6. Data & Information

6-1 Hydrology & Hydraulic Survey

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6-1 Hydrology & Hydraulic Survey

1. Study Area

The study area is the basins of the tributaries which flow into the Sunkoshi River in-between Nepalthok and Khurkot stretch of the river in Sindhuli district. The study is conducted to estimate high water level (HWL) in the mainstream and tributaries for assisting on designing works of culverts, bridges and bank protection works in 31 km of Section III (Nepalthok-Khurkot) of Sindhuli Road.

2. Meteorological Condition in Project Area

The meteorological conditions of the project area like monthly rainfall and air temperature distribution patterns have been analyzed. For this, monthly maximum and minimum air temperature records of Sindhuli Gadhi and Dhulikhel stations were analyzed. Similarly, monthly rainfall records of Sindhuli Gadhi and Nepalthok stations were also analyzed.

2. 1 Air Temperature

The monthly maximum and minimum air temperature during 1993-2005 of Sindhuli Gadhi station were analyzed. The highest value of average monthly maximum temperature is 31.7 ^{o}C in April. The lowest value of average monthly maximum temperature is 21.0 ^{o}C in January (Table 1 & Fig. 1).

Table 1 Monthly Maximum Air Temperature (Sindhuli Gadhi)

Year	Monthly Maximum Temperature (^{o}C)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993		25.0	26.2	30.4	31.1	30.7	29.8	28.8	28.8	28.4	24.9	22.3
1994	20.9	22.0	27.9	32.3	32.9	31.3	31.2	31.3	31.8	30.3	27.9	23.3
1995	20.3	22.4	28.4	32.6	34.0	30.5	29.6	30.1	29.3	29.1	26.3	22.5
1996	19.8	24.2	28.4	33.4	29.7	30.6	30.2	30.1	29.9	28.5	26.9	24.0
1997	20.9	22.3	28.7	28.7	32.8	32.3	30.7	30.6	29.5	28.1	26.3	21.4
1998	20.5	23.9	26.2	30.7	32.6	33.3	30.3	29.6	30.2	29.8	27.2	24.2
1999	22.8	27.2	30.6	34.3	30.9	31.0	30.0	29.4	29.6	28.6	26.9	24.2
2000	21.8	22.3	28.4	31.9	31.0	30.9	31.2	29.8	29.3	29.9	26.0	23.3
2001	21.2	25.0	29.6	32.6	30.6	30.9	31.2	30.9	29.9	29.1	26.5	23.0
2002	21.7	24.6	29.2	30.5	30.9	31.3	30.1	29.5	30.2	29.0	26.9	23.4
2003	21.3	23.0	26.8	30.7	31.2	31.3	30.8	30.8	30.1	29.2	26.2	23.7
2004	20.8	24.5	29.9	30.9	31.0	31.5	29.6	30.9	30.4	28.3	26.0	24.4
2005	20.4		29.5	32.5	31.0	32.3	30.6					
Mean	21.0	23.9	28.4	31.7	31.5	31.4	30.4	30.2	29.9	29.0	26.5	23.3

At Sindhuli Gadhi station, the highest value of average monthly minimum temperature is 22.8 ^{o}C in July and August. The lowest value of average monthly minimum temperature is 7.2 ^{o}C in January (Table 2 & Fig. 1).

Table 2 Monthly Minimum Air Temperature (Sindhuli Gadhi)

Year	Monthly Minimum Temperature (°C)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993		8.5	11.3	17.3	20.0	21.4	21.8	20.6	19.2	15.6	13.0	
1994	8.3	10.2	15.5	17.1	21.4	23.7	23.6	23.1	22.3	17.9	12.9	8.9
1995	7.0	9.5	14.0	19.0	22.6	23.7	23.4	23.1	22.4	19.1	13.7	10.3
1996	9.0	10.9	14.7	18.0	19.4	22.6	23.5	23.2	22.2	18.7	13.1	9.6
1997	7.7	7.7	13.5	16.5	19.6	22.1	23.6	23.4	21.9	16.2	12.9	9.5
1998	7.3	9.9	12.7	17.3	21.7	24.2	24.2	24.0	22.7	20.6	15.8	9.9
1999	7.5	11.6	13.6	20.2	21.6	22.6	23.4	23.2	22.4	19.0	13.4	10.2
2000	7.3	8.5	13.1	17.8	21.5	23.0	22.9	23.1	21.4	18.0	14.4	8.3
2001	7.0	10.0	13.6	17.9	20.0	22.3	23.3	21.2	19.9	16.3	11.1	6.1
2002	5.3	8.5	11.7	15.7	18.4	20.1	21.9	24.0	21.0	19.0	13.1	9.2
2003	5.9	9.6	13.1	17.3	19.0	21.9	22.7	22.7	21.8	18.4	12.5	8.1
2004	6.6	9.5	15.0	17.8	19.4	21.5	21.6	22.3	20.8	16.2	11.0	8.5
2005	7.1		12.5	15.0	17.2	20.3	20.7					
Mean	7.2	9.5	13.4	17.5	20.1	22.3	22.8	22.8	21.5	17.9	13.1	9.0

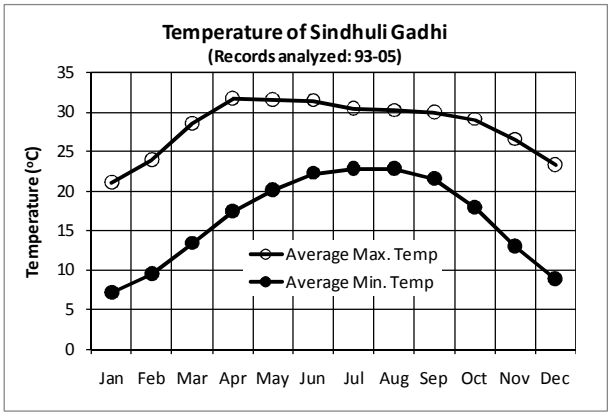


Fig. 1 Monthly Maximum and Minimum Temperature (Sindhuli Gadhi)

Further, monthly maximum and minimum air temperature during 1993-2004 of Dhulikhel station were analyzed. The highest value of average monthly maximum temperature is 26.6 °C in May. The lowest value of average monthly maximum temperature is 14.1 °C in January (Table 3 & Fig. 2).

Table 3 Monthly Maximum Air Temperature (Dhulikhel)

Year	Monthly Maximum Temperature (°C)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	15.8	19.1	22.4	25.4	27.2	27.1	25.9	25.4	24.9	23.5	20.1	17.9
1994	16.0	17.2	23.3	26.6	28.1	27.3	26.9	26.7	25.2	22.5	18.0	15.0
1995	12.2	14.9	21.9	27.0	29.1	24.9	25.1	25.7	25.5	22.7	18.6	15.6
1996	13.4	16.6	22.2	25.7	28.3	25.5	25.7	25.5	24.5	22.7	19.7	15.7
1997	13.0	15.4	21.9	21.6	26.3	27.1	26.8	26.3	25.1	20.7	18.3	13.8
1998	13.8	16.7	19.0	24.0	25.7	28.7	25.5	24.8	25.0	23.8	19.5	15.8
1999	15.0	20.6	23.7	29.2	26.6	26.1	25.2	24.8	24.8	21.8	18.8	15.1
2000	14.5	16.0	21.0	25.8	25.5	26.0	26.1	27.3	25.6	23.3	19.0	15.1
2001	14.0	18.5	22.5	26.3	25.6	26.9	26.4	25.9	24.3	22.7	19.5	15.2
2002	14.8	17.8	21.4	23.8	24.5	26.4	25.4	25.6	23.9	22.3	18.8	15.3
2003	13.9	15.9	20.4	25.5	25.9	25.9	25.6	25.9	24.3	22.6	18.7	14.3
2004	13.3	16.9	23.2	24.6	26.0	25.9	24.4	26.0	24.2	21.4	17.1	15.4
Mean	14.1	17.1	21.9	25.5	26.6	26.5	25.8	25.8	24.8	22.5	18.8	15.4

At Dhulikhel station, the highest value of average monthly minimum temperature is 18.1 °C in July and August. The lowest value of average monthly minimum temperature is 3.4 °C in January (Table 4 & Fig. 2).

Table 4 Monthly Minimum Air Temperature (Dhulikhel)

Year	Monthly Minimum Temperature (°C)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	3.3	5.5	6.4	10.7	14.8	17.4	18.9	18.9	16.7	12.8	7.6	3.8
1994	2.8	2.9	8.3	10.2	14.4	17.6	18.3	18.1	16.7	11.2	5.9	3.4
1995	2.2	4.8	8.8	12.2	16.9	18.9	18.9	18.9	17.6	13.4	8.8	5.5
1996	4.1	6.2	10.6	11.9	15.1	17.4	19.1	18.3	17.5	13.2	9.2	5.2
1997	3.3	3.8	8.4	11.0	13.6	17.0	19.3	19.1	17.2	10.7	8.2	4.5
1998	3.5	5.9	8.0	12.1	16.2	19.2	19.6	19.3	17.9	15.6	10.5	5.9
1999	3.9	8.3	9.6	14.8	16.0	18.0	19.0	18.9	18.1	13.9	8.9	6.2
2000	3.9	3.8	7.8	12.4	16.3	18.5	19.0	19.0	17.4	13.3	9.6	4.7
2001	3.9	6.1	8.6	11.9	11.6	9.7	10.5	10.2	9.0	5.1	2.2	4.0
2002	2.8	5.3	8.5	10.8	14.9	17.8	18.5	18.4	16.6	12.4	8.2	4.7
2003	3.0	4.8	7.8	11.6	12.8	16.7	18.2	18.6	17.6	13.4	8.6	4.6
2004	3.6	5.5	11.0	13.0	15.4	17.5	18.4	19.0	17.9	12.2	7.8	5.1
Mean	3.4	5.2	8.7	11.9	14.8	17.1	18.1	18.1	16.7	12.3	8.0	4.8

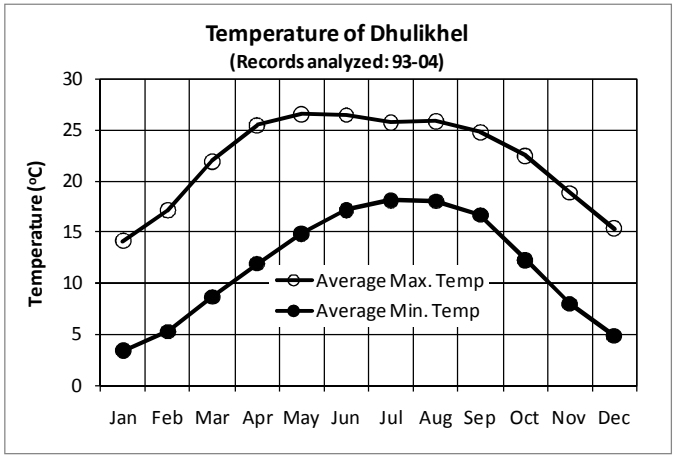


Fig. 2 Monthly Maximum and Minimum Temperature (Dhulikhel)

2. 2 Rainfall

The monthly rainfalls during 1993-2006 of Sindhuli Gadhi station were analyzed. The highest value of average monthly rainfall is 745.8 mm in July. The lowest value of average monthly rainfall is 7.4 mm in December. The average annual rainfall is 2613 mm (Table 5 & Fig. 3).

Table 5 Monthly Rainfall (Sindhuli Gadhi)

Year	Monthly Rainfall (mm)												Annual (mm)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1993			34.2	124.9	183.7	393.4	1193.4	681.2	172.7	226.1	0.0	0.0	
1994	64.2	36.1	36.0	55.1	171.6	226.8	578.8	267.6	439.2	46.2	2.4	0.0	1924
1995	8.0	24.9	13.9	37.0	129.9	409.0	598.3	827.1	274.2	42.6	53.2	52.6	2471
1996	39.8	3.8	3.0	56.6	107.7	570.5	891.1	443.6	401.5	80.4	0.0	0.0	2598
1997	18.0	0.0	6.0	186.3	72.6	352.2	555.4	594.0	515.0	17.9	0.0	0.0	2317
1998	0.0	8.8	92.0	245.2	226.4	412.1	840.8	650.4	334.0	71.5	37.3	0.0	2919
1999	0.0	0.0	0.0	15.3	480.0	458.7	759.8	738.5	559.8	235.9	0.0	0.0	3248
2000	4.0	0.0	7.4	109.6	343.3	551.3	537.7	827.6	249.4	73.2	2.6	0.0	2706
2001	1.7	15.2	0.0	80.3	483.6	496.5	499.2	731.4	300.8	153.3	25.0	0.0	2787
2002	58.7	14.8	5.1	110.4	220.4	232.3	1184.2	642.3	444.3	4.5	2.1	0.0	2919
2003	34.7	58.4	58.4	147.4	25.0	519.1	656.4	536.4	449.3	54.5	8.2	38.0	2586
2004	17.3	4.5	117.7	207.7	151.4	529.4	1206.4	282.1	424.4	189.2	3.4	0.0	3134
2005	41.1	4.6	44.0	90.2	138.7	244.8	539.6	284.8	417.9	255.9	0.0	0.0	2062
2006	0.0	0.0	56.0	104.4	186.3	512.7	399.6	332.7	548.3	149.5	2.1	12.5	2304
Mean	22.1	13.2	33.8	112.2	208.6	422.1	745.8	560.0	395.1	114.3	9.7	7.4	2613

Further, the monthly rainfalls during 1990-2004 of Nepalthok station were analyzed. The highest value of average monthly rainfall is 296.3 mm in July. The lowest value of average monthly rainfall is 9.0 mm in November. The average annual rainfall is 887 mm (Table 6 & Fig. 3).

Table 6 Monthly Rainfall (Nepalthok)

Year	Monthly Rainfall (mm)												Annual (mm)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1990	0.0	36.2	17.4	28.7	132.4	64.0	305.2	287.0	92.7	75.4	0.0	0.0	1039
1991	34.3	9.3	52.2	46.6	79.4	100.1	26.9	57.2	48.5	0.0	1.3	15.1	471
1992	2.2	9.2	0.0	15.1	53.5	43.4	197.7	97.4	38.3	34.6	19.2	0.0	511
1993	18.2	18.1	35.2	99.2	38.5	110.6	286.8	238.2	42.8	0.0	0.0	0.0	888
1994	36.4	18.1	14.4	42.7	30.3	210.5	111.4	142.2	112.8	0.0	0.0	0.0	719
1995	0.2	25.8	9.4	0.0	70.1	269.4	132.7	167.8	61.0	2.4	97.4	16.2	852
1996	64.9	3.6	25.0	5.3	43.8	274.2	284.5	242.0	55.1	42.2	0.0	0.0	1041
1997	22.6	0.0	12.4	66.1	44.5	126.5	253.1	203.1	40.6	18.4	0.3	123.5	911
1998	0.0	11.6	91.0	64.8	24.2	126.7	423.2	207.3	134.3	8.5	17.5	0.0	1109
1999	0.4	0.0	0.0	3.1	71.6	289.8	366.2	256.1	130.0	184.5	0.0	0.0	1302
2000	0.0	2.1	0.0	93.8	53.7	82.2	265.6	194.3	36.4	0.0	0.0	0.4	729
2001	0.0	12.0	19.1	14.5	104.7	128.3	213.6	110.5	99.0	50.2	0.0	0.0	752
2002	28.3	14.0	40.4	64.3	157.8	32.3	622.4	211.8	97.5	17.1	0.0	16.0	1302
2003	0.0	55.3	18.0	3.4	52.3	96.2	397.8	106.9	5.1	0.0	0.0	42.5	778
2004	7.3	0.0	3.0	40.0	136.3	91.7	556.7	34.2	37.1	0.0	0.0	0.0	906
Mean	14.3	14.4	22.5	39.2	72.9	136.4	296.3	170.4	68.7	28.9	9.0	14.2	887

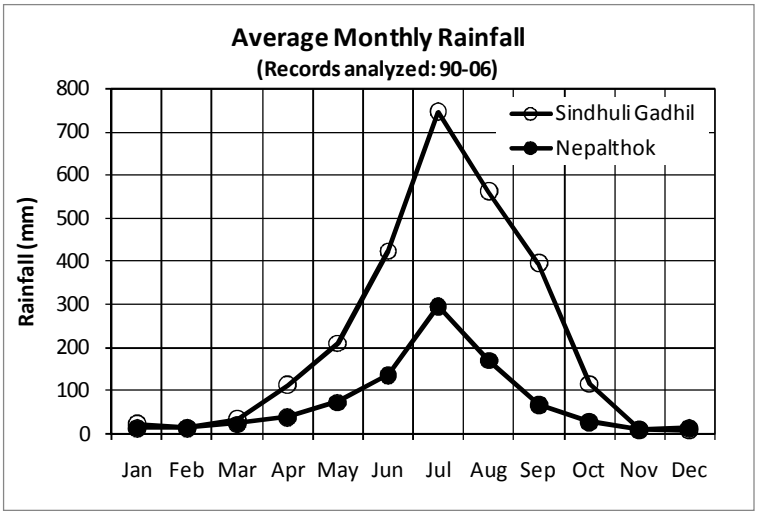


Fig. 3 Average Monthly Rainfall in Project Area

3. Tributaries and Their Basins

The basins of the tributaries are delineated to know their catchment areas for rainfall-runoff analysis to estimate HWL in the tributaries. The tributaries and their catchment areas are presented in figure and table (Fig. 4 and Table 7). Dhamile Khola has the largest catchment area of 28.35 km^2 among the tributaries. The tributaries like Bhalu Khola and Gadaule Khola have very small catchment areas.

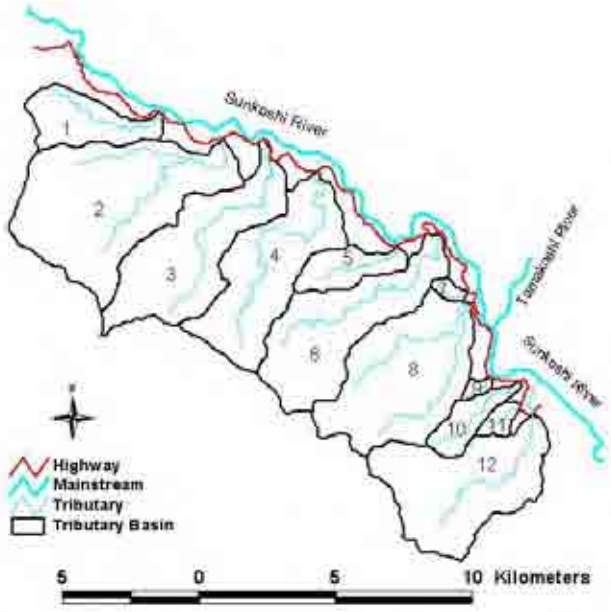


Fig. 4 Tributaries and Their Basins

Table 7 Basin Area of Tributaries

S. N.	Tributary	Basin Area (km^2)
1	Sadhi Khola	7.21
2	Dhamile Khola	28.35
3	Gangate Khola	19.03
4	Bhote Khola	18.04
5	Khahare Khola	4.53
6	Chainpur Khola	18.16
7	Gadaule Khola	0.73
8	Dhobi Khola	21.70
9	Bhalu Khola	0.58
10	Bhadaure Khola	3.66
11	Jagire Khola	1.23
12	Andheri Khola	19.45

4. Frequency Analysis of River Discharge

Frequency analyses of discharges of the Sunkoshi River and Rosi Khola are performed for estimating the high water level in the rivers.

4.1 Sunkoshi River Discharge Analysis

The time series of annual maximum daily discharge of the Sunkoshi River at Pachuwar Ghat, which is the only nearest gauging station from the project area, was used for frequency analysis (Fig. 5 and Table 8).

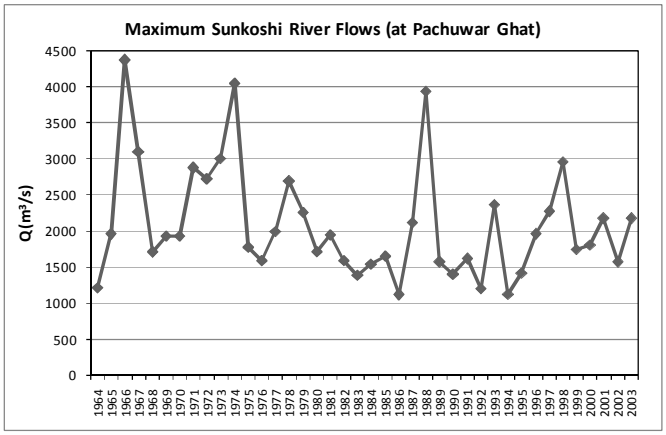


Fig. 5 Maximum Discharge of the Sunkoshi River (at Pachuwar Ghat)

Table 8 Annual Maximum Discharge of the Sunkoshi River (at Pachuwar Ghat)

Year	Annual Max. Discharge (m^3/s)	Year	Annual Max. Discharge (m^3/s)	Year	Annual Max. Discharge (m^3/s)
1964	1220	1978	2690	1992	1210
1965	1960	1979	2260	1993	2370
1966	4370	1980	1720	1994	1130
1967	3100	1981	1950	1995	1420
1968	1710	1982	1590	1996	1960
1969	1940	1983	1390	1997	2270
1970	1940	1984	1550	1998	2960
1971	2880	1985	1660	1999	1750
1972	2730	1986	1120	2000	1810
1973	3010	1987	2120	2001	2180
1974	4050	1988	3940	2002	1570
1975	1780	1989	1570	2003	2180
1976	1590	1990	1410		
1977	2000	1991	1620		

The annual maximum discharge records of 1964-2003 of the Sunkoshi River at Pachuwar Ghat station were analyzed to determine the design discharges at different return period levels. The most commonly used Lognormal (LN) distribution function was employed for frequency analysis of the discharge records (Fig. 6). The relation of cumulative distribution function (cdf) of Lognormal (LN) distribution is as presented below:

$$F(x) = \phi\left[\frac{\ln(x) - \mu}{\sigma}\right] \qquad (1)$$

Where,

F(x) = Cumulative distribution function (cdf)

Φ = cdf of standard normal distribution

x = Variable

μ, σ = Normal parameters

Further, 50-year return period specific discharge to Sunkoshi River was calculated based on 50-year return period discharge estimated at Pachuwar Ghat and upstream river basin area at that point. From frequency analysis, 50-year return period discharge of the Sunkoshi River at Pachuwar Ghat is 3950 m^3/s (Table 9). The upstream river basin area at that point is 4920 km^2 and 50-year return period specific discharge of the river is 0.803 $m^3/s/km^2$. Based on the 50-year return period specific discharge, the river discharge at Nepalthok is estimated. Hence, 50-year return period discharge of Sunkoshi River at Nepalthok is 4749 m^3/s.

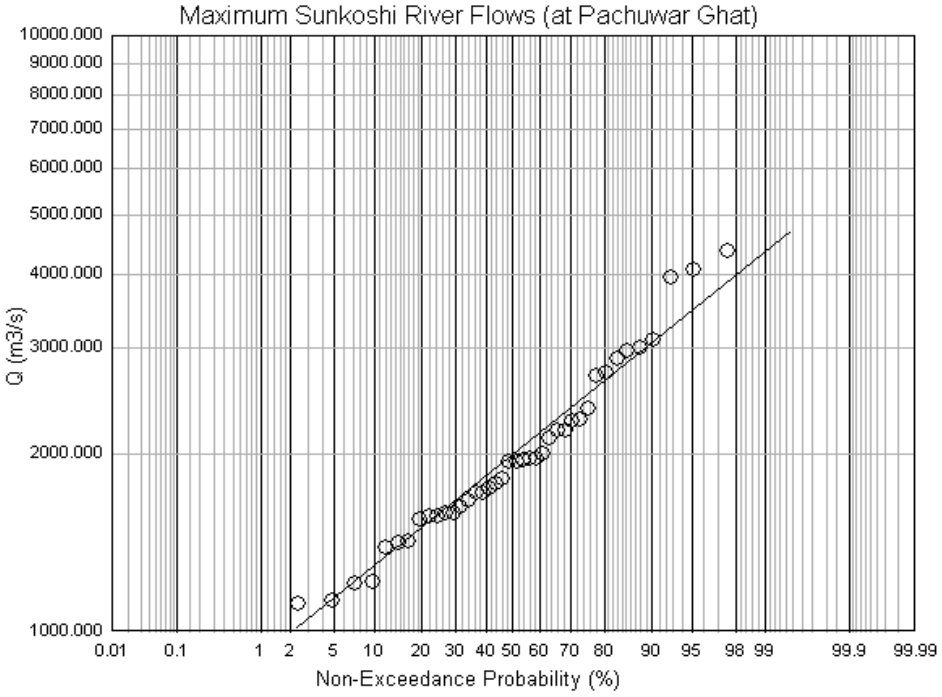


Fig.6 Lognormal (LN) Distribution Fitting of Sunkoshi River's Maximum Discharges

Table 9 Design Discharge of Sunkoshi River

Item	Return Period (year)					
	2	3	5	10	25	50
1- **At Pachuwar Ghat** (Basin Area: 4920 km^2)						
Discharge (m^3/s)	1980	2300	2650	3045	3570	3950
Sp. Discharge ($m^3/s/km^2$)	0.402	0.467	0.539	0.619	0.726	0.803
2- **At Nepalthok** (after Rosi Khola Confluence, Basin Area: 5915 km^2)						
Discharge (m^3/s)	2380	2765	3186	3661	4292	4749

4.2 Rosi Khola Discharge Analysis

The annual maximum daily discharges of Rosi Khola at Panauti were analyzed during detailed design preparation of Section-4 of Sindhuli Road. The catchment area and river course of Rosi Khola are shown (Fig. 7). Further, the design Rosi Khola discharges at

various sections of the river course reported in the detailed design report are presented (Table 10). The design discharges at different sections of the river were estimated from specific discharge determined at Panauti. As mentioned in the report, the 50-year discharge of Rosi Khola at Nepalthok is estimated 1080 m^3/s.

Fig. 7 Rosi Khola River Basin

Table 10 Design Discharge of Rosi Khola

Item	Retrun Period (year)					
	2	3	5	10	25	50
1- **At Panauti** (Basin Area: 87 km^2)						
Discharge (m^3/s)	46	64	85	111	144	168
Sp. Discharge ($m^3/s/km^2$)	0.53	0.74	0.98	1.27	1.65	1.93
2- **After Dapcha Khola Confluence (**Basin Area: 400 km^2)						
Discharge (m^3/s)	212	296	392	511	663	774
3- **After Narke Khola Confluence (**Basin Area: 446 km^2)						
Discharge (m^3/s)	235	330	435	569	738	861
4- **After Kenne Khola Confluence (**Basin Area: 465 km^2)						
Discharge (m^3/s)	246	344	445	594	771	899
5- **After Bhyakure Khola Confluence (**Basin Area: 503 km^2)						
Discharge (m^3/s)	266	372	492	642	833	972
6- **After Mamati Khola Confluence (**Basin Area: 536 km^2)						
Discharge (m^3/s)	283	397	523	684	887	1035
7- **At Nepalthok (**Basin Area: 560 km^2)						
Discharge (m^3/s)	296	414	547	714	927	1080

5. Frequency Analysis of Rainfall

The frequencies of annual maximum daily rainfalls of stations, nearby the project area, were analyzed. Annual maximum daily rainfall time series of Melung, Hariharpur Gadhi, Nepalthok and Sindhuli Gadhi stations are analyzed.

5. 1 Sindhuli Gadhi Rainfall Station

The time series of annual maximum daily rainfall of Sindhuli Gadhi station was collected for frequency analysis (Fig. 8 and Table 11).

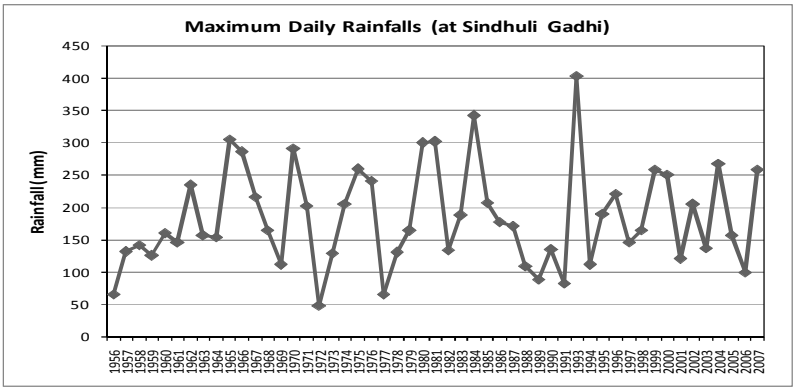


Fig. 8 Maximum Daily Rainfall at Sindhuli Gadhi

Table 11 Annual Maximum Daily Rainfall at Sindhuli Gadhi

Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)
1956	66.0	1974	206.0	1992	NA
1957	132.1	1975	260.0	1993	403.2
1958	142.2	1976	242.0	1994	111.8
1959	126.1	1977	66.0	1995	190.3
1960	161.0	1978	130.4	1996	221.2
1961	146.0	1979	165.0	1997	146.6
1962	235.0	1980	300.0	1998	165.8
1963	157.0	1981	302.0	1999	258.6
1964	155.2	1982	135.0	2000	251.5
1965	306.0	1983	188.0	2001	121.4
1966	286.4	1984	342.0	2002	205.5
1967	216.6	1985	208.0	2003	138.0
1968	166.0	1986	178.0	2004	268.3
1969	112.0	1987	172.0	2005	157.6
1970	291.2	1988	110.0	2006	100.3
1971	202.5	1989	89.5	2007	258.5
1972	48.5	1990	136.1		
1973	130.2	1991	83.0		

The frequencies of annual maximum daily rainfall records of 1956-2007 were analyzed employing the Lognormal (LN) distribution function (Fig. 9). From the fitting of the distribution function, the design rainfalls of 3, 5, 10, 25 and 50-year return periods are 206, 245, 300, 368 and 423 mm, respectively (Table 12).

