

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

Project Preparatory Consultant (PPC-2 Road) of
Transport Project Preparatory Facility (TPPF)
(ADB GRANT NO. 0227-NEP)



**Detail Design Report
For
Upgrading of Mugling - Pokhara Road**

Volume 3.A – Main Report

**MMM Group, Canada
In association with
ITECO Nepal (P) Ltd.
Total Management Services Pvt. Ltd.
Material Test Pvt. Ltd.**

March 2018

Report Volumes

For preparing Feasibility Study and Detail Design reports, 13 nos. of project roads are divided in 3 Groups. Group 1 comprises of 3 nos. of EEAP Roads, Group 2 comprises of 3 nos. of roads to be 4-laned and Group 3 comprises of 7 nos. of other Feeder Roads.

Feasibility study report is prepared for all roads in each group as one volume. Detail Design Report for each of the 13 road sections is prepared in separate groupwise volumes.

Poverty and Social Assessment Reports are prepared in separate volumes for each of 13 roads.

Resettlement Plan and Indigenous People Plan are prepared in separate volumes for each of 13 roads.

Environmental assessment reports (IEE/EIA) for each road has been prepared as separate volume.

Bidding Documents for are prepared for each contract for works.

Detail Design Report (Group 2) for Mugling Pokhara Road has been prepared in four (4) parts of Volume 3 as detailed below:

Detail Design Report (Group 2)	Volume 3.A:	Main Report
	Volume 3.B:	Annexes (Part 1, 2 and 3)
	Volume 3.C:	Drawings Plan, Profile, Typical, Bio-engineering List of Structures etc.
	Volume 3.D:	Engineer's Estimate
	Volume 3.D.1:	Rate Analysis

DETAIL DESIGN REPORT FOR MUGLING-POKHARA ROAD

Volume 3.A: Main Report

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For Reference Only

ABBREVIATIONS

AADT	Annual Average Daily Traffic
ACV	Aggregate Crushing Value
AIV	Aggregate Impact Value
AMSL	Average Mean Sea Level
ASL	Average sea level
CBO	Community Based Organization
CBR	California Bearing Ratio
CFUG	Community Forestry Users Group
CSB	Crushed Stone Base
Cu.m	Cubic Meter
DADO	District Agriculture Development Office
DBST	Double Bituminous Surface Treatment
DCP	Dynamic Cone Penetration
DDC	District Development 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
FGD	Focus Group Discussion
GESU	Geo Environmental And Social Unit
GoN	Government Of Nepal
GPS	Global Positioning System
GSB	Gravel Sub-Base
HH	House Holds
IEE	Initial Environmental Examination
IFD	Intensity Frequency Duration
IRR	Internal Rate of Return
ISB	Improved Sub-Base
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
NAB	Natural Aggregate Base
NGO	Non Governmental Organization
NPV	Net Present Value
OD	Origin and Destination
OMC	Optimum Moisture Component
OS	Otta Seal
PI	Plasticity Index
PPC	Project Preparatory Consultant
RCC	Reinforced Cement Concrete
RL	Reduced Level
RMDP	Road Maintenance and Development Project
RoW	Right of Way
STDs	Sexually Transmitted Disease
TPPF	Transport Project Preparatory Facility
VAT	Value Added Tax
VCDP	Vulnerable Community Development Plan
VDC	Village Development Committee

EXECUTIVE SUMMARY

0.1 Brief Project Background

A contract for Consultancy Services was made on 26 June 2015 between the Department of Roads, the Client and MMM Group, Vancouver, Canada, the Consultant in association with ITECO Nepal Pvt. Ltd., Total Management Services Nepal Pvt. Ltd. and Material Test Pvt. Ltd. to carry out the Feasibility Study as well as Detailed Engineering Design for Upgrading of 3 Road sections to 4-lane highway, 7 feeder road sections to 2-lane highway (as required) and 86 bridges. Subsequently Feasibility Study and Detail Design for 3 Road Section under Earthquake Emergency Assistance Program (EEAP) was also included through a variation to the contract agreement. Thirteen road sections for which Feasibility Study as well as Detailed Design for upgrading to 2 / 4 lane standards are to be carried out as per TOR of the contract.

0.2 Existing Road

Existing road from **Mugling – Pokhara (0+000 to 90+000)** is a section of **Prithivi Highway**, designated as a National Highway; H04 as per SSRN/DoR and passes through mostly steep rocky mountainous terrain hill and terraces of river valleys sections of Tanaun and Kaski Districts. This road starts from the right bank of the Trishuli river near the location of new bridge site in Mugling (256 m amsl), Tanaun District and ends at Sahid chowk of Pokhara Bazar, at about Km 88.810 (843 m amsl) in Kaski district. This section of Prithivi Highway was constructed as a 7m wide road with Chinese Government Assistance in 1967 as bituminous road. The project road crosses 28 rivers. The road runs mostly in steep rocky hill section and river valley terraces with various land use pattern, mostly forest, urban and rural settlements, cultivated land. This road is of great importance to provide connectivity to the people of west district and tourists from Kathmandu Valley and the rest of country connect. This road is of strategic importance to boost tourism industry in the western districts of the country and is therefore proposed for 4-laning.

0.2 Design standards

Detailed Engineering Design for upgrading of the Mugling-Pokhara road to 4-lane highway is done as per the Asian Highway standards and NRS 2070. Detail design for the other road sections has been carried out as per latest Nepal Road Standards. Reference has also been made to the AASHTO, BS, TRRL and IRC standards as required. For design of bridges Nepal Bridge Standards (2010) has been followed and reference has been made to the IRC, BS and AASHTO standards as required

0.3 Survey and Investigation

The consultants are engaged for feasibility study as well as detailed engineering design, therefore they carried out, at the feasibility study phase, surveys and investigatory work to the level of design as per ToR requirements. Consultants carried out detailed assessment of condition of existing road, structures, bridges, pavement, drainage capacity and adequacy of existing structures; topographical and hydrographical surveys; Geotechnical Investigation of Subsoil for road and bridges; traffic and axle load surveys; soil and materials sampling and testing ; road safety audits; collection of secondary data and reports from different sources.

0.4 Material Investigation

Consultants also carried out through investigations for materials along the road corridor. Along the road, and materials are available from Marsangadi river (km 10), Maadi river (km 42) and Seti river (km 71) etc. along the alignment. Most of the materials available are weathered rocks and river bed gravel

only. Materials from 3 main quarry sources have collected and tested. Embankment fill materials are to be obtained from cut sections, hill sections where available and from private land owners after paying the owners.

0.5 Geological Study

Mugling-Damauli-Pokhara road alignment lies in high-low to medium hazard zone, of the total length less than 1% of the alignment passes through high hazard area and includes the active rock fall/landslide in between Mugling-Abukhaireni, the slumping of road edge around Niure-Rithepani.

About 10% of the alignment passes through medium hard zone where uphill slope excavation during widening can induce slope failure involving colluvial, alluvial, residual and slope scree material, the alignment between Ch 8+850 to Ch 9+975, Ch42+725 to Ch 48+125, Ch 53+175 to Ch 53+375, 59+700 to Ch60+900 and Ch 71+500 to Ch72+375 are identified as the terrain with possibility of instabilities induced during hill ward excavation. The instabilities will be of shallow depth and can be treated with minor engineering means involving retaining and breast wall, masonry wall etc. and bioengineering. The instabilities in the rocky terrain can be corrected by proper slope trimming, shortcreting and construction of retaining and breast wall.

Rock weathering, precipitation, groundwater, under cutting of slope for road construction, poor surface water management and gully erosion are the main cause of instability. At moments most of the cut slopes are in stable conditons.

0.6 Road safety

This road is being designed for a speed of 60 / 40 kmph based on the terrain, accordingly safety requirements along the road are studied in detail. During the preliminary design process necessary safety provisions like safe junctions, vehicles U turning locations, pedestrian crossings etc. has been made at required locations in the design. Further safety measures provided include road signs, delineators, chevron signs, w-beam crash barriers, gabion crash barriers, road marking, speed restrictions in busy areas etc.

0.7 Alignment design

Detailed Engineering Design for upgrading of the Mugling - Pokhara road to 4-lane highway is proposed as per Nepal Road Standards. Reference has also been made to the AASHTO, BS, TRRL and IRC standards as required. For design of bridges Nepal Bridge Standards (2010) has been followed and reference has been made to the IRC, BS and AASHTO standards as required.

Hence the geometric design standard for this road generally has been followed as for the Class II and III road as under NRS 2070. Reference to AASHTO "A policy on Geometric Design of Highway and Streets" 2001 and Overseas Road Note 6 "A Guide to Geometric Design" published by TRRL 1988 has been made as required. For Traffic sign and road marking design, DOR Traffic Manual 2007 has been followed. The design speed of road for plain and rolling section has been 60km /hour and for hill section, it is 40 km /hour.

In double lane section, total road width of 9m, 7m and 12.5 meter has been adopted and total **double lane=8.250km**

Cross section features adopted for in 4 lane from Abu Khaireni to Bijayapur seti Bridge start are summarized under.

A. Rural and forest area, Abukhareni-Dumre (15.15km), Dumre-Damauli-Bazar (16.48km) and Damauli-Dulegauda (20.300km). Total road width=18m and total km=51.930.
--

Formation Width	:	Total= $4 \times 3.5 + 2 \times 0.5$ (kerb shyness) + 1 (Median) + 2×1.0 (shoulder) = 18m
Service lane	:	-
Shoulders	:	Paved 1.0 m both side
Pavement Camber	:	2.5 % on either sides from centre
B. Bazar area, Dumre Bazar (550m) and Damauli Bazar (970m) .Total road width=42.5m and total km=1.520 km		
Formation Width	:	Total= $4 \times 3.5 + 2 \times 0.5$ (kerb shyness) + 1 (Median) + $2 \times 2.5.0$ (shoulder) + NJ Barrier (0.75/.75m) + service road (6m/6m) + footpath (2/2m) + drain in both side (1/1m) = 42.5 m
Shoulders	:	Paved 2.5m both side,
Pavement Camber	:	2.5% on either sides from centre
C. Bazar area, Dulegauda, Belchautara and Thati Bazar (5.040 km), Gagangauda-Sainik basti (2.34km), Kotrebazar (300 m). Bhandarik - Bijayapur (6.910km) and Bijayapur (84+570 to 88+583) to start of seti bridge (4.013km), Total road width=46.2m and total km=18.603 km		
Formation Width	:	Total= $4 \times 3.5 + 2 \times 0.5$ (kerb shyness) + 3 (Median) + $2 \times 2.5.0 + 2 \times 0.60$ (shoulder+curbschy) + service road+ curbschy (6m/6m+ 2×0.60) + footpath (2/2m) + drain in bothside (2.4/2.4m) = 46.2 m
Service road	:	6m/6m both side
Shoulders	:	Paved 2.5/2.5m both side
Pavement Camber	:	2.5 % on either sides from centre
D. Rural area,Thati-Kotre Bazar(3.470km),Kotre-Gagangauda(4.090km) and Bijayapur(650m) Total road width=23.0m and total km=8.210 km		
Formation Width	:	Total= $4 \times 3.5 + 2 \times 0.5$ (kerb shyness) + 3m (Median) + $2 \times 2.5.0$ (shoulder) = 23.0m
Shoulders	:	Paved 2.5m both side,
Pavement Camber	:	2.5% on either sides from centre

There are 10 no of major junction out of 10 there are 4 way Junction and 6 no of 3 way junction Similarly direct access to and from local road and drive way into main road are closed`

There are 75 locations along this road where provision of U-turn has been considered and designed. Similarly, Road furniture has been provided in the form of road signs, crash barriers, road markings, delineators, foot paths, covered side drains. Details have been given in Table below:

W beam Crash barrier (Rm)	Road marking (sqm)	Delineator post(No)	Footpath (m2) in 21.303km of service road 2m wide (sqm).	Cover side drain (m)	Tick type drain (m)	Precast kerb Stone (m)	NJ concrete Barrier (m)
87168	89591	12250	86413	6080	58610	203873	3040

Medians have been provided as per road safety requirements. In Mugling – Pokhara road sufficient traffic signs and road sign has been provided. In the design there are 1658 no of single post and 94 no of double or more posts proposed for the erection depicting different type of traffic signs. The provision for the relocation of Public Utilities has been proposed in the design and cost estimate under provisional sums.

0.8 Traffic Studies and Analysis

Three days 24 hours continuous traffic counts were conducted in Mugling Bridge West (H0405), just west from the approach, Musi Khola Bridge west (H0409), west from Damauli, Talchowk (H0411), about 500 m west from the PRM¹/ Talchowk junction and Bijayapur Khola Bridge (H0412), just east from the bridge. Traffic projections have been made for various sections for 10. 20 and 30 years in

¹PRM= Prithvi Rajmarg

PCU /day as below. It may be noted that there is very high percentage of motorcycles (30-40%) in these numbers.

Section	Year (Traffic in PCU)				
	2016	2019	2029	2034	2039
Section A: Mugling- Abukhaireni (KM 0+000~ KM 7+670)	8,156	11,175	24,322	34,790	49,972
Section B: Abukhaireni- Damauli (KM 7+670 ~ KM 41+785)	7,364	10,131	22,225	31,566	44,671
Section C: Damauli West ~ Bijayapur East (KM 41+754 ~KM 85+028)	10,240	14,188	31,960	45,803	65,212
Section D: Bijayapur West ~ Prithivi Chowk (KM 85+028 ~ KM 88+092)	17,181	24,616	61,685	92,614	137,153

Traffic loadings for pavement design, Equivalent Standard Axles (ESA) have been estimated in million standard axles (msa) for the 10 years respectively as in table below.

10 yr. ESA			
Main carriageway sections	ESA (Million)	Service roads in market area Section	ESA (M)
Section A: Mugling- Abukhaireni (KM 0+000~ KM 7+670) 2-lane	6.142099	Dumre bazar (23+.400 to 23+950)	0.3533
Section B: Abukhaireni- Damauli (KM 7+670 ~ KM 41+785) 4-lane	3.213441	Damauli to Bijayapur (in 14 locations-km 40 +430 to 83+920km)	0.298429
Section C: Damauli West ~ Bijayapur East (KM 41+754 ~KM 85+028) 4-lane	5.430349	Bijayapur to start of Seti Bridge	0.872245
Section D: Bijayapur West ~ Prithivi Chowk (KM 85+028 ~ KM 88+583)4 lane	5.28576		

0.9 Pavement Design

Pavement design has been carried out as per DoR's Pavement design Guidelines (2014), Overseas Road Note 31 (TRRL), IRC-37 (2011) for the traffic loadings given in traffic chapter. The pavement design has been adopted for whole road is as given in table below;

Pavement Details in Main Carriageway with DBST surfacing					
SN	Locations		Capping Layer	Sub Base	Base Course
	From	To	(mm)	(mm)	(mm)
1	0+000	4+000	0	250	200
2	4+000	12+000	0	250	200
3	12+000	18+000	0	325	200
4	18+000	40+000	0	325	200
5	40+000	61+700	0	325	200
6	61+700	88+583	300	325	200
Pavement Details in Service Road with DBST surfacing					
SN	Locations		Capping Layer	Sub Base	Base Course
	From	To	(mm)	(mm)	(mm)
1	23+400	23+950	0	175	150
2	40+430	41+400	0	200	150
3	61+700	66+740	0	200	150
4	70+210	70+510	0	200	150
5	74+600	76+940	0	200	150

6	77+010	83+920	0	200	150
7	84+570	88+583	0	200	150

0.10 Hydrological and Drainage Design

Hydrological studies has been carried out for the project area, based on the rainfall data collected from DHM for Damuli, Khairitar and Pokhara Airport stations and intensity duration curves are created. Design discharges are worked out using rational formula. It is planned to replace all culverts with new structures for wider / 4-lane configuration. Eight bridges with 2-lane width shall be designed as per four laning configuration of road section with Side drains in urban areas and wherever required shall be designed.

Summary of Location and No of proposed cross Drainage

Road cross sections	slab culvert					Remarks
	2m span	3m span	4 m span	5m span	6m span	
Double lane						Extend the existing slab culvert or replace with new one as per condition of existing culvert to fit in the cross section road.
width of road =9m	1	6				
width 12.5 m		4	1			
Four lane						
width18.5 m	90	65	11	2	3	
width 23 m	11	5				
width 43m			1			
width 47 m	23	5			2	
length	3008	1656.5	259	37	149.5	
No	125	85	13	2	5	
Road width of different section	7m	9m	12.5m	18.5	23m	47m
Box culvert 1.2m x1.2m	0	3	1	44	7	7
Existing Pipe culverts of 900mm dia has been proposed to replace with box culvert of 1.2mx1.2m						

0.11 Geotechnical studies and investigations

Geotechnical studies and investigations are carried out for i) Understanding of the general geology of the project area, ii) Collection of available soil and slope data in the vicinity of road area, iii) Verification of cross slope, stability conditions during field visit and with survey data and iv) Bearing capacity analysis for high retaining structure using DCPT tests etc... DCPT tests were conducted to classify soil type soil type and to evaluate bearing capacity using correlation with a penetration value on various location and grouped accordingly. For design of slopes, embankment, slope stability analysis were done and result are presented in detailed in respective chapter. The Bioengineering approach of slope stabilization is adopted in the design. The plantation of grass turfing, tree and shrubs are proposed for the stabilization of high fill slope and high cut slope of hill.

