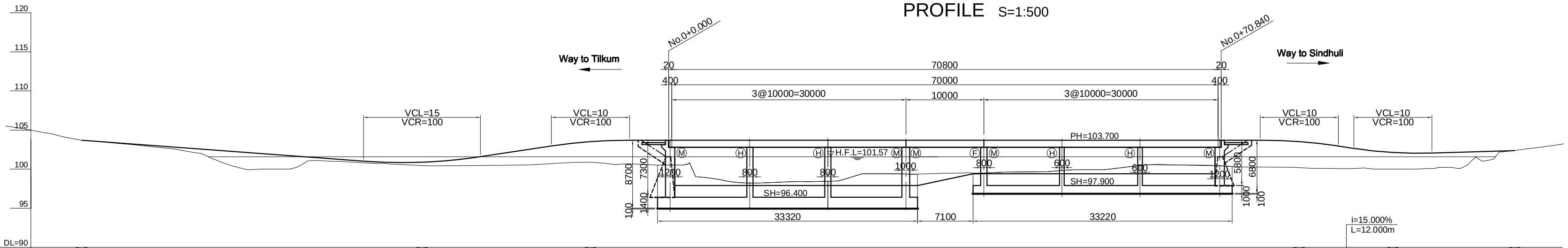
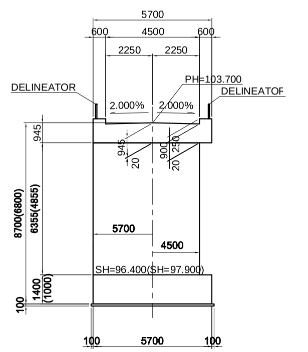
3-5 GENERAL VIEW OF GIRGHA KHOLA BRIDGE

PROFILE S=1:500

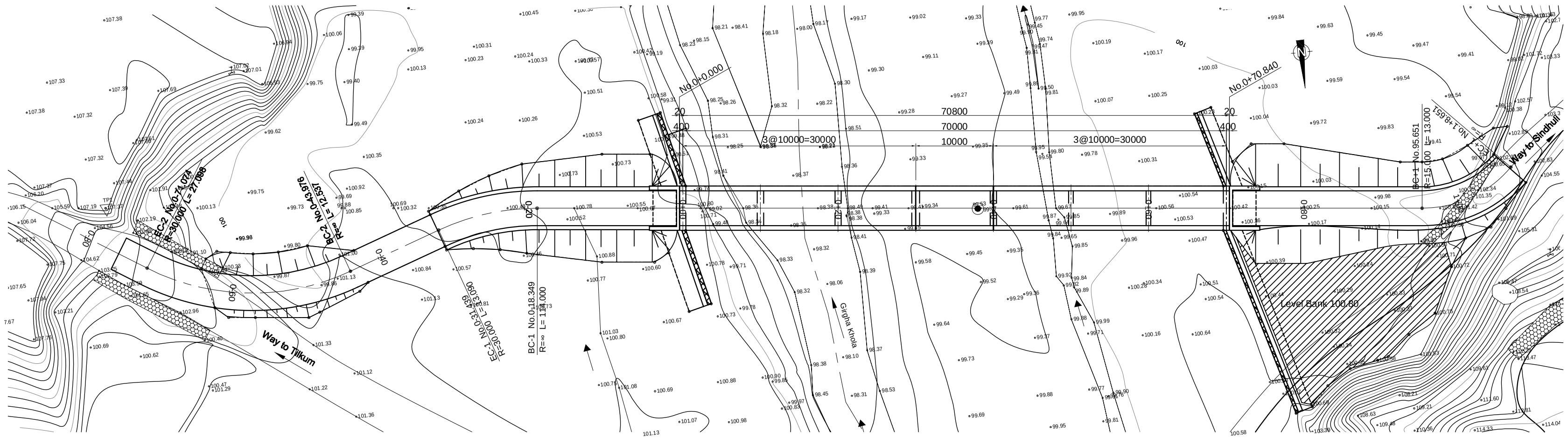


	0-75.200	0-71.074 EC-2	0-60.000	0+43.976 BC-2	0-40.000	0-31.600	0-31.439 EC-1	0-20.000	0-18.349 BC-1	0-10.000	0+0.000	0+20.000	0+40.000	0+60.000	0+70.840	0+80.000	0+80.840	0+92.840	0+95.651 BC+1	1+0.000	1+8.440	1+8.651 EC+1
GRADE	103.700	i=7.431% L=43.600m				100.460	i=15.000% L=21.600m			103.700	LEVEL L=90.840m					103.700		101.900	i=3.000% L=15.600m		102.368	
PROPOSED HEIGHT	103.700	103.393	102.570	101.379	101.084	100.881	101.127	102.500	102.698	103.513	103.700	103.700	103.700	103.700	103.700	103.570	103.513	102.125	102.027	102.115	102.368	
GROUND HEIGHT	103.70	103.34	102.02	101.05	100.86	100.45	100.45	100.50	100.52	100.67	100.50	98.44	99.49	100.40	100.42	100.25	100.21	100.00	100.00	100.23	102.39	102.42
CURVE ELEMENT	R=∞ L=4.126	R= 30.000 L= 27.098			R=∞ L=12.537	R= 30.000 L= 13.090				R=∞ L=114.000									R= 15.000 L= 13.000		R=∞	
SUPER ELEVATION	2.000%																					

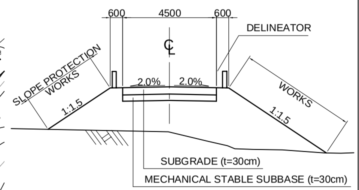
TYPICAL CROSS SECTION S=1:200



PLAN S=1:500



APPROACH ROAD S=1:200

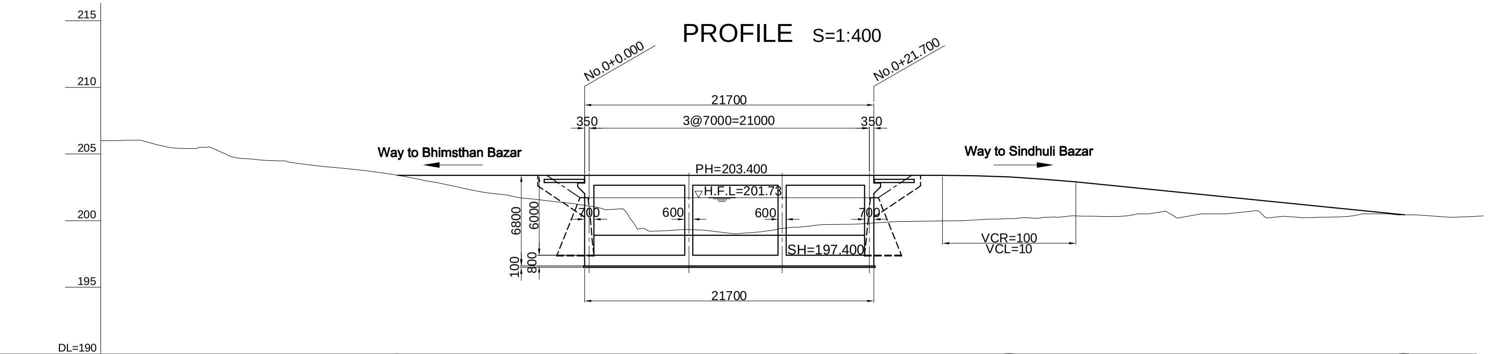


Note: The details around abutments including the lengths will be determined based on the actual site condition. The contractor has to prepare the shop drawings for the shape and dimension of embankment slopes, retaining walls and other structures necessary to complete the works based on the site condition for approval of the engineer. No claim except adjustment of quantities shall be made by this adjustment.

OUTLINE DESIGN OF RIVER CROSSING STRUCTURES	THE PROJECT FOR THE IMPROVEMENT OF COMMUNITY ACCESS IN NEPAL LOT - 10	DRAWING TITLE: 3-5 GENERAL VIEW OF GIRGHA KHOLA BRIDGE	PROVINCE	Sindhuli	SCALE: AS SHOWN	DRAWING NO: 31
			ROAD NAME	Sindhulimadi-Bhimsthan		
			SITE NO.	3-5		
			RIVER NAME	GIRGHA KHOLA		

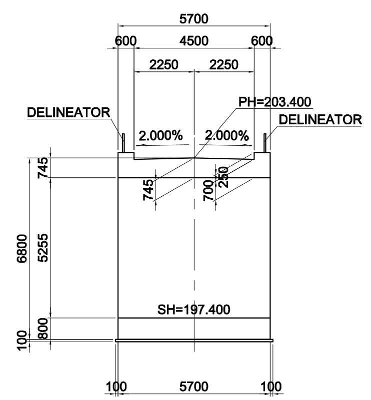
3-2 GENERAL VIEW OF BASERA KHOLA BRIDGE

PROFILE S=1:400

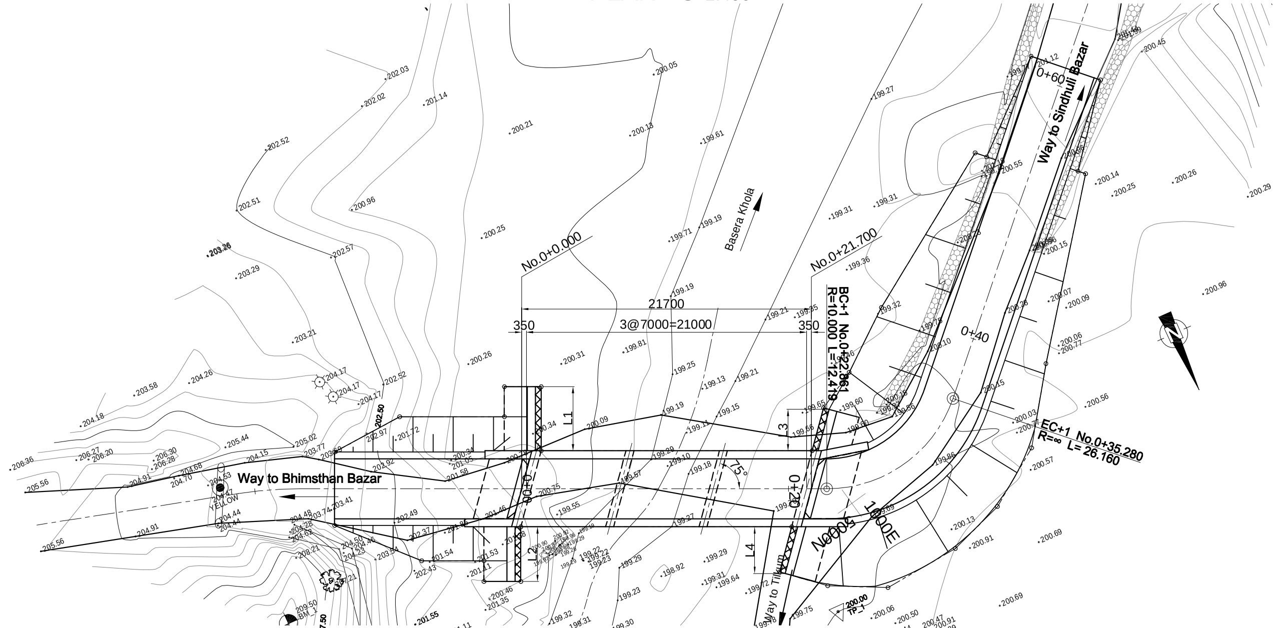


GRADE	203.400	LEVEL L=41.840m			203.400	i=-10.000% L=29.600m			200.440
PROPOSED HEIGHT	203.400	203.400	203.400	203.400	203.275	203.044	202.584	200.584	200.440
GROUND HEIGHT		201.15	199.73	199.89		200.28	200.31	200.50	200.50
STATION	0-14.016	0+0.000	0+20.000	BC+1	0+31.840	EC+1	0+40.000	0+60.000	0+61.440
CURVE ELEMENT	R=∞ L=32.861			R= 10.000 L= 12.419		R=∞ L=26.160			
SUPER ELEVATION	2.000%								

