Government of Nepal
Ministry of Physical Infrastructure and Transport
Department of Roads
Project Directorate (ADB)

Project Preparatory Consultants

Under

SASEC HIGHWAY IMPROVEMENT PROJECT (SHIP-PPC)

(ADB Loan No: 3722 Nep)
Contract No. SHIP/PPC/2020/02

Detail Design of Final Report for Butwal - Gorusinghe Section of East-West Highway

Volume I	**:**	**Main Report**
Volume II	**:**	**Annexure**
Volume III	**:**	**Drawings**
Volume IV	**:**	**Cost Estimate**
Volume V	**:**	**Design Calculation**

December, 2022

Submitted by

SOOSUNG ENGINEERING & CONSULTING in association with

Report Volumes:

Detail Design Report for Butwal-Gorusinghe (50.00 km) Section of East-West Highway has been prepared in five Volume as detailed below:

Detail Design Report:

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ABBREVIATIONS

AADT	Annual Average Daily Traffic
AC	Asphalt Concrete
ACV	Aggregate Crushing Value
ADB	Asian Development Bank
AIV	Aggregate Impact Value
AMSL	Average Mean Sea Level
ASL	Average Sea level
BC	Benefit Cost
CBO	Community Based Organization
CBR	California Bearing Ratio
CBS	Central Bureau of Statistics
C-ESMP	Contractors Environmental and Social Management Plan
CFUG	Community Forestry Users Group
CoI	Corridor of Impact
CSB	Crushed Stone Base
Cum	Cubic Meter
DADO	District Agriculture Development Office
DBM	Dense Bituminous Macadam
DBST	Double Bituminous Surface Treatment
DCID	Development Cooperation Implementation Division
DCP	Dynamic Cone Penetration
DCC	District Coordination Committee
DFO	District Forest Office
DHM	Department of Hydrology and Meteorology
DoR	Department of Roads
EEAP	Earthquake Emergency Assistance Project
EMAP	Environmental Management Action Plan
EPR	Environmental Protection Rule
ESA	Equivalent Standard Axles
ESMP	Environmental and Social Management Plan
FGD	Focus Group Discussion
GAB	Granular Aggregate
GESI	Gender Equity and Social Inclusion
GESU	Geo Environmental and Social Unit
GoN	Government of Nepal
GPS	Global Positioning System
GSB	Granular Sub-Base
HH	House Holds
IEE	Initial Environmental Examination
IFD	Intensity Frequency Duration

IRR	Internal Rate of Return
ISB	Improved Sub-Base
BG	Butwal-Gorusinghe
LCF	Local Consultative Forum
LL	Liquid Limit
MC	Moisture Content
MDD	Modified Dried Density
MoPIT	Ministry of Physical Infrastructure and Transport
MSA	Million Standard Axles
NGO	Non-Governmental Organization
NPV	Net Present Value
OD	Origin and Destination
OMC	Optimum Moisture Component
PCC	Plain Cement Concrete
PD	Project Directorate
PI	Plasticity Index
PPC	Project Preparatory Consultant
PSA	Poverty Social Assessment
RCC	Reinforced Cement Concrete
RL	Reduced Level Project Preparatory Consultant under SASEC Road Connectivity (SRCP)
RMDP	Road Maintenance and Development Project
RoW	Right of Way
STDs	Sexually Transmitted Disease
TPPF	Transport Project Preparatory Facility
VAT	Value Added Tax
WB	World Bank

EXECUTIVE SUMMARY

1. Introduction

A contract was made on **August 24, 2020** between Government of Nepal, Ministry of Physical Infrastructure and Transport, Department of Roads, Project Directorate (ADB) (hereinafter referred to **The Client**) and SOOSUNG Engineering Co. in association with Environment and Resource Consultant and Tech Studio of Engineering (hereinafter referred to **The Consultant**) for preparatory activities of upgrading of about 270.620 km(Kakarvitta-Laukahi Section, 120.620 km, Pathalaiya-Narayanghat Section, 100.00 Km, Butawal-Gorusinghe Section-50.00) road to 4 lane standard and bridge along the stretches and also to improve road safety of 1027 km of East West Highway under SASEC Road Improvement Project. This report has been prepared for Butwal-Gorusinghe (Imiliya) Section.

East West Highway is the main national as well as international trade corridor of Nepal forming South Asia Association for Regional Cooperation SAARC corridor. The proposed project will support capacity, quality, and safety improvements of the East–West Highway (EWH). The proposed East-West Highway is the part of the Asian Highway 2 (AH2).

2. Project Road and Bridges

The starting point of the proposed road is Butwal (just after the Tinau Bridge), located in Butwal Sub-Metropolitan Municipality in Lumbini Province of Nepal.

The proposed road runs almost through plain terrain except initial 1km where the alignment passes through at the foot of the hillock. At this section debris flow and landslides due to the past monsoon were observed. The alignment passes through the major settlements such as Butwal, Rani Bagaiya, Murgiya, Saina Maina, Bansgadhi, Saljhundi, Pipara, Jitpur, Banaganga, Gorusinghe and Imiliya. It crosses 30 nos major and minor Rivers. Among them Banaganga River is the major river having a bridge length more than 300 m. Similarly, the proposed road has 10 number of major junctions namely 590+510-Butwal Municipality Road, 592+820-Santi Chowk, 602+210-Jharbaira Chauki, 605+710-Kalauni, Sainamaina, 607+570-Basgadi, 613+950-Fireline, 625+720-Bangai Chowk, 634+540-Taulihawa Chowk (Gorusinghe), 634+940-Gorusinghe-Argakhachi Chowk and 639+000-Buddhi Chowk. The proposed road ends at 640+000.

From 611+800 to 617+900 (Pipara), from Kaila Khola Bridge (627+200) to Gorusinghe junction (634+900) and 637+720 to 640+000 (Budhi Jungle) the alignment passes through forest area. Considerable number of trees will be required to be cut in this section while upgrading the road.

3. Design Standards for Road

The proposed design standards for the project road are based on provisions of following standard documents.

- Nepal Road Standards (NRS) 2070

- Asian Highway design standards (AHDS) 1993
- Indian Roads Congress (IRC)

Adopted design standard are shown in table below:

i.	Design Speed Km/hr	:	100
ii.	Level of Service	:	B
iii.	Roadway Width	:	**In urban case:** 50m **In semi urban case:** 37.40m **In non-urban case:** 24m
iv.	Roadway Elements	:	**In urban case:** Carriageway 4-lane-2x7.5m Paved Shoulder- 2x2.50m (with Rumble Strip as required) Central Median - 3.00m, Service lane-2x6.5m with 1.50 m Side Median and Foot Path-2x5.5m. **In semi urban case:** Carriageway 4-lane- 2x7.5m Paved Shoulder- 2x2.50m (with Rumble Strip as required) Central Median- 3.00m Additional Lane -2 x 5.50 m additional lane (upgradable to 6.50m) with 2x1.2 m lane separator and drain. Verge: 0.50 m **In non-urban case:** Carriageway 4-lane- 2x7.5m Paved Shoulder- 2x2.50m (with Rumble Strip as required) Central Median - 3.00m. Verge-2 x 0.5m (In some exceptional cases adaptation of the cross section are different from the above 3 types which are presented in drawing Volume)
v	Camber	:	Carriageway: 2% Shoulder: 3%
vi	Right of Way	:	50.00 m
vii	General Embankment/ Cutting Slope	:	In Filling: 1V:1.50H In Cutting: 2V: 1H (varies as per soil type)
viii	Stopping Sight Distance	:	190m-design speed of 100km/hr
ix	Super-elevation	:	7%
x	Min. Radii for Horizontal Curves	:	Plain / Level Terrain - 375 m (100km/hr)
xi	Ruling Gradient	:	4-5% Minimum Gradient 0.50 %
xii	Minimum K-Factor	:	

	Summit Curve	:	85 for Design speed of 100 km/hr (Only considering Stopping Sight Distance)
	Valley Curve	:	45 for Design speed of 100 km/hr (Only considering Stopping Sight Distance)
xiii	Bridge Clearance	:	
	Vehicular underpass	:	4.75 m
	Interchanges / Grade Separator	:	5.50m
	Cattle / Community Crossing underpass	:	3.50 m
	Wildlife	:	6.50 m
	Minimum Drainage Channel Width	:	0.40

4. Design Standards for Bridge

The designs have been followed basically the guidelines by the Indian design codes as well as DOR Bridge Standards whatever are applicable. Since the DOR has now adopted Limit State Method of analysis and design of bridges, the same method has been followed in the designs. It is recommended that construction of all bridges /culverts shall conform to the **Standard Specification for Road and Bridges Works** published by Ministry of Physical Planning and Works, Department of Roads-2073/2016 with second amendment 2078/2022.

Regarding the major and minor bridges, some understandings have been developed after several meetings with the ADB/PD and DOR authorities which have been considered while designing the bridges.

5. Engineering Survey

In order to develop detailed design, following survey and investigations have been carried out:

- Inventory Survey of Road and Condition Survey of Bridges
- Topographical Survey
- Axle Load Survey
- Traffic Survey

6. Geological Investigation

Geologically and geomorphologically, the studied East-West Highway from Butwal to Gorusinghe sector mostly lies in the Terai Ares except a small stretch (1 Km) of Siwalik. Therefore, snow drifts and rock avalanching activities cannot be expected. The Highway section runs on the deposit of river sediments that are comprised by gravels, sands, silts and muds. Major geological thrusts and faults are not encountered on the surface along the Highway corridor.

Abutments of the proposed bridges are situated on the upper river terrace deposits. River banks at U/S and D/S are protected by hardware engineering structures, however, mining activities of construction materials from the active channel area triggered channel morphological degradation in some cases. Subsurface sediments obtained in core samples from bridge alignment sections represent dominant silty gravelly sands (Sp), silty fine sands with gravels and boulders (Gp), and minor proportion of sandy silt (Sm).

Long-term sub-surface hydrological monitoring is suggested in order to ascertain liquefaction potential area mapping in the major bridge sites.

7. Geotechnical Investigation

This section of report presents the road pavement subgrade strength evaluation and sub surface geological-geotechnical information and the analysis of the data required for the design of foundations.

To determine the subgrade strength, 1m deep trial pits were excavated at every 1 km interval under the wheel path and at the edge of shoulder. Likewise, DCPT was performed in the in-situ soil.

Pits dug revealed an average gravel base course of 150 mm while the depth of sub base is 200 mm. Visual examination of base course material shows that it is on the verge of disintegrating, indicating remaining of structural life of about 3 to 5 years. Hence, the existing sub base and base course could either be:

a. Remolded as sub base material to construct new sub base layer when widening, or
b. Remove this material to blend it into the new sub grade to increase its in situ CBR at locations as an additional measure to prevent longitudinal cracks between the existing and new road formation

The soil investigation work mainly consists of advancement of bore hole by appropriate drilling method like rotary drilling, percussion drilling up to the required depth, conducting Standard Penetration Test/Dynamic Cone Penetration Test of the road alignment at 100 m interval, collection of disturbed and undisturbed soil samples for different laboratory tests, measurement of natural water table and analysis and interpretation of the obtained data and their recommendations for application in the foundation design of the structures required for the project.

The use of existing sub base and base course layers makes economic sense. If the existing thickness of base and sub base of about 350 mm is uniform and spread over 20 m of carriageway and shoulder, the resulting thickness of such sub base would be in the range of about 20% of the required sub base material even after accounting a loss of 40% when scarifying and re-profiling. Hence, the designed thickness could be reduced by the corresponding thickness subject to the provision that any additional compacted layer placed on top should not be less than 100 mm.

For the bridges, boring investigation was performed in the sub soil to abstract the information of soil parameters, thickness and depth of each layer etc.

8. Construction Material Investigation

A construction material survey was carried out. The survey mostly concentrated in construction materials for base course, sub-base, boulders sand and concrete aggregates to be used in proposed road construction. Most of the sources are located in the vicinity of the project road. Along the road, the construction materials are available from Tinau River, Dano Khola, Badganga Khola, Jingwa Khola, Kanchan Khola, and Surahi Khola, etc.

Other materials such as cement, reinforcement, structural steel, filling materials can be acquired from the surrounding markets.

Potential sources and Tentative Estimation of Quantities of Construction Materials is shown in table below:

S.n.	Name of the Source	Location	Available Materials	Estimated Available Quantities (m^3)	Remarks
1	Surahi Khola	25 Km away from Chainage 639+600 End Point (Gorusinghe) on Left Hand Side (LHS) of Mahendra Highway	Cobbles, Gravels and Sand	810000	20 km Black topped road and 5 km earthen road
2	Jokahi Khola	30 Km away from Chainage 639+600 End Point (Gorusinghe) on Left Hand Side (LHS) of Mahendra Highway	Cobbles, Gravels and Sand	135000	25 km Black topped road and 5 km earthen road
3	Belgurduwa Nadi	5 Km away from Chainage 639+600 End Point (Gorusinghe) on Left Hand Side (LHS) of the road alignment	Sand and Silt	60000	5 Km gravel road from end chainage
4	Banganga Khola	At chainage 622+00 and 5 km away on Left Hand Side the road alignment	Cobbles, Gravels and Sand	90000	2 km black topped road and 3 km earthen road
5	Jhingwa Khola	About 13 km away from chainage 640+100 on Right Hand Side of our road alignment	Boulders, Cobbles, Gravels and Sand	150000	About 7 km black topped road and 5 km earthen road
6	Danav Khola	At chainage 598+400 and 5 km away on Left Hand Side of the road alignment	Gravels and Sand	45000	About 5 km earthen road
7	Kanchan Khola	At chainage 611+400 and 5 km away from the road alignment at Saljhandi on Right hand Side of the road alignment	Cobbles, Gravels and Sand	45000	About 5 km earthen road

S.n.	Name of the Source	Location	Available Materials	Estimated Available Quantities (m^3)	Remarks
8	Tinau Khola	10 Km away from Chainage 589+600 Start Point (Butwal) on Left hand Side of the road alignment	Boulders, Cobbles, Gravels and Sand	675000	About 5 km black topped road and 5 km earthen road
9	Rohini Khola	12 Km away from Chainage 589+600 Start Point (Butwal) on Right Hand Side of Mahendra Highway	Boulders, Cobbles, Gravels and Sand	75000	About 7 km black topped road and 5 km earthen road
10	Godhaha Khola	18 Km away from Chainage 589+600 Start Point (Butwal) on Right Hand Side of Mahendra Highway	Boulders, Cobbles, Gravels and Sand	300000	About 13 km black topped road and 5 km earthen road
11	Turiya Khola	23 Km away from Chainage 589+600 Start Point (Butwal) on Right Hand Side of Mahendra Highway	Boulders, Cobbles, Gravels and Sand	202500	About 20 km black topped road and 3 km earthen road

9. Hydrological Investigation

A hydrological investigation was carried out at the field. The investigation was concentrated to gather information to determine hydrological parameters like design flood, scour depths and required length for the design of bridges and also to finalize the hydrological and hydraulic design of cross drains, side drains and River training works.

10. Traffic Study and Analysis

Generally, the current traffic volume is determined by conducting traffic volume surveys on site. There is prevailing trend of forecasting future traffic demand considering data obtained from survey and in consideration with the historical traffic volume statistics. However, due to the pandemic of COVID 19, the movement of vehicle is comparatively low and considering these data as current traffic volume in forecasting future demand is found unreasonable. Therefore, past traffic volume data of the proposed road have been considered while analyzing. The traffic characteristics such as vehicle type composition, daily traffic volume fluctuation was also analyzed based on the past traffic volume data

The future traffic demand has been calculated as sum of normal traffic and generated traffic and presented in table below.

Future Traffic demand (unit: veh/day)

Excluding 2~3wheels

Link code	Link name	2018	2029	2033	2038	2043	2048
H0150	Gorusinghe-Chanauta	5,168	10,099	12,749	16,419	20,537	25,070
H0149	Jitpur-Gorusinghe	3,428	7,332	9,556	12,764	16,463	20,641
H0148	Kothi River-Jitpur	3,428	7,332	9,556	12,764	16,463	20,641
H0147	Bamaha Khola-Kothi River	5,908	12,697	16,581	22,198	28,698	36,056
H0146	Butwal-Bamaha Khola	5,908	12,697	16,581	22,198	28,698	36,056
Average		4,887	10,408	13,550	18,076	23,299	29,198
growth rate			7.11%	6.82%	5.93%	5.21%	4.62%

Including 2~3wheels

Link code	Link name	2018	2029	2033	2038	2043	2048
H0150	Gorusinghe-Chanauta	6,717	13,264	16,786	21,606	26,976	32,850
H0149	Jitpur-Gorusinghe	8,102	16,888	21,744	28,422	35,901	44,132
H0148	Kothi River-Jitpur	8,102	16,888	21,744	28,422	35,901	44,132
H0147	Bamaha Khola-Kothi River	16,867	35,098	45,151	58,905	74,265	91,122
H0146	Butwal-Bamaha Khola	16,867	35,098	45,151	58,905	74,265	91,122
Average		12,655	26,287	33,802	44,096	55,599	68,231
growth rate			6.87%	6.49%	5.46%	4.75%	4.18%

11. Road Safety

Required road safety improvement such as junction improvement, access control, overpass, pedestrian underpass, animal pass, vehicle u turn, accelerating/deaccelerating lane and footpath have been provisioned to make the safer road. Similarly, other safety like crash barriers, road signs, delineators and road marking have been proposed.

Overpasses has been proposed at Ch 592+302 while have been provisioned at Jitgadhi Chowk, 594+450, Nayagaun Chowk, 597+100, Tamnagar Chowk, 602+895, Murgya Bazzar, 604+235, Buddhanagar Chowk, 620+362, and Charnumber Chowk.

12. Design of Road

As stated earlier, the Consultant has considered the Nepal Road Standard 2070 / Asian Highway design standards 1993 / Indian Roads Congress (IRC) Documents for geometric design of the proposed road.

The proposed cross-section of the project road comprises of 4 lane carriageways with the median at centre and having shoulder on both sides including service lane and footpath in urban area. Cross-sections are developed in light of Terrain Classification and site condition which are as follows:

In urban are:

- Carriageway : 4-Lane- 2x7.5m
- Paved Shoulder : 2x2.50m (with Rumble Strip as required)
- Central Median : 3.00m,
- Service Lane : 2x6.50m

- Side Median : 2x1.50 m
- Foot Path : 2x5.50 m.

In semi urban area:

- Carriageway : 4-Lane- 2x7.5m
- Paved Shoulder : 2x2.50m (with Rumble Strip as required)
- Central Median : 3.00m,
- Additional lane : 2x5.50m
- Lane Separator : 2x1.20 m
- Verge :2*0.50 m

In rural area:

- Carriageway : 4-Lane- 2x7.5m
- Paved Shoulder : 2x2.50m (with Rumble Strip as required)
- Central Median : 3.00m
- Verge : 2 x 0.5

13. Pavement Design

The project primarily envisages reconstructing of existing two-lane carriageway with widening it to four lanes for augmenting capacity and significantly extending the service life of the project road.

The pavement works for implementing the above proposals will mainly consist of:

- Scarifying of the existing 2-lane main bituminous carriageway;
- Construction of carriageways with flexile pavement to widen the existing 2-lane main carriageway to proposed 4 lane divided configuration
- Construction of flexible pavement for rest area, truck lay-by and bus bays

The Pavement Design is based on DoR Pavement Design Guidelines (Flexible Pavement), 2014 (Second Edition-2021) and TRL Road Note 31. The input parameters for the pavement design are the California Bearing Ratio (CBR) and design traffic in terms of millions of equivalent standard axle (msa).

Final Result of Pavement Thickness for Carriage way shown in table below:

S.No.	Chainage		Total Pavement Thickness, mm	Pavement Composition					**Remarks**
				Bituminous Surfacing		Granular Base, mm	Granular Sub-Base, mm	Capping Layer, mm	
	From	to		Asphalt Concrete, mm	Dance Bituminous Macadam, mm				
1	590+000	591+000	600.00	50.00	50.00	200.00	300.00		
2	591+000	593+000	600.00	50.00	50.00	200.00	300.00	100.00	Replace Sub-grade by sub-base material
3	593+000	596+000	500.00	50.00	50.00	150.00	250.00		
4	596+000	597+000	600.00	50.00	50.00	200.00	300.00		

S.No.	Chainage		Total Pavement Thickness, mm	Pavement Composition					**Remarks**
				Bituminous Surfacing		Granular Base, mm	Granular Sub-Base, mm	Capping Layer, mm	
	From	to		Asphalt Concrete, mm	Dance Bituminous Macadam, mm				
5	597+000	600+000	500.00	50.00	50.00	150.00	250.00		
7	600+000	601+000	600.00	50.00	50.00	200.00	300.00		
8	601+000	602+000	700.00	50.00	50.00	300.00	300.00		
9	602+000	604+000	600.00	50.00	50.00	200.00	300.00		
10	604+000	607+000	500.00	50.00	50.00	150.00	250.00		
11	607+000	608+000	700.00	50.00	50.00	300.00	300.00	250.00	Replace Sub-grade by sub-base material
12	608+000	611+000	600.00	50.00	50.00	200.00	300.00		
13	611+000	612+000	500.00	50.00	50.00	150.00	250.00		
14	612+000	613+000	600.00	50.00	50.00	200.00	300.00		
15	613+000	613+000	600.00	50.00	50.00	200.00	300.00		
16	613+000	614+000	500.00	50.00	50.00	150.00	250.00		
17	614+000	616+000	700.00	50.00	50.00	300.00	300.00	100.00	Replace Sub-grade by sub-base material
18	616+000	620+000	500.00	50.00	50.00	150.00	250.00		
19	620+000	621+000	600.00	50.00	50.00	200.00	300.00	100.00	Replace Sub-grade by sub-base material
20	621+000	623+000	500.00	50.00	50.00	150.00	250.00		
21	623+000	625+000	600.00	50.00	50.00	200.00	300.00		
22	625+000	627+000	700.00	50.00	50.00	300.00	300.00	100.00	Replace Sub-grade by sub-base material
23	627+000	628+000	600.00	50.00	50.00	200.00	300.00		
24	628+000	629+000	700.00	50.00	50.00	300.00	300.00	100.00	Replace Sub-grade by sub-base material
25	629+000	631+000	500.00	50.00	50.00	150.00	250.00		
26	631+000	633+000	600.00	50.00	50.00	200.00	300.00		
27	633+000	635+000	400.00	50.00	50.00	150.00	150.00		
28	635+000	636+000	700.00	50.00	50.00	300.00	300.00	100.00	Replace Sub-grade by sub-base material
29	636+000	637+000	700.00	50.00	50.00	300.00	300.00		
30	637+000	638+000	600.00	50.00	50.00	200.00	300.00		
31	638+000	640+000	760.00	60.00	100.00	300.00	300.00	100.00	Replace Sub-grade by sub-base material

Final Result of Pavement Thickness for Service Lane shown in table below

S.No.	Chainage		Total Pavement Thickness, mm	Pavement Composition					Remarks
				Bituminous Surfacing		Granular Base, mm	Granular Sub-Base, mm	capping Layer, mm	
	From	to		Asphalt Concrete, mm	Dance Bituminous Macadam, mm				
1	590+000	601+000	400.00	50.00	0.00	150.00	200.00		
2	601+000	602+000	400.00	50.00	0.00	150.00	200.00	100.00	Replace Sub-grade by sub-base material
3	602+000	607+000	400.00	50.00	0.00	150.00	200.00		
4	607+000	608+000	400.00	50.00	0.00	150.00	200.00	200.00	Replace Sub-grade by sub-base material
5	608+000	610+000	400.00	50.00	0.00	150.00	200.00		
6	610+000	611+000	400.00	50.00	0.00	150.00	200.00	100.00	Replace Sub-grade by sub-base material
7	611+000	614+000	400.00	50.00	0.00	150.00	200.00		
8	614+000	616+000	400.00	50.00	0.00	150.00	200.00	200.00	Replace Sub-grade by sub-base material
9	616+000	625+000	400.00	50.00	0.00	150.00	200.00		
10	625+000	627+000	400.00	50.00	0.00	150.00	200.00	100.00	Replace Sub-grade by sub-base material
11	627+000	635+000	400.00	50.00	0.00	150.00	200.00		
12	635+000	636+000	400.00	50.00	0.00	150.00	200.00	100.00	Replace Sub-grade by sub-base material
13	636+000	638+000	400.00	50.00	0.00	150.00	200.00		
14	638+000	640+000	400.00	50.00	0.00	150.00	200.00	200.00	Replace Sub-grade by sub-base material

14. Hydrologic and Hydraulic Studies

The report on hydrologic and hydraulic detail studies of Butwal-Gorusinghe section of existing East West Highway has been prepared based on feasibility study, detail survey and field investigations of this section. The report provides hydrological and hydraulic parameters like Flood, HFL, Bridge Length and Scour Depth for the design of bridges and box bridges over the rivers of this section. Similarly, hydrology and hydraulics of cross drains and side drains are also provided with their types and sizes. All pipe and slab culverts have been replaced by box culverts. RCC precast side drains of suitable size have been recommended. River training works are also recommended wherever necessary.

Effect of climate change has been considered while designing the drainage structures.

Following table gives the future rainfall increment in monsoon of Nepal which can be considered for flood estimation of drainage structures.

Comparison of historical rainfall and CCKP output for Nepal (Source: CCKP Portal)

Month	Historical rainfall in mm (1980-2015)	Predicted Rainfall in mm (2020-2099)	Increment
July	326	342	4.9 %
August	279	325	16.5 %
September	202	205	1.5 %

For the design of drainage structures of this road section the design floods have been estimated in safe side considering 16% increase in extreme rainfall in future. Also, for verification purposes floods were estimated by different methods including regional empirical methods which also give reasonable flood estimates. Again, for being in safe side the largest flood value estimated from different methods has been adopted for the design.

15. Design of Bridge, Culvert and Other Structure

The bridges are designed following limit state method prescribed by Indian Road Congress (IRC) and Indian Standard (IS) design codes. In some cases, AASHTO guidelines are followed where the Indian standards do not cover the required methodology, particularly for the design of the signature bridges.

Most of the existing bridges in the proposed section of the East-West Highway (EWH) included in the present scope of works are found to be still intact and believed to have considerable number of years of useful life. A condition survey based on visual observation was carried out and recommendations have been made to improve the service level of the existing bridges in separate chapters of the main report. Reviewing the upgrading of previous sections of EWH such as Butwal Narayanghat and Kamala–Kanchanpur Sections, an understanding was developed not to replace existing major bridges unless they are unfit structurally or functionally. Since then, it has been practiced to add a new bridge at the side of the existing one. There are 43 nos of major, minor bridges (including VOP and Wildlife crossings) and 155 Nos culverts.

In the non-urban area bridges, the main carriageway width is kept as 8.0m (7.5m + 0.5m curb-shyness width) as in the previous designs for upgrading of the EWH. Footpath is provided at one side (outer side) with a clear width of 2.75m.

In the urban/semi-urban area bridges, the main carriageway width is kept as 8.0m (7.5m + 0.5m curb-shyness width) as in the previous one. A 5.0m service lane has been provided separated by a double-sided crash barrier. Raised footpath is provided at the side of the service lane with a clear width of 2.2m

16. Social and Resettlement Issues

The social analysis of the project area has identified numerous issues of poor, disadvantaged peoples, gender inequality, accessibility of different facilities and services, status or possibility of HIV/ AIDS and human trafficking. The linkage between poverty and social exclusion and inadequate or lack of access due to lack of roads or improvement in the transport sector have been widely recognized.

In order to address the above issues like gender inequality, poverty, social risks such as HIV/AIDs and human trafficking, child labour; the mitigation measures should be incorporated in enhancement measures and also livelihood support programs in Resettlement Action Plan under Livelihood Restoration Programs.

17. Resettlement Plan

The Resettlement Plan (RP) is guided by the ADB Safeguard Policy Statement 2009, Land Acquisition Act of Nepal 2034 (1977) and other relevant policies and guidelines.

Through Gazette, Government of Nepal has declared total 50m Right of Way for East West highway. The project road has no land acquisition since the 50m Right of Way is clear throughout the section.

18. Environmental Assessment

As per the statutory legal requirement; Environmental Protection Act (EPA) 2076, and Environmental Protection Rule (EPR) 2020, (2077B.S); Schedule 3, Rule 3, Road sector E (6); Environmental Impact Assessment (EIA) is mandatory for upgrading of national highways or feeder roads of length more than 50 km. However, in accordance with the ADB's Safeguard Policy Statement (SPS), 2009, the project is categorized as category 'B', warranting an initial environmental examination (IEE). The Consultant has been preparing IEE (As upgrading length of road is only 50 km) of the proposed road.

19. Performance Based Maintenance Contract

Performance Based Maintenance of 5 years period will be applied after the Defect Liability period. PBM includes the Road Asset Management (RAM) or road maintenance of the pavement surface in a predefined service level condition including formation width, side drains, bridges and cross drainages, road side structures, road furniture, road marking, traffic sign boards, slope protection and safety elements of the road etc. for at least 5 years time frame.

PBCs need a conducive environment for successful implementation. The most important factors are

- strong commitment and support by key decision makers, especially from the ministry of finance, the ministry in charge of roads, and the road organization;
- a positive attitude from road organization staff;
- client, contractors, and consultants have the capacity to plan and manage this new kind of contract;
- an adequate road asset management system to support the requirements of PBCs;
- long-term funding; and
- a competitive road maintenance market.

20. Cost Estimate

Cost Estimate has been prepared considering District Rate of Rupandehi and Kapilbastu fiscal year 2079/2080. Standard Norms for Rate Analysis of Government of Nepal has also been adopted.

A. Road and Bridge Component

Item No.	Part of BOQ	Description of Works	Amount (NRs.)		Total Amount
		Section Length, Km	25	25	50
			Package#1	Package#2	
1	PART 1	General	79,596,902.56	215,625,844.01	295,222,746.57
2	PART 2	Road Works	6,581,990,550.54	4,900,117,520.00	11,482,108,070.54
3	PART 3	Bridge, Overpass and Animal Pass Structures Works	1,683,475,939.27	941,469,929.64	2,624,945,868.91
4	PART 4	Bridge Maintenance Works	23,045,353.47	39,856,989.50	62,902,342.97
5	PART 5	Environmental Mitigation, wildlife friendly, Social and Bioengineering Works	20,743,421.01	34,467,984.84	55,211,405.85
6	PART 6	Performance Based Maintenance Woks and Services	243,502,861.64	169,373,880.00	412,876,741.64
7	PART 7	Schedule of Day Works	54,642,436.00	54,055,605.00	108,698,041.00
8	PART 8	Provisional Sums	476,030,647.00	274,952,443.71	750,983,090.71

A)	Total Cost 1-8	9,163,028,111.49	6,629,920,196.70	15,792,948,308.19
B)	Total without PS	8,686,997,464.49	6,354,967,752.99	15,041,965,217.48
C)	Provision for Physical Contingencies @ 10% of B	868,699,746.45	635,496,775.30	1,504,196,521.75
D)	Provision for Price Escalation @ 10% of B	868,699,746.45	635,496,775.30	1,504,196,521.75
E)	Provision for Contingencies @ 4% of B	347,479,898.58	254,198,710.12	601,678,608.70
F)	VAT @ 13%	1,129,309,670.38	826,145,807.89	1,955,455,478.27
G)	Grand Total	2,377,217,173.35	8,981,258,265.31	21,358,475,438.66
H)	Cost per KM	495,088,686.93	359,250,330.61	427,169,508.77

Package#1: Ch 590+000~615+000 and Package#2: Ch 615+000~640+000

Thus, the total cost of the project including both road and bridge is:

Total Net Construction Cost (Total of A) : NRs. 15,792,948,308.19
Total of Gross Project Cost (Total of H) : NRs. 21,358,475,438.66

Procurement Works

As implementing authority of this section is DCID-Development Cooperation Implementation Division, DoR, for the proposed road **"Procurement of Works without pre-qualification Bidding Process (Single Envelop)"** based on the Standard Bidding Document of World Bank's January 2021 has been adopted.

ICB (International Competitive Bid) procedure shall be adopted to enhance the contract administration effectively and to provide opportunity to participate by numbers of professional Contractors to achieve the quality works in stipulated time. It is therefore recommended that ICB procedures to be adopted and contract packaging shall be arranged accordingly for Butwal-Gorusinghe (Imiliya) Section of East-West Highway. The Road works (50.00 Km) have been divided into two packages.

The proposed contract packages for Butwal-Gorusinghe (Imiliya) Section of East-West Highway are tabulated below:

The Proposed Contract Packages

Road Name	Package	Lots	Chainage		Length (Km)	Contract ID No	Approx. Contract Value (NRs)
			From	To			
Butwal-Gorusinghe (Imiliya) Section of East West Highway	I	1	590+000	625+000	25+000	ACCESS-DOR-W-BGC-ICB-1	9163.03 mil.
		2	625+000	640+000	25+000	ACCESS-DOR-W-BGC-ICB-2	6629.92 mil.

21. Economic Analysis

An economic analysis has been carried out to judge the project by comparing the costs to the project with the benefits arising from the project's effect.

The project road has been found to be economically viable because the IRR is higher than the applied discount rate of 9.0% and the NPV value has a positive value. The summary of the economic indicator is tabulated below:

Economic Indicators Summary: (unit: Millions of NRs.)

Alt.	Present Value of total Agency costs	Present Value of Agency Capital costs	Increase in Agency Costs(C)	Decrease in User Costs(B)	Net Present Value (NPV=B-C)	Internal Rate of Return (IRR)
Base	594	481				
Add Lane	8,964	8,574	8,875	32,051	23,176	**23.30**

SECTION I GENERAL

1 Introduction

1.1 Background

Nepal is a land bounded and Hilly country, lies on the lap of the Himalayas bounded by Peoples Republic of China to the north and Republic of India in east, west and south. Geographically, it is divided into three ecological strips – plain land in the south, hilly area in the midland and mountain in the northern belt. There is a sharp increase in elevation as one goes from the flat terrain of Terai (elevation about 58 amsl) towards north to the Higher Himalayas (the highest peak of the World Mt. Everest-elevation: 8,848 amsl). The country covers an area of 147,516 sq. km. Its length is about 885 km from east to west and width varies from 130 to 255 km. The country is famous for the majestic Himalayas and surprising geographic beauty that includes pristine forests, crystal clear lakes, towering peaks and ancient valley cities.

Difficult topography, young geology and deep river crossings are the hurdles for the construction of transport network in Nepal.

For a developing country like Nepal, roads play a vital role in lifting up the country's economic condition. History of road construction in Nepal is not that long. Development of roads can be linked closely with development of human civilization. Together with human civilization it was necessary to visit and communicate between the groups of human settlements and thus resulted in the development of roads. In this context road is one of the major infrastructures that is required for overall development of a country.

Long term goals of the 15th Plan is "Prosperous Nepal, Happy Nepali". One of the objectives for fulfillment of the Goal is Prosperity: "Accessible modern infrastructure and intensive connectivity" and Happiness: "Well-being and decent life" and one of the strategies is "sustainable reduction of poverty". In this contest, it has suggested to select road projects to achieve its goal by supporting socio-economic development. Besides this, Nepal is connected by two Asian Highways. They are Asian Highway 2 (AH2) and Asian Highway 42 (AH42). The proposed East-West Highway is the part of the Asian Highway 2 (AH2). The total length of these two sectors within the country is 1324 km. AH2 originates from Dhaka in Bangladesh and ends in New Delhi in India. It can be further linked with another Asian Highway Network. Therefore, proposed road sections to be upgraded to the Asian Highway Standard.

East West Highway is the main domestic as well as international trade corridor of Nepal forming South Asia Association for Regional Cooperation SAARC corridor. The proposed project will support capacity, quality, and safety improvements of the East–West Highway (EWH).

Asian Development Bank (ADB), which has been playing a leading role in advancing Nepal's transport sector since early 1970s, has instituted a comprehensive Country Partnership Strategy for Nepal. In this context, GON has received a loan from the Asian Development Bank (ADB) for the SASEC Highway Improvement Project (SHIP). It intended to engage international firm in association with domestic consultant to undertake preparatory activities for the processing of new loan project funded by ADB. For the preparatory activities, the contract was made on **August 24, 2020** between Government of Nepal, Ministry of Physical Infrastructure and Transport, Department of Roads, Project Directorate (ADB) (hereinafter referred to **The Client**) and SOOSUNG Engineering Co. in association with Environment and Resource Consultant and Tech Studio of Engineering (hereinafter referred to **The Consultant**).

Among the three road sections of East West Highway of this project, Kakarbhitta-Laukahi Section and Pathlaiya-Hetauda-Narayanghat Section of total length 220.62 Km including major, minor and special bridges will be upgraded under SASEC Road Improvement Project funded by ADB. Whereas, Butwal-Gorusinghe, Imiliya Section (50 km) will be upgraded under BBIN-The Bangladesh, Bhutan, India, Nepal (BBIN) sub regional initiative with the support of the World Bank. **Figure 1.1** presents the location of the project roads.

The **World Bank Group** has been a development partner in Nepal for the past four decades, providing financing, technical assistance and advice. The World Bank provided its first technical assistance grant to Nepal in 1964 to finance and organize a transport survey. But the first credit was approved in 1969 for a telecommunications project. The Bank's support has evolved in focus and form to meet the changing needs of Nepal. The Bank's assistance focused mainly on agriculture, irrigation and infrastructure development in telecommunications, highways, power, and water supply and sanitation.

1.2 Project Objective

The main objectives of the proposed assignment are to carryout feasibility study and detail engineering design of upgrading of road and bridges of following sections of East-West Highway and also to carryout Road Safety Improvement and Black Spots elimination of East-West Highway.

a) Kakarbhitta-Laukahi Section (120.620 km)
b) Pathlaiya-Hetauda-Narayanghat Section (100 km)
c) Butwal-Gorusinghe (Imiliya) (50 km)

This Report elaborates Butwal-Gorusinghe (Imiliya) Section (50.00 km) (The project under BBIN-The Bangladesh, Bhutan, India, Nepal (BBIN) sub regional initiative) among the above-mentioned Roads included in the project.

The overall study consists of:

i) Inventory survey of Road and condition survey of Bridges;
ii) Detailed engineering survey
iii) Geotechnical investigation, Hydrological study, Material and Geological study
iv) Detailed engineering design, specification, cost estimate, bill of quantities;
v) Economic analysis;

vi) Social and Environmental Assessment based on ADB Safeguard Policy Statement (2009), ADB's Environmental Assessment Guideline (2003) as well as Government Regulations and Policies;

vii) Road Safety Improvement and Black Spots elimination in East-West Highway Based on identification and recommendation by ADB's TA Consultant;

viii) Preparation of bidding document for the Improvement of works;

ix) Procurement assistance; and

x) Other assistance as required by the Client.

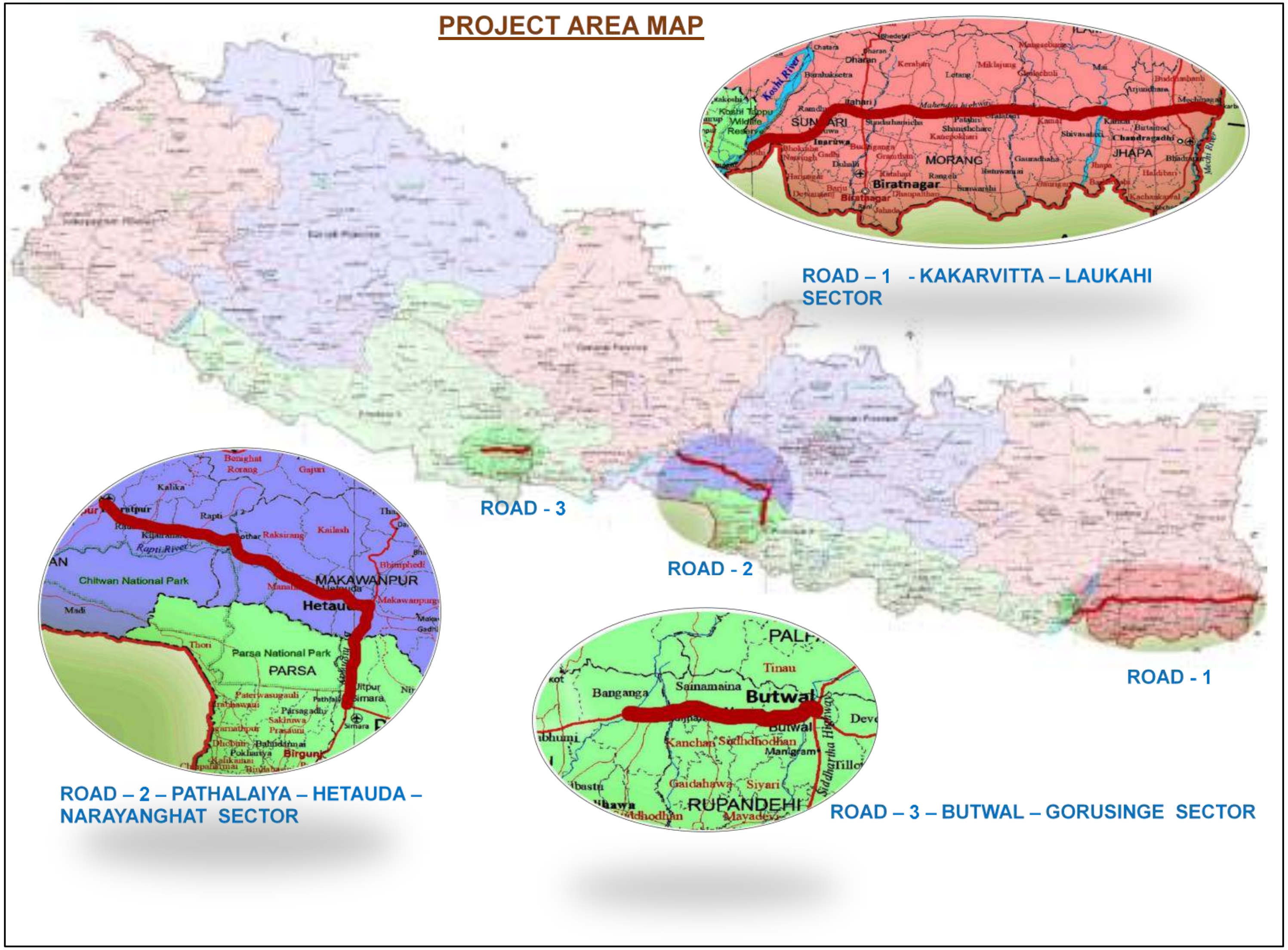


Figure 1.1: Location Map of the Project Area

1.3 Scope of Services

Scope of works are elaborated in detail in TOR for various activities in various stages. The Consultant has carefully reviewed each and every aspect of the scope of works prior to initiate the assignment. The major activities as per TOR include:

- Details of Survey and Studies
  - Topographical Survey and Mapping
  - Hydrological Survey
  - Geotechnical Survey
  - Geological and Seismological Survey
  - Material Availability Survey
  - Traffic Study and Analysis Axle Load Survey
  - Condition Survey of Bridges, Culverts and Structures
  - Inventory Survey of Road and Road Side Structures
  - Miscellaneous Studies and Investigations
- Detail Design Works
  - Design of Roads
  - Design of Pavement
  - Design of Drainage Structure
  - Design of Bridges including Special Bridges
  - Road Safety, Road Furniture and Road Marking
- Economic Analysis
- Social Assessment
- Resettlement and Indigenous People Assessment
- Environmental Assessment
- Noise, Air Pollution and Water Quality Parameters
- Wildlife Survey
- Procurement Assistance
- Capacity Development

1.4 Approach and Methodology

1.4.1 Approach

The Project preparation activities have been carried out in accordance with Terms of Reference (TOR) in following stages:

Stage I:	Inception Report
Stage II:	Road Inventory and Bridge Condition Survey Report
Stage III:	Feasibility Study Report
Stage IV:	Field Survey Report
Stage V:	Detail Design of Roads and Bridges
Stage VI:	Social Assessment Report
Stage VII:	Resettlement and Indigenous People Assessment

Stage VIII: Environmental Assessment

The above-mentioned work stages have been further divide into several activities as presented in the Figure 1.2. Many tasks have been carried out simultaneously and modified/adjusted as per the project needs and field condition.

Approach to qualitative work: The Consultant has paid a great deal of attention to get quality of the all survey and design works. In order to avoid any deviation of survey and investigation, the Consultant had deputed engineers for continues monitoring of the works at the site.

In order to achieve quality output, the Consultant had prepared a Quality Assurance/Control Plan (QACP) in desk study stage and has followed the plan throughout the survey, investigation and design period. The QACP comprises of activities and procedure to be used for verifying, checking and reviewing of designs, drawings, specification, cost estimate and other related documents. The Quality Assurance Control Plan is given in **Figure1.2.**

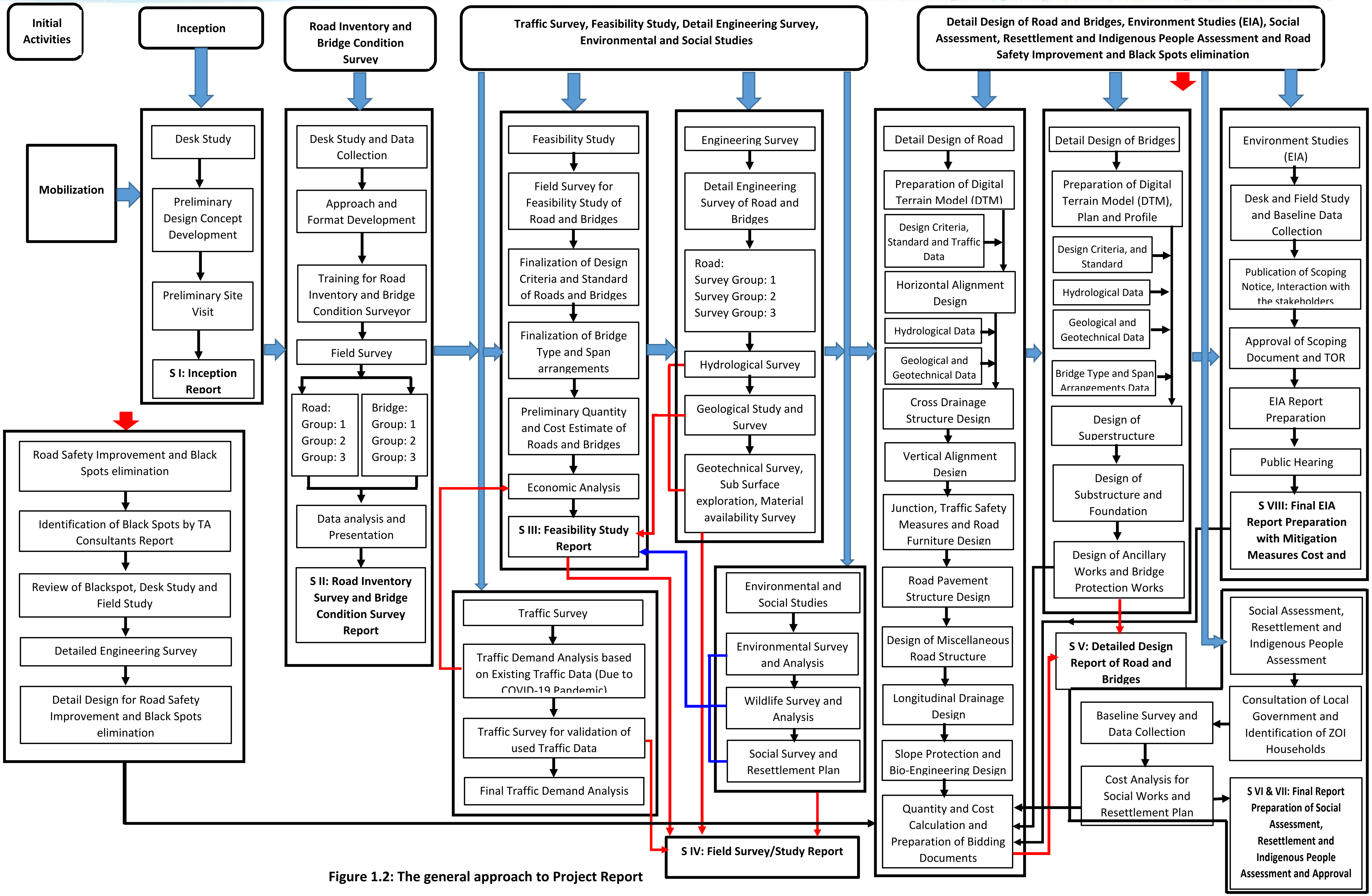


Figure 1.2: The general approach to Project Report

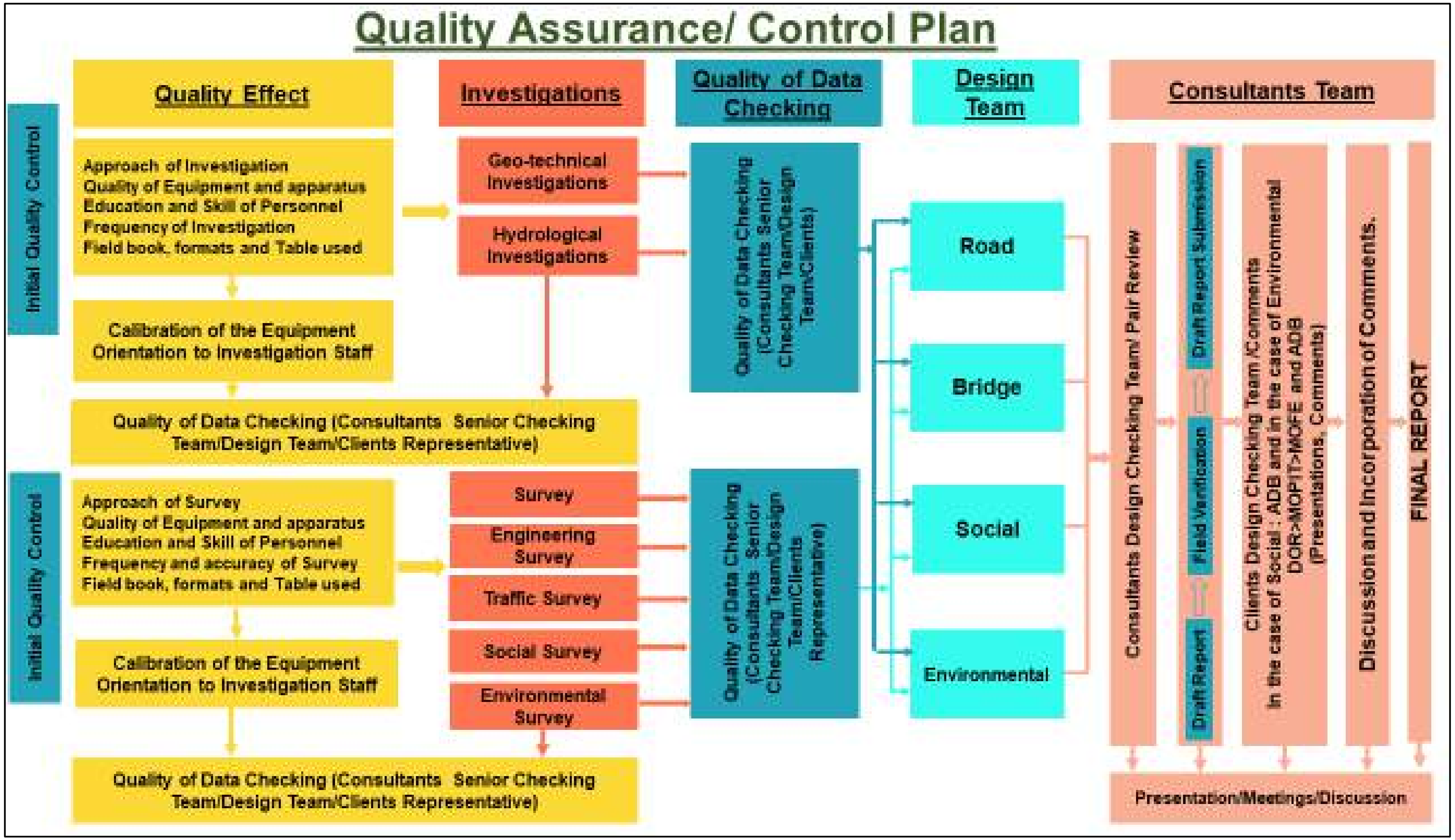


Figure 1.3: The Quality Assurance/Control Plan

1.4.2 Methodology

In consideration of general approach as mentioned above, the methodology for each task is described in the subsequent sections.

The methodologies have been prepared in light of following aspects:

- Provisions of the Terms of Reference – objectives and scope of works;
- Previous experience of the firms in similar projects;
- Standard internationally accepted engineering theory, practices, principle and management principles.
- National and International standard, code and practices.

2 Project Road/Bridge Description

2.1 General

The project road is a section of the East West Highway. Presently, East West Highway has been playing a vital role in transportation. Earlier, traveling east to west was limited to either Hulaki Road or expensive limited air travel. The highway passes through the Terai from east to west covering length of 1,027 kilometres. The Major urban area/ settlement along/around the highway are Mechinagar, Birtamod, Damak, Itahari, Biratnagar, Dharan, Inaruwa, Lahan, Janakpur, Birgunj, Hetauda, Narayanghat, Siddharthanagar, Butwal, Nepalgunj, Dhangadhi and Bhimdutta. The proposed East-West Highway is also the part of the Asian Highway 2 (AH2).

Figure 2.1: Asian Highway Networks.

2.2 Road

The starting point of the proposed road is Butwal (just after Tinau Bridge), Butwal Sub Metropolitan, and Rupandhehi District Lumbini Province of Nepal. The road ends near starting of Belwagerda Nadi Bridge of Kapilbastu District. The length of this section is 50 Km. Width of existing road is 8.00 m including 6 m wide carriageway and 1m wide shoulder on both sides.

The proposed road runs almost through plain terrain whereas initial 1km of the alignment passes through at the foot of the siwalik hillock. At this section debris flow and landslides due to the past monsoon were observed. The alignment passes through the major settlements such as Butwal, Rani Bagaiya, Murgiya, Saina Maina, Bansgadhi, Saljhundi, Pipara, Jitpur, Banaganga, Gorusinghe and Imiliya. It crosses 30 nos major and minor Rivers. Among them Banaganga River is the major river having a bridge length more than 300 m. In addition to the river crossing some animal passes and under passes are proposed in the design. Similarly, the proposed road has 10 number of major junctions located at 590+510-Butwal Municipality Road, 592+820-Santi Chowk, 602+210-Jharbaira Chauki, 605+710-Kalauni, Sainamaina, 607+570-Basgadi, 613+950-Fireline, 625+720-Bangai Chowk, 634+540-Taulihawa Chowk (Gorusinghe), 634+940-Gorusinghe-Argakhachi Chowk and 639+000-Buddhi Chowk. The proposed road ends at 640+000.

The alignment passes through forest area from 611+800 to 617+900 (Pipara), Kaila Khola Bridge (627+200) to Gorusinghe junction (634+900) and 637+720 to 640+000 (Budhi Jungle) the alignment passes through forest area.

Existing Road Condition

The Consultant had reviewed the pavement condition data collected by DOR before COVID 19. Based on data reviewed and the Consultants observation in the field, the pavement of the proposed road can be considered to be in fair to poor condition. However, cracks and maintained pot holes can be observed in few locations. The pavement data collected by DOR is presented below:

Table 2.1: IRI and SDI Value of Butwal-Gorusinghe (Imiliya) Section of East-West Highway

Link No	Link Name	Length, Km	IRI Value	SDI Value
H0146U	Butwal - Bahama Khola	9.54	7.79	2.00
H0147	Bahama khola - Kothi River	17.24	8.16	2.00
H0148	Kothi River - Jitpur	4.92	8.57	2.00
H0149	Jitpur - Gorusinghe	14.60	10.30	2.13

Table 2.2: Evaluation of IRI Value

Link No	Link Name	Length, Km	Pavement Condition (IRI)			
			Good	Fair	Poor	Bad
			< 4	>4-6	>6-8	>8
H0146U	Butwal - Bahama Khola	9.54			7.79	
H0147	Bahama khola - Kothi River	17.24				8.16
H0148	Kothi River - Jitpur	4.92				8.57
H0149	Jitpur - Gorusinghe	14.60				10.30

Table 2.3: Evaluation of SDI Value

Link No	Link Name	Length, Km	Pavement Condition (SDI)		
			Good	Fair	Poor
			0.00-1.70	>1.70-3.00	>3.00-5.00
H0146U	Butwal - Bahama Khola	9.54		2.00	
H0147	Bahama khola - Kothi River	17.24		2.00	
H0148	Kothi River - Jitpur	4.92		2.00	
H0149	Jitpur - Gorusinghe	14.60		2.13	

Based on road Condition Survey conducted by the Department of Roads and consultant's observation the pavement condition is considered to be in fear to poor condition with respect to IRI and as per SDI. Interconnected racks, routing, undulation and maintained pot holes were observed in few locations.

The total number of existing bridges is 30. Among them Badganga Bridge is the longest bridge with length of 306 m.

There are few retaining structures along the road alignment and they are fear to poor condition. Traffic sign, delineator post, road painting, crash barrier is in poor condition and most of them are missing.

Slab culverts and pipe culverts were used as cross-drain and small, medium and large bridges were observed at place. In settlement areas, drains are not properly managed. At many settlement areas longitudinal drains are not functioning well due to the lack of maintenance. At some places inlet and out let of the cross-drainage structures are closed, mainly due to and construction of building by road Neighbor.

Figure 2.2: Butwal-Gorusinghe (Imiliya) Section of East-West Highway

2.3 Bridges

The total number of existing bridges is 30. Among them Badganga Bridge is the longest bridge with length of 306 m.

The existing road comprises of all together 30- number of bridges of different types such as T-Beam type (11 nos), PSC (11 nos), and Box Bridge (8 nos). Majority of bridges are of reinforced cement concrete and overall condition of these bridges can be considered satisfactory.

Banaganga Bridge is the longest bridges with the length more than 300.00 m. These bridges have been serving since more than last 50-years. Several common faults/defects are observed in these bridges due to lack of major maintenances in the past.

The bridges namely Jitgadhi, Narasinga Dry Nala, Dry Nala (590+698), Dry Nala (590+759), and Pakha Pani have completed their design life and are proposed to be replaced by 4-lane crossings.

3 Design Standard for Roads

3.1 Introduction

Design standards of proposed road have been determined in consideration with Nepal Road Standard (NRS) 2070 / Asian Highway design standards (AHDS) 1993 / Indian Roads Congress (IRC) Stipulations and ASSTHO.

While deciding the design standard, the Consultant has considered importance of safety and free flow of traffic with passenger comfort. At the same time, the Consultant has proposed economically viable design, which meets future traffic requirements, encourages consistency and uniformity of operation.

3.2 Review of Design Standards for Roads

The proposed design standards for the project road are based on provisions of following standard documents.

- Nepal Road Design Standards (NRS) 2070.
- Asian Highway design standards (AHDS) 1993
- Indian Roads Congress (IRC)

Besides above design standards, the following guidelines and standard practices of design have been followed for designing different components of the road such as pavement, drainage system, slope protection measures and other auxiliary facilities for road safety, etc.

3.2.1 Pavement Design

- Pavement Design Guideline (Flexible Pavement), DOR, 2014, Second Edition 2021), Kathmandu.
- Manual for Dense Graded Bituminous Mixes (DBM/BC), DOR, 2018, Kathmandu.
- TRL Overseas Road Note 31 for Pavement Design
- AASHTO Guide for Pavement Design – 1993
- Guidelines for Design of Flexible Pavements, IRC: 37 - 1984

3.2.2 Drainage System

- Hydrological Records of Nepal, Stream flow Summary, Department of Hydrology and Meteorology, HMG Nepal, 1998.
- Methodologies for Estimating Hydrologic Characteristics of Ungagged Locations in Nepal, Department of Hydrology and Meteorology, July 1990.

3.2.3 Road Geometry Design

- Nepal Road Standard, 2070
- Indian Road Congress (IRC) Standards
- A Policy on Geometric Design of Highways and Streets by AASHTO (2004)
- Geometric Design Guide for Canadian Roads by TAC (1999)
- Road Side Design Guide by AASHTO

- Guide Specifications for Highway Construction by AASHTO (1998)

3.2.4 Road Safety

- Traffic Signs Manual for Nepal Roads
- Road Safety Notes published by Traffic Engineering and Safety Unit of DOR, Nepal
- Nepal Road Safety Action Plan, MoPIT, 2013, Kathmandu
- Road Safety Audit Toolkit for ADB Funded Projects

3.2.5 Earth Retaining Structure

- Overseas Road Note 16, Principle of low-cost road engineering in mountainous region
- Mountain Risk Engineering Handbook, ICIMOD.
- DOR Typical Drawings
- Consultants Design

3.2.6 Bio-engineering and Slope Protection Works

- Publications of Geo-Environment Unit of DOR

3.2.7 Wildlife crossing

- "Basic Guideline for Wildlife Friendly Infrastructures" published by GON, Ministry of Forest and Environment.
- "Green Infrastructure Design for Transport Projects-A Roadmap to protecting Asia's wildlife biodiversity- December 2019", published by ADB

3.3 Design Standard for Road Projects

The highway design consists of the basic roadway alignment, drainage structures, interchange structures, retaining walls, embankments, foundations, etc. The standards are given below for each element of road in the form of values to be adopted. The factors affecting the design of highways are function for highways, volume of traffic, speed, terrain, population density and land use pattern. Summary of the adopted design standard for project road is tabulated below:

Table 3.1: Summary of the adopted design standard

i.	Design Speed Km/hr	:	100
ii.	Level of Service	:	B
iii.	Roadway Width	:	**In urban case:** 50m **In semi urban case:** 37.40m **In none urban case:** 24m
iv.	Roadway Elements	:	**In urban case:** Carriageway 4-lane- 2x7.5m Paved Shoulder- 2x2.50m (with Rumble Strip as required) Central Median - 3.00m, Service lane-2 x6.5 m with 1.50 m Side Median and Foot Path-2 x 5.5m.

			In semi urban case: Carriageway 4-lane- 2x7.5m Paved Shoulder- 2x2.50m (with Rumble Strip as required) Central Median- 3.00m Additional Lane -2 x 5.50 m additional lane (upgradable to 6.50m) with 2x1.2 m lane separator and drain. Verge: 0.50 m **In none urban case:** Carriageway 4-lane- 2x7.50m Paved Shoulder- 2x2.50m (with Rumble Strip as required) Central Median - 3.00m. Verge -2 x 0.50m
v	Camber	:	Carriageway: 2% Shoulder: 3%
vi	Right of Way	:	50.00 m
vii	General Embankment/ Cutting Slope	:	In Filling: 1V:1.50H In Cutting: 2V: 1H (varies as per soil type)
viii	Stopping Sight Distance	:	190m-design speed of 100km/hr
ix	Super-elevation	:	7%
x	Min. Radii for Horizontal Curves	:	Plain / Level Terrain - 375 m (100km/hr)
xi	Ruling Gradient	:	5-6% Minimum Gradient 0.50 %
xii	Minimum K-Factor	:	
	Summit Curve	:	85 for Design speed of 100 km/hr (Only considering Stopping Sight Distance)
	Valley Curve	:	45 for Design speed of 100 km/hr (Only considering Stopping Sight Distance)
xiii	Bridge Clearance	:	
	Vehicular underpass	:	4.75 m
	Interchanges / Grade Separator	:	5.50m
	Cattle / Community Crossing underpass	:	3.50 m
	Wildlife	:	6.50 m
	Minimum Drainage Channel Width	:	0.40 m

3.3.1 Road Classification

Roads in Nepal are classified under two categories that are Administrative Classification, and Technical/Functional Classification.

According to the Administrative Classification roads are categorized as National Highway, Feeder Roads, District Roads and Urban Roads.

The proposed road is categorized as National Highway in accordance with administrative classification. Since the proposed road is the section of East West Highway, it is under Asian Highway (Code AH2).

Technical/Functional Classification: For assigning various geometric and technical parameters for design, roads are categorized into classes from Class I to Class IV in accordance with average daily traffic.

Class I	Class I roads are the highest standard roads with divided carriageway and access control (Expressways) with ADT of 20,000 PCU or more in 20 yrs. perspective period. for design of this class of roads in plain terrain is120 km/h
Class II	Class II roads are those with ADT of 5000-20000 PCU in 20 yrs. perspective period. Design speed adopted for design of this class of roads in plain terrain is 100 km/h.
Class III	Class III roads are those with ADT of 2000-5000 PCU in 20 yrs. perspective period. Design speed adopted for design of this class of roads in plain terrain is 80 km/h
Class IV	Class IV roads are those with ADT of less than 2000 PCU in 20 yrs. perspective period.

Adopted design speed for proposed road is 100 km/hr, and therefore it is categorized in Class II under technical and functional classification.

3.3.2 Road Geometry

3.3.2.1 General

Geometric design of the proposed road has been carried out considering road function, type and volume of traffic, traffic hazards, safety and road user's friendly. Accordingly, the horizontal alignment, vertical alignment and the road cross-section have been designed. For geometric design of proposed road, Asian Highway Design Standards 1993 and Nepal Road Standards 2070 have been adopted.

3.3.2.2 Design Speed

The project road passes through plain terrain. The design speed of the proposed road has been adopted so that it corresponds to general topography and adjacent land use. Aspects such as Travel needs and behavior of the road users have also been considered in selection of the design speed. For the proposed road, the ruling design speed corresponding to the plain terrain is as follows:

Table 3.2: Design Speed Standards

Terrain	Ruling Design Speed (km/hr)	
	NRS-2070	AHDS-1993
Plain/ Level	120.00	120.00-100.00

In light of mix traffic on the proposed road, a ruling design speed of 100.00 km/h has been adopted. Use of speed regulatory signs have been proposed at sharp curves where design speed of 100.00 km/hr cannot be maintained.

3.3.2.3 Capacity and Level of Service

The Level of Service (LOS) characterizes the operating conditions on the roadway in terms of traffic performance measures related to speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience. The levels of service range from level-of service A (least congested) to level-of-service F (most congested). The Highways Capacity Manual (HCM) provides the following levels of service definitions:

Table 3.3: Standard Level of Service

Level of Service (LoS)	General Operating Condition
A	Free flow
B	Reasonably free flow
C	Stable flow
D	Approaching unstable flow
E	Unstable flow
F	Forced or breakdown flow

In accordance with Nepal Road Standards, following consideration has been adopted for the proposed road:

a. Among six Levels of Services, it is recommended to adopt category "B" for the design capacity of roads.
b. Under this condition, there may be traffic congestion and inconvenience during some of the peak hours, which is acceptable.
c. Design capacity governs the number of lanes required for the design volume of traffic.
d. At the level of service B, volume of traffic will be around 45 percent of maximum capacity under mixed traffic condition. Design traffic volume has been taken as the volume at the end of the design life considering the equivalency factors as shown in **Table 3.4** Vehicle Type and Equivalency Factor.
e. Recommended design service volumes for single lane, intermediate lane, and two lane and multi lane roads are presented in **Table 3.5** Capacity of Roads PCU/day.

Table 3.4: Vehicle Type and Equivalency Factor.

S.No.	Vehicle Type	Equivalency Factor
1	Car, Auto Rickshaw, SUV, Light Van and Pick Up	1.00
2	Light (Mini) Truck, Tractor, Rickshaw	1.50
3	Truck, Bus, Minibus, Tractor with trailer	3.00
4	Bicycle, Motorcycle	0.50
5	Non-motorized carts	6.00

Table 3.5: Capacity of Roads PCU/day

S. No.	Category	Plain	
		Low curvature (0-50 deg/km)	High curvature (>50 deg/km)
1	Four lane road with a minimum 3.m wide median	40000	35000

3.3.2.4 Cross Sectional Elements

I. Road Width for Highway

Adequate roadway width has been provided including the shoulders and a central media. Based on international standards and road safety, the following values are provisioned for the proposed road as presented in the **Table 3.6** and **Figure 3.5.**

Table 3.6: Road Cross Section

S. No.	Element of Road	Urban Area	Semi Urban Area	None Urban Area	Landslide Area	Remarks
1	Carriageways, m	2 * 7.50	2 * 7.50	2 * 7.50	2 * 7.50	
2	Service Lane, m	2*6.50			2*6.50	
2	Additional Lane, m		2 * 5.50			Upgradable to 2*6.50m with footpath
2	Central Median, m	3.00	3.00	3.00	3.00	
3	Side Median, m	2*1.50			1*1.5	
4	Separator/Drain, m		1.20*2		1.00*1*	*Initial chainage
5	Foot Path, m	2*5.50			1*2 to 5.50	
6	Paved Shoulder, m	2*2.50	2*2.50	2*2.50	2*2.50	
7	Verge, m		2*0.50	2*0.50		
8	Total Formation Width, m	50.00	37.40	24.00	29.25~39.50	

II. Lane Width

The lane width recommended by the Nepal Road Standards is 3.5m / 3.75 m respectively for design speed of 100 km/h. The Lane width of 3.75m has been adopted for the proposed road.

III. Shoulders

Asian Highway standards / Nepal road standard recommends a Granular shoulder of 3.0 to 2.5m. The shoulder with Dense Bituminous Macadam of 2.5m width has been adopted on either side for proposed road.

Figure 3.1: Cross Section of the Highway for Urban Area with Service Lane (total width=50.00m)

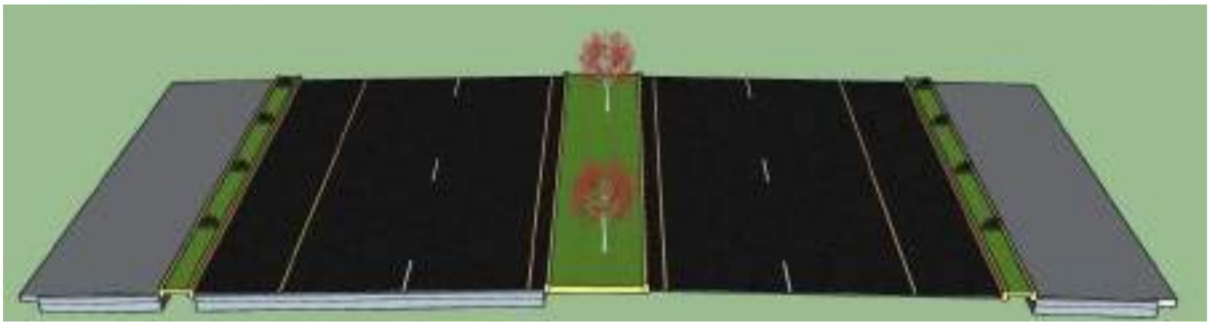


Figure 3.2: Cross Section of the Highway for Semi-Urban Area with Additional Lane for Motorcycle, Three wheeler and Carts (total width=37.70m)

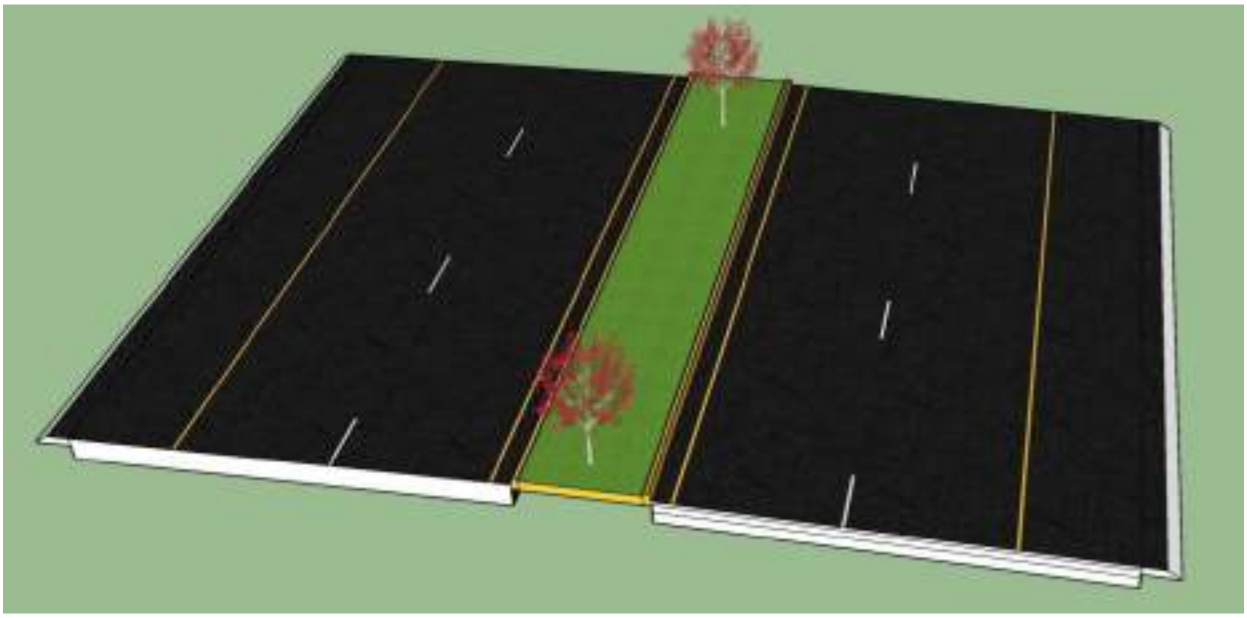
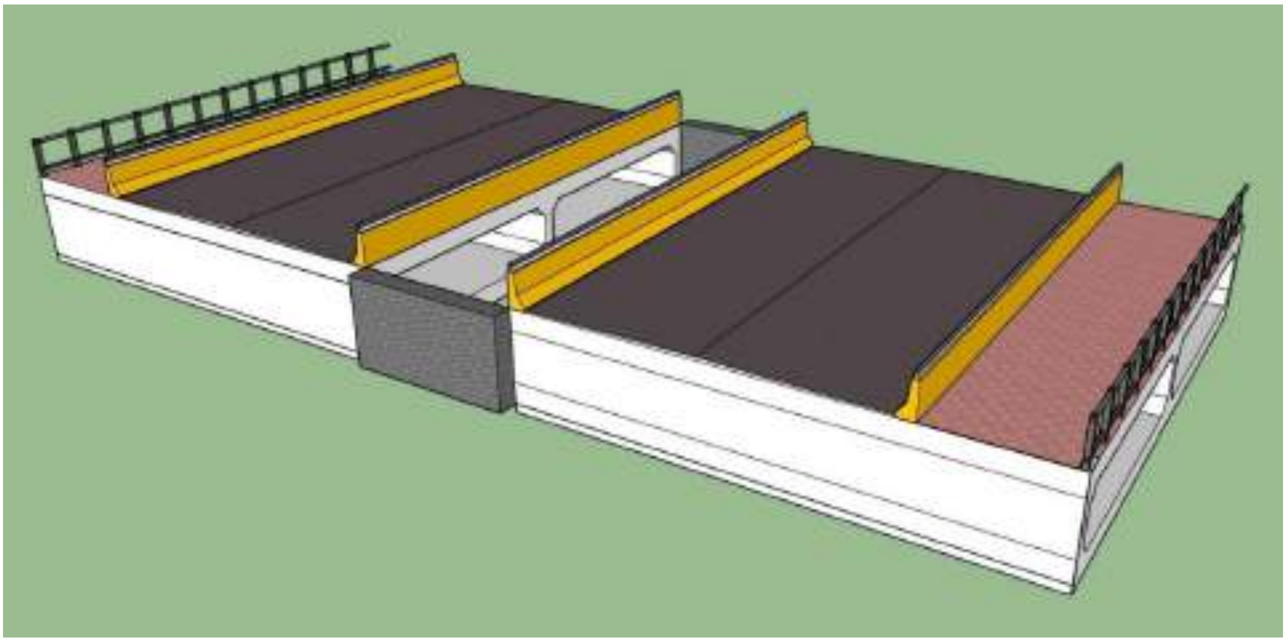
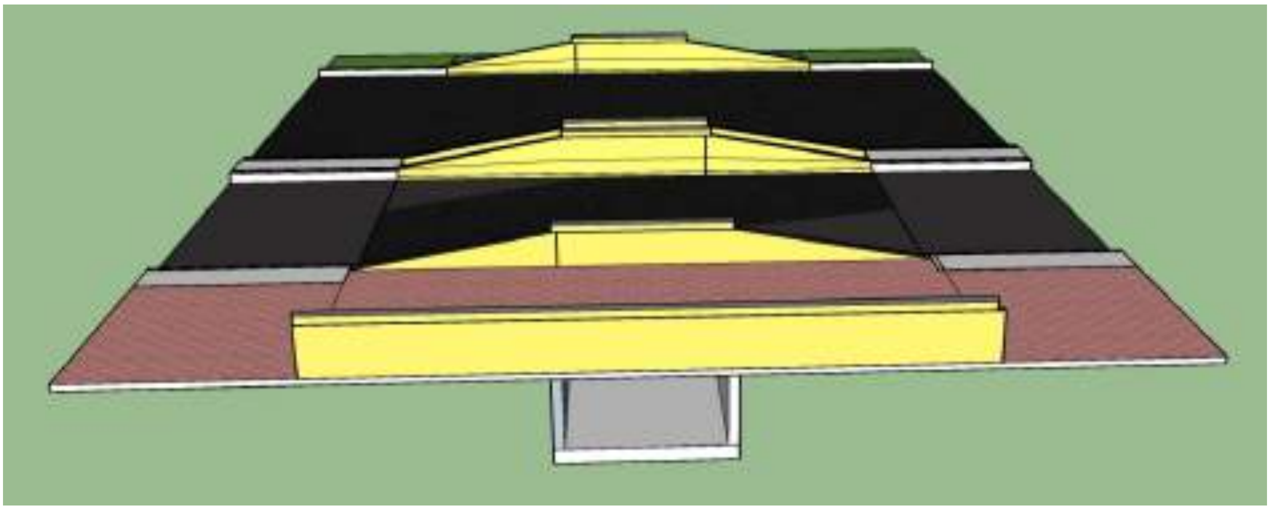


Figure 3.3: Cross Section of the Highway for Non-Urban Area (total width=24.00m)





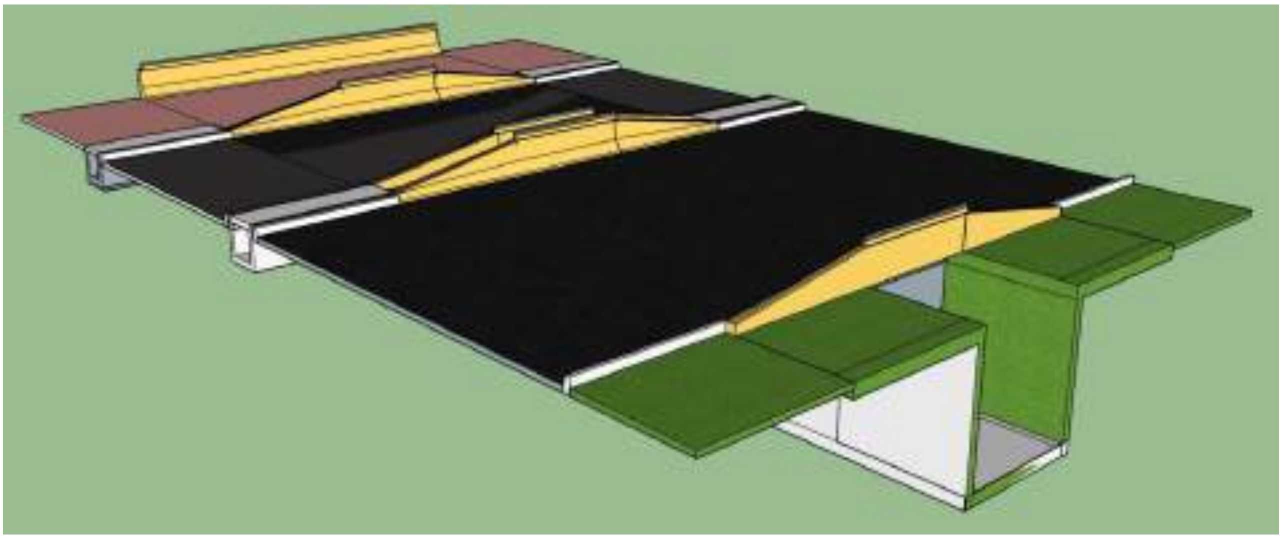
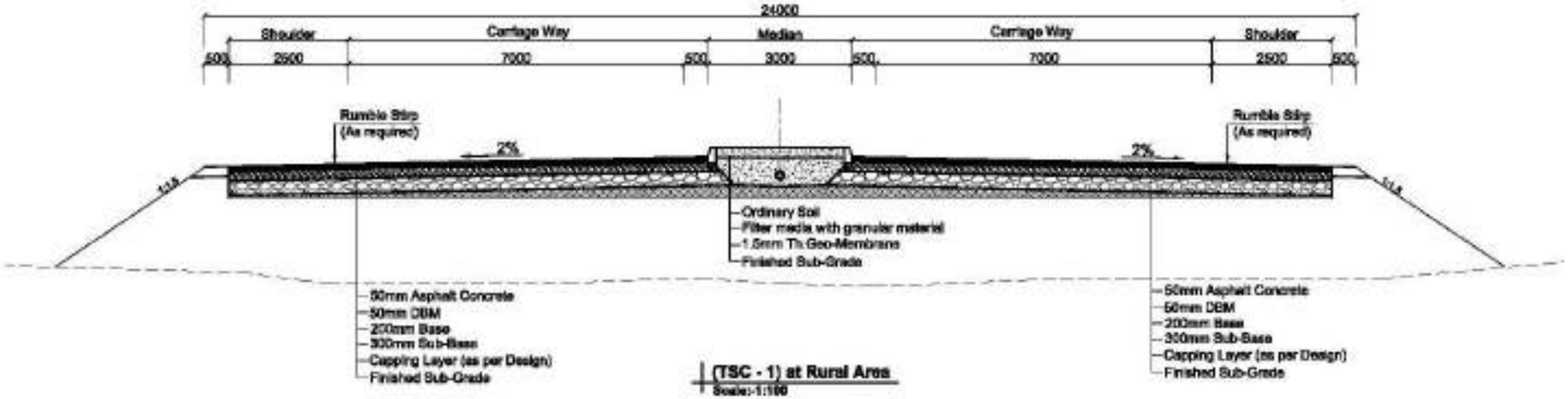
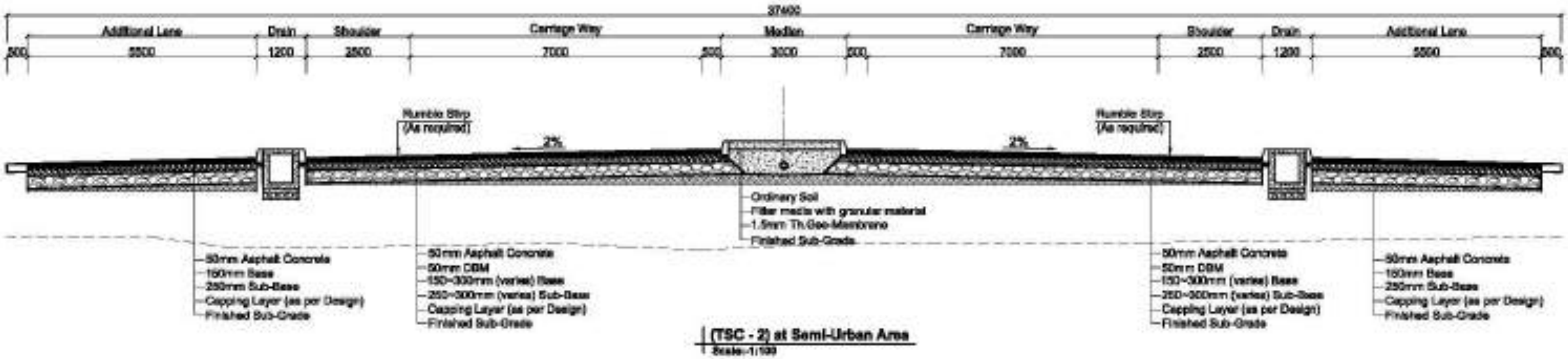
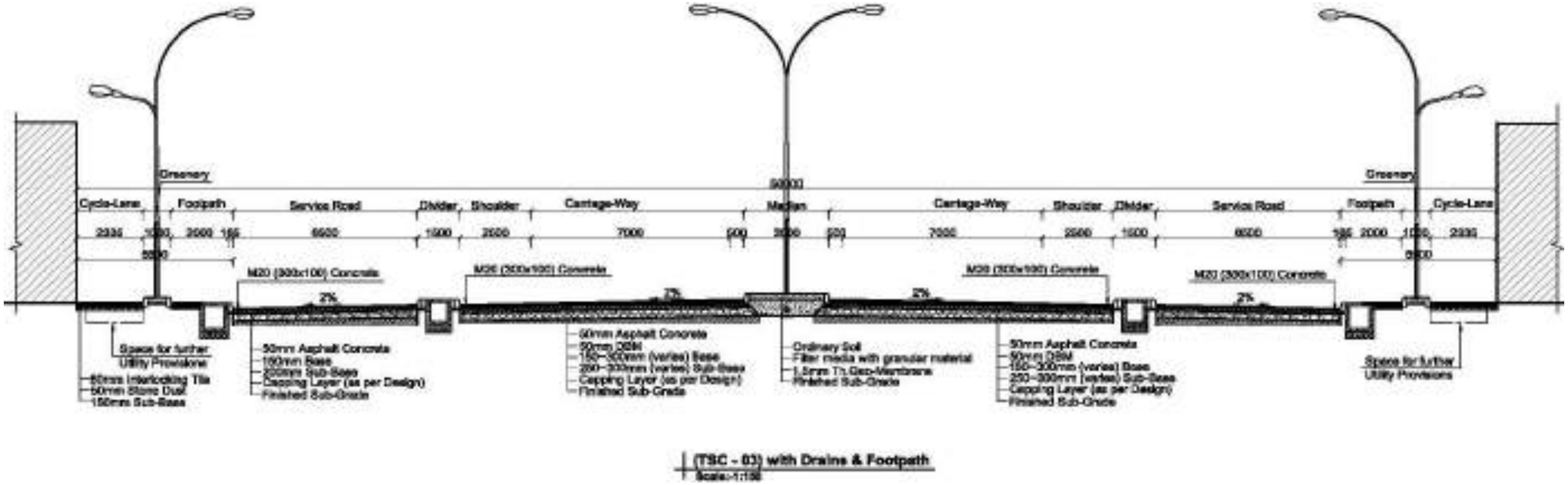


Figure 3.4: 3D view of the Highway for Major and Minor Bridges

Drawings with dimensions is presented below **Figure3.5**







Urban Area

Figure 3.5: Cross Section of Proposed Road (Urban, Semi Urban and Non-Urban Sections)

IV. Pavement Camber (Cross Falls)

Considering Asian Highway Standard for bituminous surfacing, the Consultant has proposed a camber of 2.0 % and 3.0% for the main carriageway and paved shoulder respectively.

V. Right of Way

As per Nepal Road Standard 2070 and Public Road Act 2031 recommend Right of Way of East-West Highway as 50.00 m which is followed for the proposed road as well.

VI. Embankment Slope in filling

The slope of embankment is linked with its height. In accordance with the Safety Standard in Road Design, the followings have been adopted for Embankment in Fill:

The Consultant proposed to provide slopes of 1.5H: 1V in Fill sections.

VII. Embankment slopes in Cutting:

Cut slopes are proposed as 1H: 2V or steeper with Intermediate berms in general, however, the steeper slopes have been specifically analyzed for stability.

3.3.2.5 Horizontal Alignment

a) General

Horizontal alignment has been designed considering design speed and surrounding topography.

b) Horizontal Curve

The minimum radius of horizontal curve is the limiting value of curvature for a given design speeds and has been determined based on the maximum rate of super elevation and the side friction factor. The minimum ruling radii of Horizontal curve has been adopted based on Asian highway Design Standards corresponding to plain terrain which is presented in table below:

Table 3.7: Horizontal Curves Radius

Type of Terrain	Minimum Radius of Horizontal Curve for Class A, m	
	Desirable Minimum	Minimum
Plain/Level	600	350

c) Transition Curve

The minimum transition curve length has been adopted considering Asian Highway Design standards corresponding to plain terrain condition which is presented in the table below. However, at locations having right of way and River bank constraints, it is proposed to keep minimum Transition Curve in accordance with Rate of Change of centrifugal acceleration and Rate of Change of Super-elevation.

Table 3.8: Minimum Transition Curve Length

Terrain	AHS Class I, m
Plain/ Level	85

d) Super-Elevation

The Asian Highway Design Standards proposes a maximum super-elevation rate of 10% for all terrain. The Nepal Road Standard proposes rate of maximum 7 % for plain and rolling terrain. Therefore, Super-elevation has been limited to 7% for geometric design.

e) Extra-widening

Value of extra widening of proposed road is adopted as shown below in Table (as per NRS-2070).

Table 3.9: Value of Extra Widening

Radius of Curve, m	40-60	60-100	100-300	>300
Extra width, m (for Multi Lane Road, N-number of Lane)	0.60n	0.45n	0.30n	nil

3.3.2.6 Vertical Alignment

- **General**

The vertical alignment has been designed in such a way that; the smooth longitudinal profile consistent with standard of the road and terrain. Wherever possible; horizontal and vertical curvature have been combined to enhance the safety and operational efficiency of the road.

- **Gradient**

The criterion for gradient provided in Asian Highway Design Standards has been tabulated as below.

Table 3.10: Asian Highway Standard for 4-Lane Highways

Highway Classification		Primary (4 or more lanes)				Class I (4 or more lanes)			
Terrain Classification		L	R	M	S	L	R	M	S
Design Speed (Km/hr)		120	100	80	60	100	80	50	50
Width (m)	Right of Way	(50)				(40)			
	Shoulder	3.00		2.50		3.00		2.50	
	Meridian Strip	4.00		3.00		3.00		2.50	
Min. radii of Horizontal Curve (m)		520	350	210	115	350	210	80	
Pavement Slope (%)		2				2			
Shoulder Slope (%)		3-6				3-6			
Type of Pavement		Asphalt/Cement Concrete				Asphalt/Cement Concrete			

Highway Classification	Primary (4 or more lanes)				Class I (4 or more lanes)			
Max Super elevation (%)	10				10			
Max. Vertical grade (%)	4	5	6	7	4	5	6	7
Structure Loading (minimum)	HS 20-44				HS 20-44			

- **Vertical Curve**

Vertical curves such as valley curve and summit curve have been selected in such a way that the rate of change of grade throughout the curve is uniform. A quadratic parabola has been used as vertical curve in proposed design as it satisfies the above condition.

3.3.2.7 Miscellaneous

a) Highway Lighting

Suitable Highway lightings have been proposed generally at Urban Areas, Interchange locations, Bus Bays.

b) Road Sign

In consideration with Nepal Traffic Signs Manual (Volume-1 &2), appropriate road signs have been proposed. The signs are provided on embankment so that extreme edge of sign would be 2.5m away from the edge of the carriageway. The location of each sign has been decided in accordance with the guidelines therein.

c) Road Marking

Road markings have been proposed for centre and edge lines using reflective thermoplastic paints. Appropriate road markings have also been proposed at junctions, Interchanges / merging and diverging of slip road and other places.

d) Crash Barrier

Crash Barriers have been provided at high embankments, sharp curves and bridge approaches. The barriers have been located at the edge of paved shoulders.

3.3.2.8 Road User Facilities

a) Bus Bays

Bus Bays with covered bus shelter of size 3.0 m x 6.0 m with seating provision have been provided at needy places. Bus-bay has been separated from main carriageway by a yellow line. Sufficient sight distances for entry taper and exit taper have been provided for the Bus-Bay located on curved section.

Typical bus shelter is shown in **Figure 3.6**

Figure 3.6: Typical Bus Shelter (3D View)

b) Pedestrian Crossing

Provisions for pedestrian crossings have been provided at appropriate locations and with suitable types. The types of pedestrian crossing are level crossing (Zebra Crossing), overhead crossing, underground crossing, signalized pedestrian crossing and pedestrian push/call button signal. Typical pedestrian crossings are shown below in **Figure 3.7.**

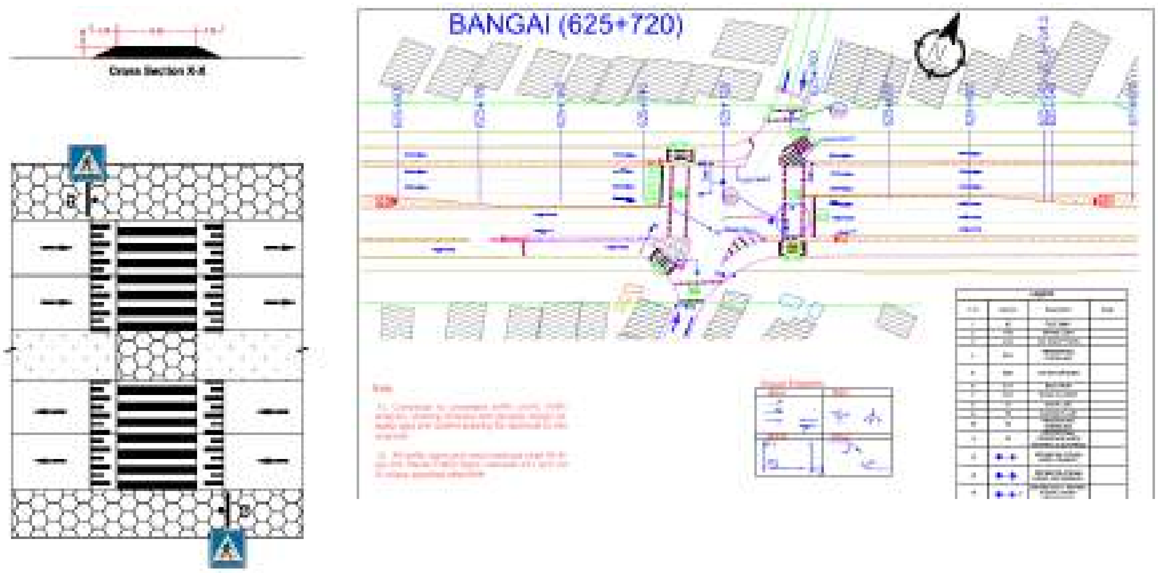


Figure 3.7: Typical Pedestrian Crossings

3.4 General Road Design Consideration

The followings major considerations are recommended for the project road:

- Raise the embankment to provide a minimum subgrade level of 0.5 m above natural ground level or 0.6 m above highest flood level to meet hydraulic requirements;
- Improve horizontal and vertical alignment to allow a minimum design speed of 100 km/h on level terrain and 80 km/h in rolling terrain;
- Replace existing cross drainage structure of span up to 10.00 m by appropriate type of cross drainage structure;
- Avoid causeways;
- Provide guard barriers at bridge approaches, sharp horizontal curves and embankments with high greater than 3.00 meters;
- Provide appropriate interchange mechanism at intersections;
- Provide sufficient road furniture including road safety elements such as signs, delineator posts, kilometer posts, rumble stripes etc. and additional signs where there are high pedestrian activities and a high possibility of accidents;
- Provide pedestrian crossings and speed controls at key locations such as outside schools and hospitals and in other areas where there are high pedestrian movements;
- Provide bus bays at important bus stop locations and additional road formation width for two lanes in market areas.
- Provide pleasant road architectural views;

3.5 Access Control

Access Control is essential for safety reasons for smooth operation of the road. In light of this, limited access has been provisioned whereas access from schools, hospitals and other institutions have been provided taking consideration with safety factor.

4 Design Standard for Bridges

4.1 General Bridge, Underpass, Overpass and wildlife crossing Design Consideration

Regarding the major and minor bridges, the following understandings have been developed after several meetings with the ADB/PD and DOR authorities:

- Old bridges of length less than 10m or multi-cell box/Hume Pipe culverts and any other bridges rated as unsuitable for further use will be dismantled and replaced by either new box bridges/culverts or twin double lane bridges.
- For all other bridges in serviceable condition, a new double lane bridge to be constructed at the upstream or downstream side of the existing one. The approach alignment will be adjusted near the bridges with sufficient length conforming to the geometric parameters of the road. Suitable gap (approximately 4 m) will be provided between existing and new bridges.
- Unless otherwise dictated by the site conditions, downstream side is preferred for a new bridge so that river training costs are minimized.
- The span arrangement of the new bridge at the side of an existing one will be chosen in a manner such that the substructures of existing and new bridges are aligned along the river course to avoid debris traps.
- For the new bridge at the side, longer spans will be chosen as far as practical so that number of foundations is minimized.
- For non-urban areas the total width of the main lanes will be 8.0m with curb shyness width confined within the crash barriers. Remaining 2.75m will be used as pedestrian/ cycle paths. Total bridge width will be 11.75m including hand-rails and crash barriers. The bridge will be designed with the provision of a third lane in the future, the inner crash barrier can be dismantled providing nearly 11 m carriageway. A separate footbridge can be constructed for the pedestrians in future.
- Three lane bridges are proposed in built-up areas with main two lanes of total 8.0m eliminating the curb-shyness width, one service lane of 5.00 m and 2.20 m. raised footpath at one side. The main and service lanes will be separated by a double sided crash barrier. Total bridge width will be 16.45m including hand-rails and crash barriers. In future, if the service lane needs will be widened, the footpath can be dismantled and used as carriageway. In that case separate footbridge needs to be constructed at the side of the main bridge.
- Sufficient lateral and vertical clearance for underpasses, overpasses and wildlife crossing shall be provided.

4.2 General Design Scheme

The design scheme for major and minor bridges (length less than 300 m) is elaborated below:

- Review of existing bridge inventory, detailed site survey and investigation for the bridge parameters such as length, type and span arrangement. Sorting and grouping of the span lengths for standard spans for new bridges.
- Preparation of final scheme for locations of new additional bridges (upstream or downstream of existing bridges); replacement of multi cell pipe culverts with twin bridges and preparation of tentative span arrangement plan on the basis of preliminary scheme, site survey and investigation.
- Confirmation of bridge locations and span arrangement for new additional bridges on the basis of Detail Engineering Survey, Geological, Geotechnical and Hydrological studies.

The span lengths of the bridges in proposed road sector range from 6 m to 42.00 m (excluding culverts).

As a general principle, the length of the new additional bridge should not less than the existing one unless there is a substantial decrease in water flow in the river or stream due to some permanent change at the upstream. Such condition has been verified by the hydrological analysis. The substructure of the additional bridges has been aligned with that of the existing one. Keeping these factors in mind, the span arrangements of the additional bridges have been carried out in such a manner that a number of short spans are covered by a single longer span as far as practical.

Basically, for major and minor bridges RCC and PSC superstructures and for multi-cell culverts RCC box bridges are proposed.

4.3 Design Standard

The Consultant is aware of the fact that the proposed bridges should also match the standards of Asian Highway. Two separate bridges will be constructed for both direction of traffic. Similarly, the geometric parameters of previously upgraded/designed sections of this highway such as **Kakarbhitta-Laukahi, Narayanghat-Butwal** and **Kamala – Kanchanpur** are also considered for similarity.

As already stated above (Sub Chapter 4.1), an additional bridge has been proposed for additional lanes retaining the existing bridge unless it is unfit for further use. Wherever the existing bridge needs to be dismantled, a twin bridge separated by a width approximately equal to the median has been proposed to have overall 4 lanes with footpaths at the outer sides of the carriageway.

For the additional bridge at the side of the existing one, a minimum clear gap of 4.0 meter is provisioned. Larger gaps between two bridges have not been considered to avoid large deviation between the approach's alignments. On the other hand, the gaps should be sufficient enough to carry out maintenance activities for both bridges and also to avoid structural discrepancy to the existing foundation.

4.4 Design Principle, Coad and Guideline

The designs have been followed basically the guidelines by the Indian design codes as well as DOR Bridge Standards whatever are applicable. Since the DOR has now adopted Limit State Method of analysis and design of bridges, the same method has been followed in the designs. It is recommended that construction of all bridges /culverts shall conform to the **Standard Specification for Road and Bridges Work**s published by Ministry of Physical Planning and Works, Department of Roads-2073 (With Second amendment 2078).

Design has been carried out keeping in mind that sub structure/foundation has to resist worst combination of live, earthquake, impact, temperature; and horizontal forces caused by lateral earth force. The foundation has been designed to withstand the worst combination of loads and forces evaluated in accordance with the provision of **clause 706 of IRC 078-2000 Foundation Bridge**. The foundation has been designed to such depth that it is not affected by scour.

The following documents are also considered in design of bridges, underpass, overpass and wildlife crossing:

IRC:5-2015	Standard Specifications and Code of Practice for Road Bridges, Section I– General Features of Design
IRC:6-2017	Standard Specifications and Code of Practice for Road Bridges, Section-II Loads and Load Combinations
IRC:22-2015	Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction (Limit States Design)
IRC:24-2010	Standard Specifications and Code of Practice for Road Bridges, Steel Road Bridges (Limit State Method)
IRC:78-2014	Standard Specifications and Code of Practice for Road Bridges, Section VII-Foundations and Substructure
IRC:83-2018 (Part II)	Standard Specifications and Code of Practice for Road Bridges, Section : IX – Bearings (Elastomeric Bearings)
IRC:83-2018 (Part III)	Standard Specifications and Code of Practice for Road Bridges, Section IX – Bearings, Part III: POT, PIN, Metallic Guide and Plane Sliding Bearings
IRC:89-2019	Guidelines for Design and Construction of River Training & Control Works for Road Bridges
IRC:112-2019	Code of Practice for Concrete Road Bridges
IRC: SP-105-2015	Explanatory Handbook to IRC:112-2011: Code of Practice for Concrete Roads Bridges
IRC: SP:114-2018	Guidelines for Seismic Design of Road Bridges
IRC: SP-69-2011	Guideline and Specification for Expansion joints
IRC: 54-1974	Lateral and Vertical Clarence at Underpass for Vehicular Traffic
Rajpatra Sec. 5-2079	Wildlife Friendly Infrastructure Construction Guideline-2078, Nepal

Apart from the above documents, other suitable IRC documents as well as Indian Standards (IS codes) are also followed as per requirement.

4.5 Bridge Construction Material

4.5.1 Cement

For construction of structures, 43 grade ordinary Portland cement conforming to IS: 8112 and 53 grade ordinary Portland cement conforming to IS: 12269 have been adopted. In order to improve workability of concrete, an Admixtures conforming to IS: 9103 has been adopted. It is recommended to use clean, hard, strong, dense, non-porous and durable crushed stone for coarse aggregates and natural particles for sand. The aggregates should conform to IS: 383 and should be tested to conform to IS: 2386 parts I to VIII. Size of coarse aggregate should be selected as per mix design requirement.

4.5.2 Water

Water used for mixing and curing should be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. The pH value of water should not be less than 6.

4.5.3 Concrete

The grade of concrete should be as per design requirement and as mentioned in execution drawings for each component of the structure. Cement and water content should be as per mix design requirement.

4.5.4 Reinforcement

Deformed or TMT reinforcement bar conforming to IS: 1786 has been adopted for components of the structures. The reinforcement grade will be Fe500.

4.5.5 Pre-Stressing Steel

Pre-stressing tendons normally take the form of separate wires, wires spun together helically to form strands or bars. For pre-tensioned steel, wires, strands and occasionally bars are used, simply to permit the concrete to bond directly to them; when post-tensioning is used, it is common practice to group the separate tendons together, so as to reduce the number of anchorages and ducts required to accommodate them. When grouped in this way, the tendons in each duct are usually termed a cable. Uncoated stress relieved low relaxation steel conforming to IS: 14268 should only be used for pre-stressing steel so as to reduce losses due to relaxation. Data in respect of modulus of elasticity, relaxation loss at 1000 hours, minimum ultimate tensile strength, stress-strain curve etc. should necessarily be obtained from manufacturers. Pre-stressing steel should be subjected to acceptance tests prior to actual use on the works (guidance may be taken from BS: 4447). The modulus of elasticity value, as per acceptance tests, should conform to the design value which should be within a range not more than 5 percent between the maximum and minimum.

Many cables with different arrangements of wires and strands and different methods of anchorage are available as pre-stressing steel. So, type and size of cable and methods of anchorage should be decided on the basis of design requirement.

SECTION II SURVEY, INVESTIGATION AND ANALYSIS

5 Engineering Surveys and Investigations

5.1 General

A sound engineering approach was developed based on Terms of Reference for conducting the field surveys and investigations. Primary data were collected from the site whereas secondary data were obtained from desk study. Followings primary field surveys and investigations were carried out for the project road:

Inventory:

- Road
- Bridge and Cross Drainage Structures

Topographic Survey:

- Road corridor
- Bridges

Axle Load Survey

Traffic Survey

5.2 Inventory Survey of Road and Condition Survey of Bridges

The scope of improvement measures and economic justification thereon depend on the condition of the existing road and its associated inventory. To collect the inventory of the existing road and allied features of road and structures, inventory surveys were carried out.

5.2.1 Road Inventory Survey

While conducting Inventory Survey of Road the existing physical features and surrounding condition of the project road were determined. Firstly, a throughout two-way videography of the proposed road section along with GPS device was conducted followed by geotagging of each video frame. The features such as chainage, latitude and longitude were overlaid on the video frames. Furthermore, inventory items along with their location were retrieved by a Software developed by the Consultant. Final processing was done at the office by watching the video and identifying the inventory items.

Secondly, Team of engineers was engaged to carry out field survey and take measurements of all road inventory items along the road. While measuring, classification of the items along left/right side of the road were made. The team was provided with the android device compatible to *kml files with road alignment and chainages, so that they could know their exact locations on the field. Simultaneously, the team checked/verified the items that were retrieved from the video frame. Items that could not be identified from the video such as cross drainage structures, retaining wall etc. were given emphasis while taking the data on the separate formats developed by the Consultant.

The information collected was analyzed and cross-checked to constitute the core database for formulating upgrading design. The information has been utilized to decide the following:

- Decision on the widening of the carriageway either concentric or on left-side or right side.
- Formulate the best-fit cross section with due consideration to terrain conditions, available land width and roadside features.
- Decision on the identification of missing cross drainage structure due to urbanization, new location for the cross-drainage structures and, requirement of longitudinal drainage.
- Treatment to be given to congested built-up stretches.
- Provision of roadside facilities.
- Existing utility lines by type, location and extent that would require relocation.

5.2.2 Bridge Inventory/Condition Survey

Bridge Inventory/Condition survey was carried by team of engineers. Prior to initiate inventory/condition survey work, the team established the safe working condition and undertook the general appraisal of the site.

After completing the preparatory work, the detailed Inventory/Condition survey of the bridge was initiated. The information about the existing bridges has been collected through the inventory survey. Preliminary inspection in accordance with the relevant provisions contained in Nepal Bridge Standard was carried out to ascertain the present condition of the existing two-lane bridges.

The following information were gathered during Bridge Condition Survey:

- History of the structure with available HFL/OWL and materials used in the construction;
- Geometric aspects, including bridge widths and whether the existing structure can be economically incorporated into the new road geometry.
- Condition of each element of the structure viz. foundation, sub-structure, bearings, super-structure, railings, drainage spouts, river protection works, returns and wearing course;
- Approach road conditions.
- Waterway conditions and information of high flood level and mark of scoring.
- The capability of the structure to meet the proposed design standards for traffic loading;
- Repair needs or the requirement of reconstruction of one element or the complete structure based on the present distress level.
- Ease of maintenance and future maintenance costs.

Each part of the bridge was inspected thoroughly and recorded the condition using the appropriate inspection report forms which are included in **Appendix C** of Guideline for Inception and Maintenance of Bridges.

Photographs and Videography were taken to supplement the completed forms for permanent record of the observations.

The information has been utilized to decide the following:

- Decision on the Bridge type selection and span arrangements.
- Decision on the identification of the location of the additional bridge U/S or D/S.
- Finalization of degree and type of maintenance according to the defects identified on the bridge, to be carried out on the existing bridge.
- Identification of serviceability of the existing bridge
- Decision on the overall planning for Bridge Information Management Plan (BIMP)

5.3 Topographical Survey and Data Analysis

The complete methodology adopted for conducting topographical survey for the project road comprised of the following activities:

5.3.1 Consultation with Project Office/FRSMO

First step of the consultant in field study was consultation with the concerned Federal Road Supervision and Monitoring Office (FRSMO) and Division Road Offices. The Consultant had taken information regarding proposed road along with the document related to the proposed road.

5.3.2 Establishment of main control by DGPS

5.3.2.1 Establishment of Benchmark

Prior to initiate the engineering survey, permanent survey monuments were established along the road. Bench marks in the form of concrete of size 15 cm x 15 cm x 60 cm were established. The benchmarks were established at 500 m intervals along the road alignment. The monument/ Bench-Marks were raised at least 5 cm above the ground level. Additionally, required offsets survey points were established so that detail topographic feature of the proposed area can be taken. The bench mark survey was initiated incorporating the established National Geodetic Grid in the vicinity of the road alignment. The survey was done by fly leveling (Level Instrument-GEOMAX-2AL-124). **The Consultant used DGPS instruments** namely EMLID-REACH-RS-2 and DGPS-EMLID -REACH-RS-2 in order to check the benchmark and Travers control.

For the future reference, description cards (D-cards) of all bench marks were prepared with appropriate reference. The bench mark surveys were completed with tolerable error not more than square root of distance in Km. Location Map of DGPS Station and Benchmarks is shown at **Annexure: I,** List of DGPS Station and Benchmark is attached at **Annexure: II,** and D-Card of every Benchmark is attached at **Annexure: III.**

5.3.2.2 Traverse Survey

After bench mark survey, the Consultant had started traverse survey of the road alignment. As all bench mark were checked by the DGPS, detailed Travers survey was not needed, however, all additional Travers stations were surveyed and closed. The survey was carried out using Total Station (Topcon and Sokkia ES and Mi model). The survey was conducted applying standard practice. The closing error was within tolerable limits. The distances ware measured with the accuracy 5 mm + 5 ppm x base line length. The error has been distributed based on the lengths of the respective lines.

