	100	500	0.298	619.928	-	619.928
Sec-19	STA.5+800	622.370	4.35	100	500	0.193	622.563	-	622.563
Sec-20	STA.5+900	623.180	5.93	100	550	0.326	623.506	-	623.506
Sec-21	STA.6+150	627.080	4.23	120	800	0.137	627.217	-	627.217
Sec-22	STA.6+550	632.070	3.94	130	800	0.129	632.199	-	632.199
Sec-23	STA.6+800	634.770	6.70	140	800	0.401	635.171	-	635.171
Sec-24	STA.7+375	641.690	5.12	120	800	0.201	641.891	-	641.891
Sec-25	STA.7+625	646.900	4.65	120	350	0.378	647.278	648.266	648.266
Sec-26	STA.7+900	649.490	4.53	140	350	0.419	649.909	650.467	650.467
Sec-27	STA.8+450	654.380	5.18	160	350	0.626	655.006	-	655.006

River Cross Sec.No.	Road Sta. No.	h (m)	U (m/s)	B(m)	rc(m)	Δh (m)	h+Δh (m)	HFL on Jul.2002 (m)	Estimated H.W.L.
Sec-28	STA.9+450	675.490	4.19	130	0	0.000	675.490	-	675.490
Sec-29	STA.9+900	679.640	8.94	170	0	0.000	679.640	-	679.640
Sec-30	STA.10+400	688.170	4.33	160	0	0.000	688.170	-	688.170
Sec-31	STA.10+900	696.330	5.53	120	220	0.851	697.181	-	697.181
Sec-32	STA.11+400	706.570	6.23	40	200	0.396	706.966	-	706.966
Sec-33	STA.11+850	709.290	7.63	40	200	0.594	709.884	-	709.884
Sec-34	STA.13+050	730.800	6.61	50	0	0.000	730.800	-	730.800
Sec-35	STA.14+450	756.110	5.57	50	0	0.000	756.110	-	756.110
Sec-36	STA.14+900	763.050	6.25	50	100	0.996	764.046	-	764.046
Sec-37	STA.15+325	768.810	5.96	80	0	0.000	768.810	-	768.810
Sec-38	STA.16+500	780.710	6.61	40	0	0.000	780.710	-	780.710
Sec-39	STA.16+850	793.160	6.30	50	400	0.253	793.413	-	793.413
Sec-40	STA.17+725	809.100	4.73	80	0	0.000	809.100	-	809.100
Sec-41	STA.18+350	816.180	6.98	40	0	0.000	816.180	-	816.180
Sec-42	STA.18+600	820.800	5.58	110	0	0.000	820.800	823.200	823.200
Sec-43	STA.18+750	821.310	5.83	130	80	2.818	824.128	823.710	823.710
Sec-44	STA.19+000	824.020	5.66	90	0	0.000	824.020	-	824.020
Sec-45	STA.20+125	838.730	6.11	50	0	0.000	838.730	-	838.730
Sec-46	STA.21+000	851.480	5.83	50	80	1.084	852.564	-	852.564
Sec-47	STA.21+150	852.420	6.74	90	80	2.607	855.027	854.960	855.027
Sec-48	STA.21+350	854.980	5.40	80	200	0.595	855.575	-	855.575
Sec-49	STA.22+000	861.230	9.02	90	0	0.000	861.230	-	861.230
Sec-50	STA.22+675	878.320	4.49	80	0	0.000	878.320	-	878.320
Sec-51	STA.23+000	881.320	7.00	90	0	0.000	881.320	-	881.320

(2) Design Criteria for Countermeasures against Scouring[K.S4]

1) Assumed Maximum Scouring Depth

For the design of a countermeasure against scouring, estimation of maximum scouring is required. The embedment level of wall foundation is set up with reference to maximum scouring depth. The maximum scouring depth is adopted from whichever is greater among the following.

- Scouring depth due to the recent flood event.
- Estimated scouring depth based on water depth calculated by non-uniform flow analysis.
- Scouring depth based on the 2.5-dimension river bed fluctuation analysis computed with 48-hour average flood discharge.

2) Non-uniform Analysis

Boundary Condition

The boundary condition is taken as uniform water depth at the upstream section.

Coefficient of Roughness

The coefficient of roughness is adopted 0.035.

3) Estimated scouring depth based on water depth

The scouring depth is estimated by following equation

$$H_{\max} = C \times H_d$$

Where, Hmax : Maximum scouring depth (m)

Hd : Design water depth (m)

C : Proportion of Hmax and Hd estimated from the following figure by substituting the "b/r"

b : Width of river channel (m)

r : Radius of the river channel (m)

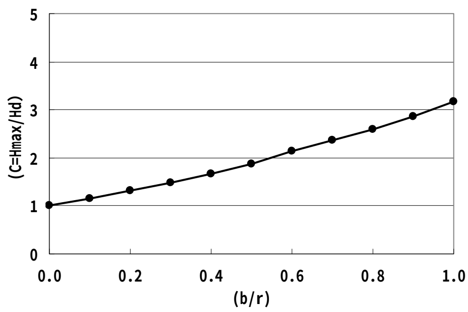


Figure 3-9 Proportions of Hmax and Hd

4) Input Data Set for of 2.5-dimension River Bed Fluctuation Analysis

The input data required for 2.5-dimension riverbed fluctuation analysis is as follows;

- River bed slope
- Average discharge (maximum 48-hour average flood discharge among the 72-hour duration flood hydrograph)
- Coefficient of roughness (n=0.035)
- Average diameter of river bed material

5) Results

Sample results from 2.5-dimension riverbed fluctuation analysis are shown in Figure 2-1. Details of the result for each damaged section are shown in Appendix-6.

Estimated Maximum Scouring Depth is listed in Table 3-6.

Table 3-6 Estimated Maximum Scouring Depth (without foot protection)

Damaged Section	Assumed Maximum Scouring Depth (m)			
	Scouring depth at the recent flood event	non-uniform flow analysis	2.5-dimension fluctuation analysis	Applied Depth
Sta.00+370 - 00+455	2.3	0.7	2.6	2.6
Sta.03+370 - 03+730	2.0	1.5	1.4	2.0
Sta.04+245 - 04+360	-	2.4	1.2	2.4
Sta.05+300 - 05+205 Sta.05+500 - 05+560	2.2	1.5	3.0	3.0
Sta.06+065 - 06+206	2.3	0.6	1.8	2.3
Sta.07+625 - 08+000	-	1.3	2.0	2.0
Sta.11+489 - 11+577	-	1.4	5.0	5.0
Sta.13+262	-	0.5	-	0.5
Sta.14+885 - 14+925	-	4.0	4.2	4.2
Sta.22+915	-	3.9	-	3.9

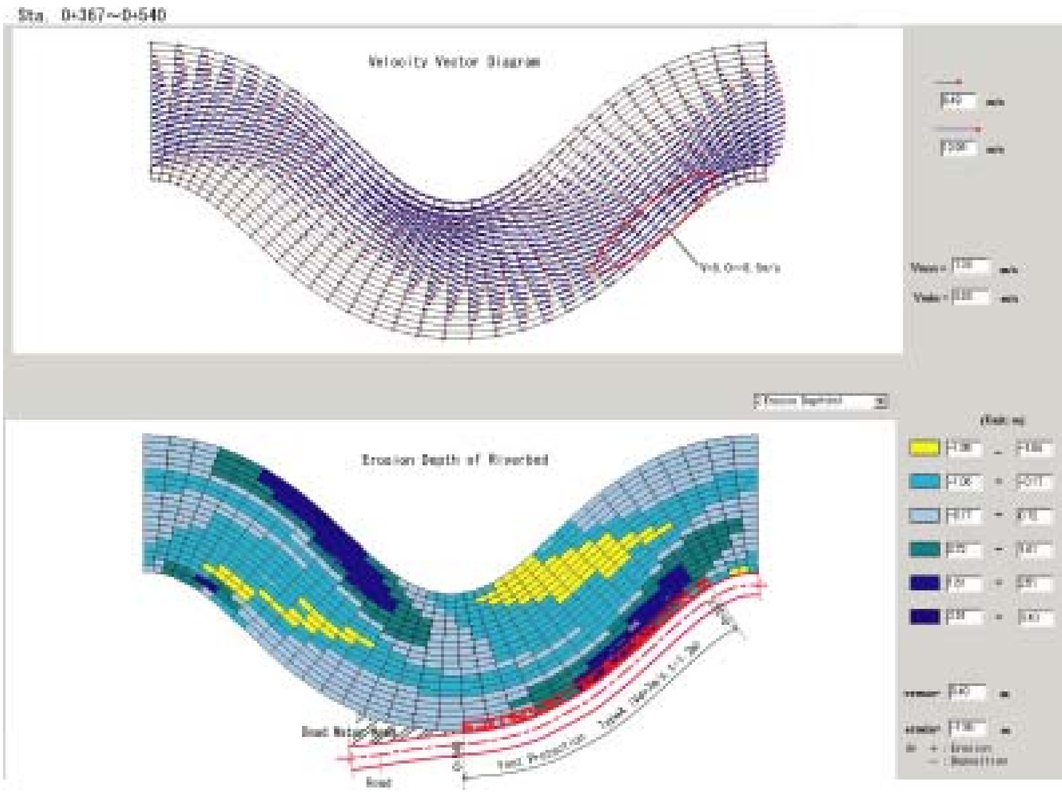
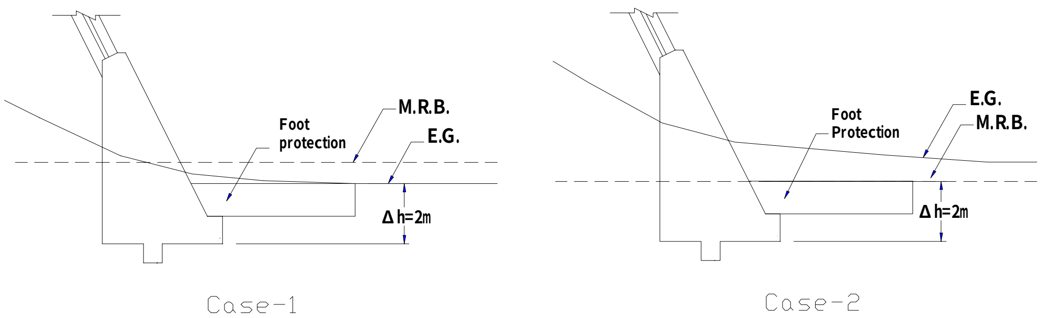


Figure 3-10 Calculation result of 2.5-dimension riverbed fluctuation analysis

6) Embedment level for wall foundation

The embedment level of wall foundation is usually set at a maximum scour depth measured below the lowest level between mean riverbed level and existing ground. Since the assumed maximum scouring depths for all cases exceed 2 m. And it is difficult excavate more than 2 m, the design embedment level is thus set as 2 m in conjunction with foot protection works.

The two cases of embedment level with respect to the relationship between the Mean River Bed level (MRB) and the existing ground level (EG) are illustrated in Figure 3-11.



- Case-1 （M.R.B. is higher than E.G.）
- Case-2 （M.R.B. is lower than E.G.）

Figure 3-11 Design policy for Embedment level with foot protection

7) Design Velocity for Foot Protection

The greater among the following velocity has been adopted as the design velocity for foot protection;

- Velocity, estimated by multiplying adjustment coefficient, and velocity calculated by non-uniform flow analysis
- Local velocity estimated using the 2.5-dimension river bed fluctuation analysis with 48-hour average flood discharge.

i) Non-uniform flow Analysis

Boundary Condition:

The boundary condition is taken as the critical water depth at the upstream section.

Coefficient of Roughness:

The coefficient of roughness is adopted as 0.035.

ii) Maximum Velocity based on Non-uniform flow analysis.

The estimated maximum velocity based of the non-uniform flow is calculated using the following equations;

$$V_d = \alpha_1 \times \alpha_2 \times V_m$$

$$\alpha_1 = 1 + \frac{\Delta Z}{2H_d} + \frac{B}{2r} \quad \text{(outside of bend、without toe protection)}$$

$$\alpha_1 = 1 + \frac{B}{2r} \quad \text{(inside of bend, with toe protection)}$$

Where, Vd : Design Velocity (m/s)

α1 : adjustment coefficient at bend in the river.

α2 : adjustment coefficient of toe protection

bw / Hd >1: α2 =0.9, bw/Hd <=1: α2 =1.0

bw : Total width of toe protection (m)

Vm : Average velocity calculated by non-uniform flow analysis (m)

ΔZ : Scouring Depth (m)

In case applying toe protection, ΔZ=0

Hd : Water depth calculated by non-uniform flow analysis (m)

B : Width of river channel (m)

r : Radius of river channel (m)

iii) Input data set for 2.5-dimension River Bed Fluctuation Analysis

As mentioned earlier.

iv) Results

Calculation results are listed in Table 3-7

Table 3-7 Design Velocity for Foot Protection

Damaged Section	Foot Protection Section	Design Velocity for foot Protection(m/s)			Note
		non-uniform analysis with adjustment factor	2.5-deminsion riverbed fluctuation analysis	adoption	
Sta.00+370 - 00+455	Sta.00+367 - 00+540	5.5	6.5	7.0	
Sta.03+370 - 03+730	Sta.03+320 - 03+370	5.0	5.4	6.0	

Damaged Section	Foot Protection Section	Design Velocity for foot Protection(m/s)			Note
		non-uniform analysis with adjustment factor	2.5-deminsion riverbed fluctuation analysis	adoption	
Sta.03+370 - 03+730	Sta.03+370 - 03+600	5.4	6.2	7.0	
	Sta.03+600 - 03+730	4.8	4.2	6.0	Since there is a possibility in changes in the flow direction, the actual velocity should be more than calculated one. The design velocity is thus adopted 6m/s which is 1 rank higher than calculated velocity.
Sta.04+245 - 04+360	Sta.04+254 - 04+360	6.0	5.9	6.0	
	Sta.04+390 - 04+420	–	–	5.0	There are deposited shoal and not flow channel from STA. 4+390 to 4+420. Since the section will become flow channel due to the erosion by anticipated flood, the design velocity at the section is adopted 5m/s which is one rank less than the value adopted in the upstream section.
Sta.05+190 - 05+205	Sta.05+137 - 05+223	–	–	4.0	The flow condition around the revetment by previous flood was incidental. Therefore the design velocity is adopted 4m/s which is one-rank less than the value adopted in the upstream section. This value is least among the design velocity.
Sta.05+300 - 05+205 Sta.05+500 - 05+560	Sta.05+300 - 05+550	5.3	6.8	7.0	
	Sta.05+550 - 05+600	–	–	6.0	There are deposited shoal and not flow channel from STA. 5+550 to 4+600. Since the section will become flow channel due to the erosion by anticipated flood, the design velocity at the section is adopted 6m/s which is one rank less than the value adopted in the upstream section.
Sta.06+065 - 06+206	Sta.06+000 - 06+100	4.1	4.8	5.0	
	Sta.06+100 - 06+250	4.1	5.5	6.0	
	Sta.06+250 - 06+300	3.8	4.8	5.0	

Damaged Section	Foot Protection Section	Design Velocity for foot Protection(m/s)			Note
		non-uniform analysis with adjustment factor	2.5-deminsion riverbed fluctuation analysis	adoption	
Sta.07+625 - 08+000	Sta.07+550 - 07+620	5.0	6.0	6.0	
	Sta.07+620 - 07+800	5.0	6.3	7.0	
	Sta.07+800 - 07+850	5.0	4.5	6.0	Since there is a possibility in changes in the flow direction, the actual velocity should be more than calculated one. The design velocity is thus adopted 6m/s which is 1 rank higher than calculated velocity.
	Sta.07+850 - 07+900	5.0	4.0	5.0	
Sta.11+489 - 11+577	Sta.11+450 - 11+500	—	5.6	6.0	
	Sta.11+500 - 11+600	6.9	5.8	7.0	
	Sta.11+500 - 11+650	—	5.2	6.0	
	Sta.11+650 - 11+700	—	4.2	5.0	
Sta.13+262	Sta.13+200 - 13+250	—	straight river channel	5.0	There is impingement protection from STA. 13+200 to 13 +250. The design velocity is adopted 5m/s which is one rank less than the value adopted in the upstream section.
	Sta.13+250 - 13+300	5.9	straight river channel	6.0	
Sta.13+262	Sta.13+300 - 13+350	—	straight river channel	5.0	There is impingement protection from STA. 13+300 to 13 +350. The design velocity is adopted 5m/s which is one-rank less than the value adopted in the upstream section.
Sta.14+885 - 14+925	Sta.14+715 - 14+825	6.7	6.2	7.0	
	Sta.14+875 - 14+925	6.7	5.8	7.0	
	Sta.14+925 - 14+975	-	5.2	6.0	
Sta.22+915		6.3	impossible	7.0	

8) Design of Foot Protection Structure

[Weight and Thickness]

Since the design velocity for the foot protection is too high and the weight of toe protection is too heavy, the in-site casting of foot protection works was adopted. The required weight of foot protection works was estimated using the following equations.