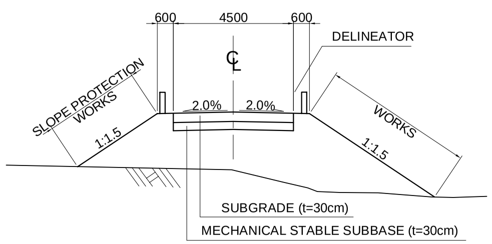
TYPICAL CROSS SECTION S=1:200



PLAN S=1:400



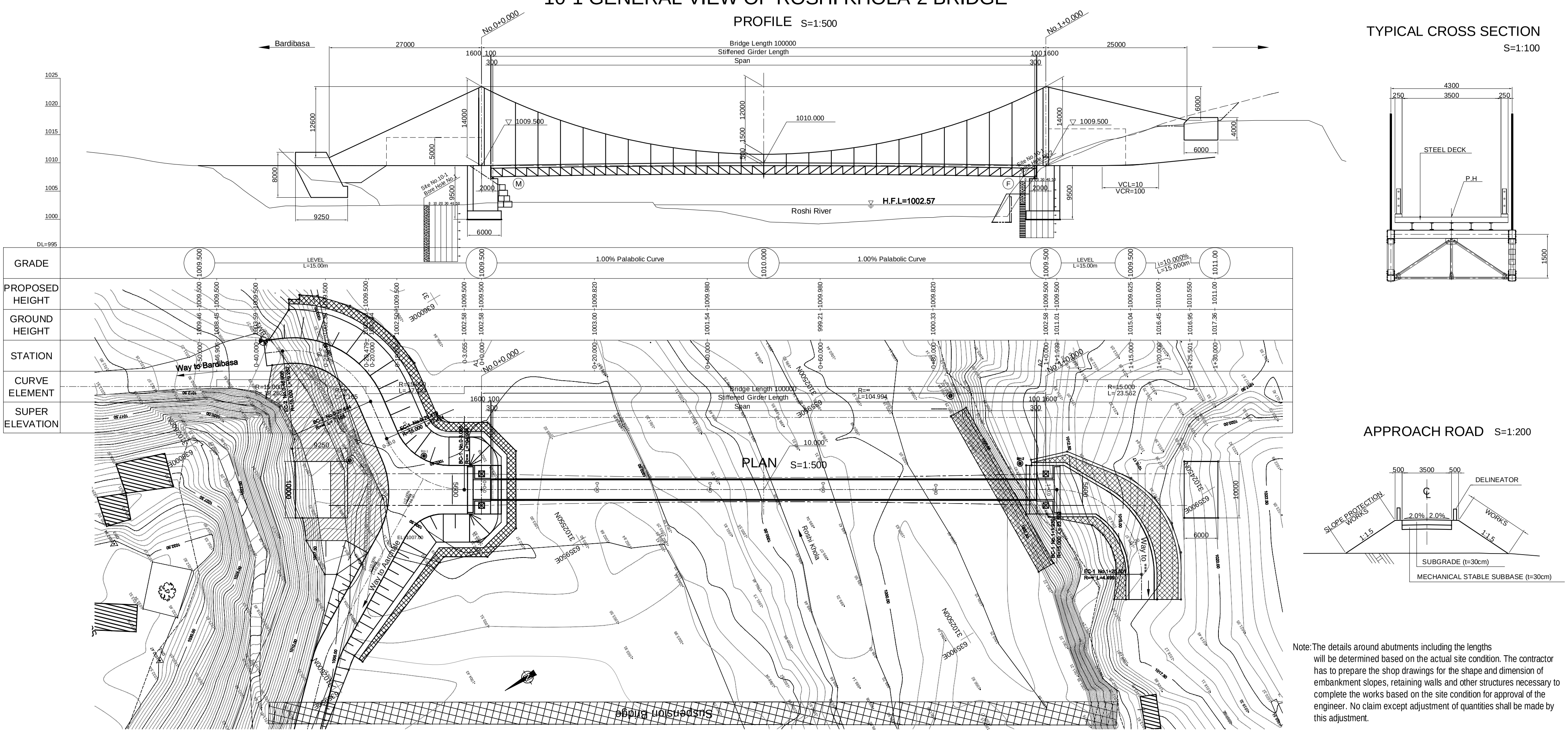
APPROACH ROAD S=1:200



Note: The details around abutments including the lengths of L1, L2, L3 and L4 will be determined based on the actual site condition. The contractor has to prepare the shop drawings for the shape and dimension of embankment slopes, retaining walls and other structures necessary to complete the works based on the site condition for approval of the engineer. No claim except adjustment of quantities shall be made by this adjustment.

OUTLINE DESIGN OF RIVER CROSSING STRUCTURES	THE PROJECT FOR THE IMPROVEMENT OF COMMUNITY ACCESS IN NEPAL LOT - 10	DRAWING TITLE: 3-2 GENERAL VIEW OF BASERA KHOLA BRIDGE	PROVINCE	Sindhuli	SCALE AS SHOWN	DRAWING NO: 32
			ROAD NAME	Sindhulimadi-Bhimsthan		
			SITE NO.	3-2		
			RIVER NAME	BASERA KHOLA		

10-1 GENERAL VIEW OF ROSHI KHOLA-2 BRIDGE

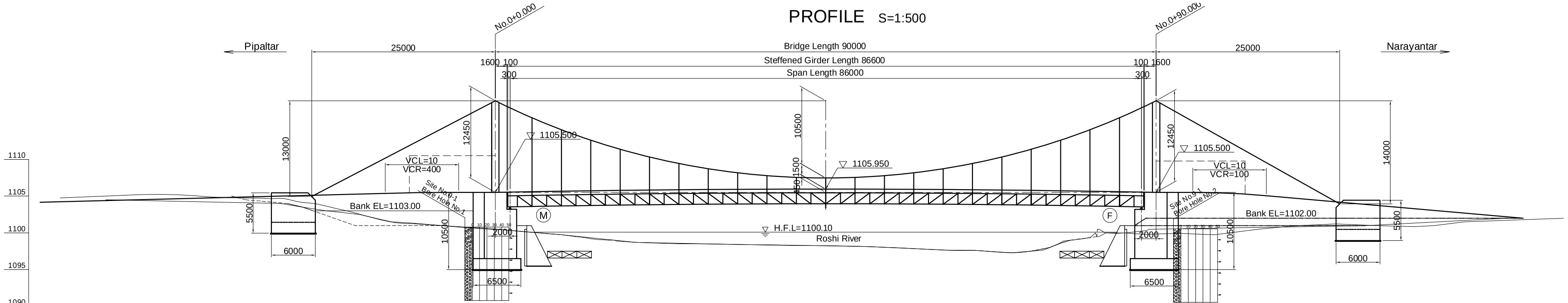


Note: The details around abutments including the lengths will be determined based on the actual site condition. The contractor has to prepare the shop drawings for the shape and dimension of embankment slopes, retaining walls and other structures necessary to complete the works based on the site condition for approval of the engineer. No claim except adjustment of quantities shall be made by this adjustment.

OUTLINE DESIGN OF RIVER CROSSING STRUCTURES	THE PROJECT FOR THE IMPROVEMENT OF COMMUNITY ACCESS IN NEPAL LOT - 11	DRAWING TITLE: 10-1 GENERAL VIEW OF ROSHI KHOLA-2 BRIDGE	PROVINCE	Kavrepalanchowk	SCALE	DRAWING NO:
			ROAD NAME	Katunjebesi-Bankhu	AS SHOWN	33
			SITE NO.	10-1		
			RIVER NAME	ROSHI KHOLA-2		

9-1 GENERAL VIEW OF ROSHI KHOLA-1 BRIDGE

PROFILE S=1:500



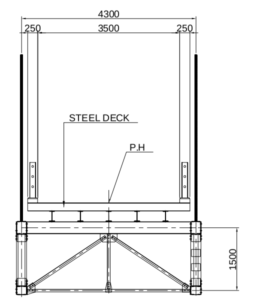
GRADE: I=2.558%, L=52.000m; LEVEL L=10.00m (1105.500 – 1105.500); 1.00% Palabolic Curve; LEVEL L=10.00m (1105.500 – 1105.500); I=8.750%, L=40.00m; 1104.170; 1102.000

STATION	PROPOSED HEIGHT	GROUND HEIGHT
0-62.000	1104.170	
0-60.280	1104.214	
0-44.572	1104.616	1105.24
0-21.876	1005.196	1103.37
0-11.843	1105.440	1101.30
0-10.000	1105.468	1101.17
0- 1.810	1105.500	1100.67
A1 0+0.000	1105.500	1100.51
0+20.000	1105.811	1098.54
0+40.000	1105.944	1098.31
0+45.000	1105.950	1098.24
0+60.000	1105.900	1097.72
0+80.000	1105.678	1099.51
A2 0+90.000	1105.500	1100.52
0+92.213	1105.500	1100.56
1+0.000	1105.391	1100.67
1+3.055	1105.216	1100.74
1+13.897	1104.284	1100.92
1+20.000	1103.750	1101.08
1+24.314	1103.373	1101.29
1+33.247	1102.591	1101.76
1+40.000	1102.000	

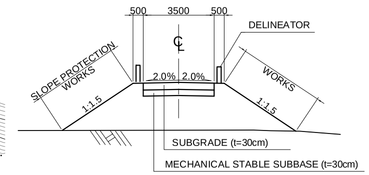
CURVE ELEMENT: R=∞ L=1.720; R=20.000 L=15.708; R=∞ L=22.696; R=10.000 L=10.033; R=10.000 L=10.033; R=∞ L= 94.023; R=10.000 L=10.842; R=10.000 L=10.842; R=∞ L=10.417; R=15.000 L=8.933; R=∞ L=6.753