5.3.2.3 Topographical Survey

A detailed topographical survey was conducted along the road corridor of appropriate width on either side of centre line. Features included were buildings, structures, monuments, burial grounds, place of worship, streams, rivers, canals, utility services such as electric and telephone lines, poles, etc. Topographical surveys for additional areas around cross-drainage sites and road intersection points were carried out, so as to enable proper designing of cross drainage works and junctions. The survey also covered the existing road structures such as retaining wall, check dams, longitudinal and cross drainage structures and other structures of the existing road.

Similarly, a topographical survey of the bridge site was conducted by Senior Surveyor on guidance of Team Leader, Bridge Engineer and Hydrologist.

The survey covered 700 m upstream, 300 m downstream (as suggested by the Hydrologist) from the bridge axis and 200 m from the river banks on either side of the river as required by the ToR. Bench Marks were established with RCC post of size 15 cm x 15 cm in plan and 1 m length. At least two Bench Marks were established on right and left bank at safe places from flood.

The cross-sections of the river were taken by means of precise automatic level at an interval 25m. Similarly, two more cross-sections each at 100m upstream and downstream of the proposed bridge axis were taken. The riverbed slope was also taken by means of level.

5.4 Axle Load Survey

The Axle load surveys were carried out on the proposed road section at Butwal (west of Tinau Bridge) with the objectives to determine Vehicle Damage Factor (VDF) from the axle load spectrum data. Several factors such as gross weight, tire pressure, number of wheels and wheel configuration, number of repetitions etc. affecting the design and performance of pavement were considered during Axle load Survey. The structural damage to a pavement system is caused by the commercial vehicles, which are expected to use it during its design life. In Nepal, overloading of trucks has assumed menacing proportions, endangering the pavement stability and road safety. The road pavement deteriorates under the action of vehicle wheel loads. The damaging effect of vehicle loads is cumulative in nature i.e., if the traffic is more and wheel loads are higher, the pavement deteriorates at higher rate.

Axle loads and gross vehicle weights can be measured by static or dynamic methods. The Consultant had adopted static method in which vehicles were stopped to measure their axle loads by means of portable weighing bridge and the wheel weighing pad. The axle load surveys were conducted for two days (48 hrs) at the proposed road section. Utmost care was taken in selecting the site for placing the pads, so that the effect of camber and longitudinal slope is nullified. The survey was conducted for two days (48 hours) in both directions with simultaneous volume count of commercial vehicles (Trucks and LCV) and random selection of vehicles for axle load measurement, ensuring a representative sample for each category of commercial vehicle including empty vehicles. A few samples of buses were also taken to weigh the axle loads.

While the vehicles were being weighed, information about the axle-type was recorded. Detail Data of Axle Load Survey is attached at **Annexure: IV**

Vehicle Damage Factor

The survey data has been verified, computerized and rechecked. Before the load spectrum analysis, the modal split of commercial vehicles and the percentage sample obtained in load measurements have been assessed with necessary data processing. From the recorded data, the commodity wise movement of the goods has been analyzed.

The Vehicle Damage Factor (VDF) is an index characterizing the traffic loading for a highway and is defined as a multiplier for converting the number of commercial vehicles of different axle loads to Standard Axle Loads (SAL). Equivalency factor (EF) is normally worked out by using the Fourth Power Rule derived by AASHTO. However, TRRL has suggested a factor of 4.5 for developing countries. In the present study however, the Fourth Power Rule given by CRRI has been adopted. With the help of equivalency factors and frequency distribution of axle loads, Equivalent Axle Loads (EAL) has been computed.

VDF = Total EAL / Number of vehicles weighed

Due to the uncontrolled loading and movement of the local vehicles (mainly trucks) having a load of Stone, Aggregates and sand vehicle damage factor is very high at this section. Therefore, the Consultant strongly recommended to develop controlling mechanism for axle load. Adopting these data for design is not justifiable and uneconomical. Therefore, vehicle damage factor for pavement design has been used from Pavement Design Guideline (Flexible Pavement), 2014 (Second Edition 2021), Kathmandu published by the Department of Roads.

Table 5.1: Shown the adopted VDF for vehicles.

Vehicle Type	VDF (Actual from the Axle Load Survey)
Bus Mini	0.35
Buses	0.50
Light Trucks	1.00
Heavy Trucks	4.75
Multi-axle Trucks	6.50

5.5 Traffic Survey

5.5.1 General

A systematic methodology has been followed to assess the characteristics of the traffic on the project road before and after the proposed improvement. The details pertaining to the data collection, primary as well as secondary, and results from its analysis are presented in the following sections.

5.5.2 Traffic Survey Location

The traffic volumes in the proposed road prevailed in early April 2021 were found to be normal as before the lockdown due to Covid-19. It was necessary to divide project road into sections with homogeneous road characteristics and traffic levels. Based on the observed traffic levels in different sections of the project road, traffic survey points were selected to obtain traffic volumes of homogeneous sections. Table 5-2 shows traffic survey points along the road section. The traffic surveys were conducted from 7th April 2021 to 9th April 2021.

The surveys were conducted for 3 days for 24 hours each day starting from 6 am morning. The collected traffic data were analyzed to obtain Annual Average Daily Traffic (AADT).

Based on the AADTs of the road, HDM4 was run to perform economic analyses to obtained EIRRs of the proposed project. The results are presented in **Chapter 22 Economic and Financial Analysis**

Table 5.2: Traffic Survey Locations in Butwal-Gorusinghe Road Section

Station	SSRN Chainage	St_Name	Description	Long	Lati
90	589+837	Butwal West	West of Tinau River End	83.45908	27.70452
91	611+720	Saljhandi West	Near Kanchan River	83.26061	27.69859
92	621+074	Jitpur West	500 m West of Jitpur Chowk	83.17093	27.68741
94	634+472	Gorusinghe East	500 m East of Gorusinghe Chowk	83.05198	27.6636

Selection of count stations were done so that capture the movement of traffic on all direction of the proposed road could be done. Classified Traffic count survey was conducted at each count station for 3 continuous days. Traffic in both directions were counted by vehicle type such as slow-moving vehicles, motorized two wheelers, light vehicles (car, jeep, van), Buses (standard, mini and micro) and trucks. Following image figure 5-1 shows the location of traffic count stations along the proposed road:

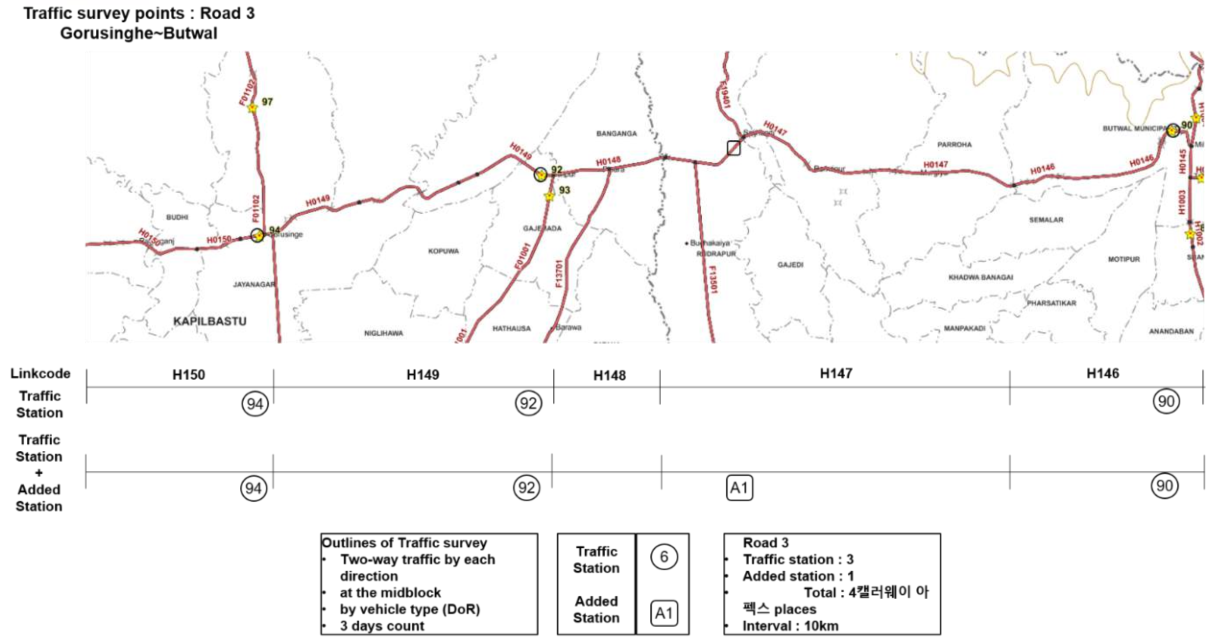


Figure 5.1: Locations of traffic count survey

5.5.3 VIDEO Acquisition Process and Classified Vehicle Type

Video based traffic count survey was conducted for more accuracy. For video graphic traffic count survey, the consultant has utilized digital video cameras with computerized and infrared recording (for recording at night). Traffic Video acquisition process is shown in **Figure 5.2** below:

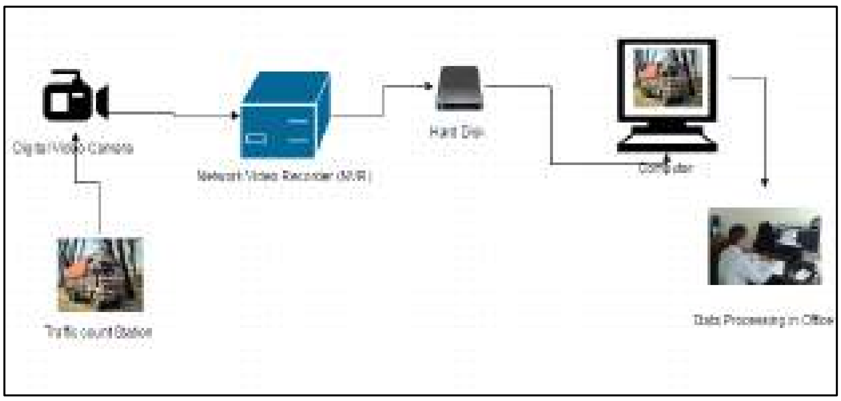


Figure 5.2: Traffic Video acquisition process

From the videos, traffic counts were conducted at project office and the results are presented in the Road Network Database System (RNDS) format of DOR.

Following **Table 5.3** and **Figure 5.3** shows the vehicle types used in the traffic count and classification survey:

Table 5.3: Classified Vehicle Type

Vehicle Type	Vehicle Characteristics
Multi-Axle Truck	Standard / heavy trucks, trailers/articulated. (≥3 axles)
Heavy Truck	Standard / heavy trucks, trailers/articulated. (2 axles)
Mini Truck	Mid-sized trucks with single rear-axle (usually 4-wheeled, <8 tons GVW)
Standard Bus	Buses having seating capacity of 35-50 seats
Mini-bus	Medium size buses having seating capacity of 20-35 seats.
Micro-bus	Small buses and vans having seating capacity of 10-15 seats.
Car	Passenger car taxis and vans (≤ 5 seats).
Utility Vehicles	Pickups or 4-wheeled vehicles with single/twin cabin and load compartment (open/hooded), Light freight vehicles
Tractor	Farm tractors
Four Wheel Drive	Vehicles strictly having four-wheel gears (seating approximately 10) such as Mitsubishi Pajero, Prado etc.
Three-Wheeler	Electrical or gasoline/LPG fueled 3-wheeled vehicles (excluding power tillers, farm tractors)
Power Tiller	Motorized four-wheel vehicles used for carrying goods and mainly driven by hands and not steering.
Motorcycle	Motorized two wheelers such as scooters and motorcycles
Bullock/Hand cart	Bullock, horse or manually driven vehicles (non-motorized)
Rickshaws	Non-motorized cycle rickshaws

Classified Vechicle Types


Multi-Axle Truck


Heavy truck


Light Truck


Big Bus


Mini Bus


Micro Bus


Car


Motorcycle


Utility Vehicle


Tractor


Motorized Three Wheeler


Four Wheel Drive


Power Tiller


Rickshaw


Bullock Cart/Tanga

Figure 5.3: Classified Vehicle Type

Due consideration was given to following points during the field work:

- Following COVID safety protocols.
- The safety of vehicle drivers, survey personnel, video data acquisition devices (camera, computer, monitor etc.) and accessories
- Undisrupted power supply for video recording
- The site distance required for carrying out the survey
- Avoiding multiple counting of local traffic and abnormal traffic situations (e.g., transportation strikes, festivals, long holidays)

Following section deals with details and analyses of the traffic volume and vehicle Classification Surveys carried out by the consultant.

5.5.4 Data Analysis

Traffic data have been presented in terms of Annual Average Daily Traffic (AADT) and expressed both in vehicles per day (vpd) and Passenger Car Unit (PCU).

In order to accurately understand the capacity of the road under mixed traffic conditions, vehicles per day (vpd) count of different types of vehicles have been converted to a common unit of PCUs (passenger car unit) by multiplying the total number of each type of vehicle with its equivalent PCU factor.

Passenger Car Unit is a vehicle unit used for expressing highway capacity. One car is considered as a single unit, cycle, motorcycle is considered as half car unit. Bus, truck causes a lot of inconvenience because of its large size and is considered equivalent to 3 cars or 3 PCU.

The Passenger Car Units (PCU/veh) for different types of vehicles are presented in following **Table 5.4**.

Table 5.4: Passenger Car Unit (PCU) Equivalency Factors

SN	Vehicle Type	PCU Equivalency Factor		SN	Vehicle Type	PCU Equivalency Factor
1	Car	1.0				
2	Heavy Truck	3.0		9	Utility	1.0
3	Light Truck	3.0		10	Fore wheel Drive**	1.0
4	Multi Axle Truck*	3.0		11	Motorcycle	0.5
5	Tractor	1.5		12	Rickshaw	1.5
6	Bus	3.0		13	Three-Wheeler (Auto Rickshaw)	1.0
7	Minibus	3.0		14	Power Tiller***	1.5
8	Micro Bus	1.5		15	Bullock Cart or Horse Cart	6.0

Source: Nepal Road Standards, 2070
*PCU of Multi-Axle truck was taken as PCU of Heavy truck
** PCU of Four-Wheel Drive was taken as PCU of car
*** PCU of power Tiller was taken as PCU of Tractor

The DOR seasonal variation factors for the corresponding survey month and counting location have been used for converting the Average Daily Traffic from the 72 hours survey (ADT) to Annual Average Daily Traffic (AADT), i.e.:

AADTs=Seasonal variation factor s, m*ADTs, m

Where suffixes s and m denote station and month of traffic survey respectively.

Seasonal Variation: As there is variation in traffic flow during different times of the year, corresponding seasonal factors for different months to account this variation have been used. The traffic count surveys were taken in the month of April 2021 so the seasonal factor for the month of April has been used to calculate AADT from ADT. The general seasonal variation factors have been adopted for the stations not specified in the Table: 5.5

Table 5.5: Seasonal Variation Factors

Location	Road Link	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
General	A0000	0.93	0.91	0.91	0.90	0.92	0.93	1.19	1.24	1.14	1.06	1.04	0.98
Bharatpur	H0502U	0.90	0.91	0.93	0.92	0.93	0.98	1.20	1.25	1.06	1.02	1.04	0.98
Gajuri	H0402	0.92	0.92	0.92	0.92	0.95	0.97	1.21	1.26	1.10	0.98	1.00	0.98
Mujheliya	H0603U	1.08	0.88	0.89	0.83	0.87	0.88	1.17	1.15	1.34	0.92	1.20	1.14
Pathlaiya	H0128	0.90	0.88	0.88	0.83	0.94	0.93	1.27	1.26	1.21	1.17	1.10	0.94
Tikauli	H0134	0.91	0.92	0.92	0.90	0.95	0.98	1.19	1.27	1.17	1.02	0.96	0.96
Chaku	H0315	0.99	1.10	0.97	0.81	0.76	0.76	1.48	1.54	1.30	1.14	1.02	0.93
Panchkhal	H0311	0.99	0.97	1.00	0.95	0.95	0.92	1.19	1.22	1.08	0.92	0.98	0.98
Thankot	H0203	0.97	0.94	0.96	0.95	0.95	0.99	1.09	1.07	0.97	1.10	1.05	1.00
Itahari	H0804	0.95	0.97	0.95	0.92	0.89	0.88	1.07	1.16	1.13	1.09	1.10	1.02
Itahari	H0111	0.99	0.91	0.85	0.85	0.91	0.88	1.13	1.38	1.22	1.04	1.05	1.03
Lahan	H116U	1.01	0.98	0.92	0.82	0.87	0.87	1.30	1.35	1.27	1.17	1.04	1.01
Attaria	H1402	0.87	0.86	0.89	0.89	0.94	0.87	1.30	1.35	1.27	1.17	1.04	0.89
Attaria	H0164	0.91	0.85	0.91	0.86	0.75	0.77	1.52	1.55	1.44	1.21	1.11	0.99
Attariya	H1403	0.86	0.88	0.79	0.77	0.81	0.85	1.43	1.9	1.66	1.40	1.00	0.86
Babai	H0159	1.07	0.78	0.80	0.80	0.69	0.99	1.52	1.74	1.48	1.17	0.97	1.03
Kohalpur	H1205	0.99	0.85	0.85	0.89	0.95	0.87	1.09	1.18	1.15	1.15	1.20	1.07
Kohalpur	H1204	0.93	0.90	0.89	0.85	0.88	0.85	1.22	1.27	1.19	1.20	1.10	1.00
Lamahi	H0153	0.86	0.94	0.92	0.88	0.84	0.98	1.12	1.28	1.24	1.04	1.13	1.00
Bardaghat	H0140	0.86	0.84	0.85	0.89	0.94	0.95	1.33	1.34	1.21	1.16	1.05	0.93
Butwal	H1003	0.94	0.91	0.94	0.96	0.92	0.92	1.15	1.21	1.07	1.09	1.04	0.96
Chanauta	H0150	0.89	0.89	0.85	0.91	0.90	0.91	1.22	1.40	1.26	1.09	1.05	0.95
Walling	H1010	0.95	0.92	0.89	085	1.01	0.95	1.34	1.31	1.09	0.97	1.01	1.02

Source: Department of Roads, HMIS Unit

5.5.5 Results and Discussion

The summary of traffic count for 4 stations of Butwal-Gorusinghe section is presented in following **Table 5.6** and **Figure 5.4, 5.5** and **5.6.** Detail Data of Traffic Survey is attached in **Annexure: V.**

Table 5.6: Summary of Traffic Count Survey

Sta. No.	Station Name	Survey Date From	Survey Date To	Seasonal Factor	ADT	ADT exc. MC and Rickshaw	AADT	AADT exc. MC and Rickshaws	AADT in PCU	AADT in PCU exc. MC and Rickshaws
1	Butwal West	7-Apr-21	9-Apr-21	0.90	40961	15643	36883	14079	34655	23064
2	Saljhandi West	7-Apr-21	9-Apr-21	0.90	11482	6273	10334	5646	13990	11646
3	Jitpur West	7-Apr-21	9-Apr-21	0.90	13989	6181	12590	5563	14152	10614
4	Gorusinghe East	7-Apr-21	9-Apr-21	0.90	7748	4738	6972	4264	10361	9007

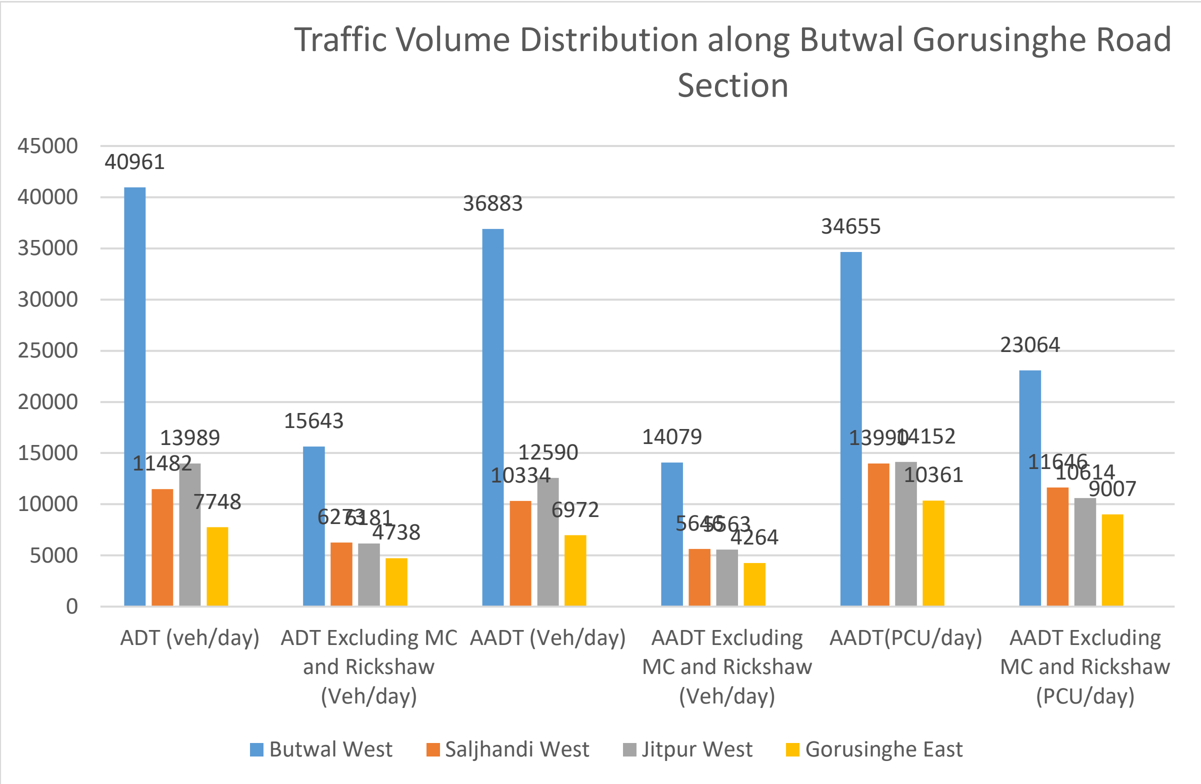


Figure 5.4: Traffic Volume Distribution along Butwal Gorusinghe Road Section

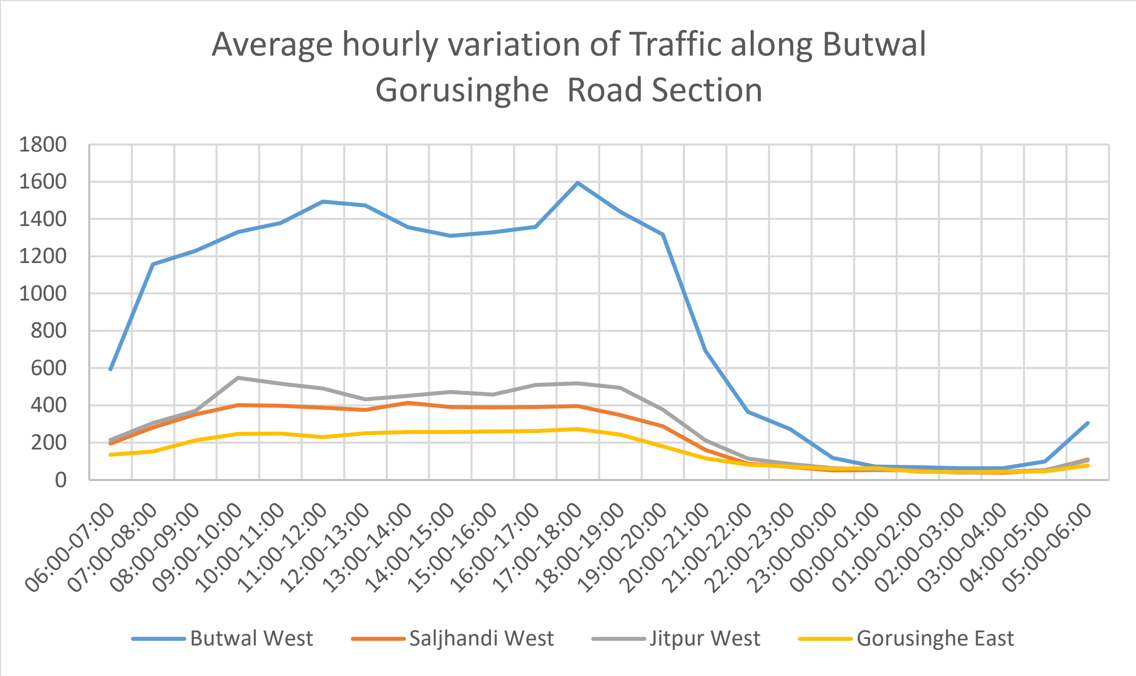


Figure 5.5: Average Hourly Variation of Traffic

It is evident from the above table and graphs that the highest AADT traffic is in Butwal West with 40946 veh/day and the lowest AADT traffic is in Gorusinghe East with 7748 veh/day.

The following graph **(Figure 5.6)** shows the vehicular distribution along 4 stations of Butwal-Gorusinghe (Imiliya) section.

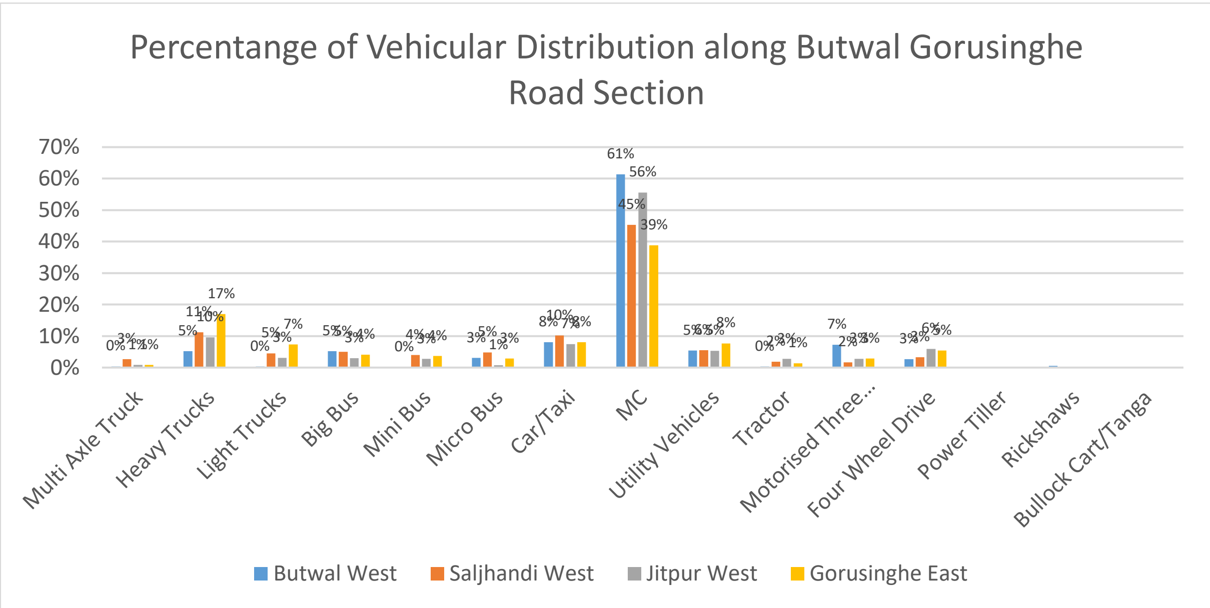


Figure 5.6: Vehicular Distribution

5.6 Environmental, Wildlife and Social Survey

Detail regarding environmental, wildlife and social survey are presented in **Chapter 16, 17 and 18**.

6 Geological Survey and Investigation

6.1 Introduction

A Geological study has been performed along the existing East-West Highway from Butwal to Gorusinghe (Imiliya) sector for widening purpose to four/six lane of the existing road section. The study has focused on geology of road alignment and bridges that located along the Highway. Additionally, the study was concentrated on identification of major and minor faults in rock strata and their impacts, slip prone areas, areas subject to landslides, rock fall, and erosion including geological details of the plain of the road corridor. As the area lies in the low lands, which is characterized by warmer climatic weather as well as having low relief along the studied road section, snow drifts and rock avalanching activities cannot be expected although mentioned in the ToR of the project.

The existing road alignment in the study area passes through Terai plain having low geological hazardous zones, however, river bank erosional area, flooding prone zone and liquefaction potential area in the Terai plain should be attentively considered.

6.2 Regional Geomorphology and Geology

6.2.1 Regional Geomorphology

The alignment of East-West Highway passes, geo-morphologically, through Terai plain and Siwalik Range. Studied road sector are geo-morphologically classified based on chainage of the road segments, which is shown in **Table 6.1.**

Table 6.1: Geo-morphological sub-division of the area along the East-West alignment with chainage

SN	Road sector	Geomorphological sub-division	Chainage	
			From	to
1	Butwal to Gorusinghe (Imiliya)	Siwalik (Churiya) Range	590+000.000	591+400.000
		Upper Terai	591+400.000	640+000.000

The geomorphological units of these individual zones are described below:

Chure Range: The East-West Highway enter into the Siwalik Range from 590+000 (west of Butwal) that passes across the range up to 591+400 (up to 1.40km from Butwal). Then the Highway runs along the east-west trending Upper Terai. The range is characterized by gentle to steep slopes (<55°) with low relief (<100m) and is mostly covered by forest. The road corridor mostly passes through foot hill of Siwalik Range.

Upper Terai: The Upper Terai region is also known as Bhabar zone, which is found from the junction of Chure Range and Terai plain to the downstream plain area of Terai. Altitude of the area ranges from 210 to 105 m above mean sea level (**Figure 6.1**). The area is consisting of very coarse to coarse sediments developing gently sloping surface toward south. Most of the south flowing rivers originated in the hinterland area manifest braided river pattern.

Generally, debris flows, river bank erosion and river channel shifting are the major hazardous events in the zone. In Butwal-Gorusinghe road sector, the chainage section from 591+400 to 640+000 belongs to the Bhabhar zone.

Figure 6.1: General north-south topographical profile across the East-West Highway, which shows the various geomorphic zones

6.2.2 Regional Geology

Geologically, the road alignment from Butwal-Gorusinghe (Imiliya) passes through mostly Upper Terai plain. Brief regional geology of the studied road segments is described below:

In the regional geological scale of the surveyed area, particularly around the mountainous part i.e. Chure range is composed of coarse- to fine-grained sandstones, siltstones and mudstones, while the Terai plain consists of river sediments comprising of gravels, sands, silts and muds. The road alignment from Butwal to Gorusinghe lies in the Terai plain that is composed of river deposits (**Figure 6.2**: Regional geological map).

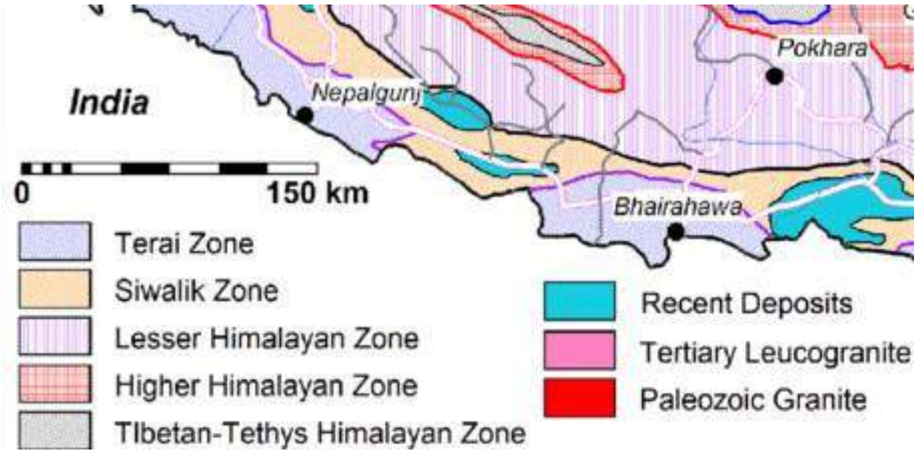


Figure 6.2: Regional geological map of the project area

Sediments of Terai plain: The northern plain area of the Terai situated at a distance of about 5-10 km from the mountain front to south is comprised by dominantly coarser sediments. Most of the road segments lying in the Upper Terai plain is comprised by dominantly coarse-grained sediments like gravels and coarse sands. These sediments represent the proximal alluvial fan of south flowing rivers debouched from the hinterland area, which are characterized by well graded boulders, cobbles, pebbles and minor amount of sands and muds (silts and clay). In the Butwal-Gorusinghe Road sector, relief of terrace with respect to higher level terrace is low and sediments are fine grained in comparison to the terrace level.

Towards southern part from the Upper Terai, sediments are composed dominantly of rather finer grained like sands, silt and clay with small gravel size rock fragments. Gravels are sub-rounded to well-rounded and size decreases as the distance from the mountain front increases to the southern plain area. To the upper part of the deposit, soil horizons are developed due to pedogenesis that produced several horizon consisting of organic matter, fine silty sands, and clays and partially altered recent sediments. These sediments constitute the area of Middle Terai **(Figure 6.3).** Small segments of the Highway intermittently run through the Middle Terai.

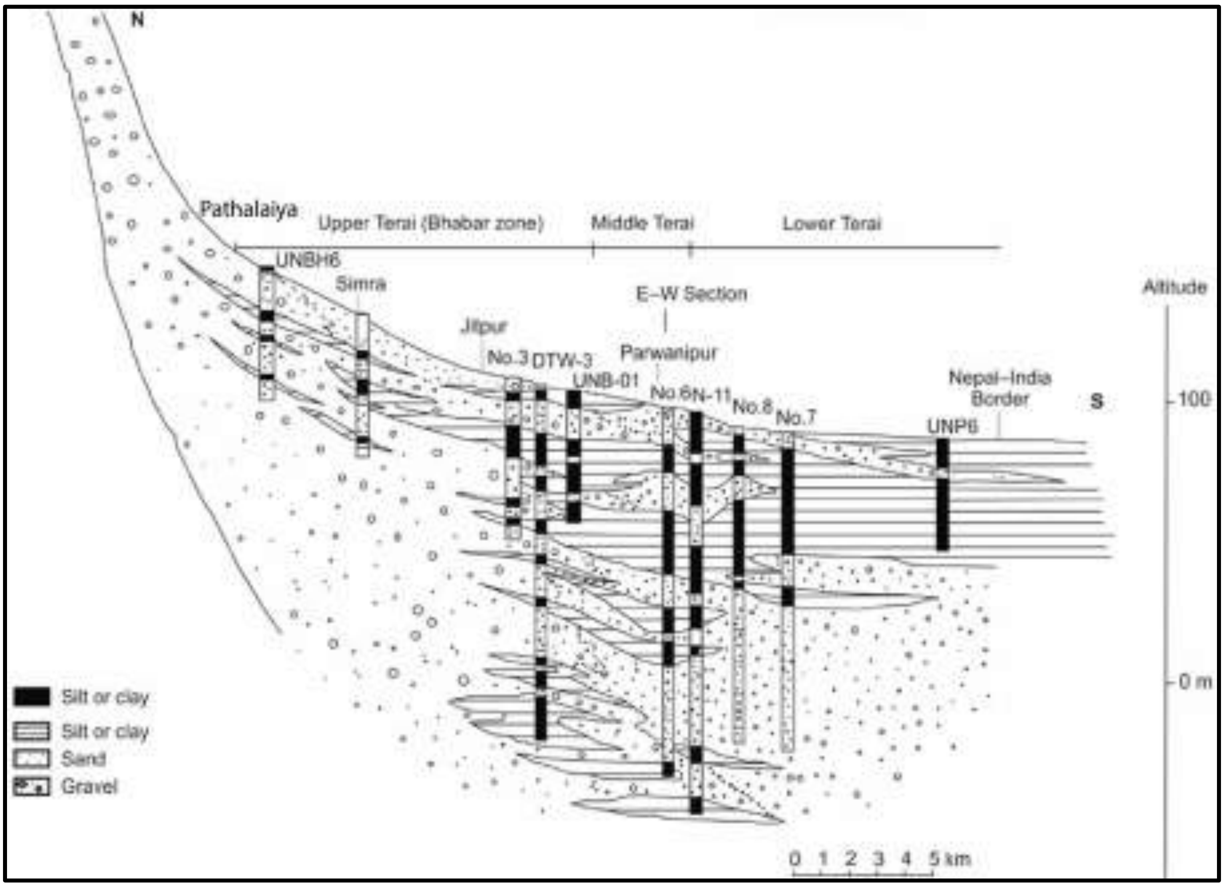


Figure 6.3: Typical Geological cross-section of Terai plain showing Upper Terai, Middle Terai and Lower Terai with a large vertical exaggeration of scale (modified from Dhital, 2015)

Churia Range is divided into Lower Siwalik, Middle Siwalik and Upper Siwalik. In the surveyed area, the road alignment initial segment of 1.40km located in the Lower range, however, geology of the proximal mountain range is briefly mentioned.

Lower Siwalik is separated from the Terai plain by Himalayan Frontal Thrust, which is normally traced at the junction between the mountain front and the Terain plain. It is an active thrust fault in the Himalaya. Lower Siwalik is consisting of alternating mudstone, siltstone and fine sandstone, while Middle Siwalik is composed of coarse sediments that is very coarse sandstones with siltstones and mudstones.

Middle Siwalik is further sub-divided in to lower middle Siwalik (Ms1), and upper middle Siwalik (Ms2). Ms1 is composed of fine to coarse-grained sandstones alternating with thick layer of mudstones. Because of cementation by calcium carbonate in sandstone, these are compact and very hard, while the mudstones are poorly cemented and fragile than sandstones. Ms2 are consisting pebbly conglomerates, coarse to very coarse-grained sandstones and mudstones. Pebbly conglomeratic layers are lying at the base of very coarse-grained sandstones. Small coal lenses are also sometimes encountered within the sandstone beds.

Upper Siwalik is comprised by very coarse sediments i.e., very coarse sandstones and gravel to boulder conglomerates with mudstone inter-beds.

Lesser Himalaya: The Lesser Himalayan rocks are composed of sedimentary to metamorphosed types which are transported in the Highway area by Midland Rivers. These rocks are not exposed along the East-West Highway **(Figure 6.4).**

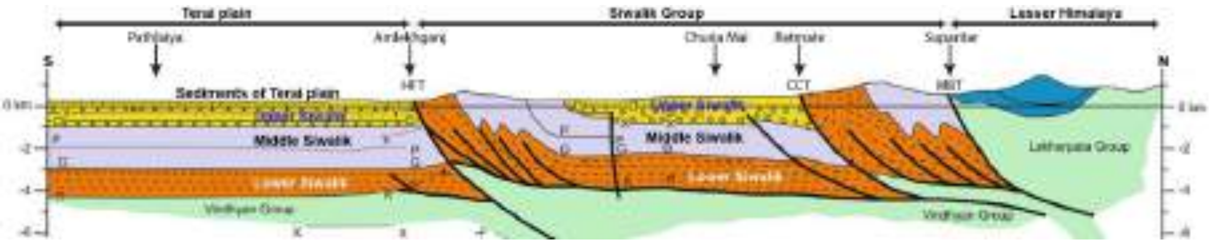


Figure 6.4: Typical Geological cross-section across Siwalik Group showing major geological structures Himalayan Frontal Thrust (HFT), Central Churia Thrust (CCT) and Main Boundary Thrust (MBT) with names of major bazar (modified from Dhital, 2015)

Major Geological Structures: Tectonic structures are important to delineate for the East-West Highway widening project in order to understand its role on the instability along the alignment, however the alignment does not cross major tectonic structures. There are two major large scale thrust faults namely Himalayan Frontal Thrust (HFT) and Central Churia Thrust/Main Dun Thrust, both are located at a distance to the north from the alignment.

6.3 Inventory of geologically sensitive areas

Geologically relative sensitive area with respect to landslides, rock falls erosion has been studied in field and the data collected are analyzed and discussed below.

6.4 Seismological study

6.4.1 Seismic analysis and liquefaction assessment of bridges

The Himalaya seismicity, in general, owes its origin to the continued northward movement of Indian plate after the continental collision between Indian plate and Eurasian plate. The Himalayas are located near plate boundary. Therefore, the Himalayan region is considered to be seismically active zone. The magnitude, recurrence and the mechanism of continental collision depend upon the geometry and plate velocity of Indian plate in relation to southern Tibet (Eurasian Plate). Recent results suggest that the convergence rate in the Himalayan region is about 20 mm / year and the Indian plate is sub-horizontal below the Sub- Himalaya and the Lesser Himalaya. Recent seismicity condition and historical records indicate that the Himalaya has experienced recurrence of large earthquakes. National Seismological Centre (Department of Mines and Geology, 2006) has been recording small to medium sized earthquakes that frequently occurring in the territory of Nepal. Earthquakes Epicenter Map of Nepal shows that medium sized earthquakes (6 to 7 magnitude) are mostly confined to the Main Himalayan Thrust (MHT) between the foot hills and the Higher Himalaya (**Figure 6.5).**

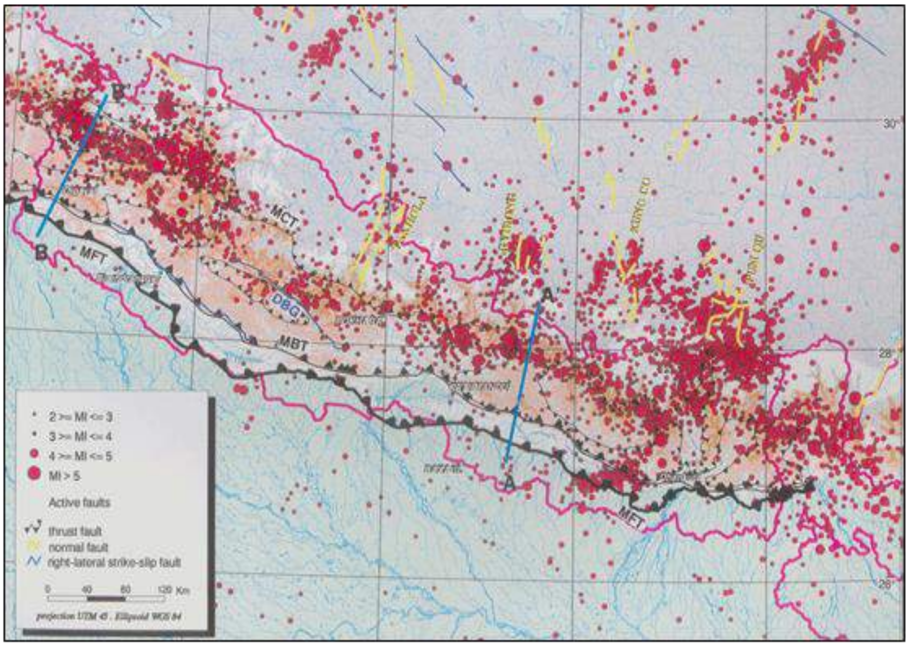


Figure 6.5: Earthquake epicenter distribution map of Nepal (adopted after DMG)

The data of the recorded earthquake indicates that the recurrence of earthquake 6<M<7 in western Nepal is one time in six years (DMG, 2006).

6.4.2 Seismo-tectonic structure of the Himalayas

South Tibetan Detachment System (STDS) is the tectonic contact between the Higher Himalayas and Tibetan Tethys Sediment Zone. It is the less active seismo-tectonic structure. Main Central Thrust (MCT) is the tectonic contact between the lesser and Higher Himalaya. Lesser Himalaya is separated in the south by Main Boundary Thrust and north by the Main Central Thrust. The MCT was active during the early phases of Himalayan orogeny but is now considered to be less active as compared to Main Boundary Thrust (MBT). Based on historical records (1800's to 1986) the largest earthquake recorded in the MCT zone in the Himalaya was a 7.5 magnitude event in August 28, 1916 and 7.8 magnitude event in April 2015. The bridge site along the east west highway is located at south of MCT and is far from the bridge site. Therefore, seismic risk associated with MCT is considered to be less. Main Boundary

Thrust (MBT) is the active tectonic contact between the Lesser Himalayas and the Siwaliks. The MBT has been the source of very large earthquakes in the past.

Active faults along MBT, though considered to be reverse faults, do not always have a displacement of the same nature in this area (Nakata et al., 1989) that is active faults close to the MBT are of normal type (Mugnier et al., 1994). It is reported that the maximum potential earthquakes in this feature have a magnitude of 8.0 (Dixit et al., 1993). The bridge site is located south of MBT and is considered medium seismic risk associated with this feature is expected for the bridge site area.

Himalayan Frontal Thrust (HFT) is a tectonic feature located at the boundary of the Siwalik and the Terai plain. This fault is also considered to be active. According to Dixit et al., (1993), the maximum earthquake potential of this fault is 6.5 in magnitude. The bridge site is located near from this feature hence high seismic risk caused due to this feature is expected.

6.5 Geological Study of Bridges

There are small and major bridges along the East-West Road. These bridges are located in Terai plain.

Generally, the major river courses in Terai plain are wider. Therefore, Terai plain are prone to river bank erosion, sediment aggradation and channel morphological degradation due to extensive mining of river bed materials. The geology of the proposed bridge sites is described below.

The Geological characteristics of the existing bridge sites along the road corridor from Butwal to Gorusinghe are described below.

Table 6.2: The Geological characteristics of the existing bridge

S. No.	Chainage	Name of Bridge/Khola	Geological and geomorphological characteristics
1	590+048	Jitgadhi	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS(Gravel) • rock at depth- No • river flow direction- flow from north to south Straight River
2	590+187	Narasingha Dry Nala	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS(Gravel) • rock at depth- No
3	590+698	Dry Nala	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS (Colluvial Deposits) • rock at depth-
4	590+759	Dry Nala	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS (Colluvial Deposits) • rock at depth-
5	590+991	Pakhapani	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS(Colluvial Deposits) • rock at depth-Yes (Sandstone and mudstone)

S. No.	Chainage	Name of Bridge/Khola	Geological and geomorphological characteristics
6	596+093	satgadi no 1	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS(Gravel) • rock at depth- No • river flow direction- flow from north to south • Straight River
7	596+364	Satgadhi-2	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS(Gravel) • rock at depth- No • river flow direction- flow from north to south • Straight River
8	597+461	Soila	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS(Gravel) • rock at depth- No • river flow direction- flow from north to south • Straight River
9	597+778	Rajpur	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS(Gravel) • rock at depth- No • river flow direction- flow from north to south • Straight River
10	598+254	Bamaha	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS(Gravel) • rock at depth- No • river flow direction- flow from north to south • Straight River
11	603+566	Ghamaha	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS(Gravel) • rock at depth- No • river flow direction - flow from north to south • Riparian around the channel
12	603+826	Tulbuliya	Depth to Soil/bed rock at foundation and abutment: • sediment cover – Boulder mixed soil (Sand and Grave) • rock at depth – No • Small Gully • Fluvial deposits
13	604+882	Marthirwa	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS(Gravel) • rock at depth- No • river flow direction - flow from north to south • Riparian around the channel
14	604+975	Meghawa	Depth to Soil/bed rock at foundation and abutment: • sediment cover – Boulder mixed soil (Sand and Gravel) • rock at depth – No

S. No.	Chainage	Name of Bridge/Khola	Geological and geomorphological characteristics
			• Small Gully • Fluvial deposits
15	606+684	Inguria	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS(Gravel) • rock at depth- No • river flow direction - flow from north west to south • meandering river system
16	607+187	Banarhwa	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS(Gravel) • rock at depth- No • river flow direction - flow from north west to south • Riparian around the channel
17	607+834	Dry Nala	Depth to Soil/bed rock at foundation and abutment: • sediment cover - Boulder mixed soil (Sand an d Grave) • rock at depth – No • Small Gully • Fluvial deposits
18	610+998	Pahila Nadi	Depth to Soil/bed rock at foundation and abutment: • sediment cover – Boulder mixed soil (Sand and Gravel) • rock at depth – No • Small Gully • Fluvial deposits
19	611+105	Dry Nala	Depth to Soil/bed rock at foundation and abutment: • sediment cover – Boulder mixed soil (Sand and Gravel) • rock at depth – No • Small Gully Fluvial Deposits
20	611+411	Kanchan	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS (Sand and Gravel)
21	615+264	Kothi river	Depth to Soil/bed rock at foundation and abutment: • sediment cover – Boulder mixed soil (Sand and Gravel) • Narrow River • rock at depth – No • river flow direction- north to South flow • Forest area
22	619+440	Gageda khola	Depth to Soil/bed rock at foundation and abutment: • sediment cover – Boulder mixed soil (Sand and Gravel) • Meandering River • rock at depth – No • river flow direction- north to south flow

S. No.	Chainage	Name of Bridge/Khola	Geological and geomorphological characteristics
			• Fluvial sediments
23	622+027	Banganga	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS (Sand and Gravel)
24	627+155	Kaila khola	Depth to bed rock/Soil at foundation and abutment: • sediment cover – BMS (Sand and Gravel)
25	629+439	Balhundra khola	Depth to Soil/bed rock at foundation and abutment: • sediment cover – Boulder mixed soil (Sand and Gravel) • rock at depth – No • river flow direction- north to south flow • Forest area
26	631+000	Harkon Khola	Depth to Soil/bed rock at foundation and abutment: • sediment cover – Boulder mixed soil (Sand and Gravel) • rock at depth – No • river flow direction- North to South flow • Straight river near the bridge site area • Narrow River channel
27	633+352	Dry Nala	Depth to Soil/bed rock at foundation and abutment: • sediment cover – BMS (Sand) • rock at depth- No • river flow (Small Gully) direction- flow from North to south
28	633+710	Kundra Khola	Depth to Soil/bed rock at foundation and abutment: • sediment cover –BMS (Sand and Gravel) • rock at depth- No • river flow direction- flow from north to south • Meandering river
29	636+765	Ghorai Nala khola	Depth to Soil/bed rock at foundation and abutment: • Sediment cover –BMS (Sand and Gravel) • rock at depth- No • Small Gully
30	639+831	Dry Nala	Depth to Soil/bed rock at foundation and abutment: • sediment cover –BMS (Sand and Gravel) • rock at depth- No • Small Gully

6.6 Risk and Hazard Assessment

As the area lies in the low lands, which is characterized by warmer climatic weather as well as having low relief along the studied road section, snow drifts and rock avalanching activities cannot be expected although mentioned in the ToR of the project. The existing road alignment in the study area passes through Terai plain having low geological hazardous zones, however, river bank erosional area, flooding prone zone and liquefaction potential area in the Terai plain should be attentively consider during the detail project phase.

6.7 Recommendations

- Geologically and geomorphologically, the studied East-West Highway from Butwal-Gorusinghe sector lies in the Terai plain area, therefore, snow drifts and rock avalanching activities cannot be expected.
- The Highway section runs on the deposit of river sediments that are comprised by gravels, sands, silts and muds.
- Major geological thrusts and faults are not encountered on the surface along the Highway corridor.
- Abutments of the proposed bridges are situated on the upper river terrace deposits. River banks at U/S and D/S are protected by hardware engineering structures, however, mining activities of construction materials from the active channel area triggered channel morphological degradation in some cases.
- Subsurface sediments obtained in core samples from bridge alignment sections represent dominant silty gravelly sands (Sp), silty fine sands with gravels and boulders (Gp), and minor proportion of sandy silt (Sm).
- Long-term sub-surface hydrological monitoring is suggested in order to ascertain liquefaction potential area mapping in the major bridge sites.

6.8 Geology of the Landslide Area

6.8.1 General

6.8.1.1 Introduction

A preliminary geological investigation was carried out at highway site to study the major landslide and its geological causes of failure. The present investigation was mainly focused on the identification of local geological setting and its relation with the failure of the landslide.

6.8.1.2 Geomorphology

North-south elongated ridge with south-east facing slope of Siwalik hill (Chure Hill) is situated at the right hill slope of Tinau River valley. The river valley floor is covered with alluvial fan deposit of the river, which is now densely covered by settlement. Maximum elevation in of the ridge in the landslide area is about 410 m above sea level and the exiting East-West Highway alignment oriented along the junction between the alluvial plain and the Chure hill slope is about 181 m above mean sea level. South-east facing slope of the Chure hill in the landslide area is about 30-40°.

6.8.1.3 Land use

The Land use type around the study area covered by forest and bushes.

6.8.1.4 Objectives

The following were the major objectives of the present fieldwork

- To study the Slide details (landslide, identify type of slide and its geological reason of failure).
- To study the slope stability condition of the landslide area
- Generation of Geomorphological features in drawing format
- To suggest suitable stability measures for the stabilization of landslide.

6.8.1.5 Methodology

The present geological investigation began with the desk study which included the collections of survey data and soil parameter conducted and collected by the consultant as well as the secondary data related to this study. It included a literature review, aerial photo interpretation and map study. The bulk work of the investigation was centered on the field study which included the geological mapping of the landslide zone. Also includes the description of geology and tectonics of the region, collection of data on nature of landslide, its geologic- tectonic association, and further risk of failure.

6.8.2 Geology of the Landslide Area

6.8.2.1 Regional Geology of the Landslide Area

The rock formation near the landslide area belongs to the Swalik Group of rocks. Locally, the rock formation exposed around the landslide area Consists of Sandstone and siltstone.

6.8.2.2 Geology of the Landslide Area

Geologically, the landslide area is situated in lower Siwalik. The area is comprised by 2-3m thick, very fine to fine grained, grey sandstones is interbedded with 2-3 m thick, grey siltstones and mudstones (Figure-6.6). Mudstones and sandstones are characterized by joint and fractured discontinuities. Sandstones contain calcareous cementing materials, while the mudstone are more fragile. The Siwalik rocks are partially covered by boulder mixed soils (BMS) that range in thickness from 2 to 10 meters. The well graded BMS shows angular rock fragments of Siwalik with silt and clay matrix.

6.8.2.3 Geological Survey and study

Geology is the major controlling factor of the landslide. Rock type, fault structure, joint of rock, soil type, seismic activity and pore water pressure are some geological causes of landslide. The mechanism and extent of any landslide are the result of the regional geology of the area and more specifically site geological factors. The site geology of the landslide area was prepared from the field visit and using GIS and Auto CAD tools (Figure-6.7).

Figure 6.6: Rock Type observed near the Landslide area

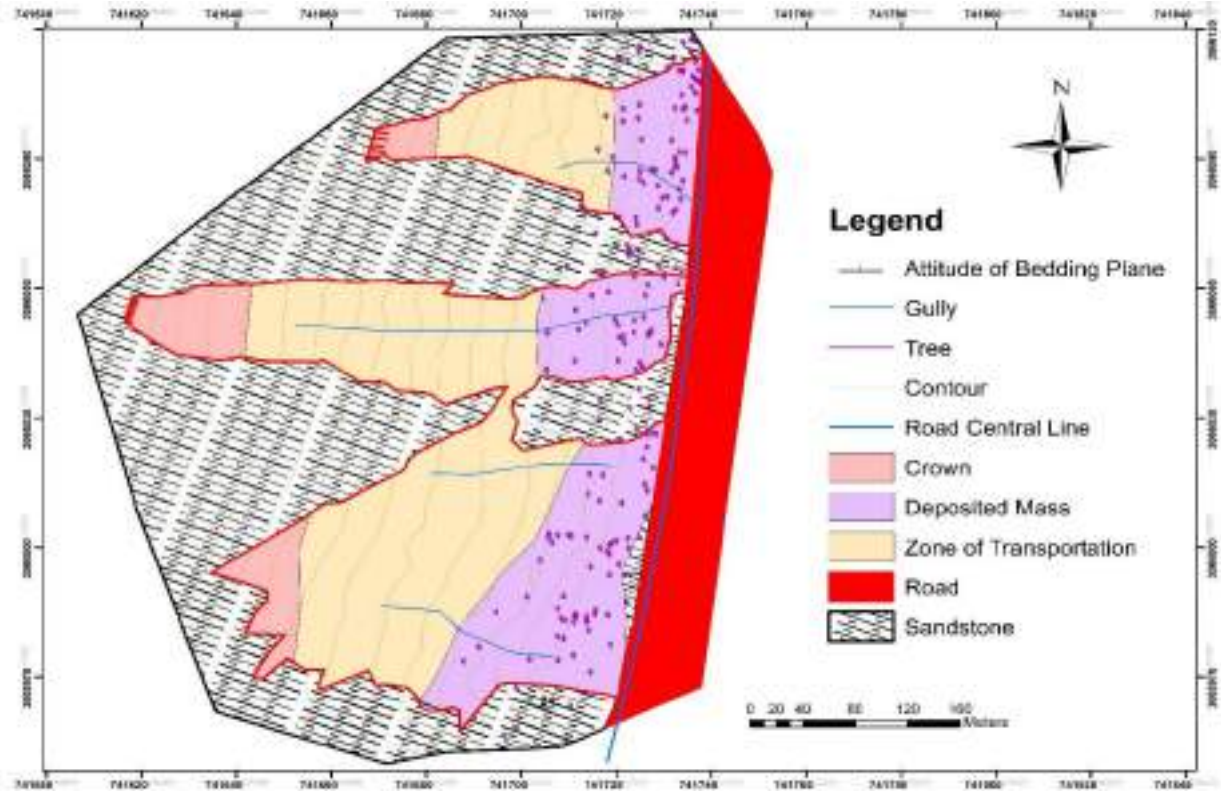


Figure 6.7: Geomorphology and Geological Map around Landslide area

6.8.3 Study of the Landslide

Description of the Landslide

A detailed description of the landslide is categorized under the following sub-headings:

6.8.3.1 Landslide morphology

1. Landslide morphology and materials: There are three closely isolated landslides on the south-east slope of the Chure hill. From the geographical position of these landslides, each landslide is named as Landslide-1, Landslide-2 and Landslide-3 from south to north direction, respectively (Figure-6.8). Occurrence of landslide events is found on the rocky as well as debris covered areas (Figure- 6.9). Landslide materials are composed of boulder to pebble size fragments of Siwalik rocks and muds (Figure-6.10) as well as fragments of plants. Small galleys are developed on the landslide deposit mass that is lying on the uphill slope from East-West Highway (Figure-6.10). Technical features of the landslide is described in Table 6.3. The dimension of active landslide is about 2-5 m deep, 80 m height and 100 m in length. The average slope angle of the crown (Figure-6.8) is steep (30-40°). No direct seepage was observed. Inactive landslide is observed at upslope of the active landslide (Figure 6.8). Technical features of the landslide are shown in Table-6.3.

Figure 6.8: Butwal Landslide delineation observed at chainage 591+300 to 591+400

Table 6.3: Technical features of the landslide

S. N	Parameters	Description
1	Length (m)	100
2	Height (m)	70 averages
3	Direction and inclination of the slope	South-East (120/36)
4	Land use	Forest
5	Activity	Unconsolidated active land slide
6	Type of landslide	Rock + Debris Slide
7	Geological Unit	Siwalik Rocks
8	Type of Rock	Sandstone and siltstone
9	Type of Soil	Boulder mixed soil
10	Thickness of Soil	2-5 m

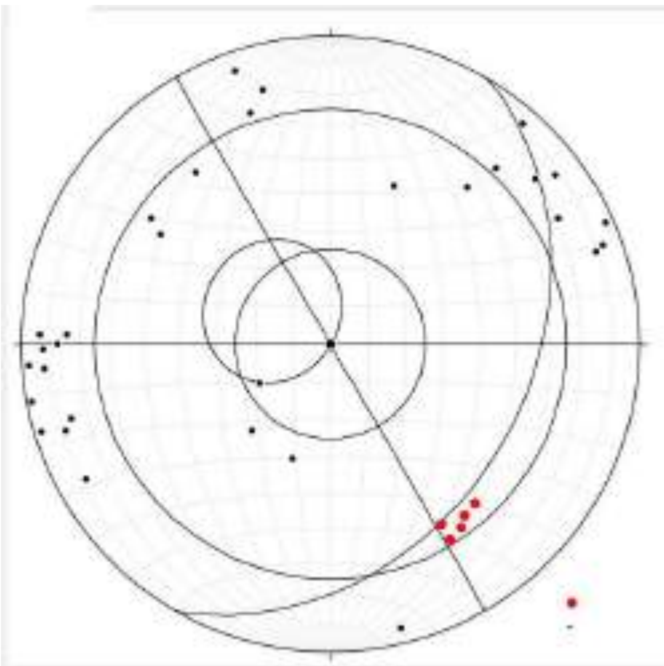
S. N	Parameters	Description
11	Presence of water	No
12	Causes of Landslide	Debris flow which happened along two distinct gullies on either side of the landslide extent and Gravitational forces acting them to move down the slopes and accumulate as distinctive deposits along the lower portions of the slope.
13	Damage/Risk	Risk to road Site area
14	Possibility of Expansion	have high expansion rate

Figure 6.9: Debris slide, Rock slide observed in landslide area

Figure 6.10: Landslide Deposit and Gully in Landslide

2. Landslide slope stability: Landslides are found in mostly rock (Figure-6.11) covered and partly in debris covered area. Rock slope stability analysis using stereographic projection of discontinuities data shows that the southeast facing slope of Chure hill was failed due to unstable wedges of the discontinuities (Figure-6.12). Existing forest and Gabion wall are supportive software and hardware structures that help to reduce landslide risk on the Highway.

Figure 6.11: Photograph basement rock exposed in the landslide area



- Intersection of discontinuity to viable failure
- Pole Plot

Figure 6.12: Stereographic projection of major discontinuities measured at chainage 591+300 for slope stability analysis

6.8.4 Proposed Mitigating Measures

The main aim of preparing the Report of Landslide is to mitigate landslides and to avoid further land degradation. Landslide mitigation refers to the mass movement of rocks and other man-made activities on slopes to lessen the effect of landslides. Landslides can be triggered by excessive weight above the slope, shallow erosion or reduction of shear strength caused by seasonal rainfall.

- Construction of water management structures, gabions walls, and check dam with use of appropriate bio-engineering methods protection against surface by overland flow.
- Holding the debris flow that flow down the gully for this purpose construction of gabion bolster are recommended.
- Provision of channeling runoff water safely to adjacent gulley by proper drainage works

- Holding the mass that flow down the river
- Protection against the surface by overland flow.
- Management of runoff water safely to adjacent gulley by proper drainage works.

7 Geotechnical Survey and Investigation

7.1 General

The highway alignment from Butwal-Gorusinghe (Imiliya) section of East-West Highway passes through Indo-Gangetic plain. This section of report presents the road pavement subgrade strength evaluation and sub surface geological-geotechnical information and the analysis of the data required for the design of foundations.

To determine the subgrade strength, 1m deep trial pits were excavated at every 1 km interval under the wheel path and at the edge of shoulder. Likewise, DCPT was performed in the in-situ soil.

The soil investigation work mainly consists of advancement of bore hole by appropriate drilling method like rotary drilling, percussion drilling up to the required depth, conducting Standard Penetration Test/Dynamic Cone Penetration Test of the road alignment at 100m interval, collection of disturbed and undisturbed soil samples for different laboratory tests, measurement of natural water table and analysis and interpretation of the obtained data and their recommendations for application in the foundation design of the structures required for the project.

The soil investigation works was carried out from December 2021 to March 2022. The soil investigation work comprised advancement of 110 no of boreholes including field and laboratory tests. The depth of bore holes varies from 12 m to 20.0m. The total depth explored in bore holes was 3459m.

7.2 Approach and Methodology

Based on the provision made in ToR for soil investigation work as well as the experience of the consultant in previous works, the consultant has prepared soil investigation program with location and depth of each individual drill hole. The soil investigation program was presented to the client and the program was principally approved by the client subjected to change as per site condition and specific site requirement.

In order to get geotechnical engineering data required for the design of the project, in-situ survey, site investigation work, laboratory tests were performed as planned.

Geotechnical Investigation	Review of existing data	Data collection, analysis, previous reports study and analysis
	In-situ survey	Topography, geology and soil distribution, deployment of appropriate drilling equipment
	Site Investigation	Surface geological survey
		Boring –Percussion and rotary
		Standard penetration test, Dynamic cone Penetration test of the road alignment etc.
		Sampling material for Lab. test
		Test Pit and sampling for identification of sub-soil condition, scour depth and construction

		material survey
	Laboratory test	Laboratory test on soil & rock samples of geotechnical and construction material survey
	Result analyses	Soil strength parameter, structure foundation; slope stability, liquefaction

7.3 Road Pavement

7.3.1 Subgrade Characteristics and Strength

a. Determination of Sub-soil condition through pitting

To determine the subgrade strength, 1m deep trial pits were excavated at every 1 km interval under the wheel path and at the edge of shoulder.

Soil Samples were collected from 1.00m×1.00m×1.00m sized Trial Pits which were excavated to sub grade level. The texture and type were described and pit log was made. Samples of the encountered sub grade material was collected and transported for laboratory testing at **Geotechnical and Associates Pvt. Ltd.** to find out the properties of existing sub-grade soil.

Soil samples extracted to present the different strata from pits tests along the road alignment were subjected to standard laboratory soil testing for evaluation and analysis in accordance with AASHTO standard methods and specification to specify them for their engineering values. All tests performing in following standard procedures:

- Particle Size Distribution IRC-5-1998,
- Determination of OMC and MDD
- California Bearing Ratio CHR IS 2720

Bulk samples taken from test pits on the existing sub-grade were subjected to Procter Test under IS 2720 Part 8 testing procedure. Method B or D was adopted depending on the gradation of the soil or aggregate material. A (4.89Kg) hammer was used. Five trials were performed for each compaction test.

The sub-grade strength and other engineering characteristics were determined using the California Bearing Ratio (CBR) tests. The three points CBR method was adopted, where the specimens were soaked for 96 hours. The method allows interpolating the CBR values at various dry densities of soil. Three points obtained from CBR test represented the different compaction energies at 10, 30 and 65 blows using 4.89 Kg hammer dropped at a height of 0.45m for five layers of soil in the compaction cylinder mould.

Simultaneously, the pavement composition survey has also been carried out using the excavated test pits. The pavement layers details were measured and noted. After completion the pits were refilled and properly compacted.

b. DCPT-For Existing Pavement Evaluation

Quality road construction requires an assessment of the adequacy of a subgrade to behave satisfactorily beneath a pavement. The dynamic cone penetration test (DCPT) was originally developed as an alternative for evaluating the properties of flexible pavement or subgrade soils. The DCP is operated by two persons, and is a quick test to set up, run, and evaluate on site. Due to its economy and simplicity, better understanding of the DCPT results can reduce significantly the efforts and cost for evaluation of pavement and subgrade soils.

The field study as well as laboratory tests were performed for the geotechnical properties of soil along the Butwal Gorusinghe Section (50.00 Km) of East-West Highway alignment.

DCPT was performed in the in-situ soil. Laboratory test were performed for the classification of the sub-grade soil, and to determine the optimum moisture content. Results reveal that most part of the road is aligned through the alluvial river deposits consisting of sand, silt, clay and gravels.

DCPT can be used to evaluate the mechanical properties of compacted sub grade soils. DCPT results consist of number of blow counts versus penetration depth. Since the recorded blow counts are cumulative values, results of DCPT in general are given as incremental values defined as follows:

$$PI = \frac{\Delta D_p}{\Delta BC}$$

Where, PI = DCP penetration index in units of length divided by blow count;
ΔDp = penetration depth;
BC = blow counts corresponding to penetration depth ΔDp.

As a result, values of the penetration index (PI) represent DCPT characteristics at certain depths.

The DCP test was carried out at 100 m interval. DCP Cone having 60º cone has been used for the test There are several empirical relationships to calculate the CBR from DCP test. Some of the empirical co-relationships mentioned in oversees road note 31 are shown in **Figure 7.1** and **Table 7.1.**

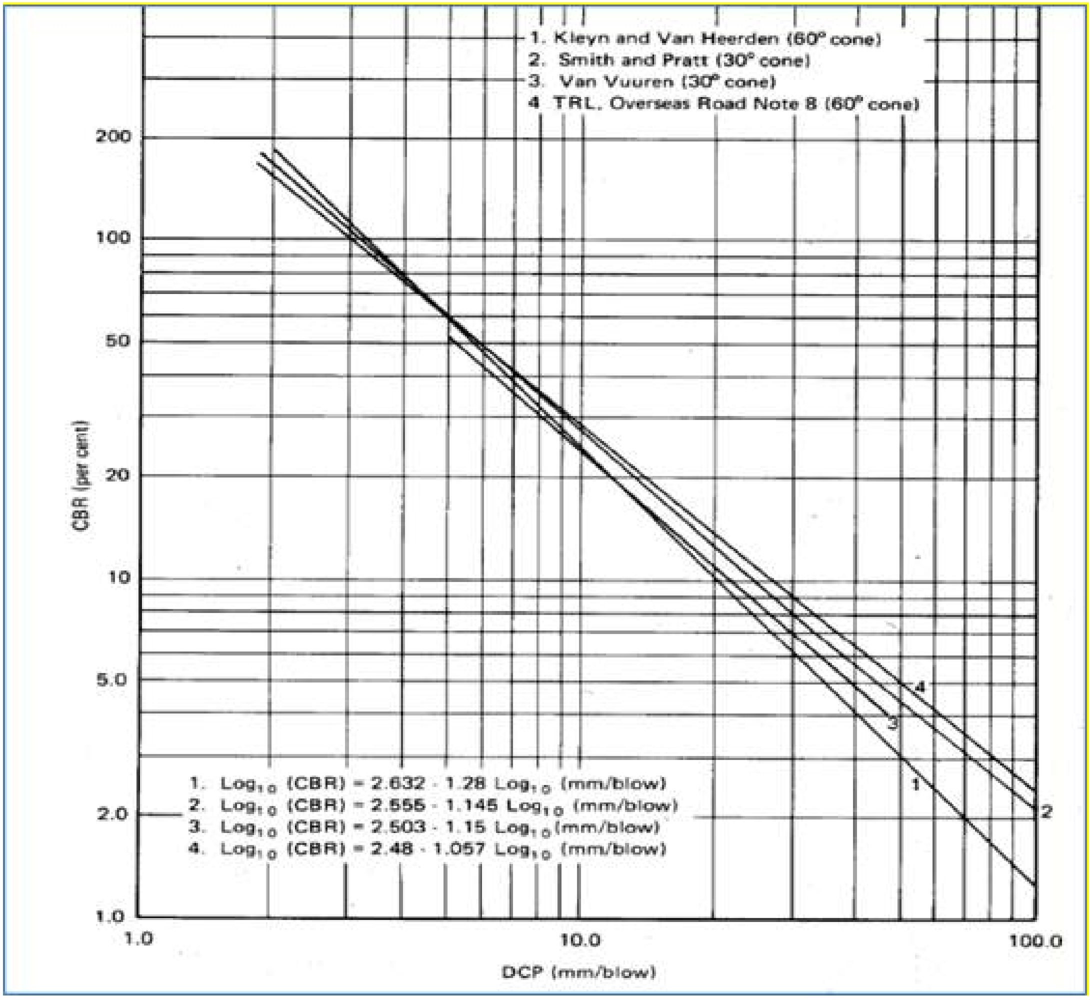


Figure 7.1: DCP – CBR relationships (Oversees Road Note 31, 4th edition, 1993)

Table 7.1: Correlation to find CBR from DCP Test

Author	Correlation	Field or Laboratory based study	Material used
Kleyn (1975)	$\log CBR = 2.62 - 1.27(\log PI)$	Laboratory	unknown
Harison (1987)	$\log CBR = 2.56 - 1.16(\log PI)$	Laboratory	Cohesive
Harison (1987)	$\log CBR = 3.03 - 1.51(\log PI)$	Laboratory	Granular
Livneh et al. (1994)	$\log CBR = 2.46 - 1.12(\log PI)$	Field and laboratory	Granular and cohesive
Ese et al. (1994)	$\log CBR = 2.44 - 1.07(\log PI)$	Field and laboratory	ABC*
NCDOT (1998)	$\log CBR = 2.6 - 1.07(\log PI)$	Field and laboratory	ABC* and cohesive
Coonse (1999)	$\log CBR = 2.53 - 1.14(\log PI)$	Laboratory	Piedmont residual soil
Gabr (2000)	$\log CBR = 1.4 - 0.55(\log PI)$	Field and laboratory	ABC*

Here, the CBR has been evaluated using Kleyn and Van Heerden.

Log CBR=2.48-1.057(log P I)

In calculating the CBR, the soil layer is divided into different layers based on penetration index (PI) or the slope of the depth vs. penetration curve. Among the different layers, the layer with minimum CBR is assumed as the CBR of the sub grade soil. In many cases, the original sub grade might have been graveled and in such case CBR is estimated below that depth (which represents true existing sub grade).

7.3.2 Data Analysis

Survey data received from field survey and laboratory tests results were analyzed and used in design works.

The chainage wise details of the gradation and compaction characteristics of subgrade soil in field and laboratory is tabulated in in chapter: 13.3.3 Test Pits and Laboratory Tests.

7.3.3 Recommendations

Pits dug revealed an average gravel base course of 150 mm while the depth of sub base is 200 mm. Visual examination of base course material shows that it is on the verge of disintegrating, indicating remaining of structural life of about 3 to 5 years. Hence, the existing sub base and base course could either be:

a) Remolded as sub base material to construct new sub base layer when widening, or

b) Remove this material to blend it into the new sub grade to increase its in situ CBR at locations as an additional measure to prevent longitudinal cracks between the existing and new road formation

The use of existing sub base and base course layers makes economic sense. If the existing thickness of base and sub base of 350 mm is uniform and spread over 20 m of carriageway and shoulder, the resulting thickness of such sub base would be in the range of about 20% of the required sub base material even after accounting a loss of 40% when scarifying and re-profiling. Hence, the designed thickness could be reduced by the corresponding thickness subject to the provision that any additional compacted layer placed on top should not be less than 100 mm.

7.4 Bridge

7.4.1 Field Investigation and Sub-surface Geotechnical Investigations

Geo-technical exploration work for sub soil is one of the major parts of foundation design work. The engineering properties of sub soil required for foundation design of any engineering structure could be ascertained by geo-technical exploration work and various laboratory tests conducted on retrieved samples from exploration work. Hence, optimum foundation design could be done only if correct and reliable sub soil engineering information could be ascertained by sub soil exploration work or other modern methods.

The boring investigation was performed in the sub soil to abstract the information of soil parameters, thickness and depth of each layer etc. During advancement of bore holes, different soil strata encountered, existence of cavities and change in soil strata were carefully observed and recorded.

In order to get proper size of undisturbed sample for carrying out required laboratory tests, the diameter of bore holes used are from Hx, Nx and Bx size. The bore holes were continuously logged at field and it included visual soil classification, records of SPT/DCPT value, record of ground water table and any other information detected during drilling like water loss, existence of cavities etc. The field bore logs were corrected after getting the results of laboratory tests on collected soil samples. The updated borehole logs are presented in Appendix including general ground water table, SPT/DCPT value and soil type.

Drilling, sampling and in-situ tests such as SPT or DCPT were carried out as per IS code or equivalent standards.

Standard Penetration tests (SPT) were carried out in the boreholes at various depth intervals of 1.5 m. Spilt spoon sampler of 35 mm internal diameter and 50 mm external diameter coupled with a standard cutting shoe at its lower end was driven into the ground at the base of the borehole by means of a 63.5 kg hammer falling from a height of 706 mm. After an initial 150 mm seating penetration the sampler was driven to a further depth of 300 mm. The number of blows required to penetrate the final 30cm length of SPT was recorded as the N-value.

When gravel and cobbles mixed with fine soil is encountered, Dynamic Cone Penetration Test is used for determining resistance of soil by penetrating steadily under static pressure. A Cone with a base of 10 cm2 and an angle of 60°.The cone is carried at the lower end of a steel driving rod which passes through a mantle with external diameter equal to the base of a cone. Either the cone or the tube, or both together were forced into the soil by means of hammering.

The nature of the subsoil was investigated from the collected samples and wash cuttings at different depths to identify the stratification and type of soil at initial stage. Disturbed soil samples were retrieved from boring tools at depth interval of 1.5 m down to the termination depth of the Boreholes. The samples were wrapped in plastic bags, labeled and placed in a core box and photographs were taken.

To establish the ground water level, water level was recorded in the boreholes at least 24 hours after boring was completed.

Laboratory tests were immediately performed after the soil samples from each borehole arrived in the laboratory. **The coordinate and drilled depths of each individual bore holes are presented in the Annexure VI.**

7.4.1.1 Rotary Drilling

The rotary core drilling is primarily for investigation in rocks, but the method is also used in soils and gravelly soils. The drilling rig consists of derrick, power unit, winch, pump and a drilling head to apply high-speed rotary drive and downward thrust to the drilling rods. The drilling rods are attached with core barrel and bits at the bottom. The diamond bits of different pattern and carat depending on the hardness and rock type are used for drilling. The barrel and bit assemble can be changed in various sized and system.

Rotary action combined with downward force is used to grind away the material to be drilled. Simultaneously the water is pumped down the hollow rods and passes under pressured through narrows in the bit. The pumped water cools and lubricates the drilling tools and carried the loose debris to the surface between the rods and the sides of the hole. In core drilling the bits cut an annular hole in the material and an intact core enters the barrel to be removes as a sample. A double tube barrel, swivel type core barrel was used to recover rock/soil samples.

7.4.1.2 Percussion Drilling

This method of drilling is suitable in soils containing pebbles, cobbles, sand, and silt and clay material. If the area contains a large and hard boulder this method may not be feasible. In this method bailer of different diameter will be assembled at the bottom of the drill string, which will advance and penetrate in ground by percussion method of driving. The penetrated material will retrieve in the bailer, which is assembled with non-return valve at the bottom of the bailer. Finally, the bailer will pull out of the hole periodically to collect sample and clean the bore hole for further advancing.

The assembly of a drill rig contains a mast of 6m height attached with a heavy-duty winching drum scooped with wire rope. The rig will operate by a diesel power unit. A bailer made of MS 20mm thick 1.50m long coupled with carbide shoes at the bottom, which will penetrate the ground of different material. The shoe of the bailer is designed with a non-return type valve to trap cutting of the deposit. The depth of the hole is advanced as the bailer penetrates the ground with penetrating drive force with its weight and additional weight as per requirement. The process of penetration is repeated to advance the depth of the hole. The bailer will pull out of the hole after penetrating required interval of depth.

7.4.2 Laboratory Testing

All the requisite laboratory tests were carried out in accordance with IS standard specifications. Standard laboratory test was carried out to characterize the soil strata. The laboratory testing included the following tests: Moisture Content, Grain Size Analysis, Bulk Density, Specific Gravity, and Direct Shear Tests of granular soil.

A. Physical Classification Tests

As far as possible all requisite laboratory tests on collected samples were conducted according to standard procedure prescribed for the test in Indian Standard (IS).

i. Natural Moisture Content and Bulk Density

The natural water content was carried out under the standard IS: 2720 (part 2)-1973 and bulk density was carried out under the standard IS: 2386 -3 (1963)

ii. Specific Gravity

The specific test was carried out under the standard (IS 2720-3(1980).

iii. Grain size Analysis

The grain size analysis (gradation test) was carried out according to (IS: 2386 (part 1)-1963.

iv. Atterberg Limits

The Atterberg Limits namely, the liquid limit and plastic limit were determined according to the standard procedure outlined in IS 2720 (part 5) - 1963.

B. Mechanical Strength Tests

Soil mechanics is a branch of engineering mechanics that describes the genesis and composition of soil, the distinction between pore water pressure and inter-granular effective stress, capillary action of fluids in the pore spaces, soil classification, seepage and permeability, time dependent change of volume due to squeezing of water out of tiny pore spaces, also known as consolidation, shear strength and stiffness of soils. The shear strength of soils is primarily derived from friction between the particles and interlocking, which are very sensitive to the effective stress.

Generally, at least 2 sets of soil samples were selected assuming at least two in situ layers and conducted laboratory tests from each borehole in order to discern the shear related strengths and stress-strain responses of soils. All of the laboratory tests were numbered sequentially. The test number and the prefix were used as test and specimen identifiers.

Direct Shear Test

Direct shear tests were carried out under the standard IS 2720 (part 13)-1986.

Summary of Laboratory test results are shown in **Annexure VII**

7.4.3 Engineering Analysis

7.4.3.1 Correlation between SPT and DCPT Value

The actual field measure of SPT 'N' and DCPT 'N' values of different bore holes have been presented in the corresponding bore logs (shown in Appendix) without any correction. However, for engineering analyses, the corrected SPT 'N' value was derived based on correlation between SPT 'N' and DCPT 'Nc' as below:

Nc = 1.50 N for depths up to 3 m Nc= 1.75 N for depths 3 to 6 m

Nc= 2.00 N for depths greater than 6 m

7.4.3.2 SPT Correction

Once the DCPT 'Nc' values are standardized to SPT 'N', the SPT values have been corrected in accordance with the proposal of Skempton, (1986) and Liao and Whitman (1987) as outlined below with consideration of field procedure, hammer efficiency, borehole diameter, and sample and rod length.

Correction of SPT N-value using the relation after Skempton, 1986

N60 = Em*CB*CS*CR*N

Where:

N60 = SPT N value corrected for engineering analyses.

Em= Hammer Efficiency

CB = borehole diameter correction CS = Sample Correction

CR = rod length correction

N = Raw SPT-N value recorded or derived from DCPT 'Nc' in the field the correction factors taken are:

Em =0.55 for hand drop hammer efficiency, due to lack of true verticality and proper speed of SPT blow

CB =1.0 for 65 mm to 115 mm dia. Borehole,

=1.05 for 115 mm to 150 mm dia. Borehole,

=1.15 for 115 mm to 150 mm dia. Borehole,

Cs =1.0 for standard sampler,

=1.2 for sampler without liner,

CR =0.7 for rod length 0.00 - 2.99,

=0.75 for rod length 3.00-3.99 m,

=0.85 for rod length 4.00 - 5.99 m,

=0.95 for rod length 6.00 - 9.99 m,

=1 for rod length beyond 10.00 m, Correction for overburden

Correction of corrected N60 field value for overburden pressure using the relation after Liao and Whitman, 1987

$$(N1)60 = N60\sqrt{100KPa/\sigma'z}$$

Where:

N60 = SPT N value corrected for field procedure

(N1)60 = SPT N-value corrected for field procedures and overburden stress Measured SPT N-value is shown in borehole logs.

Similarly,

The correction for values of N should be made for the field SPT values for depths. Modified correction in 1974, peck, Hanson and Thornburn with suggested standard pressure of 100

KN/m2corresponding to a depth of 5 m of soil with bulk density 20kN/m2 can be represented by the following equation:

(N1)60 = N60 Cn

Cn=0.77log (2000/p0)

Where, p0 is effective overburden pressure in KN/m2. Correction for silts and fine sands below water table.

The correction for values of N greater than 15 in fine sands below water level is as follows;

N=15 + 0.5 (Nc-15)

This correction is due to the fact that higher values are liable to be recorded due to shallow aquifer's high pore pressure.

After correcting with energy correction to 55%, it is very conventional to modify with dilatancy.

Approximate relationship between Cone penetration resistance (qc) and SPT value (N1)60 with Stress- Strain Modulus Es (Bowles, 1982) are given below:

Soil Type	: Coarse sand with small gravels
qc/N	: 3.5-8
Es (KN/m2)	: 0.5 qc

General Assumptions for engineering analyses:

- Each stratum was considered as a combination of different heterogeneous layer, so maximum thickness considered for unique properties was limited to 1.5 m otherwise as tested.
- Corrected SPT value beyond depth of exploration was same as that of adjacent borehole and interpolated with a help of two adjacent borehole logs.
- In between two tested samples, properties of soil in middle section have been interpolated as relevancy of data.
- Design data have been interpolated between semi empirical data form field test and lab test results.
- Some of input and output data were reviewed as per relevancy with correlated data.
- The frequently used values of angle of friction of sand from various literature marked as ϕ = 0.3 N+27 or $\sqrt{20\mathrm{N}} + 15$ degrees.
- Similarly, Cohesion c can be represented as $\mathrm{c} = 4\mathrm{N}$ kPa

7.4.3.3 Axil Pile Capacity Analysis

IS method is very common in this region, the engineering analysis as follows is used for the design:

For IS Code IS 2911 (Part 1/ Sec 2): 2010 as per ANNEX B

$$Q_{u1} = A_p\left(\frac{1}{2}D_r N_r + P_D N_q\right) + \sum_{i=l}^{n} KP_{Di} \tan\delta . A_{si}$$

$$Q_{u2} = A_p CNc + \alpha c . A_{si}$$

$$Q_u = Q_{u1} + Q_{u2}$$

Where,

A_p =Cross sectional area of pile toe

D =Pile Stem diameter

ɣ =effective unit weight of soil at pile toe

P_D =effective over burden pressure at pile toe

$N_ɣ$ & N_q=bearing capacity factor depending upon the angle of internal friction at toe.

$\sum_{i=l}^{n}$ =summation of n layers in which pile is installed.

Ø =angle of internal friction

K =coefficient of earth pressure $\left(= \frac{1-\sin\phi}{1+\sin\phi}\right)$

P_{di} =effective over burden pressure for the i th layer where i varies from 1 to n.

δ =angle of wall friction between the pile

A_{si} =surface area of pile stem in the i th layer

c = Cohesion of Soil

N_c = Skemption factor and

α = Adhesion Factor

As per IS 2911 (Part 1/Sec 2), Section B-5 Minimum Factor of Safety (FoS) shall me 2.5.

* As per IS code 2911 (Part 1/Sec 2): 2010, Annex B, Section B-1, Note 3, Value of Earth Pressure Coefficient is mentioned only for Driven Pile and not limited to any value. LRFD, ASTM, European codes limits earth pressure coefficient of large pile (Drill Shaft) to certain values, Whereas O'Neill and Reese or Meyerhof limits earth pressure coefficient to value ranging from 0.5 to 1.8 as per performance-based results.

* As per LRFD, O'Neill and Reese or Meyerhof end bearing as well of skin friction must be limited to certain value based on performance-based results irrespective of compactness or

relative density of strata, which is not clearly mentioned on Indian Standard IS 2911 (part1/Sec 2): 2010.

* Proposed bridge site is located on area base (South toe) of Chure Hill, due to turbulent flow, Flash Flood and nature of River, erratic soil distribution and continuous flow of water (hydrogeological movement) is prompt even in dry season.

Considering all these factor FoS of 4 is recommended on specific bridge site.

7.4.3.4 Result of the Pile Foundation Analysis

Table 7.2: Result of the Pile Foundation Analysis for Bridges

Br. SN	Bridge Name	Pile length		Design working load, kN		Bearing capacity (scour case), kN		Bearing capacity (non-scour case), kN		Remarks
		Abu-nt	Pier	Abu-nt	Pier	Abu-nt	Pier	Abu-nt	Pier	
287	Guhye Khola (Jitgadi Khola)	16		~~1713~~		~~2165~~		~~2265~~		Changed to Open foundation
288	Narshing khola(Dry Nala)	17		~~1584~~		~~2153~~		~~2252~~		Changed to Open foundation
292	Satgadi no 1	19	17	1724	1102	2243	1630	2371	1841	
293	Satgadi no 2	20		1970		2537		2711		
295	Rajpur khola	16		2071		2367		2711		
296	Bamaha khola	19		2199		2612		3399		
297	Ghamaha khola	**30**	~~21~~	**2538**	~~1279~~	**3046**	~~1711~~	**3046**	~~2089~~	Changed to single span. Designed with scour protection
298	Tulbuliya (Left)	19.91		2463		4766		5962		
	Tulbuliya (Right)	**28**		**2236**		**2683**		**2711**		
299	Marthirwa khola	**28**		**1499**		**1852**		**1990**		
300	Meghawa khola	**30**		**2012**		**2492**		**2638**		
301	Inguria nadi	**26**	~~20~~	**2425**	~~1285~~	**3403**	~~2447~~	**3731**	~~3013~~	Changed to single span
302	Banarhwa Nadi	**25**		**2454**		**3306**		**3306**		
304	Pahila Nadi	15	17	1576	894	2835	1673	3019	1706	
306	Kanchan	**29**	**23.7**	**1608**	**1227**	**1942**	**2750**	**2059**	**3618**	
307	Kothi river	17		2151		4769		5299		
309	Banganga (Left abutment, Left 4 piers)	16	17	2275	988	1218	1564	1279	1843	Confirmatory soil investigation required
	Banganga (Right abutment, Right 5 piers)	15	17	1797	1220	2354	1811	2603	2252	2 spans decreased
310	Kaila khola	22	27	2475	1162	3738	1823	3738	5651	(Design with full scour protection works)
311	Balhundra khola	19		1726		2169		2225		
312	Harkon Khola	21		1763		2711		4330		

Br. SN	Bridge Name	Pile length		Design working load, kN		Bearing capacity (scour case), kN		Bearing capacity (non-scour case), kN		Remarks
		Abu-nt	Pier	Abu-nt	Pier	Abu-nt	Pier	Abu-nt	Pier	
313	Dry Nala	18		1890		2339		2407		
314	Kundra Khola	**26**		**2304**		**2814**		**3303**		Span length increased
315	Ghorai Nala	20		1751		2259		4106		

Ultimate and Allowable Axial Pile Capacity Analysis Calculation Sheet are presented in Annexure VIII

7.4.4 Liquefaction

7.4.4.1 Introduction:

Seismic liquefaction refers to a sudden loss in stiffness and strength of soil due to cyclic loading effects of an earthquake. The loss arises from a tendency for soil to contract under cyclic loading, and if such contraction is prevented or curtailed by the presence of water in the pores that cannot escape, it leads to a rise in pore water pressure and a resulting drop in effective stress. If the effective stress drops to zero, the strength and the stiffness also drop to zero and the soil behaves as a heavy liquid. This phenomenon continues until the excess pore water pressure dissipates. Factors influencing are – soil type, relative density, confining pressure, stress due to earthquake, duration of earthquake and drainage condition etc.

Depending upon the location and extension of liquefiable soil layer below foundation, the foundation of any structure is susceptible to damage due to liquefaction. Hence, predicting soil liquefaction resistance is an important step in the engineering design of any engineering structure in seismic prone region.

The liquefaction analysis for proposed project corridor has been performed based on "Design Guide AGMU (All Geotechnical Manual User) Memo 10.1 - Liquefaction Analysis-January 2010".

7.4.4.2 Identification of liquefaction area:

Nepal lies within the Himalayan range which is a product of continental collision between the Indian subcontinent and Eurasia. The convergence of the two continents has produced high levels of seismicity and high rates of active tectonic deformation which has resulted in four major earthquakes within the Himalayan region in the last 100 years with magnitudes greater than M 8.4 (UNDP, UNCHS, 1994).

Geologically, the proposed highway alignment passes on the medium dense and thick quaternary sediments of the Indo-Gangetic Plain, located at the southern part of the nation. This zone is geographically known as the Terai Plain and it is the foot hill of Siwalik Range.

The present site consists of loose to medium dense gravelly sandy/silty deposit and the ground water table encountered during drilling operation was at shallow depth. Hence liquefaction potential analysis was performed for these sites.

During drilling and logging ground water table encountered are at deeper depth but it rises significantly up during monsoon season. As per hydrological and hydro-geological consideration, water encountered at upper depth during drilling operation may be seepage water traces and even water table was not encountered in drill holes of various sections within explored depth.

Strong ground water table monitoring system is needed for proper liquefaction analysis.

Considering the worst case, liquefaction analysis for the project site was carried out with an assumption that natural water table lies on the ground level.

According to the Seismic Hazard Map of Nepal prepared by National Seismological center, Departments of mines and geology, Nepal, the proposed maximum ground acceleration for entire section of highway alignment is 0.36g for structural design. However, GA value of 0.40g was used for liquefaction analysis. The liquefiable locations and summary of result of analysis as well as the proposed method for rectification is shown in Table below.

7.4.4.3 Liquefaction potential analysis:

Liquefaction potential analysis for the limited section of project sites was carried out based on the soil data obtained from the soil investigation.

The “Simplified Method” described by Youd et al. (2001) as well as refinements suggested by Cetin et al. (2004) was used to estimate liquefaction potential as contained herein. The simplified method compares the resistance of a soil layer against liquefaction (Cyclic Resistance Ratio, CRR) to the seismic demand on a soil layer (Cyclic Stress Ratio, CSR) to estimate the FS of a given soil layer against triggering liquefaction. The FS for each soil sample should be computed to allow thin, isolated layers to be discounted and the specific locations and extent of those determined liquefiable to be indicated in the SGR and accounted for in design. An Excel spreadsheet that performs these calculations has been prepared to assist a liquefaction analysis.

$$\mathrm{FS} = \frac{\mathrm{CRR}}{\mathrm{CSR}}$$

Where:

CRR = CRR7.5Kσ KαMSF

$$\mathrm{CSR} = 0.65 \times \mathrm{As} \times \left(\frac{\sigma_{vo}}{\sigma'_{vo}}\right) \times \mathrm{r_d}$$

CRR7.5 = cyclic resistance ratio for magnitude 7.5 earthquake

$$= \frac{1}{34 - (\mathrm{N1})_{60CS}} + \frac{(\mathrm{N1})_{60CS}}{135} + \frac{50}{[10(\mathrm{N1})_{60CS} + 45]^2} - \frac{1}{200}$$

Kσ = Overburden correction factor

$$= \left(\frac{\sigma'_{vo}}{2.12}\right)^{(f-1)} \text{ and } 1.5 \leq K\sigma \geq 9^{(f-1)}$$

f = soil relative density factor

$=0.831-\frac{(N1)_{60CS}}{160}$ and $0.6 \leq f \leq 0.8$

Kα = sloping ground correction factor

= 1.0 for generally level ground surfaces or slopes flatters than 6 degrees.

MSF = magnitude scaling factor= 87.2(Mw)-2.215

Mw = earthquake moment magnitude.

AS = peak horizontal acceleration coefficient at the ground surface= Fpga PGA

Fpga = site amplification factor for zero-period spectral acceleration (refer LRFDArticle3.10.3.2)

PGA = peak seismic ground acceleration on rock.

σvo = total vertical soil pressure for final condition (ksf)

σvo' = effective vertical soil pressure for final condition (ksf)

rd = soil shear mass participation factor

7.4.5 Recommendations

Construction works should be as per the general specification of Department of Roads as well as according to the special specification. Care should be taken for the following during excavation and construction of the bridge foundation but not limited to the followings:

Excavation, Monitoring & Dewatering

- Adequate monitoring of the existing foundation (possibly min. daily) should be carried out continuously during excavation and until the foundation of the proposed bridge is completed.
- All excavation should be carried out with a slight slope base to drain the water from seepage and rain. Accumulation and flow of surface water should be prevented by various means. During the excavation adequate water pumping system should be used to prevent water ponding not more than 1 hours.
- Excavation of the last 30 cm to founding level should be inspected by an experienced Geotechnical Engineer before the blending of lean concrete. If the sub soil condition is found different than originally anticipated, additional investigation or redesign of foundation should be carried out.

Pile Installation and Grouting

- There is no information of the foundation of the existing bridge available. It is anticipated that there could be instability if excavation for the pile cap is carried out first and drilling and installation for the piles is carried out later. Hence, drilling and installation for piles should be carried out from the river bed level which could help in strengthening of the soil below pile cap level (at the Lowest River bed level).

- Temporary casing should be used to the bottom of the pile or refusal depth to prevent necking and bulging of the pile. If collapse of the drill hole or heavy heave of the bottom is anticipated then drilling should be advanced with thick Bentonite or Barite mud.

Ultimate Load Test Pile

- Prior to the construction of working piles, at least one Ultimate Load Test Pile based on static pile load test (with grouting pipe and Telltale setup) per bridge should be carried out as per Standard Specification of Road and Bridge Works-2073 (2^{nd} Amendment 2078) or other equivalent standards.

During construction, temporary measures for the stability of the cut slope and construction effect on the road and traffic flow has to be carried out.

If the location of the bridge shifted beyond 20 m range for the proper alignment of the road and during construction if the subsurface conditions are found different than the original assumed soil condition, confirmatory borehole has to be carried out during construction.

7.4.6 Limitations

The information data base and the analysis in this report should not be used for other works than the assigned work in this contract.

The recommendations and discussions presented in this report are based on the sub-surface conditions encountered during the site work at the time of investigation and on the result of the field and laboratory testing on samples obtained from limited number of boreholes. There may be, however, conditions pertaining to the site which have not been into account due to the limited number of boreholes. If the ground conditions encountered during construction are different than the assumed in this report, re-evaluation should be carried out as per the recommendations of an expert Geotechnical Engineer.

The ground water levels indicated on the logs of borings represents the measured levels at the time of investigations and immediately 24 hours after completion of drilling works. However, it should be noted that ground water levels are subject to variation caused by flood and weather seasonal variations and by changes of local drainage and or pumping conditions, and may at the times be significantly different to those measured during the investigation.

Ground acceleration due to earthquake (PGA) value used on this analysis report is based on a map prepared by Department of mines and Geology, Nepal, which was only preliminary indication, due to lack of sufficient data, which cannot forestall some diverse situation if large earthquake occurs in nearby area.

8 Soil and Material Investigations

8.1 General

Sub grade soil investigation plays an important role in the design of road pavement. Selection of sources of suitable aggregates for sub-base, base, concrete and the filling materials is very important in a road construction project. Aggregates form the greater part of the body of the road which bears the main stresses occurring in the road and to resist wear from surface abrasion. The properties of aggregates are therefore of considerable importance to the road engineer and characteristics of aggregate is helpful in the design of road structure. Geo-technical investigations along the road alignment were carried out in order to evaluate the sub-grade characteristics. Investigations for material sources were carried out for the determination of the quality as well as the available quantities of the construction materials. A material survey was carried out along the proposed road to find out the potential sources of construction materials for base course, sub-base, boulders sand and concrete aggregates to be used in proposed road construction by team led by Material Engineer with Civil Engineers and Lab Technicians.

The purposes of material survey were to:

- investigate, test, and define sources of construction materials;
- assess the potential sources of natural construction materials (e.g., quarry sites);
- provide data regarding available quantity of the materials and the haulage distances from the construction site in order to estimate the cost and the sufficiency of quantity and quality required for the construction;
- carry out suitability tests;
- prepare a comprehensive report.

During the site visit for construction Material survey, it was observed that the alignment of Butwal-Gorusinghe Section of East-West Highway also passes through the built-up areas and cultivated lands. The road alignment generally passes through plain area. Most of the sources are located in the vicinity of the project road. Along the road, the construction materials are available from Surahi Khola, Jokahi Khola, Belgurduwa Nadi, Badganga Khola, Jingwa Khola, Dano Khola, Kanchan Khola, Tinau River, Rohini Khola, Godahaha Khola, and Turiya Khola etc. Samples were collected from the excavated trial pits in sufficient quantities, labelled and transported to the laboratory in Kathmandu. Extents of depths of deposits were also measured. Based upon the area and the depth of deposits, quantities of materials were estimated for each quarry site. Samples were collected and brought to Kathmandu laboratory for tests. A list of quarries and details of all including availability of approximate quantity are presented **Table 8.7 Potential sources and Tentative Estimation of Quantities of Construction Materials.**

8.2 Methodology for Sampling

The nature, engineering characteristics and location/availability of construction materials are essential aspects of the road design and construction. Detailed specifications to safeguard the requirements are generally defined in terms of properties such as grading, strength, petrographic and plasticity. Natural construction materials are used to satisfy a range of general requirement for road construction within a road environment, namely:

- as pavement materials,
- as bridge and culvert material,
- as a surfacing medium,
- as concrete aggregate,
- as filter mediums,
- as masonry or gabion fill, and
- as material for maintenance purpose.

It is becoming increasingly recognized that a key objective in sustainable road construction is to best match with the locally available material to its road task and suit its local environment. Construction costs of the pavement structures are typically about 35~40 per cent of the total road construction cost and it is clear that, the identification and characterization of available road construction materials is an important stage for a road design and the following are seen as crucial points with respect to the ability of a material to carry out its assigned task within a road pavement design information of the engineering properties of the material.

- the method required for the processing of the material,
- the governing road environment, and
- Probable future alterations to the road environment.

8.3 Investigation of Existing Sub-Grade

In road construction, there is a need to assess the adequacy of a sub grade to behave satisfactorily beneath a pavement. Proper pavement performance requires a satisfactorily performing sub grade.

The investigation of existing sub-grade was done by both field tests and laboratory tests.

Detail of this investigation is presented in **Chapter 7.3.1 Subgrade Characteristics and Strength.**

8.4 Material Type and their detailed description

Based on the field and laboratory investigations, the following statements can be made on the materials availability, their required specifications, existing condition, quantity, required quality, required quality, etc.

8.4.1 Sub-Grade Material

Mostly, the sub-grade soils on the existing pavement were found dominant of brownish silty to very silty medium to fine sand with traces of few gravels. Compaction tests were carried out using modified proctor tests. The findings of laboratory tests revealed that the optimum moisture contents (OMC) of sub-grade material on the existing pavement were found in the range of 5.97 % to 17.47 %. Maximum dry densities are in the range of 1.63 to 2.13 gm/cc. The CBR values obtained from laboratory compaction tests are in range of 3.6 % to 18.65 % and CBR from field DCP test results ranges from 3.13 % to 17.73 %. The summary of the test results which depicts the material types of existing subgrade, laboratory and field tests to compute CBR values per chainage wise is tabulated in **Chapter: 13.3.3 Test Pits and Laboratory Tests.**

8.4.2 Sub-Base Material

The subbase material can be naturally occurring quarzitic gravel, river gravels and transported gravels, or materials resulting from the weathering of rocks, or clayey/silty sand. The material to be used for the work shall be natural sand, crushed gravel, and crushed stone, crushed slag or combination thereof depending upon the grading requirement. The physical requirement for Subbase is as follows **(Table 8.1):**

Table 8.1 : Physical Requirement for Materials for Granular Sub Base

S.N.	Physical Properties	Test Method	Requirement Value
1	Aggregate Impact Value	IS 2386-4 or IS 5640	Maximum 40
2	Liquid Limit	IS 2720-5	Maximum 25
3	Plasticity Index	IS 2720-5	Maximum 6
4	CBR at 95 % dry density (IS 2720-Part 8)	IS 2720-5	Minimum 30

Routine inspection and testing should be carried out by the contractor to verify the quality of the materials mentioned in the potential sources. The used subbase material should fall under following grading envelope **(Table 8.2)** during the time of construction while placing in the ground. The required gradation can be obtained by screening or mixing if not acquired in natural state. Grading I and II is for upper subbase and Grading III is for lower subbase.

Table 8.2: Grading Envelope for Granular Subbase Materials.

Sieve Sizes as per IS designation in mm	Percentage passing by weight		
	Grading I	Grading II	Grading III
75	100		
53	80-100	100	100
26.5	55-90	79-90	55-75
9.5	35-65	50-80	
4.75	25-55	40-65	30-Oct
2.36	20-40	30-50	
0.425	10-15	10-15	
0.075	< 5	< 5	< 5

In the project area, sources of material that can be used as subbase can be extracted from Surahi Khola, Jokahi Khola, Belgurduwa Nadi, Badganga Khola, Jingwa Khola, Dano Khola, Kanchan Khola, Tinau River, Rohini Khola, Godahaha Khola, and Turiya Khola which meet the requirements of granular subbase as mentioned above.

8.4.3 Base Material

Base material which is laid over subbase, shall consist of clean, crushed aggregates mechanically interlocked by rolling and bonded together with binding material. Base can be crushed or broken stone. The crushed or broken stone shall be hard, durable and free from excess flat, elongated, soft and disintegrated, dirt and other deleterious materials. The physical requirements of materials to be used for base are as follows **(Table 8.3):**

Table 8.3: Physical requirement for material for base

S.N.	Physical Properties	Test Method	Requirement Value
1	Loss Angeles Abrasion Value (LAA) OR Aggregate Impact Value	IS 2386-4 IS 2386-4 or IS 5640	Maximum 40 Maximum 30
2	Combined Flakiness and Elongation Index	IS 2386-1	Maximum 35
3	Water Absorption	IS 1386-3	2 % Max
4	Liquid Limit of the material passing 425-micron sieve	IS 2720-5	25 Max
5	Plasticity index of material passing 425-micron sieve	IS 2720-5	6 Max
6	Soundness (Sodium or Magnesium)	5 Cycles	
a	Sodium Sulphate	IS:2386 Part V	12 % Max
b	Magnesium Sulphate	IS:2386 Part V	18 % Max
Note: If Water absorption is more than 2 %, Soundness Test shall be carried out as per IS 2386-5			

Surahi Khola, Jokahi Khola, Belgurduwa Nadi, Badganga Khola, Jingwa Khola, Dano Khola, Kanchan Khola, Tinau River, Rohini Khola, Godahaha Khola, and Turiya Khola are the major sources of base materials which meet the requirement.

8.4.4 Material for Road Pavement

The materials to be used for road pavement should be tested for required specification prior to their use. The materials to be used in road pavement is described below:

- **Bitumen**

The bitumen shall be Viscosity Grade: 30 paving bitumen complying with the Indian Standard Specification IS: 73, modified bitumen complying with IS: 15462. Further description of these bitumen is provided in **Chapter 8.7.3.**

- **Coarse Aggregates**

The coarse aggregates shall consist of crushed rock, crushed gravel or other hard material retained on 2.36 mm sieve. It shall be clean, hard, durable and cubical in shape, free from dust and soft organic and other deleterious substances. Where crushed gravel is proposed for use as aggregate, not less than 90 percent by weight of the crushed material retained on 4. 75 mm sieve shall have at least two fractured faces resulting from crushing operation. Before approval of the source, the aggregates shall be tested for stripping. The physical property of coarse aggregate to be used is listed below **(Table: 8.4):**

Table 8.4 : Physical Properties of coarse aggregates

Property	Test	Requirement	Test Method
Cleanliness	Grain size analysis	Maximum 5 % passing 75-micron sieve	IS:2386 Part I
Particle Shape	Combined Flakiness and Elongation Indices	Maximum 35 %	IS:2386 Part I
Strength	Los Angeles Abrasion Value	Maximum 30 %	IS:2386 Part IV
	OR		
	Aggregate Impact Value	Maximum 24 %	IS:2386 Part IV
Durability	Soundness (Sodium or Magnesium)	5 cycles	
	Sodium Sulphate	Maximum 12 %	IS:2386 Part V
	Magnesium Sulphate	Maximum 18 %	IS:2386 Part V
Polishing	Polished Stone Value	Minimum 55	BS:812-114
Water absorption	Water absorption	Maximum 2 %	IS:2386 Part III
Stripping	Coating and Stripping of Bitumen Aggregate	Minimum Retained Coating 95 %	IS: 6241
Water sensitivity	Retained Tensile Strength	Minimum 80 %	AASHTO 283

The quarry sites like Surahi Khola, Jokahi Khola, Belgurduwa Nadi, Badganga Khola, Jingwa Khola, Dano Khola, Kanchan Khola, Tinau River, Rohini Khola, Godahaha Khola, and Turiya Khola are suitable for coarse aggregates.

- **Fine Aggregates**

Fine aggregates shall consist of crushed or naturally occurring mineral material, or a combination of the two, passing the 2.36 mm sieve and retained on the 75-micron sieve. These shall be clean, hard, durable, dry and free from dust, and soft or friable matter, organic or other deleterious matter. Natural sand shall not be allowed in binder courses. However, natural sand up to 50 percent of the fine aggregate may be allowed in base courses. The fine aggregate shall have a sand equivalent value of not less than 50 when tested in accordance with the requirement of IS: 2720 (Part 37). The plasticity index of the fraction passing the 0.425 mm sieve shall not exceed 4, when tested in accordance with IS: 2720 (Part 5).

- **Filler**

Filler shall consist of finely divided mineral matter such as rock dust, hydrated lime or cement.

The filler shall be free from organic impurities and have a plasticity Index not greater than 4. The Plasticity index requirement shall not apply if filler is cement or lime. The filler shall be graded within the limits as shown below **(Table: 8.5):**

Table 8.5: Grading Requirements for Mineral Filler

IS Sieve (mm)	Cumulative Percent Passing by Weight of Total Aggregate
0	100
0.3	98-100
0.075	85-100

8.4.5 Material for Cement Concrete

The major composition for cement concrete is cement, aggregates, sand, water and admixtures. The description of cement and water is elaborated in **chapters 8.6 and 8.7.** Admixtures are materials in the form of powder or fluids that are added to the concrete to give it certain characteristics not obtainable with plain concrete mixes. Different types of admixtures are accelerators, plasticizers, pigments, etc. depending upon the required function can be used in the concrete that are readily available in the local market. Major components of cement concrete are fine and coarse aggregates and they shall consist of naturally occurring (crushed) stones, sand or combination of all of them. They shall be hard, strong, dense, durable, clear and free from veins and adherent coating; and free from injurious amounts of disintegrated pieces, alkali, vegetable matter and other deleterious substances. As far as possible, flaky, coriaceous and elongated pieces should be avoided. Aggregates shall not contain any harmful material such as pyrites, coal, lignite, mica, shale or similar laminated material, clay, alkali, soft fragments, sea shells and organic impurities in such quantity so as to affect the strength or durability of the concrete. Aggregates to be used for reinforced concrete shall not contain any material liable to attack the steel reinforcement. The aggregates should meet the grading depending upon the types of concrete to be prepared as per IS 383-1970 and other specific physical requirements of aggregates as mentioned below **(Table 8.6):**

Table 8.6: Physical requirements of Aggregates to be used in cement concrete

S.N.	Physical Properties	Test Method	Requirement Value
1	Aggregate Crushing Value	IS 2386 (Part IV)-1963	Maximum 45 % for concrete other than wearing surfaces
			Maximum 30 % for concrete for wearing surfaces like roads, runways and pavements
2	Aggregate Impact Value	IS 2386 (Part IV)-1963	Maximum 45 % for concrete other than wearing surfaces
			Maximum 30 % for concrete for wearing surfaces like roads, runways and pavements
3	Loss Angeles Abrasion Value (LAA)	IS 2386 (Part IV)-1963	Maximum 50 % for concrete other than wearing surfaces
			Maximum 30 % for concrete for wearing surfaces like roads, runways and pavements
4	Soundness (Sodium or Magnesium)	5 Cycles	For coarse Aggregates
a	Sodium Sulphate	IS 2386 (Part V)-1963	12 % Max
b	Magnesium Sulphate	IS 2386 (Part V)-1963	18 % Max
5	Soundness (Sodium or Magnesium)	5 Cycles	For fine Aggregates
a	Sodium Sulphate	IS 2386 (Part V)-1963	10 % Max
b	Magnesium Sulphate	IS 2386 (Part V)-1963	15 % Max
Note: Aggregate crushing value and aggregate impact value can be tested as alternatives			

Selection of river aggregates can be done based on the lab tests results for wearing surfaces or concrete. The sources in the vicinity of the project road can fulfil the requirement of agreement for the project.