[Check for stability against sliding]

$$W > Fs \cdot \left(\frac{C_1 C_D + C_2 \mu C_L}{2\mu} \right)^3 \cdot \frac{1}{K_V^2} \cdot \left(\frac{\rho_W}{\rho_b - \rho_W} \right)^3 \cdot \frac{\rho_b}{g^2} \cdot \left(\frac{V_d}{\beta} \right)^6$$

[Check for stability against tipping]

$$W > Fs \cdot \left(\frac{C_1 C_D + C_2 C_L l_b / h_b}{2 L_s / h_b} \right)^3 \cdot \frac{1}{K_V^2} \cdot \left(\frac{\rho_W}{\rho_b - \rho_W} \right)^3 \cdot \frac{\rho_b}{g^2} \cdot \left(\frac{V_d}{\beta} \right)^6$$

Where,

W	: Weight of the block (ton)
F_s	: safety factor
C_1	: Ratio between projected areas of the block along the drag force and area of square lb(m) on side.
C_2	: Ratio between area of top face of the block and area of square lb(m) on side.
C_D	: Coefficient of drag force of the block (0.7 for square type)
C_L	: Coefficient of lift force of the block (0.1 for square type)
l_b	: Flagship length of the block (m)
h_b	: Thickness of the block (m)
L_s	: horizontal length between supporting point to gravity point of the block. (m)
K_v	: Ratio between actual volume and volume of rectangular solid b(m) on side.
ρ_w	: Density of water (102 kgf·s^2/m^4)
ρ_b	: Density of concrete block (2.3*102 kgf·s^2/m^4)
μ	: Coefficient of dynamic friction (0.63)
β	: Coefficient of compound (1.5 for square type)

The calculation results are listed in Table 3-8, where Type A, B and C are concrete block type based on above calculation.

Table 3-8 Parameters of Foot Protection Structures

Items	Type-A	Type-B	Type-C
Type	Concrete block		
Design Velocity (m/s)	7.0	6.0	5.0
Width of a single block (m)	2.0	2.0	2.0
Length of a single block (m)	2.5	2.5	2.5
Thickness (m)	1.2	0.9	0.6
Weight (ton)	13.8	10.3	6.9

Note: In case design velocity is lower than 4m/s, small scale foot protection structure will be adopted.

[Width of Foot Protection]

Total width of foot protection is estimated by the following equation.

$$B_C = L_n + \Delta Z / \sin\theta$$

Where, B_c : Total width of foot protection structure (m)

L_n : Width of flat portion in front of the revetment.

(adopting width of a single block of 2m)

ΔZ : Calculated scoring depth.(m)

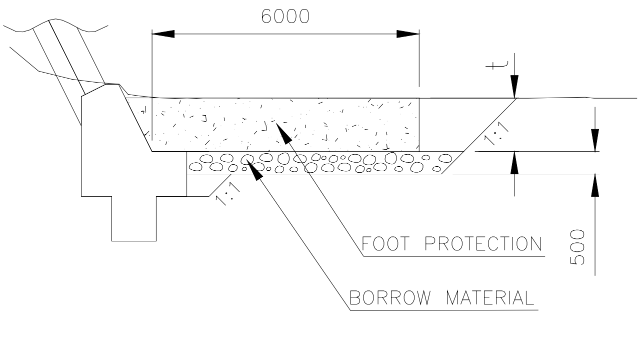
θ : River bed slope of river after scouring.

(adopting angle of repose of sand 30°)

The width of foot protection structure is estimated using an adopted scour depth of 2.0m

$$B_C = 2(m) + 2(m)/\sin 30 = 6(m)$$

Hence, the total width of foot protection structure is 6.0m consisting of three blocks of 2m-width each as mentioned Figure 3-12.



Type	Thickness :t (m)
A	1.2
B	0.9
C	0.6

Figure 3-12 Typical cross section of Foot Protection Structure

(3) Design Principles for Countermeasures against Suction

As foot protection structure with proper embedment levels were adopted, the revetment structures will have resistance against suction. Beside that, boulders will be used for backfilling the wall and foot protection structure to increase the resistance of structure against suction.

3.2.4. Basic Plan

(1) Road Design

Following design criteria for the Urgent Rehabilitation of Section IV will be adopted, as per the original plan of section IV.

Design speed	：	30km/hr
Formation width	：	4.75m （Exceptional 4.00m）
Camber	：	4% （Gravel）、2.5% （Double surface treatment）
Minimum curvature	：	25m. (30km/hr)
Widening on curves	：	To be widened by adequate width for semi-trailer
Minimum vertical curve radius	：	300m
Maximum grade	：	9%
Interval of passing place	：	To be constructed by adequate interval according to the site condition

(2) Earth Works

Cut and embankment slopes will be selected from the following table according to the EarthWork Manual, Japan Road Association, as per the original plan of section IV.

[Cut slope]

Classification		Applied slope
Rock		1：0.3～1：0.8
Soft rock		1：0.5～1：1.2
Sandy Soil	Dense	1：0.8～1：1.0
	Loose	1：1.0～1：1.2
Gravel, Soil	Dense	1：0.8～1：1.0
	Loose	1：1.0～1：1.2

[Embankment slope]

Classification	Height	Applied slope
Well graded sand, Gravel	<5m	1：1.5～1：1.8
	5～15m	1：1.8～1：2.0
Poorly graded sand	<10m	1：1.8～1：2.0
Crushed Rock	<10m	1：1.5～1：1.8
	10～20m	1：1.8～1：2.0
Sandy soil	<5m	1：1.5～1：1.8
	5～10m	1：1.8～1：2.0

(3) Drainage works

The types of side ditch and cross drainage structures will be applied in the Urgent Rehabilitation as per the original plan of section IV.

(4) Pavement Structure

A gravel pavement structure, consisting of river gravel in the 15cm thick lower layer and crusher-run in the 15cm thick upper layer will be applied for this project.

Double Bituminous Surface Dressing (DBSD) will be applied along the steep gradient (>5%) sections, as per the original plan of section IV

And for the section, having possibility of overflow, DBSD will be applied for the purpose of protection for road surface.

(5) Revetment structures

Masonry work is a commonly used in road construction for retaining walls, revetments and slab-culvert walls in Nepal. Furthermore, masonry is effective from the view of maximum usage of locally available materials.

Masonry had been applied for the revetment works at almost all damaged sections. Through observation of each damaged section, it was judged that the cause of road wash-away was not because of the weakness of the masonry but due to the scouring of the riverbed since gravity foundations suffered damaged. Therefore, as per the original design, masonry work will be applied for revetment works as much as possible.

(6) Associated Facilities

Traffic signs, distance signs and delineators will be installed, following the original plan of section IV.

(7) Slope Protection Works at STA.13+300

Damages around STA.13+300 were due to scouring of the slope below the constructed wall foundations. These foundations now lack stability. Since the slope grade is not so steep (1:0.8) revetment and concrete crib works will be applied as a countermeasure to arrest further scouring as shown in Figure 3-13.

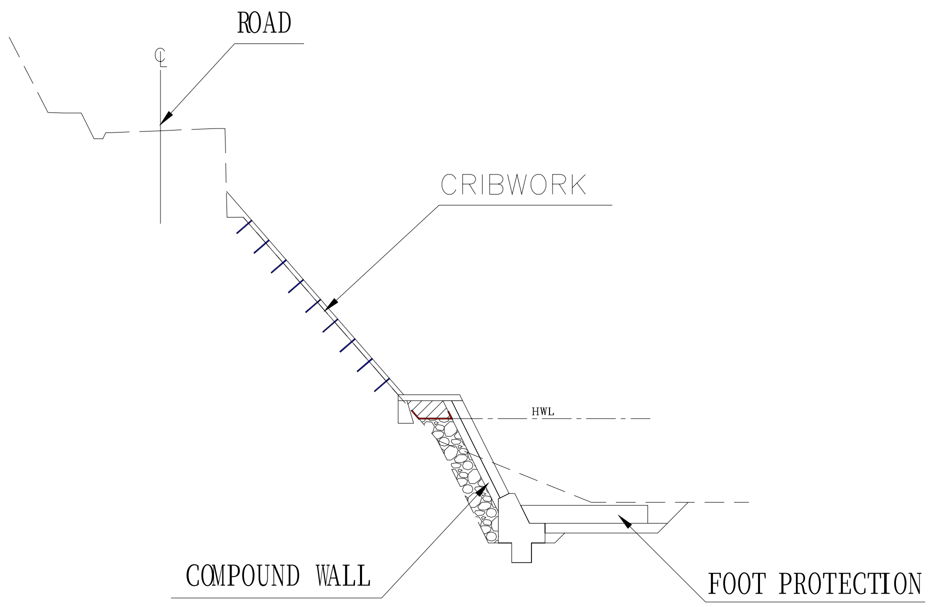


Figure 3-13 Countermeasure for slope failure due to scouring around Sta.13+300

(8) Slope Protection Works at STA.22+900

High water pressure during the flood has triggered a landslide on the natural slope below the road, destabilizing the riverside retaining wall. The size of slope failure is small and about 15m in width. Further extension of the failure will cause serious traffic disturbance since the road is located 25m above the riverbed.

The geology of the project site is characterized by the fault adjoining gneiss and granite. The hill slopes over granite rock are very fragile. There is an abrupt change in flow at the site just down stream of Dapcha River and Roshi River confluence. As there are existing deposits at the foot of the slope (riverbank), countermeasures should be planned as mentioned below:

- Construction of revetments as countermeasures against the erosion of deposit from flood and for further possible slope failure
- Slope protection work (crib work) as countermeasures against the erosion of deposit from surface water
- Against further slope failure just below the road

There are three options of countermeasure against the further slope failure just below the road. These are a retaining wall, anchor work or soil-nailing work. For the protection of the small size slope failures, the soil-nailing method is usually applied as the most economic.

The soil-nailing work will be designed as per the design guideline “Design and Construction Guideline for Soil-nailing Work” Japan Highway Corporation, Oct. 1999. An outline of the countermeasure for the site is shown in Figure 3-14.

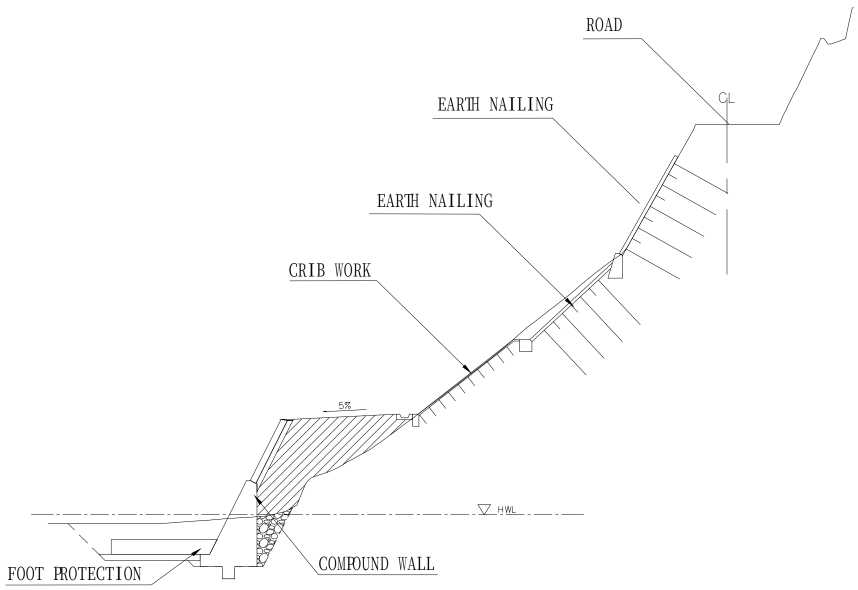


Figure 3-14 Countermeasures for slope failure due to scouring around STA.22+900

3.2.5. Comparison between design details of this project and the original plan of Section IV

A comparison between design details of this project and the original plan of section IV is summarized in Table 3-9.

1) Horizontal Alignment

Along the damaged area, the horizontal alignment will be moved up the mountain side as far as the right of way allows for the purpose of reducing the impact of the Roshi River current on revetment structures.

2) Vertical Alignment and DBSD

Along the damaged sections lying below H.W.L.+ freeboard subject to high runoff, the vertical alignment will be moved up to reduce the erosive impact of surface water and overtopping river flow.

For the stretches not subject to high runoff flowing over it and/or the move-up of the alignment force to destroy the existing structures, only DBSD will be applied to protect the road surface rather than moving the alignment.

3) Cross Section

The cross section will be designed as follows;

- Embedment levels are the depths studied in 3.2.3.
- Boulder and rubble are used for backfilling material to lower down the residual water level.
- Embankment Slopes in mountainous side will be leveled to prevent water accumulation.
- In two sections having damaged high slope under the road, compound wall, crib works and earth nailing will be applied.

4) Drainages

Pipe culverts used as cross drainage will be moved up to prevent them from being flooded. Pipe culverts will be set with some degree turning down stream.

5) Foot protection

Foot protections works will be designed as per 3.2.3.

Table 3-9 Comparison of design between original plan and this study

Section	Horizontal Alignment	Vertical Alignment and DBSD	Cross section	Drainage	Foot Protection		Wall type	
					Install	Section (TYPE)	type	Condition of existing Foundation
00+370－00+455	No change	No change	Strengthening backfill against suction (boulder and rubble)	Cross drainage Set with some degree turning down stream Cross drainage Shifted up	Re-Installed	00+367 - 00+540 (A)	Compound	Re-constructed due to serious damages
03+370－03+730	Shifted up to mountain side	Sifted up to upper side DBSD (run-off area only)	Strengthening backfill against suction (boulder and rubble)	Cross drainage Set with some degree turning down stream Cross drainage Shifted up	Re-Installed	03+320 - 03+370 (B) 03+370 - 03+600 (C) 03+600 - 03+750 (C)	Compound	Re-constructed due to serious damages
04+245－04+360	Shifted up to mountain side	No change	Strengthening backfill against suction (boulder and rubble)	Cross drainage Set with some degree turning down stream Cross drainage Shifted up	Added	04+254 - 04+390 (B) 04+390 - 04+420 (C)	Compound	Re-constructed due to serious damages
05+075－05+135	No change	No change	Strengthening backfill against suction (boulder and rubble)	Cross drainage Shifted up to upper side	-	-	Met masonry	Re-constructed due to serious damages
05+190－05+205	No change	No change	Strengthening backfill against suction (boulder and rubble)	—	Added	05+137 - 05+223 (D)		
05+300－05+461	No change	DBSD	Strengthening backfill against suction (boulder and rubble) Back filling mountain side slope	Settled with some degree turning down stream Shifted up to upper side	Re-Installed	05+300 - 05+550 (A)	Compound	Re-used partially
05+500－05+560	No change	No change	Strengthening backfill against suction (boulder and rubble)	—	Added	05+550 - 05+600 (B)		
06+065－06+206	No change	No change	Strengthening backfill against suction (boulder and rubble)	Cross drainage Set with some degree turning down stream Cross drainage Shifted up	Added	06+000 - 06+100 (C) 06+100 - 06+250 (B) 06+250 - 06+300 (C)	Compound	Re-constructed due to serious damages
07+625－08+000	Shifted up to mountain side	Sifted up to upper side DBSD (run-off area only)	Strengthening backfill against suction (boulder and rubble) Back filling mountain side slope	Cross drainage Set with some degree turning down stream Cross drainage Shifted up	Added	07+550 - 07+620 (B) 07+620 - 07+800 (A) 07+800 - 07+850 (B) 07+850 - 07+900 (C)	Compound	Re-constructed due to serious damages
11+489－11+577	No change	DBSD	Strengthening backfill against suction (boulder and rubble) Back filling mountain side slope	Cross drainage Set with some degree turning down stream Cross drainage Shifted up	Re-Installed	11+450 - 11+500 (B) 11+500 - 11+600 (A) 11+600 - 11+650 (B) 11+650 - 11+700 (C)	Met masonry	Re-used
13+262	No change	No change	Reinforcing high slope under the road	—	Added	13+200 - 13+250 (C) 13+250 - 13+300 (B) 13+300 - 13+350 (C)	Compound	Re-used
14+885－14+925	No change	No change	Strengthening backfill against suction (boulder and rubble)	—	Added	14+850 - 14+925 (A) 14+925 - 11+975 (B)	Compound	Constructed newly because there are no wall structure in original design
18+558－18+581	No change	DBSD	Strengthening backfill against suction (boulder and rubble)	—	Completed in Phase2	18+580 - 18+700 (A)	Met masonry	Re-constructed due to washing away
21+015－21+056	No change	DBSD	Strengthening backfill against suction (boulder and rubble)	—	Completed in Phase2	21+040 - 21+165 (A)	Compound	Re-used
22+915	No change	No change	Reinforcing high slope under the road Constructing wall at shore	—	Added	22+830 - 22+930 (A)	Compound	Constructed newly because there are no wall structure in original design

Note: Foot protection type (A), (B) and (C) correspond to types in Table 3-8. Type D indicates a type for the section where design velocity is less than 4m/s.