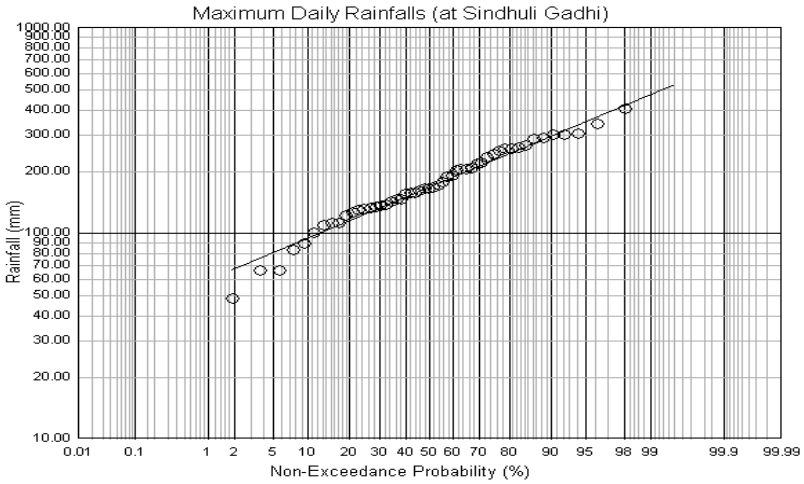


Fig. 9 Lognormal (LN) Distribution Fitting of Sindhuli Gadhi's Maximum Rainfalls

Table 12 Design Daily Rainfall of Sindhuli Gadhi

Return Period (year)	2	3	5	10	25	50
Rainfall (mm)	169	206	245	300	368	423

5.2 Nepalthok Rainfall Station

The time series of annual maximum daily rainfall of Nepalthok station was collected for frequency analysis and the records are as presented (Fig.10 and Table 13).

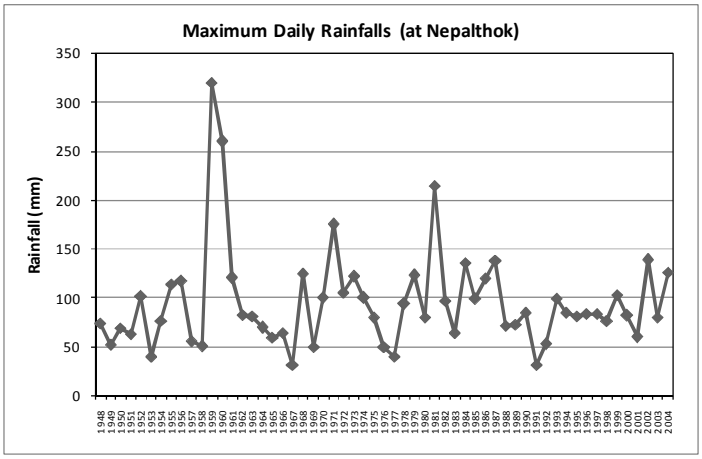


Fig. 10 Maximum Daily Rainfall at Nepalthok

Table 13 Annual Maximum Daily Rainfall at Nepalthok

Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)
1948	74.2	1967	32.4	1986	120.3
1949	52.7	1968	125.0	1987	138.2
1950	69.6	1969	50.4	1988	72.0
1951	63.5	1970	100.2	1989	73.2
1952	101.6	1971	175.4	1990	85.3
1953	40.6	1972	105.5	1991	32.2
1954	76.4	1973	122.0	1992	53.0
1955	114.3	1974	100.2	1993	100.0
1956	117.3	1975	80.2	1994	85.1
1957	55.9	1976	50.4	1995	82.0
1958	50.8	1977	40.2	1996	84.2
1959	320.4	1978	94.4	1997	84.0
1960	260.0	1979	123.4	1998	77.1
1961	120.8	1980	80.4	1999	103.3
1962	83.0	1981	215.0	2000	82.2
1963	81.3	1982	97.3	2001	60.3
1964	70.0	1983	64.4	2002	139.2
1965	60.0	1984	136.2	2003	80.1
1966	65.0	1985	99.2	2004	126.2

The frequencies of annual maximum daily rainfall records of 1948-2004 were analyzed employing the Lognormal (LN) distribution function (Fig. 11). From the fitting of the distribution function, the design rainfalls of 3, 5, 10, 25 and 50-year return periods are 106, 126, 154, 190 and 218 mm, respectively (Table 14).

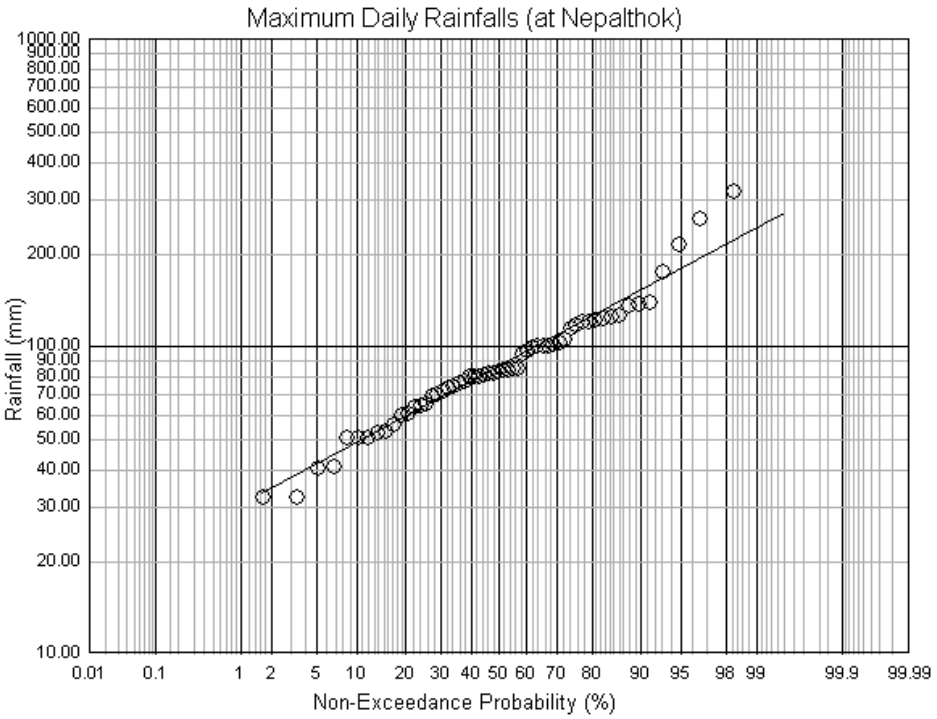


Fig. 11 Lognormal (LN) Distribution Fitting of Nepalthok's Maximum Rainfalls

Table 14 Design Daily Rainfall of Nepalthok

Return Period (year)	2	3	5	10	25	50
Rainfall (mm)	86	106	126	154	190	218

5.3 Hariharpur Gadhi Rainfall Station

The time series of annual maximum daily rainfall of Hariharpur Gadhi station was collected for frequency analysis and the records are as presented (Fig. 12 and Table 15).

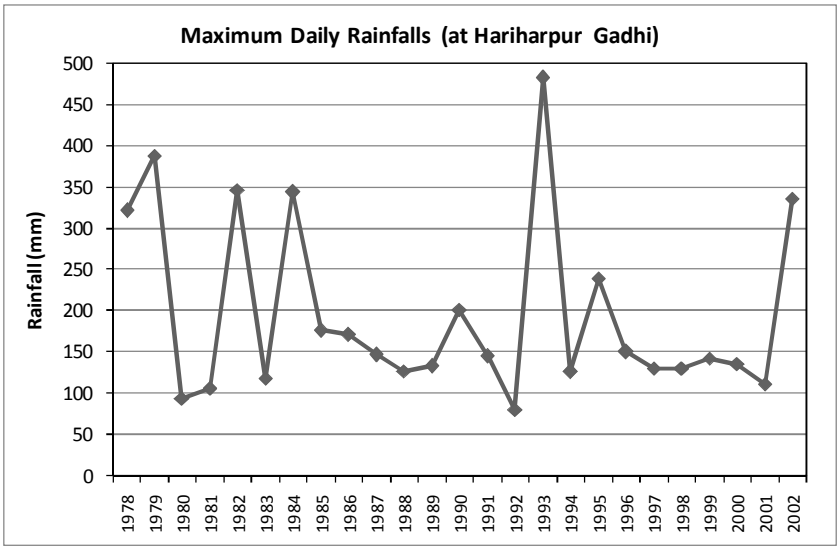


Fig. 12 Maximum Daily Rainfall at Hariharpur Gadhi

Table 15 Annual Maximum Daily Rainfall at Hariharpur Gadhi

Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)
1978	321.5	1991	145.1
1979	387.5	1992	80.1
1980	94.2	1993	482.2
1981	105.8	1994	126.1
1982	347.1	1995	239.1
1983	118.0	1996	150.2
1984	344.2	1997	130.4
1985	176.4	1998	130.2
1986	171.3	1999	142.2
1987	146.7	2000	136.0
1988	127.3	2001	112.0
1989	133.3	2002	336.1
1990	201.3		

The frequencies of annual maximum daily rainfall records of 1978-2002 were analyzed employing the Lognormal (LN) distribution function (Fig. 13). From the fitting of the distribution function, the design rainfalls of 3, 5, 10, 25 and 50-year return periods are 215, 261, 325, 407 and 475 mm, respectively (Table 16).

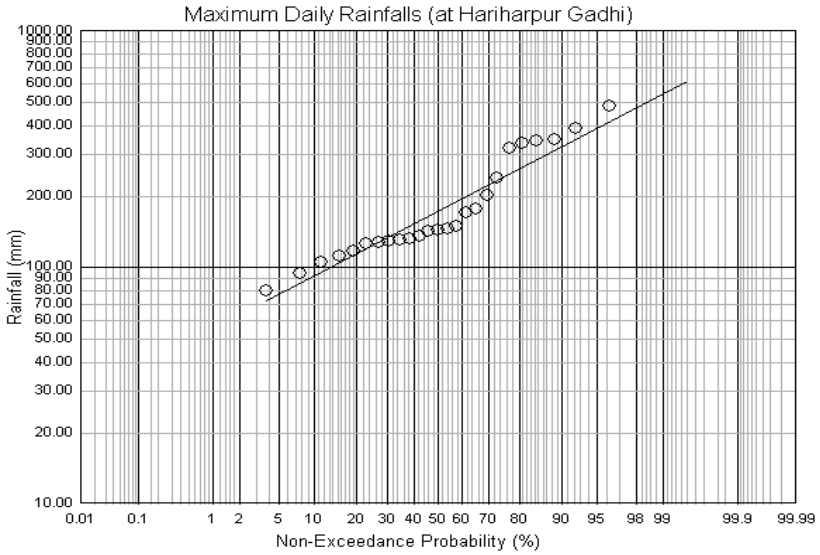


Fig. 13 Lognormal (LN) Distribution Fitting of Hariharpur Gadhi's Maximum Rainfalls

Table 16 Design Daily Rainfall of Hariharpur Gadhi

Return Period (year)	2	3	5	10	25	50
Rainfall (mm)	173	215	261	325	407	475

5.4 Melung Rainfall Station

The time series of annual maximum daily rainfall of Melung station was also collected for frequency analysis and the records are as presented (Fig. 14 and Table 17).

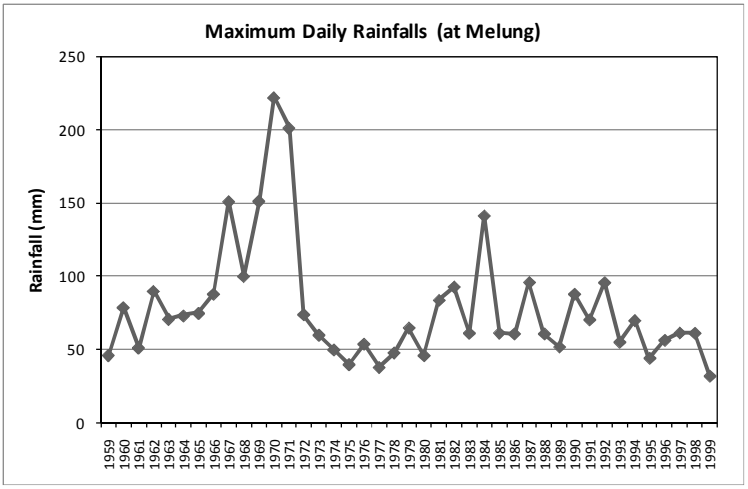


Fig. 14 Maximum Daily Rainfall at Melung

Table 17 Annual Maximum Daily Rainfall at Melung

Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)	Year	Annual Max. Daily Rainfall (mm)
1959	46.2	1973	60.0	1987	96.1
1960	78.8	1974	50.0	1988	61.0
1961	51.4	1975	40.0	1989	52.0
1962	90.0	1976	54.0	1990	88.0
1963	70.9	1977	38.0	1991	70.5
1964	73.2	1978	48.0	1992	96.0
1965	75.0	1979	65.0	1993	55.2
1966	88.0	1980	46.1	1994	70.0
1967	151.2	1981	83.9	1995	44.3
1968	100.2	1982	93.0	1996	56.5
1969	151.4	1983	61.4	1997	61.6
1970	222.2	1984	141.5	1998	61.3
1971	201.4	1985	61.5	1999	32.1
1972	74.0	1986	61.0		

The frequencies of annual maximum daily rainfall records of 1959-1999 were analyzed employing the Lognormal (LN) distribution function (Fig. 15). From the fitting of the distribution function, the design rainfalls of 3, 5, 10, 25 and 50-year return periods are 86, 102, 124, 151 and 172 mm, respectively (Table 18).

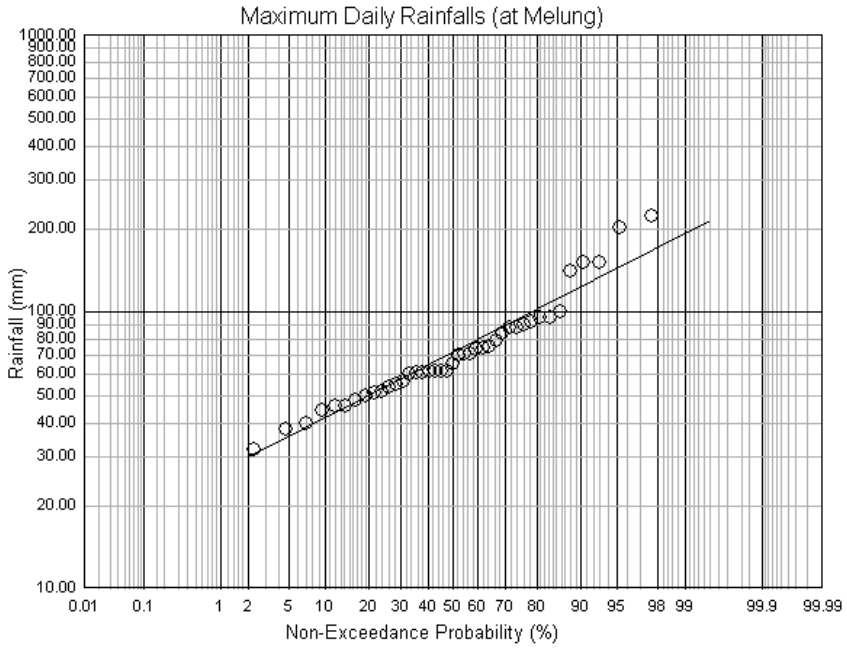


Fig. 15 Lognormal (LN) Distribution Fitting of Melung's Maximum Rainfalls

Table 18 Design Daily Rainfall of Melung

Return Period (year)	2	3	5	10	25	50
Rainfall (mm)	72	86	102	124	151	172

6. Basin Rain Determination

The basin rains for rainfall-runoff process analysis in tributaries were determined with developing the Thiessen Polygons (Fig. 16). For this, nearby stations from the project site like Melung, Hariharpur Gadhi, Sindhuli Gadhi and Nepalthok stations were taken into consideration for Thiessen Polygons development. It has been found that Nepalthok station completely covered 1-3 nos. sub-basins of tributaries whereas for 5-12 nos. sub-basins of tributaries are completely covered by Sindhuli Gadhi station. However, in the case of sub-basin no. 4 of tributary, 39% area of the sub-basin is covered by Nepalthok station and 61% area of the sub-basin is covered by Sindhuli Gadhi station. Moreover, as presented in the frequency analyses of daily rainfall of the stations, Hariharpur Gadhi receives the highest amount of rainfall, Sindhuli Gadhi receives the middle amount of rainfall and Nepalthok receives the lowest amount of rainfall among the three stations. Further, Nepalthok station located at lower elevation, but most of the parts of the sub-basins have higher elevation, therefore, Nepalthok station's rainfall may not properly represent the basin rainfall. Since, Sindhuli Gadhi station located at the higher elevation, so its rainfall may properly represent basin rainfall. Therefore, Sindhuli Gadhi's design rainfall is used as basin rainfall in all sub-basins for peak runoff estimation in the tributaries (Table 19). The 50-year return period basin rainfall is 423 mm. However, for estimating discharges in drains along the road, 50-year design rainfall of Nepalthok (which will be more or less equivalent to 5-year design rainfall of Sindhuli Gadhi)

should be used in all sections of the road because it passes through the lower elevations (Table 20).

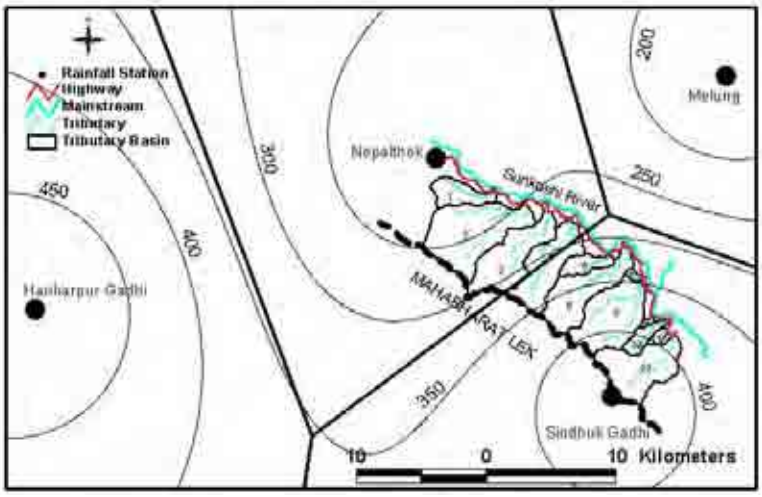


Fig. 16 Thiessen Polygons with 50-year Probable Daily Rainfall Isohyets

Table 19 Design Rainfall for Causeway and Bridge Designing

Return Period (year)	2	3	5	10	25	50
Basin Rainfall (mm/d)	169	206	245	300	368	423

Note: Design rainfall of Sindhuli Gadhi station

Table 20 Design Rainfall for Road Side Ditch and Cross-Drain Designing

Return Period (year)	2	3	5	10	25	50
Rainfall (mm/d)	86	106	126	154	190	218

Note: Design rainfall of Nepalthok station

7. Frequency Analysis of Short Duration Rainfall

The short duration rainfall depths are necessary for runoff estimation. For this purpose, the design short duration rainfall depths of Kathmandu Airport station are used. Frequency analysis of short duration rainfall depths at Kathmandu Airport station were carried out during the study of the Section II of Sindhuli Road. For reference, frequency analyses of short duration rainfall depths of 10-min and 60-min and 24-hour rainfall of Kathmandu Airport cited in the report is presented (Table 21).

Table 21 Design Rainfall Intensity at Kathmandu Airport

Return Period (year)	10-min		60-min		24-hour
	$I_{10\text{-min}}$ (mm)	$I_{10\text{-min}} / I_{24\text{-hour}}$ (Fraction)	$I_{60\text{-min}}$ (mm)	$I_{60\text{-min}} / I_{24\text{-hour}}$ (Fraction)	$I_{24\text{-hour}}$ (mm)
2	12	0.21	31	0.56	56
3	14	0.23	35	0.55	62
5	16	0.24	38	0.55	69
10	19	0.25	43	0.55	78
25	23	0.25	48	0.54	89
50	25	0.26	52	0.54	97

Using the ratios of short duration rainfalls to 24-hour rainfall ($I_t/I_{24\text{-hour}}$) of Kathmandu Airport, short duration rainfall depths (i_t) are estimated from 24-hour rainfall ($i_{24\text{-hour}}$) of Sindhuli Gadhi.

$$i_t = i_{24-hour} \cdot \left(\frac{I_t}{I_{24-hour}} \right) \qquad (2)$$

Where,

i_t = Rainfall amount of 't' duration at Sindhuli Gadhi (mm)

$i_{24\text{-hour}}$ = 24-hour rainfall amount at Sindhuli Gadhi (mm)

I_t = Rainfall amount of 't' duration at Kathmandu Airport (mm)

$I_{24\text{-hour}}$ = 24-hour rainfall amount at Kathmandu Airport (mm)

Short duration rainfall depths of various return period levels of Sindhuli Gadhi station were estimated using the above equation. Based on the estimated short duration rainfalls of various return period levels, the IDF-Curves of Sindhuli Gadhi were developed (Fig. 17). The relation used for the IDF-Curve is presented and values of constants determined for different return period levels are tabulated (Table 22).

$$I = \frac{a}{(t^n + b)} \qquad (3)$$

Where,

I = Rainfall intensity (mm/hr)

t = Duration (minute)

a,b,n = Constants

Table 22 IDF-Curve Constants (for Sindhuli Gadhi)

Return Period (year)	Constants		
	n	b	a
2	1	30	8561
3	1	23	9492
5	1	21	11107
10	1	19	13132
25	1	18	15575
50	1	16	17289

The design rainfall depths of various durations are estimated based on frequency analysis of 24-hour rainfall time series of Sindhuli Gadhi and IDF-Curves (Table 23).

Table 23 Design Rainfall Depths of Various Durations (Sindhuli Gadhi)

Duration	Return Period (year)					
	2	3	5	10	25	50
24-hour Rainfall (mm)	169	206	245	300	368	423
60-min Rainfall (mm)	95	113	135	165	199	228
30-min Rainfall (mm) *	71	90	109	134	162	188
15-min Rainfall (mm) *	48	62	77	97	118	139
10-min Rainfall (mm)	35	47	59	75	92	110
5-min Rainfall (mm) *	20	28	36	46	56	69

* Estimated by IDF-Curve

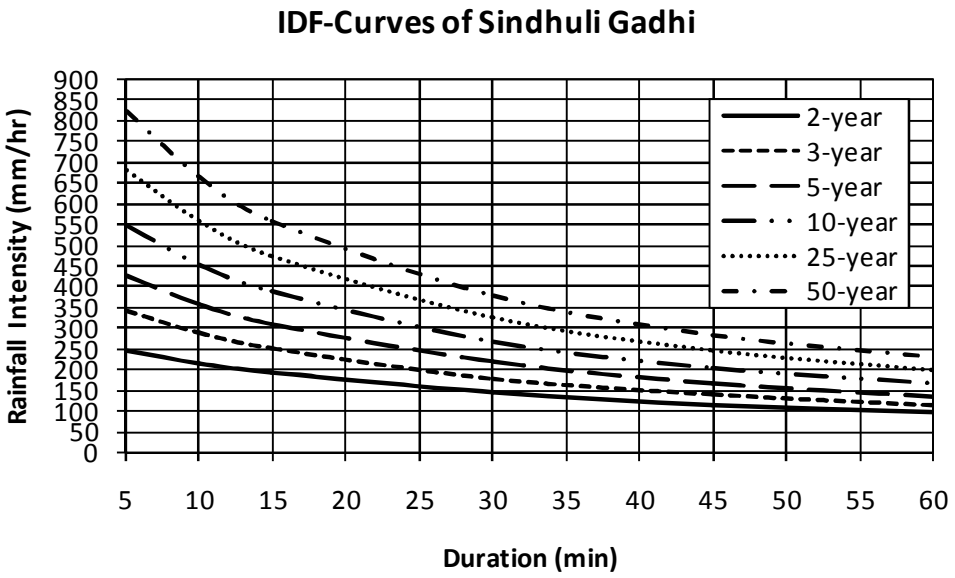


Fig. 17 The IDF-Curve of Sindhuli Gadhi Station

Similarly, short duration rainfall depths of various return period levels of Nepalthok station were estimated and the IDF-Curves were also developed (Fig. 18). The constants of the IDF-Curves determined for Nepalthok station are tabulated (Table 24).

Table 24 IDF-Curve Constants (for Nepalthok)

Return Period (year)	Constants		
	n	b	a
2	1	29.83	4335.46
3	1	22.80	4845.98
5	1	20.54	5620.97
10	1	18.81	6695.50
25	1	17.93	8012.42
50	1	16.24	8962.29

The design rainfall depths of various durations are estimated based on frequency analysis of 24-hour rainfall time series of Nepalthok and IDF-Curves (Table 25).

Table 25 Design Rainfall Depths of Various Durations (Nepalthok)

Duration	Return Period (year)					
	2	3	5	10	25	50
24-hour Rainfall (mm)	86	106	126	154	190	218
60-min Rainfall (mm)	48	58	69	85	103	118
30-min Rainfall (mm)	36	46	56	69	84	97
15-min Rainfall (mm)	24	32	40	50	61	72
10-min Rainfall (mm)	18	24	30	39	48	57
5-min Rainfall (mm)	10	15	18	23	29	35

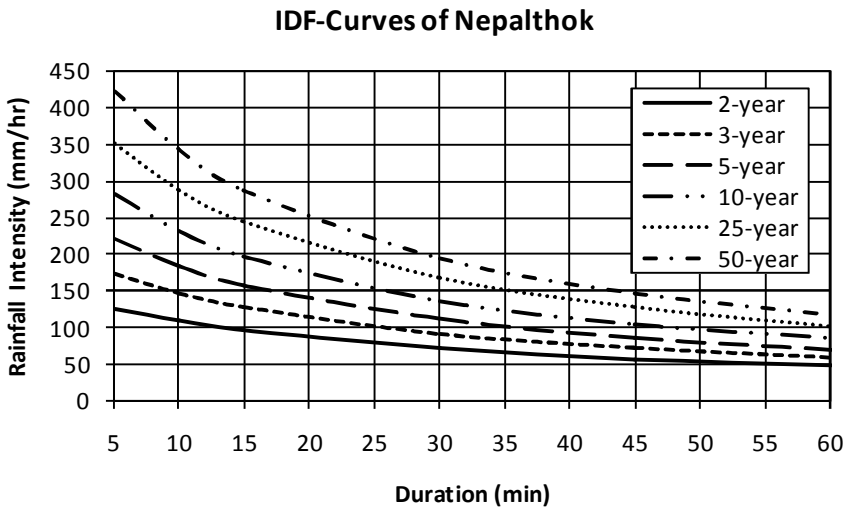


Fig. 18 The IDF-Curve of Nepalthok Station

8. Runoff Concentration Time

The runoff concentration time (equivalent to duration of design rainfall) is determined with following relations.

$$t = t_1 + t_2 \tag{4}$$

$$t_1 = 1.445x\left(\frac{n.L}{S^{0.5}}\right)^{0.467} \tag{5}$$

$$t_2 = \frac{60xL}{V} \tag{6}$$

Where,

t = Runoff concentration time (minutes)

t_1 = Overland flow time (minutes)

t_2 = Channel flow time (minutes)

n = Kerby's coefficient of roughness (0.2)

L = Stream length (m)

S = Slope

V = Flow velocity (m/s)

9. Runoff Estimation

The peak runoffs in the tributaries are computed using rational method based on the design rainfall intensities and catchment area. The estimated peak runoffs in the tributaries are tabulated (Table 26 and 27).

$$Q_P = \frac{CIA}{3.6} \qquad (7)$$

Where,

Q_P = Peak runoff (m^3/s)

I = Design basin rainfall intensity (mm/hr)

A = Basin area (km^2)

C = Runoff coefficient

Road Earthworks and Drainage Design Guideline of Japan Road Association recommends the values of Runoff Coefficient C as 0.8 and 0.4 for a design of cross drain and a design of side ditch, respectively for steep mountainous areas and in consideration for the importance of structures.

Table 26 Design Runoff in the Tributaries (with C=0.8)

S. N.	Tributary	Basin Area (km^2)	Peak Discharge (m^3/s)					
			2-year	3-year	5-year	10-year	25-year	50-year
1	Sadhi Khola	7.21	152	182	216	264	318	366
2	Dhamile Khola	28.35	596	714	849	1040	1252	1439
3	Gangate Khola	19.03	400	479	570	698	840	966
4	Bhote Khola	18.04	379	454	540	661	797	916
5	Khahare Khola	4.53	95	114	136	166	200	230
6	Chainpur Khola	18.16	382	457	544	666	802	922
7	Gadaule Khola	0.73	15	18	22	27	32	37
8	Dhobi Khola	21.70	456	546	650	796	958	1101
9	Bhalu Khola	0.58	12	15	17	21	26	29
10	Bhadaure Khola	3.66	77	92	110	134	162	186
11	Jagire Khola	1.23	26	31	37	45	54	62
12	Andheri Khola	19.45	409	490	582	713	859	987

Table 27 Design Runoff in the Tributaries (with C=0.4)

S. N.	Tributary	Basin Area (km^2)	Peak Discharge (m^3/s)					
			2-year	3-year	5-year	10-year	25-year	50-year
1	Sadhi Khola	7.21	76	91	108	132	159	183
2	Dhamile Khola	28.35	298	357	424	520	626	720
3	Gangate Khola	19.03	200	240	285	349	420	483
4	Bhote Khola	18.04	190	227	270	331	398	458
5	Khahare Khola	4.53	48	57	68	83	100	115
6	Chainpur Khola	18.16	191	229	272	333	401	461
7	Gadaule Khola	0.73	8	9	11	13	16	19
8	Dhobi Khola	21.70	228	273	325	398	479	551
9	Bhalu Khola	0.58	6	7	9	11	13	15
10	Bhadaure Khola	3.66	38	46	55	67	81	93
11	Jagire Khola	1.23	13	15	18	23	27	31
12	Andheri Khola	19.45	205	245	291	357	429	494

10. Capacity of Cross Drains Estimation

The flow capacities of cross drains or tributaries are checked using Manning's relation.

$$Q = \frac{AxR^{\frac{2}{3}}xS^{\frac{1}{2}}}{n} \qquad (8)$$

Where,

Q = Flow capacity (m^3/s)

A = Cross-section area (m^2)

R = Hydraulic radius (m)

S = Gradient

n = Manning's roughness

11. Determination of Manning's Friction Coefficient (n)

The Manning's friction coefficient (n) has been determined by analyzing the grain size of bed materials in rivers. The relations are based on the diameter of grains (dR).