8.5 Potential Sources of Construction Materials

A survey was carried out to find out the potential sources of construction materials. Most of the sources are located in the vicinity of the project road. The survey mostly concentrated in construction materials for base course, sub-base, boulders sand and concrete aggregates to be used in proposed road construction. Samples were collected from excavated trial pits in sufficient quantities, labelled and transported to the laboratory in Kathmandu. Extent of depths of deposits was also measured. Based upon the area and the depth of deposits, quantities of material were estimated for each quarry site. The potential sources identified and investigated are presented in table below **(Table 8.7):**

Table 8.7: Potential sources and Tentative Estimation of Quantities of Construction Materials

S.n.	Name of the Source	Location	Available Materials	Estimated Available Quantities (m^3)	Quality of Material	Erosion Condition	Remarks
1	Surahi Khola	25 Km away from Chainage 639+600 End Point (Gorusinghe) on Left Hand Side (LHS) of Mahendra Highway	Cobbles, Gravels and Sand	810000	Quality is satisfactory and is confirmed by lab-test. Quality of aggregate meets the specification requirement; hence it can be used as subbase and base.	River is flowing widely and can cause problems of flooding during heavy rainfall. So, bank protection should be focused.	20 km Black topped road and 5 km earthen road
2	Jokahi Khola	30 Km away from Chainage 639+600 End Point (Gorusinghe) on Left Hand Side (LHS) of Mahendra Highway	Cobbles, Gravels and Sand	135000	Quality of aggregate is satisfactory and is confirmed by lab-test. Quality of river shingles meets the specification requirement; hence it can be used in sub-base and base and in concrete aggregates.	River is flowing widely and can cause problems of flooding during heavy rainfall. So, bank protection should be focused.	25 km Black topped road and 5 km earthen road
3	Belgurduwa Nadi	5 Km away from Chainage 639+600 End Point (Gorusinghe) on Left Hand Side (LHS) of the road alignment	Sand and Silt	60000	Quality of sand is satisfactory. Can be used as per required by screening.	There is no such critical condition caused by this nadi.	5 Km gravel road from end chainage
4	Banganga Khola	At chainage 622+00 and 5 km away on Left Hand Side the road alignment	Cobbles, Gravels and Sand	90000	Quality of aggregate is satisfactory and is confirmed by lab-test. Quality of river shingles meets the specification requirement; hence it can be used in sub-base, base and crusher produced asphalt chips.	There is no such critical condition caused by this nadi.	2 km black topped road and 3 km earthen road

S.n.	Name of the Source	Location	Available Materials	Estimated Available Quantities (m^3)	Quality of Material	Erosion Condition	Remarks
5	Jhingwa Khola	About 13 km away from chainage 640+100 on Right Hand Side of our road alignment	Boulders, Cobbles, Gravels and Sand	150000	Quality of aggregate is satisfactory and is confirmed by lab-test. Quality of river shingles meets the specification requirement; hence it can be used in sub-base and base.	There may be bank undercutting and thus the river should be protected by gabion walls both upstream and downstream.	About 7 km black topped road and 5 km earthen road
6	Dano Khola	At chainage 598+400 and 5 km away on Left Hand Side of the road alignment	Gravels and Sand	45000	Quality of aggregate is satisfactory and is confirmed by lab-test. Quality of river shingles meets the specification requirement; hence it can be used in sub-base and base.	There may be bank cutting and thus the river should be protected by gabion walls both upstream and downstream.	About 5 km earthen road
7	Kanchan Khola	At chainage 611+400 and 5 km away from the road alignment at Saljhandi on Right hand Side of the road alignment	Cobbles, Gravels and Sand	45000	Quality of aggregate is satisfactory and is confirmed by lab-test. Quality of river shingles meets the specification requirement; hence it can be used in sub-base and base.	There may be bank cutting and thus the river should be protected by gabion walls both upstream and downstream.	About 5 km earthen road
8	Tinau Khola	10 Km away from Chainage 589+600 Start Point (Butwal) on Left hand Side of the road alignment	Boulders, Cobbles, Gravels and Sand	675000	Quality of aggregate is satisfactory and is confirmed by lab-test. Quality of river shingles meets the specification requirement; hence it can be used in sub-base.	There may be bank undercutting and thus the river should be protected by gabion walls both upstream and downstream	About 5 km black topped road and 5 km earthen road

S.n.	Name of the Source	Location	Available Materials	Estimated Available Quantities (m^3)	Quality of Material	Erosion Condition	Remarks
9	Rohini Khola	12 Km away from Chainage 589+600 Start Point (Butwal) on Right Hand Side of Mahendra Highway	Boulders, Cobbles, Gravels and Sand	75000	Quality of aggregate is satisfactory and can be used in sub-base.	There may be bank undercutting and thus the river should be protected by gabion walls both upstream and downstream.	About 7 km black topped road and 5 km earthen road
10	Godhaha Khola	18 Km away from Chainage 589+600 Start Point (Butwal) on Right Hand Side of Mahendra Highway	Boulders, Cobbles, Gravels and Sand	300000	Quality of aggregate is satisfactory and can be used in sub-base and base.	There may be bank undercutting and thus the river should be protected by gabion walls both upstream and downstream	About 13 km black topped road and 5 km earthen road
11	Turiya Khola	23 Km away from Chainage 589+600 Start Point (Butwal) on Right Hand Side of Mahendra Highway	Boulders, Cobbles, Gravels and Sand	202500	Quality of aggregate is satisfactory and can be used in sub-base and base.	There may be bank undercutting and thus the river should be protected by gabion walls both upstream and downstream	About 20 km black topped road and 3 km earthen road

8.6 Water for Construction Purpose

Water is readily available in the rivers like Surahi Khola, Jokahi Khola, Belgurduwa Nadi, Badganga Khola, Jingwa Khola, Dano Khola, Kanchan Khola, Tinau River, Rohini Khola, Godahaha Khola, and Turiya Khola etc. located along the road alignment in abundant quantity.

Water to be used for mixing and curing of concrete, plastering, etc. shall be reasonably clear and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may deleterious to concrete or steel. Potable water is generally considered satisfactory for concrete. The pH value of water shall not be less than 6. Water found satisfactory for mixing is also suitable for curing of concrete. However, water used for curing should not produce any objectionable stain or unsightly deposit on the concrete surface. The presence of tannic add or iron compounds is objectionable. The permissible limit of organic matter, inorganic matter, Sulphates, Chlorides, suspended matter, etc. in the water and their corresponding tests are listed as below **(Table 8.8)**

Table 8.8: Permissible Limits for Solids in Water used for construction purposes

S.N.	Solids	Tested as per	Permissible Limit
1	Organic	IS 3025 (Part 18)	200 mg/L
2	Inorganic	IS 3025 (Part 18)	3000 mg/L
3	Sulphates	IS 3025 (Part 24)	400 mg/L
4	Chlorides	IS 3025 (Part 32)	2000 mg/L for concrete not containing embedded steel and 500 mg/L for reinforced concrete works
5	Suspended Matter	IS 3025 (Part 17)	2000 mg/L

8.7 Manufactured Materials

8.7.1 Cement

Cement to be used in the project can be acquired from local market. Various types of cement such as Argakhanchi Cement, Bishal Cement, Agni Cement, Hongsi Cement, Brij Cement, etc are available in the local market. Ordinary and High Strength Portland Cement (OPC and HSPC) shall be sampled according to IS: 3535 and tested according to NS: 123/IS: 4031. The requirements of the physical characteristics of cement and their related tests are listed below **(Table: 8.9).**

Table 8.9: Requirement on the physical Characteristics of Cement

S.N.	Physical Characteristics	OPC/PSC	HSPC	Reference Method of Test
1	Fineness m^2/kg: (by Blaine's Air Permeability Method)	225	225	

S.N.	Physical Characteristics	OPC/PSC	HSPC	Reference Method of Test
2	Setting Time:			NS 123
a	Minimum Initial Setting Time (minutes)	45	45	
b	Maximum Final Setting Time (minutes)	600	600	
3	Soundness by Le Chatelier's Method, mm, Maximum	10	10	
4	Compressive Strength			NS 123
	Minimum average Compressive Strength of three Mortar Cube (N/mm^2)			
a	3 days	16	27	
b	7 days	22	37	
b	28 days	33	53	

8.7.2 Reinforcement

All reinforcement shall be free from loose mill scales, loose rust and coats of paints, oil, mud or any other substances which may destroy or reduce bond. Sand blasting or other treatment is recommended to clean reinforcement. Special precautions like coating of reinforcement may be required for reinforced concrete elements in exceptional cases and for rehabilitation of structures. The reinforcement shall be any of the following:

- Mild steel and medium tensile steel bars confirming to IS 432 (Part 1).
- High strength deformed steel bars conforming to IS 1786.
- Hard- drawn steel wire fabric conforming to IS 1566.
- Structural steel conforming to Grade A of IS 2062.

Reinforcement is easily available in abundant quantity in the local market.

Asphalt concrete is the dense graded premixed bituminous mixture consisting of carefully proportioned mixture of dry coarse aggregate, fine aggregate, mineral filler and bitumen. Bitumen can be acquired from Amlekhgunj which is located along second project road. Bituminous Binder to be used in the project is VG 30 and should have following specifications and should be confirmed by providing related tests as enlisted below **(Table 8.10).**

Table 8.10: Requirement on the physical Characteristics of Bitumen

S.N.	Characteristics	Bitumen - VG 30	Reference Method of Test
1	Penetration at 25 ºC, 100 g, 5s,0.1 mm, Min	45	NS: 221:2047 (Part III)/ IS: 1203
2	Absolute Viscosity at 60 ºC, Poises	2400-3600	NS: 237:2050 (Part VIII)/IS:1206-2
3	Kinematic Viscosity at 135 ºC, cSt, Min	350	NS: 237:2050 (Part VIII)/IS:1206-3
4	Flash point (Cleveland open cup), ºC, Min	220	NS: 237:2049 (Part VII)/IS:1448-69
5	Solubility in Trichloroethylene, percent, Min	99	NS 221:2047 (Part IV) IS:1216
6	Softening point (R & B), ºC, Min	47	NS / IS:1205

S.N.	Characteristics	Bitumen - VG 30	Reference Method of Test
7	Tests on residue from rolling thin film oven test		
a	Viscosity ratio at 60 ºC, Max	4	NS: 221:2046 (Part II)/IS:1206-2
b	Ductility at 25 ºC, cm, Min	40	NS 221:204 (Part I)/IS:1208

8.7.3 Structural Steel

Structural Steel are easily available in sufficient quantity in the local market. The most popular brands that can be easily acquired from the nearby vendors of the project road are Panchakanya Steel, Jagdamba Steel, Hama Steel, Himal Steel, Shree Steel, Laxmi Steel, Shalimar Steel, Hulas Steel, etc. The modulus of elasticity of steel shall be taken as 200 kN/mm2. The characteristic yield strength of different steel shall be assumed as the minimum yield stress/0.2 percent proof stress specified in the relevant Indian Standard. Before fabrication, all structural steel shall comply with the requirements of the following Indian Standards.

IS: 226: Structural Steel (Standard Quality)
IS: 961: Structural steel (High Tensile)
IS: 2062: Wieldable Structural Steel
IS: 8500: Wieldable Structural Steel (medium & high strength qualities)
IS: 1148: Hot rolled rivet bars (up to 40 mm dia.) for structural purposes
IS: 1149: High tensile rivet bars for structural purposes
IS: 1161: Steel tubes for structural purposes
IS: 4923: Hollow Steel sections for structural use
IS: 11587: Structural weather resistant steel
IS: 808: Specifications for Rolled Steel Beam, Channel and Angle Sections
IS: 1239: Mild Steel Tubes
IS: 1730: Dimension for Steel Plate, sheet and strip for structural and general engineering purposes
IS: 1731: Dimension for Steel flats for structural and general engineering purposes
IS: 1732: Dimension for round and square steel bars for structural and general engineering purposes
IS: 1852: Rolling and cutting tolerances for hot rolled steel products

8.7.4 Filling Materials

The filling materials (soil) can be obtained from the rivers or local site material can be mixed with river bed materials and should meet following specifications;

- The maximum size of the coarse material in the mixture shall not exceed 75 mm for general earth fill.
- For this Project area, mixing river bed materials below 75 mm with locally available cohesion less granular soil will be appropriate.

- The soil with less than 15 percent passing 0.075 mm sieve should be used.
- Co-efficient of uniformity (Cu) of the backfill shall be greater 2 and the peak angle of internal friction should be greater than or equal to 30 degrees.
- The fill materials shall also be free from organic or other deleterious materials so as not to cause corrosion of the soil reinforcement and the facia panels.
- The CBR value of any embankment fill materials should be greater than 5%.
- The material shall have liquid limit not exceeding 35 plasticity index value should not be greater than 6.
- Where necessary, embankment foundations shall be excavated/furrowed and brought under Optimum Moisture Content and re-compacted in layers of 150 mm each in order to achieve the required level of compaction.
- Layers of material other than rock fill shall not exceed 150 mm compacted depth.
- The following properties of existing soil in foundation (assumed) can be adopted. However, it depends upon the location of the site (assumed): -

  Cohesion (C) =…0. kN/m^2
  Angle of internal friction (Φ) =…28-30. degrees
  Unit weight (γ) =…16. kN/m^3

- The following properties of structural fill / soil for back fill can be adopted (assumed):-

  Cohesion (C) =…0-5. kN/m^2
  Angle of internal friction (Φ) =…30-32. degrees
  Unit weight (γ) =…18. kN/m^3

8.8 Laboratory Test Results of Quarry Sites

The samples were subjected to the following tests in the laboratory.

- Sieve Analysis
- Aggregate Impact Value Test (AIV)
- Water Absorption
- Liquid Limit and Plastic Limit
- Clay Content
- Los Angeles Abrasion Test (LAA)

The assessments of materials from various sources have revealed that the materials in natural state are blended with boulders, gravels, sand and silt. The pavement design is based on the properties of materials from listed sources.

Based on the result of field investigations and laboratory testing, the construction materials from various sources which are found to be suitable for various construction works are listed below **(Table 8.11)** and can be selected based on their suitability.

Table 8.11: Laboratory Test Results of Potential Quarry Sites and construction materials

S.N.	Location	Aggregate Impact Value % (AIV)	Los Angeles Abrasion % (LAA)	Water Absorption	Plasticity	Clay Content %	Material Suitability	Remarks
1	Arjun khola	17.75	20.85	0.84	Non-plastic		Subbase and Base both	
2	Arjun Khola - 10 mm down aggregate	18.68	19.24				Asphalt Chips	Collected from Samrat Crusher
3	Rapti River	12.06	24.26	0.64	Non-plastic		Subbase and Base both	
4	Rapti River - Base material	15.74	23.25	1.49	Non-plastic		Subbase and Base both	Collected from Deukhari Valley Crusher, Kalakate
5	Rapti River - 10 mm down aggregate	12.25	17.61				Asphalt Chips	
6	Ransin Khola	15.5	21.8	0.98	Non-plastic		Subbase and Base both	Collected from Saptarishi Aggregate
7	Ransin Khola - 10 mm down aggregate	14.78	24.34	1.01			Asphalt Chips	
8	Surahi Khola	27.46	38.2	1.59	Non-plastic		Subbase and Base both	
9	Jokahi Khola	25.35	34.55	1.11	Non-plastic		Subbase and Base both	
10	Belgurduwa Nadi				Non-plastic	1.11	Sand	
11	Banganga Khola	17.33	25.18	1.14	Non-plastic		Subbase and Base both	
12	Banganga Khola - 10 mm down aggregate	20.56	19.88	0.73			Asphalt Chips	
13	Jhingwa Khola	15.63	23.67	0.84	Non-plastic		Subbase and Base both	
14	Kanchan Khola	14.23	18.26	0.67	Non-plastic		Subbase and Base both	
15	Danav Khola	16.2	31.26	0.89	Non-plastic		Subbase and Base both	

S.N.	Location	Aggregate Impact Value % (AIV)	Los Angeles Abrasion % (LAA)	Water Absorption	Plasticity	Clay Content %	Material Suitability	Remarks
16	Tinau Khola	12.68	19.70	1.03	Non-plastic		Subbase and Base both	Collected from Butwal, Ward No-03
17	Tinau Khola	17.15	29.85	1.26	Non-plastic		Subbase and Base both	Collected from Bagauda Crusher, Motipur-04
18	Tinau Khola	22.97	26.26	1.52	Non-plastic		Subbase and Base both	Collected from Tilottama-13, Tikoligadh
19	Tinau Khola	25.1	34.85	0.70	Non-plastic		Subbase and Base both	Collected from SR Roda Udyog
20	Turiya Khola	25.2	27.70	0.80	Non-plastic		Subbase and Base both	

Summary of Laboratory test results of Construction Materials are shown in **Annexure: IX**

9 Hydrological and Hydraulic Investigations

9.1 Introduction, Objectives and Methodology

9.1.1 Introduction

This hydrological investigation report has been prepared for **Butwal-Gorusinghe** section of existing East West Highway.

The investigation was concentrated on identification of hydrological parameters like design flood, scour depths and required length for the design of bridges and also to finalize the hydrological and hydraulic design of cross drains, side drains and River training works.

This section of existing highway mostly runs from east to west and cross many rivers, streams and canals flowing based on topographical gradient from north to south. In addition, the alignments are mostly in plain region, where the rivers and streams are meandered and braided due to less gradient and alluvium bed.

9.1.2 Objectives

The main objective of this hydrological investigation was to verify the inventory records and to check the computed and estimated hydrological parameters of drainage structures of this section and to recommend the final length of bridges and sizes of culverts.

9.1.3 Methodology:

- Local enquiry for identification of lost culverts due to encroachments
- Local inquiry from old age people about heavy flooding and water levels for verification purposes
- Tape measurements wherever necessary
- Identification of scouring at piers of bridges
- Local inquiry about flowing nature of rivers in the vicinity of bridges
- Photography of drainage structure

9.2 Findings and Recommendations Field Survey

9.2.1 Minor and Major Bridge

List of all bridges except special is provided in **Chapter 15: Bridge Culvert and Other Structural Design** along with their existing and recommended sizes. Some of them are adequate to pass the design flood and therefore existing lengths have been recommended. Whereas minimum required length is calculated and recommended for such existing bridges that are not adequate to pass the design flood (Q100). Moreover, vertical clearance has to be increased for most of the bridges.

9.2.2 RCC Box Bridge

Some small bridges having in-sufficient height and some big sab culverts having good clearance are recommended for box bridges.

9.2.3 Box Culverts

All existing pipe and slab culvert are proposed to be replaced by the RCC Box culverts. The hydrological investigation was carried out accordingly.

9.2.4 Longitudinal Drain

It was observed that many cross drains are blocked by building and other structures. The proposed side drains have to consider flow from these blocked cross drains too. Therefore, size of longitudinal drains has to be increased in urban area. It is proposed to canalize the water of longitudinal drains to nearby Khola or River.

9.3 Determination of Weighted Mean Diameter of Particles

For determination of weighted mean diameter of partitas representative samples were taken from the core of drilling at every change of strata up to maximum anticipated scour depth. About 500 gms of representative samples and sieved by a set of standards as mentioned in IRC 5:1998, Appendix II, Clause 110.1.3 and weight of soil retained in each sieve was taken and weighted mean diameter was calculated as per IRC 5:1998, Appendix II, Clause 110.1.3.

SECTION III DETAILED ANALYSIS AND DESIGN

10 Traffic Studies, Analysis and Forecast

10.1 Approach and Methodology

Traffic analysis is to determine the traffic volume of the project road, vehicle type composition, and daily traffic volume fluctuations.

Generally, the current traffic volume is determined by conducting traffic volume surveys on site. There is prevailing trend of forecasting future traffic demand considering data obtained from survey and in consideration with the historical traffic volume statistics. However, due to the pandemic of COVID 19, the movement of vehicle is comparatively low and considering these data as current traffic volume in forecasting future demand is found unreasonable. Therefore, past traffic volume data of the proposed road have been considered while analyzing. The traffic characteristics such as vehicle type composition, daily traffic volume fluctuation was also analyzed based on the past traffic volume data.

The table below shows the details of station considered during traffic study and analysis.

Table 10.1: Identification Traffic stations and Highway link code on the Road Butwal-Gorusinghe (Imiliya) Section.

Link code	H0146	H0147	H0148	H0149	H0150
Link name	Butwal-Bamaha Khola	Bamaha Khola-Kothi River	Kothi River-Jitpur	Jitpur-Gorusinghe	Gorusinghe-Chanauta
Distance (km)	9.5	17.2	4.9	14.6	4
Traffic station	Sta. 90		Sta. 92		Sta. 94

10.2 Desk study and Data Collection

The Consultant has reviewed the past traffic data that presented in the SSRN of DOR. Based on the available data of 2009 to 2018, the vehicle type composition ratio and daily traffic volume fluctuation data have been determined. Since there is no statistic of travel speed, it was analyzed through a field survey.

10.3 Current Traffic Situation

a) Traffic volume & composition

Daily traffic volume of the proposed road has been determined as 15,600 ~ 33,600 veh/day. Since Butwal-Bamahakhola section mostly passes through urban area, it possesses higher traffic volume.

Table 10.2: 2018 Traffic volume: (unit: veh/day)

Traffic station			Sta.90	Sta.92	Sta.94	Total
Link code			H0147	H0149	H0150	
			H0146	H0148		
Link name			Kothi River - Butwal	Jitpur-Kothi River	Gorusinghe-Chanauta	
MV	Truck	multi-axle	28	57	1,124	1,209
		heavy	131	162	1,091	1,384
		light	68	15	20	103
		sub	227	234	2,235	2,696
	Bus	Big	152	237	572	961
		mini	79	29	364	472
		micro	200	77	122	399
		sub	431	343	1,058	1,832
	car	car	1,483	748	662	2,893
		four wheels	620	423	314	1,357
		sub	2,103	1,171	976	4,250
	utility vehicle		771	309	528	1,608
	others	tractor	16	43	102	161
		power tiler	5	0	0	5
	2-3 wheel	motorcycle	10,959	4,674	3,323	18,956
		motorized three-wheeler	372	145	74	591
		sub	11,331	4,819	3,397	19,547
NMV	rickshaw		0	0	0	0
Total			14,884	6,919	8,296	30,099

Source: every station data of the website of the Department of Roads,

Among the total volume of traffic, over 70% is occupied by 2~3wheel vehicles followed by cars (14%), buses (6%) and trucks (9%).

Table 10.3: 2018 Traffic composition ratio: (unit: veh/day)

Traffic station			Sta.90	Sta.92	Sta.94	sum
Link code			H0147	H0149	H0150	
			H0146	H0148		
Link name			Kothi River - Butwal	Jitpur-Kothi River	Gorusinghe-Chanauta	
MV	Truck	multi-axle	0.20%	0.80%	13.50%	4.00%
		heavy	0.90%	2.30%	13.20%	4.60%
		light	0.50%	0.20%	0.20%	0.30%
		sub	**1.50%**	**3.40%**	**26.90%**	**9.00%**
	Bus	Big	1.00%	3.40%	6.90%	3.20%
		mini	0.50%	0.40%	4.40%	1.60%
		micro	1.30%	1.10%	1.50%	1.30%
		sub	**2.90%**	**5.00%**	**12.80%**	**6.10%**
	car	car	10.00%	10.80%	8.00%	9.60%

		four-wheel drive	4.20%	6.10%	3.80%	4.50%
		sub	**14.10%**	**16.90%**	**11.80%**	**14.10%**
	utility vehicle		5.20%	4.50%	6.40%	5.30%
	others	tractor	0.10%	0.60%	1.20%	0.50%
		power tiler	0.00%	0.00%	0.00%	0.00%
	2-3 wheel	motorcycle	73.60%	67.60%	40.10%	63.00%
		motorized three-wheeler	2.50%	2.10%	0.90%	2.00%
		sub	**76.10%**	**69.60%**	**40.90%**	**64.90%**
NMV	rickshaw		0.00%	0.00%	0.00%	0.00%
Total			**100.00%**	**100.00%**	**100.00%**	**100.00%**

b) Traffic hourly variation

The peak traffic volume in morning is at 11:00 am (7.6%) whereas in daytime and in afternoon are at 12:00 pm (7.2%) and 17:00 pm (7.8%) respectively. From above mentioned data it can be assumed that traffic flow due to different activities such as social, transportation of goods, tourism and commercial is relatedly greater than the traffic due to fixed activities of operation of organizations such school, companies, government office etc.

Table 10.4: Traffic daily fluctuation

hour	Sta.90	Sta.92	Sta.94	sum
Link code	H0147	H0149	H0150	
	H0146	H0148		
Link name	Kothi River -Butwal	Jitpur-Kothi River	Gorusinghe-Chanauta	
0:00	0.60%	1.70%	2.00%	1.20%
1:00	0.40%	0.70%	1.50%	0.80%
2:00	0.30%	0.90%	0.80%	0.60%
3:00	0.40%	0.30%	1.10%	0.50%
4:00	0.60%	1.20%	1.80%	1.00%
5:00	1.20%	1.20%	2.20%	1.50%
6:00	2.70%	2.30%	3.20%	2.80%
7:00	4.30%	3.50%	4.10%	4.10%
8:00	6.10%	5.40%	4.10%	5.40%
9:00	6.60%	7.30%	6.90%	6.80%
10:00	7.10%	7.40%	**6.90%**	7.10%
11:00	**8.10%**	**7.50%**	6.50%	**7.60%**
12:00	**7.70%**	7.00%	6.50%	**7.20%**
13:00	6.60%	7.20%	**7.80%**	7.10%
14:00	7.10%	7.40%	7.00%	7.20%
15:00	7.00%	**7.70%**	7.00%	7.10%
16:00	7.00%	7.60%	**6.70%**	7.00%

17:00	**8.40%**	**8.30%**	6.20%	**7.80%**
18:00	7.90%	6.60%	5.90%	7.10%
19:00	4.80%	2.60%	4.80%	4.30%
20:00	2.60%	3.00%	2.60%	2.70%
21:00	1.40%	2.00%	2.20%	1.80%
22:00	1.10%	1.20%	2.10%	1.40%
sum	100.00%	100.00%	100.00%	100.00%

Source: 3days traffic survey data in 2018 on the website of the Department of Roads.

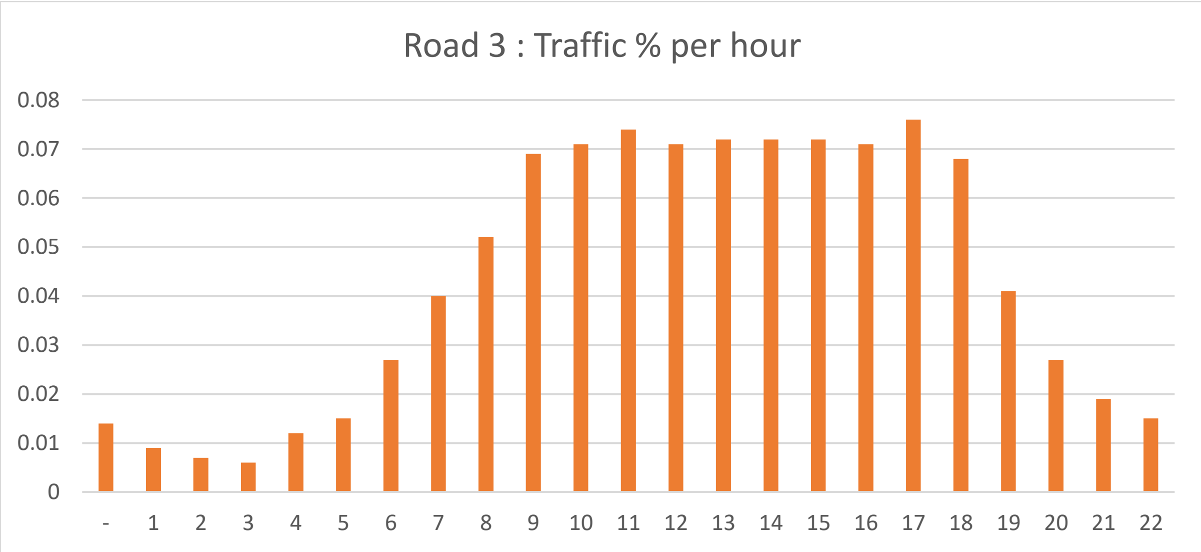


Figure 10.1 : Traffic hourly variation:

c) Traffic travel speed

It was observed that at least 1.04 hr is required to travel the proposed section of length 50 km resulting average travel speed 48.4Km/hr which seems too low for the National Highway. High urban settlement along the proposed road and poor road condition at some stretches are the main reasons of reducing the travel time.

Table 10.5: Travel speed:

Link code	**H0146**	**H0147**	**H0148**	**H0149**	**H0150**	**Total**
Link name	**Butwal-Bamaha Khola**	**Bamaha Khola-Kothi River**	**Kothi River-Jitpur**	**Jitpur-Gorusinghe**	**Gorusingh e-Chanauta**	
Distance, Km	9.5	17.2	4.9	14.6	4	50.3
Travel time, hr	0.25	0.33	0.1	0.27	0.09	1.04
Travel speed, km/hr	37.8	51.8	51.5	53.5	46.8	48.4

Source: Field survey

10.4 Traffic Count Survey

Based on possible traffic growth rates, past trends, GDP, elasticity of transport demand, land use pattern and other development activities, the consultant has identified 8 traffic count stations for the proposed road section. Detail of traffic count survey is presented in **Chapter: 5.5 Traffic Survey**

10.5 Traffic forecast

10.5.1 Methodology

Future traffic demand is predicted in this analysis by applying a demand forecasting method based on historical traffic volume trend data.

Although different sections of the proposed road have different traffic characteristics, the Consultant has determined one common Increase Rate which has been applied for all sections of proposed road while forecasting the future traffic.

Moreover, the analysis of future traffic has also considered diverted traffic where there is plan of new road implementation around the project area. In a like manner induced traffic due to the large-scale development around the project area has also been considered while analyzing future traffic demand.

The traffic demand forecasting approach applied for the analysis is elaborated in the **Table 10.6** below.

Table 10.6: Approach for Traffic Demand Forecasting:

Step 1: Analyze and adjust existing traffic growth rate	-Analyze existing traffic volume trend -Adjust existing traffic growth rate, if needed.
Step 2: Figure out traffic demand elasticity	-Identify relationship between existing traffic growth rate & socio-economic indicators -Real GDP growth rate is applied as indicator
Step 3: Establish projected traffic growth rate	-Estimate future traffic growth rate based on the prediction of future real GDP growth rate -Adjust future traffic growth rate regarding overestimation
Step 4: Estimate future normal traffic demand	-Apply traffic growth rate -Adjust the normal traffic demand based on the statistical traffic volume by comparing the survey traffic volume and the predicted traffic demand
Step 5: Calculate generated traffic	-Review the generating elasticity -Reflect the reduced traffic cost using travel time.
Step 6: Consider diverted traffic	-Analyze the effect from the other road project -Calculate the diverted traffic
Step 7: Consider induced traffic	-Analyze the traffic demand relevant Development plan -Calculate the induced traffic

Step 8: Calculate future traffic demand	-Calculate normal + Diverted + Induced traffic

10.5.2 Traffic demand Forecast

Calculation of future traffic demand has been calculated as follows:

Project Schedule: 4 years Design and construction period (2025~2028), Opening to the traffic 2029-year, Analysis period 20 years (2029~2048)

a) Existing traffic growth trend

The table below shows the stations-wise average growth rate of the traffic from 2009 to 2018. Reviewing the overall past increased rate of proposed road, it has been found that passenger cars has increased by 9.3%, Trucks 1.4% and 2-3 wheelers by 32.4% whereas buses has decreased by 0.1%. The table shows that there are decreases of buses in some sections of the proposed road. However, there is significate increase of all type of traffic including trucks and cars while analyzing increase rate from 2016 to 2018.

Table 10.7: Traffic growth trend

Period	MV						NMV
	Station	Truck	Bus	Car	MC	Total	rickshaw
2009~2018	94	6.8%	9.7%	15.1%	16.3%	11.2%	-45.5%
	92	-2.5%	0.0%	12.8%	10.6%	7.9%	-27.3%
	90	-5.0%	-6.5%	6.1%	5.2%	3.2%	-46.9%
	Tot	1.4%	-0.1%	9.3%	7.4%	5.7%	-63.2%
2016~2018	Tot	16.9%	-7.7%	30.0%	32.4%	24.4%	-100.0%

Source: Every year station data of the website of the Department of Roads,

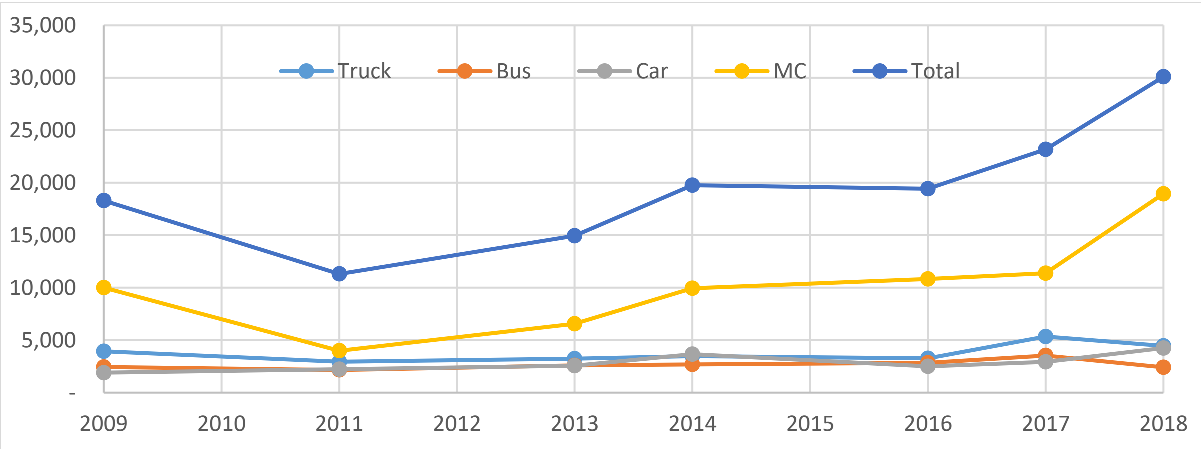


Figure 10.2: Traffic growth trend

It is not reasonable to forecast future traffic based on the original past traffic growth trend. Therefore, the past growth rate of all vehicle for all section of the proposed road has been adjusted in consideration with the fact that there must be positive growth rate in phenomena of economic development. Due consideration has been paid to avoid overestimation of the traffic volume.

Adjusted growth rates of different type of traffic are presented in the table below:

Table 10.8: Adjusted Traffic growth trend

Period	MV						NMV
	Station	Truck	Bus	Car	MC	Total	rickshaw
2009~2018	94	7.6%	9.7%	15.1%	7.2%	8.6%	-45.5%
	92	5.6%	9.4%	12.8%	10.6%	9.8%	-27.3%
	90	0.7%	2.3%	6.1%	5.2%	4.3%	-46.9%
	Tot	4.5%	5.7%	9.3%	6.2%	6.1%	-63.2%
2016~2018	Tot	37.9%	19.2%	30.0%	26.0%	27.7%	-100.0%

Source: Consultant's estimation

b) Traffic demand elasticity

Changes in traffic volume have a deep relationship with socio-economic activities. In general, the real GDP growth rate, fuel consumption, registered vehicle number, etc., are the socio-economic indicators that can be used in the future traffic demand forecast. To select the most suitable indicators, a correlation analysis was conducted on the variable indicators. More details about the indicators and data are shown below.

Table 10.9: Traffic volume, socioeconomic indicators, and registered vehicle numbers

	Traffic volume trend					Socio-economic-indicators			Registered vehicle number trend				
Year	Truck	Bus	Car	MC	Total	GDP (RP Million)	GDP per capita (USD)	Population (Million)	N_Truck	N_Bus	N_Car	N_MC	N_Total
2009	4,178	2,452	1,904	10,000	18,534	565,759	490	26	10,186	1,991	6,857	83,536	102,570
2011	2,946	2,155	2,218	3,988	11,307	614,637	610	27	14,363	1,727	8,510	139,040	163,640
2013	3,225	2,586	2,575	6,548	14,934	674,227	720	27	19,877	3,478	9,595	175,533	208,483
2014	3,489	2,677	3,656	9,940	19,762	694,269	730	28	19,939	2,971	11,372	164,061	198,343
2016	3,270	2,842	2,515	10,815	19,442	749,550	741	28	27,799	8,103	28,361	279,502	343,765
2017	5,344	3,528	2,918	11,385	23,175	797,146	891	29	42,480	23,965	21,292	356,522	444,259
2018	6,216	4,038	4,250	17,181	31,685	850,928	961	29	37,865	21,115	24,338	354,296	437,614

Source: - The traffic volume trend is the adjusted average traffic volume of the Butwal - Gorusinghe section

-Socioeconomic indicators were referenced in the ADB annual report, Key indicators for ASIA AND PACIFIC.

-Registered vehicle number trend was referenced in the: 'https://old.dotm.gov.np/uploads/files/vehicles%20data%20till%202074-75.pdf'.

-The registered vehicle fleet data in the projected-influenced area are not available. So, the registered vehicle fleet data of the whole of Nepal was used.

Looking at the result, it is analyzed that all indicators have strong positive linear correlations with the traffic volume trend, except the registered private (car) vehicle.

Table 10.10: Result of correlation ship analysis

	Truck	Bus	Car	MC	Total	GDP	GDP per capita	Population	N_Truck	N_Bus	N_Car	N_MC	N_Total
Truck	1.000												
Bus	0.916	1.000											
Car	0.608	0.753	1.000										
MC	0.856	0.894	0.712	1.000									
Total	0.910	0.945	0.777	0.986	1.000								
GDP	**0.689**	**0.917**	**0.773**	**0.750**	**0.804**	1.000							
GDP per capita	**0.686**	**0.899**	**0.808**	**0.673**	**0.757**	0.979	1.000						
POPULATION	**0.600**	**0.862**	**0.775**	**0.699**	**0.749**	0.989	0.967	1.000					
N_Truck	**0.734**	**0.903**	**0.612**	**0.676**	**0.743**	0.950	0.938	0.931	1.000				
N_Bus	**0.871**	**0.931**	**0.556**	**0.724**	**0.796**	0.871	0.863	0.819	0.960	1.000			
N_Car	**0.470**	**0.724**	**0.449**	**0.673**	**0.652**	0.853	0.735	0.854	0.809	0.710	1.000		
N_MC	**0.696**	**0.895**	**0.604**	**0.688**	**0.742**	0.967	0.934	0.946	0.985	0.931	0.882	1.000	
N_Total	**0.707**	**0.900**	**0.600**	**0.697**	**0.750**	0.965	0.930	0.943	0.986	0.936	0.883	1.000	1.000

The socio-economic indicator should have stability and availability in calculating the future status because the indicator will be utilized for forecasting for the next 20 years.

Looking at the result, the registered vehicle number showed a bit high growth rate rather than the socioeconomic indicators. And it is judged that there is a difficulty in forecasting the future growth rate of the registered vehicle because it is not easy to assume for estimation for the future situation in the developing countries like Nepal.

Table 10.11: Growth rate of Indicators

Year	GDP	GDP per capita	Population	N_Truck	N_Bus	N_Car	N_MC
2009	565,759	490	26	10,186	1,991	6,857	83,536
2011	614,637	610	27	14,363	1,727	8,510	139,040
2013	674,227	720	27	19,877	3,478	9,595	175,533
2014	694,269	730	28	19,939	2,971	11,372	164,061
2016	749,550	741	28	27,799	8,103	28,361	279,502
2017	797,146	891	29	42,480	23,965	21,292	356,522
2018	850,928	961	29	37,865	21,115	24,338	354,296
‘09- ‘18 rate	4.6%	7.8%	1.3%	15.7%	30.0%	15.1%	17.4%

On the contrary, macro socio-economic indicators turned out to be more stable than the registered vehicle number. And the indicator like GDP per capita has the advantage that IMF, internationally reputational authority, provides the future growth rates.

Therefore, traffic demand elasticity has been analyzed by identifying the relationship between real GDP growth rate and traffic volume trend.

Table 10.12: Nepal's Real GDP growth rate (unit: Rs. in million)

Item	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	'09~' 18
Real GDP	565,759	587,534	614,637	637,771	674,227	694,269	695,688	749,550	797,146	850,928	
Rate (%)		3.85	4.61	3.76	5.72	2.97	0.20	7.74	6.35	6.75	4.60

Source: Macroeconomic Indicators of Nepal, November 2020, NEPAL RASTRA BANK, Table 4

Considering the relationship between increase in traffic volume and change in real GDP growth rate in past, traffic demand elasticities of various type of vehicles have been calculated which are presented in the table below. The elasticities calculated of all type of vehicles are in the standard range of 1.0 to 2.0.

Table 10.13: Traffic demand elasticity

Item		Truck	Bus	Car	MC
Rate ('09~'18)	TRAFFIC (a)	4.51%	5.70%	9.33%	6.20%
	Real GDP (b)	4.60%	4.60%	4.60%	4.60%
Elasticity	(a/b)	0.98	1.24	2.03	1.35

Table 10.14: Traffic demand elasticity by vehicle type

vehicle type	Truck			Bus			Car		2-3wheel		utility vehicle	others	
	multi-axle	heavy	light	Big	mini	micro	car	four wheels	motorcycle	three wheels	utility vehicle	tractor	power tiler
growth rate type	Truck	Truck	Truck	Bus	Bus	Bus	Car	Car	MC	Bus	Truck	Truck	Truck
Elasticity	0.980	0.980	0.980	1.240	1.240	1.240	2.030	2.030	1.350	1.240	0.980	0.980	0.980

c) Projected traffic growth rates

The future traffic demand growth rate has been calculated considering future GDP growth rate to the traffic demand elasticity. IMF has published economic outlook of Nepal, where there is projection of real future GDP of Nepal considering negative impact of COVID -19 pandemic. This economic outlook is found more reliable and therefore considered to determine future growth rate in the present analysis.

It is anticipated that Nepal's real GDP affected by COVI -19 pandemic will recover after 2022.

Table 10.15: Estimation for Future Real Growth rate of Nepal, (unit: %)

Item		2018	2019	2020	2021	2022	2023	2024	2025	2030	2040	2040 after
IMF Country Report	Feb. 2020[1)]			6.0	5.7	5.5	5.4	5.3	5.3	5.3	5.3	5.4
	May. 2020[2)]		7.1	1.0	3.5	6.5	5.4	5.2	5.2	5.2	5.2	4.8
IMF, Data Mapper	October 2020[3)]	6.7	7.1	0.0	2.5	6.0	5.2	5.0	5.0			
Applied rate		6.7	7.1	0.0	2.5	6.0	5.2	5.0	5.0	5.0	5.0	4.6

Source: 1. IMF Country Report No.20/96, p8

2. IMF Country Report No.20/155, p3

3. IMF DATAMAPPER, COUNTRY PROFILE, KEYINDICATORS, TREND (1980-2025)

By applying traffic demand elasticity to Nepal's future real GDP growth rate, the future traffic demand growth rate was calculated. The future traffic demand growth rate, which applies traffic demand elasticity to Nepal's real GDP growth rate in the future, is calculated as follows.

Table 10.16: Projected Traffic growth rate (unit: %)

vehicle type		Truck			Bus			Car		2-3wheel		utility vehicle	others	
		multi-axle	heavy	light	Big	mini	micro	car	four wheels	M/C	three wheels	utility vehicle	tractor	power tiler
2019	7.1	7.0	7.0	7.0	8.8	8.8	8.8	14.4	14.4	9.6	8.8	7.0	7.0	7.0
2020	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2021	2.5	2.5	2.5	2.5	3.1	3.1	3.1	5.1	5.1	3.4	3.1	2.5	2.5	2.5
2022	6.0	5.9	5.9	5.9	7.4	7.4	7.4	12.2	12.2	8.1	7.4	5.9	5.9	5.9
2023	5.2	5.1	5.1	5.1	6.4	6.4	6.4	10.6	10.6	7.0	6.4	5.1	5.1	5.1
2024~	5.0	4.9	4.9	4.9	6.2	6.2	6.2	10.2	10.2	6.8	6.2	4.9	4.9	4.9
2026~	5.0	4.4	4.4	4.4	5.6	5.6	5.6	9.1	9.1	6.1	5.6	4.4	4.4	4.4
2031~	5.0	4.0	4.0	4.0	5.0	5.0	5.0	8.2	8.2	5.5	5.0	4.0	4.0	4.0
2036~	5.0	3.6	3.6	3.6	4.5	4.5	4.5	7.4	7.4	4.9	4.5	3.6	3.6	3.6
2041~	4.6	3.0	3.0	3.0	3.7	3.7	3.7	6.1	6.1	4.1	3.7	3.0	3.0	3.0
2046~	4.6	2.7	2.7	2.7	3.4	3.4	3.4	5.5	5.5	3.7	3.4	2.7	2.7	2.7

Note: traffic demand elasticity for economic growth rate generally decreases according to future economic level improvement, elasticity decreases by 5% every 5 years.

d) Future normal traffic demand

The normal traffic demand for each section of proposed road calculated by applying the estimated future traffic growth rate is presented in the table below.

Table 10.17: Projected normal traffic (unit: veh/day)

H0146 (Butwal-Bamaha Khola), H0147 (Bamaha Khola-Kothi River): Sta.90

Year	Truck			Bus			Car		2-3wheel		utility vehicle	others		Total (v/d)	
	multi-axle	heavy	light	Big	mini	micro	car	four wheels	M/C	three-wheeler	utility vehicle	tractor	power tiler	in.MC	ex.MC
2018	189	940	68	152	1,092	200	1,483	620	10,959	372	771	16	5	16,867	5,908
2029	301	1,500	108	274	1,963	360	3,810	1,591	20,763	671	1,232	25	5	32,603	11,840
2033	354	1,762	128	334	2,400	440	5,266	2,199	25,869	820	1,446	29	5	41,052	15,183
2038	426	2,119	153	421	3,019	554	7,637	3,189	33,237	1,032	1,738	34	5	53,564	20,327
2043	500	2,484	180	513	3,677	674	10,521	4,393	41,260	1,257	2,039	39	5	67,542	26,282
2048	574	2,855	206	610	4,371	802	13,907	5,807	49,862	1,495	2,343	44	5	82,881	33,019

H0148 (Kothi River-Jitpur), H0149 (Jitpur-Gorusinghe): Sta.92

Year	Truck			Bus			Car		2-3wheel		utility vehicle	others		Total (v/d)	
	multi-axle	heavy	light	Big	mini	micro	car	four wheels	M/C	three-wheeler	utility vehicle	tractor	power tiler	in.MC	ex.MC
2018	448	162	190	237	272	436	748	423	4,674	145	309	43	14	8,102	3,428
2029	717	258	303	426	490	784	1,922	1,087	8,856	261	492	71	23	15,690	6,834
2033	842	303	356	522	599	958	2,656	1,502	11,033	320	578	83	27	19,779	8,746
2038	1,013	365	428	656	753	1,206	3,852	2,178	14,175	403	695	98	32	25,854	11,679
2043	1,189	428	502	801	917	1,469	5,307	3,001	17,598	491	815	115	37	32,670	15,072
2048	1,367	492	577	952	1,091	1,746	7,016	3,967	21,268	584	936	131	42	40,169	18,901

H0150 (Gorusinghe-Chanauta): Sta.94

Year	Truck			Bus			Car		2-3wheel		utility vehicle	others		Total (v/d)	
	multi-axle	heavy	light	Big	mini	micro	car	four wheels	M/C	three-wheeler	utility vehicle	tractor	power tiler	in.MC	ex.MC
2018	1,124	1,091	215	572	364	122	662	314	1,548	74	528	102	0	6,717	5,168
2029	1,794	1,739	345	1,026	654	219	1,700	807	2,934	134	843	163	0	12,358	9,424
2033	2,107	2,044	405	1,254	800	268	2,350	1,114	3,656	164	990	191	0	15,343	11,687
2038	2,534	2,458	487	1,578	1,006	336	3,410	1,615	4,696	207	1,191	230	0	19,748	15,052
2043	2,973	2,883	572	1,922	1,225	410	4,698	2,226	5,830	252	1,396	270	0	24,657	18,827
2048	3,416	3,313	657	2,285	1,456	488	6,211	2,942	7,045	300	1,604	310	0	30,027	22,982

As a result of comparing the forecasted normal traffic demand with the current traffic volume surveyed in 2021, it has been determined that passenger traffic (car, bus) is 130% less than the forecasted demand, and cargo traffic (truck) is 192% more. Overall, the current traffic volume is 180% lower than the forecasted traffic demand. This is because of greater impact of COVID -19 on inter-regional passenger travel and reduced tourist demand.

Table 10.18: Comparison traffic demand with traffic survey volume (2021 year)

Item	Year	Truck	Bus	Car	MC	Total(v/d)	
						in.MC	ex.MC
Traffic demand(a)	2021	4,902	2,721	5,111	21,482	34,216	12,734
Survey volume(b)	2021	9,415	7,894	6,599	35,545	59,453	23,908
Ratio(b/a)		192%	290%	129%	165%	174%	188%

Note: a. traffic demand using traffic growth rate

e) Traffic Count

In order to achieve realistic data, the Consultant has carried out an analysis to determine normal traffic demand considering effect of COVID-19. IMF has predicted contraction of economy activities due to effect of COVID -19 resulting reduction of traffic volume. It is expected that this contraction will overcome from year 2023 to 2025. The analysis has been done assuming traffic demand in 2026 would be 5% less than normal traffic demand.

The normal traffic demand adjusted considering the COVID-19 impact is presented in the table below.

Table 10.19: Adjusted-projected normal traffic (unit: veh/day)

H0146 (Butwal-Bamaha Khola), H0147 (Bamaha Khola-Kothi River): Sta.90

Year	Truck			Bus			Car		2-3wheel		utility vehicle	others		Total (v/d)	
	multi-axle	heavy	light	Big	mini	micro	car	four wheels	M/C	three-wheeler	utility vehicle	tractor	power tiler	in.MC	ex.MC
2018	189	940	68	152	1,092	200	1,483	620	10,959	372	771	16	5	16,867	5,908
2029	315	1,574	114	287	2,062	379	4,000	1,670	21,801	703	1,292	26	5	34,228	12,427
2033	370	1,848	134	351	2,520	463	5,528	2,308	27,161	859	1,517	30	5	43,094	15,933
2038	444	2,223	161	441	3,171	582	8,016	3,348	34,896	1,082	1,824	35	5	56,228	21,332
2043	521	2,608	188	538	3,862	707	11,043	4,613	43,319	1,318	2,140	40	5	70,902	27,583
2048	599	2,998	217	640	4,591	841	14,598	6,098	52,350	1,568	2,459	45	5	87,009	34,659

H0148 (Kothi River-Jitpur), H0149 (Jitpur-Gorusinghe): Sta.92

Year	Truck			Bus			Car		2-3wheel		utility vehicle	others		Total (v/d)	
	multi-axle	heavy	light	Big	mini	micro	car	four wheels	M/C	three-wheeler	utility vehicle	tractor	power tiler	in.MC	ex.MC
2018	448	162	190	237	272	436	748	423	4,674	145	309	43	14	8,102	3,428
2029	752	270	318	447	514	824	2,019	1,141	9,300	275	517	74	24	16,475	7,175
2033	883	317	373	547	629	1,008	2,790	1,576	11,587	336	607	86	28	20,767	9,180
2038	1,062	381	450	688	791	1,268	4,048	2,287	14,886	423	729	103	33	27,149	12,263
2043	1,245	447	527	838	963	1,544	5,578	3,151	18,479	515	854	121	38	34,300	15,821
2048	1,431	514	605	997	1,145	1,834	7,372	4,165	22,332	612	981	140	43	42,171	19,839

H0150 (Gorusinghe-Chanauta): Sta.94

Year	Truck			Bus			Car		2-3wheel		utility vehicle	others		Total (v/d)	
	multi-axle	heavy	light	Big	mini	micro	car	four wheels	M/C	three-wheeler	utility vehicle	tractor	power tiler	in.MC	ex.MC
2018	1,124	1,091	215	572	364	122	662	314	1,548	74	528	102	0	6,717	5,168
2029	1,884	1,828	362	1,077	686	230	1,786	847	3,080	142	884	171	0	12,977	9,897
2033	2,213	2,146	425	1,317	838	281	2,469	1,171	3,838	174	1,038	201	0	16,111	12,273
2038	2,661	2,582	512	1,656	1,054	354	3,581	1,698	4,931	219	1,248	241	0	20,737	15,806
2043	3,121	3,028	599	2,017	1,284	431	4,934	2,340	6,121	267	1,464	283	0	25,889	19,768
2048	3,586	3,481	689	2,398	1,527	513	6,521	3,093	7,396	317	1,682	325	0	31,528	24,132

f) Generated traffic

The generated traffic is the additional trips made due to lower costs of travel on the project road. The price elasticity is the proportional change in the number of trips per unit changes in travel costs.

By reviewing the relevant report, the following elasticities are set.

Table 10.20: Price elasticity for generated traffic

Item	Passenger car	Truck
DPR report 1	-0.40	-0.15
ADB report 2	-0.40	-0.10
General	-0.35	-0.35
Average Elasticity	-0.38	-0.20

Sources:

- *DPR report 1 is the report of 「The Detailed Project Report of Belghari-Pachok Road (DRCN Code No: 37DR026) Rehabilitation & Reconstruction Road Project (Km 0+000 to Km 12+590), (ADB Loan No. 3260 – NEP) 」*
- *ADB report 2 is the report of 「ADB TA 7411-NEP Road Connectivity Project, Supplementary Appendix 1, Traffic RCP 2, December 2010」*

It has been analyzed that the travel speed would be improved by about 30% by this project. If the travel time elasticity is considered, 11% of passenger traffic and 5.7% of cargo traffic would be additionally generated.

Table 10.21: Calculation % for generated traffic

Item	Travel speed (km/h)		% Time savings	Price elasticity		% Generated traffic	
	Before	After		Passenger	Cargo	Passenger	Cargo
Value	50	70	28.6%	-0.38	-0.20	-11.0%	5.7%

In the analysis 50% of generated traffic has been assigned in the initial year of operation of the proposed road whereas 100% has been considered in one year after the operation. The generated traffic for each section is presented in the table below.

Table 10.22: Generated traffic, (unit: veh/day)

H0146 (Butwal-Bamaha Khola), H0147 (Bamaha Khola-Kothi River): Sta.90

Year	Truck			Bus			Car		2-3wheel		utility vehicle	others		Total (v/d)	
	multi-axle	heavy	light	Big	mini	micro	car	four wheels	M/C	three-wheeler	utility vehicle	tractor	power tiler	in.MC	ex.MC
2029	5	27	2	8	60	11	81	34	600	20	22	0	0	872	271
2033	12	60	4	19	138	25	206	86	1,409	47	50	1	0	2,059	650
2038	15	73	5	24	174	32	298	125	1,811	59	60	1	0	2,677	867
2043	17	85	6	30	212	39	411	172	2,248	72	70	1	0	3,364	1,116
2048	20	98	7	35	252	46	543	227	2,716	86	80	2	1	4,114	1,397

H0148 (Kothi River-Jitpur), H0149 (Jitpur-Gorusinghe): Sta.92

Year	Truck			Bus			Car		2-3wheel		utility vehicle	others		Total (v/d)	
	multi-axle	heavy	light	Big	mini	micro	car	four wheels	M/C	three-wheeler	utility vehicle	tractor	power tiler	in.MC	ex.MC
2029	13	5	5	13	15	24	41	23	256	8	9	1	0	413	157
2033	29	10	12	30	35	55	104	59	601	18	20	3	1	977	376
2038	35	13	15	38	43	70	151	85	772	23	24	3	1	1,272	500
2043	41	15	17	46	53	85	207	117	959	28	28	4	1	1,601	642

2048	47	17	20	55	63	101	274	155	1,159	33	32	4	1	1,961	802

H0150 (Gorusinghe-Chanauta): Sta.94

Year	Truck			Bus			Car		2-3wheel		utility vehicle	others		Total (v/d)	
	multi-axle	heavy	light	Big	mini	micro	car	four wheels	M/C	three-wheeler	utility vehicle	tractor	power tiler	in.MC	ex.MC
2029	32	31	6	31	20	7	36	17	85	4	15	3	0	288	203
2033	72	70	14	73	46	15	92	44	199	9	34	7	0	675	476
2038	87	84	17	91	58	19	133	63	256	12	41	8	0	869	614
2043	102	99	20	111	71	24	184	87	318	14	48	9	0	1,085	768
2048	117	114	22	132	84	28	243	115	384	17	55	11	0	1,322	938

g) Diverted traffic

Diverted traffic has not been taken into account in the analysis since there are no new road projects around the project area.

h) Induced traffic

Since, there are not new large scaled infrastructures projects around the project area which would affect the traffic flow of the project road, induced traffic has not been considered in calculation.

i) Future traffic demand

Taking into account the above consideration, the future traffic demand has been calculated as sum of normal traffic and generated traffic. Future traffic demands for different year are presented below in the Table.

Table 10.23: Future Traffic demand (unit: veh/day)

Excluding 2~3wheels

Link code	Link name	2018	2029	2033	2038	2043	2048
H0150	Gorusinghe-Chanauta	5,168	10,099	12,749	16,419	20,537	25,070
H0149	Jitpur-Gorusinghe	3,428	7,332	9,556	12,764	16,463	20,641
H0148	Kothi River-Jitpur	3,428	7,332	9,556	12,764	16,463	20,641
H0147	Bamaha Khola-Kothi River	5,908	12,697	16,581	22,198	28,698	36,056
H0146	Butwal-Bamaha Khola	5,908	12,697	16,581	22,198	28,698	36,056
Average		4,887	10,408	13,550	18,076	23,299	29,198
growth rate			7.11%	6.82%	5.93%	5.21%	4.62%

Including 2~3wheels

Link code	Link name	2018	2029	2033	2038	2043	2048
H0150	Gorusinghe-Chanauta	6,717	13,264	16,786	21,606	26,976	32,850
H0149	Jitpur-Gorusinghe	8,102	16,888	21,744	28,422	35,901	44,132
H0148	Kothi River-Jitpur	8,102	16,888	21,744	28,422	35,901	44,132
H0147	Bamaha Khola-Kothi River	16,867	35,098	45,151	58,905	74,265	91,122
H0146	Butwal-Bamaha Khola	16,867	35,098	45,151	58,905	74,265	91,122
Average		12,655	26,287	33,802	44,096	55,599	68,231
growth rate			6.87%	6.49%	5.46%	4.75%	4.18%

Table 10.24: Future Traffic demand by years, (unit: veh/day)

H0146 (Butwal-Bamaha Khola), H0147 (Bamaha Khola-Kothi River): Sta.90

Year	Truck			Bus			Car		2-3wheel		utility vehicle	others		Total (v/d)	
	multi-axle	heavy	light	Big	mini	micro	car	four wheels	M/C	three-wheeler	utility vehicle	tractor	power tiler	in.MC	ex.MC
2029	320	1,601	116	295	2,122	390	4,081	1,704	22,401	723	1,314	26	5	35,098	12,697
2030	340	1,697	123	320	2,297	422	4,526	1,890	24,331	783	1,393	28	5	38,155	13,824
2031	353	1,765	128	335	2,412	443	4,898	2,044	25,669	822	1,449	29	5	40,352	14,683
2032	368	1,835	133	352	2,532	465	5,299	2,212	27,081	863	1,507	30	5	42,682	15,601
2033	382	1,908	138	370	2,658	488	5,734	2,394	28,570	906	1,567	31	5	45,151	16,581
2034	398	1,985	144	389	2,791	513	6,204	2,590	30,142	952	1,630	32	5	47,775	17,633
2035	413	2,064	150	408	2,931	538	6,712	2,803	31,800	999	1,695	33	5	50,551	18,751
2036	428	2,139	155	426	3,063	562	7,209	3,010	33,358	1,044	1,756	34	5	53,189	19,831
2037	443	2,216	160	445	3,201	588	7,742	3,233	34,992	1,092	1,819	35	5	55,971	20,979
2038	459	2,296	166	465	3,345	614	8,314	3,473	36,707	1,141	1,884	36	5	58,905	22,198
2039	475	2,378	172	486	3,496	641	8,929	3,730	38,506	1,193	1,952	37	5	62,000	23,494
2040	493	2,464	179	508	3,653	670	9,590	4,006	40,393	1,247	2,022	38	5	65,268	24,875
2041	507	2,538	184	527	3,788	694	10,175	4,251	42,048	1,293	2,083	39	5	68,132	26,084
2042	523	2,615	189	547	3,929	719	10,795	4,510	43,772	1,341	2,146	40	5	71,131	27,359
2043	538	2,693	194	568	4,074	746	11,454	4,785	45,567	1,390	2,210	41	5	74,265	28,698

2044	555	2,774	200	589	4,225	773	12,153	5,076	47,435	1,442	2,276	42	5	77,545	30,110
2045	571	2,857	207	611	4,381	802	12,895	5,386	49,380	1,496	2,344	44	5	80,979	31,599
2046	587	2,935	212	632	4,530	829	13,604	5,683	51,207	1,546	2,407	45	5	84,222	33,015
2047	602	3,014	218	653	4,684	858	14,352	5,995	53,102	1,599	2,472	46	6	87,601	34,499
2048	619	3,096	224	675	4,843	887	15,141	6,325	55,066	1,654	2,539	47	6	91,122	36,056

H0148 (Kothi River-Jitpur), H0149 (Jitpur-Gorusinghe): Sta.92

Year	Truck			Bus			Car		2-3wheel		utility vehicle	others		Total (v/d)	
	multi-axle	heavy	light	Big	mini	micro	car	four wheels	M/C	three-wheeler	utility vehicle	tractor	power tiler	in.MC	ex.MC
2029	765	275	323	460	529	848	2,060	1,164	9,556	283	526	75	24	16,888	7,332
2030	811	291	343	498	573	918	2,285	1,291	10,379	306	558	79	26	18,358	7,979
2031	843	303	356	523	601	964	2,473	1,397	10,950	322	580	83	27	19,422	8,472
2032	877	315	371	550	632	1,013	2,675	1,511	11,553	338	603	86	28	20,552	8,999
2033	912	327	385	577	664	1,063	2,894	1,635	12,188	354	627	89	29	21,744	9,556
2034	948	341	401	606	696	1,116	3,131	1,768	12,858	372	652	92	30	23,011	10,153
2035	986	354	417	636	731	1,172	3,388	1,914	13,565	391	677	96	31	24,358	10,793
2036	1,021	367	433	665	764	1,225	3,639	2,056	14,230	409	702	99	32	25,642	11,412
2037	1,058	380	448	694	799	1,280	3,909	2,208	14,927	427	727	102	33	26,992	12,065
2038	1,097	394	465	726	834	1,338	4,199	2,372	15,658	446	753	106	34	28,422	12,764
2039	1,136	408	481	759	872	1,398	4,510	2,547	16,425	466	780	110	35	29,927	13,502
2040	1,177	422	499	792	911	1,461	4,844	2,736	17,230	487	808	115	36	31,518	14,288
2041	1,212	435	513	822	945	1,515	5,139	2,903	17,937	505	831	118	37	32,912	14,975
2042	1,248	448	529	852	980	1,571	5,452	3,081	18,672	524	856	121	38	34,372	15,700
2043	1,286	462	544	884	1,016	1,629	5,785	3,268	19,438	543	882	125	39	35,901	16,463
2044	1,324	475	561	917	1,054	1,689	6,138	3,467	20,235	563	909	129	40	37,501	17,266
2045	1,363	490	577	951	1,093	1,751	6,512	3,679	21,065	584	936	133	41	39,175	18,110
2046	1,400	503	593	983	1,130	1,810	6,870	3,881	21,844	604	961	136	42	40,757	18,913
2047	1,438	516	608	1,017	1,168	1,871	7,248	4,095	22,652	624	986	140	43	42,406	19,754
2048	1,478	531	625	1,052	1,208	1,935	7,646	4,320	23,491	645	1,013	144	44	44,132	20,641

H0150 (Gorusinghe-Chanauta): Sta.94

Year	Truck			Bus			Car		2-3wheel		utility vehicle	others		Total (v/d)	
	multi-axle	heavy	light	Big	mini	micro	car	four wheels	M/C	three-wheeler	utility vehicle	tractor	power tiler	in.MC	ex.MC
2029	1,916	1,859	368	1,108	706	237	1,822	864	3,165	146	899	174	0	13,264	10,099
2030	2,031	1,970	390	1,200	764	256	2,022	958	3,438	158	953	185	0	14,325	10,887
2031	2,113	2,049	406	1,260	802	269	2,187	1,037	3,627	167	991	192	0	15,100	11,473
2032	2,197	2,130	422	1,323	842	283	2,367	1,122	3,827	175	1,031	199	0	15,918	12,091
2033	2,285	2,216	439	1,390	884	296	2,561	1,215	4,037	183	1,072	208	0	16,786	12,749
2034	2,377	2,305	456	1,459	928	311	2,770	1,314	4,259	193	1,115	216	0	17,703	13,444
2035	2,472	2,397	475	1,532	975	327	2,998	1,422	4,494	202	1,160	224	0	18,678	14,184
2036	2,561	2,484	493	1,601	1,019	342	3,219	1,527	4,713	212	1,201	232	0	19,604	14,891
2037	2,653	2,573	510	1,672	1,065	358	3,458	1,640	4,945	221	1,244	241	0	20,580	15,635
2038	2,748	2,666	529	1,747	1,112	373	3,714	1,761	5,187	231	1,289	249	0	21,606	16,419
2039	2,847	2,762	547	1,826	1,162	390	3,989	1,892	5,441	241	1,335	258	0	22,690	17,249
2040	2,949	2,862	567	1,909	1,214	408	4,285	2,032	5,707	252	1,384	267	0	23,836	18,129
2041	3,038	2,947	583	1,979	1,260	423	4,546	2,155	5,941	261	1,425	276	0	24,834	18,893
2042	3,129	3,036	601	2,052	1,306	439	4,823	2,287	6,185	271	1,467	284	0	25,880	19,695
2043	3,223	3,127	619	2,128	1,355	455	5,118	2,427	6,439	281	1,512	292	0	26,976	20,537
2044	3,320	3,221	637	2,207	1,405	472	5,430	2,575	6,703	292	1,557	301	0	28,120	21,417
2045	3,419	3,318	657	2,288	1,457	489	5,761	2,732	6,977	302	1,604	310	0	29,314	22,337
2046	3,511	3,408	674	2,367	1,507	506	6,077	2,882	7,235	313	1,647	318	0	30,445	23,210
2047	3,606	3,500	693	2,447	1,558	523	6,411	3,041	7,502	324	1,692	326	0	31,623	24,121
2048	3,703	3,595	711	2,530	1,611	541	6,764	3,208	7,780	334	1,737	336	0	32,850	25,070

10.6 Analysis the number of lanes

10.6.1 Approach and Methodology

The number of lanes has been determined according to the standard, chapter 5. Capacity and Level of Service of Nepal Road Standard 2070, July 2013, DoR.

Table 10.25: Capacity of Roads (unit: PCU/day)

Category	Plain		Rolling		Mountainous	
	low curv.	high curv.	low curv.	high curv.	low curv.	high curv.
Single Lane Road (3.75 m) with good quality shoulders at least 1.0m wide	2,000	1,900	1,800	1,700	1,600	1,400
Intermediate lane Road (5.5m) with good quality shoulders at least 1.0m wide	6,000	5,800	5,700	5,600	5,200	4,500
Double lane Road (7.0m) with good quality shoulders at least 1.0m wide	15,000	12,500	11,000	10,000	7,000	5,000
Four lane road with a minimum 3.m wide median	40,000	35,000	32,500	30,000	25,000	20,000
Six lane road with a minimum 3.m wide median	>40,000	>35,000	>32,500	>30,000	>25,000	>20,000

Source: 「Nepal Road Standard 2070, July2013, DoR」, p4

Greater traffic volume of 2~3 wheeled traffic plays an important role in traffic flow in urban area. Separate calculation for number of lanes has been carried out for both urban and rural area.

In urban areas, a service lane has been proposed separately for smooth functioning of traffic flow.

The number of lanes on the carriageway has been analyzed based on the traffic demand excluding 2~3 wheeled vehicles. Similarly, the number of lanes for the service road has been determined based on the traffic demand of 2~3 wheeled vehicles.

10.6.2 Number of lanes:

a) Calculation of the number of lanes on the carriageway of urban and rural areas

Number of lanes in carriageway for both urban and rural area have been calculated based on the traffic demand excluding 2~3 wheeled vehicles. The calculation reveals that four lanes are required for all sections of the proposed road to cater future demand of traffic in projected year i.e., 2048.

Table 10.26: Future traffic demand excluding 2~3wheels (unit: pcu/day)

Link	H0146 Butwal-Bamaha Khola	H0147 Bamaha Khola-Kothi River	H0148 Kothi River-Jitpur	H0149 Jitpur-Gorusinghe	H0150 Gorusinghe-Chanauta
2029	20,720	20,720	12,455	12,455	23,193
2030	22,417	22,417	13,456	13,456	24,842
2031	23,657	23,657	14,189	14,189	26,025
2032	24,978	24,978	14,973	14,973	27,259
2033	26,375	26,375	15,791	15,791	28,568
2034	27,871	27,871	16,662	16,662	29,938
2035	29,444	29,444	17,588	17,588	31,383
2036	30,957	30,957	18,477	18,477	32,753
2037	32,553	32,553	19,410	19,410	34,181
2038	34,240	34,240	20,406	20,406	35,675
2039	36,020	36,020	21,448	21,448	37,246
2040	37,912	37,912	22,547	22,547	38,897
2041	39,555	39,555	23,508	23,508	40,325
2042	41,287	41,287	24,513	24,513	41,811
2043	43,091	43,091	25,570	25,570	43,361
2044	44,988	44,988	26,672	26,672	44,973
2045	46,975	46,975	27,826	27,826	46,644
2046	48,864	48,864	28,920	28,920	48,224
2047	50,829	50,829	30,061	30,061	49,860
2048	52,888	52,888	31,266	31,266	51,556

Source: Consultant's estimation

Table 10.27: The number of lanes of dual carriageway for urban & rural areas in case of excluding 2~3wheels

Link	H0146 Butwal-Bamaha Khola	H0147 Bamaha Khola-Kothi River	H0148 Kothi River-Jitpur	H0149 Jitpur-Gorusinghe	H0150 Gorusinghe-Chanauta
2029	2	2	2	2	2
2030	2	2	2	2	2
2031	2	2	2	2	2
2032	2	2	2	2	2
2033	2	2	2	2	2
2034	2	2	2	2	2
2035	2	2	2	2	4

2036	4	4	2	2	4
2037	4	4	2	2	4
2038	4	4	2	2	4
2039	4	4	2	2	4
2040	4	4	2	2	4
2041	4	4	2	2	4
2042	4	4	2	2	4
2043	4	4	2	2	4
2044	4	4	2	2	4
2045	4	4	2	2	4
2046	4	4	2	2	4
2047	4	4	4	4	4
2048	4	4	4	4	4

b) Calculation of the number of lanes for service road in urban areas

The number of lanes of the service road in urban areas has been considered difference between the number of lanes on the carriageway of the urban areas based on the traffic demand including 2~3 wheeled vehicles and the number of lanes on the carriageway excluding 2~3 wheeled vehicles.

Table 10.28: Future traffic demand including 2~3wheels (unit: pcu/day)

Link	H0146	H0147	H0148	H0149	H0150
	Butwal-Bamaha Khola	**Bamaha Khola-Kothi River**	**Kothi River-Jitpur**	**Jitpur-Gorusinghe**	**Gorusinghe-Chanauta**
2029	31,920	31,920	17,233	17,233	24,776
2030	34,582	34,582	18,646	18,646	26,561
2031	36,492	36,492	19,664	19,664	27,838
2032	38,518	38,518	20,749	20,749	29,173
2033	40,660	40,660	21,885	21,885	30,586
2034	42,942	42,942	23,091	23,091	32,068
2035	45,344	45,344	24,370	24,370	33,630
2036	47,636	47,636	25,592	25,592	35,110
2037	50,049	50,049	26,874	26,874	36,653
2038	52,593	52,593	28,235	28,235	38,268
2039	55,273	55,273	29,660	29,660	39,967
2040	58,108	58,108	31,162	31,162	41,751
2041	60,579	60,579	32,476	32,476	43,295
2042	63,173	63,173	33,849	33,849	44,904
2043	65,874	65,874	35,289	35,289	46,581
2044	68,706	68,706	36,789	36,789	48,324
2045	71,665	71,665	38,358	38,358	50,133

2046	74,468	74,468	39,842	39,842	51,842
2047	77,380	77,380	41,387	41,387	53,611
2048	80,421	80,421	43,011	43,011	55,446

Table 10.29: The number of lanes of the carriageway for urban areas

In case of including 2~3wheels

Link	H0146	H0147	H0148	H0149	H0150
	Butwal-Bamaha Khola	Bamaha Khola-Kothi River	Kothi River-Jitpur	Jitpur-Gorusinghe	Gorusinghe-Chanauta
2029	4	4	2	2	2
2030	4	4	2	2	2
2031	4	4	2	2	2
2032	4	4	2	2	2
2033	4	4	2	2	4
2034	4	4	2	2	4
2035	4	4	2	2	4
2036	4	4	2	2	4
2037	4	4	2	2	4
2038	4	4	2	2	4
2039	4	4	2	2	4
2040	4	4	4	4	4
2041	4	4	4	4	4
2042	4	4	4	4	4
2043	4	4	4	4	4
2044	4	4	4	4	4
2045	4	4	4	4	4
2046	4	4	4	4	4
2047	4	4	4	4	4
2048	6	6	4	4	4

It has been determined that service road with one-way at either side are sufficient to cater projected 2~3 wheeled vehicles in urban area.

Table 10.30: The difference of the number of lanes of including 2~3 & excluding 2~3wheels for urban areas

Link	H0146	H0147	H0148	H0149	H0150
	Butwal-Bamaha Khola	Bamaha Khola-Kothi River	Kothi River-Jitpur	Jitpur-Gorusinghe	Gorusinghe-Chanauta
2029	2	2	0	0	0
2030	2	2	0	0	0
2031	2	2	0	0	0

2032	2	2	0	0	0
2033	2	2	0	0	2
2034	2	2	0	0	2
2035	2	2	0	0	0
2036	0	0	0	0	0
2037	0	0	0	0	0
2038	0	0	0	0	0
2039	0	0	0	0	0
2040	0	0	2	2	0
2041	0	0	2	2	0
2042	0	0	2	2	0
2043	0	0	2	2	0
2044	0	0	2	2	0
2045	0	0	2	2	0
2046	0	0	2	2	0
2047	0	0	0	0	0
2048	2	2	0	0	0

c) Result of the number of lanes

It has been determined that the carriageway in the whole stretches of proposed road would have dual carriageway roads (with 2-Lane carriageway). Additional service roads of one-way on either side have been proposed in the urban area. This would satisfy Level of service ‘B’ as stipulated.

Table 10.31: The number of lanes (unit: two-way, 2046y)

Link		H0146	H0147	H0148	H0149	H0150
		Butwal-Bamaha Khola	**Bamaha Khola-Kothi River**	**Kothi River-Jitpur**	**Jitpur-Gorusinghe**	**Gorusinghe-Chanauta**
Urban area	Carriage way	4	4	4	4	4
	Service road	2	2	2	2	2
Rural area		4	4	4	4	4

10.7 Pavement Design Loading

In order to carry out pavement design, the ESA for commercial vehicles such as all category of trucks, bus and minibus including the corresponding pavement design load over a twenty-year period have been calculated and presented in **Table 10.32** to **Table 10.36** Below.

Table 10.32 : Pavement Design Load for H0146: Butwal-Bamaha Khola

For Carriage Way

Type of Commercial Vehicle	AADT (Year 2046)	VDF	Total esa	Per year esa	Each direction esa	Total esa per Lane	Total, esa for dual carriageway	Total, msa
Multi Axle Truck	493	6.50	3205	1169825	701895			
Heavy Truck	2,464	4.75	11704	4271960	2563176			
Light Truck	179	1.00	179	65335	39201			
Bus Large	508	0.50	254	92710	55626			
Bus Mini	3,653	0.35	1279	466835	280101	69186042	51889532	51.89

For Service Lane

Type of Commercial Vehicle	AADT (Year 2046)	VDF	Total esa	Per year esa	Each direction esa	Total esa per Lane	Total, esa for dual carriageway	Total, msa
Multi Axle Truck	50	6.50	325	118625	71175			
Heavy Truck	493	4.75	2342	854830	512898			
Light Truck	90	1.00	90	32850	19710			
Bus Large	254	0.50	127	46355	27813			
Bus Mini	2,192	0.35	768	280320	168192	12636489	9477367	9.48

Table 10.33: Pavement Design Load for H0147: Bamaha Khola-Kothi River

For Carriage Way

Type of Commercial Vehicle	AADT (Year 2046)	VDF	Total esa	Per year esa	Each direction esa	Total esa per Lane	Total, esa for dual carriageway	Total, msa
Multi Axle Truck	493	6.50	3205	1169825	701895			
Heavy Truck	2,464	4.75	11704	4271960	2563176			
Light Truck	179	1.00	179	65335	39201			
Bus Large	508	0.50	254	92710	55626			
Bus Mini	3,653	0.35	1279	466835	280101	69186042	51889532	51.89

For Service Lane

Type of Commercial Vehicle	AADT (Year 2046)	VDF	Total esa	Per year esa	Each direction esa	Total esa per Lane	Total, esa for dual carriageway	Total, msa
Multi Axle Truck	50	6.50	325	118625	71175			
Heavy Truck	493	4.75	2342	854830	512898			
Light Truck	90	1.00	90	32850	19710			
Bus Large	254	0.50	127	46355	27813			
Bus Mini	2,192	0.35	768	280320	168192	12636489	9477367	9.48

Table 10.34: Pavement Design Load for H0148: Kothi River-Jitpur

For Carriage Way

Type of Commercial Vehicle	AADT (Year 2046)	VDF	Total esa	Per year esa	Each direction esa	Total esa per Lane	Total, esa for dual carriageway	Total, msa
Multi Axle Truck	1,177	6.50	7651	2792615	1675569			
Heavy Truck	422	4.75	2005	731825	439095			
Light Truck	499	1.00	499	182135	109281			
Bus Large	792	0.50	396	144540	86724			
Bus Mini	911	0.35	319	116435	69861	45255474	33941606	33.95

For Service Lane

Type of Commercial Vehicle	AADT (Year 2046)	VDF	Total esa	Per year esa	Each direction esa	Total esa per Lane	Total, esa for dual carriageway	Total, msa
Multi Axle Truck	118	6.50	767	279955	167973			
Heavy Truck	85	4.75	404	147460	88476			
Light Truck	250	1.00	250	91250	54750			
Bus Large	396	0.50	198	72270	43362			
Bus Mini	547	0.35	192	70080	42048	6262674	4697006	4.7

Table 10.35: Pavement Design Load for H0149: Jitpur-Gorusinghe

For Carriage Way

Type of Commercial Vehicle	AADT (Year 2046)	VDF	Total esa	Per year esa	Each direction esa	Total esa per Lane	Total, esa for dual carriageway	Total, msa
Multi Axle Truck	1,177	6.50	7651	2792615	1675569			
Heavy Truck	422	4.75	2005	731825	439095			
Light Truck	499	1.00	499	182135	109281			
Bus Large	792	0.50	396	144540	86724			
Bus Mini	911	0.35	319	116435	69861	45255474	33941606	33.95

For Service Lane

Type of Commercial Vehicle	AADT (Year 2046)	VDF	Total esa	Per year esa	Each direction esa	Total esa per Lane	Total, esa for dual carriageway	Total, msa
Multi Axle Truck	118	6.50	767	279955	167973			
Heavy Truck	85	4.75	404	147460	88476			
Light Truck	250	1.00	250	91250	54750			
Bus Large	396	0.50	198	72270	43362			
Bus Mini	547	0.35	192	70080	42048	6262674	4697006	4.7

Table 10.36: Pavement Design Load for H0150: Gorusinghe-Chanauta

For Carriage Way

Type of Commercial Vehicle	AADT (Year 2046)	VDF	Total esa	Per year esa	Each direction esa	Total esa per Lane	Total, esa for dual carriageway	Total, msa
Multi Axle Truck	2,949	6.50	19169	6996685	4198011			
Heavy Truck	2,862	4.75	13595	4962175	2977305			
Light Truck	567	1.00	567	206955	124173			
Bus Large	1,909	0.50	955	348575	209145			
Bus Mini	1,214	0.35	425	155125	93075	144539781	108404836	108.41

For Service Lane

Type of Commercial Vehicle	AADT (Year 2046)	VDF	Total esa	Per year esa	Each direction esa	Total esa per Lane	Total, esa for dual carriageway	Total, msa
Multi Axle Truck	295	6.50	1918	700070	420042			
Heavy Truck	573	4.75	2722	993530	596118			
Light Truck	284	1.00	284	103660	62196			
Bus Large	955	0.50	478	174470	104682			
Bus Mini	729	0.35	256	93440	56064	19603609	14702707	14.71

11 Road Safety

11.1 Introduction

Chapter 11 describes the various road safety issues related to the upgrade of the Butwal - Gorusinghe (BG) Section of the East West Highway, which is the subject of this report. Section 1 first introduces the Chapter and provides background information which will be useful to understand the framework for the work presented in this report. It then sets the context in which road safety issues are addressed.

Section 2 provides an overview of the road safety methodology employed in addressing the issues and recommending measures to keep road users safe. Firstly, it describes briefly the overarching approach and principle of managing road safety in the project section of the East West Highway. It also describes the requirement of road safety measures in terms GESI compliance. Road Safety Standards are described next. Various methodological considerations used in the process of addressing road safety issues such as road safety audit, road safety assessment, black spot identification, are described.

Section 3 to Section 11 contains the description of various road safety measures suggested for the highway. These are described under various strategic themes. Most of the measures are incorporated in the design cost and estimate. A few are proposed for consideration by the Project in future.

Section 12 introduces work place health and safety measures and temporary traffic management measures to be implemented by the contractor during construction. This is usually a neglected area in road safety engineering practice in Nepal but very important from safety perspective.

Most road projects involve the delivery of infrastructure components only. Many components of road safety infrastructure and facilities are new to road users and they do not know how to use these facilities safely. Section 13 aims at filling this gap. Various resource materials are identified and listed in this Section for use by road agencies. A pilot program of road safety awareness campaign is suggested for implementation during the construction and post construction phase.

Section 14 contains monitoring and evaluation of the performance of the suggested road safety measures in delivering desired road safety outcomes. Selected indicators of road safety performance outputs and outcomes are described and the reporting requirements are suggested.

Section 15 describes the findings of the road safety audit and recommendations to address the deficiencies identified during the audit. Most road safety measures are incorporated in the design itself. In this sense, this Section is expected to contain only the residual road safety deficiencies to be addressed by the Project during the defect liability period or later depending on the availability fund, priority and urgency.

11.1.1 Background and Scope

The Butwal-Gorusinghe (50 Km) represents one of the three sections of the East West Highway under the scope of the Project Preparatory Consultancy (PPC) works under SASEC Highway Improvement Project (SHIP). Other two sections are (a) Kakarbhitta - Laukahi (120 km) and (b) Pathlaiya – Gondrang/ Bharatpur (100 Km). While many road safety issues are common in all three sections of the highway, this report concerns with the first, Butwal-Gorusinghe, section only. Two more sections e.g., Narayangadh-Butwal section of the East West Highway (114 Km) and Kamala – Kanchanpur Section (85 Km), which is not the scope of this contract, is already under construction. Many road safety issues/ deficiencies identified for this Section and measures proposed for implementation to address these issues/ deficiencies are similar and this work benefits significantly from the experience gained in those two projects.

A separate road safety project (TA 9604) which was recently completed, identifies safety deficiencies on existing roads. The project is also undertaking detailed design stage road safety audits of under construction Narayangadh-Butwal and the Kamala-Kanchanpur sections of the Highway. Further, it has identified 273 black spots along the East West Highway, 20 top black spots have been recommended for inclusion in the first year of Black Spot Improvement Program (BSIP) in accordance with the requirements of the Terms of Reference. Only those black spots which are located along the 478 km section of the highway are included in the detailed design and estimate. A total of 9 high priority black spots which are located in 478 km sections are recommended for treatment. The remaining black spots are in under construction sections including in Dhan Khola - Shiva Khola Section. These nine black spots were inspected closely during the field visit and remedial measures recommended by the TA Project were verified for their suitability.

With the above project background in perspective, the scope of the SHIP PPC work as applied to B-G section is envisaged to be as follows. The road safety tasks provided in the TOR have been reviewed and scope more precisely defined to avoid duplication of this Project with the TA Project.

- Undertake additional analysis of road “accident” data to supplement the analysis already carried out by the TA Project;
- Review documents capturing black spots and possible “accident” prone locations (road deficiencies) prepared by the TA Consultant and carry out additional analysis to supplement the works if needed;
- Undertake additional road safety audits of the B-G section under this Project to supplement and/or reconfirm the audit finding and recommendations by the TA road safety auditors;
- Undertake safety analysis of the proposed design;
- Review reports (on RSA, RDRP, BSIP, RDAP) provided by the TA Consultant;
- Prepare detailed design for road safety improvements and black spot elimination;

- Design and prepare drawings of the road safety measures as applied to B-G Section;
- Review and reconfirm the appropriateness of the road safety measures proposed by the TA Consultant;
- Prepare detailed design road safety audit/assessment report of the B-G section;
- Conduct meetings with stakeholders and discuss the design;
- Deliver training on road safety measures; and
- Contribute to the technology transfer to local engineers.

11.1.2 Setting the Context

Current road safety scenario and related previous works provides the context for the various road safety measures proposed in the subject section of the East West Highway. A review of the existing institutional arrangement for road safety management in the country, legal framework, funding levels and the state of the technical knowledge on road safety all are important considerations for the recommendation of the remedial measures.

The Government of Nepal (GON) developed National Road Safety Action Plan (2013- 2020), in compliance with the UN mandate for the Decade of Action 2011-2020. NRSAP (2013-2020) follows the format of the Global Action Plan. However, the progress towards implementing various interventions outlined in the NRSAP (2013- 2020) was not encouraging. Expected outcomes from the Plan was also not achieved. Instead of reductions, recorded fatalities from road crashes actually increased during the plan period from 1,816 in 2013 to 2,787 in 2019, implying an annual average growth rate of 6.3%. Reported cases of serious injuries also increased significantly, though the increase was not as significant as fatalities (i.e., from 4,018 in 2011-12 to 4,376 serious injuries in 2018-19 resulting in an annual increase of 1%). The Government of Nepal (GON) has also developed new National Road Safety Action Plan (NRSAP) for the second UN Decade of Action (2021- 2030). Currently in its draft form, NRSAP 2021-2030 contains many actions on Safer Roads and Safer Speeds fronts, which are expected to inform this Project.

The National Transport Policy 2075 (NTP 2075) was drafted in 2018, however it is yet to be formally adopted by the Government. It is understood that the policy is in the final stage of its approval for adoption. The policy captures broader areas extending from planning, design, construction, maintenance, urban transportation and, parking management. The NTP 2075 draft includes policies that have relevance to road safety. It lists out working policies such as (i) developing roadside service centres along highways; (ii) controlling direct access to highways; (iii) maintaining compatibility of the road cross-section with the design speed involved; (iii) adoption of intelligent transport system technologies for traffic management; (iv) introduction of safe vehicle guidelines; (vi) introduction of the graduated driving licensing systems; (vi) improving parking management; (vii) improving transport safety through road safety audits, blackspot analysis and establishing trauma centre for improved post-crash response and (vii) development of universally accessible road infrastructures, etc. NTP 2075 provides excellent framework for implementing road safety measures in the proposed project road section.

The Road Safety Bill 2017 has been drafted but it is yet to be enacted by the Parliament to make it a law. The bill sets out the establishment of an autonomous National Road Safety Council (NRSC). The NRSC is expected to have the far-reaching authority to coordinate road safety horizontally across multi-sectorial agencies and to monitor safety performance outcomes vertically within each agency. It stipulates the interventions across all five pillars of road safety and pursues other road safety management policies required for the delivery of road safety actions. Other important issues such as conducting road safety audits and blackspot analysis; work zone safety management at roadwork, post-crash response and road safety management system are also captured by the Bill.

The development of the Road Safety Bill preceded the drafting of the National Road Safety Policy (NRSP). The NRSP is developed under the same TA Project (TA-9604) which is developing Road Safety Improvement Program for the entire length of the East West Highway. The draft NRSP informs the Road Safety Act and the later provides legal, institutional and funding framework for the implementation of the Policy under development. The road safety remedial measures proposed for the B-G Section support the implementation of the policy. The implementation of the measures proposed in this Project is required by law (once the bill becomes law).

A draft National Road Safety Strategy (NRSS) has also been prepared by the same TA project that developed NRSP. It has a life of 10 years (2021-2030). Mid-term review is proposed at the end of 2025. NRSS 2030 which contains high level strategic interventions, informs the development of the NRSAP 2021-2030 mentioned above. A National Road Safety Investment Plan (NRSIP) is also drafted. The NRSIP, when fully funded, is expected to provide additional funding for the implementation of various road safety initiatives in the country in addition to the funding secured for road safety measures under each specific project.

NRSP, NRSS, NRSAP and NRSIP developed under the TA-9604 Project together with the draft NTP and RSB as well as other low level road safety related study reports on RSA, BSIP, RDRP and RDAP and technical reference materials (manuals, guide, safety notes) provides excellent context for the development and implementation of road safety works proposed under the Project.

11.2 Methodology

Identification of potential safety issues arising from four laning of roads is based on the rapid appraisal of the roads, road sides and the existing operating environment and assessment of likely situations resulting from the proposed upgrade design. A drive through visual inspection of the corridor was made on different occasions. Video clips were recorded capturing the entire length of road along with the field notes on major features to allow examine major road safety issues later in the office in detail. Replaying of videos also helped in detecting minor issues that were missed out during the rapid field assessment. Distance from the start was recorded from the odometer. Date, GPS locations (Latitude and Longitude) as well as driving speed at any point of road section are recorded in the videos and these details can be picked up at any time in future during replays.

Information from the survey and design team has been used to augment the drive through information and to pin point the locations for the proposed safety treatments. For example, locations of crash barriers and intersections have been identified using the survey and design data. Information on locations of schools for implementing reduced posted speed limit and road crossings were obtained from social and environment teams. Plans, profiles and cross sections of road and design drawings of other road and roadside elements have also been reviewed. In fact, because of the time factor for design and report submissions, safety issues were identified and measures incorporated in the design concurrently with the design works.

In order to identify road safety issues along the road corridor, the B-G road is divided into two distinct sections as safety issues and method of treatment could vary remarkably and different along these types of sections. These are:

- Sections of roads predominantly along the urban (built up and semi-built up) areas; and
- Sections of roads predominantly along the rural areas

In recommending potential strategies and safety countermeasure options, those measures that were identified in the National Road Safety Notes (DOR) and tested and proven in the country to deliver required outcomes were considered first. Only in cases, where those measures that could treat the potentially risk sites better than by those recommended locally are suggested for consideration by the Project. Where a number of options are available, quick checks on potential costs, benefits and residual risks are assessed subjectively during the feasibility stage safety review based partly on experiential judgment and the option (or host of options) that best could resolve the identified safety issue (s) is recommended.

A few innovative treatments which were developed tried and tested elsewhere and which represented best practice safety treatments from around the world are recommended for consideration for trial in the Project. These treatments are explained under relevant sections rather than including in a separate section.

Suggested countermeasures are detailed out fully to enable construction and these are reflected in the plans, profile and cross-sections as the case require. Many safety elements are identified during the detailed design, but some are to be identified during the construction stage audits and pre-opening audits (these audits are recommended to be included in the construction supervision consultants' Terms of References). In this sense, the detailed design phase recommendations and detailing should be adjusted or added in those stages of the project delivery. At this detailed design stage, illustrations (in the form of pictures and diagram are included in the report to illustrate the types of suggested treatments to enable the CAD engineers and clients to fully understand the need to implement suggested treatments. These treatments are shown in the plans, profiles and cross-section where feasible. Specific details are included in the detailed design drawings.

While the focus of this report is primarily on safer roads and road side environment, additional recommendations are made to incorporate some of the key elements of safer users (e.g., enforcement), safer speed (e.g., implementation of posted speed limits), safer vehicles (e.g., provision for parking breakdown vehicles) and post-crash response management system (e.g., inclusion of at least one post-crash response facilities along the road). Delivery of safer roads alone is not adequate to address safety issues. How people use improved "safer" roads is equally important for delivering desired road safety outcomes.

It has not been possible to obtain details of crash data specific to the B-G Road corridor. Road crash data obtained from Traffic Police Headquarter are aggregated to district and regional level and are not particularly useful for safety analysis. Records of crashes along the road are necessary. Historical records of traffic accident report forms completed by the Police Officer at the crash scenes are not systematically stored and are destroyed when the crash cases are resolved. The Road Safety TA Project (TA-9604) has collected crash data for all districts dissected by the East West Highway and identified blackspots based on the methodology adopted specifically for the Project. Crash data as well as black spot analysis as applicable to B-G section have been disaggregated and examined further closely before detailing out remedial measures.

11.2.1 Safe System Approach

The draft National Road Safety Policy envisages the use of Safe System Approach that has been proven to be very effective in delivering desired road safety outcomes in many countries. The same approach is used in the safety analysis and in the recommendation of road safety measures for this Project.

The Safe System approach recognizes that people will make mistakes but ensures that deaths and serious injuries from crashes are minimized in the event of a crash. In other words, the emphasis is on developing forgiving roads and road side environments to achieve the stated objectives of the Safe System. The Safe System is made of four component elements which have significant influence on road safety outcomes.

- Safer roads and roadsides;
- Safer speeds;
- Safer vehicles; and
- Safer road users.

While the primary focus of the road safety measures in this Project is on building safer roads and roadsides and applying and enforcing speed limits appropriate to the road use environment, it is recommended that a set of selected measures to control the use of vehicles on roads in unsafe manner (e.g., overloading/ overcrowding) and measures to raise awareness of road users specifically living along the roadside on how to use roads are also considered for implementation. Measures (e.g., enforcement bays, vehicle pull-over bay for random breath and saliva testing, speed cameras) that deters motorists to practice unsafe driving behavior are also identified and included in the road safety design. Application of the safe system approach in managing road safety along the B-G section of the East West Highway is expected to set the example, which in turn supports the realization of the Government's "Towards Zero" vision aspired in the draft National Road Safety Policy.

11.2.2 GESI in Road Safety

Ministry of Physical Infrastructure and Transport (MOPIT) has released its Gender Equity and Social Inclusion (GESI) Operational Guidelines. TA-9604 Project is undertaking extensive training to streamline GESI initiatives across all the departments and jurisdictions under it. Consistent with the Constitution of the country and ensuing Disability Discrimination Act, all infrastructure including roads and transport are required to be GESI compliant.

In accordance with this requirement, all road safety measures proposed for implementation by this Project are designed to be GESI compliant.

11.2.3 Road Safety Standards

The Government of Nepal has a vision of zero road deaths and serious injuries as committed in its National Road Safety Policy (NRSP) and National Road Safety Strategy 2021-2030 (NRSS) (both in draft stage), In order to achieve this vision, the Department of Roads (DOR) supports the adoption of Safe System principles, process and practices in the implementation of all its road projects including in the East West Highway.

The application of Safe System approach in the design means the use of safe system principles, processes and practices across all four pillars – Safer Roads and Roadsides, Safer Speeds, Safer Road Users and Safer Vehicles. While most of the interventions in Safer Road Users and Safer Vehicles require actions from multiple agencies, the DOR is the lead agency for the management of the first two pillars – Safer Roads and Roadsides, and Safer Speeds (enforcement accepted).

Road Safety Standards need to be formalized and accepted as part of DOR's Road Design Guidelines. The design guide should be based on its core design document, Nepal Road Standards 2070 and other supplementary documents such as Road Safety Notes and standard drawings developed and used over time in the implementation of various large scale road projects. Where the provisions of NRS-2070 may put road users at risk, a new set of safety standards have been proposed.

At this stage, it is not known what level of safety standards the Department would like to adopt in the design and delivery of road projects. There is no firm guidance available to the consultants at this stage. The only documents available for planning and design of road safety measures are a few obsolete Road Safety Notes prepared in mid to late 1990's. A consistent approach in the application of safety standards is therefore lacking. It is partly because there is no single unified document to guide the agencies involved in the delivery of road projects.

Accordingly, following interim road safety standards **(Table 11.1)** are suggested for adoption in all projects under SHIP-PPC. In fact, these or similar standards should preferably be adopted along the entire section of the East West Highway. This will ensure consistency.

Table 11.1: Safety Standards

Safety Issue	Safety Standards
Safety of motorcyclists	All road safety barriers and terminals shall be fitted with motorcyclist injury reduction countermeasures suitable for the types of barriers. These include a) Underruns along the W-beam guard rails. b) W-beam terminal treatments appropriate to the site. c) Crash cushions at the end of RCC barriers facing traffic.
Safety of vulnerable users (Safety of pedestrians generally)	In all urban environments and where demand exists or may develop in a rural environment, design of road will include provisions for pedestrians, cyclists and people with disability, including footpaths and crossings. Following safety interventions will be provided at minimum (examples only). a) Banning pedestrians, cyclists and other non-motorized vehicles in main highways (designated sections excepted). b) Banning zebra crossings on main roads with more than two lanes (both directions). In cases, pedestrian crossings cannot be avoided (or are absolutely necessary), these will be two stage type of crossings with adequate pedestrian refugees' space in the median and provided with raised platforms with transverse rumble strips on the approaches and higher level of illuminations. c) Controlled (signalized) mid-block pedestrian crossings on roads with more than two lanes. d) Non-climbable vandal-proof median fencing along the entire urban sections of the highway and along the selected rural sections with relatively high volume of pedestrians. e) Reduced speed limits of 30 km/hr along service roads where pedestrians, cycles and other non-motorized vehicles mix with motorized two, three and four wheelers. f) Reduced speed limits of 60 km/hr along the urban sections of main highway. g) Limit speed to a maximum of 80km/hr along the rural sections of highway (where infrastructure risks are considered to be low) and install speed limit signs at the beginning of rural sections and

Safety Issue	Safety Standards
	repeater signs at regular intervals as per available international practices.
Safety of pedestrians at intersections	a) Pedestrian crossings should be provided on all approaches at signalized intersections. b) Pedestrian crossing protection (delayed start to vehicle movements) is to be considered. c) Installation of zebra crossings (uncontrolled/ un-signalized) should not be permitted on approaches to intersections with two and more lanes in one direction. If absolutely necessary, raised intersections with warning signs, lights and transverse rumble strips should be considered to force motorists to slow down and give way to pedestrians. d) Un-signalized (free) left turn slip lanes should generally be avoided at intersections (unless signalized with pedestrian protection). e) All intersections along urban sections should be signalized to allow safe crossing of roads by pedestrians unless they are spaced closer than 500 m.
Safety of motorists at intersections (Urban)	a) All intersections (signalized) must have a separate right turning lane on major road. b) All signalized intersections must have protected right turn lanes on major road. c) Permissive phase (filtered green arrows) will not be permitted unless justified by a risk assessment. d) All right turns and U-turns from all approaches (both major and minor roads) will not be permitted at un-signalized intersections in case if these intersections cannot be avoided. e) All remaining minor intersections will be designed for LILO operation.
Safety of motorists at intersections (Rural)	a) Use of Basic Right Turning lanes (BAR) as well as Auxiliary Right Turning lanes (AUR) will not be permitted on approaches of the major road. b) Where right turning manoeuvres cannot be banned at un-signalized intersections, at least a Channelized Short Right Turning Lane (CHR-S) should be provided at all approaches of the major road. c) All right turning manoeuvres from minor roads to the major road will not be permitted unless protected by traffic signals. These movements will be managed by left turns followed by strategically

Safety Issue	Safety Standards
	located U-turn facilities at safe places along the major road (adequate distance for safe weaving). d) Where a high volume of left turning traffic is present on rural roads (with 80km/hr speed limit), sight lines must not be obscured for traffic entering from the minor road. Depending on sight lines and traffic volumes, left turn lanes may need to be repositioned or channelized. Side road throat widths should be considered for widening to allow STOP/GIVE WAY lines to be brought as far forward towards the edge of shoulder as possible, with appropriate sealed area for design vehicle turning path. e) Transverse rumble strips will be provided at the approaches to the minor roads to reduce speed of vehicles entering into the main road. f) A raised pedestrian crossing (Wombat Crossing) will be provided at minor road approaches. g) Pedestrian crossings (uncontrolled) will not be permitted at the intersections of rural sections of the main road. These will be provided away from intersections suitably (midblock locations). h) Vandal-proof non-climbable median fencing shall be installed at rural intersections where pedestrians are likely to cross the road at intersections. The fencing should extend to the nearest mid-block crossings located on either side of the intersection.
Reducing risk of head on crashes	a) All highways/ roads along rural sections with the AADT equal to and greater than 4000 PCUs per day should have a wide Centre Line Treatment (WCLT) with Audible Tactile Line Marking (ATLM). Where raised medians are provided, they shall be at least 3 m wide. b) All highways/ roads (urban or rural) with the posted speed equal to or greater than 70 km/hr will be divided by raised medians. c) For all divided roads with posted speed limit equal to or greater than 70 km/hr medians will be clear of all hazards unless protected by roadside barriers. d) For all divided roads with posted speed limit equal to or greater than 80 km/hr, if permitted) and AADT greater than 10,000 PCUs per day physical separation by median barrier is required.
Reducing the risk and/or severity of run off road crashes (departure to the left)	a) Audible Tactile Line Marking (ATLM) will be installed on edge lines and centre lines on all rural sections of the highway with sealed shoulder greater than 0.5m and a history of fatigue related crashes. b) All roadside hazards within the clear zone will be removed. In case these cannot be removed from other considerations, they should

Safety Issue	Safety Standards
	be first protected by roadside barriers or delineated clearly for increased visibility and warning. c) All rural sections of highway with fill slope higher than 2m will be protected by roadside barriers. Similarly, if the side slope is steeper than 1:3 will be provided with road side barriers. These can be either steel W-beam or RCC rigid type barriers (of appropriate profile). For lower height and flatter side slope, risk can also be managed by using RCC delineator posts with retro-reflective plates. Further guidance is available from DOR's Road Safety Notes #6.
Containing vehicles within the lane or carriage way	a) Line marking shall be provided in accordance with the provision of Nepal Traffic Sign Manual 1997. Where the provision is not adequate equivalent IRC or other international practices will be adopted. b) All permanent line marking shall be cold applied plastic. c) Retro-Reflective Pavement Markers (RRPM) or road studs (cats' eyes) will be provided where risks from lane departure during night time are very high.
Access rationalization and control measures	a) All direct access to and from individual property and local roads will not be permitted. b) All direct access to the East West Highway to and from collector roads will not be permitted. In case if a collector street provides access to emergency services such as hospital, ambulance or fire stations, direct access to East West Highway will be permitted with LILO arrangement only. c) Access from all major north south highways and major arterial roads or feeder roads (strategic roads) will be managed either by grade separated or at-grade intersections. In urban sections, safety will be managed either by a combination of free flow interchanging ramps and traffic signals or solely by traffic signals. In case of rural sections, traffic signals, four way or two ways stop control operation will be implemented to manage safety and reduce intersection related crashes. RTs will be banned unless they are absolutely necessary. d) Lane control signs sill be erected to deliver message to motorists that entry into these lanes is prohibited. It may be reinforced by flashing signs with red X signs.

Safety Issue	Safety Standards
	e) Pedestrian access crossings will be banned on main roads except at designated places.
Speed management and control measures	a) Speed limit along the urban sections of the East West Highway will be 60 km/hr (default speed limit) unless signed otherwise. Default speed limits will not be sign posted. All road users are required to know this default speed limit. b) Speed along the rural sections of the East West Highway will be limited to a maximum of 80 km/hr except signed otherwise. In sections where infrastructure risk is high and measures to address these risks are cost prohibitive, speed will be limited to an appropriate level (70, 60 or 50 km/hr). c) All service roads will have the default speed limit of 30 km/hr. Service roads speed limit need not be sign posted. All road users are required to know the speed limit of service roads. d) Where pedestrians, cycles and other non-motorized vehicles are likely to mix with motorized vehicles on the East West Highway itself (e.g., pedestrian crossings, school zones), special speed reduction devices will be installed with appropriate warning signs to force motorists to reduce speed. e) Gateway treatments (township entry treatments will be provided at sections where the East West Highway transition from rural to urban section or where the East West Highway passes through rural townships, major settlements and urban areas.
Fatigue management and control measures	a) In addition to the provision of ATLM edge line marking to help awake sleepy drivers and roadside barriers, all rural sections of the east West Highway will have stopped bays every 30 km. b) Rest areas will be provided every 90 km.
Measures for overloading control	a) WIM bridges will be provided at strategic locations. b) Weight limit signs will be installed at the approaches to bridges where required.
ITS measures to improve safety	a) All urban sections of roads will have street lighting (illumination level?) b) All rural intersections will have street light with enhanced level of illumination. c) All mid-block pedestrian crossings shall have enhanced illumination level as per standard practice to increase night visibility of pedestrians.

Safety Issue	Safety Standards
	d) Variable Speed Limit (VSL) signs at strategic locations along the highway. e) Other Variable Message Signs (VMS) may also be installed on need basis.
Campaign on safe use of roads and related facilities	a) Local people along the road corridor will be invited to participate on the campaigns on how to use roads safely. b) On-site trainings will be offered to all class of road users on the use of roads and related facilities such as use of zebra crossings, push button at signalized intersections, give ways and other safety measures and markings. c) Flyers and videos will be developed and distributed widely on the opening of upgraded roads. d) Community events will be organized at the time of opening road to traffic and on regularly basis thereafter.
Enforcement measures	Appropriate provisions (facilities for use by police officers) will be made along the east West Highway to facilitate the control of over-speeding, overloading overcrowding as well as driving under the influence (of alcohol or drugs). a) Point to Point camera infrastructure, including the provision of footings with associated structures, electrical and internet (optical fiber) supply, suitably placed for enforcement during operation by enforcement agencies. b) Enforcement pads/ bays for use by mobile speed camera vans encompassing electrical power supply with concrete base at appropriate locations (locations to be identified in consultation with local police offices). c) Vehicle pull over bays for Random Breath Testing (RBT) and Random Drug Testing (RDT). The current practice of stopping vehicle abruptly on traffic lane is unsafe.
Other traffic control and safety devices	All provisions of DOR Road Safety Notes should be followed to address safety issues not addressed by the proposed road safety standards. Above are the minimum standards. Additional measures from national regional and international practices may be implemented to improve safety.

Note: Motorists in the above table include users of all types of motorized vehicles

These interim safety standards are default requirements. These default standard requirements are based on the proven countermeasures which are considered to be good practice to proactively reduce the risk of fatal and serious injury crashes. Justification is provided for design exception where site constraints demand relaxation on the default standards. Design by exception is a standard engineering practice implemented in many resourceful countries like Canada and Australia and there is no reason why the designers in Nepal should not use this practice. Over time DOR may wish to formalize the new approach in the design process and safety standards for consistent application across all of its major road projects. The experience can be used to revise/ update its two-decade old Road Safety Notes.

11.2.4 Assessment of Crash Risk

A number of methods can be employed in the assessment of crash risks in the subject road safety analysis. These methods can be broadly divided into two categories.

- Collective Risk Method
- Individual Risk Method

Collective risk method uses an indicator called crash /km. Crash in turn can be expressed either in terms of EPDO, number of fatalities or number of FSI crashes or crash cost or ERU (Equivalent Risk Unit). Individual risk uses similar measure in the numerator but uses mvkt (million vehicle kilometers travelled) or vkt (vehicle kilometers travelled) in the denominator. Although not used anywhere, unique situation in Nepal may require the use of pkt (person-kilometres travelled) rather than vkt, the reason being the need to identify high risk locations along the road used by more people than by more vehicles. A road with 500 buses per day and a road with 500 passenger cars per day are considered being equally important in safety assessment if vkt indicator is used for exposure.

Definition of high crash locations is the key in this categorization. For example, a black spot can be considered simply as the location along the road where crashes are clustered at that point. Similarly, a black link (or high crash section or high crash zone) can be considered simply as a section of road with high number of crashes in comparison with an average over a link. EPDO is yet another method that attempts to convert all types of crashes into one single number called EPDO.

Methods involving the use of absolute number of crashes has some problems owing to the need to consider different types of crashes. Considering only fatality, for example, in risk assessment could lead to incorrect prioritization of roads. A black spot with 3 fatalities may get more attention of road safety managers than the spot with 30 severe injury crashes. This problem is addressed by EPDO method in a simplistic way. A better way is to reduce all types of crashes into one single denominator. This is done by assigning higher cost for fatal crashes in one extreme and lower cost for property damages only types of crashes in another extreme.

Use of crash cost for risk assessment has also problem. Crash cost by severity types and by DCC types varies each year and need update. In Nepal, however, crash cost is not updated on annual basis. In such a case, ERU method can be used with advantage. The ERU method involves normalizing crash costs of each type in the available year with respect to the cost of the same year and using these figures to estimate single type of risk, called ERU.

Various methods can thus be developed to assess crash risk. There is no single method that would address all circumstances and deficiencies in data. It is also a matter of preference. Any or all of the methods can be used in Nepal provided data are available.