0.12 Culverts and other structures

There are 43 rivers crossings listed in the Mugling Pokhara road sector with 12 major bridges and 31 minor bridges. Out of 12 major bridges, only 8 bridges will be constructed as to cater traffic in upgrading of Mugling-Pokhara road. Trishuli River, Madi Bridge and Seti Bridge are not in the scope of the consultant. Ruwa Khola Bridge in the ch 3+764, due to Marshyangdi Power house site no addition or extension of existing bridge work has been proposed. In eight bridges, one new bridge has proposed to improve the curve. To cater the four lane traffic following two options were considered: 1) Demolish the existing structure and provide full width 4lane - new bridge; 2) provide a new 2-lane bridge at the side of the existing one, upstream or downstream as appropriate. Demolishing of the existing bridge

has to be decided as per condition survey report carried by the consultant. The condition survey report of all major bridges did not show any poor rating of bridge, which need to be replaced with new one (except one bridge at Nala (24+803km) Crack is seen in bridge deck which will be replaced by double bridge with 1.5m gap.) . Hence it was decided to provide a new bridge for the additional two lanes for major bridge .The list of proposed cross drainage structures are given in section 0.10 above.

However for minor bridges and culverts it has been proposed to demolish or extension on both side or add new bridge in downstream or upstream site or extend the existing bridge/ culvert as per the condition of structure and topography of the alignment of road . The list of structures different types of walls are given in Drawings.

0.13 Social Study

Social assessment has been made all along the 90 km length of the road by carrying out social surveys in 1297 households with population of 6828. Data collected has been analysed and findings about population structure, caste / ethnic composition, education / literacy, occupation, income, poverty status, food sufficiency, health / drinking water / sanitation condition etc. provided. This data shall work as the base line for the future assessment reviews.

0.14 Resettlement Plan and Indigenous People Assessment

Various groups of Indigenous People are found in the project districts and influence area. Most of the socio-economic status of the IP is similar to non-IP. There is not significance variation on the lifestyle of IP and non IP and have social cohesion and harmony among them.

This road has an already acquired RoW of 50m width (25m on either side of centreline). As the centreline is being kept same so there is very minimum land acquisition requirement. Regarding resettlement of affected persons a detailed survey in the field has been carried out and it is not that: Affected structures – 817 nos., land acquired – 133 land parcel with area 12,219.33sqm, and overall resettlement cost estimate is NRs1,170,604,123.40.

0.15 Environmental Assessment

As per ToR of the contract the consultant has prepared IEE including Environmental Management Plan, Environmental Monitoring Plan and its summary in accordance with ADB's Safeguard Policy Statement 2009 (SPS), ADB's Environmental Assessment Guidelines(2003) as well as Government regulations and policies and submitted to ADB.

Assessment of environmental mitigation measures has been made minimising the impact of road upgrading and EMP has been made to minimize the same

0.16 Rate analysis

From preliminary design the quantities of works have been estimated. Lead for materials sources have been taken from the nearest markets and identified quarries. It is understood that embankment fill material shall have to be purchased from locals, so necessary costs have been included. Rate analysis has been carried out using approved Norms "NORMS for RATE ANALYSIS as per Standard Specifications for Road and Bridge Works-2008" (Approved by Ministry of Physical Planning and Works, Department of Roads) and approved district rates of fiscal year 2074/75 were applied. Similarly, rates of equipment were referred to latest DOR equipment rates published by mechanical branch. Cost estimates have been made accordingly.

0.17 Procurement Works

International Competitive Bidding (ICB) with post-qualification has been selected as the preferred

method of procurement of works. Post-qualification process is focused on the bidder's capacity to successfully perform a contract based upon the qualification criteria stated in the bidding document. ADB's Standard Bidding Documents for the Procurement of Works – Single Stage: Two-Envelope Bidding Procedures – edition December 2015 has been used. Procurement for works is to be carried out for Mugling – Pokhara road in one ICB contract.

0.18 Economic Analysis

Economic analysis has been carried out for three options of MP road in feasibility study and is shown below.

Options	NPV (NRs Mill.)	EIRR%
Option I	7099.33	16.74
Option II	1233.31	12.64
Option III	10295.52	20.33

It can be seen that all of the three options tested are economically viable. The highest rate of return of 20.33% EIRR is obtained with Option III.

The detailed design report of third option is carried out. The cost estimate in the draft detailed design work is only 8.165% more than the feasibility cost of option III.

0.19 Sensitivity Tests

The impact of adjusting some of the key input values has been tested to show the sensitivity of the EIRR to the changes. The tests applied were construction costs increased by 20%, and road user costs (VOC and passenger time savings) reduced by 20%. The results are shown in table below.

Sensitivity Analysis Results (EIRR %)

Options	Base Case	Capital Costs	RUC Savings
		+20%	-20%
Option I	16.74	13.82%	13.82%
Option II	12.64	10.20%	6.49%
Option III	20.33	16.96%	12.10%

The Sensitivity Analysis Results (EIRR%) test done for FS cost as per given above table shows that 8% increase in detailed design cost of option III will be still above the EIRR limit of 12%. So, it is economically viable.

1. INTRODUCTION AND PROJECT OVERVIEW

1.1 Contract for Consultancy Services

Detail Design report has been prepared and submitted as per the requirements of the Terms of Reference, Appendix A to the agreement for the Consultancy Services for the Transport Project Preparatory Facility (TPPF), Project Preparatory Services (PPC 2) under ADB Grant: 0227 – NEP.

Professional services under the contract are provided by the MMM Group Ltd., Vancouver, Canada in association with ITECO Nepal Pvt. Ltd., Total Management Services Nepal Pvt. Ltd. and Material Test Pvt. Ltd. who are collectively referred to as the Consultant in this report. Contract agreement for the consultancy services was signed on 26 July 2015. The consultants mobilized the team and started the work on 02 August 2015.

Prior to the commencement of services, the Client instructed the Consultants to prepare a variation order for including the work of additional feasibility studies and detail design for 122 km of roads along 3 road sections funded by the Asian Development Bank (ADB) under the Earthquake Emergency Assistance Project (EEAP). Consultants prepared the VO-01 and sought an extension of time for 1 (one) month to compensate for the prevailing difficult working conditions (fuel shortages and blockade / unrest in Tarai, thereby extending the project period to 19 (nineteen) months.

1.2 Project Background

The Government of Nepal intend to review its Priority Investment Plan (2007- 2016) for the development of the strategic road network. Under the TPPF PPC 1, previous Consultants have already carried out feasibility studies for 400 km length of high priority roads. Under the current project TPPF PPC 2, Consultants were to carryout feasibility study of another 400 km length of roads and then prioritise about 400 km length of roads (refer RFP) to be taken up for improvement to 2-lane standards under the project. During the contract negotiations, Client provided list of 400 km length of prioritised roads (including about 210 km length to be 4-laned).

The Government of Nepal wants to develop tourism sector and economic activities therefore Mugling – Pokhara road has been put in high priority for the upgrading and widening of this road. The upgrading of existing Mugling- Pokhara will promote road connectivity and it has strategic importance to boost tourism sector and economic activities in western districts - Gorkha, Tanahun, Manang, Lamjung and Kaski of the country as well as connectivity to western hills. Therefore the detailed study of this road has been put under TPPF (PPC-2) for the Project Appraisal for funding of this upgrading project.

1.3 Project Objectives

Main objective of the project for the Government of Nepal is the improvement of the economic status of the people of Nepal through improvement of road network. This can be achieved by linking the roads to the remote areas, leading to faster movement of people and goods in Nepal and also in the region. Under this project it is intended to upgrade 222km length of road to 4-lane 198km of other SRN roads to 2-lane and 86 no. of bridges.

EEAP Roads: Three EEAP roads (122km) being upgraded (to intermediate lane to two lane standard bituminous roads) under this project are linking to the communities in the remote and earthquake affected areas. Much of the existing household of the poor people and other infrastructure in these areas were seriously damaged and need to re-habilitate. Improving of these roads shall facilitate the rehabilitation of the devastated populations in these areas.

SASEC Roads: Under the present scope of the SASEC Road Improvement Project it is proposed to improve the two road sections i.e. Narayanghat – Butwal Road and Bhairahawa – Lumbini – Taulihawa Road. Narayanghat – Butwal road is being improved to 4-lane road in its entire length of 114 km with asphalt concrete surfacing, service roads in urban / populated sections, at grade intersection, provision of climbing lane in hill section, adding new two lane bridges next to existing major bridges, replacing all minor bridges and culverts with 4-lane structure / bridges etc. Similarly other road to be improved under this program is also being 4-laned partially in the Bhairahawa –Lumbini section.

Consultants shall also be carrying out improvement design of remaining feeder roads as shown in **Table 1.1** as per project requirements.

For the Consultants there are two main project objectives of this study. First objective is to prepare the feasibility study report comprising of technical investigations, traffic studies, preliminary design, cost estimation, economic analysis, study of environmental and economic impacts, including resettlement and indigenous people issue. Second objective is to carry out detail engineering design, preparation of bidding documents, facilitation of bidding, evaluation and award of bids divided into appropriate size works packages suitable for International Competitive Bidding (ICB),

As per the Consultancy agreement, Consultants are required to carry out the detail engineering design, the feasibility study shall determine the optimum timing for the construction and phasing out of development if any section of the road does not justify improvement up to the desired / proposed level.

Results of this feasibility study for the project roads, including investigations and recommendations provide independent and unbiased determination of the feasibility for improving the road to desired level.

Accordingly following 13 road sections have been prioritized by the DoR for improvement under the Transport Project Preparatory Facility (TPPF), Project Preparatory Facility (PPC 2) funded by the Asian Development Bank (ADB). The list of roads proposed for upgrading to 2-lane and 4-lane design is given below.

Group	Road	Length for DD Km	
		2 lane	4 lane
1	Dolakha – Singati (2 lane)	35	
	Gorkha – Dhading (2lane)	46	
	Panchkhal– Timbu (2 lane)	41	
2	Bhairahawa – Lumbini (4 lane- 22 km): Lumbini – Taulihawa (2 lane- 23 km)	23	22
	Narayanghat – Butwal (4 lane); Feasibility all length 115 km, design 93 km only		93
	Mugling – Pokhara (4 lane)		90
3	Kanchanpur – Diman – Rajbiraj (2 lane)	22	
	Janakpur – Basbitti – Manara – Bathana (2 lane)	14	
	Khopasi – Dhunkark – Chamarangbesi – Kaleshwor Bhardev – Lele (2 lane); Length 44 km, feasibility 24 km, design 44 km	44	
	Janakpur – Kurtha – Bhramarpur – Ramgopalpar (2 lane)	20	
	Nagarkot – Banepa – Dhulikel (2 lane)	25	
	Parsa Border – Parasauni – Jagannathpur – Bara Border (2 lane)	32	
	Lahan – Bhagabanpur – Thadi (2 lane)	18	
Total	FS 527 & DD 525	320	205

1.4 Detail Design Scope

The detail design report is prepared covering all aspects of design for the road improvement to the desired standards, resettlement plan for the project affected persons and environment assessment

plan for incorporating the necessary mitigation measures into the contract for works for upgrading the road section.

The resettlement plan requires 100% assessment of the losses likely to be incurred by the persons owning the land / properties in the corridor of impact i.e. 7.5m on either side of the road centreline. Reports on environmental and social impact assessment are prepared along with design report so that necessary compensation may be made to the affected persons before start of the execution of works.

Carrying out of the detail design for the existing road section which is presently a maintained single lane gravel road, shall comprise of the following activities.

- Road inventory and condition survey
- Topographic surveys including establishing of permanent bench marks
- Preparation of digital terrain model and geometric design
- Pavement investigations and condition surveys
- Condition survey of side drains, culverts and other structures
- Traffic surveys and projections
- Finalizing of the width and other design standards
- Design of horizontal and vertical alignment
- Hydrological investigations and design of drainage structures
- Investigations for construction material sources
- Pavement design
- Design of retaining and other structures
- Design of road safety measures including road furniture and ancillary works
- Estimation of quantities, analysis of rates and cost estimate
- Carrying of economic analysis with updated costs
- Preparation of Resettlement Action Plan (RAP)
- Preparation of detail design reports

After the detail design report, bidding documents shall be prepared. As this road section is likely to be tendered as a single ICB contract package, so documents shall be prepared accordingly and bidding carried out.

1.5 Project Road Description

Mugling- Pokhara Road is a section of Prithivi Highway. Out of 174km length of Prithivi highway 90km of Prithivi highway falls under the project road: Mugling –Pokhara road.

The starting point of the road (0+000) starts from the new bridge construction site of Trishuli River towards Tanahun District and last point is Prithivi Chowk of Pokhara Bazar, a tourist city in the western Nepal. Originally construction of this road was started in 1967 with the Assistance from the Chinese Government. The construction was completed in 1974. This road passes mostly through hill sections and terraces of river valleys. The average gradient of this road is 3-4% and maximum gradient is 7% in short section. The road passes through two districts -Tanahun and Kaski. The road starts with altitude of 256m at Mugling and ascends to 843.7m elevation amsl in Pokhara bazar.

The road passes through major settlement areas: Abu Khaireni, Satrasayabhat, Bimal Nagar Dumre, Chhirkini Bhanjang, Damaili, Jamune, Kotre Dulegauda, Gagangauda, Lekhanath and Pokhara Bazar.

There are altogether 43 bridges excluding the motorable suspension bridge in Trishuli River in Mugling. There are 411 number of Pipe culverts and 138 number of slab culverts of different size.

1.6 The Existing Road

1.6.1 Topography

The topography of the project area is hill section and rolling along terrace of river valleys From Mugling to Abu Khaireni alignment passes along steep rocky section and from Abu-khaireni to Pokhara

alignment passes along hill and terraces of river valleys The road starts with altitude of 260.46m at Mugling and ascends to 843.7m elevation amyl in Pokhara bazar.

1.6.2 Climate and Rainfall

The proposed road alignment is located in midland (Middle Mountain) physiographic region. The climate of the project area is sub-tropical. Maximum temperature of the project road ranges from 35 °C to 26 °C in summer and winter the temperature range is (- 1 to 18°C) Similarly, average annual precipitation in the project district ranges from 2037.33 mm to 1701.70 mm.

1.6.3 Alignment Description

The road section was opened as bituminous paved surface with the width of 7m. The alignment initially traverses from the right bank of Marshyangdi River passing through Marshyangdi Bridge. Initially road passes through forest area and semi-urban area with Shakargaon at Ch: 2+100 with some rocky cliff area at Ch: 2+450 to 2+900, Marshyangdi Power house at Ch: 3+750. Similarly, Road alignment traverses through forest area from Ch: 3+800 with rocky cliff at Ch: 4+800 to Ch: 5+200 and Ch: 5+500 to Ch 5+800 and enters in Abhukhaireni Bazar with access to the road towards city with historical importance Gorkha Bazar at North at Ch: 6+850. Road then traverses through forest and semi urban area with Rodhi Khola Bridge at 12+900, Baradi Bazar at Ch: 15+550, Shatrashaya Phant at Ch: 16+250.. After Shatrashya phant, the alignment passes through semi forest and terraces with some scattered settlement whereas the alignment passes through narrow section with vertical cliff of lime stone deposition just before Bimal Nagar Bazar ch 21+250.