SUPER ELEVATION

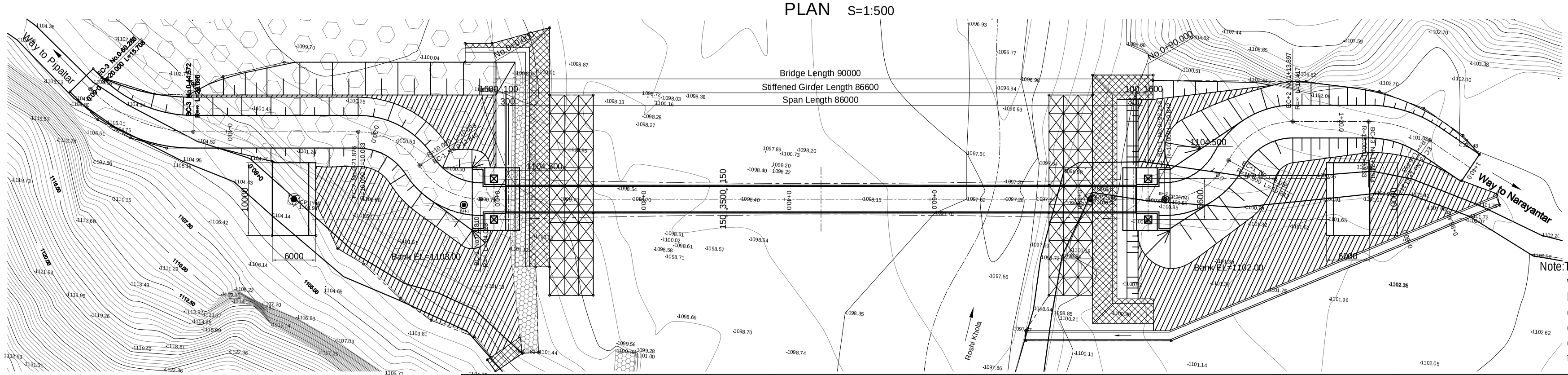
TYPICAL CROSS SECTION S=1:100



APPROACH ROAD S=1:200



PLAN S=1:500

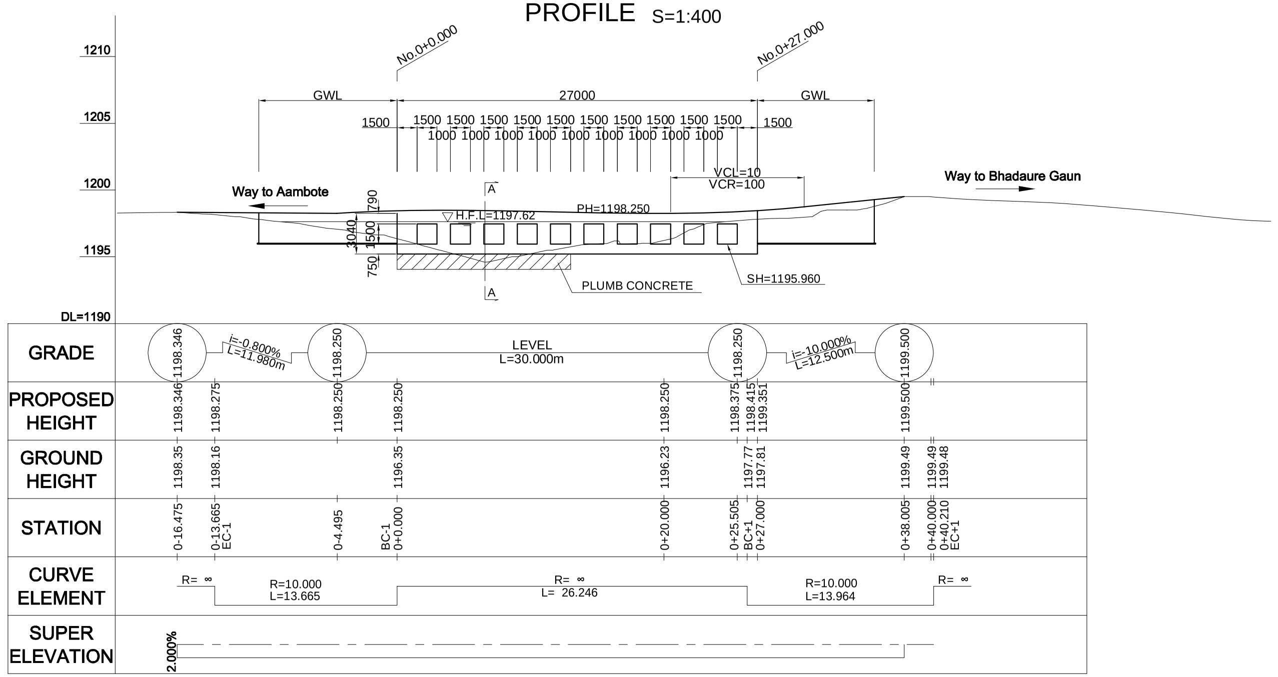


Note: The details around abutments including the lengths will be determined based on the actual site condition. The contractor has to prepare the shop drawings for the shape and dimension of embankment slopes, retaining walls and other structures necessary to complete the works based on the site condition for approval of the engineer. No claim except adjustment of quantities shall be made by this adjustment.

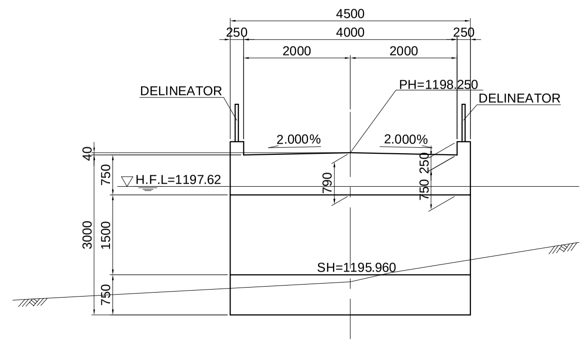
OUTLINE DESIGN OF RIVER CROSSING STRUCTURES	THE PROJECT FOR THE IMPROVEMENT OF COMMUNITY ACCESS IN NEPAL LOT - 12	DRAWING TITLE: 9-1 GENERAL VIEW OF ROSHI KHOLA-1 BRIDGE	PROVINCE	Kavrepalanchowk	SCALE: AS SHOWN	DRAWING NO: 34
			ROAD NAME	Kavrebhanjyang-Dapcha-Kakare		
			SITE NO.	9-1		
			RIVER NAME	ROSHI KHOLA-1		

9-2 GENERAL VIEW OF ANDHERI KHOLA BRIDGE

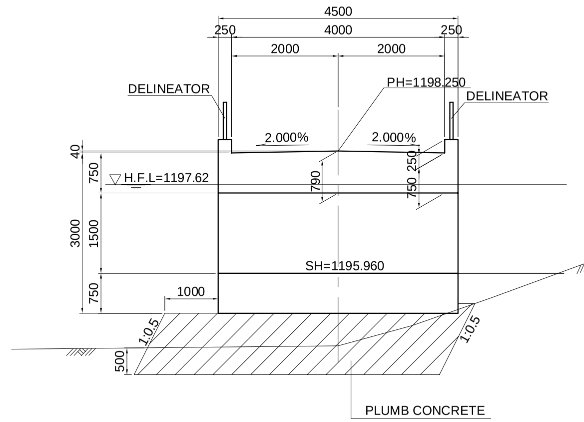
PROFILE S=1:400



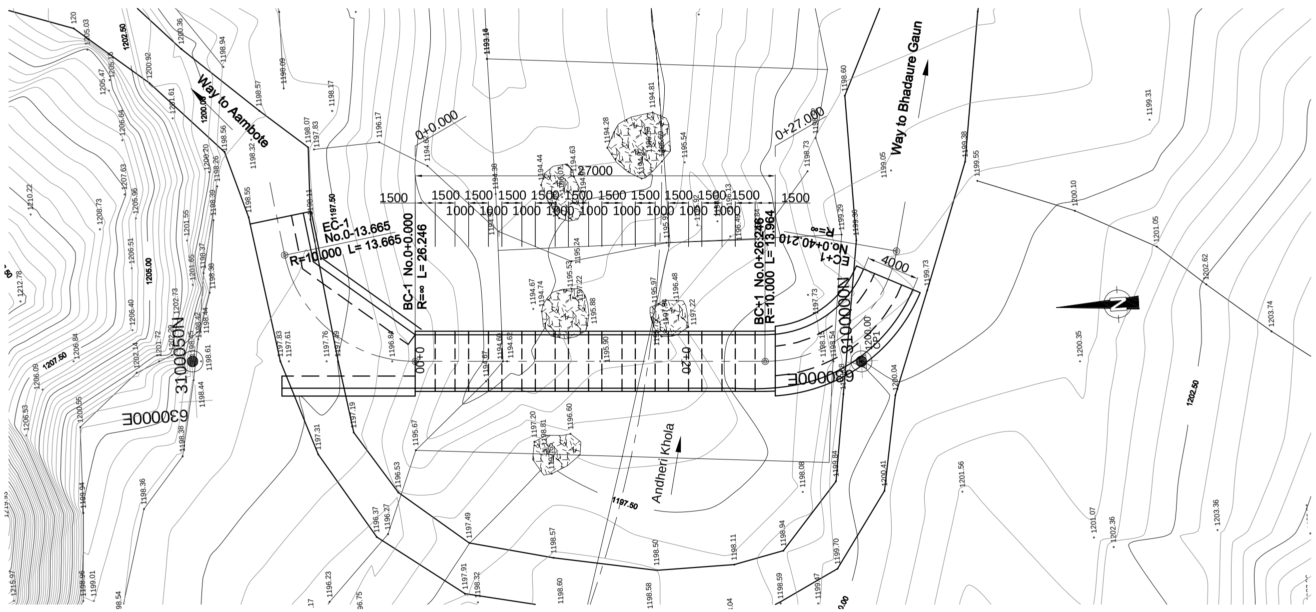
TYPICAL CROSS SECTION S=1:100



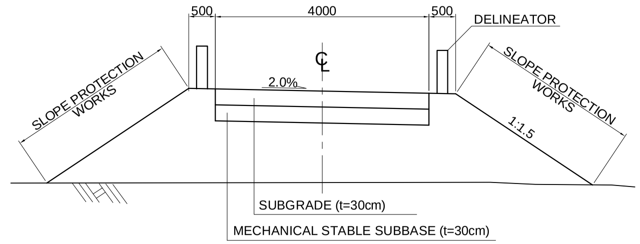
A-A



PLAN S=1:400



APPROACH ROAD S=1:100



Note:The details around abutments including the lengths will be determined based on the actual site condition. The contractor has to prepare the shop drawings for the shape and dimension of embankment slopes, retaining walls and other structures necessary to complete the works based on the site condition for approval of the engineer. No claim except adjustment of quantities shall be made by this adjustment.

OUTLINE DESIGN OF RIVER CROSSING STRUCTURES	THE PROJECT FOR THE IMPROVEMENT OF COMMUNITY ACCESS IN NEPAL LOT - 12	DRAWING TITLE: 9-2 GENERAL VIEW OF ANDHERI KHOLA BRIDGE	PROVINCE	Kavrepalanchowk	SCALE: AS SHOWN	DRAWING NO: 35
			ROAD NAME	Kavrebhanjyang-Dapcha-Kakare		
			SITE NO.	9-2		
			RIVER NAME	ANDHERI KHOLA		

８．　水文解析結果（要約）

HYDROLOGICAL STUDY

1. Study Area

The study area covers the catchments of rivers which cross the 11 community access rural roads of 5 districts (Sindhupalchowk, Kavrepalanchowk, Sindhuli, Ramechhap and Mahottari). Hence, the study area covers some parts of catchments of Indrawati River in Sindhupalchowk; catchments of Rosi Khola and Sunkoshi River in Kavrepalanchowk; catchments of Marin Khola and Kamala River in Sindhuli; catchments of Khimti Khola, Likhu Khola and Tamakoshi River in Ramechhap; and catchments of Dholan Khola, Hardi Khola and Maraha Khola in Mahottari.

2. Climate

2.1 Climates of Nepal

Climate is the collected weather patterns of an area. The climate of Nepal differs drastically in different places and seasons, it has cosmopolitan climates. In general, Nepal has cold and dry winter, hot and dry summer, and heavy monsoon periods. Globally most of the regions have four seasons, however, Nepal has six, they are: Spring or Vasant (Mid-March to Mid-May), Summer or Grishma (Mid-May to Mid-July), Monsoon or Varsa (Mid-July to Mid-September), Autumn or Sharad (Mid-September to Mid-November), Hemant (Mid-November to Mid-January) and Shishir (Mid-January to Mid-March). Further, Nepal has mainly five types of climates which are determined based on altitude ranges (Fig. 1). The climates found in Nepal are as mentioned below.

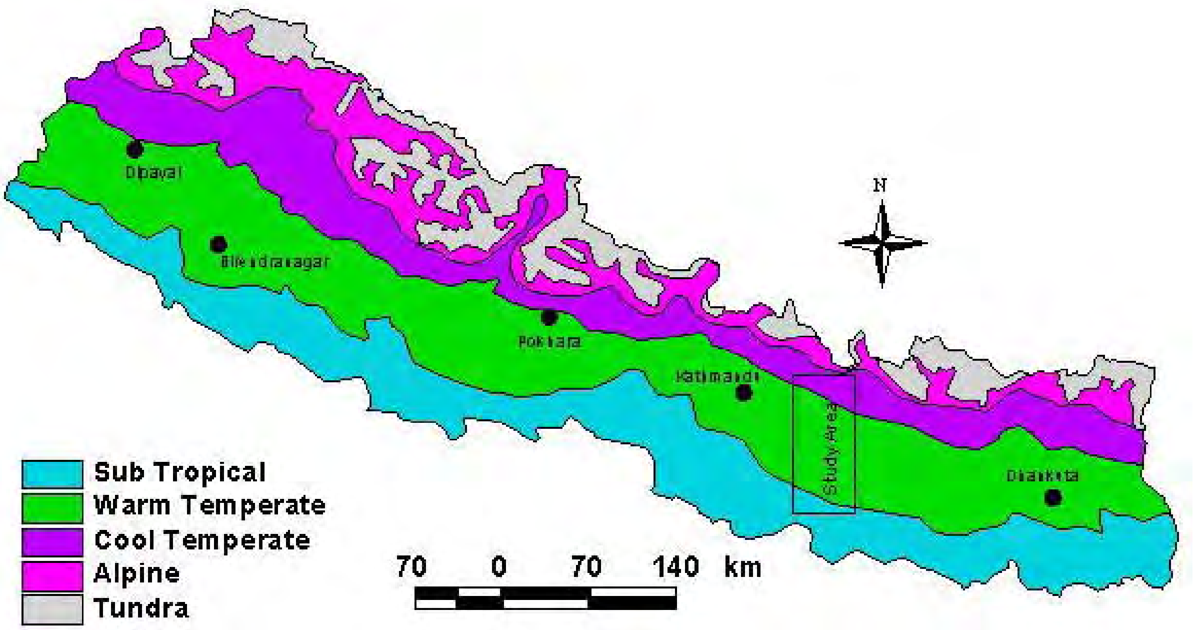


Fig. 1 Climatic Types in Nepal

<u>Tundra Climate:</u> This climate is found in the Himalayan region which falls above 5000 m from the mean sea level (MSL). The temperature in winter is quite less than the freezing point, while in summer it is slightly less than the freezing point. No vegetation is found in this climate.