- EPDO Method: A section or location of road with highest EPDO represents highest risk and treatment priority assigned accordingly. All road sections or spots along a particular road, can be ranked for establishing risk and safety fund investment priority. In some countries (e.g., in India) it is also called Severity Index (SI) Method.
- Black Spot Method: A formal definition of black spot along with the criteria for prioritization will ensure consistency across the country for funding black spot improvement program. Both the definition and criteria for prioritization do not exist in Nepal and requires urgent attention.
- Black Link Method: This method is similar to Black Spot with difference only in that we consider here a section rather than a specific location. The method is useful in cases where crashes are not clustered in a particular location but spread along certain section of road. A definition of what constitutes a black link and criteria for prioritization is necessary to be able to use this method.
- HRR Method: The High-Risk Road (HRR) method is useful if the interest is to come up with the list of high-risk roads along the entire road network under consideration. As in above, a definition of what constitutes a high-risk road and criteria for prioritization is required. This method is employed in situations where crashes are scattered along the entire roads.
- ERU Method: A readymade table with ERUs for each type of crashes (either by severity or by DCC) should be developed first based on crash data and crash cost analysis. When this is done the method consists of simply multiplying crashes by corresponding ERU obtained from the table and summing up by crash types to get a single figure of ERU value for each road spot, road link or roads (as the case may be). The ERU is a type of risk measure. Higher the ERU, riskier the road is.

These methods were reviewed and findings are presented in the TA 9604 Report. For illustration purpose, a definition of black spot used in Queensland, is cited below. It is expected that Nepal develops its own definition to meet its specific needs.

For individual sites such as intersections, mid-block or short road sections, there should be a history of at least three casualty crashes over a five-year period. For lengths of road, there should be an average of 0.2 casualty crashes per kilometer per annum over the length in question over five years. Further, a black spot project proposal should be able to demonstrate a benefit to cost ratio of at least 2 to 1.

Nepal may have too many locations with three casualty crashes or more. The definition of black spot used in Queensland, which considers only casualty crashes, should not be used directly. If this definition is adopted, Roads in Nepal may have thousands of black spots. This does not look good for road agencies. A judicious approach based on crash data, current socio-economic situation, government policy, and fund availability should be considered in recommending the formal definition of a black spot in the country.

The criteria used for the definition of black spot, black link or high-risk roads may vary from country to country. There is no need of consistency internationally. The important issue is that there must be a formal definition of black spot used in road safety management practice which can guide the development of black spot improvement program in a more rational manner. For example, Nepal may start defining black spots having at least five casualties out of which one should be fatality. The program development may also specify a threshold BC Ratio for funding eligibility.

Various cash risk assessment methods are briefly introduced in this section with the objective of informing road agencies about the issues involved in the assessment of crash risks and the problems associated with using these methods in the subject project. Owing to serious problems in crash data collection and storage, none of the above methods can be used in crash risk assessment (black spot analysis) at this stage. A modified method has been therefore developed and used in identifying black spots in Road Safety TA Project (TA-9604). The recommendation of the black spots and remedial measures from the TA Project is considered in the detailed design of the subject road section. Refer to the TA Report for details on the black spot methodology. Black spots for the entire East West Highway can be found in the TA Report, those located within the B-G section as identified by the TA Study and the recommended remedial measures are implemented in the design. The Black Spot methods used in the TA Project is briefly described in Section 11.2.6.

11.2.5 Assessment of Infrastructure Risk

A number of methods are available for the assessment of infrastructure risks. These methods are based on the risks a person is likely to be exposed to while using the road. These risks are the outcome of the deficiencies in road infrastructure and surrounding environment. Measure of risks varies from one method to the other method, but the principle behind the risk assessment process remains the same.

Depending on how risk is assessed an infrastructure risk assessment method can be:

- Subjective Method; and
- Objective Method

Depending on the level of details, a subjective assessment method can be

- Safety Inspection / Assessment / Study / Review; and
- Road Safety Audit

The safety inspection/ assessment/ study can be undertaken at various stages: planning, design, operation and maintenance in a more informal way. It is conducted in a more informal process.

Road Safety Audit, on the other hand, is a very regulated, formal and structured process of safety assessment. Since it is regulated and formal, guidance is developed on how to structure the process.

Examples of objective method include:

- Star Risk Score (SRS) such as in iRAP;
- Road Network Safety Assessment (RNSA);
- International Road Assessment Program (iRAP);
- Variation of iRAP (EuroRAP, AusRAP, KiwiRAP, IndiaRAP, ChinaRAP, SARAP, usRAP, MyRAP, BrazilRAP, etc.);
- Road Risk Scores Methodology (RRS);
- Infrastructure Risk Rating (IRR) Model; and
- Australian National Risk Assessment Model (ANRAM)

Each method has its own strength and weaknesses and can be used in a variety of situations. Resource including crash data, traffic data, and cost data availability is the key. Interested readers may wish to refer to the final report on Road Safety TA Project (TA-9604) which contains detailed review of the following three objective road risk assessment methods.

- International Road Assessment Program (iRAP) used internationally in many countries;
- Infrastructure Risk Rating (IRR) Model used in New Zealand and in some states of Australia; and
- Road Risk Scores Methodology (RRS) used in Canada

Based on the review of various risk assessment methods, Nepal Risk Assessment Program (NeRSAP) has been developed and recommended for trial in Nepal in the interim while NepRAP (based on the iRAP methodology) would be developed fully for Nepal. **Figure 11.1** provides an overview of the NeRSAP process for the assessment of infrastructure risk. Details on NeRSAP is available in the Road Safety TA Project Report. A Users'' Guide has also been developed for NeRSAP.

Figure 11.1: NeRSAP Road Risk Assessment Process

NeRSAP has been used for the assessment of road risks of the existing road and the designed road. The reduction in risk score represents the safety benefits of road improvement works. It is a tool to evaluate safety benefits objectively. The TA Project have used NeRSAP in the western section (west of Gorusinghe leaving the section covered by MCC Project) to assess risks and prioritize road safety improvement programs. For the subject section (Butwal-Gorusinghe), road safety audit is carried out for infrastructure assessment and remedial measures incorporated in the design. RSA process is briefly described in detail in Section 11.2.7. During the design itself many road safety features are incorporated to meet the safety standards provided in **Table 11.1.**

11.2.6 Black Spot Analysis

Nepal Road Safety Note 8: Identifying and Treating 'Accidents' provides some guidance on treatment of crash locations which can be translated into "Black Spot Analysis" in some ways. Although the methodological framework is weak owing to the absence of crash data specifically collected for the section of road under consideration, the method as developed and suggested by the Road Safety TA Project (TA-9604) seems to be the only way forward for identification and treatment of black spots at this stage. There is an urgent need to collect, report and store crash data by road. Currently crash data are aggregated at district level only.

The Black Spot Method suggested by the TA-9604 Project consists of the 5 steps as shown in **Figure 11.2.** The implicit assumption in this method is that most of the crashes happening in the district are along the East West Highway. Given the relatively high volume of traffic and vehicle kilometer travelled along the East West Highway compared to other roads in the district as well as the higher travel speed on the EWH than along other roads, this assumption may not be too far from reality. Since identifying and ranking black spots along the East West Highway is a relative and not an absolute process, additional crashes that actually did not happen along the East West Highway but loaded into the East West Highway in the district uniformly over its length, it is believed that the identification and ranking of the black spots based on severity index will give fairly reasonable results. More important and complex issue is the identification of suitable treatment measures and this process can be done only on the basis of the information obtained from local people and experience of the road safety experts.

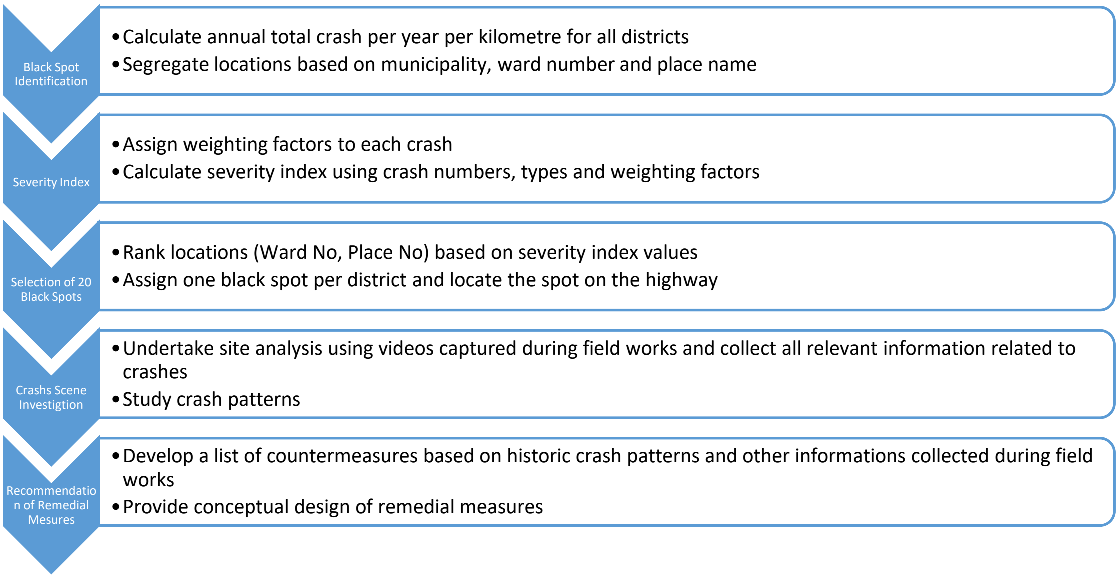


Figure 11.2: Framework for Black Spot process

11.2.7 Road Safety Audit

One of the powerful tools for identifying road safety issues in the design of road or in existing roads is the formal process "Road Safety Audit". The process was first implemented in the UK in 1980s and introduced in Nepal in mid 1990s. Albeit dated, Nepal has its own Road Safety Audit Manual[1] which can be used with some changes in this Project.

It appears that many engineers in Nepal confuse road safety audit process with the technical /design audit process. In order to ensure uniformity in the understanding, an attempt has been made in this section to explain briefly what constitutes road safety audit process and how it is undertaken, since it has implication in the way we carry out road safety task s of the TOR in this Project.

A road safety audit, as defined in the literature[2] is a formal examination of a future road or traffic project or an existing road, in which an independent, qualified team of safety experts report on the project's crash potential and safety performance. The road safety audit process concerns the safety of all road users, not just motorists. Nepal Road Safety Audit Manual also requires independency of the audit team and process from the design team and design process. This requirement has been ignored at large in the Consultant's TOR.

[1] Road Safety Note 4 Road Safety Audit Manual, DOR 1997

[2] Guide to Road Safety Part 6: Road Safety Audit, Austroads 2009

The essential elements of the definition are that it is:

- *"a formal process and not an informal check;*
- *carried out by people who are independent of the design or the road authority if an existing road;*
- *carried out by people with appropriate experience and training; and*
- *restricted to road safety issues."*

A road safety audit is concerned with the safety requirement of all road users, whereas a road design may have considered the safety and efficiency needs of only motorists. To clarify further, a road safety:

- *"is **not** a way of assessing or rating a project as good or poor;*
- *is **not** a means of ranking or justifying one project against others in a works program;*
- *is **not** a way of rating one option against another;*
- *is **not** a check of compliance with standards*
- *is **not** a substitute for design checks*
- *is **not** a crash investigation;*
- *is **not** a redesign of a project;*
- *is **not** something to be applied only to high-cost projects or only to projects involving safety problems; and*
- *is **not** the name used to describe informal checks, inspections or consultation."*

The outcome of the road safety audit is a Road Safety Audit Report, that identifies any road safety deficiencies and which may or may not make recommendations to remove these deficiencies or to implement measures to reduce the severity of crashes resulting from those safety deficiencies. The benefit of the safety audit is that, even if the designer or the client is not in a position for some reason to implement safety treatments proposed during the detailed design stage audit, at least the asset owner would be aware of the likely risks of these deficiencies. The asset owner and/or operator is either ready to accept the risk from not implementing these recommendations because there is no, for example, money, or program for implementing these recommendations gradually over time.

Review of the existing legislative, institutional, funding and technical framework in relation to the road safety suggest that there are no comprehensive and updated local procedural or policy requirements or method of auditing roads in Nepal. In absence of such comprehensive policies, procedures, guide, the process adopted in this audit is based on one of the internationally available best practice road safety audits as described by the following steps **(Figure 11.3)** and adopted by all road authorities in Australia. Road Safety Audit Guidelines for ADB funded projects[3] follows the similar approach. Nepal Road Safety Audit Manual is also used to ensure the process meets local requirements.

[3] Road Safety Audit for Road Projects: An Operational Tool Kit, ADB, 2013

While the road safety specialist will assist local road safety engineer to undertake "audit" of the design to meet the requirements of the TOR, the findings will not be presented in the form of a Standard Audit Report. A Road Safety Study Report will be presented instead. The format will be similar to the audit report though, but its legal status will not be the same as that of the audit report.

The type of Road Safety Audit that is envisaged to carry out in this Project is concerned with is Detailed Design Stage Road Safety Audit. B-G Road is planned for major rehabilitation and upgrade to multi-lane standards. The existing road will be significantly changed in terms of its geometric parameters and the new road will have much higher operating speed with the resulting potential consequence of increased number and severity of crashes if the road design will be left with safety deficiencies unidentified and unattended.

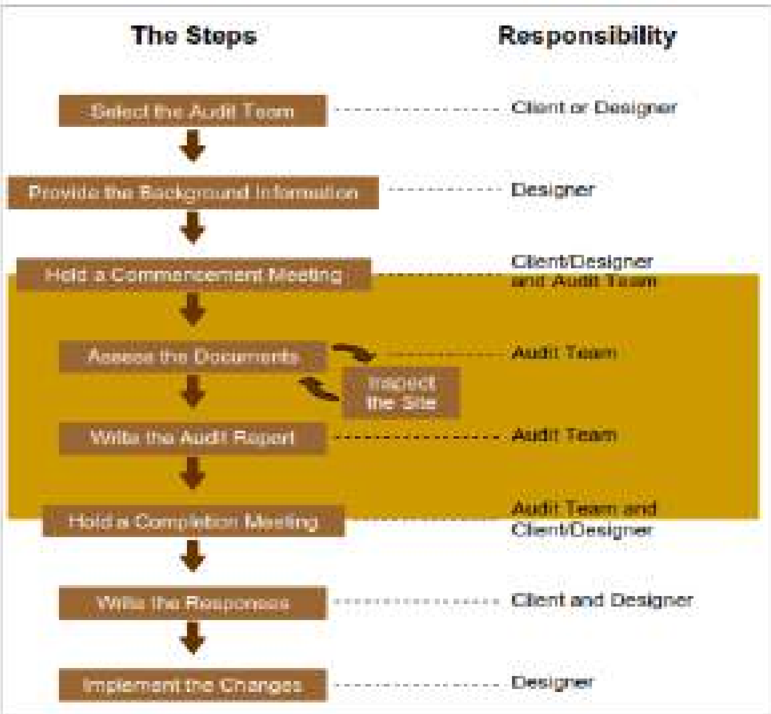


Figure 11.3: Road Safety Audit Process

Understanding about the operation of existing road and safety deficiencies in it provide important clues on the likely road safety problems in the proposed design. Therefore, a "snap-shot" safety review of existing road has also been undertaken at the beginning of detailed design stage safety study process. Remaining sections of the report deal exclusively with the safety design input to the design team.

11.3 Access Rationalization and Control Measures

Access rationalization and control (ARAC) strategy is one of the major road safety strategies in Safer Roads Pillar. Number of accesses to and from main arterial roads or highways determines the level of infrastructure as well as crash risks. National regional and international evidences of intersection related crashes are in abundance. These constitute bulk of road crashes in Nepal too. Higher the number of driveways, intersections higher the number of crashes and lower the efficiency of roads. Intersections if not managed properly forms major bottlenecks and create significant congestion. In particular, uncontrolled and frequent direct connections to adjacent properties and intersections to side streets (lower order) compromises functional integrity of arterial roads which are major traffic carriers. These are also responsible for reduced speed.

Unfortunately, the functional integrity of the East West Highway including of B-G Section is largely compromised by unauthorized accesses and uncontrolled ribbon development. Thus, many sections of highway pass through major regional urban centres including along the subject section. Managing these access and egress points becomes critical in improving safety. Pedestrian safety is a significant issue along most sections including in rural sections of the highway.

Most roads in Nepal are built and upgraded with little or no consideration on traffic entering to, and exiting from, main roads. Warrant analysis for intersections is not carried out and intersections are left without improving it while widening/upgrading main roads. Intersection operation and control measures are also ignored in the design. Traffic signals may be required for managing safety of vehicular cycle and pedestrian traffic but the same are not provided. Existing East West Highway is not an exception. There are no traffic lights nor properly designed intersection along most of the existing sections of the highway even if many sections pass through heavily built-up areas. Inadequate or incorrect provision of right turning, left turning, u-turning facilities and traffic control measures are the main reasons for intersection related crashes which constitute a significant proportion of overall road crashes in the country.

Absence of access rationalization and control strategy for national highways has led to improper corridor planning and design. Corridor management plan becomes very important especially along the urban sections with heavily built-up area. Absence of ARAC strategy and corridor management are also creating congestion, reducing speed, compromising functional integrity of the East West Highway. There is no paucity of evidence on the benefits of access rationalization and control measures for the improvement of safety performance. While road crash statistics in Nepal do not allow us to estimate the share of road “accidents” related to intersections (access control), there are enough international evidence to believe that poor on unsafe design of intersections and operation control are responsible to contribute significant number of road crashes. In 2011, for instance, over 30% of hospitalizations in the State of Queensland in 2011 was a result of intersections related crashes in 60 km/hr speed environment (typical for arterial roads in urban areas similar to the sections of East West Highway passing through densely populated towns.

This Section describes various measures that have been implemented in the detailed design of the subject section of the highway in order to reduce fatal and serious injury crashes (FSIs) which could result from poor access control and intersection design. All suggested measures are informed by the draft National Road Safety Strategy and draft National Road Safety Action Plan and are consistent with the draft National Road Safety Policy. When implemented, these measures support the delivery of the desired road safety output/ outcome targets set by the Government.

11.3.1 Basic Principles

Access management (rationalization) and control is directly related to the functional classification (road hierarchy) of the individual road. For arterial roads and higher order roads (e.g., expressways and freeways), where mobility / traffic carrying is the primary function, direct access is prohibited. On the other hand, for collector and lower order roads (e.g., local roads and *galleys* (alleys)), where the provision of access to adjacent land and properties is the primary function, limited or no access controls are needed (refer **Figure 11.4**).

Keeping in mind the functional hierarchy of the East West Highway and suggested access/ intersection control methods, following basic principles are adopted in the design of road safety measures as far as possible. Application of these principles in the design helps to reduce most of the intersection related crashes and to deliver desired road safety outcomes. These principles are consistent with the road safety standards outlined in Section 11.2.3 **(Table 11.1):**

- Close all existing direct accesses to, and from, the highway;
- Close all existing intersections with local and collector roads; Intersections with local or collector roads with access to fire brigade, ambulance, police and other emergency services and facilities will not be closed but will be turned into LILO operation;
- Existing accesses to, and egresses from the properties located on one side of the highway to the properties located on the other side of the highway are ensured by a combination of left turning, U-turning and left turning arrangements. That means all RT movements are converted into safer and more efficient movements. This applies to the management of through movements at four-way intersections.
- All commercial and residential properties along the highway will be accessed only from service roads;
- All low volume local / residential streets, driveways and collector roads with low volume of traffic will be connected to service roads only;
- All service roads will have two-way traffic (short sections with access to only a couple of properties can be one way). These will be clearly shown in the plan;

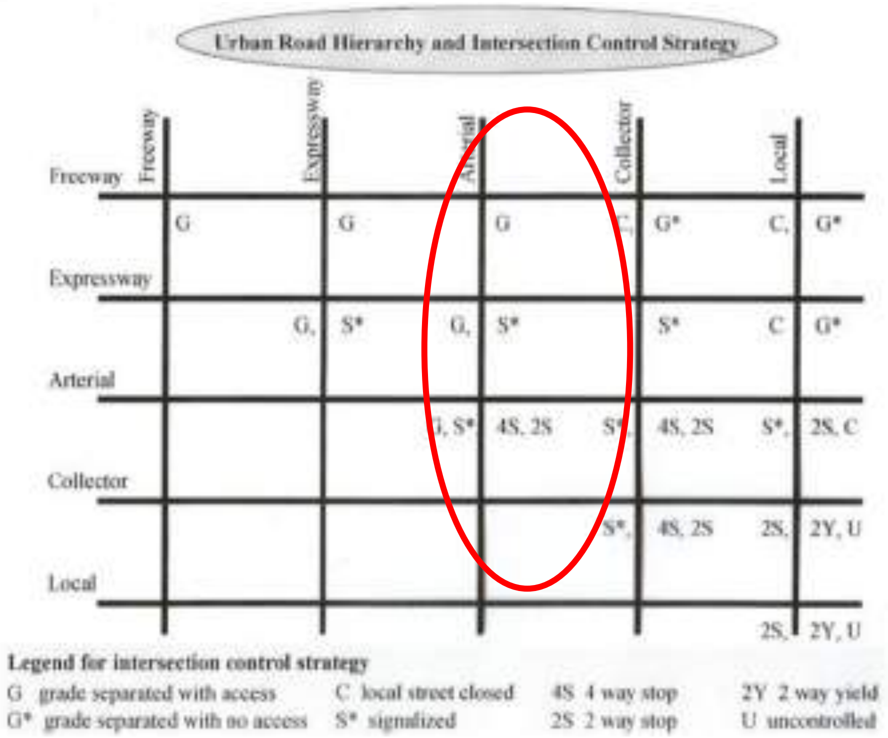


Figure 11.4: Access Management and Control Methods

- All intersections with N-S highways and other arterial roads of strategic importance will have traffic lights;
- All traffic lights must have protected RT phase and fully protected pedestrian phase. This means left turn arrow will have early cut off or late start to allow safe pedestrian movements.
- Free left turn slip lanes will not be permitted normally. Where required by capacity or other considerations, pedestrian crossings at slip lanes will be signalized;
- Major four-way intersections with through movements will not be permitted without traffic lights in any circumstances. It is very dangerous (as well as very inefficient due to nosing of vehicles on minor roads with give way or stop control signs) for RT and T vehicles to cross four lane main roads (five / six or more lanes where additional turning lanes are provided);
- Two stage pedestrian crossings will be considered as far as possible at all signalized intersections;
- Grade separation is considered where warranted by traffic analysis or where policy decisions are made by the Department to do so;
- Interchanges will be Considering users' poor discipline and understanding of road rules, intersections are simplified by terminating all service roads at intersections (except where grade separations are provided);
- Access to pedestrians at mid-blocks of main road will be provided only at designated pedestrian crossings, Priority will be given to install mid-block signalized pedestrian crossings;

- Zebra crossings, for sake of safety of pedestrians, are not provided on multi-lane highways (drivers from far lane cannot see pedestrians on zebra crossings putting pedestrians at significantly high risk), it is not permitted in many countries with good safety performance. If absolutely necessary, raised pedestrian crossing (wombat crossing) with adequate warning and safety measures (e.g., transverse rumble strip, saw teeth white painting, enhance illumination, yellow flashing lights and other warning traffic signs, reduced speed) will have to be considered.
- Selected ITS devices may be considered additionally to ensure safety of vulnerable road users.

11.3.2 Driveways

In terms of infrastructure, all driveways are exclusively connected to service roads only. All direct accesses to the highway from service roads are closed in the proposed design. All entries to, and exits from, the highway is regulated and are exclusively operated in left in and left out (LILO) mode). Crossing, right turning and U-turning movements at highway with four lane roads from these service roads are to be totally banned since the gaps between the vehicles stream along the highway are very low. If these movements are allowed, traffic in the highway will have to stop, which should not be the case unless at designated places. These designated places can be either signalized intersections (at urban sections) or specifically designed / provided U-turn facilities.

Regarding the operation and management, local residents, business owners as well as regular users of the highway would have to be informed about the benefits and needs for such arrangements. Marketing and communication strategy should go side by side with the infrastructure development if the built infrastructure is to serve the community better. Such roads developed with the aim to separate local traffic with through traffic by using service roads are new to many road users. Many traffic signs and line markings introduced for the safe and efficient operation and management of traffic are also to be understood by road users. Flyers can be distributed and roadside campaigns organized for this purpose towards opening of new facilities. It can be conveniently done in the Social Action Plan. For instance, reversing from driveways into service roads should be discouraged and the movement will be permitted only in exceptional basis (to be determined on case-by case basis). Parking on service roads is also to be discouraged or regulated depending on traffic volume and frequency of entries to and exits from highways, bus stops, and the length of the service road at any section. Management of driveways and service roads as well as traffic operation need to be continually reviewed by the Department after the widened road is open for traffic.

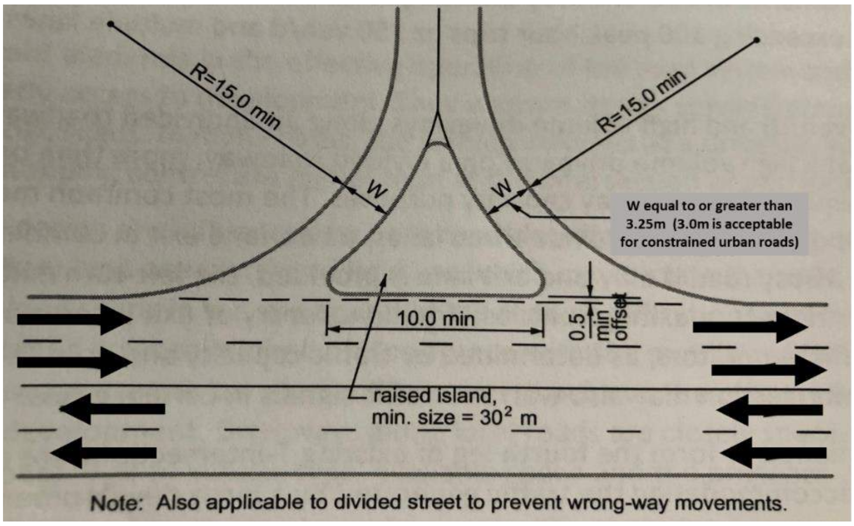
Line marking, designation of stops for local bus service, taxi and three-wheeler ranks and other operational features are identified and delineated in the plan. It is not customary to do centre line marking along the service roads, most of them being with intermediate lane. Double line parking along busy service roads even for short duration where allowed is to be considered as traffic offence and local government should be authorized to issue parking tickets to offenders. No stopping signs are erected closer to the intersections and interchanges where service roads terminate due to the need to provide on- and off- ramps to and from flyovers. Terminal treatments are designed for enabling vehicles to turn around. These are indicated in the plans and typical drawings. Edges where parking is prohibited are marked with yellow continuous line backed up by appropriate “No parking” traffic sign). Yellow bus boxes are painted on service roads at designated bus stops. Bus stops are not meant to wait for passengers, they must leave as soon as alighting and boarding is over. It is the proposal of the road safety engineer not to provide indented bus bays / stops along the main highway passing through the urban areas. In rural areas, these are sufficiently pushed behand with full separation of passengers from moving traffic. In urban areas with service roads, buses from the highway enter into service roads from the designated exits and enter into the highway from designated entries. Without rules of operation, enforcement including penalties, use of new facilities will be chaotic and benefits from the improvement of the facilities will not be realized.

All essential traffic signs (regulatory, warning, direction, informatory), road markings and painting are shown in the plan. These are taken from Nepal Traffic Sign Manual. Where special signs and marking not included in the NTSM are used these are shown separately in the drawing sets with full dimension.

11.3.3 Minor Intersections

Two types of minor intersections are provided. The first is three-legged (Tee) and the second is four-legged (Cross). These minor intersections are all ROW rule controlled or sign controlled. These are provided where traffic volumes along minor roads are relatively low and right turning traffic to the East West Highway and volume of traffic crossing (in case of four-legged intersections) the East West Highway is low and can be managed by forcing them to do left turning manoeuvre followed by the U-turning manoeuvre before they are dispersed to either opposing minor leg (in case of traffic otherwise needed to cross the highway - four legged intersections) and straight to opposite direction along the highway (in case of traffic wishing to turn right either from three- or four-legged intersections.

All minor intersections along rural sections without service roads, whether these were three legged or four legged intersections before the design, will be exclusively turned into three-way intersections with LILO operation after the design of the highway. Each such intersection is designed in an integrated manner with U-turn facilities downstream of the intersections. U turn facilities are necessary to complete crossing and right turning manoeuvres which are banned for ensuring safety of motorists. Openings at median separation are not permitted at minor intersections. The aim is to prevent banned unsafe movements (right turning and crossing). Left in Left out (LILO) movements are enforced by carefully selected geometric parameters. (See **Figure 11.5**). Additional road safety treatments and regular traffic signs and line marking as per standard NTSM are implemented. The proposed design with Splitter Island also prevents motorists and motorcyclists to enter into wrong direction.



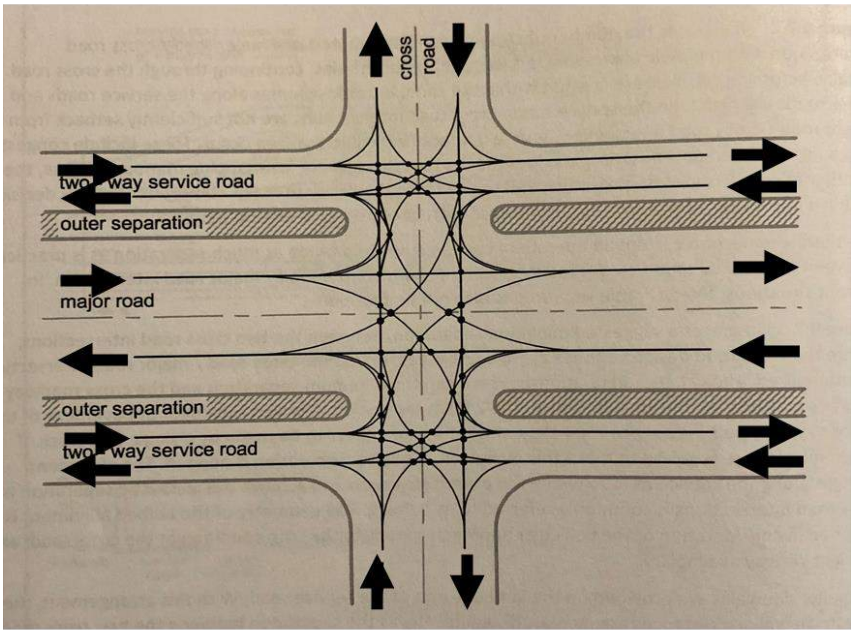
(Source: TAC 2017, revised for traffic requiring to keep left)

Figure 11.5: Right Turn Restrictions (shown for undivided road but equally applicable for divided road)

Along the urban sections where service roads are provided, safety treatment of minor intersections is different. All roads which intersect the highway forming T-junctions or Y-junctions or similar are terminated at service roads. All vehicles from side roads are banned from entering into the highway directly at intersections. This is done so to physically prohibit dangerously unsafe movements such as right turning and crossing. Raised outer separation just ensures these movements would not happen.

By banning direct movements for sake of safety, we are not closing access to, and egress from, the highway to minor side roads. People can still have access to highway. The only difference is that motorists and motorcyclists are to find alternative ways that are proposed in the design. It is believed that a bit of extra travel is worth for enhanced safety. Enough directional signs are proposed to guide drivers and riders where they can enter to, or exit from the highway. As shown in the plan, motorists and motorcyclists from side roads are required to enter into the service road (left or right) first and find the designated access / openings to access the highway and turn left only (median separation stops from making illegal right turns). Depending on the direction of travel, they can proceed ahead or they change to the inner lane safely and find U-turn facility provided at strategic locations to get into the other direction of travel. This arrangement will ensure elimination of highly risky conflicting manoeuvres, remove the concentration of conflict points and convert more risky manoeuvres to less risky manoeuvres. The arrangement also improves travel time and results in efficiency. “Nosing”, which is main problem of congestion and inefficiency at intersections is addressed. Nosing should also be addressed by enforcing “Give Way” rule (Refer Draft Nepal Road Rules 2016). In terms of exits from the highway to access the side road, motorists and motorcyclists are required in the similar fashion to find the designated opening to service roads before they can turn left to their required side road. Acceleration and deceleration lanes are also proposed additionally were indicated but are not essential safety features.

Figure 11.6 illustrates the concentration of conflict points at the intersection of side roads with service roads and main highway. Such a concentration of conflict point does not help to make the intersections safe nor efficient, unless we implement traffic light with complex phasing scheme. Lessons learnt from the intersections in Madan Bhandari Path and Ring Road of Kathmandu have been considered in the design of intersection in the highway.



(Source: TAC, 2017, modified for traffic requiring to keep left)

Figure 11.6: Crossing Conflicts at Intersections with Two Parallel Two-Way Service Roads

While it is possible to make all minor T-intersections to LILO operation to, and from service roads, along the urban sections too as in rural sections, LILO operation is not proposed at this stage in absence of turning movement data. It is recommended that the Department's Divisional Offices closely monitors the operation of each intersection after the upgraded highway is opened to traffic at least for the first year and change the intersection control strategy.

Locations of minor intersections along the urban sections as identified during the detailed design stage will be included in the final report.

Each intersection can be slightly different – some with Splitter Island, others with additional channelizing islands, but most of them are simple un-channelized T-type or Y-types. In principle, whenever the traffic volume at the intersection exceeds the threshold volume for a simple intersection, it is required to move to partial or full channelization. However, physical constraints do not allow for the upgrade. Only basic and essential road safety measures are incorporated in the design. Over time as the traffic volume on the highway and side road increase, minor intersections may be upgraded gradually to the ultimate at-grade intersection with signal control. The actual design is determined by the available right of way along the side road and on sight triangles. It is not possible to develop site specific design for each location. It is customary to ask the contractor to develop shop drawings during the construction and engineer can approve these specific designs.

11.3.4 Major Intersections

When the minor road intersecting major road represents a major arterial or minor arterial type of strategic network with significant volume of traffic, the capacity and safety management strategy involving reducing crossing conflicts by way of converting them into diverging conflicts (left turn), weaving conflicts (lane changing) and merging conflicts (after U-turns) may not serve the intended purpose. In urban sections, use of service roads to handle high volume of crossing, left turn and right turn traffic will not be acceptable.

Where an arterial or sub-arterial road meets the East West Highway at locations with predominantly rural environment (without service road), safety and capacity are managed by one of the following intersection treatment types:

A. Case 1: Uninterrupted Flow Conditions

Intersections carrying light crossing and turning volumes are operated in uninterrupted flow conditions. **Table 11.2** shows the maximum traffic volume (total of all two-way turning and crossing on one approach) for uninterrupted flow conditions.

Table 11.2: Intersection Capacity - for Uninterrupted Flow Conditions

Major Road Types	Major Road Flow (veh/hr)	Minor Road Flow (veh/hr)
Two-lane	400	250
	500	200
	650	100
Four-lane	1000	100
	1500	50
	2000	25

Note: Threshold volume combinations for two lane road included for additional information
(Source: QDTMR 2006)

Such intersections are designed without carrying intersection capacity analysis (SIDRA INTERSECTION) and in such cases, intersections approaches are not flared, additional turning lanes are not provided. Separate left or right turning vehicles may be added to the major road for safety reasons or for future provision. At this stage, since, neither the traffic count nor the crash data are available for the design, no turning lanes are provided. There is no channelizing or any splitter islands at such intersections. In other words, a simple intersection without partial or full channelization is the recommended solution. Exception applies to the situation where the TA Project has identified intersection as a black spot and remedial measures are suggested. These intersections if any are designed as proposed by the TA Project and remedial measures are included in the design.

B. Case 2: Interrupted Flow Conditions

When the volume of traffic is expected to exceed (best guess estimate in case of no traffic count) the specified threshold values as above**,** intersections are channelized (partially or fully depending on specific site situations and associated ROW constraints). International practice is to carry out capacity analysis of the intersection in the un-signalized state to achieve the desired gap acceptance and delay criteria. Delay is the measure of the Level of Service too.

Capacity analysis is undertaken for those major intersections where traffic count data are available. SIDRA INTERSECTION 9 is used for the analysis. In case there are no traffic count, major intersections are identified on the basis of consultation with the Department. In rural sections, only a limited number of intersections are signalized. The selection is based on several practical considerations such as presence of pedestrians, past history of crashes, importance of the minor road and consultation with key stakeholders.

It is recommended though that the Department monitors the safety and delay performance of all critical intersections and plans for signalization over time. It is not desirable to leave the intersection un-signalized when it starts experiencing uninterrupted flow conditions.

In terms of urban sections, all major intersections are proposed for signalization. This is because of the need to ensure pedestrians are able to cross multilane roads safely in controlled environment. Where intersections are spaced very closely (less than 500m or so), these can be left un-signalized provided there are median fencing to prevent pedestrians from jay walking.

Type of intersections and reference to relevant details can be seen from the respective plan and profile sheets.

Schedule of all major intersections (un-channelized, channelized and signalized) proposed along the road shown in Table: 11.3 below.

Table 11.3: Schedule of Major Intersections

S. No	Chainage	Type of Junction	Nearby Location
1	590+100	Signalized Three Way	Butwal Municipality Road, Butwal
2	592+820	Channelized Four Way	Santi chowk
3	602+210	Channelized Three Way	Jharbaira Chowki
4	605+710	Signalized Three Way	Kalauni, Saina Maina
5	607+570	Channelized Three Way	Basgadi, Saina Maina
6	611+250	Channelized Three Way	Bansgadhi Bridge
7	613+950	Channelized Three Way	Fireline (Way to Lumbini)
8	625+720	Signalized Four Way	Bangai Chowk
9	634+540	Channelized Three Way	Towards Taulihawa (Gorusinghe)
10	634+940	Channelized Three Way	Gorusinghe Arghakhachi Chowk
11	639+000	Channelized Four Way	Buddhi Chowk

Recommendation of the NRS 2070 regarding the selection of the type of intersections is not considered since it is believed that (a) safety is not taken into account and (b) ADTs throughout the East West Highway exceeds the threshold ADT for all at-grade intersections implying that all intersections are to be grade separated (rural sections). The chart given in the NRS 2070 is applicable for ensuring free flow conditions for highways and high level of service (LOS). This chart is not to be applied for urban sections and where pedestrians are present which interrupt flow. Further, for situations with budget constraints, ensuring free flow condition along the entire rural sections is not always practical. Safety should be the main consideration though.

NRS 2070 does not provide any guidance on the warrants for signalization. On the other hand, traffic signal is the most frequently used and effective form of intersection control from safety as well as operational efficiency considerations. In urban sections, traffic signal is the most important type of safety treatment for protecting vulnerable users like pedestrians, elderlies, children and pedestrians with disabilities. Compared to civil infrastructure (flyovers), traffic lights are low-cost safety solutions for intersections. Fly overs, interchanges (grade separated intersections), under- or over-passes are the ultimate capacity and safety solutions.

Traffic signals are proposed (a) to safely manage vehicle and pedestrian conflicts and (b) to improve operational efficiency. Following warrants for signalizing intersections are proposed for the Project[4].

a) **Traffic volume:** When the major road carries at least 600 veh/hr (two way) and the minor road concurrently carries at least 200 veh/hr (two way) on one approach over any 4 hours of an average day.
b) **Continuous traffic:** Where traffic on the major road is sufficient to cause undue delay or hazard for traffic on a minor road. Traffic on minor road will not get enough gaps when the major road carries 900 veh/hr (two way) or more and the minor road concurrently carries 100 veh/hr (two way) on one approach, over any 4 hours of an average day. This warrant applies when no alternative and reasonably accessible signalized intersection is present on the major road which will break platoon in the traffic stream along the main road.
c) **Pedestrians:** To help pedestrians cross a road in safety, signals may be considered when over any four hours of an average day, the major road carries 600 veh/hr (two-way) and 150 ped/hr or more cross the road. If a central median is available, pedestrians can move through traffic in two separate movements. A median width of 1.2m is the absolute minimum required to stage pedestrians and 1.5m is a more desirable minimum. In such cases the traffic volume warrant on the major road can be increased to 1000 veh/hr (two-way) over any four hours. Where the 85th percentile speed on the major road exceeds 70km/h, the 600 veh/hr and 1000 veh/hr traffic volume warrants should be decreased to 450 and 750 veh/hr respectively.
d) **Crashes:** To reduce crashes, signals may be considered if there is a 3-year average of 3 or more reported crashes per year of a type which can be eliminated or reduced by traffic control, and the traffic volume is at least 0.8 times the volume warrants given

[4] Road Planning and Design Manual, QDTMR, 2006

in (a) or (b). While installation of traffic signals will reduce the overall crash rate and relatively severe right angle and right turn against crashes, the number of crashes of another type may increase (e.g., rear-end collisions). Signals should only be installed if simpler devices will not be effective in reducing the crash rate.

e) **Combined factors:** In exceptional cases, signals occasionally may be justified where no single warrant specified above is satisfied but where two or more warrants are satisfied to the extent of 0.8 times or more of the stated values.

11.3.5 Grade Separation

Interchanges are not proposed in B-G Section. Such facilities are not warranted based on our experience. The use of an interchange is a valid solution and should be proposed if and only if significant capacity constraints are experienced by at-grade intersections. In addition to traffic volume (capacity constraints), a number of additional warrants such as functional classification of intersecting roads, safety (desired form of control), topography, user benefits, capital cost are used to justify the need. At times, strategic policy decision, client's appetite also play a role in the provision of interchanges (fly overs).

Many forms of flyovers/ interchanges are possible at any intersection sites – from a simple overpass or underpass (just limiting flow of crossing traffic with no provision to change from one road to the other) to full free flow turning interchanging ramps (for example, full cover leaf). The selection depends primarily on the availability of ROW. In existing built environment with tight restriction on available ROW, such as along the project road, Signalized Diamond Interchange (SDI) is the most suitable type of facility and can be recommended for consideration in future. Where feasible, DoR may wish to acquire land where and when opportunities are available.

The Consultant has received policy directives from the Department to provide a couple of underpasses along the proposed road. These locations are included in Table 11.4. The Consult holds the view that underpasses and over-passes are to be the first items to be considered for exclusion if there is any need to reduce the cost.

Table 11.4: List of Underpass

S. No	Chainage	Type of Junction	Junction Name
1	592+302	Underpass	Jitgadhi Chowk
2	594+450	Underpass	Nayagaun Chowk
3	597+100	Underpass	Tamnagar Chowk
4	602+895	Underpass	Murgya Bazzar
5	604+235	Underpass	Buddhanagar Chowk
6	620+362	Underpass	Charnumber Chowk

11.3.6 Road Rules on Access Rationalization and Control

Road infrastructure is to be planned and designed with due consideration for safety. Infrastructure is only one part of the road safety solution. Safety cannot be improved by infrastructure alone if road users do not know how to use the infrastructure correctly. This requires road rules be developed in tandem with the new infrastructure and safety campaigns launched at the time new road is opened to traffic and on regular (at least annually) basis.

MVTA and MVTR provides legal basis for designing roads and regulating its use. Regulation includes in the areas of access rationalization, management, movement permit, control, enforcement and penalties. Draft Nepal Road Rules[5] is a supplementary document that explains in details on how roads are to be used safely. At this stage it has no legal status. However, it is a very useful tool for ensuring safety of all road users. Safe use of roads also improves efficiency. Some key road rules are:

- Rules for making left turns (Division 1 Part 4)
- Rules for making right turns (Division 2 Part 4)
- Rules for making U-turns (Division 4, part 4)
- Rules for changing direction and using stop signals (Division 1, 2, Part 5)
- Rules on using traffic lights and traffic arrows, (Division 1, 2, Part 6)
- Rules for giving way (Part 7)
- Rules on following traffic signs and road markings (Part 8)
- Selected rules on prohibition of parking and stopping (Part 12)
- Regulation on kerb/ street parking (e.g., Division 2, Part 12
- Prohibition of stopping and parking on yellow bus box (Division 5, Part 12)
- Rules on the prohibition of reversing from driveways into the service roads (Division 3, Part 7);

11.4 Speed Management and Control Measures

Analysis of crash data undertaken during the NRSS development shows that 'over-speeding' is the second major cause of road crashes contributing to about 10% to 15%6. Driving over the safe speed limit is the primary contributing factor for many roll-overs, hit object, hit pedestrian, departure to the left (run away) and departure to the right (e.g., head-on), rear end, over-turning and many other types of crashes leading to multiple fatalities and serious injuries. While "over-speeding" is primarily behavioral problem and has to be addressed through large scale community outreach programs, several opportunities exist to reduce the number and severity of road crashes by implementing various interventions on infrastructure front. Installing speed limit signs, speed calming measures, forewarning of sharp curves, development and application of speed limit review process in the implementation of safe and appropriate speed limits and ITS technology for the detection of speed limits are proposed for managing speed and its control and enforcement.

In absence of any formal strategy for speed management and control on roads in Nepal as well as any process for speed limit review along the road over the life of the road operation,

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[5] Parajuli P., Draft Nepal Road Rules, KSUTP 2016

[6] PwC, Draft National Road Safety Strategy, DOR, 2021.

motorists are free to drive with the speed they want. There is no practice of determining appropriate speed limits and posting of speed limit signs to make motorists legally binding. Speeding tickets are issued by the Traffic Police on ad-hoc basis.

Roads are designed with the speed higher than the speed that is safe for all users. Design speeds are not the same as posted speed limits or safe operating speeds. No consideration is given on the presence of vulnerable users and mixes of traffic in the selection of design speed. Classification of roads and terrain are the only consideration in the selection of design speed. Design speed is confused with a safe speed limit and design engineers do not give attention to the need to implement reduced speed limits where vehicular traffic mixes with pedestrian traffic. Speeding is #1 killer in most roads. Inappropriate and unsafe speeds are encouraged and signing of speed limit, enforcement of speed limit by design measures are not considered in many cases. Motorists drive at speeds they want to drive. It is not clear on what are the legal speed limits on roads beyond which motorists are given speeding tickets in absence of the speed management strategy.

This Section describes various measures that have been implemented in the detailed design of the subject section of the highway in order to reduce fatal and serious injury crashes (FSIs) resulting from inadequate speed management and control leading to encourage motorists to drive at higher speed than it is safe for the road use environment. All suggested measures are informed by the draft National Road Safety Strategy and draft National Road Safety Action Plan and are consistent with the draft National Road Safety Policy. When implemented, these measures support the delivery of the desired road safety output/ outcome targets set by the Government.

11.4.1 Basic Principles

Measures for speed management and control are based on the Safe System approach. This approach has been used with a renewed level of ambition, and incorporates research and ideas from both international and local road safety practitioners.

Speed management and control related interventions proposed in the design are coordinated externally across multiple road safety pillars of the Safe System as well as internally within the Safer Speed Pillar of the Safe System. Measures suggested for inclusion in the design are mostly, if not all, based on the Draft national Road Safety Strategy and national Road Safety Action Plan. Thus, the basic principles employed in recommending measures to reduce road crashes due to speeding are consistent with the national policy and strategy soon to be formally adopted by the Government.

Speed management and control measures involve interventions in Engineering, Education and Enforcement fronts. While the design of roads essentially focusses on the engineering measures, this does not imply that measures in other fronts are ignored. Role of interventions in education and enforcement is very important for engineering measures built into the design work effectively. Some of the education and enforcement measures require engineering facilities such as roadside traffic safety awareness signs/ billboards with right messages, speed cameras (both covert and overt types), CCTVs, VMSs, VLSs. Enforcements can also be made more effective by various LATM measures. Some of these measures are incorporated in the design and described later in this Section (Section 11.4.5).

Internationally, the practice of posting legal speed limits is being switched from the principle of using 85th percentile speed to safe and appropriate speed limits based on the results of risk analysis. Higher the risk to road users, lower is the signposted legal speed limit. This new approach comes from the Safe System approach for managing road safety. National Road Safety Strategy and Action Plan 2021-2030 also envisages the use of this approach in Nepal. Accordingly, the recommendation to signpost speed limits along the subject road section as discussed below is considered to be consistent with the Government's policy on road safety.

11.4.2 Posted Speed Limits (PSL)

The practice of installing posted speed limit (PSL) signs including repeater signs (to remind drivers of the legal speed limits) does not exist in Nepal. Absence of the requirement of signposting speed limits by road agencies keep enforcement agencies in difficult position (legally weak) to issue speeding fines. Design speed is not the same as the posted speed limits. Motorists are not concerned with and, in fact, do not know the design speed. If a speed limit, on the other hand is posted with the sign, they are legally required not to exceed this speed. This is the international practice and it is followed in the design of the subject road. Road safety standards specified earlier in Chapter 11 (Section 11.2.3) specify measures in five key areas and these measures are incorporated in the design. There are also certain overlaps in the measures for reducing speed management and control and measures for reducing run off the road crashes as well as other types of crashes.

Irrespective of the design speed, all urban sections of the subject road are signposted with 60 km/hr speed limit signs. Speed along all sections of service roads is limited to 30 km/hr. All rural sections are 80km/hr signposted unless otherwise specified specifically for certain high-risk sections. Some rural sections may have large number of stocks / animals using the road and there could be many bullock carts using the shoulder. Such sections, if identified during the design stage, will be proposed for signing reduced speed limit to manage risks related to speeding. Repeaters speed limit signs are proposed to reinforce speed limit enforcement as follows (provisions from international practices7 modified to suit local use environment).

[7] QDTMR, Manual for Uniform Traffic Control Devices, Part 4: Speed Control, 2003 Edition, Eighth Issue, 2015.

Table 11.5: Recommended Speed Limits and Spacing of Speed Limit Repeater Signs

Speed Limit	Spacing of Repeater Signs	Criteria and Comments
30 km/hr	0.5 km	Over time, once community understands the concept of default speed limits for service roads / local roads, posting of speed limit signs (includes repeater signs) is not required.
50 km/hr	NA	To be installed 300 m before the intersections on all urban sections and all rural sections without traffic signals
40 km/hr		Where the highway in rural sections passes through school zone and highways in rural sections do not have signalized pedestrian crossings for school children
60 km/hr	1.0 km	Over time, once community understands the concept of default speed limits for urban roads posting speed limit signs (including repeater signs) is not required
70 km/hr	1.5 km	For rural sections of roads where risk is relatively high. This is also the default speed limit of the East West Highway in rural sections
80 km/hr	3.0 km	For rural sections of roads where risk is relatively low

Note: NeRSAP can be used for guidance[8]

For the benefit of the drivers which have turned from a road with speed limit different than that of the East West Highway and vice versa, repeater signs are placed at a suitable distance beyond the intersection (20-40m). Where merged lanes / diverge lanes are provided, repeater signs are placed at least 20 m past the end of the taper section.

Repeater signs are placed on both sides of the roadway on the East West Highway (with medians). On side roads without medians, these are placed only on the left side.

Speed limits do not have to remain the same as posted at the opening of the road for traffic after construction. The suitability of the posted speed limits is to be continually reviewed. As the road use environment changes so the speed limits.

With the installation of speed limit signs or introduction of the concept of default speed limit of 30 km/hr on service roads/ local roads and 80 km/hr default speed limit for highways with median separator in rural sections, it is possible to reduce the cost of installing speed limit

[8] PwC, Nepal Road Safety Assessment Program (NeRSAP) Users' Guide (Draft), DOR, 2021

signs. Installation of speed limit signs helps enforcement agencies to define what constitutes "speeding". It empowers police officers to issue speeding tickets.

11.4.3 Speed Data Speed Limits (SDSL)

The SDSL is the speed limit that is determined through analysis of speed data for the speed zone that is under consideration. This speed is representative of the general perception of a reasonable travel speed on a particular section of road or network of roads. The mean speed, 85th percentile speed, upper limit of the 15 km.hr pace, and the percentage within the pace are determined using a standard speed survey and calculation procedure involving statistics.

In absence of data from speed survey, it is not possible to establish SDSL for the subject road. This aspect is mentioned here only for the completeness of the speed management and control process.

11.4.4 Risk Assessed Speed Limits (RASL)

In the past, speed limits on roads were determined based on 85th percentile speed or the upper limit of the 15 km/hr pace Both method gives approximately the same prevailing speed adopted by the majority of drivers on the road. The recent trend is to determine safe and appropriate speed limits based on risk management principles in accordance with Safe System Approach. NeRSAP developed as a part of the TA-9604 Project can be used to assess road risk score and establish corresponding Risk Assessed Speed Limits (RASL). RASL can be established for existing roads using NeRSAP. For new roads, it is considered that the risk is managed fully by incorporating appropriate safety measures and posted speed limit is established either using design speed (design speed – 10km/hr) or from the set of Criteria Based Speed Limit (CBSL) (See below).

11.4.5 Criteria Based Speed Limits (CBSL)

Criteria Based Speed Limits are determined in accordance with specific criteria for each type of road and road use environment. In absence of any formal speed limit review process being used in the country and absence of any guidance, speed limits as recommended in **Table 11.6** are used for sign posting. These speed limits meet specific criteria capturing road type, land use, and potential risks.

Schedule of the recommended posted speed limits for safety risk management along the main road is given in **Table 11.6.** These are mainly based on the CBSLs of **Table 11.5.** It is proposed that NeRSAP be used to assess risks and speed limits recommended in **Table 11.6** be updated continually as a part of road operation after the widened road is fully opened for traffic. By this time, it will be possible to assess infrastructure risks based on what safety measures recommended in the design are incorporated and what not. The speed limits recommended in the Table are for the opening stage. As is the international practice, suitability of any initially posted speed limits are to be re viewed every three to five years depending on the rate of changes in road and traffic environments.

Table 11.6: Recommended Speed Zones

S. No	Sections of main road (Chainages)		Recommended	Length	Comments/ Explanatory Notes
	From	To	PSLs (Km/hr)	m	
1	589+880	591+600	80	1720.00	Rural Area
2	591+600	595+780	60	4180.00	Urban Area/Huge settlement
3	595+780	601+860	80	6080.00	Rural Area
4	601+860	603+420	60	1560.00	Urban Area
5	603+420	626+000	80	22580.00	Rural Area
6	626+000	626+880	60	880.00	Urban Area
7	626+880	635+160	80	8280.00	Rural Area
8	635+160	636+480	60	1320.00	Small Urban Area
9	636+480	640+220	80	3740.00	Rural Area

Note: Speed at service roads is limited to 20 km/hr

Proposed posted speed limits along the entire section of service roads are 30 km/hr (shared zones and special time period/ hat bazar days, for instance, are accepted). Following the introduction of the concept of default speed limits in the VTMA / VTMR, installation of speed limits for service roads will not be needed thereby saving cost for the installation and replacement of signs.

Speed limits at short sections such as sharp bends, approaches to intersections with inadequate sight triangle etc., are managed by advisory speed limit signs and risks managed by other safety measures. It is not possible nor is the practice to install reduced posted speed limit signs as frequent changes in speed limits are also not desirable from safety perspective. For this reason, minimum lengths of speed zones are also specified in other countries. This has not been done so in this Project but may be considered by the Department at the time of implementation.

11.4.6 Speed Limit Review

Over time, road use environment is bound to change. Land use along the road corridor may change from rural to semi-urban or urban type. Many accesses may be added, Volume of pedestrian traffic may increase. These and other changes could be the new predictors of risks. The functional classification of road may itself change.

International best practice of speed management and control is that suitability of sign posted speed limits recommended during the design stage be reviewed at least every 3-to-5-year interval depending on the rate of change in development along the road corridor.

11.4.7 Speed Control Measures

Following speed control measures are selected and recommended for implementation in the design. These are in addition to basic initiatives such as establishing safe and appropriate speed limits and installing posted speed limit signs. Speed limit signs are installed at the beginning of each speed zone and at intervals as specified in **Table 11.5.**

In many situations, installing posted speed limit signs alone does not work well. Motorists ignore speed limits and traffic police cannot be present everywhere. Low speed environment is to be maintained along the entire sections of service roads. Speed limits are reduced at the approaches to uncontrolled intersections to reduce severity of crashes as well as at the approaches to pedestrian crossing (especially zebra crossings) by implementing various devices that force motorists to slow down. These measures are supplemented by other education and enforcement measures too.

Speed control measures used in the subject road are divided into the following three groups:

a) Engineering Measures
   - Round profile road humps at selected locations along the service roads.
   - Mini roundabouts and/ or mid-block splitter islands along the service roads.
   - Carriageway / lane narrowing (throttling) at selected locations of service roads.
   - Flat top road humps at selected locations along the service roads and along the rural sections of main roads (approaching zebra crossings).
   - Wombat crossings at selected locations along service roads and main roads.
   - Raised pavements.
   - Slow points (angled or straight) at service roads.
   - Centre blister islands for service roads.
   - Shared zone (street market area).
   - Intersections with raised platform with transverse rumble strips (suitable for both service roads and the main roads).
   - Transverse rumble strips at the approaches to uncontrolled intersections or raised pedestrian crossings for main road.
   - Gateway or township entry or threshold treatments for main roads.
   - Give way signs.
   - Stop signs.
   - Tactile surface treatments.

Location of these measures are shown in respective plan and profile sheets. Detailed drawings will be given in the final drawing file.

b) Education Measures

   Resource materials for education and awareness campaigns are already available in abundance. ADB TA 9604 Project has compiled all available materials in the country which are used in a pilot Road Safety Awareness Campaign in accordance with its TOR.

Behavioral survey was also undertaken to understand the current state of knowledge on road safety, attitude towards, and the actual use practice. The survey findings from, and resource materials developed by, the TA Project can be replicated and used for any planned road safety education and awareness campaigns along the subject road sections under this Project.

c) Enforcement Measures

No matter how safe the subject road is designed and constructed or road users made aware of safety matters, there would always be a few users who would like to take the traffic rules in their hand and tend to drive in an unsafe manner. Maintaining law and order on roads including monitoring and enforcing road rules and adhering to posted speed limits along the road is a routine task police officers are required to do. Speeding fines are issued based on the level of exceedance. Draft Nepal Road Rules suggested differential penalties and demerit points for speeding offences. VTMA and VTMR empower police officers to issue speeding fines on the spot. Surveillance needs to be increased once improved road is opened to traffic as in Nepal drivers tend to drive much faster with unsafe speed when road surface is new.

The design of road safety measures also incorporates the installation of a number of ITS devices. Project may consider the following depending on the level of sophistication it would like to introduce in Nepal. The selection is to be based on what is available in the local market, what can be affordable for the Project and what can be maintained and operated with the current state of knowledge on the technology. The actual type of devices, locations will be determined at the time of the review of the draft report and the estimate will be done and included in the final report.

- Variable Speed Limit (VSL) signs: The red circle will blink with the new speed limit against the regular posted speed limit (non-blinking red circle). The speed reductions may be called in by the traffic "accidents", inclement weather, road works (urgent repair or planned repair and maintenance) or any reason (e.g., mass protests, *julus*, or festival gatherings on road) which the asset owning agency (DOR) or enforcement agency (NPS) considers when the regular speed limit is unsafe. These signs can be combined with lane control signs installed on gantry girder depending on the site-specific circumstances.
- Rural Intersection Active Warning Signs (RIAWS): Coupled with the blinking "SLOW DOWN" electronic signs, RIAWS can be installed at the approaches to rural intersection with minor side road with a very low traffic volume. The reduced speed limit will be displayed in the main road upon arrival of the vehicle on the side road. The detector will notify the RIAWS of the vehicle in side road waiting to cross or right turn.
- Red light cameras.

- Speed cameras (Mobile Cameras, Covert Cameras, Overt Cameras, Point 2 Point, also called P2P Cameras, Automated Number Plate Recognition ANPR cameras).
- Road Speed Limiters, Electronic Data Recorders, and Alcohol Interlock Device: This is the matter for DOTM and NPS but DOR may make suggestions. The technology is available for use to control motorists and motorcyclists who are involved in repeated speeding offences.
- Various warning yellow signs with additional message to slow down.
- Variable Message Signs (VMS) of various types such as "Check your Speed", "Slow for Shyam", "Speed Cameras are in Use", "Go Slow Children Crossing Ahead".

11.4.8 Road Rules on Speed Management and Control

Speed management and control measures become effective only if motorists abide by road rules that are designed to enable them understand and follow speed limits as well as to empower police officers to enforce speed limits. Apart from active physical countermeasures (both civil and ITS infrastructure) that encourage or force (as the case may be) motorists to slow down, many sections of road are only have posted speed limit signs (static or variable). Road rules, VTMA and VTMR from which emanate powers for DOTM and NPS to implement on the road, support the road safety measures related to speed management and control.

Draft Nepal Road Rules 2016 in Part 3 details out the rules and regulations in detail regarding road users' obligations requirement in obeying speed limits and penalties in not following the posted (or default) speed limits. Some of the important rules from infrastructure delivery and usage perspective include:

- Obeying speed limits.
- Application of speed limit signs (static and variable) along a section of a road.
- Application of speed limits in a speed limited area.
- Application of speed limit in a school or children play area.
- Application of speed limit in a shared zone along service roads.
- Application of Speed limits for certain vehicles (bus trucks, tractors etc.)
- Application of speed limits elsewhere (sections of roads with default speed limit if any defined by the Government).

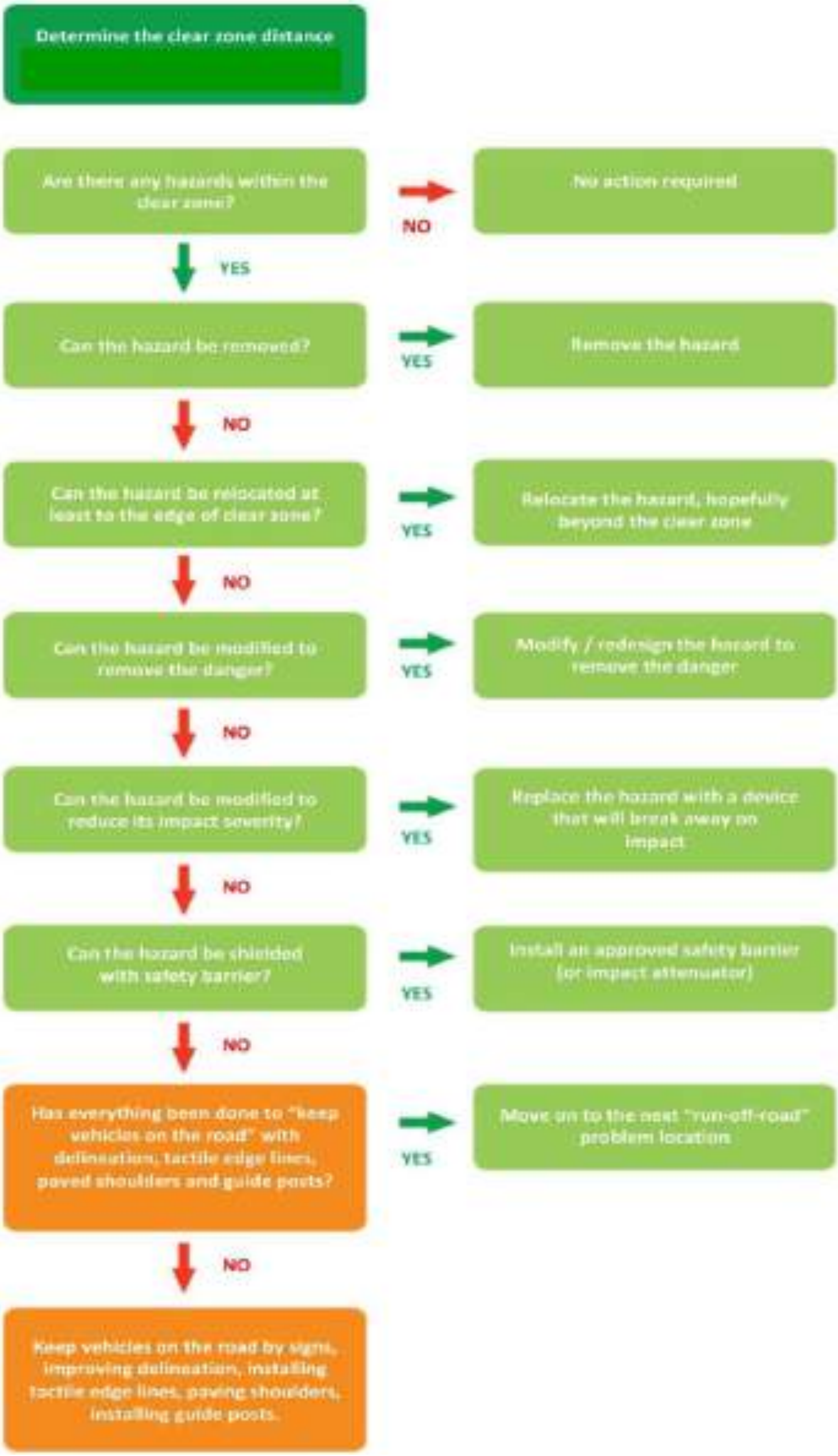
Nepal Traffic Sign Manual provides details on the size and shape of the speed limit signs but it does not provide guidance on the where, how and what speed limit signs should be posted on the road. Where guidance are not adequate, other international practices may be followed with certain customization.

11.5 Roadside Hazard Management Measures

Roadside departure/ Lane departure crashes (to left or to right) make up a significant proportion of total crashes in the country leading to many fatalities and serious injuries.

Installation of roadside barriers, median separations, hazard markers, hazard protection, hazard removal, ATLM along the edges and even along the centerline do not cost much compared to the other cost components of road yet these measures are omitted in the design of many roads in the past. The proposed design aims to incorporate most of these measures as much as possible. These are integral component of safer roads as envisioned by the National Road Safety Strategy and Action Plan.

Table 11.7: Flow Chart for Roadside Hazard Management[9]



[9] ADB, CAREC Road Safety Engineering Manuals, Manual 3 – Roadside Hazard Management

11.5.1 Basic Principles

Roadside hazards are managed best if hazards are identified and treated during the design itself. However, up until recently, design of roads mainly focused on the design of horizontal alignments, vertical alignments, plans, profiles, cross sections, bridges, culverts, side drains, pavements and other road ancillary facilities. Design of roadsides was usually ignored.

Following the adoption of safe system approach in road safety management, the issue related to how road and roadsides can be made more forgiving to road users' mistakes have got prominence in the design. It is now realized that roadside hazards are not something that are to be attended after the road will be put in operation, it should be an integral part of the design process. Many international design guides are now available for the design of roadsides.

Many reference materials are available locally and internationally for the warrant analysis and design of roadside hazard management measures. These are referred in the preparation of the design of roadsides and management of roadside hazards for this Project.

- TESU, Road Safety Notes 5 – Delineation Measures, DOR, Nepal, March 1996
- TESU, Road Safety Notes 6 – Safety Barriers, DOR, Nepal, July 1997
- TESU, Road Safety Notes 2 – Design of Safe Side Drains, DOR, Nepal November 1996
- TESU, Road Safety Notes 7 – Safety at Bridge, DOR, Nepal, July 1997
- Chiu, M., Clayton, C., Millen, G., et al., Geometric Design Guide for Canadian Roads: Chapter 7- Roadside Design, TAC, Canada, June 2017
- Veith, G., Guide to Road Design Part 6: Roadside Design, Safety and Barriers, Austroads, 2010
- Tziotis, M., Roper, P., Guide to Road Safety Part 9: Roadside Hazard Management, Austroads, Australia 2008

Following design principles are used in the provision of roadside design based on the review of these literature. The six-tiered approach in the design of safer roadsides and implementation of remedial measures involves:

Tier 1: Keep errant vehicles within the road (containment of vehicles away from hazards);
Tier 2: Remove hazards;
Tier 3: Relocate hazards;
Tier 4: Modify hazards;
Tier 5: Shield hazards; and
Tier 6: Delineate hazards (improvement of conspicuity of hazards)

The first step in making the road safer is to identify roadside hazards along it. This requires a clear definition of roadside hazard which ensure consistency. For this purpose, a concept of clear zone is introduced. Only those rigid hazards which are located within the clear zone are to be managed.

A roadside hazard for the purpose of this project is defined as any object with a diameter of 100 mm or more. Further, any other features such as un-drivable fill and cut slopes, deep side drains, vertical drops especially along valley side of hill roads are also roadside hazards. A long list of potential hazardous features is available in the above given reference materials. Differentiation is made between a point hazard and a continuous hazard since the preferred treatment for these two types of hazards can be different.

Clear zones are determined for main roads using the **Figures 11.7 and 11.8.** All hazards located within this zone proposed to either eliminate completely, or protect (shied) or delineate with conspicuous devices using the three-tiered approach. The process used in the selection and design of hazard management measures is given in **Figure 11.7.**

11.5.2 Features of Forgiving Roadsides

Roadsides are made forgiving by employing several measures. These include:

- Use of wide shoulders (paved, graveled or grassed) to enable errant vehicles to recover;

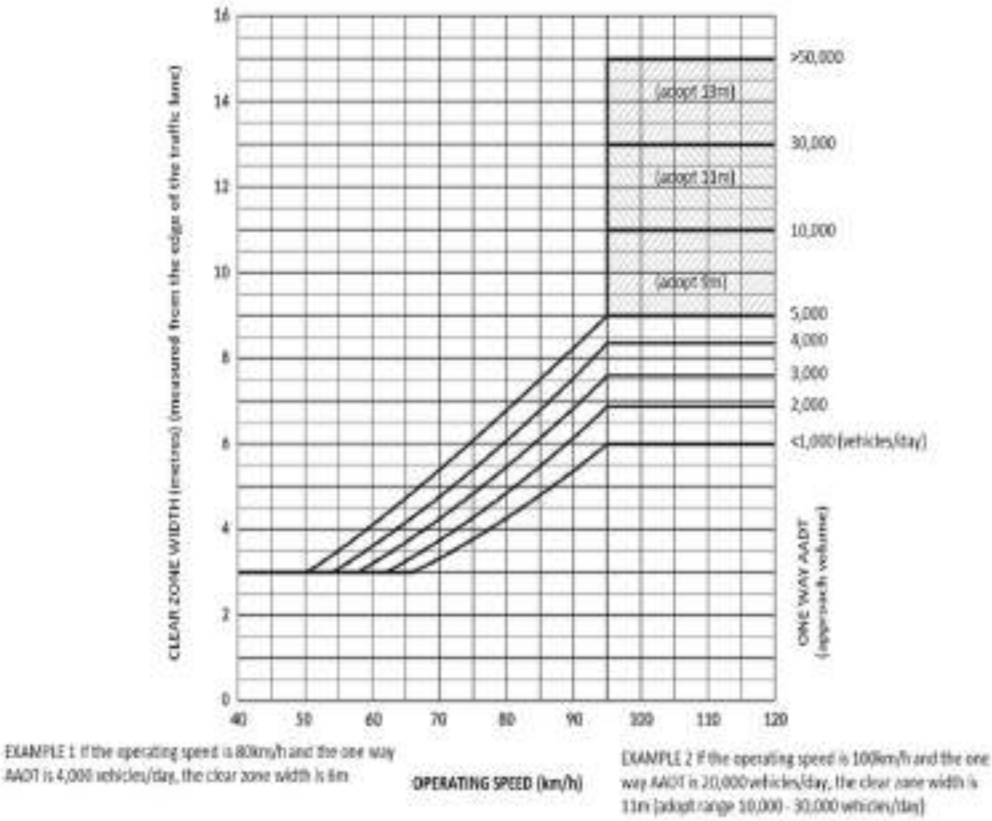


Figure 11.7: Clear Zone Chart

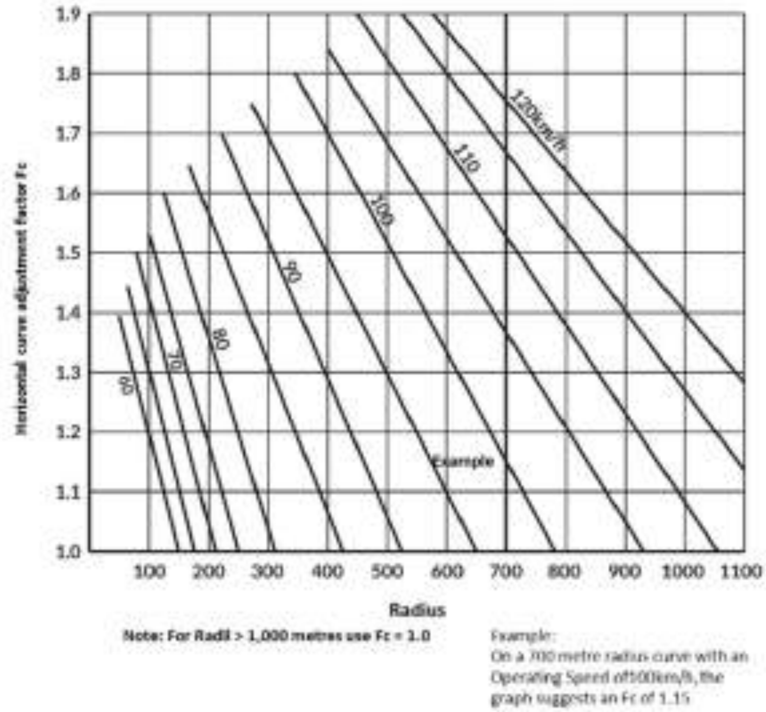


Figure 11.8: Clear Zone Adjustment Factors for Curves

- Use of drivable fill or cut slopes (1:4 and flatter) as much as possible to enable drivers to recover their vehicles;
- Use of tactile edge lines to warn motorists and motorcyclists in advance so that they have the time to recover;
- Use of various types of delineation measures (RSN #5);
- Use of frangible delineator posts with retro reflective marker plate on the top;
- Avoiding the use of deep open side drains and where necessary use of covered side drains (RSN #2);
- Removal of all trees of girth greater than 100 mm and rigid electrical and street light poles;
- Use of slip-based poles for street lighting poles and traffic sign posts as far as possible;
- Removal of trees and other hazardous rigid objects from within the clear zones;
- Use of safety barriers (RSN #6) (see below);
- Making bridges and approaches to bridges more user friendly with the provisions for proper curves for approach road alignments and cross-sections, pedestrians, parapets, delineation, safety barriers, signs and road markings (RSN #7)

Schedule of tactile edge lines along with the chainage wise locations will be given in the final report. Schedule of delineator posts along with their types (frangible poles, concrete posts, confidence blocks proposed along the subject section of roads will be given in the final report. Typically, these elements are proposed only along the rural sections, however, where the embankment is high (such as approaches to bridges, underpasses), tactile edge lines are proposed and shown in the plan separately. Other measures as needed are incorporated in the design and where applicable are directly shown in the respective plans.

11.5.3 Roadside Barriers

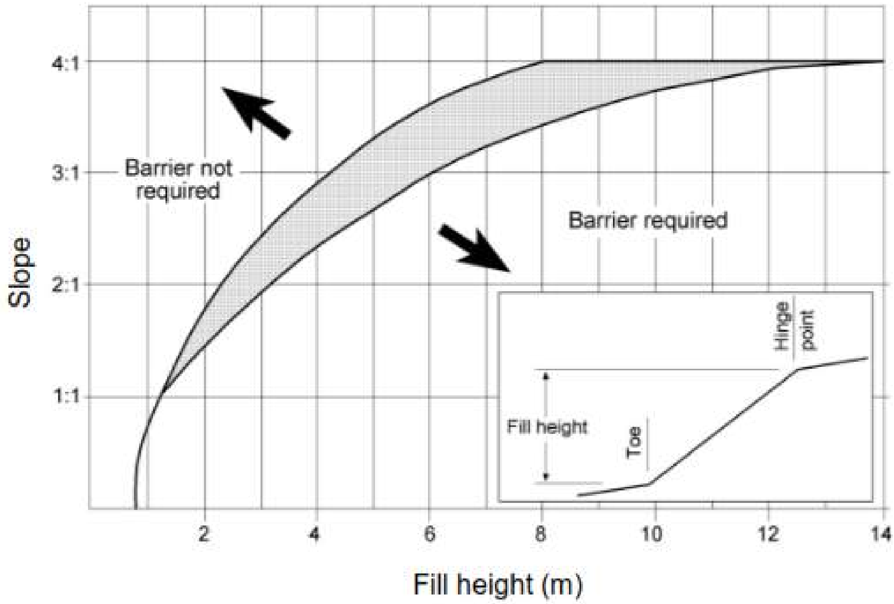
Where errant vehicles are likely to be exposed to serious risk of getting rolled over the high embankment slopes or plunging into the water bodies near roadsides, which could result in multiple fatalities or serious injuries (catastrophic consequences), safety treatments like wide shoulders, tactile edge lines or delineation by various devices such as frangible poles, delineator concrete posts, confidence blocks etc. alone are not adequate. Speeding errant vehicles must be fully stopped even if the vehicles get damaged and motorists get minor injuries. Roadside barriers are to be used in these situations to “forgive” the motorists and motorcyclists for their mistakes by containing them within the roadway. In absence of strong roadside barriers, the consequence of runaway vehicles can be severe to catastrophic.

Roadside barriers do not prevent from road crashes happening. It will only reduce severity. Roadside barriers can themselves be hazard, especially if these are not designed and installed properly. Timely maintenance of W-Beam barriers is also required for them to properly work and prevent from being hazardous to errant vehicles. Accordingly, priority is given first to manage safety using the measures under tier 1-3 measures.

Tier 4 measures involve shielding hazards. This is done in several ways. One most popular is the installation of roadside barriers.

Warrants for the installation of roadside barriers are determined using the chart given in **Figure 11.9.** RSN #6 provides guidance for the selection of roadside barrier types by material types in general. It does not relate to the level of risk and severity of consequences. This guidance is supplemented by the following thumb rules on the basis of the potential consequences from the risks of crashes (catastrophic, serious, major, and minor) as follows:

- Sections with fill slope steeper than 1:4 (V:H) and height of fill or drop of existing ground slope ≤3m:
  - In case if the retaining wall is of RRM (for example at the approaches to bridges), RRM or plum concrete continuous wall (allow for surface drain/ construction joints) are used; short blocks like those used currently on many hill roads are not proposed. These devices do not work as crash barriers but work only as confidence blocks to delineate motorists (Details as per RSN #6).
  - In case if the retaining wall is of gabion (for example at the approaches to bridges), gabion walls are extended to build roadside barriers on top of it (also to be continuous) (Details as per RSN #6).
  - In case if there are no retaining walls, one of those types (RRM or Plum Concrete) or RCC or steel beam are proposed depending on the available width for barrier construction.



(Source: AASHTO, 1996)

Figure 11.9: Warrants for Roadside Barriers

- A Sections with drop depth >3m but ≤ 5m:
  - o As above, but additional strength to road side barriers made of RRM or Plum concrete are suggested (e.g., dowel bars – following the discussion with structural engineer for ways to provide measures to resist impact load (failure to resist impact). Failure in containing vehicles within the road may have the risk of mass casualties. Also, hazard markers (at minimum) or impact absorbing measures are provided on the side facing traffic).
- Sections with drop depth >5m:
  - o RCC road barrier with details as per RSN#6 are provided. Failure in containment of vehicles on road can result in mass casualties, hence highest level of protection is needed. Hazard markers or crash cushions are suggested on the face of the barriers fronting traffic.
- Sections with restricted width and drop depth ≥3m
  - o W -Beam barrier is provided with appropriate terminal treatment (Typical details as per RSN #6).

Schedule of roadside barriers along with their types and locations (Chainages) will be given in the final report**.** Owing to maintenance issues, wire rope barriers are not recommended in the design.

Notes:

- Ensure that continuous road side barriers do not obstruct drainage of pavement surface.
- Consider deflection zone as per best practice W-Beam installation requirement.
- All road side barriers end should be fitted with red retro-reflective roadside hazard markers (at a minimum).

- Connection from semi rigid to rigid barriers (generally at approaches to bridge) needs special consideration (Please refer RSN #6, Page 12).

11.5.4 Median Barriers

Median barriers are not provided generally. Most sections of dual carriageways (along rural or urban sections are at the same level. However, where there are cases of split carriageways, W-Beam barriers are provided on the higher-level carriageway facing traffic to prevent errant vehicles from landing over the opposing traffic which may have catastrophic consequences.

Additionally, W-beam median barriers are proposed on the outer separation too along the urban sections of the highway to prevent vehicles from higher level main road to service roads located on the lower level. Off-ramps from main road at interchanges are typical locations where such median barriers are very much essential.

Schedule of median barriers along the main road and along the outer separation will be given in the final report.

11.5.5 Under runs End Treatments and Crash Cushions

Under runs: Under runs are proposed where W- Beam guard rails are provided. These are considered to be the only available safety treatments to ensure motorcyclists, who have lost control and hit the guard rail would not slide under the guard rail. The consequence of such run and hit crashes could be catastrophic as there is a potential that they might got trapped and cut under the sharp edge of the beam. While under-runs are not yet used in Nepal, it is commended to introduce in this Project. These are widely used in recent times in Australia on roads with relatively higher number of motorcycle traffic. Motorcycles in Nepal make up significant proportion of traffic both along urban and rural sections and it makes sense to spend some fund on their safety. Under runs are rectangular hollow steel bars that are placed additionally below the guard rails.

At this stage, the use of under-runs is limited to the W-Beam guard rails placed along the outer edge of curves with high embankment, typical along the approaches to bridges since this is a relatively new concept in the country. These are potential locations for motorcyclists at high speed to lose control. Schedule of under runs proposed will be given in the final report.

End Treatments: All rigid (e.g., concrete, stone masonry) and semi-rigid (e.g., gabion wall, W-Beam) barriers' ends, especially those facing traffic, are provided with measures that protect errant vehicles from hitting head on or spearing. Concrete and gabion barriers end profiles are recommended to design with gentle slopes fronting the traffic as shown in **Figure 11.10.** While international practice is to use crash cushions (impact attenuators) in high-speed roads, these are not recommended for use in the subject project. First, these are costly and secondly, they may not available easily in the country. For roads with posted speed of 60 km/hr, a design solution with sloppy may be acceptable since the consequence may not be severe at this speed. Sand filled bags and drums, although not recommended in many countries, can be placed to provide added protection of occupants.

Figure 11.10: End Treatment of Concrete Barriers

Many proprietary and non-proprietary end treatments are available for guard rails in international and regional markets. Among them, most widely used and recommended for consideration in this project are illustrated in **Figure 11.11.**

(a) Stubby Nose End

(b) Bull Nose End

(c) MELT (ET2000)

(d) X-Tension 350

(e) Fish Tail End

Figure 11.11: Type of End Treatments for Steel Beam Guard Rail

Modified Eccentric Loader Terminal (MELT ET 2000) or X-Tension 350 is recommended if available in the market. Else, Bull nose end treatment is to be used if the first two are not available. Stubby nose end is the last one to be selected for end treatments facing traffic. Fish tail end treatments are recommended for ending guard rails opposing traffic flow. This treatment may also be used at the end of guardrails which are provided to protect pedestrians at some sections of service roads. Fish tail end treatment can be used at the end facing traffic as well for all low-speed roads.

Installation of guard rails should confirm to the specification and instructions made available by the suppliers. Design drawings provided by the consultants are indicative only. Detailed drawings of these treatments along with the steel w-beam or thrie beam guard rails should be obtained from the supplier by the contractor and submitted to the engineer for approval.

11.5.6 Hazard Markers

Many objects along the road which are within the clear zone cannot be removed for many valid reasons (such as head walls and end walls of existing culverts, trees or any rigid objects like statues/ monuments), nor they can be altered to make impacts less severe (e.g., frangible posts, slip-based poles). Residual hazards are bound to exist along many sections of roads even if every effort is made to remove or relocate or alter them. Such hazardous objects are identified and are recommended for shielding. In many situations shielding is not possible due to severe funding constraints.

When such design environment is encountered, the last resort used to make road relatively safer (less risk) is to make these object more conspicuous with painting marking. All trees, electric poles or any rigid objects (statues or sculptures) which are roadside hazards and which are not removed, are identified and marked with bright colored retro-reflective paints. Alternatively, retro-reflective hazard marker plates (Refer to Traffic Sign Manual) can also be installed.

It is proposed that all culvert head walls and end wall as well as parapets be painted. Approaches to bridges railings and raised footpath are also proposed for painting. These are directly shown in relevant plans, profiles, sections and details.

Where painting is not an option, hazard markers are proposed. These are warning plate no B43 included in Nepal Traffic Sign manual (dangerous obstruction). B44 signs are proposed to delineate any hazard in the centre of the main road B45 signs are installed at all T intersections opposite to the terminating T road. Alternatively, B13 sign or one way sign (A28/D13) can also be installed on the median to indicate there is a median hazard and traffic is required to turn left (right turn prohibited). CAMS or sharp bend signs (B46) are proposed to indicate hazardous/ unsafe turnings. Schedule of hazard markers will be given in the final report

11.5.7 Roadside Design in Urban Environments

Most of the safety measures related to reducing the risks from roadside hazards recommended in the above sections are applicable for sections of roads along rural environment. It is because the guidelines influencing the clear zone design domain are intended for use on rural highways, urban and rural freeways and urban expressways. Urban environment requires different approach for roadside design from amenity and aesthetic consideration.

Urban road environment is typically characterized by lower operating speeds, denser development, limited right of way, closely spaced intersections and access points, higher traffic volumes, and mixes of traffic (delivery trucks, public transport vehicles, bicycles, pedestrians and other non-motorized / animal powered vehicles). Special considerations required for urban roads – objects installed on roadsides for improving amenities, for beautifying roadsides, for protecting pedestrians and cyclists, and other objects such as bike path separation hazard, footpath kerb hazard bus stop separation islands may act as hazard to motorists and motorcyclists. However, these are to be accepted on roads and roadsides.

Accordingly, the following features are integrated in the proposed design to manage risks[10].

- Roadside furniture pedestrian and bicycle supportive amenities (e.g., benches, trash cans, bicycle racks) are located far away from the traffic lane;
- Minimum shy from the edge of travel lane to the face of the curb on straight: 0.5m;
- Minimum shy from the edge of travel lane to the face of the curb at intersections and curves: 0.9m;
- Desirable off set from the edge of travel lane to other roadside objects: 1.0m - 1.2m
- Sightlines to pedestrian facilities such as zebra crossings, sight triangles should be made clear off obstructions

11.6 Overload Management and Control Measures

Anecdotal evidence suggests that driving overloaded vehicles (passenger busses, freight trucks and even some SUVs and motorcycles) is one of the main risky behaviors of drivers in the country, which have serious consequences on safety outcomes. A number of engineering, education and enforcement measures are recommended for implementation in National Road Safety Strategy/ Action Plan 2021-2030 to address the risk arising from driving overloaded vehicles.

Design and construction of Weigh-In-Motion (Weighing Bridge) is the only engineering measure/ action suggested under the overload management strategy in the National Road Safety Action Plan 2021-2030. This Project however does not include any of such WIMs in the subject section. It is proposed that appropriate education and enforcement measures be included in post-construction road safety campaigns as one of the components of social safeguard monitoring program.

[10] TAC, Geometric design Guide for Canadian Roads Chapter 7 – Roadside Design, Transportation Association of Canada, June 2017

11.7 Black Spot Improvement Measures

Existing black spots along the entire sections of the East West Highway are identified by the TA 9604 Project. Conceptual plans of the black spots remedial measures prepared by the Project which are located within the subject section are reviewed, amended as necessary in the context of implementing new design features and detailed out as necessary for inclusion in the project cost. Where the suggested black spots are already treated by the road safety measures proposed in the design (such as related to access and intersection improvement, speed management and roadside hazard management) as above, no additional improvement measures are suggested.

Black Spot Improvement Program (BSIP) suggested by the TA project is based on the existing road condition. These black spots may have been removed unknowingly by the new design. It may move to different locations along the subject section or beyond. The remedial measures suggested on the basis of existing design may no more be relevant for the proposed new design. The detailed design of remedial measures is thus based on the reassessment of the situation and modified accordingly. These measures are integrated into the overall design process as much as possible.

As a result of new road operating environment following the completion of construction, a new location could turn into black spots. This is not predictable at this stage since crash causation factors are too many. By definition, black spot treatments are reactive measures. One has to wait for crashes to happen to know where the black spots are, which would require the collection and study of crash data for at least consecutive three years, preferably five years. Running NeRSAP following the completion of road construction helps to estimate sections with high potential of crash risks resulting from road safety deficiencies. This tool provides important clues to road safety engineers to guess where crashes may happen in future but road deficiency is just one casual / contributory factor for crashes. Road safety deficiencies identified at the end of the design (by detailed design road safety audit) are treated by suitable remedial measures. The potential solutions for addressing design stage safety deficiencies are suggested in the list of recommendations of detailed design stage road safety audit findings. This is the subject of Section 11.15. Detailed design of selected road safety deficiency measures is covered in Section 11.8.

11.8 Road Safety Deficiency Remedial Measures

Although every effort has been made to incorporate all essential safety features, it is not uncommon to overlook some of the deficiencies in the design. Residual road safety deficiencies bound to exist in the design. Detailed design road safety audit aims to pick up these deficiencies and depending on level of risks and associated consequences make recommendations. Funding constraints may force the Project (asset owner) to accept some of the risks and let deficiencies untreated especially when the risk is low and consequence from the crash is not expected to be catastrophic.

TA 9604 Study has conducted safety audits of the entire section of East West Highway including the project section. These audit findings and recommendation for remedial measures are based on the risks on existing roads. It has developed Road Deficiency Remedial Program (RDRP) for the entire section of the highway on the basis of the audit findings and recommendations.

The RDRP captures most pro-active road safety remedial measures to address existing deficiencies. However, for the road section under design the existing deficiencies can only be considered as indicative since the new road environment after widening will be entirely different than what it is now. A review of the RSA recommendations from TA-9604 has been made, however, to appreciate the potential road safety deficiencies based on the past trends. Most of the recommendations from existing road safety audit are used only as a trigger for closer examination of the safety issues in the new road but the actual remedial measures are based on the detailed design stage road safety audit. Nevertheless, some specific recommendations on making intersections safer are implemented in the design.

11.9 Fatigue Management Measures

Driving tired is another risky behavior of drivers in the country. Either under pressure of the owner/ operator of public and freight transport or not knowing the consequences of driving in the state of fatigue, drivers of buses and trucks, motorists and motorcyclists are found driving when they are tired. Vehicles of tired drivers tend to micro sleep behind the wheel and display inattentiveness to the driving environment. Both these conditions could keep him/herself and others at risk. Vehicles can go out of travel lane and with serious consequences of head on, side swipe, and roll over other crashes.

There are two prongs of safety measures to deal with fatigue management in the area of Safer Roads. The first set of measures involve building rest areas along the project road so that motorists and motorcyclists get the opportunity to make a stop over and have rest. For long distance travel the standard practice is to take 15 min rest after each 2 hours of continuous driving. Thus, it makes sense to provide one rest area somewhere towards the end of the subject section. But this has been checked with the recommendations made by the TA-9604 Project in its Rest Area Development Program (RADP) for the east West Highway.

Rest areas are proactive safe measures for fatigue related crashes. When motorists and motorists do not use and continue driving or riding long haul without rest, they may fall asleep and vehicle may veer of their travel lane and collide with oncoming vehicles (departure to the right) or run off the road (departure to the left). Audio tactile Line Marking (ATLM) on the edge of travel lanes supplemented by wide shoulder and roadside barriers (where required) are the reactive measures to prevent sleepy drivers from running away from the travel lane and from falling over cliffs or slopes or hitting objects. These are already described under roadside hazard management measures (Section 11.5). Shoulders are wide enough along most sections. This shoulder is enough to allow sleepy drivers of vehicle to recover once they cross ATLM while asleep.

11.10 Safety Measures for Vulnerable Road Users

In most developing countries including in Nepal, pedestrians’ cyclists' and motorcyclists’ fatality is a major safety concern, yet the strategy for protecting them is lacking in the design, development and delivery of roads. For instance, zebra crossings (uncontrolled) are provided even in four lane roads with significant volume of traffic without median refugee. International practice is to protect pedestrian crossings on multi-lane roads with pedestrian traffic lights. Most roads are designed with no consideration of the needs of pedestrians, cyclists and motorcyclists. While ADB promotes the implementation of its GESI Guidelines, projects funded by ADB in the past did not contain even pram ramps, pedestrian tactile push buttons and other measures that ensure equity. Needs of women, children and differently abled peoples are ignored in pedestrian facility design, putting them at risk. Recent projects have, however, started including these measures in the design. The proposed design attempts to incorporate all basic essential measures that enable pedestrians, cyclists, motorcyclists and other users of different ability to use the project road as safely as possible.

Engineering safety measures for vulnerable road users are targeted to (a) pedestrians (b) cyclists and (c) motorcyclists. Some of the safety measures for pedestrians and bicyclists may be common. And there are quite a limited engineering measures for improving motorcyclists’ safety.

11.10.1 Safety Measures for Pedestrians

Where applicable, following measures are incorporated in the design for ensuring pedestrian safety:

a) Signalized pedestrian crossings at intersections: Traffic signals for pedestrians are located on busy intersections to stop vehicles and allow large numbers of people on foot to cross safely. Scramble crossings stop all vehicles and permit pedestrians to walk in all directions. All intersections with traffic signals are proposed with non-conflicting pedestrian phases.

b) Signalized pedestrian crossings at mid-block sections: Where two adjacent intersections with traffic signals are located farther apart (say 500m min-1000m max), pedestrians will need to walk more to access safe pedestrian crossings. Long walks involved to access pedestrian crossings may encourage people to In such cases traffic signals for pedestrians are installed at some mid-block locations where there are many people (young, older or pedestrians with disabilities) wishing to cross the road. The locations are shown in the plans. We recommend that zebra crossings be not provided at multi-lane roads in accordance with international practice and that where mid-block crossings are warranted, they be signalized.

c) Pedestrian Countdown Timers: Where pedestrian traffic signals are provided (at intersections and at mid-blocks), it is recommended to select the system that has pedestrian countdown timer. When educated and made aware of how to interpret and use countdown timer, it will guide pedestrians to start and finish crossing before the light turns red. In a standard signal system, international practice is that pedestrians start crossing when the light indicates green only. When red flashing person is on, they should not start crossing. This flashing red time is to allow pedestrians who are already on road to finish crossing. Draft Nepal Road Rules too has this provision.

d) Zebra Crossings: Not every pedestrian crossing requires signal control. When there are traffic lights upstream there will be a break in traffic stream downstream and pedestrians can use this gap in the traffic stream to cross the road safely. The gap in the traffic stream created by the red light upstream is considered to be highly beneficial to manage pedestrian crossings and minor intersections downstream. Where additional pedestrian crossings are required in between two traffic lights to reduce walking distance, simple (uncontrolled) painted zebra crossings are provided. Normal painted zebra crossings on four lane road are accompanied with pedestrian refugee islands (see below) to allow two stage crossings. A two-stage crossing is safer than one stage crossings since pedestrians are still required to negotiate crossing against the vehicles entering from minor intersections (un-signalized) downstream of the traffic lights. Although these vehicles will be a few, it is still recommended to limit to crossing one direction traffic at a time to reduce exposure to risks while negotiating zebra painted crossings.

e) Raised Pedestrian Crossings: Most motorists and motorcyclists in the country do not understand that pedestrians have the priority in using road space painted zebra. Even if they know they are impatient and do not tend to yield to pedestrians waiting to cross or allow to complete crossing. Some notorious drivers and motorcyclists are seen even speeding while approaching zebra crossings rather than slowing down as required by traffic rule. For this reason, where the risks to crossing pedestrians from the motorists and motorcyclists are identified to be high, raised pedestrian crossing (also called wombat crossing) is provided.

Figure 11.12: Examples of Raised Pedestrian Crossings

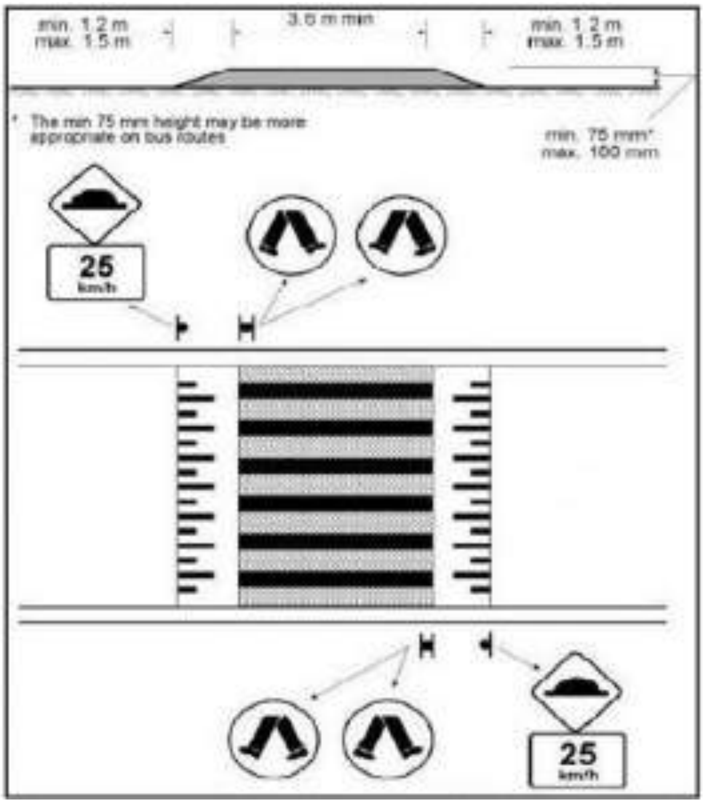


Figure 11.13: Details of Raised Pedestrian Crossing

f) Children Crossings/ School Zone Crossings: Children crossings/ school zone crossings are provided on rural sections where East West Highway crosses school zones. In urban sections, these are combined with normal pedestrian crossings. Children crossings can be manned or controlled by traffic light, depending on DOR District's preference. Normal zebra crossings are also used as children crossings. During school opening and closing hours, when the use is shared, international practice is to use red flags on either side of road to alert drivers about the presence of children. Schools may be asked to manage children crossings.

g) Pelican Crossings: Along rural and semi-rural sections, speed is usually higher than along the urban sections. Rural people are still required to cross road in this high-speed environment. Vertical (e.g., humps, wide humps, raised platforms or pedestrian crossings) or horizontal deflections (narrowing/ throttling, chicanes) are not permitted along rural highways. However, we cannot put pedestrians at risks, even if there are a few of them. In such situations pelican crossings are provided.

The signals for pedestrians at pelican crossings are the same as those at normal mid-block pedestrian signals. However, when the "DON'T WALK" pedestrian symbol (or symbol of person) flashes, drivers see a flashing yellow light. If there is no risk of a collision, drivers may proceed through the crossing with caution. This way vehicles need not to be stopped for long or altogether.

h) Pedestrian Fencing: In rural sections of roads with high pedestrian and bicycle movements and in all urban sections, median fencing is provided to prevent illegal and unauthorized crossing of main roads. The erection of median fencing also helps to direct pedestrians towards the nearest controlled crossings. These median fencing is of purpose made design. The median fencing is strong, vandal proof and non-climbable.

The common practice in urban roads to prevent pedestrian intrusion on roads is to provide hand rails along either side of the footpath. These are climbable, not strong enough and subject to vandalism, therefore are not effective. Provision of strong median fencing as opposed to conventional footpath hand rails is expected to be more cost effective also because we need only one set instead of two parallel hand rails along the footpath on two sides. A typical design of median fencing will be given in the detailed drawing sheet.

i) Pedestrian Refugee Islands: East West Highway is a relatively busy wide road with multiple lanes. International practice is not to provide zebra crossings on such roads. However, in Nepal it is a common practice to provide zebra crossings even in multi-lane roads. The increased risk is managed by implementing two stage crossings.

In rural sections, formal zebra crossings may not be required because of low volume of pedestrians. In this case, staged crossings are beneficial for safe crossing of roads. Staged crossings are particularly useful for sections where elderlies use the road. Pedestrian refugees can be made safer by providing bollards or caging as shown in **Figure 11.14.**

Figure 11.14: Two types of Pedestrian Refugee Islands

j) Street Lighting: Mid-block pedestrian crossings (signalized as well as un-signalized) and intersections require higher illumination level to increase visibility of pedestrians and improve safety. Also raised platforms and humps can be hazardous if these are not visible to motorists and motorcyclists well ahead to enable them to slow down. Street lighting is not provided in rural sections. Specific spots such as zebra crossings, raised platforms, humps as above require lighting for protecting vulnerable road users. Urban sections have normal street lighting. Higher illumination street lighting is provided at pedestrian crossings and other hazardous locations along urban sections.

k) Grade Separated (Overhead or Underground) Pedestrian Crossings: Where capacity is the issue and volume of pedestrian traffic is relatively high, grade separated pedestrian crossings either in the form of overhead bridges or underpasses (subway) are proposed. Locations and their details are included in respective drawing sheets. We do not recommend the use of overhead bridges for pedestrian crossings. However, if the Department would like to do so, we have provided the standard design drawings for the same.

l) Pedestrian Friendly Speed Limits: This is the last option proposed for consideration if, for some reasons, (which could include budgetary constraints), the above safety measures cannot be implemented. Speed limit on service roads is already proposed to safe limit of 30 km/hr. In certain sections, where shared zones are implemented (e.g., during hat bazar), we may need to reduce speed limit to 10 km/hr.

For main roads where safety measures for vulnerable users cannot be incorporated, it is recommended to reduce speed limit to 40 km/hr. This is in consistent with international practice. Proposed schedule of pedestrian safety measures shown in table 11.8 below:

Table 11.8: Proposed Schedule of Pedestrian Safety Measures

S. N	Road Safety Features	Short Description
1.	Overhead Crossing	Proposed in different sections mainly to: a) Reduce vehicle conflicts and delays. b) Increases safety by separating local and highway traffic. c) Uninterrupted flow increases the capacity of the road as well.
2.	Pedestrian Underpass	Proposed at locations near Overhead Crossing in order to facilitate pedestrian flow through the ramp section of overhead crossing.
3.	Overhead Pedestrian Crossing	Proposed in rare situations, to separate pedestrian traffic from vehicular traffic at a busy location, to avoid interruption of vehicular flow. The use of overhead crossing is kept at a minimum to make roads more disable friendly.
4.	At Grade Crossing	**Zebra Crossing** is proposed in the location where there is heavy foot traffic, especially in schools, colleges, offices, and residential areas. **Midblock crossings** are provided with **transverse rumble strips** in order to alert the vehicle drivers of an incoming pedestrian crossing.
5.	Raised Pedestrian Crossing	**Wombat Crossing** is proposed especially on service roads to ease pedestrian crossing and **reduce the chances of over speeding** of vehicles on service roads.
6.	Wide Footpath with Audio Tactile Tiles and Disabled Friendly Ramps	A wide footpath is proposed in the urban area which is equipped with **audio-tactile tiles** and **ramps** to make the footpath disable friendly. The audio-tactile tiles not only guide the blind about the footpath line but also alert the user about the junctions based on the sounds of the tiles.
7.	Junction Improvement	Selected junctions which are vital in the proposed road section are developed: a) Intersections along rural sections are **Left in Left out (LILO)** with **U-turn** facilities at a suitable distance.

		b) **Right turn and Left lanes** are proposed at the defined intersection to improve the safety of the intersection by avoiding conflicts. c) **Channelization** is provided at the junction for the smooth conflict-free movement of vehicles. d) Intersections on urban / heavily built-up sections are **signalized**. e) Intersections are disabled-friendly **with ramps and pedestrian refuge islands**, where required. f) Use of **primary and secondary traffic lights** to avoid accidents occurring due to obstruction of lights by taller vehicles. g) Use of **Mast Arm** for traffic lights is proposed where required to maintain visibility of traffic signals.
8.	Traffic Signs	Sufficient traffic signs including but not limited to **advance direction signs, gantry direction signs, speed signs, regulatory signs, warning signs, informatory signs, emergency information boards, and other signs** are proposed along the road. The signs conform to Nepal Traffic sign Manual.
9.	Wide Raised Median	Wide raised medians are proposed which not only increase road capacity but also reduce crashes and act as a pedestrian refuge, among several other advantages.
10.	Median Fencing	**Vandal-proof non-climbable** median fencing is proposed at strategic locations to avoid haphazard pedestrians and animals crossing the road, especially in Urban/Built-up areas.
11.	Footpath Railing	A footpath railing is provided in key locations, especially in areas with a high embankment to reduce the risk of pedestrians falling off the edge of the footpath.
12.	Road marking and direction arrows	Sufficient road markings including but not limited to **lane marking, edge making, chevron marking, guidelines, ghost island marking, direction signs,** etc. are provided along the road to guide road users towards safer road use. Thermoplastic paint is proposed where warranted.
13.	Semi-Rigid and Rigid barriers	Use of semi-rigid barriers like **W beam and Thrie beam** along with rigid barriers like **New Jersey barrier, vertical face barrier,** etc are proposed for injury avoidance and reduction along the road section. In sensitive areas like the river approach, an **RCC concrete block connected to the W beam connected to the Thrie beam** is proposed. **W beam** is used in embankments with high edge slope (difficult self-recovery). W beam barrier with **underrun** is proposed in sensitive areas. In areas such as underpasses, Thrie beam barriers are used to prevent heavier trucks from derailing from the overpass and ramps.
14.	Edge Rumble Strips	Rumble strips on the shoulders reduce run-off-the-road crashes by warning drivers they are leaving their lane. Such speed control measures are proposed in locations where the natural course correction is difficult.
15.	Transverse Rumble Strips	Transverse rumble strips are provided in **areas of hazards** and at locations of **Midblock crossing** to alert the drivers and mitigate the risk of injuries to road users.
16.	Road Lighting	Necessary road lighting has been proposed of **sufficient luminous intensity** at medians and service roads to provide visibility to **vehicles**

		on the highway, service roads, pedestrian crossing and pedestrians on footpaths. Enough lighting has been proposed for **pedestrian safety at the bus bays.**
17.	Delineator Post	Have been proposed to mark road edges of roads to warn vehicles of edge drops.
18.	Road Studs	Road studs are deployed to indicate a line that should not be crossed with the aim to delineate the **right-hand edge and left-hand edge** of the running carriageway in case of multi-lane divided carriageways.
19.	Emergency Information Board	Emergency Information Board is proposed in sparingly populated areas of the highway to act as a place and vital information marker. The board contains informatory numbers in case of accidents, vehicular issues, or other roadside facilities.

Engineering measures alone are not enough to keep pedestrians on roads safe. Pedestrians need to follow all traffic/ road rules to stay safe. Road rules for pedestrians can be found in detail in draft Nepal Road Rules. It is recommended that on opening of new widened road for traffic, DOR and NPS with support from local NGOs, launch road safety campaigns focusing on motorists, motorcyclists, cyclists and pedestrians and explain how they should use roads safely.

Engineering measures proposed for pedestrian safety are as follows:

Foot Path: 29.06 km

Footpath Railing: 4.37 km

Zebra Crossing: 44 locations

Overhead Pedestrian Crossing: 2 nos

Underpass Pedestrian Crossing: 18 locations

Bus Bay with bud stop: 48 nos

11.10.2 Safety Measures for Bicyclists

Urban sections have the provision of separate cycle lane on either side of the service roads (Total 29.06 km). All local cycle trips will be made on this segregated / protected cycle lane. Cyclists who wish to make long intercity trips, are required to enter the main road from the designated access point and exit to other roads as motorists do but they need to use shoulder exclusively. Cyclists are not permitted on main lanes.

Apart from this, it is recommended that the cycle traffic be regulated by a number of cycle related traffic signs. Cyclists are required to demount while using pedestrian crossings. Pedestrians have priority where cycle and pedestrian traffic need to mix.

Road rules for cyclists in detail can be found in draft Nepal Road Rules.

11.10.3 Safety Measures for Motorcyclists

Motorcycle safety measures incorporated in the design include (a) motorcycle box at approaches to intersections with traffic lights or police control, wide raised polygonal humps (in lieu of short parabolic humps, where speed reductions are enforced for pedestrian safety), under-runs, advisory speed limit signs at sharp turning curves for smooth cornering and transverse rumble strips at the approaches to very sharp curves to force motorists to slow down before entering to curved path. Schedule of under-runs is included in Section 11.5.5. Not many engineering measures are available for improving motorcycle safety even internationally. Best way to improve safety of motorcyclists, many of which are novice license holders with little experience and riding skill, is therefore to train and produce responsible riders by introducing Graduated Licensing Scheme.

Limiting speed by posting speed limit signs frequently, enforcing posted speed limits by using mobile radar gun, patrolling, increased presence of police officers on highways, installing covert and overt speed cameras, red light running cameras may have great impact on motorcycle safety indirectly. Other two main road rules which DOR should encourage NPS implement on its roads include control of filtering traffic stream moving at speed higher than 10 km/hr and overtaking from left at speed higher than 10 km/hr. While these safety measures do not fall under DOR's jurisdictions, safety on its roads is expected to improve significantly with the enforcement of road rules for motorcyclists especially and all users generally.

11.10.4 Safety Measures for Differently Abled People

Following measures are incorporated in the design;

- Pram ramps at all approaches to pedestrian crossings to allow people in wheel chair and with babies on prams to cross road safely
- Audio-Tactile pavement surface along the footpath and on pram ramps to allow visually impaired people to walk safely
- Audible push button at all traffic signal pedestrian signal post to allow visually impaired people to cross roads safely when pedestrian green light is on
- Ramps to climb overhead pedestrian bridges and descend to subway in conjunction with stairs
- Audio-Tactile pavement at the edges of bus shelter to indicate the limit of raised portion with the bus bay

11.11 Other Traffic Control Devices and Safety Measures

Many devices used in road / traffic operation and control also help to improve efficiency and safety. For instance, traffic signals at intersections and at mid-block pedestrian crossings enhance both efficiency and safety. When a stream of vehicles gets green in the upstream in a system of traffic signals working in coordination, vehicles do not have to stop at red in the downstream intersections or mid-block pedestrian crossings. Centerline markings and edge-line markings also enhances safety greatly. When supplemented by audio tactile features, these line markings help to reduce many head on, run-off-road / roll over crashes. Lane control signs assign lanes to traffic sufficiently in advance so that motorists and motorcyclists can choose the correct lanes before turning left or right or going straight. Crashes due to sudden lane changing and short weaving can be reduced significantly with lane control signs.