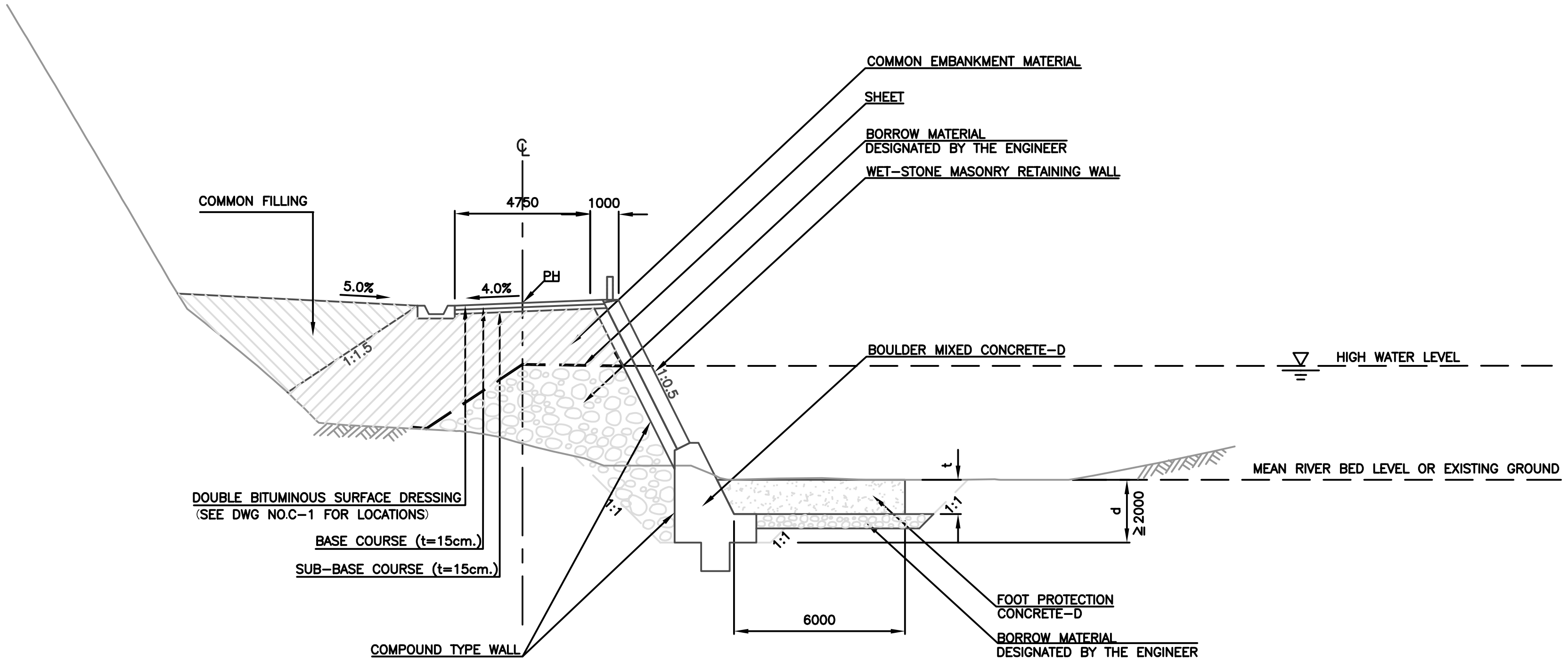
3.2.6. Basic Design Drawing

The following drawings have been prepared for the purpose of cost estimation and construction management and planning.

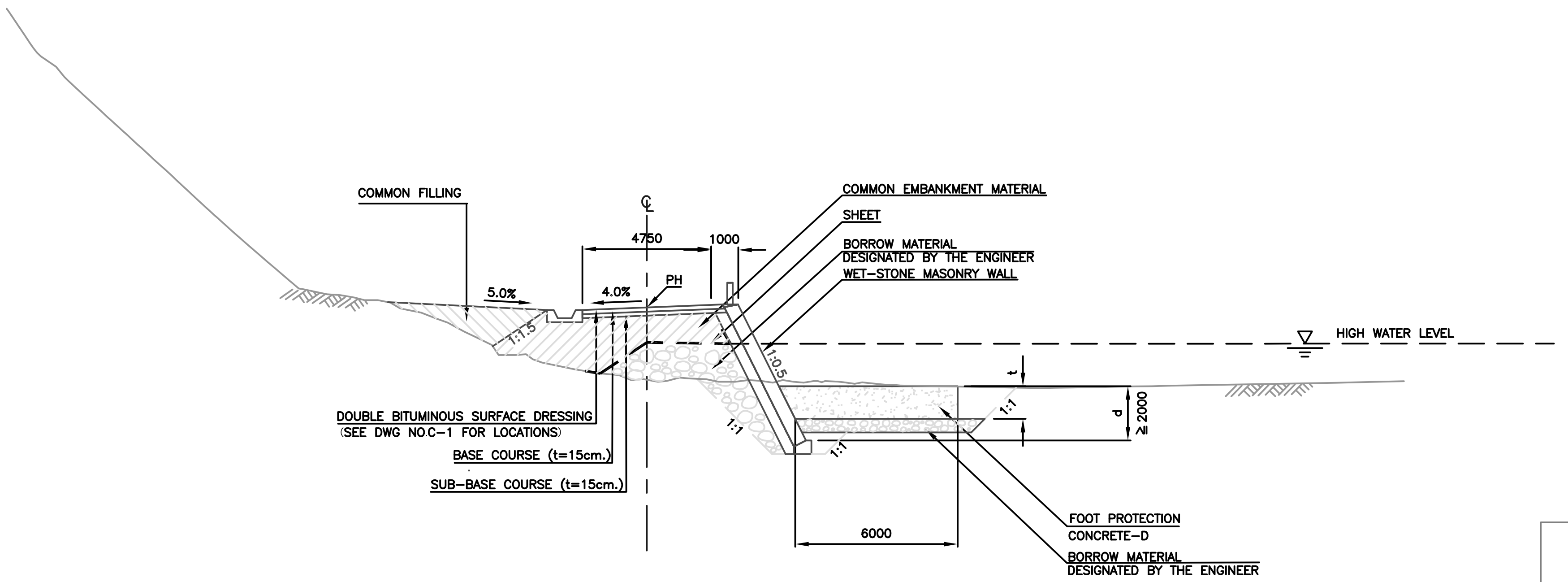
- A Typical Cross Section
- B Plan, Profile, Cross Sections and Cross Drainages
  - Plan
  - Profile
  - Cross Sections
  - Corss Drainages
- C Details of Structures
  - Pavement Works
  - Foot Protection Structures
  - Drainage Structures
  - Wet Masonry Wall
  - Compound Wall
  - Slope Protection Works
  - Traffic Sign and Traffic Safety Facilities

TYPICAL CROSS SECTIONS (1)

CASE–A FULL WIDTH RESTORATION–1



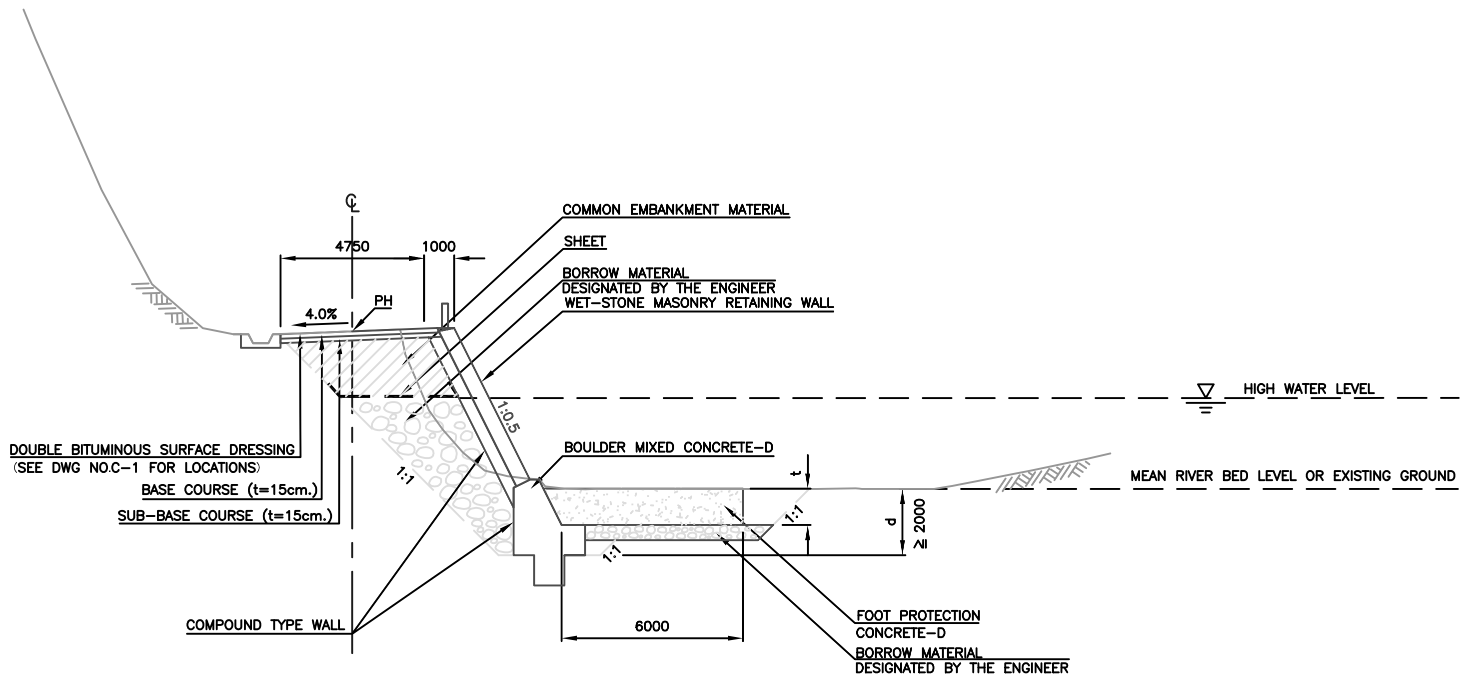
CASE–B FULL WIDTH RESTORATION–2



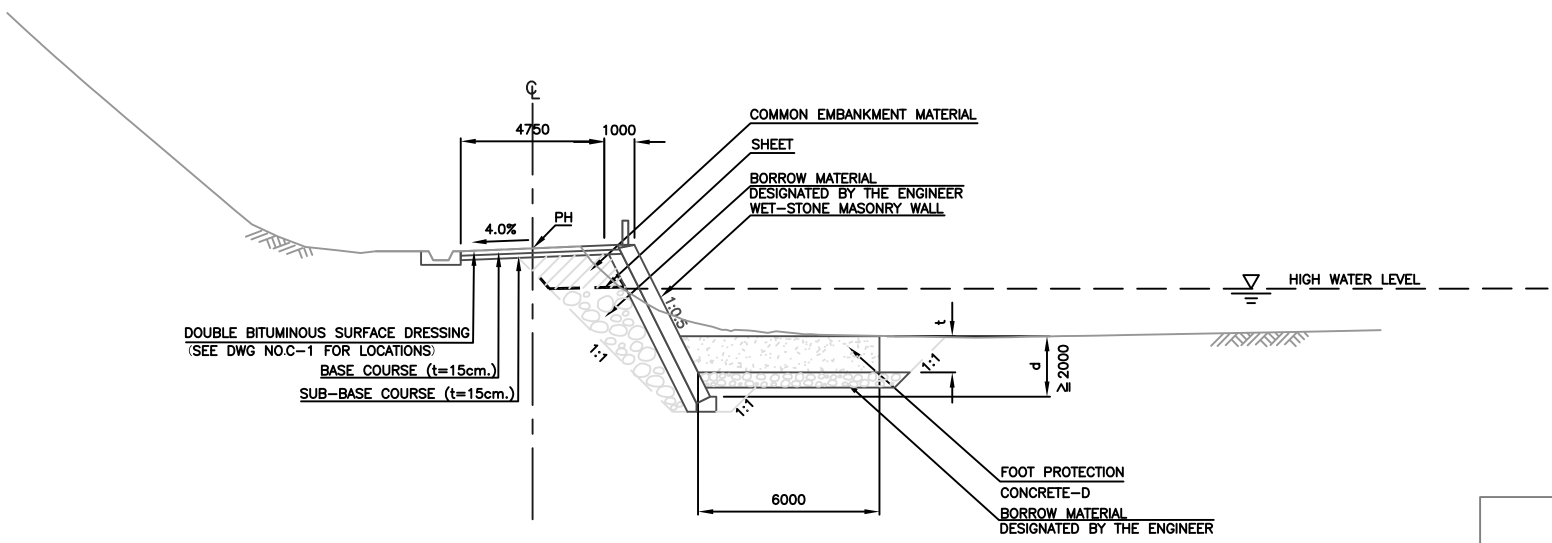
TYPICAL CROSS SECTIONS (1)

TYPICAL CROSS SECTIONS (2)

CASE–C PARTIAL WIDTH RESTORATION–1



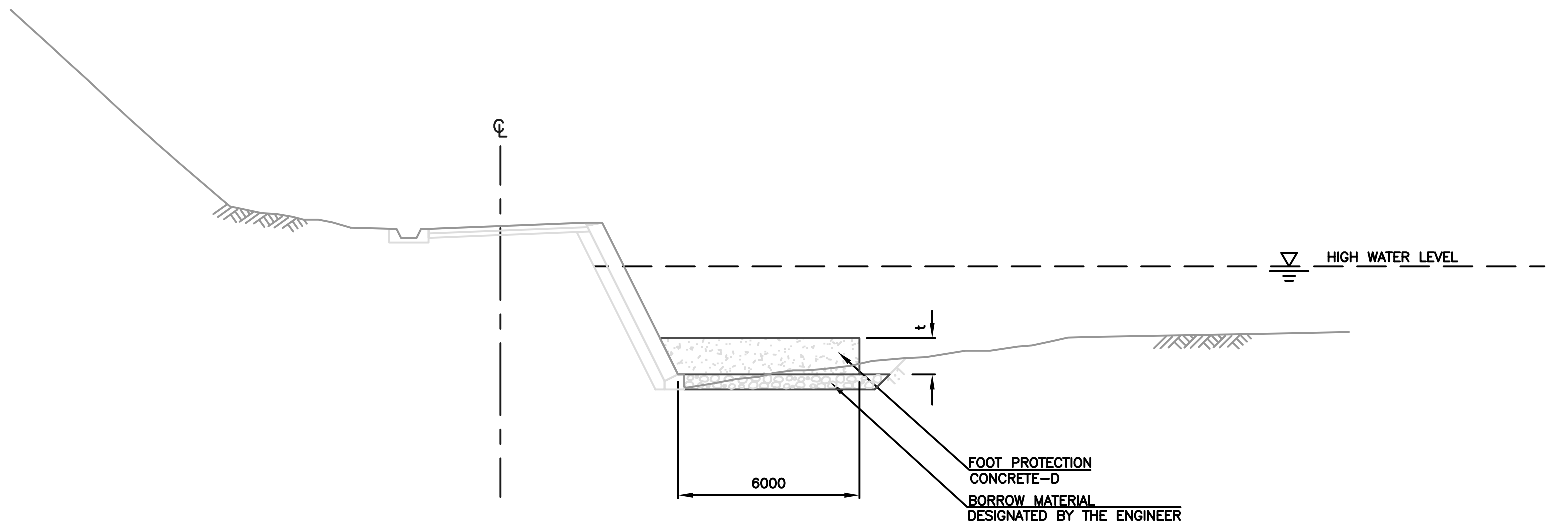
CASE–D PARTIAL WIDTH RESTORATION–2



TYPICAL CROSS SECTIONS (2)

TYPICAL CROSS SECTIONS (3)

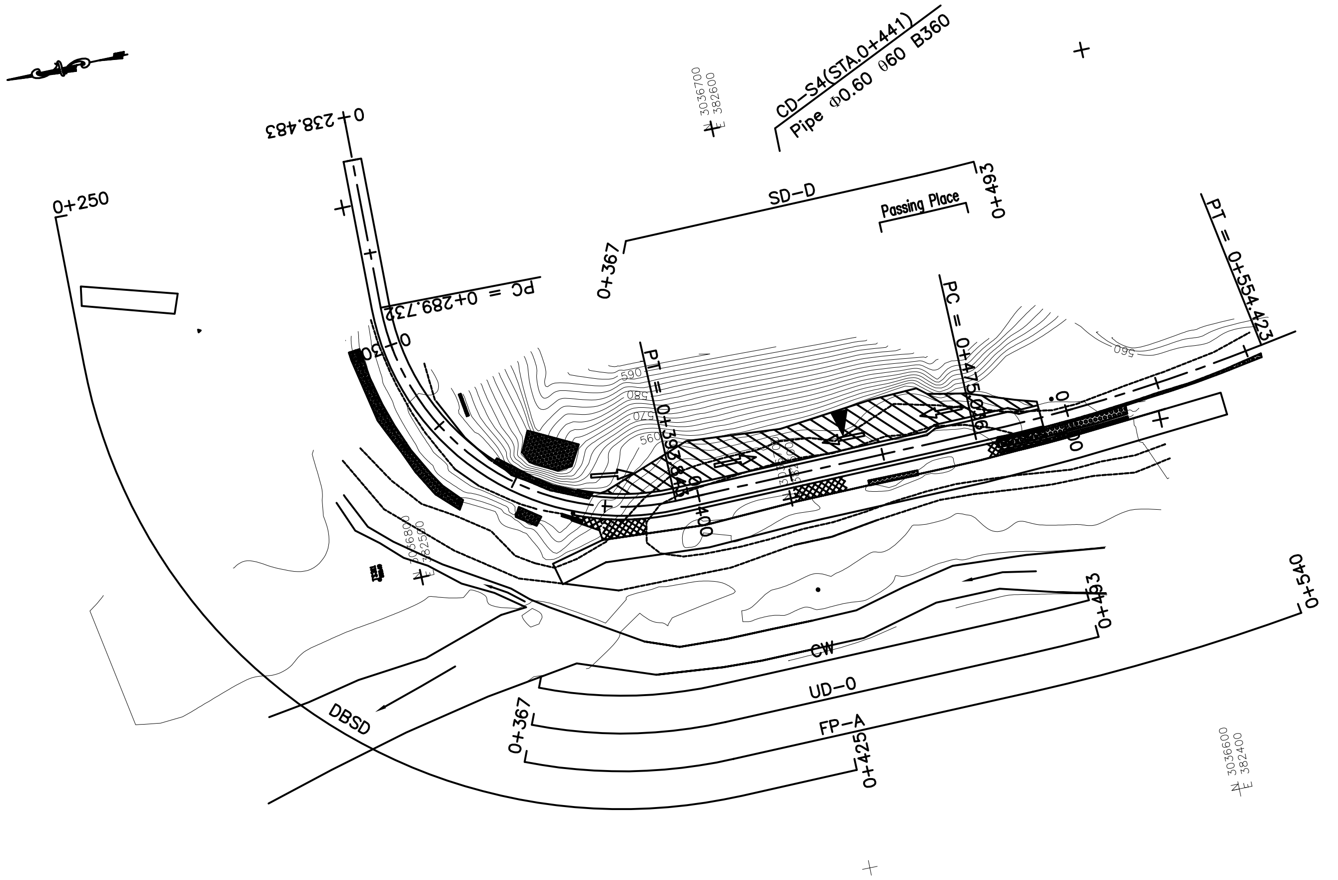
CASE–E INSTALATION OF FOOT PROTECTION ONLY