Alpine Climate: This climate is prevailed in higher hilly region which falls in the range of 3300-5000 m from the MSL. The temperature in winter is less than the freezing point but in summer it ranges from 5-15 ^oC. Alpine forests are found in this climate.

Cool Temperate Climate: This climate is found in central hilly region between 2100-3300 m from the MSL. In winter, temperature is less than freezing point while in summer it ranges from 15-20 ^oC. Coniferous forests are found in this climate.

Warm Temperate Climate: This climate is found in lower hilly region and in the valley which ranges from 900-2100 m from MSL. In winter, temperature ranges from 0-18 ^oC while in summer it ranges from 17-30 ^oC. Deciduous forests are found in this climate.

Sub-Tropical Climate: This climate is found in the Mahabharat hills and terai which ranges below 900 m from the MSL. The temperature in winter ranges from 6-25 ^oC, while in summer it is 25-40 ^oC. Evergreen forests are found in this climate.

2. 2 Climatic Conditions of the Project Area

To get ideas on climatic conditions of the project area, monthly maximum and minimum air temperature records of Sindhuli Gadhi and Dhulikhel stations are analyzed and similarly, monthly rainfall records of Sindhuli Gadhi and Nepalthok stations are also analyzed.

2. 2.1 Air Temperature

The monthly maximum and minimum air temperatures during 1993-2005 of Sindhuli Gadhi station are analyzed. The highest value of average monthly maximum temperature of 31.7 ^oC is found in April. The lowest value of average monthly maximum temperature of 21.0 ^oC is found in January (Table 1 & Fig. 2).

Table 1 Monthly Maximum Air Temperature of Sindhuli Gadhi

Year	Monthly Maximum Temperature (^oC)											
	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 of 22.8 ^oC is found in July and August. The lowest value of average monthly minimum temperature of 7.2 ^oC is found in January (Table 2 & Fig. 2).

Table 2 Monthly Minimum Air Temperature of 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

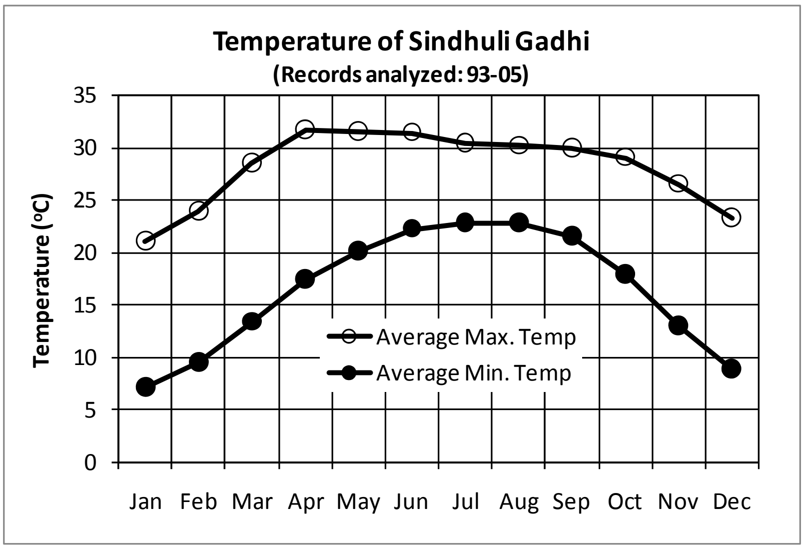


Fig. 2 Monthly Maximum and Minimum Temperature of Sindhuli Gadhi

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

Table 3 Monthly Maximum Air Temperature of 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 of 18.1 ^{o}C is found in July and August. The lowest value of average monthly minimum temperature of 3.4 ^{o}C is found in January (Table 4 & Fig. 3).

Table 4 Monthly Minimum Air Temperature of Dhulikhel

Year	Monthly Minimum Temperature (^{o}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

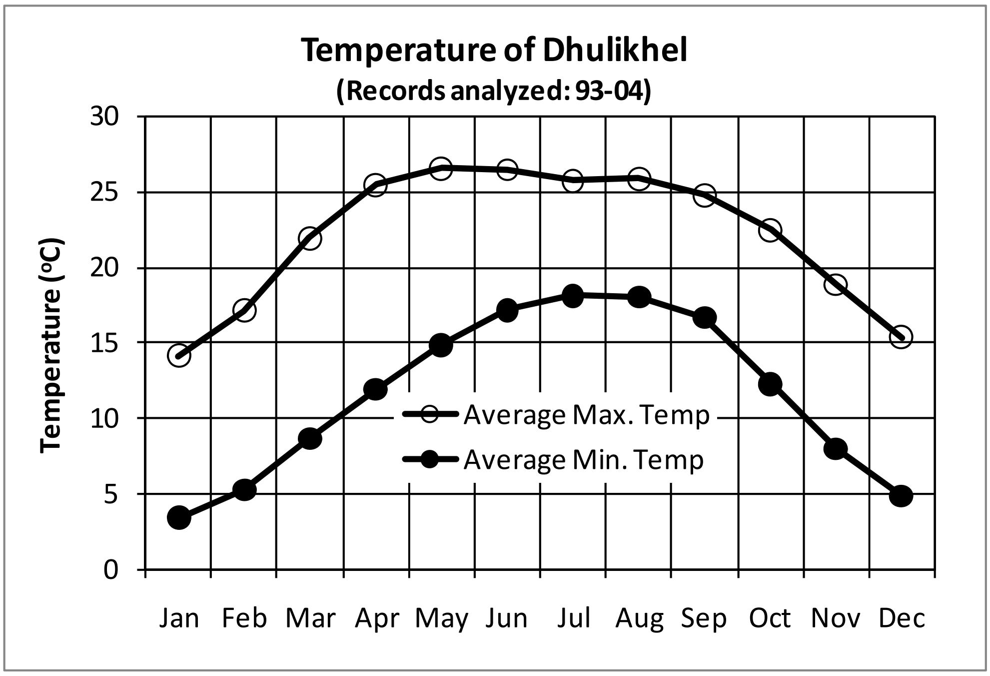


Fig. 3 Monthly Maximum and Minimum Temperature of Dhulikhel

2. 2.2 Rainfall

The monthly rainfalls records of 1993-2006 of Sindhuli Gadhi station are analyzed. The highest value of average monthly rainfall of 745.8 mm is found in July. The lowest value of average monthly rainfall of 7.4 mm is found in December. The average annual rainfall is 2613 mm (Table 5 & Fig. 4).

Table 5 Monthly Rainfall of 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 records of 1990-2004 of Nepalthok station are also analyzed. The highest value of average monthly rainfall of 296.3 mm is found in July. The lowest value of average monthly rainfall of 9.0 mm is found in November. The average annual rainfall is 887 mm (Table 6 & Fig. 4).

Table 6 Monthly Rainfall of 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

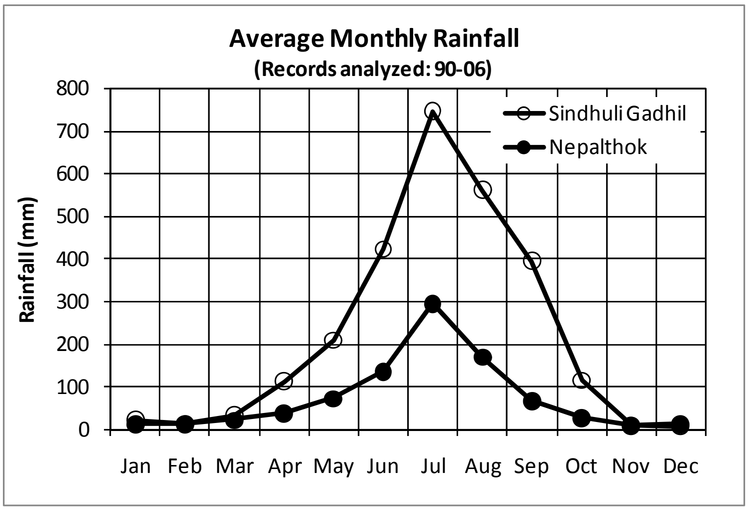


Fig. 4 Average Monthly Rainfalls in Project Area

3. Rosi Khola Discharge Analysis

Rosi Khola and its basin area is shown in Fig. 5. The annual maximum daily discharges of Rosi Khola at Panauti were analyzed during detailed design preparation of Section-4 of Sindhuli Road. The estimated design discharge of Rosi Khola at Panauti is presented in Table 7. The design specific discharges of Rosi Khola at Panauti are: 1.65 $m^3/s/km^2$ (25-year) and 1.93 $m^3/s/km^2$ (50-year). The design discharges of Rosi Khola at bridges sites are determined based on the design specific discharge at Panauti and are presented in Table 8.

Table 7 Design Discharge of Rosi Khola

Item	**Return period (year)**					
	2	**3**	**5**	**10**	**25**	**50**
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

Source: Detailed Design Report of Section – 4 of Sindhuli Road & Calculations

Table 8 Design Discharges of Rosi Khola at Bridges Sites

Site No.	**River**	**Basin Area at Bridge Site (km^2)**	**25-year Specific Discharge**		**25-year Q at Bridge Site (m^3/s)**	**50-year Specific Discharge**		**50-year Q at Bridge Site (m^3/s)**
			Station	**Sp. Q. ($m^3/s/km^2$)**		**Station**	**Sp. Q. ($m^3/s/km^2$)**	
9-1	Rosi	357.28	Panauti	1.65	590	Panauti	1.93	690
10-1	Rosi	392			647			757
11-3	Rosi	545			899			1052

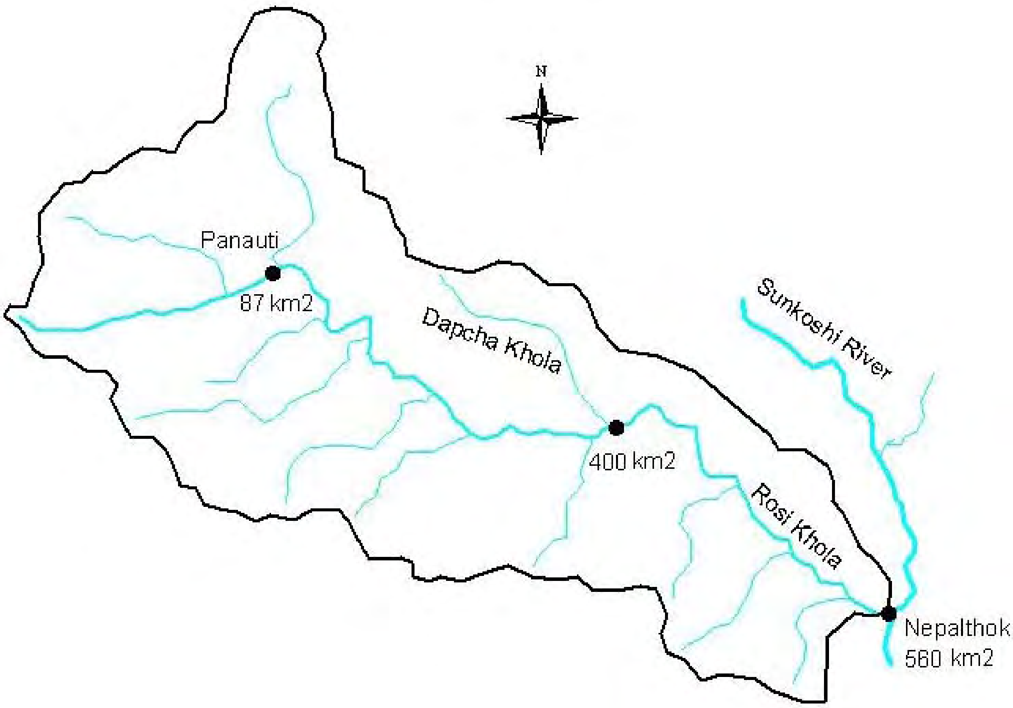


Fig. 5 Rosi Khola River Basin

4. Frequency Analysis of Maximum Daily Rainfall

The frequency of annual maximum daily rainfall of stations like Sindhuli Gadhi, Nepalthok, Hariharpurgadhi, Dolalalghat, Pachuwarghat, Dhap, Melung, Manthali, Bahuntilpung, Tulsi, Chisapani and Gaushala are analyzed.