Regulatory signs, advance warning and information signs help road agencies to ensure orderly movement of traffic on roads. Speed limit signs and other regulatory signs give clarity to users on how they should use roads without making traffic offences and to empower enforcement agency to issue infringement notices which are legally robust. Non-obeyance of messages delivered by regulatory signs and signals is a traffic offence. It attracts monetary penalties and at times jail terms depending on the seriousness of the offence.

Most of the traffic control devices used in the design are taken from Traffic Sign Manual DoR 1997 (TSM). Where additional signs not available in TSM are required, these are taken from Schedule 2 of draft Nepal Road Rules (NRR). Traffic signs from TSM or draft NRR generally conform to the 1968 United Nations World Convention of Road Signs and Signals (The Vienna Convention). These signs, markings, and signals are similar to those used in India and other SASEC countries. NRR (draft) also recommends penalties for not obeying regulatory traffic control devices but these penalties currently have no legal basis, pending the consideration and approval by the DoTM.

Reference is also made to the Manual of Uniform Traffic Control Devices of selected countries for getting insight on good Australian UK, US and Canadian Practices on the use of traffic signs, signals and road marking as and when necessary.

Traffic signs signals markings are provided to control, warn and guide road users to promote road safety. These are used only when they serve intended purpose. Guidance on the selection of these traffic control devices, their locations, color, message, siting and details of installation is available in Traffic Sign manual 1997 and other reference materials cited above.

11.11.1 Regulatory Traffic Signs

Regulatory signs are used to regulate traffic. Regulatory signs prohibit actions road users should not do and give instructions on what road users must do while using roads. Size, colour, shape and siting are as recommended by the Traffic Sign Manual.

Sometimes, instruction and prohibition messages become more effective if they are painted on roads. At times road marking are used to reinforce / supplement message delivered by traffic signs erected on posts. Road marking/ paintings are covered in Section 11.11.6.

A total of 33 signs under this category has been proposed in the Manual. All of these are used in this section of roads. A complete list of regulatory signs used in the subject section will be given in the final report.

Supplementary plates below regulatory signs as recommended by TSM are also used where applicable. Where used, these are also noted in the Table.

Nepal Traffic Sign Manual 1997 clearly makes recommendations in Section E2.3 what speed limits should be posted by mandatory traffic speed restriction signs on roads of various environments. It is strongly recommended that these recommendations be followed except for frontage roads, for which, in accordance with new UN recommendations about "Streets for Life", it is proposed to use 30 km/hr speed limit. For rural sections with no animal stock and pedestrians, the recommended posted speed limit is 70 km/hr. While international practice on speed limits for rural highways with median separator is 80km/hr or more, it is proposed to limit the speed limit to 70km/hr maximum given the presence of vulnerable users like motorcyclists on main roads.

11.11.2 Warning Traffic Signs

Warning (also called cautionary) signs alert road users to road hazards or dangers ahead. These signs aim to deliver the message that they need to take additional precaution for safety. Nepal Traffic Sign Manual 1997 provides guidance on when and how to use them. The manual also recommends colour, size, shape and siting of these warning signs.

A total of 48 traffic signs are listed in the Traffic Sign Manual. Additional warning signs, where needed, are taken from draft Nepal Road Rules.

A complete list of warning signs used in the subject section will be given in the final report Supplementary plates as recommended by the TSM are also used in conjunction with warning signs where applicable. Where used, these are also noted in the Table (Comment column).

11.11.3 Informatory / Directional Traffic Signs

Two groups of signs are proposed to use in the design in accordance with the recommendations from Nepal Road Safety Manual. Direction signs are popular in Nepal. These signs give road users information to enable them to find ways to their desired destinations. Apart from other uses, these signs also help to improve road safety since road users can change their lanes in advance before turning to their desired direction.

Informatory signs widely vary. Standard information and direction signs from Traffic Sign Manual are proposed for consistency and uniformity. Where additional type is required, these are taken from draft Nepal Road Rules or other international manuals of uniform traffic control devices.

A total of 29 traffic signs are proposed in the TSM under two categories: direction signs and other information signs. For consistency and uniformity, size, shape, colour and letters on the sign are adopted from the TSM as far as possible. Generally, these signs should be adequate. For gantry signs along main roads, their design and installation details would be different. These details are given in the respective drawing sheets.

11.11.4 Lane Control Signs

Multi-lane roads with partial or full control of access and egress require lane control signs. These are usually installed overhead using gantry girder. Lane control signs can be static or dynamic. Dynamic (variable) signs are discussed in Section 11.11.9.

Lane control signs are proposed at the approaches to fly overs, major intersections and other locations where additional traffic lanes (left or right or U-turn) are common. These are also proposed before the beginning of major towns warning motorists and motorcyclists to slow down.

11.11.5 Parking and Stopping Control Signs

Details of parking and stopping control signs are covered in Section 11.11.1 as these signs are intended to prohibit or permit parking or stopping. Their details on design, size, shape and colour are as shown in the TSM. The TSM also advises the use of supplementary plates to indicate distance but is silent on time over which parking is permitted or prohibited. It is recommended to use additional parking control or stopping control signs as recommended in the draft NRR. Loading zones, stopping bays, passenger pick up and drop off zones are all to be designated by respective traffic signs which are not available in the TSM. Traffic signs to regulate time-based parking are also not available in the TSM. These are also too be taken from the draft NRR.

Time based parking and stopping signs are not proposed however in the design. Depending on which agency (local or state or federal government) is made responsible for managing and controlling kerb side (street) parking, location of these signs including time periods (5min P, 15 min P, 30 min P, 1P, 2P and so on) and will have to be determined by the respective agencies in consultation with local residents and businesses once the road is opened for traffic. This is an operational issue and not the design issue as such and are changing all the times as demand for parking changes. As a guide, potential sections suitable for parking are identified during the design process.

Parking on service roads is to be permitted in such a way that vehicles can move freely and it is to be permitted only on one side of streets for the length where opposing traffic can have clearance to pass each other. The rule is that vehicles wanting to use the opposing lane for passing parked vehicle must give way to the opposing vehicles. Drivers must be courteous where these clearances are not maintained.

Except in emergency situations and breakdown, parking or stopping on shoulders along the main road is not permitted. Emergency bays may be provided where vehicles can pull over in case of urgent calls or police operation or breakdown. These and other measures are too be covered by rules of operating strategic roads.

If parking or stopping is prohibited on 24/7 basis, it is more prudent to use road marking (see below). It is also customary to use both signs and marking for managing and controlling parking. Local residents and business owners as well as motorists, motorcyclists and drivers of commercial vehicles are to be educated and made aware of parking rules and regulations on service roads and main roads on regular basis.

Parking and stopping are also not to be permitted within 20 m of any intersections to provide intervisibility of vehicles approaching to intersections from main and side roads. These sections can be marked with no parking line marking (see below) and reinforced by traffic signs.

Kerb side parking prohibition for safety reasons that are implemented in the design are indicated in the respective plans and profile sheets with details in the detailed drawing sheets. These are typically at the approaches to intersections; local bus stops including the entry and exit sections of bus stops and other locations as identified by the road safety audit.

It is also necessary to provide emergency bays for parking of vehicles along main roads. These bays are used by operation vehicles/ enforcement agencies or by motorists in case of breakdown of their vehicles or need to pull over for breath testing or issuing speeding tickets to keep traffic lane clear off obstruction while waiting for towing trucks or ambulance. These bays are also used for emergency phone calls. DOR with support from telephone companies may consider installing emergency telephone booths which can be used by motorists or motorcyclists to inform police officers in case of emergencies.

All line markings (longitudinal and transverse) are adopted from the TSM, except where they are combined with audio tactile type. Road marking are used in conjunction with traffic signs or in isolation in some cases. Lane marking and centre line marking are very useful to maintain lane discipline. All line markings are reflectorized. Detailed dimensions of various types of line marking are drawn from the TSM.

Edge line marking for parking control are continuous yellow. Double continuous centre line marking can either be yellow or white. Double continuous lines in the centre indicate motorists are prohibited to cross to go to opposing traffic lanes. Most sections of roads are designed with central median to separate opposing traffic. Service roads and main roads are also separated by outer separation strip. Hence the use of double centre line marking is limited to the approaches to intersections where RT lane is provided using the space for median (where residual median width is less than 1 m).

A total of 12 different line marking is recommended for use by the TSM. These types are normally adequate. Additional types of marking are proposed for some locations such as raised pedestrian crossings. These are detailed out separately and are indicated in the respective drawing sheets.

Retro-Reflective Pavement Markers (RRPM) or simply Reflective Road Studs (RRS) are provided to augment line markings. These increase the visibility of line marking during wet weather and night time. These are helpful when the line marking fades away over time. Depending on the availability in the local market either bonded or anchored road studs may be used.

The TSM does not elaborate the use of color studs. Following color codes are recommended to apply consistently:

- White: to augment lane lines;

- Yellow: to augment the dividing lines (separating opposing traffic), right hand edge lines of one -way carriage ways, the outline on the traffic islands and painted medians;
- Red: to augment left hand edge lines; and
- Blue: to mark the position of water or sewer valves, fire hydrants and similar objects so that these are easily identified.

Schedule of road studs and their locational are shown in table 11.9 below:

Table 11.9: Schedule of Road Studs.

Road Studs					Remarks
Chainage		Length	Sides	No	
Start	End	(m)			
590+200	590+280	80	2	16	
591+280	591+400	120	2	24	
595+880	596+000	120	2	24	
596+360	596+480	120	2	24	
597+380	597+440	60	2	12	
601+570	601+670	100	2	20	
603+340	603+440	100	2	20	
603+840	603+940	100	2	20	
604+500	604+600	100	2	20	
604+960	605+060	100	2	20	
606+480	606+580	100	2	20	
607+190	607+290	100	2	20	
210+800	210+900	100	2	20	
611+090	611+190	100	2	20	
611+720	611+820	100	2	20	
617+620	617+720	100	2	20	
621+400	621+500	100	2	20	
622+120	622+220	100	2	20	
623+200	623+300	100	2	20	
623+600	623+700	100	2	20	
624+020	624+120	100	2	20	
626+720	626+820	100	2	20	
626+800	626+900	100	2	20	
635+040	635+140	100	2	20	
636+400	636+500	100	2	20	
636+720	636+820	100	2	20	
637+340	637+440	100	2	20	
Total with 30% Extra				**702**	

Indented bus bays are provided on main roads to serve long haul inter city buses (e.g., Butwal-Kathmandu) only in exceptional cases. It is considered that long haul buses are permitted to pick up passengers only from the designated bus stops located off the road somewhere in major cities. All other local and regional transit vehicles such as three wheelers, micro- and mini-buses as well as conventional buses servicing local and surrounding towns will exit to service roads, stop on yellow bus boxes provided to drop off and pick up passengers and enter into main road at the end of service road via the entry points to the main road provided at selected locations.

Suitable pedestrian crossings at indented bus bays along main roads and yellow bus boxes along service roads are provided to ensure pedestrians cross the road safely to get to the other side of the road from the bus stops. Locations of bus stops (yellow boxes) long the service roads and indented bus bays along the main road are decided in a coordinated manner.

Locations of indented bus bays on the main road are shown in table 11.10 below:

Table 11.10: Location of Bus Bays

Bus Bay (Type A=45m) with Shelter and Lighting			
S. N	**Chainage**	**Left**	**Right**
1	589+920	1.00	-
2	589+970	-	1.00
3	593+660	1.00	-
4	593+695	-	1.00
5	596+910	-	1.00
6	597+240	1.00	-
7	598+100	1.00	-
8	600+030	1.00	-
9	600+040	-	1.00
10	602+670	-	1.00
11	602+980	1.00	-
12	605+470	-	1.00
13	605+915	1.00	-
14	606+470	1.00	-
15	606+475	-	1.00
16	607+430	-	1.00
17	607+620	1.00	-
18	611+310	1.00	-
19	618+200	1.00	-
20	617+920	-	1.00
21	620+180	-	1.00
22	620+525	1.00	-
23	622+285	-	1.00
24	622+780	1.00	-
25	625+495	-	1.00
26	625+900	1.00	-
27	626+490	-	1.00
28	626+825	1.00	-
29	634+730	-	1.00
30	635+070	1.00	-
31	635+885	-	1.00
32	635+920	1.00	-
33	637+180	-	1.00
34	637+620	1.00	-
35	638+800	-	1.00
36	639+160	1.00	-
Total		**9.00**	**17.00**

Bus Bay (Type B=30m) with Shelter and Lighting			
S. N	**Chainage**	**Left**	**Right**
1	594300	-	1.00
2	601130	-	1.00
3	602310	1.00	-
4	613800	-	1.00
5	614080	1.00	-
6	617360	1.00	-
7	619660	1.00	-
8	621680	1.00	-
9	624340	1.00	-
10	624200	-	1.00
11	626340	1.00	-
12	638270	1.00	-
Total		**8.00**	**4.00**

Bus Bay Lighting Summary		
Bus Bay	**Type A**	**Type B**
	36.00	12.00
Total	**48.00**	

It is recommended to introduce a new traffic sign as shown below to be posted on the back of the transit vehicles. With this sign, motorists, motorcyclists and even the cyclists and other non-motorized vehicle operators behind are required to give way to the transit vehicles when they are indicating their intention to move from the bus stops. The implementation of this rule helps transit vehicles to merge to main traffic stream safely. But the initiative should come from the DOTM. DOR, in the interest of managing its asset safely should pursue with the DOTM for its implementation.

Figure 11.15: Traffic Signs to Give Way to Buses

11.11.6 Night Safety Measures

A significant proportion of road crashes happens during night time. Pedestrians crossing the road are not easily visible to motorists and motorcyclists and are hit often. Hence, for improving both pedestrian safety and safety of the motorists and motorcyclists as well as cyclists, it is recommended to provide street lighting throughout the entire urban sections.

Both service roads and main roads have adequate illumination level as required by acceptable standards. The height of the pole as well as spacing and mount overhang are determined by electrical engineer to ensure uniform illumination level on the road surface.

Rural sections of the highway are not generally lighted. Lighting is provided only where pedestrian/ zebra crossings are proposed. Street lighting is also required for night safety at all major intersections and roundabouts. Additional considerations may be

Apart from the street lighting, night safety is also improved by providing RRPMs and retro-reflective frangible poles to delineate road boundaries. All objects which are within clear zones, which are essential road features (such as culver head/ end walls) and which cannot be removed, are marked with retroreflective paints to make them conspicuous. Retro-reflective hazard markers are fitted in all objects such as electric poles, trees, end of the guard rails, concrete barriers etc. for making them easily visible at night if painting is not an option.

Retro Reflective Pavement Markers together with reflective white and black paintings on the kerb of footpaths and raised traffic islands provide additional safety to motorcyclists and motorists.

All of these works are identified and included in the project cost. On opening road for traffic, road safety auditor in his/her post-construction or pre-opening road safety audit report is expected to identify any deficiencies on roads that may make roads unsafe for night travel and suggest remedial measures.

11.11.7 Traffic Signals and Other ITS Devices

Warrants for signal installation, capacity analysis and design of traffic signals involving green red amber time etc.) are discussed in Section 11.3 (for intersections) and Section 11.10 (for mid-block pedestrian crossings). Traffic lights are used to control the movement of both vehicular and pedestrian movements by providing time separation where the control by signs and by rule only will no more work. Warrant analysis precisely determines where rule of road will be effective, where sign control would be adequate, where time separation is essential and where space separation (flyovers or pedestrian overhead bridges) is needed. In absence of the local guidance in the country, decision on the type of intersection and pedestrian crossing control for safe road operation are being made on ad-hoc basis.

Within the limitation of the project design environment (Covid), a system of warrant analysis is introduced and piloted in some of the major intersections. It is the intention to extend the warrant analysis to all major intersections and pedestrian crossings within the limitations of the project resources.

Having determined the need of one or other types of control, recommendations from the TSM are implemented for the design and detailing of traffic lights. While the international practice is to provide primary secondary and tertiary signal heads, TSM's provision is only for the primary and secondary heads. It is recognized that the TSM is not revised since 1997 and DOR may wish to provide tertiary signal heads too. This will increase the cost of the traffic light but can be done later after consultation on the draft report.

The TSM does not mention about the pedestrian push button but briefly mentions about the simultaneous audible signals. The first feature improves the efficiency in vehicular traffic movements and the second feature aids visually impaired people to cross roads safely. When there are no pedestrians (for example at nights) pedestrian phase will not be called unnecessarily and vehicles get more green lights.

Requirements on the placement of signal poles, phasing schemes, movement groups and timing for green red and amber lights are determined by the traffic engineer taking into consideration of the volume of approaching/ turning traffic so also the lane configuration at the approach and exit sides. Further design and detailing of traffic lights are undertaken by ITS specialist or by electrical engineer with support from communication specialists. Design details for each intersection or mid-block crossings vary and plans are signed off by the ITS specialist to ensure electrical safety. Underground conducting and cablings are to be done prior to pavement placement.

Traffic lights at intersections and at mid-block crossings are provided as shown in the respective plan and profile sheets. Analysis and design are covered in those sections. Installation details as recommended in the TSM or other international guides may be used.

Other ITS devices that may be considered in future, subject to the availability of funding, but not considered in the design at this stage, could include:

- Variable Message Signs (VMS)
- Variable Speed Limit Signs (VSLS)
- Check Your Speed Signs (CYSS)
- Vehicle Activated Signs (VAS)
- Rural Intersection Active Warning System (RIAWS)
- Curve Warning System (CWS)
- Rural Intersection Conflict Warning System (RICWS)
- Through Route Activated Warning Signs (TRAWS)
- Automated Number Plate Recognition System (ANPRS)
- Point to Point Speed Camera System (P2PCS)
- School Zone Warning Signs (SZWS); and
- Many other ITS devices DOR would like to install

11.12 Safer Road Works and Temporary Traffic Management

National Road Safety Strategy supports the implementation of good practice workplace health and safety measures to ensure zero harms to workers and travelling public at work sites. Health and well-being of the workers and members of the community during the construction period are no less important than the safety of road users after construction.

Workplace health and safety issues are covered by other design and construction components such as environmental management plan and social action plan typically developed and implemented for most ADB funded projects. The topic is briefly included in the report for completeness only.

11.12.1 Workplace Health and Safety Measures

Road safety brings both social and economic benefits to the community. Both the social and economic benefits are included in the Projects Benefits and Monitoring Evaluation (PBME) and reported on regular basis following the completion of the project (typically for five years). During the construction period, implementation of the environment management action plan (EMAP) is expected to address health and safety concerns such as dust control, air pollution, water pollution, sediment control and so on. Provision of toilets for both male and female works, maintaining hygiene, ensuring the supply of clean water to workers, provision of safe and healthy construction camp sites and temporary housing for workers, provision of first aid package, implementation of other GESI friendly measures (such as breast-feeding room, day care room) for construction workers are ensured by including special provisions in the Conditions of Contract (CoC). Some of the items of works related to the workplace health and safety measures are also captured by the Specification of Works (SOW) and Bills of Quantities (BOQ).

It is recommended that each new construction worker, heavy vehicle operator and truck driver, traffic controller be given safety induction by the contractor in presence of engineers' representative. The content of induction training and training details will be certified by safety officer of the contractor, engineer and client as required by local law. All vehicles used in worksites should have flashing light and beeping sound. All workers should use appropriate PPEs (e.g., high visibility vests, safety boots and hard helmets, where risk is high). All these and other basic workplace health and safety measures are covered by standard construction contract documents and are not described here further.

11.12.2 Temporary Traffic Management Measures

Safety of workers while accessing or exiting from construction sites in the transportation of materials, equipment and workers as well as the safety of the travelling public at roadworks is ensured by developing and implementing temporary traffic management plans. Site specific temporary traffic management plans are developed by the contractor and submitted to the engineer for approval. These plans will be developed based on the typical plans supplied to the contractor following the standard local and international practices. While international construction sites have stringent requirement on temporary traffic management at road works, it is recommended to limit to the basic minimum requirements laid by the Traffic Sign Manual 1997 in this Project. In all major construction sites, temporary traffic management plans, proposal for keeping the traffic moving safely (such as diversion road, lane closure, road closure, depuration of traffic marshals) are prepared by the contractor, audited by the road safety auditor and approved by the engineer in charge before the start of construction at any section. This has not been the common practice in the country as yet and therefore recommendation is made to follow the guidance provided in the TSM 1997.

Most commonly used temporary traffic signs, basic layout of signs for lane or spot closure and road diversions are available from the TSM 1997. The Manual recognizes that it is the contractor's responsibility to provide / install temporary traffic signs and make roadwork site safe by following standard code of practice. The maximum speed limit at work site is usually 40 km/hr internationally but it is recommended to limit to 30 km/hr in this project. The rationale is that lighting of construction site, training of workers and safety awareness of road users and enforcement of road rules are all weaker than in the international practice.

Figure 11.16 : The Six Zone Concept for developing Temporary Traffic Management Plan[11]

Further details on the approach for developing temporary traffic management plans can be obtained from any internationally available manuals for uniform traffic control devices or the above quoted reference. Taper zones are required only for multi-lane roads in order to enable traffic to change lane. Length of zones other than given in the diagram varies on the speed limit and can be found from the Manual.

11.13 Road Safety Education and Awareness

It is believed that safety measures incorporated in the design as described in earlier sections will make road safe only if road users understand the importance of these measures follow the messages delivered by these signs, signals and markings. Road users will be safe only if they use these features correctly. It is therefore recommended that the Project considers implementing basic minimum road safety education and awareness campaigns on at least new features introduced in the design. If road users do not know how to use road and the specific features built into it including road safety elements safely and correctly, it is difficult to get the benefits from the improved infrastructure and facilities. Some of these features may instead kill more people. For instance, if a motorist enters into an intersection while the traffic light is red by assuming that it can proceed if there are no other vehicles coming from other approaches, the collision at high speed is imminent. Similarly, if a pedestrian ignores a red light for him/her and attempts to cross the road, vehicles can hit him/her at high speed. Instead of saving, signalized crossings will more likely kill more pedestrians. It is therefore recommended that road agency takes the lead in delivering road safety education, awareness and training program soon after the widened road is opened to traffic. These campaigns will ensure that road users are better prepared to adapt to new environment of East West Highway following its widening to four lanes in a safe and efficient manner.

It is recommended to follow the following steps in developing and delivering road safety campaigns on the proposed project road:

- Identification of hot issues (or selected themes) of road safety that needs awareness raising;

[11] Source: ADB, CAREC Road Safety Engineering Manual 2 Safer Road Works, Asian Development Bank, March 2018

- Identification and development of missing safety rules on the currently available Vehicle and Transport Management Regulations (VTMR) relevant to the operation of multi-lane roads and recommendation of selected rules to fill the gaps;
- Compilation, customization and reproduction of road safety awareness materials required for the delivery of actual education and awareness campaign programs. Assistance may be sought from the communication and media sub consultants to design and develop awareness materials that represent the good practice communication tools which are highly effective and best understood by the target groups;
- Testing of the materials by the Project and approval of the materials to be used in the Program. This will involve screening the documentary films and video /audio clips for TV advertisement to DOR DOTM and NPS officials including the approval of the materials to go the media and to the general public;
- Identification of the target groups for the delivery of off-road and on-road awareness campaigns. This would be done based on the discussion with PD/ADB Project, Traffic Police officers, school communities and other Non-Governmental Organizations (NGO) involved in the delivery of road safety campaigns;
- Delivery of actual awareness campaigns and ongoing improvements of the materials based on the preceding campaigns (e.g., TA Pilot Campaign) for following campaigns;
- Benefits monitoring and evaluation of road safety awareness campaigns: This is proposed to be included in regular Project Benefit and Monitoring Evaluation (PBME).

Mode of delivery of road safety campaigns can be similar to those already used in similar SASEC projects funded by ADB. Sociologist engaged for the implementation of Social Action Plan during and post-construction period can lead the road safety campaign. An alternative to this is to engage an NGO with strong communication, media and marketing specialists in the team, if funding is available. The latter is more effective that the former mode.

11.13.1 Selected Infrastructure-related Themes for Safety Campaigns

It may not be possible, although highly desirable (from Benefit Cost Ratio perspective) to include large scale road safety awareness campaigns in a road design and construction project. It is, however, essential to raise awareness on issues that are new to most road users and that have significant impact on road safety outcomes. Key hot topics requiring attention by the campaign program managers are identified based on field observations on how people are using roads in general in the country and East West Highway in particular. Many of the issues are also related to how roads and road facilities are designed. These are identified in the detailed stage road safety audit. Other issues are related to users' behaviour. Results of KAP Survey undertake as a part of TA-9604 project suggest where knowledge gaps are, where attitudinal problem exist among road users and where unsafe road use practices are prevalent. Targeted engineering, education and enforcement interventions emanate from the results of KAP survey in addition to the analysis of crash types, patterns, distributions along the subject road.

A simplified identification process involving gap analysis and needs assessment may also be used to supplement the results of KAP survey for specific sections as the KAP survey was more of the generic nature. This would be done through discussions in the meeting with the officers in PD/ADB, Traffic Police Service and other relevant stakeholders (relevant PGs and LGs along the road corridor).

Examples of some of the hot topics / new emerging issues together with the development of improved infrastructure could include, but are not limited to:

- Correct use of road space at intersections;
- Correct use of un-signalized (zebra) and signalized (mid-block) pedestrian crossings;
- Better understanding of the priority rules in different types of pedestrian crossings (unprotected);
- Correct understanding and use of mid-block protected and partially protected crossings
- Use of pedestrian crossings at intersections (fully protected/shared)
- Use of two stage crossings (especially relevant in using multilane high capacity, high speed roads);
- Use of fully protected right turns, filtered (permissive) and shared turns;
- Heavy / slow moving vehicles to use correct lane;
- Role and responsibility of cyclists, animal drawn vehicle operators and stock keepers;
- Control of stray animals/ stock and stock crossings;
- Double right turns at intersections on multi-lane roads (only if provided);
- Double left turns on multi-lane roads (only if provided);
- Priority rules for buses and mini, micro buses and three-wheelers exiting from indented bus bays, bus boxes and transit vehicle stops;
- Pedestrian safety caging (protected) and its correct layout and usage;
- Unprotected median pedestrian refugee space and its correct usage;
- Fatigue management and control specially for long distance heavy vehicle drivers);
- Encroachment and /or unauthorized use of road space for private use

11.13.2 Selected Road Rules requiring Safety Campaigns

Road users’ behaviour is an important consideration in the safety performance of new roads. Use of multi-lane roads with concurrent frontage roads on either side with partial control of access is a relatively new experience for many road users in Nepal. Most road users are not conversant with safe and efficient use of intersections, traffic lights at intersections and pedestrian crossings, painted zebra crossings, parking on service roads, time-based parking, stopping, giving way to buses etc. typical for the subject road. It is therefore recommended that consideration be given at least, but not limited, to educate and raise awareness on the following road traffic rules for use of multi-lane roads with partial control of access:

- Rules for keeping left
- Rules for overtaking

- Rules for motorists passing cyclists
- Rules for changing lanes
- Rules for merging
- Rules for making U-turns
- Rules for using overhead control signs
- Rules for making right turns left turns on multi-lane roads
- Rules for overtaking at the approaches to zebra pedestrian crossings
- Rules for keeping intersections clear off stop lines
- Rules on priority at zebra crossings
- Rules to stop or park close to intersections
- Rules to stop or park close to mid-block pedestrian crossings (Zebra)
- Rules for giving way to buses exiting from indented bus bays
- Rules for maintaining safe clearance with cyclists
- Rules for cyclists
- Rules for animal driven carts
- Rules for trucks requiring to use left most lane only
- Rules regarding motorists and motorcyclists to use left lane (lanes) unless turning at intersections or overtaking slow moving vehicles (e.g., animal drawn cart or mopeds or cyclists);
- Rules on unauthorized use of road spaces (e.g., footpath by vendors);
- Rules for unauthorized / Not permitted turnings; and
- Other rules as deemed necessary based on the outcome of KAP survey

The list of additional rules can be updated following the completion of the first round of discussion with the DOR, DOTM and NPS officers on what could be done better to manage traffic safely in the East West Highway. The discussion is expected to occur as a part of consultative meeting on the delivery of road safety awareness campaigns. Results of Knowledge Attitude and Practice (KAP) survey undertaken as apart of TA-9604 Project

Change of traffic safety rules (road rules) has its own administrative process. Whether the existing VTMR contain these rules or not (VTMR was developed and updated perhaps without considering the need of safe operation of multi-lane roads) key safety rules relevant to the use of multilane roads and promote the use of these rules must be adopted for safety purpose. Draft Nepal Road Rules is the basic reference document for all likely rules for consideration in the interim.

As a part of NRSS, road agencies are required to develop road operation strategy and provide training, campaign and education to motorists, pedestrians, cyclists, and public transport passengers. Road agencies responsibility should not be limited to just designing, building and maintaining roads. Many ADB road construction projects included road safety awareness campaigns (RSACs) in the past. It can be included as a part of SAP (Social Action Plan) or a separate Road Safety Management Action Plan (RSMAP similar to SAP or EMAP). ADB and the road agency usually gives a lot of attention in monitoring SAP, EMAP, PBME and allows adequate input of sociologist and environmentalists in the supervision consultants' TOR, however, the TOR does not allow the required input of road safety specialists in the design and construction supervision projects. The latter is related to life and death of road users so it should draw equal if not more attention in the implementation of Road Safety Management Action Plan (RSMAP).

11.13.3 Resource Materials for Safety Campaigns

Many resource materials for road safety education and awareness campaigns as well as trainings are available and can be replicated for the road safety campaigns in this project. TA9604 Project has implemented pilot road safety awareness campaign. It has compiled a lot of resource materials for campaign from various sources. These resource materials should be accessible to use in this Project. NPs has also many resource materials so also many NGOs/ INGOs involved in road safety. Many INGOs and international agencies (e.g., WHO, ADB, WB, EBRD) are happy to provide these materials free of charge.

11.13.4 On-site Pilot Safety Campaigns

Soon after the widened multi-lane roads are opened to traffic, which could be in stages, pilot road safety campaigns, Project with support from its consultants and contractors run a pilot road safety campaign in each 10 km section (or similar) of road. Local NGOs and CBOs need to be involved so they can continue their campaigns. Saving local community members and road users' lives and serious injuries (road trauma) is an internationally accepted charity initiative and many INGOs, NGOs, CBOs and other community organizations are keen to be involved. Local resource persons, campaign materials compiled and used for the pilot campaigns can continue with ongoing programs for developing good habits of using roads thereby contributing to save innocent lives on roads.

11.13.5 Enforcement of Traffic Rules

After the safety engineering measures are implemented and road users are educated and made aware of the rules on the use of roads, enforcement of rules by competent authorities such as Traffic Police, Traffic controllers/ inspectors from local governments become very vital for the delivery of sustained safety outcome. It is recommended that the government agencies give extra efforts in enforcement for at least 6 months from the road is opened to traffic. In fact, road safety campaigns should be an ongoing process for better road safety outcomes. Every day, new drivers are on the road and their behaviour on the road should be monitored.

11.14 Road Safety Monitoring and Evaluation

National Road Safety Policy (NRSP) and National Road Safety Strategy (NRSS) both lay emphasis on the monitoring and evaluation of the performance at various levels of road safety management functions. While these policy documents capture monitoring and evaluation across all five pillars of road safety, DOR is responsible for the performance monitoring of Safer Roads and part of Safer Seed only.

Consistent with the results framework provided in the NRSS, Key Performance Indicators KPI) and reporting requirements are proposed for three levels of monitoring system: final outcomes, intermediate outcomes and outputs.

11.14.1 Key Performance Indicators

What to measure (Performance Measure)	What to achieve when (Target)
Outputs: (1) Road safety engineering practices are incorporated in the design and construction of Butwal - Gorusinghe section of the East West Highway	All applicable road safety measures from existing Road Safety Notes are incorporated
	Proposed safety standards are ensured in the delivered design
	Road safety audits at all stages are undertaken
	Work zone safety and traffic management plans are developed
(2) Planning and design considers workplace health and safety issues	Work place health and safety measures are strictly implemented by the contractor and temporary traffic management plans are prepared approved by the engineer and implemented by the contractor.
Intermediate Outcomes: (1) Posted speed limits are obeyed (2) Pedestrian cross roads safely (3) Traffic movements at all major intersections are made orderly and safe	1. Number of overspending cases are reduced by 50% by 2030 compared to the base case (Before the construction started) 2. Number of cases of jaywalking are reduced by 50% by 2030 compared to the base case (Before the construction started). 3. All major intersections are designed and delivered to accepted road safety standards by the date widened highway is opened to traffic.
Speeds are managed to safe level	All speed limit signs proposed in the design are posted and enforced; Cases of over-speeding reduces by 50% compared to the base case (Before the construction started)

Road construction sites are made safe	There are zero deaths in work sites (work persons or traveling public) during the entire duration of construction
Final Outcome: Reduction in the number of fatalities and serious injuries on the subject section of the East West Highway by 30% compared to the B	1. Consistent with the target set in the NRSS, by 2030, the number of fatalities and serious injuries on the subject section of road is reduced at least by 30% compared to the FSIs in the base year (before the construction started) 2. Consistent with the target set in the NRSS, by 2050, the number of fatalities and serious injuries on the subject section of road is reduced at least by 50% compared to the FSIs in the base year (before the construction started) *

* Note: Data on FSIs (number of casualties not the number of crashes) by section need to be collected every year by section. If this level of disaggregation (by section) is not possible to collect, it is recommended to select by greater length.

In order to compare success of the road improvement in delivering safety outcomes/ outputs at the end of the prescribed year with respect to the base year (without improvement; i.e., before the construction started), it is important to have similar data collected for the year before the construction starts

The suggested performance measures are indicative examples and for guidance only. DOR may develop its safety performance monitoring and evaluation framework and all projects including this may contribute to report the performance. At project level, ADB may require additional measures which should also be included.

11.14.2 Performance Reporting and Evaluation

For output level performance, reporting is done at the end of the design or construction depending on the nature of the performance measure.

Annual survey needs to be done for reporting measures for intermediate and final outcomes. These outcomes are monitored and reported every year. These may be published in the project or department’s report cards.

For the first five-year period performance monitoring and evaluation may be combined with the Project Benefit and Monitoring Evaluation (PBME), which is a well-established process for ADB funded projects. Road safety performance can be reported as a part of social benefits of the projects.

11.15 Detailed Design Stage Road Safety Audit

No matter how well a road is designed, road safety issues are bound to exist in the detailed design. While some elements of design related to efficiency which may have further improvement opportunities and can be implemented as and when funds become available, those elements that compromise safety of road users cannot be left for future since these may result in significant fatalities and serious injuries. We may compromise efficiency to reduce cost and works may be postponed but we cannot do so for safety as this is related to people's lives.

Detailed design road safety audit aims to identify residual road safety deficiencies in the design and to recommend remedial measures.

Road safety audit of this section of road has also been undertaken for the existing environment by TA 9604 Project. These recommendations have also been reviewed and remedial measures considered in the design where applicable. Many of these recommendations will no more be applicable, however, since the new road will have no more such deficiencies.

Following the completion of detailed design road safety audit, it is also important to undertake the following audit tasks

- Audit of the compliance of the detailed design stage audit recommendations;
- Audit of construction work zone traffic management plans (see Section 11.12); and
- Construction/ Pre-opening stage road safety audits
    - Part 1: Verification audit (also called Pre-construction stage audit);
    - Part 2: Construction stage audit; and
    - Pre-opening stage audit

11.15.1 Approach

Safety audit of the detailed design is undertaken using the same approach as described briefly in Section 11.2.7. The approach is similar to that used in international practice.

The road safety audit process as described in Nepal Road Safety Audit Manual, ADB Road Safety Tool Kit and other manuals available regionally and internationally suggests that the audit should be conducted by a team of road safety experts who are independent from the design team. The Terms of Reference of Consultants allow relaxation in this requirement. In absence of policy and legal instruments, road safety audit recommendations have no legal status as is the usual case in many other countries. It is however a very useful tool for identifying safety deficiencies on roads. DOR may consider implementing audit recommendations or in absence of sufficient fund, may defer the implementation pending the approval of budget and program.

11.15.2 Findings and Recommendations

Findings on road safety deficiencies from the detailed design road safety audit and recommendations on remedying these deficiencies will be included in the Final Report. The recommendations are prioritized based on the expected risk level and nature of consequences. Depending on the availability of budget, the Project can determine the urgency and develop a program for implementing remedial treatments.

It is not uncommon to accept certain risks and not implement road safety recommendations. It is for the project manager to determine what recommendations to implement and what not. It is an internationally accepted practice to defer the implementation of safety measures proposed by the auditor and accept risks since funding is a constraint everywhere.

12 Design of Road

12.1 Introduction

In order to carry out detailed design of proposed road, the Consultant has considered the Nepal Road Standard 2070 / Wildlife Friendly Infrastructure Construction Guideline-2078, Nepal/Asian Highway design standards 1993 / Indian Roads Congress (IRC) Documents and ASSTHO documents. After careful review of all available data/documents and the reports of the project road, the proposed Design Standards have been adopted.

12.2 Cross Sections

The proposed cross-section of the project road comprises of 4 lanes with divided carriageway and having shoulder on both sides including service lane in urban area. Typical cross-sections are developed in light of Terrain Classification and site condition which are described below:

In urban case:

- Carriageway : 4-Lane- 2x7.5m
- Paved Shoulder : 2x2.50m (with Rumble Strip as required)
- Central Median : 3.00m,
- Service Lane : 2 x 6.50m
- Side Median : 2x1.50 m
- Foot Path : 2 x 5.50 m.

In semi urban case:

- Carriageway : 4-Lane- 2x7.5m
- Paved Shoulder : 2x2.50m (with Rumble Strip as required)
- Central Median : 3.00m,
- Additional lane : 2x5.50m
- Lane Separator : 2x1.2 m
- Verge : 2 x 0.50

In none urban case:

- Carriageway : 4-Lane- 2x7.5m
- Paved Shoulder : 2x2.50m (with Rumble Strip as required)
- Central Median : 3.00m
- Verge : 2 x 0.50

A detailed Cross section has been provided in **Volume: III, Drawings**

12.3 Geometric Design of Alignment

Geometric design of the road has been carried out adopting the design standards given in **Chapter 3: Design Standard for Roads**.

12.3.1 Horizontal Alignment

To apply the approved geometric standards and formulate alignment plan for the project road the following aspects have been taken into consideration:

- Availability of Land (ROW);
- Minimum shifting of existing wayside infrastructure;
- Application of Super-elevation;
- Minimize broken back curves;
- Obviate curved bridges, especially in case of major bridges; and
- Ease in construction
- Comfort and safety in design speed and in future traffic volume
- Eccentric widening scheme to minimize land acquisition issues and to ensure maximum utilization of existing carriageway.
- Achievement of average design speed.

a. Horizontal Curve

The minimum radius of horizontal curve adopted in the design is 420m. As far as possible the curves are designed to maintain the design speed of proposed road.

At some locations as listed in the Table below, the existing curvatures are less than the adopted minimum due to unavoidable circumstances such as bridge locations and settlement.

Table 12.1: The existing curvature is less than adopted minimum at few unavoidable locations

IP-No.	Easting (X)	Northing (Y)	Radius (m)	Transition Length (m)
4	742181.25	3066888.22	120	48
5	742064.55	3066850.45	60	35
6	741883.26	3066607.15	150	60
8	741750.89	3066237.07	300	90
13	741403.85	3065334.28	300	110
36	735063.93	3064219.97	280	95
69	726488.14	3064802.09	150	40
70	726219.79	3064776.11	270	85
71	726082.85	3064995.18	300	40
80	724414.03	3066344.06	180	85
81	724201.99	3066327.44	150	85
82	723999.41	3066531.51	180	90
85	723271.99	3066279.21	300	90

92	722102.44	3064939.11	300	120
120	712899.92	3065286.43	300	100
129	709122.64	3063096.31	270	120
130	708742.62	3063781.00	250	100
134	707117.64	3063031.67	245	85
135	706759.29	3063210.63	300	100
140	705071.22	3062608.39	225	80
141	704700.65	3062836.99	250	100
145	703367.76	3062428.22	250	85
165	697339.19	3060591.24	100	90

12.3.2 Calculation of Horizontal Curvature

a) **Horizontal Curve:** The horizontal curves are, by definition, circular curves of radius R. The elements of a **horizontal curve** are shown in **Figure12.1.**

$$T = R\tan\frac{\Delta}{2}$$

$$L = \frac{\pi}{180}R\Delta = \frac{100\Delta}{D}$$

$$D = \frac{100\left(\frac{180}{\pi}\right)}{R} = \frac{18{,}000}{\pi\ R}$$

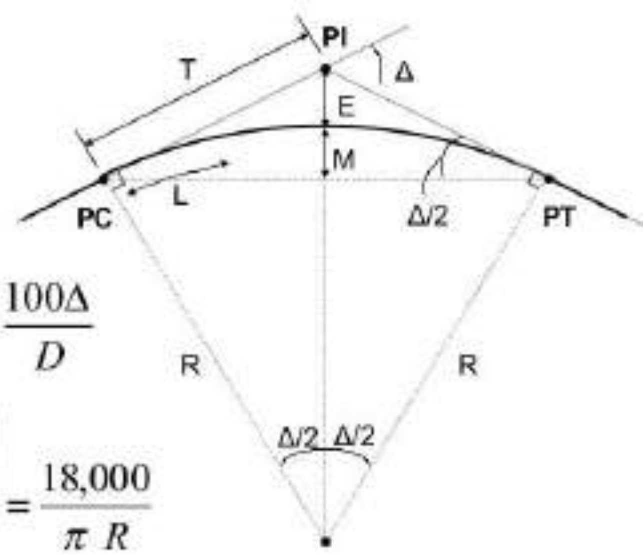


Figure 12.1: The Elements of Horizontal Curve

Radius of Horizontal Curve: -

- On a horizontal curve, the centrifugal force is balanced by the combination of super-elevation and side friction.
- The basic equation for this condition of equilibrium is:

e+f=V ^2/127R

where,

V = Speed in kmph
e = Super elevation (5% or 7% max)
f = Friction factor (0.15 for BT)
R= Radius of Curve (m)

Thus, R = V^2/[127(e+f)]

b. Transition Curve: Transition curve is a curve in plan which is provided to change the horizontal alignment from straight to circular curve gradually means the radius of transition curve varies between infinity to R or R to infinity.

i. Length of transition curves is decided based on the allowable rate of change of centrifugal acceleration acting on the vehicle so that the driver can steer the vehicle easily from straight section to a circular curve section of the road.

$$L = \frac{V^3}{CR}$$

Where, L = minimum length of spiral, m;
V = speed, km/h; CR V L 47 3
R = curve radius, m;
C = rate of increase of lateral acceleration, m/s^3($C = \frac{80}{75V}$) subject to the condition, 0.50<C<0.80)

ii. It is not possible to place a transition curve between straight and circular sections if following condition is not fulfilled

$$\boldsymbol{L \leq \Delta R}$$

Where,
L-length of the spiral, m
Δ-Deflection angle, in radians
R-Radius of circular curve, m
Since Δ is always less than π, from the above it follows that

$$\boldsymbol{L \leq \pi R}$$

iii. No transition curve is required if the lateral shift (S in Figure 12-2) of the circular curve due to transition curve is less than 0.25m.i.e.

$$\frac{L^2}{24R} \geq 0.25$$

Where, L-length of the spiral, m R-Radius of circular curve, m

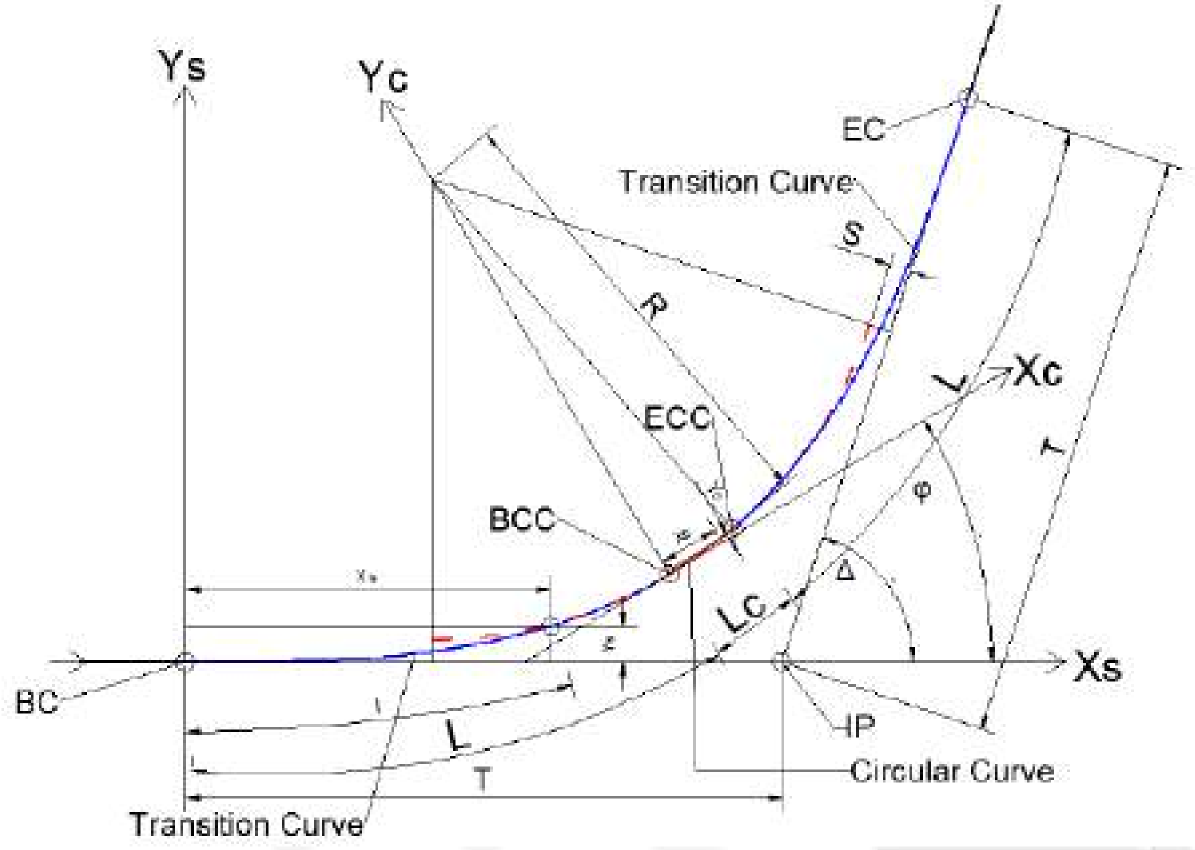


Figure 12.2: Elements of a transition or spiral curve

Notations to **Figure 12.2:**

BC-Beginning of the curve

EC-End of the curve

BCC-Beginning of the circular curve

ECC-End of the circular curve

R-Radius of the circular curve

xs, ys- Abscissa and ordinate of any point on the spiral (origin of coordinates at tangent point or BC with direction of abscissa towards IP)

l- Length of the spiral from BC to the current point (xs, ys)

xc, yc-Abscissa and ordinate of any point on the circular curve (origin of coordinates at the BCC with direction of abscissa along the tangent at that point)

L-Length of the spiral

T- Tangent length

IP-Intersection point

Lc-length of the circular curve

s- Shift of the spiral

Δ -Deflection angle

φ-angle of the spiral

c. **Super-Elevation:** Super-elevation is the transverse slope provided to counteract the effect of centrifugal force and reduce the tendency of vehicle to overturn and to skid laterally outwards by raising the pavement outer edge with respect to inner edge. **Super-elevation** is represented by "e". Value of super-elevation is calculated using following formula:

$$e = \frac{V^2}{127R} - f$$

e- Value of super-elevation, m/m
R-Radius of horizontal curve
V-Design Speed, km/h
f- Coefficient of lateral friction, depends on the vehicle speed
The maximum super-elevation adopted to provide is 7%

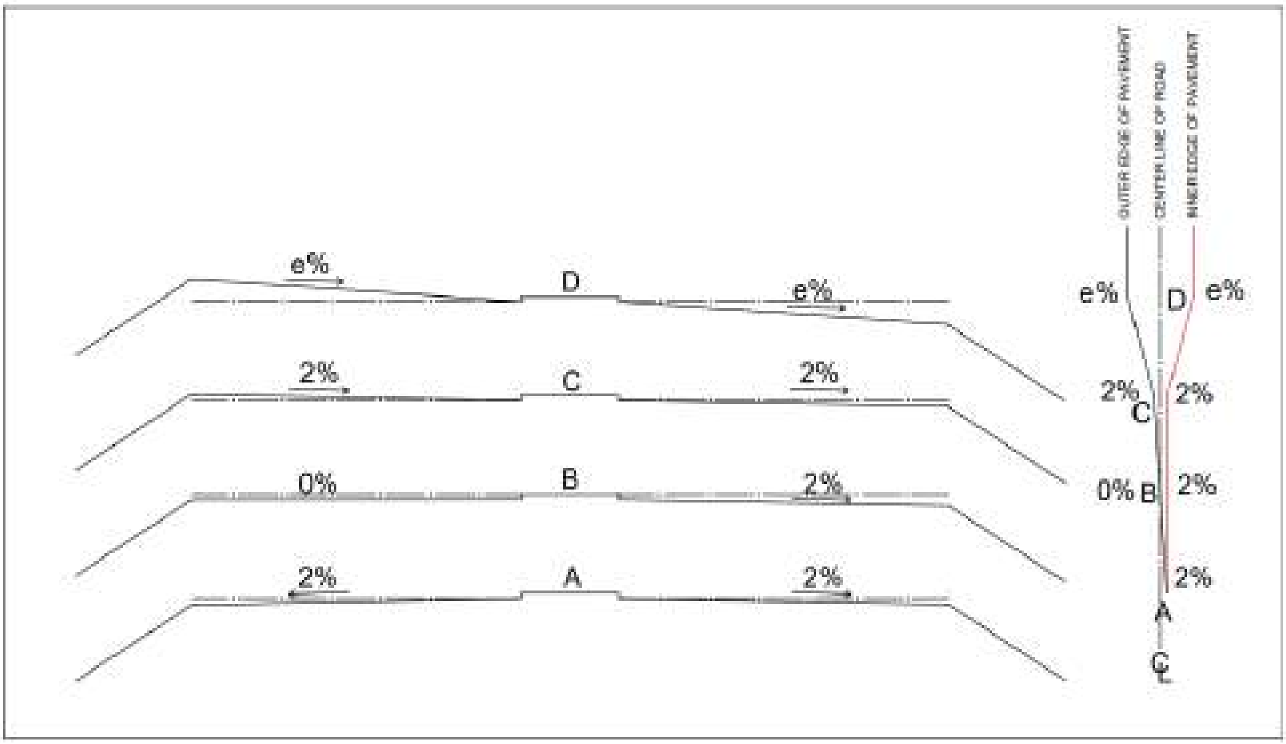


Figure 12.3: Schematic Diagram-Method of Attending Super Elevation

d. **Extra- widening:** Extra widening at the curves has been provided taking into account the mechanical and psychological widening requirements. Full amount of widening is provided on the inner side of the curves with radii more than 90 m and up to 300 m. Values adopted for extra widening of the carriage way are 0.3 n to 0.45 n, where n is number lane of road i.e., 2 for each carriage way.

12.3.3 Vertical Alignment

Based on the approved geometric standards and formulated horizontal plan of the proposed project road. While designing the vertical profile the following aspects were considered:

- Cost effectiveness by designing the facility as at-grade sections with gentle gradients to minimize construction of elevated structures;
- Level of major and minor bridges;
- Levels of at-grade junctions;
- Method of pavement rehabilitation- overlay or reconstruction for Existing Road;
- Extent of submergence zone; and
- Minimum clearance in case of grade-separator / underpass.
- Minimum Sight Distance requirement as per design standards.

Firstly, to minimize the additional load on large structures like major bridges and few minor bridges, the deck level would remain unchanged (barring a thin layer of bituminous wearing course) in case of existing carriageway. On new carriageway, deck levels based on hydraulic considerations govern the profile criteria. This criterion has necessitated adjustment of the vertical alignment at approaches to bridges. Where feasible due consideration of the existing culverts was also given for the setting of vertical profile.

Secondly, the influence of the pavement rehabilitation method on vertical alignment design was most significant. The method of pavement strengthening by overlay determines the vertical profile of the finished road. However, more liberties have been taken while designing the profile for the reconstruction stretches.

Finally, a few road stretches are affected by water logging during heavy rains, and require raising of embankment height. The vertical alignment at these stretches was designed to accommodate the recommended rise in embankment height.

The horizontal and vertical alignments at and near super elevated sections require special attention to comply the standard of transition curve, tangent run-off and the method of attainment of super-elevation.

12.3.4 Calculation of Vertical Curvature

The length of a vertical curve has been calculated using the following equation: (As per Nepal Road Standard 2070)

$$\mathbf{L = K \times A,}$$

Where:
L = Length of vertical curve in meters;
K = Coefficient, a measure of the flatness of a vertical curve; and
A = Algebraic difference of grade lines (%)

Schematic figure of Summit and Valley vertical curve is shown in **Figure 12.4** and **12.5**

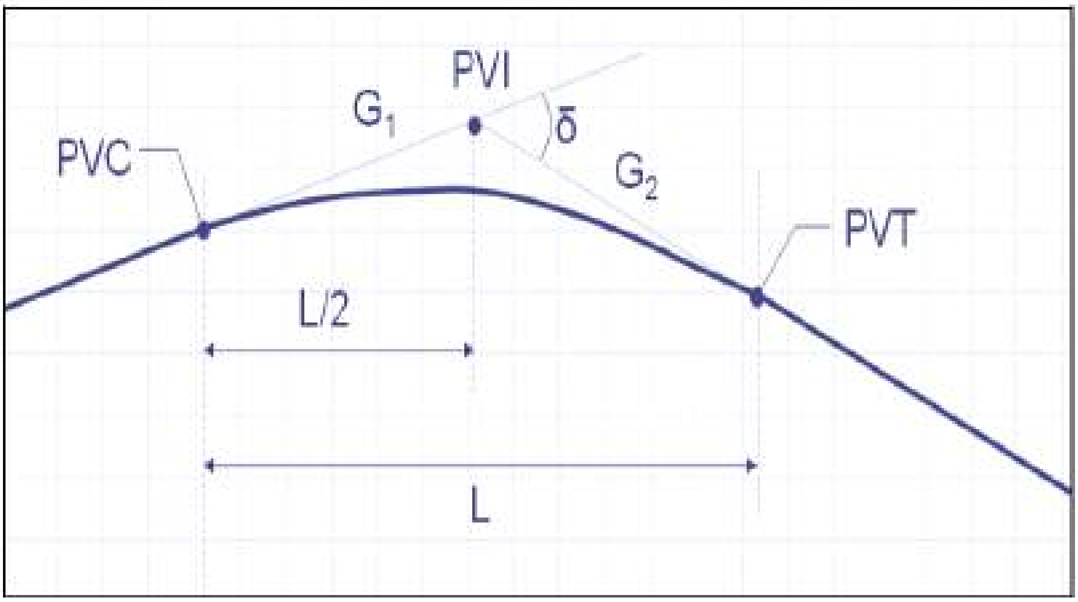


Figure 12.4: Summit Vertical Curve

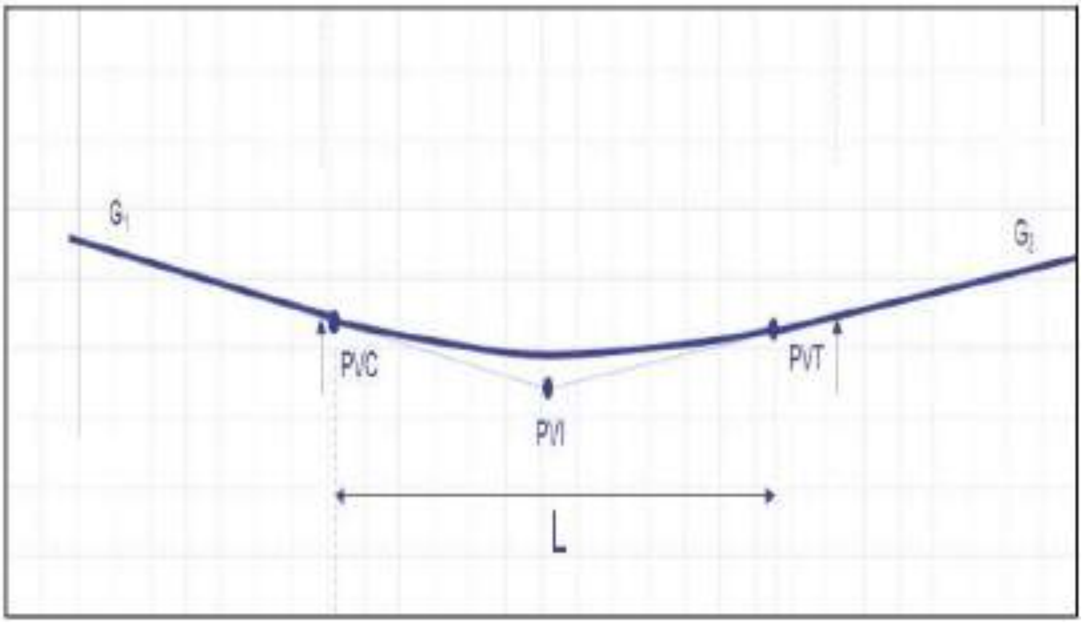


Figure 12.5 : Valley Vertical Curve

The layout data of Horizontal and Vertical Alignment are presented in Annexure: X

12.3.5 Road Junction Design

Butwal-Gorusinghe (Imiliya) Section of East-West Highway connects secondary roads, villages and settlement areas. In order to have safe traffic operation on roads, it is essential to impose adequate traffic regulation and traffic control devices. The designs of the Intersections for access to approach for other connecting roads are to be provided to ensure the safety vehicles diverging from or merging into high-speed roads. For the selection of the types of the intersection, the NRS 2070 has provided the following graphs (Figure 12-6).

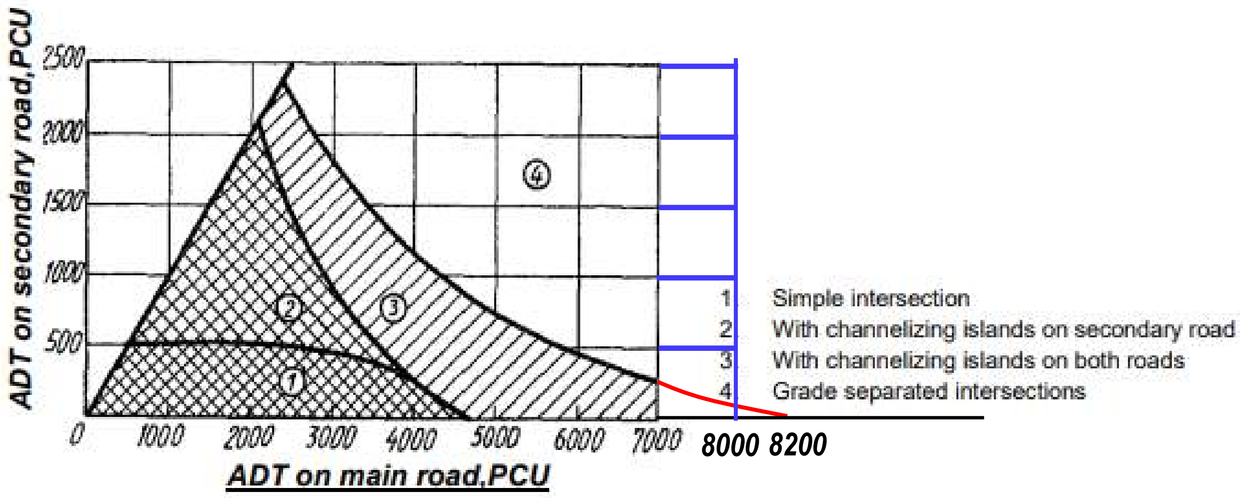


Figure 12.6: Graph for selection of the type of intersection

The forecasted traffic ADT rang in this section is 31266 to 52888 pcu. From this data and extended figure, each and every junctions are required to provide Grade Separated Intersections. For road safety reasons in urban area, junctions at-grade are undesirable because of the need for right turning, U-turning traffic, whether from side roads or from the main carriageway, to cross the main traffic flow either to merge with the traffic flow in the desired direction of travel, or to turn into side roads from the main carriageway. Road safety is only improved substantially where grade-separated intersections are adopted, but unfortunately the cost of such intersections is prohibitive for the project road except where major roads intersect. Considering the cost factor, the Consultant has developed "selection criteria" for type of junction improvement recommendation. Following are the main criteria considered:

- Urban Influence Area of Intersection
- Road Junction Type (connection)
- Secondary Road Type
- Institutions in Influence Area
- Place Importance

After scoring based on the above criteria basis for the selection of intersection type made on the following basis:

Obtained Score	**Type of Intersection**
0-100	No Intersection Design
100-200	Channelized Intersection Design
200-300	Signalized Intersection Design
300-400	Underpass design
>400	Grade Separated Intersection Design

Detail of Selection criteria is presented in Annexure: XI

The approach of designing junctions is elaborated in the **Chapter 11 Road Safety**. As the improvement measures, following Types of intersections have been designed and proposed:

Intersections:

1. Major Junctions:
   - Signalized Four Way Intersections
   - Signalized Three Way Intersections
   - Channelized Four Way Intersections
   - Channelized Three Way Intersections

Other Junctions and Facilities:

2. U-Turn Facilities
3. Over passes for facilitation of U-Turn and pedestrian facility in urban area
4. Additional Lane
5. Accelerating Lane, Deaccelerating Lane (Speed Change Lane)

The location of the above-mentioned type of intersections are tabulated below: **(Table 12.2)**

Table 12.2: Location of the different types of Intersections

S. No.	Type of Intersection	Total Number	Location/Chainage
1	Major Junction	11	**Signalized Four Way:** 625+720-Bangai Chowk **Signalized Three Way:** 590+510-Butwal Municipality Road **Channelized Four Way:** 592+820-Shanti Chowk 639+000-Buddhi Chowk **Channelized Three Way:** 602+210-Jhabaria Chowk 605+710-Kalauni, Saina Maina 607+570-Bansgadhi, Saina Maina 611+250- Bansgadhi Bridge 613+950-Fire-Line, way to Lumbini 634+540-Taulihawa Chowk, Gorusinghe 634+940-Arghakhanchi Chowk
2	U-Turn Facilities		Space between two U-Turn not closer than: In Urban Area: 500m In Rural Area: 3.00 Km
3	Over passes for facilitation of U-Turn and pedestrian facility in urban area	6	592+302-Jitgadhi Chowk 594+540-Nayagaun Chowk 597+100-Tamnagar Chowk 602+895-Murgya Bazzar 604+235-Buddhanagar Chowk 620+362- Charnumber Chowk

S. No.	Type of Intersection	Total Number	Location/Chainage
4	Additional Lane	18	**589+700~612+000:** **Left Side:** **Right Side:** 590+000~590+230 590+000~590+230 597+470~597+740 597+490~597+740 597+800~598+220 597+800~598+220 611+160~611+360 611+160~611+360 611+440~611+820 611+440~611+820 **612+000~626+000:** 622+220~623+300 622+220~623+700 624+120~626+140 624+120~626+140 **626+000~640+000:** 626+000~626+930 626+000~626+850 636+820~637+440 636+820~637+440
5	Accelerating, Deaccelerating Lane (Speed Change Lane)	8	616+610~616+800- Accelerating 616+803~617+173- Deaccelerating 634+320~634+510- Accelerating 634+520~634+890- Deaccelerating 634+800~634+905- Deaccelerating 634+915~635+105- Accelerating 628+800~638+900- Accelerating 639+000~639+090- Deaccelerating

Urban Area:

It has been noted that there is conflict between vehicles and pedestrians as well as vehicles themselves on the road in urban area due to lack of footpath, crossing structures, dividers and adequate provision of traffic signal. Considering this safety requirement and also to fulfil the projected traffic demand, required service lanes and foot paths are provided. For the safety reason all side drains in urban area are proposed to be covered.

Service roads have been added at nine settlement areas whereas intermediate lanes at four locations as listed in **Table 12.3:**

Table 12.3: Location of Service and Intermediate (Lane Distribution Data)

Lane Distribution (Road-3)						
S. No	Chainage		Lane Type			Remarks
	From	To	4 (Rural)	Semi Urban	6 (Urban)	
1	590+000	590+220		220.00		Both side
2	590+220	591+400		1180.00		Left
3	591+400	595+920			4520.00	
4	595+920	596+480		560.00		Left
5	596+480	597+380			900.00	
6	597+380	601+650		4270.00		Both side
7	601+650	603+440			1790.00	
8	603+440	603+940		500.00		Left

Lane Distribution (Road-3)						
S. No	Chainage		Lane Type			Remarks
	From	To	4 (Rural)	Semi Urban	6 (Urban)	
9	603+940	604+600			660.00	
10	604+600	605+060	460.00			
11	605+060	606+580			1520.00	Both side
12	606+580	607+290	710.00			
13	607+290	610+900		3610.00		Both side
14	610+900	611+190	290.00			
15	611+190	611+820		630.00		Both side
16	611+820	617+720	5900.00			
17	617+720	621+500			3780.00	
18	621+500	622+220	720.00			
19	622+220	623+300		1080.00		Both side
20	623+300	623+700		400.00		Right-side
21	623+700	624+120	420.00			
22	624+120	626+820		2700.00		Both side
23	626+820	626+900		80.00		Left
24	626+900	635+140	8240.00			
25	635+140	636+500			1360.00	
26	636+500	636+820	320.00			
27	636+820	637+440		620.00		Both side
28	637+440	640+000	2560.00			Left
TOTAL LENGTH			**19620.00**	**15850.00**	**14530.00**	

Similarly, Road furniture such as road signs, crash barriers, road markings, delineators, foot paths, covered side drains have been provided.

12.3.6 Services/Access Roads and Restriction of Direct Access

Number of access roads connect with the proposed Highway. Addressing all these roads for providing direct access to the Highway is not possible in light of road safety. Intersections have been proposed for feeder roads and district roads. Further, minor intersections have been provisioned for those village /minor roads of length more than 3 km having semi-dense settlement. Traffic from private properties adjacent to the service lane are given access through the particular places to enter into the highway by using service road.

In order to reduced number of access to the highway, nearest parallel village/minor roads running towards the highway have been realigned to provide a single access.

Median openings have been provided at the interval of 2 km in rural area and at least 500m in built up area with median opening of 18m to 20m.

Upgrading of existing access road to the highway up to 15 m beyond the ROW of highway has been proposed and included in the quantity and cost estimate.

Access management and control measures are elaborated in details in **Chapter 11 Road Safety**

12.3.7 Road Furniture and Ancillary Works

These are the fixture or structure on the road or within the Right of Way intended to provide information or safety to road user. Some of them are:

a. Road Signs

Road signs have been proposed according to Nepal Traffic Signs Manual (Volume-1 &2). The signs are provided on embankment so that extreme edge of sign would be 2.0m away from the edge of the carriageway. The location of each sign is to be decided in accordance with the guidelines therein.

b. Road Markings

Road markings are proposed for centre and edge lines using reflective thermoplastic paints. Appropriate road markings have also been proposed at junctions and Interchanges / merging and diverging of slip road.

c. Crash Barriers

Crash barriers are protective devices those are placed between traffic and a potential hazard off the roadway, with the intention of reducing the severity of a collision when an errant vehicle leaves the travelled portion of the roadway. Barriers have been provided at high embankments, sharp curves and bridge approaches. The barrier is to be located at the edge of paved shoulders.

d. Highway Lightings

Highway lightings have been proposed at Interchange locations, and Bus Bays. Highway lighting have also been provided for entire length of Highway within the Urban Areas with minimum Lux level.

e. Foot Path

Foot Path with concrete block and tactile paving strips has been proposed at Urban Area.

f. Rumble Strips

Rumble Strips have been provided in sharp curve and areas where probability of obtaining high speed to alert the driver.

Detail of Road furniture and ancillary works are described in **Chapter-11, Road Safety.** Summary of the Road Furniture and Ancillary Works is presented in **Table12.4,** below.

Table 12.4: Summary of the Road Furniture and Ancillary Works

S. No.	Type of Safety Measures	Quantity	Unit
1	W Beam	10478	m
2	Thrie Beam	11630	m
3	RCC End Block	120	Nos

4	Hazard Plates	60	Nos
5	Emergency Boards	9	Nos
6	Edge Rumble Strip	33354	m
7	Transverse Rumble Strip	737	Sqm
8	Delineator	465	Nos
9	Road Studs	702	Nos
10	Footpath With Cycle Lane and Tactile Tiles	29060	m
11	Footpath Railing	4370	m
12	Zebra Crossing	44	Locations
13	Overhead Pedestrian Crossing	11	Locations

S.N	Description	Type						
		Regulatory	Warning			Informatory **	Route/ other Signs	Advance Direction Sign
		Circular (B 75)	Rectangle (C: 60*45)	Rectangular (D: 100*50)	Triangle (A :90)	Rectangle (C: 60*45)	Rectangle (E: 130*90)	
1	Speed signs	232.00	-	-	-	-	-	-
2	Chevron signs	-	178	-	-	-	-	-
3	Hazard Signs in Bridge	-	-	60.00	-	-	-	-
4	Pedestrian Crossing	-	-	-	88.00	88.00	-	-
5	Children/Pedestrian ahead	-	-	-	20.00	-	-	-
6	Recommended route for Cyclist	-	-	-	-	1,938.00	-	-
7	Recommended route for Pedestrian	-	-	-	-	1,938.00	-	-
8	No Entry	28.00	-	-	-	-	-	-
9	Place Identifiers	-	-	-	-	-	20.00	-
10	Bridge Identifiers	-	-	-	-	-	60.00	-
11	Emergency Boards	-	-	-	-	-	9.00	-
12	Route Identifiers	-	-	-	-	-	40.00	-
13	Gantry	-	-	-	-	-	-	14.00
14	T Junctions	24.00	-	-	24.00	24.00	-	-
15	Cross Junctions	35.00	-	-	30.00	25.00	-	-
16	LILO Junction	52.00	-	-	52.00	-	-	-
17	Minor Junction	-	-	-	904.00	-	-	-
18	Service	-	-	-	-	150.00	-	-
19	Animal Crossing	-	-	-	-	-	36.00	-
20	Bus Bays	-	-	-	-	48.00	-	-
21	School	-	-	-	-	-	20.00	-
22	Entry/Exit	-	-	-	-	-	30.00	-
23	Other/Extra	40.00	25	12	30.00	40.00	16.00	1.00
	Total	**411.00**	**203.00**	**72.00**	**1148.00**	**4251.00**	**231.00**	**15.00**

g. Rest Area

The Rest Area is one of the several types of roadside facilities that provide opportunities for travelers to safely stop, rest and manage their travel needs and safely access some of the recreational facilities. These roadside facilities include rest areas with and without tourism information centers located in the rest area building, open safety parking area, access for scenic overlooks and other sites. These facilities are functional and desirable elements of the highway facility.

Location of the Rest Area: A provisional proposed rest place are located at chainage 627+600~ 628+500 for both Left Side and Right Side**.** The Department of Roads shall obtain land for rest place. Rest area development costs are included in the cost estimate, after the construction of rest area the Department of Roads shall provide the rest area to the other public or private entity for its operations. Master Plan and other detail for the rest place is included in Drawing Volume-III.

Facility shall be included in the Rest Area:

Open parking, Fuel/Charging Station, Coffee Shop, Restaurant, Mini Grocery, First Aid Centre, Vehicle Repairing centre etc.

Other facility included in the design are:

Market centres: Enhancement of the following market place

1. **Right hand side of near Ch 618+000 Pipara Bazzar**

Public Toilet: Enhancement of the following Public Toilets

1. Buddhabhumi Municipality, Gorusinghe Chowk, Ward-2

Cost for enhancement of market place and public toilet are included in the cost estimate as a provisional sum, after the construction of market place and public toilet the Department of Roads shall provide the market place and public toilet to the other public or private entity for its operations. Drawings and other detail for the market place and public toilet is included in Drawing Volume-III.

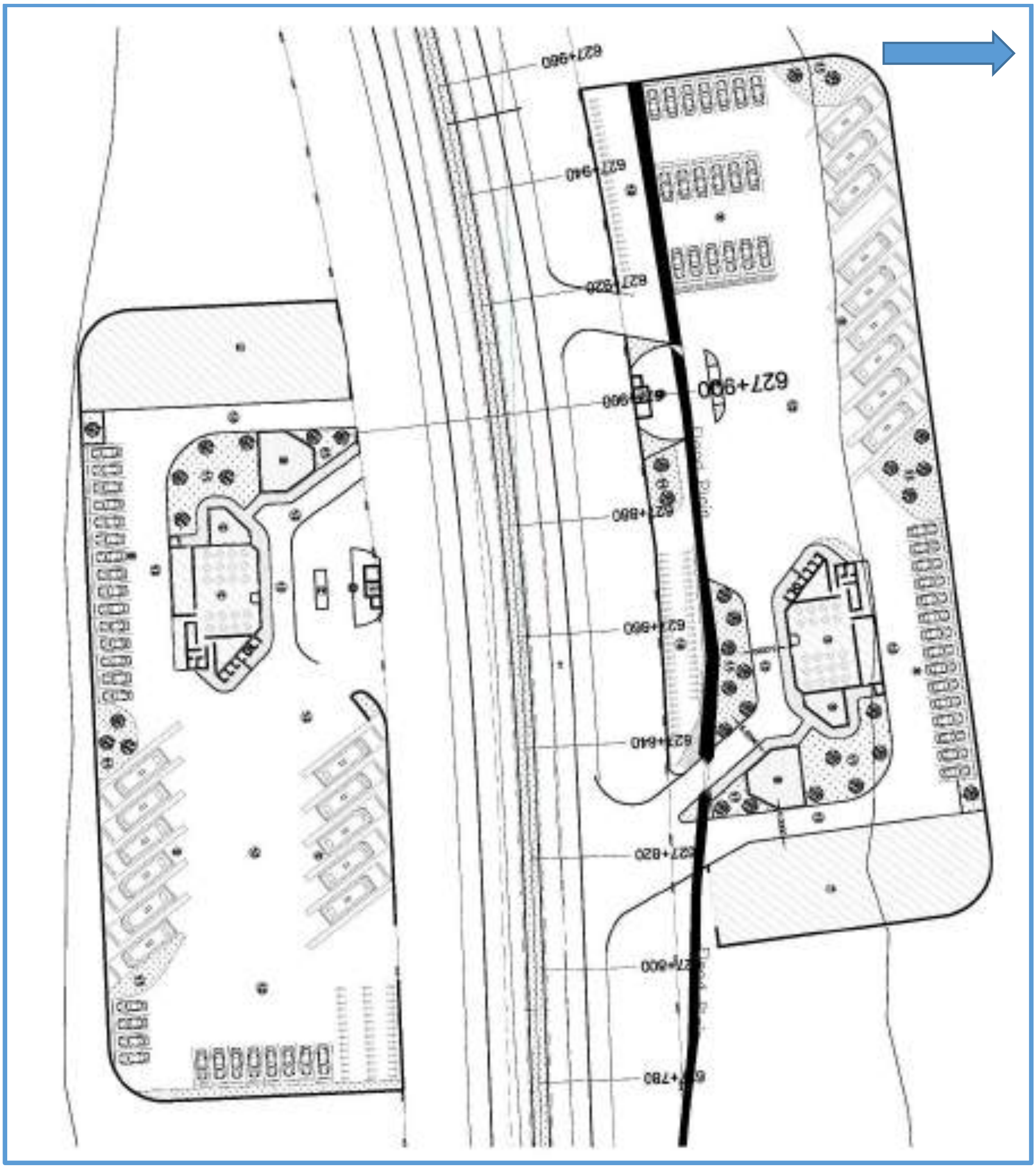


Figure 12.7: Master plan of Resting Place

Figure 12.8: Master plan of Market Place

12.3.8 Landslide Stabilization

As mentioned in geological investigation report a landslide exists at chainage 591+040~591+240. The causes and mechanism of the landslide are as following:

Causes of Landslide: Surface runoff

Mechanism of Landslide: Debris flow and Rotational slide

Functions shall be addressed:

- Reduce Stress (Additional Load)
- Catch
- Armor
- Reinforce
- Drain

Proposed Stabilization Method:

Bio-engineering technique in combination with small scale civil engineering structures are proposed to address above mentioned engineering functions for stabilization of the existing landslide.

Reduce Stress (Additional Load): Trimming of the existing landslide area and lowering the slope angle.

Catch: Toe wall at the middle and toe of the landslide, construction of the gabion wire bolster and Gabion Check Dam with grass and shrubs plantation at the lower part of the landslide, Grass and shrubs plantation at the upper part of the landslide.

Armor: Grass and Shrubs Plantation.

Reinforce: Shrubs Plantation, Gabion Bolster with nailing

Drain: Construction of Area Drain, Diagonal Bolster, Diagonal Grass Plantation, Vegetative Rip Rap and Gully Protection.

Drawings for the landslide stabilization works are presented in Vol. III Drawings. As the Department of Roads decided to conduct detailed investigation and design of stabilization of this landslide, so that proposed stabilization works are not included in cost estimate.

12.4 Engineering Drawings

The engineering drawing are prepared and presented to reflect the design concept in details. The drawings are prepared with sufficient details for bidding and execution of works in appropriate size, scale and format as defined in ToR. National and International practices are considered in preparation of drawing which are acceptable to the Client. Detailed Engineering Drawing, consisting of key plan, alignment plan & profile, and cross-sections have been prepared in appropriate scales. Plan, Profile and Cross-Sections of roads have been prepared by road design software namely SOFTWEL and then exported to AutoCAD for further processing. Whereas, other drawings have been prepared in AutoCAD. Drawings are presented in **Volume III Drawings.**

12.4.1 Preparation of Engineering Drawings

The following drawings are prepared to complete the design study:

- Location Map
- Site plan of the road alignments in topographic maps
- Road plan
- Road profile
- Typical Drawings
- Road cross sections at required interval
- Plan and profile containing details of geometry viz. horizontal alignment with coordinates of IP, Chainage of IP, curve data etc.
- Material sources maps
- Standard charts of mentioned cross drainage structures, retaining/Brest wall and protection works, side drain, typical cross section of the road according to types of soil, passing zone (if provided).

The drawings have been systematically catalogued contract wise so that future scrutiny becomes convenient.

12.4.2 Plan Drawings

Plan Drawings present the horizontal alignments of existing and upgraded road. Road design features such as centerline, edge of pavement, cut slope and embankment, toe line, drain details and horizontal curve details have been shown in the Plans. The plans also cover roadside features (natural and man-made), topography and existing infrastructure.

12.4.3 Profile Drawings

The profile drawings comprise of vertical alignment of the road with existing ground level along the centerline of the road. The levels of both existing and design levels along the road centerline have been shown, generally at 10m intervals.

12.4.4 Cross-section Drawings

Cross-section drawing is the combine production of the Plan and Profile drawings. Cross-section Drawings are prepared at 10m interval with details of existing and designed elements.

12.4.5 Miscellaneous Road Structures Drawings

All other miscellaneous road structure drawings such as Road furniture drawings, road safety drawings, typical drawings for other civil engineering structures, bio engineering structures, drainage drawings are prepared in appropriate scales.

13 Pavement Design

13.1 Scope of Pavement

The project primarily envisages reconstructing of existing two-lane carriageway with widening it to four lanes for augmenting capacity and significantly extending the service life of the project road.

The pavement works for implementing the above proposals will mainly consist of:

- Scarifying of the existing 2-lane main bituminous carriageway;
- Construction of carriageways with flexile pavement to widen the existing 2-lane main carriageway to proposed 4 lane divided configuration
- Construction of flexible pavement for rest area, truck lay-by and bus bays

13.2 Design Methodology

13.2.1 General Methodology

The Pavement Design is based on DoR Pavement Design Guidelines (Flexible Pavement), 2014 (Second Edition-2021) and TRL Road Note 31. The input parameters for the pavement design are the California Bearing Ratio (CBR) and design traffic in terms of millions of equivalent standard axle (msa).

The design process broadly involved the following:

a) Estimate of the amount of traffic and subsequently the cumulative number of equivalent standard axles of 10.2 t (ESA20) for a pavement design life of 20 years.
b) Assessment of the CBR of the sub grade over which the pavement and shoulder are proposed to be laid. The laboratory CBR (soaked CBR) was considered to arrive at the design CBR of the sub grade.
c) At locations of high embankment, design CBR has been arrived after considering the CBR of fill materials from the approved tipping sites.
d) Assessment of the existing thickness of sub base & base, and their conditions have been carried out which is presented as the Test Pit Logs in the **Annexure XII**. The information could prove useful to broadly define the construction procedure.
e) Assessment on the improvement required for sub grade required based on visual inspection of existing pavement/shoulder surface deformations, test pits, CBR and land use pattern.
f) Selection of the most economical combinations of pavement materials and layer thicknesses that will provide satisfactory services for the design life of 20 years of the pavement structure.

The design also considers multi-layered elastic theory to check on the vertical and tensile stresses at various pavement interfaces.

13.2.2 Standards and Literature

Standards and literature referred for pavement design were:

a) Nepal Road Standards 2070;
b) Pavement Design Guidelines, Government of Nepal, Ministry of Physical Infrastructure and Transport, Department of Roads, 2014 (Second Edition-2021), Kathmandu;
c) Overseas Road Note 31, A guide to the structural design of bitumen-surfaced roads in tropical and sub-tropical countries, TRL Limited, Crowthorne, Berkshire United Kingdom;
d) Overseas Road Note 18, A guide to the pavement evaluation and maintenance of bitumen-surfaced roads in tropical and sub-tropical countries TRL Limited, Crowthorne, Berkshire United Kingdom;
e) IRC-37, Guidelines for the Design of Flexible Pavement (Third Revision), Indian Road Congress July 2012;
f) Asian Highway classification and design standards.

13.3 Design Approach

13.3.1 General

The Project Road is an integral part of East West Highway, with Butwal at km 590+000 and Gorusinghe (Imiliya) at km 640+000. This section of the road serves as an important passenger and freight corridor for various villages and towns that lie to the north and south. Hence, its importance cannot be underestimated in the context of the Nepali strategic road network.

The following subsequent sections describe the findings from field investigations, tests and literature review; these findings have been used as inputs for pavement design.

The field and laboratory tests, traffic analysis and the findings are detailed in the preceding Chapters. Only major findings have been extracted, summarized and presented in this Chapter for the sake of general fluidity.

13.3.2 Pavement Condition and Pavement Design Standards

The Carriageway width along the alignment in average is about 6m with 1m wide shoulder on both sides. As per Pavement Condition Survey conducted by the Department of Roads and the Consultants observation in the field the pavement condition is observed to be in fair condition with cracks and maintained pot holes in few locations.

Pits dug revealed an average gravel base course of 150 mm while the depth of sub base is 200 mm. Visual examination of base course material shows that it is on the verge of disintegrating, indicating remaining of structural life of about 3 to 5 years. Hence, the existing sub base and base course could either be:

a) Remolded as sub base material to construct new sub base layer when widening, or

b) Remove this material to blend it into the new sub grade to increase its in situ CBR at locations as an additional measure to prevent longitudinal cracks between the existing and new road formation

The use of existing sub base and base course layers makes economic sense. If the existing thickness of base and sub base of 350 mm is uniform and spread over 20 m of carriageway and shoulder, the resulting thickness of such sub base would be in the range of about 70 mm even after accounting a loss of 40% when scarifying and re-profiling. Hence, the designed thickness could be reduced by the corresponding thickness subject to the provision that any additional compacted layer placed on top should not be less than 20% of the total volume of the works.

This pavement design is based on the requirement for a four-lane highway of "Asian Highway" standard. The main characteristics of the proposed highway consist of a 7.5 m dual carriageway including curb shy with two sealed 2.5 m shoulders on either side (20 m wide carriageway). The dual carriageway is proposed to be separated by a 3 m wide median.

In built-up areas, two 6.5 m wide service roads are foreseen. These service roads will be, separated from the 2.5 m wide shoulders by a 1.5 m wide belt. Further, there is also provision for a 5.5 m wide foot path on either side in the built-up areas.

The design also accommodates four side drains. These are located on the verge side of the shoulders and the footpaths.

For the most part, Butwal-Gorusinghe (Imiliya) Road Section of East-West Highway is built on flat terrain. Roadside drains would be provided in accordance with the geometrics.

13.3.3 Test Pits and Laboratory Tests

Laboratory CBR tests were conducted on samples collected from the areas outside the existing formation width. These areas represent the probable surface that will constitute the new sub grade. The findings are summarized in **Table13.1.**

DCP tests were conducted in the field and the CBR values from such tests have been included in **Annexure XIII** Details of Investigation and Tests conducted for road pavement is described in **Chapter: Geotechnical Survey and Investigation.**

Table 13.1: Summary of Sub Grade Properties from Laboratory CBR

Chainage	Grain Size Analysis			Compaction		Laboratory CBR (%)	CBR Value from DCP (%)
	Gravel (%)	Sand (%)	Silt + Clay (%)	OMC (%)	MDD (KN/m^3)		
590+000	6.65	19.15	74.21	12.60	1.98	11.60	21.80
591+000	26.51	34.08	39.41	12.00	1.94	10.25	12.70
592+000	7.21	23.54	69.25	10.60	2.00	8.09	10.60
593+000	12.96	54.35	32.69	11.60	1.95	9.44	18.30
594+000	7.17	34.83	58.00	12.00	1.94	12.38	5.50

595+000	3.08	18.32	78.61	12.60	1.95	13.48	7.00
596+000	21.76	37.22	41.02	11.00	2.00	20.76	7.70
597+000	5.65	17.63	76.72	13.00	1.92	10.67	4.30
598+000	5.47	4.17	90.36	12.20	1.86	24.27	11.50
599+000	3.16	58.80	38.04	13.20	1.86	20.50	8.90
600+000	0.31	6.51	93.18	11.00	1.90	16.99	2.80
601+000	3.79	7.75	88.46	15.20	1.91	9.98	2.20
602+000	1.31	6.50	92.20	12.20	1.88	7.42	3.80
603+000	5.07	8.20	86.73	12.40	1.97	9.44	2.70
604+000	1.89	14.21	83.91	11.80	1.94	9.30	2.90
605+000	6.83	14.27	78.89	12.40	1.97	17.80	8.00
606+000	6.54	16.31	77.15	7.80	1.94	13.22	2.90
607+000	22.61	37.94	39.46	11.60	1.96	30.48	4.10
608+000	5.10	6.49	88.40	6.80	1.90	4.99	4.90
609+000	3.41	9.18	87.41	11.00	1.90	8.90	4.40
610+000	6.57	18.74	74.69	11.20	1.98	8.63	10.10
611+000	13.57	47.19	39.24	11.60	1.95	7.28	5.20
612+000	16.44	20.20	63.36	13.00	1.93	14.29	10.50
613+000	4.50	24.60	70.90	9.00	1.97	10.25	7.30
614+000	30.67	28.70	40.62	12.20	1.94	25.09	14.20
615+000	6.63	36.74	56.63	14.40	1.93	7.14	12.70
616+000	7.18	24.47	68.34	13.80	1.83	5.93	8.60
617+000	5.85	28.36	65.79	11.00	1.99	23.73	12.70
618+000	10.56	32.44	57.00	13.80	1.97	21.43	8.00
619+000	18.08	41.69	40.23	11.40	1.92	33.33	12.10
620+000	23.11	31.89	45.01	10.00	1.94	9.98	14.70
621+000	6.95	19.83	73.22	13.00	1.85	7.55	4.70
622+000	30.06	46.88	23.06	7.00	2.04	24.00	10.10
623+000	1.42	17.49	81.10	11.60	1.92	22.11	7.70
624+000	9.10	27.77	63.14	12.80	1.94	8.57	9.60
625+000	4.49	25.57	69.94	9.80	1.97	7.82	12.10
626+000	0.19	4.56	95.26	12.40	1.89	5.12	8.30
627+000	2.04	6.34	91.62	13.40	1.93	5.39	11.50
628+000	2.24	9.65	88.11	11.00	1.96	10.52	6.10
629+000	0.82	12.00	87.18	13.80	1.90	5.12	8.30
630+000	5.34	12.00	82.66	11.00	1.96	37.22	12.70
631+000	15.99	22.74	61.27	13.20	1.93	20.00	8.30
632+000	30.74	24.81	44.45	12.20	1.89	8.57	13.80
633+000	6.45	21.05	72.50	9.20	1.92	9.17	17.00
634+000	4.67	39.19	56.15	12.20	1.88	30.00	6.80
635+000	2.07	10.15	87.78	11.20	1.95	11.32	8.00
636+000	3.09	8.31	88.60	12.80	1.97	8.63	5.40

637+000	0.55	8.23	91.22	9.40	1.96	10.48	4.00
638+000	3.15	24.60	72.25	11.20	1.91	22.66	5.40
639+000	1.95	21.45	76.61	11.80	1.90	6.74	12.70
640+000	6.55	34.89	58.56	12.60	1.97	6.48	6.10

The design CBR proposed are not based on the DCP values; rather they have been taken as guidance to locate areas if any which would require a capping layer because of very weak soil conditions (high moisture content, predominantly weak clay, very weak soaked CBR on remolded samples of existing soil).

Visual examination of the subgrade area during design phase field visit did not reveal any marshy conditions; however, standing water were observed outside the existing formation width in borrow area pits from previous road upgrading.

13.3.4 Land Use Adjacent to Corridor

The land use adjacent to the Corridor is predominantly agricultural and tea estate interspaced with market area and forest area. Most of the road formation is in embankment, except for small stretches in minor cut.

13.3.5 Design CBR

Field DCP CBR at a depth of 300 mm below the proposed subgrade display low values right along the whole Butwal-Gorusinghe (Imiliya) Section of East-West Highway. But these values have not been adopted as it would lead to a very conservative design. In fact, the older version of the IRC 37 - 2012 clearly recommends that the design of pavement should be based on lab CBR rather than field DCP. Hence, the laboratory CBR (4 days shocked) values have been adopted in the present design. **Table 13.2** Laboratory CBR Values for Design of Highway Pavement.

Table 13.2: Laboratory CBR Values for Design of Highway Pavement.

S.No.	Chainage		CBR		Subgrade Strength as per ORN-31	Remarks
	From	to	Average Designed	Adopted		
1	589+000	591+000	10.920	10	S4	
2	591+000	593+000	8.760	8	S4	
3	593+000	595+000	12.930	12	S4	
4	595+000	596+000	20.760	15	S3	
5	596+000	597+000	10.670	10	S3	
6	597+000	600+000	20.590	15	S4	
7	600+000	601+000	9.980	10	S3	
8	601+000	602+000	7.420	7	S4	

S.No.	Chainage		CBR		Subgrade Strength as per ORN-31	Remarks
	From	to	Average Designed	Adopted		
9	602+000	604+000	9.430	9	S4	
10	604+000	607+000	20.500	12	S4	
11	607+000	608+000	4.990	5	S3	
12	608+000	610+000	8.760	8	S4	
13	610+000	611+000	7.280	7	S3	
14	611+000	612+000	14.290	12	S4	
15	612+000	613+000	10.250	10	S4	
16	613+000	614+000	25.090	15	S5	
17	614+000	616+000	6.540	6	S3	
18	616+000	619+000	26.170	15	S5	
19	619+000	620+000	9.980	10	S4	
20	620+000	621+000	7.550	7	S3	
21	621+000	623+000	23.060	15	S4	
22	623+000	625+000	8.020	8	S4	
23	625+000	627+000	5.260	5	S3	
24	627+000	628+000	10.520	10	S4	
25	628+000	629+000	5.120	5	S3	
26	629+000	631+000	28.610	15	S5	
27	631+000	633+000	8.870	8	S4	
28	633+000	634+000	30.000	15	S5	
29	634+000	635+000	11.320	11	S4	
30	635+000	636+000	8.630	8	S4	
31	636+000	637+000	10.480	10	S4	
32	637+000	638+000	22.660	15	S5	
33	638+000	640+000	6.610	6	S3	

13.3.6 Traffic Survey, Lane Factor

a) Traffic Data

A traffic analysis and forecast have been made to determine future traffic demand of the proposed road which is presented in details in the **Chapter: Traffic Studies, Analysis and Forecast.**

Similarly, the Equivalent Standard Axle for the next 20 years were subsequently calculated on the basis of years based on the traffic data from above data and assumptions. These are detailed out in a separate **Chapter: Traffic Studies, Analysis and Forecast** but has been nevertheless reproduced in **Table 13.3** and **13.4** for continuity's sake.

Table 13.3: ESA from Traffic Study for Carriageway

S.No.	Chainage		MSA20 for Carriageway	Traffic Class as per Road Note 31	Remarks
	From	to			
1	589+000	591+000	51.89	>T8	
2	591+000	593+000	51.89	>T8	
3	593+000	595+000	51.89	>T8	
4	595+000	596+000	51.89	>T8	
5	596+000	597+000	51.89	>T8	
6	597+000	600+000	51.89	>T8	
7	600+000	601+000	51.89	>T8	
8	601+000	602+000	51.89	>T8	
9	602+000	604+000	51.89	>T8	
10	604+000	607+000	51.89	>T8	
11	607+000	608+000	51.89	>T8	
12	608+000	610+000	51.89	>T8	
13	610+000	611+000	51.89	>T8	
14	611+000	612+000	51.89	>T8	
15	612+000	613+000	51.89	>T8	
16	613+000	614+000	51.89	>T8	
17	614+000	616+000	51.89	>T8	
18	616+000	619+000	33.95	>T8	
19	619+000	620+000	33.95	>T8	
20	620+000	621+000	33.95	>T8	
21	621+000	623+000	33.95	>T8	
22	623+000	625+000	33.95	>T8	
23	625+000	627+000	33.95	>T8	
24	627+000	628+000	33.95	>T8	
25	628+000	629+000	33.95	>T8	
26	629+000	631+000	33.95	>T8	
27	631+000	633+000	33.95	>T8	
28	633+000	634+000	33.95	>T8	

S.No.	Chainage		MSA20 for Carriageway	Traffic Class as per Road Note 31	Remarks
	From	to			
29	634+000	635+000	33.95	>T8	
30	635+000	636+000	108.41	>T8	
31	636+000	637+000	108.41	>T8	
32	637+000	638+000	108.41	>T8	
33	638+000	640+000	108.41	>T8	

Note: All value is '>T8' so that pavement design using TRL Road Note 31 was not possible.

Table 13.4: ESA from Traffic Study for Service Road

S.No.	Chainage		MSA20 for Carriageway	Traffic Class as per Road Note 31	Remarks
	From	to			
1	589+000	591+000	9.48	T6	
2	591+000	593+000	9.48	T6	
3	593+000	595+000	9.48	T6	
4	595+000	596+000	9.48	T6	
5	596+000	597+000	9.48	T6	
6	597+000	600+000	9.48	T6	
7	600+000	601+000	9.48	T6	
8	601+000	602+000	9.48	T6	
9	602+000	604+000	9.48	T6	
10	604+000	607+000	9.48	T6	
11	607+000	608+000	9.48	T6	
12	608+000	610+000	9.48	T6	
13	610+000	611+000	9.48	T6	
14	611+000	612+000	9.48	T6	
15	612+000	613+000	9.48	T6	
16	613+000	614+000	9.48	T6	
17	614+000	616+000	9.48	T6	
18	616+000	619+000	4.70	T5	
19	619+000	620+000	4.70	T5	
20	620+000	621+000	4.70	T5	
21	621+000	623+000	4.70	T5	
22	623+000	625+000	4.70	T5	
23	625+000	627+000	4.70	T5	
24	627+000	628+000	4.70	T5	
25	628+000	629+000	4.70	T5	
26	629+000	631+000	4.70	T5	
27	631+000	633+000	4.70	T5	
28	633+000	634+000	4.70	T5	

S.No.	Chainage		MSA20 for Carriageway	Traffic Class as per Road Note 31	Remarks
	From	to			
29	634+000	635+000	4.70	T5	
30	635+000	636+000	14.71	T7	
31	636+000	637+000	14.71	T7	
32	637+000	638+000	14.71	T7	
33	638+000	640+000	14.71	T7	

b) Lane Factor

Due to unbalanced traffic movement on the road, the traffic in each direction was assumed 60% of the sum in both directions. Lane Factor adopted for the four-lane dual carriageway is 0.40. This is in accordance with the Pavement Design Guidelines published by DoR (GoN, MoPIT) 2014 (Second Edition-2021).

13.3.7 Design Period and ESA

a) Design Period

Pavement Design Life adopted for sub base, base courses and wearing course is 20 years. This design life is in accordance to DoR's published Pavement Design Guidelines, 2014 (Second Edition-2021) Kathmandu.

b) Design ESA

Design ESA for 20 years for the main carriageway and service lanes where applicable are laid out under Chapter: Traffic Studies, Analysis and Forecast.

Proposed Design Traffic, as per TRL, for 20 years of design life ESA15 for main carriageway and service road as presented in **Table 13.4: MSA from Traffic Study for Carriageway and Service Road**

13.3.8 Pavement Material and Structure

General, material requirement, physical properties and construction methods of the pavement material shall conform the Specification of Road and Bridge Works, published by Department of Roads-2075 (Second Amendment 2078).

Pavement structure shall comprise of sub-grade, capping layer (if any), sub base, granular base course and two layers of bituminous wearing course (DBM and AC). Typical pavement cross section is shown in **Figure 13.1.**

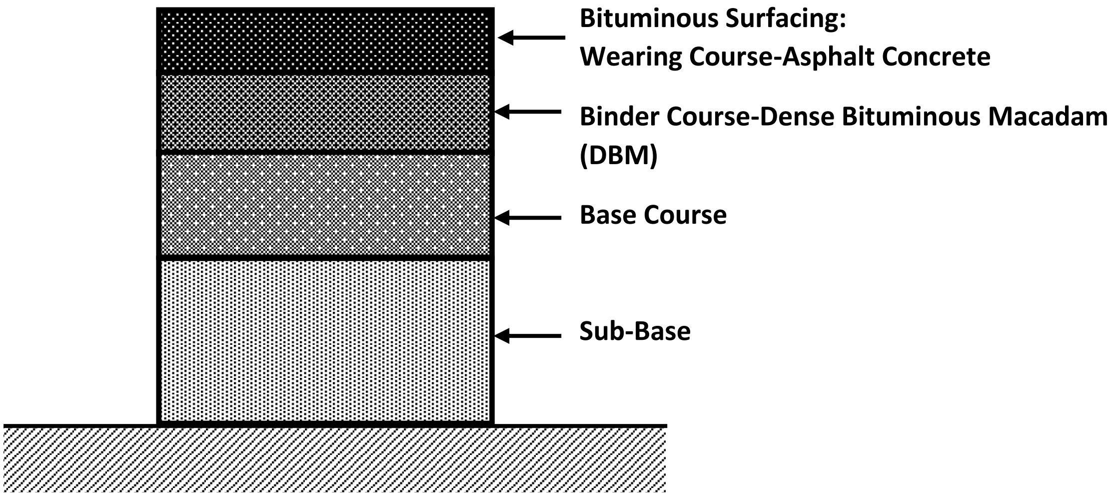


Figure 13.1: Typical pavement cross section.

13.4 Structural Pavement Design

13.4.1 Summary of Parameters for Design Inputs

Major inputs for the design of pavement are: CBR value of Sub-grade, Design period, Design ESA, and material to be used for construction of pavement structure. The inputs for design of pavement structure are summarized below. The backgrounds to arrive at such input parameters have been discussed in Subchapters of 13.3.5, 13.3.6 and 13.3.7.

The input parameters for design are tabulated below in **Table 13.5.**

Table 13.5: Basic Design Parameters for Pavement Design

Parameters	Particulars	Reference
CBR of Sub-grade	5-15	Design CBR, Chapter 13.3.5
Design Period	20 years	Design Period, Chapter 13.3.7(a)
ESA	T8 and >T8 as per TRL Road Note 31. Refer to Design ESA Table 13.4 for Design ESA if DoR Pavement Design Guidelines are to be followed	Design ESA, Chapter 13.3.7(b) and Chapter 13.3 6
Type of Sub-Base and Base Course	Natural Gravel (for sub base) and Graded Crushed Stone for base course (wet mix)	As per Pavement Design Guidelines of DoR

13.4.2 Flexible Pavement Design

Pavement design is the process of developing the most economical combination of pavement layers, with respect to thickness and type of material, to protect the soil foundation from the cumulative loading of traffic for the design life.

The Pavement Design Guideline (Flexible Pavement), 2021 Published by Department of Roads has been adopted for design of different components of pavements.

The object of the design is lay out the various possible alternatives and to form a basis for narrowing down the alternatives that is the best pavement for Butwal-Gorusinghe Section of East-West Highway. Apart from technical issues, emphasis is placed on the most economical solution and consideration of climate change effects.

As mentioned in the preceding Chapters, Butwal-Gorusinghe Section of East-West Highway has been divided into multiple numbers of homogeneous sections on the basis of CBR and traffic loads.

Design results of the pavement design is shown in **Table 13.6**, below.