There are densely populated urban area like Anbu kharieni Bazar, Dumre Bazar (23km to 24km with houses within the RoW both side of the road alignment. There are many obstacles related to ROW clearance and social issues for upgrade of existing road. The alignment after Dumre 23+800 the alignment climbs upto 30 +500km Chirkini Bhanjang with average +3.6% grade. Road alignment from ch 30 +500 descend to Damauli Bazar (40 +150) after crossing the Madi river bridge road alignment passes through number of settlements and forest area up to Phokara Bazar. With average gradient of not 5% up and down. The major market areas along the road corridor are listed as below:

Table 1.1: Major Settlements along the Road Corridor

SN	Chainage		Remarks
	From	To	
1	6+650.00	8+050.00	Abukhaireni
2	16+700.00	17+500.00	Satrasaya Bazar
3	21+400.00	21+600.00	Bimal Nagar
4	24+410.00	24+650.00	Dumre Bazar
5	40+300.00	41+000.00	Damuli Bazar
6	53+700.00	54+060.00	Tharpu Bazar
7	61+320.00	66+500.00	Kahirenitar Bazar
8	71+800.00	84+460.00	Kotre, Dhulegaunda, Belchautar, Gagangaunda, Lekhnath
9	84+460.00	88+810.00	Talchowk, Pokhara Bazar

1.7 This Report

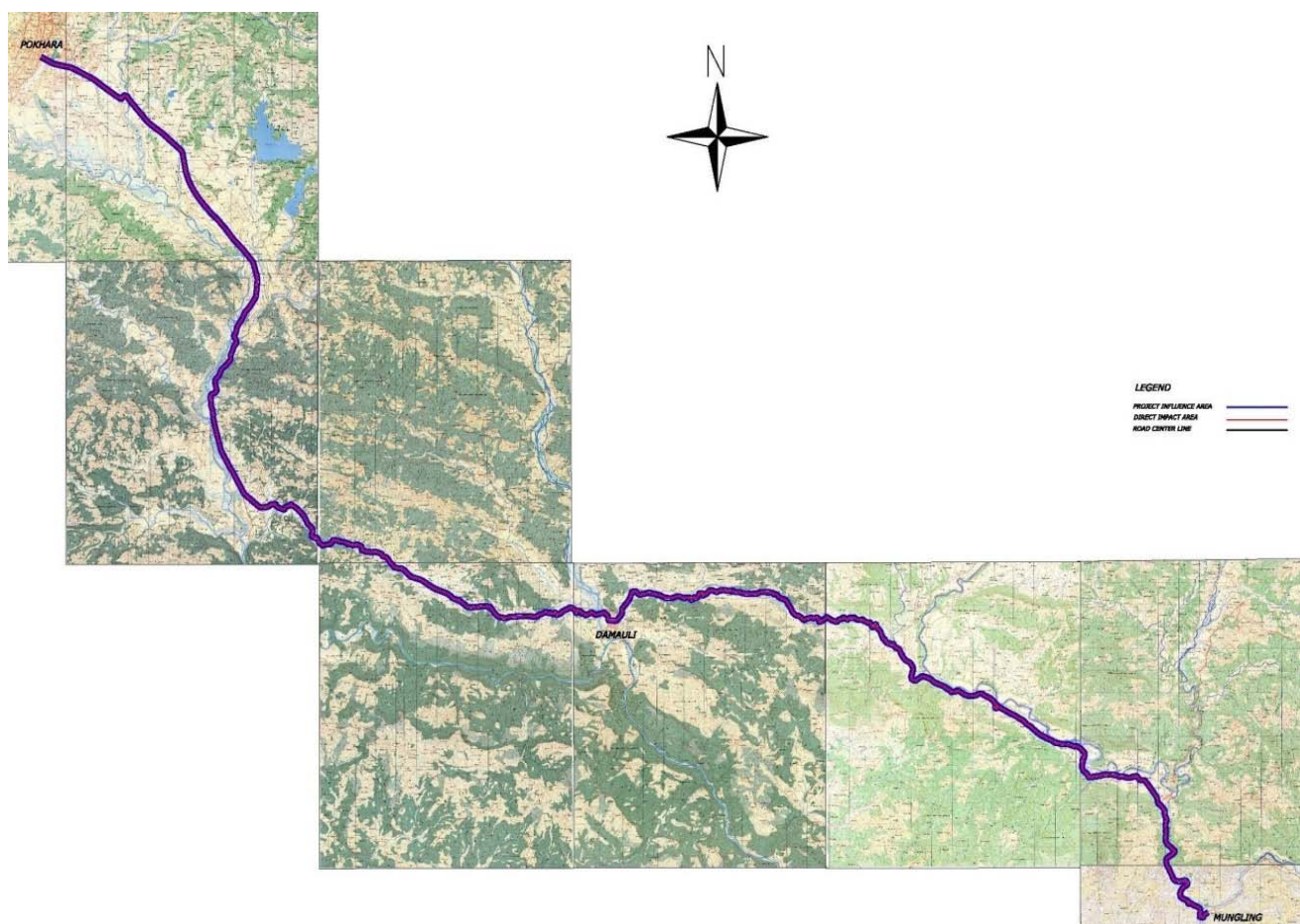
This design report has been prepared after carrying out the feasibility study for the project road condidering various improvement options, selecting the viable option and getting the concurrence of

the Client. *During the feasibility study appraisals were carried out for the Mugling-Pokhara Road for various improvement options i.e.*

In the feasibility study, economic analysis, among all three options, with option III with revision is most economically option and during the presentation of FS, the client advised the consultant to go for detailed design work on this option. This design report is based on revised option III.

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Figure 1.1: Road Alignment in Topography Map



2. DESIGN STANDARDS

2.1 Introduction

For the improvement of the up grading of Mugling-Pokhara road the design standard has been considered based on requirement of the future growth, comfort, safe and safety for the road users and road neighbour. The Ultimate aim must be to arrive at an economically viable design, which is in balance with the physical and social environment, which meets future traffic requirements and which encourages consistency and uniformity of operation.

Highway design is the process whereby the layout of the road in specific terrain is designed to meet the needs of the road users, keeping in view the road function, type and volume of traffic, potential traffic hazards and safety, capital cost, maintenance costs, vehicle operating costs, environment impacts, aesthetics as well as convenience of the road users. The principal geometric features for fulfilment of these objectives are road classification, the horizontal alignment, vertical alignment and the road cross-section.

According to project requirements the proposed design standards for the study roads is based basically on provisions of following standard sections.

2.2 DoR and other Design Standards

The Consultants have referred to the latest Nepal Road Standards regarding design standards for Highways as well as the international including Indian, American, British and Canadian (geometric design guidelines). The relevant Nepal design standards consulted include:

Nepal Road Standards-2077, Second Revision 2070 (NRS-2070)

Pavement Design Guidelines-2014 (Flexible Pavement)

The second version of Nepal Road standard-2070 has been prepared compiling all previous additional revision, new advancement in technology and to make uniformity in design, construction & its management and maintenance of roads & bridges. Now NRS are to be applied for all roads being constructed in Nepal and apply mostly for non-urban roads (in open country outside built-up area).

The classification and design standards provide the standards and guidelines for the construction, improvement and maintenance of roads. It is desired to make every possible effort to conform to these provisions both in constructing new roads and in upgrading and modernizing existing ones. The Nepal Road Standard (NRS) 2070 classified the roads as under.

Table 2.1: Classification of Road as per NRS 2070

Administrative Classification	
Classification	Description
National Highway	National Highways are main roads connecting East to West and North to South of the Nation
Feeder Road	Feeder roads are important roads of localized nature. These serve the community's wide interest and connect District Headquarters, Major economic centres, Tourism centres to National Highways or other feeder roads.
District Roads	District Roads are important roads within a district serving areas of production and markets, and connecting with each other or with the main highways
Urban Road	Urban Roads are the roads serving within the urban municipalities
Technical/ Functional Classification	

Administrative Classification	
Classification	Description
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.
Class II	Class II roads are those with ADT of 5000-20000 PCU in 20 yrs. perspective period.
Class III	Class III roads are those with ADT of 2000-5000 PCU in 20 yrs. perspective period.
Class IV	Class IV roads are those with ADT of less than 2000 PCU in 20 yrs. perspective period.

For the design of roads the class of the road is taken as the basic deciding factor, which is ascertained based on the traffic volume on the road. Further an approximate correlation can be established between the administrative and functional classifications of the roads as follows in Table 2.2.

Table 2.2: Approximate Correlation between administrative and functional classification

Roads	Plain and Rolling terrain	Mountainous and steep terrain
National Highway	I,II	II,III
Feeder Roads	II,III	III,IV

The NRS 2070 has recommended design service volumes for single lane, intermediate lane, two lane and multi-lane roads are presented (Table 2.3) based on recommended Level of Service B. It is specified that at the level of service B, volume of traffic will be around 45 percent of maximum capacity under mixed traffic condition.

Table 2.3: Capacity of Roads, PCU/day as per NRS 2070

S. No.	Category	Plain		Rolling		Mountainous and steep	
		Low curvature (0-50 deg/km)	High curvature e(>50 deg/km)	Low curvature e(0-100 deg/km)	High curvature e(>100 deg/km)	Low curvature e(0-200 deg/km)	High curvature e(>200 deg/km)
1	Single Lane Road(3.75 m) with good quality shoulders at least 1 .0m wide	2000	1900	1800	1700	1600	1400
2	Intermediate lane Road(5.5m) with good quality shoulders at least 1 .0m wide	6000	5800	5700	5600	5200	4500
3	Double lane Road(7.0m) with good quality shoulders at least 1 .0m wide	15000	12500	11000	10000	7000	5000
4	Four lane road with a minimum 3.m wide median	40000	35000	32500	30000	25000	20000

The design speeds for the various classes of roads based on terrain types are specified by NRS 2070 which is tabulated below in Table 2-4. Design standards are given based on speeds and terrain types which are depicted in Table 2-5.

Table 2.4: Design Speeds for Terrain Types (NRS 2070)

Road Class	Plain (P)	Rolling (R)	Mountainous (M)	Steep (S)
I	120	100	80	60
II	100	80	60	40
III	80	60	40	30
IV	60	40	30	20

Table 2.5: Recommended Design Parameters for various classes of Roads (NRS 2070)

Design Parameter	Road Class				Remarks
	I	II	III	IV	
Design Capacity, PCU day	>20000	5000-20000	2000-5000	<2000	For LOS 'B'
Design speed, km/h	P-120,	P-100	P-80	P-60	
	R-100	R-80	R-60	R-40	
	M-80	M-60	M-40	M-30	
	S-60	S-40	S-30	S-20	
No. of lanes	4 min.	>=2	2	<2	
Lane width	3.5	3.5	3.5	3.75 ^a or 5.5	^a -3.00m in Difficult Situation
Shoulder	P, R-3.75	P, R-2.5	P, R-2.0	P, R-1.5	
width(minimum), m	M, S-2.5	M, S-2.0	M, S-1.0	M, S-0.75	
Recommended Median width, m	5.0 (3.0 in restricted areas)	-	-	-	
Minimum radius of hor. Curve(when super elevation is not provided), m	P-1730	P-870	P-440	P-200	
	R-870	R-440	R-200	R-70	
	M-440	M-200	M-70	M-30	
	S-200	S-70	S-30	S-20	
Minimum K- value for vertical curves(summit/valley)	P-807/441	P-427/236	P-231/111	P-94/42	
	R-427/236	R-231/111	R-94/42	R-29/17	
	M-231/111	M-94/42	M-29/17	M-4/6	
	S-94/42	S-29/17	S-4/6	S-2/3	
Maximum longitudinal gradient, %	P-4	P-5	P-6	P-7	
	R-5	R-6	R-7	R-9	
	M-6	M-7	M-9	M-10	
	S-7	S-9	S-10	S-12	

Table 2.6: Asian Highways Classification

Classification	Description
Primary	Access controlled motorway
Class I	4 or more lane highway
Class II	2 lanes
Class III	2 lanes (narrow)

The minimum standard for Asian Highway Network is bituminous paved road with two lanes. Asian Highway Design Standards propose following design speeds for various terrains. AH Design standards based on speeds and terrain types are given in Table 2.7.

Table 2.7: Design Speeds for Terrain Types (Asian Highway)

Terrain			Primary	Class I	Class II	Class III
Level (L)			120	100	80	60
Rolling (R)			100	80	60	50
Mountain (M)			80	60	50	40
Steep (S)	60	60	40	30		

Overall Asian Highway Standards are given in Table 2.8.

Table 2.8: Asian Highways Design Standards (1993)

Highway classification	Primary (4 or more lanes)				Class I (4 or more lanes)				Class II (2 lanes)				Class III (2 lanes)			
Terrain classification	L	R	M	S	L	R	M	S	L	R	M	S	L	R	M	S
Design speed (km/h)	120	100	80	60	100	80	60	50	80	60	50	40	60	50	40	30
Width (m)	(50)				(40)				(40)				(30)			
Right of way	3.50				3.50				3.50				3.00 (3.25)			
Lane	3.00				3.00				2.50				1.5 (2.0)			
Shoulder	2.50				2.50				2.00				0.75 (1.5)			
Median strip	4.00				3.00				N/A				N/A			
Min. radii of horizontal curve (m)	520	350	210	115	350	210	80		210	115	80	50	115	80	50	30
Pavement slope (%)	2				2				2				2 - 5			
Shoulder slope (%)	3 - 6				3 - 6				3 - 6				3 - 6			
Type of pavement	Asphalt/cement concrete				Asphalt/cement concrete				Asphalt/cement concrete				Dbl. bituminous treatment			
Max. superelevation (%)	10				10				10				10			
Max. vertical grade (%)	4	5	6	7	4	5	6	7	4	5	6	7	4	5	6	7
Structure loading (minimum)	HS20-44				HS20-44				HS20-44				HS20-44			

Notes: Figures in parentheses are desirable values.

Minimum radii of horizontal curve should be determined in conjunction with superelevation.

The recommended width of the median can be reduced with the proper type of guard fence.

The Parties should apply their national standards when constructing structures such as bridges, culverts and tunnels along the Asian Highway.

2.3 Design Vehicle

With the recent improvement of road infrastructures, much heavier buses and container carrying semi-trailer/full-trailers are plying on most roads. To match this situation the following vehicle categories of AASHTO have been considered in setting up the design criteria:

Vehicle Category	Vehicle Length (m)	Minimum Design Turning Radius (m)	Maximum Inside Radius (m)
Semi-trailer Full trailer combination (WB 19)	20.88	13.7	6.8
Single Unit Bus (Large)	9.15	12.8	7.4
Single Unit Truck	9.15	12.8	8.64
Passenger Car	5.79	7.3	4.39

Based on the above, the following minimum radii have been used:

- For major intersection, minimum turning radius of 13.7m and minimum inside radius of 8.64m

- For intersection with local road, minimum turning radius of 7.3m and minimum inside radius of 4.2m

2.4 Recommended Design Standards

Basically **NRS** is adopted for design of Mugling –Pokhara Road and Nepal Road Standard has been referred to extent where AHDS is silent. The adopted design standards for the project road from Mugling –Pokhara Road are tabulated in Table 2.9

Table 2.9: Design Standard for Rolling and hill Sections of Mugling –Pokhara Road (Double and Four Lane Road)

SN	Design Parameters	Design standard adopted in Mugling – Pokhara road		Remarks
		Double lane (from km0+000 to 8+500	4-lane from (km 8+500 to km 88+583)	
1	Terrain	Hill and steep	Plain and Rolling	
2	Road Class Identified as per NRS 2070	Class III	Class II	NRS 2070
3	No of lanes	2.00	4.00	
4	Design Speed	40km/hr.	60km/hr.	NRS
5	Carriageway Width, m/lane	3.50	3.50	NRS
6	Shoulder Width (m) on either side	1 to 2.5 varies as per site situation	2x0.75	NRS
7	Median (m)	0.5	3.0	NRS
8	Kerb shy near median	0	0.5	
7	Formation Width (m)	9m to 12m	Varies from 18, 23, 42.5 and 46.2 as per site situation.	NRS
8	Drain Width	1.25	1.25	NRS
9	Right of way, m (Total)	50.0	50.0	NRS
10	Sight Distance			
10.a	Stopping Distance, m	50	80	NRS
10.b	Overtaking Distance, m	60	135	NRS
11	Horizontal Alignment			
11.a	Minimum Radius of Horizontal Curves	50	80	Calculated for e=0.70 and f=0.14
11.b	Length of Transition curve, m	35	40	NRS
11.c	Extra widening ,m	0.9	1.2	NRS
12	Vertical Alignment			
12.a	Maximum Gradients%	7	7	NRS
12.b	Maximum(critical) Length, m	300	300	NRS
12.c	Minimum Value of K** for summit curves, m/%	29	94	NRS
12.d	Minimum Value of K** for valley curves, m/%	17	42	NRS
13	Super Elevation (%) (max)	7	7	NRS
14	Camber (%)	2.5	2	NRS
15	Shoulder slope (%)	3	3	
15	Minimum culvert size (mm dia.)	900	900	NRS

NB: In difficult sections and prohibitive areas the specified standard might need to be relaxed for short sections. In these cases signs would be erected warning of substandard sections.

2.5 Design Guidelines and Practices for Other Components

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

Pavement Design

- TRL Overseas Road Note 31 for Pavement Design
- AASHTO Guide for Pavement Design – 1993
- Guidelines for Design of Flexible Pavements, IRC: 37 - 1984
- Guidelines for Strengthening of Flexible Pavements using Benkelman Beam Deflection Technique, IRC: 81 - 1997

Drainage System

- Hydrological Records of Nepal, Stream flow Summary, Department of Hydrology and Meteorology, HMG Nepal, 1998.
- Methodologies for Estimating Hydrologic Characteristics of Ungauged Locations in Nepal - Department of Hydrology and Meteorology, July 1990
- Design Guidance Notes-Mahakali Irrigation Project-Stage I, 1984

Road Widening Structures

- Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Stresses, IRC: 6 – 2000
- Standard Specifications and Code of Practice for Road Bridges, Section III – Cement and Concrete, IRC: 21 – 2000
- Standard Specifications and Code of Practice for Road Bridges, Section II – Foundations and Substructure, IRC: 78 – 2000
- Indian Standard Criteria for Earthquake Resistant Design of Structures, IS: 1893 - 2002

Earth Retaining Structures

- Overseas Road Note 16, Principle of low cost road engineering in mountainous region, Overseas Centre, Transport Research Laboratory, Crowthorne, Berkshire, United Kingdom
- Mountain Risk Engineering Handbook, International Centre for Integrated Mountain Development (ICIMOD).

Bio Engineering

- Publications of Geo-Environment Unit of DOR,

Road Safety

- Nepal Road Safety Measures
- Traffic Signs Manual for Nepal Roads
- Road Safety Notes published by Traffic Engineering and Safety Unit of DOR, Nepal
- Nepal Road Standards and DOR guidelines

3. SURVEY AND INVESTIGATIONS

3.1 Road Inventory and Condition Survey

A detailed inventory of the existing road listing road width, side drains, cross drainage / irrigation structures, retaining structures including their condition has been prepared and is presented as **Annex 3.1**.

This survey provides road inventory of existing road sections, the existing utilities along the road and identifies the required rehabilitation and improvement works.