If dR > 2 cm:

$$n = \frac{K_s^{\frac{1}{6}}}{7.66\sqrt{g}} = \frac{dR^{\frac{1}{6}}}{24} \qquad (9)$$

If dR ≤ 2 cm:

$$n = \frac{H_d^{\frac{1}{6}}}{\sqrt{g}.\phi} \quad (10)$$

$$\phi = 6.0 + 5.75.\log\left[\frac{H_d}{2.5xdR}\right] \quad (11)$$

Where,

n	=	Manning friction coefficient
Ks	=	Relative roughness
dR	=	Average grain size (m)
Hd	=	Depth of water in river (m)
g	=	Acceleration due to gravity (m/s^2)

The grain size of river bed materials and values of Manning's friction coefficient determined for Rosi Khola and the Sunkoshi River are presented (Table 28).

Table 28 Grain Size and Manning's Friction Coefficient (n)

River	Sample No.	Station	Sieve D60 (mm)	Grid Method (mm)	dR (mm)	n
Rosi	TP-1	31+100	30	30	32	0.023
	TP-2	30+600	30	43		
	TP-3	30+300	22	34		
	Average		28	36		
Sunkoshi	TP-4	27+800	28		14	0.023
	TP-5	27+200	10			
	TP-6	26+600	1.3			
	Average		14			

1. Hydraulic Model

The HEC-RAS, developed by Hydrologic Engineering Center, US Army Corps of Engineers, is a professional engineering software package for simulating flows and scour depths in rivers. The HEC-RAS is a fully dynamic, one-dimensional modelling tool for the detailed analysis, design and management of both simple and complex river systems. The unsteady flow simulation module of HEC-RAS solves the Saint Venant equations for conservation of continuity and momentum. Therefore, one-dimensional river flows and water levels were generated using fully dynamic flow routing procedure. The continuity equation of conservation of mass is expressed as:

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q \qquad (1)$$

The momemtum equation is:

$$\frac{\partial Q}{\partial t} + \frac{\partial (Q^2 / A)}{\partial x} + gA(\frac{\partial h}{dx} + S_f) = 0 \qquad (2)$$

The friction slope S_f is estimated by using Manning's equation as given:

$$S_f = \frac{n^2 \mid Q \mid Q}{A^2 R^{4/3}} \qquad (3)$$

Where,

Q	=	River flow (m^3/s)
A	=	Cross-sectional area of flow (m^2)
q	=	Lateral inflow per unit distance ($m^3/s/m$)
x	=	Longitudinal distance (m)
t	=	Time elapsed (s)
S_f	=	Friction slope
h	=	Water surface elevation (m)
R	=	Hydraulic radius (m)
n	=	Manning's friction coefficient
g	=	Acceleration due to gravity (m/s^2)

The governing equations (Eqs. 1 & 2) are solved with initial and boundary conditions to estimates one-dimensional river flows and water levels in the river system.

Manning's Friction Coefficient (n): The Manning's friction coefficients for tributaries and mainstream were determined based on the river bed conditions or materials prevailed. The Manning's friction coefficients used in the river flow analysis are as tabulated (Table 1).

Table 1 Manning's Friction Coefficients (n)

S. N.	River	n
1	Sadhi Khola	0.029
2	Dhamile Khola	0.034
3	Gangate Khola	0.042
4	Bhote Khola	0.038
5	Khahare Khola	0.036
6	Chainpur Khola	0.038
7	Gadaule Khola	0.028
8	Dhobi Khola	0.040
9	Bhalu Khola	0.040
10	Bhadaure Khola	0.035
11	Jagire Khola	0.035
12	Andheri Khola	0.035
13	Rosi Khola	0.023
14	Sunkoshi River	0.023

Cross-Section Data: The cross-sections data required for river flow simulations in tributaries were extracted from the elevation contours of topo-maps, whereas cross-sections of Rosi Khola and the Sunkoshi River were surveyed. For flow simulation in tributaries, cross-sections of two to three sections like: (1) U-U Section (River section U/S of highway crossing point), (2) H-H Section (River section at highway crossing point), and (3) D-D Section (River section D/S of highway crossing point) are used. For river flow simulations in the Sunkoshi River and Rosi Khola, surveyed cross-sections at certain intervals along the river reach were used.

2. Scenarios of Flow Simulations

River flow in 12 tributaries, Rosi Khola and the Sunkoshi River were generated considering various scenarios of simulation.

2. 1 Scenarios for Tributaries Flow Simulation

The scenarios of HWL estimation in tributaries are as presented.

Case-1: River flow profile is generated with 50-year peak discharge (Q_P) estimated by Rational Method as: $Q_P = C.I.A/3.6$.

Case-2: River flow profile is generated with estimated debris flow (Q_{DF}). The debris flow is estimated as: $Q_{DF} = 4.7\ Q_P$.

Case-3: River flow profile is generated with sand and gravel flow (Q_{SG}). The sand and gravel flow is estimated as: $Q_{SG} = Q_P(1+\beta)$ where $\beta = 0.3$.

2. 2 Scenario for the Sunkoshi River Flow Simulation

Flow profile of the Sunkoshi River is generated with single scenario of 50-year design discharge.

2. 3 Scenarios for Rosi Khola Flow Simulation

At first, HWLs in Rosi Khola were estimated with assuming that 50% of flood runoff goes to road alignment from the river bifurcation point (which lies near to STA 31+000

km) and remaining portion of runoff flows directly to the Sunkoshi River. Considering the 50-year design discharge of 1080 m^3/s in Rosi Khola as reported in the detailed design (D/D) report, the 50% of design discharge i.e. 540 m^3/s was used for flow simulation in the river course along the road alignment. However, the simulated HWL with 50% design discharge became 60 cm lower than the surveyed HWL at STA 31+000 km. Being HWLs in the river under estimated with the discharge as boundary condition, therefore, the surveyed HWLs were chosen to use as boundary condition in the simulation model.

With the surveyed HWLs as boundary condition, the amount of runoff that flows towards river course along the road alignment is estimated of 992 m^3/s which is about 74% of revised design discharge of Rosi Khola i.e. 1344 m^3/s. The design discharge of Rosi Khola was revised while conducting Basic Design Study of Sindhuli Road (Section-IV).

Finally, with taking the surveyed HWLs as boundary condition, the flow profile of Rosi Khola is generated considering two-scenarios as presented.

Case-1: Flow simulation with existing river condition.

Case-2: Flow simulation considering river condition after road construction.

3. River Flow Simulation

River flows are simulated under different scenarios in 12 tributaries, Sunkoshi River and Rosi Khola. The simulated water surface profile and HWLs with river cross-sections are presented for every river and tributary. Location maps of cross-sections used for HWLs estimation are also presented.

Summary Tables of HWLs in Rivers:

River	Scenarios	Q (m^3/s)	Section	HWL (m)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Bhalu Khola	Case-1 ($Q_{Rational}$)	29.00	U-U	474.78	6.27	6.72	4.62	0.78
			H-H	463.65	5.75	8.25	5.05	0.65
	Case-2 (4.7 $Q_{Rational}$)	136.00	U-U	475.84	10.59	8.91	12.86	1.84
			H-H	464.66	9.60	9.83	14.20	1.66
	Case-3 (1.3 $Q_{Rational}$)	38.00	U-U	474.92	6.75	7.01	5.58	0.92
			H-H	463.76	6.34	8.40	5.94	0.76

River	Scenarios	Q (m^3/s)	Section	HWL (m)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Dhobi Khola	Case-1 ($Q_{Rational}$)	1101.00	U-U	484.48	5.34	161.58	206.37	2.48
			H-H	481.46	3.23	186.79	340.08	3.97
			D-D	477.73	9.77	93.71	112.64	2.73
	Case-2 (4.7 $Q_{Rational}$)	5175.00	U-U	486.61	9.00	177.38	575.21	4.61
			H-H	483.26	7.59	190.00	682.02	5.77
			D-D	479.24	12.44	246.66	415.72	4.24
	Case-3 (1.3 $Q_{Rational}$)	1431.00	U-U	484.73	5.78	166.93	247.72	2.73
			H-H	481.88	3.40	188.17	421.15	4.39
			D-D	478.19	8.05	204.97	177.65	3.19

River	Scenarios	Q (m^3/s)	Section	HWL (m)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Gadaule Khola	Case-1 ($Q_{Rational}$)	37.00	U-U	512.96	7.89	6.86	4.69	0.99
			H-H	509.86	7.61	7.48	4.86	1.28
			D-D	505.48	6.91	8.85	5.35	1.03
	Case-2 (4.7 $Q_{Rational}$)	174.00	U-U	513.76	8.98	20.31	19.36	1.79
			H-H	510.85	12.28	10.98	14.16	2.27
			D-D	506.19	9.89	20.01	17.59	1.74
	Case-3 (1.3 $Q_{Rational}$)	48.00	U-U	513.12	6.90	17.76	6.97	1.15
			H-H	510.00	8.08	8.24	5.95	1.42
			D-D	505.68	6.19	16.95	7.72	1.23

River	Scenarios	Q (m^3/s)	Section	HWL (m)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Chainpur Khola	Case-1 ($Q_{Rational}$)	922.00	U-U	497.12	3.54	166.11	260.61	4.12
			H-H	492.50	9.42	49.01	97.82	3.16
			D-D	490.32	4.99	139.38	184.81	2.32
	Case-2 (4.7 $Q_{Rational}$)	4333.00	U-U	501.35	4.34	186.12	1002.23	8.35
			H-H	495.25	18.42	50.00	235.22	5.91
			D-D	492.36	8.77	162.35	493.70	4.36
	Case-3 (1.3 $Q_{Rational}$)	1199.00	U-U	497.60	3.52	167.21	340.30	4.60
			H-H	492.82	10.51	50.00	113.96	3.48
			D-D	490.55	5.51	141.38	217.28	2.55

River	Scenarios	Q (m^3/s)	Section	HWL (m)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Khahare Khola	Case-1 ($Q_{Rational}$)	230.00	U-U	494.16	7.44	30.62	30.93	1.16
			H-H	485.41	4.99	84.91	46.03	0.87
	Case-2 (4.7 $Q_{Rational}$)	1081.00	U-U	495.63	12.19	46.35	88.71	2.63
			H-H	486.26	8.53	100.00	126.67	1.72
	Case-3 (1.3 $Q_{Rational}$)	299.00	U-U	494.35	8.08	33.01	37.00	1.35
			H-H	485.52	5.45	86.78	54.87	0.98

River	Scenarios	Q (m^3/s)	Section	HWL (m)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Bhote Khola	Case-1 ($Q_{Rational}$)	916.00	U1-U1	508.44	7.75	52.41	118.12	2.78
			U2-U2	507.12	6.01	75.65	152.43	2.92
			U3-U3	506.48	6.54	58.06	139.98	3.51
			U4-U4	505.46	8.39	45.65	109.13	3.10
			H-H	503.17	8.76	40.00	104.48	3.68
			D1-D1	501.97	7.74	50.00	118.21	3.97
			D2-D2	500.23	5.08	81.19	180.29	3.06
			D3-D3	497.11	6.68	151.08	137.02	2.47
	Case-3 (1.3 $Q_{Rational}$)	1191.00	U1-U1	508.82	8.62	53.10	138.19	3.16
			U2-U2	507.53	6.49	76.31	183.35	3.33
			U3-U3	506.92	7.21	58.38	165.23	3.95
			U4-U4	505.91	9.15	47.51	130.10	3.55
			H-H	503.61	9.75	40.00	122.10	4.12
			D1-D1	502.38	8.58	50.00	138.79	4.38
			D2-D2	500.49	5.89	81.32	202.10	3.32
			D3-D3	497.27	7.37	151.20	161.44	2.63

River	Scenarios	Q (m^3/s)	Section	HWL (m)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Gangate Khola	Case-1 ($Q_{Rational}$)	966.00	U-U	536.88	5.13	116.62	188.42	2.88
			H-H	534.78	7.68	57.90	125.79	2.78
			D-D	532.38	6.05	99.71	159.67	2.38
	Case-2 (4.7 $Q_{Rational}$)	4540.00	U-U	540.08	7.69	133.00	590.03	6.08
			H-H	537.75	13.30	80.00	341.31	5.75
			D-D	534.99	7.97	196.93	569.81	4.99
	Case-3 (1.3 $Q_{Rational}$)	1256.00	U-U	537.25	5.42	120.03	231.86	3.25
			H-H	535.15	8.51	59.79	147.52	3.15
			D-D	532.73	6.27	133.88	200.21	2.73

River	Scenarios	Q (m^3/s)	Section	HWL (m)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Dhamile Khola	Case-1 ($Q_{Rational}$)	1439.00	U-U	525.49	9.54	69.37	150.87	3.37
			H-H	522.76	7.94	66.41	181.12	4.25
			D-D	521.34	8.68	77.23	165.76	4.08
	Case-2 (4.7 $Q_{Rational}$)	6763.00	U-U	529.34	13.46	117.93	502.58	7.22
			H-H	526.09	16.50	70.00	409.84	7.58
			D-D	524.31	11.39	200.34	593.90	7.05
	Case-3 (1.3 $Q_{Rational}$)	1871.00	U-U	525.94	10.23	73.73	182.83	3.82
			H-H	523.17	8.98	66.61	208.34	4.66
			D-D	521.71	9.62	78.02	194.46	4.45

River	Scenarios	Q (m^3/s)	Section	HWL (m)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Sadhi Khola	Case-1 ($Q_{Rational}$)	366.00	U-U	533.23	6.90	63.13	53.01	1.23
			H-H	528.41	7.09	56.01	51.63	1.41
			D-D	523.60	7.74	46.94	47.27	1.60
	Case-2 (4.7 $Q_{Rational}$)	1720.00	U-U	534.54	12.57	65.20	136.87	2.54
			H-H	529.85	12.61	61.48	136.37	2.85
			D-D	525.11	13.55	55.22	126.96	3.11
	Case-3 (1.3 $Q_{Rational}$)	476.00	U-U	533.37	7.70	63.35	61.76	1.37
			H-H	528.58	7.77	56.59	61.20	1.58
			D-D	523.79	8.39	49.46	56.67	1.79

River	Scenarios	Q (m^3/s)	Section	HWL (m)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Sunkoshi River	Case-1 (Q_{Design})	4749.00	28+500	523.18	5.38	357.00	882.76	7.20
			28+000	521.64	5.09	431.21	933.72	5.46
			27+500	519.88	4.26	687.63	1115.46	5.84
			27+000	519.31	3.06	768.15	1551.75	4.94
			26+500	516.94	5.00	414.14	949.90	7.85

River	Scenarios	Q (m^3/s)	Section	HWL (m)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Rosi Khola	Case-1 (Existing Condition)	992.00	31+000	546.40	3.65	108.29	272.15	4.17
			30+800	544.85	4.10	291.29	241.92	2.81
			30+600	542.18	4.10	337.18	241.72	2.15
			30+400	540.05	4.14	246.59	239.27	2.05
			30+200	537.73	4.81	203.16	206.35	2.00
			30+000	536.40	2.24	295.70	442.67	3.41
	Case-2 (After Road Construction)	982.00	31+000	546.40	3.61	108.29	272.15	4.17
			30+800	544.85	4.13	282.61	237.88	2.81
			30+600	542.24	4.06	360.39	241.90	2.21
			30+400	540.06	4.33	236.56	226.78	2.06
			30+200	537.74	4.82	185.05	203.60	2.01
			30+000	536.50	2.30	274.40	427.25	3.51

River	Scenarios	Q (m^3/s)	Section	HWL (m)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Bhadaure Khola	Case-1 ($Q_{Rational}$)	186.00	U-U	494.51	9.06	32.94	20.53	0.74
			H-H	489.09	5.29	39.51	35.13	0.98
			D-D	487.22	8.29	27.05	22.43	1.60
	Case-2 (4.7 $Q_{Rational}$)	874.00	U-U	495.55	15.69	34.95	55.72	1.78
			H-H	490.39	9.45	47.51	92.46	2.28
			D-D	488.46	13.01	42.09	67.16	2.84
	Case-3 (1.3 $Q_{Rational}$)	242.00	U-U	494.63	9.90	33.17	24.42	0.86
			H-H	489.26	5.77	40.82	41.92	1.15
			D-D	487.40	8.81	29.94	27.43	1.78

River	Scenarios	Q (m^3/s)	Section	HWL (m)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Jagire Khola	Case-1 ($Q_{Rational}$)	62.00	U-U	508.57	6.12	20.66	10.14	0.57
			H-H	501.90	3.25	25.58	19.08	1.40
			D-D	500.01	4.22	45.00	14.67	0.49
	Case-2 (4.7 $Q_{Rational}$)	291.00	U-U	509.39	9.69	27.40	30.06	1.39
			H-H	502.83	6.63	28.35	43.92	2.33
			D-D	500.67	6.26	51.09	46.53	1.15
	Case-3 (1.3 $Q_{Rational}$)	81.00	U-U	508.67	6.64	21.63	12.14	0.67
			H-H	502.02	3.62	25.66	22.25	1.52
			D-D	500.10	4.28	45.84	18.85	0.58

River	Scenarios	Q (m^3/s)	Section	HWL (m)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Andheri Khola (Existing Condition)	Case-1 ($Q_{Rational}$)	987.00	U1-U1	508.73	4.80	154.72	205.43	2.94
			U2-U2	505.51	5.92	110.82	166.81	2.66
			H-H	502.22	4.81	159.15	205.22	2.46
			D1-D1	498.30	5.23	193.15	188.58	1.69
			D2-D2	494.16	4.57	201.24	215.53	1.80
Andheri Khola (After Road Construction)	Case-1 ($Q_{Rational}$)	987.00	U1-U1	508.89	4.69	146.88	210.62	3.10
			U2-U2	505.69	6.18	100.86	159.72	2.84
			H-H	502.24	4.99	145.94	197.71	2.48
			D1-D1	498.30	5.23	193.15	188.58	1.69
			D2-D2	494.16	4.57	201.24	215.53	1.80
	Case-2 (4.7 $Q_{Rational}$)	4639.00	U1-U1	511.32	8.08	150.29	573.95	5.53
			U2-U2	508.10	11.23	106.22	413.04	5.25
			H-H	504.09	9.38	172.54	494.65	4.33
			D1-D1	499.87	9.06	215.35	511.64	3.26
			D2-D2	495.82	8.19	217.26	566.09	3.46
	Case-3 (1.3 $Q_{Rational}$)	1283.00	U1-U1	509.16	5.11	148.38	250.94	3.37
			U2-U2	505.98	6.76	104.73	189.71	3.13
			H-H	502.48	5.50	150.56	233.24	2.72
			D1-D1	498.48	5.73	196.58	223.93	1.87
			D2-D2	494.36	5.02	202.48	255.52	2.00

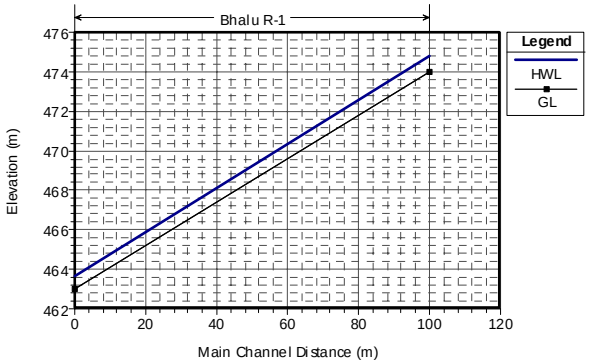
3.1 BHALU KHOLA

Case-1: Flow Simulation with Q_P (Rational Method)

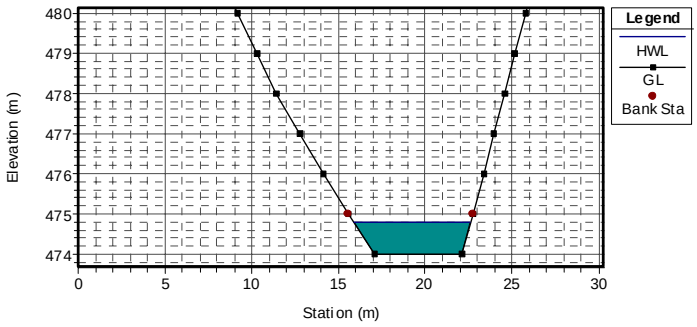
Hydraulic Properties of Flow (Bhalu Khola)

River	Section	Dist. To H-H (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Bhalu Khola	U-U	100.00	474.00	11.00	474.78	29.00	6.27	6.72	4.62	0.78
	H-H	0.00	463.00		463.65	29.00	5.75	8.25	5.05	0.65

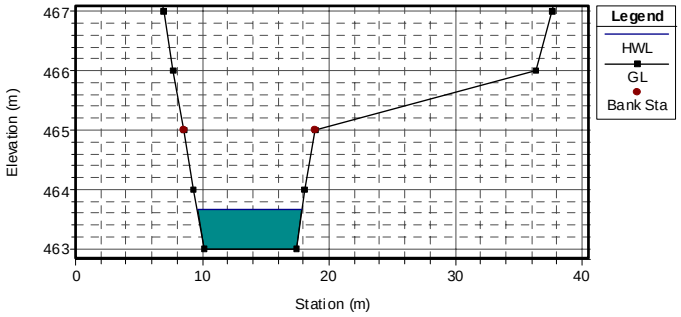
U-U: River section U/S of HW H-H: River section at HW D-D: River section D/S of HW HW: Highway



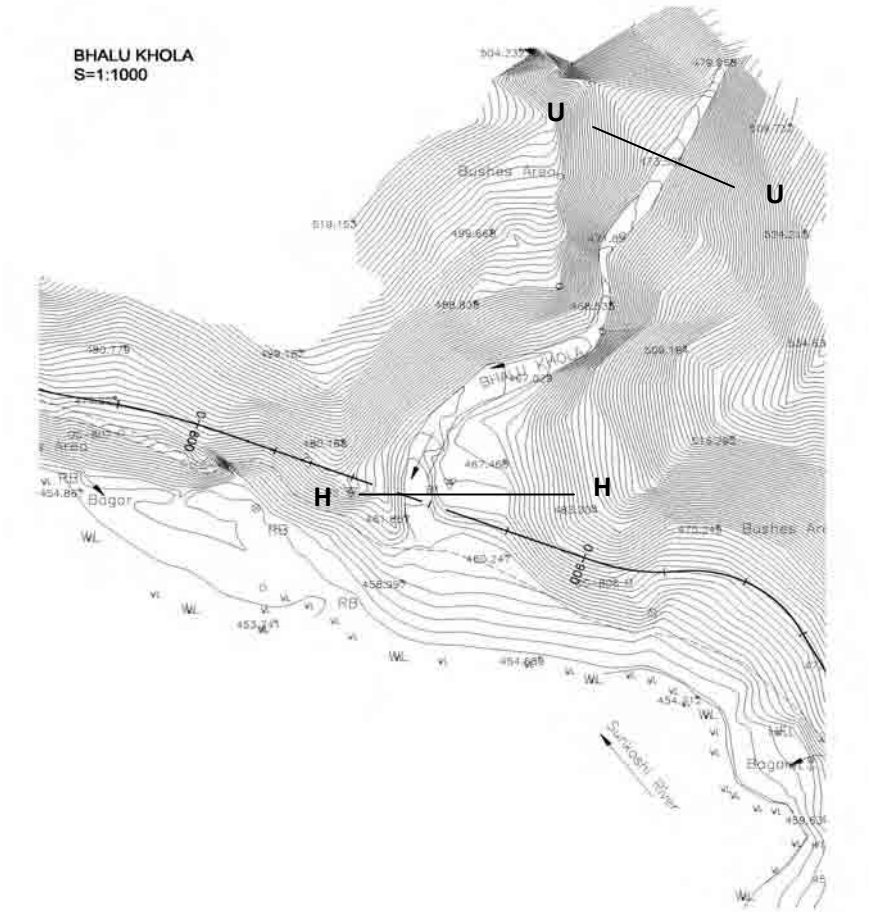
Water Surface Profile (Bhalu Khola)



HWL at U-U Section (Bhalu Khola)



HWL at H-H Section (Bhalu Khola)



Locations of Cross-sections Used (Bhalu Khola)

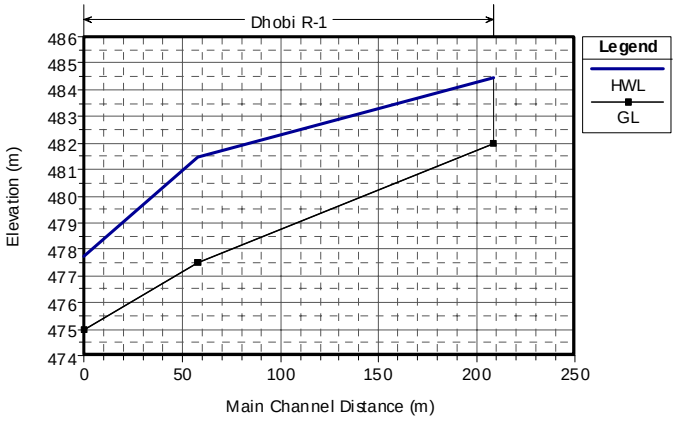
3.2 DHOBI / NIGULE KHOLA

Case-1: Flow Simulation with Q_P (Rational Method)

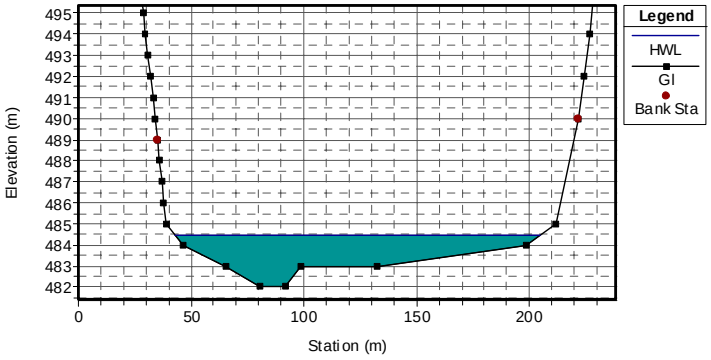
Hydraulic Properties of Flow (Dhobi Khola)

River	Section	Dist. To H-H (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Dhobi Khola	U-U	150.00	482.00	3.37	484.48	1101.00	5.34	161.58	206.37	2.48
	H-H	0.00	477.49		481.46	1101.00	3.23	186.79	340.08	3.97
	D-D	58.00	475.00		477.73	1101.00	9.77	93.71	112.64	2.73

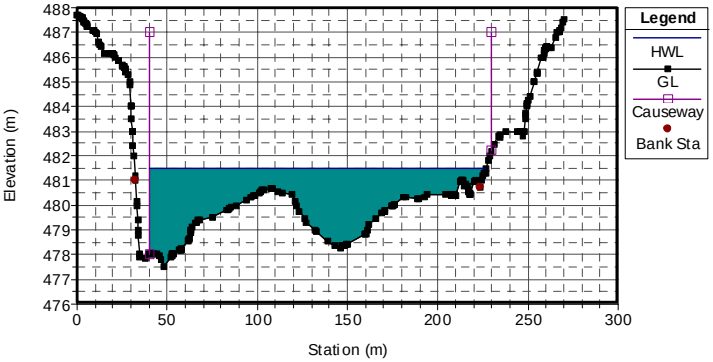
U-U: River section U/S of HW H-H: River section at HW D-D: River section D/S of HW HW: Highway



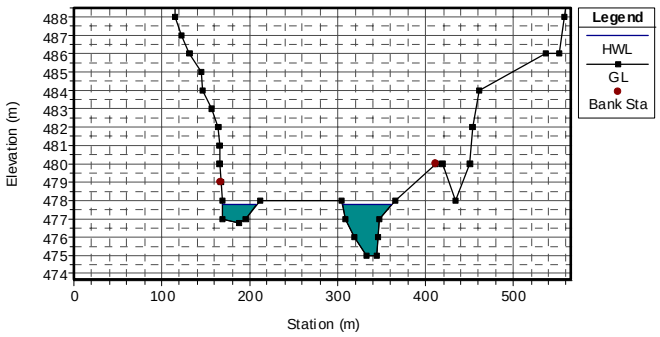
Water Surface Profile (Dhobi Khola)