Table 13.6: Pavement design for Carriageway

S. No.	Chainage		CBR		msa		Total Pavement Thickness, mm	Pavement Composition				Total Pavement Thickness, mm	Adopted Pavement Composition			
										Bituminous Surfacing					Bituminous Surfacing	
	From	to	Average Designed	Adopted				Granular Sub-Base, mm	Granular Base, mm	Dance Bituminous Macadam, mm	Asphalt Concrete, mm		Granular Sub-Base, mm	Granular Base, mm	Dance Bituminous Macadam, mm	Asphalt Concret e, mm
1	590+000	591+000	10.920	10	51.89	50	590.00	300.00	200.00	50.00	40.00					
						70	600.00	300.00	200.00	60.00	40.00					
							590.95	300.00	200.00	50.95	40.00	600.00	300.00	200.00	50.00	50.00
2	591+000	593+000	8.760	8	51.89	50	650.00	300.00	250.00	60.00	40.00					
						70	655.00	300.00	250.00	65.00	40.00					
							650.47	300.00	250.00	60.47	40.00	600.00	300.00	200.00	50.00	50.00
3	593+000	595+000	12.930	12	51.89	50	490.00	250.00	150.00	50.00	40.00					
						70	500.00	250.00	150.00	60.00	40.00					
							490.95	250.00	150.00	50.95	40.00	500.00	250.00	150.00	50.00	50.00
4	595+000	596+000	20.760	15	51.89	50	390.00	150.00	150.00	50.00	40.00					
						70	490.00	250.00	150.00	50.00	40.00					
							399.45	159.45	150.00	50.00	40.00	500.00	250.00	150.00	50.00	50.00
5	596+000	597+000	10.670	10	51.89	50	590.00	300.00	200.00	50.00	40.00					
						70	600.00	300.00	200.00	60.00	40.00					
							590.95	300.00	200.00	50.95	40.00	600.00	300.00	200.00	50.00	50.00
6	597+000	600+000	20.590	15	51.89	50	390.00	150.00	150.00	50.00	40.00					
						70	490.00	250.00	150.00	50.00	40.00					
							399.45	159.45	150.00	50.00	40.00	500.00	250.00	150.00	50.00	50.00
7	600+000	601+000	9.980	10	51.89	50	590.00	300.00	200.00	50.00	40.00					
						70	600.00	300.00	200.00	60.00	40.00					
							590.95	300.00	200.00	50.95	40.00	600.00	300.00	200.00	50.00	50.00
8	601+000	602+000	7.420	7	51.89	50	700.00	300.00	300.00	60.00	40.00					
						70	710.00	300.00	300.00	70.00	40.00					
							700.95	300.00	300.00	60.95	40.00	700.00	300.00	300.00	50.00	50.00
9	602+000	604+000	9.430	9	51.89	50	550.00	250.00	200.00	60.00	40.00					
						70	605.00	300.00	200.00	65.00	40.00					
							555.20	254.73	200.00	60.47	40.00	600.00	300.00	200.00	50.00	50.00

S. No.	Chainage		CBR		msa		Total Pavement Thickness, mm	Pavement Composition				Total Pavement Thickness, mm	Adopted Pavement Composition			
										Bituminous Surfacing					Bituminous Surfacing	
	From	to	Average Designed	Adopted				Granular Sub-Base, mm	Granular Base, mm	Dance Bituminous Macadam, mm	Asphalt Concrete, mm		Granular Sub-Base, mm	Granular Base, mm	Dance Bituminous Macadam, mm	Asphalt Concrete, mm
10	604+000	607+000	20.500	12	51.89	50	490.00	250.00	150.00	50.00	40.00					
						70	500.00	250.00	150.00	60.00	40.00					
							490.95	250.00	150.00	50.95	40.00	500.00	250.00	150.00	50.00	50.00
11	607+000	608+000	4.990	5	51.89	50	750.00	300.00	300.00	110.00	40.00					
						70	790.00	300.00	300.00	150.00	40.00					
							753.78	300.00	300.00	113.78	40.00	700.00	300.00	300.00	50.00	50.00
12	608+000	610+000	8.760	8	51.89	50	650.00	300.00	250.00	60.00	40.00					
						70	655.00	300.00	250.00	65.00	40.00					
							650.47	300.00	250.00	60.47	40.00	700.00	300.00	300.00	50.00	50.00
13	610+000	611+000	7.280	7	51.89	50	700.00	300.00	300.00	60.00	40.00					
						70	710.00	300.00	300.00	70.00	40.00					
							700.95	300.00	300.00	60.95	40.00	700.00	300.00	300.00	50.00	50.00
14	611+000	612+000	14.290	12	51.89	50	490.00	250.00	150.00	50.00	40.00					
						70	500.00	250.00	150.00	60.00	40.00					
							490.95	250.00	150.00	50.95	40.00	500.00	250.00	150.00	50.00	50.00
15	612+000	613+000	10.250	10	51.89	50	590.00	300.00	200.00	50.00	40.00					
						70	600.00	300.00	200.00	60.00	40.00					
							590.95	300.00	200.00	50.95	40.00	600.00	300.00	200.00	50.00	50.00
16	613+000	614+000	25.090	15	51.89	50	390.00	150.00	150.00	50.00	40.00					
						70	490.00	250.00	150.00	50.00	40.00					
							399.45	159.45	150.00	50.00	40.00	500.00	250.00	150.00	50.00	50.00
17	614+000	616+000	6.540	6	51.89	50	715.00	300.00	300.00	75.00	40.00					
						70	740.00	300.00	300.00	100.00	40.00					
							717.36	300.00	300.00	77.36	40.00	700.00	300.00	300.00	50.00	50.00
18	616+000	619+000	26.170	15	33.95	30	390.00	150.00	150.00	50.00	40.00					
						40	390.00	150.00	150.00	50.00	40.00					
							390.00	150.00	150.00	50.00	40.00	500.00	250.00	150.00	50.00	50.00
19	619+000	620+000	9.980	10	33.95	30	490.00	250.00	150.00	50.00	40.00					
						40	540.00	250.00	200.00	50.00	40.00					
							509.75	250.00	169.75	50.00	40.00	500.00	250.00	150.00	50.00	50.00

S. No.	Chainage		CBR		msa		Total Pavement Thickness, mm	Pavement Composition				Total Pavement Thickness, mm	Adopted Pavement Composition			
	From	to	Average Designed	Adopted				Granular Sub-Base, mm	Granular Base, mm	Bituminous Surfacing			Granular Sub-Base, mm	Granular Base, mm	Bituminous Surfacing	
										Dance Bituminous Macadam, mm	Asphalt Concrete, mm				Dance Bituminous Macadam, mm	Asphalt Concrete, mm
20	620+000	621+000	7.550	7	33.95	30	600.00	250.00	250.00	60.00	40.00					
						40	650.00	300.00	250.00	60.00	40.00					
							619.75	269.75	250.00	60.00	40.00	600.00	300.00	200.00	50.00	50.00
21	621+000	623+000	23.060	15	33.95	30	390.00	150.00	150.00	50.00	40.00					
						40	390.00	150.00	150.00	50.00	40.00					
							390.00	150.00	150.00	50.00	40.00	500.00	250.00	150.00	50.00	50.00
22	623+000	625+000	8.020	8	33.95	30	590.00	300.00	200.00	50.00	40.00					
						40	590.00	300.00	200.00	50.00	40.00					
							590.00	300.00	200.00	50.00	40.00	600.00	300.00	200.00	50.00	50.00
23	625+000	627+000	5.260	5	33.95	30	715.00	300.00	300.00	75.00	40.00					
						40	730.00	300.00	300.00	90.00	40.00					
							720.93	300.00	300.00	80.93	40.00	700.00	300.00	300.00	50.00	50.00
24	627+000	628+000	10.520	10	33.95	30	490.00	250.00	150.00	50.00	40.00					
						40	540.00	250.00	200.00	50.00	40.00					
							509.75	250.00	169.75	50.00	40.00	600.00	300.00	200.00	50.00	50.00
25	628+000	629+000	5.120	5	33.95	30	715.00	300.00	300.00	75.00	40.00					
						40	730.00	300.00	300.00	90.00	40.00					
							720.93	300.00	300.00	80.93	40.00	700.00	300.00	300.00	50.00	50.00
26	629+000	631+000	28.610	15	33.95	30	390.00	150.00	150.00	50.00	40.00					
						40	390.00	150.00	150.00	50.00	40.00					
							390.00	150.00	150.00	50.00	40.00	500.00	250.00	150.00	50.00	50.00
27	631+000	633+000	8.870	8	33.95	30	590.00	300.00	200.00	50.00	40.00					
						40	590.00	300.00	200.00	50.00	40.00					
							590.00	300.00	200.00	50.00	40.00	600.00	300.00	200.00	50.00	50.00
28	633+000	634+000	30.000	15	33.95	30	390.00	150.00	150.00	50.00	40.00					
						40	390.00	150.00	150.00	50.00	40.00					
							390.00	150.00	150.00	50.00	40.00	400.00	150.00	150.00	50.00	50.00
29	634+000	635+000	11.320	11	33.95	30	440.00	200.00	150.00	50.00	40.00					
						40	490.00	250.00	150.00	50.00	40.00					
							459.75	219.75	150.00	50.00	40.00	400.00	150.00	150.00	50.00	50.00

S. No.	Chainage		CBR		msa		Total Pavement Thickness, mm	Pavement Composition				Total Pavement Thickness, mm	Adopted Pavement Composition			
	From	to	Average Designed	Adopted				Granular Sub-Base, mm	Granular Base, mm	Bituminous Surfacing			Granular Sub-Base, mm	Granular Base, mm	Bituminous Surfacing	
										Dance Bituminous Macadam, mm	Asphalt Concrete, mm				Dance Bituminous Macadam, mm	Asphalt Concrete, mm
30	635+000	636+000	8.630	8	108.41	100	675.00	300.00	250.00	75.00	50.00					
						110	725.00	300.00	300.00	75.00	50.00					
							717.05	300.00	292.05	75.00	50.00	700.00	300.00	300.00	50.00	50.00
31	636+000	637+000	10.480	10	108.41	100	615.00	300.00	200.00	75.00	40.00					
						110	665.00	300.00	250.00	75.00	40.00					
							657.05	300.00	242.05	75.00	40.00	700.00	300.00	300.00	50.00	50.00
32	637+000	638+000	22.660	15	108.41	100	550.00	250.00	200.00	60.00	40.00					
						110	600.00	300.00	200.00	60.00	40.00					
							592.05	292.05	200.00	60.00	40.00	600.00	300.00	200.00	50.00	50.00
33	638+000	640+000	6.610	6	108.41	100	770.00	300.00	300.00	110.00	60.00					
						110	775.00	300.00	300.00	115.00	60.00					
							774.21	300.00	300.00	114.21	60.00	760.00	300.00	300.00	100.00	60.00

Table 13.7: Pavement design for Service Lane

S.No.	Chainage		CBR		msa		Total Pavement Thickness, mm	Pavement Composition				Total Pavement Thickness, mm	Adopted Pavement Composition			
	From	to	Average Designed	Adopted				Granular Sub-Base, mm	Granular Base, mm	Bituminous Surfacing			Granular Sub-Base, mm	Granular Base, mm	Bituminous Surfacing	
										DBM, mm	Asphalt Concrete, mm				DBM, mm	Asphalt Concrete, mm
1	590+000	591+000	10.920	10	9.48	5	340.00	150.00	150.00	0.00	40.00					
						10	340.00	150.00	150.00	0.00	40.00					
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
2	591+000	593+000	8.760	8	9.48	5	390.00	200.00	150.00	0.00	40.00					
						10	440.00	250.00	150.00	0.00	40.00					
							434.80	244.80	150.00	0.00	40.00	400.00	200.00	150.00		50.00
3	593+000	595+000	12.930	12	9.48	5	340.00	150.00	150.00	0.00	40.00					
						10	340.00	150.00	150.00	0.00	40.00					
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
4	595+000	596+000	20.760	15	9.48	5	340.00	150.00	150.00	0.00	40.00					
						10	340.00	150.00	150.00	0.00	40.00					
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
5	596+000	597+000	10.670	10	9.48	5	340.00	150.00	150.00	0.00	40.00					
						10	340.00	150.00	150.00	0.00	40.00					
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
6	597+000	600+000	20.590	15	9.48	5	340.00	150.00	150.00	0.00	40.00					
						10	340.00	150.00	150.00	0.00	40.00					
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
7	600+000	601+000	9.980	10	9.48	5	340.00	150.00	150.00	0.00	40.00					
						10	340.00	150.00	150.00	0.00	40.00					
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
8	601+000	602+000	7.420	7	9.48	5	390.00	200.00	150.00	0.00	40.00					
						10	490.00	250.00	200.00	0.00	40.00					
							479.60	244.80	194.80	0.00	40.00	400.00	200.00	150.00		50.00
9	602+000	604+000	9.430	9	9.48	5	340.00	150.00	150.00	0.00	40.00					
						10	390.00	200.00	150.00	0.00	40.00					
							384.80	194.80	150.00	0.00	40.00	400.00	200.00	150.00		50.00

S.No.	Chainage		CBR		msa		Total Pavement Thickness, mm	Pavement Composition				Total Pavement Thickness, mm	Adopted Pavement Composition			
	From	to	Average Designed	Adopted				Granular Sub-Base, mm	Granular Base, mm	Bituminous Surfacing			Granular Sub-Base, mm	Granular Base, mm	Bituminous Surfacing	
										DBM, mm	Asphalt Concrete, mm				DBM, mm	Asphalt Concrete, mm
10	604+000	607+000	20.500	12	9.48	5	340.00	150.00	150.00	0.00	40.00					
						10	340.00	150.00	150.00	0.00	40.00					
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
11	607+000	608+000	4.990	5	9.48	5	490.00	200.00	250.00	0.00	40.00					
						10	540.00	250.00	250.00	0.00	40.00					
							534.80	244.80	250.00	0.00	40.00	400.00	200.00	150.00		50.00
12	608+000	610+000	8.760	8	9.48	5	390.00	200.00	150.00	0.00	40.00					
						10	440.00	250.00	150.00	0.00	40.00					
							434.80	244.80	150.00	0.00	40.00	400.00	200.00	150.00		50.00
13	610+000	611+000	7.280	7	9.48	5	390.00	200.00	150.00	0.00	40.00					
						10	490.00	250.00	200.00	0.00	40.00					
							479.60	244.80	194.80	0.00	40.00	400.00	200.00	150.00		50.00
14	611+000	612+000	14.290	12	9.48	5	340.00	150.00	150.00	0.00	40.00					
						10	340.00	150.00	150.00	0.00	40.00					
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
15	612+000	613+000	10.250	10	9.48	5	340.00	150.00	150.00	0.00	40.00					
						10	340.00	150.00	150.00	0.00	40.00					
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
16	613+000	614+000	25.090	15	9.48	5	340.00	150.00	150.00	0.00	40.00					
						10	340.00	150.00	150.00	0.00	40.00					
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
17	614+000	616+000	6.540	6	9.48	5	440.00	200.00	200.00	0.00	40.00					
						10	540.00	250.00	250.00	0.00	40.00					
							529.60	244.80	244.80	0.00	40.00	400.00	200.00	150.00		50.00
18	616+000	619+000	26.170	15	4.70	5	340.00	150.00	150.00	0.00	40.00					
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
19	619+000	620+000	9.980	10	4.70	5	340.00	150.00	150.00	0.00	40.00					
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00

S.No.	Chainage		CBR		msa		Total Pavement Thickness, mm	Pavement Composition				Total Pavement Thickness, mm	Adopted Pavement Composition			
								Granular Sub-Base, mm	Granular Base, mm	Bituminous Surfacing			Granular Sub-Base, mm	Granular Base, mm	Bituminous Surfacing	
	From	to	Average Designed	Adopted						DBM, mm	Asphalt Concrete, mm				DBM, mm	Asphalt Concrete, mm
20	620+000	621+000	7.550	7	4.70	5	390.00	200.00	150.00	0.00	40.00					
							390.00	200.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
21	621+000	623+000	23.060	15	4.70	5	340.00	150.00	150.00	0.00	40.00					
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
22	623+000	625+000	8.020	8	4.70	5	390.00	200.00	150.00	0.00	40.00					
							390.00	200.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
23	625+000	627+000	5.260	5	4.70	5	490.00	200.00	250.00	0.00	40.00					
							490.00	200.00	250.00	0.00	40.00	400.00	200.00	150.00		50.00
24	627+000	628+000	10.520	10	4.70	5	340.00	150.00	150.00	0.00	40.00					
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
25	628+000	629+000	5.120	5	4.70	5	490.00	200.00	250.00	0.00	40.00					
							490.00	200.00	250.00	0.00	40.00	400.00	200.00	150.00		50.00
26	629+000	631+000	28.610	15	4.70	5	340.00	150.00	150.00	0.00	40.00					
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
27	631+000	633+000	8.870	8	4.70	5	390.00	200.00	150.00	0.00	40.00					
							390.00	200.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
28	633+000	634+000	30.000	15	4.70	5	340.00	150.00	150.00	0.00	40.00					
							0.00									
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00
29	634+000	635+000	11.320	11	4.70	5	340.00	150.00	150.00	0.00	40.00					
							0.00									
							340.00	150.00	150.00	0.00	40.00	400.00	200.00	150.00		50.00

S.No.	Chainage		CBR		msa		Total Pavement Thickness, mm	Pavement Composition				Total Pavement Thickness, mm	Adopted Pavement Composition			
	From	to	Average Designed	Adopted				Granular Sub-Base, mm	Granular Base, mm	Bituminous Surfacing			Granular Sub-Base, mm	Granular Base, mm	Bituminous Surfacing	
										DBM, mm	Asphalt Concrete, mm				DBM, mm	Asphalt Concrete, mm
30	635+000	636+000	8.630	8	14.71	10	440.00	250.00	150.00	0.00	40.00					
						20	460.00	200.00	200.00	0.00	60.00					
							449.42	226.45	173.55	0.00	49.42	400.00	200.00	150.00		50.00
31	636+000	637+000	10.480	10	14.71	10	340.00	150.00	150.00	0.00	40.00					
						20	360.00	150.00	150.00	0.00	60.00					
							349.42	150.00	150.00	0.00	49.42	400.00	200.00	150.00		50.00
32	637+000	638+000	22.660	15	14.71	10	340.00	150.00	150.00	0.00	40.00					
						20	360.00	150.00	150.00	0.00	60.00					
							349.42	150.00	150.00	0.00	49.42	400.00	200.00	150.00		50.00
33	638+000	640+000	6.610	6	14.71	10	540.00	250.00	250.00	0.00	40.00					
						20	510.00	250.00	200.00	0.00	60.00					
							525.87	250.00	226.45	0.00	49.42	400.00	200.00	150.00		50.00

13.4.3 Final Design

The interpolations of thicknesses of the pavement layers from the Design Catalogues as suggested in the Section 7 of the Pavement Design Guidelines – 2014 (Second Edition 2021) resulted in the various combinations of pavement layers and their thicknesses as shown in the table No. 8.4 (a) and (b).

For the sake of simplicity and convenience during the construction phase, the various combinations of the pavement thicknesses have been revisited to find a common thickness of each layer of Asphalt Concrete (wearing course) as 50 mm, Dense Bituminous Macadam (DBM) as 50 mm only in one case 60 and 100mm with necessary compensatory adjustments in the thicknesses of sub base and capping layers. For Asphalt Concrete and DBM, bitumen with Viscosity Grade 30 has been proposed.

In order to determine the necessary compensatory adjustments in the thicknesses of sub base/capping layers as the consequences of modifications in the thicknesses of DBM and base, the Structural Number (SN) of each pavement layer have been assessed from the AASHTO method.

The Structural Layer Coefficients of the various pavement layers are taken as tabulated below:

Table 13.8: Structural Layer Coefficient

Pavement Material	Structural Layer Coefficient
DBM	0.40
Crushed Stone Base	0.14
Granular Sub-Base	0.10

The drainage coefficients for base and sub base have been taken 1.00 each.

The calculation shows that the compensatory adjustment of 1 mm of DBM is equivalent to 4 mm of sub base and 1 mm of crushed stone base is equivalent to 1.4 mm of sub base. Considering the same, the revised combinations of thicknesses of pavement layers have been obtained and is presented as the recommended Pavement Design in **Table 13.9** and **13.10.**

Table 13.9: Final Pavement Thickness for Carriage way

S.No.	Chainage		Total Pavement Thickness, mm	Pavement Composition					Remarks
				Bituminous Surfacing		Granular Base, mm	Granular Sub-Base, mm	capping Layer, mm	
	From	to		Asphalt Concrete, mm	Dance Bituminous Macadam, mm				
1	589+000	591+000	600.00	50.00	50.00	200.00	300.00		
2	591+000	593+000	600.00	50.00	50.00	200.00	300.00	100.00	Replace Sub-grade by sub-base material
3	593+000	596+000	500.00	50.00	50.00	150.00	250.00		
4	596+000	597+000	600.00	50.00	50.00	200.00	300.00		
5	597+000	600+000	500.00	50.00	50.00	150.00	250.00		
7	600+000	601+000	600.00	50.00	50.00	200.00	300.00		
8	601+000	602+000	700.00	50.00	50.00	300.00	300.00		
9	602+000	604+000	600.00	50.00	50.00	200.00	300.00		
10	604+000	607+000	500.00	50.00	50.00	150.00	250.00		
11	607+000	608+000	700.00	50.00	50.00	300.00	300.00	250.00	Replace Sub-grade by sub-base material
12	608+000	611+000	600.00	50.00	50.00	200.00	300.00		
13	611+000	612+000	500.00	50.00	50.00	150.00	250.00		
14	612+000	613+000	600.00	50.00	50.00	200.00	300.00		
15	613+000	613+000	600.00	50.00	50.00	200.00	300.00		
16	613+000	614+000	500.00	50.00	50.00	150.00	250.00		
17	614+000	616+000	700.00	50.00	50.00	300.00	300.00	100.00	Replace Sub-grade by sub-base material
18	616+000	620+000	500.00	50.00	50.00	150.00	250.00		
19	620+000	621+000	600.00	50.00	50.00	200.00	300.00	100.00	Replace Sub-grade by sub-base material
20	621+000	623+000	500.00	50.00	50.00	150.00	250.00		
21	623+000	625+000	600.00	50.00	50.00	200.00	300.00		
22	625+000	627+000	700.00	50.00	50.00	300.00	300.00	100.00	Replace Sub-grade by sub-base material

S.No.	Chainage		Total Pavement Thickness, mm	Pavement Composition					Remarks
				Bituminous Surfacing		Granular Base, mm	Granular Sub-Base, mm	capping Layer, mm	
	From	to		Asphalt Concrete, mm	Dance Bituminous Macadam, mm				
23	627+000	628+000	600.00	50.00	50.00	200.00	300.00		
24	628+000	629+000	700.00	50.00	50.00	300.00	300.00	100.00	Replace Sub-grade by sub-base material
25	629+000	631+000	500.00	50.00	50.00	150.00	250.00		
26	631+000	633+000	600.00	50.00	50.00	200.00	300.00		
27	633+000	635+000	400.00	50.00	50.00	150.00	150.00		
28	635+000	636+000	700.00	50.00	50.00	300.00	300.00	100.00	Replace Sub-grade by sub-base material
29	636+000	637+000	700.00	50.00	50.00	300.00	300.00		
30	637+000	638+000	600.00	50.00	50.00	200.00	300.00		
31	638+000	640+000	760.00	60.00	100.00	300.00	300.00	100.00	Replace Sub-grade by sub-base material

Table 13.10: Final Pavement Thickness for Service Lane

S.No.	Chainage		Total Pavement Thickness, mm	Pavement Composition					Remarks
				Bituminous Surfacing					
	From	to		Asphalt Concrete, mm	Dance Bituminous Macadam, mm	Granular Base, mm	Granular Sub-Base, mm	capping Layer, mm	
1	589+000	601+000	400.00	50.00	0.00	150.00	200.00		
2	601+000	602+000	400.00	50.00	0.00	150.00	200.00	100.00	Replace Sub-grade by sub-base material
3	602+000	607+000	400.00	50.00	0.00	150.00	200.00		
4	607+000	608+000	400.00	50.00	0.00	150.00	200.00	200.00	Replace Sub-grade by sub-base material
5	608+000	610+000	400.00	50.00	0.00	150.00	200.00		
6	610+000	611+000	400.00	50.00	0.00	150.00	200.00	100.00	Replace Sub-grade by sub-base material
7	611+000	614+000	400.00	50.00	0.00	150.00	200.00		
8	614+000	616+000	400.00	50.00	0.00	150.00	200.00	200.00	Replace Sub-grade by sub-base material
9	616+000	625+000	400.00	50.00	0.00	150.00	200.00		
10	625+000	627+000	400.00	50.00	0.00	150.00	200.00	100.00	Replace Sub-grade by sub-base material
11	627+000	635+000	400.00	50.00	0.00	150.00	200.00		
12	635+000	636+000	400.00	50.00	0.00	150.00	200.00	100.00	Replace Sub-grade by sub-base material
13	636+000	638+000	400.00	50.00	0.00	150.00	200.00		
14	638+000	640+000	400.00	50.00	0.00	150.00	200.00	200.00	Replace Sub-grade by sub-base material

13.5 Consideration of Climate Change Effect in Road Design

Pavements are climate sensitive infrastructure, where climate can impact their deterioration rate, performance of the pavement, subsequent maintenance, and life-cycle costs. Therefore, there are substantial impacts on the pavement infrastructure due to the climate change. Similarly, Soil embankments are vulnerable to climate change due to their continuous exposure to the environment. The Consultant has paid their attention to consider climate change effect while designing the pavement and embankment.

- Embankment height has been raised in an average 0.50m, at the stretches where there is possibility of effect of flood due to the climate change.
- In order to protect embankment from seepage and for purpose of rain water harvesting, there is provision of draining the water accumulated in median to main drain by using perforated pipes.
- Grass and shrubs plantation on the slope of embankment has been included.
- For wearing coat, bitumen of viscosity grade 30 (VG 30) has been proposed in order to address climate change effect. Bitumen of VG 30 having good thermal susceptibility, has higher specific gravity and softening point (47-degree Celsius). Furthermore, it can be used in higher temperature and rainy season as well.
- In order to control deterioration rate and to increase performance, thickness of pavement layer has been increased.
- Considering effect of the climate change, design floods have been increased by 16% in extreme rainfall while designing the drainage structure. To be in safe side floods were estimated applying various method and adopted largest value estimated from different methods.

14 Hydrologic and Hydraulic Studies

The report on hydrologic and hydraulic detail studies of **Butwal-Gorusinghe** section of existing East West Highway has been prepared based on feasibility study, detail survey and field investigations of this section. The report provides hydrological and hydraulic parameters like Flood, HFL, Bridge Length and Scour Depth for the design of bridges and box bridges in the rivers of this section. Similarly, hydrology and hydraulics of cross drains and side drains are also provided with their types and sizes. All pipe and slab culverts have been replaced by box culverts. RCC precast side drains of suitable size have been recommended. River training works are also recommended wherever necessary.

The catchment characteristics were defined using GIS and Google Earth Pro. Frequency analyses of extreme rainfall and flood series have been conducted for the estimation of design floods by different methods. The effect of climate change on monsoon of Nepal having localized intense rainfall creating heavy floods in recent years has been accounted in estimating design floods. Hydraulic design parameters for bridges and box bridges were estimated by modeling in HEC-RAS software. Box culverts are designed with adequate floor slope creating self-flushing velocity even at low flows. Field visits and experience have also been used for deciding the hydrologic and hydraulic parameters.

Bridges and box bridges of this section are designed for 100 years return period flood. Box culverts have been designed for passing 50 years return period floods whereas side drains have been designed for 25 years return period flood. Some small bridges and large slab culverts are replaced by box bridges. All pipe culverts, slab culverts and causeways are replaced by box culverts based on design floods. Some additional box culverts are also provided wherever required. Adequate free board for all bridging structures has been provided. Adequate scour depths have been recommended for the foundation design of bridges and box bridges structures.

The frequency analyses of maximum daily rainfall have been conducted for representative rainfall stations of this section for flood estimation of rivers and drainages by rainfall-runoff models. Similarly, the frequency analysis of available annual instantaneous flood series in Tinau River at Butwal has been conducted to predict the design floods for drainage structures of this section. **The increased floods in future due to climate change have been considered while designing the drainage structures.**

14.1 Hydrometric and Rainfall Stations in the Project Area

Among several rivers in this section, only one hydrometric gauging station is found. The details of this station are depicted in Table 14.1. Representative rainfall stations with their details for this road section are provided in Table 14.2. Both hydrometric and rainfall data are provided in Hydrology **Annexure XIV.**

Table 14.1: Hydrometric Gauging Stations in the Project Area

St. No.	River	Location	Latitude	Longitude	Elevation (m)	Catchment Area (km^2)	Published Data	Data Quality
390	Tinau	Butwal	27.70	83.46	184	554	1964-1969	Fair

Table 14.2: Rainfall Stations in the Project Area with Annual, Monsoon and Maximum Daily Rainfalls

Index No.	Station name	Latitude	Longitude	Elevation	Record Length,	Av. Rainfall, mm		Extreme Rainfall, mm	
		degree	degree	(m)		Annual	Monsoon	Max. Daily	Date (D/M/Y)
0701	Ridibazar	27.95	83.43	442	60	1422	1146	230.4	13/06/1999
0702	Tansen	27.67	83.58	1067	60	1517	1273	194.3	10/07/1995
0703	Butwal	27.70	83.47	205	59	2501	2209	354.0	**14/07/1996**
0715	Khanchikot	27.93	83.15	1760	45	1810	1469	258.3	15/07/1989
0716	Taulihawa	27.55	83.07	94	45	1622	1411	298.5	10/07/1986
0721	Patharkot	27.77	83.05	200	43	2319	2046	296.0	22/07/1987

14.2 Frequency Analysis of Daily Maximum Rainfall

Hydrologic systems are sometimes impacted by extreme events, such as severe storms and floods. The magnitude of an extreme event is inversely related to its frequency of occurrence, very severe events occurring less frequently than more moderate events. Hence the frequency analysis of extreme rainfall is required for flood estimation by Rainfall-Runoff Models like Rational, Snyder, and PCJ 1996. In Nepal, annual series of maximum daily rainfalls are available by DHM which can be used to predict the design floods.

Annual series of Daily Maximum Rainfall (DMR) of representative rainfall stations for this road section are depicted in Table 14.3.

Table 14.3: Annual Series of Daily Maximum Rainfall (mm) at Representative Stations of BG Road Section

Year	701	702	703	715	716	721
	Ridi Bazar	Tansen	Butwal	Khanchikot	Taulihawa	Patharkot
1971				71.4		
1972				69.4		
1973				208.4		185.2
1974				66.9		140.2
1975				313.2		106
1976				78		60

Year	701	702	703	715	716	721
	Ridi Bazar	Tansen	Butwal	Khanchikot	Taulihawa	Patharkot
1977				199.6		127.2
1978				130		164
1979				103.5		97
1980				354.4		248.4
1981				380.9		284
1982				158		139
1983	103.4	100.7	92.1	191.6	91.6	149
1984	142.3	157.3	242.5	151.3	110.5	239.3
1985	90.5	123.2	130.9	155	142	223
1986	100.5	127.8	190	123	298.5	131.5
1987	100.5	118.4	240.4	166.3	117	296
1988	77.4	88	200.5	131.7	112.2	128.5
1989	98.8	177	163.9	258.3	171.6	116
1990	80.5	38	290.5	79.8	138.5	88.5
1991	130.4	26	143	104.7	186	175
1992	79.5	105	97.5	82	109.2	178
1993	107	115.4	171	152.5	167.2	178
1994	118	155.6	178	110.8	165	180
1995	123.4	194.3	220.8	100.8	116	160
1996	82.6	169	354	127.4	115	248
1997	68.6	80.4	146.2	134.5	72.5	142
1998	100.4	140.5	53	190.3	53	212
1999	230.4		65.6	51.3	163	147
2000	114.1		78.5	83	67	150.3
2001	82.4	103.2	112	78.8	87.5	170
2002	110	63	95.6	70.7	98	108
2003	116	170	156	257.3	95	98
2004	68	98	128.4	93.2	80	120
2005	128.5	123	175	180.3	104	240
2006	86.5	125	200.5	71.5	106	199
2007	102.6	96	244.2	155	183.6	121
2008	179.2	152	104	168	120	261
2009	174.2	182	84.2	216.4	128	252
2010	76.3	103	294.1	115.5	99.2	181
2011	156	68	88.4	250	218.4	178
2012	100.2	148	84.4	147.5	276	214
2013	130.5	181	174.4	192.2	249.5	179

The frequency analysis of daily maximum rainfall at selected stations was executed by computer software namely “CumFreq”, which has the facility to execute all available distributions in the software and select the best fitted distribution. Hence goodness of fit analysis is not required. Using CumFreq software the daily maximum rainfall of 50, 100 and 200 years at all stations were predicted by best fitted distributions and are presented in Table 14.4. For comparison the maximum observed daily rainfall along with number of observed years are also presented in Table 14.4.

Considering increase in monsoon rainfall in future due to climate change (Ref. 10 & 11), the average predicted rainfalls have been increased by 16%.

Table 14.4: Observed and Predicted Daily Maximum Rainfall at Representative Stations

Index	Station Name	Observed, mm		Predicted, mm			Best fitted Distribution
		Years	Max	50 Year	100 Year	200 Year	
0701	Ridibazar	31	230.4	232.6	270.6	314.4	Logistic Generalized
0702	Tansen	29	194.3	259.2	266.8	272.8	Fisher-Tippett type III
0703	Butwal	31	354.0	423.0	458.0	490.8	Generalized Exponential Poisson
0715	Khanchikot	43	380.9	451.2	512.1	575.3	Generalized Gumbel
0716	Taulihawa	31	298.5	494.8	587.0	698.8	Frechet (Fisher-Tippet type II)
0721	Patharkot	41	296.0	443.1	470.0	495.6	Fisher-Tippett type III
Average for BG Section				**384.0**	**427.4**	**474.6**	
Add 16% for Future Climate Change				**445.4**	**495.8**	**550.6**	

The hourly rainfall intensities (Table 14.5) are derived from daily maximum rainfall for representative stations which will be used for prediction of floods by PCJ 1996 rainfall-runoff model. **Considering increase in monsoon rainfall in future due to climate change (Ref. 10 and 11), the average predicted hourly rainfall intensities have been increased by 16%.**

Table 14.5: Predicted Hourly Rainfall Intensity at Representative Rainfall Stations

Index No.	Station Name	Predicted Hourly Rainfall Intensity (HRI), mm/min		
		50 Year	100 Year	200 years
701	Ridibazar	1.47	1.71	1.99
702	Tansen	1.64	1.69	1.73
703	Butwal	2.68	2.90	3.11
715	Khanchikot	2.86	3.24	3.64
716	Taulihawa	3.13	3.72	4.43
721	Patharkot	2.81	2.98	3.14
Average Hourly Rainfall Intensity		**2.43**	**2.71**	**3.01**
Add 16% for Future Climate Change		**2.82**	**3.14**	**3.49**

14.3 Consideration of Climate Change on Daily Maximum Rainfall

World Bank Group and Asian Development Bank have published Climate Risk Country Profile for Nepal (**Ref.10**) through Climate Change Knowledge Portal (CCKP) and concluded following effects of climate change on temperature and precipitation:

- Warming in Nepal is projected to be higher than the global average. By the 2080s, **Nepal is projected to warm by 1.2°C–4.2°C**, under the highest emission scenario, RCP8.5, as compared to the baseline period 1986–2005. The range in possible temperature rises highlights the significantly lower rates of warming expected on lower 21st century emissions pathways.

- Rises in maximum and minimum temperatures are expected to be stronger than the rise in average temperature, likely amplifying the pressure on human health, livelihoods, and ecosystems. Temperature increase is expected to be strongest during the winter months.
- Climate change is already having significant impacts on the environment in Nepal, species' ranges are shifting to higher altitudes, glaciers are melting, and the **frequency of precipitation extremes is increasing.**
- Natural hazards such as drought, heatwave**, river flooding, and glacial lake outburst flooding are all projected to intensify over the 21st century**, potentially exacerbating disaster risk levels and putting human life at risk.
- Modelling has suggested that the **number of people annually affected by river flooding could more than double by 2030 as a result of climate change**. **At the same time the economic impact of river flooding could triple.**

Following table gives the future rainfall increment in monsoon of Nepal which can be considered for flood estimation of drainage structures.

Table 14.6: Comparison of historical rainfall and CCKP output for Nepal (Source: CCKP Portal)

Month	Historical rainfall in mm (1980-2015)	Predicted Rainfall in mm (2020-2099)	Increment
July	326	342	4.9 %
August	279	325	16.5 %
September	202	205	1.5 %

The Bay of Plenty Regional Council, New Zealand (Ref. 11) has adopted the Intergovernmental Panel on Climate Change **(IPCC)** estimates for climate change in the region's rivers, drainage schemes and storm water systems. Climate change and in particular the global warming has the potential to increase the magnitude, level and frequency of flooding. Hence the capacity of existing and proposed flood protection and storm water assets must be reviewed periodically when the new flow data becomes available.

Hydrological design data may need to be adjusted for design purposes to account for future climate change that includes sea level rise and increased frequency and magnitude of floods. Adverse effect of global warming is that the **frequency and magnitude of high intensity rainfalls are expected to increase**. It will be important to take account of increased frequency and magnitude of flooding when reviewing the flood protection of assets. When key structures and those difficult to retrofit (e.g., flood walls) come up for construction or renewal then they should be designed for the likely intensification of flows during their design life.

Designers should also be aware that due to the non-linearity of the rainfall-runoff relationship, the percentage increase in flood flows will be greater than the percentage increase in rainfall. This is because the relative proportion of rainfall losses decreases and the proportion of runoff thus increases with increasing rainfall depths. Unit hydrograph studies carried out by the regional council have shown that **for a 16% increase in rainfall, the flows increased by 20% or slightly more.**

Guidelines for Hydrologic and Hydraulic Analysis and River Training Works for Bridge Design, Department of Roads, Government of Nepal, 2020 (Ref. 12) has recommended in 1.1.5 (Consideration of Climate Change): Most of the climate change models project increase in rainfall during monsoon in Nepal. **The design discharge shall be increased by 10% to consider the impact of climate change in flood.**

For the design of drainage structures of this road section the design floods have been estimated in safe side considering 16% increase in extreme rainfall in future (Table 14.4 and Table 14.5). Also, for verification purposes floods were estimated by different methods including regional empirical methods which also give reasonable flood estimates. Again, for being in safe side the largest flood value estimated from different methods has been adopted for the design.

14.4 Intensity Duration Frequency Curves

The rainfall intensity of different duration and different frequency at representative stations has been established by Mononobe's equation, which is generally applied in mountainous catchment and presented by the following equation:

$$R_{t_c} = \frac{R_{24}}{24}\left(\frac{24}{t_c}\right)^{\frac{2}{3}}$$

Where, R_{tc} = Rainfall intensity in t_c hours (mm/hr); R_{24} = 24 hours maximum rainfall (mm) of required frequency; t_c= Time of flood concentration in hour, which is derived from Kirpich formula:

$$t_c = \left(\frac{0.87L^3}{h}\right)^{0.385}$$

Where, L=Stream length in km; h=Difference of the maximum and minimum elevations in m

The rainfall Intensity values of different duration and different frequency for this section considering climate change is presented in Table 14.7 and the Intensity Duration Frequency Curve for the road section is shown in Figure 14.1.

Table 14.7: Predicted rainfall intensity in mm/hr of different duration and frequency for BG Section

Return Period in Years	**50**	**100**	**200**
Max. Daily Rainfall in mm	**445.4**	**495.8**	**550.6**
Duration in hour/RI_T	RI_{50}	RI_{100}	RI_{200}
0.25	389.08	433.11	480.98
0.5	245.11	272.84	303.00
0.75	187.05	208.22	231.23
1	154.41	171.88	190.88
2	97.27	108.28	120.25

4	61.28	68.21	75.75
6	38.60	42.97	47.72
8	29.46	32.79	36.42
12	24.32	27.07	30.06
16	20.96	23.33	25.91
20	18.56	20.66	22.94
24	154.41	171.88	190.88

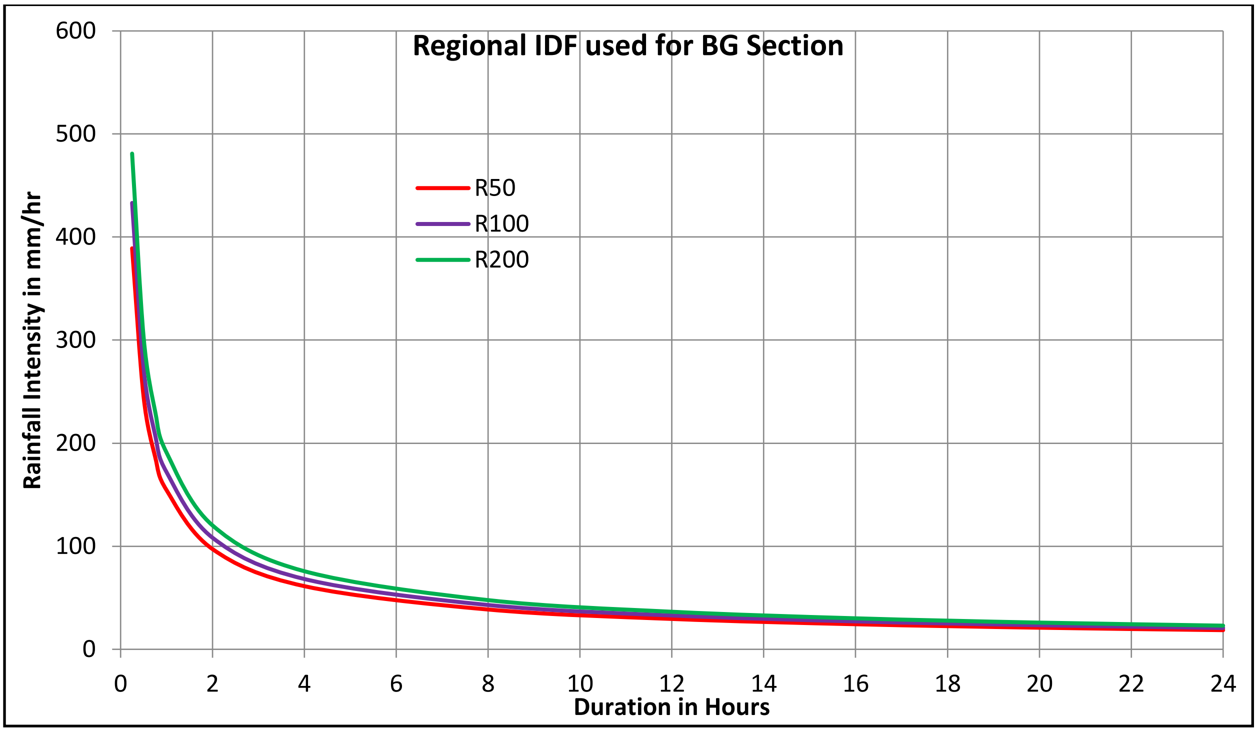


Figure 14.1: Intensity Duration Frequency Curve for Butwal-Gorusinghe Section

14.5 Frequency Analysis of Annual Flood Series at Hydrometric Station

There is only one stream gauging station in the project area of this section in Tinau at Butwal which is used to estimate the design floods of Tinau River and some nearby rivers considering same hydrological region. The annual series of maximum instantaneous flood data of this gauging station have been collected from DHM (Table 14-8) and frequency analysis of annual floods at this station has been carried out by MS Excel. The fitted Excel trend line to annual floods of this river is presented in Figure 14.2.

Table 14.8: Annual Flood Series with Specific Flood Series at Hydrometric Station of BG Section

Year	Annual Flood Series in m^3/s	Specific Flood Series in $m^3/s/km^2$
	Tinau at Butwal	Tinau at Butwal
	Catchment Area = 554 km^2	Catchment Area = 1 km^2
1964	417	0.7527
1965	2220	4.0072
1966	1180	2.13

1967	1950	3.5199
1968	2000	3.6101
1969	600	1.083
Maximum	**2220**	**4.0072**

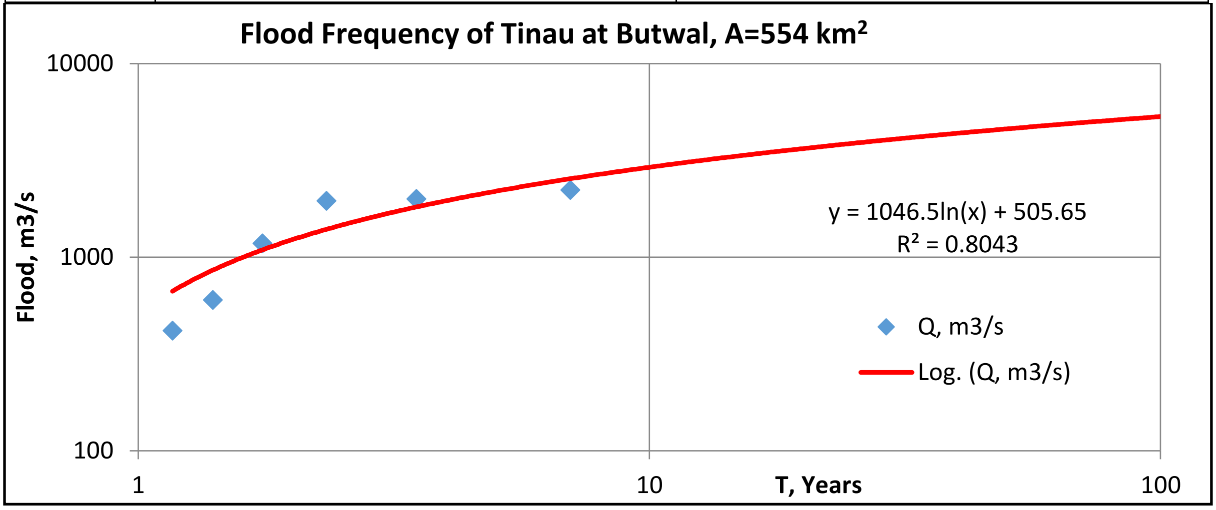


Figure 14.2: Log-Excel Trend Line fitted to Annual Floods of different Frequency in Tinau River

Annual floods of Tinau at Butwal are not sufficient for frequency analysis however they are well fitted to Log-Excel Trend Line as shown in figure 14.2. Floods and specific floods of different return periods of Tinau at Butwal are presented in Table 14.9 which are estimated from well fitted Log-Excel Trend Line. For predicting design floods in other ungauged rivers of this section, the specific floods of required frequency will be used.

Table 14.9: Predicted Floods and Specific Floods in m³/s of different frequency in Tinau at Butwal

Station	River/Location	Area km²	Return Periods in Years							
			5	10	33	50	100	300	500	1000
390	Tinau/Butwal	554	2190	2915	4165	4600	**5325**	6475	7009	7735
		1	3.95	5.26	7.52	8.30	**9.61**	11.69	12.65	13.96

14.6 Estimation of Design Floods

14.6.1 Frequency of Design Floods

The design flood frequency is determined with the basic consideration of the risk involved and the cost of minimizing that risk. The risk factor is dependent on the type and size of structure, volume of water impounded by it and the extent of damage in the event of failure of the structure, which depends on the population and property downstream of the structure likely to be affected by the worst eventuality of the failure of the structure.

According to Nepal Bridge Standards-2067 BS, all permanent bridges should be designed for a design life of minimum 50 years and for a design flood of 100 years return period. The reliability of bridges so designed will be 60.5% or the risk will be 39.5%.

In the detail design of railways in Nepal, it is found that bridges of big perennial rivers were designed for 200 years return period flood for greater reliability. The reliability of bridges increases to 78% (associated risk 22%) for 200 years' design flood considering the minimum design life of railway bridges similar to highway bridges i.e., 50 years.

Hence it is decided to design all the bridges of this section for 100 years return period flood and check the large bridges for 200 years return period flood.

The box culverts are designed for a design flood of 50 years return period and the side drains are designed for 25 years return period flood.

14.6.2 Methods for Estimation of Design Floods

Five methods are applied for the estimation of design floods in this section. Short description of these methods is given below.

a) **Specific Flood Frequency of Tinau at Butwal (Regional HSC)**
The estimated specific floods of Tinau at Butwal (Table 14-9) was used to estimate the design floods for similar rivers of this section. The specific flood was simply transposed to the rivers based on their catchment area.

b) **PCJ 1996 (Based on Hourly Rainfall Intensity)**

In absence of flood data, the flood can be determined by using design rainfall intensity and catchment characteristics. This method is used to obtain floods from the daily maximum annual rainfall series of surrounding stations. The method uses the hourly rainfall intensity of required frequency and other watershed-related factors, such as the rainfall distribution factor, infiltration factor, flood reduction factor, etc., to derive floods of required frequencies. It is applicable to small as well as large catchments (from 0.1 to 100,000 km^2). This method was developed for Nepal in 1996 by PC Jha (Ref. 3) and has been used in many projects of Nepal.
Using this method, the maximum rainfall design discharge Q_p in m^3/s for the required exceedance probability p can be computed using the equation,

$$Q_p = 16.67 a_p o_p \phi F k_F$$

Where a_p is the maximum rainfall design intensity for p, o_p is the infiltration coefficient of the basin, ϕ is the reduction coefficient of maximum discharge that depends on the basin size and the power reduction indicator n (n= 0.33 for Nepal), and k_F is a coefficient that reflects the unequal distribution of rainfall in different size of basin captured by one rain. In this equation,

$$a_p = a_{hr} k_t$$

Where a_{hr} is the hourly rainfall intensity for p whose values are given in ref. 3 and k_t is a reduction coefficient of hourly rainfall intensity that depends on the size of the catchment area. The term o_p depends on the exceedance probability p and is equal to 1.0, 0.95, 0.85, 0.714, 0.678 and 0.50 for values of p equal to 0.1, 1, 2, 4, 5 and 10 percent respectively. Table 14.10 shows the flood estimation of **Banganga River by PCJ 1996** method as a sample.

Table 14.10: Flood Estimation for Banganga River by PCJ 1996 Method

Rainstorm Floods by PCJ 1996 (Regional, based on Hourly Intensity)						
Name of the River			Banganga			
Location			EWH MRM			
Total Basin Area, km^2				**198.0**		
Basin Area below 5000 m, km^2			**198.0**			
Basin Area below 3000 m, km^2				**198.0**		
Rainfall Stations	**Return Period in Years**					**Name of Stations**
	10	**33**	**50**	**100**	**300**	
	Hourly Intensity in mm/min					
715	1.94	2.76	2.98	3.29	3.85	Khanchikot
703	2.01	2.6	2.77	3.01	3.42	Butwal
721	1.63	2.05	2.19	2.43	3.00	Patharkot West
Average	**1.86**	**2.47**	**2.65**	**2.91**	**3.42**	
K_t	0.91	0.91	0.91	0.91	0.91	
a_p	1.69	2.25	2.41	2.65	3.12	
O_p	0.5	0.75	0.85	0.95	1	
Φ	0.182	0.182	0.182	0.182	0.182	
K_f	0.997	0.997	0.997	0.997	0.997	
F	198	198	198	198	198	
Q, m^3/s	**506.8**	**1008.7**	**1008.7**	**1505.0**	**1864.1**	

c) DHM 2004 (Empirical method):

This method is based on the flow records of DHM primary gauges from whole Nepal. The method can be used for any ungauged point of Nepal and require catchment area below 5000 m and the average monsoon rainfall over the basin. It gives daily and instantaneous flood peaks for different return periods. It estimates the flood values at ungauged locations in general for whole Nepal hence it may not give the accurate results for particular basin. However this method is used here mainly for the purpose of cross-checking and verification.

Flood results by this method may be obtained directly by the software called "HYDEST2004" by using catchment area and monsoon wetness index at any location of Nepal.

d) MHSP 1997 (Empirical Method):

This method was developed basically for hydropower projects by NEA. Based on the MHSP method (MHSP/CIWEC, 1997), the flood peak Q in m^3/s can be computed using the relation $Q = k*A^b$, where k and b are constants which depend on the return period T and their values for eastern region of Nepal are provided in Table 14-11.

Table 14.11: MHSP 1997 Coefficients for Flood Estimation in Eastern Region of Nepal

T,	5	20	50	100	1000	10000
K	7.400	13.084	17.605	21.518	39.903	69.780
b	0.786	0.7535	0.7380	0.7281	0.6969	0.6695

e) Rational Method:

Because of areal limitations, this method was not applied for big and medium rivers (i.e., for bridges and box bridges). However, this method was applied for small streams and drains (i.e., for design of box culverts and side drains). Daily maximum rainfall at representative stations were used to derive the design intensity for this method.

Rational formula was used to calculate the floods from the catchments by using design rainfall intensities for the time of concentration. The formula is as follows:

$$Q_P = \frac{C\ I\ A}{3.6}$$

Where, Q_p= Maximum flood discharge in m^3/s; I = Intensity of rainfall within the time of concentration in mm/hour; A = Catchment area in km^2; C = Dimensionless run-off coefficient, assumed equal to 0.3 to 0.5 for small watersheds based on catchment and experience.

14.6.3 Comparison of 100-year floods estimated by different methods

For cross check and validation of results by different approaches, flood comparison graphs are developed for the study area and they are presented in Figure 14.3. These graphs confirm that the floods estimated by different methods are more or less similar and adopted design floods are in safe side. 100-year design floods for different catchments of BG section estimated by different methods have been compared and shown in Figure 14.3.

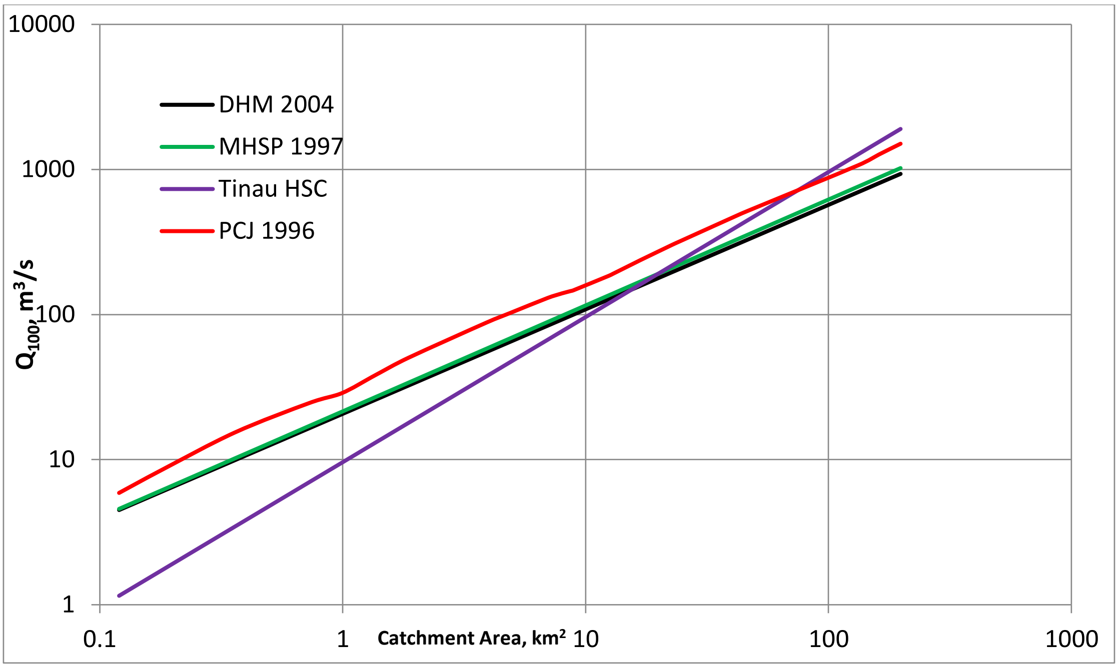


Figure 14.3: Flood comparison graphs of BG section (Estimated Q_{100} versus catchment areas)

14.6.4 Design Floods for Bridges and Box Bridges

For bridges and box bridges of this section, four methods (Tinau HSC Specific flood, DHM 2004, MHSP 1997 and PCJ 1996) are used for estimation of design floods (Q_{100}) and the maximum flood among the methods is adopted as design flood (Table 14.12). In Table 14.12, it is seen that for big rivers the maximum flood values are estimated by flood data of Tinau which is the largest river in this section and for other rivers the maximum flood values are obtained by PCJ 1996 method using maximum hourly rainfall intensity of representative rainfall stations. Other two methods DHM 2004 and MHSP 1997 are regional empirical and do not use rainfall and are estimating lesser floods but are comparable.

Table 14.12: Estimation of floods for bridges and box bridges by different methods and adopted design flood

SN	Chainage	River/Khola	A, km²	100 Year Design Flood (Q_{100}), m³/s					Add 10% for CC	Adopted Method	Remarks
				Tinau HSC	DHM 2004	MHSP 1997	PCJ 1996	Adopt			
1	590+048.5	Jitgadi Khola	1.87	18.0	32.5	34.0	50.5	50.5	55.6	PCJ 1996	Bridge
2	590+187	Narsinga Dry Nala	0.73	7.0	16.5	17.1	26.4	26.4	29.0	PCJ 1996	Bridge
3	590+698	Dry Nala	0.36	3.5	9.9	10.2	15.4	15.4	16.9	PCJ 1996	BoxBridge
4	590+760	Dry Nala	0.18	1.7	6.0	6.2	8.5	8.5	9.4	PCJ 1996	BoxBridge
5	590+992	Pakhapani Khola	0.12	1.2	4.5	4.6	5.9	5.9	6.5	PCJ 1996	BoxBridge
6	596+090	Satgadi -1 River	8.11	77.9	93.4	99.2	140.9	140.9	155.0	PCJ 1996	Bridge
7	596+331	Satgadi -2 River	6.97	67.0	83.8	88.8	130.1	130.1	143.1	PCJ 1996	Bridge
8	597+459	Soila Khola	0.36	3.5	9.9	10.2	15.4	15.4	16.9	PCJ 1996	BoxBridge
9	597+785	Rajpur Khola	14.0	134.5	138.4	147.7	203.7	203.7	224.0	PCJ 1996	Bridge
10	598+251	Bamaha Khola	12.5	120.1	127.6	136.0	185.4	185.4	203.9	PCJ 1996	Bridge
11	603+565	Ghamaha Khola	16.3	156.6	154.4	165.1	231.2	231.2	254.3	PCJ 1996	Bridge

SN	Chainage	River/Khola	A, km²	100 Year Design Flood (Q_{100}), m³/s					Add 10% for CC	Adopted Method	Remarks
				Tinau HSC	DHM 2004	MHSP 1997	PCJ 1996	Adopt			
12	603+825	Tulbuliya Khola	8.71	83.7	98.4	104.5	145.5	145.5	160.1	PCJ 1996	Bridge
13	604+680	Marthirwa Khola	1.31	12.6	25.1	26.2	36.9	36.9	40.6	PCJ 1996	Bridge
14	604+974	Meghawa Khola	0.99	9.5	20.6	21.4	28.7	28.7	31.6	PCJ 1996	Bridge
15	606+683	Inguria River	24.5	235.4	207.1	222.3	320.4	320.4	352.4	PCJ 1996	Bridge
16	607+184	Banarhwa River	10.35	99.4	111.4	118.5	157.6	157.6	173.4	PCJ 1996	Bridge
17	607+844.5	Dry Nala	1.48	14.2	27.5	28.7	41.2	41.2	45.3	PCJ 1996	BoxBridge
18	610+995	Pahila River	16.8	161.4	157.8	168.8	237.2	237.2	260.9	PCJ 1996	Bridge
19	611+101.5	Dry Nala	1.13	10.9	22.6	23.5	32.3	32.3	35.5	PCJ 1996	BoxBridge
20	611+406	Kanchan River	47.0	451.6	331.0	357.7	522.2	522.2	574.4	PCJ 1996	Bridge
21	615+258	Kothi River	12.9	123.9	130.5	139.2	190.3	190.3	209.3	PCJ 1996	Bridge
22	620+013	Gageda Khola	1.42	13.6	26.6	27.8	39.7	39.7	43.7	PCJ 1996	BoxBridge
23	622+020	Banganga River	198.0	1902.3	932.3	1021.9	1505	1902.3	2092.5	Tinau HSC	Bridge
24	627+144	Kaila Khola	135.0	1297.0	707.6	772.7	1086.2	1297.0	1427	Tinau HSC	Bridge
25	629+426	Balhundra Khola	4.86	46.7	64.6	68.2	102.1	102.1	112.3	PCJ 1996	Bridge
26	631+598	Harkon Khola	7.84	75.3	91.2	96.8	138.6	138.6	152.5	PCJ 1996	Bridge
27	633+334	Dry Nala	3.91	37.6	55.3	58.2	88.1	88.1	96.9	PCJ 1996	Bridge
28	633+692	Kundra Khola	42.1	404.5	305.8	330.0	482.5	482.5	530.8	PCJ 1996	Bridge
29	636+746	Ghorai Nala	22.8	219.1	196.6	210.9	303.4	303.4	333.7	PCJ 1996	Bridge
30	639+814	Dry Nala	0.12	1.2	4.5	4.6	5.9	5.9	6.5	PCJ 1996	BoxBridge

14.6.5 Design Floods for Box Culverts (Q_{50})

Existing slab and pipe culverts are replaced by appropriate sizes of box culverts based on adopted design floods. The design floods for 50 years return period were estimated by four methods (Rational, PCJ 1996, MHSP 1997 and DHM 2004) and the maximum flood was adopted among them for the design of box culverts. The estimated design floods for different sizes of box culverts are presented in subsequent sections below. Some changes are incorporated in this final report based on field verification after submission of the draft report.

14.6.5.1 Estimation of Floods for all Box Culverts with adopted Design Flood

The estimated floods of 50 years return period by different methods and adopted design floods for all box culverts of this section are presented in Table 14-13.

Table 14.13: Estimated and adopted Design Floods for all Box Culverts of BG Section

SN	Existing Structure	Chainage	Catch Area	50 Year Flood (Q50), m3/s					Adopted Method	Remarks
		Km	Km²	Rational	PCJ 1996	MHSP 1997	DHM 2004	Adopt		
1	Slab	590+323	0.0075	0.36	0.50	0.47	0.43	**0.50**	PCJ 1996	Steep &
2	Slab	590+350	0.0138	0.66	0.82	0.75	0.68	**0.82**	PCJ 1996	Steep &
3	Slab	590+473	0.0317	1.53	1.73	1.38	1.26	**1.73**	PCJ 1996	Steep &
4	Slab	590+535	0.0744	3.58	3.33	2.59	2.36	**3.58**	Rational	Steep &
5	Slab	590+624	0.0315	1.52	1.72	1.37	1.25	**1.72**	PCJ 1996	Steep &
6	Pipe	590+901	0.0094	0.45	0.59	0.56	0.52	**0.59**	PCJ 1996	Steep &
7	Slab	591+296	0.0251	1.21	1.42	1.16	1.06	**1.42**	PCJ 1996	
8	Slab	591+789	Kulo from Tinau flowing from east to west (Q~0.40)							Opposite
9	Pipe	593+810	Kulo from Tinau flowing from east to west (Q~0.90)							Opposite

SN	Existing Structure	Chainage Km	Catch Area Km^2	50 Year Flood (Q50), m3/s					Adopted Method	Remarks
				Rational	PCJ 1996	MHSP 1997	DHM 2004	Adopt		
10	Slab	593+899	Kulo from Tinau flowing from east to west (Q~0.40)							Opposite
11	Slab	594+538	0.0700	3.37	3.19	2.47	2.26	**3.37**	Rational	
12	Pipe	594+741	0.0121	0.58	0.73	0.68	0.62	**0.73**	PCJ 1996	
13	Pipe	594+801	0.0167	0.80	0.98	0.86	0.79	**0.98**	PCJ 1996	
14	Pipe	594+948	0.0238	1.15	1.35	1.12	1.02	**1.35**	PCJ 1996	
15	Slab	594+982	0.0192	0.92	1.12	0.95	0.87	**1.12**	PCJ 1996	
16	Pipe	595+140	0.0334	1.61	1.80	1.43	1.31	**1.80**	PCJ 1996	
17	Slab	595+342	0.0366	1.76	1.94	1.53	1.40	**1.94**	PCJ 1996	
18	Pipe	595+578	0.0509	2.45	2.51	1.96	1.79	**2.51**	PCJ 1996	
19	Slab	595+821	0.0333	1.60	1.80	1.43	1.31	**1.80**	PCJ 1996	
20	Pipe	596+536	0.0142	0.68	0.85	0.76	0.70	**0.85**	PCJ 1996	
21	Pipe	596+580	0.0060	0.29	0.43	0.40	0.37	**0.43**	PCJ 1996	
22	Pipe	597+235	0.0289	1.39	1.60	1.29	1.18	**1.60**	PCJ 1996	
23	Pipe	597+577	0.0065	0.31	0.46	0.43	0.39	**0.46**	PCJ 1996	
24	Slab	598+402	0.0165	0.79	0.97	0.85	0.78	**0.97**	PCJ 1996	
25	Slab	598+557	0.0698	3.36	3.18	2.46	2.25	**3.36**	Rational	
26	Slab	598+685	0.0999	4.81	4.02	3.22	2.93	**4.81**	Rational	
27	Pipe	599+088	0.0288	1.39	1.59	1.28	1.17	**1.59**	PCJ 1996	
28	Pipe	599+375	0.1500	7.22	5.87	4.34	3.96	**7.22**	Rational	
29	Pipe	599+450	0.0900	4.33	3.78	2.98	2.72	**4.33**	Rational	
30	Pipe	599+563	0.0466	2.24	2.35	1.83	1.67	**2.35**	PCJ 1996	
31	Pipe	599+895	0.0541	2.60	2.63	2.05	1.87	**2.63**	PCJ 1996	
32	Slab	600+074	0.1490	7.17	5.83	4.32	3.94	**7.17**	Rational	
33	Pipe	600+549	0.2123	10.21	8.03	5.61	5.11	**10.21**	Rational	
34	Slab	600+747	0.1845	8.88	7.09	5.06	4.61	**8.88**	Rational	
35	Slab	601+064	0.8997	26.24	22.25	16.28	15.59	**26.24**	Rational	
36	Slab	601+154	0.0180	0.87	1.05	0.91	0.83	**1.05**	PCJ 1996	
37	Pipe	601+262	0.0203	0.98	1.17	0.99	0.91	**1.17**	PCJ 1996	
38	Pipe	601+417	0.0888	4.27	3.74	2.95	2.69	**4.27**	Rational	
39	Pipe	601+621	0.4313	16.60	14.39	9.47	8.61	**16.60**	Rational	
40	Pipe	601+797	0.2115	10.18	8.01	5.59	5.10	**10.18**	Rational	
41	Slab	601+946	0.3277	12.61	11.63	7.73	7.04	**12.61**	Rational	
42	Slab	602+256	0.4295	16.53	14.35	9.44	8.67	**16.53**	Rational	
43	Pipe	602+574	0.2483	9.56	9.21	6.30	5.74	**9.56**	Rational	
44	Slab	602+980	0.1215	5.85	4.83	3.72	3.39	**5.85**	Rational	
45	Slab	604+145	0.0584	2.81	2.79	2.16	1.98	**2.81**	Rational	
46	Pipe	604+562	0.1346	6.48	5.31	4.01	3.65	**6.48**	Rational	
47	Slab	605+292	0.1150	5.53	4.58	3.57	3.25	**5.53**	Rational	
48	Slab	605+624	0.1224	5.89	4.86	3.74	3.41	**5.89**	Rational	
49	Slab	605+850	0.7535	25.15	20.32	14.29	13.65	**25.15**	Rational	
50	Pipe	605+897	0.0430	2.07	2.21	1.73	1.58	**2.21**	PCJ 1996	
51	Pipe	605+959	0.0370	1.78	1.96	1.55	1.41	**1.96**	PCJ 1996	
52	Pipe	606+062	0.0710	3.42	3.23	2.50	2.28	**3.42**	Rational	
53	Slab	606+244	0.1100	5.29	4.40	3.45	3.15	**5.29**	Rational	
54	Slab	606+518	0.1313	6.32	5.19	3.94	3.59	**6.32**	Rational	
55	Pipe	608+762	0.0282	1.36	1.57	1.27	1.16	**1.57**	PCJ 1996	

SN	Existing Structure	Chainage Km	Catch Area Km^2	50 Year Flood (Q50), m3/s					Adopted Method	Remarks
				Rational	PCJ 1996	MHSP 1997	DHM 2004	Adopt		
56	Slab	608+891	0.0316	1.52	1.72	1.38	1.26	**1.72**	PCJ 1996	Two way
57	Pipe	610+019	0.0096	0.46	0.59	0.57	0.52	**0.59**	PCJ 1996	Opposite
58	Pipe	610+112	0.0105	0.51	0.64	0.61	0.56	**0.64**	PCJ 1996	
59	Slab	610+513	0.1701	8.18	6.58	4.76	4.34	**8.18**	Rational	
60	Pipe	610+701	0.0367	1.77	1.95	1.54	1.40	**1.95**	PCJ 1996	
61	Pipe	610+929	0.0083	0.40	0.54	0.51	0.47	**0.54**	PCJ 1996	
62	Slab	611+274	Irrigation Canal from Kanchan Nadi							
63	Pipe	611+717	0.0530	2.55	2.59	2.01	1.84	**2.59**	PCJ 1996	
64	Pipe	611+844	0.0527	2.54	2.58	2.01	1.83	**2.58**	PCJ 1996	
65	Additional	612+600	0.1061	5.10	4.25	3.36	3.07	**5.10**	Rational	
66	Pipe	613+005	0.1052	5.06	4.22	3.34	3.05	**5.06**	Rational	
67	Pipe	613+281	0.1624	7.81	6.31	4.60	4.25	**7.81**	Rational	
68	Pipe	613+715	0.1447	6.96	5.68	4.23	3.95	**6.96**	Rational	
69	Additional	616+825	0.2047	9.85	7.78	5.46	5.12	**9.85**	Rational	
70	Slab	617+568	0.0480	2.31	2.40	1.87	1.71	**2.40**	PCJ 1996	
71	Slab	617+658	0.0586	2.82	2.80	2.17	1.98	**2.82**	Rational	
72	Slab	617+756	0.0340	1.64	1.83	1.45	1.33	**1.83**	PCJ 1996	
73	Slab	617+960	0.4705	22.64	15.33	10.09	9.18	**22.64**	Rational	
74	Slab	617+990	0.0965	4.64	3.94	3.13	2.86	**4.64**	Rational	
75	Slab	618+047	0.0078	0.38	0.52	0.49	0.45	**0.52**	PCJ 1996	
76	Slab	618+063	0.0075	0.36	0.51	0.48	0.44	**0.51**	PCJ 1996	
77	Slab	618+082	0.0234	1.13	1.33	1.10	1.01	**1.33**	PCJ 1996	
78	Pipe	618+311	0.0368	1.77	1.95	1.54	1.41	**1.95**	PCJ 1996	
79	Pipe	618+459	0.0614	2.95	2.90	2.25	2.05	**2.95**	Rational	
80	Pipe	618+510	0.1052	5.06	4.22	3.34	3.05	**5.06**	Rational	
81	Pipe	618+737	0.0978	4.71	3.97	3.17	2.95	**4.71**	Rational	
82	Slab	618+780	0.1473	7.09	5.77	4.28	3.91	**7.09**	Rational	
83	Slab	618+993	0.2654	12.77	9.76	6.61	6.02	**12.77**	Rational	
84	Slab	619+111	0.0834	4.01	3.60	2.81	2.57	**4.01**	Rational	
85	Slab	619+190	0.0380	1.83	2.00	1.58	1.44	**2.00**	PCJ 1996	
86	Slab	619+329	0.0386	1.86	2.03	1.59	1.46	**2.03**	PCJ 1996	
87	Slab	619+400	0.0110	0.53	0.67	0.63	0.58	**0.67**	PCJ 1996	
88	Slab	619+440	0.0270	1.30	1.51	1.22	1.12	**1.51**	PCJ 1996	
89	Pipe	619+492	0.0022	0.11	0.19	0.19	0.18	**0.19**	PCJ 1996	
90	Slab	619+510	0.0035	0.17	0.28	0.27	0.25	**0.28**	PCJ 1996	
91	Slab	619+720	0.0443	2.13	2.26	1.76	1.61	**2.26**	PCJ 1996	
92	Slab	620+230	0.2562	12.33	9.47	6.44	6.11	**12.33**	Rational	
93	Slab	620+580	0.2121	10.20	8.03	5.61	5.11	**10.20**	Rational	
94	Pipe	620+674	0.0170	0.82	1.00	0.87	0.80	**1.00**	PCJ 1996	
95	Pipe	620+738	0.0196	0.94	1.14	0.97	0.88	**1.14**	PCJ 1996	
96	Slab	620+863	0.1212	5.83	4.82	3.71	3.38	**5.83**	Rational	
97	Slab	621+050	0.0626	3.01	2.94	2.28	2.08	**3.01**	Rational	
98	Slab	621+206	0.0953	4.58	3.91	3.11	2.83	**4.58**	Rational	
99	Slab	621+541	0.2716	13.07	9.95	6.73	6.13	**13.07**	Rational	
100	Slab	622+613	0.0619	2.98	2.92	2.26	2.06	**2.98**	Rational	
101	Pipe	623+025	0.0256	1.23	1.44	1.18	1.08	**1.44**	PCJ 1996	

SN	Existing Structure	Chainage Km	Catch Area Km^2	50 Year Flood (Q50), m3/s					Adopted Method	Remarks
				Rational	PCJ 1996	MHSP 1997	DHM 2004	Adopt		
102	Slab	623+092	0.0639	3.07	2.99	2.31	2.11	**3.07**	Rational	
103	Pipe	623+509	0.1203	5.79	4.78	3.69	3.36	**5.79**	Rational	
104	Slab	623+723	0.0515	2.48	2.53	1.97	1.80	**2.53**	PCJ 1996	
105	Pipe	623+801	0.0350	1.68	1.88	1.48	1.36	**1.88**	PCJ 1996	
106	Slab	624+182	0.6910	33.24	19.58	13.40	12.19	**33.24**	Rational	
107	Slab	624+346	0.0405	1.95	2.11	1.65	1.51	**2.11**	PCJ 1996	
108	Slab	624+602	0.2500	12.03	9.27	6.33	5.77	**12.03**	Rational	
109	Slab	624+717	0.0768	3.69	3.41	2.65	2.42	**3.69**	Rational	
110	Slab	624+810	0.0438	2.11	2.24	1.75	1.60	**2.24**	PCJ 1996	
111	Slab	624+882	0.0210	1.01	1.21	1.02	0.93	**1.21**	PCJ 1996	
112	Slab	625+045	0.0125	0.60	0.75	0.69	0.64	**0.75**	PCJ 1996	
113	Slab	625+155	0.0469	2.26	2.36	1.84	1.68	**2.36**	PCJ 1996	
114	Pipe	625+222	0.0329	1.58	1.78	1.42	1.29	**1.78**	PCJ 1996	
115	Slab	625+269	0.0182	0.88	1.06	0.92	0.84	**1.06**	PCJ 1996	
116	Slab	625+463	0.1128	5.43	4.50	3.52	3.21	**5.43**	Rational	
117	Slab	625+650	0.1485	7.14	5.82	4.31	4.14	**7.14**	Rational	
118	Slab	626+421	0.0346	1.66	1.86	1.47	1.34	**1.86**	PCJ 1996	
119	Pipe	626+939	0.0835	4.02	3.60	2.82	2.57	**4.02**	Rational	
120	Additional	628+070	0.1428	5.50	5.61	4.19	3.91	**5.61**	PCJ 1996	
121	Pipe	628+406	0.1393	4.83	5.48	4.11	3.85	**5.48**	PCJ 1996	
122	Pipe	628+570	0.1444	4.86	5.67	4.22	3.92	**5.67**	PCJ 1996	
123	Pipe	629+488	0.0395	1.90	2.07	1.62	1.48	**2.07**	PCJ 1996	
124	Slab	629+693	0.9898	38.10	23.39	17.47	16.75	**38.10**	Rational	
125	Slab	629+868	0.8865	42.65	22.10	16.11	14.64	**42.65**	Rational	
126	Pipe	630+308	0.1591	7.65	6.20	4.53	4.13	**7.65**	Rational	
127	Pipe	630+495	0.1251	6.02	4.96	3.80	3.46	**6.02**	Rational	
128	Slab	631+010	0.5508	26.50	17.20	11.34	10.31	**26.50**	Rational	
129	Slab	631+157	0.2967	14.27	10.70	7.18	6.54	**14.27**	Rational	
130	Slab	632+125	0.1619	7.79	6.30	4.59	4.19	**7.79**	Rational	
131	Slab	632+393	0.1700	8.18	6.60	4.76	4.34	**8.18**	Rational	
132	Slab	632+505	0.1282	6.17	5.10	3.87	3.53	**6.17**	Rational	
133	Pipe	632+856	0.1555	7.48	6.07	4.46	4.10	**7.48**	Rational	
134	Slab	633+160	0.1445	6.95	5.67	4.22	3.95	**6.95**	Rational	
135	Slab	634+668	0.3108	14.95	11.10	7.43	6.77	**14.95**	Rational	
136	Slab	635+344	0.6767	32.56	19.39	13.20	12.55	**32.56**	Rational	
137	Slab	635+799	0.4545	15.31	14.96	9.84	8.85	**15.31**	Rational	
138	Slab	636+179	1.2870	43.34	29.59	21.21	20.55	**43.34**	Rational	
139	Pipe	636+308	0.1052	5.06	4.22	3.34	3.05	**5.06**	Rational	
140	Slab	637+133	0.0582	2.80	2.80	2.16	1.97	**2.80**	Rational	
141	Slab	637+287	0.0281	1.35	1.60	1.26	1.15	**1.60**	PCJ 1996	
142	Slab	637+337	0.1639	7.89	6.40	4.63	4.22	**7.89**	Rational	
143	Pipe	637+514	0.0583	2.80	2.80	2.16	1.97	**2.80**	Rational	
144	Slab	637+579	0.1365	6.57	5.38	4.05	3.75	**6.57**	Rational	
145	Slab	638+021	0.3470	16.69	12.20	8.06	7.34	**16.69**	Rational	
146	Slab	638+443	0.2700	12.99	9.90	6.70	6.10	**12.99**	Rational	
147	Slab	639+038	0.1461	7.03	5.73	4.26	4.05	**7.03**	Rational	

SN	Existing Structure	Chainage	Catch Area	50 Year Flood (Q50), m3/s					Adopted Method	Remarks
		Km	Km^2	Rational	PCJ 1996	MHSP 1997	DHM 2004	Adopt		
148	Slab	639+414	0.3476	11.71	12.19	8.07	7.35	**12.19**	PCJ 1996	
149	Slab	639+578	0.0918	4.42	3.80	3.02	2.76	**4.42**	Rational	

14.6.5.2 Design floods with existing culverts and proposed sizes of box culverts

Table 14.14 provides adopted design floods with existing size of cross drains, required size of box culverts based on design flood and final size recommended after field verification.

Table 14.14: Design floods with existing size of cross drains, required size of BC based on flood and final size

SN	Existing C/D	Chainage	Q_{50}, m^3/s	Existing Size	Flood Based	Final Size	Remarks
1	Slab Culvert	590+323	0.50	2x2	1.5x1.5	**3x2**	steep slope with gravel & debris
2	Slab Culvert	590+350	0.82	1x2	1.5x1.5	**3x2**	steep slope with gravel & debris
3	Slab Culvert	590+473	1.73	3x2	2x2	**5x3**	steep slope with boulders
4	Slab Culvert	590+535	3.58	3x3	2x2	**5x3**	steep slope with boulders
5	Slab Culvert	590+624	1.72	2x3	2x2	**3x3**	steep slope with gravel & debris
6	Pipe Culvert	590+901	0.59	0.9x1	1.5x1.5	**3x3**	steep slope with boulders
7	Slab Culvert	591+296	1.42	2x3	2x2	**3x3**	
8	Slab Culvert	591+789	0.40	2x1.2	3x1.5	**2x1.5**	Reverse flow (Kulo from Tinau)
9	Pipe Culvert	593+810	0.90	0.9x2	1.5x1.5	**3x1.5**	Reverse flow (Kulo from Tinau)
10	Slab Culvert	593+899	0.40	2x1.3	1.5x1.5	**2x1.5**	Reverse flow (Kulo from Tinau)
11	Slab Culvert	594+538	3.37	2x1.2	2x1.5	**2x1.5**	
12	Pipe Culvert	594+741	0.73	0.9x1	1.5x1.5	**1.5x1.5**	
13	Pipe Culvert	594+801	0.98	0.9x1	1.5x1.5	**1.5x1.5**	
14	Pipe Culvert	594+948	1.35	0.9x1	1.5x1.5	**1.5x1.5**	
15	Slab Culvert	594+982	1.12	1.5x0.3	1.5x1.5	**1.5x1.5**	
16	Pipe Culvert	595+140	1.80	0.9x1	1.5x1.5	**1.5x1.5**	
17	Slab Culvert	595+342	1.94	1x1	1.5x1.5	**1.5x1.5**	
18	Pipe Culvert	595+578	2.51	0.9x1	1.5x1.5	**1.5x1.5**	
19	Slab Culvert	595+821	1.80	1.5x1	1.5x1.5	**1.5x1.5**	
20	Pipe Culvert	596+536	0.85	0.9x2	1.5x1.5	**1.5x1.5**	
21	Pipe Culvert	596+580	0.43	0.6x1	1.5x1.5	**1.5x1.5**	
22	Pipe Culvert	597+235	1.60	0.9x1	1.5x1.5	**1.5x1.5**	
23	Pipe Culvert	597+577	0.46	0.9x1	1.5x1.5	**1.5x1.5**	
24	Slab Culvert	598+402	0.97	5.5x0.6	1.5x1.5	**2x1.5**	not functioning, small catch area
25	Slab Culvert	598+557	3.36	5.4x2.5	1.5x1.5	**6x3**	
26	Slab Culvert	598+685	4.81	5.5x0.6	3x1.5	**6x1.5**	
27	Pipe Culvert	599+088	1.59	0.9x1	3x1.5	**2x1.5**	
28	Pipe Culvert	599+375	7.22	0.9x1	2x1.5	**1.5x1.5**	
29	Pipe Culvert	599+450	4.33	0.9x1	2x1.5	**1.5x1.5**	
30	Pipe Culvert	599+563	2.35	0.6x1	1.5x1.5	**1.5x1.5**	
31	Pipe Culvert	599+895	2.63	0.9x2	1.5x1.5	**3x1.5**	

SN	Existing C/D	Chainage	Q_{50}, m^3/s	Existing Size	Flood Based	Final Size	Remarks
32	Slab Culvert	600+074	7.17	4x1	2x1.5	**4x1.5**	
33	Pipe Culvert	600+549	10.21	0.9x1	3x1.5	**3x1.5**	
34	Slab Culvert	600+747	8.88	1.5x1	3x1.5	**3x1.5**	
35	Slab Culvert	601+064	26.24	5x2	6x2	**5x2**	
36	Slab Culvert	601+154	1.05	2x1	1.5x1.5	**1.5x1.5**	
37	Pipe Culvert	601+262	1.17	0.9x1	1.5x1.5	**2x1.5**	
38	Pipe Culvert	601+417	4.27	0.9x1	2x1.5	**2x1.5**	
39	Pipe Culvert	601+621	16.60	0.9x1	4x2	**4x2**	
40	Pipe Culvert	601+797	10.18	0.45x4	3x1.5	**4x2**	
41	Slab Culvert	601+946	12.61	2.5x1	3x1.5	**5x2**	
42	Slab Culvert	602+256	16.53	3x1	5x1.5	**4x2**	
43	Pipe Culvert	602+574	9.56	0.6x4	3x2	**3x2**	
44	Slab Culvert	602+980	5.85	1x1	2x1.5	**1.5x1.5**	
45	Slab Culvert	604+145	2.81	1x1	1.5x1.5	**1.5x1.5**	
46	Pipe Culvert	604+562	6.48	0.9x1	2x1.5	**1.5x1.5**	
47	Slab Culvert	605+292	5.53	6x1.7	3x2	**4x2**	
48	Slab Culvert	605+624	5.89	2.5x1	2x1.5	**3x2**	
49	Slab Culvert	605+850	25.15	4x2	6x2	**5x2**	
50	Pipe Culvert	605+897	2.21	0.9x1	1.5x1.5	**2x1.5**	
51	Pipe Culvert	605+959	1.96	0.9x1	1.5x1.5	**2x1.5**	
52	Pipe Culvert	606+062	3.42	0.9x1	1.5x1.5	**1.5x1.5**	
53	Slab Culvert	606+244	5.29	1x0.9	2x1.5	**1.5x1.5**	
54	Slab Culvert	606+518	6.32	0.9x0.5	2x1.5	**1.5x1.5**	
55	Pipe Culvert	608+762	1.57	0.9x1	1.5x1.5	**1.5x1.5**	
56	Slab Culvert	608+891	1.72	2x1	1.5x1.5	**3x1.5**	two-way flow (first from south then back from north)
57	Pipe Culvert	610+019	0.59	0.6x1	1.5x1.5	**1.5x1.5**	Reverse flow, very deep in d/s in north
58	Pipe Culvert	610+112	0.64	0.9x1	1.5x1.5	**1.5x1.5**	
59	Slab Culvert	610+513	8.18	2.5x1.8	3x2	**3x1.5**	
60	Pipe Culvert	610+701	1.95	0.6x1	1.5x1.5	**1.5x1.5**	
61	Pipe Culvert	610+929	0.54	0.9x1	1.5x1.5	**1.5x1.5**	
62	Slab Culvert	611+274		3x3	3x3	**4x3**	Irrigation Canal from Kanchan Nadi
63	Pipe Culvert	611+717	2.59	0.9x1	1.5x1.5	**1.5x1.5**	
64	Pipe Culvert	611+844	2.58	0.9x1	1.5x1.5	**2x1.5**	
65	Additional	612+600	5.10		2x1.5	**2x1.5**	
66	Pipe Culvert	613+005	5.06	0.9x1	2x1.5	**2x1.5**	
67	Pipe Culvert	613+281	7.81	0.9x1	3x1.5	**2x1.5**	
68	Pipe Culvert	613+715	6.96	0.9x1	3x1.5	**2x1.5**	
69	Additional	616+825	9.85		3x1.5	**3x1.5**	
70	Slab Culvert	617+568	2.40	2x1	1.5x1.5	**2x1.5**	
71	Slab Culvert	617+658	2.82	1x1	1.5x1.5	**1.5x1.5**	
72	Slab Culvert	617+756	1.83	2x1	1.5x1.5	**2x1.5**	
73	Slab Culvert	617+960	22.64	6x1	5x1.5	**5x2**	

SN	Existing C/D	Chainage	Q_{50}, m^3/s	Existing Size	Flood Based	Final Size	Remarks
74	Slab Culvert	617+990	4.64	4x1.5	2x1.5	**3x2**	
75	Slab Culvert	618+047	0.52	3.8x1.2	1.5x1.5	**1.5x1.5**	
76	Slab Culvert	618+063	0.51	3.3x1.5	1.5x1.5	**2x1.5**	
77	Slab Culvert	618+082	1.33	4.5x0.6	1.5x1.5	**1.5x1.5**	
78	Pipe Culvert	618+311	1.95	0.9x1	1.5x1.5	**1.5x1.5**	
79	Pipe Culvert	618+459	2.95	0.9x1	1.5x1.5	**1.5x1.5**	
80	Pipe Culvert	618+510	5.06		1.5x1.5	**1.5x1.5**	
81	Pipe Culvert	618+737	4.71	0.45x2	3x1.5	**1.5x1.5**	
82	Slab Culvert	618+780	7.09	6x1.5	3x1.5	**6x1.5**	
83	Slab Culvert	618+993	12.77	4.5x1.5	4x1.5	**4x1.5**	
84	Slab Culvert	619+111	4.01	2.5x1.3	2x1.5	**1.5x1.5**	
85	Slab Culvert	619+190	2.00	0.9x1	1.5x1.5	**1.5x1.5**	
86	Slab Culvert	619+329	2.03	5x1.8	1.5x1.5	**1.5x1.5**	
87	Slab Culvert	619+400	0.67		1.5x1.5	**1.5x1.5**	u/s not found, covered
88	Slab Culvert	619+440	1.51		1.5x1.5	**1.5x1.5**	
89	Pipe Culvert	619+492	0.19	0.6x2	1.5x1.5	**1.5x1.5**	
90	Slab Culvert	619+510	0.28		1.5x1.5	**1.5x1.5**	
91	Slab Culvert	619+720	2.26	2.5x0.5	1.5x1.5	**1.5x1.5**	
92	Slab Culvert	620+230	12.33	4x1.5	4x1.5	**4x1.5**	u/s not found, covered
93	Slab Culvert	620+580	10.20	3x2	3x2	**3x2**	
94	Pipe Culvert	620+674	1.00	0.6x3	1.5x1.5	**2x1.5**	
95	Pipe Culvert	620+738	1.14	0.9x1	1.5x1.5	**1.5x1.5**	
96	Slab Culvert	620+863	5.83	4.5x1.8	3x1.5	**3x1.5**	
97	Slab Culvert	621+050	3.01		2x1.5	**2x1.5**	
98	Slab Culvert	621+206	4.58	2x0.8	2x1.5	**1.5x1.5**	
99	Slab Culvert	621+541	13.07	6x2.5	4x2	**6x2**	
100	Slab Culvert	622+613	2.98	2x2.5	2x2	**3x3**	
101	Pipe Culvert	623+025	1.44	0.9x2	1.5x1.5	**1.5x1.5**	
102	Slab Culvert	623+092	3.07	2x0.5	2x1.5	**2x1.5**	
103	Pipe Culvert	623+509	5.79	0.9x1	2x1.5	**2x1.5**	
104	Slab Culvert	623+723	2.53	2x1	1.5x1.5	**1.5x1.5**	
105	Pipe Culvert	623+801	1.88	0.6x2	1.5x1.5	**1.5x1.5**	
106	Slab Culvert	624+182	33.24	6x2.5	6x2.5	**6x2.5**	
107	Slab Culvert	624+346	2.11	3x0.8	1.5x1.5	**1.5x1.5**	
108	Slab Culvert	624+602	12.03	6x2	4x2	**6x2.5**	
109	Slab Culvert	624+717	3.69	1.5x0.6	2x1.5	**1.5x1.5**	
110	Slab Culvert	624+810	2.24	1.5x0.4	1.5x1.5	**1.5x1.5**	
111	Slab Culvert	624+882	1.21	2.5x1	1.5x1.5	**1.5x1.5**	
112	Slab Culvert	625+045	0.75	1.5x1	1.5x1.5	**1.5x1.5**	
113	Slab Culvert	625+155	2.36	1.5x0.6	1.5x1.5	**1.5x1.5**	
114	Pipe Culvert	625+222	1.78	0.9x1	1.5x1.5	**1.5x1.5**	
115	Slab Culvert	625+269	1.06	1.5x0.6	1.5x1.5	**1.5x1.5**	
116	Slab Culvert	625+463	5.43	2.5x0.3	2x1.5	**2x1.5**	

SN	Existing C/D	Chainage	Q_{50}, m^3/s	Existing Size	Flood Based	Final Size	Remarks
117	Slab Culvert	625+650	7.14	3x0.7	3x1.5	**2x1.5**	
118	Slab Culvert	626+421	1.86	2x0.5	1.5x1.5	**1.5x1.5**	
119	Pipe Culvert	626+939	4.02	0.9x2	2x1.5	**2x2**	
120	Additional	628+070	5.61		3x1.5	**2x1.5**	
121	Pipe Culvert	628+406	5.48	0.9x2	2x1.5	**2x1.5**	
122	Pipe Culvert	628+570	5.67	0.9x2	2x1.5	**2x1.5**	
123	Pipe Culvert	629+488	2.07	0.9x2	1.5x1.5	**1.5x1.5**	
124	Slab Culvert	629+693	38.10	6x3	6x3	**6x3**	
125	Slab Culvert	629+868	42.65	6x3	6x3	**6x3**	
126	Pipe Culvert	630+308	7.65	0.9x2	2x1.5	**2x1.5**	
127	Pipe Culvert	630+495	6.02	0.9x2	2x1.5	**2x1.5**	
128	Slab Culvert	631+010	26.50	6x0.4	5x1.5	**5x3**	
129	Slab Culvert	631+157	14.27	6x0.5	6x2	**6x3**	
130	Slab Culvert	632+125	7.79	3.5x5	3x3	**4x4**	
131	Slab Culvert	632+393	8.18	3x3	3x3	**3x3**	
132	Slab Culvert	632+505	6.17	2.5x1.5	3x2	**3x1.5**	
133	Pipe Culvert	632+856	7.48	0.9x1	2x1.5	**2x1.5**	
134	Slab Culvert	633+160	6.95	1.5x0.5	2x1.5	**2x1.5**	
135	Slab Culvert	634+668	14.95	3x2	4x2	**4x2**	
136	Slab Culvert	635+344	32.56	6x2	6x2	**6x2**	
137	Slab Culvert	635+799	15.31	3x1.5	5x2	**4x2**	
138	Slab Culvert	636+179	43.34	4x3	5x3	**5x3**	
139	Pipe Culvert	636+308	5.06	0.45x2	2x1.5	**1.5x1.5**	
140	Slab Culvert	637+133	2.80	2x1	1.5x1.5	**1.5x1.5**	
141	Slab Culvert	637+287	1.60	1.5x1.5	1.5x1.5	**1.5x1.5**	
142	Slab Culvert	637+337	7.89	2.5x2	3x2	**3x2**	
143	Pipe Culvert	637+514	2.80	0.9x1	1.5x1.5	**1.5x1.5**	
144	Slab Culvert	637+579	6.57	1.5x1	3x1.5	**2x1.5**	
145	Slab Culvert	638+021	16.69	1.5x3	3x3	**3x3**	
146	Slab Culvert	638+443	12.99	1.5x2.5	3x3	**3x2**	
147	Slab Culvert	639+038	7.03	1.5x1.3	3x1.5	**2x1.5**	
148	Slab Culvert	639+414	12.19	6x3	4x2	**6x3**	
149	Slab Culvert	639+578	4.42	1.5x1.5	2x1.5	**2x1.5**	

14.6.5.3 Quantity of Box Culverts of different Sizes

The adopted sizes of culverts were verified in field and some of them are changed based on-site conditions. Some of the large and medium box culverts can be used for wild animal and cattle crossings. The quantity of box culverts having different sizes are summarized in Table 14.15.

Table 14.15: Quantity of Box Culverts of different sizes in BG Section

SN	Width (m)	Height (m)	Max. Flow m³/s	No. of BC	Remarks
1	1.5	1.5	5.85	62	
2	2	1.5	8.10	33	
3	2	2	10.39	1	
4	3	1.5	12.75	9	
5	3	2	16.31	8	
6	3	3	24.31	6	
7	4	1.5	14.29	3	
8	4	2	20.71	6	
9	4	3	36.36	1	
10	4	4	52.97	1	
11	5	2	27.60	4	
12	5	3	49.24	4	
13	6	1.5	23.55	2	
14	6	2	34.70	2	
15	6	2.5	46.74	2	
16	6	3	51.18	5	
Total				**149**	

14.6.6 Design Floods for Side Drains (Considering 16% increase in rainfall)

Two kinds of side drains are introduced in this road section: Main Road Side Drains (MRSD) and Service Road Side Drains (SRSD). The MRSD is designed on both sides of 4 lanes as required and the SRSD is designed on both sides of 6 lane road in urban areas only.

These side drains are designed to pass 25 years return period flood. For estimation of design flood by Rational formula, the 25 years return period maximum rainfalls are predicted for representative stations and are provided in Table 14.16.

Table 14.16: Observed Maximum and Predicted 25-Year Rainfall for Side Drain of BG Section

Index	Station Name	Observed Rainfall (mm)		Predicted	Best fitted Distribution
		Data Years	Maximum	R_{25}(mm)	
0701	Ridibazar	31	230.4	199.5	Logistic Generalized
0702	Tansen	29	194.3	249.4	Fisher-Tippett type III
0703	Butwal	31	354.0	385.4	Generalized Exponential Poisson
0715	Khanchikot	43	380.9	392.4	Generalized Gumbel
0716	Taulihawa	31	298.5	418.4	Frechet (Fisher-Tippet type II)
0721	Patharkot	41	296.0	414.6	Fisher-Tippett type III
0730	Sitapur	13	256.3	335.5	Gumbel Standard and Mirrored
Average for BG Road Section				**342.2**	
Add 16% for future Climate Change				**396.9**	

The average of predicted 25-Year rainfall (342.2 mm) at representative stations is increased by 16% for increased rainfall due to climate change and 396.9 mm is used for intensity duration frequency analysis (Table 14.17) and the IDF curve for 25-Year design rainfall is presented in Figure 14.4

Table 14.17: Intensity Duration of 25-Year Frequency for BG Section

Return Period in Years	25
Average Maximum Daily Rainfall for BG Section (mm)	396.9
Time (hour)	R_{25} (mm/hour)
0.25	346.71
0.5	218.42
0.75	166.68
1	137.59
2	86.68
4	54.60
8	34.40
12	26.25
16	21.67
20	18.67
24	16.54

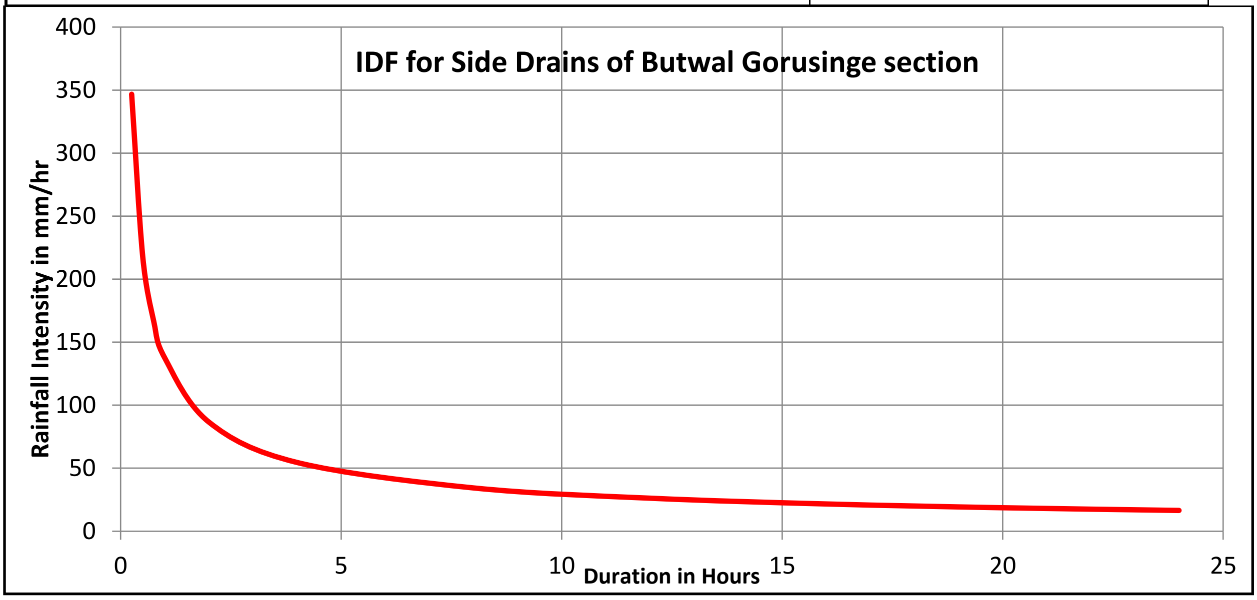


Figure 14.4: Intensity Duration Curve of 25-Year Frequency for BG Section

14.6.6.1 Design Floods for Main Road Side Drain (MRSD) in 4 Lane

The design floods for MRSD (having road surface width of 10 m) are estimated by different methods (Table 14.18) assuming the length of drain equal to 100 m and then converted to discharge per meter length of drain so that the discharge can be estimated for different lengths of MRSD.

Table 14.18: Estimation of 25-Year Flood by different Methods for Main Road Side Drains (MRSD)

Width	Length	Catch Area	Rational	PCJ 1996	MHSP 1997	DHM 2004	Adopted Flood	Adopted Method
m	m	km^2	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s	
10	100	0.001	0.099	0.088	0.095	0.082	**0.099**	Rational
10	1	0.00001	0.00099	0.00088	0.00095	0.00082	**0.00099**	

14.6.6.2 Design Floods for Service Road Side Drain (SRSD) in 6 Lane

The design floods for SRSD (having road surface and residential width of 43 m) are estimated by different methods (Table 14.19) assuming the length of drain equal to 100 m and then converted to discharge per meter length of drain so that the discharge can be estimated for different length of SRSD.

Table 14.19: Estimation of 25-Year Flood by different Methods for Service Road Side Drains (SRSD)

Width	Length	Catch Area	Rational	PCJ 1996	MHSP 1997	DHM 2004	Adopted Flood	Adopted Method
m	m	km^2	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s	
43	100	0.0043	0.427	0.315	0.322	0.267	**0.427**	Rational
43	1	0.000043	0.0043	0.0032	0.0032	0.0027	**0.0043**	

14.7 Hydraulic Design of Drainage Structures

14.7.1 Hydraulic Design of Bridges

The HEC-RAS computer program, developed by US Army Corps of Engineers, was used to compute the water surface profiles corresponding to the recommended design floods of 100 years return periods for all bridges of this section. The HEC-RAS software performs one dimensional gradually varied steady state flow conditions to determine the water surface profile of a natural or artificial channel assuming that a level water surface exists across each cross-section. The computational procedure is based on an iterative solution of the one-dimensional energy equation with energy loss due to friction with Manning's equation, generally known as the Standard Step Method.

Resistance to flow is defined by the Manning's roughness coefficient (n), which is specified for three segments of a given cross-section, viz. left-over bank (LOB), main channel and right over bank (ROB). The value of "n" is assessed on the basis of the type of bed and bank materials. For a natural channel this resistance value will be changing in each section. Generally small value of "n" is assumed for main channel and large values for over banks. Again, value of "n" is a function of discharge (velocity, slope and hydraulic radius). As the flow increases the resistance decreases. Hence it is very difficult to define the value of "n" for each section and for different discharges. However, it can be assumed either by experience or calibrated by flow measurements.

In the absence of flood hydrographs unsteady flow analysis cannot be performed, hence steady flow simulation has been conducted for all the bridges. Longitudinal flow profile (Figure 14.5) and flowing cross section at bridge axis (Figure 14.6) simulated by HEC-RAS software for Banganga River are presented here as a sample.

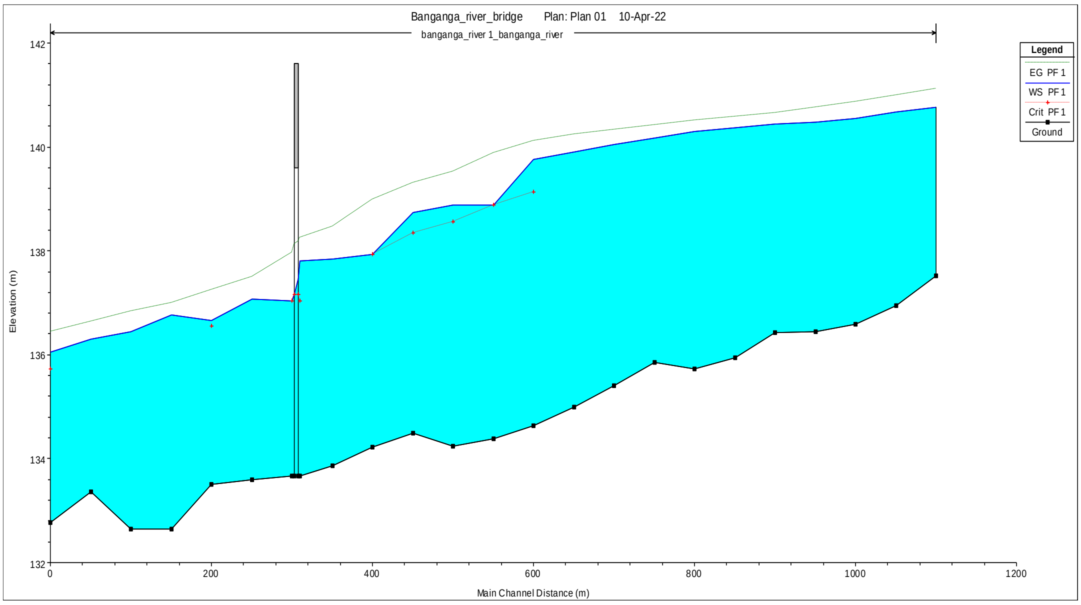


Figure 14.5: Longitudinal Flow Profile of Banganga River for Q_{100} (2092.5 m^3/s) with Proposed Bridge

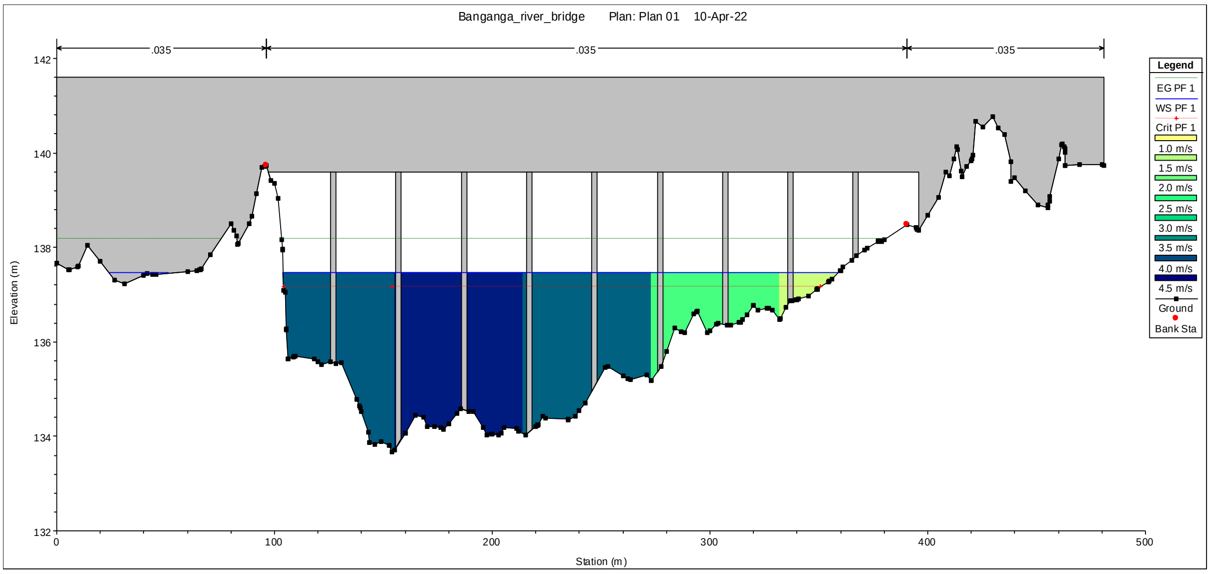


Figure 14.6: Flowing Cross Section of Banganga River for Q_{100} (2092.5 m^3/s) at Proposed Bridge Axis

The hydraulic design parameters of bridges of this road section are presented in Table 14.20. Sample of calculation sheet for hydraulic parameters of Banganga River are shown in Table 14.21.

Table 14.20: Hydraulic Parameters of Bridges of Butwal-Gorusinghe Section

SN	Chainage	River/Khola	Q_{100}, m^3/s	Bridge Length, m		HFL	LBL	Depth	Vel.	FB	Soffit L	Ex Rd L
				Exist.	Prop.	m	m	m	m/s	m	m	m
1	590+048.5	Jitgadi Khola	55.6	21.35	22.0	180.90	179.23	1.67	2.40	1.00	181.90	185.92
2	590+187	Narsinga Dry Nala	29.0	16.80	17.0	182.60	180.27	2.33	2.47	1.00	183.60	188.51
3	596+090	Satgadi -1 River	155.0	64.50	66.0	133.70	131.19	2.51	1.95	1.00	134.70	138.10
4	596+331	Satgadi -2 River	143.1	28.60	30.0	134.10	131.29	2.81	2.40	1.00	135.10	138.15
5	597+785	Rajpur Khola	224.0	26.60	27.0	128.00	122.98	5.02	2.58	1.20	129.20	132.57
6	598+251	Bamaha Khola	203.9	32.80	33.0	125.00	121.53	3.47	3.26	1.20	126.20	130.10
7	603+565	Ghamaha Khola	254.3	51.00	51.0	118.80	113.48	5.32	3.20	1.20	120.00	124.90
8	603+825	Tulbuliya Khola	160.1	42.90	42.0	119.20	115.09	4.11	3.07	1.20	120.40	123.84
9	604+680	Marthirwa Khola	40.6	16.45	17.0	119.30	115.94	3.36	1.42	1.00	120.30	124.54
10	604+974	Meghawa Khola	31.6	21.40	22.0	119.60	117.17	2.43	1.32	1.00	120.60	125.14
11	606+683	Inguria River	352.4	41.25	51.0	121.10	115.69	5.41	2.93	1.50	122.60	127.13
12	607+184	Banarhwa River	173.4	39.60	40.0	121.00	115.91	5.09	1.74	1.00	122.00	126.05
13	610+995	Pahila River	260.9	49.35	51.0	136.00	133.51	2.49	3.14	1.20	137.20	139.52
14	611+406	Kanchan River	574.4	64.20	66.0	135.20	130.91	4.29	5.04	1.50	136.70	138.87
15	615+258	Kothi River	209.3	43.00	42.0	145.70	142.17	3.53	2.67	1.00	146.70	149.58
16	**622+020**	**Banganga River**	**2092.5**	**290.0**	**300.0**	**137.50**	**133.67**	**3.83**	**3.77**	**2.00**	**139.50**	**140.62**
17	627+144	Kaila Khola	1427	92.70	99.0	120.50	114.95	5.55	3.77	1.50	122.00	125.26
18	629+426	Balhundra Khola	112.3	20.90	22.0	117.40	114.19	3.21	2.82	1.00	118.40	121.80
19	631+598	Harkon Khola	152.5	20.90	22.0	117.20	113.59	3.61	2.94	1.00	118.20	120.65
20	633+334	Dry Nala	96.9	21.30	22.0	114.50	110.14	4.36	1.96	1.00	115.50	118.93
21	633+692	Kundra Khola	530.8	29.00	30.0	116.54	109.56	6.98	4.63	1.50	118.04	118.93
22	636+746	Ghorai Nala	333.7	21.50	22.0	116.00	112.29	3.71	4.50	1.20	117.20	119.58

Table 14.21: Sample of Calculation Sheet for Hydraulic Parameters (Banganga River)

Catchment area	A	198.000	km^2	From GIS Map & Google Map
Design Discharge (Q_{100})		1902.300	m^3/s	From TINAU HSC Method
Design Discharge (Q_{100})		2092.530	m^3/s	Increase 10% discharge for climate change
Design Discharge (Q_{100}) for foundation design		2720.29	m^3/s	increase 30% discharge for foundation design, as per IRC78-2000, Clause 703.1.1
Mean Particle Size (D_m)		0.534	mm	Grain size analysis as per IRC 5-1998
Silt Factor	f	1.286		
Proposed Bridge length	L	**300.000**	m	As per site condition (PSC 30x10)
Linear Water Way	P	274.465	m	From Lacey equation=4.5XQ^0.5, (ref: IRC 5-1998, Clause104.3)
Linear Water Way of bridge site		248.000	m	From HEC RAS Analysis top width of river during HFL (ref: IRC 5-1998, Clause101.8)
Effective Linear water way		**273.000**	m	Ref: IRC 5-1998, Clause101.9
Ratio	D_b	10.969		Design discharge/Effective linear water way
Mean depth of scour from HFL	d_m	6.083	m	Ref: IRC 5-1998, Clause110.1.3
Maximum Scour Depth for Abutments from HFL	D_{abut}	7.725	m	Take 1.27*d_m (without seismic condition) as per IRC78-2000, Clause 703.1.1.1
Maximum Scour Depth for piers from HFL	D_{pier}	12.166	m	Take 2*d_m (without seismic condition) as per as per IRC78-2000, Clause 703.1.1.1
Bed Level of River		**133.670**	m	From field survey data

High Flood level		**137.500**	m	From HEC RAS Analysis
Calculated Scour Depth for pier	d_{pier}	8.336	m	From Low Bed Level 133.67 m
Calculated Scour Depth for abutments	d_{abut}	3.895	m	
Adopted Scour Depth for pier	$\mathbf{d_{finalp}}$	**8.336**	**m**	
Adopted Scour Depth for abutments	$\mathbf{d_{finala}}$	**3.895**	**m**	
Free Board	FB	2	m	As per Nepal Bridge standard 2067
Scour Level of Abutment	**SLA**	**129.775**	**m**	
Scour Level of Pier	**SLP**	**125.334**	**m**	
Main channel velocity	v	**3.77**	m/s	
Soffit Level	SL	**139.500**	m	
Existing Bridge Level	EBL	**140.616**	m	From Survey data

The scour depths for bridges of this section are estimated and provided in Table 14.22.

Table 14.22: Scour Depths for Bridges of Butwal-Gorusinghe Road Section

SN	Chainage	River/Khola	Dm (mm)	Scour Depth from HFL, m			Scour Depth from LBL, m			Remarks
				MSD	Abutment	Pier	MSD	Abutment	Pier	
1	590+048.5	Jitgadi Khola	2.35	2.351	2.986		0.68	1.316		1 Span
2	590+187	Narsinga Dry Nala	2.00	2.647	3.362		0.32	1.032		1 Span
3	596+090	Satgadi -1 River	0.31	3.156	4.008	6.312	0.65	1.498	3.80	
4	596+331	Satgadi -2 River	0.43	4.406	5.596		1.60	2.786		1 Span
5	597+785	Rajpur Khola	0.15	7.649	9.714		2.63	4.694		1 Span
6	598+251	Bamaha Khola	0.34	5.453	6.925		1.98	3.455		1 Span
7	603+565	Ghamaha Khola	0.14	5.56	7.065	11.126	0.24	1.745	5.81	
8	603+825	Tulbuliya Khola	0.13	5.036	6.396		0.93	2.286		1 Span
9	604+680	Marthirwa Khola	0.01	5.088	6.462		1.73	3.102		1 Span
10	604+974	Meghawa Khola	0.02	3.493	4.436		1.06	2.006		1 Span
11	606+683	Inguria River	0.09	7.26	9.220	14.52	1.85	3.810	9.11	
12	607+184	Banarhwa River	0.12	4.746	6.027		-0.34	0.937		1 Span
13	610+995	Pahila River	2.00	3.801	4.827	7.602	1.31	2.337	5.11	
14	611+406	Kanchan River	0.18	5.324	6.761	10.648	1.03	2.471	6.36	
15	615+258	Kothi River	0.27	4.873	6.189		1.34	2.659		1 Span
16	**622+020**	**Banganga River**	**0.53**	**6.083**	**7.725**	**12.166**	**2.25**	**3.895**	**8.34**	
17	627+144	Kaila Khola	0.48	8.966	11.387	17.932	3.42	5.837	12.38	
18	629+426	Balhundra Khola	0.17	5.292	6.721		2.08	3.511		1 Span
19	631+598	Harkon Khola	0.73	6.653	8.449		3.04	4.839		1 Span
20	633+334	Dry Nala	0.30	4.469	5.676		0.11	1.316		1 Span
21	633+692	Kundra Khola	0.56	10.101	12.828		3.12	5.848		1 Span
22	636+746	Ghorai Nala	0.85	8.322	10.569		4.61	6.859		1 Span

14.7.2 Recommended River Training Works for Bridges

River training are essential part of bridges especially in upstream which works to direct the flood discharge towards bridge openings. Most of the bridges of this section don’t require training works because of sufficient length of bridging. However, some bridges require river training in upstream and/or in downstream. Table 14.23 shows the required river training works for these bridges.

Table 14.23: Proposed River Training Works for Bridges of BG Road Section

Sn	Name of Structure	Chainage Center	Bridge		River Training				Type of River training Works
					Upstream (m)		Downstream (m)		
			Span	Length	RB	LB	RB	LB	
		Km	m	m					
1	Jitgadi Bridge	590+048	22.00	22.00					
2	Narsinga Dry Nala	590+187	16.00	16.00					
3	Satgadi -1 Bridge	596+093	22.00	66.00	70	70	20	20	Revetment
4	Satgadi -2 Bridge	596+364	30.00	30.00	30	30	10	10	Revetment
5	Rajpur Bridge	597+778	27.00	27.00	30	30	10	10	Revetment
6	Bamaha Bridge	598+254	33.00	33.00	35	35	10	10	Revetment
7	Ghamaha Bridge	603+566		51.00	60	60	15	15	Revetment
8	Tulbuliya Bridge	603+826	42.00	42.00	50	50	15	15	Revetment
9	Marthirwa Bridge	604+682	17.00	17.00	20	20	10	10	Revetment
10	Meghawa Bridge	604+975	21.00	21.00					
11	Inguria Bridge	606+684		51.00	60	60	15	15	Revetment
12	Banarhwa Bridge	607+187	40.00	40.00	40	40	10	10	Revetment
13	Pahila Bridge	610+998	17.00	51.00	50	50	15	15	Revetment
14	Kanchan Bridge	611+411	22.00	66.00	70	70	20	20	Revetment
15	Kothi Bridge	615+264	42.00	42.00	515	515	150	150	
16	Badganga Bridge	622+027	32.00	288.00		300	200		Embankment
17	Kaila Bridge	627+155	33.00	99.00	100	100	25	25	Revetment
18	Balhundra Bridge	629+439	22.00	22.00					NA
19	Harkon Bridge	631+611	22.00	22.00					NA
20	Dry Nala Bridge	633+352	22.00	22.00					NA
21	Kundra Bridge	633+710	30.00	30.00					NA
22	Ghorai Bridge	636+765	22.00	22.00					NA

Total Length: Revetment Type=1580.00 m and Average height 4.00m and Embankment Type=500.00m and average height 5.00m

14.7.3 Hydraulic Design of Box Bridges

There are many small existing bridges in this road section which are replaced by box bridges after checking the design discharge. Similarly, some existing vented causeways and series of pipe culverts are also found which are also replaced by box bridges. Hydraulic parameters of box bridges are depicted in Table 14.24.