TYPICAL CROSS SECTIONS (3)

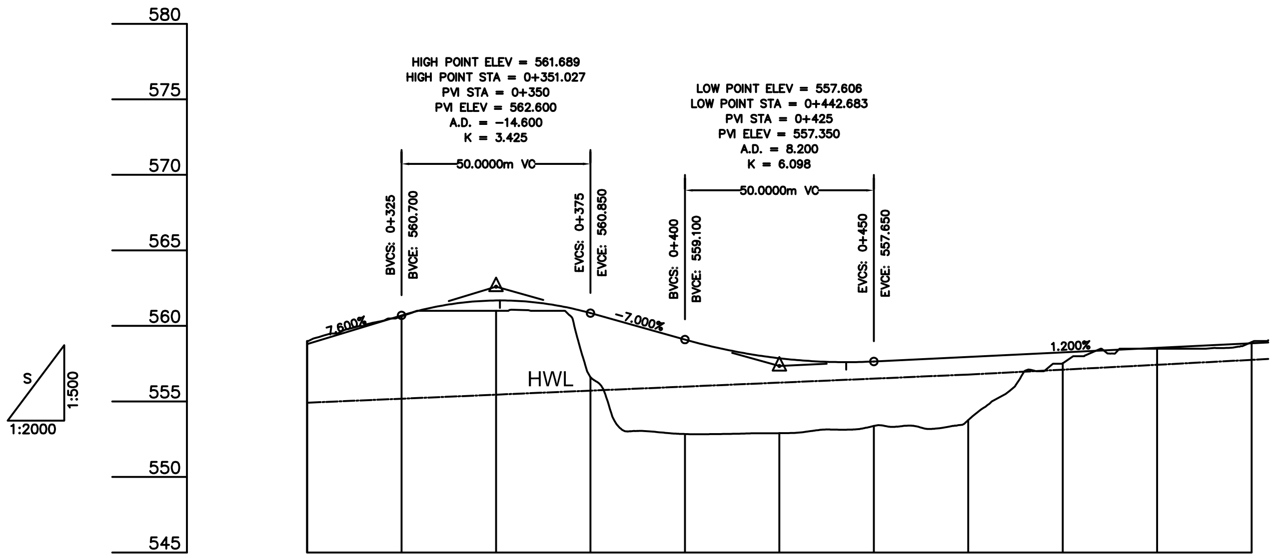
PLAN AND PROFILE (1)

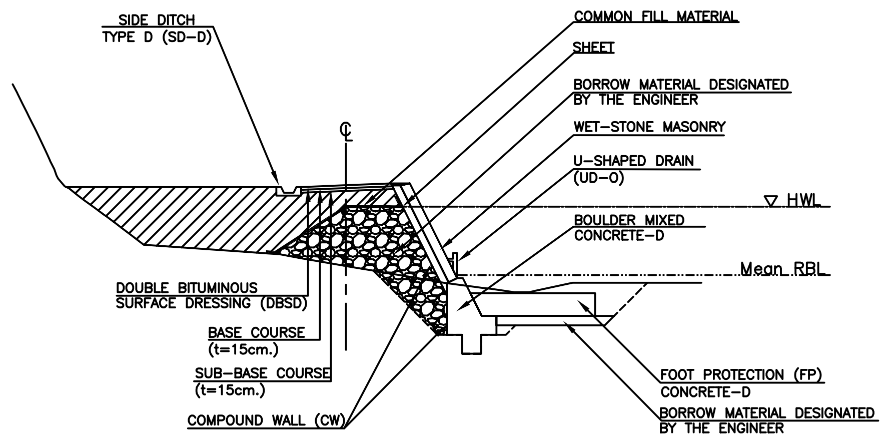
SECTION A STA.0+250～0+540



HIGH WATER LEVEL DATA

STATION	HWL
STA.0+367	555.634
STA.0+375	555.719
STA.0+400	555.985
STA.0+425	556.251
STA.0+450	556.517
STA.0+475	556.783
STA.0+493	557.019
STA.0+500	557.110
STA.0+525	557.437

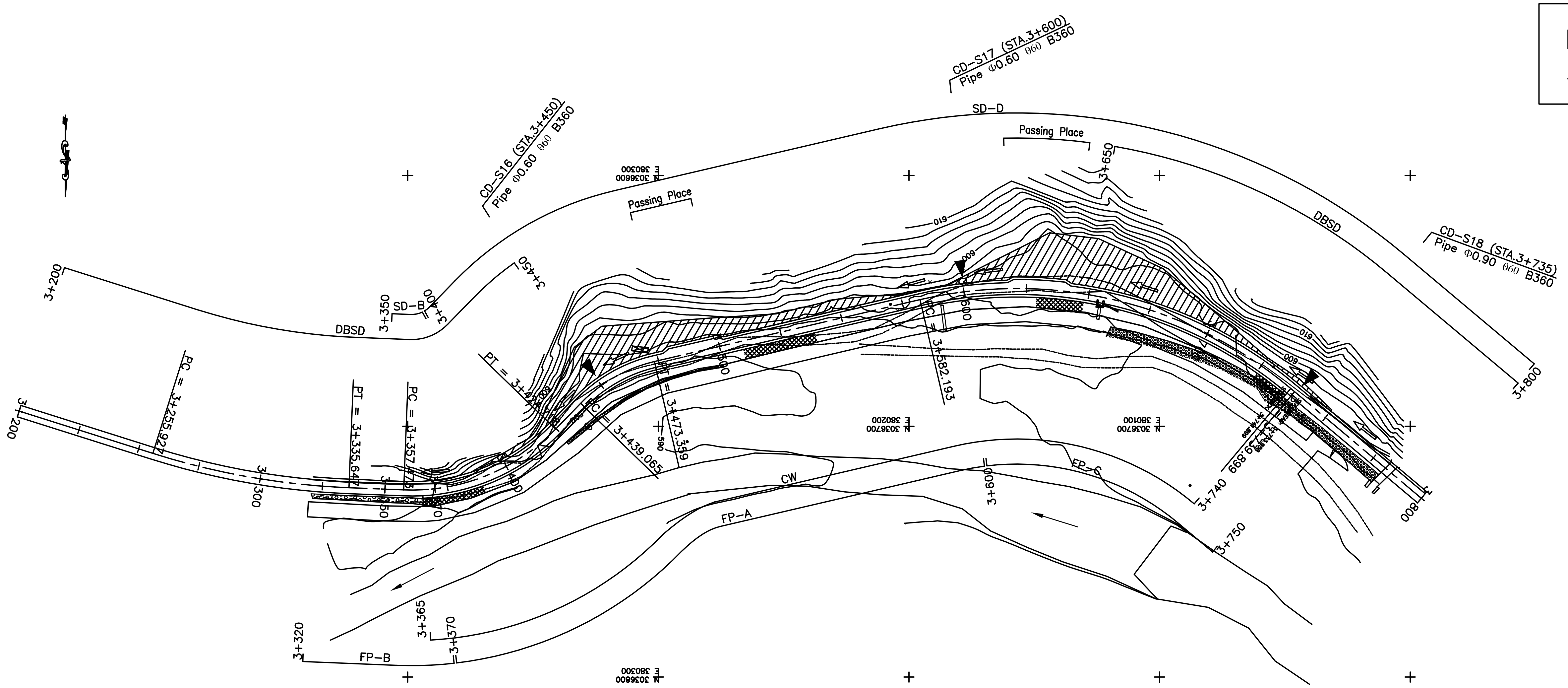




GRADE		7.600%	562.600	-7.000%		557.350			1.200%		
PROPOSED HEIGHT	558.800	560.700	561.688	560.850	559.100	557.862	557.650	557.950	558.250	558.550	558.850
GROUND HEIGHT	559.000	560.646	561.000	556.610	552.846	552.904	553.380	553.773	557.532	558.500	558.932
STATION	0+300	0+325	0+350	0+375	0+400	0+425	0+450	0+475	0+500	0+525	0+550
CURVE ELEMENT			R = 65.000 L = 104.111			R= 00 L = 81.193				R = 500.000 L = 79.388	

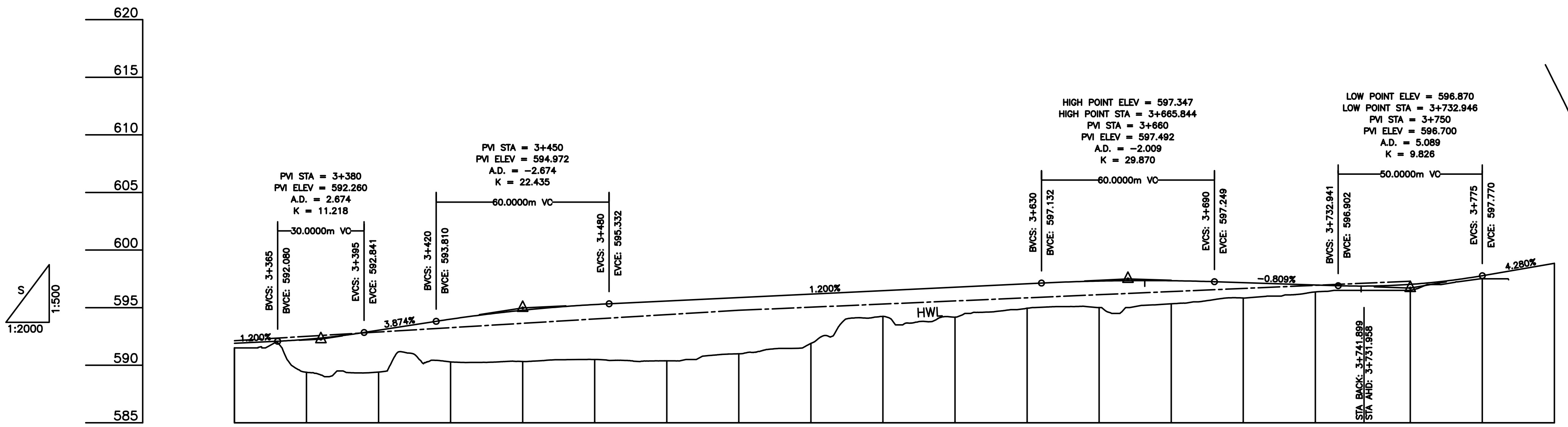
PLAN AND PROFILE (2)

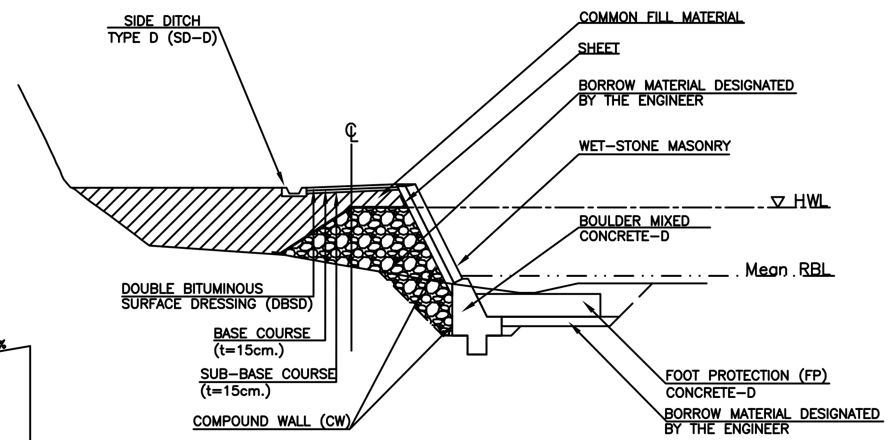
SECTION B STA.3+200～3+800



HIGH WATER LEVEL DATA

STATION	HWL
STA.3+325	591.755
STA.3+350	592.131
STA.3+365	592.357
STA.3+375	592.508
STA.3+400	592.884
STA.3+425	593.260
STA.3+450	593.637
STA.3+475	594.013
STA.3+500	594.390
STA.3+525	594.766
STA.3+550	595.047
STA.3+575	595.327
STA.3+600	595.608
STA.3+625	595.888
STA.3+650	596.169
STA.3+675	596.450
STA.3+700	596.730
STA.3+710	596.843
STA.3+725	597.011
STA.3+740	597.179
STA.3+750	597.291





GRADE: 1.200% — 592.260 — 3.874% — 594.972 — 1.200% — 597.492 — -0.809% — 596.700 — 4.280%

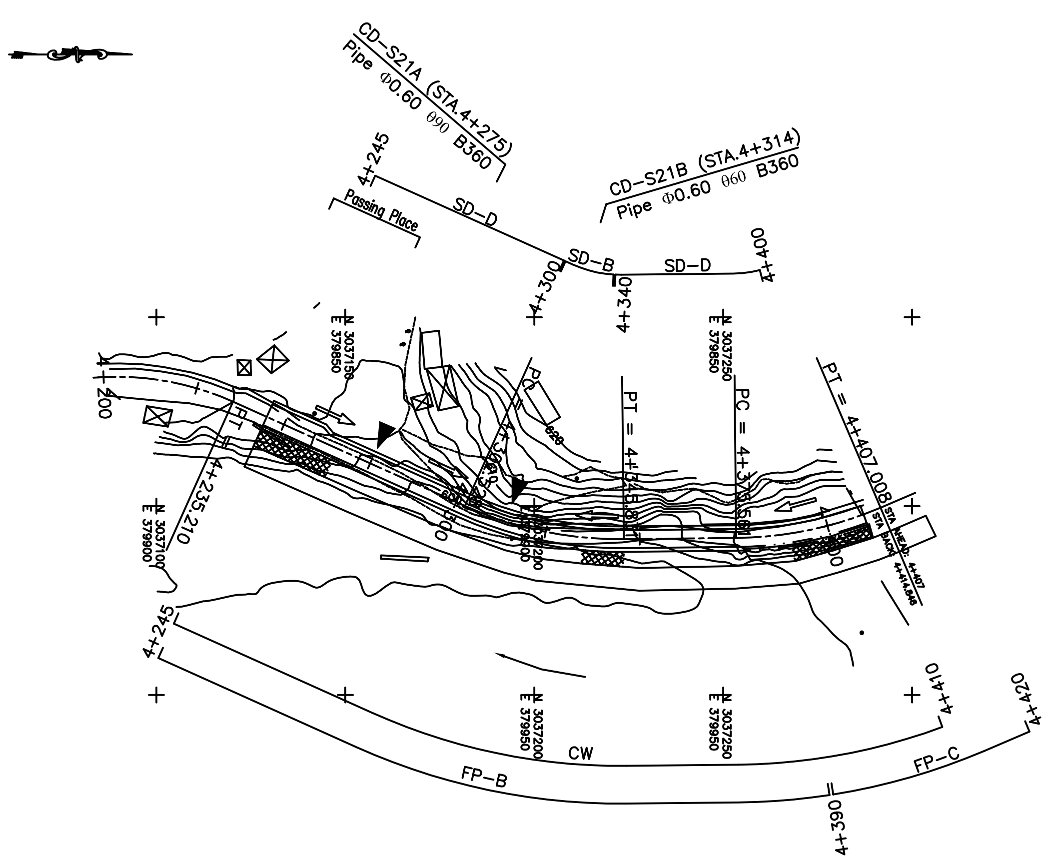
STATION	PROPOSED HEIGHT	GROUND HEIGHT
3+350	591.900	591.500
3+375	592.245	589.386
3+400	593.035	589.408
3+425	593.998	590.285
3+450	594.771	590.320
3+475	595.266	590.497
3+500	595.572	590.380
3+525	595.872	590.993
3+550	596.172	591.897
3+575	596.472	594.237
3+600	596.772	594.172
3+625	597.072	594.946
3+650	597.305	595.000
3+675	597.333	595.332
3+700	597.169	595.831
3+725	596.966	596.362
3+742	596.912	596.500
3+767	597.462	597.253
3+792	598.500	
3+800	598.840	

CURVE ELEMENT: R= 00, L = 7.473; R = 80.000, L = 67.244; R= 00, L = 14.347; R = 60.000, L = 34.295; R= 00, L = 108.834; R = 170.000, L = 157.706; R= 00, L = 68.042