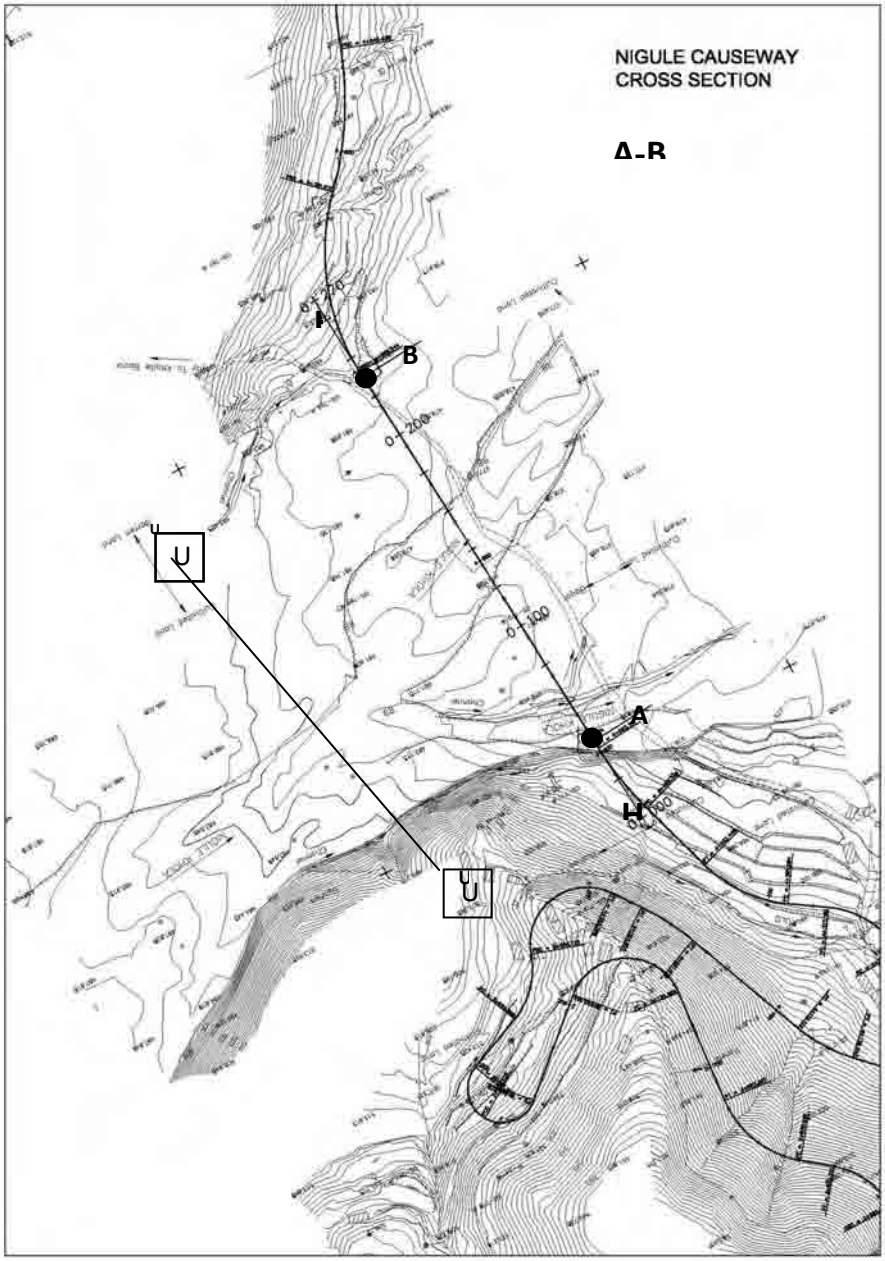
HWL at U-U Section (Dhobi Khola)



HWL at H-H Section (Dhobi Khola)



HWL at D-D Section (Dhobi Khola)



Locations of Cross-sections Used (Dhobi/Nigule Khola)

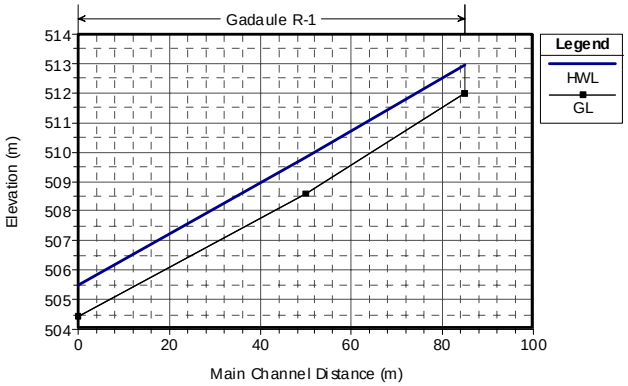
3.3 GADAULE KHOLA

Case-1: Flow Simulation with Q_P (Rational Method)

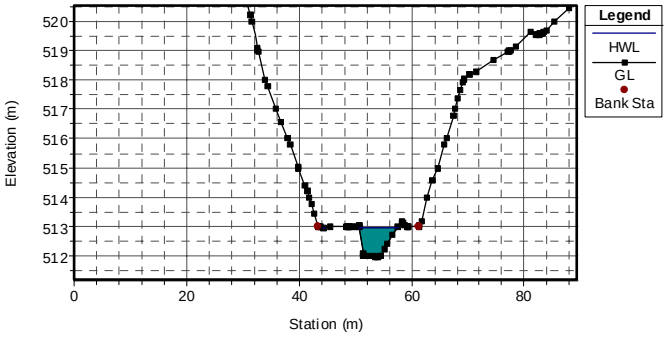
Hydraulic Properties of Flow (Gadaule Khola)

River	Section	Dist. To H-H (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Gadaule Khola	U-U	35.00	511.97	8.85	512.96	37.00	7.89	6.86	4.69	0.99
	H-H	0.00	508.58		509.86	37.00	7.61	7.48	4.86	1.28
	D-D	50.00	504.45		505.48	37.00	6.91	8.85	5.35	1.03

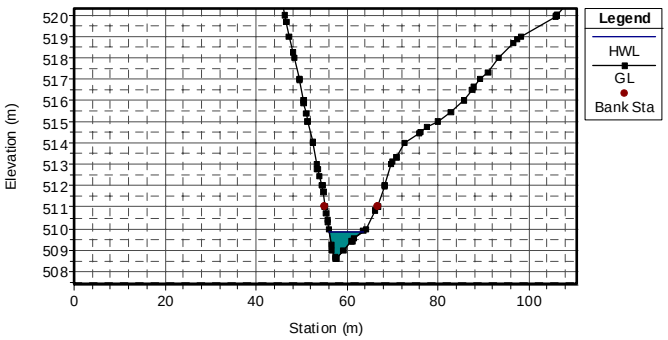
U-U: River section U/S of HW H-H: River section at HW D-D: River section D/S of HW HW: Highway



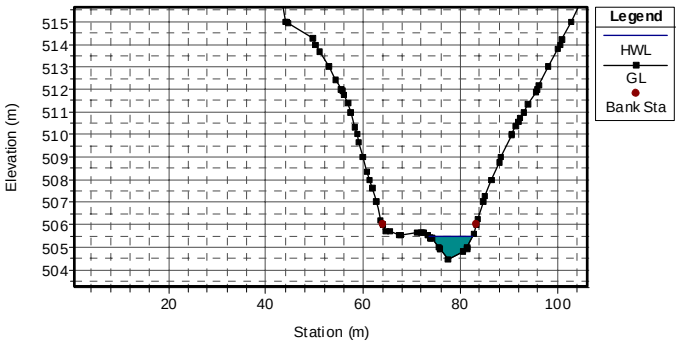
Water Surface Profile (Gadaule Khola)



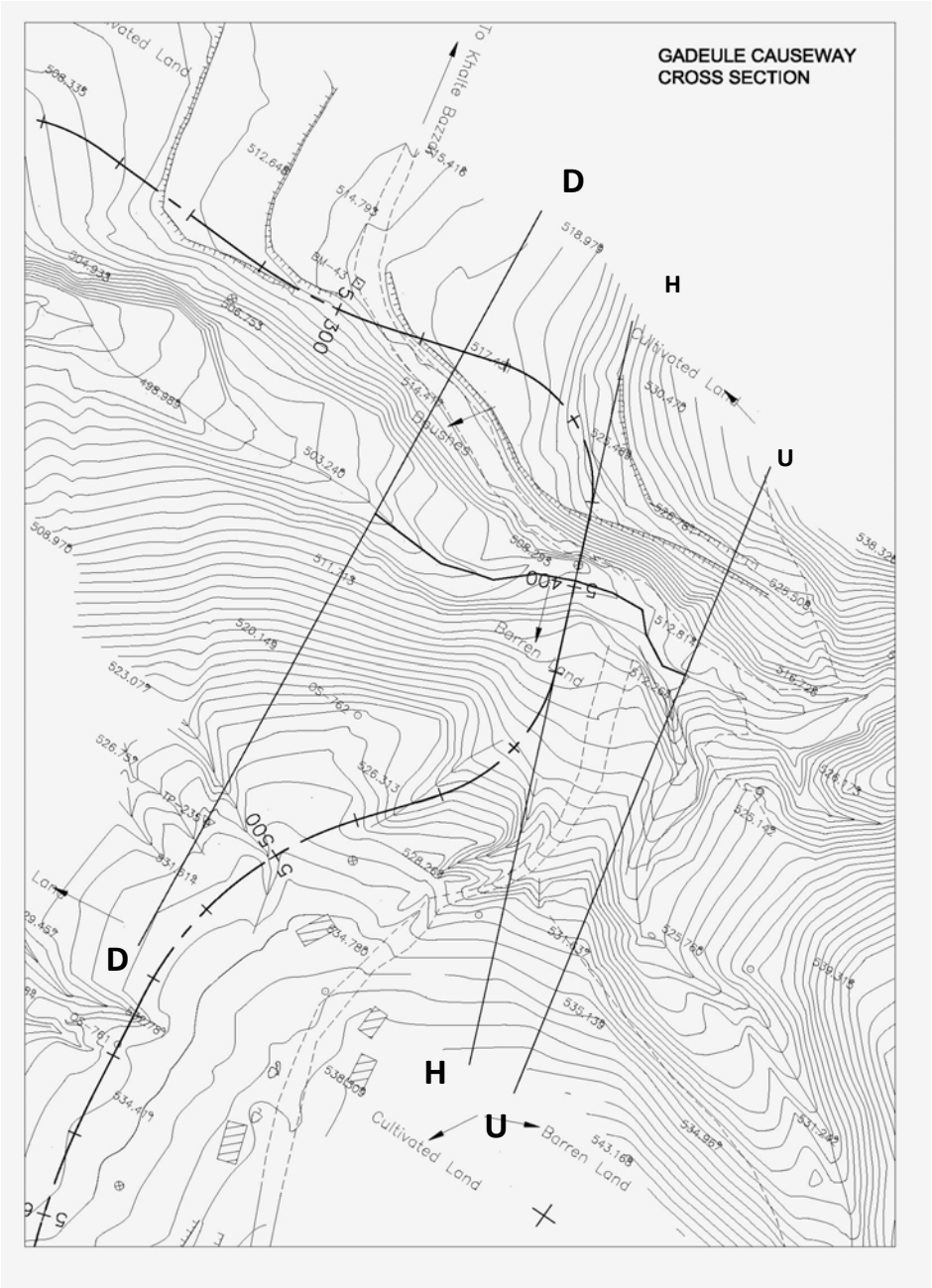
HWL at U-U Section (Gadaule Khola)



HWL at H-H Section (Gadaule Khola)



HWL at D-D Section (Gadaule Khola)



Locations of Cross-Sections Used (Gadaule Khola)

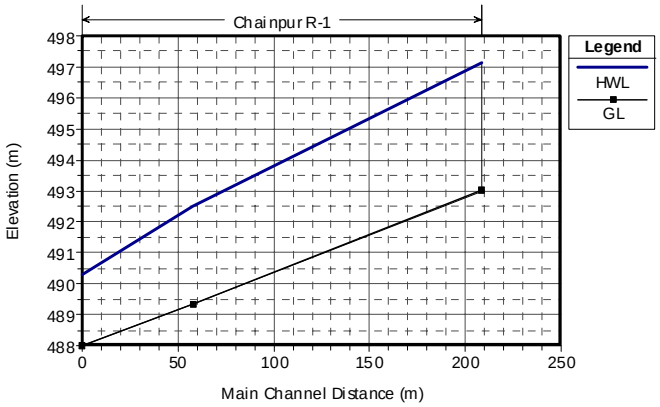
3.4 CHAINPUR KHOLA

Case-1: Flow Simulation with Q_P (Rational Method)

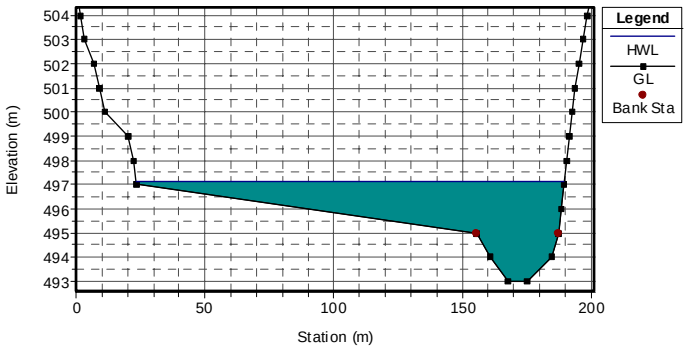
Hydraulic Properties of Flow (Chainpur Khola)

River	Section	Dist. To H-H (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Chainpur Khola	U-U	150.00	493.00	2.40	497.12	922.00	3.54	166.11	260.61	4.12
	H-H	0.00	489.34		492.50	922.00	9.42	49.01	97.82	3.16
	D-D	58.00	488.00		490.32	922.00	4.99	139.38	184.81	2.32

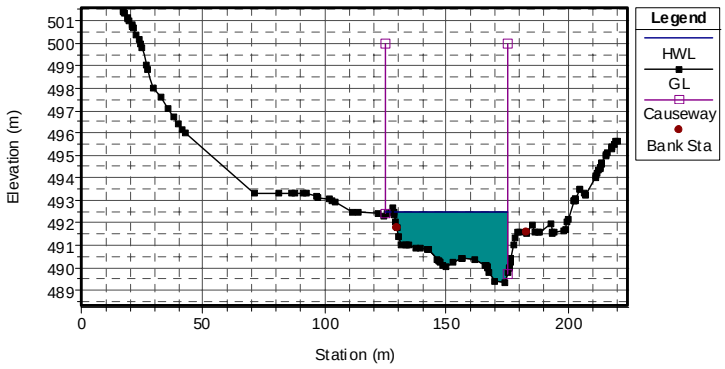
U-U: River section U/S of HW H-H: River section at HW D-D: River section D/S of HW HW: Highway



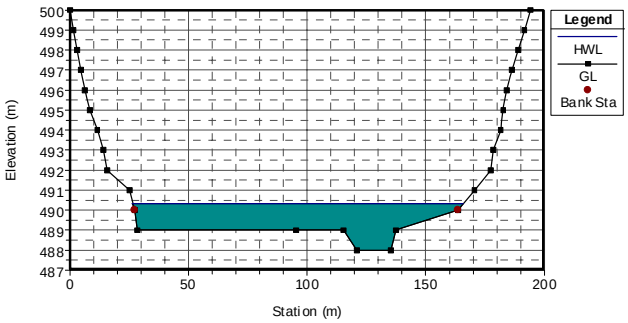
Water Surface Profile (Chainpur Khola)



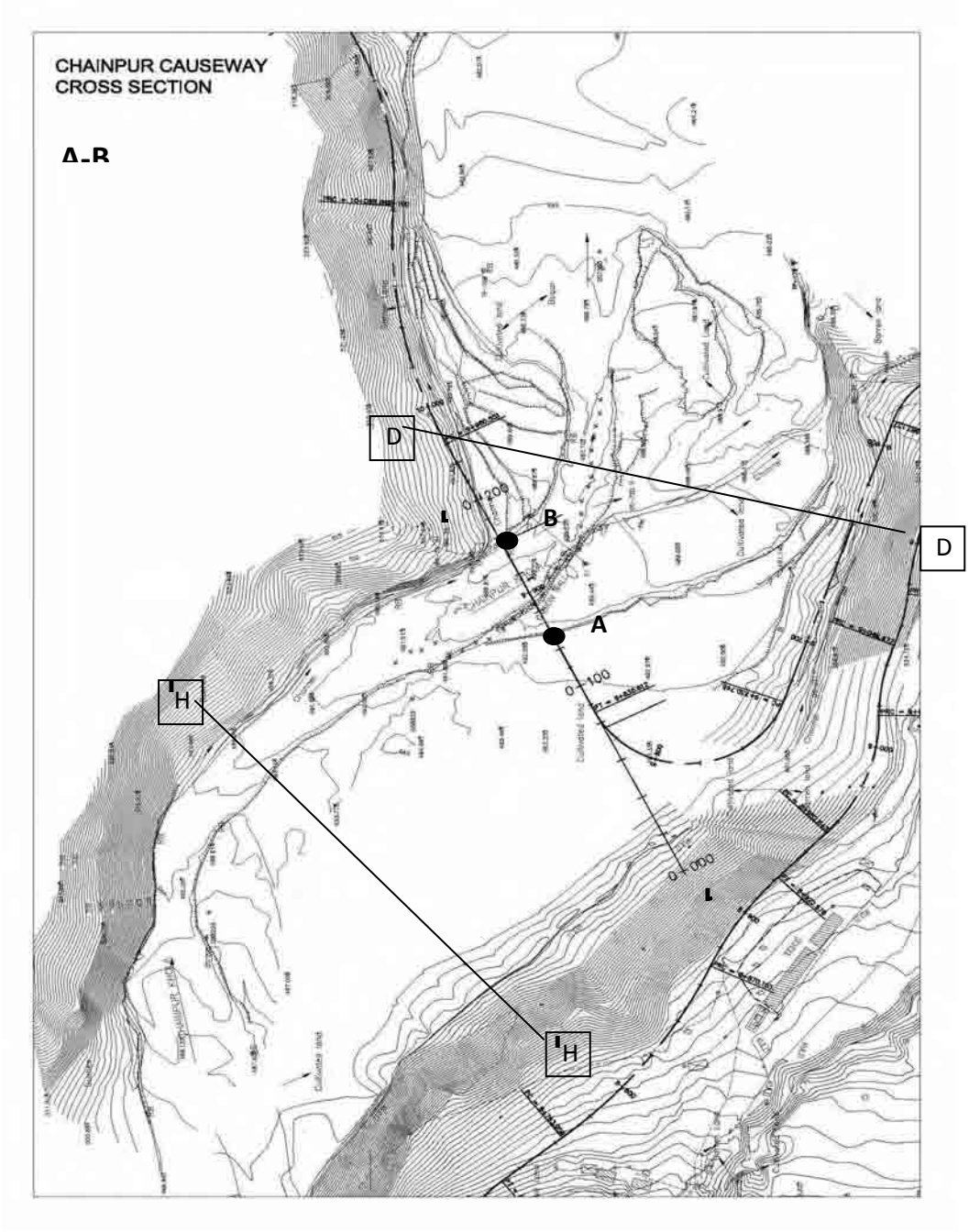
HWL at U-U Section (Chainpur Khola)



WL at H-H Section (Chainpur Khola)



HWL at D-D Section (Chainpur Khola)



Locations of Cross-Section Used (Chainpur Khola)

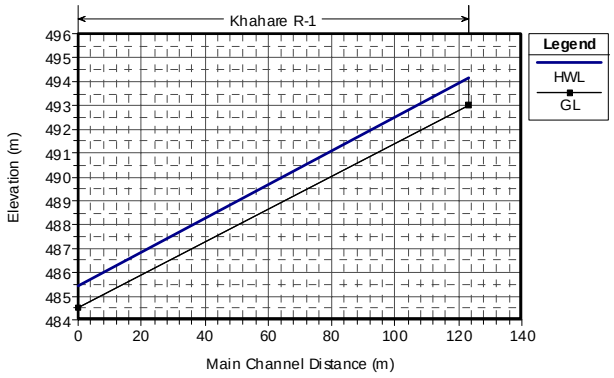
3.5 KHAHARE KHOLA

Case-1: Flow Simulation with Q_P (Rational Method)

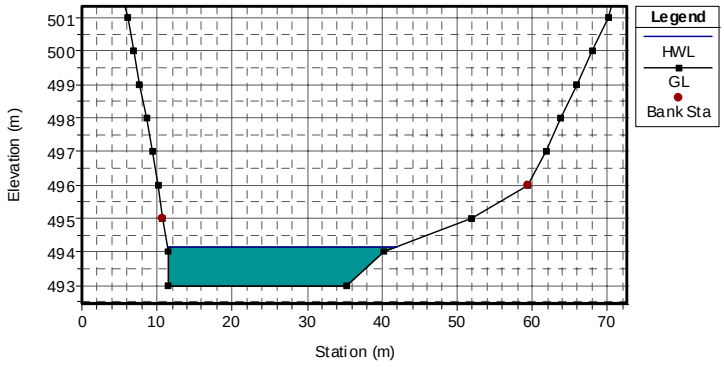
Hydraulic Properties of Flow (Khahare Khola)

River	Section	Dist. To H-H (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Khahare Khola	U-U	123.00	493.00	6.88	494.16	230.00	7.44	30.62	30.93	1.16
	H-H	0.00	484.54		485.41	230.00	4.99	84.91	46.03	0.87

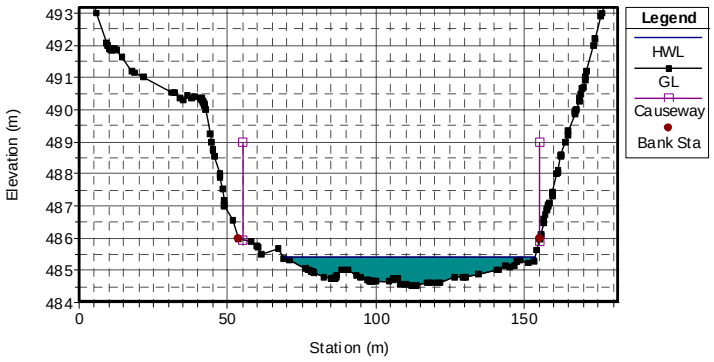
U-U: River section U/S of HW H-H: River section at HW D-D: River section D/S of HW HW: Highway



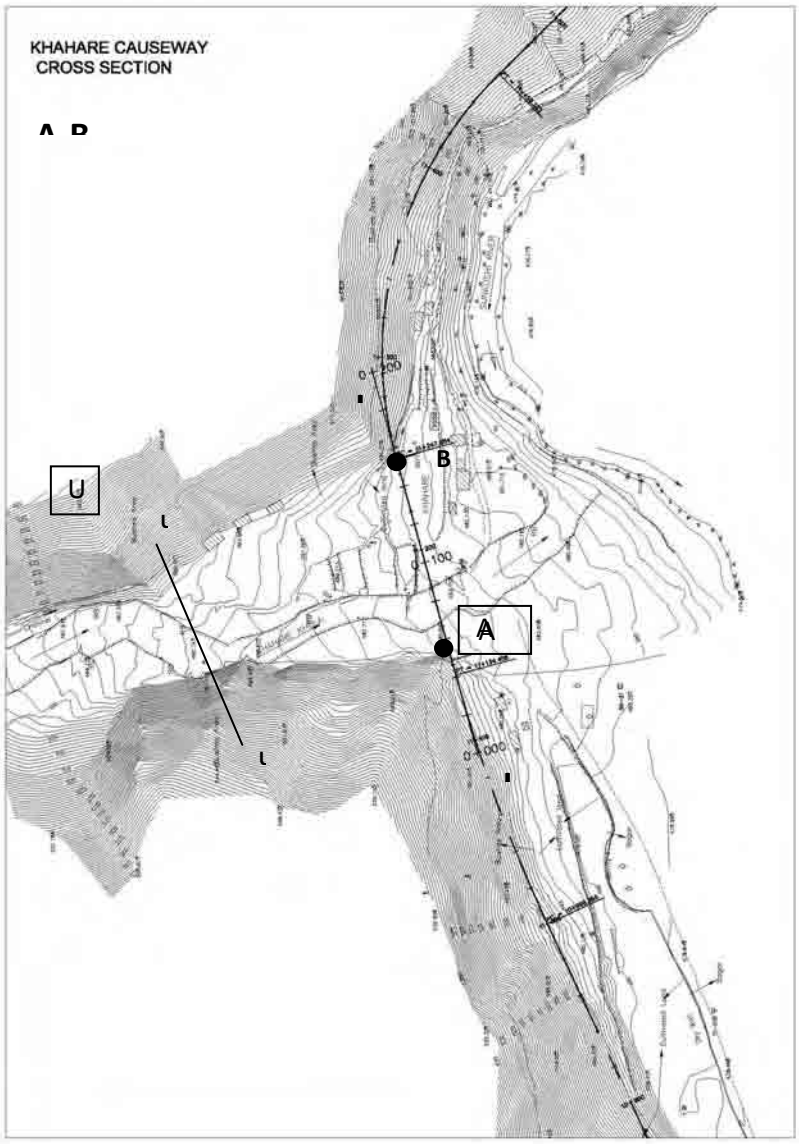
Water Surface Profile (Khahare Khola)



HWL at U-U Section (Khahare Khola)



HWL at H-H Section (Khahare Khola)



Locations of Cross-Sections Used (Khahare Khola)

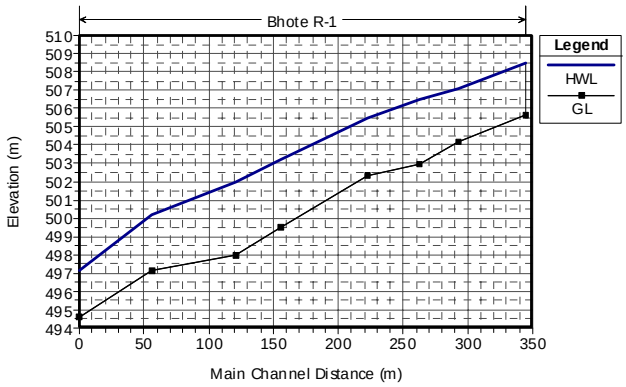
3.6 BHOTE KHOLA

Case-1: Flow Simulation with Q_P (Rational Method)

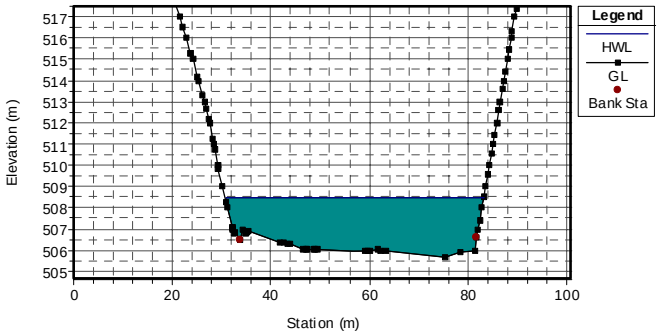
Hydraulic Properties of Flow (Bhote Khola)

River	Section	Dist. To H-H (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Bhote Khola	U1-U1	189.00	505.66	3.19	508.44	916.00	7.75	52.41	118.12	2.78
	U2-U2	137.00	504.20		507.12	916.00	6.01	75.65	152.43	2.92
	U3-U3	106.00	502.97		506.48	916.00	6.54	58.06	139.98	3.51
	U4-U4	67.00	502.36		505.46	916.00	8.39	45.65	109.13	3.10
	H-H	0.00	499.49		503.17	916.00	8.76	40.00	104.48	3.68
	D1-D1	35.00	498.00		501.97	916.00	7.74	50.00	118.21	3.97
	D2-D2	100.00	497.17		500.23	916.00	5.08	81.19	180.29	3.06
	D3-D3	156.00	494.64		497.11	916.00	6.68	151.08	137.02	2.47

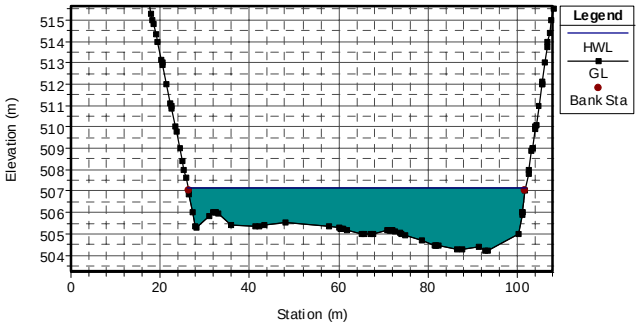
U-U: River section U/S of HW H-H: River section at HW D-D: River section D/S of HW HW: Highway



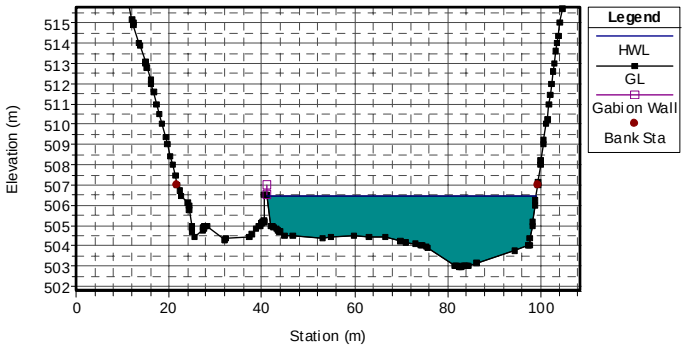
Water Surface Profile (Bhote Khola)



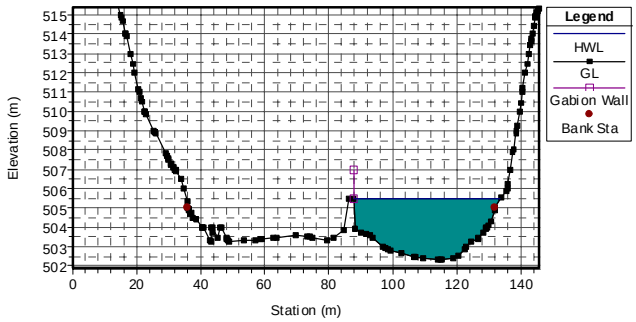
HWL at STA-1 (U1-U1 Section of Bhote Khola)



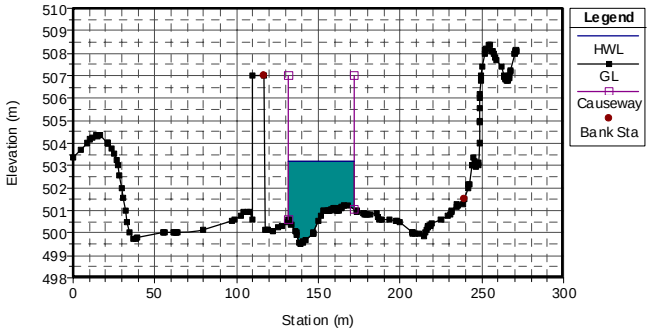
HWL at STA-2 (U2-U2 Section of Bhote Khola)