Table 14.24: Hydraulic Parameters of Box Bridges of Butwal-Gorusinghe Section

SN	Chainage	River/Khola	Q_{100}, m^3/s	Length (m)		HFL	LBL	Depth	Vel.	Ex. Road L
				Exist.	Prop.	m	m	m	m/s	m
1	590+698	Dry Nala	16.9	7.20	10.0	180.00	178.30	1.70	2.0	187.01
2	590+760	Dry Nala	9.4	7.50	10.0	177.40	176.53	0.87	1.68	186.37
3	590+992	Pakhapani Khola	6.5	10.30	10.0	179.30	178.46	0.84	1.43	184.97
4	597+459	Soila Khola	16.9	13.30	12.0	129.00	127.36	1.64	0.55	130.69
5	607+844.5	Dry Nala	45.3	11.80	12.0	121.57	118.40	3.17	1.64	126.13
6	611+101.5	Dry Nala	35.5	10.80	12.0	135.25	132.66	2.59	1.16	139.24
7	620+013	Gageda Khola	43.7	8.80	12.0	144.40	142.48	1.92	2.76	145.52
8	639+814	Dry Nala	6.5	13.30	15.0	108.23	106.33	1.90	0.32	111.77

14.7.4 Hydraulic Design of Box Culverts

All slab and pipe culverts are replaced by box culverts. The minimum vertical span of box culvert has been designed equal to 1.5 m considering the debris flow and maintenance of structure. The maximum height of box culvert has been limited to 4 m considering structural safety and road level. The minimum width of box culvert has been designed equal to 1.5 m whereas maximum width has been designed up to 6 m. In small streams box culverts are designed of square sizes (1.5mx1.5m; 2mx2m; 3mx3m) but for larger width of streams these are designed as rectangular (4mx2m; 4mx3m; 5mx2m; 5mx3m; 6mx2m). All box culverts are designed as single cell considering the economics. The small sizes can be used as precast.

The 50-year return period design floods have been adopted for all size of box culverts and checked with maximum discharging capacity of box culverts.

14.7.4.1 Hydraulics of Box Culverts

The slope of RCC floor of box culverts is designated by trial so that the minimum flushing velocity of about 1 m/s can be created at minimum flow depth of 0.2 m. Table 14.25 shows the design parameters for all sizes of box culverts at minimum flows with minimum velocities.

Table 14.25: Hydraulics of box culverts of all sizes at minimum flow with minimum velocity

Width	Height	Min. Flow depth	Manning's n	Flow Area	Peri-meter	Hydraulic Radius	Design Slope	Min. Vel.	Fr. No.	Min. Flow
m	m	m		m^2	m	m		m/s		m^3/s
1.5	1.5	0.2	0.017	0.3	1.9	0.15789474	0.007	1.44	1.03	0.43
1.5	2	0.2	0.017	0.3	1.9	0.15789474	0.007	1.44	1.03	0.43
1.5	3	0.2	0.017	0.3	1.9	0.15789474	0.007	1.44	1.03	0.43
2	1.5	0.2	0.017	0.4	2.4	0.16666667	0.006	1.38	0.99	0.55
2	2	0.2	0.017	0.4	2.4	0.16666667	0.005	1.26	0.90	0.50

2	2.5	0.2	0.017	0.4	2.4	0.16666667	0.005	1.26	0.90	0.50
2	3	0.2	0.017	0.4	2.4	0.16666667	0.005	1.26	0.90	0.50
3	1.5	0.2	0.017	0.6	3.4	0.17647059	0.005	1.31	0.93	0.79
3	2	0.2	0.017	0.6	3.4	0.17647059	0.004	1.17	0.84	0.70
3	3	0.2	0.017	0.6	3.4	0.17647059	0.003	1.01	0.72	0.61
3	3.5	0.2	0.017	0.6	3.4	0.17647059	0.003	1.01	0.72	0.61
3	4	0.2	0.017	0.6	3.4	0.17647059	0.003	1.01	0.72	0.61
4	1.5	0.2	0.017	0.8	4.4	0.18181818	0.003	1.03	0.74	0.83
4	2	0.2	0.017	0.8	4.4	0.18181818	0.003	1.03	0.74	0.83
4	2.5	0.2	0.017	0.8	4.4	0.18181818	0.003	1.03	0.74	0.83
4	3	0.2	0.017	0.8	4.4	0.18181818	0.003	1.03	0.74	0.83
4	4	0.2	0.017	0.8	4.4	0.18181818	0.003	1.03	0.74	0.83
5	2	0.2	0.017	1.0	5.4	0.18518519	0.003	1.05	0.75	1.05
5	2.5	0.2	0.017	1.0	5.4	0.18518519	0.003	1.05	0.75	1.05
5	3	0.2	0.017	1	5.4	0.18518519	0.003	1.05	0.75	1.05
5	3.5	0.2	0.017	1	5.4	0.18518519	0.003	1.05	0.75	1.05
6	1.5	0.2	0.017	1.2	6.4	0.18750000	0.003	1.06	0.75	1.27
6	2	0.2	0.017	1.2	6.4	0.18750000	0.003	1.06	0.75	1.27
6	2.5	0.2	0.017	1.2	6.4	0.18750000	0.003	1.06	0.75	1.27
6	3	0.2	0.017	1.2	6.4	0.18750000	0.003	1.06	0.75	1.27
6	4	0.2	0.017	1.2	6.4	0.18750000	0.003	1.06	0.75	1.27

Keeping some free board for open channel flow in box culverts and providing the design slope, the maximum flow capacities with maximum flow velocities are estimated. The maximum flow velocities are within limit for RCC (less than 4 m/s) and Froude Numbers are less than one which indicates that there will be sub critical flow condition during maximum flows in all box culverts. Table 14.26 shows the design parameters for all sizes of box culverts at maximum flows with maximum velocities.

Table 14.26: Hydraulics of box culverts of all sizes at maximum flow with maximum velocity

Width m	Height m	Max. Flow depth m	Manning's n	Flow Area m^2	Perimeter m	Hydraulic Radius m	Design Slope	Max. Vel. m/s	Fr. No.	Max. Flow m^3/s	U/S Scour Depth m	D/S Scour Depth m
1.5	1.5	1.3	0.017	1.95	4.1	0.47560976	0.007	3.00	0.84	5.85	1.03	1.25
1.5	2	1.7	0.017	2.55	4.9	0.52040816	0.007	3.18	0.78	8.12	1.17	1.45
1.5	3	2.6	0.017	3.9	6.7	0.58208955	0.007	3.43	0.68	13.38	1.47	1.9
2	1.5	1.3	0.017	2.6	4.6	0.56521739	0.006	3.11	0.87	8.10	1.03	1.25
2	2	1.7	0.017	3.4	5.4	0.62962963	0.005	3.06	0.75	10.39	1.17	1.45
2	2.5	2.1	0.017	4.2	6.2	0.67741935	0.005	3.21	0.71	13.47	1.30	1.65
2	3	2.6	0.017	5.2	7.2	0.72222222	0.005	3.35	0.66	17.41	1.47	1.9

3	1.5	1.3	0.017	3.9	5.6	0.69642857	0.005	3.27	0.92	12.75	1.03	1.25
3	2	1.7	0.017	5.1	6.4	0.79687500	0.004	3.20	0.78	16.31	1.17	1.45
3	3	2.6	0.017	7.8	8.2	0.95121951	0.003	3.12	0.62	24.31	1.47	1.9
3	3.5	3.0	0.017	9	9	1.00000000	0.003	3.22	0.59	29.00	1.60	2.1
3	4	3.5	0.017	10.5	10	1.05000000	0.003	3.33	0.57	34.95	1.77	2.35
4	1.5	1.3	0.017	5.2	6.6	0.78787879	0.003	2.75	0.77	14.29	1.03	1.25
4	2	1.7	0.017	6.8	7.4	0.91891892	0.003	3.05	0.75	20.71	1.17	1.45
4	2.5	2.1	0.017	8.4	8.2	1.02439024	0.003	3.27	0.72	27.50	1.30	1.65
4	3	2.6	0.017	10.4	9.2	1.13043478	0.003	3.50	0.69	36.36	1.47	1.9
4	4	3.5	0.017	14	11	1.27272727	0.003	3.78	0.65	52.97	1.77	2.35
5	2	1.7	0.017	8.5	8.4	1.01190476	0.003	3.25	0.80	27.60	1.17	1.45
5	2.5	2.1	0.017	10.5	9.2	1.14130435	0.003	3.52	0.78	36.95	1.30	1.65
5	3	2.6	0.017	13	10.2	1.27450980	0.003	3.79	0.75	49.24	1.47	1.9
5	3.5	3.0	0.017	15	11	1.36363636	0.003	3.96	0.73	59.43	1.60	2.1
6	1.5	1.3	0.017	7.8	8.6	0.90697674	0.003	3.02	0.85	23.55	1.03	1.25
6	2	1.7	0.017	10.2	9.4	1.08510638	0.003	3.40	0.83	34.70	1.17	1.45
6	2.5	2.1	0.017	12.6	10.2	1.2352941	0.003	3.71	0.8	46.7	1.30	1.65
6	3	2.6	0.017	15.6	11.2	1.39285714	0.002	3.28	0.65	51.18	1.47	1.9
6	4	3.5	0.017	21	13	1.61538462	0.002	3.62	0.62	76.06	1.77	2.35

14.7.4.2 Hydraulic Design of Box Culverts

Based on hydraulics of all box culverts worked out in Table 14.25 and 14.26, the hydraulic design of all box culverts of different sizes have been performed and depicted in Table 14.27. The upstream floor level of the culverts has been fixed equal to upstream bed level of the stream based on survey data. The design slopes of box culverts are provided based on permissible velocity and discharging capacity. The downstream floor levels have been fixed according to the culvert lengths and the head loss. Table 14.27 also provides the box top level and rise in road level compared to existing road level at culvert location so that the vertical alignment of the road can be designed. The proposed sizes of box culverts, design floods and discharging capacities are also provided in Table 14.27.

Table 14.27: Hydraulic Design of Box Culverts in BG Road Section

SN	Chainage	Box Size	Q_{50}	Q_{MC}	Lane	Box Length	Exist Road Level	U/S Floor Level	Depth of BC	Box Top Level	Rise in Road Level	Design Slope	Head Loss	D/S Floor Level
	Km+m	mxm	m^3/s	m^3/s	No.	m	m	m	m	m	m	%	m	m
1	590+323	3x2	0.50	16.31	6	50.0	186.73	184.66	2.00	187.06	0.33	0.4	0.20	184.46
2	590+350	3x2	0.82	16.31	6	50.0	187.12	183.95	2.00	186.35	-0.77	0.4	0.20	183.75
3	590+473	5x3	1.73	49.24	6	50.0	188.03	185.36	3.00	188.76	0.73	0.3	0.15	185.21
4	590+535	5x3	3.58	49.24	6	50.0	188.94	186.21	3.00	189.61	0.67	0.3	0.15	186.06
5	590+624	3x3	1.72	24.31	6	50.0	184.09	181.50	3.00	184.90	0.81	0.3	0.15	181.35
6	590+901	3x3	0.59	24.31	6	50.0	184.96	182.00	3.00	185.40	0.44	0.3	0.15	181.85
7	591+296	3x3	1.42	24.31	6	50.0	179.99	176.94	3.00	180.34	0.35	0.3	0.15	176.79
8	591+789	2x1.5	Kulo	8.10	6	50.0	165.38	164.22	1.50	166.12	0.74	0.6	0.30	163.92
9	593+810	3x1.5	Kulo	12.75	6	50.0	148.30	146.36	1.50	148.26	-0.04	0.5	0.25	146.11

SN	Chainage	Box Size	Q_{50}	Q_{MC}	Lane	Box Length	Exist Road Level	U/S Floor Level	Depth of BC	Box Top Level	Rise in Road Level	Design Slope	Head Loss	D/S Floor Level
	Km+m	mxm	m^3/s	m^3/s	No.	m	m	m	m	m	m	%	m	m
10	593+899	2x1.5	kulo	8.10	6	50.0	148.22	146.89	1.50	148.79	0.57	0.6	0.30	146.59
11	594+538	2x1.5	3.37	8.10	6	50.0	143.18	141.89	1.50	143.79	0.61	0.6	0.30	141.59
12	594+741	1.5x1.5	0.73	5.85	6	50.0	142.21	140.93	1.50	142.83	0.62	0.7	0.35	140.58
13	594+801	1.5x1.5	0.98	5.85	6	50.0	141.75	140.58	1.50	142.48	0.73	0.7	0.35	140.23
14	594+948	1.5x1.5	1.35	5.85	6	50.0	140.40	139.80	1.50	141.70	1.30	0.7	0.35	139.45
15	594+982	1.5x1.5	1.12	5.85	6	50.0	140.16	139.14	1.50	141.04	0.88	0.7	0.35	138.79
16	595+140	1.5x1.5	1.80	5.85	6	50.0	139.17	138.38	1.50	140.28	1.11	0.7	0.35	138.03
17	595+342	1.5x1.5	1.94	5.85	6	50.0	138.08	136.98	1.50	138.88	0.80	0.7	0.35	136.63
18	595+578	1.5x1.5	2.51	5.85	6	50.0	137.88	136.40	1.50	138.30	0.42	0.7	0.35	136.05
19	595+821	1.5x1.5	1.80	5.85	6	50.0	137.54	136.56	1.50	138.46	0.92	0.7	0.35	136.21
20	596+536	1.5x1.5	0.85	5.85	6	50.0	135.72	134.40	1.50	136.30	0.58	0.7	0.35	134.05
21	596+580	1.5x1.5	0.43	5.85	6	50.0	135.49	134.49	1.50	136.39	0.90	0.7	0.35	134.14
22	597+235	1.5x1.5	1.60	5.85	6	50.0	131.43	129.80	1.50	131.70	0.27	0.7	0.35	129.45
23	597+577	1.5x1.5	0.46	5.85	6	50.0	130.70	129.08	1.50	130.98	0.28	0.7	0.35	128.73
24	598+402	2x1.5	0.97	8.10	INT	33.0	130.73	129.18	1.50	131.08	0.35	0.6	0.20	128.98
25	598+557	6x3	3.36	51.18	INT	33.0	129.97	126.58	3.00	129.98	0.01	0.2	0.07	126.51
26	598+685	6x1.5	4.81	23.55	INT	33.0	129.99	128.90	1.50	130.80	0.81	0.3	0.10	128.80
27	599+088	2x1.5	1.59	8.10	INT	33.0	129.45	127.97	1.50	129.87	0.42	0.6	0.20	127.77
28	599+375	1.5x1.5	7.22	5.85	INT	33.0	128.37	126.52	1.50	128.42	0.05	0.7	0.23	126.28
29	599+450	1.5x1.5	4.33	5.85	INT	33.0	128.11	125.95	1.50	127.85	-0.25	0.7	0.23	125.72
30	599+563	1.5x1.5	2.35	5.85	INT	33.0	127.59	126.18	1.50	128.08	0.49	0.7	0.23	125.95
31	599+895	3x1.5	2.63	12.75	INT	33.0	126.63	124.52	1.50	126.42	-0.21	0.5	0.17	124.36
32	600+074	4x1.5	7.17	14.29	INT	33.0	126.25	124.81	1.50	126.71	0.46	0.3	0.10	124.71
33	600+549	3x1.5	10.21	12.75	INT	33.0	125.04	122.75	1.50	124.65	-0.39	0.5	0.17	122.59
34	600+747	3x1.5	8.88	12.75	INT	33.0	125.14	124.26	1.50	126.16	1.02	0.5	0.17	124.10
35	601+064	5x2	26.24	27.60	INT	33.0	124.55	122.37	2.00	124.77	0.22	0.3	0.10	122.27
36	601+154	1.5x1.5	1.05	5.85	INT	33.0	124.41	122.94	1.50	124.84	0.43	0.7	0.23	122.71
37	601+262	2x1.5	1.17	8.10	INT	33.0	124.07	122.72	1.50	124.62	0.55	0.6	0.20	122.52
38	601+417	2x1.5	4.27	8.10	INT	33.0	124.44	123.50	1.50	125.40	0.96	0.6	0.20	123.30
39	601+621	4x2	16.60	20.71	INT	33.0	123.18	121.18	2.00	123.58	0.40	0.3	0.10	121.08
40	601+797	4x2	10.18	20.71	6	50.0	123.28	121.45	2.00	123.85	0.57	0.3	0.15	121.30
41	601+946	5x2	12.61	27.60	6	50.0	123.45	121.41	2.00	123.81	0.36	0.3	0.15	121.26
42	602+256	4x2	16.53	20.71	6	50.0	123.80	122.80	2.00	125.20	1.40	0.3	0.15	122.65
43	602+574	3x2	9.56	16.31	6	50.0	123.90	121.39	2.00	123.79	-0.11	0.4	0.20	121.19
44	602+980	1.5x1.5	5.85	5.85	6	50.0	123.96	123.06	1.50	124.96	1.00	0.7	0.35	122.71
45	604+145	1.5x1.5	2.81	5.85	6	50.0	123.10	121.50	1.50	123.40	0.30	0.7	0.35	121.15
46	604+562	1.5x1.5	6.48	5.85	INT	33.0	124.46	122.30	1.50	124.20	-0.26	0.7	0.23	122.07
47	605+292	4x2	5.53	20.71	INT	33.0	122.70	120.61	2.00	123.01	0.31	0.3	0.10	120.51
48	605+624	3x2	5.89	16.31	INT	33.0	123.37	122.08	2.00	124.48	1.11	0.4	0.13	121.95
49	605+850	5x2	25.15	27.60	INT	33.0	124.45	122.09	2.00	124.49	0.04	0.3	0.10	121.99
50	605+897	2x1.5	2.21	8.10	INT	33.0	124.47	122.26	1.50	124.16	-0.31	0.6	0.20	122.06
51	605+959	2x1.5	1.96	8.10	INT	33.0	124.37	122.60	1.50	124.50	0.13	0.6	0.20	122.40
52	606+062	1.5x1.5	3.42	5.85	INT	33.0	124.45	123.81	1.50	125.71	1.26	0.7	0.23	123.58
53	606+244	1.5x1.5	5.29	5.85	INT	33.0	124.46	123.27	1.50	125.17	0.71	0.7	0.23	123.04
54	606+518	1.5x1.5	6.32	5.85	INT	33.0	126.72	125.29	1.50	127.19	0.47	0.7	0.23	125.06
55	608+762	1.5x1.5	1.57	5.85	INT	33.0	129.30	128.13	1.50	130.03	0.73	0.7	0.23	127.90
56	608+891	3x1.5	1.72	12.75	INT	33.0	129.33	127.72	1.50	129.62	0.29	0.5	0.17	127.56
57	610+019	1.5x1.5	0.59	5.85	INT	33.0	154.98	150.37	1.50	152.27	-2.71	0.7	0.23	150.14
58	610+112	1.5x1.5	0.64	5.85	INT	33.0	155.95	154.09	1.50	155.99	0.04	0.7	0.23	153.86

SN	Chainage	Box Size	Q_{50}	Q_{MC}	Lane	Box Length	Exist Road Level	U/S Floor Level	Depth of BC	Box Top Level	Rise in Road Level	Design Slope	Head Loss	D/S Floor Level
	Km+m	mxm	m^3/s	m^3/s	No.	m	m	m	m	m	m	%	m	m
59	610+513	3x1.5	8.18	12.75	INT	33.0	152.43	152.17	1.50	154.07	1.64	0.5	0.17	152.01
60	610+701	1.5x1.5	1.95	5.85	INT	33.0	144.64	142.80	1.50	144.70	0.06	0.7	0.23	142.57
61	610+929	1.5x1.5	0.54	5.85	INT	33.0	139.48	136.02	1.50	137.92	-1.56	0.7	0.23	135.79
62	611+274	4x3	canal	36.36	INT	33.0	138.75	133.64	3.00	137.04	-1.71	0.3	0.10	133.54
63	611+717	1.5x1.5	2.59	5.85	INT	33.0	135.6	133.78	1.50	135.68	0.08	0.7	0.23	133.55
64	611+844	2x1.5	2.58	8.10	4	24.0	136.93	133.25	1.50	135.15	-1.78	0.6	0.14	133.11
65	612+600	2x1.5	5.10	8.10	4	24.0	147.45	146.27	1.50	148.17	0.72	0.6	0.14	146.13
66	613+005	2x1.5	5.06	8.10	4	24.0	147.03	145.27	1.50	147.17	0.14	0.6	0.14	145.13
67	613+281	2x1.5	7.81	8.10	4	24.0	148.09	146.59	1.50	148.49	0.40	0.6	0.14	146.45
68	613+715	2x1.5	6.96	8.10	4	24.0	149.54	147.69	1.50	149.59	0.05	0.6	0.14	147.55
69	616+825	3x1.5	9.85	12.75	4	24.0	152.39	151.01	1.50	152.91	0.52	0.5	0.12	150.89
70	617+568	2x1.5	2.40	8.10	4	24.0	151.11	150.12	1.50	152.02	0.91	0.6	0.14	149.98
71	617+658	1.5x1.5	2.82	5.85	4	24.0	151.12	149.92	1.50	151.82	0.70	0.7	0.17	149.75
72	617+756	2x1.5	1.83	8.10	4	24.0	151.10	149.53	1.50	151.43	0.33	0.6	0.14	149.39
73	617+960	5x2	22.64	27.60	6	50.0	151.30	149.42	2.00	151.82	0.52	0.3	0.15	149.27
74	617+990	3x2	4.64	16.31	6	50.0	151.53	149.51	2.00	151.91	0.38	0.4	0.20	149.31
75	618+047	1.5x1.5	0.52	5.85	6	50.0	151.57	149.95	1.50	151.85	0.28	0.7	0.35	149.60
76	618+063	2x1.5	0.51	8.10	6	50.0	151.48	149.47	1.50	151.37	-0.11	0.6	0.30	149.17
77	618+082	1.5x1.5	1.33	5.85	6	50.0	151.35	150.60	1.50	152.50	1.15	0.7	0.35	150.25
78	618+311	1.5x1.5	1.95	5.85	6	50.0	148.95	147.48	1.50	149.38	0.43	0.7	0.35	147.13
79	618+459	1.5x1.5	2.95	5.85	6	50.0	147.90	146.26	1.50	148.16	0.26	0.7	0.35	145.91
80	618+510	1.5x1.5	5.06	5.85	6	50.0	147.71	146.75	1.50	148.65	0.94	0.7	0.35	146.40
81	618+737	1.5x1.5	4.71	5.85	6	50.0	145.29	143.79	1.50	145.69	0.40	0.7	0.35	143.44
82	618+780	6x1.5	7.09	23.55	6	50.0	145.27	143.90	1.50	145.80	0.53	0.3	0.15	143.75
83	618+993	4x1.5	12.77	14.29	6	50.0	145.87	144.34	1.50	146.24	0.37	0.3	0.15	144.19
84	619+111	1.5x1.5	4.01	5.85	6	50.0	147.49	146.05	1.50	147.95	0.46	0.7	0.35	145.70
85	619+190	1.5x1.5	2.00	5.85	6	50.0	147.8	145.97	1.50	147.87	0.07	0.7	0.35	145.62
86	619+329	1.5x1.5	2.03	5.85	6	50.0	148.47	147.05	1.50	148.95	0.48	0.7	0.35	146.70
87	619+400	1.5x1.5	0.67	5.85	6	50.0	148.36	147.48	1.50	149.38	1.02	0.7	0.35	147.13
88	619+440	1.5x1.5	1.51	5.85	6	50.0	148.27	145.91	1.50	147.81	-0.46	0.7	0.35	145.56
89	619+492	1.5x1.5	0.19	5.85	6	50.0	148.05	146.72	1.50	148.62	0.57	0.7	0.35	146.37
90	619+510	1.5x1.5	0.28	5.85	6	50.0	147.9	145.69	1.50	147.59	-0.31	0.7	0.35	145.34
91	619+720	1.5x1.5	2.26	5.85	6	50.0	146.14	144.81	1.50	146.71	0.57	0.7	0.35	144.46
92	620+230	4x1.5	12.33	14.29	6	50.0	144.53	141.72	1.50	143.62	-0.91	0.3	0.15	141.57
93	620+580	3x2	10.20	16.31	6	50.0	142.68	141.28	2.00	143.68	1.00	0.4	0.20	141.08
94	620+674	2x1.5	1.00	8.10	6	50.0	142.34	140.49	1.50	142.39	0.05	0.6	0.30	140.19
95	620+738	1.5x1.5	1.14	5.85	6	50.0	142.63	140.42	1.50	142.32	-0.31	0.7	0.35	140.07
96	620+863	3x1.5	5.83	12.75	6	50.0	143.39	141.91	1.50	143.81	0.42	0.5	0.25	141.66
97	621+050	2x1.5	3.01	8.10	6	50.0	143.06	142.30	1.50	144.20	1.14	0.6	0.30	142.00
98	621+206	1.5x1.5	4.58	5.85	6	50.0	142.35	141.26	1.50	143.16	0.81	0.7	0.35	140.91
99	621+541	6x2	13.07	34.70	4	24.0	139.57	136.93	2.00	139.33	-0.24	0.3	0.07	136.86
100	622+613	3x3	2.98	24.31	4	24.0	138.51	135.55	3.00	138.95	0.44	0.3	0.07	135.48
101	623+025	1.5x1.5	1.44	5.85	4	24.0	136.1	134.00	1.50	135.90	-0.20	0.7	0.17	133.83
102	623+092	2x1.5	3.07	8.10	4	24.0	135.92	134.78	1.50	136.68	0.76	0.6	0.14	134.64
103	623+509	2x1.5	5.79	8.10	4	24.0	133.4	131.79	1.50	133.69	0.29	0.6	0.14	131.65
104	623+723	1.5x1.5	2.53	5.85	4	24.0	133.27	132.17	1.50	134.07	0.80	0.7	0.17	132.00
105	623+801	1.5x1.5	1.88	5.85	4	24.0	132.62	130.34	1.50	132.24	-0.38	0.7	0.17	130.17
106	624+182	6x2.5	33.24	46.74	4	24.0	131.83	128.86	2.50	131.76	-0.07	0.3	0.07	128.79
107	624+346	1.5x1.5	2.11	5.85	4	24.0	132.62	131.54	1.50	133.44	0.82	0.7	0.17	131.37

SN	Chainage	Box Size	Q_{50}	Q_{MC}	Lane	Box Length	Exist Road Level	U/S Floor Level	Depth of BC	Box Top Level	Rise in Road Level	Design Slope	Head Loss	D/S Floor Level
	Km+m	mxm	m³/s	m³/s	No.	m	m	m	m	m	m	%	m	m
108	624+602	6x2.5	12.03	46.74	4	24.0	130.47	128.27	2.50	131.17	0.70	0.3	0.07	128.20
109	624+717	1.5x1.5	3.69	5.85	4	24.0	130.22	129.48	1.50	131.38	1.16	0.7	0.17	129.31
110	624+810	1.5x1.5	2.24	5.85	4	24.0	129.58	128.00	1.50	129.90	0.32	0.7	0.17	127.83
111	624+882	1.5x1.5	1.21	5.85	4	24.0	128.92	127.43	1.50	129.33	0.41	0.7	0.17	127.26
112	625+045	1.5x1.5	0.75	5.85	4	24.0	127.9	126.93	1.50	128.83	0.93	0.7	0.17	126.76
113	625+155	1.5x1.5	2.36	5.85	4	24.0	128.19	127.64	1.50	129.54	1.35	0.7	0.17	127.47
114	625+222	1.5x1.5	1.78	5.85	4	24.0	128.29	125.34	1.50	127.24	-1.05	0.7	0.17	125.17
115	625+269	1.5x1.5	1.06	5.85	4	24.0	128.27	126.92	1.50	128.82	0.55	0.7	0.17	126.75
116	625+463	2x1.5	5.43	8.10	4	24.0	128.12	127.73	1.50	129.63	1.51	0.6	0.14	127.59
117	625+650	2x1.5	7.14	8.10	4	24.0	128.08	127.50	1.50	129.40	1.32	0.6	0.14	127.36
118	626+421	1.5x1.5	1.86	5.85	4	24.0	123.19	121.86	1.50	123.76	0.57	0.7	0.17	121.69
119	626+939	2x2	4.02	10.39	4	24.0	123.83	118.41	2.00	120.81	-3.02	0.5	0.12	118.29
120	628+070	2x1.5	5.61	8.10	4	24.0	123.1	121.81	1.50	123.71	0.61	0.6	0.14	121.67
121	628+406	2x1.5	5.48	8.10	4	24.0	121.90	119.68	1.50	121.58	-0.32	0.6	0.14	119.54
122	628+570	2x1.5	5.67	8.10	4	24.0	122.81	120.33	1.50	122.23	-0.58	0.6	0.14	120.19
123	629+488	1.5x1.5	2.07	5.85	4	24.0	122.01	118.65	1.50	120.55	-1.46	0.7	0.17	118.48
124	629+693	6x3	38.10	51.18	4	24.0	121.35	116.74	3.00	120.14	-1.21	0.2	0.05	116.69
125	629+868	6x3	42.65	51.18	4	24.0	121.32	116.50	3.00	119.90	-1.42	0.2	0.05	116.45
126	630+308	2x1.5	7.65	8.10	4	24.0	124.07	120.89	1.50	122.79	-1.28	0.6	0.14	120.75
127	630+495	2x1.5	6.02	8.10	4	24.0	125.17	122.25	1.50	124.15	-1.02	0.6	0.14	122.11
128	631+010	5x3	26.50	49.24	4	24.0	123.97	117.37	3.00	120.77	-3.20	0.3	0.07	117.30
129	631+157	6x3	14.27	51.18	4	24.0	122.92	117.17	3.00	120.57	-2.35	0.2	0.05	117.12
130	632+125	4x4	7.79	52.97	4	24.0	122.58	116.40	4.00	120.80	-1.78	0.3	0.07	116.33
131	632+393	3x3	8.18	24.31	4	24.0	122.58	118.98	3.00	122.38	-0.20	0.3	0.07	118.91
132	632+505	3x1.5	6.17	12.75	4	24.0	122.85	121.24	1.50	123.14	0.29	0.5	0.12	121.12
133	632+856	2x1.5	7.48	8.10	4	24.0	122.54	118.48	1.50	120.38	-2.16	0.6	0.14	118.34
134	633+160	2x1.5	6.95	8.10	4	24.0	119.31	118.65	1.50	120.55	1.24	0.6	0.14	118.51
135	634+668	4x2	14.95	20.71	4	24.0	116.67	114.21	2.00	116.61	-0.06	0.3	0.07	114.14
136	635+344	6x2	32.56	34.70	6	50.0	116.08	115.92	2.00	118.32	2.24	0.3	0.15	115.77
137	635+799	4x2	15.31	20.71	6	50.0	116.81	115.11	2.00	117.51	0.70	0.3	0.15	114.96
138	636+179	5x3	43.34	49.24	6	50.0	116.7	113.50	3.00	116.90	0.20	0.3	0.15	113.35
139	636+308	1.5x1.5	5.06	5.85	6	50.0	118.85	114.52	1.50	116.42	-2.43	0.7	0.35	114.17
140	637+133	1.5x1.5	2.80	5.85	4	24.0	117.40	116.37	1.50	118.27	0.87	0.7	0.17	116.20
141	637+287	1.5x1.5	1.60	5.85	4	24.0	116.15	113.52	1.50	115.42	-0.73	0.7	0.17	113.35
142	637+337	3x2	7.89	16.31	4	24.0	116.14	113.66	2.00	116.06	-0.08	0.4	0.10	113.56
143	637+514	1.5x1.5	2.80	5.85	4	24.0	116.09	114.06	1.50	115.96	-0.13	0.7	0.17	113.89
144	637+579	2x1.5	6.57	8.10	4	24.0	115.96	113.97	1.50	115.87	-0.09	0.6	0.14	113.83
145	638+021	3x3	16.69	24.31	4	24.0	115.68	112.59	3.00	115.99	0.31	0.3	0.07	112.52
146	638+443	3x2	12.99	16.31	4	24.0	115.90	113.36	2.00	115.76	-0.14	0.4	0.10	113.26
147	639+038	2x1.5	7.03	8.10	4	24.0	116.34	115.23	1.50	117.13	0.79	0.6	0.14	115.09
148	639+414	6x3	12.19	51.18	4	24.0	115.84	111.30	3.00	114.70	-1.14	0.2	0.05	111.25
149	639+578	2x1.5	4.42	8.10	4	24.0	115.07	112.96	1.50	114.86	-0.21	0.6	0.14	112.82

14.7.5 Hydraulic Design of Side Drains

Side drains are designed only in 6 lane sections. The main road side drains (MRSD) are designed both sides at the end of 4 lanes and the service road side drains (SRSD) are designed both sides at the end of 6 lanes. All side drains will be RCC precast of rectangular size with RCC cover. The MRSD is of 0.6mx0.7m (BxD) size and the SRSD is of 0.7mx0.8m (BxD) size.

The longitudinal slope of side drains is kept same as the longitudinal slope of the adjacent road and the capacity of side drains are checked for design discharge. The sample of estimating design slope and checking the discharge of side drains is provided in Table 14.28. Where the discharging capacity is not sufficient, the width, depth and slope of side drains are increased to cater the increased flow.

The 25-year return period design floods have been adopted for both type of side drains and the discharge per meter length of side drains are estimated in Table 14.18 and Table 14.19.

Table 14.28: Sample of estimated design slope and checking the discharging capacity of side drains of BG Section

Main Road Side Drain (MRSD) Q=0.00099 m^3/s per m length of drain (BG)

Right Side Drain (Width 0.6 m; Depth 0.7 m)

Chainage (m)		Outfall BC/BB/B			DL	QH	Road Level		Drain Level		Drain Slope	DD	FA	P	HR	V	Qsd	Check
From	To	Ch.	W	H	m	m3/s	Start	End	Start	End		m	m2	m	m	m/s	m3/s	
590175	590105	590+105	Free		70	0.069	188.376	187.674	187.576	186.874	0.0100	0.70	0.42	2.00	0.21	2.36	0.99	TRUE
590240	590195	590+187	DNBridge		45	0.045	188.924	188.385	188.124	187.585	0.0120	0.70	0.42	2.00	0.21	2.58	1.08	TRUE
590240	590320	590+323	3.0	2.0	80	0.079	188.924	187.46	188.124	186.657	0.0183	0.70	0.42	2.00	0.21	3.19	1.34	TRUE
590325	590350	590+350	3.0	2.0	25	0.025	187.441	187.428	186.641	186.628	0.0005	0.70	0.42	2.00	0.21	0.54	0.23	TRUE
590470	590350	590+350	3.0	2.0	120	0.119	188.591	187.455	187.791	186.655	0.0095	0.70	0.42	2.00	0.21	2.29	0.96	TRUE
590534	590473	590+473	5.0	3.0	61	0.060	189.184	188.631	188.384	187.831	0.0091	0.70	0.42	2.00	0.21	2.24	0.94	TRUE
590540	590624	590+624	3.0	3.0	84	0.083	188.199	187.756	187.399	186.956	0.0053	0.70	0.42	2.00	0.21	1.71	0.72	TRUE
590630	590690	590+698	DNBridge		60	0.059	187.619	186.492	186.819	185.692	0.0188	0.70	0.42	2.00	0.21	3.23	1.36	TRUE
590710	590750	590+760	DNBridge		40	0.040	186.778	186.176	185.978	185.376	0.0151	0.70	0.42	2.00	0.21	2.89	1.21	TRUE
590770	590901	590+901	3.0	3.0	131	0.130	186.171	185.912	185.371	185.112	0.0020	0.70	0.42	2.00	0.21	1.05	0.44	TRUE
590910	590980	590+992	Bridge		70	0.069	185.844	185.189	185.044	184.389	0.0094	0.70	0.42	2.00	0.21	2.28	0.96	TRUE

Service Road Side Drain (SRSD) Q=0.0043 m^3/s per m length of drain (BG)

Right Side Drain (Width 0.7 m; Depth 0.8 m)

Chainage (m)		Outfall BC/BB/B			DL	QH	Road Level		Drain Level		Drain Slope	DD	FA	P	HR	V	Qsd	Check
From	To	Ch.	W	H	m	m3/s	Start	End	Start	End		m	m2	m	m	m/s	m3/s	
591400	591788	591+789	2.0	1.5	388	1.668	178.50	166.33	177.60	165.43	0.0314	0.80	0.56	2.20	0.25	4.74	2.65	TRUE
591790	593809	593+810	3.0	1.5	2019	8.682	166.29	148.47	165.39	147.57	0.0088	0.80	0.56	2.20	0.25	2.51	1.41	FALSE
593812	593898	593+899	2.0	1.5	86	0.370	148.47	148.44	147.57	147.54	0.0003	0.80	0.56	2.20	0.25	0.50	0.28	FALSE

All hydrological Analysis and Calculations are presented in: Annexure XV

15 Bridge, Culvert and Other Structures Design

15.1 Introduction

Most of the existing bridges in the proposed section of the East-West Highway (EWH) included in the present scope of works are found to be still intact and believed to have considerable number of years of useful life. A condition survey based on visual observation was carried out and recommendations have been made to improve the service level of the existing bridges in separate chapters of the main report. Reviewing the upgrading of previous sections of EWH such as Kakarbhitta-Laukahi Sections, Butwal-Narayanghat, and Kamala –Kanchanpur an understanding was developed not to replace existing major bridges unless they are unfit structurally or functionally. Since then, it has been practiced to add a new bridge at the side of the existing one.

During several meetings with the DOR, it has been agreed for the present works to proceed as follows:

- Replace the multi-cell culverts with box culverts or Twin bridge as appropriate
- Replace old bridges which are unusable or unsuitable by structural/ functional or other road parameters with a twin bridge at the same location.
- New bridges to be placed either upstream or downstream of the existing bridge, but downstream is preferred as far as possible to minimize river training works. Factors that dictate placement are: approach road curvature, vegetation (environmental issue), property acquisition, existing structure or any other technical issue.

The above guidelines have been followed during selection of the construction plan, type of the bridges and their locations.

15.2 Bridge Geometry

The highway is being upgraded from double lane to four lanes at non-urban areas and six lanes at urban areas, with median at the center. A bridge has to be streamlined with the elements of the road cross section. The bridges have been grouped in two area categories: **Non-urban area bridges** and Urban/Semi-urban area bridges.

15.2.1 Non-urban area bridges

In the non-urban area bridges the main carriageway width is kept as 8.0m (7.5m + 0.5m curb-shyness width) as in the previous designs for upgrading of the EWH. Footpath is provided at one side (outer side) with a clear width of 2.75m. In the future, if required the footpath can also be used as driving lane by shifting the crash barrier separating the footpath to the outer side. In that case the total width of the carriageway will be 10.95m. Additional bridge for vehicles and/or pedestrians can be added to the side, if required. The design has been checked for both the cases. **The cross-section parameters are shown in the Figures 15.1, 15.2, and 15.3 below.**

Non-urban area bridges

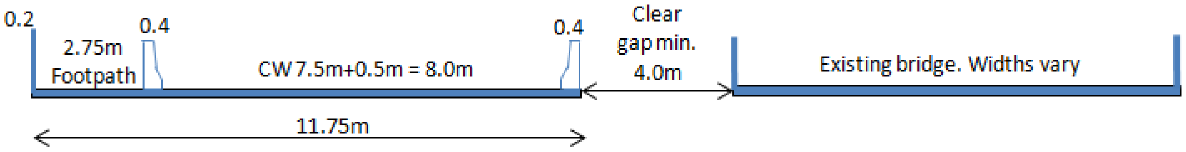


Figure 15.1: New Bridge added adjacent to the existing one

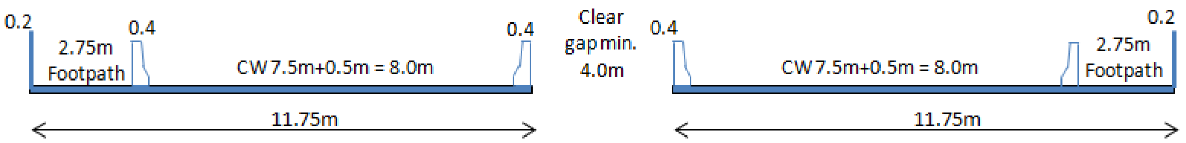


Figure 15.2: In case of dismantling existing bridge and construction of Twin Bridge

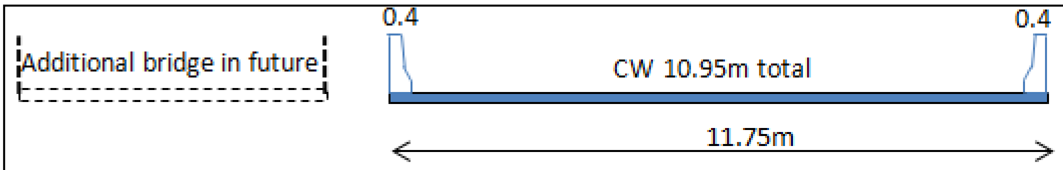


Figure 15.3: expansion of carriageway with additional bridge at the side (optional)

15.2.2 Urban or Semi-urban area bridges

In the urban/semi-urban area bridges, the main carriageway width is kept as 8.0m (7.5m + 0.5m curb-shyness width) as in the previous one. A 5.0m service lane has been provided separated by a double-sided crash barrier. Raised footpath is provided at the side of the service lane with a clear width of 2.2m. In the future, if required the footpath can also be used as driving lane, by dismantling the raised platform and providing a crash barrier at the outer side. In that case the total width of the service lane will be 7.0m. Additional bridge for pedestrians can be added to the side. The design has been checked for both the cases. The cross-section parameters are shown in the **Figures 15.4, 15.5**, and **15.6** below.

Urban/Semi-urban area bridges

Figure 15.4: New Bridge added adjacent to the existing one

Figure 15.5: In case of dismantling existing bridge and construction of Twin Bridge

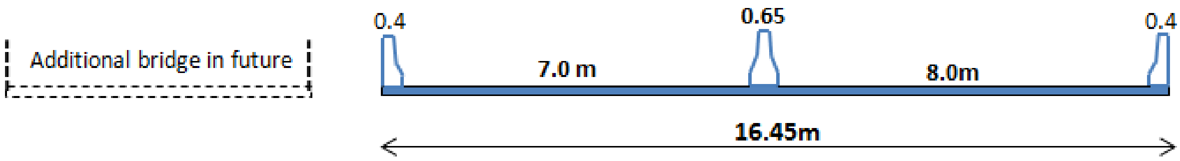


Figure 15.6: expansion of service lane carriageway with additional foot-bridge at the side (optional)

15.3 Design Constraints

Since the new bridges are to be constructed in an existing built-up environment, there are a few things which guide the design parameters. The new structures should be in harmony with the existing ones.

15.3.1 Span lengths and arrangement

It was generally agreed during the meetings with the DOR that wherever possible the span lengths are to be as long as feasible to reduce the number of intermediate substructure/foundations. In case of addition of a new bridge adjacent to the existing one the span arrangement should also address the hydraulic aspect. Since the new bridge would be quite close to the existing one the piers of the new bridge should be aligned with those of the existing one so that that there is minimum obstruction to debris flow. Span Arrangement and Bridge Type of Bridges are shown in the **Table 15.1** below:

Table 15.1: Span Arrangement and Bridge Type of Bridges

S. N	Name of Bridge	Lane	New Proposed Bridge Parameter									
			Type of Bridge	Bridge ID	Design Chainage	Span			Bridge Length	Chainage		Upstream (US) / Downstream (DS) / Twin
						No	Span	Length		Starting	End	
1	Jitgadi Bridge	6	RCC	46 / HOO1 / 287_AB	590+048.50	1	22.00	22.00	22.70	590+037.15	590+059.85	Twin (New)
2	Narsinga Dry Nala Bridge	6	RCC	46 / HOO1 / 288_AB	590+187	1	17.00	17.00	17.70	590+178.15	590+195.85	Twin (New)
3	Dry Nala Bridge	6	BOX	46 / HOO1 / 289_AB	590+699	2	5.00	10.00	10.00	590+694.00	590+704.00	Twin (New)
4	Dry Nala Bridge	6	BOX	46 / HOO1 / 290_AB	590+760	2	5.00	10.00	10.00	590+755.00	590+765.00	Twin (New)
5	Pakhapani Bridge	6	BOX	46 / HOO1 / 291_AB	590+992	2	5.00	10.00	10.00	590+987.00	590+997.00	Twin (New)
6	Vehicular Underpass	6	BOX	46 / HOO1 / 291.1_A	592+302.00	1	13.00	13.00	13.00	592+295.50	592+308.50	Twin (New)
7	Vehicular Underpass	6	BOX	46 / HOO1 / 291.2_A	594+450.00	1	13.00	13.00	13.00	594+443.50	594+456.50	Twin (New)
8	Satgadi -1 Bridge	6	RCC	46 / HOO1 / 292_A	596+090	3	22.00	66.00	68.14	596+055.93	596+124.07	DS
9	Satgadi -2 Bridge	6	PSC	46 / HOO1 / 293_A	596+331	1	30.00	30.00	31.20	596+315.40	596+346.60	DS
10	Vehicular Underpass	6	BOX	46 / HOO1 / 293.1_A	597+100.00	1	13.00	13.00	13.00	597+093.50	597+106.50	Twin (New)
11	Soila Bridge	6	BOX	46 / HOO1 / 294_A	597+459	2	6.00	12.00	10.00	597+454.00	597+464.00	DS
12	Rajpur Bridge	6	PSC	46 / HOO1 / 295_A	597+777	1	27.00	27.00	28.20	597+762.90	597+791.10	DS
13	Bamaha Bridge	6	PSC	46 / HOO1 / 296_A	598+252	1	33.00	33.00	34.20	598+234.90	598+269.10	DS
14	Vehicular Underpass	6	BOX	46 / HOO1 / 296.1_A	602+715.00	1	13.00	13.00	13.00	602+708.50	602+721.50	Twin (New)
15	Ghamaha Bridge	INT	PSC	46 / HOO1 / 297_A	603+566	3	10+30+10	50.00	52.68	603+539.66	603+592.34	DS
16	Tulbuliya Bridge	4	PSC	46 / HOO1 / 298_A	603+826	1	42.00	42.00	43.20	603+804.40	603+847.60	DS

S. N	Name of Bridge	Lane	New Proposed Bridge Parameter								
			Type of Bridge	Bridge ID	Design Chainage	Span			Bridge Length	Chainage		Upstream (US) / Downstream (DS) / Twin
						No	Span	Length		Starting	End	
17	Vehicular Underpass	6	BOX	46 / HOO1 / 298.1_A	604+235.00	1	13.00	13.00	13.00	604+228.50	604+241.50	Twin (New)
18	Marthirwa Bridge	4	RCC	46 / HOO1 / 299_A	604+682	1	17.00	17.00	17.70	604+673.15	604+690.85	DS
19	Meghawa Bridge	INT	RCC	46 / HOO1 / 300_A	604+975.5	1	21.00	21.00	21.70	604+964.65	604+986.35	DS
20	Inguria Bridge	INT	PSC	46 / HOO1 / 301_A	606+684	3	10+30+10	50.00	52.68	606+657.66	606+710.34	DS
21	Banarhwa Bridge	INT	PSC	46 / HOO1 / 302_A	607+186	1	40.00	40.00	41.20	607+165.40	607+206.60	DS
22	Dry Nala Bridge	INT	BOX	46 / HOO1 / 303_A - B	607+844.50	2	6.00	12.00	12.00	607+838.50	607+850.50	Twin (New)
23	Pahila River Bridge	INT	RCC	46 / HOO1 / 304_A	610+995	3	17.00	51.00	53.14	610+968.43	611+021.57	DS
24	Dry Nala Bridge	INT	BOX	46 / HOO1 / 305_A	611+101.50	2	6.00	12.00	12.00	611+095.50	611+107.50	DS
25	Kanchan Bridge	INT	RCC	46 / HOO1 / 306_A	611+406	3	22.00	66.00	68.14	611+371.93	611+440.07	DS
26	Medium Animal Crossing	4	BOX	46 / HOO1 / 306.1_A-B	612+600	1	8.00	8.00	8.00	612+596.00	612+604.00	Twin (New)
27	RCC Box Bridge	4	BOX	46 / HOO1 / 306.2_A-B	613+709	1	8.00	8.00	8.00	613+705.00	613+713.00	Upgraded to Twin (New)
28	Kothi Bridge	4	PSC	46 / HOO1 / 307_A	615+258	1	42.00	42.00	43.20	615+236.40	615+279.60	Also proposed for large wildlife crossing/DS
29	Medium Animal Crossing	4	BOX	46 / HOO1 / 307.1_A-B	616+825	1	8.00	8.00	8.00	616+821.00	616+829.00	Twin (New)
30	Gageda Bridge	4	BOX	46 / HOO1 / 308_A	620+006	2	5.00	10.00	10.00	620+001.00	620+011.00	Twin (New)
31	Vehicular Underpass	6	BOX	46 / HOO1 / 308.1_A-B	620+362.00	1	13.00	13.00	13.00	604+228.50	604+241.50	Twin (New)
32	Banganga Bridge	4	PSC	46 / HOO1 / 309_AB	622+020	10	30.00	300.00	312.18	621+863.91	622+176.09	DS

S. N	Name of Bridge	Lane	New Proposed Bridge Parameter									
			Type of Bridge	Bridge ID	Design Chainage	Span			Bridge Length	Chainage		Upstream (US) / Downstream (DS) / Twin
						No	Span	Length		Starting	End	
33	Kaila Bridge	4	PSC	47 / HOO1 / 310_A	627+144	3	32.00	96.00	99.64	627+094.18	627+193.82	DS
34	Balhundra Bridge	4	RCC	47 / HOO1 / 311_A	629+426	1	22.00	22.00	22.70	629+414.65	629+437.35	DS
35	RCC Box Bridge	4	BOX	47 / HOO1 / 311.1_A-B	629+476	1	8.00	8.00	8.00	629+472.00	629+480.00	Upgraded to Twin (New)
36	RCC Box Bridge	4	BOX	47 / HOO1 / 311.2_A-B	631+141	1	8.00	8.00	8.00	631+137.00	631+145.00	Upgraded to Twin (New)
37	Harkon Bridge	4	RCC	47 / HOO1 / 312_A	631+598	1	22.00	22.00	22.70	631+586.65	631+609.35	DS
38	Dry Nala Bridge	4	RCC	47 / HOO1 / 313_A	633+334	1	22.00	22.00	22.70	633+322.65	633+345.35	DS
39	Kundra Bridge	4	PSC	47 / HOO1 / 314_A	633+692	1	30.00	30.00	31.20	633+676.40	633+707.60	DS
40	RCC Box Bridge	4	BOX	47 / HOO1 / 314.1_A-B	635+326	1	8.00	8.00	8.00	635+322.00	635+330.00	Upgraded to Twin (New)
41	Ghorai Nala Bridge	4	RCC	47 / HOO1 / 315_A	636+746	1	22.00	22.00	22.70	636+734.65	636+757.35	DS
42	RCC Box Bridge	4	BOX	47 / HOO1 / 315.1_A-B	638+004	1	8.00	8.00	8.00	638+000.00	638+008.00	Upgraded to Twin (New)
43	RCC Box Bridge	4	BOX	47 / HOO1 / 315.1_A-B	639+021	1	8.00	8.00	8.00	639+017.00	639+025.00	Upgraded to Twin (New)
44	Dry Nala Bridge	4	BOX	47 / HOO1 / 316_A	639+817	2	5.00	10.00	10.00	639+812.00	639+822.00	DS

Summary of Box culverts are tabulated as below **Table: 15.2**

Table 15.2: Summary of Box culverts, Wildlife Crossing and Pedestrian Underpass

S.No.	Size of Culvert (Span*Height)	Non-Urban/ Semi Urban/ Urban	Location (Chainage)			Total	Remarks
1	Single Cell Box Culvert **(1.5 X 1.5) m**	Non-Urban (24.00 m)	617+652	625+147			
			623+017	625+213			
			623+714	625+261			
			623+792	626+413			
			624+338	637+117			
			624+707	637+269			
			624+810	637+498			
			624+874				
			625+037			**16 Nos**	
		Semi Urban (37.50 m)	599+376	606+245	610+697		
			599+451	606+517	610+925		
			599+564	608+762	611+712		
			601+154	610+018			
			606+063	610+111			
						13 Nos	
		Urban (50.00 m)	594+740.0	597+578	619+185		
			594+800	602+981	619+329		
			594+947.5	604+145	619+396		
			594+988.5	604+563	619+432		
			595+139	618+041	619+486		
			595+341	618+076	619+507		
			595+577	618+305	619+713		
			595+819	618+452	620+731		
			596+534	618+501	621+200		
			596+578	618+731	636+290		
			597+235	619+105			
						32 Nos	

S.No.	Size of Culvert (Span*Height)	Non-Urban/ Semi Urban/ Urban	Location (Chainage)			Total	Remarks
2	Single Cell Box Culvert **(2.0 X 1.5) m**	Non-Urban (24.00 m)	611+838	625+642			
			613+000	628+070			
			613+276	628+552			
			617+562	630+293			
			617+750	630+480			
			623+084	632+840			
			623+500	633+143			
			625+455	637+562		**16 Nos**	
		Semi Urban (37.50 m)	598+402	601+263	605+898		
			599+089	601+418	605+960	**6 Nos**	
		Urban (50.00 m)	591+789	618+057			
			593+898.5	620+668			
			594+537	621+050		**6 Nos**	
3	Single Cell Box Culvert **(2.0 X 2.0) m**	Non-Urban (24.00 m)	614+640	628+389			
			615+760				
			626+925			**4 Nos**	
4	Single Cell Box Culvert **(3.0 X 1.5) m**	Non-Urban (24.00 m)					
			632+488				
						1 No	
		Semi Urban (37.50 m)	599+895	600+747	610+510		
			600+549	608+891			
						5 Nos	
		Urban (50.00 m)	593+808				
			620+857				
						2 Nos	
5	Single Cell Box Culvert **(3.0 X 2.0) m**	Non-Urban (24.00 m)	637+320				
			638+426				
						2 Nos	
		Semi Urban (37.50 m)	590+325				
						1 No	
		Urban (50.00 m)	602+574	617+984			
			605+625	620+574		**4 Nos**	

S.No.	Size of Culvert (Span*Height)	Non-Urban/ Semi Urban/ Urban	Location (Chainage)			Total	Remarks
6	Single Cell Box Culvert (3.0 X 2.5) m	Non-Urban (24.00 m)	639+561			1nos	1 No Animal Crossing
7	Single Cell Box Culvert (3.0 X 3.0) m	Non-Urban (24.00 m)	622+604				
			632+377				
						2 Nos	
		Semi Urban (37.50 m)	590+351	590+900			
			590+622	591+296		4 Nos	
		Urban (50.00 m)	592+220	597+040	604+160		
			592+380	597+170	604+310		
			594+330	602+640	620+300		
			594+550	602+810	620+430	12 Nos	12 Pedestrian Underpass
8	Single Cell Box Culvert (4.0 X 1.5) m	Semi Urban (37.50 m)	600+075				
						1 No	
		Urban (50.00 m)	618+987				
			620+230				
						2 Nos	
9	Single Cell Box Culvert (4.0 X 2.0) m	Non-Urban (24.00 m)	634+679				
						1 No	
		Semi Urban (37.50 m)	601+622				
						1 No	
		Urban (50.00 m)	601+798	635+778			
			602+257				
			605+293			4 Nos	
10	Single Cell Box Culvert (4.0 X 3.0) m	Semi Urban (37.50 m)	611+267				
						1 No	
11	Single Cell Box Culvert (4.0 X 4.0) m	Non-Urban (24.00 m)	632+108				
						1 No	
12	Single Cell Box Culvert (5.0 X 2.0) m	Semi Urban (37.50 m)	601+065				
			605+851			2 Nos	
		Urban (50.00 m)	601+947				
			617+954			2 Nos	

S.No.	Size of Culvert (Span*Height)	Non-Urban/ Semi Urban/ Urban	Location (Chainage)			Total	Remarks
13	Single Cell Box Culvert **(5.0 X 3.0) m**	Non-Urban (24.00 m)	**630+993**				
						1 No	
		Semi Urban (37.50 m)	590+473				
						1 No	
		Urban (50.00 m)	636+161				
						1 No	
14	Single Cell Box Culvert **(6.0 X 1.5) m**	Semi Urban (33.00 m)	598+685				
						1 No	
		Urban (50.00 m)	618+766				
						1 No	
14	Single Cell Box Culvert **(6.0 X 2.0) m**	Non-Urban (24.00 m)	621+534				
						1 No	
		Semi Urban (37.50 m)	590+534				
						1 No	
15	Single Cell Box Culvert **(6.0 X 2.5) m**	Non-Urban (24.00 m)	624+174				
			624+593			2 Nos	
16	Single Cell Box Culvert **(6.0 X 3.0) m**	Non-Urban (24.00 m)	629+679				
			629+853	639+397		3 Nos	
		Semi Urban (37.50 m)	598+557				
						1 No	
TOTAL						**155 Nos**	
17	Pedestrian Over Head Crossing	Urban area	592+980	598+500	599+920		
			606+410	610+060	611+220		
			618+050	618+780	626+660		
			627+860	636+020		**11 Nos**	

15.3.2 Wild Life Crossing

Total 18 nos of wildlife crossing are proposed in the design. Some of them are the default structures with enhancement. There are following handbooks and guideline exists for proposing the size of the wildlife crossing.

a. Wildlife Crossing Structure Handbook, Design and Evaluation in North America, US, Department of Transportation, Federal Highway Administration, March, 2011.
b. Eco-Friendly Measures to Mitigate Impact of Linier Infrastructure on Wildlife, Wildlife Institution of India, Ministry of Environment and Climate Change, National Highway Authority of India and World Bank Group.
c. Green Infrastructure Design for Transport Projects, A Road Map to Protecting Asia's Wildlife Biodiversity, Asian Development Bank, December 2019.
d. Wildlife Friendly Infrastructure Construction Guideline 2078/2022, Government of Nepal, Ministry of Forest and Environment.

However, the Consultant have used the Government of Nepal's guideline (Table 15.3 below) with some modifications based on other three handbooks and guidelines.

Table 15.3: Standard size for wildlife structure as per Government of Nepal "Wildlife Friendly Infrastructure Construction Guideline 2078/2022"

SN	Types of wildlife	Underpass structures	Category of Green structures (underpass/overpass)			
			Category A Length < 20 m		**Category B** Length > 20 m	
			Width (m)	Height (m)	Width (m)	Height (m)
1	Small wildlife species	Culvert	2.00	2.00	3.00	2.50
2	Medium size wildlife species	Culvert or bridge	6.00	3.00	8.00	3.00
3	Large wildlife species	Bridge	10.00	4.00	15.00	4.50
4	Very Large wildlife species	Bridge	12.00	6.50	15.00	6.50

The flow of small to big animals is reported underneath the Kothi Bridge (615+260) of Saljhandi-Pipra forest, mainly because of availability of water for drinking and crossing by animal is seen due to height of the bridge which provided a clear visibility of southern side of the highway. As per the GON (2022), Big and Medium Category mammals together with other species were reported to be using this underpass beneath the Kothi Bridge. Besides Kothi Bridge section, remaining parts of the Saljhandi-Pipra forest and whole stretch of Gorusinghe and Budhhi forests were reported crossed by small (B) mammals. The 24 mammals reported from the IEE study could be categorized as per the GON (2022) are as follows:

- **Big animals:** 1) Sambar deer, 2) Nilgai, 3) Indian Spotted Deer, 4) Striped Hyaena
- **Medium:** 5) Common Leopard, 6) Barking Deer, 7) Fishing Cat, 8) Bengal Fox, 9) Golden Jackal, 10) Jungle Cat, 11) Wild Boar, and

- **Small** – 12) Rhesus Macaque, 13) Terai Grey Langur, 14) Five-striped Palm Squirrel, 15) Yellow-throated Marten, 16) Indian Hare, 17) Crab Eating Mongoose, 18) Indian Grey Mongoose, 19) Small Asian Mongoose, 20) Masked Palm Civet, 21) Small Indian Civet, 22) Large Indian Civet, 23) Indian Crested Porcupine, and 24) Honey Badger.

The underpass (Table 15.4) is supported by funneling fencing on either sides of the crossing. Rest of the forest stretch have been fenced with openings at all 18 crossings (without Kothi Bridge), supporting as underpass for the small and some medium category mammals and herpetofauna. Among 18 underpasses 3 nos (612+600, 616+825 and 639+561) are dedicated for wildlife crossing other 15 are the existing cross drainage structurs and it is proposed to upgrade for climate resilient and wildlife friendly crossing. For the light penetration, median of all crossing are opened and length of the crossings are kept shorter i.e. 10 m only. Proposed underpasses crossings should minimize the road-kill/accidents of wildlife. These culverts will have openings in the median, the base will be improved to have natural base and gutters on both the sides for flow of water. Mostly the culverts are dry most of the year. Summary of the wildlife crossings is tabulated as below in Table 15.4:

Table 15.4: Summary of Wildlife and Climate Resilient and Wildlife Friendly Crossing

S.No.	Ch.	Category of Crossing	Size of Crossing (Span* Height)	Remarks
1	612+600	Medium Wildlife Crossing	8*3	Dedicated Wildlife Crossing
2	613+709	RCC Box Bridge	8*3	Upgraded Crossings
3	615+264	Kothi Bridge (Large wildlife crossing	42*4.5	Existing Kothi Bridge also proposed for large wildlife crossing
4	616+825	Medium Wildlife Crossing	8*3	Dedicated Wildlife Crossing
5	628+389	RCC Box Culvert	2*2	Upgraded Crossings
6	629+476	RCC Box Bridge	8*3	Upgraded Crossings
7	629+679	RCC Box Culvert	6*3	Upgraded Crossings
8	629+853	RCC Box Culvert	6*3	Upgraded Crossings
9	630+993	RCC Box Culvert	5*3	Upgraded Crossings
10	631+141	RCC Box Bridge	8*3	Upgraded Crossings
11	632+108	RCC Box Culvert	4*4	Upgraded Crossings
12	632+377	RCC Box Culvert	3*3	Upgraded Crossings
13	634+679	RCC Box Culvert	4*2	Upgraded Crossings
14	635+326	RCC Box Bridge	8*3	Upgraded Crossings
15	638+004	RCC Box Bridge	8*3	Upgraded Crossings
16	638+426	RCC Box Culvert	3*2	Upgraded Crossings for reptiles
17	639+021	RCC Box Bridge	8*3	Upgraded Crossings
18	639+397	RCC Box Culvert	6*3	Upgraded Crossings
19	639+561	Small Wildlife Crossing	3*2.50	Dedicated Wildlife Crossing for reptiles

15.3.3 Bridge length, height and freeboard

Since the road alignment follows the existing one it is desirable to provide new structures in harmony with the existing structures. It was generally agreed that the length and soffit level of the new bridges not be less than those of the existing ones. It dictated to adjust the bridge height to match the height of the existing bridges. Where the span length of the new bridge covered a number of shorter spans of the existing one the height difference between the two bridges would be substantially large (up to 3 m in some cases). In such case the design of the approach road stretch needs particular attention.

15.3.4 Gap between the adjacent bridges and design of foundation

Considering minimum damage to and other effects to the construction activities it is better to build the new bridge as far away as possible from the existing one. But it would require additional land acquisition for the approach roads which is not desirable at the moment. The bridge inventory available in the DOR does not provide clear information on the types and sizes of the foundation of the existing bridges. During field visits it was generally observed that well foundation is provided in many of the longer span bridges (span lengths longer than 20m); the diameter of the wells is usually ranging between 5 to 7m. Other short span bridges could have shallow spread footings with unknown dimensions. No authentic records regarding the foundations were available.

To minimize the damage to the existing foundations and considering terrestrial and aquatic species movement and habitat it was decided to provide Bored & Cast-in-situ piles for the new bridges. It required less excavation and further to reduce vibrations only rotary or oscillatory method of boring can be allowed. Well foundations are comparatively more stable than shallow footings. The type of top soil of the river bed also plays role in stability of the foundation. Considering all these facts, sheet- piling is proposed before excavation wherever considered necessary.

15.4 Choice of Structural Forms

The bridges in the present works can be broadly categorized into four types:

- Minor bridges, culverts and wildlife crossing;
- Major & medium bridges;
- Road Overpass/Underpass;

Cross drainage structure with length up to 6m are categorized as culverts. It has been decided during the meetings with the DOR that all existing Hume-pipe culverts to be replaced by box culverts.

15.4.1 Minor bridges, culverts and wildlife crossings

Bridges with length up to 20m with insignificant scour tendency are grouped as Minor bridges and the structural form adopted for such bridges is Box cells with various sizes. The box sizes are selected considering height, length, thickness of cushion over the deck surface and can be single celled or multi-celled boxes. Sufficient bedding material is provided beneath the box floor and cut-off wall provided to prevent scouring under the bed. Normal simply supported bridge is provided where there is possibility of significant scouring.

The designs for culverts are based on the following considerations:

- Old bridges less than 10m or multi-cell box/Hume Pipe culverts and any other bridge rated as unsuitable for further use will be dismantled and replaced by either new box bridge/culvert or twin double lane bridge;
- All the culverts are proposed RCC box type and checked with hydrology including consideration of the climate change;
- Minimum size of Box Culvert is kept 1.50*1.50 m, considering maintenance of culverts.
- For Culverts the protective measures have been provided based on the standard practice.
- Such type of minor bridges and culverts are proposed for wildlife crossings with funnel fencing and other requirements as per site condition.

15.4.2 Major & Medium bridges

Bridges with length more than 20.00m are grouped as major/medium Bridge. Two types of structural forms are selected for these bridges:

- Cast-in-situ RCC T-girder deck – for bridges with span lengths up to 22m
- Precast composite PSC I-girder and cast-in-situ RCC deck – for bridges with span lengths more than 22m

For major and medium bridges, the abutments are designed as inverted cantilever type RCC walls and the piers are designed as circular RCC columns with hammer-head cap. Bridges at non-urban areas (width 11.75m) have single column whereas those in the urban areas (width 16.45m) have double column portal frame type piers. As already mentioned above the foundations are designed as bored and cast-in-situ RCC piles.

15.4.3 Road Overpass / Underpass

Overpass or Underpass is provided at the junctions with other roads, where grade separated crossings are necessary. The bridge structure in such case consists of cast-in-situ RCC T-girder deck with wall type RCC abutments with open foundation. The approach embankment for such crossing is proposed to be Reinforced Earth filling encased in RCC panel fascia. The overpass/underpass bridge will have no designated footpath; instead the additional width will serve as emergency lane.

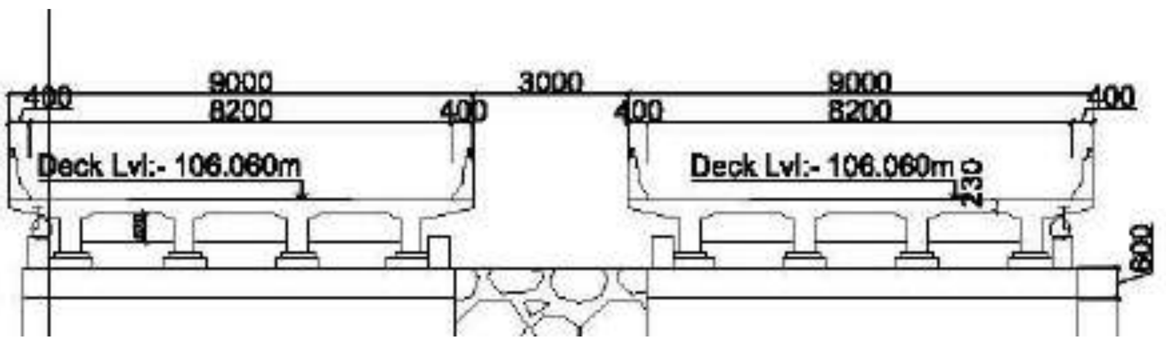


Figure 15.7: A typical Overpass / Underpass Bridge, wildlife crossing

15.5 Design guidelines and criteria

The bridges are designed following limit state method prescribed by Indian Road Congress (IRC) and Indian Standard (IS) design codes. In some cases, AASHTO guidelines are followed where the Indian standards do not cover the required methodology, particularly for the design of the signature bridges.

Nepal Bridge Standards (2067) is followed for some parameters of design. The list of guidelines/codes used for analysis and design are as follows:

- Nepal Bridge Standards (2067) for general guidelines and some hydraulic parameters
- IRC:05-2015 for General features of design
- IRC:06-2017 for loads and their combinations
- IRC:112-2019/2020 for limit state analysis and design of RCC and PSC elements (together with IRC: SP:105-2015 for explanatory notes on IRC:112)
- IRC: SP:114-2018 for Seismic analysis and design
- IRC:24-2010 for design of steel structure
- IRC:22-2015 for Limit state design of composite construction
- IRC:78-2014 for analysis and design of substructure and foundations
- IRC:83-2018 (Part II) for design of elastomeric bearings
- IRC:83-2018 (Part III) for POT-PTFE bearings
- IRC: SP-69-2011 Guideline and Specification for Expansion joints
- IRC:89-2019 Guidelines for Design and Construction of River Training & Control Works for Road Bridges

15.6 Design of Bridge elements

As mentioned above all the elements of the bridge are analyzed and designed with limit state method. Limit state method allows adopting ultimate strength of materials with partial factor of safety on loads/forces and material. The load combinations and the partial factor of safety for different cases are given in Tables B1 through B4 in IRC: 06-2017, Annex B. and IRC: 78-2014, clause 706. These combinations are adopted as per their relevance to the particular situation and element as follows:

For equilibrium of the structure

- ULS Basic Combination
- ULS Accidental Combination
- ULS Seismic Combination

The resultant forces for overturning/sliding and restoring/resisting effects are assessed separately

For analysis of Structural Strength

- ULS Basic Combination
- ULS Accidental Combination

- ULS Seismic Combination

For verification of serviceability Conditions

- SLS Rare Combination
- SLS Frequent Combination
- SLS Quasi Permanent Combination

For Checking of Base Pressure and Design of Foundation as well as assessment of axial loads on piles, provisions of IRC: 78-2014 (clause 706) have been followed.

The structure is designed for ultimate loads and checked for limit state of serviceability, basically deflection, material stress and crack development. This method of design allows to minimize the element sections with certain amount of yielding. During large natural forces such as high magnitude earthquake, the failure mechanism is designed such that the structure may render repairable damages but does not collapse altogether or gives early warnings about possible hazard. Such designs are based on elasto-plastic optimization wherever applicable (e.g., analysis for formation of plastic hinges in columns). The design methods, procedures and parameters for each element are briefly described below.

15.6.1.1 Design of Superstructure

Short span slab bridges, culvers and box bridges are analyzed with customized spreadsheets, basically following effective width method of analysis. Design is based on limit state method as described above.

RCC T-girder or PSC I-girder decks are analyzed with mixed usage of finite element method and customized spreadsheets. Since moving load analysis of wide bridges and/or with divided carriageways is quite complicated, SAP2000 (finite element software capable to analyze the moving load along longitudinal direction together with transverse variation) has been used. Dead loads and other forces are assessed with customized spreadsheets.

The design of main girders, cross girders and deck slabs have been checked for two cases as described in the chapter Bridge Geometry above. The moving loads in different combinations depending upon the carriageway width have been considered according to IRC: 06-2017, 204.3 **(Table 6)**

S.No	Carriageway Width (CW)	Number of Lanes for Design Purposes	Load Combination (Refer Table 6A for diagrammatic representation)
1)	Less than 5.3 m	1	One lane of Class A considered to occupy 2.3 m. The remaining width of carriageway shall be loaded with 500 kg/m^2
2)	5.3 m and above but less than 9.6 m	2	One lane of Class 70R OR two lanes for Class A
3)	9.6 m and above but less than 13.1 m	3	One lane of Class 70R for every two lanes with one lanes of Class A on the remaining lane OR 3 lanes of Class A
4)	13.1 m and above but less than 16.6 m	4	One lane of Class 70R for every two lanes with one lane of Class A for the remaining lanes, if any, OR one lane of Class A for each lane.
5)	16.6 m and above but less than 20.1 m	5	
6)	20.1 m and above but less than 23.6 m	6	

Three types of vehicles are considered: Class A, Class 70R-Wheeled and Class 70R-Tracked.

- Class A vehicle - Gross weight 55.4 Ton distributed in 8 axles over 18.8m length
- Class 70R-Wheeled vehicle – Gross 100 Ton distributed in 7 axles over 13.4m length
- Class 70R-Tracked vehicle – Gross 70 Ton on track with length 4.57m (15.32 Ton/m)

Impact effects for each type of vehicle depending upon type of bridge and span length have been considered as per clause 208 of IRC: 06-2017.

Pedestrian load in appropriate combination is taken as 5kN/m^2.

All the elements of RCC T-girder deck have concrete with grade M30 and the reinforcing bars conforming to grade Fe500. Forces are assessed at different sections along the length of the main girders: At support; 1/8 span; 1/4 span; 3/8 span and mid span. Reinforcement is curtailed according to the force demands at different sections.

Effect of temperature variation has been considered using the temperature gradient charts from clause 215 of IRC: 06-2017.

15.6.1.2 Design of substructure and foundation

The types of abutments, piers and foundations are already discussed above.

The main forces acting upon the substructure and their incorporation in analysis have been considered as follows:

- Dead loads (from the superstructure and self-weight of substructure itself)
- Surfacing loads (wearing course etc.)
- Live loads (vehicles and pedestrians)
- Tractive / Braking force from vehicles

- Lateral earth pressure and gravity of earth mass
- Live load surcharge
- Buoyant forces
- Water current
- Temperature effects
- Seismic forces

These forces are assessed separately are applied in their respective direction with modified magnitude by multiplying with prescribed partial factor of safety according to different combinations.

The abutments and single column piers are analyzed with custom developed spreadsheets. The piers with double columns (portal frame type) and pile caps for all foundations have been analyzed with mixed usages of finite element analysis software and customized spreadsheets. The piles are analyzed and designed with custom developed spreadsheets.

The abutment stems for river bridges are designed as cantilever wall with vertical force, and inverted T-type retaining walls with vertical force for overpass/underpass.

The pier stems and piles are designed as circular columns and checked with P-M interaction curves.

Open foundations are checked for stability (overturning and sliding) with the factored loads as prescribed by IRC: 06-2017 (Annex B). The piles are considered as columns restrained to rotation at both ends. The base of the piles is assumed to be fixed at virtual depth of fixity determined by method prescribed in IS: 2911, Part-1, Sec.-2, and Appendix – C. The pile cap is considered as rigid plate allowing movement only in horizontal plane. The base pressure of open foundation and axial force on the piles are assessed for different combinations as per IRC: 78-2014 clause 706.

15.6.1.3 Design of Bearings

Basically, two types of bearings are proposed in the designs of simply supported superstructures. Elastomeric bearings for RCC bridges up to a span of 26m and Pot-PTFE bearings for longer span PSC girders. Box bridges will have no bearings.

Design of the bearings also depends upon the production arrangement of the manufacturers. It has been a practice to provide all the necessary information about loads and deformations, according to which the manufacturer will produce bearings with all the desired stiffness and restrain properties. However, in case of elastomeric bearings a tentative design has been done to assess the seismic forces transmitted to the substructure.

The bearings are supposed to allow rotation about all axes, partial longitudinal movement and restrained at transverse direction. The Pot bearings will have in-built arrangement to allow or resist the desired planar and rotational movement. For the elastomeric bearings special arrangements are required to allow or resist the movements such as dowel pins or stopper blocks. All the elastomeric bearings are proposed to have the arrangement shown in the figure: 15.8 below, or with approval from the engineer design it will dowel pins.

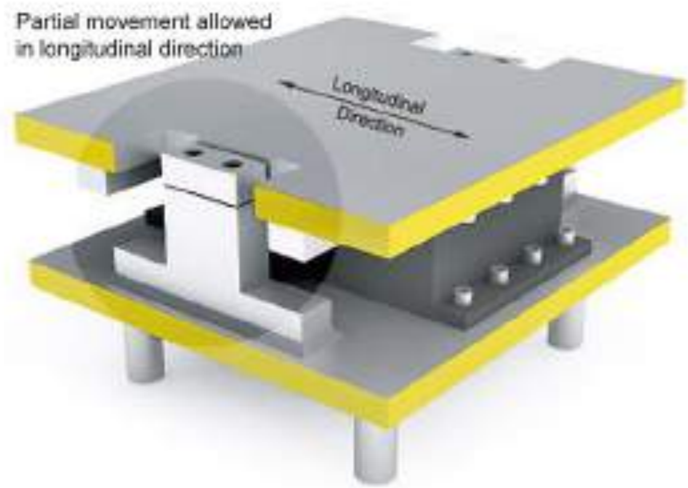


Figure 15.8: Typical Elastomeric bearing restrained at transverse direction and partially free at longitudinal direction.

15.6.1.4 Expansion Joints

Two types of expansion joints suggested by IRC: SP-69-2011 are proposed in the designs.

- Compression seals as per clause 5.2.1 for spans up to 26m, with allowable movement up to 40mm

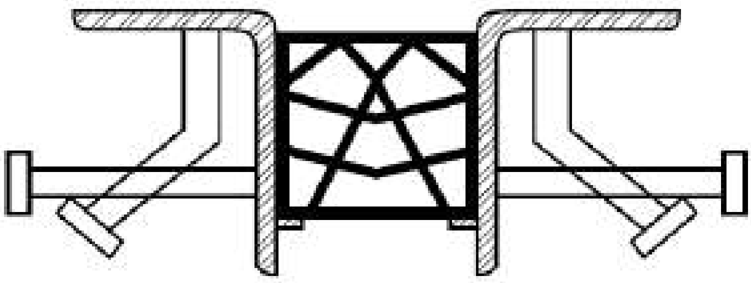


Figure 15.9: Compression Seal Expansion Joint

- Reinforced elastomeric joints as per clause 5.2.3 for span longer than 26m, with allowable movement up to 80mm

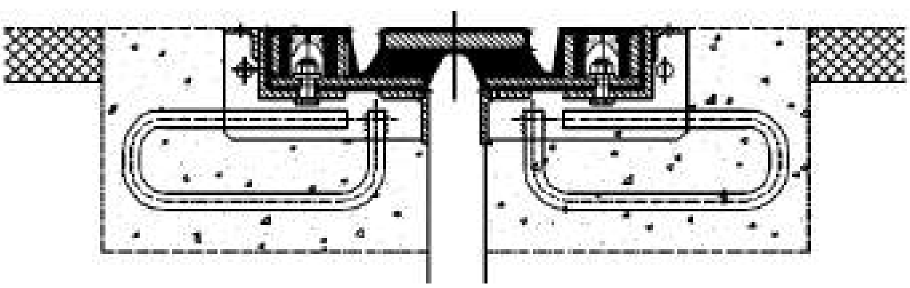


Figure 15.10: Reinforced Elastomeric Expansion Joints

15.6.1.5 Design of Crash Barriers and hand-rails

Crash barriers are supposed to absorb the impact of vehicle and keep them within the roadway or carriageway in case of crash. New Jersey shaped (Type F) concrete parapet wall is used as crash barriers with the bridge deck. The type, shape and reinforcement of the crash barriers have been adopted from the approved design from Federal Highway Administration, USA (FHWA). The height of the parapet is 800mm and base width 400mm. Two types of barriers are used in design: Single faced and double faced. The double-faced barrier is used to separate the service lane from the main carriageway in urban bridges, whereas single faced barriers are used to separate the main carriageway from the footpath in non-urban bridges and at the inner sides of the bridge to prevent the vehicles from falling down. The shape and dimensions of the crash barriers are shown in the **Figure 15.11** below.

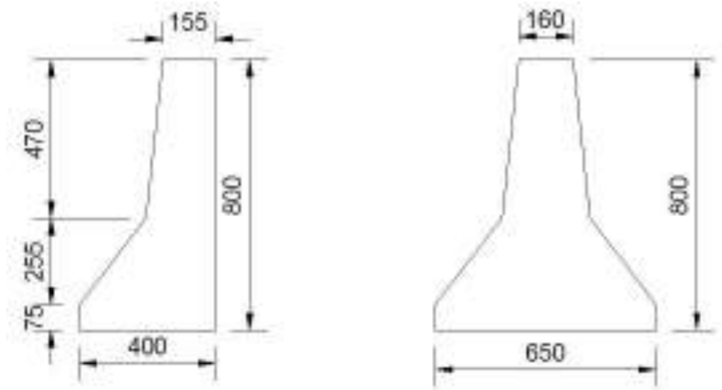


Figure 15.11: Single faced and double-faced F-type New Jersey barriers

Handrails are proposed to be vertical bar fence instead of parallel horizontal bars to prevent children from climbing up. The gap between the vertical bars is kept as 150 mm to prevent a child's head to stuck in the railings.

15.6.1.6 Seismic Consideration in Design

It is a well-known fact that Nepal lies in highly active seismic zone. As per seismic zoning in IRC: 06-2017 Nepal's position is in Zone – V.

The seismic force is computed as: F_eq = Ah*(Dead load + appropriate live load)

Where, Ah = [(Z/2)*I*(Sa/g)] / R

Where,

Z = Zone factor = 0.36 for Zone –V

I = Importance factor, taken as 1.2 for bridges in major strategic highway

Sa/g = Average coefficient of seismic acceleration for 5% damping depending upon the fundamental period (T) of the structure and type of soil (obtained from the spectra in IRC: SP: 114-2018, section 5.2.1)

R = Response Reduction factor corresponding to structural connections. (When elastomeric bearings are used R is taken as 1.0, and for Pot-PTFE bearings it is taken as 3.0)

Seismic consideration for simply supported superstructures is generally excluded since the effects of live loads and impacts are usually more severe than the vertical seismic forces. The substructures (abutments and piers) are designed for Design Basis Earthquake (DBE) with Capacity Design method as prescribed by IRC: SP-114-2018 Chapter 7.

Fundamental period is obtained from the method described in clause 5.2.1 of IRC: SP: 114. The pier/abutment is considered as a column with a mass at the top, thus creating single degree of freedom (SDOF) model.

$T = 2\sqrt{(D/1000F)}$

Where, D = Appropriate Dead load+live load

F = Horizontal force (in kN) to be applied at the center of the mass for transverse direction and at the level of bearings for longitudinal direction to displace it 1mm.

General principle of Capacity Design is to design the element for Ultimate Limit State. Then for exceptional forces a plastic hinge is allowed to be formed at predefined location, which is easily visible and accessible for repair. The plastic hinge will be detailed with combination of longitudinal and transverse reinforcement to remain ductile while preventing sudden collapse. The sections outside of the plastic hinge region should remain elastic all the time. Normally in bridges the locations for plastic hinges are chosen at the base of the abutment/pier stems. Plastic hinges are usually avoided in piles since those are buried under the soil and difficult to reach and repair.

15.6.1.7 Traffic Safety Considerations

The following aspects are considered while designing for traffic safety in the bridges:

- Crash barriers as described above to protect the vehicles from falling down, overrunning to the footpath side and colliding to other vehicles
- The end faces of the bridge elements hazardous to traffic and the surfaces of the crash barriers to be painted in zebra fashioned stripes with contrasting colors
- Fences with vertical GI bars to be provided as handrails. This type of fence will prevent the children from climbing up the railing or stuck their head between the bars.
- Thrie-beam barrier to be provided as transition from the concrete barriers to the roadside curbs
- The concrete crash barriers on the bridge deck separating the footpath or service lane from the main carriageway to be tapered down and flushed with the surface of the approach slab to minimize head on collision.

15.7 Maintenance of Existing Bridges

As mentioned earlier, most of the existing bridges are still functioning and have a substantial amount of useful life. Dismantling those bridges will have a significant impact on cost as well as create a lot of traffic problems during construction. Hence it was decided during the meetings that the existing bridges to remain in place, unless those are either structurally vulnerable or unfit to the functional requirements of the new road standards. Further it was concurred to assess the condition of those bridges and prepare a repair and maintenance plan.

A condition survey based on visual observation was carried out and all the damages recorded. A separate chapter of the report deals with the findings of the survey and recommendation for improvement. Most of the non-structural damages are summarized as:

- Broken or non-functional expansion joints
- Broken hand-rails and curbs
- Chipped off surfaces of wearing course
- Worn out deck surfaces exposing the reinforcements
- Exhausted or broken bearings, bearing pads
- Worn out paints, missing or damaged bridge sign posts
- Heavy scours in the river bed
- River meandering and vulnerable approach embankments

Remedial measures for such damages or potential hazards with cost estimates are proposed separately in the report.

A few bridges are proposed to be dismantled and replaced by twin bridges in the following cases:

- The bridge sustains irreparable structural damage
- The carriageway is too narrow to cater double lane traffic (less than 6m)
- The bridge has insufficient waterway and/or freeboard for the design flood
- The bridge is vulnerable to be clogged by debris flow
- There are constraints to build a new bridge at the side (e.g., difficult terrain or hydraulic obstacles, other important infrastructure or restrictions due to environmental/social issues, etc.)

15.8 Considerations on effects of climate change in structural design of bridge elements

Until this date no proper guidelines are available regarding climate change consideration during structural design of bridges. Effects due to changes in hydraulic parameters, such as increased discharge and design flood level are already reflected in height and length of the bridge and consequently sections and reinforcement of the bridge elements. Some other expected effects, particularly, increase in global temperature and carbon levels were discussed during design and have been concluded as follows:

- One of the major effects in structure due temperature variation is expansion and contraction of the elements. The variation in daily temperature has been taken as 30 degrees Celsius in design calculations. From different climatic records it has been found that average daily variation between maximum and minimum temperature in the Terai region is from 15 to 20 degrees and the yearly maximum variation is 25 degrees Celsius. Further, since the major bridges have been designed as simply supported with alternating fixed and free bearings, which means there will be minimum restrains on lateral expansion or contraction of the superstructure. Hence the effect due to temperature variation is expected to be negligible.

- It has been envisaged that there will be an increased level of carbon in the atmosphere due to various domestic, industrial and agricultural activities. The main effect of carbon is accelerated corrosion of the steel reinforcement. To overcome the adverse effect of carbon penetration, dense concrete and sufficient cover to the reinforcement has to be ensured. In design of the bridge elements the minimum grade of concrete has been taken as M30 (30 Mpa) except for non-structural elements. Similarly, clear cover to the reinforcement has been taken from 40 to 75mm. Cover has to be ensured with properly sized cement cubes or other approved devices. No loose stones or wooden pieces are allowed. It is believed that these measures are quite sufficient to resist the adverse effects of the climate change on to the bridge structures.

All design calculations are presented in separate volume.

SECTION IV: SOCIAL AND ENVIRONMENTAL STUDIES

16 Social and Resettlement Issues

16.1 General

The proposed road is the part of East-West Highway which passes through two districts, namely, Rupandehi and Kapilbastu. The proposed road crosses the Rupendehi and Kapilvastu districts. The proposed road starts from the vicinity of Tinahu River, Butwal of Butwal sub-metropolitan city, ward no 1 under Rupendehi district and passes through 1 Rural Municipality, 3 Municipalities, 1 sub-Metropolitan city and 23 wards. It finally ends at Belwagardwa Nadi in Gorusinghe of Buddhabhumi Municipality ward no 4 under Kapilvastu district. Fulbari, Nayabasti, Taamnagar, Baansgadhi, Saljhundi, Kanchan gate and Gorusinghe are the major settlements traversed by this road alignment. The total length of this road sub project is 50 km.

16.2 Objectives of the Study

Objectives of the study are: to carry socio-economic baseline surveys, specifically related to the socio-economic condition of the people, people's perception towards the upgrading and new road construction, identification of poor and vulnerable people, poverty level, gender status, participation of the stakeholders in the project design and implementation. The basic objectives of the study are:

- to analyze the socioeconomic conditions along the road project;
- to identify the poor and socially vulnerable groups;
- to carry out consultations with the stakeholders about how to involve them in the project activities;
- to assess the status of women and deprived/ marginalized groups of people for their social empowerment in the future.

16.3 Methodology

The study consists of both qualitative and quantitative data from primary and secondary sources. The primary data were collected from sample household survey along the project road whereas the secondary data were obtained from the published materials such as the report prepared by the previous consultant, CBS publication, ADB guidelines and other relevant reports and research papers.

The questionnaire for household survey was prepared in local language i. e. Nepali. The field works for the Butwal-Gorusinghe road section of East-West Highway were conducted over a period December 2021 to Feb 2022. Approximately, 200 households were interviewed during the course of census survey of affected households. Besides, Group Interview, Focus Group Discussion (Public Consultation) and Key Informants Interviews were also administered. The Baseline survey of 20% households residing within 500 m either side of road corridor is planned to start between August 200-to September 2022 and key finding of survey yet to be received. However, census survey of affected households is presented in this report. The questionnaires investigated the following main parameters:

- Household profile
- Socio-economic and demographic information
- Health and education
- Family income and expenditure patterns
- Community perceptions towards road upgrading
- Human trafficking
- Need assessment
- Gender equality

16.4 Defining Zone of Influence

16.4.1 ZOI:

The project impact area includes all the areas where activities related to the road construction will take place. This area shall be studied in greater detail regarding the impacts on physical, biological as well as socio-economic and cultural environment. The areas within the RoW of proposed road (25 m on either side from the centre line of the road) are referred as Corridor of impact (CoI) in this Report. Whereas the area, within which upgrading work is being carried out, is referred as formation width (varies from 25 to 50 meters).

16.4.2 Indirect Impact Area (IIA):

Impact on physical and biological environment in this area will be minimum. However, it is anticipated that the influx of labour from these areas may affect the socio-economic and cultural environment of the project area. The concerned areas of Municipalities and Rural Municipalities within 300-500 m from the Centre line of road on either side are referred as Indirect Impact area (IIA) in this study.

16.4.3 Selection of Sample

The Zone of Influence is defined in terms of impacts and benefits of projects. The ZOI is indeed a corridor of impact (i.e. 300-500 meter either side of the central line of road). A total number of households by settlement located in the Zone of Influence (ZOI) were identified from the household lists acquired through the Key Informants and local government. Similarly, a random purposive sampling of 20 percent of total household within the ZOI was carried out. Purposive sampling was an attempt to cover all types of socio-economic, cultural groups. So, the people from different cultural and social background were also identified with the help of key informants. Thus, it is also a stratified random sample of the respondents to make representation of each and every type of cultural groups within the settlement. It includes, among others, major ethnic/caste groups, Dalit, indigenous people; poor families. Total 1500 households will be surveyed which is around 20% of total households residing zone of influence (300-500m) along the alignment. Total 407 households are directly impacted and these households are treated as encroachers and non-titleholder. Demographic information of the impacted households is presented in **Table 16.1** below:

Table 16.1: Survey Population structure of surveyed households Population

Project Road	Interviewed HHs	Male	Female	Total	Family Size
Butwal-Gorusinghe	1563	4123	3785	7908	5.05

Source: Field Survey December, 2021

16.4.4 Key Survey Findings of affected households

1563 HHs were interviewed with total population of 7908. Among them 52.14% are male and 47.86% are female. The average household size is 5.05

The project area is predominantly inhabited by Brahmin/Chhetri with 1092HHs (69.87%), followed by Indigenous People (IP) with 376 HHs (24.06%), Terai Caste/Madhesi with 8 HHs (0.51%), Dalit with 86 HHs (5.50%) and Muslims with 1HHs (0.06%). The Magar, Newar, and Gurung castes make up a majority of the indigenous population.

The survey revealed that the major occupations of the inhabitants of the project influence areas are foreign employment, business, agriculture service and non-agriculture wage labour.

Almost all the households reported that the project would have positive impact on the people due to access to education, health facilities, reducing in travel time from one place to another place, creation and expansion of market for agricultural products, increase in land price and employment creation. Few households and stakeholders were apprehensive of the transmission of HIV/AIDs due to influx of the people, human trafficking, loss of agricultural land, loss of income and social disturbances.

16.5 Consultation and Participation

A total of 39 consultation meetings including (1 consultation meeting with women) were held at different places in the project areas with the representatives of different municipalities and wards, the participants had shown concern about safety related matters especially zebra crossing, proper light system and proper management of waste water drainage. Additionally, it was emphasized to have provision of over and under pass to cross the road during consultation meetings. One of the most important benefits of the proposed project as perceived by women is easy access to reach health facilities particularly during childbearing. Besides, discussions among the women revealed that the improved transport facilities would enhance their mobility by reducing the travel time. Similarly, the project would increase opportunity for woman to be engaged in small trade for selling and purchasing goods. Likewise, they were also of the opinion that commencement of road may also provide them employment opportunity during construction phase.

Regarding women participation, some changes have been encountered after local level election. There is provision in the Constitution of Nepal, 2072 that at least 33 percent should be women in parliamentary position in provincial and the central level parliamentary elections. However, they have yet to get opportunities to equal participation in political and social activities. Remarkably, it can be noticed that women are engaged in their own saving and credit groups and self-help groups presenting collective feeling and strength for women. There are number of women's groups like cooperative saving groups which are expected to assist in the financial and economic matters of the households.

16.6 Social Issues

16.6.1 Gender

The illiteracy rate of the women has been found as 7.68% in the project area. Women in the project area are considerably involved in small hotel, highway-based business, grocery shops, farming, and household activities. Extensive involvement of women in business is due to prevailing tendency of male going for foreign employment. However, the engagement of women in service-related business is extremely low. The establishment of private industries has created opportunity for women in income generation. Women are involved in mainly hotel, beauty parlour, tea shop and other small shops. Domestic chores are still the major responsibility of women in the project area.

In the rural areas of Nepal, women's mobility is limited to household work, agricultural activities and visiting the relatives. In contrast, in the project area, mobility of women has reported for job and other income generating activities. In addition, it has been reported that women's mobility has been gradually increasing in the project districts due to change of social dimension.

The project is expected to ensure employment opportunities to the women during construction and their involvement or participation in other project activities will also increase substantially.

Poverty

In the project area, only 1.73% of the populations live below the poverty level which is less than the national figure. Further, the access to basic services like drinking water, education, health, sanitation is considered good in comparison to other parts of Nepal. Majority of people are using LPG gas and all the households are connected in national grid for electric facilities.

It is expected that the project will bring positive impact through employment creation and providing life skill training to the vulnerable, poor including women in the project areas.

Indigenous People

The government of Nepal has classified Indigenous People (IP) in 4 major groups. Magar, Chaudhary (Tharu), Newar and Gurung are the major IPs along this road. Only 19.08 of the total household population is indigenous in the project influence area. The community expects that the project will create opportunities of employment and income generation through expansion of trade and agricultural business. Further, life skill training, if provisioned for the IPs in the project area, will certainly enhance their living standard.

16.7 Social Risks

Discussions were also made during Focus Group Discussion on the wage rate of male and female and the involvement of child labour in the project construction works. It has been reported that women are getting low wages than the males for same nature of work. It is expected that the project will review this matter carefully and will make provision of the appropriate terms and conditions to address the above issues while preparing the contract documents. During the public consultation, people demanded for implementation of the concrete programs to combat HIV/AIDS and human trafficking.

16.8 Conclusions and Recommendations

The social analysis of the project area has identified numerous issues of poor, disadvantaged peoples that include gender inequality, accessibility of different facilities and services, situation of HIV/AIDS and human trafficking. The linkage between poverty and social exclusion and inadequate or lack of access due to lack of roads or improvement in the transport sector have been widely recognized.

In order to address the above issues like gender inequality, poverty, social risks such as drugs, HIV/AIDs and human trafficking, child labour; the mitigation measures should be incorporated in enhancement measures along with livelihood support programs in Resettlement Action Plan under Livelihood Restoration Programs.

17 Resettlement Plan

17.1 General

The Resettlement Plan (RP) is guided by the ADB Safeguard Policy Statement 2009, Land Acquisition Act of Nepal 2034 (1977) and other relevant policies and guidelines. The main objective of the Plan is to identify impacts and measures to mitigate various losses due to the road subproject.

Through Gazette, Government of Nepal has declared total 50m Right of Way for East West highway. The project road has no land acquisition since the 50m Right of Way is clear throughout the section. However, nontitle encroachers will be eligible to get compensation and other assistance as per Government Nepal land acquisition act and ADB Social Safeguards Policy 2009.

17.2 Objectives of Inventory Survey

The principal objective of this Resettlement Planning document is to determine measures to compensate, rehabilitate and relocate (if applicable) to those who might be affected due to resettlement impacts resulted by the Project. For the feasibility purpose, the major objective of RP document is to estimate the budget and to be familiar with the intensity of resettlement impact.

Most of the houses in road alignment are operating small/medium size of business such as hotels and tea shops targeting the highway passengers. It was observed that more than 60% houses are operating different types of business in their houses that form the major sources of income of people. The upgrading and construction of roads require relocation of structures that significantly affects source of income of local people.

The project has envisaged direct impact to the structures and other property loss. Significant adverse impact of the project will be displacement of the people from their original places because livelihood pattern of these people will be seriously affected.

17.3 Methodology

Resettlement impact in the project road has been finalized by conducting a detailed field survey, and consultations with stakeholders in different field locations. Some of the key stakeholders consulted include local communities, family members of affected households, local key informants, officials of relevant district level agencies and representatives of local level institutions etc. One-day orientation was conducted to resettlement team prior to the fieldwork for making them familiar with the objective and method of detailed census survey and also to train them on using the information collection tools (census questionnaire and inventories formats, socio-economic questionnaire, and checklists). Under the guidance of resettlement expert, the team carried out field survey across the corridor of project road to collect information on probable resettlement impacts on different assets and socio-economic information from the affected households.

Assets Inventory

As part of detailed study, the inventory survey was also conducted by the survey team consisting of Resettlement Specialist, Resettlement Officer, and Enumerators. The engineering design team had helped during finalization of the road alignment and COI of the road.

An inventory of affected houses and other structures, private trees, public properties and common property resources was prepared. Walkover survey throughout the road alignment was carried out. Affected households also participated in the process. Due to absence of private land to be acquired, the cadastral survey was not required As per RAP, total 120 HHs (660 persons) lose 122 structures and except the private structures, 5 institutions lose 5 structures along the alignment.

Census Survey

The census survey was carried out from all identified households having impact on their assets. Information on family members and their affected assets were collected through the census survey. A total 120 households along with 5 institutions were impacted along the alignment and out of which 74 households were surveyed whereas 46 HHs were absent during survey.

Socio-economic Survey

Socio-economic survey of the directly affected households were carried out to assess the key socio-economic indicators of the affected households. They were: sources of income and average annual income of the affected households, vulnerability status of the households, issues related to resettlement impact in the households and other relevant information aiming to solicit their views in the report.

Table: 15.2 Detailed Survey of Affected Structures

Project Road	Total affected HHs	Interviewed HHs	Male	Female	Total	Family Size
Butwal-Gorusinghe	120 (5 Institutions)	74	214	193	407	5.5

Source: Field Survey Jan, 2022

120 HHs along with 5 institutions were affected by the BG road upgrading project. Out of total 120 HHs, 74 were surveyed and interviewed whereas remaining 46 HHs were absent as they were out of the district. The total population of project affected surveyed HHs was 407 (52.58% males and 47.42% females). The size of the family of the project affected surveyed HHs was 5.5, greater than the national figure of 4.8. Out of total surveyed population, 40 HHs (54.05%) comprised of Brahmins followed by 22 Janajati/IPs (29.72%), 3 Dalits (4.05%), 8 Muslims (10.81%) and 1 Madhesi (1.35%).

As per RAP, total 120 HHs (660 persons) lose 122 structures and except the private structures, 5 institutions lose 5 structures along the alignment.

The survey revealed that the major occupations of the inhabitants of the project influence areas are: foreign employment, business, agriculture service and non-agriculture wage labour. 5.41% of the households are living below the poverty line in the project area. 17.4% households are below the poverty level based on national poverty records (2019).

Public Consultation and Participation

While preparing the Resettlement Plan (RP), series of formal and informal consultations, and meetings were carried out with relevant stakeholders at different levels (e.g., DoR officers at central and district level, representatives from municipalities, team members of PPC consultant, likely Affected Persons including the local community and other relevant agencies). The meetings were held with the stakeholders such as farmers, teachers, local politicians, business persons, students. It was intended to inform them about the project and to get feedback so as to incorporate their perceptions for the project. Such consultations and participations with the stakeholders were mainly focused on sharing information and knowledge about the project and its activities for preparing the RP.

17.4 Estimated Structure Cost

Cost estimates for rehabilitation/shifting of minor structures were prepared. The costs were estimated by computing the additional structures to be acquired in the RoW/CoI of project road and in consideration with the government compensation rates applicable in each district or rates recently paid on similar road projects. ADB Guidelines on Involuntary Resettlement and Safeguard Policy Statements (SPS) were also considered. An additional amount of 10% was added to cover rehabilitation and other costs. The CoI and the estimated structural cost of Butwal-Gorusinghe have been summarized in Table below.

Table 17.1: Estimated Resettlement Costs of the Project Roads

S. N	Items	Nos of structures	Total Estimated Cost (NPRs.)
1	Compensation of private structures	127	25906665.00
2	Cost for displacement assistance	25	630,000.00
3	Fruit Trees	8	135000.00
4	Assistance to vulnerable households	15	337, 500.00
5	Public Structures	206	9154062.00
6	RAP implementation activities	1	78,0000.00
7	Completion Audits Cost (NRs)	1	475000.00
8	Livelihood restoration program	25	150,0000.00
	Total (A)		**38,918,227.00**
	Grand Total Estimated (A+B)		**38,918,227.00**

17.5 Estimated Training cost for PSA/GESI Implementation:

Training cost PSA Implementation: During implementation of PSA, skill development training should be provided particularly to the affected and vulnerable HHs on the basis of Training Need Assessment (TNA) for livelihood enhancement and awareness program and road safety awareness. Estimated cost is NRS 4,500,000.00.

18 Environment Assessment

18.1 Background

The proposed road from Butwal to Gorusinghe road having length 50 km will be upgraded under the financial assistance of the World Bank. As per the statutory legal requirement; Environmental Protection Act (EPA) 2019 (2076 B.S) and Environmental Protection Rule (EPR) 2020, (2077B.S); Schedule 2, Rule 3, Road sector D (8); an Initial Environmental Examination (IEE) is mandatory for upgrading of the any National Highway of length upto 50 Km. Similarly, an ESIA study is required in n accordance with the World Bank ESF.

The project scope of the study is to reconstruction/rehabilitation and widening of existing road and bridges without any new bypasses with more or less similar environmental setting viz. climate, terrain, land use and temporal extent. This report highlights the road specific environmental issues and based on detailed engineering design, field investigations and stakeholder consultations to meet the requirements for environmental assessment process and documentation as per GoN's EPA EPR and World Bank safeguard policy. The study of environmental aspects of upgrading of Butwal-Gorusinghe road section of East West Highway aims to address the issues on physical, biological, socio-economic and cultural environments. This report briefly present impact, proposed mitigation measures for the potential impacts, Environmental Management Plan (ESMP) and the budgetary arrangements for implementing the ESMP.

An ESIA is prepared for the Butwal-Gorusinghe Road section of the East-West Highway based on the design to assess the environmental and social risks and impacts before execution of the project in accordance with the World Bank's Environmental and Social Framework (ESF). Similarly, an IEE is prepared in accordance with the GON's Environmental Protection Act (EPA) 2019 (2076 B.S) and Environmental Protection Rule (EPR) 2020, (2077 B.S).

18.2 Project Description

The Butwal-Gorusinghe (BG) road is located in the Rupandehi and Kapilbastu districts of Lumbini Province. The alignment begins at 300 m west from the Tinau Bridge, Butwal. It passes through Butwal, Rani Bagaiya, Murgiya, Saina Maina, Bansgadhi, Saljhundi, Pipara, Jitpur, Banaganga, Gorusinghe and Imiliya. The starting chainage of the road is KM 590+000 (this chainage is referenced to the East-West Highway) and the proposed road ends at KM 640+000. This road section is 50 km in length. The road alignment passes through one sub-metropolitan city, 3 municipalities and 1 rural municipality.

For most of the section, the width of the existing road is 8.00 m including 6 m wide carriageway and 1m shoulder on both sides. Initially, the alignment passes through the foot of the hillock, then onward the road passes through plain area. There are major junctions at Jitpur, Char-number Chowk, Bangai and Gorusinghe including twelve minor junctions which need to be upgraded. From 611+800 to 617+900 (Pipara) and from Kaila Khola Bridge (627+200) to Gorusinghe junction (634+900) the alignment passes through dense forest area.

Considerable numbers of roadside tree cutting are required in this section while upgrading the road. There are relatively minimum obstacles such as buildings, houses within the ROW. However, there are number of buses waiting sheds, resting place (Chautari), electrical poles and cables, water supply pipes, irrigation canal, telecommunication facilities etc. within the ROW which have to be relocated during expansion of the road. In the road alignment, there are 30 existing minor and major bridges. Among them Badganga Bridge is the longest bridge with length of 304 m. The existing right of way (ROW) of the road is 50m, and the proposed works will be implemented within the available existing ROW.

18.3 Baseline Environmental Conditions

The Butwal-Gorusinghe Road lies within the Terai region, with an elevation of 117 to 158 m amsl (above mean sea level). The road alignment falls on the sediment of the Gangetic Plain (Upper Terai). The existing land use patterns along the Butwal-Gorusinghe road alignment are predominantly built-up areas (61%), followed by forests (21%), farmlands (16%), and remaining are water bodies. The 50 m RoW (25m on both sides from centre line) of road is almost clear and the existing formation width of the road is 7 to 12m. The road lies in a tropical climate with humid and hot characteristics. Most of the major rivers in the project area originate from Siwalik and Mahabharat hills. Some of these rivers are prone to flash floods during the monsoon but dry during the remaining seasons. Landslide, gully erosion and old slide scarp are observed in the initial one-kilometer section of the Butwal – Gorusinghe Road. The air quality monitored at 9 locations showing that the PM2.5 exceeds the National Ambient Air Quality Standard except in the forest area. The average 24-hours noise level varies from 30.1dB (A) to 129.1 dB (A). The maximum noise level is recorded in Butwal, and a minimum is at Forest Area. The noise levels at Butwal exceeded National Noise Quality Standard Limit and World Bank EHS standards. In terms of drinking water quality, all the parameters are within the permissible standard value of the Nepal Drinking Water Quality Standard.

About 15.4 km of the proposed road alignment passes through the forest, dominated by *Shorea robusta (Sal)* forest and patches of *Dalbergia-Acacia* forests along the riverine sections. There are three major blocks of forest traversed by the BG Road and they are (i) from the chainage KM 611+870 to KM 617+730 (Saljhandi-Pipara Forest block) (ii) KM 626+970 to KM 635+200(Gorusinghe Forest block), and (iii) KM 637+720 to KM 639+000 (Badhare/Budhi Forest block) *(The starting chainage of the road is KM 590+000* and ends at KM 640+000). These forests are predominantly (>80%) community forests used for multiple purposes, including community use and production for timber, firewood and fodder. The forests located within 50m RoW (25m from the center of the existing road to both sides) are owned by DoR and are already disturbed and degraded. There are no nationally or internationally designated protected areas, including identified wildlife migration corridors within the corridor of impact and project zone of influence.

The field survey indicated that the endangered Stripped Hyaena (Saljhandi forest), Fishing cat (Gorusinghe forest) and near threatened Leopard (Butwal Community Forest) were found in the project area. Among 93 species of bird identified, conservation significant *Sarcogyps calvus, Gyps tenuirostris and Gyps bengalensis* are critically endangered and resident to Nepal. Similarly, *Leptoptilos* javanicus (vulnerable) and *Gyps himalayansis* (near threatened) are also resident. The only migrant species requiring conserved is *Aquila nipalensis* which is endangered. Among herpetofauna, *Indotestudo elongate* is globally critically endangered. Species like *Melanochelys tricarinata, Aspideretes gangeticus* and *Morenia petersi* are globally endangered and *Aspideretes hurum* is globally vulnerable. However, considering critical habitat screening (CHS) applying IFC PS6 thresholds, these CR and EN species are widely distributed in South East Asia and South Asia (the Himalayas and in Nepal). No nationally or internationally designated protected areas is found close to the project site (the nearest protected area is located at about 50 km from the BG road and the nearest key biodiversity area is located about 10 km from the road). The species have been identified following Ecologically Appropriate Area of Analysis (EAAA, 1 km either side of the Road). The CHS activity states that it is unlikely that there are critical habitats in the project zone of influence of BG road, and the improvements of Butwal – Gorusinghe section are not expected to affect the global population of these species.

The project area covers Rupandehi and Kapilbastu districts. The alignment passes through Butwal Sub-metropolitan City, Sainamaina Municipality, and Kanchan Rural Municipality in Rupandehi district and Banganga Municipality, Buddhabhumi Municipality in Kapilbastu district. The project affected wards are 22. The caste and ethnic groups found in the project area are Brahmin, Chhetri, Magar, Gurung, Newar, Tharu, Dalit, Muslims, Madheshi and Janajatis. In the project area, there are five IP groups, namely Newar, Gurung, Magar, Rai and Chaudhari (Tharu). The total population of the influence area, covering 22 wards, is 144914. Out of this population, males and females are 68232 and 76652, respectively. Some sections of the right of way are encroached by 120 households. The total population of the project-affected households is 660 and the average family size is 5.5.

18.4 Stakeholder Engagement and Public Consultation

Stakeholder engagement is an inclusive process to engage stakeholders throughout the project lifecycle. ESS10 Stakeholder Engagement and Information Disclosure recognize the voice of different stakeholders. Stakeholder consultations carried out during IEE preparation address the issues of project affected, other and interested parties and vulnerable and marginalized groups. The project affected parties are the parties that are directly affected by the project activities and located within the corridor of impact, and they include households that have encroached into the ROW, local population, public service providers, and local health facilities. The other interested parties are local governments (1 Sub-metropolitan City, 3 Municipalities and 1 Rural Municipality), local non-governmental organizations (NGOs), civil society, teachers, political leaders, women groups, local entrepreneurs, local user groups (forest, water, irrigation etc.), etc.

Consultations were held with all the above stakeholders to share the project information and to document and incorporate their initial feedback in the project concept and the environmental and social concerns related to the concept. Initial walkover surveys were carried out, followed by individual interviews with local government officials. The tools such as Focus Group Discussions (FGD) and Key Informant Interviews (KII) were used to conduct discussions. 27 Consultation meetings at different municipalities/RM offices of Rupandehi and Kapilbastu district during December 2021and January 2022 were taken place. 442 participants comprising 332 males and 110 females attended these consultations. Additional consultations with the specific groups such as the department of forest, forest users group, women, affected people, and other interested parties were carried out.

The key issues raised by the stakeholders during consultations are: compensation for affected private and public structures and utilities; air pollution, construction of foot over bridges in the settlement area, skill development and Employment opportunities to local people, protection from landslide areas, additional side drain and cross drainage facilities, granting ownership of harvested trees to respective forest user groups, roadside plantation, fence in community forest area along roadside; and stakeholder engagement during road upgrading works.