The most commonly used Lognormal (LN) distribution function is employed for frequency analysis of the annual maximum daily rainfall records. 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

For reference the frequency analysis of annual maximum daily rainfall of Sindhuli Gadhi station is presented below:

<u>Sindhuli Gadhi Station</u>

The annual maximum daily rainfall records of 1956-2007 of the Sindhuli Gadhi station are analyzed to determine the design daily rainfall of different return period levels. The time series of annual maximum daily rainfalls of Sindhuli Gadhi station are presented in Figure 6 and Table 9.

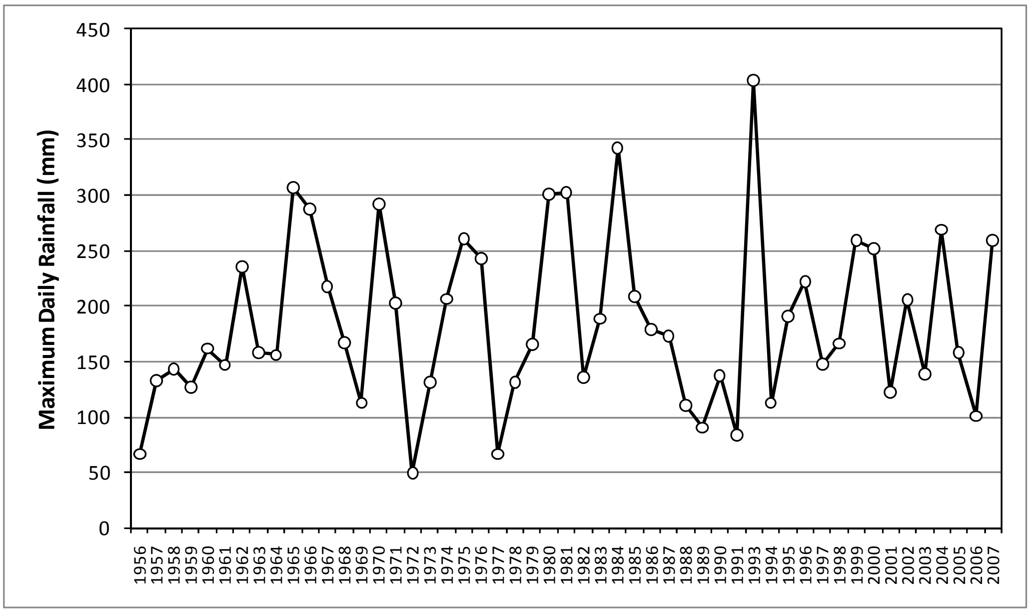


Fig. 6 Maximum Daily Rainfall at Sindhuli Gadhi

Table 9 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 frequency of annual maximum daily rainfall records of 1956-2007 are analyzed employing the Lognormal (LN) distribution function (Fig. 7). The frequency analysis shows, the design rainfalls of 3, 5, 10, 25 and 50-year return periods are 206, 245, 300, 368 and 423 mm, respectively (Table 10).

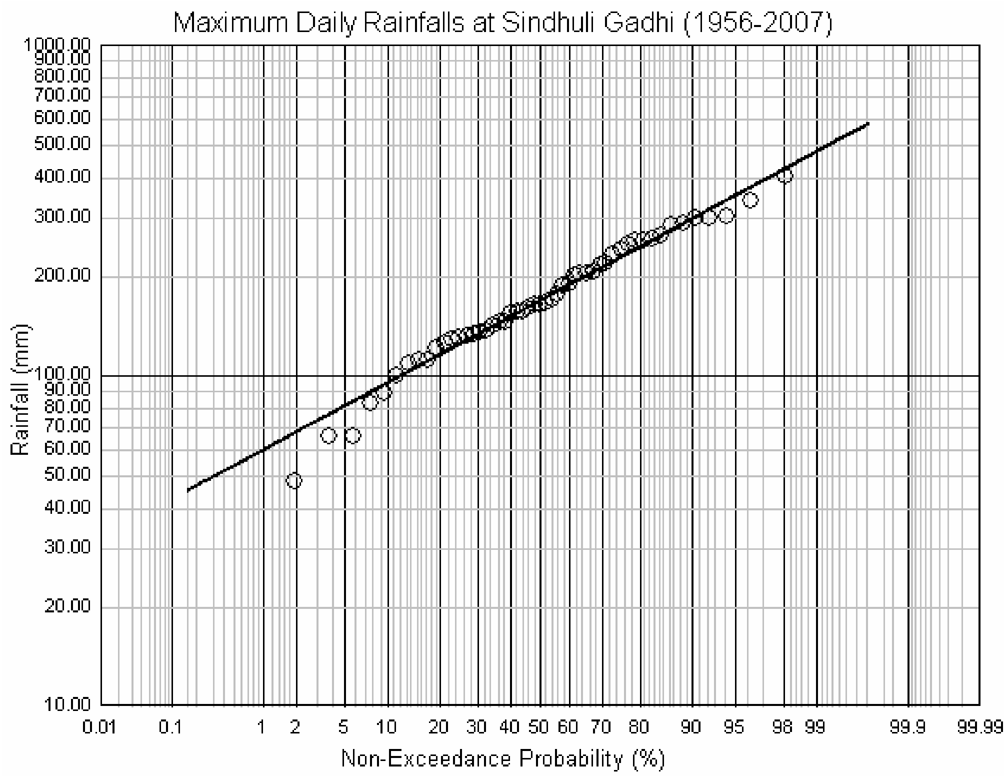


Fig. 7 Lognormal (LN) Distribution Fitting of Sindhuli Gadhi's Maximum Rainfalls

Table 10 Design Daily Rainfall of Sindhuli Gadhi

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

5. Isohyets of Design Daily Rainfalls of the Project Area

The isohyets of 50-year daily rainfall of the project area has been developed analyzing the frequency of the maximum annual daily rainfalls data of 21 stations located in and around the project area (Fig. 8). The isohyets show that two heavy rainfall pockets areas are prevailed in the project area. The first heavy rainfall pocket area is Hariharpur Gadhi which has 50-year daily rainfall of 475 mm. The second heavy rainfall pocket area is Sindhuli Gadhi which has 50-year daily rainfall of 423 mm (Table 11). Similarly, Pachuwarghat and Dolalghat are identified as the lowest rainfall pocket areas with 50-year daily rainfall of 124 mm and 134 mm, respectively. The developed isohyets of 50-year daily rainfall of the project area provide ideas on rainfall distributions in the basins of the rivers.

Table 11 Design 50-year Daily Rainfall of Stations

S. N.	Station No.	Location	District	Latitude (N)	Longitude (E)	Elevation (m)	50-year Daily Rainfall (mm)
1	1006	Gumthang	Sindhpalchowk	27°52’	85°52’	2000	215
2	1008	Nawalpur	Sindhupalchowk	27°48’	85°37’	1592	154
3	1009	Chautara	Sindhpalchowk	27°47’	85°43’	1660	145
4	1016	Sarmathang	Sindhpalchowk	27°57’	85°36’	2625	198
5	1017	Dubachaur	Sindhpalchowk	27°52’	85°34’	1550	144
6	1018	Bahunepati	Sindhpalchowk	27°47’	85°34’	845	147
7	1023	Dolalghat	Kavrepalanchowk	27°38’	85°43’	710	134
8	1024	Dhulikhel	Kavrepalanchowk	27°37’	85°33’	1552	177
9	1025	Dhap	Sindhupalchowk	27°55’	85°38’	1240	157
10	1027	Bahrabise	Sindhupalchowk	27°47’	85°54’	1220	183
11	1028	Pachuwarghat	Kavrepalanchowk	27°34’	85°45’	633	124
12	1049	Panauti	Kavrepalanchowk	27°35’	85°31’	1517	175
13	1104	Melung	Dolakha	27°31’	86°03’	1536	172
14	1107	Sindhuligadhi	Sindhuli	27°17’	85°58’	1463	423
15	1108	Bahuntilpung	Sindhuli	27°11’	86°10’	1417	327
16	1110	Tulsi	Dhanusa	27°02’	85°55’	457	289
17	1112	Chisapani	Dhanusa	26°55’	86°10’	165	279
18	1115	Nepalthok	Sindhuli	27°27’	85°49’	1098	218
19	1117	Hariharpurgadhi	Sindhuli	27°20’	85°30’	250	475
20	1119	Gaushala	Mahottari	26°53’	85°47’	200	184
21	1123	Manthali	Ramechhap	27°28’	86°05’	495	161

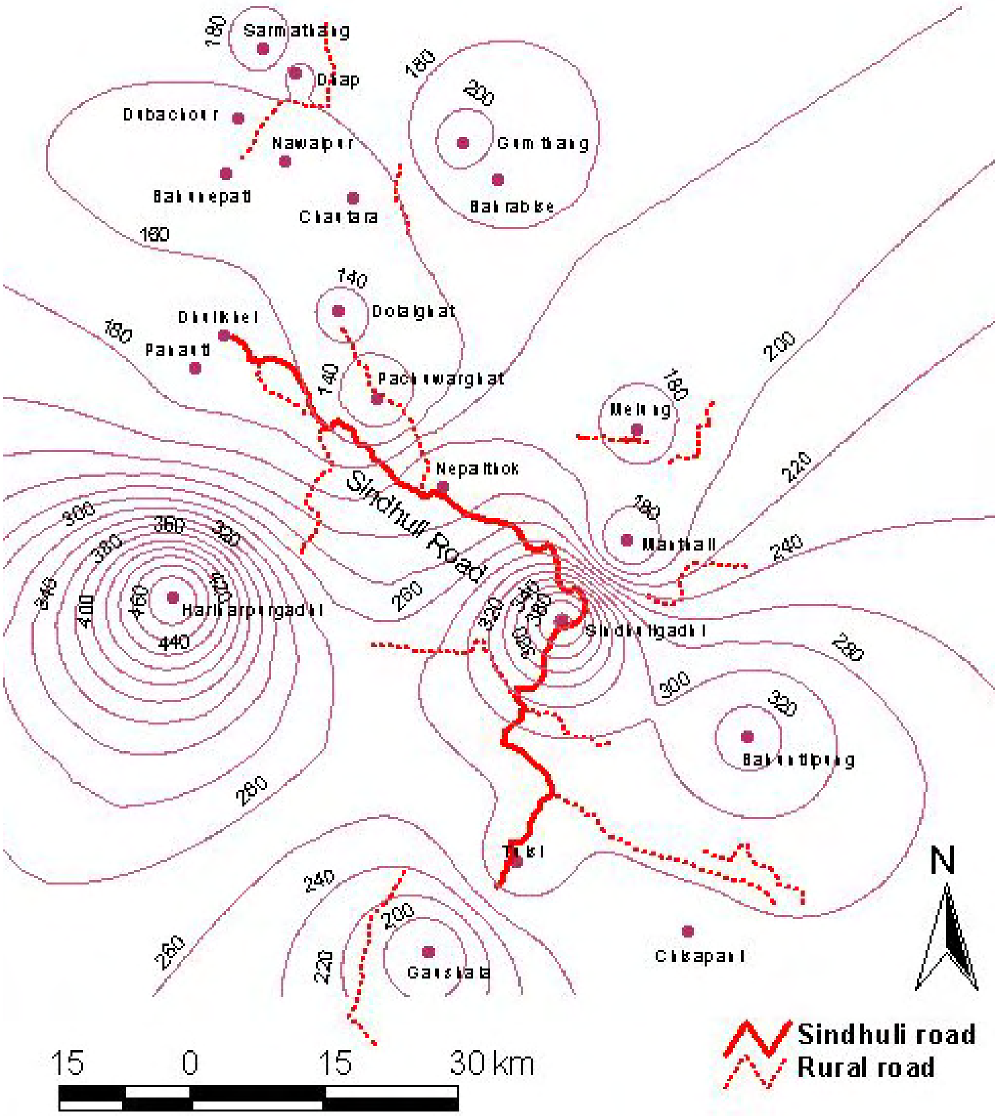


Fig. 8 Isohyets of 50-year Daily Rainfall of the Project Area

6. Frequency Analysis of Short Duration Rainfall

The short duration rainfall depths are necessary for peak discharge estimation in rivers. For this purpose, the design short duration rainfall depths of Kathmandu Airport station are used as reference. Frequency analysis of short duration rainfall depths at Kathmandu Airport station were carried out during the study of the Section II of Sindhuli Road. The 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 in Table 12.