3.2 Topographical Survey

3.2.1 Objective

To start with topographic survey, a preliminary alignment had been drawn on satellite imagery following the design standards. The topographic survey was planned to cover a strip of about 100 m plus the areas anticipated to be required for alignment improvement. Survey was carried out by Total Station, DGPS and Auto Levelling equipment. Topo survey was generally aimed at the following:

- Preparation of Detailed Project Report for the Upgrading and Improvement of the existing facility.
- Ascertaining/identification and improving of the following:
 - Geometry of existing road
 - Elevation of project road
 - Obstruction/constraints in improvement of road

3.2.2 Scope

The topographical survey had been carried out involving following activities:

- Pillar construction
- Fixing of Control point by DGPS.
- Total Station traverse
- Leveling
- Detailed engineering survey

The field survey data was transferred to the computer for preparation of DTM.

The centreline of the existing road has been marked on the strip map. Based on the final geometric design, the centreline of the project road, however, gets changed in order to suit the geometry as per the design standard.

As far as possible, the existing centreline and grade has been followed for design to minimize land acquisition and cost. However, quite often the shifting of the design centreline became necessary to accommodate the proposed roadside drains, minimize earthwork and structures and to facilitate the improvement in road geometry.

After finalizing the centreline, longitudinal profiles and plans of the roads have been prepared using the computer software.

The design drawings of plans, longitudinal profiles and cross sections of the project roads are submitted under **Volume 3C (Drawings)**.

Details of Description Card (D-Card) of Bench Mark and control points are given in **Annex 3.2**.

3.2.3 Methodology

The topographical survey had been carried out by using Total Station with angular accuracy of 3" and survey grade differential GPS and auto Level. The Control Points and Benchmarks monuments had been erected in the specified and required intervals and the all control points were in PVC cased precast concrete pegs with nail point. D-cards were made for all control points and BMs with 3 references and 2 photographs. The three inter-visible control points surveyed by DGPS, were established at 5km interval and the traverse was closed for all control points with minimum linear accuracy of 1:30,000. Fly levelling was made for vertical control with error not exceeding 10 mm for all traverse control points and all traversed distances and angles were checked with reciprocal observations.

The detailed topographical survey was carried out to cover to cover 100m strip (50m both sides of road centreline using the control points established. All feature strings such as road, walls, edges, drains, ridges, gullies etc. were taken for the preparation of topographical map. All drains, parapets, culverts, poles, houses, sheds and km posts were surveyed. The Chainage marking at sites were done.

DTM was generated using SW_DTM and verified in field all feature lines and configurations were completed in AutoCAD compatible maps. Field sketches were referenced in preparation DTM.

3.3 Pavement Investigations

3.3.1 General

Pavement Investigation works was conducted in order to define the characteristic as well as condition of the existing pavement and sub – grade materials. The results of such investigations are used in the design of the embankment, slope as well as road pavement. More importantly, the investigations emphasize to divide the roads into homogenous sections for the purpose of sample collections for laboratory soaked CBR, design of pavement in well-defined groups/section and slope stability analysis.

The scope of investigation comprises digging of trial pits on the side (shoulder/compacted section), on extended part of pavement as well as centre of road section of the road pavement at about 500 m intervals and important field tests on the sub – grade as well as measuring the thickness of gravel layer and measure its quality at 2 km interval. The scope of work also comprises conducting the in – situ Dynamic Cone Penetration tests (DCPs) at suitable intervals as per ToR.

Division of Homogenous Sections

During the field assessment of the road alignment, Narayanghat-Butwal, is divided into homogenous sections based on

Type of terrain (plain, rolling, hilly or mountainous). Special distinction of market and rural areas were not made as this distinction would not have any significant influence on the structural design of pavement.

- Soil type (silty clay, clayey silt, laterite with or without coarse grained material, conglomerate or soft to hard rock).
- Drainage condition (as assessed from ponding of water, type of vegetation, river crossings etc.)

3.3.2 Sub Grade Investigations

Test Pitting

For investigation 1 m × 1 m × 1m size trial pits were excavated to sub grade level at an average of 1 km intervals and wherever the change of sub-grade material was noticed. 57 Nos of test pits were excavated in the new proposed sub-grade level, two test pit at centre of road and 10 pits in the shoulder in a staggered manner. Generally, pavement with river bed gravel is termed as base-sub base and pavement beneath river bed material is considered as a sub grade. About 60 to 70 Kg of samples of the sub grade encountered was collected for classification, compaction and CBR testing. Bags of soil sample of sub – base materials also were taken for Natural Moisture Content and Sieve tests.

The visual classification and the thickness of all the soil layers (including pavement materials) were noted. Sub – soil profile log prepared for each pit are included along with DCPT Test results and are summarized. Details and summary of this test results are presented in Annex.

3.3.3 Dynamic Cone Penetrometer (DCP) Test

Dynamic cone Penetration (DCP) test were undertaken in the sub – grade layer to evaluate the in – situ' CBR values at suitable intervals.

The DCP tests were conducted using hardened steel of 20mm diameter with 60° cone angle driven by the impact of a hammer of 8 kg weight with a free fall of 575 mm. the tests were carried out in the sub – grade; recording hammer blows versus penetration to an average depth of 1,000mm or to refusal depth to derive the sub-grade strength. The field data were analysed and assessed manually using the following TRL Road Note 31Kleyn and Van Heerden equation to obtain DCP based CBR values.

$$\text{TRL RN. 31 equation: } \log_{10}(\text{CBR}) = 2.632 - 1.28 \times \log_{10}(\text{Strength})$$

Where, Strength = Penetration in mm/blow.

In – situ DCP test results including pit logging are presented in **Annex 3.3** and derived CBR based on above equation and the results are summarized in **Annex 3.3**.

3.3.4 Construction Material Collection

Probable quarry site, natural river bed materials are assessed and collected from probable sites, crushers identified during expert's site visit. From different probable sources (including natural materials) and crusher plants requisite materials were collected with proper identifications and transported to laboratory for further testing .

3.3.5 Assessment of Slope Material

3.4 Laboratory Testing

3.4.1 Sub – Grade

Soil and aggregate sample has brought to Material Testing laboratory at Kathmandu.

The sub-grade soil samples were categorized into different groups of a similar nature. Representative soil samples were subjected to a series of laboratory testing as per the following codes:

- Natural Moisture Content - AASHTO – T – 265 – 86, T – 121 or BS 1377
- Sieve Analysis - AASHTO – T88 or BS1377
- Atterberg Limits - AASHTO – T 89 – T90 or BS 1377
- Specific Gravity - ASTM D 854 – 83 or BS1377
- Modified Proctor Compaction Test AASHTO T- 180 or BS 1377
- California Bearing Ratio Test AASHTO T – 193

Natural Moisture content, Sieve analysis, atterber's limit, Specific gravity, modified proctor density and CBR tests were conducted for representative three samples and values are summarized in **Annex**.

3.4.2 Sub – Base

Natural moisture, sieve analysis, atterberg limits, specific gravity, water absorption test, Aggregate Crushing value, Aggregate impact value, flakiness index test, Los Angeles abrasion test, Compaction and California Bearing Ratio tests were conducted for representative base/sub-base samples.

The details of in situ and lab tests results for sub – grade material are presented in **Annex**.

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4. MATERIALS INVESTIGATIONS

4.1 General

Mugling-Pokhara Road, the road alignment passes through the Marsangdi Hydro Powerhouse station, community forest covered area with cultivated land, human settlement area and Built up areas - markets. Road having gentle climbing and rolling gradient all-weather for traffic movements. The study for availability of construction materials (boulders, cobble, gravel and sand) in river basin and pit quarries, existing local crusher plant were made. There are local crusher plants at 10+000 and 71+000 kotre area of the alignment. Source of gravel are Marsangdi River, Maadi River, Seti river basin and Borrow Pit at Kotre area adjacent of the road alignment. Their capacity and the haulage distances to the construction site were noted in order to estimate the cost and the sufficiency of quantity and quality required for the construction. Samples were collected and brought to Kathmandu laboratory for test. A list of quarries and test result of material sources are listed below in Table 4.1 and details are presented in Annexes.

The Engineering characteristics and location/availability of construction materials are essential aspects of the road design and construction. The acceptance of an appropriate design methodology carries with it a recognition that established criteria for road materials need to be looked at closely in terms of actual engineering purpose within individual road environment. Detailed specifications to safeguard these 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 within a road environment, namely

- as fill materials,
- pavement materials,
- 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 recognised that a key objective in sustainable road construction is to best match 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 characterisation 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 and it has to compliance with STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE WORKS Section 600.

- 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.

Material samples from selected sources were taken to the laboratory in Kathmandu and subjected to various testing with a view to evaluate the suitability and characteristics strength of the materials. The laboratory test results are summarized in Table 4.1.

Sieve Analysis

The grain size analysis (gradation test) was carried out according to (IS: 2386 (part 1)-1963. Standard procedures were followed by receiving the sample through a stack of sieve from 63 mm to 0.075 mm in diameter. The mass of material retained in each individual sieve was determined and the cumulative percentage was calculated. Sieve analysis of the sub grade, riverbed materials, sub base materials were carried out. The gradation ratios of the gravel, sand, silts, and are shown in the Table 4.1.

Atterberg Limits (PI)

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

Los Angeles Abrasion Test (LAAV)

The Los Angeles Abrasion test was carried out according to the standard procedures outlined by (IS 2386- PART 4 1963). The percentage of abrasion was calculated on the basis of the tests. Samples collected from different river basin across the alignment and away from the alignment as elsewhere sources etc.

Tested results of different probable quarry are as a Natural Gravel from Marsangdi River 27.26%, Maadi River 36.8% and Seti river basin Borrow pit 34.64% Observed.

These above said possible quarry tested vales are closer as indicated in **STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE WORKS**. Hence, these locally available materials are suitable as Construction materials. This is the scenario of Sewalik range materials Index. These sources of material can be used as the Base Course (CSB), Pavement sealing aggregates and the aggregate for Concrete works. It can be used as an aggregate as a material for wearing courses well as road Pavement Structure materials, the reference Index properties of materials are indicated in Table 4.1.

Aggregate Crushing Value Test (ACV)

The Aggregate Crushing Value test was carried out according to IS: 2386 (part IV)-1963 standard. The aggregate crushing value of different location of above said river bed material as Natural river gravel of Marsangdi River basin, Maadi River basin and Sati river basin are 15.87%, 26.5% and 26.4% respectively. To ensure the good pavement Structure materials and sealing aggregates must be resistance to crushing under gradually applied compressive load, abrasion effect etc. Usually aggregates with crushing values less than 10% are regarded as strong and above 35% are normally weak for use in road surface. The above figure indicates the border range as said in **STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE WORKS**, the tested results are summarized in Table 4.1.

Aggregate Impact Value Test (AIV)

The Aggregate Impact Value test was carried out according to IS: 2386 (part IV)-1963 standard. The AIV value of material from different location of river banks material listed in fig.4.3 as a Natural aggregate tested values are 17.7%,23.1% and 22.91% are complying with **STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE WORKS**, section 1202, Table 12.3 and Section 1303,Table 13.5 Physical requirements of Chippings. The test results of available materials are indicated in Table 4.1.

Flakiness Index (FI)

Flakiness Index test is carried out according to IS: 2386 (part IV)-1963 Standard. The flakiness Index of above said river bed Natural materials are indicated in Table 4.1.

Specific Gravity Test (Sp.Gr.)

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

Maximum Dry Density “Procter” Test (MDD)

Compaction test is carried out to determine Maximum Dry Density (MDD) and Optimum Moisture Capacity (OMC). This test follows BS 1377-4:1990. Modified 4.5 Kg of rammer is used for BS heavy compaction test. Height of drop is 450 mm and compaction is carried out till 56 no of blows. Graph of dry density v/s moisture content is plotted and MDD is determined. The Maximum dry density occurs at optimum moisture content.

The materials obtained from different location of above said river banks, river gravel along the alignment possibly sources of construction materials as a suitability quarry are tested and tabulated in Table: 4.1.

California Bearing Ratio Test (CBR)

The Three Point CBR test was conducted for both road sub grade and proposed quarry materials. For sub grade ASTM D1883-5 method was adopted, whereas for Suitability of quarry materials AASHTO T 193-81 code was followed. The CBR at 95% modified MDD (heavy compaction) after 4 days soak was noted for Subgrade and Sub-base material.

Whereas for Suitability of quarry Construction materials for the project from different location of river bed material as Natural gravel for sub base and Local Crusher Plant Stocked pile material (CSB) the CBR values are presented in Table 4.1.

Figure 4.1: Graphical representation of CBR Calibration.

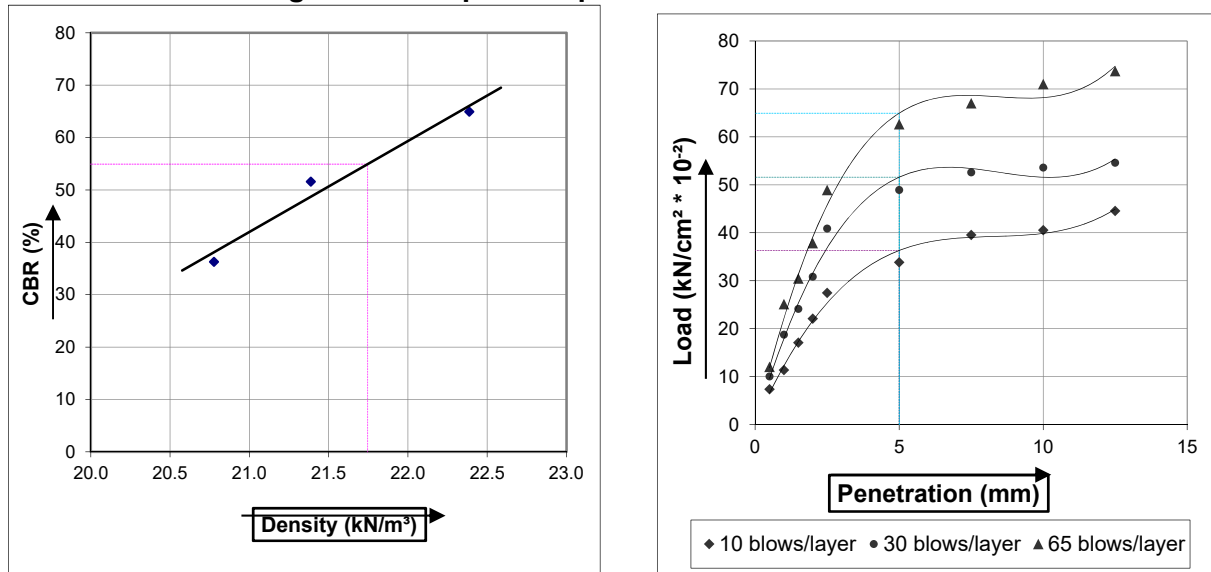


Table 4.1: Summary of Possible Construction Material Sources and the Laboratory Test Results.

S.N	Location/ Chainage	Natural Deposit Details	Crushed stone Aggregate(Base Course)						Natural Aggregate Material(Sub – Base)							Sand Approx. Qty & Composition		Remarks
			Qty*, m ³	FI%	AIV%	ACV%	LAA %	CBR %,@ 98% MDD	Qty*, m ³	LAAV, %	AIV, %	ACV, %	MDD (gm/c m ³)	OMC %	CBR, % @95% MDD	Qty*, m ³	Compositi on %	
1	Marsangdi River Basin Ch.9+000	Alluvial deposit comprised of boulder, cobble, gravel and sand of predominantly gneiss, quartzite and Schist. Visual Approx. Qty.= 35,450.0m ³	11344.0	19.57	-	-	-	80.1	12,408.0	27.26	17.7	15.87	2.29	6.3	-	8,863.0	G= 74.84 S=24.89 C& Si=0.18	River Boulders are for Stone masonry works. If the gravel screened and selected boulders are properly crushed for Base material, course aggregate for concrete and S.D. aggregates suitable.
2	Maadi River Basin Ch.42+000	Alluvial deposit comprised of boulder, cobble, gravel and sand of predominantly gneiss, quartzite and Schist. Visual Approx. Qty.=373,750 m ³	93,438.0	18.0	-	-	-	-	186,875.0	36.8	23.1	26.5	2.21	8.0	34	48,587.0	G= 87.69 S=12.25 C& Si=0.06	River Boulders for Stone masonry works. If the gravel screened and selected boulders are properly crushed for Base material, course aggregate for concrete and S.D. aggregates applicable.
3	Sati River Basin Ch.71+000,Kotre area Borrow pit	Alluvial /Colluvium deposit comprised of boulder, cobble, gravel and sand of predominantly gneiss, quartzite and Schist. Visual Approx. Qty.=460,000 m ³	230,000.0	16.5	19.18	23.1	34.8	84.75	92,000.0	34.64	22.91	26.4	2.2	7.7	37.1	115,000.0	G=69.5 S=27.94 C& Si=2.56	River basin deposited gravel and Private land (borrow pit) gravel and boulders for masonry works. If the gravel screened and selected boulders are properly crushed for Base material, course aggregate for concrete and S.D. aggregates suitable.

Note: N=Natural (uncrushed), G=Gravel, S=Sand, Si= Silt, C= clay, *= Estimates Quantity, N.A. = Not applicable/ Not available at present.

1. Sources of water for construction works available from Stream/Khola across the road alignment.
2. All above quantities are approximately assessed by vicinal inspection assuming 1.0 m depth excavation.
3. Contractor can explore other material sources as well.