SUPER ELEVATION: ——— Left; — — — Right

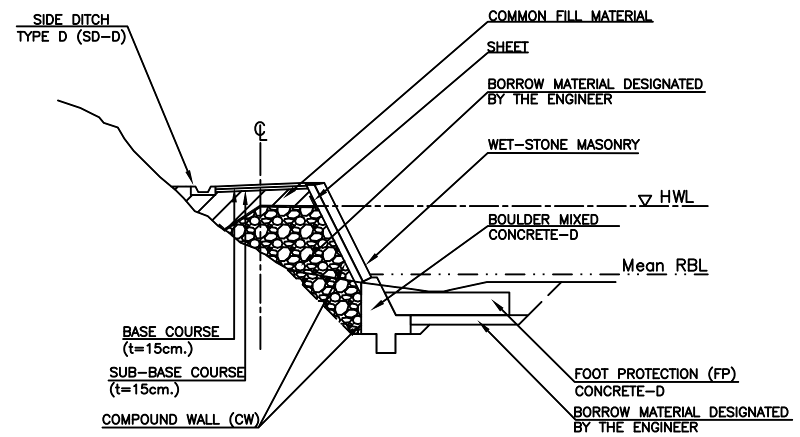
PLAN AND PROFILE (3)

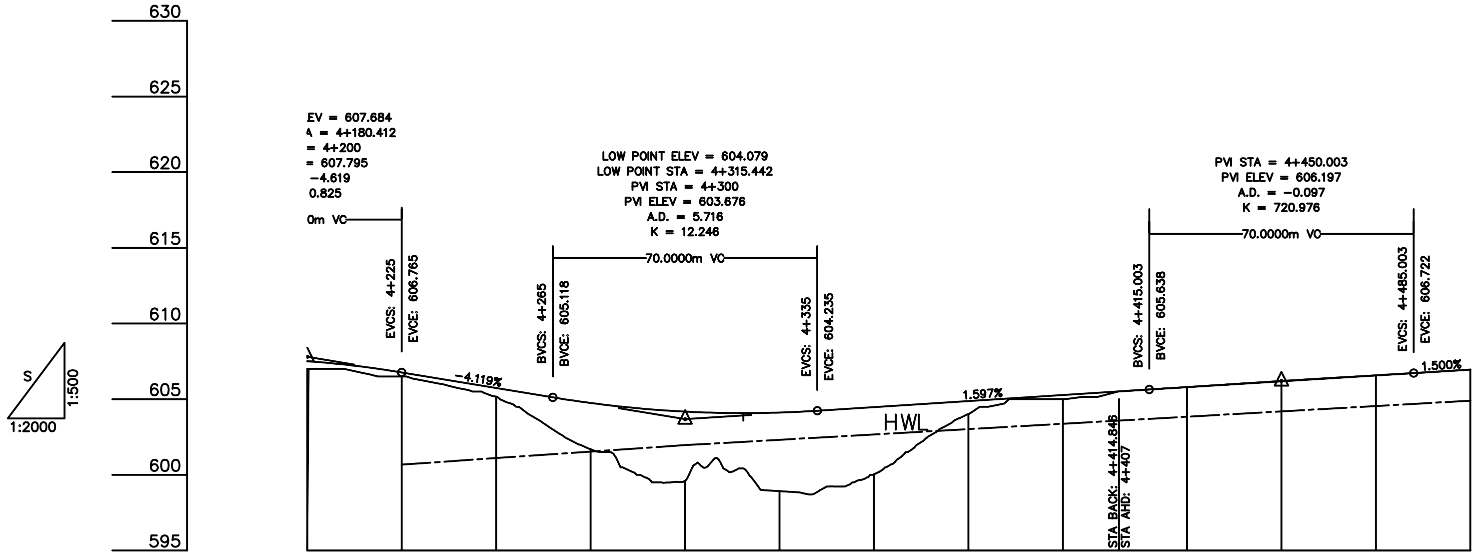
SECTION C STA.4+245～4+420



HIGH WATER LEVEL DATA

STATION	HWL
STA.4+245	601.020
STA.4+250	601.106
STA.4+275	601.534
STA.4+300	601.963
STA.4+325	602.316
STA.4+350	602.669
STA.4+375	603.022
STA.4+390	603.234
STA.4+400	603.375
STA.4+410	603.516
STA.4+420	603.657

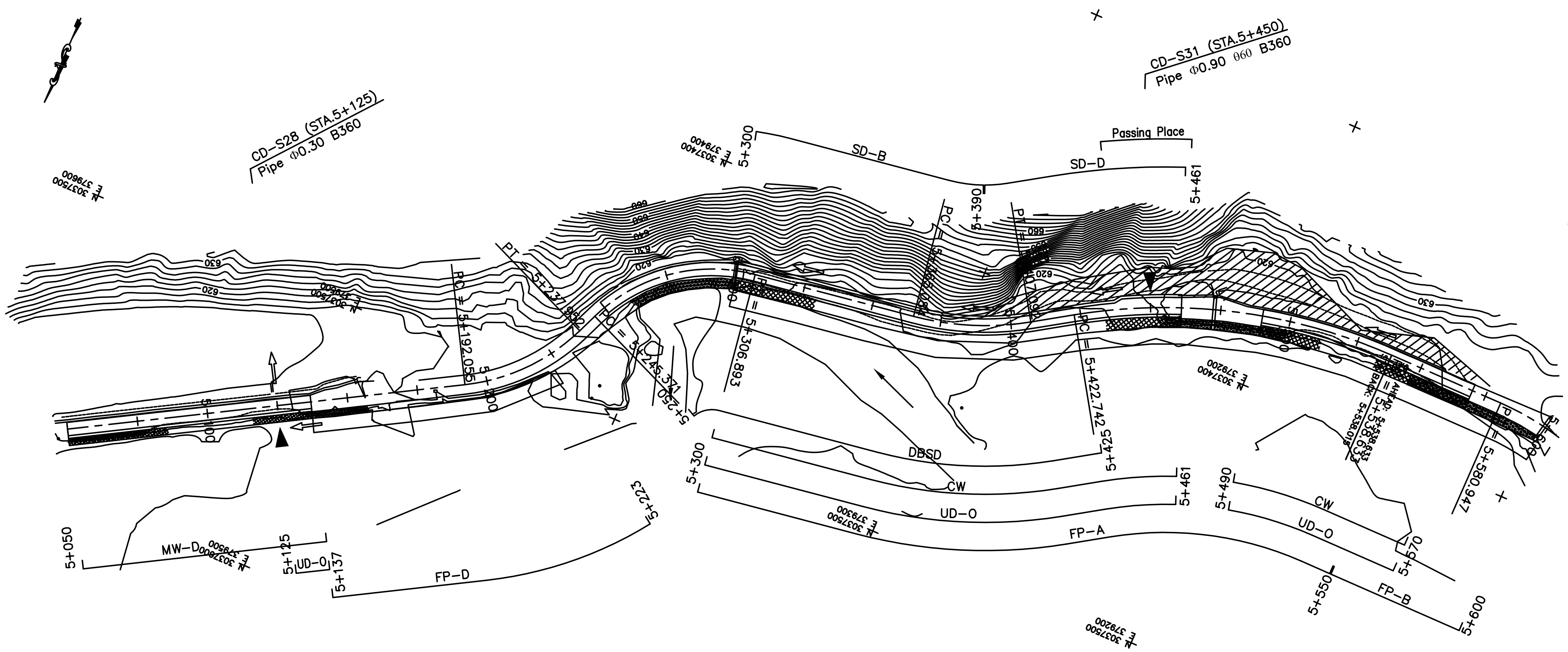


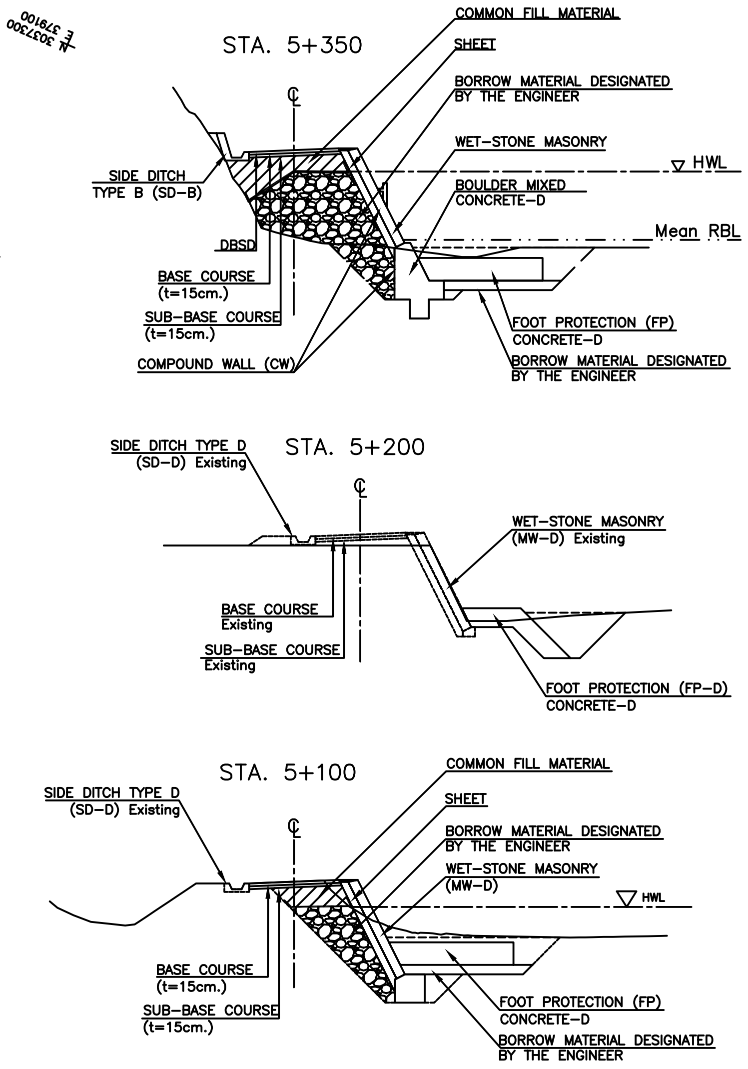


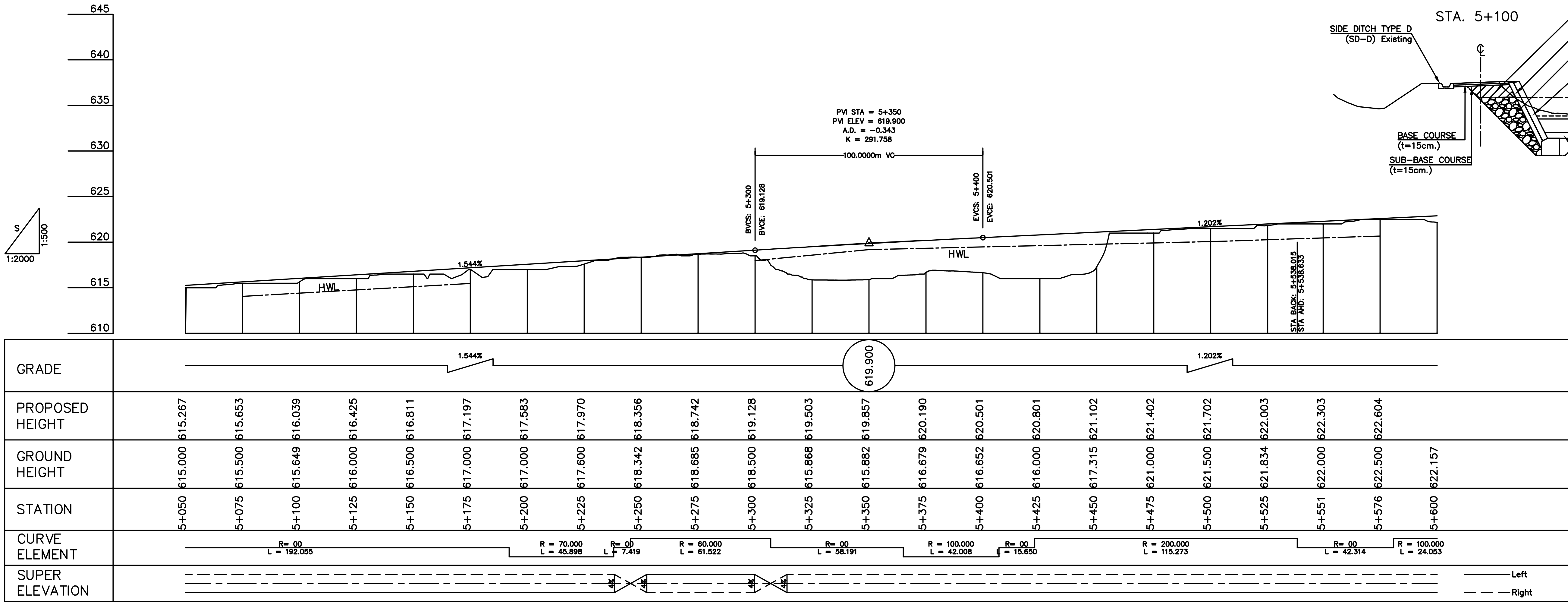
GRADE	607.795	-4.119%			603.676			1.597%			606.197	1.500%	
PROPOSED HEIGHT	607.506	606.765	605.735	604.747	604.176	604.116	604.475	604.874	605.273	605.672	606.067	606.452	606.829
GROUND HEIGHT	607.000	606.500	605.162	601.703	599.611	598.925	600.039	604.007	605.000				
STATION	4+200	4+225	4+250	4+275	4+300	4+325	4+350	4+375	4+400	4+417	4+442	4+467	
CURVE ELEMENT	R = 75.000 L = 37.876	R= 00 L = 67.318	R = 100.000 L = 43.303	R= 00 L = 29.730	R = 100.000 L = 39.293	R= 00 L = 74.722							

PLAN AND PROFILE (4)

SECTION D STA.5+050～5+600







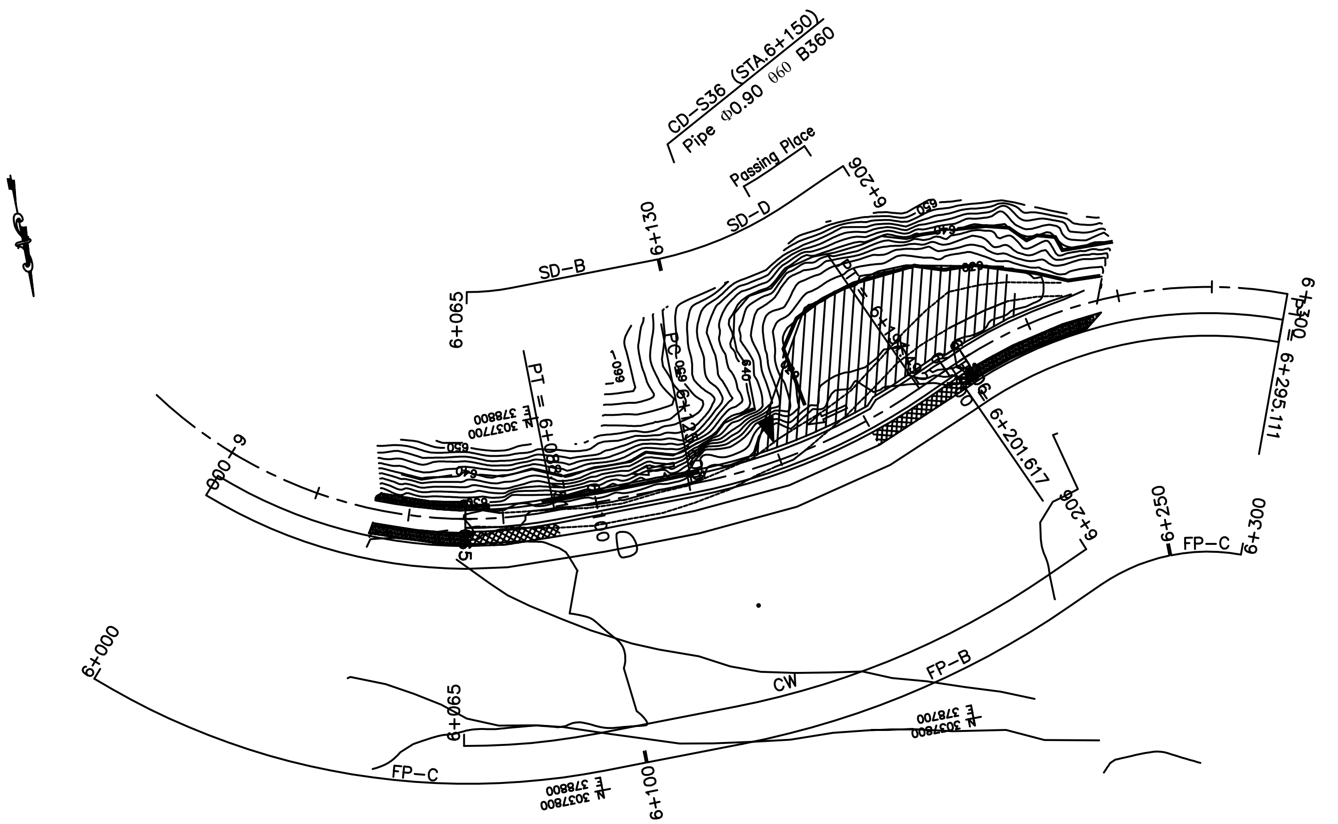
STATION	PROPOSED HEIGHT	GROUND HEIGHT
5+050	615.267	615.000
5+075	615.653	615.500
5+100	616.039	615.649
5+125	616.425	616.000
5+150	616.811	616.500
5+175	617.197	617.000
5+200	617.583	617.000
5+225	617.970	617.600
5+250	618.356	618.342
5+275	618.742	618.685
5+300	619.128	618.500
5+325	619.503	615.868
5+350	619.857	615.882
5+375	620.190	616.679
5+400	620.501	616.652
5+425	620.801	616.000
5+450	621.102	617.315
5+475	621.402	621.000
5+500	621.702	621.500
5+525	622.003	621.834
5+551	622.303	622.000
5+576	622.604	622.500
5+600		622.157