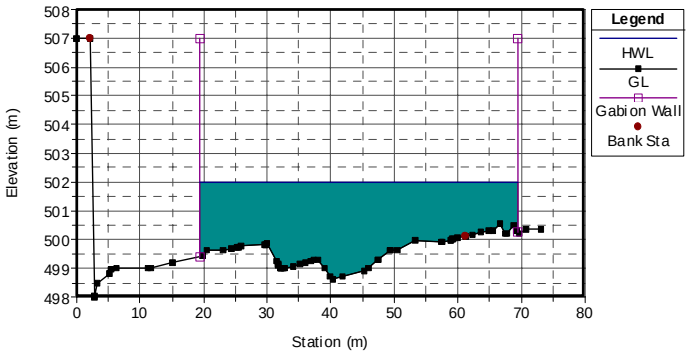
HWL at STA-3 (U3-U3 Section of Bhote Khola)



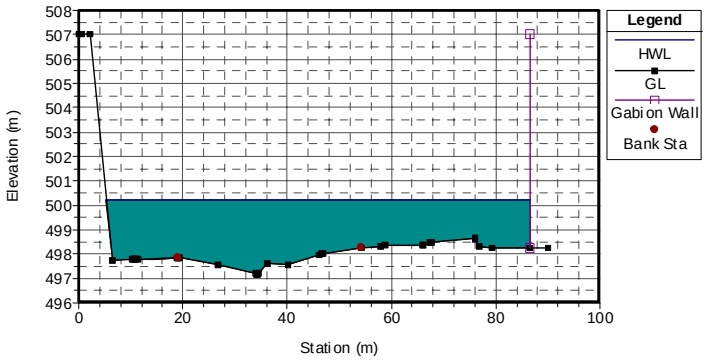
HWL at STA-4 (U4-U4 Section of Bhote Khola)



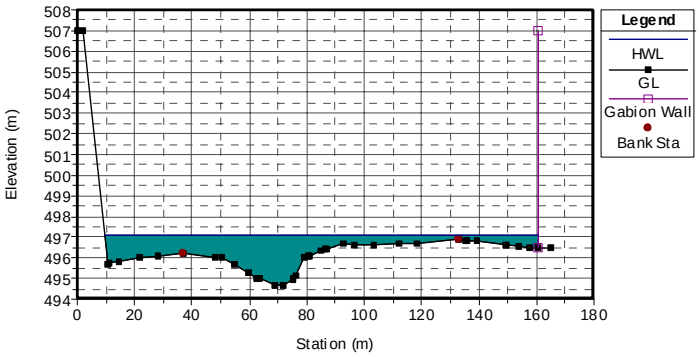
HWL at STA-5 (H-H Section of Bhote Khola)



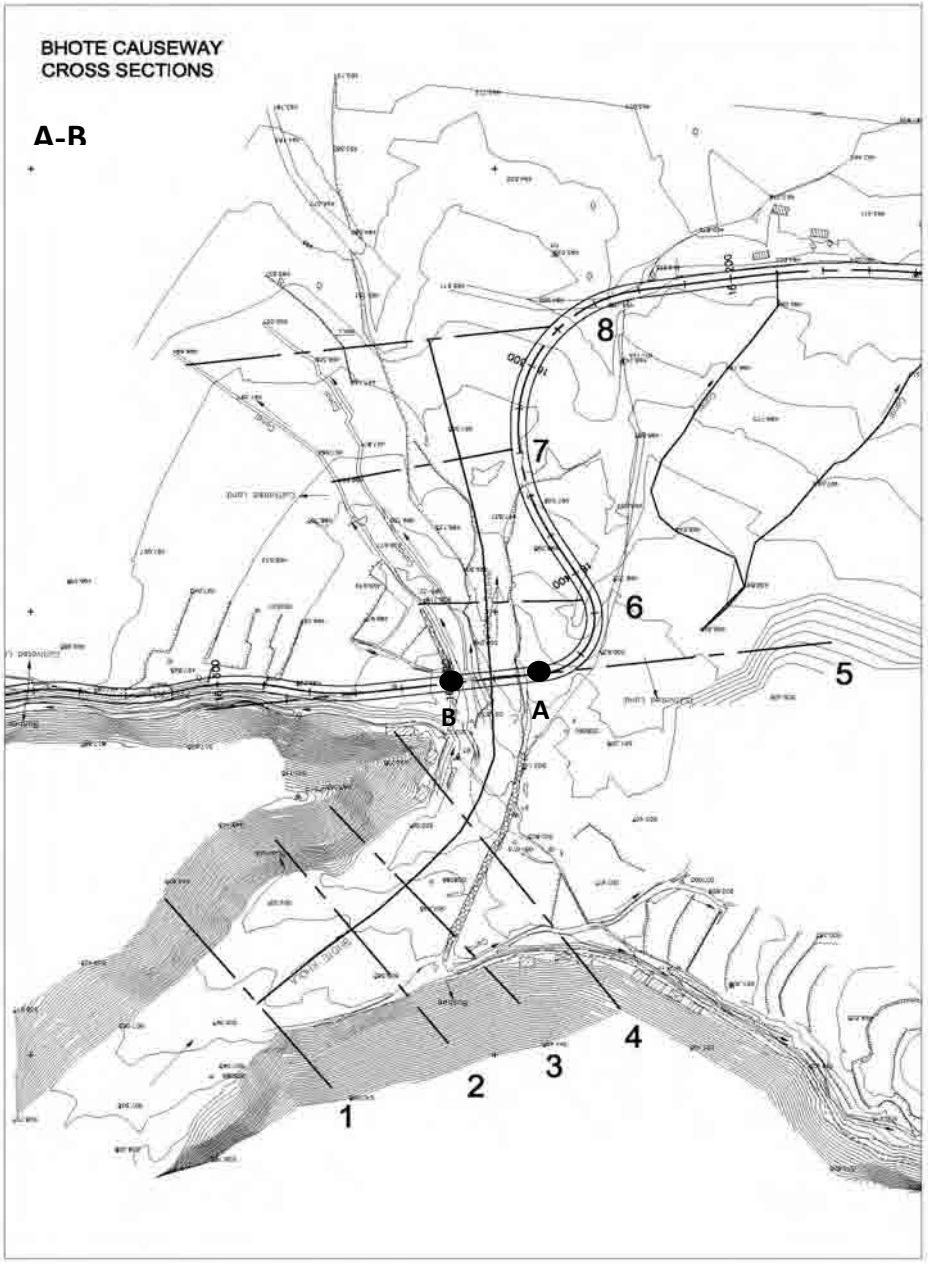
HWL at STA-6 (D1-D1 Section of Bhote Khola)



HWL at STA-7 (D2-D2 Section of Bhote Khola)



HWL at STA-8 (D3-D3 Section of Bhote Khola)



Locations of Cross-Sections Used (Bhote Khola)

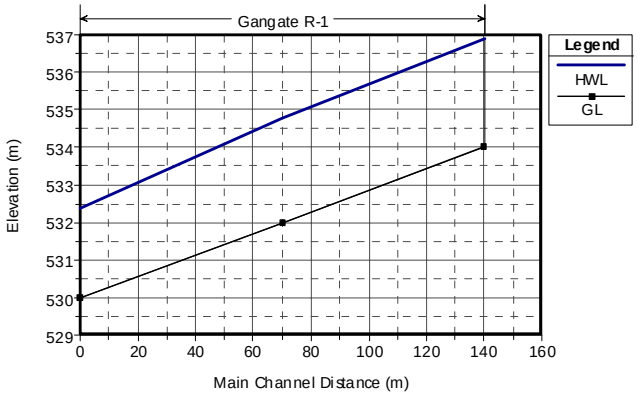
3.7 GANGATE KHOLA

Case-1: Flow Simulation with Q_P (Rational Method)

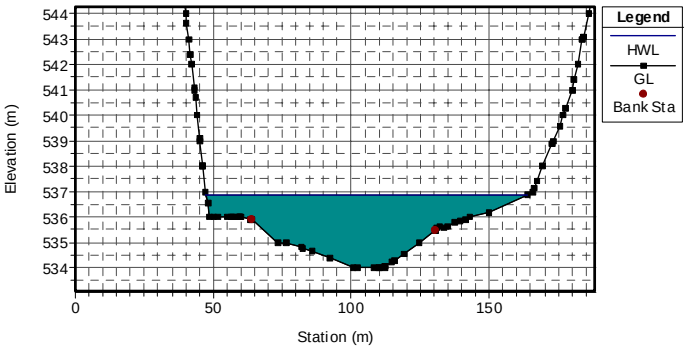
Hydraulic Properties of Flow (Gangate Khola)

River	Section	Dist. To H-H (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Gangate Khola	U-U	70.00	534.00	2.86	536.88	966.00	5.13	116.62	188.42	2.88
	H-H	0.00	532.00		534.78	966.00	7.68	57.90	125.79	2.78
	D-D	70.00	530.00		532.38	966.00	6.05	99.71	159.67	2.38

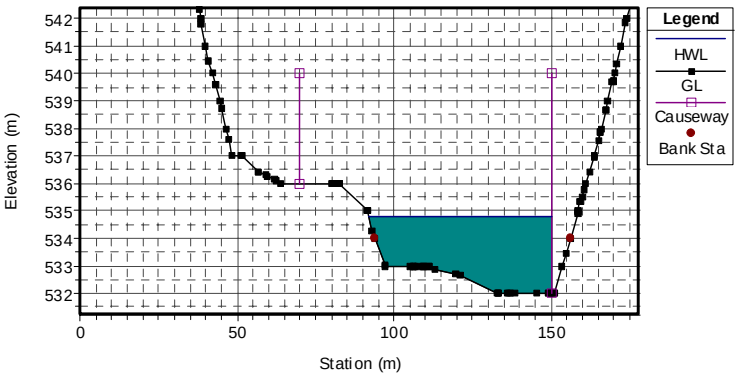
U-U: River section U/S of HW H-H: River section at HW D-D: River section D/S of HW HW: Highway



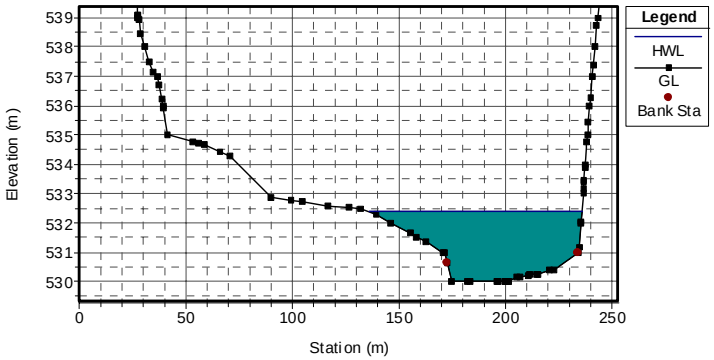
Water Surface Profile (Gangate Khola)



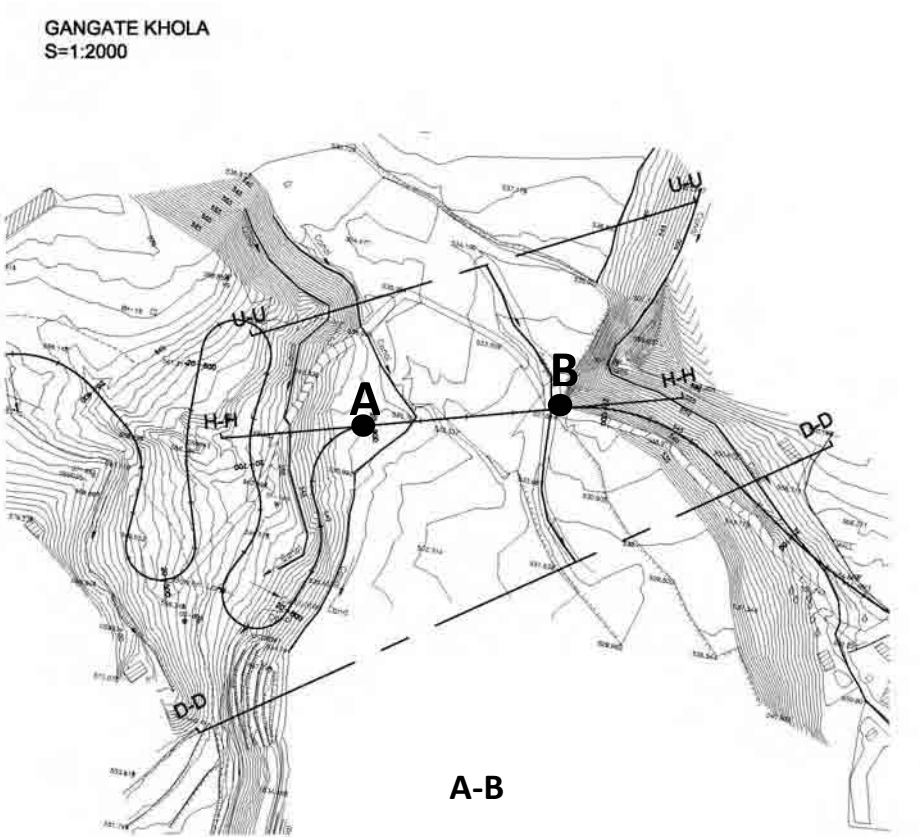
HWL at U-U Section (Gangate Khola)



HWL at H-H Section (Gangate Khola)



HWL at D-D Section (Gangate Khola)



Locations of Cross-Sections Used (Gangate Khola)

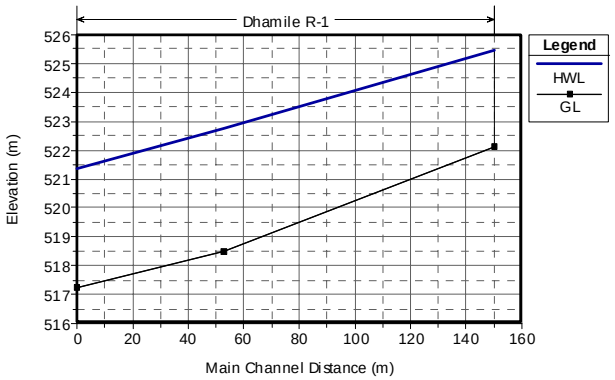
3.8 DHAMILE KHOLA

Case-1: Flow Simulation with Q_P (Rational Method)

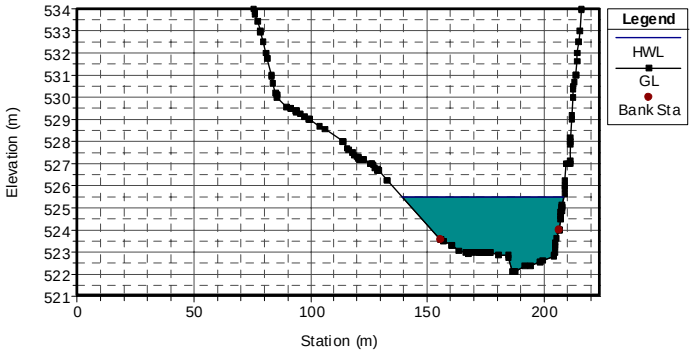
Hydraulic Properties of Flow (Dhamile Khola)

River	Section	Dist. To H-H (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Dhamile Khola	U-U	97.00	522.12	3.24	525.49	1439.00	9.54	69.37	150.87	3.37
	H-H	0.00	518.51		522.76	1439.00	7.94	66.41	181.12	4.25
	D-D	53.00	517.26		521.34	1439.00	8.68	77.23	165.76	4.08

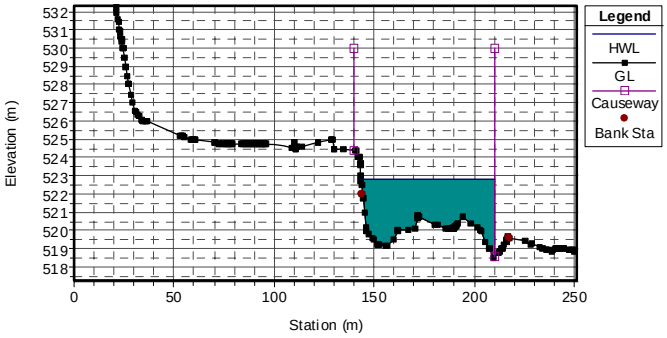
U-U: River section U/S of HW H-H: River section at HW D-D: River section D/S of HW HW: Highway



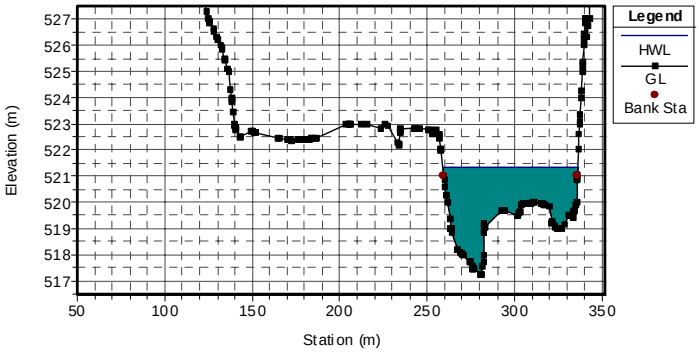
Water Surface Profile (Dhamile Khola)



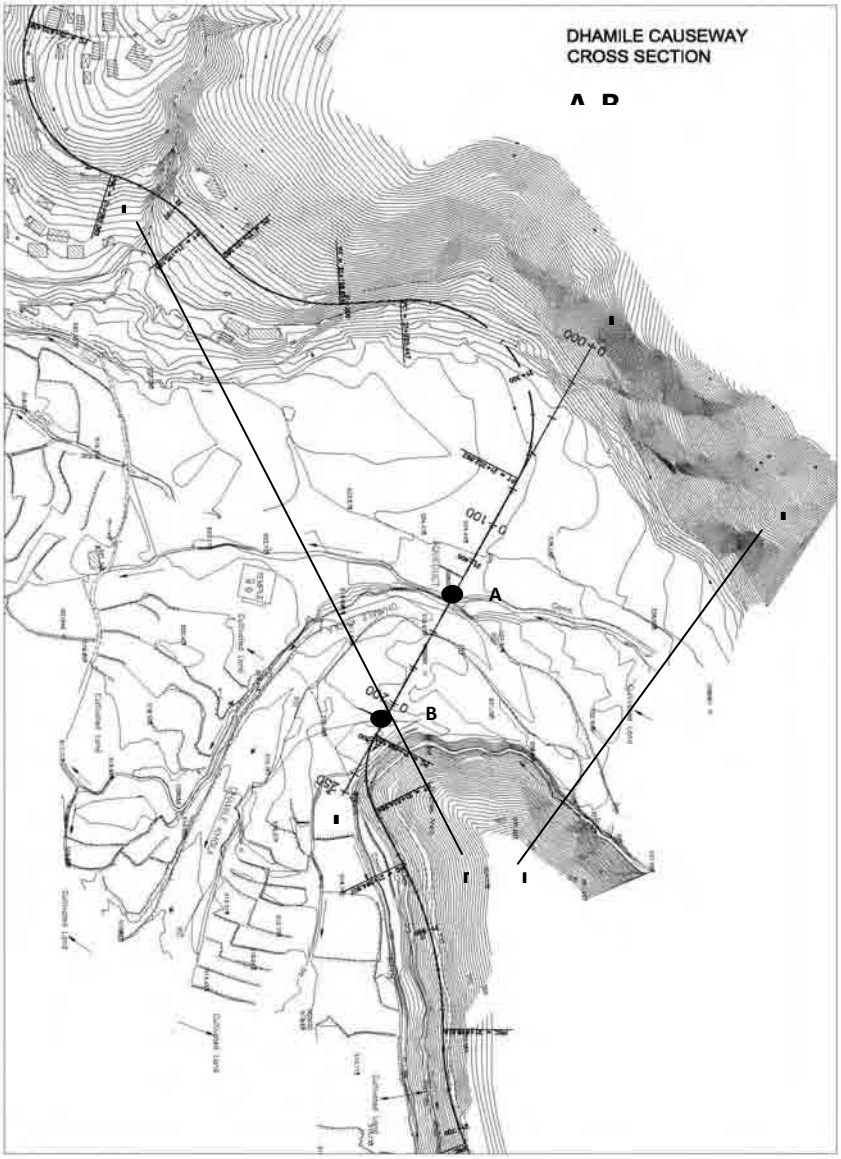
HWL at U-U Section (Dhamile Khola)



HWL at H-H Section (Dhamile Khola)



HWL at D-D Section (Dhamile Khola)



Locations of Cross-Sections Used (Dhamile Khola)

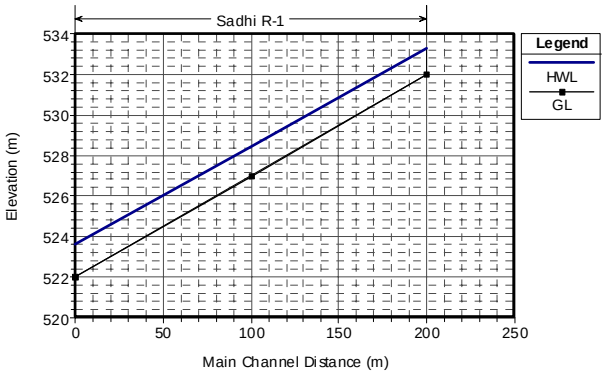
.9 SADHI KHOLA

Case-1: Flow Simulation with Q_P (Rational Method)

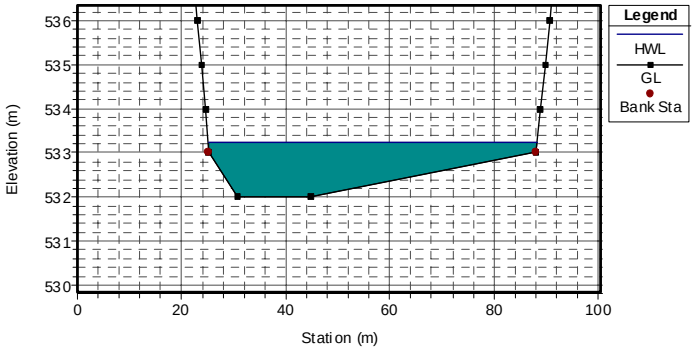
Hydraulic Properties of Flow (Sadhi Khola)

River	Section	Dist. To H-H (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Sadhi Khola	U-U	100.00	532.00	5.00	533.23	366.00	6.90	63.13	53.01	1.23
	H-H	0.00	527.00		528.41	366.00	7.09	56.01	51.63	1.41
	D-D	100.00	522.00		523.60	366.00	7.74	46.94	47.27	1.60

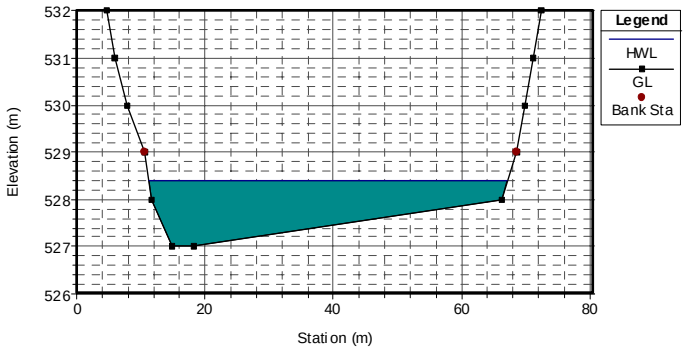
U-U: River section U/S of HW H-H: River section at HW D-D: River section D/S of HW HW: Highway



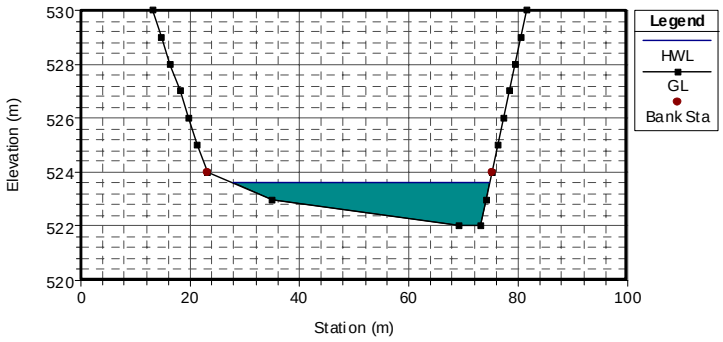
Water Surface Profile (Sadhi Khola)



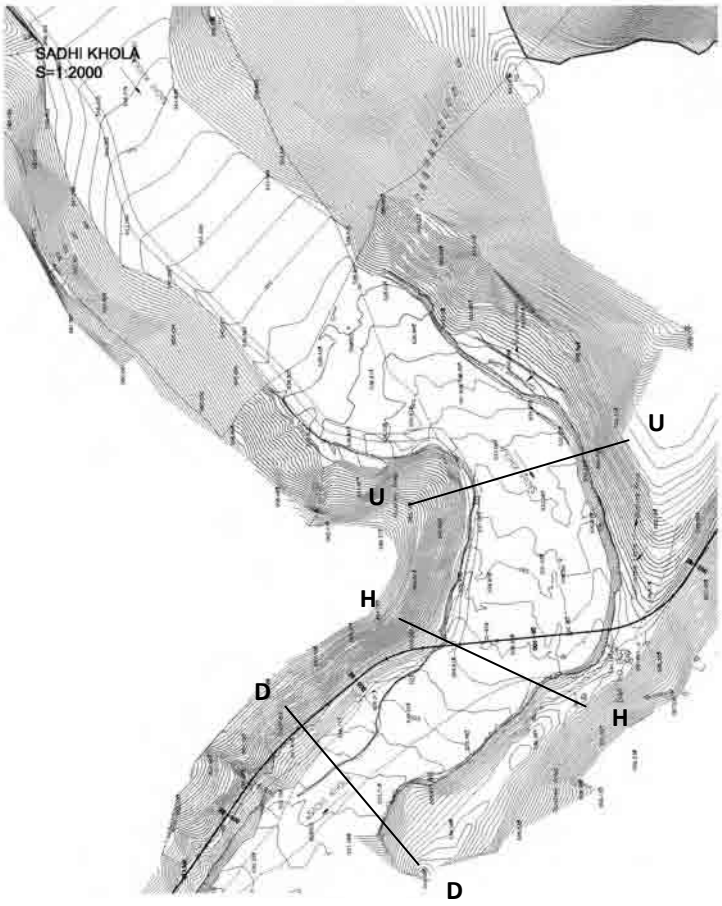
HWL at U-U Section (Sadhi Khola)



HWL at H-H Section (Sadhi Khola)



HWL at D-D Section (Sadhi Khola)

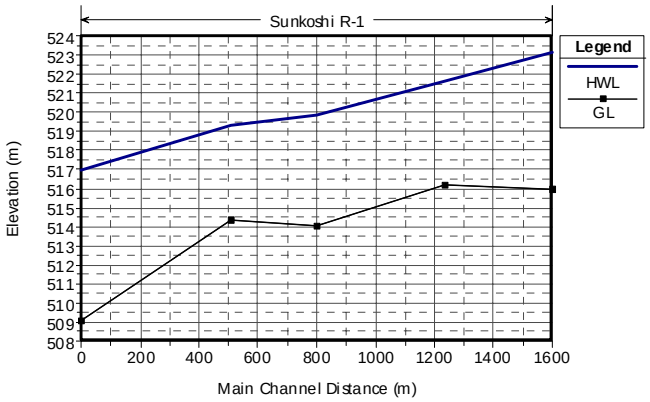


Locations of Cross-Sections Used (Sadhi Khola)

3.10 SUNKOSHI RIVER

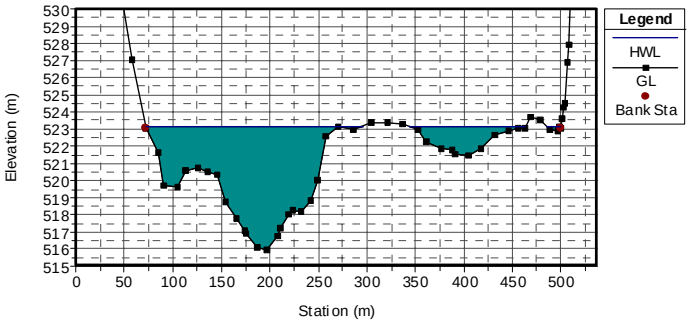
Hydraulic Properties of Flow (Sunkoshi River)

River	Section	Reach (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Sunkoshi	28+500	363.00	515.98	0.43	523.18	4749.00	5.38	357.00	882.76	7.20
	28+000	436.00	516.18		521.64	4749.00	5.09	431.21	933.72	5.46
	27+500	290.00	514.04		519.88	4749.00	4.26	687.63	1115.46	5.84
	27+000	510.00	514.37		519.31	4749.00	3.06	768.15	1551.75	4.94
	26+500	0.00	509.09		516.94	4749.00	5.00	414.14	949.90	7.85



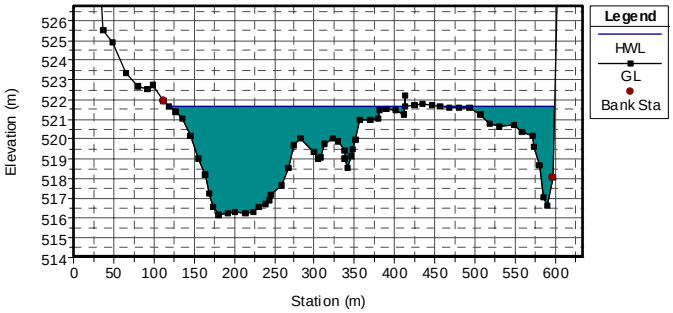
Water Surface Profile (Sunkoshi River)

STA 28+500:



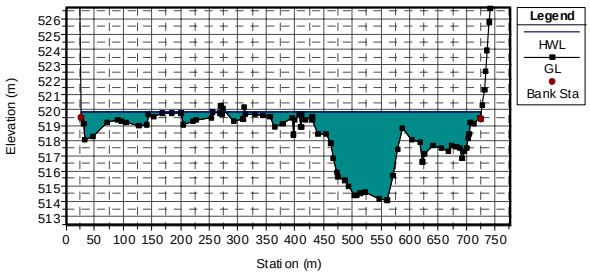
HWL at STA 28+500 (Sunkoshi River)