Table 12 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.

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

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 are estimated using the above equation. Based on the estimated short duration rainfalls of various return period levels, the IDF-Curves of Sindhuli Gadhi are developed. The relation used for developing the IDF-Curve is as presented below.

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

Where,

I = Rainfall intensity (mm/hr)

t = Duration (minute)

a,b,n = Constants

Frequency analysis of short duration rainfall of 9 stations, namely, Sindhuli Gadhi, Nepalthok, Bahuntilpung, Tulsi, Chisapani, Melung, Manthali, Gaushala and Dhap are carried out. For reference, IDF-Curve and constants of Sindhuli Gadhi station are presented below. Summary table of the results of short duration rainfall analysis of all 9 stations is also presented.

Sindhuli Gadhi Station

Values of the constants of IDF-Curve determined for the station are presented in Table 13; and design rainfall depths of various durations are presented in Table 14. The developed IDF-Curve of Sindhuli Gadhi station is presented in Figure 9. The 50-year rainfall depth of 5, 10, 15, 30 and 60 minutes durations of the station are 69, 110, 139, 188 and 228 mm, respectively.

Table 13 IDF-Curve Constants of 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

Table 14 Design Rainfall Depths of Various Durations of 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

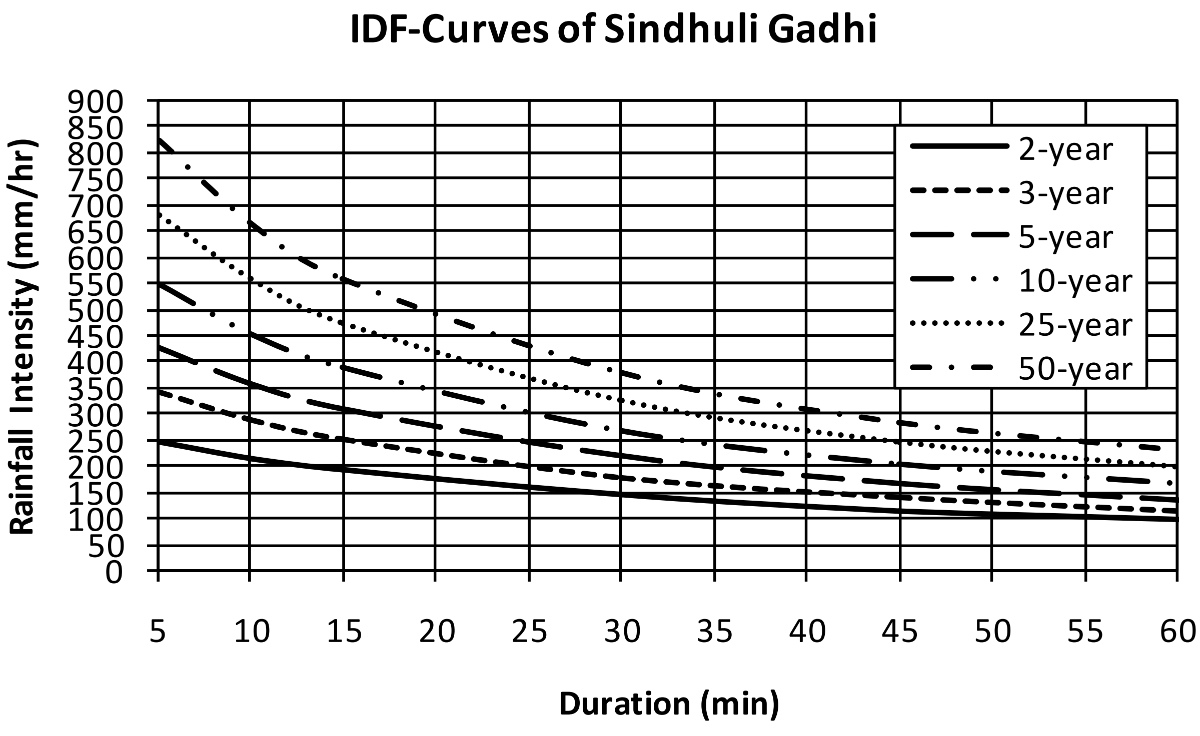


Fig. 9 The IDF-Curve of Sindhuli Gadhi Station

Summary of Short Duration Rainfall Analysis of Stations

Summary table for design rainfall depths of various durations are presented in Table 15. The 50-year rainfall depth of 5, 10, 15, 30 and 60 minutes durations of Sindhuli Gadhi station are 69, 110, 139, 188 and 228 mm, respectively. Similarly, the 50-year rainfall depth of 5, 10, 15, 30 and 60 minutes durations of Nepalthok station are 35, 57, 72, 97 and 118 mm, respectively. The 50-year rainfall depth of 5, 10, 15, 30 and 60 minutes durations of Melung station are 28, 45, 57, 76 and 93 mm, respectively. Further, the 50-year rainfall depth of 5, 10, 15, 30 and 60 minutes durations of Bahuntilpung station are 53, 85, 108, 145 and 177 mm, respectively. Moreover, the 50-year rainfall depths of various durations of Tulsi, Chisapani and Gaushala stations are also presented. The 50-year rainfall depth of 5, 10, 15, 30 and 60 minutes durations of Tulsi station are 47, 75, 95, 128 and 156 mm, respectively. Similarly, the 50-year rainfall depth of 5, 10, 15, 30 and 60 minutes durations of Chisapani station are 45, 73, 92, 124 and 151 mm, respectively. The 50-year rainfall depth of 5, 10, 15, 30 and 60 minutes durations of Gaushala station are 30, 48, 61, 82 and 99 mm, respectively. Further, the 50-year rainfall depth of 5, 10, 15, 30 and 60 minutes durations of Manthali station are 26, 42, 53, 72 and 87 mm, respectively. The 50-year rainfall depth of 5, 10, 15, 30 and 60 minutes durations of Dhap station are 25, 41, 52, 70 and 85 mm, respectively.

Table 15 Design Short Duration Rainfall Depths of the Stations

Station	**Duration**	**Return period (year)**					
		2	**3**	**5**	**10**	**25**	**50**
Sindhuli Gadhi	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
Nepalthok	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
Melung	24-hour Rainfall (mm)	72	86	102	124	151	172
	60-min Rainfall (mm)	40	47	56	68	82	93
	30-min Rainfall (mm)	30	37	45	55	67	76
	15-min Rainfall (mm)	20	26	32	40	48	57
	10-min Rainfall (mm)	15	20	24	31	38	45
	5-min Rainfall (mm)	9	12	15	19	23	28
Bahuntilpung	24-hour Rainfall (mm)	122	151	182	225	283	327
	60-min Rainfall (mm)	68	83	100	124	153	177
	30-min Rainfall (mm)	52	66	81	101	125	145
	15-min Rainfall (mm)	34	46	57	72	91	108
	10-min Rainfall (mm)	26	35	44	56	71	85
	5-min Rainfall (mm)	15	21	26	34	43	53
Tulsi	24-hour Rainfall (mm)	136	161	185	218	258	289
	60-min Rainfall (mm)	76	89	102	120	139	156
	30-min Rainfall (mm)	57	70	82	97	114	128
	15-min Rainfall (mm)	38	49	58	70	83	95
	10-min Rainfall (mm)	29	37	44	55	65	75
	5-min Rainfall (mm)	16	22	27	33	40	47
Chisapani	24-hour Rainfall (mm)	107	132	158	194	242	279
	60-min Rainfall (mm)	60	73	87	107	131	151
	30-min Rainfall (mm)	45	57	70	87	107	124
	15-min Rainfall (mm)	30	40	50	62	78	92
	10-min Rainfall (mm)	22	30	38	49	61	73

	5-min Rainfall (mm)	13	18	23	29	37	45
Gaushala	24-hour Rainfall (mm)	73	90	107	130	161	184
	60-min Rainfall (mm)	41	50	59	72	87	99
	30-min Rainfall (mm)	31	39	48	58	71	82
	15-min Rainfall (mm)	21	27	34	42	52	61
	10-min Rainfall (mm)	15	21	26	33	40	48
	5-min Rainfall (mm)	9	12	16	20	25	30
Manthali	24-hour Rainfall (mm)	80	93	106	124	146	161
	60-min Rainfall (mm)	45	51	58	68	79	87
	30-min Rainfall (mm)	34	40	47	55	64	72
	15-min Rainfall (mm)	23	28	33	40	47	53
	10-min Rainfall (mm)	17	21	25	31	37	42
	5-min Rainfall (mm)	10	13	15	19	22	26
Dhap	24-hour Rainfall (mm)	100	111	121	132	147	157
	60-min Rainfall (mm)	56	61	67	73	79	85
	30-min Rainfall (mm)	42	48	54	59	65	70
	15-min Rainfall (mm)	28	34	38	42	47	52
	10-min Rainfall (mm)	21	26	29	33	37	41
	5-min Rainfall (mm)	12	15	18	20	23	25

7. Estimation of Peak Discharge in the Rivers

The peak discharges in the rivers are estimated using Rational method. For this, at first, time of concentration of flow in rivers and then basin rainfall intensities are determined.

7.1 Time of Concentration of Flow

The time of concentration flow (equivalent to duration of design rainfall) is determined considering overland flow travel time and channel flow travel time of runoff.

Overland flow travel time:

The overland flow travel time of runoff is estimated using Kerby's equation. The retardance coefficients for different ground cover are presented in Table 16.

$$T_1 = 1.445 \times \left(\frac{n.L}{S^{0.5}} \right)^{0.467} \quad (4)$$

Where,

T_1 = Overland flow time (minutes)

n = Kerby's coefficient of roughness

L = Overland flow length (m)

S = Slope of ground surface

Table 16 Kerby's Retardance Coefficient

Ground Cover	Kerby's retardance coefficient (*n*)

Timberland with deep forest litter or dense grass	0.8
Deciduous timberland	0.6
Pasture or average grass	0.4
Poor grass, cultivated row crops of moderately rough bare soil	0.2
Smooth, packed bare soil	0.1
Smooth, impervious surface	0.02

<u>Channel flow travel time:</u>

After concentrating the runoff from the overland, runoff starts to flow in the channel. The channel flow travel time of runoff is estimated by given relation.

$$T_2 = \frac{L}{60 \times V} \quad (5)$$

Where,

T_2 = Channel flow time (minutes)

L = Stream length (m)

V = Flow velocity (m/s)

<u>Time of concentration:</u>

Finally, the time of concentration of runoff is estimated with summing up the overland flow travel time and channel flow travel time of the runoff.

$$T = T_1 + T_2 \quad (6)$$

Where,

T = Time of concentration (minutes)

T_1 = Overland flow time (minutes)

T_2 = Channel flow time (minutes)

7.2 Determination of Basin Rainfall Intensity of T-min Duration

The proximity analysis of the stations to the catchment area of a particular river is performed. Based on the percentage of basin area coverage by stations weight factors (W) are fixed for the stations. Further, rainfall intensities (I) of the stations for T-min (time of concentration) duration are determined based on the relation and constants of the IDF Curve. Basin rainfall intensities are determined from the points (stations) rainfall intensities. Using the weight factors and rainfall intensities of T-min duration of stations, the basin rainfall intensity of T-min duration is determined as shown below. The estimated basin rainfall intensities are presented in Table 17.

$$I_B = \sum_{i=1}^{n} I_i \cdot W_i \tag{7}$$

Where,

I_B	=	Basin rainfall intensity of T-min duration (mm/hr)
I_i	=	Rainfall intensity of i^{th} station of T-min duration (mm/hr)
W_i	=	Weight factor for i^{th} station
i	=	Index of station
n	=	Total number of stations considered