4.1.1 Material Sources and Quarry Survey

For the study of construction material and the possibility of quarry for construction materials (boulders, cobble, gravel and sand), All quarries, existing Local crusher plant's, crushed material were inspected and identified for the project as a sources of construction materials. The quarries availability of quantity, quality of material, accessibility and the haulage distances from the construction site were distinguished in order to assessment the cost of the project and the competence of quality required for the construction. Samples were collected from the probable quarries and tested at Kathmandu Laboratory. A list of suitable quarries and test results of material sources are listed in Table 4.1 and details location of quarry are presented in Annexes too.

The major sources for the Construction of Off-road Structures and Pavement Structures as a Pavement aggregates materials are Marsangdi river basin, Maadi river basin, Sati river basin and Private Land at Kotre area(borrow pits) which are shown in Table 4.1 and Annex 4.1A linear diagram and Annex 4.1B.

The stones/boulder for masonry and flexible retaining structures works is river deposited, Colluvium and residual sediments deposited along the above said locations, which are the possible quarries, the Contractor has to quarry himself with consulting the responsible authority holder agencies at the time of construction. The quantity of the construction materials are available as required from the above said location as a probable sources, the available material tested results were complies with the STANDARD SPECIFICATION FOR ROAD AND BRIDGE WORKS. The materials from possible Sources were considered as construction materials for the Project are indicated in Table 4.1.

At the time of acquiring Construction materials, Contractor should also confirm that the extraction of material from these sources will be environmentally acceptable and conserved the local human settlements and flora and fauna habitats.

The quality of materials from located sources and quantity availability of material such as boulder, gravel and sand, were found satisfactory, can be acquired using proper extraction methodology. Investigation and Study for possibility of construction materials had been done by collecting the samples from surveyed sources, which are shown in Table: 4.1 and Fig.4.2.

The Water required for Construction works are available along the road Kholas/Streams across the alignment, the Contractor may have to prepare temporary access road at various locations for quarry development and water sources and the quarry has to reinstated contractor himself after quarried the construction materials.

The information given in Table 4.1 is approximately assessed by vicinal inspection and indicative only, the Contractor must satisfy himself for availability, suitability and quantities of materials prior to bidding. The Contractor has to confirm that the extraction of materials at these sources will be environmentally acceptable.

Figure 4.2: Location of Probable Quarry for Construction Materials.

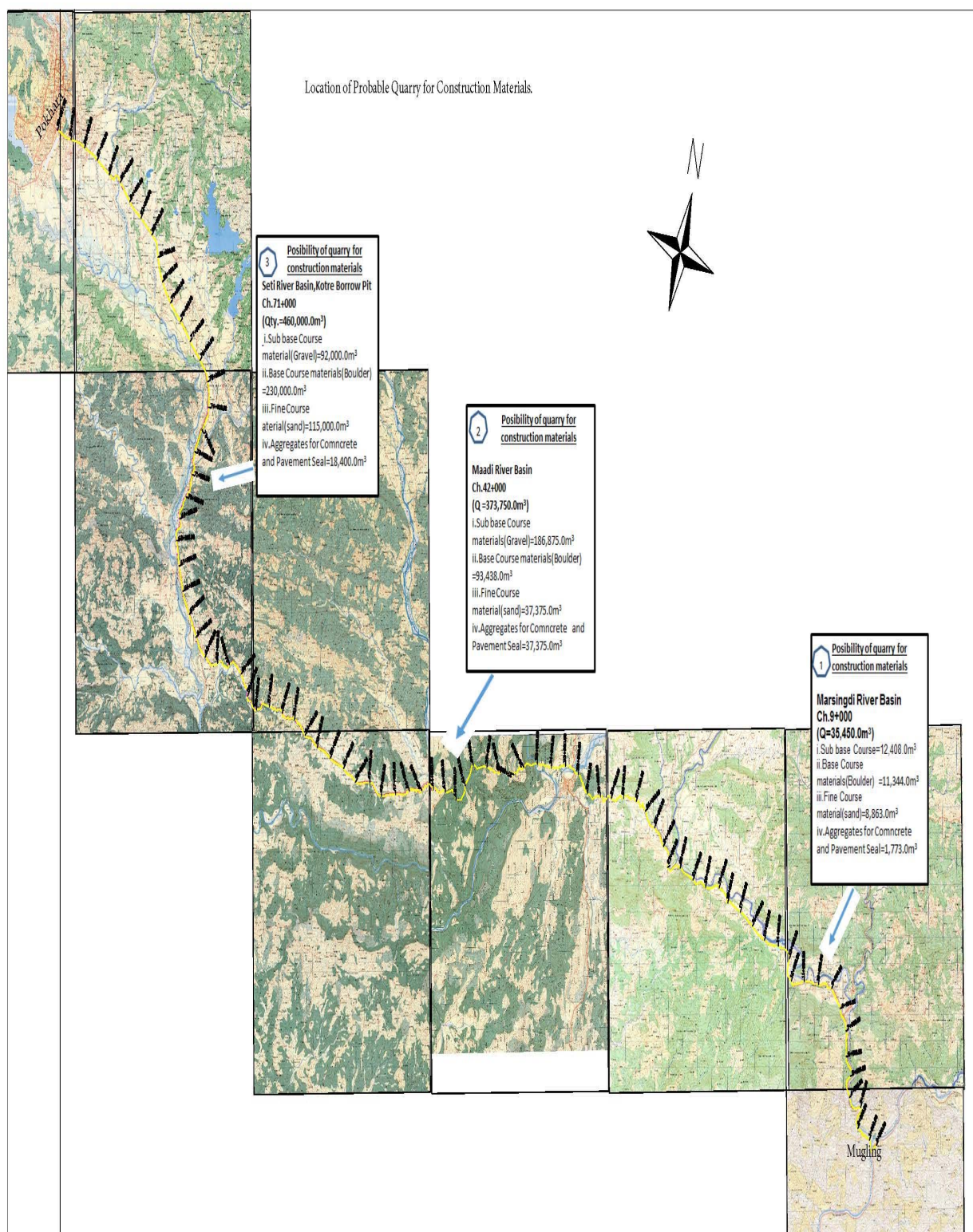
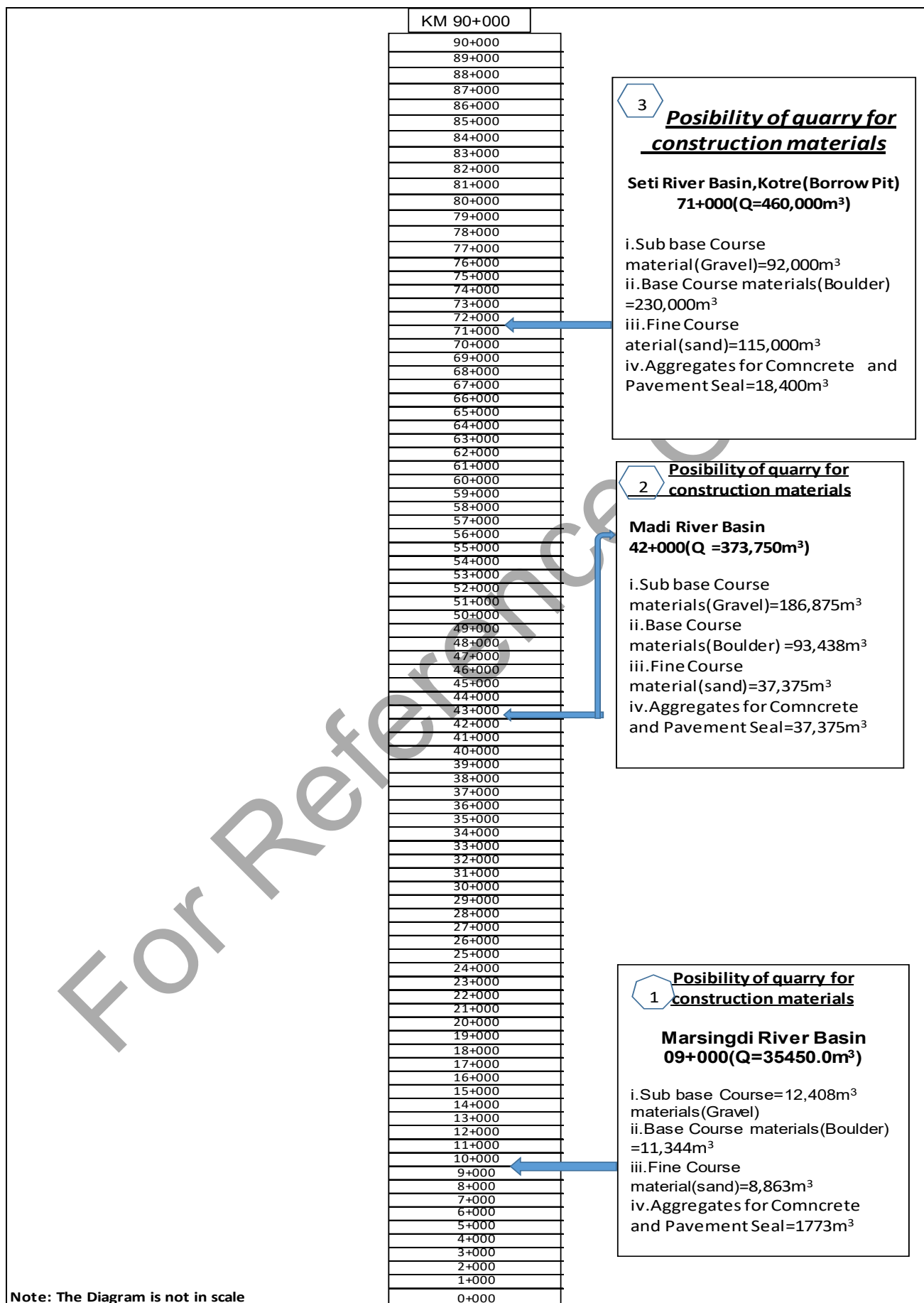


Figure 4.3: Location of Probable Quarry for Construction Materials.



4.2 Materials for Embankment and Sub-grade

4.2.1 Embankment Fill

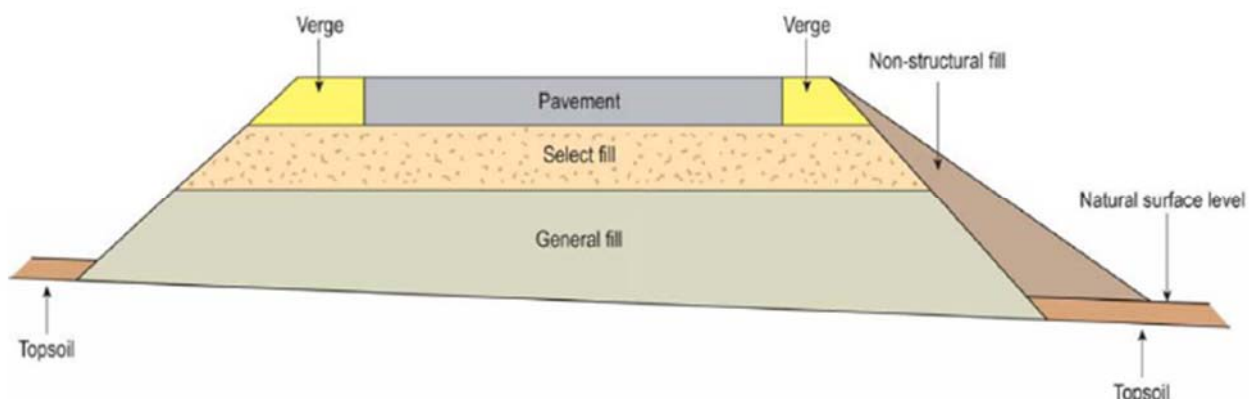
An embankment denotes to a volume of earthen material that is placed and compacted for the purpose of raising the grade of a roadway, above the level of the existing surrounding ground surface. Embankment fill refers to placed and compacted for the purpose of filling in the low level or drop section of existing ground level as formation level of road. Embankment fills are constructed of materials that usually consist of soil, but may also include aggregate, rock, or crushed paving material.

Generally, the fill materials are placed at base of the embankment (formation level) in order to provide a firm foundation, also to facilitate drainage and improve prevent withstand bearing capacity. The top portion of an embankment usually is constructed of relatively high-quality, well-compacted subgrade material that is capable of supporting the overlying pavement layers and imposed wheel loadings without deflection or undesirable movement. The embankment fill material must be capable of meeting applicable specification quality requirements and be capable of maximum achievable density and bearing strength.

Embankment fill or backfill is a very important part of every road structure. The embankment has to support the road pavement structures and shall further distribute the forces, applied onto the pavement structure, over the subsoil without exhibiting unacceptably large deformations. During constructing an embankment one should take into account a great number of variable properties of both the construction materials to be applied and the subsoil, the embankment determines the performance of the overlying road pavement structure. Normally the soil is an essential construction material.

It follows that insight into the behaviour of soil is necessary for the design and construction of roads. It has to be known how this behaviour must be analysed and how should be anticipated on this behaviour.

Figure 4.4: Composition of pavement structures layers and Embankment fill.



All fill material shall be obtained from required excavations and designated borrow areas. Embankments fill are typically constructed by compacting earthen materials in place, so the compaction properties of the material (optimum water content and maximum dry density) are very important to performance. The selection, blending, routing, and disposition of material in the various fills shall be subject to used.

4.2.2 Improved Sub-grade

The “subgrade” is the in situ material upon which the pavement structure is placed. Although there is a tendency to look at pavement performance in terms of pavement structure and mix design alone, the subgrade can often be the overriding factor in pavement performance.

The road alignment passes through formation encountering rocks, conglomerate and soft rock, mixed lattices soil with fragmented rocks and earth in sections. The sub grade and formation is mainly earthen or gravel mixed earth having either nil or low plasticity properties. Results of grain size analysis, strength characteristics and compaction, Strength of Sub grade is low, it can be improved by replacing existing material with superior quality of materials as Capping layer or by increasing the thickness of Sub –base course.

Sub-grade investigation comprises of determining the in situ CBR and other geological and geomorphologic observations along the alignment.

4.3 Pavement Construction Materials

4.3.1 Sub-base

In highway engineering, sub-base is the layer of aggregate material laid on the subgrade, on which the base course layer is located. It may be omitted when there will be only foot traffic on the pavement, but it is necessary for surfaces used by vehicles.

The sub-base shall be constructed after checking that the underlying layer conforms to the specified requirements or not, the underlying layer of Base Course to improve the Load bearing capacity of Sub-grade deficiencies. The location of Sources and test results for construction materials are presented in Table 4.1 and fig.4.3.

- Crusher run stone aggregate (CBR > 60 %) for crusher run modified sub-base, and
- Gravel (CBR > 30 %) for sub-base

Quality of Sub-base materials should comply with the standard Specifications Road and Bridge Works, Section 1201.

4.3.2 Base Course

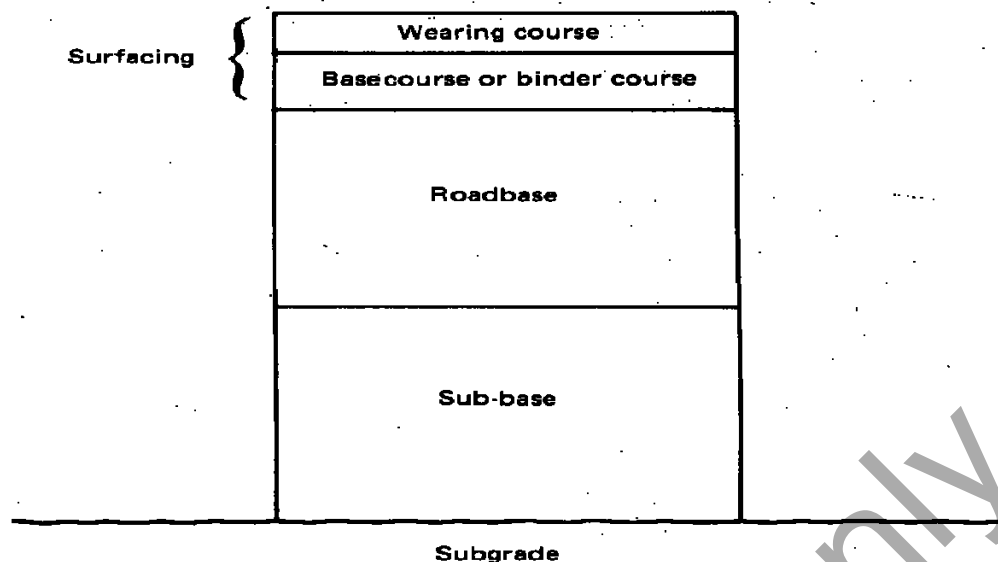
A layer of Crushed Stone material of specified thickness constructed on the subgrade or sub-base of a pavement to serve one or more functions, such as distributing loads, providing drainage, or minimizing frost action.

The Crushed Stone aggregates shall consist of both fine and coarse fragments of crushed stone or crushed gravel mixed or blended with sand, screenings, or other similar approved materials. The crushed stone shall consist of hard, durable particles or fragments of stone and shall be free from excess flat, elongated, soft or disintegrated pieces, dirt, or other objectionable matter.

The method used in production of crushed gravel shall be such that the fractured particles occurring in the finished product shall be as nearly constant and uniform as practicable and Comply with Standard Specifications for Road and Bridge works Clause 1202.