HIGH WATER LEVEL DATA

STATION	HWL
STA.5+050	613.710
STA.5+075	614.062
STA.5+100	614.415
STA.5+125	614.767
STA.5+137	614.936
STA.5+150	615.119
STA.5+175	615.472
STA.5+200	615.824
STA.5+223	616.148
STA.5+225	616.176
STA.5+250	616.778
STA.5+275	617.380
STA.5+300	617.982
STA.5+325	618.584
STA.5+350	619.186
STA.5+375	619.333
STA.5+400	619.479
STA.5+425	619.626
STA.5+450	619.773
STA.5+461	619.837
STA.5+475	619.919
STA.5+490	620.007
STA.5+500	620.066
STA.5+525	620.269
STA.5+550	620.471
STA.5+570	620.633
STA.5+575	620.674
STA.5+600	620.876

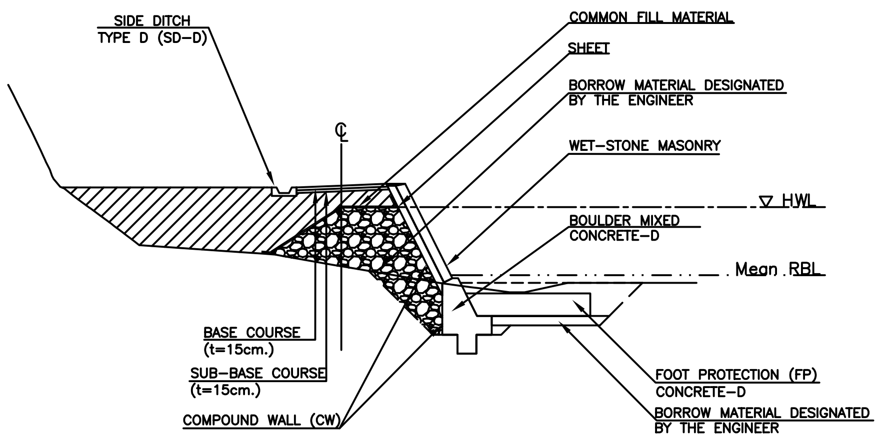
PLAN AND PROFILE (5)

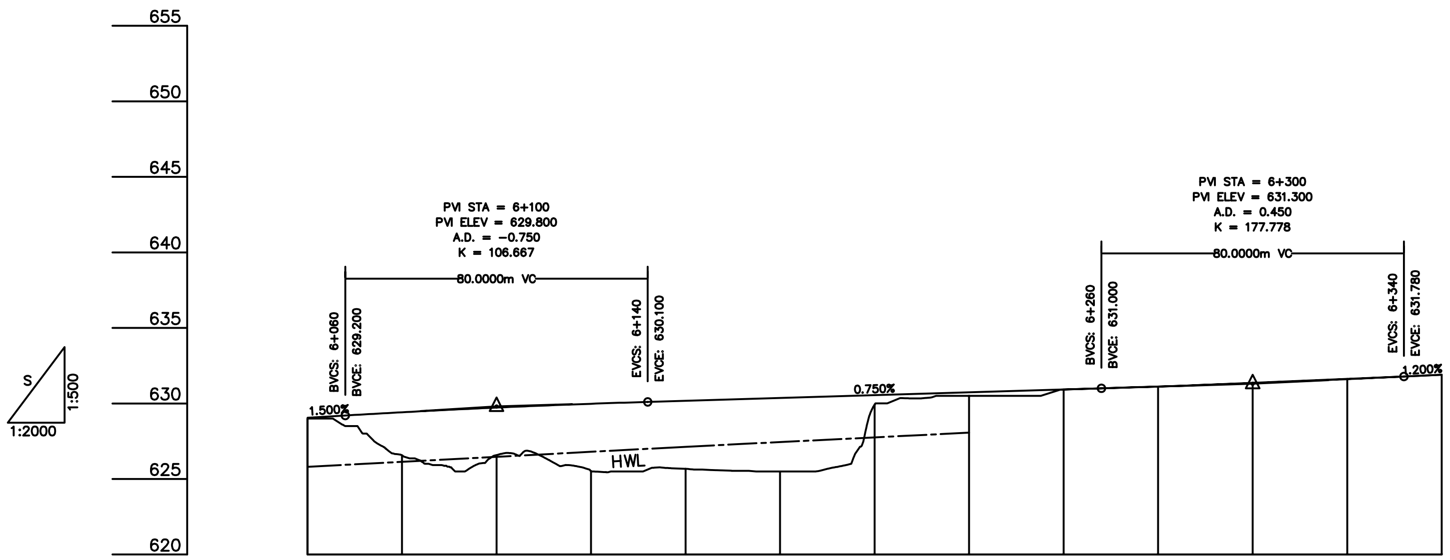
SECTION E STA.6+000～6+300



HIGH WATER LEVEL DATA

STATION	HWL
STA.6+000	625.142
STA.6+025	625.473
STA.6+050	625.804
STA.6+065	626.003
STA.6+075	626.136
STA.6+100	626.467
STA.6+125	626.798
STA.6+150	627.130
STA.6+175	627.441
STA.6+200	627.753
STA.6+206	627.828
STA.6+225	628.065
STA.6+250	628.377
STA.6+275	628.689
STA.6+300	629.001

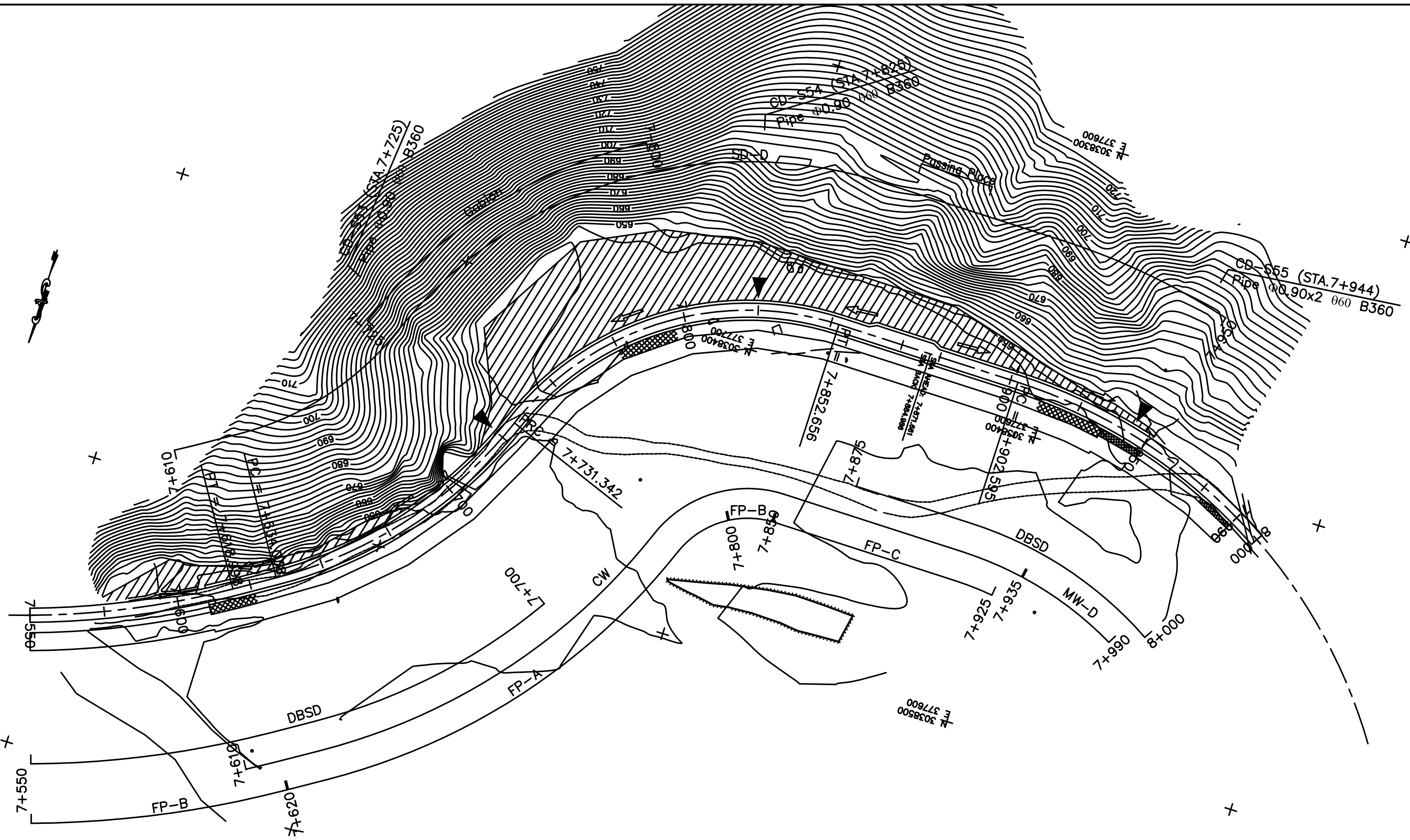




GRADE	1.500%		629.800				0.750%				631.300	1.200%
PROPOSED HEIGHT	629.050	629.414	629.725	629.977	630.175	630.363	630.550	630.738	630.925	631.119	631.345	631.606
GROUND HEIGHT	629.000	626.569	626.580	625.527	625.673	625.500	629.916	630.500	630.925	631.119		
STATION	6+050	6+075	6+100	6+125	6+150	6+175	6+200	6+225	6+250	6+275	6+300	6+325
CURVE ELEMENT	R = 120.000 L = 113.877		R= 00 L = 37.051		R = 160.000 L = 65.689		R= 00 L = 10.125	R = 120.000 L = 93.494			R= 00 L = 54.889	

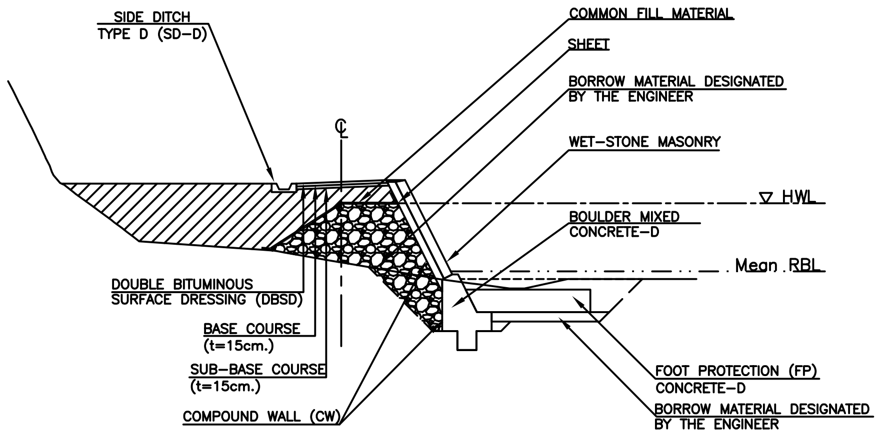
PLAN AND PROFILE (6)

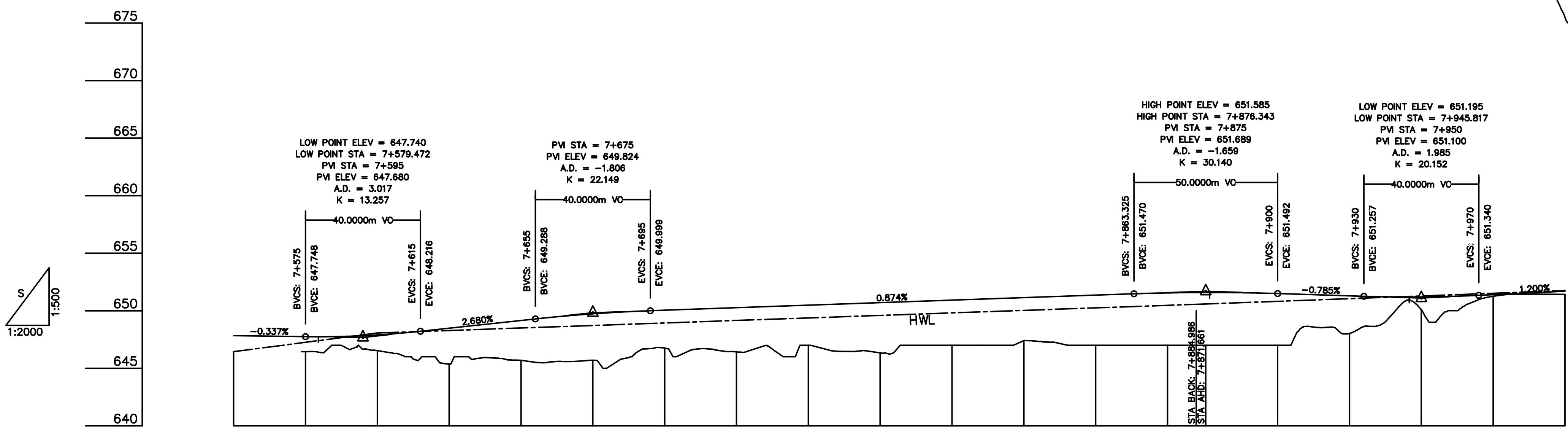
SECTION F STA.7+550～8+000



HIGH WATER LEVEL DATA

STATION	HWL
STA.7+550	646.688
STA.7+575	647.214
STA.7+600	647.740
STA.7+610	647.950
STA.7+620	648.161
STA.7+625	648.266
STA.7+650	648.466
STA.7+675	648.666
STA.7+700	648.866
STA.7+725	649.066
STA.7+750	649.267
STA.7+775	649.467
STA.7+800	649.667
STA.7+825	649.867
STA.7+850	650.067
STA.7+875	650.267
STA.7+900	650.467
STA.7+925	650.706
STA.7+935	650.801
STA.7+950	650.944
STA.7+975	651.183
STA.7+990	651.326





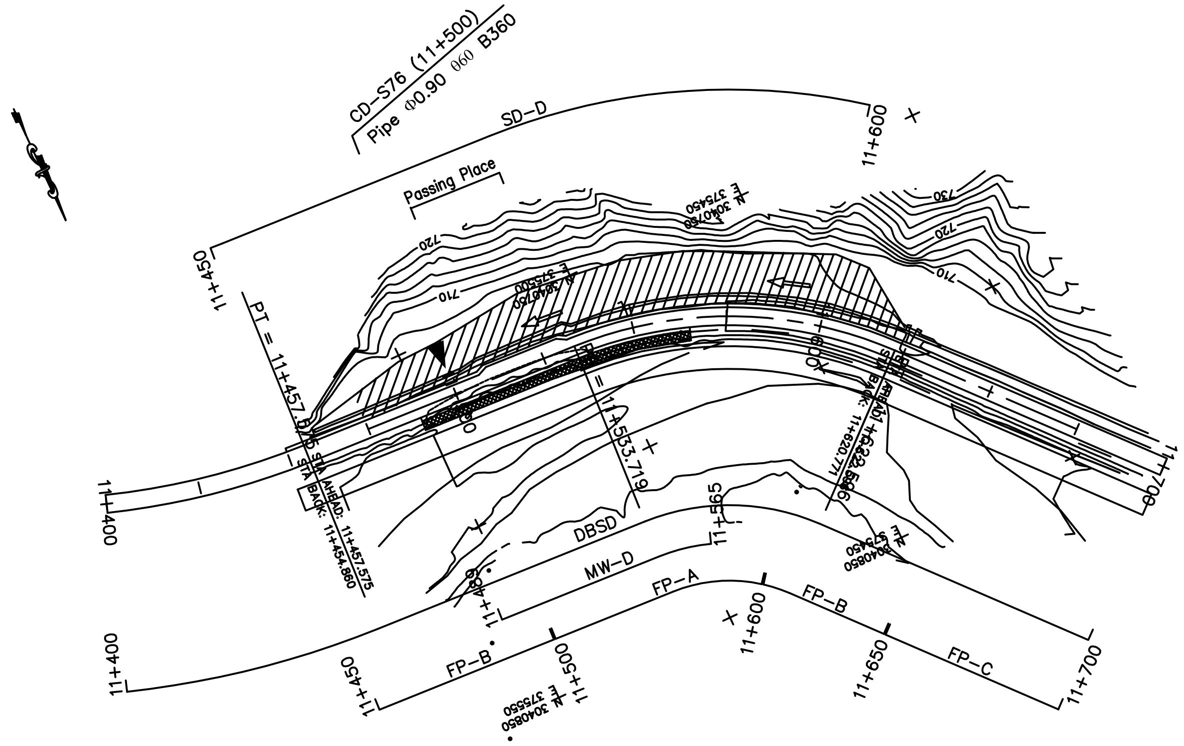
STATION	PROPOSED HEIGHT	GROUND HEIGHT
7+550	647.832	
7+575	647.748	646.447
7+600	647.899	646.535
7+625	648.484	645.378
7+650	649.154	645.689
7+675	649.734	645.695
7+700	650.043	646.753
7+725	650.261	646.426
7+750	650.480	647.000
7+775	650.698	646.342
7+800	650.917	647.000
7+825	651.135	647.406
7+850	651.354	647.000
7+875	651.550	647.000
7+887	651.568	647.000
7+912	651.401	648.611
7+937	651.216	648.892
7+962	651.257	650.000
7+987	651.540	651.419
8+012	651.840	