Table 17 Estimated Basin Rainfall Intensity of T-min Duration

Road	Site No.	River	River Length (m)	T-Time of Concentration (min)	Weight Factors of Stations	Basin Rainfall Intensity of T-min Duration (mm/hr)	
						25-year	50-year
Laxmaniya - Raghunathpur	1-1	Dholan	13710	99.18	0.7 (Gaushala), 0.3 (Tulsi)	69	77
Laxmaniya - Raghunathpur	1-2	Kantawa	1600	37.95	1.0 (Gaushala)	121	140
Sindhulimadhi - Kapilakot	2-1	Marin	26880	171.07	1.0 (Sindhuligadhi)	82	92
Sindhulimadhi - Kapilakot	2-4	Ancho	366	17.26	1.0 (Sindhuligadhi)	442	520
Sindhulimadhi - Kapilakot	2-5	Deojar	5250	50.22	1.0 (Sindhuligadhi)	228	261
Sindhulimadhi - Kapilakot	2-6	Maheshot	6880	56.62	1.0 (Sindhuligadhi)	209	238
Sindhulimadhi - Kapilakot	2-7	Chadauli	6230	53.01	1.0 (Sindhuligadhi)	219	251
Sindhulimadhi - Bhimsthan	3-1	Dhamile	8620	64.79	1.0 (Sindhuligadhi)	188	214
Sindhulimadhi - Bhimsthan	3-2	Besare	3400	39.12	1.0 (Sindhuligadhi)	273	314
Sindhulimadhi - Bhimsthan	3-5	Jirghaha	14950	103.29	0.7(Sindhuligadhi), 0.3 (Bahuntilpung)	119	135
Bhiman - Dhansari	4-43	Dhansari	5450	53.42	1.0 (Chisapani)	143	165
Dakaha - Dudhauli	5-1	Tamorni	5490	51.55	0.8 (Chisapani) 0.2 (Bahuntilpung)	152	175
Dakaha - Dudhauli	5-2	Thakur-1	22590	148.64	0.05 (Chisapani) 0.95 (Bahuntilpung)	71	82
Dakaha - Dudhauli	5-3	Thakur-2					
Dakaha - Dudhauli	5-4	Thakur-3					
Dakaha - Dudhauli	5-5	Thakur-4					
Dakaha - Dudhauli	5-7	Kuruwa	3250	36.46	0.8 (Chisapani) 0.2 (Bahuntilpung)	193	225

Dakaha - Dudhauli	5-8	Talko	4130	43.17	0.7 (Chisapani) 0.3 (Bahuntilpung)	175	203
Dakaha - Dudhauli	5-9	Pipre	2010	26.54	1.0 (Chisapani)	229	268
Dakaha - Dudhauli	5-11	Kolta	8870	67.68	0.1 (Chisapani) 0.9 (Bahuntilpung)	137	159
Ramechhap - Sangutar	6-1	Sukhajor	8000	64.67	1.0 (Manthali)	74	82
Betali - Khimti	8-1	Palati	3900	37.32	1.0 (Melung)	115	132
Betali - Khimti	8-2	Bohore	2000	24.06	1.0 (Melung)	152	175
Betali - Khimti	8-3	Haluwa	3800	39.01	1.0 (Melung)	112	128
Betali - Khimti	8-4	Pharpu	6300	49.24	1.0 (Melung)	95	108
Betali - Khimti	8-5	Chatwane	5300	48.13	1.0 (Melung)	96	110
Kavrebhanjyang - Dapcha	9-2	Ambote	9700	72.57	1.0 (Nepalthok)	89	101
Melamchi - Bhotang	13-1	Anderi	4300	40.63	1.0 (Dhap)	106	113
Melamchi - Bhotang	13-6	Khalte	5300	47.85	1.0 (Dhap)	94	101
Melamchi - Bhotang	13-8	Tipeni	8200	63.46	1.0 (Dhap)	76	81
Melamchi - Bhotang	13-10	Mahadev	9000	68.68	1.0 (Dhap)	71	76
Melamchi - Bhotang	13-14	Hadi	12900	89.57	1.0 (Dhap)	58	61

7.3 Determining Peak Discharges by Rational Method

The peak discharges of the rivers are estimated using Rational method. Basin area, basin rainfall intensity of T-min duration (equivalent to time of concentration of runoff) and runoff coefficient are used for estimating the peak discharges in the rivers. The relation used for peak discharges estimation in the rivers is as presented below. The estimated design discharges of rivers are presented in Table 18.

$$Q_P = \frac{C \cdot I_B \cdot A}{3.6} \qquad (8)$$

Where,

Q_P = Peak discharge of the river (m^3/s)

I_B = Basin rainfall intensity of T-min duration (mm/hr)

A = Basin area (km^2)

C = Runoff coefficient

<u>**Consideration of Runoff Coefficient:**</u>

Road Earthworks and Drainage Design Guideline of Japan Road Association recommends the values of Runoff Coefficient (*C*) as 0.8 for designing of cross drains and 0.4 for designing of side ditches along the roads for steep mountainous areas considering the importance of structures.

Table 18 Design Discharges of the Rivers from Rational Method

Site No.	River	Basin Area (km^2)	25-year			50-year		
			Basin Rainfall of T-min Duration (mm/hr)	Discharge with C=0.4 (m^3/s)	Discharge with C=0.8 (m^3/s)	Basin Rainfall of T-min Duration (mm/hr)	Discharge with C=0.4 (m^3/s)	Discharge with C=0.8 (m^3/s)
1-1	Dholan	11.84	69	90	180	77	102	204
1-2	Kantawa	0.93	121	13	25	140	14	29
2-1	Marin	138.79	82	1265	2529	92	1419	2837
2-4	Ancho	1.05	442	52	103	520	61	121
2-5	Deojar	10.66	228	270	540	261	309	618
2-6	Maheshot	12.03	209	279	559	238	318	636
2-7	Chadauli	14.64	219	356	712	251	408	817
3-1	Dhamile	14.18	188	296	592	214	337	674
3-2	Besare	3.50	273	106	212	314	122	244
3-5	Jirghaha	38.31	119	507	1013	135	576	1153
4-43	Dhansari	4.03	143	64	128	165	74	148
5-1	Tamorni	12.81	152	216	433	175	249	498
5-2	Thakur-1	101.17	71	803	1606	82	926	1851
5-3	Thakur-2	101.17						
5-4	Thakur-3	101.17						
5-5	Thakur-4	101.17						
5-7	Kuruwa	3.68	193	79	158	225	92	184
5-8	Talko	5.52	175	108	215	203	124	249
5-9	Pipre	1.06	229	27	54	268	32	63
5-11	Kolta	14.05	137	214	428	159	248	495
6-1	Sukhajor	22.78	74	187	375	82	208	415
8-1	Palati	6.42	115	82	164	132	94	188
8-2	Bohore	2.54	152	43	86	175	49	99
8-3	Haluwa	9.06	112	113	225	128	129	258
8-4	Pharpu	15.93	95	168	336	108	191	382
8-5	Chatwane	7.72	96	82	165	110	94	189
9-2	Ambote	17.13	89	169	339	101	192	384
13-1	Anderi	4.56	106	54	107	113	57	115
13-6	Khalte	10.27	94	107	215	101	115	231
13-8	Tipeni	16.28	76	137	275	81	147	293
13-10	Mahadev	15.51	71	122	245	76	131	262
13-14	Handi	48.75	58	314	628	61	330	661

8. Hydraulic Model

8.1 River Flow Simulation Model

The HEC-RAS, developed by Hydrologic Engineering Center, US Army Corps of Engineers, is a professional engineering software package for simulating flows 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 are generated using fully dynamic flow routing procedure. The continuity equation of conservation of mass is expressed as:

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q \qquad (9)$$

The momentum equation is:

$$\frac{\partial Q}{\partial t} + \frac{\partial (Q^2 / A)}{\partial x} + gA(\frac{\partial h}{dx} + S_f) = 0 \qquad (10)$$

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

$$S_f = \frac{n^2 \mid Q \mid Q}{A^2 R^{4/3}} \qquad (11)$$

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. 9 & 10) are solved with initial and boundary conditions to estimates one-dimensional river flows and water levels in the river system.

Cross-Section Data: Field surveys were carried out for the river cross-sections data required for river flow simulations. River cross-sections surveys were performed at three sections of the rivers, they are: (1) U-U Section (River section U/S of road centerline), (2) C-C Section (River section at road centerline), and (3) D-D Section (River section D/S of road centerline).

8.2 Scenarios of River Flow Simulations

Rivers flows are simulated considering three scenarios they are:

Scenario-1: River flow is simulated to determine high water level (HWL) when there is 25-year design flow in the river.

Scenario-2: River flow is simulated to determine high water level (HWL) when there is 50-year design flow in the river.

Scenario-3: River flow is simulated to determine high water level (HWL) considering debris flow in the river.

Peak discharge of large sized debris flow:

$$Q_{DF} = 4.7Q_P \qquad (12)$$

Peak discharge of normal debris flow:

$$Q_{DF} = (1+\beta)Q_P \qquad (13)$$

Where,

Q_{DF} = Peak discharge for debris flow (m^3/s)

Q_P = Peak discharge of 50-year normal flood flow (m^3/s)

The value of β is based on gradient of river as presented below:

Value	River Gradient
$\beta = 0.3$	> 1/20
$\beta = 0.2$	1/60 - 1/20

Further, nature of flow in the river is also determined by the gradient of the river as given below:

Type of Flow	River Gradient
Normal flood flow	1/100 – 1/60 (1^o)
Normal debris flow	1/60 (1^o) – 1/20 (3^o)
Stopping section of debris flow	1/20 (3^o) – 1/5 (10^o)
Large sized debris flow	1/5 (10^o) - 1/3 (15^o)

8.3 Flow Distributions in Branches of Thakur Khola

Thakur Khola is divided into 4 branches before it confluence with the Kamala River. The branches are named as: Thakur Khola-1 (5-2), Thakur Khola-2 (5-3), Thakur Khola-3 (5-4) and Thakur Khola-4 (5-5). The flow areas distribution pattern in the branches of Thakur Khola is analyzed to distribute total discharge coming from the catchment. For this, flow areas of the branches at water level 499.00 m are determined and flow distribution factors are established. The flow distribution factors of total flow coming from the catchment for branches 1, 2, 3 and 4 are 0.222, 0.321, 0.391 and 0.065, respectively (Table 19).

Table 19 Flow Distribution Factor of Thakur Khola

Site No.	River	Water Level (m)	Flow Area (m^2)	Flow Distribution Factor
5-2	Thakur Khola-1	499	137	0.222
5-3	Thakur Khola-2	499	198	0.321
5-4	Thakur Khola-3	499	241	0.391
5-5	Thakur Khola-4	499	40	0.065

The 25-year flow, 50-year Flow and debris flow of each branch of Thakur Khola are estimated and presented below (Table 20).

Table 20 Design Flow in the Branches of Thakur Khola

Item	Thakur Khola	Thakur Khola-1	Thakur Khola-2	Thakur Khola-3	Thakur Khola-4
25-year flow (m^3/s)	1606	357	516	628	104
50-year flow (m^3/s)	1851	411	594	724	120
Debris flow (m^3/s)	2221	493	713	868	144

8.4 Bridge Modeling

The bridge modeling module of HEC-RAS has been used for simulating flow through the bridge. The module uses the momentum balance method for simulation of the flow through bridge. The momentum method is based on performing a momentum balance from cross section downstream of bridge to cross section upstream of bridge. The bridge routines in HEC-RAS allow the modeler to analyze a bridge with several different methods without changing the bridge geometry. Hence, the bridge routines have ability to model different types of flows through the bridge.

8.5 Design HWLs in Rivers

The high water levels (HWLs) are estimated at 35 bridges sites in different rivers employing HEC-RAS river flow simulation model. The estimated HWLs at bridges sites of the rivers are presented in Table 21.