If necessary to meet this requirement or to eliminate an excess of fine, uncrushed particles, the gravel shall be screened before crushing. All stones, rocks, and boulders of inferior quality in the pit shall be removed. The Physical requirements of Graded Crushed Stone Base course requirement of Table 12.3, standard Specifications Road and Bridge Works.

Figure 4.5: Composition of pavement structures layers



4.3.3 Stone Aggregates

Pavement Cover aggregate Index properties must be fulfil the standard and shall be natural screened gravel or crushed hard rock/stone, clean and free from adhering dust, achieved by washing and drying, or any other detrimental substance that could impair the adhesion of bitumen and shall conform to the requirements of Table 13.5 Standard Specifications Road and Bridge Works Section 1303.

4.3.4 Bitumen

Bitumen is a non-crystalline viscous material, black or dark brown, which is substantially soluble in carbon disulphide (CS₂), possessing adhesive and water-proofing qualities. It consists essentially of hydrocarbons and would typically comprise at least 80% carbon and 15% hydrogen, the remainder being oxygen, sulphur, nitrogen and traces of various metals. The bitumen binder shall consist of Penetration grade bitumen, cutback bitumen or bitumen emulsion. Penetration Grade Bitumen is commonly used in road surfacing, and some industrial applications.

Penetration Test determines the hardness of Bitumen by measuring the depth (in tenths of a mm) to which a standard, and loaded needle will vertically penetrate in 5 seconds, a sample of Bitumen maintained at a temperature of 25°C. Hence the softer the bitumen, the greater will be its number of penetration units (80/100, 60/70, 40/50) in Table 4.3.

Cutback bitumen binder shall comprise penetration grade 80/100 bitumen and cutter which shall be diesel or kerosene or a mixture of both prepared on Site". The type and proportion of cutter as required shall be add on Site, in the range 1 % to 10% after design of the surface dressing in accordance with the procedures set out in Chapter 5 of TRRL-ORN 3. The preparation of cutback bitumen shall be carried out in accordance with the TRRL Research Report RR104 "Preparation of cutback Bitumen (Hitch and Stewart). An extract from this Report is included in the Appendices and describes the preparation of cutbacks under site conditions.

Bitumen which will be using in this project should comply as said in STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE WORKS Section 618.

Table 4.2: Selection Criteria for Viscosity-Graded (VG) Paving Bitumen Based on Climatic Conditions

Lowest Daily Mean Air Temperature, °C	Highest Daily Mean Air Temperature, °C			Remarks
	Less than 20°C	20 to 30°C	More than 30°C	
More than -10°C	VG-10	VG-20	VG-30	
-10°C or lower	VG-10	VG-10	VG-20	

Table: 4.3 Specification of Penetration Grade Bitumen.

PROPERTY	GRADES			STANDARD
	BITUMEN 80/100	BITUMEN 60/70	BITUMEN 40/50	ASTM / AASHTO
Specification Gravity @25/25 °C	1.01/1.06	1.00-1.05	1.00-1.05	D-70
Penetration @ 25 ° C	80/100	60/70	40/50	D-5
Softening Point ° C	45/52	49/56	52/60	D-36
Ductility @ 25 ° C CMS	100 MIN	100 MIN	100 MIN	D-113
Loss on Heating (wt.)%	0.5 MAX	0.2 MAX	0.2 MAX	D-6
Drop in Penetration After Heating %	20 MAX	20 MAX	20 MAX	D-6 & D-5
Flash Point °C	225 MIN	250 MIN	250 MIN	D-92
Solubility in CS@ (wt.)%	99.5 MAX	99.5 MAX	99.5 MAX	D-4
Spot Test	NEGATIVE	NEGATIVE	NEGATIVE	-
Density @25° C	1.01/1.06	1.00/1.05	1.00/1.05	D70

4.3.5 Adhesion Agents (Anti-stripping additives)

Liquid adhesive agent /Anti Stripping Agent shall be added to the bitumen/cutback to increase the bond (active and passive adhesive) between the aggregates and binder. The agent used shall be good affinity with aggregates. Its application shall be in accordance to the manufacturer specifications unless otherwise instructed by the Engineer.

The agent used shall conform to the relevant IS requirements and conduct some additional periodic tests such as "under water coating tests", "stripping value for passive adhesive", "thermal stability" or "solubility in high speed diesel" to confirm that the Adhesive agent to be used.

4.4 Availability of Materials for Concrete Works

4.4.1 General

Availability of construction material within economical distances and their suitability for different use investigated. During the field survey sources of boulder, cobble, gravel and sand quarry sites were identified in the vicinity of the alignment. Efforts have been made to identify as many sources along the alignment as possible to reduce the haulage distances. Major three locations for possibility sources are along the alignment are acknowledge and are listed in Table 4.1 The Contractor can explore other material sources as well at the time of construction.

4.4.2 Aggregates

Aggregates are inert granular materials such as sand, gravel, or crushed stone that, along with water and Portland cement, are an essential ingredient in concrete.

For a good concrete mix, aggregates need to be clean, hard, strong particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete. Aggregates, which account for 60 to 75 percent of the total volume of concrete, are divided into two distinct categories fine and coarse. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 4.75 mm sieve. Coarse aggregates are any particles greater than 4.75 mm, but generally range between 4.75 mm and 15 mm in diameter. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder.

Natural gravel and sand are usually dug or dredged from a pit and river basin. Crushed aggregate is produced by crushing quarry rock, boulders, cobbles, or large-size gravel. Sometime recycled concrete is a viable source of aggregate and has been satisfactorily used in granular sub-bases, soil-cement, and in new concrete.

Aggregates strongly influence concrete's freshly mixed and hardened properties, mixture proportions, and economy. Consequently, selection of aggregates is an important process. Although some variation in aggregate properties is expected, characteristics that are considered include:

- grading
- durability
- particle shape and surface texture
- abrasion and skid resistance
- unit weights and voids
- absorption and surface moisture

Grading refers to the determination of the particle-size distribution for aggregate. Grading limits and maximum aggregate size are specified because these properties affect the amount of aggregate used as well as cement and water requirements, workability, pump ability, and durability of concrete. In general, if the water-cement ratio is chosen correctly, a wide range in grading can be used without a major effect on strength. When gap-graded aggregate are specified, certain particle sizes of aggregate are omitted from the size continuum. Gap-graded aggregate are used to obtain uniform textures in exposed aggregate concrete. Close control of mix proportions is necessary to avoid segregation and the quality of materials should complies with Standard Specifications Road and Bridge Works of Section 2003(4). Locally available materials possible sources are listed in fig.4.3.

4.4.3 Natural Coarse Sand

The quality and quantity availability of material such as gravel, sand and stones were surveyed and found to be available from the different location of the river basin with satisfactory quality and can be obtained using proper extraction methodology and the location of availability and quality are listed in Table 4.1 and located in fig.4.2.

Stone for masonry works can be obtained from the river bed as indicated in Table 4.1 sources, provided that the extraction of stone is done in an environmentally safe way with the approval of the Engineer, and the quality of materials should complies with Standard Specifications Road and Bridge Works of Section 2003(3).

4.4.4 Cement

Cement is a binder, a substance that sets and hardens and can bind other materials together. The most important uses of cement are as a component in the production of mortar in masonry, and of concrete, a combination of cement and an aggregate to form a strong building material.

Portland cement is by far the most common type of cement in general use around the world, Portland cement blends are often available as inter-ground mixtures from cement producers. Cement is manufactured through a closely controlled chemical combination of calcium, silicon, aluminium, iron and other ingredients. Cements which will be using in this project should comply as said in STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE WORKS Section 614.

Table 4.4: Comparison of Chemical and Physical Characteristics

Components of Cement Comparison of Chemical and Physical Characteristics					
Property	Portland Cement	Siliceous (ASTM C618 Class F) Fly Ash	Calcareous (ASTM C618 Class C) Fly Ash	Slag Cement	Silica Fume
SiO ₂ content (%)	21.9	52	35	35	85–97
Al ₂ O ₃ content (%)	6.9	23	18	12	—
Fe ₂ O ₃ content (%)	3	11	6	1	—
CaO content (%)	63	5	21	40	< 1
MgO content (%)	2.5	—	—	—	—
SO ₃ content (%)	1.7	—	—	—	—
Specific surface (m ² /kg)	370	420	420	400	15,000–30,000
Specific gravity	3.15	2.38	2.65	2.94	2.22
General use in concrete	Primary binder	Cement replacement	Cement replacement	Cement replacement	Property enhancer
a Values shown are approximate: those of a specific material may vary.					
b Specific surface measurements for silica fume by nitrogen adsorption (BET) method, others by air permeability method (Blaine).					

4.4.5 Admixtures

Chemical admixtures are the ingredients in concrete other than Portland cement, water, and aggregate that are added to the mix immediately before or during mixing. Producers use admixtures primarily to reduce the cost of concrete construction; to modify the properties of hardened concrete; to ensure the quality of concrete during mixing, transporting, placing, and curing; and to overcome certain emergencies during concrete operations.

Admixtures play a vital role in production of quality concrete and mortars in all segments of the industry—Ready-mix, Precast and Site-batch. It is the ingredients in concrete other than cement, water and aggregate that is added to the mix immediately before or during mixing. Used primarily to reduce the cost of concrete construction; to modify the properties of hardened concrete; to ensure the quality of concrete during mixing, transporting, placing, and curing; and to overcome certain emergencies during concrete operations.

Admixtures are those components in concrete other than cement, water, and aggregates that are added to the mixture immediately before or during mixing. Admixtures can be classified by function as follows:

1. Air-entraining admixtures
2. Water-reducing admixtures
3. Plasticizers

4. Accelerating admixtures
5. Retarding admixtures
6. Hydration-control admixtures
7. Corrosion inhibitors
8. Shrinkage reducers
9. Alkali-silica reactivity inhibitors
10. Coloring admixtures
11. Miscellaneous admixtures such as workability, bonding, damp proofing, permeability reducing, grouting, and gas-forming, ant washout, foaming, and pumping admixtures.

4.4.6 Water

Water for Construction works could be Potable and available from the stream or khola across the road alignment, Contractor may have to quarry the sources of water and build a temporary access road at various locations.

4.4.7 Steel

Steel is a consequence that will strengthen an organism's future behaviour whenever that behaviour is preceded by a specific antecedent stimulus. Reinforcement bars shall be of high yield strength deformed (HYSD) Fe 500, Thermo mechanically Tested, having specified minimum 0.2 percent proof stress of 500 Mpa, Conforming to IS: 1139 or IS: 1786 or equivalent or specified on the Drawings. This strengthening effect may be measured as a higher frequency of behaviour (e.g., pulling a lever more frequently), longer duration (e.g., pulling a lever for longer periods of time), greater magnitude (e.g., pulling a lever with greater force), or shorter latency (e.g., pulling a lever more quickly following the antecedent stimulus).it increases or strengthens the behaviour. Steel which are using in this projects should comply as said in STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE WORKS Section 620.

4.5 Disposal Sites

The soil and rocks may derive from the road cut during the road construction period. Most of the cut materials along the road can be used as the construction materials for Back fill, if the available material comply the Technical Specification's requirement, if not the materials can be disposed into the designated area of the road alignment or elsewhere. The unused materials are disposal area is mentioned in Table 4.5.

Table 4.5: Possible Locations for Disposal of Excavated Material

SN	Location/Chainage	Geomorphology	Stability condition	Tentative area for disposal soil
1	1+360-1+480	Hill side Slope	Stable slope	> 1080 m ²
2	2+200 – 2+670	Hill side Slope	Stable slope	> 5170 m ²
3	6+480 – 6+900	Hill side Slope	Stable slope	>6720 m ²
4	8+320 – 8+800	Hill side Slope	Stable slope	>5280 m ²
5	10+700 – 12+520	Hill side Slope	Stable slope	>27300 m ²
11	57+420 – 57+520	Hill side Slope	Stable slope	> 2200m ²

4.6 Conclusions

4.6.1 Summary and Recommendation

One of the most common reasons for construction costs to escalate, once construction has started and material sources fully explored, are that the materials are found to be sufficient or deficient in quality or quantity. This leads to expensive delays whilst new sources are investigated or the road is redesigned to take account of the actual materials available. (TRL, 2005) Material investigation therefore often requires an extensive programme of site and laboratory testing, especially if the materials are of marginal quality, quantity and accessibility in the project area.

Traditionally materials are selected on their ability to perform defined engineering tasks in a road. The ability of the material to perform these tasks is normally assessed by their compliance, or non-compliance, with construction material specifications. Standard specifications and guidelines for using granular materials, such as those in set out in Overseas Road Note 31 (TRL, 1993), need to be of a general nature. Theoretically these guidelines and other specifications refer to the material as it is finally compacted/laid on the road. The relative quality and in-service performance characteristics of road pavement materials are largely determined as required for the following main tasks

- Common embankment fill
- Capping layer (imported subgrade)
- Sub-base and road-base aggregate
- Road surfacing aggregate
- Aggregates for structural concrete
- Filter/drainage material

If the project is in an area where good quality construction materials are scarce or unavailable, alternate solutions that make use of the local materials should be considered to avoid long and expensive haulage. For example consideration should be given to,

- modifying the design requirements
- modifying the material (e.g. lime or cement stabilization)
- material processing (e.g. crushing and screening)
- Innovative use of non-standard materials (particularly for low traffic volume projects).
- using a central quarry of good quality aggregate and budget for increased haulage costs
- blending materials to achieve a material that is within specification

At the time of materials investigations should take into account any future needs of the road. This is particularly important in the case of upgrading roads, gravel roads for all-weather. Sources of good material could be depleted with the result that haul distances and costs will increase. Furthermore, good quality material may be required at a later stage in the road's life when the standard needs to be improved to meet increased traffic demands.

Due respected collection of samples from different possibilities sources along the alignment and tested. Test results are varying with marginal and the availability of quantity in sources is not enough for the project, hence it is required to go for other sources of materials. So, the physical requirements of Graded Crushed Stone Base Course requirement of Table 12.3 and physical requirements of Chippings Table 13.5 and AC requirement of Course aggregates Table 13.17 of **Standard Specifications for Road and Bridge Works** has to revised the value of **LAAV maximum and AIV/ACV maximum 40% and 30%** respectively. The test result of locally available sources materials are given in Table 4.1.

5. GEOLOGICAL STUDY

5.1 Introduction

Mugling-Damauli-Pokhara (~86 km) marks a stretch of Prithvi Highway, a major highway connecting western Nepal with rest of the country and is also a trunk route connecting the hill town like Gorkha, Besisahar, Bandipur, Syangja etc. Construction of this highway was started on 1964 and was completed in 1974. The highway at present is two lane single carriage way road with double bituminous surface treatment in almost all the section.

Growth in population as well as expansion of cities connected by the road, boost in construction of bigger and better infrastructure and subsequent increase in traffic has congested the highway and need for widening along with upgrading of the existing stretch of the highway is inevitable. The project is formulated to investigate and prepare detail design for upgrading and widening of the aforesaid stretch of the highway, for this purpose the whole stretch is subdivided as Mugling-Damauli (~42km) **Figure 5.1** and Damauli-Pokhara (~46Km) **Figure 5.2**

In this regard, geological field visit was carried out to access the geological condition of the alignment with foremost focus on the existing instabilities and the probable instabilities that may arise while widening and upgrading of the alignment. This report consists the geological and geotechnical findings and general observation of the Mugling-Damauli-Pokhara road alignment.