GRADE: -0.337% / 647.680 / 2.680% / 649.824 / 0.874% / 651.689 / -0.785% / 651.100 / 1.200%

CURVE ELEMENT: R = 280.000, L = 76.027 / R= 00, L= 15.040 / R = 150.000, L = 97.304 / R = 100.000, L = 121.314 / R= 00, L = 63.264 / R = 180.000, L = 176.231

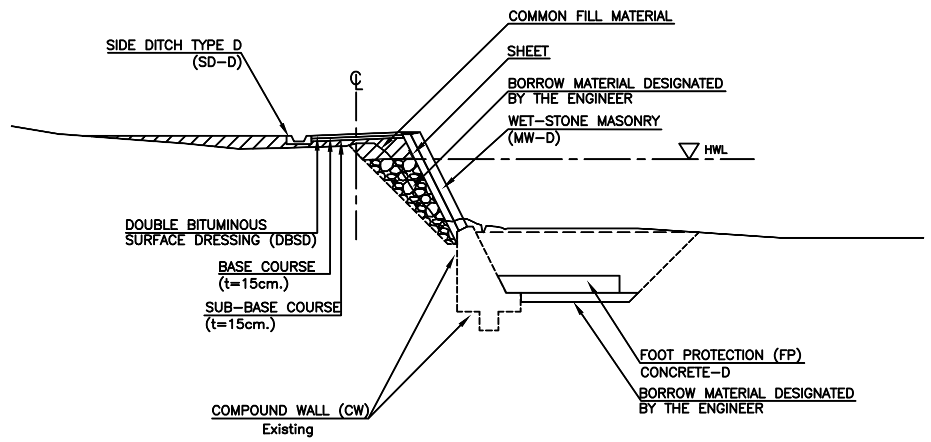
PLAN AND PROFILE (7)

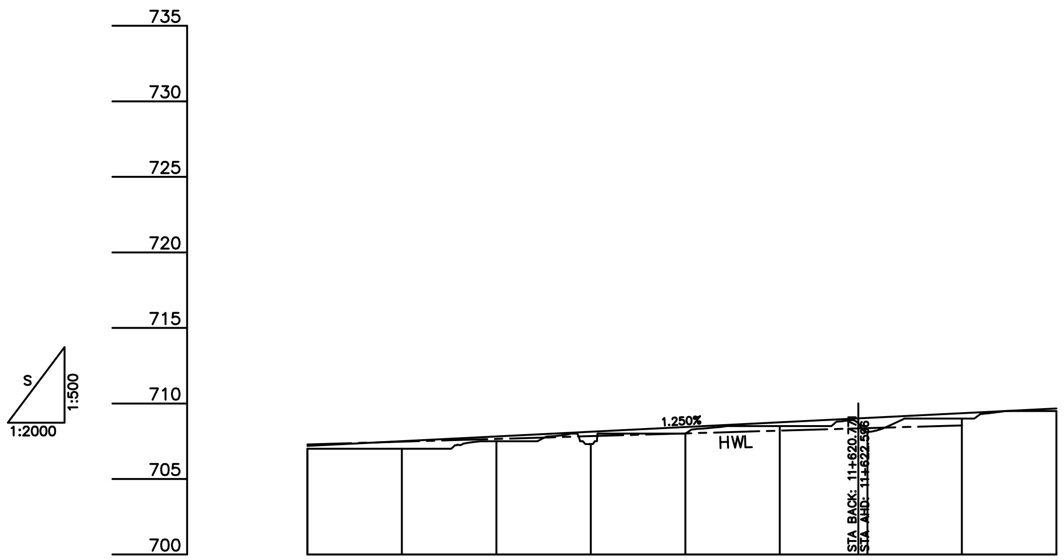
SECTION G STA.11+400～11+700



HIGH WATER LEVEL DATA

STATION	HWL
STA.11+450	707.108
STA.11+475	707.288
STA.11+489	707.388
STA.11+500	707.468
STA.11+525	707.648
STA.11+550	707.828
STA.11+565	707.936
STA.11+575	708.008
STA.11+600	708.188
STA.11+625	708.368
STA.11+650	708.548
STA.11+675	708.728
STA.11+700	708.908

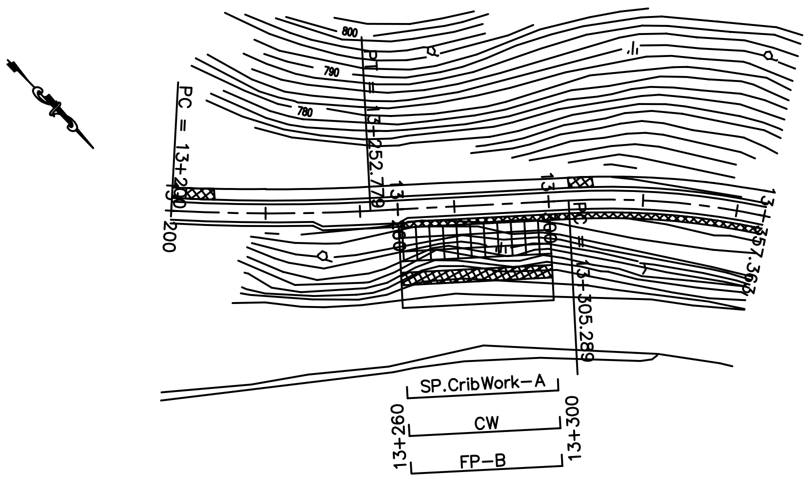




GRADE	1.250%								
PROPOSED HEIGHT	707.188	707.500	707.812	708.125	708.437	708.750	709.062	709.375	
GROUND HEIGHT	707.000	707.000	707.500	707.314	708.000	708.500	708.171	709.000	
STATION	11+475	11+500	11+525	11+550	11+575	11+600	11+627	11+652	11+675
CURVE ELEMENT	R= 00 L = 58.719		R = 110.000 L = 87.052				R= 00 L = 52.404		

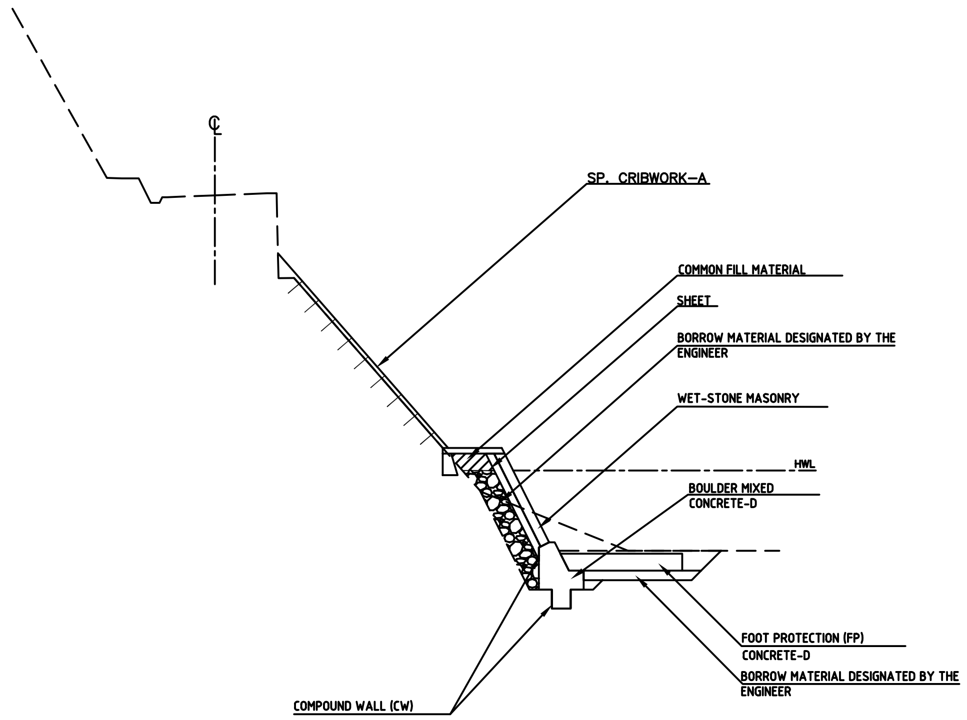
PLAN AND PROFILE (8)

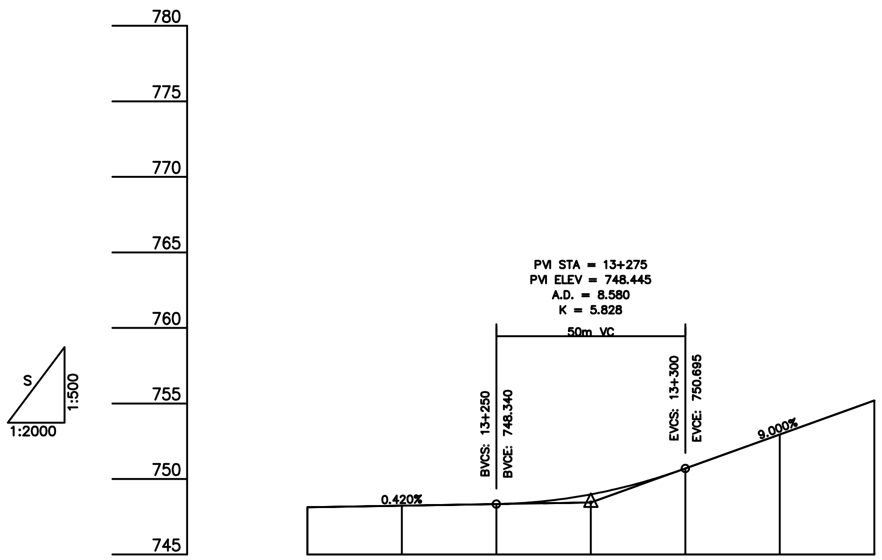
SECTION H STA.13+260～13+300



HIGH WATER LEVEL DATA

STATION	HWL
STA.13+260	734.920
STA.13+275	735.187
STA.13+300	735.632

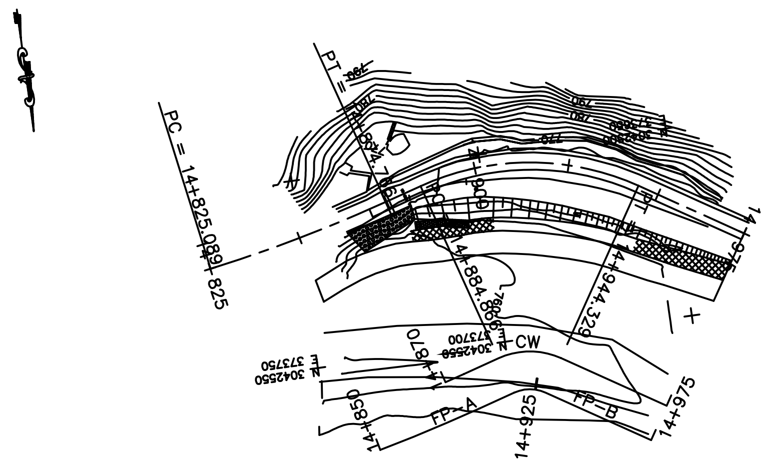




GRADE	0.420%			748.445		9.000%	
PROPOSED HEIGHT	748.130	748.235	748.340	748.981	750.695	752.945	755.195
GROUND HEIGHT	748.130	748.235	748.340	748.445	750.695	752.945	755.195
STATION	13+200	13+225	13+250	13+275	13+300	13+325	13+350
CURVE ELEMENT	R = 500.000 L = 52.779		R= 00 L = 52.511		R = 200.000 L = 52.073		

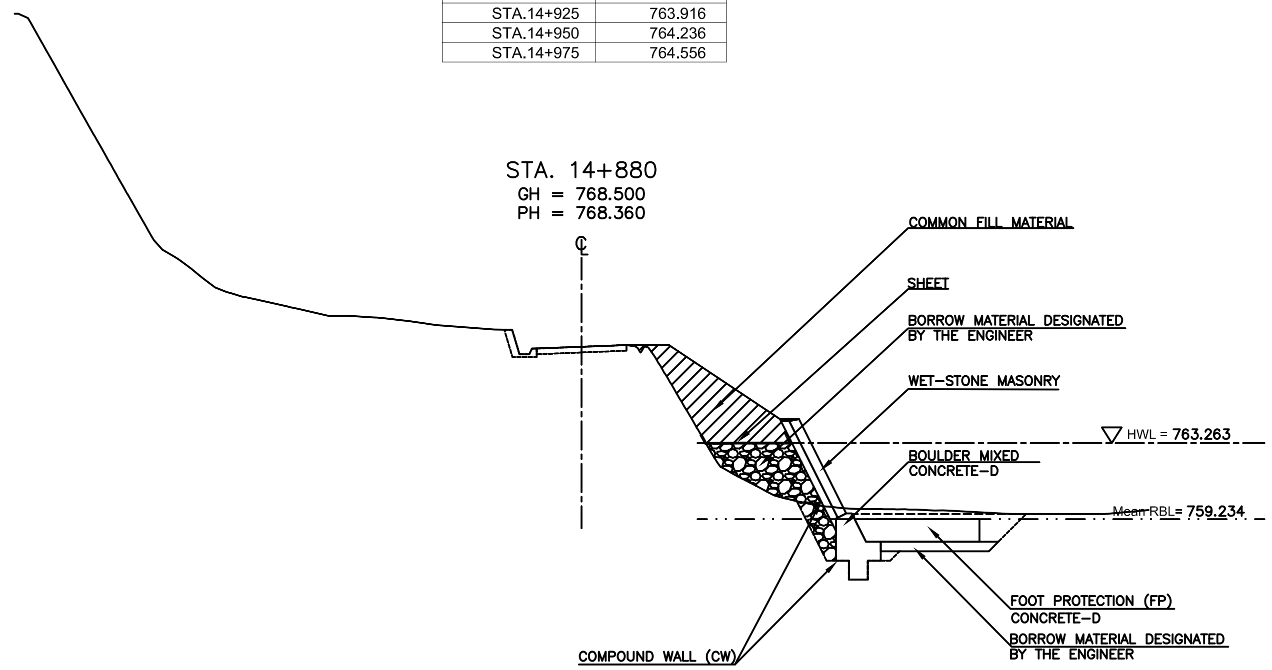
PLAN AND PROFILE (9)

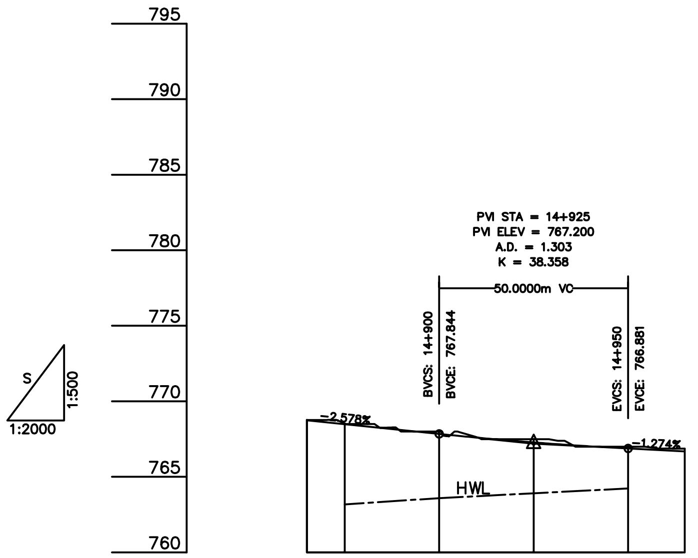
SECTION I STA.14+850～14+975



HIGH WATER LEVEL DATA

STATION	HWL
STA.14+850	762.764
STA.14+875	763.180
STA.14+880	763.263
STA.14+900	763.596
STA.14+925	763.916
STA.14+950	764.236
STA.14+975	764.556