STA 28+000:



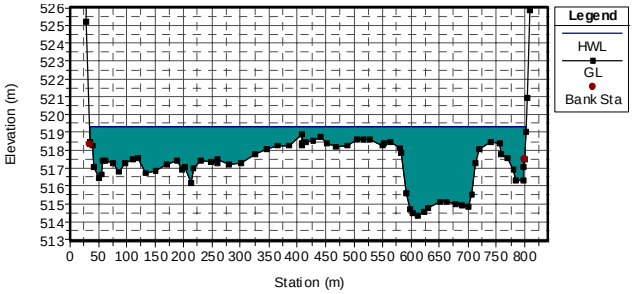
HWL at STA 28+000 (Sunkoshi River)

STA 27+500:



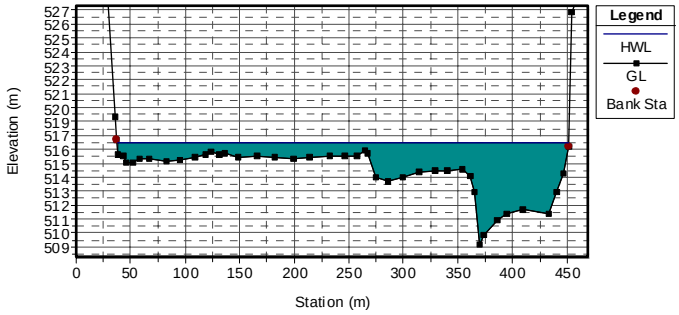
HWL at STA 27+500 (Sunkoshi River)

STA 27+000:



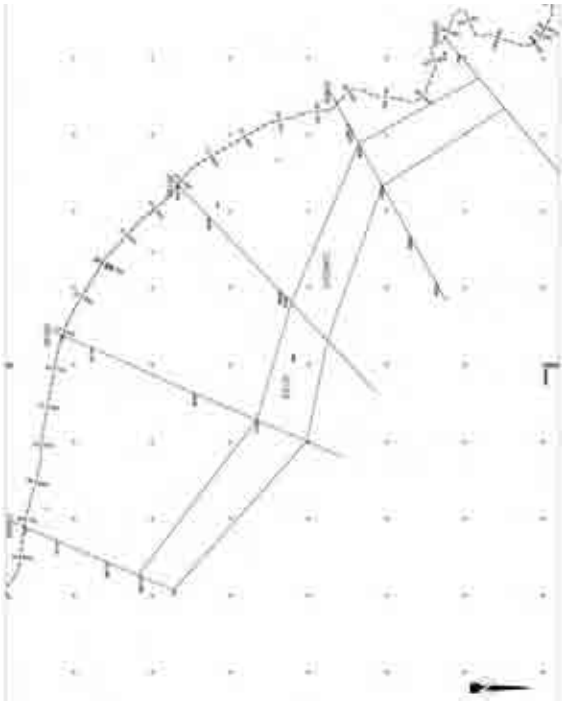
HWL at STA 27+000 (Sunkoshi River)

STA 26+500:



HWL at STA 26+500 (Sunkoshi River)

Locations of Cross-Sections Used (Sunkoshi River and Rosi Khola)



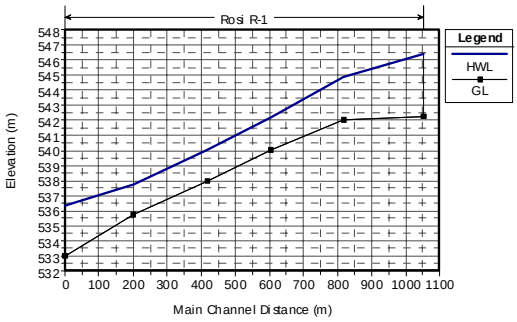
Locations of Cross-Sections Used (Sunkoshi River)

3.11 ROSI KHOLA

Case-1: River Flow in Existing Condition

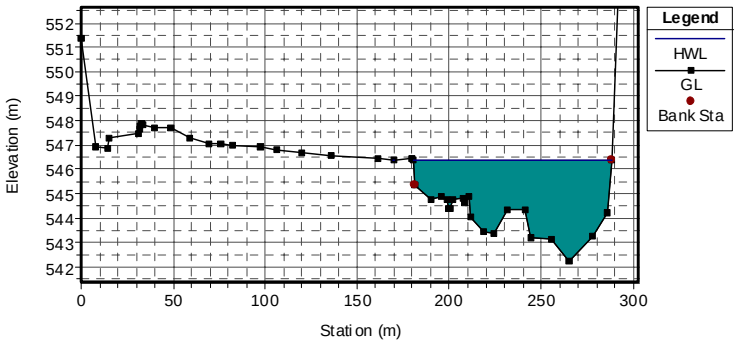
Hydraulic Properties of Flow (Rosi Khola)

River	Section	Reach (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Rosi	31+000	234.00	542.23	0.88	546.40	992.00	3.65	108.29	272.15	4.17
	30+800	215.00	542.04		544.85	992.00	4.10	291.29	241.92	2.81
	30+600	185.00	540.03		542.18	992.00	4.10	337.18	241.72	2.15
	30+400	218.00	538.00		540.05	992.00	4.14	246.59	239.27	2.05
	30+200	200.00	535.73		537.73	992.00	4.81	203.16	206.35	2.00
	30+000	0.00	532.99		536.40	992.00	2.24	295.70	442.67	3.41



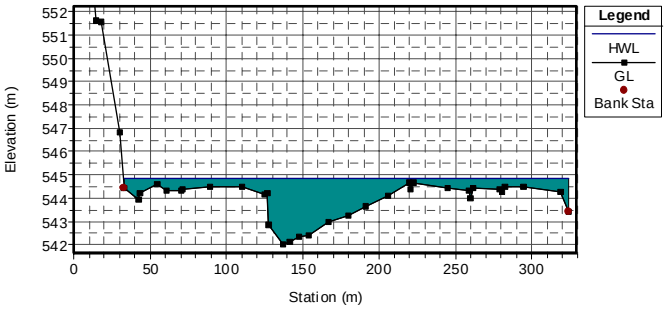
Water Surface Profile (Rosi Khola)

STA 31+000:



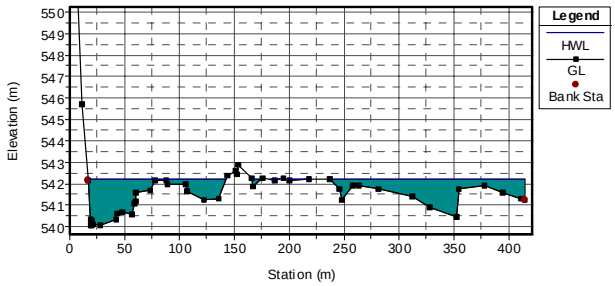
HWL at STA 31+000 (Rosi Khola)

STA 30+800:



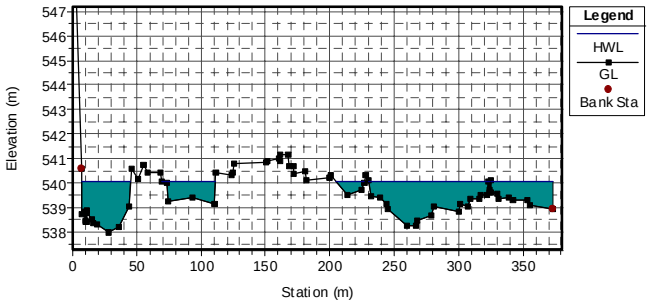
HWL at STA 30+800 (Rosi Khola)

STA 30+600:



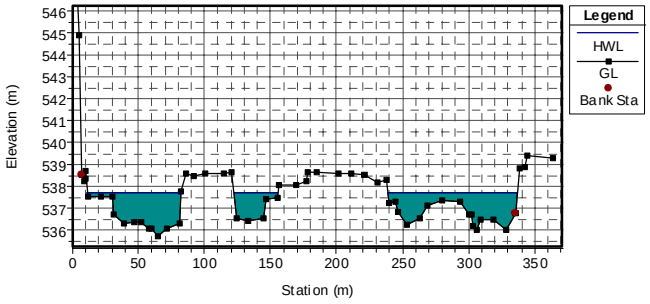
HWL at STA 30+600 (Rosi Khola)

STA 30+400:



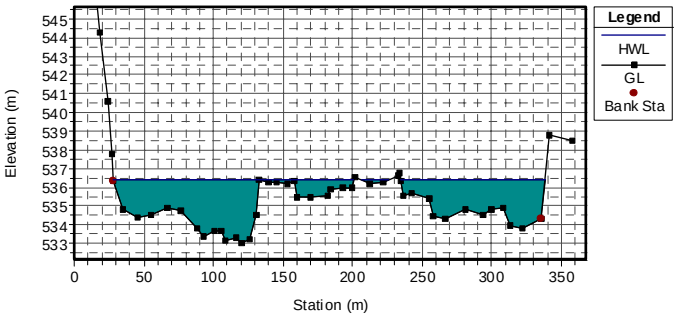
HWL at STA 30+400 (Rosi Khola)

STA 30+200:



HWL at STA 30+200 (Rosi Khola)

STA 30+000:

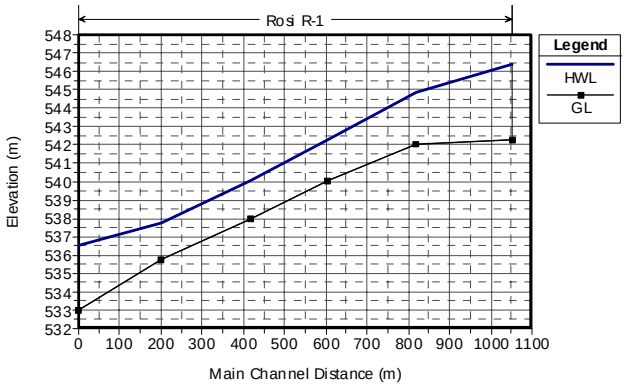


HWL at STA 30+000 (Rosi Khola)

Case-2: River Flow After Road Construction

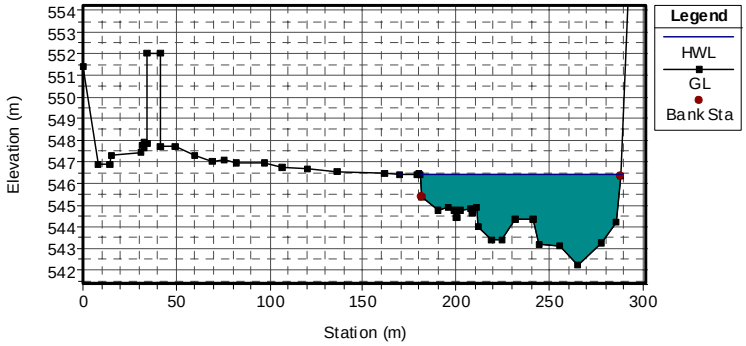
Hydraulic Properties of Flow (Rosi Khola)

River	Section	Reach (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Rosi	31+000	234.00	542.23	0.88	546.40	982.00	3.61	108.29	272.15	4.17
	30+800	215.00	542.04		544.85	982.00	4.13	282.61	237.88	2.81
	30+600	185.00	540.03		542.24	982.00	4.06	360.39	241.90	2.21
	30+400	218.00	538.00		540.06	982.00	4.33	236.56	226.78	2.06
	30+200	200.00	535.73		537.74	982.00	4.82	185.05	203.60	2.01
	30+000	0.00	532.99		536.50	982.00	2.30	274.40	427.25	3.51



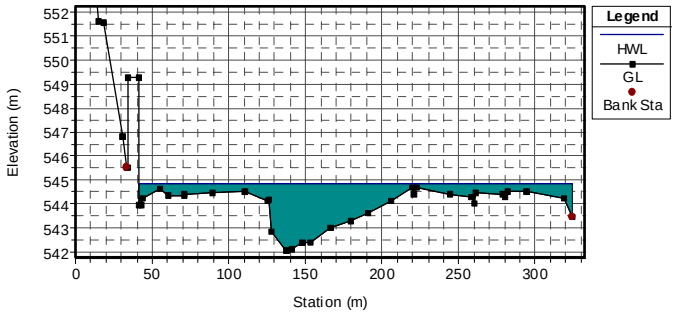
Water Surface Profile (Rosi Khola)

STA 31+000:



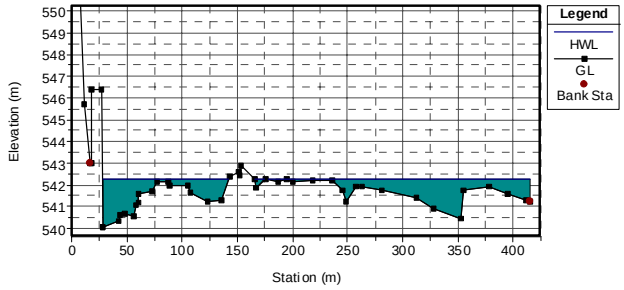
HWL at STA 31+000 (Rosi Khola)

STA 30+800:



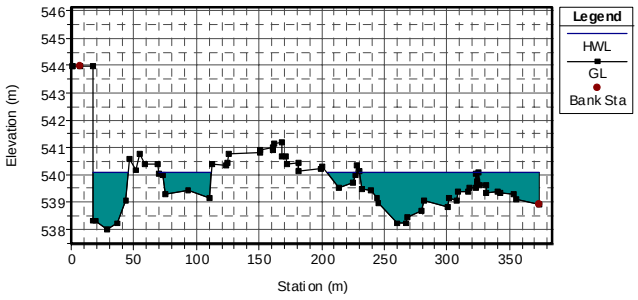
HWL at STA 30+800 (Rosi Khola)

STA 30+600:



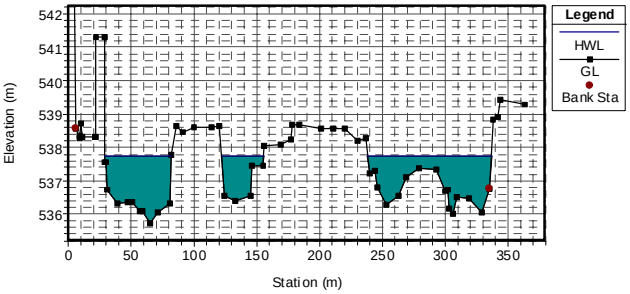
HWL at STA 30+600 (Rosi Khola)

STA 30+400:



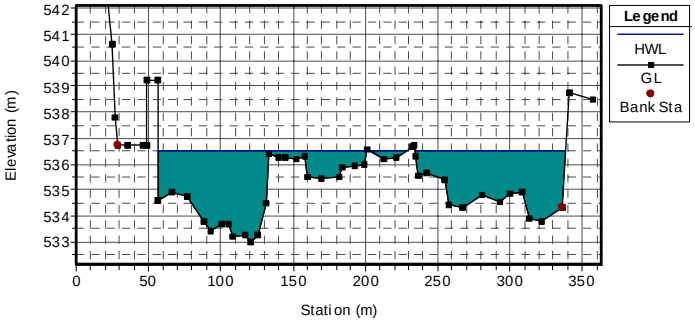
HWL at STA 30+400 (Rosi Khola)

STA 30+200:

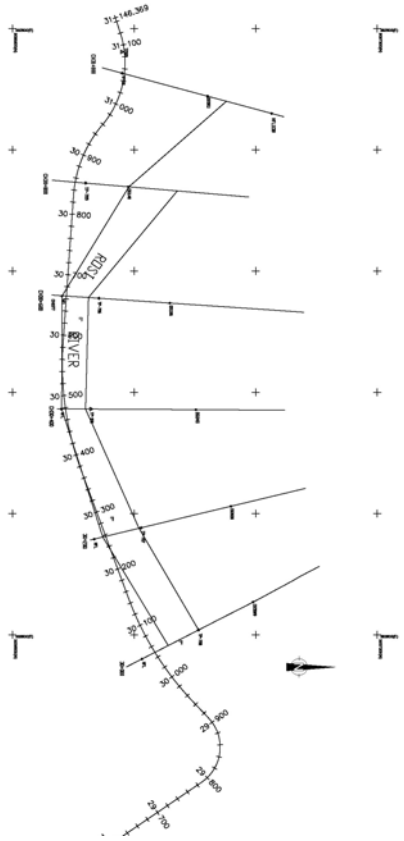


HWL at STA 30+200 (Rosi Khola)

STA 30+000:



HWL at STA 30+000 (Rosi Khola)



Locations of Cross-Sectioned Used (Rosi Khola)

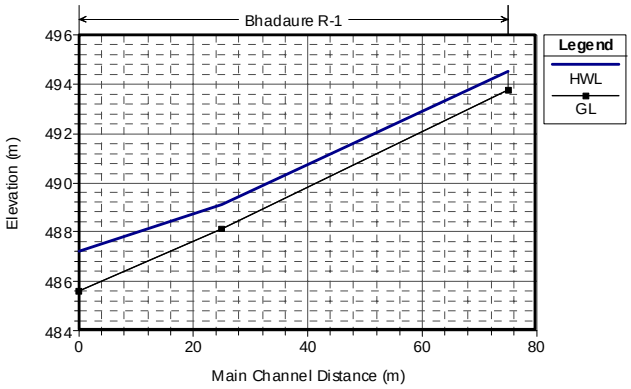
3.12 BHADAURE KHOLA

Case-1: Flow Simulation with Q_P (Rational Method)

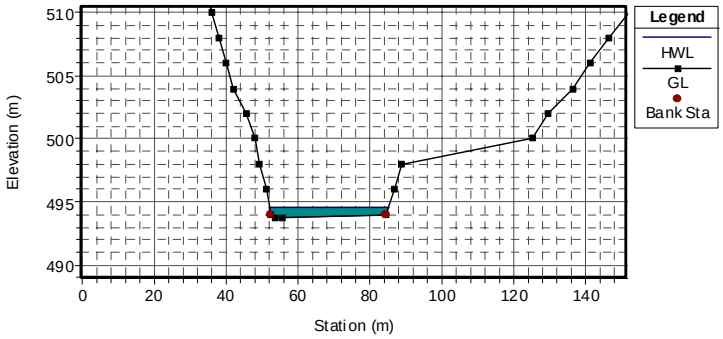
Table Hydraulic Properties of Flow (Bhadaure Khola)

River	Section	Dist. To H-H (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Bhadaure Khola	U-U	50.00	493.77	10.87	494.51	186.00	9.06	32.94	20.53	0.74
	H-H	0.00	488.11		489.09	186.00	5.29	39.51	35.13	0.98
	D-D	25.00	485.62		487.22	186.00	8.29	27.05	22.43	1.60

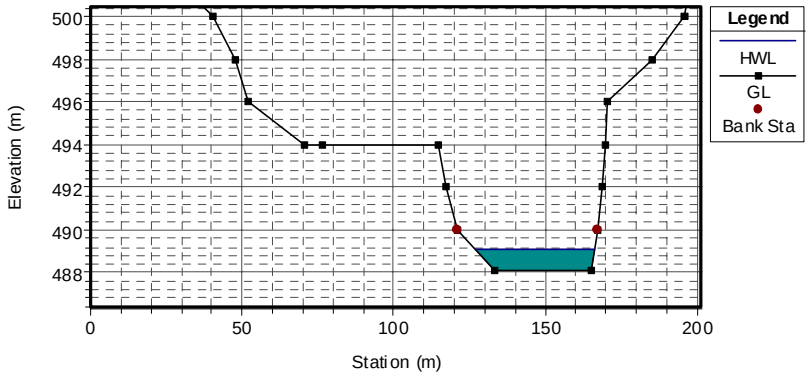
U-U: River section U/S of HW H-H: River section at HW D-D: River section D/S of HW HW: Highway



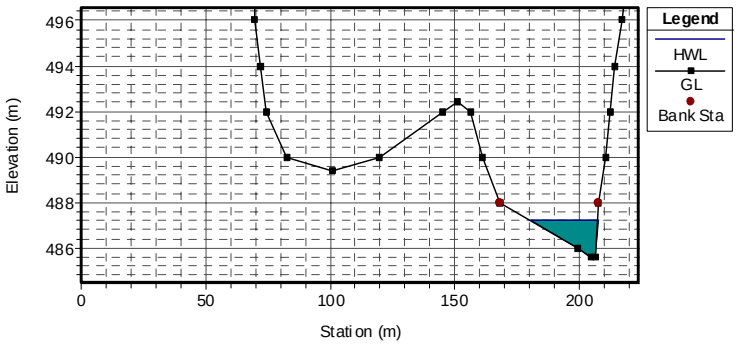
Water Surface Profile (Bhadaure Khola)



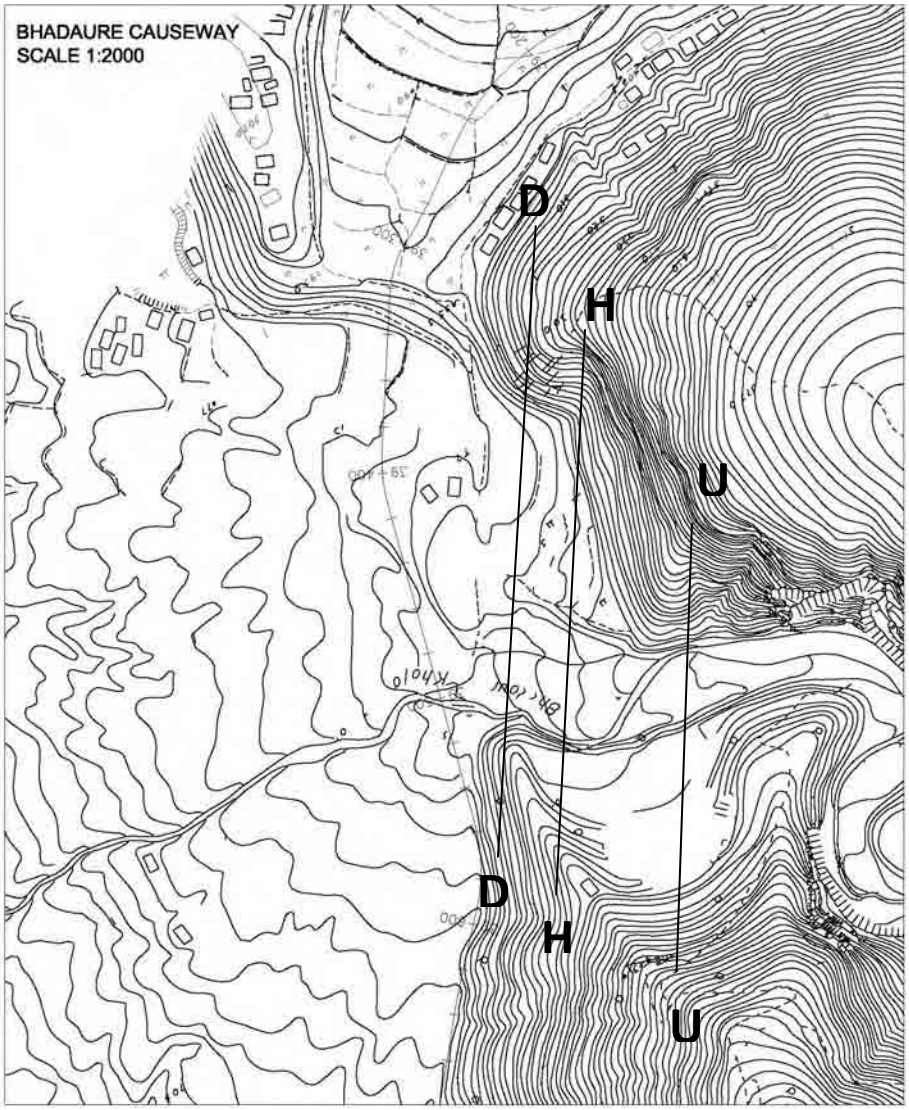
HWL at U-U Section (Bhadaure Khola)



HWL at H-H Section (Bhadaure Khola)



HWL at D-D Section (Bhadaure Khola)



Locations of Cross-Sections Used (Bhadaure Khola)

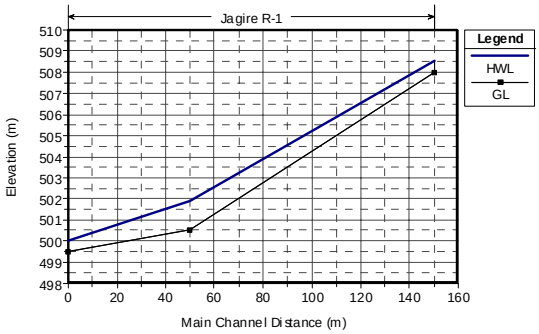
3.13 JAGIRE KHOLA

Case-1: Flow Simulation with Q_P (Rational Method)

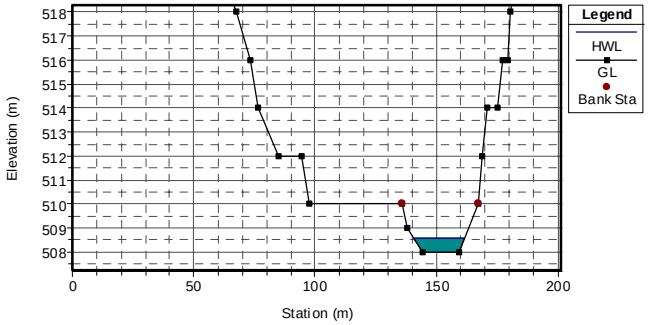
Hydraulic Properties of Flow (Jagire Khola)

River	Section	Dist. To H-H (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Jagire Khola	U-U	100.00	508.00	5.65	508.57	62.00	6.12	20.66	10.14	0.57
	H-H	0.00	500.50		501.90	62.00	3.25	25.58	19.08	1.40
	D-D	50.00	499.52		500.01	62.00	4.22	45.00	14.67	0.49

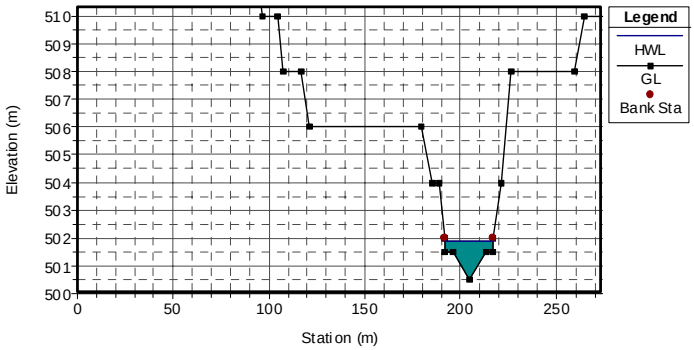
U-U: River section U/S of HW H-H: River section at HW D-D: River section D/S of HW HW: Highway



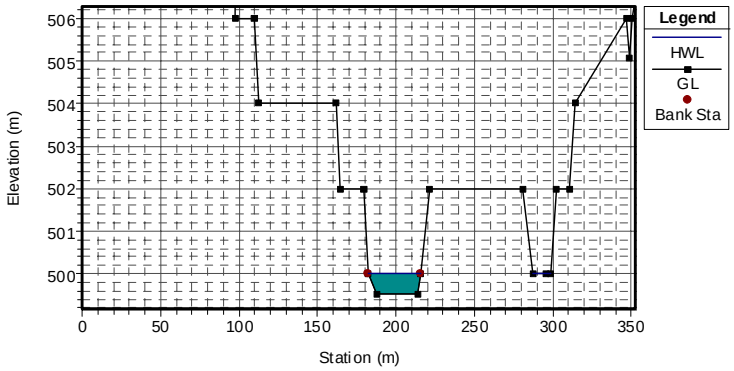
Water Surface Profile (Jagire Khola)



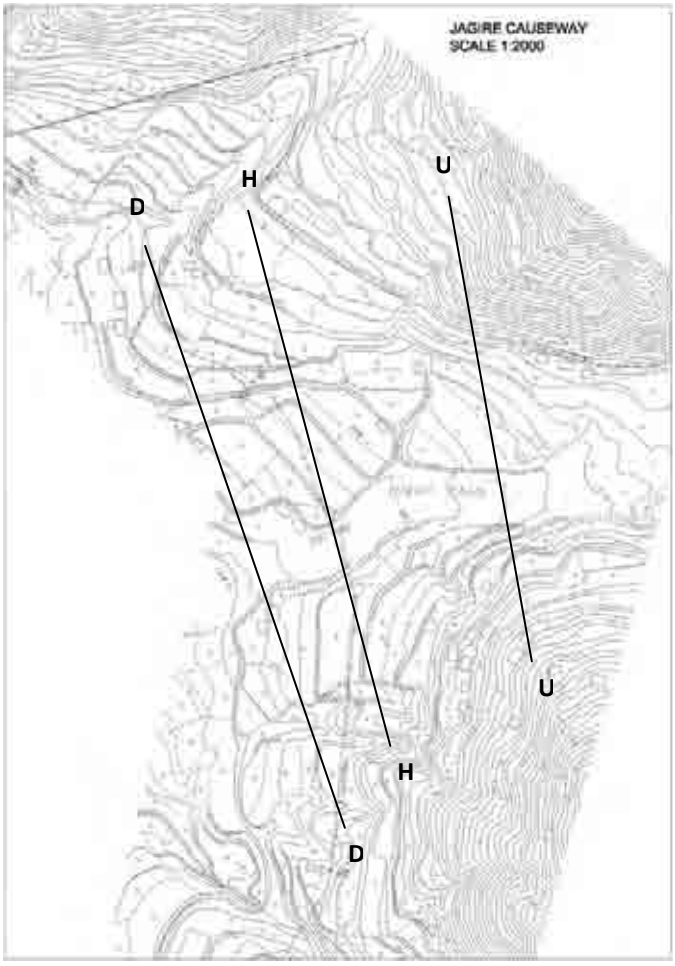
HWL at U-U Section (Jagire Khola)



HWL at H-H Section (Jagire Khola)



HWL at D-D Section (Jagire Khola)



Locations of Cross-Sections Used (Jagire Khola)