Figure 5.1: Mugling-Damauli road sector traced on Google map that passes through various land cover

(Source: Google Map)

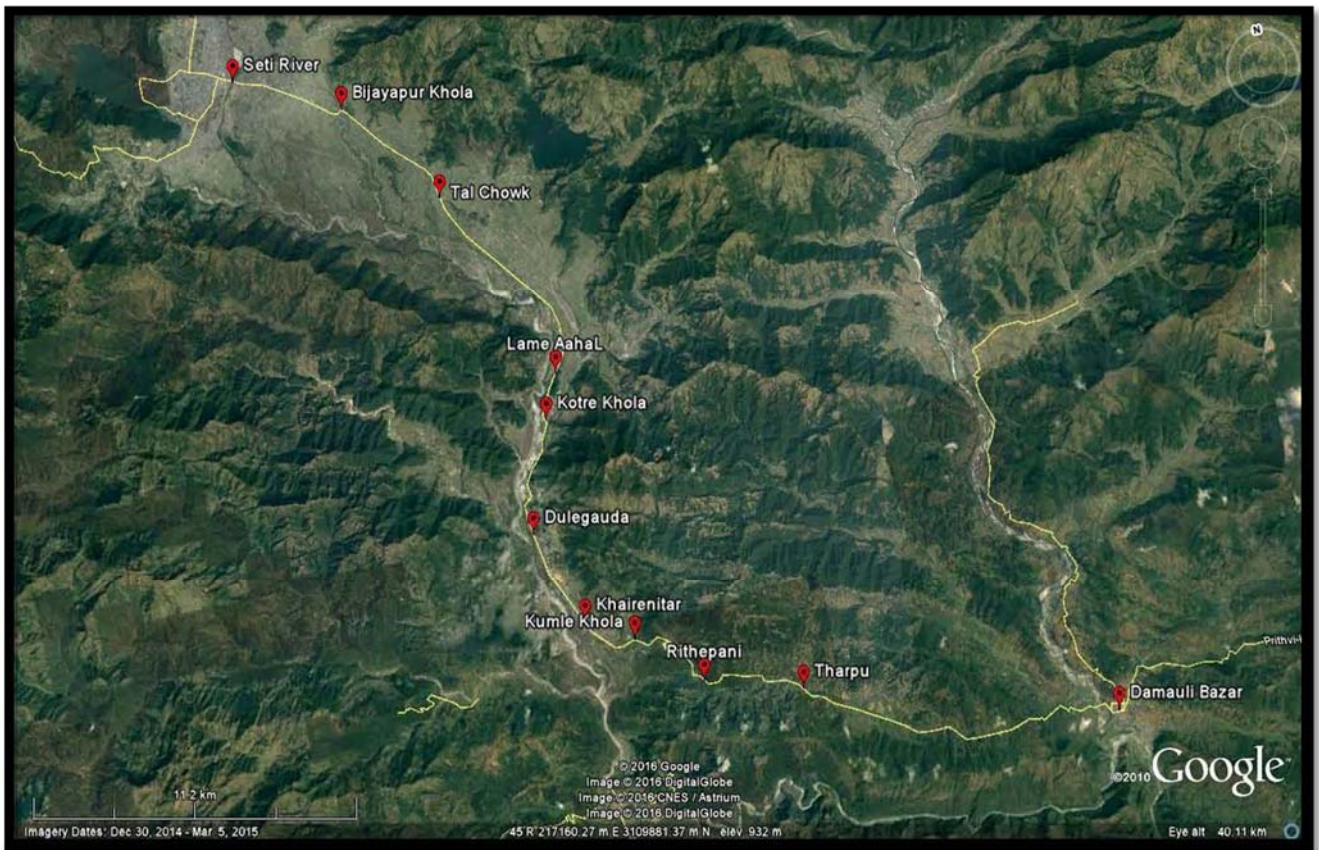


Figure 5.2: Damauli-Pokhara road sector traced on Google map that passes through various land cover

(Source: Google Map)

The Mugling-Damauli-Pokhara road alignment passes through numerous flat to gentle sloped terraces, moderate to gentle hill slope with a few exceptions, where the road alignment passes through rocky terrain consisting vertical to sub-vertical rocky cliff. The terraces consists of very thick to thick alluvial to colluvial deposits consisting boulder, gravel, sand silt/clay mix of dense to medium dense nature with varying bench height measuring up to few tens of meter. The hill slope is either covered with medium thick to thick residual to colluvial deposits or slope scree material. The rocky terrain along which the alignment passes consists of phyllitic, silicious, calcareous rock of varying grade of weathering and strength.

The alignment from Khairenitar onwards up to the Seti river bridge (Pokhara) passes through Pokhara valley floor characterized by recent quaternary Pokhara Valley sediments consisting of slightly to moderately cemented silty/sandy gravel.

5.2 Regional Geology

Geological Map of Nepal, 1997 (Figure: 5.3) best depicts the regional geology of the alignment. Almost all of the alignment passes through Lesser Himalayan metasedimentary rock sequence characterized by low grade metamorphic rock to sedimentary rock belonging to Nuwakot and Kunchha Group. The Nuwakot Group consists of phyllites, sandstones, quartzites and calcareous sandstone along with limestone, dolomite and slates while Kunchha Group consists of phyllites, metasandstone, quartzites. The topographic depressions along the alignment is covered by very thick to thin sequence of quaternary deposits characterised either as alluvial (terraces at and around river valley) or colluvial deposits or residual soil (hill slope terraces). Apart from this some part of the alignment especially the alignment near Pokhara Valley passes through quaternary, slightly to moderately cemented fluvial/fluvioglacial gravels, conglomerates and lacustrine clay deposit of very thick to thick nature.

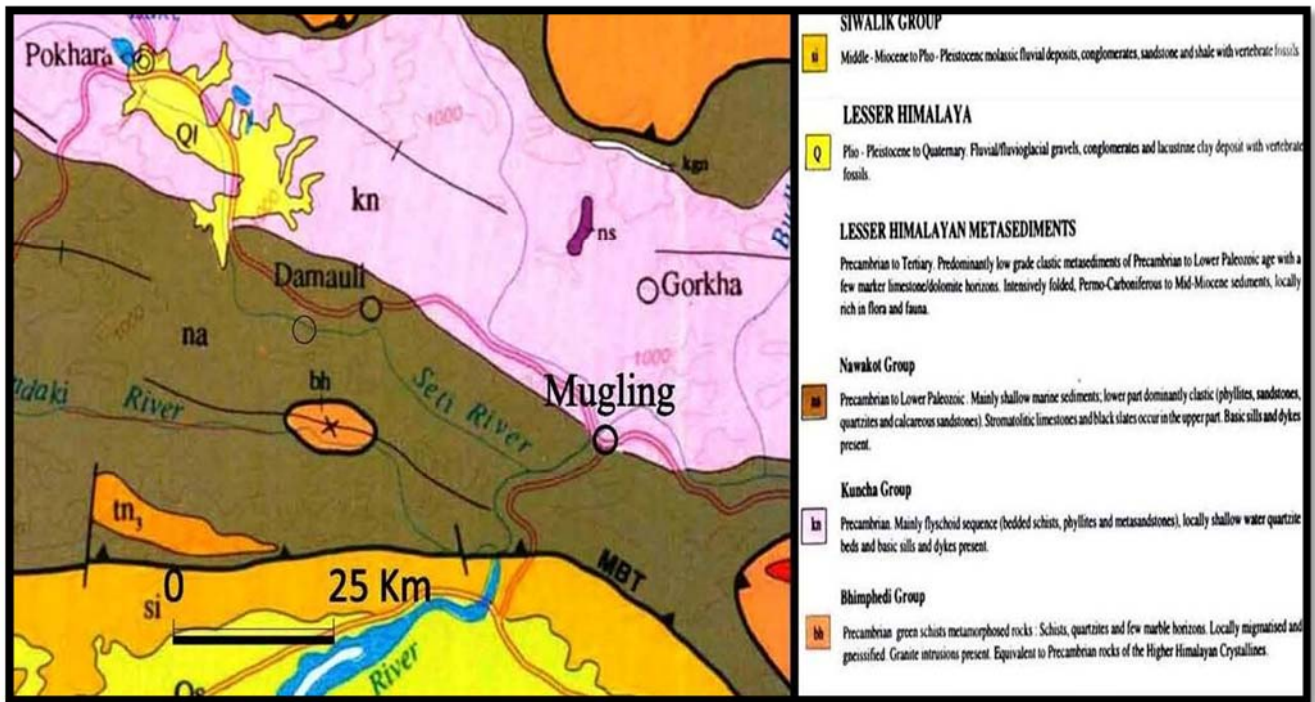


Figure 5.3: Simplified Geological Map of the road alignment

(Source Geological Map of Nepal, 1994)

The rock exposed along the alignment consists of varying rock types ranging from hard (quartzite) to soft (phyllite, slate) with varying grade of weathering. The rocks are massive to thinly foliated, jointed and fractured to crushed at places. The rocks are mostly covered by thin to thick, alluvial-colluvial-residual to slope scree material along the hill slope.

5.3 Engineering Geology

Engineering geological study was carried out to assess the road conditions focusing on the major landslides and instabilities. Following section describes the general geological conditions of the road stretch. Mugling-Damauli (42.225km) section of the alignment is being widened and upgraded by excavating up to 6m towards hill side from the existing road edge while Damauli-Pokhara (46.346km) section of the alignment is being widened and upgraded by excavating 10m towards hill side from the road edge where ever possible and necessary.

Mugling-Damauli Road section (0+00-42+253)

The Mugling-Damauli Road (**Photo 1**) starts from the Mugling from the right abutment of the bridge under construction over Trishuli River and ends at Madi Khola Bridge, right abutment near Chapaghat. The road alignment from Mugling up to Bimal Nagar runs parallel to the Marsyangdi River traversing along the extended terraces. The alignment from Mugling to Abu Khairane runs through moderate to steep hill slope consisting numerous hill slope terrace like Benitar, Bhawanitar and Aapchaur. The hill slope within this stretch consists of vertical cliff with exposure of phyllitic to quartzitic rock mass.

The alignment after Abu Khairane Bazar passes through gentle sloped terrace like Pipal tar, Dhaktar, Dhakaitar, Eelkle Phat, Satrasaya Phat, Bimal Tar, Dumre. The terrace bench are up to 5m high and consists of precarious exposure at places. The terraces are cultivated and are marked by built up area. After Dumre and crossing Nala Khola the alignment passes through places like Sumira, Nala, Banjare, Bel Bhanjyang, Banitar, Pipalthok, and Chhirkene Bhanjyang marked by gentle to moderate sloped area consisting thick to medium thick residual to colluvial soil with brief exposure at places. The terrain is cultivated and with scattered settlement and rest are covered by vegetation. After Chhirkene

Bhanjyang the alignment up to Deurali passes through rocky terrain with exposure consisting quartzitic rock mass.

From Deurali onwards up to end of Tallaghare the alignment passes through moderate hill slope consisting numerous terrace and colluvial cone and with few to brief exposure at places. After wards the alignment passes through relatively flat lying area at Damauli Bazar up to the Madi Bridge consists of residual soil. The chainage wise description is presented below:



Photo 1: Mugling Ch 0+000

Ch 0+000 to Ch 2+375

The alignment passes through rocky terrain consisting vertical cliff (0+000 to 0+250), the exposed rock consists of slightly weathered, thinly foliated phillitic rock mass (soft rock). The attitude of discontinuities of rocks and the hill slope are in favourable condition, obviously major problem regarding rockfall and the related phenomenon won't be the major instability issues while excavation. The hillslope consists of thin to medium thick slope scree material at places and is covered by vegetation. Terrace consisting colluvial to alluvial deposits with thickness up to 5m are frequent, such terraces are cultivated and are inhabited. Stability wise the section does not possess any major threats, minor instability involving sliding of the slope scree material can result in during excavation which can be managed by constructing retaining wall where necessary.

Ch 2+375 to Ch 3+000

The alignment is marked by rocky terrain with exposure consisting foliated, jointed and fractured silicic rock mass with alternating bluish grey phyllitic rock, the topographic depression are covered by thin to medium thick slope scree material.

Foliation Plane Fp 220°/49°

Joint Plane Jp 200°/18°, 020°-050°/45°, 305°/88°, 240°/35°

Instability caused by discontinuities within the rock will not result in wedge or planar failure, however sliding of slope scree material or the colluvial deposits can be anticipated, such resulting instability will not be of significant volume and can be managed by proper slope trimming and construction of retaining walls where necessary.

Ch 3+000 to Ch 3+725

The hill slope consists of thick to medium thick colluvial-alluvial deposits consisting boulder, gravel, sand and silt/clay mix the thickness ranging up to 5m, the deposit is medium dense in nature. The stretch does not possess any major threats regarding slope stability.

Ch 3+725 to Ch 5+375

The alignment passes through numerous Khorja/Terrace consisting thick to medium thick colluvial deposits consisting boulder, gravel of phyllitic and silicic rock mass. Exposures of moderately weathered, foliated and jointed quarzitic rockmass with intercalated phyllitic rockmass are frequent. The joints are persistent, irregular, open and are slightly filled with clayey silty material.

A recent minor rockfall of dimension of 2m*1m (**Photo 2**) was observed between Ch 4+400 to Ch 4+625. Incident of frequent rockfall involving boulder up to 20cm in diameter is common scene within this stretch. Planar failure can be anticipated within the Ch 5+000 to Ch 5+200 (**Photo 3**). Beside boulder slide of up to 50cm in diameter can be seen along the road indicating instable nature of the terrain. From Ch 5+200 to Ch 5+375 (**Photo 4**) the hill side slope consists of prominent vertical cliff measuring more 20m with overhang at places and the exposed rock consists slightly weathered jointed and fractured strong quartzite. The rockfall along the stretch owes to the fact that rocks are foliated jointed and are fractured at places resulting in dislodging of such blocks/lumps of rock. Extending of road form 5+300 to 2+375 along the hill side slope will be difficult due to near vertical rocky cliff consisting hard rock (quartzite) measuring up to 30m in height.

Foliation Plane Fp 220°/49°, 295°/45°

Joint Plane Jp 113°/47°, 055°-060°/45°-75°, 095°/60°, 165°/35°

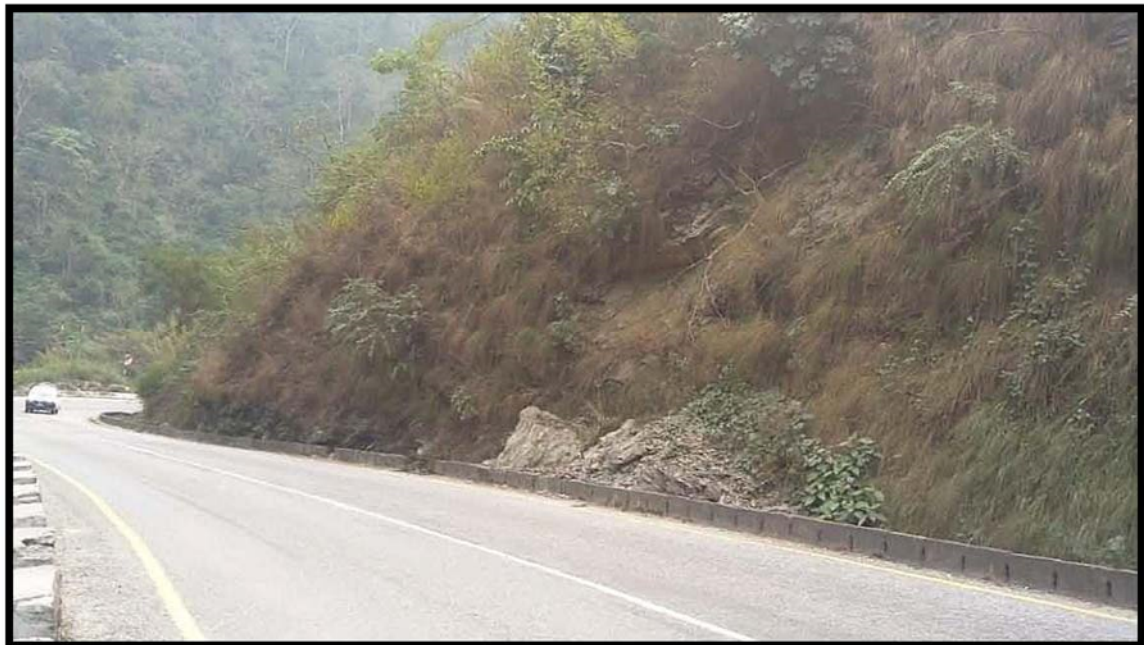


Photo 2: A minor rock fall at Ch 4+625



Photo 3: Rockfall observed at Ch 5+200 (planer failure)



Photo 4: Jointed and fractured rockmass exposed at Ch 5+375 with possibility of wedge failure.

Excavation along the hill side may pose difficulties due to shear height of the cliff and nature of rock. Planar failure and wedge failure with block measuring up to a meter in diameter at places along with sliding of colluvial boulder can be anticipated within the stretch. Slope trimming, construction of retaining/breast wall, bioengineering and shortcreting at places can serve as remedial measure for addressing such instability.

Ch5+375 to Ch5+875

The alignment passes through moderate to steep hill slope consisting thin to medium thick slope scree material. Exposure of moderately weathered foliated phyllitic rock mass with intercalation of quartzitic rockmass is frequently observed. The hill slope is covered by medium dense to dense vegetation. The gabion wall along the hill side shows sign of bulging indicating creeping movement of colluvial material (**Photo 5**). Slope trimming and construction of the retaining wall can address the instability problem.

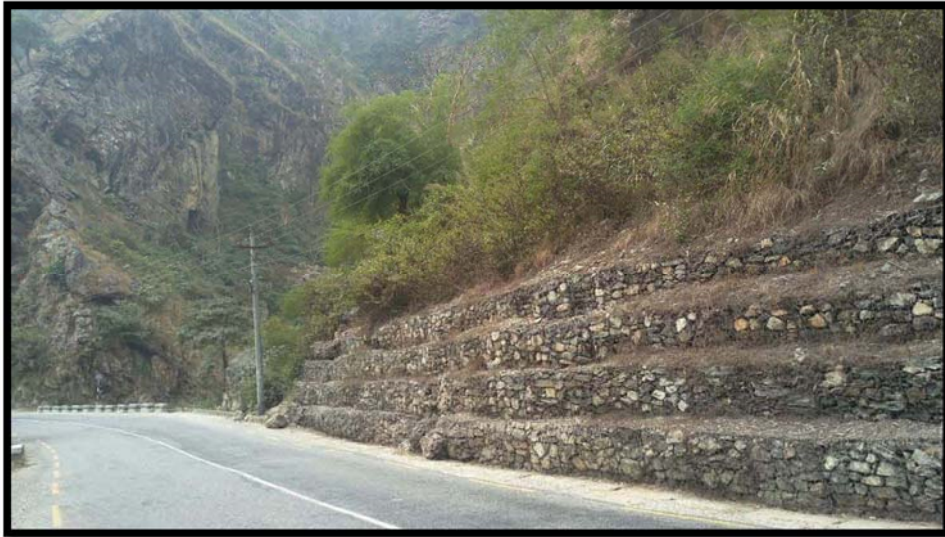


Photo 5: Bulging of the existing gabion wall between Ch5+400 to Ch 5+450



Photo 6: A minor recent rockfall at Ch 5+625 to Ch 5+650



Photo 7: A major landslide between Ch5+825 to Ch 5+875

The major slide measuring 50m by 20m is observed at Ch 5+825 to Ch 5+875 (**Photo 7**) and is in proceeding composure the sliding material consists of quarzitic rockmass, residual and colluvial soil. The rocks is highly jointed and fractured the major cause of the slide is due to weak nature of rockmass

caused by presence of dense discount unities within the exposure. The uppermost portion of the slide consists a meter thick colluvial-residual soil. Slope trimming and removal of loose material from crown up to the toe and rerouting the water by construction of drain along upper reaches of the slide, construction of retaining wall and shortcreting at places can serve as the corrective measure. **Photo 8** gives overall view of the terrain form Ch 3+725 to Ch 5+875

Foliation Plane Fp 295°/19°, 285°/35°

Joint Plane Jp 120°/65°, 010°/55°, 045°/35°, 095°/75°, 200°/65°



Photo 8: View between Ch 3+725 to Ch 5+875

Ch-5+875 to Ch-6+800

The alignment passes through the moderate to steep hill slope with exposure at places. The topographic depression consisted of the colluvial cone of medium dimension (20m*10m) and is marked as earlier but stable landslide. Presently the instability is addressed by construction of the gabion wall which shows the sign of bulging indicative of creeping movement of the material (**Photo 9**).