Table 21 Design HWLs in Rivers

Bridge No.	Bed Level (m)	Bed Slope (%)	Discharge (m^3/s)			HWL (m)		
			25-yr	50-yr	Debris Flow	25-yr	50-yr	Debris Flow
1-1	98.20	0.823	180	204	245	100.02	100.11	100.24
1-2	93.49	0.183	25	29	35	95.48	95.61	95.82
2-1	401.8	0.012	2529	2837	3404	406.44	406.73	407.22
2-4	694.38	6.45	103	121	568.7	695.58	695.69	696.94
2-5	491.67	3.96	540	618	741.6	495.86	496.07	496.36
2-6	197.07	1.99	559	636	763.2	199.56	199.67	199.85
2-7	197.8	1.17	712	817	980	200.77	200.96	201.24
3-1	498.2	1.85	592	674	809	500.75	500.87	501.06
3-2	199.1	0.463	212	244	293	201.57	201.73	201.96
3-5	98.36	1.27	1013	1153	1384	101.44	101.57	101.76
4-43	93.79	1.26	128	148	177.6	95.79	95.91	96.10
5-1	297.84	0.259	433	498	597.6	300.62	300.80	301.08
5-2	497.18	0.739	357	411	493	499.16	499.24	499.35
5-3	497.03	0.109	516	594	713	499.79	499.99	500.29
5-4	494.60	1.48	628	724	868	497.96	498.19	498.43
5-5	497.37	0.922	104	120	144	499.46	499.70	500.06
5-7	97.85	2.31	158	184	221	99.50	99.59	99.73
5-8	198.57	1.02	215	249	299	200.08	200.18	200.31
5-9	397.06	3.32	54	63	75.6	398.15	398.21	398.29
5-11	298.24	0.609	428	495	594	301.51	301.72	302.03
6-1	497.47	3.81	375	415	540	499.24	499.31	499.52
8-1	485.87	29.88	164	188	884	489.10	489.26	491.73
8-2	495.41	19.69	86	99	465	496.69	496.76	497.98
8-3	493.73	19.61	225	258	1213	497.00	497.12	499.09
8-4	495.31	8.76	336	382	1795	498.34	498.53	501.41
8-5	499.22	10.96	165	189	888	501.03	501.15	503.12
9-1	1097.28	1.53	590	690	828	1099.92	1100.10	1100.32
9-2	1194.61	6.71	339	384	1807	1197.49	1197.62	1199.78
10-1	998.95	1.10	647	757	908	1002.31	1002.57	1002.91
11-3	898.65	1.23	899	1052	1262	901.74	901.93	902.16
13-1	993.34	9.87	107	115	541	995.09	995.15	996.66
13-6	995.49	8.44	215	231	1086	997.01	997.07	998.83
13-8	1043.44	11.98	275	293	1377	1046.21	1046.29	1048.46
13-10	1098.39	6.19	245	262	1231	1100.37	1100.44	1102.68
13-14	1189.70	10.9	628	661	3107	1193.24	1193.31	1196.37

8.6 Simulation Result of Marin Khola Bridge (2-1)

For reference, the result of flow simulation through the proposed bridge of Marin Khola is presented. The river cross-sections presented in DOR report and proposed bridge design with total length of 141.96 m and 5 piers of 1.5 m width each at 23.6 m intervals are used for flow simulation through the bridge. The simulated figures of water surface profile and high water level (HWL) during 50-year design flow in the river are presented in Figures 10 and 11. The simulated 50-year design HWL of Marin Khola Bridge is 406.73 m.

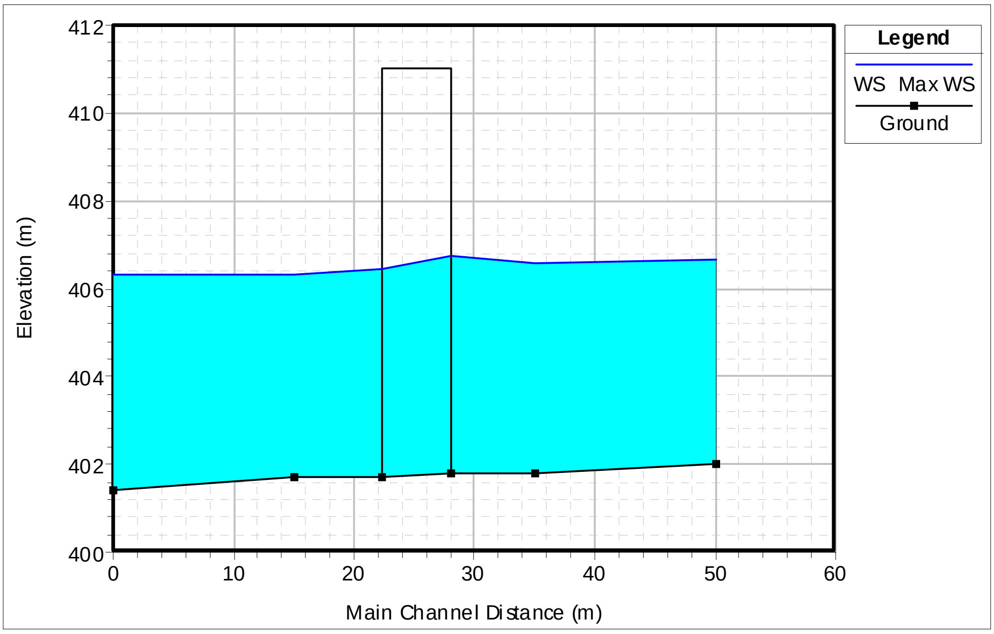


Fig. 10 Water Surface Profile of 50-year Design Flow of Marin Khola Bridge

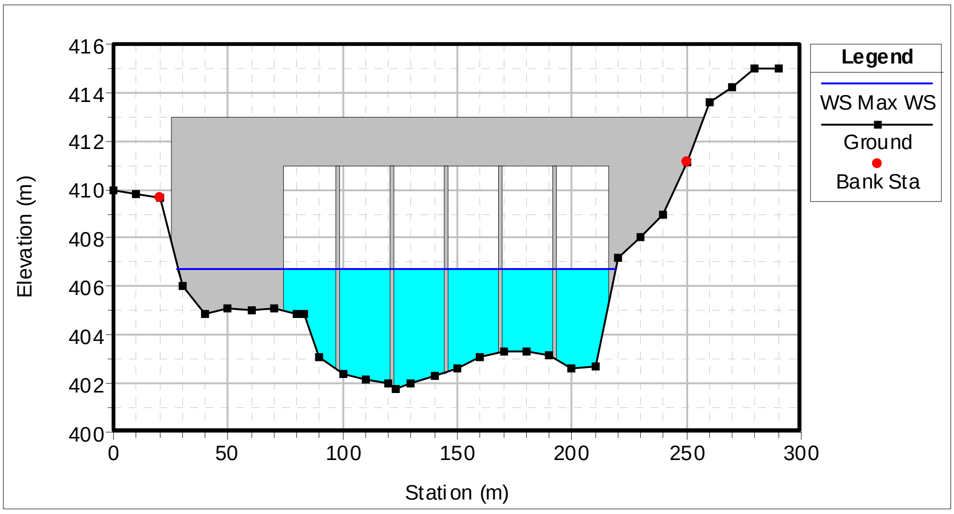


Fig. 11 HWL of 50-year Design Flow of Marin Khola Bridge

9. Conclusions

The conclusions drawn from the study are as follows:

1. The peak discharges in all rivers except Roshi Khola of the project site are estimated by employing Rational method. For securing good accuracy on the estimated peak discharges of rivers, rainfall intensity duration frequency (IDF) curves of 9 stations, time of concentration of flow in rivers and basin area of rivers at bridges sites are determined. Basin rainfall intensities for the duration of time of concentration of flow in the rivers are computed and then peak discharges in rivers are determined also using basin area and runoff coefficient.

2. Design discharge of Roshi Khola at bridges sites are determined based on the specific discharge of the river at Panauti. Because the basin area of Roshi Khola at Panauti is 87 km^2, whereas basin areas of the river at proposed bridges sites 9-1, 10-1 and 11-3 are 357 km^2, 392 km^2 and 545 km^2, respectively. Due to having the basin areas of the Roshi Khola at bridges sites larger than at Panauti, the specific discharge of the river at Panauti is used for design discharge estimation in the river. Because in this situation the estimated design discharges of the river at bridges sites will not be underestimated and are considered reasonable.

3. The low and high rainfall pocket areas are found in the project area. The high rainfall pocket areas are: Hariharpur Gadhi (50-year daily rainfall of 475 mm), Sindhuli Gadhi (50-year daily rainfall of 423 mm), and Bahuntilpung (50-year daily rainfall of 327 mm). Similarly, the low rainfall pocket areas are: Pachuwarghat (50-year daily rainfall of 124 mm) and Dolalghat (50-year daily rainfall of 134 mm). The catchments areas of the rivers which cross the road nos. 2, 3 and 5 fall in the high rainfall pocket areas, therefore, higher amount of runoff in the rivers can be expected which is reflected in the estimated discharges of the rivers.

4. Thakur Khola is bifurcated into 4-branches with covering wide area of floodplain just before mixing it with Kamala River. Therefore, it will be difficult to divide the total discharge of Thakur Khola in each branch precisely, so the estimated high water level in each branch may not be so accurate. Because of this situation, it is recommended to ask with local residents on the observed highest water level in each branch of Thakur Khola in past to verify the estimated HWL of the branches. After interviewing the local residents, do assess the reasonable values of HWL for the branches and use them.

5. River cross-sections at road centerline, u/s of road centerline and d/s of road centerline are used for river flow simulation. For maintaining high accuracy in the estimated HWLs of the rivers, flows are simulated incorporating the cross-sections of the rivers in the widely used river flow simulation model HEC-RAS. Similarly, for modeling flow through bridge, locations and dimensions of piers and abutment are incorporated in the simulation model. Therefore, estimated HWLs by the model possess good accuracy.

6. However, the sites 1-1, 2-5, 2-6, 2-7, 3-1, 3-2, 3-5, 5-1, 5-2, 5-3, 5-4, 5-5, 5-8 and 5-11 in rivers are lying on flat floodplains, therefore, estimated HWLs in rivers on these sites are overestimated. Because, cross-sections of the rivers are not covering enough width of floodplains and the cross-sections are also almost plain thus river overflows both banks while performing simulation of river flow. To control overflow from river bank, tall levees are considered at both ends of the cross-sections and river flow simulation is

performed. Hence, the model is overestimating HWL in the rivers. Because of these situations, construction of continuous box-bridge at the sites will not make the HWL in the rivers further higher. Therefore, it is recommended to verify and adjust the estimated HWL of the sites by field survey and asking with local residents and assess the reasonable HWL of the sites.

7. Flow through Marin Khola Bridge (2-1) is simulated using river cross-sections presented in DOR report and incorporating the proposed design of the bridge. The bridge dimensions used for the flow simulation are: 141.96 m total bridge length and 5 piers of 1.5 m width placed at 23.6 m intervals. River bed level at bridge site is 401.8 m. The design high water levels (HWLs) of bridge are: 406.44 m (25-year flood), 406.73 m (50-year flood) and 407.22 (Mud flow).

8. The river flow simulation of Hadi Khola (13-14) is carried out using river cross-sections of 6 locations which covers the long stretch of the river. Therefore, the shifted new road centerline falls within the river stretch of which cross- sections are used for flow simulation in the river. New road centerline falls along the second cross-section location (2-2), at this section river bed level is 1195.33 m and design HWLs are 1198.26 m (25-year flood), 1198.31 m (50-year flood) and 1200.77 m (Debris flow).

9. The elevation of bench mark used in topographic survey of Bohore Khola (8-2) is found different in the data given for hydrological study and for detailed design of the bridge. In the data given for hydrological study to estimate high water level in the river, the river bed elevation (at road centerline) is 495.41 m and estimated high water levels are: 496.69 m (25-year flood), 496.76 m (50-year flood) and 497.98 m (Debris flow). For converting the HWLs into the bench mark system used in topo-data for detailed design of bridge, the difference in elevations of river bed in the data given for hydrological study and for designing bridge should be added/subtracted to/from the estimated HWLs. In the topo-data given for bridge designing, the river bed elevation at road centerline is 497.61 m, therefore, there is a difference of 2.2 m in elevations between two sets of data. Hence, while designing bridge HWL should be considered as: 498.89 m (25-year flood), 498.96 m (50-year flood) and 500.18 m (Debris flow).