3.14 ANDHERI KHOLA

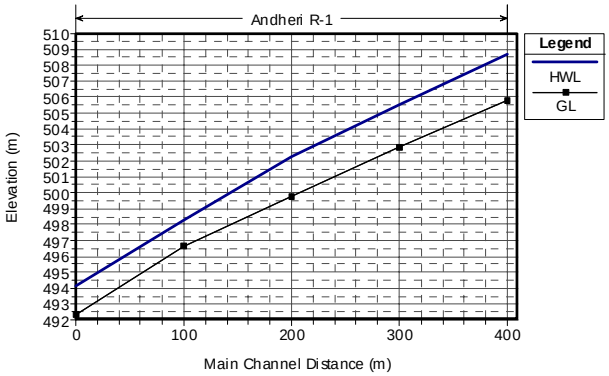
3.14.1 River Flow in Existing Condition

Case-1: Flow Simulation with Q_P (Rational Method)

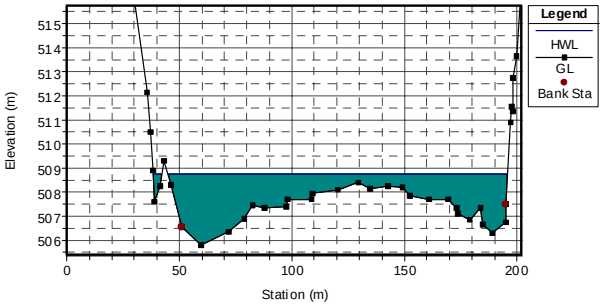
Hydraulic Properties of Flow (Andheri Khola)

River	Section	Dist. To H-H (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Andheri Khola	U1-U1	200.00	505.79	3.36	508.73	987.00	4.80	154.72	205.43	2.94
	U2-U2	100.00	502.85		505.51	987.00	5.92	110.82	166.81	2.66
	H-H	0.00	499.76		502.22	987.00	4.81	159.15	205.22	2.46
	D1-D1	100.00	496.61		498.30	987.00	5.23	193.15	188.58	1.69
	D2-D2	200.00	492.36		494.16	987.00	4.57	201.24	215.53	1.80

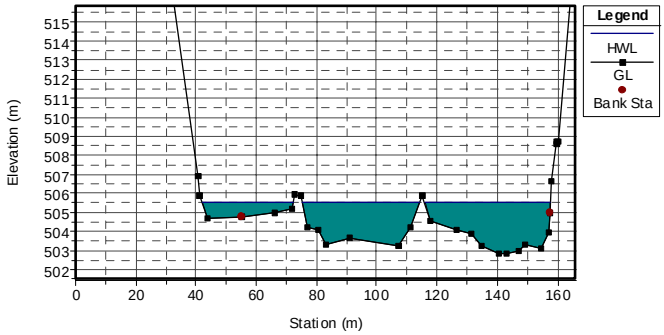
U-U: River section U/S of HW H-H: River section at HW D-D: River section D/S of HW HW: Highway



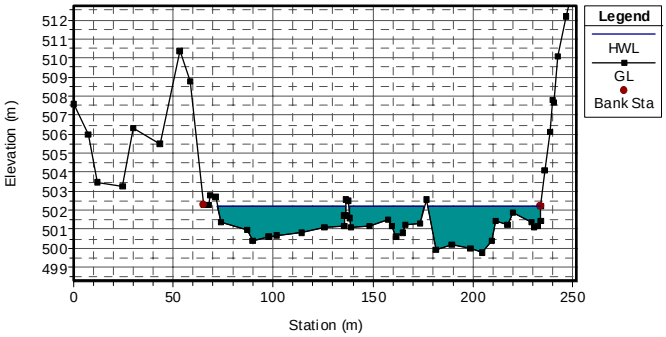
Water Surface Profile (Andheri Khola)



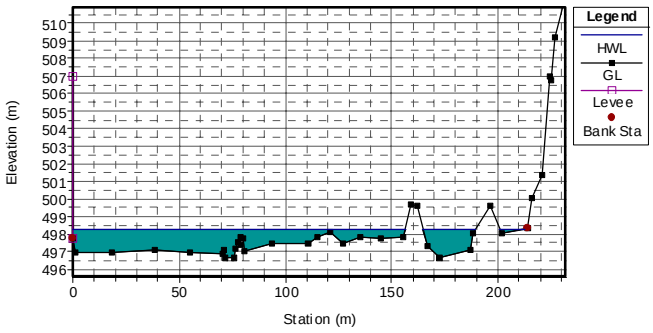
HWL at 200 m U/S (U1-U1 Section of Andheri Khola)



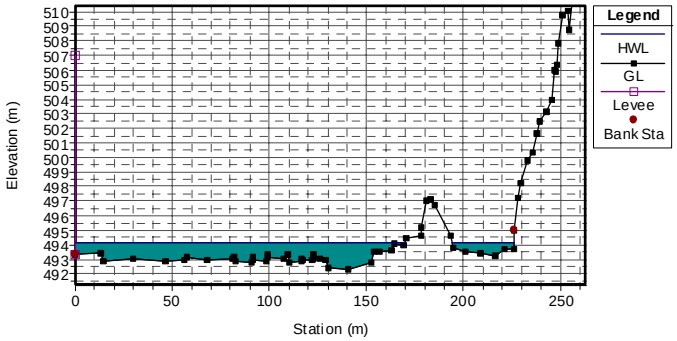
HWL at 100 m U/S (U2-U2 Section of Andheri Khola)



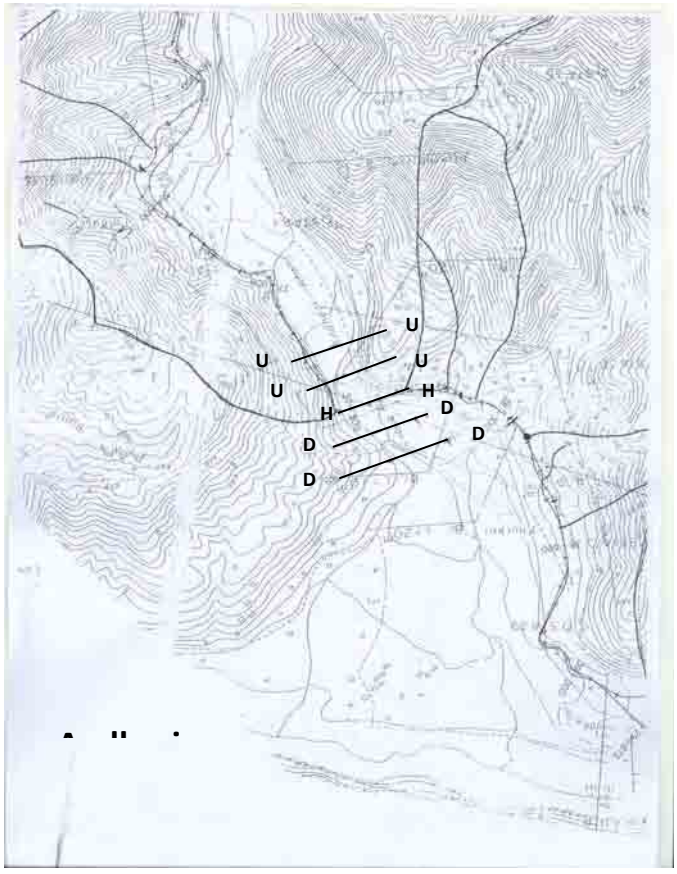
HWL at 0 m Centerline (H-H Section of Andheri Khola)



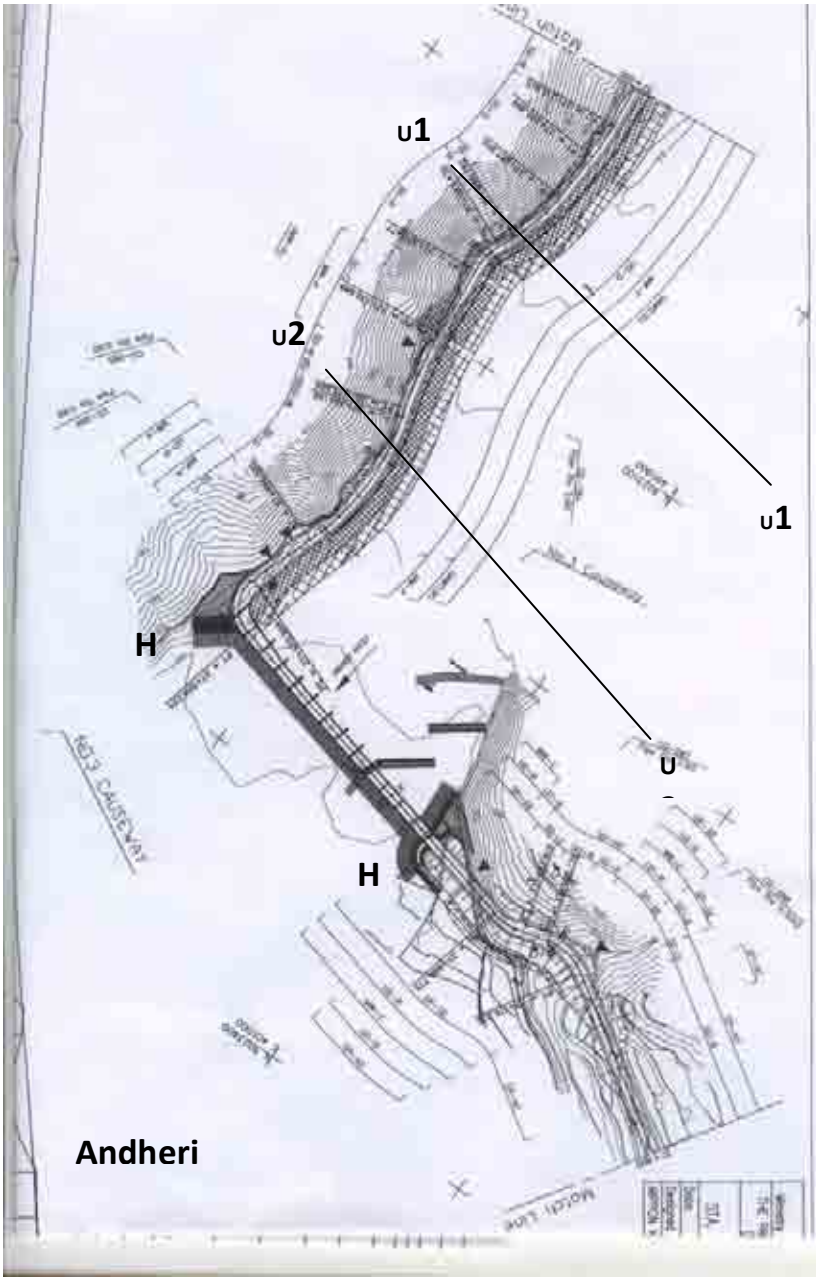
HWL at 100 m D/S (D1-D1 Section of Andheri Khola)



HWL at 200 m D/S (D2-D2 Section of Andheri Khola)



Locations of Cross-Sections Used-1 (Andheri Khola)



Locations of Cross-Sections Used-2 (Andheri Khola)

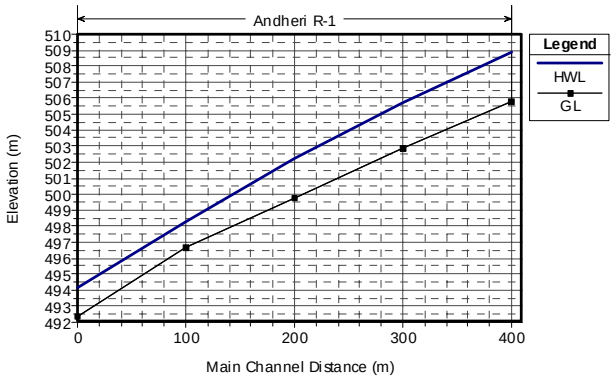
3.14.2 River Flow After Road Construction

Case-1: Flow Simulation with Q_P (Rational Method)

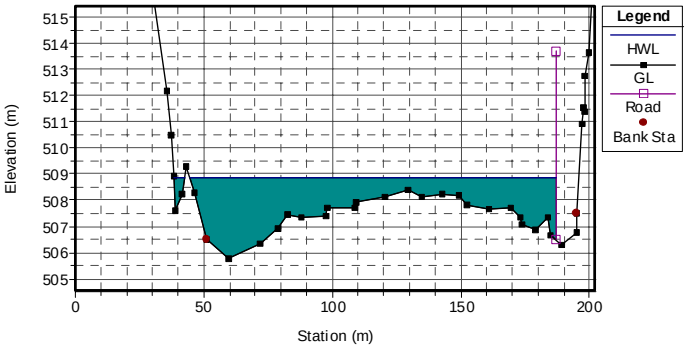
Hydraulic Properties of Flow (Andheri Khola)

River	Section	Dist. To H-H (m)	Bed EL (m)	Bed Slope (%)	HWL (m)	Q (m^3/s)	Velocity (m/s)	Top Width (m)	Area (m^2)	Water Depth (m)
Andheri Khola	U1-U1	200.00	505.79	3.36	508.89	987.00	4.69	146.88	210.62	3.10
	U2-U2	100.00	502.85		505.69	987.00	6.18	100.86	159.72	2.84
	H-H	0.00	499.76		502.24	987.00	4.99	145.94	197.71	2.48
	D1-D1	100.00	496.61		498.30	987.00	5.23	193.15	188.58	1.69
	D2-D2	200.00	492.36		494.16	987.00	4.57	201.24	215.53	1.80

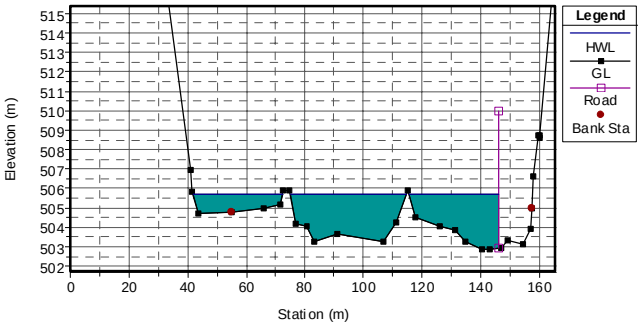
U-U: River section U/S of HW H-H: River section at HW D-D: River section D/S of HW HW: Highway



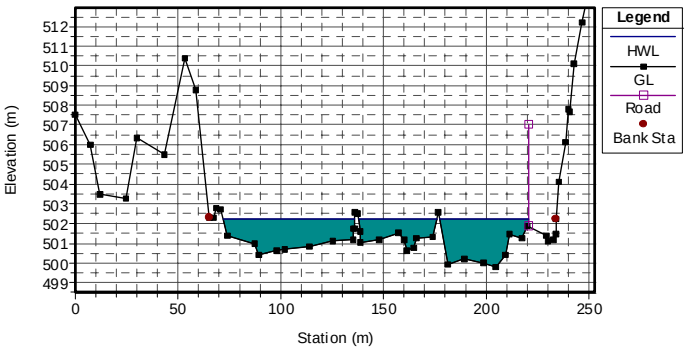
Water Surface Profile (Andheri Khola)



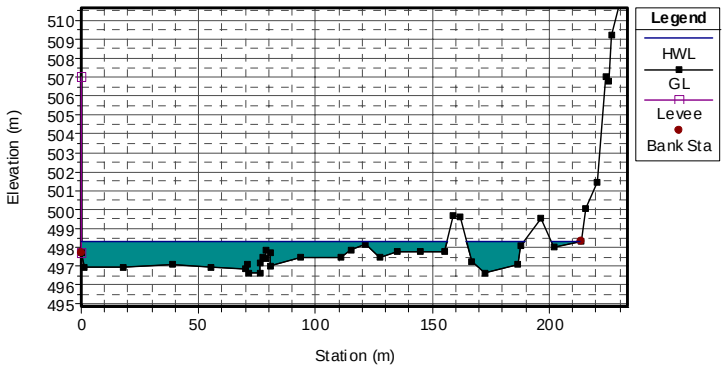
HWL at 200 m U/S (U1-U1 Section of Andheri Khola)



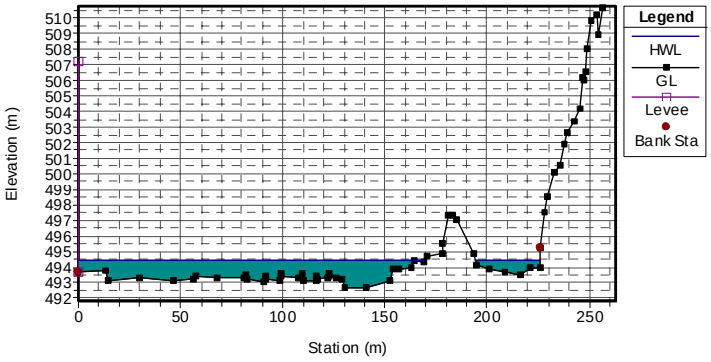
HWL at 100 m U/S (U2-U2 Section of Andheri Khola)



HWL at 0 m Centerline (H-H Section of Andheri Khola)



HWL at 100 m D/S (D1-D1 Section of Andheri Khola)



HWL at 200 m D/S (D2-D2 Section of Andheri Khola)

6-2 Hazard Map


Legend
Land slide
Talus
Alluvial cone
Failure
Gully
Red terrace
Terrace
Low land
Fan
River deposit
Debris flow sediment
SCALE
STA. 0+000 To 0+600 - 01

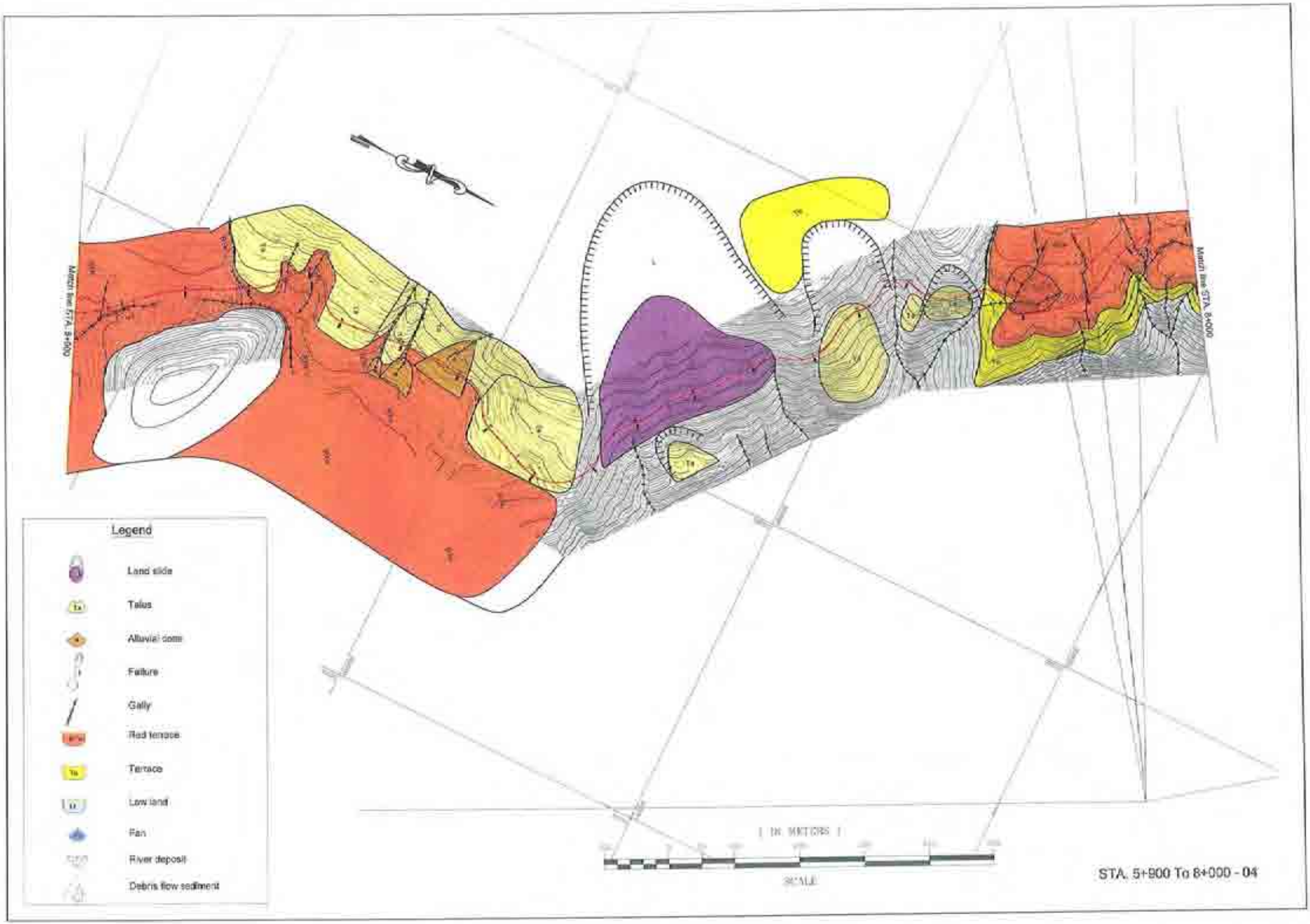
A6-2-1


Legend
Land slide
Talus
Alluvial cone
Failure
Gully
Red terrace
Terrace
Low land
Fan
River deposit
Debris flow sediment
Match line STA. 0+600
Match line STA. 2+600
STA. 0+600 To 2+600 - 02

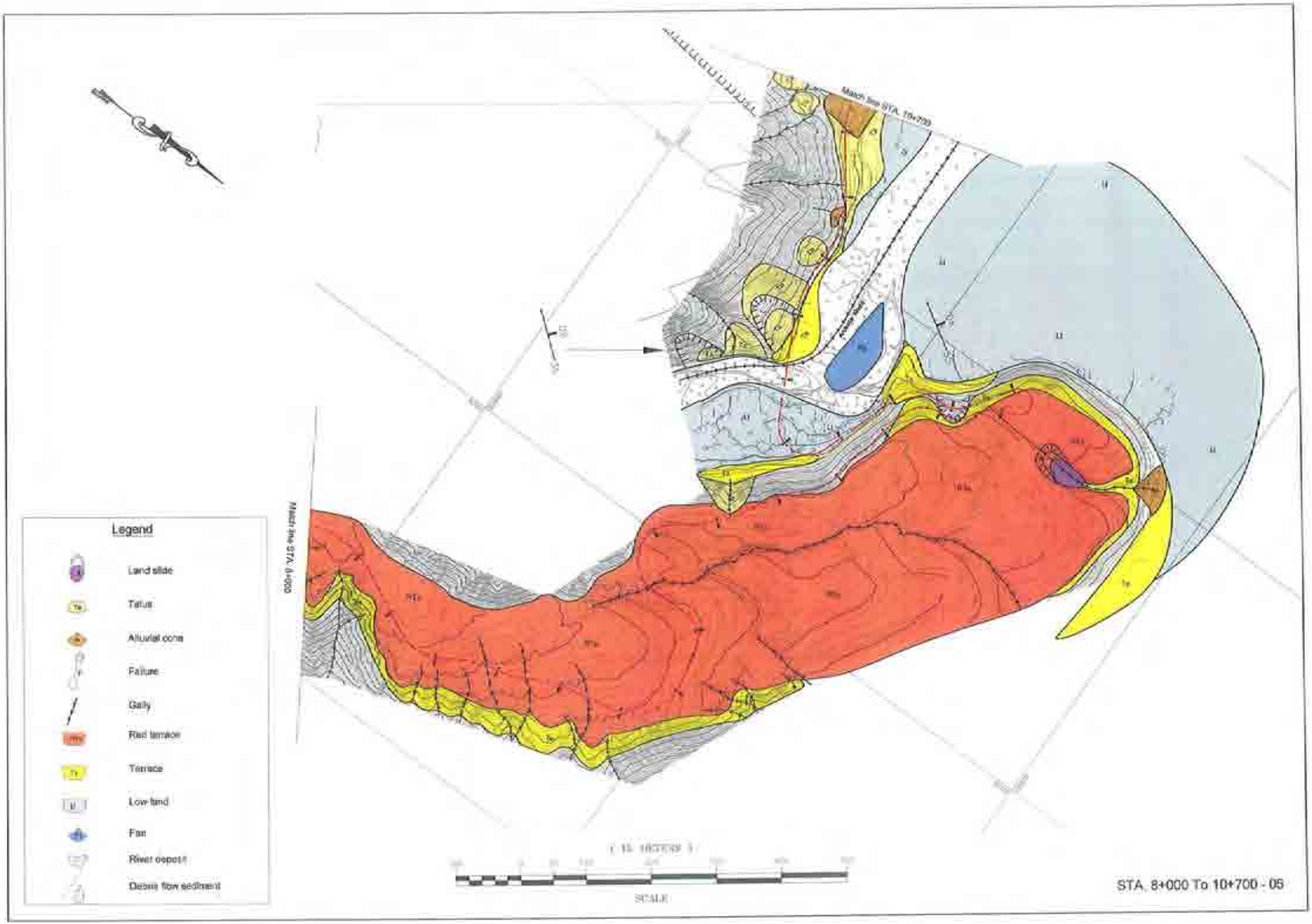
A6-2-2

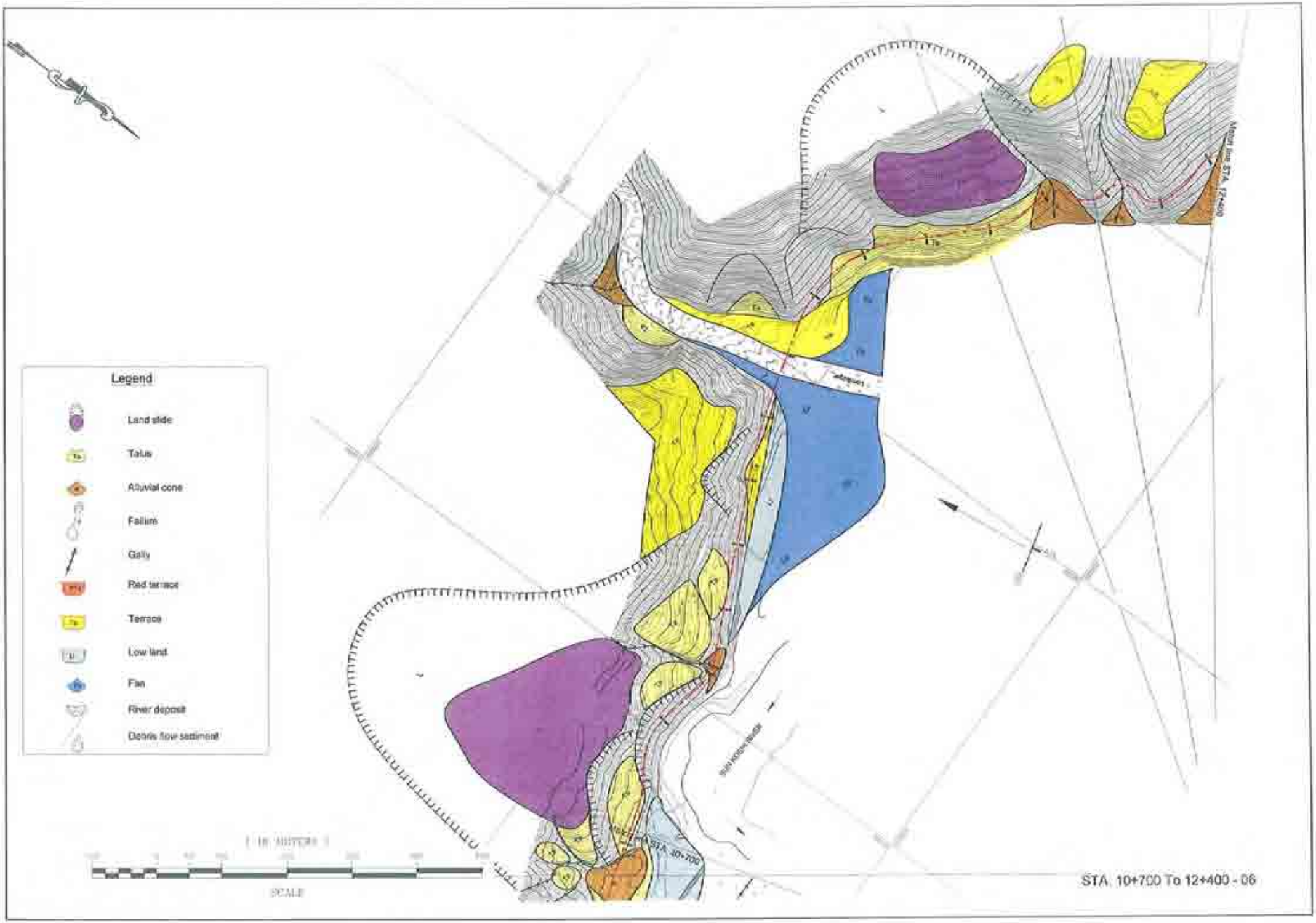

Legend
Land slide
Talus
Alluvial cone
Failure
Gully
Red terrace
Terrace
Low land
Fan
River deposit
Debris flow sediment
Match line STA. 5+900
Match line STA. 2+600
SUN KOSHI RIVER
SUN KOSHI RIVER
(10 METERS)
SCALE
STA. 2+600 To 5+900 - 03

A6-2-3


Legend
Land slide
Talus
Alluvial cone
Failure
Gully
Red terrace
Terrace
Low land
Fan
River deposit
Debris flow sediment
Matzh line STA. 5+900
Matzh line STA. 8+000
(IN METERS)
SCALE
STA. 5+900 To 8+000 - 04