18.5 Anticipated Environmental Impacts

Environmental Issues Mainstreamed in the Project Design

Environmental and social aspects have been considered in the planning and design of the Project facilities. These include:

- Road safety has been considered all along the road especially at the major and intersections with the local roads and near the major villages and market areas. These measures include:
  - Raised pedestrian footpaths and cycle lanes in urban areas
  - Installation of traffic lights in all major intersections along with zebra crossings and road humps
  - Foot bridges underpass at intersections where schools, colleges and hospitals are located
  - Other safety measures such as provision of road signs, delineators, barriers and pavement markings, minor realignment at identified black spots including pedestrian foot paths in market areas.
  - Universal access measures for disabled and elderly for road crossings.
  - Protection of landslides and river banks from erosion
  - Implementation of Bioengineering and retaining structures specifically RCC modified wall, for slope protection
  - Avoidance of haphazard excavation of slopes.
  - Bank protection works near the proposed bridge sites
  - Stabilizing the excavated slopes and river banks with retaining structures

- Construction of funneling fence of 1 km (250 m) on either side of the KOTHE river bridge for funneling of large mammal
- Construction of new and reinstallation of affected fences, approximately 74 km of barbed wire fence (six strand and two diagonal). Length of fence is approximately 10.72 km of Saljhandi-Pipara Forest (611+870 to 617+730 km); 16.46 km of Gorusinghe Forest (626+970 to 635+200 km) and 2.56 km of Badhare/Budhi Forest (637+720 to 639+000 km)).
- Construction of waterholes and salt leak; plant grass and fodder tree species
- Reduction of speed limits in the forest areas with warning, educational sign boards and speed breakers in every wildlife crossing points
- Two Box culverts for snake and turtle crossing (last one kilometer section) in Buddhi Forest and improve box culverts to be used by wildlife (annex 1) in addition to snake and turtle above
- Development of underpass structures for wildlife to cross at KOTHE river of Saljhandi-Pipra forest

Environmental Impacts

Implementation of the proposal will have significant beneficial impacts on human life, income generation from employment, skill enhancement during the construction stage and increased income from improved access for market to agricultural products. The upgraded road will provide smooth, easy and quick access to traffic eliminating existing traffic congestion and reduction in roadway accidents. Most importantly, the upgrading of the road will reduce travel time and cost of people, running costs of vehicles such as fuel economy, reduction in wear and tear of vehicle parts, reduce greenhouse gas emission due to better riding quality. The trans-boundary impact will be that the upgraded highway will be Asian Highway (AH2) standard and will benefit transportation of goods and people.

All impacts were categorized in terms of their magnitude and significance. The following sections summarize the environmental and social risks and impacts of the BG road improvement works by each relevant environmental and social standard.

Assessment and Management of Environmental and Social Risks and Impacts (ESS1): The widening and improvements of BG Road from 2 lanes to 4 lanes will be carried out within the existing RoW. However, some sections of the ROW have been encroached with residential and commercial structures, and they will be partially affected by the widening works. Further, the widening will require the clearing of 28 acres of forest land within ROW which is already owned by DoR. The proposed works will partially affect 122 private structures, mainly their front porches (*verandas*), including commercial structures affecting the livelihood of these households. 122 private structures belonging to 120 households and 5 structures owned by institutions are getting affected by the BG road upgrading project within the 50 m RoW. Altogether 127 structures including 5 structures owned by institutions will be affected along the alignment. 122 private structures include 50 residences, 15 small business structures, 45 residences/business, and 12 other structures. Out of total 120 project affected HHs, 19 HHs will be physically displaced. Out of 19 affected HHs, 16 will lose their residences and 3 will lose residence/business structures. The number of HHs losing business structures only will be 6 within 50m RoW. Of total 120 project affected HHs, 15 belong to vulnerable HHs. Out of which 2 are women-headed, 4 are below poverty level. *(According to the Nepal Living Standard Survey (NLSS Survey 2011), an individual is considered poor if his/her per capita total annual consumptions are below NRs.35738 at 2020/2021 prices (Rs. 19,261 in 2010/11 prices))*, among them as well 3 are ethnic minorities (Muslims) and 1 is differently abled and 8 ethnic minorities. Among 2 women headed HHs, one belongs to Brahmin whereas other Newar. Therefore, this impact on IPs do not warrant free, prior and informed consent (FPIC) in this circumstance. Impacts during construction mainly relate to dust and noise pollution, increased risk to health and safety of workers and communities, increased traffic flow and traffic-related accidents and social issues related to resettlement and livelihood impacts, labor influx impacts such as sexual exploitation and abuse sexual harassment (SEA/SH), communicable diseases and child/forced labor, all anticipated during construction. The improvements of BG Road is also assessed to have no significant cumulative impacts as works are mainly confined within the existing ROW and in an area that has already been altered, fragmented and highly disturbed for many decades as a result of human population growth, encroachment and establishment of new settlements along the highway, land transformation, agriculture development and other associated development as seen in the land use map. With or without improvement works in BG Road, land-use change and land transformation have already taken place and will continue to take place as a result of other factors such as urbanization and development of rural areas resulting from increase federalization and decentralization of development in the provinces. In addition, the surrounding rural roads have been constructed in recent years, generally without any environmental and social assessment and mitigation measures. Increased density of the road networks and lack of protective measures have aggravated the adverse impacts on the environment that have already taken place, such as siltation and sedimentation of rivers, the threat of poor water drainage and community health and safety. The impacts might be exacerbated by climate change and the uncoordinated development of local communities, which may cause significant economic losses.

Labour and Working Conditions (ESS2): The BG Road project is expected to involve direct, contracted and primary supply workers. The project will employ about 500 direct and contracted workers, who may be exposed to risks such as poor conditions in labor camps, non-payment of wages or other benefits, discrimination in Employment, child labour or forced labour, occupational health and safety (OHS) issues including workplace accidents, grievances related to workers and SEA/SH. The contracted workers are more susceptible to such risks. The project will employ about 500 to 600 workers, and about 40% of workers will be hired from local communities. A labor grievance mechanism will be established for the workers as part of the LMP.

Resource Efficiency and Pollution Prevention Management (ESS3): ESS3 refers to several risks and impacts, including landscape aesthetic, air and noise pollution, potential hazards and solid waste management, and pollution of water sources. The project's impacts and risks would be of significance on sensitive receptors due to waste disposal; slope stability and erosion; blocking of seasonal streams during cross drainage construction; stressing water sources used by the community; emission from construction vehicles, equipment and plants; dust from earthworks, cutting, stack yard, transportation of materials, noise pollution and settlements along road; damage to structure vibration from movement of machine and equipment; handling of hazardous and non-hazardous wastes, quarry and borrow area. All these impacts are more prominent during the construction stage and can be managed through generic and specific measures described in the mitigation chapter according to national standards for air, noise and water quality as well as through best practices applicable to road construction projects.

Community Health and Safety (ESS4): During construction, transporting construction materials may cause nuisances and health and safety risks to the local communities. Project activities such as hill cutting (about 1 km length), road excavation, and the use of vibration equipment might result in landslides and dust pollution. The stockpiling of construction materials debris generated during construction may disturb the landscape and cultivated lands and contaminate the water bodies. Impacts on existing traffic are likely with the construction activities, plying of construction vehicles, and storage of construction materials in proximity to the existing highway. The presence of an outside labour force in the project area may cause negative impacts on the environment and local communities and should be managed to prevent conflict situations, including SEA/SH. The project area lacks a well-defined and coordinated response mechanism. SEA/SH risks associated with labour influx indicate a 'substantial' level of SEA/SH risk. Furthermore, a lack of institutional and infrastructural capacity of the GBV service providers may result in inadequate responses to GBV survivors. Further, risks associated with labour influx and increased mobility of outsiders may aggravate the spreading of infectious diseases, including COVID 19, HIV/AIDS and STIs. A stand-along SEA/SH Action Plan is being prepared to manage risks related to SEA/SH associated with labor influx.

Land Acquisition, Restrictions of Land Use and Involuntary Resettlement (ESS5): In total, 122 structures belonging to 120 households (HHs) will be affected which are built within the existing right of way. No new land acquisition is required for the project. Of the total 122 private structures 50 are residential, 15 small business structures, 45 residential cum business, and 12 other structures. Of the 50 residential 16 are fully affected whereas out of 15 small business structures, 6 are fully affected. Similarly, out of 45 residences/business, only 3 (very nominal) are fully affected. Likewise, out of 12 other structures, 9 are fully affected. The project will affect 206 public/community structures. Out of them, 105 are chautara/resting places (majority of which are under the canopy of big trees), 65 are passenger waiting sheds, 14 are temples/shrines, 10 are police check posts/entrance gates/traffic direction posts, 2 public figure statues (Buddha stambha) and 1 notice board, 4 are public water tanks/taps and 2 are public toilets along the road corridor. In addition, 1 snake-bite treatment centre, 2 higher secondary schools (Ujirsingh and Jana Chetana) are also affected. Further, electric poles and drinking water taps etc will require relocation. Construction-related impacts will be avoided through design to avoid and minimize impacts; and to compensate for residual impacts before commencement of construction works as per the procedures outlined in the Resettlement Action Plan (RAP) for the Butwal-Gorusinghe Road project.

Biodiversity Conservation and Sustainable Management of Living Natural Resources (ESS6): Saljhandi-Pipra, Gorusinghee and Budhi forests are major blocks of natural habitat. Other habitats within the ROW and surrounding areas of the BG Road are largely modified, and patches of natural habitats, which are already fragmented, and anthropogenic pressure on the area is prevalent due to its long history of development and human settlements. The field survey indicated the presence of three critically endangered bird species, one endangered bird species, one critically endangered amphibian, and three endangered amphibian species within the Project zone of influence. These are detailed in chapter 1.3 and 1.5.

The ESIA further indicated that the improvement of the existing BG road would affect a total of 28 hectares of forest within RoW along 15.2 km of its length. The direct impact involves the cutting of 7,118 trees, of which 4,246 are distributed in Rupandehi district and remaining 2,872 in Kaplibastu district. For every tree cut, the project will replant 10 large saplings in an area designated by the Forest Department, nurture the plantation for 5 years before handing over as required by EPR 2020. The physical work within the ROW will not adversely impact any critical habitats or protected areas, wildlife reserves which are beyond the impact zone of the project. Modification of the highway will have impact on wildlife/mammals crossing the highway. For the safety of those, in the migratory wildlife crossing-points (identified during survey) arrangements have been made to cross the highway through underpasses, as they are all funneled. 74 km of fence will be erected funneling all the underpasses developed. The river-course under the Kothe Khola Bridge have been developed as underpass for large and medium sized mammals. There are 18 underpasses, of different sizes built in the forests, designated for large, medium and small mammals to crossover. Bottom of these box culverts are modified with gutters on both sides with raised dry natural floor base, to ease mammal's mobility. Mammal's mobility during monsoon/wet season is limited, the dry culvert-floor will enhance usability during the dry season. Further the opening of 3 m X 3 m, in the median of highway increases the light index of these underpasses considerably, which is an added improvement to enhance the usability by wildlife.

Indigenous People (ESS7): There are 5 indigenous peoples (IP) groups in the project area, namely Newar, Gurung, Magar, Rai and Chaudhari (Tharu), living as part of the mainstream local communities with no collective attachment to land. These IP community will not lose their private land because their structures are constructed within the RoW and these structures will be and partially affected. The project will not cause any direct impact to their land, will not need complete relocation of any of the IP communities, and will not cause impacts to the cultural heritage of the IP communities. These IP communities' potential impacts and risks are related to labour influx, GBV, traffic safety, air and water quality deterioration during construction, etc. Therefore, according to the requirements of free, prior and informed consent (FPIC) under ESS7, FPIC is not required under this project component. Resettlement related IP issues will be addressed as part of the RAP.

Cultural Heritage (ESS-8): ESS8 sets out general provisions on risks and impacts to tangible and intangible cultural heritage. During the ESIA, no archeologically and historically tangible heritages such as monasteries or ancient monuments were found along the road alignment, and there will be no impacts on tangible or intangible cultural heritage. There are 19 small temples/shrines within the ROW, as advised during stakeholder consultations, are not of cultural importance or significance. They will be relocated to the nearby public land in consultation with the respective families along the right of way. A Chance-finds procedure has been included in the Environmental and Social Management Plan (ESMP), which will be followed if, during construction, there are any chance finds. The chance find procedures will also be included in the bidding documents, in the contractor contract and in the contractor's ESMP (C-ESMP). The stakeholder engagement activities under the project will be leveraged to further identify and manage other cultural heritage sites and artifacts throughout the project life.

Financial Intermediaries (ESS 9): Since no financial intermediary is involved in this project, ESS9 is not applicable.

Stakeholder Engagement and Information Disclosure (ESS 10): During stakeholder consultations, the issues raised by communities included: adequate compensation for affected land; affected private and public structures and utilities; air pollution, construction of foot over bridges in the settlement area, skill development and employment opportunities to local people, landslide area need to protect, additional side drains and cross drainage facilities, ownership of harvested trees should be granted to respective forest user groups, roadside plantation, and construction of fences along the road in community forest areas. A standalone Stakeholder Engagement Plan (SEP) with a project-level GRM is prepared.

18.6 Environmental and Social Management Measures

An Environmental and Social Management Plan (ESMP) applying the mitigation hierarchy has been prepared to manage the project's environmental and social risks and impacts. It includes generic and site-specific mitigation measures, a monitoring plan, capacity building, responsibilities and reporting system and environmental and social costs.

Mitigation measures for general risks and impacts: Mitigation measures for general risks and impacts include: an erosion control plan with bioengineering and reinforcement structures; restoration of affected landscapes; development of a stockpiling and excavation management plan; recommendations for fuel-efficient machinery and carbon offset by compensatory plantation; proper relocation and restoration of all affected utilities taking the community into confidence with meaningful consultation; enforcement and control of anti-poaching regulations and underpass structures for natural flow of wildlife; establishing speed limit signs in appropriate locations; providing awareness to drivers; establishing a grievance redress mechanisms (GRM) for complaints; providing workers transportation to and from the project sites; adopting safety measures for workers such as shinning jackets (aprons), boots, gloves, and helmets; compliance with the labour laws; establishment of Worker Camp Operations Guidelines; development of a Hazardous Materials Management Plan to manage hazardous material use, storage, transport, and disposal; development a Water Quality Management Plan; community awareness and sensitization with an Emphasis on women and young girls; chemical management plan prior to construction including handling and disposal of hazardous chemical and waste. No tangible or intangible, or archaeologically important cultural heritage will be impacted.

Site-specific mitigation measures include traffic management provisions for construction sites and slope protection work (Civil engineering and Bio-engineering works). Air and Noise Quality monitoring, Water quality monitoring and Water Sprinkling will be done in dust-prone areas to reduce dust. Cross drainage structures (such as box culvert, new bridges, side drain) will be provided to reduce water logging flooding in the project area. Installation of traffic signs, road safety signs, crash barriers, pedestrian crossings/overhead for road safety. For flood protection, river training works will be implemented. Compensatory tree plantation, sign board, speed limit, display boards in forest areas will be placed in required locations for wildlife crossings. Installation of fencing and culvert/underpass at specific locations for wildlife protection and prevention of road kills in the forest areas are also proposed. Following is the proposed wildlife underpass crossing locations: 612+600, 613+709 616+825,628+389, 629+476, 629+679, 629+853, 630+993, 631+141, 632+108, 632+377, 634+679, 635+326, 638+004, 638+426 (For reptiles), 639+021, 639+397, 639+561(For reptiles).

Relocation of public utilities (Drinking water supply lines, electric poles, irrigation canal etc.), restoration of damaged community infrastructures, Safety Equipment (PPEs) and actives for additional Pandemic (COVID_19) safety measures are provided in the mitigation cost. Cost for Insurance of labours, reinstate of quarry borrow pit, batching plants, camp etc., are provided in the mitigation costs.

In addition, the ESMP provides measures to address SEA/SH issues at a project level. These measures will be further elaborated in a standalone SEA/SH action plan. The key issues regarding labour will be managed in compliance with National Labour Act, 2017 and Labour Rules, 2018 and WB ESF, 2018 through a comprehensive LMP and Occupational Health and Safety Plan (OHSP). A GRM will be provided for project workers to help workers to lodge grievances and to manage the resolution of worker-related grievances. A Worker Camp Operation Plan and Worker's Code of Conduct will be prepared, which will also discourage or minimize SEA/SH.

A separate RAP will be prepared to address physical and economic displacement resulting from project activities. All losses (private and public assets) will be compensated with replacement costs as per the Entitlement Matrix. For any additional impacts occurring during project implementation, a resettlement framework has been prepared and will be applied for the additional losses. The ESMP obligates the contractor, upon mobilization, to prepare the Contractor's ESMP (C-ESMP), which shall be prepared prior to the commencement of construction activities. The C-ESMP shall include an OHS plan, Water and Waste Management Plan, Labor Influx Management Plan, Worker's camp management plan, Traffic management and road safety management plans, Quarry/borrow area management plan, and Site Restoration Plan among others in accordance with the GoN and IFC&WB workers' accommodation guidelines.

A Stakeholder Engagement Plan (SEP) is being developed for the project to identify stakeholders and to provide a plan for engaging with stakeholders throughout the project lifecycle. The SEP will provide materials for community awareness and sensitization with ESMP is on women and young girls, promoting health seeking behaviour. The SEP includes details of a project level GRM for stakeholders to raise any questions and grievances.

18.7 The Environmental and Social Management Plan

The project specific Environmental and Social Management Plan (ESMP) has been formulated with an aim to avoid, reduce, mitigate, or compensate for adverse environmental impacts/risks and propose enhancement measures.

An Environmental and Social Management Plan (ESMP) with details on mitigation measures, timing and location for implementing the mitigation measures, costs and responsible agencies for implementing and supervising the mitigation measures has been prepared. In addition, an Environmental Monitoring Plan (EMoP) has been prepared to guide key monitoring activities to ensure effectiveness of ESMP implementation. The Department of Roads (DoR) under the Ministry of Physical Infrastructure and Transport (MoPIT) will be the implementing agency for the project road and will be responsible for the overall implementation of environment safeguards under the project. DoR will be supported by the Construction Supervision Consultants (CSC) who will include an environmental specialist in their team to oversee environment safeguard activities. NRs 1,702,546,207.00 has been proposed for the mitigation and enhancement measures. Similarly, NRs 11,300,000.00 has been proposed for environmental monitoring. The detail ESMP is given in ESIA/IEE.

18.8 The Environmental Mitigation Cost

Cost estimation for the proposed mitigation measures and enhancement measures on Physical, Biological, Socio-economic and Cultural environment of proposed road is given in the following table. The total of environmental mitigation and enhancement and social cost is NRs 1,702,546,207.00.

Table 18.1: Environmental Mitigation and Enhancement cost of Butwal-Gorusinghe Road

SN	Mitigation and enhancement activities	Estimated cost (NRs)	Remarks
A	Capacity building Training (Tool Box talk sessions /labour force leaders, affected person/local stakeholders)	1,800,000.00	
B	Physical Environment		
1	Spoil management		Included in provisional sum
2	Bio-engineering works	59,836,515.00	Included in construction cost
3	Air and noise quality monitoring	5,400,000.00	9*4*3=108*50000
4	Water quality monitoring	2,400,000.00	10*4*2=120*20000
5	Water sprinkling		Included in day works
6	Wastewater treatment facilities	2,500,000.00	
7	Drainage management work	1,061,959,371.00	Included in construction cost
8	Installation of road safety signs	15,217,182.00	Included in construction cost
9	Flood safety, river training	218,060,350.00	Included in construction cost
10	First aid facilities, PPE, COVID-19	6,250,000.00	
C	Biological Environment		
1	Compensatory tree plantation	2,420,139.00	(71180 nos with 5 year aftercare) Included in BOQ
2	Wildlife studies, monitoring, recording and community awareness raising	3,000,000.00	
3	Fencing in the forest area	31,712,975.00	Included in BOQ
D	Socio-economic and cultural environment		
1	Relocation of public utilities	243,071,448.00	Included in provisional sum
2	Compensation of damaged public and private structure	38,918,227.00	Included in provisional sum
E	Others		
1	Preparation of Contractors C-ESMP including other plans		Obligation of Contractor
2	Contractors ESHS Staff		Obligation of Contractor
	Total Cost	1,702,546,207.00	

1.9 Estimated Budget for Environmental Monitoring

The Environmental Monitoring Plan (EMoP) has been prepared for all environmental components to be monitored at different project stage with parameters, methods, locations, frequency, cost, institutional responsibility for implementation. Estimated budget for the same is presented in **Table** below:

Table 18.2: Estimated budget for Environmental Monitoring

Description	Quantity	Rate (Per month) NRs	Amount (NRs)
Environmental Specialist	36		Included in Supervision consultant cost
Sociologist	36		Included in Supervision consultant cost
Safety Inspector	36		Included in Supervision consultant cost
Field sampling and Lab Tests monitoring			
Air and Noise quality monitoring	108	50,000.00	5,400,000.00
Water quality monitoring	120	20,000.00	2,400,000.00
Wildlife movement monitoring	3	1,000,000.00	3,000,000.00
Sub-Total Costs for Environmental Monitoring Works			**10,800,000.00**
Monitoring Costs by			
Geo-Environment and Social Unit, DOR/MoPIT	LS		500,000.00
Sub-Total Costs for Monitoring Agencies			**500,000.00**
Total Estimate			**11,300,000.00**

18.7.1 Institutional and human resources

The Department of Roads/DCID will be the authority to execute the environmental and social management plan. The consultant will work under the specified organizational set up with the professional staff.

18.8 Financial resources

The implementation of the project needs execution of constructional activities taking care of the recommendations of the environmental assessment report, operation and maintenance of the road and environmental monitoring. The construction, operation and maintenance of the road come under the project cost. Further, the environmental protection measures are also a component of the project cost. The total environmental mitigation cost for the projects has been allocated in the environmental assessment report as **NRs 1,702,546,207.00**. The Executing agency shall ensure that EMP will be a part of bidding document.

18.9 Capacity Building and Training

The environmental and social training will help to ensure that the requirements of the ESMP are clearly understood and followed by all project personnel. Hence the competencies of the Consultant to be selected for capacity building training will include a thorough knowledge and experience of WB Environmental and Social Framework (ESF) and ESHGS guidelines. The trainings will be provided to different professional groups separately, such as DFO staff (road kill survey), skilled personnel, unskilled labors, and camp staff. Capacity building will be aimed at strengthening the PMU staff in the field of environmental management and social development. Safeguard staff of PMU responsible for the supervision of environmental and social mitigation measures would be trained in environmental management, environmental quality control, ecology, environmental awareness, labor and working conditions, and social development. The contractor will also be required to provide environmental and social trainings to its staff to ensure the effective implementation of the ESMP.

18.10 Bio-engineering

Various type of Bio engineering works is proposed at some stretches along the proposed road using Manuals of DoR on bioengineering techniques for protection of embankment and for enhancement of road environment. Total estimated cost of **NRs.59, 836,515.00** is also allocated for bio-engineering work for the project road.

18.11 Climate Change

The detail design of project roads has been done considering the potential effects of climate change. From a road development perspective in Nepal, impact of climate change mainly takes the form of concentrated high rainfall resulting in the accelerated surface run-off from slopes and increased flows in gullies, drainage channels, streams, and rivers. These phenomena have a consequent effect on the stability and performance of road sections, bridges, and other structures.

The project road sections fall on Terai so particularly susceptible because of the location. The detail engineering design of project road have been done considering the potential effects of climate change. From a road development perspective in this region, impact of climate change mainly takes the form of concentrated high rainfall resulting in the accelerated surface run-off from slopes and increased flows in gullies, drainage channels, streams, and rivers, possibility of flash floods/rapids, mud flows in rivers/streams, and an increase in incidence of flooding along the alignment. These phenomena have a consequent effect on the stability and performance of road sections, bridges, and other structures. For this reason, particular consideration has been given in the detail design of road formation and embankment heights and the size of waterways and soffit levels of bridges.

Key Measures for Climate Change Adaption

A. The risk screening and risk identification exercise has helped to ensure climate risks mitigation or adaptation measures in the BG road. Increase embankment height, new side drains, additional new culverts, additional new Bridges, river training works, retaining structures for embankment protection, Bio-engineering measures, and tree plantation contribute to adaptation for future increases in precipitation with climate risks.

B. The proposed hydraulic structures are designed based on the historical hydrological data and factoring climate change predictions. The proposed bridges are designed for

100-year return flows, culverts are designed for 50-year return flows, and side drains are returned for 25-year return flows. For reduce the impact from flood, the design of drainage structures of this road section the design floods have been estimated increasing an additional 10% flows are added as climate change adaptation. Adequate scour depths have been recommended for the foundation design of bridges and box bridges structures. The frequency analyses of maximum daily rainfall have been conducted for representative rainfall stations of this section for flood estimation of rivers and drainages by rainfall-runoff models. The existing 60 diameter and 90 diameter pipes has been replaced by 1-2 m box culvert due to climate change consideration (flash flood).80.494 km new side drains, 155 nos new box culverts and 43 new bridges will be constructed.

C. Increase 0.5m embankment height to reduce inundation; Include slope protection works; provision of 33.92 km additional protection works to resist erosion and scour in close proximity to adjacent rivers. Bio-engineering measures are included for 160348 Sqm road embankment protections and bridge and river side slope protection.

D. For wearing coat, bitumen of viscosity grade 30 (VG 30) has been proposed in order to address temperature effect. Bitumen of VG 30 having good thermal susceptibility has higher specific gravity and softening point (47 degree Celsius). Furthermore, it can be used in higher temperature and rainy season as well. In order to control deterioration rate and to increase performance, thickness of pavement layer has been increased.

E. A fenced Compensatory plantation will be established in possible locations of the river bank or others in coordination with the DFO. Median plantation is proposed. 71,180 number of large saplings will be planted as compensatory plantation (45 ha) at a ratio of 1:10 has been proposed.

18.12 Guidelines for Compensatory Afforestation Program

1 Introduction

The BG Road project will cause a loss of 7118 trees. After approval of tree cutting from Department of Forest and Soil Conservation (DoFSC), the project will do the agreement with DoFSC, to develop and implement a compensatory afforestation program.

As a compensatory measure for the loss of trees due to the project, plantation (afforestation) in a 1:10 ratio (planting of 10 new trees per one tree lost) will be carried out as guided by the Environment Protection Regulation 2020. The project shall plant this compensatory afforestation on land provided by DFO and shall take care of the plantations for five years and then hand them over to DFO. Otherwise, Project will do a Memorandum of Understanding (MoU) with DoFSC/DFO and all compensatory afforestation program will be executed by DoFSC/DFO.

2. Activities of the Compensatory Afforestation Program

According to the agreement between Department of Forest and Soil Conservation and Project, the compensatory plantation will be done for the loss of 7118 trees. A total of 71180 large saplings (comprising different species) will be planted by the project as compensatory afforestation.

The compensatory afforestation will require a total area of 45 ha. Afforestation sites will be in the denuded or degraded forest areas near the project area, river side. It is also proposed to have avenue plantation along the road. The compensatory afforestation is proposed to be done mainly in those forest blocks where degraded land and forest blanks are available for planting. During the identification of sites for afforestation, priority will be given to planting in large, continuous habitat areas, with due consideration of areas that might enhance habitat for wildlife. The areas of animal corridors, feeding areas, and other important habitats should be identified and planned as high priority planting areas.

As per the regulations, plantation shall be conducted in the land designated by the Division Forest Offices of the concerned district; i.e., the DFO of Rupandhehi and Kapilbastu district. The suitable site for the plantations will be finalized after discussion with near Community Forest User Groups and the Division Forest Office. Project will request the Division Forest Office to allocate the land for plantations during the early stages of project construction. The seedling production, afforestation site identification, and afforestation works are expected to progress in parallel, and continue over five years.

To produce the required types and numbers of large saplings, Project will assign the task of developing and implementing a tree nursery program to the DFO. The plantations under the afforestation program shall be mixed types of plantations, covering fuel wood, fodder, medicinal plants, economically important indigenous species, conservation tree species etc. The species for plantation will be selected considering species indigenous to the project area, altitude, aspect, biotic pressure, soil depth, and moisture.

Nursery development will be undertaken to produce the targeted amount of seedlings/large saplings (71180+10%mortality) of different plants species. For nursery development following studies will be done.

- Existing Nursery Sites: Capacity of Existing DFO nursery is assess and enhanced or additional nursery established if required.
- New Sites: An additional location have been identified for nursery development;
- Project/DFO will also support willing community forest user groups in establishing a new nursery or enhance the capacity of existing nursery, if CFUG had one already, to produce large saplings.

Plantation Program

The works for planting and maintenance of plantations will be executed by DFO. The local forest user groups could be engaged to plant tree saplings and look after the afforested area for five years. Steps required for the program include:

- Preparing the site and pitting for plantation: This requires clearing the site and digging pits (30 cm x 30 cm x 30 cm) for plantation;
- Large saplings transported and planted: large saplings will be transported from the nursery and planted at afforestation site. Planting will be undertaken in the appropriate season (Monsoon) for maximum survival.
- Maintenance: The planted saplings will need maintained for five years. The maintaining work will involve weeding, supplementary planting, and protect and maintain the fence.

Afforestation Program

A detailed Afforestation Plan will be prepared by the Project, with the coordination of the Division Forest Office. After Agreement with DoFSC/DFO activity wise detailed schedule will be developed and implemented accordingly.

SECTION V: PERFORMANCE BASED MAINTENANCE WORKS

19 Performance Based Maintenance Works

19.1 General

19.1.1 Introduction

Road maintenance has traditionally been the jurisdiction of Department of Roads. In Nepal except some exceptional cases, still there is in-house performance of road maintenance, especially routine and recurrent road maintenance. However, there is now a global trend for such work to be contracted out to the private sector. The main reason for shifting to such contracts is to improve efficiency. Provided that there are qualified road maintenance contractors with adequate competition, cost savings in between 30% to 50% have been realized in other regions of the world. Thus, some countries have turned to contractors to deliver road maintenance.

Strengthened Maintenance Division (SMD) program is one of the primary means of maintaining and renewing the SRN over the past 25 years. Though SMD process was much successful in improving the condition of the SRN in past years, it cannot be overlooked many issues that are perceived to be getting not very good. Considering these, the DoR with support from the World Bank and Asian Development Bank (ADB), implemented a series of pilot trials of Performance Based Maintenance Contracting (PBMC) over the period 2003-2012. For a variety of reasons, the results of these pilot PBMC contracts were not overwhelmingly positive, and PBMC was not further continued.

Citing the present success of PBMC in other countries, and problems faced in the effective management of routine/recurrent and periodic maintenance practices, DoR is eager in improving and mainstreaming performance-based contracts in Nepal. This Butwal-Gurusinghe (Imiliya) Section of East-West Highway is being upgraded to four/ six (in urban areas) lanes. After completion of improvement work, the PBM work will be carried out through two contract packages (from 590+000 km to 615+000 and 615+000~640+000.

Road Asset Management (RAM) or road maintenance is one of the top priorities of the Government of Nepal. Performance-based Road maintenance contracts (PBMC) are an essential element of RAM and their implementation contributes to improving the effectiveness and efficiency of the maintenance of road networks. Well-designed PBCs keep roads in predefined good condition at relatively low cost. Long-term PBCs, often referred to as Road Asset Management Contracts, require sound road asset management tools.

PBM includes the Road Asset Management (RAM) or road maintenance of the pavement surface in a predefined service level condition including formation width, side drains, bridges and cross drainages, road side structures, road furniture, road marking, traffic sign boards, slope protection and safety elements of the road etc. for at least 5 years time frame.

PBCs need a conducive environment for successful implementation. The most important factors are:

- strong commitment and support by key decision makers, especially from the ministry of finance, the ministry in charge of roads, and the road organization;
- a positive attitude from road organization staff;
- client, contractors, and consultants have the capacity to plan and manage this new kind of contract;
- an adequate road asset management system to support the requirements of PBCs;
- long-term funding; and
- a competitive road maintenance market.

19.1.2 Overview of Performance Based Maintenance

There are three types of road maintenance contracts:

a. Method based or conventional contracts with unit rates for work items and payments based on quantities of measured quantities of works completed;
b. Performance-based Road maintenance contracts (PBC) with performance levels defined for each road asset or service provided under the contract;
c. Mixed or hybrid PBCs that contain elements of both contract types.

The contractor needs to maintain the road assets in predefined good conditions or service levels during the entire contract period is common in all PBCs. Payments are based on how well the contractor manages to comply with the performance or service levels obligations defined in the contract, and not on the amount of works and services executed. It is up to the contractor how to achieve this. Therefore, work selection, design, and delivery are all the contractor's responsibility. Hence, the choice and application of technology and the pursuit of innovative materials, processes and management are all up to the contractor as long as there is compliance with the relevant laws and regulations. It should ensure that the physical condition of the roads under contract is adequate for the need of road users, over the entire period of the contract which is normally several years. Compared to conventional contract arrangements where the client determines work selection, design and delivery, PBCs allocate a higher risk to the contractor. At the same time, it opens opportunities for increased profit margins as improved efficiencies and effectiveness of design, process, technology or management can reduce the cost of achieving the specified service levels.

The Performance-Based Maintenance Contract tries to address the issue of inadequate incentives. During the bidding process, contractors compete among each other by proposing a fixed monthly lump-sum fee per km of road to be paid to them. It is important to understand that contractors are not paid directly for "inputs" or physical works (which they will undoubtedly have to carry out), but for "outputs," i.e., the initial rehabilitation of the road to pre-defined standards (if so required by the bidding documents), the maintenance service of ensuring certain quality levels on the roads under contract and specific improvements (if so required by the bidding documents). The monthly lump-sum remuneration paid to the

Contractor will cover all physical and non-physical maintenance services provided by the Contractor, except for unforeseen emergency works which would be remunerated separately.

Performance based maintenance essentially consists of two types of works namely output and performance bases works. So, it is now termed as Output and performance-based road contracts (OPRC). In the international community, the use of the Output and Performance-based Road Contracts (OPRC) has superseded the PBMC model.

Two main elements of OPRC are as follows:

- Output-based works that are specified, measured and paid by the quantities of works completed and valued at BOQ Unit Rates and Prices or at appropriate Day works Rates and Provisional Sums, in the same way as in a conventional contract especially for emergency works, and
- Performance-based works that are assessed qualitatively against service levels that describe the thresholds the Contractor is required to achieve and to be paid at a monthly payment rate. Monthly payments are reduced if the service levels are not maintained. The PBM works are regular maintenance works like drain clearing, intact road safety measures, correcting structural defects in the pavement, proper routine maintenance of bridges, as required due to environment and traffic loading.

Capacity development is an essential part of any future PBMC for its successful implementation Capacity development is therefore not to be seen as a one-off exercise, but an on-going process as occurred with the SMD implementation.

Capacity building needs to focus to all involved in implementation like Employer, contractors, and consultants. Capacity Building Programme Before and During the Tender Process, and After Tender Award is essential for understanding of the PBM model

19.2 Required Services Level Setting

19.2.1 The Objectives and Scope of Services

The major objective of this works is to satisfy the road user with good accessibility, comfort, travel speed and safety, minimized the total system cost and environmental impacts.

Major works of this project is Improvement of the Butwal-Gorusinghe (Imiliya) Section (50 km) of the East-West Highway. The performance-based maintenance works is the one of the components of the whole works. After completion of the Improvement works, the supervision consultant with consent of the Client will issue the improvement works completion certificate with commencement of PBMC component.

For fulfilment of the above-mentioned objectives the scope of works, PBMCs will cover routine and recurrent maintenance, improvement works, monsoon services, and emergency works.

Likewise, the scope of services to be provided to the Contractor includes all activities required to maintain the Operational Service Levels and other outputs, or any other requirements of the Contract. It includes the management tasks and physical works associated with the following road assets and other items.

- Pavements
- Shoulders
- Drainage system (Surface and Sub-Surface)
- Vegetation protection and control
- Slopes (cuts and embankment)
- Bridge, cross drainage, retaining and miscellaneous road structures
- Traffic signs, road marking, road marker stones, delineators and road furniture
- Road safety and Traffic management
- Data collection.

The scope of works and services of PBMCs cover:

- The management Services, and
- The Operational Services

19.2.2 The Management Services

The management services include providing the information to the Employer in order to manage the road asset during the Maintenance Phase of the Contract and to facilitate either the next tendering process or handover to the Employer. Such information are as follows:

- **Quality Assurance Plan:** Information on how the Contractor assures the quality of his services, manages the health and safety of his staff, manages emergencies, and traffic management at the work site;
- Contractor 's work programs;
- Inception and Regular progress reports (including deployed human resources, materials, machine and equipment and road closer data etc as per maintenance information formats of DOR);
- Road Condition data;
- Inventory updates, development/updating of Road Register and other data sharing requirements;
- Maintenance history.

19.2.3 The Operational Services

Operational services include the activities needed to maintain the satisfactory condition of the road assets, to assure their durability, as well as to satisfy the road users riding comfort requirement. These include, inter alia:

- Road and lane width
- Road roughness

- Scabbing
- Control of potholes and cracking
- Drainage
- Rutting
- Corrugation
- Visibility of road signs and markings
- Response times to rectify defects that compromise the safety of road users
- Vegetation control
- Littering control
- Edge break
- Depression
- Slickness/Bleeding
- Raveling
- Shoving
- Shoulder condition

19.3 Work Management

19.3.1 Requirement during Maintenance Phase

In order to carry out the PBM work, contractor has to focus on following activities during the maintenance phase:

- Establishment of Self-Control unit for Self-Monitoring and management of the contract;
- Mobilization of Contractor 's Key Personnel;
- Specifications and Work Methods and implementation of mobile maintenance team;
- Preparation of Emergency Procedures and Contingency Plan;
- Road Management Database;
- Detailed Maintenance Program;
- Handover.

The contractor has to perform contract work as the method and requirement specified in the condition of contract and specification as detailed out. Similarly, during the handing over of the contract, the employer checks all the contractor activities- condition of road pavement surface, (Pavement Roughness), road deflection measurement, structures, bridges culverts and all other road furniture 's. The contractor has to correct all non-compliance prior to the date of completion of maintenance phase work.

19.3.2 Routine Maintenance

In Routine Maintenance works, following works are to be covered to meet the specified Operational Service Levels for the duration of the Maintenance Phase;

- Providing management and working personnel as required

- Providing committed vehicles, equipment, materials, consumables, tools and any other resources necessary to carry out the Routine Maintenance works
- Undertaking regular inspections, condition surveys, monitoring, identifying defects and reporting of the conditions of all roads under the Contract at the required frequencies
- Scheduling maintenance works to meet the required Operational Service Levels
- Providing effective traffic management for all works undertaken to ensure public safety and the safety of the Contractor 's workforce
- Notifying the Employer where third parties are the cause of damage to the road assets
- Notifying the Employer immediately of any new or unusual events or circumstances affecting the road assets
- Executing repairs or remedial works to rectify the defects, damage or any deficiencies that are beyond the allowable thresholds and bring the road assets to specified Operational Service Levels
- Maintaining and submitting records of all the above works undertaken, as well as all reports and other documentation required in these Maintenance Specifications.

19.3.3 Emergency Works

Emergency Works are designed to carry out rescue, repair damage to the roads caused directly by natural or manmade phenomena with consequences occurring either in the area of the roads or elsewhere, but with a direct impact on the roads. Such phenomena may include: tropical depression, rainfall and winds of extraordinary intensity and/or duration, major landslides within or outside the right-of-way, floods with water levels above normal maximum flood levels, earthquake, major accidents or similar events causing considerable damage to the road.

The Contractor has to take the measures necessary to re-open the road to traffic at the earliest possible time and maintain the road open during emergency works, without being entitled to any separate compensation for those measures. If necessary, the Contractor has to provide temporary detour roads as approved by the Employer.

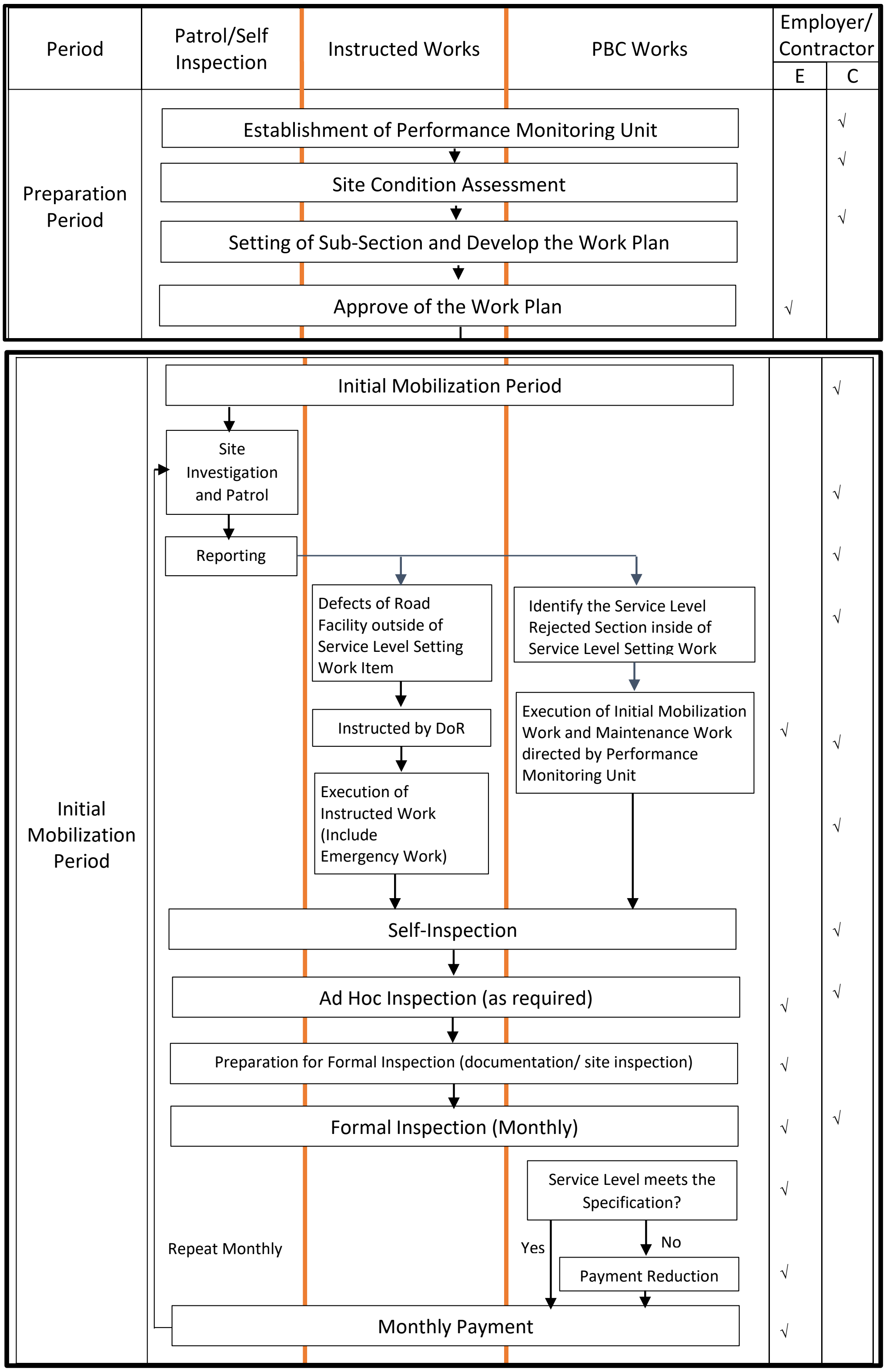
19.3.4 Environmental Management

During the implementation of PBMC contract, the contactor shall follow all the environmental requirement as per Environmental Management Plan, which is prepared by the Employer for this Contract and also compliance with the Government of Nepal's laws for the protection of the environment and other relevant legislation in force, or in the absence of these, with Asian Development Bank requirements.

19.3.5 Work Flow

A typical work flow for road maintenance under the PBMC contract is shown in **Figure 19.1.** For performance-based maintenance, the contract period is composed of the Initial Mobilization Period and the Routine Maintenance Period. During the Initial Mobilization

Period, the service levels must be brought up to the required levels. Service levels are evaluated during monthly formal inspections and the amount to be paid each month shall be determined considering the payment reduction for non-compliance with the Service Levels in the contract.



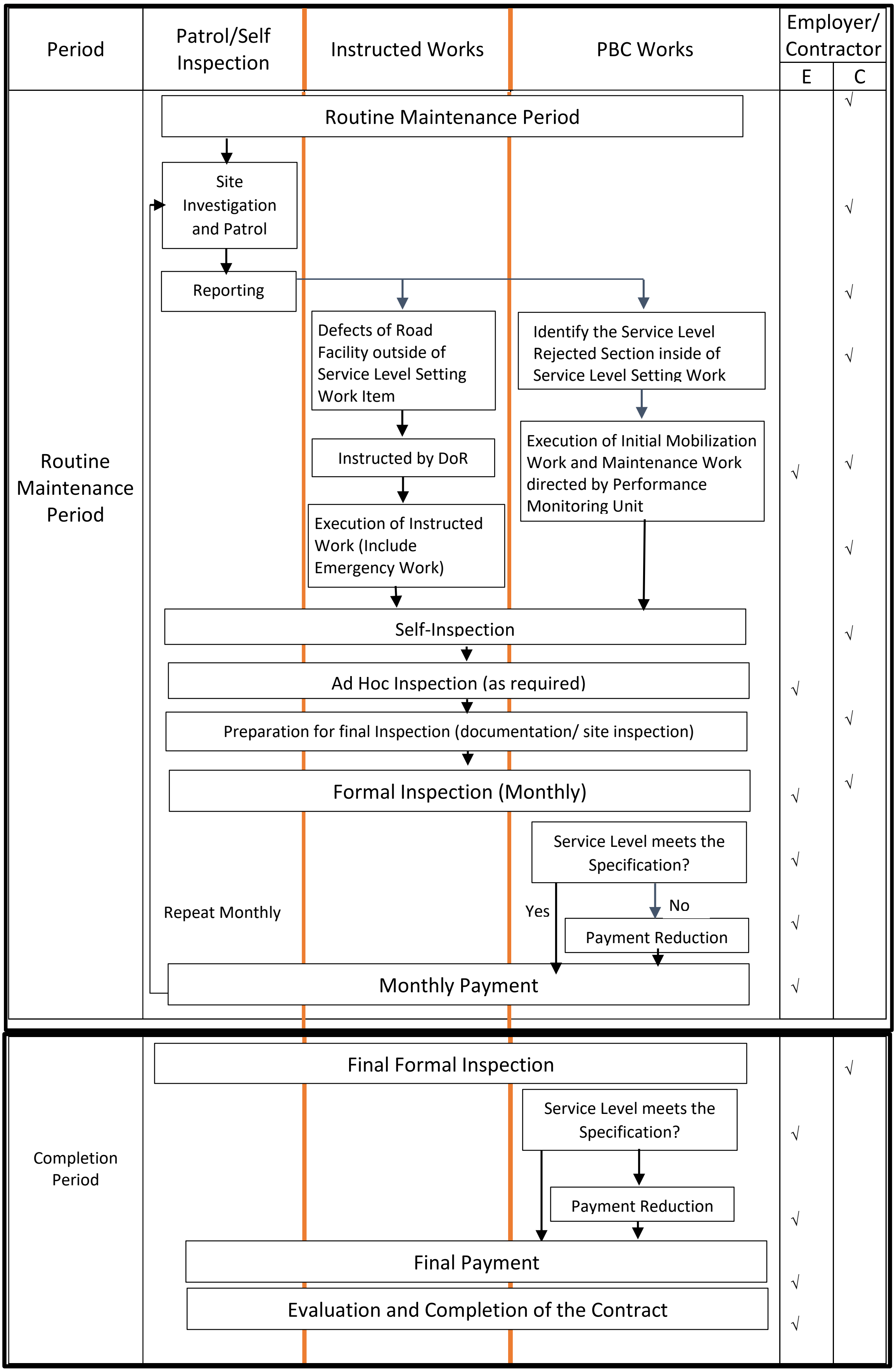


Figure 19.1: Typical Work Flow of PBM Works

19.3.6 Action by the Contractor

In PBMC the maintenance work is not undertaken based on the instruction of the client. Instead, the Performance Monitoring Unit should be established within the organizational setup of the contractor to support the Contract Manager in gathering the information needed by the contractor to manage the works and services. The information gathered is used to prepare Monthly Statements and ensures that a complete database of the road condition, both on- and off-carriageway, is available at all times.

The contractor shall establish the Performance Monitoring Unit after the award of the contract. The Performance Monitoring Unit is a team within the contractor's organization responsible for supervision of service levels while the Execution/ Routine Maintenance Unit is responsible for implementation of the work on site. The Performance Manager shall be the head the PMU.

Figure 19.2 illustrates the recommended organizational structures of the contractor.

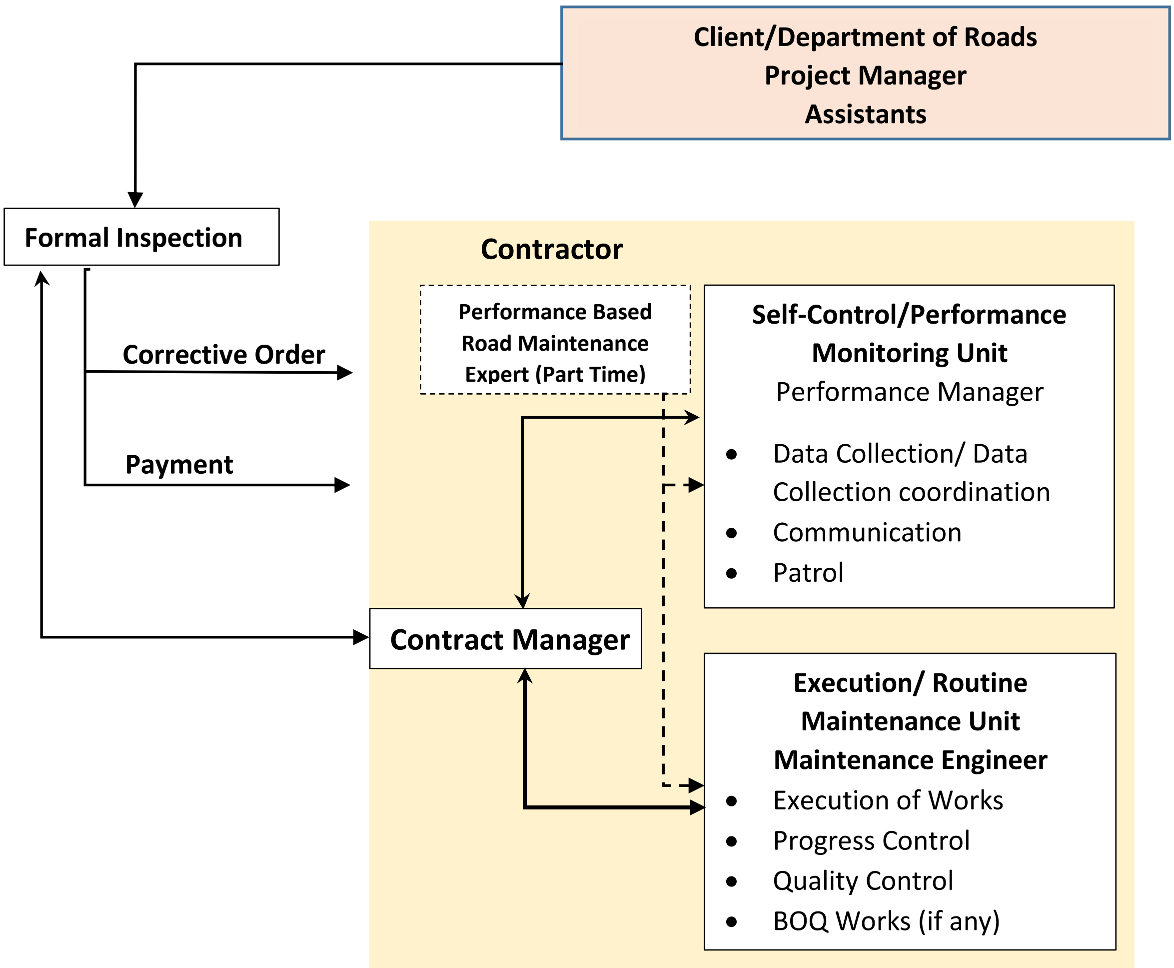


Figure 19.2: Recommended Organizational Structures of the Contractor.

19.3.7 Role of Performance Monitoring Unit

As stated above, the contractor is obliged to establish within its organization a Performance Monitoring Unit PMU staffed with qualified personnel. The roles of the PMU are:

1) Self-inspection to verify the degree of compliance with the required service levels and preparation of PBC inspection record;
2) Patrol;
3) Assessment of the road;
4) Generation and presentation of the information requested by the Road Manager for the documentation required for the monthly statement; and,
5) Formal Inspection together with Road Manager and Project Manager

Typical tasks of the Performance Monitoring Unit are shown in **Table 19.1.**

Table 19.1: Tasks of the Performance Monitoring Unit

Stage	Task	Report
Plan	Site condition assessment Development of Work Execution Plan	Report for site condition assessment of the road
Do	Data Collection/ Reporting Communication with the client Communication with road users	Daily Work Record Daily Patrol Record Photo Record Incident Report
Check	Self-inspection Formal and Ad hoc inspection Development of Draft Monthly Statement	Defect Detection and Rectification List Self-Inspection Result Report Draft Payment Reduction Calculation Table Draft Monthly Statement
Action	Remedy action to Non-compliance	Remedial work report

19.3.8 Role of the Contract Manager

The roles of the Road Manager include:

1) Drafting of Work Program including monitoring system;
2) Monthly formal inspection together with Project Manager;
3) Preparation of monthly statement; and,
4) Coordinating the work of the PMU and the Execution/Maintenance Unit

19.3.9 Role of the Execution/ Routine Maintenance Unit

The roles of the Execution/ Routine Maintenance Unit include:

1) Execution of works;
2) Quality control testing required for routine works and emergency works;
3) Progress control; and,

4) Executing Instructed (BoQ) works (if any)

19.4 Operational Performance Measures

Performance levels are minimum conditions of road, bridge, road side, and traffic assets that must be met by the contractor over the entire contract period and may cover other services such as monsoon services, the collection and management of asset inventory data, call-out and attendance to emergencies, and response to public requests, complaints, and feedback.

Minimum road conditions and Service Levels are defined through output and performance measures, and these are used to define and measure the desired performance of the Contractor. The defined performance measures are thus the accepted minimum thresholds for the quality levels of the roads for which the Contractor is responsible.

Complex performance indicators that cannot be achieved shall not be used.

Following the current practice of using 'density-based measure' wherein the quantum of defects per a given distance down the road is specified. For example, 'no more than 2 potholes per km' are permitted, with an additional measure of 'no potholes are permitted of a size > xx mm' in order to provide a backstop measure for safety and integrity of the network.

As part of the implementation of OPRC there is a rationalization of the items to be measured, and also a benchmarking of acceptable performance using the density-based approach.

The performance criteria cover all aspects of the contract, and be clearly defined and objectively measurable. Operational performance levels need to satisfy three main objectives:

19.4.1 Road User Service and Comfort Measures

Road user service and comfort measures, expressed as:

- Road Roughness;
- Travel time;
- Safety;
- Road and lane width;
- Vegetation control;
- Availability of each lane-km for use by traffic;
- Rectify the defects that affects the comfort and the safety of road users by using the density-based approach

19.4.2 Minimized Long Term System cost

- Cost to road user agency-Life cycle cost of asset;
- Response time;
- Durability of the asset;

19.4.3 Minimized Environmental Impact

- Management of road pollutant;

- Protection of road side vegetation, source of water;
- Management of road maintenance material and process;
- Management of litter along the road corridor; etc.

19.4.4 Management Performance Measures

In addition to the measures around the physical performance of the asset, there is also a need to introduce performance measures (and penalty payments) around the various management tasks within the PBMC. Specific measures are put in place to cover aspects such as: a. Accuracy and timeliness of performance reporting; b. Delivery of reports and data; c. Completion of inspection activities; and d. Compliance with environmental and social safeguards.

The contractor shall provide Employer the information regarding asset during the terms of contract and on-going maintenance through following deliverable:

- Regular progress reports;
- Safety management plan;
- Emergency procedure and contingency plan;
- Inventory updates and other data sharing requirements;
- Maintenance history;
- Management of information system.

To carry out all these services, contractor has to execute work according to the Condition of Contract for PBM works.

19.4.5 Reporting During PBM Contract Period

During the execution period of the contract, the contractor shall report the employer regarding his contract Implementation activities. The schedule of reporting and its deadline for the submission are given in **Table: 19.2** below:

Table 19.2: Reporting during PBM contract period

Item	Service Level	Control Activity	Tolerance Permitted
Inception Report	Preliminary submission within 28 days from commencement of the Maintenance Phase. During this period contractor shall establish: a. Contractors monitoring unit; b. Contractor's self-control system; c. Mobilization of Contractor 's Key Personnel; d. Maintenance and reporting methods; e. Emergency and contingency plan; f. Base line of road condition at the time of commencement of PBM contract. Submission of Approved report not later than 7 days after receipt of Employer's comments.	Review and comment / approval by Employer.	Modification must be completed within **seven (7) days** after the official letter informing of comments.
Structural Inspection Report	Submission and approval of structure inspection report. This report must initially be submitted within the first 60 days after the start of the Maintenance Phase and in each three (3) months thereafter.	Review and comment / approval by Employer.	Initial Submission by due date. Revision and resubmission must be completed within **fourteen days** after the official letter informing of comments.
Road Roughness Survey Report	Submission and approval of road roughness survey report. This report must initially be submitted within the first 90 days after the start of the Maintenance Phase and in each twelve (12) months thereafter.	Review and comment / approval by Employer.	Initial Submission by due date. Revision and resubmission must be completed within **fourteen days** after the official letter informing of comments.
Monthly Report	Submission and approval of monthly report summarizing activities carried out, progress, difficulties, updated work plan, etc. This report must initially be submitted within the first 7 days after each month of works.	Review and comment / approval by Employer.	Initial Submission by due date. Revision and resubmission must be completed within **seven (7) days** after the official letter informing of comments.
Handover Report	Preliminary submission at least 30 days before completion of the Maintenance Phase. Submission of Approved report not later than 15 days after receipt of Employer's comments.	Review and comment / approval by Employer.	To be submitted at least 30 days before completion of the contract. Modifications to be completed and submitted within **fifteen (15) days** after receipt of comments.

19.5 Cost Estimate and Payment for PBM Contract

For PBM contract, consultant will prepare all the costing required to be performed by the contractor as per DoR standard and norms during the entire period of the contract. The cost-estimate of PBMC work varies from 2-5% of the construction cost which depends on the length of road and duration of the PBMC contract period. Performance based maintenance works include all the activities as per the specification, except the activities under emergency works. The rate for the PBMC work will be on unit Kilometer- Month.

The payment to the PBMC contractor will be made on monthly basis. The contractor will submit the Interim payment to the Employer and the employer will make the payment after verification of the work in site and deduction of the payment for non-conformance of rectification work within the response –time. Duty and responsibility of the employer and the contractor will be as per specification and COC of the PBMC works. The deduction points for non-conformance of rectification work within the response–time included in the Specification has provided by the Client, as the Client was not satisfied in proposed deduction points for non-conformance of rectification work within the response–time prepared by the Consultant. The deduction points provided by the client is based on the Nagdhunga-Naubise-Mugling road project and the consultant has prepared the deduction point based on the Kakarbhitta-Laukahi Road Project, the Clients provisions is more flexible than the Consultants.

SECTION VI: PROJECT COST AND PROCUREMENT

20 Rate Analysis and Cost Estimate

20.1 General

The rate analysis and cost estimation have been prepared as per provisions made in Norms and Specification issued by Department of Roads and Public Procurement Act and Regulations. The cost estimate comprises of components such as shifting of utilities, construction of road, bridges, culverts, intersections/interchanges, underpasses, road sign and signals, road furniture, road safety elements, slope protection works and bio-engineering.

Following assumptions have been made while calculating cost of Project:

a. 13% VAT has been added and provisions for price escalation and physical contingency are also made;

b. Wherever is applicable, mechanized construction plants such as hot mix batching plant, pavers, concrete batching plant etc have been assumed while determining the rates;

c. As far as possible pre-fabricated and pre-casted element are used;

d. Those rates (machine equipment and material) which are not available in Basic Schedule (in DoR Machine Equipment rate list and District rate) have been taken from the prevailing market price;

e. Camp for supervision staff has also been provisioned;

f. It is assumed that good hygienic labor camp will be established by the contractor;

g. It is assumed that required water would be available for construction purpose within reasonable lead.

20.2 Quantities of Works

The estimate of quantities is carried out on the basis of drawings prepared based on the design of highway and bridges. The following considerations have been made while determining of quantity of works:

- Earthwork quantities have been prepared using a spreadsheet programme based on cross– sections using design software;
- The earthwork quantities have been separated into cutting, filling and excavation of foundation for bridges, culverts, retaining, drains and other structures;
- Quantities of other construction items have been worked out on chainage–wise manner in a tabular schedule of structures;
- The quantities and the costs for the major elements such as General and Site Facilities, Site Clearance, Earthworks, Pavement Works, Structures, Bridges, Culverts Road

Furniture and Traffic Safety Measures, Environmental Mitigation (including Bio-engineering), Day Works and Provisional Sums have been determined.

- While calculating quantities of works, provisions made in Standard Specification for Road and Bridge Works-2073 (With Second Amendment 2078) have been followed.

20.3 Analysis of Unit rates

20.3.1 General

Rate Analysis has been prepared considering the district rates for the labour and construction material, market price of construction material (if it is not included in district rate) and norms for the rate analysis of GoN. For that purpose, the following relevant aspects have been duly taken into considerations:

- Public Procurement Act and Regulations;
- Standard Norms for Rate Analysis of Government of Nepal;
- Wages of skilled and unskilled labours approved by Concerned District Administration Offices;
- Construction material rate approved by Concerned District Administration Offices
- Market prices of special materials (If not included in district rate);
- Availability of materials and its location, quantity and distance to be transported;
- Availability of local construction materials and its location, quantity and distance to be transported;
- Construction equipment and their hiring rates;
- Contractual overhead.

The unit rates of items are based on the approved norms of Department of Roads, Government of Nepal. The rate of items which are not available in the approved norms have been taken from the adopted norms in the similar past projects. Unit rates include three major components, which are labour, materials and the equipment involved in the works. Cost of materials also includes their transportation cost to the site.

20.3.2 District Rates for Labour

The Labour rates for cost estimation are based on Rupendhehi and Kapilbastu Districts Rates for the fiscal year 2079/2080 which are approved by the District Administration Offices of above-mentioned districts. The list labour rates of these three Districts have been adopted.

20.3.3 District Rates for Construction Materials

The rates of materials are based on Rupendhehi and Kapilbastu District Rates for the fiscal year 2079/2080. For those rates which are not available in the district rate, market rates or approved rates of adjoining districts are taken into account after adding the approved transportation charge as mentioned in the district rate or as per the DoR Norms. For locally available materials which are not included in the district rate, the local market rates are considered in the estimation.

20.3.4 Rates of Equipment and Collection of Material as per DoR Norms

Established equipment rates of Mechanical Branch of DoR have been used. The cost for collection and production of the construction materials like sand, stones, aggregate, surfacing chips, gravel material and crushed stone base have been based either on the respective district rates or on the DoR Norms, whichever are less.

20.3.5 Rates for Relocation of Utilities

There are mainly three types of utilities along the road requiring relocation i.e. i) electric/telephone poles/transformers, ii) water supply pipes & iii) utilities / temples. Rates for these have been worked out as under.

Electric Supply Lines: There are mainly 440 volts and 11 kva lines along the road requiring reallocation. Relocation of about 1873 nos. of electric/telephone poles and 67 nos of transformers is required. Costs for relocation have been worked out with the NEA rates.

Water Supply Mains: It is required to relocate the mains and distribution pipes of water supply system in the settlement areas. It is assumed that 50% of the existing pipes can be reused and the remaining 50% pipes need to be replaced by new ones. Besides, household connections have been considered.

Utilities: Some public utilities/properties located along the road have to be relocated. A budget has been allocated in Social Works to relocate these utilities.

20.4 Final Cost Estimate of the Project

Estimated cost of the project has been determined multiplying the quantities by the respective unit rates. The cost estimate also comprises of cost of environmental and social mitigation measures, VAT, physical and price contingencies.

The Cost Estimate is presented in respective Volume IV.

The costs of various components of proposed Project Road are calculated separately and are shown in the following **Table 20.1.**

21 Procurement of Works

21.1 Procurement Approach

21.1.1 Introduction

As the part of the proposed assignment, the Consultant has assisted the Client in procurement work for the proposed project.

Overall, the procurement approach has been guided by public procurement management plan which includes:

- Identify Needs,
- Preparation of Specification,
- Choose Procurement Method,
- Prepare Procurement Document and Invite Offers,
- Evaluate Offers,
- Award Contract,
- Manage Contract,
- Evaluate Procurement.

There are mainly two type of procurement system generally used in our contest.

- **Contract for Construction (Traditional)** – where design is provided by the Employer and construction bids are solicited. Under World Bank funding projects and For Building and Engineering Works Designed by Employer, FIDIC 2017 Contract which is derived from FIDIC-Red Book. (For Building and Engineering Works Designed by Employer).

- **Contract for Design/Build**–where design and construction services are undertaken by a single entity selected on the basis of a competitive response to specific requirements detailing the project parameters.

The Design/Build approach is beneficial where the works are complex or extensive. The benefit is gained by harnessing the specific expertise of bidders, in terms of experience, equipment and proprietary systems, to ensure harmonization of design of the works with construction methods.

It is clear that a Traditional approach is appropriate for the proposed works, which are neither complex nor extensive. It is therefore recommended that **"Procurement of Works without prequalification Bidding Process (Single Envelop)"** based on the Standard Bidding Document of World Bank January 2021 for the proposed **Butwal-Gorusinghe Section of East-West Highway**.

21.1.2 Contract Packaging Philosophy

It has been agreed that ICB (International Competitive Bid) procedure shall be adopted to enhance the contract administration effectively and to provide opportunity to participate by numbers of professional Contractors to achieve the quality works in stipulated time. It is therefore recommended that ICB procedures to be adopted and contract packaging shall be arranged accordingly for **Butwal-Gorusinghe (Imiliya) Section of East-West Highway**.

21.1.3 Post Qualification

Prequalification process is generally lengthier and complex. Post qualifications have been successfully adopted as the normal procedure in Nepal in many projects. It is therefore, "Post Qualification" process shall be utilized for the proposed project.

21.1.4 Bidding Process

The bidding process for works has been developing, refining and standardizing by the Department of Roads, Development Cooperation Implementation Division-DCID over many years. The standardized procedure which has been developed shall be adopted as follows:

- Preparation of cost estimate for works;
- Approval of cost estimate and procurement process;
- Preparation of bidding documents;
- Approval of bidding documents;
- Publication of procurement notice;
- Issuance of bidding documents;
- Pre-bid meeting;
- Response of quarry raised in pre-bid meeting;
- Receipt and opening of tenders;
- Evaluation of tenders and recommendation for award.

21.2 Contract Packaging

21.2.1 Methodology

As outlined above, these project works will be procured using the "Single Stage – Two Envelope Bidding Process" (post-qualification) based on the Standard Bidding Document of World Bank.

For Open Competitive Bidding (OCB) procedure, the SBD **"Procurement of Works-without pre-qualification: Single-Envelop Bidding Process"**, issued by World Bank dated January 2021 shall be used.

The formation of contract packages in relation to these roads is thus based on the desired contract value and continuity in geographic considerations.

21.2.2 Salient Feature

The Butwal-Gorusinghe (Imiliya) Sector of East-West Highway is 50.00 km long, which starts from Butwal (Km 590+000) and ends at Imiliya (Km 640+000). The road section with an estimated construction cost of about **NRs: 15792.95** million has been divided into Three (2) nos of Contract lots under One (1) Package.

This section contains the criteria to determine the lowest evaluated bid and the qualifications of the Bidder to perform the contract.

Section 4: Bidding Forms (BDF)

This section contains the forms to be completed by the Bidder and submitted as part of its Bid.

Section 5: Eligible Countries (ELC)

This section contains the list of eligible countries.

PART II REQUIREMENTS

Section 6: Employer's Requirements (ERQ)

Section 6A: Summary of Description of Works
Section 6B: Standard Specifications
Section 6C: Special Provisions to Standard Specifications
Section 6D: Drawings (In Separate Volume)
Section 6E: Personnel Requirements
Section 6F: Equipment Requirements

This section contains the Specifications, Drawings, and Supplementary Information that describe the Works to be procured, Personnel Requirements, and Equipment Requirements.

PART III CONDITIONS OF CONTRACT AND CONTRACT FORMS

Section 7: General Conditions of Contract (GCC)

This section contains the general clauses that govern the Contract. These General Conditions shall be the Conditions of Contract for Construction, "For Building and Engineering Works Designed by Employer-Red Book". These Conditions are subject to the variations and additions set out in Section 8 (Particular Conditions of Contract).

Section 8: Particular Conditions of Contract (PCC)

This section contains provisions that are specific to each contract and that modify or supplement the General Conditions of Contract. Whenever there is a conflict, the provisions herein shall prevail over those in the General Conditions of Contract.

Section 9: Contract Forms (COF)

This section contains forms that, once completed, will form part of the Contract. The forms for Performance Security and Advance Payment Security, when required, shall only be completed by the successful Bidder after contract award.

21.4 Qualification of Bidders

The bidders shall satisfy the qualification criteria as proposed and stated in Part-I, Section-3 of Bid Document as follows:

- **Eligibility**
  - Nationality
  - Conflict of Interest
  - World Eligibility
  - Government owned Entity
  - United Nations Eligibility

- **Historical Contract Non-Performance**
  - History of Non-Performing Contracts
  - Suspension Based on Execution of Bid-Securing Declaration

- **Financial Situation**
  - Historical Financial Performance
  - Average Annual Construction Turnover
  - Financial Resources

- **Construction Experience**
  - Contract of Similar Size and Nature
  - Construction Experience in Key Activities

21.5 Evaluation of Bid

Information relating to the examination, evaluation, comparison, and post-qualification of Bids and recommendation of contract award, shall not be disclosed to Bidders or any other persons not officially concerned with such process until information on the Contract award is communicated to all Bidders.

21.5.1 Evaluation of Technical Bid

The Technical Bid shall be examined to confirm that all documents and technical documentation requested in ITB have been provided, and to determine the completeness of each document submitted.

Following documents and information provided in the Technical Bid shall be confirm. If any of these documents or information is missing, the offer shall be rejected.

(a) Letter of Technical Bid;

(b) Written confirmation of authorization to commit the Bidder;

(c) Bid Security or Bid-Securing Declaration, if applicable; and

(d) Technical Proposal in accordance with ITB.

Bid's responsiveness shall determine based on the contents of the bid itself, as defined in ITB. A substantially responsive Technical Bid is one that meets the requirements of the Bidding Document without material deviation, reservation, or omission.

The technical aspects of the Bid submitted shall examine in accordance with ITB, Technical Proposal, in particular, to confirm that all requirements of Section 6 (Employer's Requirements) have been met without any material deviation, reservation, or reservation.

If a Bid is not substantially responsive to the requirements of the Bidding Document, it shall be rejected and may not subsequently be made responsive by correction of the material deviation, reservation, or omission.

If a Bid is substantially responsive, it may waive any nonconformities in the Bid that do not constitute a material deviation, reservation, or omission.

Provided that a Technical Bid is substantially responsive, the Bidder may request that the to submit the necessary information or documentation, within a reasonable period of time, to rectify nonmaterial nonconformities in the Technical Bid related to documentation requirements. Requesting information or documentation on such nonconformities shall not be related to any aspect of the Price Bid. Failure of the Bidder to comply with the request may result in the rejection of its Bid.

During the evaluation of Technical Bids whether Bidders meet the qualifying criteria specified in Section 3 (Evaluation and Qualification Criteria) shall determine.

The determination shall be based upon an examination of the documentary evidence of the Bidder's qualifications submitted by the Bidder, pursuant to ITB. Unless permitted in the BDS, the determination shall not take into consideration the qualifications of other firms such as the Bidder's subsidiaries, parent entities, affiliates, subcontractors (other than Specialist Subcontractors if permitted in ITB of the Bidding document), or any other firm(s) different from the Bidder.

An affirmative determination shall be a prerequisite for the opening and evaluation of a Bidder's Price Bid. The Employer reserves the right to reject the bid of any bidder found to be in circumstances described in GCC. A negative determination shall result into the disqualification of the Bid, in which event the unopened Price Bid shall return to the Bidder.

21.5.2 Evaluation and Comparison of Price Bids

The criteria and methodologies listed in ITB shall be used. No other evaluation criteria or methodologies shall be permitted.

During the evaluation of Price Bids, the Employer shall correct arithmetical errors on the following basis:

a. If there is a discrepancy between the unit price and the total price that is obtained by multiplying the unit price and quantity, the unit price shall prevail and the total price shall be corrected, unless there is an obvious misplacement of the decimal point in the unit price, in which case the total price as quoted shall govern and the unit price shall be corrected.

b. If there is an error in a total corresponding to the addition or subtraction of subtotals, the subtotals shall prevail and the total shall be corrected.

c. If there is a discrepancy between the bid price in the Summary of Bill of Quantities and the bid amount in item (c) of the Letter of Price Bid, the bid price in the Summary of Bill of Quantities will prevail and the bid amount in item (c) of the Letter of Price Bid will be corrected.

d. If there is a discrepancy between words and figures, the amount in words shall prevail, unless the amount expressed in words is related to an arithmetic error, in which case the amount in figures shall prevail subject to (a), (b) and (c) above.

Provided that a Technical Bidis substantially responsive, quantifiable nonmaterial nonconformities related to the Bid Price shall rectify. To this effect, the Bid Price shall be adjusted, for comparison purposes only, to reflect the price of a missing or non-conforming item or component. The adjustment shall be made using the method indicated in Section 3 (Evaluation and Qualification Criteria).

If the Bidder that submitted the lowest evaluated bid does not accept the correction of errors, its Bid shall be disqualified and its bid security may be forfeited or its Bid-Securing Declaration executed.

For evaluation and comparison purposes, the currency (ies) of the Bid shall be converted into a single currency as specified in the BDS.

To evaluate the Price Bid, following shall consider:

a. The bid price, excluding Provisional Sums and the provision, if any, for contingencies in the Summary Bill of Quantities, but including Day work items, where priced competitively;

b. Price adjustment for correction of arithmetic errors in accordance with ITB;

c. Price adjustment due to discounts offered in accordance with ITB;

d. Converting the amount resulting from applying (a) to (c) above, if relevant, to a single currency in accordance with ITB;

e. Adjustment for nonconformities in accordance with ITB;

f. Assessment whether the bid is abnormally low in accordance with ITB; and

g. Application of all the evaluation factors indicated in Section 3 (Evaluation and Qualification Criteria).

The estimated effect of the price adjustment provisions of the Conditions of Contract, applied over the period of execution of the Contract, shall not be taken into account in bid evaluation.

If the Bidding Document allows Bidders to quote separate prices for different contracts, and the award to a single Bidder of multiple contracts, the methodology to determine the lowest evaluated price of the contract combinations, including any discounts offered in the Letter of Price Bid, is specified in Section 3 (Evaluation and Qualification Criteria).

All substantially responsive Bids shall compare to determine the lowest evaluated Bid price, in accordance with ITB.

21.6 Project Implementation Schedule

Government of Nepal
Ministry of Physical Infrastructure and Transport
Department of Roads
Project Directorate (ADB)

CONSTRUCTION SCHEDULE OF DETAILED DESIGN OF ROAD_3 with BRIDGES (Butwal - Gorusinghe Sector 50 Km)

Project : Consulting Services of Project Preparatory Consultant under SASEC HIGHWAY IMPROVEMENT PROJECT (SHIP-PPC)

Period Highlight:	Plan Duration	Actual Start	% Complete	Actual (beyond plan)	% Complete (beyond plan)
[illegible]					

TASK DESCRIPTION	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Construction Phase - Construction Activities					
Site Clearance	1	6			
Earthwork Excavation	3	12			
Cross Drainage Structures	3	18			
Bridges Construction	3	30			
Retaining Structures	14	12			
Side and Drainage Structures	12	18			
Road Pavement Structures	18	16			
Bio-engineering	22	10			
Traffic Safety, Painting & Road Furniture	18	19			

MONTHS

2023				2024												2025												2026							
Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36

Figure 21.1: Project Implementation Schedule

SECTION VII: ECONOMIC AND FINANCIAL ANALYSIS

22 Economic Analysis

22.1 Approach and Methodology

22.1.1 Approach

An economic analysis has been carried out to judge the project by comparing the costs to the project with the benefits arising from the project's effect.

The project costs have been divided into existing road improvement and maintenance costs. Benefits have been analyzed in three categories: Travel Operating Costs, Travel Time Costs, and Accident Costs.

Road expansion and existing road improvement costs have been calculated through the design process. Road maintenance costs have been calculated using the HDM4 model (Highway Development and Management).

Benefits are expected to arise from the improvement of travel speed and capacity caused by expanding the existing 2 lanes to the 4~6 lanes, reflecting the reduction of travel operating costs and reducing travel time costs. Also, the reduction of accident costs caused by the decrease in the traffic accident rate due to the lane expansion has been reflected.

HDM 4 MODEL was used for the calculation and comparison of costs and benefits.

22.1.2 Assumptions

a) Shadow Exchange Rate Factor (SERF)

For imported materials, the Shadow Exchange Rate Factor (SERF), a coefficient to exclude the effect of exchange rates, has been calculated as 1.12, as shown in the table below.

Table 22.1: Calculation Shadow Exchange Rate Factor (SERF) (unit: NRs. In million)

Year	Export	Import	Export Duty	Import Duty	Total Trade	Net Trade Taxes	SCF	SERF
2013-14	91,991	714,366	1,065	64,122	806,357	65,187	0.92	1.09
2014-15	85,319	774,684	310	70,528	860,003	70,838	0.92	1.09
2015-16	70,117	773,599	156	77,803	843,716	77,959	0.91	1.10
2016-17	73,049	990,113	126	98,387	1,063,162	98,512	0.91	1.10
2017-18	81,360	1,245,103	99	121,608	1,326,463	121,707	0.91	1.10
2018-19	27,287	356,902	238	137,008	384,189	137,245	0.64	1.56
Total	429,124	4,854,767	1,994	569,455	5,283,891	571,449	0.89	1.12

Note: -SCF (Standard Conversion Factor)

- SCF = (Imports+ Exports)/((Imports + Import taxes and duties) + (Exports – Export Taxes and duties))

- SERF = 1/SCF

Source: Economic Report, Nepal Rastra Bank

b) Standard Conversion Factor (SCF) for Construction and Maintenance Costs

The SCF (Standard Conversion Factor), a coefficient for calculating the economic cost of project and maintenance expenses, has been calculated as 0.83, as shown in the table below.

Table 22.2: Calculation Standard Conversion Factor (SCF) for Construction and Maintenance Costs

Item	Details	Composition	Financial Cost (NRs.)(a)	Shadow Factor(b)	Economic Cost (NRs.)(a*b=c)
Base Cost			100		
Tradable goods		20.0%	20		
	- Cost		16	1.12	18
	- Taxes and Duties	18.0%	4		
Skilled labor		15.0%	15	1.00	15
Unskilled labor		5.0%	5	0.75	4
Non-tradable goods		60.0%	60		
	- Cost		46	1.00	46
	- Taxes and Duties	23.0%	14		
Total Cost			100		83
	Standard Conversion Factor (SCF) =				0.83

Source: Construction companies, consultants etc.

The SWR (Shadow Wage Rate), a coefficient for calculating the difference of economic wage value of the casual unskilled labor and full-time worker, has been calculated as 0.76 (= (0.79+0.73)/2), as shown in the table below.

Table 22.3: Calculation Shadow wage rate (SWR)

・ Based on the ADB guideline

Item	Monthly casual earnings[1)] (Rp/Month) (a)	Minimum wage[2)] (Rp/Month) (b)	SWR (a/b)
value	10,646	13,450	0.79

Note: - The earnings of the bottom 25%, 10,646, was used as monthly casual earnings

Source: 1) Report on the Nepal Labour Force Survey 2017/2018, Nepal Central Bureau of Statistics, p.113 (https://cbs.gov.np/wp-content/upLoads/2019/05/Nepal-Labour-Force-Survey-2017_18-Report.pdf)

2) Nepal Labor Act 2074(2017) (https://dlca.logcluster.org/display/public/DLCA/3.3+Nepal+Manual+Labor)

Table 22.4 Base on the unskilled labor & skilled labor wage

Item	Cost (Rp/day)		SWR
unskilled labor	595	595 (a)	0.76 (a/b)
semi-skilled labor	718	780 (b) (= (718+842)/2)	
skilled labor	842		

Source: https://dlca.logcluster.org/display/public/DLCA/3.3+Nepal+Manual+Labor

c) Discount rate and Interest rate

As for the social discount rate, 9.0% has been applied by referring to Nepal Rastra Bank's interest rate and the discount rate in the ADB guidelines.

Table 22.5: Discount rate (unit: %)

Nepal Rastra Bank		ADB	Apply
Fixed deposit	Lending rate		
8.37	9.52	9.00	9.00%

Source: - https://www.nrb.org.np/cmfm_rates/lending_rates, visit 27th Jan.
-ADB, Guidelines for the Economic analysis of projects, 2017, p139

d) Analysis period

The analysis period has been applied for 20 years after the road's opening, considering the road's design life.

e) Salvage value

Since the analysis period is applied to fit the road 20 years' design life, it has been analyzed that there is no salvage value for road. But it is assumed 40-year design life for the structures such as bridges. The salvage value for the structures was calculated using straight-line depreciation. And it accounted for 7.70% of the total economic cost.

Design life of the structures (year)(a)	Analysis period (year)	remaining design life (year)(b)	Ratio of remaining life(c=b/a)	Asset value of structure(d) (Rp. Million)1)	salvage value(e) (Rp. Million) (c*d)	Salvage value 2)
40	20	20	0.50	2,577	1,289	7.60%

Note: 1) Refer to the bridge cost of the project cost table below
*2) 0.0760 = (1,289 * SCF (0.83)) / 14108(economic project cost)*

22.2 Input for HDM4 Model

22.2.1 Vehicle Fleet

Vehicle fleet details have been prepared based on traffic category in the traffic count Survey. The basic and economic characteristics of vehicles used in the analysis are presented in the table below.

Table 22.6: Vehicle fleet Attributes: Basic

ID	TYPE	Physical			Utilization						Loading	
		PCSE	No. of wheels	No. of Axles	Km driven/ Year (km)	Hour driven/ Year (hrs)	Service life (years)	Private use (%)	No. of passengers (persons)	Work related passenger -trips (%)	ESAL	Operating weight (tones)
1	Multi axle Truck	1.6	10	3	60,000	2,000	15	0%	0	0.0%	14.0	24.0
2	Heavy Truck	1.4	6	2	45,000	1,500	12	0%	0	0.0%	4.0	16.0
3	Mini Truck	1.3	6	2	40,000	1,350	12	0%	0	0.0%	0.2	6.0
4	Bus	1.6	6	2	60,000	2,000	10	0%	40	40.0%	0.3	7.5
5	Mini Bus	1.5	6	2	50,000	1,750	10	0%	25	40.0%	0.1	6.0
6	Micro Bus	1.4	4	2	45,000	1,500	10	0%	13	40.0%	0.0	2.5
7	4- Wheel Drive	1.0	4	2	30,000	1,300	10	50%	5	60.0%	0.0	1.8
8	Utility Vehicle	1.0	4	2	30,000	1,300	10	50%	0	60.0%	0.0	1.5
9	Car	1.0	4	2	20,000	550	10	50%	3	25.0%	0.0	1.2
10	Motorcycle	0.5	2	2	10,000	300	10	100%	1.5	50.0%	0.0	0.15

Table 22.7: Vehicle fleet Attributes: Economic unit costs

ID	Vehicle type	New vehicle price (NRs. / unit)	Replace Tyre (NRs. / unit)	Fuel (NRs. / litre)	Main. Labor (NRs. / unit)	Crew wage (NRs. / unit)	Annual overhead (%)	Annual interest (%)	Passenger Work Time (NRs. / hour)	Passenger non-work Time (NRs. / hour)	Cargo holding time (NRs. / hour)
1	Multi axle Truck	3,054,358	32,985	52.0	289.1	481.9	0.0	9.0	0.0	0.0	135.0
2	Heavy Truck	2,511,706	27,514	52.0	278.5	464.2	0.0	9.0	0.0	0.0	84.4
3	Mini Truck	1,262,818	11,826	52.0	253.9	423.1	0.0	9.0	0.0	0.0	28.1
4	Bus	2,877,609	20,917	52.0	398.9	664.9	0.0	9.0	115.7	28.9	0.0
5	Mini Bus	1,241,994	11,826	52.0	195.9	326.4	0.0	9.0	115.7	28.9	0.0
6	Micro Bus	1,619,123	7,241	52.0	299.5	499.2	0.0	9.0	115.7	28.9	0.0
7	4- Wheel Drive Vehicle	2,463,163	8,447	52.9	299.5	0.0	0.0	9.0	253.8	63.5	0.0
8	Utility Vehicle	1,000,660	8,447	52.0	299.5	761.7	0.0	9.0	0.0	0.0	14.1
9	Car	919,264	4,774	52.9	299.5	0.0	0.0	9.0	253.8	63.5	0.0
10	Motorcycle	124,391	2,615	52.9	450.0	0.0	0.0	9.0	152.4	38.1	0.0

Sources: Dealers, Nepal Oil Corporation

22.2.2 Passenger & Cargo time Value

a. Passenger time value

The passenger time value by vehicles has been calculated using the wage rate method. The GDP per capita-based wage was used as the wage. To determine the relationship between the value of time derived by GDP per capita-based wage and the actual value of time, the study team gathered previous studies and figured out the weightage. And then, the passenger time value was calculated. The calculation is as below.

Table 22.8: Calculation GDP-based value of time

Items	2016	2017	2021
GDP (NRs, million) (a)	2,608,184	3,077,145	4,266,320
Population (million) (b)	28.47	28.88	30.53
Labor force participation rate(c)	85.1%	85.3%	85.7%
Labor force participation(million)(d=b*c)	24.23	24.63	26.16
unemployment rate(e)	2.9%	3.3%	5.1%
Working labor force(million)(f=d*e)	23.52	23.82	24.83
GDP(NRs)/capita(g=a/f)	110,869	129,176	171,844
Working hour/year(h)	2,000	2,000	2,000
Basic Working Time travel cost (NRs.)(i=g/h)	55.4	64.6	85.9
Social Overhead Cost Factor(j)	0.33	0.33	0.33
Value of Working Time/Hour (NRs.) (i*(1+j))	73.7	85.9	114.3

Note: - working hour/year = 250day*8hour

- Social overhead cost is used to identify the source of certain basic services required in the production such as transportation, communication, social welfare, and power facilities.

Source: - GDP is referred to National accounts of Nepal 2020/2021, Table 8.

-Population is referred to in the report, National Population and Housing Census 2011 (Population Projection 2011-2031), p11.

- Labor force participation rate, total (% of total population ages 15-64) (modeled ILO estimate) - Nepal | Data (worldbank.org)

- Unemployment, total (% of total labor force) (modeled ILO estimate) - Nepal | Data (worldbank.org)

Table 22.9: Calculation Weightage between GDP-based value of time and the value of time of previous studies

Items	Value of time (NRs. / h)		Ratio(/a)		Weightage
	Report 1	Report 2	Report 1	Report 2	
Motorcycle	104.00	108.00	1.41	1.26	1.33
Car / 4WD	173.00	180.00	2.35	2.10	2.22
Bus	78.00	83.00	1.06	0.97	1.01
VOT of derived by GDP per capita(a)	73.73	85.90			

Source: -Report1 is the report, SASEC Roads Improvement Project (RRP NEP 48337, Economic and

Financial analysis, 2016)

-Report2 is the report, Rural Connectivity Improvement Project (RRP NEP 48218, Economic and Financial analysis, 2017)

Table 22.10: Calculation passenger time value

Items	VOT of GDP per capita (2021)	weightage	Working Time travel cost (NRs)	non-working (NRs)	Passengers in Working Time (%)	Number of Passengers/ Vehicle	Total Value of Passengers Time/veh.
Motorcycle	114.3	1.33	152.4	38.1	0.50	1.5	142.9
Car		2.22	253.8	63.5	0.25	3.0	333.1
4WD/UV		2.22	253.8	63.5	0.60	5.0	888.3
Micro		1.01	115.7	28.9	0.40	13.0	827.0
Bus		1.01	115.7	28.9	0.40	40.0	2,544.6
Mini Bus		1.01	115.7	28.9	0.40	25.0	1,590.4

Note: - non-working time = working time value * 0.25

b. Cargo time value

The cargo time value by vehicles has been calculated using the opportunity cost method. The details are presented in the table below.

Table 22.11: Calculation Cargo time value

Items	Description	Multi axle truck	Medium Truck	Light Truck	utility vehicle
Xh	Average load in the vehicle type (ton)	24.0	15.0	5.0	
Vavg	Average value of commodity per ton (NRs. /ton)	150,000	150,000	150,000	
Int	Interest Rate in fraction	9.0%	9.0%	9.0%	
Wd	Working days in a year	300	300	300	
Wh	Working Hour per day 8 hours	8	8	8	
	Commodity Holding Cost per day	1,080	675	225	
Commodity holding cost per Hour (NRs, /veh-h) =		135	84	28	14

Source: Consultants' estimate

Note: Refer to HDM-4 MANUAL, Volume SEVEN, Modelling Road user and Environmental effects in HDM-4, p232

22.2.3 Accident rate and costs

a. Accident rate

There are few studies on accident rates and costs in Nepal, and data acquisition is not easy. However, since this project is expected to improve the traffic environment and reduce traffic accidents, the cost of traffic accidents has been calculated using direct and indirect data.

The accident rate, which represents the traffic accident rate expressed using the vehicle-km, was surveyed as 64 deaths and 104 serious injuries/100Million veh-km.

Table 22.12: Accident rate (unit: cases/100Million veh-km, 2020y)

Item	Fatal	Serious injury
Accident rate	64	104

Note: Consultants' Estimates based on the following data, Traffic Police, DoR, DoTM, Nepal Rastra Bank, International Journal of Environment Research and Public Health and RRP-SASEC Road Project-NEP 48337

Since there is no consistent data on the expected reduction rate of traffic accidents in expanding the two-lane road to four lanes, the existing research cases have been reviewed as shown in the table below.

Among the reviewed data, Nepal F/S report data has been from a specific period and region, so it is expected that regional deviations will occur. The KOREA manual refers only to Korea's case, so there will also be period and spatial shifts. In contrast, the FHWA data referenced various cases. The traffic accident rate is also within the median value of Nepal and Korea cases, so the traffic accident reduction rate of the FHWA data has been applied to this analysis.

Table 22.13: Effect on the reduction of Accident rate

Item	Fatal	Injury
F/S Report1)	50.0%	50.0%
FHWA2)	39.0%	23.0%
KOREA EVALUATION MANUAL3)	68.0%	29.0%
Apply	39.0%	23.0%

Source: 1) IDA, FEASIBILITY STUDY REPORT FOR UPGRADING OF Birgunj to Narayanghat Section, July 2011, p12-10

2) FHWA, Toolbox of Countermeasures and Their Potential effectiveness for Roadway Departure Crashes, August 2008, p6

3) MoLIT, KOREA, Evaluation Manual for Transport Facility, June 2017, p198

Table 22.14: Before and After Accident rate (unit: cases/100Million veh-km)

Item	Fatal	Serious Injury
Before (Two lanes)	64.0	104.0
After (Four lanes)	39.0	80.1

Source: Consultants' Estimates

b. Accident cost

Accident cost has been calculated using related data like the accident rate, and as of 2020, deaths were 1,080 thousand NRs. /Person, and serious injuries were 350 NRs.

Table 22.15: Accident cost

Item	Death	Serious injury
Cost (thousand NRs. /person)	1,080	350

Note: Consultants' Estimates based on the following data, Traffic Police, DoR, DoTM, Nepal Rastra Bank, International Journal of Environment Research and Public Health and RRP-SASEC Road Project-NEP 48337

22.3 Economic Analysis

To analyze the project's economic feasibility, the cost and benefits have been analyzed by setting the alternatives shown in the table below.

The project road is expected to reduce travel time cost and vehicle operation cost by improving travel speed and capacity due to expansion of the number of lanes and improvement of existing road.

Table 22.16: Alternatives for economic analysis

Alternatives		Work measures
Base	Keep two-way 2 lanes	Routine maintenance (Edge repair, pothole & crack patch etc.) Periodic maintenance (Thin overlay)

Add lane	Widen two-way 4~6 lanes	Routine maintenance (Edge repair, pothole & crack patch etc.) Periodic maintenance (Thin overlay, structure overlay)

22.3.1 Vehicle Operating Costs

a. Road conditions

The whole section of proposed road was analyzed by dividing it into 5 sections as shown in the table below according to the Department of Road's SSRN data. The number of lanes is two lanes in both directions, and the road width is about 9.2m.

Table 22.17: Road Section

ID			H0146	H0147	H0148	H0149	H0150
Section			Butwal-Bamaha Khola	Bamaha Khola-Kothi River	Kothi River-Jitpur	Jitpur-Gorusinge	Gorusinge-Chanauta
Distance		km	9.54	17.24	4.92	14.6	4.03
Cross-section	Shoulder	m	1.0	1.0	1.0	1.0	1.0
	Carriage way	m	3.6	3.6	3.6	3.6	3.6
	Median	m	0.0	0.0	0.0	0.0	0.0
	Carriage way	m	3.6	3.6	3.6	3.6	3.6
	Shoulder	m	0.0	1.0	1.0	1.0	1.0
	Total	m	8.2	9.2	9.2	9.2	9.2
Number of lanes			2	2	2	2	2

Source: Field survey

The proposed road is located on a plain terrain and has a mostly straight and level road alignment.

Table 22.18: Geometry of Road

Item	Unit	H0146	H0147	H0148	H0149	H0150
Section		Butwal-Bamaha Khola	Bamaha Khola-Kothi River	Kothi River-Jitpur	Jitpur-Gorusinge	Gorusinge-Chanauta
Cumulative Rise and Fall	m/km	11.0	5.8	2.4	3.4	9.9
Number of Rise+ Fall	place/km	8	7	4	8	7
Super elevation	%	2.5	2.5	2.5	2.5	2.5
Cumulative curvature	deg/km	43.0	35.4	18.3	30.5	29.8
Speed limit	km/h	60	60	60	60	60
Altitude	m	146	122	137	113	104

Source: Field survey

As for the condition of the proposed road, IRI has been found to be between 8 and 11, maintaining the road level of "good" and "poor."

Table 22.19: Road Condition

Item	Unit	H0146	H0147	H0148	H0149	H0150
Section		**Butwal-Bamaha Khola**	**Bamaha Khola-Kothi River**	**Kothi River-Jitpur**	**Jitpur-Gorusinge**	**Gorusinge-Chanauta**
Pavement material		DBST	DBST	DBST	DBST	DBST
IRI		7.79	8.16	8.57	10.30	10.80
SN		3.21	3.21	3.21	3.21	3.21
Cracks	%	10.0	10.0	8.0	5.0	5.0
Raveling area	%	5.0	5.0	3.0	2.0	2.0
Potholes	number/km	5	3	4	6	6
Edge Break	m^2/km	110	112	100	80	80
Rut depth	mm	6	5	5	4	3
Drainage	good/ fair/poor	poor	fair	good	good	good

Note: -DBST: Double Bituminous Surface Treatment, AC: Asphalt Concrete

b. Vehicle operating costs

As a result of the HDM 4 analysis, it has been analyzed that the vehicle operating cost per km of proposed road due to the project implementation would result in a reduction of 38 to 57 NRs. /Veh-km.

Table 22.20: Reduction in Vehicle Operating Cost per km: (unit: NRs/veh-km, 2029y)

Alternative	H0146	H0147	H0148	H0149	H0150
	Butwal-Bamaha Khola	**Bamaha Khola-Kothi River**	**Kothi River-Jitpur**	**Jitpur-Gorusinge**	**Gorusinge-Chanauta**
Base	294.66	294.05	275.44	277.76	284.15
Add lane	237.77	237.19	236.95	237.05	237.81
Difference	-56.89	-56.86	-38.49	-40.71	-46.34

22.3.2 Travel Time costs

a. Traffic flow patterns

To understand the traffic flow pattern of project road, the hourly distribution of statistical daily traffic data has been analyzed, and the traffic flow pattern for Inter-Urban has been constructed as shown in the table below.

Table 22.21: Traffic Flow Pattern

Period	Hours/day	% Per hour	Hours/year	% Per hour	AAHT
1	2	14.5%	730	7.3%	1.74
2	9	61.2%	3,285	6.8%	1.63
3	4	13.8%	1,460	3.5%	0.83

4	3	5.7%	1,095	1.9%	0.46
5	6	4.8%	2,190	0.8%	0.19
sum	24	100.0%	8,760	4.2%	1.00

Note: The daily traffic data of Traffic Stations 90, 92 and 94 were analyzed.

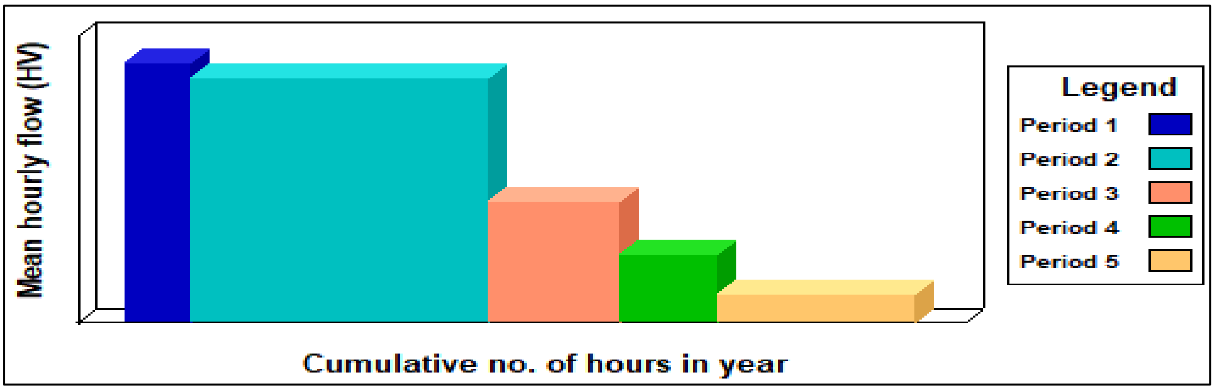


Figure 22.1: Traffic Flow Pattern

b. Traffic demand and condition

Future traffic demand is described in detail in Chapter 3 Traffic Analysis and Forecast.

c. Travel Time costs

As a result of analyzing with HDM 4, it has been determined that the vehicle travel time cost per km of proposed road due to the project implementation would reduce 39~58 NRs. /Veh-km.

Table 22.22: Reduction in Vehicle Travel Time Cost per km: (unit: NRs/veh-km, 2029y)

Alternative	H0146	H0147	H0148	H0149	H0150
	Butwal-Bamaha Khola	Bamaha Khola-Kothi River	Kothi River-Jitpur	Jitpur-Gorusinge	Gorusinge-Chanauta
Base	155.32	155.28	137.56	137.68	139.44
Add lane	98.10	97.94	97.81	97.88	98.00
Difference	-57.22	-57.34	-39.75	-39.80	-41.44

22.3.3 Road Accidents costs

As a result of the project implementation, accident cost of project road has been identified to be reduced by 5~61 million NRs/year per section.

Table 22.23: Reduction in Road Accident Costs: (unit: Million NRs/year-section, 2029y)

Alternative	H0146	H0147	H0148	H0149	H0150
	Butwal-Bamaha Khola	Bamaha Khola-Kothi River	Kothi River-Jitpur	Jitpur-Gorusinge	Gorusinge-Chanauta
Base	91.20	164.81	22.63	67.15	14.60
Add lane	57.89	104.62	14.36	42.61	9.23
Difference	-33.31	-60.19	-8.27	-24.54	-5.37

CO2 emission reduction

CO2 emissions were monetized using a unit value of $44.06 per ton of CO2 in 2021 prices, adjusted from $43.2 per ton in 2020 prices, and projected to increase by 2% annually. The project will result in a decrease in CO2 emissions, mainly as a result of the less-congested traffic resulting from the road improvement. The amount of reduction was calculated from the result of HDM4, annual emissions summary

Table 22.24: Calculation CO2 emission reduction

Id	Section	without (ton)	with (ton)	Difference	
				(ton)	Mill.USD
H0150	Gorusinge-Chanauta	318,608	286,719	-31,888	-2.29
H0149	Jitpur-Gorusinge	690,160	698,791	8,631	0.06
H0148	Kothi River-Jitpur	231,242	235,390	4,148	0.10
H0147	Bamaha Khola-Kothi River	1,367,527	1,385,162	17,635	0.90
H0146	Butwal-Bamaha Khola	757,847	766,730	8,882	0.44
Total		3,365,384	3,372,792	7,408	-0.79

22.3.4 Project costs

a. Project costs

The project cost (capital cost) consists of the costs incurred during the construction period (from 2026 to 2028). The total costs to be incurred during the construction period have been shown in the table below. The Road project would be opened to traffic in the year 2029.

The economic project cost has been calculated as 17727.14 million NRs. excluding taxes and price contingency, and the project economic cost per kilometer is 355 million NRs.

Table 22.25: Project cost: (unit: Millions of NRs.)

Item		Sum
1	General	295.22
2	Road Works	11482.11
3	Bridge, Overpass and Animal Pass Structures Works	2624.95
4	Bridge Maintenance Works	62.90

Item		Sum
5	Environmental Mitigation, wildlife friendly, Social and Bioengineering Works	55.21
6	Performance Based Maintenance Woks and Services	412.88
7	Schedule of Day Works	108.70
8	Provisional Sums	750.98
A	**Total (A)**	**15792.95**
B	Total without PS (B)	15041.97
C	Provision for Physical Contingencies @ 10% of (B)	1504.20
D	Provision for Price Escalation @ 10% of (B)	1504.20
E	Contingencies @ 4% of (B)	601.68
F	VAT @ 13% of A+C+D (E)	1955.46
G	Grand Total (T) =A+C+D+E	21358.48
	Economic cost [= (B+C+D+E)xSCF]	17727.14

Note: -15% of the environmental cost was included in the Economic cost.

Source: Consultant's estimation

Table 22.26: Economic cost per km, mil. Rs

Item	Length	Project cost		Per km	
	(km)	Financial cost	Economic cost	Financial cost	Economic cost
Road 3	50	21358.48	17727.14	427.16	354.54

The project cost input was analyzed as divided into five years.

Table 22.27: Yearly Plan for Project cost input

Year	2026	2027	2028	Sum
Ratio	30%	30%	40%	100%
Cost (Million NRs)	5318.14	5318.14	7091.86	17727.14

b. Maintenance costs

Road maintenance is divided into routine maintenance such as Potholes and Edge Break, which can be performed annually, and periodic maintenance, which has a certain period such as overlay.

Routine maintenance for before and after project implementation has been maintained the same. The thin overlay of periodic maintenance has been assumed equally before and after the project implementation, and the heavy overlay has been assumed only after the project implementation for analysis purposes.

Table 22.28: Maintenance Standards and costs

Item	Works	Interval / Intervention Level	FINANCIAL Cost/sq.m (NRs.)	ECONOMIC Cost/sq.m (NRs.)
Routine	Reseals	1-3 years	389.00	324.00
	Edge Repair	1-3 years Edge Break Area>= 5 m2/km	389.00	324.00
	Crack sealing	1-3 years Wide structure cracking >= 5%	361.00	301.00
	Pothole Repair	1-3 years Potholes >= 5 no./km	749.00	624.00
	Inlay at rut depth(20mm)	1-3 years Rut depth mean >= 20 mm	749.00	624.00
	Patching (40mm)	1-3 years Wide structure cracking >= 10%	731.00	609.00
	Patching (20mm)	1-3 years Wide structure cracking >= 5%	426.00	355.00
Periodic	Thin Overlay	5-10 years IRI => 10	1,998 .00	1,665.00
	Heavy Overlay	> 15 years IRI => 12	6,660.00	5,549.00

22.3.5 Result of Economic Analysis

a. Result of economic analysis

The project road has been found to be economically viable because the IRR is higher than the applied discount rate of 9.0% and the NPV value has a positive value.

Table 22.29: Economic Indicators Summary: (unit: Millions of NRs.)

Alt.	Present Value of total Agency costs	Present Value of Agency Capital costs	Increase in Agency Costs(C)	Decrease in User Costs(B)	Net Present Value (NPV=B-C)	Internal Rate of Return (IRR)
Base	594	481				
Add Lane	9,793	9,402	9,198	32,051	22,852	**22.2**

b. Sensitivity analysis

Sensitivity analysis has been conducted to identify how much economic feasibility can fall with changes in costs and benefits. For the sensitivity analysis, economic feasibility has been carried out, assuming the cost increased by 20% and the benefit decreased by 20%. In the worst case, the IRR is 15.4%, which is more than 9.0%, and therefore it has been found that the project is economically feasible.

Table 22.30: Sensitivity Analysis: (unit: %)

Item	Cost 0 %	Cost +10 %	Cost +20 %
Benefit - 0%	22.2	21.0	19.9
Benefit -10%	19.7	18.6	
Benefit -20%	17.4		15.4

Note: IRR was applied as an economic analysis index.

c. Conclusion of Economic analysis for Road

As described above, since this project satisfies the economic indicators even in the basic case and in the case of low demand and high cost, it is reasonable to regard it as an economic project.

d. Sustainability Analysis

The project will not generate revenue. Following ADB guidelines, the financial sustainability of the project was assessed using the sustainability of recurrent costs to be assumed by the DoR. The DoR has no financial burden for maintenance during the first 5 years as 5-year performance-based maintenance periods are included in all civil works contracts. Once the 5-year period is over, the DoR will assume responsibility for maintenance. The first 5 years of this tenure will be limited to routine interventions without major periodic interventions. Periodic interventions, including applying an overlay, will be required on an interval of 5~10 years.

The sustainability of the project was also evaluated by assessing historical budget data for road operation and maintenance at the national level. The table below summarizes the DoR's budgetary allocation and expenditure for road maintenance since fiscal year 2016. The maintenance budget increased by 21% from FY2016–FY2021. Annual expenditure varies based on actual maintenance requirements during a year; however, on an overall basis, there has been a significant increase in the maintenance budget during this period.

Table 22.31: Expenditure on National Highways Maintenance

	2016	2017	2018	2019	2020	2021	'16-'21	Rate (%)
Allocated Budget (Million. Nrs)	4,963	6,215	5,629	4,996	7,440	13,143	42,385	21.5
Expenditure, (Mil. Nrs)	2,717	3,024	3,276	3,303	3,558	5,733	21,611	16.1
Length (km)	9,449	8,216	7,707	8,411	7,955	10,117	51,855	1.4
Budget/km, (Nrs)	525,241	756,376	730,381	593,932	935,244	1,299,060	817,368	19.9
Expense/km, (Nrs)	287,518	367,998	425,123	392,716	447,327	566,621	416,755	14.5

Source: DoR, Maintenance Branch

The average annual recurrent costs of the project road are estimated at Nrs. 602,996 per km (at an estimated per km cost for routine and periodic maintenance). The average annual recurrent costs of the existing road are estimated at Nrs. 703,430 per km. Thus the project road will contribute the maintenance expenditure of DOR.

While the project' maintenance cost is may be higher than the historical expense (416,755), it is lower than the historical budget (817,368). Thus, it is expected that the project road maintenance could keep the sustainability of the project road.

The project will use high performance pavement material in construction, which is expected to increase resilience of the project road and reduce the frequency of periodic maintenance. The performance-based maintenance included in the construction contracts will support increased efficiency in routine maintenance through the engagement of the private sector in the initial years following construction. And it is expected that the budget maintenance will increase than the growth rate of the expense. It will help to keep the fair-to-good road condition.

But as the number of roads maintained by the DoR increases, adequate road maintenance funding must be in place and maintenance must be planned and implemented in a systematic manner, based on a robust maintenance budget programming framework.

e. Distribution Analysis

Distribution and poverty analysis was carried out following ADB guidelines. The share of the population living below the poverty line in the report, Poverty and Social Analysis of Butwal-Gorusinghe (Imiliya) Sector, Aprill.2022, was estimated at 17.4% in 2019 across the Nepal. In estimating the benefits accruing to the poor beneficiaries, it was assumed that (i) bus users are as poor as the general, (ii) the other passenger is as poor as half the general (iii) car owners are not poor, (iv) almost unskilled laborers involved in the project are likely to be poor.

The below table presents the distribution of the project-generated benefit of NR 14,755 million among the project beneficiaries. The estimated poverty impact ratio of 0.092 is smaller than the poverty headcount ratio (poor) of 0.174, indicating the half poor people are served by the project.

Table 22.32: Distribution Analysis and Poverty Impact Ratio (unit: Millions of NRs.)

Item	FNPV	ENPV	Difference (ENPV-FNPV)	Passenger users	Freight users	Vehicle owners	Labor	Govern ment	Total
Inflow									
Benefits		174,782	174,782	96,847	2,299	75,636			
Loan	16,254								
Outflow									
Capital&O&M	-16,254	-13,491	2,763					2,763	
Labor	-934	-710	224				224		
Net Present Value		160,581	177,769	96,847	2,299	75,636	224	2,763	

Gain and Losses	96,847	2,299	75,636	224	-14,425	160,581
Proportion of the Poor (%)	11.75%	5.00%	5.00%	90.00%	5.00%	
Net Benefits for the Poor	11,377	115	3,782	202	-721	14,755
Poverty Impact Ratio						0.092