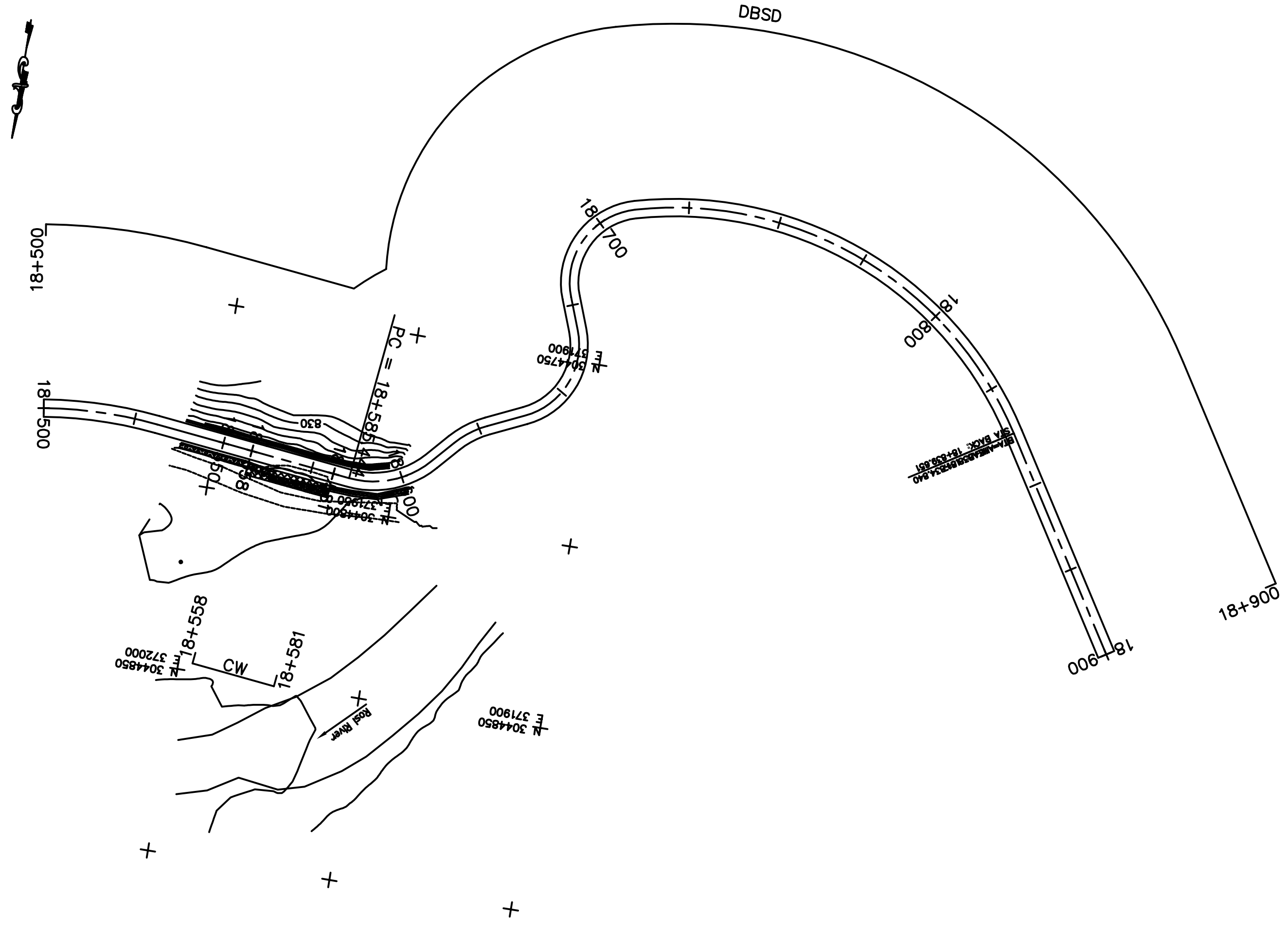




GRADE	-2.578%			767.200	-1.274%	
PROPOSED HEIGHT	768.747	768.489	767.844	767.281	766.881	766.699
GROUND HEIGHT	768.768	768.537	768.000	767.500	767.000	
STATION	14+865	14+875	14+900	14+925	14+950	14+964
CURVE ELEMENT	R = 400.000 L = 10.100	R= 00	R = 70.000 L = 59.462		R= 00	

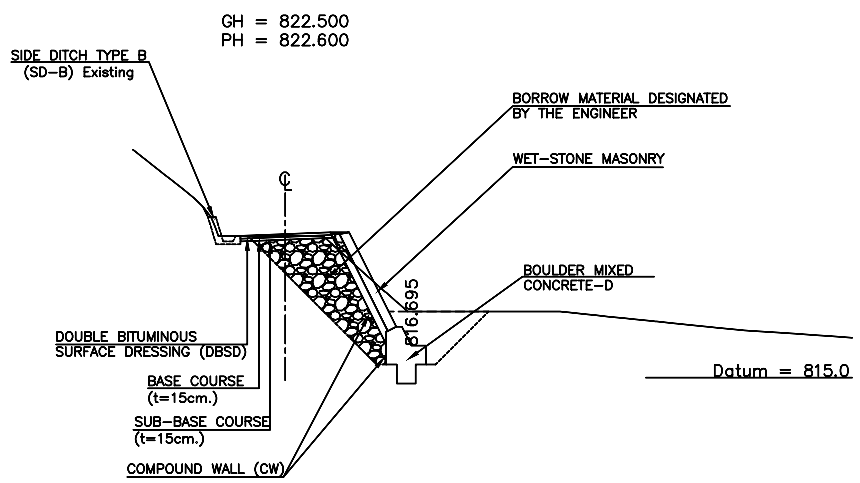
PLAN AND PROFILE (10)

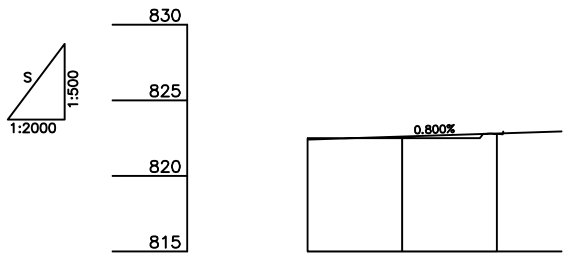
SECTION J STA.18+500～18+800



HIGH WATER LEVEL DATA

STATION	HWL
STA.18+558	822.115
STA.18+575	822.554
STA.18+581	822.709

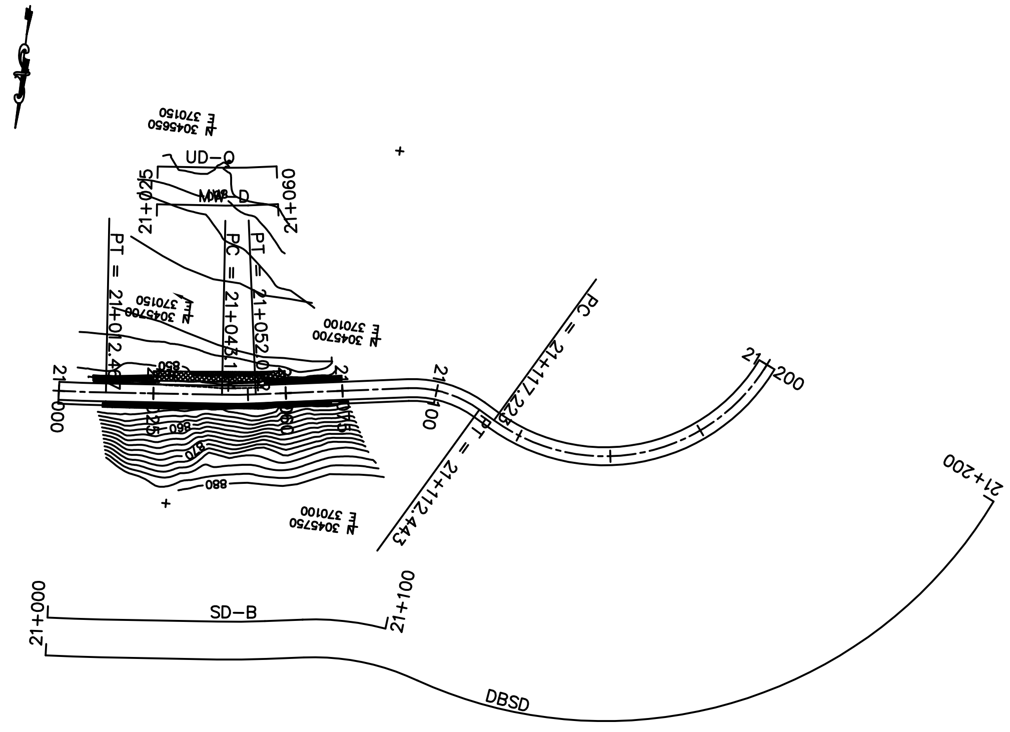




GRADE	0.800%			
PROPOSED HEIGHT	822.400	822.600	822.800	
GROUND HEIGHT	822.500	822.500	822.771	
STATION	18+550	18+575	18+600	18+617
CURVE ELEMENT	R= 00	R = 25.000 L = 23.749	R= 00	

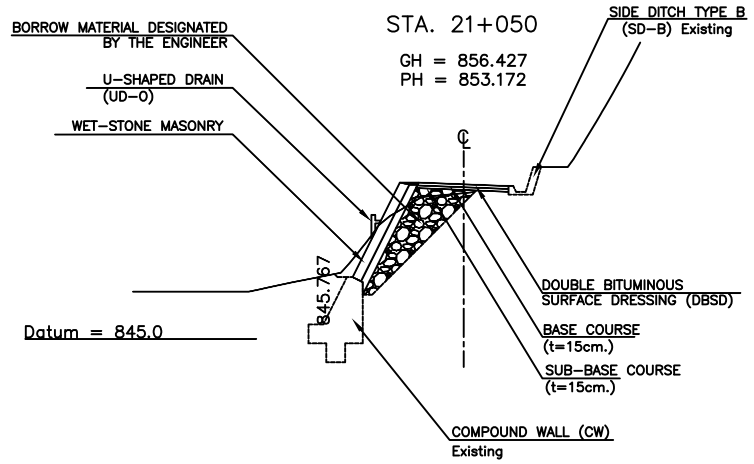
PLAN AND PROFILE (11)

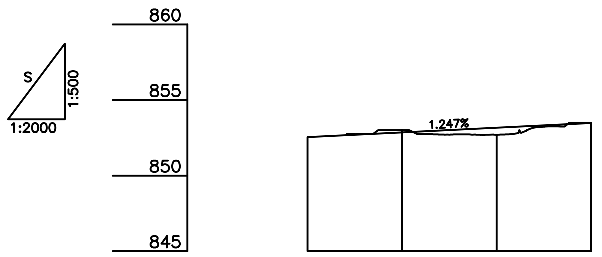
SECTION K STA.21+000～21+200



HIGH WATER LEVEL DATA

STATION	HWL
STA.21+025	853.891
STA.21+050	854.129
STA.21+060	854.225

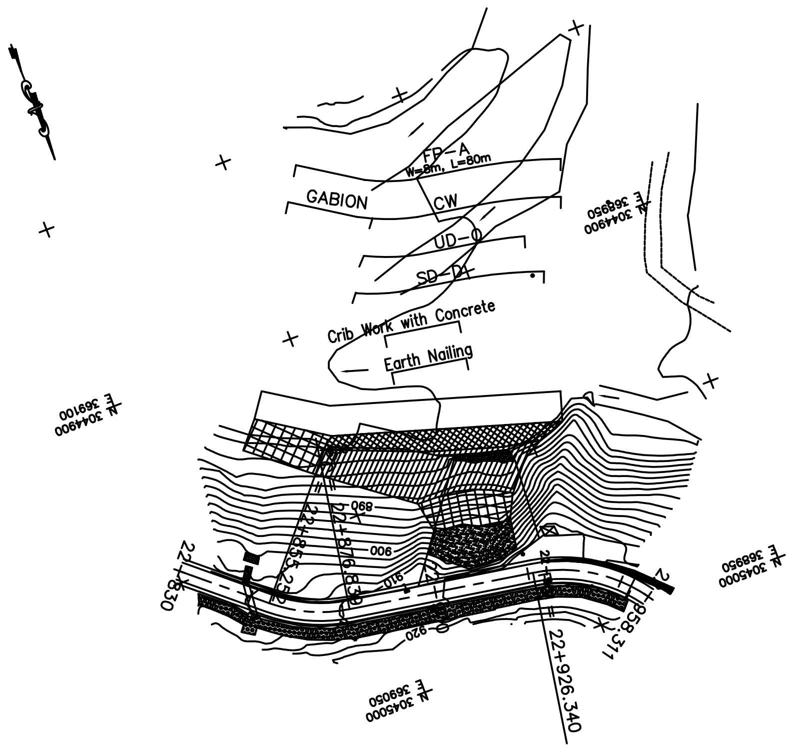




GRADE	1.247%			
PROPOSED HEIGHT	852.548	852.860	853.172	853.483
GROUND HEIGHT	852.548	853.000	852.706	853.500
STATION	21+000	21+025	21+050	21+075
CURVE ELEMENT	R = 400.000	R= 00 L = 30.677	R = 150.000 L = 8.919	R= 00

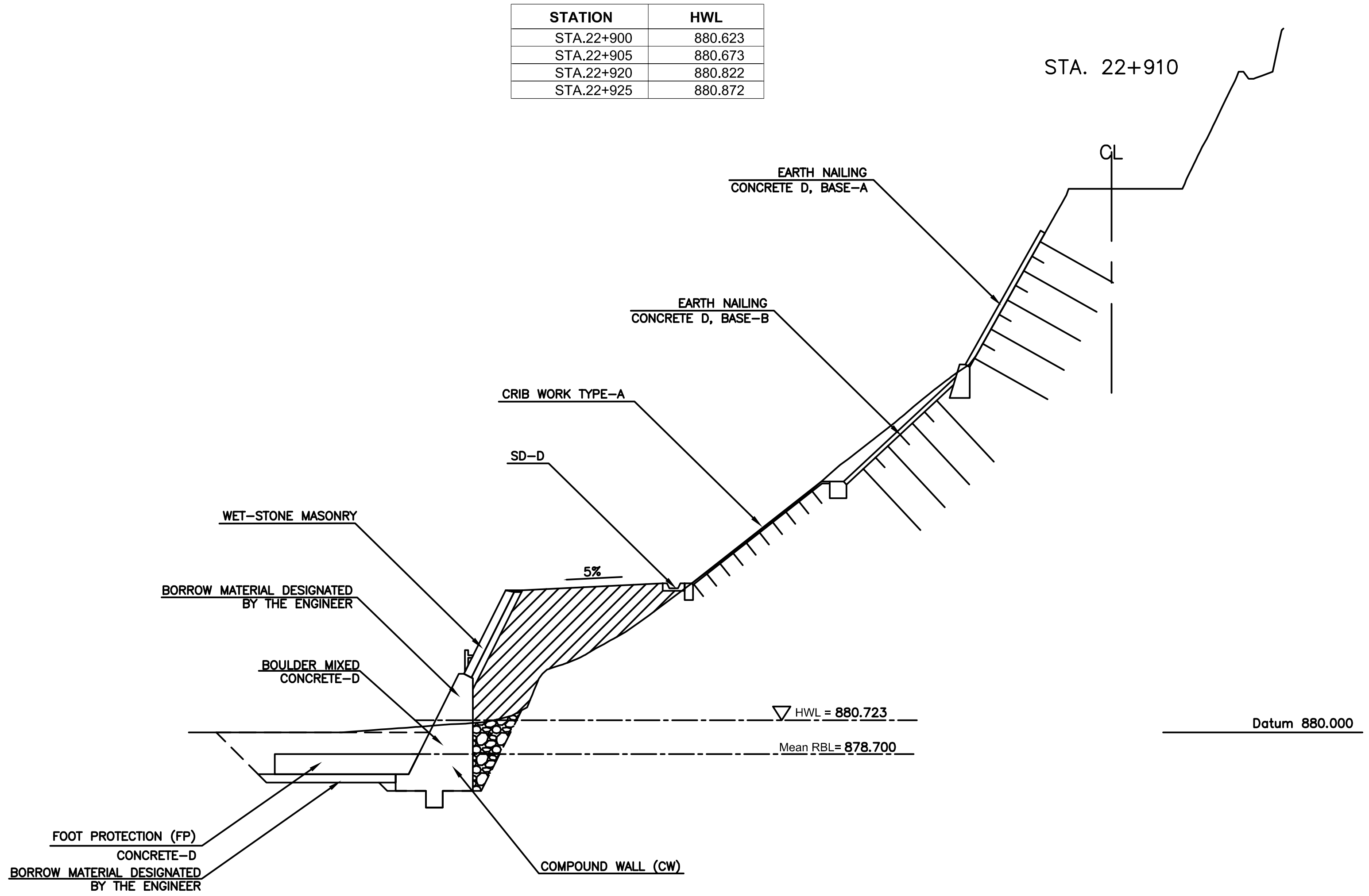
PLAN AND PROFILE (12)

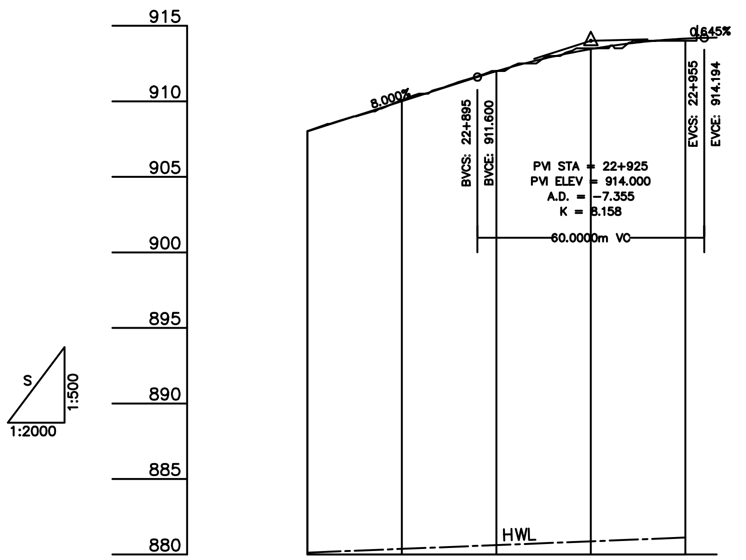
SECTION L STA.22+835～22+935



HIGH WATER LEVEL DATA

STATION	HWL
STA.22+900	880.623
STA.22+905	880.673
STA.22+920	880.822
STA.22+925	880.872





GRADE	8.000%			914.000	0.645%	
PROPOSED HEIGHT	908.000	910.000	911.985	913.448	914.146	
GROUND HEIGHT	908.020	910.080	912.000	913.500	914.000	
STATION	22+850	22+875	22+900	22+925	22+950	22+958
CURVE ELEMENT	R= 00 L = 25.252	R = 40.000 L = 21.588	R= 00 L = 49.501		R = 40.000 L = 31.971	