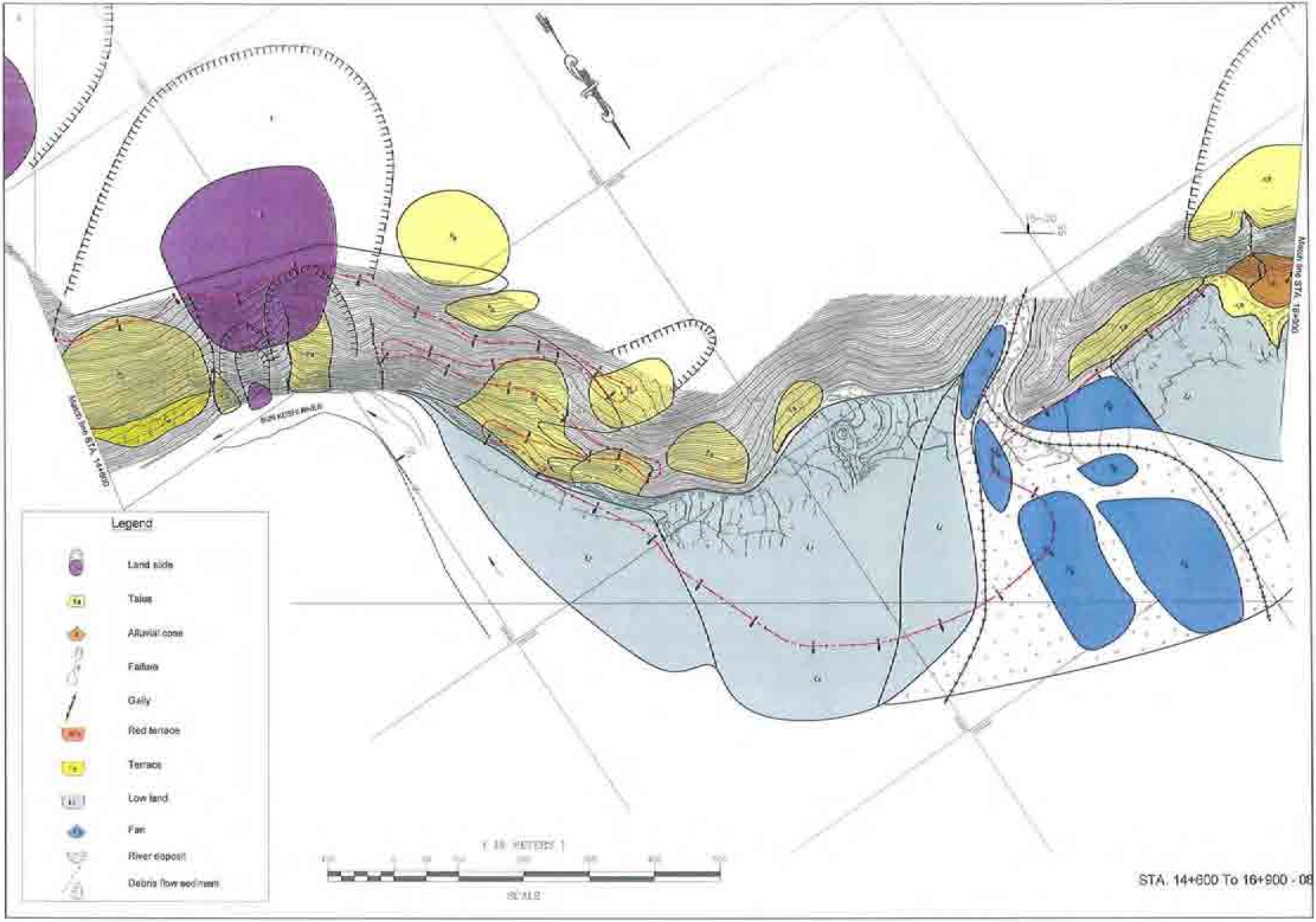
A6-2-4

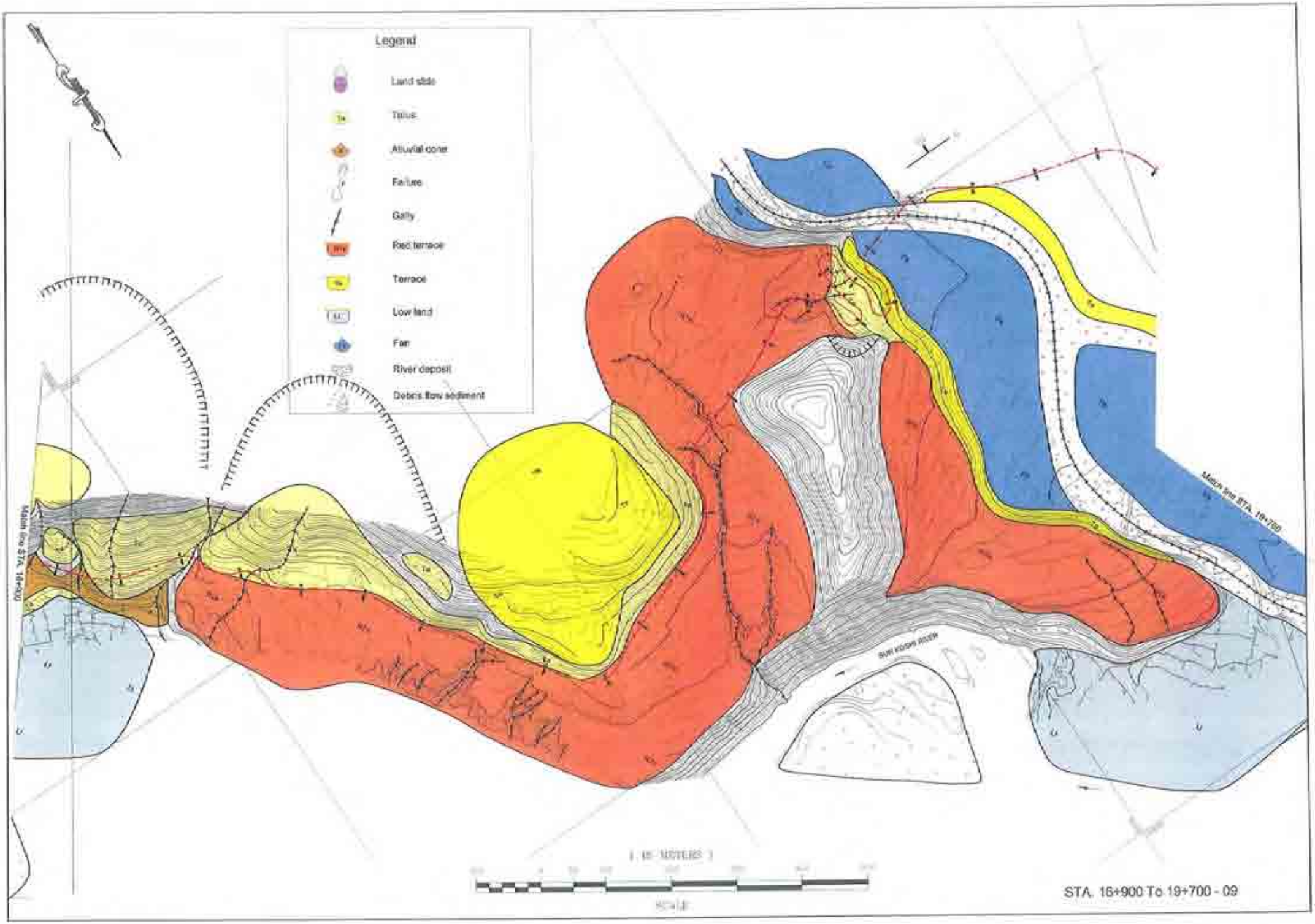

Match line STA. 10+700
Match line STA. 8+000
Legend
Land slide
Tatus
Alluvial cone
Failure
Gully
Red terrace
Terrace
Low land
Fan
River deposit
Debris flow sediment
SCALE
STA. 8+000 To 10+700 - 05

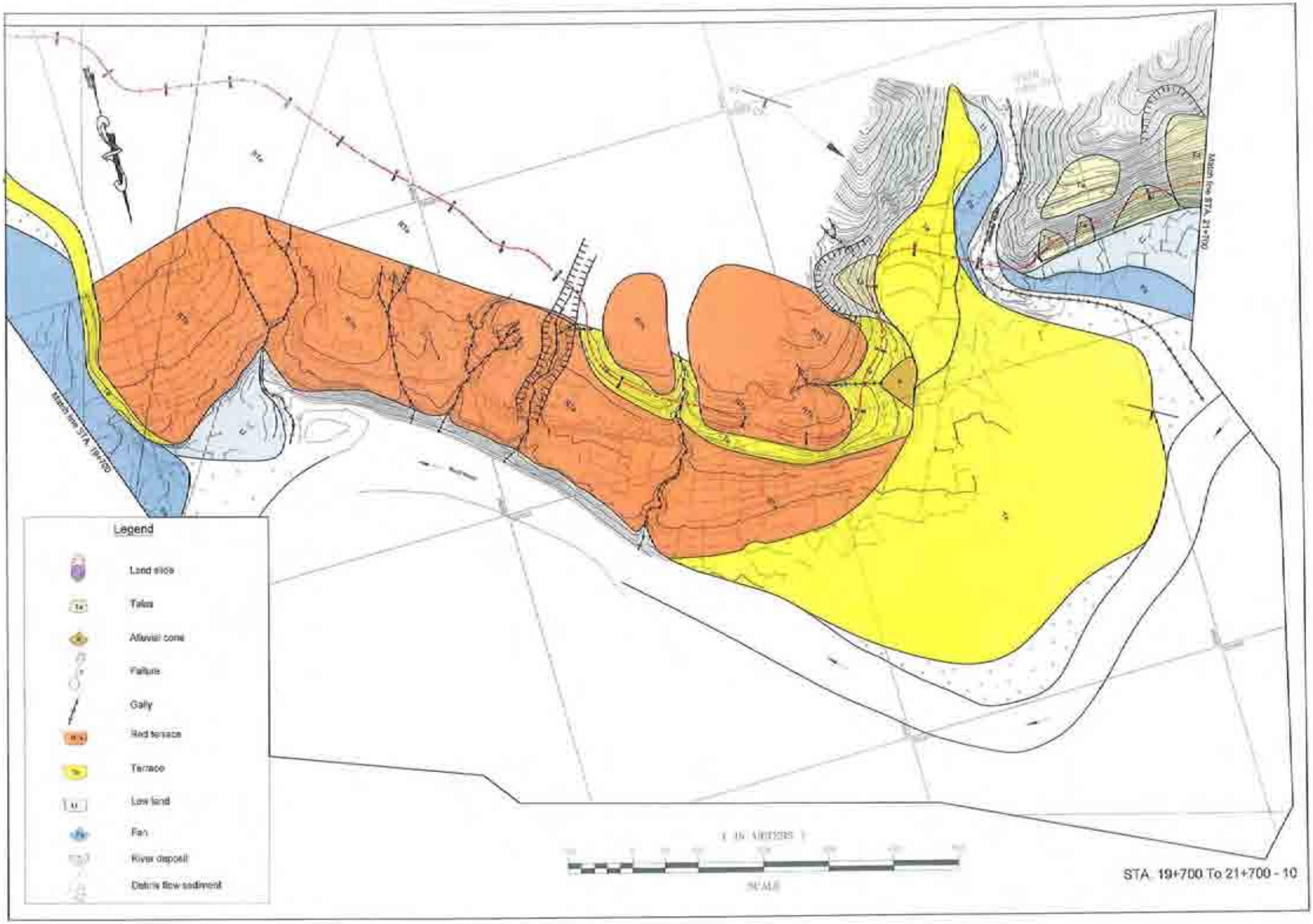

Legend
Land slide
Talus
Alluvial cone
Failure
Gully
Red terrace
Terrace
Low land
Fan
River deposit
Debris flow sediment
STA. 10+700
STA. 12+400
SCALE
STA. 10+700 To 12+400 - 06

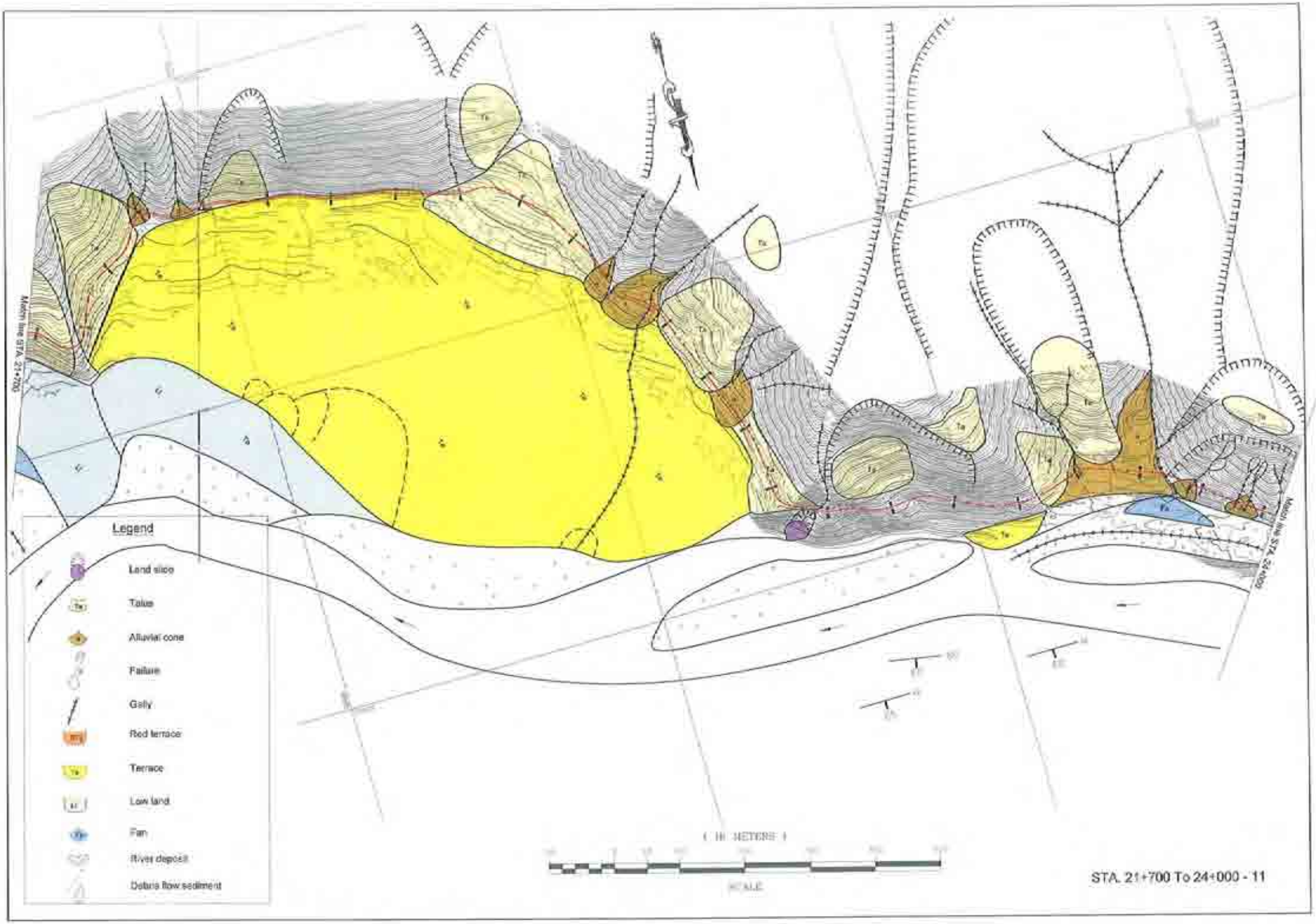
A6-2-6

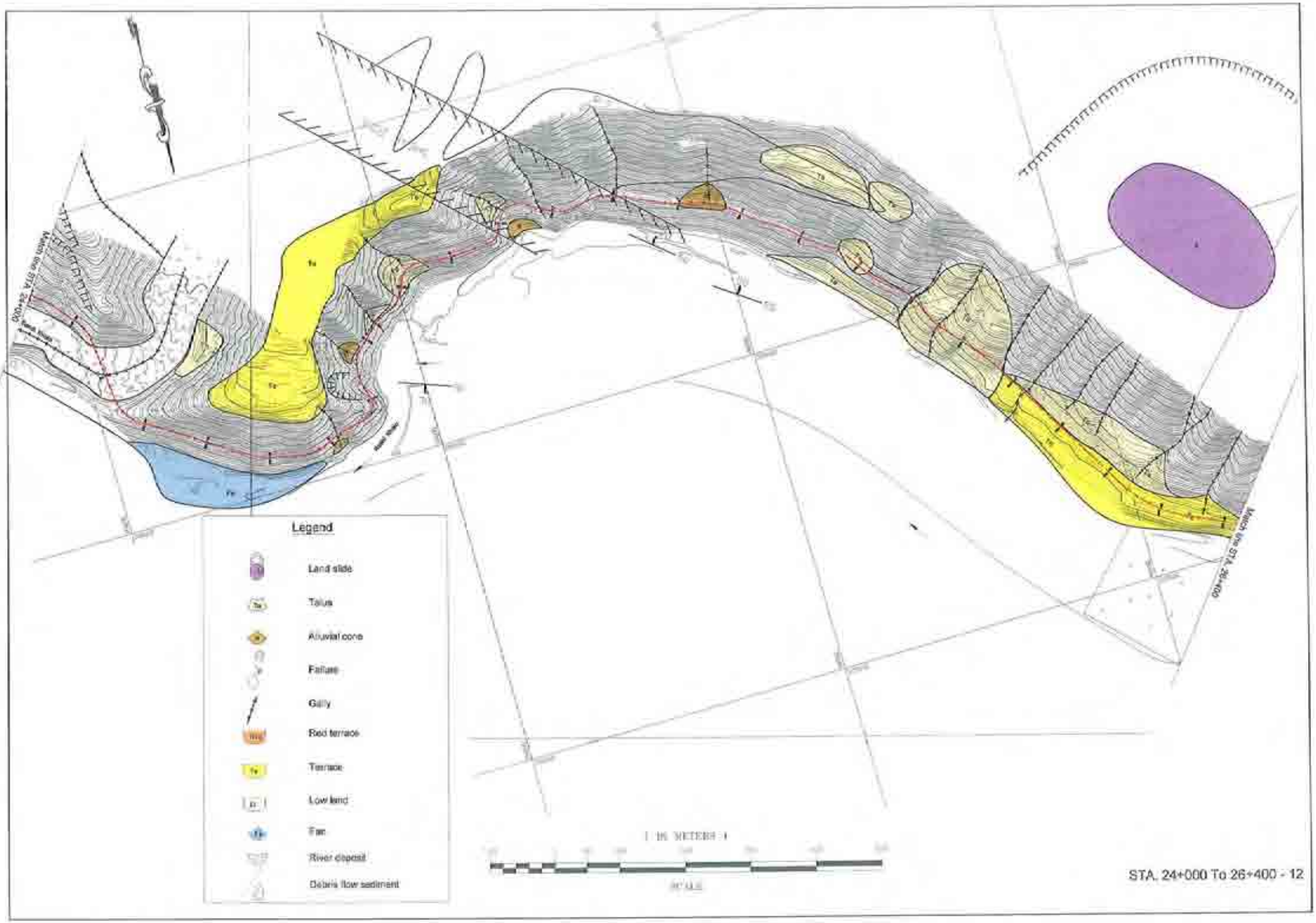

Legend
Land slide
Talus
Alluvial cone
Failure
Gully
Rec terrace
Terrace
Low land
Fan
River deposit
Debris flow sediment
(In METRE)
SCALE
STA. 12+400 To 14+600 - 07

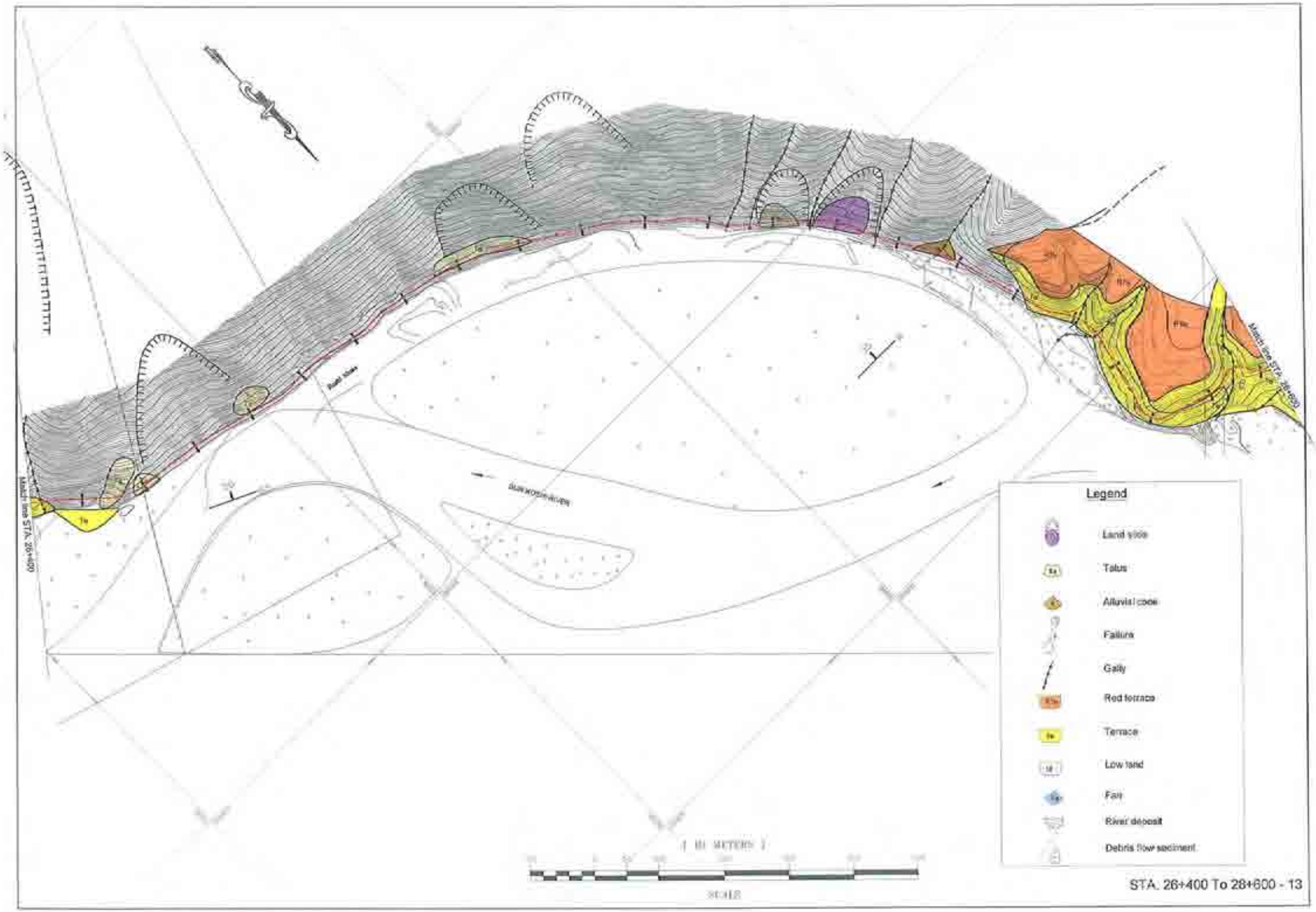

Legend
Land slide
Talus
Alluvial cone
Failure
Gully
Red terrace
Terrace
Low land
Fan
River deposit
Debris flow sediment
SCALE
STA. 14+600 To 16+900 - 08


Legend
Land slide
Talus
Alluvial cone
Failure
Gully
Rock terrace
Terrace
Low land
Fan
River deposit
Debris flow sediment
Main line STA. 16+900
Main line STA. 19+700
SUN KOSHI RIVER
STA. 16+900 To 19+700 - 09

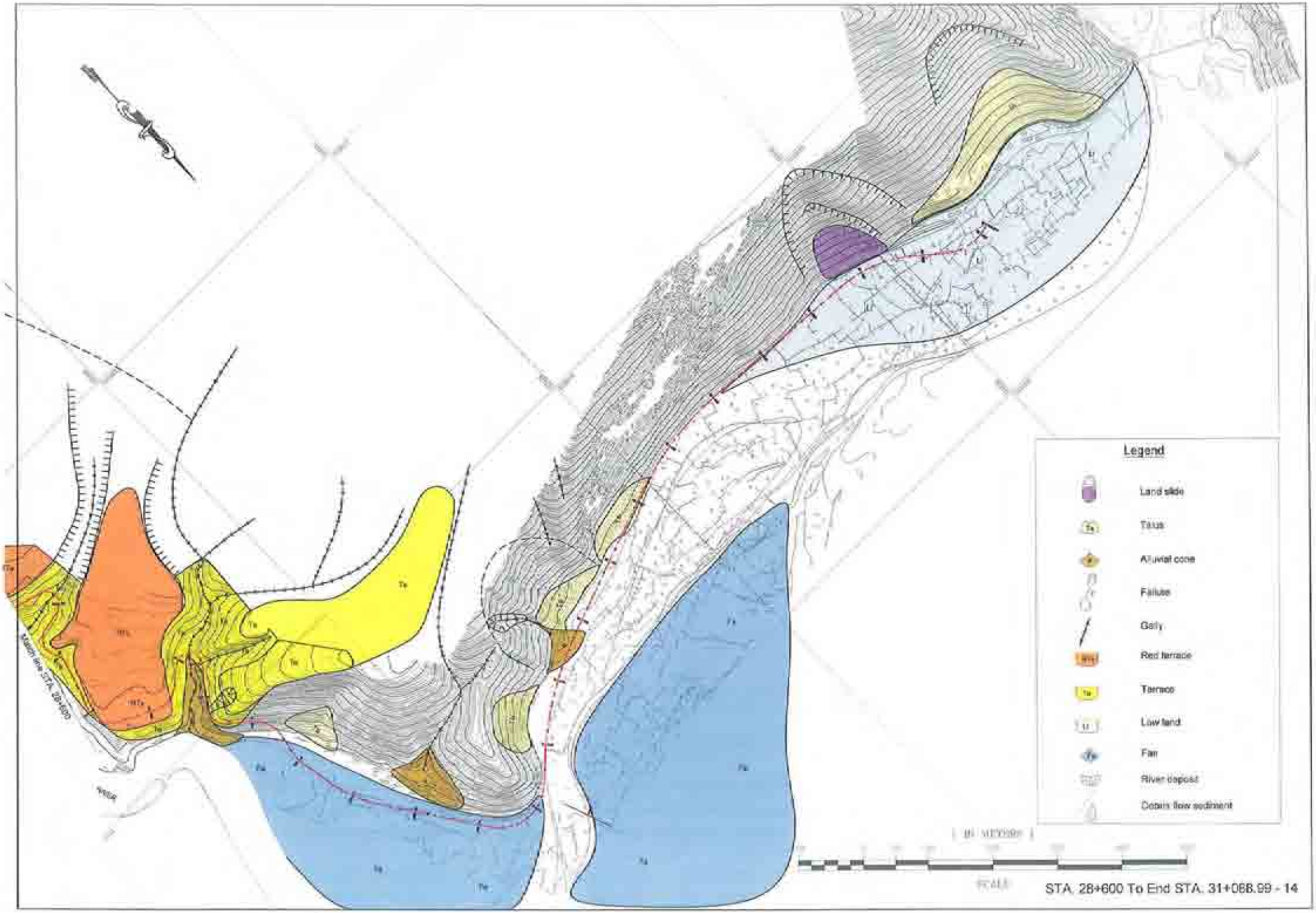

Match line STA. 19+700
Match line STA. 21+700
Legend
Land slide
Talus
Alluvial cone
Failure
Gully
Red terrace
Terrace
Low land
Fan
River deposit
Debris flow sediment
STA. 19+700 To 21+700 - 10


Legend
Land slide
Talus
Alluvial cone
Failure
Gully
Red terrace
Terrace
Low land
Fan
River deposit
Debris flow sediment
(M METERS)
SCALE
STA. 21+700 To 24+000 - 11


Legend
Land slide
Talus
Alluvial cone
Fallue
Gully
Red terrace
Terrace
Low land
Fan
River deposit
Debris flow sediment
STA. 24+000 To 26+400 - 12



STA. 26+400 To 28+600 - 13


Legend
Land slide
Talus
Alluvial cone
Failute
Gully
Red terrace
Terrace
Low land
Fan
River deposit
Debris flow sediment
STA. 28+600 To End STA. 31+088.99 - 14

6-3 Aggregate Test

6-3 Aggregate Test Results

1) Sampling and Test Results

The following sampling and laboratory tests were conducted.

Table-1. Location of Specimen Sampling

No.	Location Name
1	Ghogsila khola (Section II)
2	Andheri Khola (Section II)
3	Kurkot (Sunkoshi Nadi)
4	Niguli Khola
5	Chainpur Khola
6	Gangate Khola
7	Nepalthok (Roshi Khola)
8	Ghyampe Khola (Section IV)

Table-2. Summary of test results for aggregate

Test Item	Specimen Sampling Location							
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
Grain Size Analysis	×	×	×	×	×	×	×	×
Bulk Specific Gravity Dry	○	○	○	○	○	○	○	○
Water Absorption	○	○	○	○	○	○	○	○
Bulk Density (Compacted)	○	○	○	○	○	○	○	○
Bulk Density (Non- Compacted)	○	○	○	○	○	○	○	○
Glay lumps	×	×	×	×	×	×	×	×
Soft Particles	○	○	○	○	○	○	○	○
% Finerthan 0.075mmSieve	×	×	×	×	×	×	×	×
Floating on a liquid having a gravity of 1.95	×	×	×	×	×	×	×	×
Organic Impurities	○	○	○	○	○	○	○	○
Abrasion Loss	○	○	○	○	○	○	○	○
Sodium Sulfate Soundness	○	○	○	○	○	○	○	○
Alkali-silica Reaction Restrain	○	○	○	○	○	○	○	○
Chloride Contents	○	○	○	○	○	○	○	○
Total Evaluation	No Good	No Good	No Good	No Good	No Good	No Good	No Good	No Good

Note: ○:OK, ×: Not OK

All total evaluation results are inconformity with specifications. All aggregate materials should be screening and sieving on site for concrete material.