The exposed rock consists of slightly weathered foliated phyllitic rockmass with alternating slate and quartzite. The hill slope is covered by thin to medium thick slope scree material and is medium dense to densely vegetated. The excavation during widening of the road along the hill slope can trigger failure along the colluvial cone, slope trimming and construction of retaining and breast wall or stone masonry wall can serve the remedial solution to address such instability.



Photo 9: Bulging of the gabion wall between Ch 5+900 to Ch 6+000

Ch-6+800 to Ch-7+200

The hill side consists of rocky terrain covered with dense to medium dense vegetation and is marked by built up area, AabuKhaireni Bazzar. The area is relatively stable in nature and won't possess major stability threats during expansion.

Ch-7+200 to Ch 8+850

The alignment passes through the terrace consisting cultivated and built up area. The hill side terrace bench is up to 5m high with precarious exposure at few places. The terrace deposits consist of colluvial to alluvial deposits consisting boulder, gravel, silt/clay mix and is dense to medium dense in nature. Minor instability involving sliding of the alluvial-colluvial material can arise which can be addressed by construction of the retaining wall.

Ch 8+850 Ch 9+975

The hill side slope consists of thick slope scree material and thick colluvial cone consisting boulders in gravel, sand silt/clay mix (**Photo 10, 11**). The terrain is covered by medium dense vegetation seepage and springs are common. The existing gabion wall shows sign of bulging at places and the retaining wall are also not in good shape (**Photo 12**). Sign of recent sliding of boulder up to 50cm in diameter are common along the stretch (**Photo 13**). The wet to dripping terrain along with presence of seepage at places within the stretch is common sight.

Proper water routing and managing the seepage water, trimming away of the loose material along with construction of retaining wall and stone masonry wall at place will address the anticipated instability that will arise if the excavation is proceed along the hill side slope.



Photo 10: The colluvial cone along with the bulged gabion wall in between Ch 8+850 to Ch 9+975



Photo 11: The colluvial cone along with the retaining wall and boulder in between Ch 8+850 to Ch 9+975



Photo 12: The bulge out gabion wall between Ch 8+850 to Ch 9+975



Photo 13: The slid boulder along with the retaining wall in between Ch 8+850 to Ch 9+975

Ch 9+975 to Ch 20+075

The alignment passes through the terrace like Dhaikaitar, Markichowk, Eeklephat, Satrasayaphat, MujelGaun etc. consisting colluvial to alluvial to residual soil consisting gravel, sand, silt/clay mix. The terrace bench is up to 5m high at places and are well cultivated and are sparsely inhabited. The stretch is dissected by Khani Khola, HudiKhola. The rock exposure is limited along the river cut section and along the terrace bench. The exposure consists of silicic to calcareous rock. Instability along the terrain during the expansion and upgrading won't be of major concern within the stretch.

Ch-20+075 to Ch-21+400

The hill side slope consists of thick to medium thick residual-colluvial soil overlying the quartzitic to phyllitic rockmass and calcareous rockmass and forms near vertical cliff (**Photo 14**). The rocks especially calcareous rockmass are massive and dolomitic in nature due to distinct elephant weathering pattern. Brief problems involving dislodging of the block during expansion can be anticipated which can be addressed by slope trimming and shortcreting at places.



Photo 14: The rock exposure forming near vertical cliff around Bimal Nagar

Ch 21+400 to Ch 23+950

The alignment passes through the terrace like Bimal Nagar consisting alluvial-residual soil, and Dumre. The alignment passes through moderate to gentle hill slope consisting thick to medium thick residual-colluvial soil with exposure of calcareous to silic rock mass at places. Major stability involving sliding of the residual to colluvial soil issue will not be of significant volume, the minor instability can arise during which can be addressed by construction of the retaining wall at places with proper water management by construction of side drain.

Ch 23+950 to Ch- 31+300

The alignment passes through moderate to gentle hill slope consisting thick to medium thick yellowish red residual to colluvial soil with exposure of phyllitic rock with intercalation of slate and quartzite at place up to Chhirkinay Bhanjyang. The terrain is cultivated and with scattered inhabited area and are medium dense vegetated. Major instability won't be an issue while expansion and upgrading.

Ch 31+300 to 32+625

The alignment after crossing Chhirkinay Bhanjyang passes through moderate hill slope marked by exposure of massive grey to pink quartzitic rockmass along the hill side (**Photo 15**). The hill slope at places is covered by thin layer of slope scree material and the terrain is medium to densely vegetated. The exposed rock is relatively hard in nature, excavation along the hill side slope might be difficult however instability involving wedge failure or plane failure is at minimal, beside the resulting sliding of the thin to medium thick slope scree material during and after excavation can be addressed by trimming and construction of retaining wall.

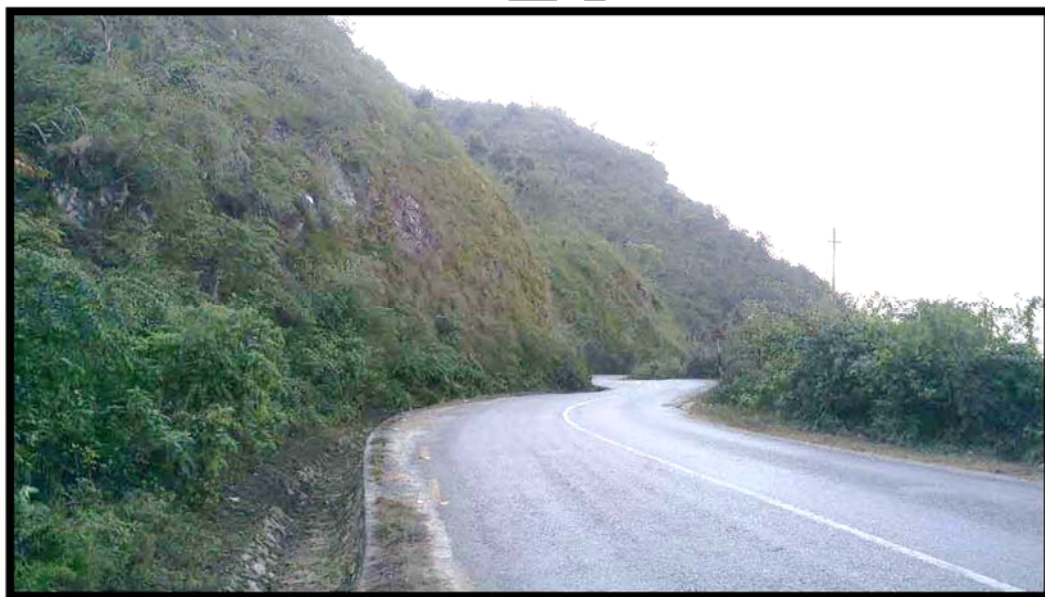


Photo 15: The outcrop of quartzitic rockmass after crossing Chhirkeni Bhanjyang towards Damauli.
32+625 to 36+050

The alignment passes through the moderate to gentle sloped terrace covered with medium thick to thick residual-colluvial soil, with brief exposure at places, the exposure consists of moderately weathered quartzite, phyllite and calcareous rocks at places. The terrace slopes are mostly cultivated and is covered with medium dense vegetation at places. Major threats of instability during the expansion can be ruled out, however possibility of minor slope failure can be anticipated and can be addressed by construction of retaining and masonry wall at places

36+050 to 36+750

The alignment passes through moderate to steep hill slope consisting numerous colluvial cone consisting boulder, gravel, sand, silt/clay mix and with exposure of quartzitic rockmass. The exposed rock is slightly weathered jointed and fractured at places. Beside the hill slope is covered with medium thick to thin slope scree material. The terrain is relative moist to dripping at places. Instability during expansion can be anticipated and can be addressed by construction of retaining and masonry wall at places with proper water routing.

36+750 to 39+175

The alignment passes through moderate slope terrace consisting thick to medium thick reddish brown residual soil and colluvial cone at places (**Photo 16**).. Brief exposure of slightly weathered foliated phyllitic to slaty rockmass are at places. Major slope instability won't be of major concern as the land forms within this stretch are relatively stable in nature. Minor slope failure can be anticipated which can be addressed by simple engineering structures.



Photo 16: The exposed showing thick sequence of residual soil in between Ch 36+750 to 39+175
39+175 to 39+200

The hill side slope consists of thinly foliated moderately weathered jointed and fractured at places, the rockmass is covered by thin residual soil. The stretch consists of recent active landslide involving thinly foliated fractured slaty rockmass covered with thin residual to slope scree material (**Photo 17**). Slope trimming and shortcreting at places will be the remedial solution to address the problem.

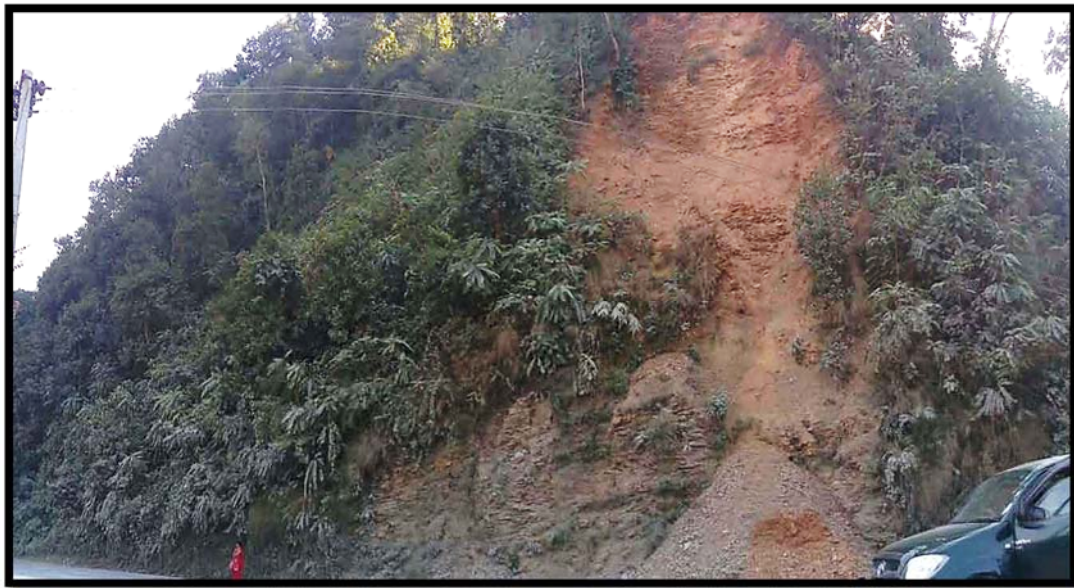


Photo 17: A minor instability observed in between 39+175 to 39+200

39+200 to 41+825

The alignment passes through moderate sloped terrace up to 40+425, the slightly weathered thinly foliated phyllitic and slaty rockmass is exposure parallel to the road up to the brief height. The terrace consists of medium to thick residual soil. Seepage areas with dripping to wet condition are at places. From Ch 40+425 to 41+400 the alignment passes through built-up area of Damauli Bazar. Afterwards up to 41+775 the alignment passes through hill slope terrace with bench height ranging from 0.5 to 10m consisting dense to medium dense residual soil. Slope instability problem will not be the major issue during the expansion of the road stretch.

Ch 41+775 to Ch 42+225 marks the bridge over the Madi Khola and end of the stretch (Mugling-Damauli).

Damauli - Pokhara Road Section (42+253 to 88+596)

The Damauli-Pokhara road alignment starts from Madi Khola right abutment at Chapaghat, the alignment passes through rather gentle to moderate hill slope up to Khairenitar. Chapaghat, Tharpu, Manahari, Chhabise, Manpang, Pipal dada, Niure, Ritthepani, Kumle Khola are the area where the alignment passes through moderate to gentle hill slope and flat low lying area marked by numerous terraces consisting thick to moderately thick residual/colluvial to alluvial soil. The hill slopes are covered by medium thick slope scree material. The colluvial cones marking the earlier but stable landslide are frequent. The area also consists of sparsely inhabited area. From Kumle Khola to Khairene bazar the alignment passes through built up area consisting residual soil.

Khairene bazar to the Chuninaymuda section of the alignment is marked by valley floor consisting residual soil, from Chuninaymuda to Lama Aahele the alignment passes through the hill slope with exposure of massive, fractured and jointed quarzitic rockmass. From Lama Aahale to Seti River left bank the alignment passes through Pokhara valley floor marked by valley sediments consisting gravel, pebble, sand silty clay of semi-consolidated dense to medium dense soil. The chainage wise description is presented below:

Ch 42+253 to Ch 42+725

The alignment after crossing Madi Khola passes through the flat lying terrace consisting residual to colluvial soil at Chapaghat. Slope instability would not be an issue within this stretch.

Ch 42+725 to 48+125

The alignment passes through the moderately to gentle foot hill slope and terrace consisting colluvial to residual soil. The road section between 43+050 to 43+075 shows sign of subsidence of about 10cm along with bulging and of the gabion wall (**Photo 18**). Exposure of rocks consisting calcareous rockmass are exposed at placed (**Photo 19**). The hill slope is covered with thin to medium thick colluvial to residual soil. Slope trimming along with construction of the retaining and masonry wall can serve as the method for addressing the existing problem.



Photo 18: The subsidence of the road and gabion wall at Ch 43+050 to 43+075



Photo 19: The exposure of calcareous rock mass at Ch 43+050 to 43+075

Ch 42+725 to 53+175

The alignment passes through relatively flat lying terrace at foot hill. The hill side slope consists of terrace bench up to 20m high consisting residual to colluvial soil with exposure of phyllitic to slaty rock mass with alternating quartzite at places at places. The terrain is cultivated and with scattered inhabited area. Hill slopes at places are covered by dense to medium dense vegetation. Major instability problem is not anticipated, however minor instability involving failure of residual-colluvial deposits can occur which can be addressed by construction of retaining structure at places where necessary.

53+175 to 53+375

The alignment is marked by thick terrace sequence protected at the toe by gabion wall (**Photo 20**). The terrace consists of residual/colluvial soil with sign of creeping movement. The soil is medium dense and is wet to moist in nature. Proper water management including side drain and bioengineering can be the remedial solution to address the slope instability that can arise during excavation and widening.



Photo 20: The gabion constructed to check the possible creeping of the thick residual soil near Thurpu

53+375 to 58+055

The alignment passes through the moderate to gentle hill slope with numerous terraces. Exposure of rock consisting of phyllite/slate with alternating quartzite is limited along the road cut section at places. The stretch consists of numerous stable terraces consisting of colluvial to residual soil along which inhabited areas like Manahari Bazar, Chhabise, Pipal Dada, Niure, Saunepani, Mauri Bazaar, Ritthevani are located. The terrain mostly is cultivated and inhabited with medium dense to dense vegetation coverage at places.

A minor recent collapse of the road along the road edge was observed between 58+050 to 58+055 (**Photo 21**) giving insight of such possibilities along this stretch. The slid material consists of colluvial to residual soil with gravel and less frequent boulder of phyllite, slate. Construction of the breast wall and stone masonry wall can serve as the remedial solution to address the instability.



Photo 21: A minor road edge failure observed in between Ch 58+050 to Ch 58+055

58+055 to 59+700

The alignment passes through similar terrain consisting of gentle sloped terraces at the foot hill. Seretar, Simaltar are terraces consisting of colluvial/residual/alluvial deposits of medium dense nature. The terrain is cultivated and is covered by medium dense to dense vegetation. A precarious hillock

consisting soft to stiff calcareous silty clay to clayey silt inter fingering towards hill pockets was observed with thickness up to 8m (**Photo 22**).



Photo 22: The hill lock consisting calcareous silty clay to clayey silt at Ch 59+675
59+700 to 60+900

The alignment passes through moderate hill slope. Exposure of rock consisting moderately weathered foliated quartzite intercalated with phyllite and slate are limited to road cut section up to 2m high (**Photo 23**). Most of the terrain is covered by dense to medium dense vegetation. The topographic depression consists of thick colluvium deposits, such topographic depression at 59+925 is marked my spring area (**Photo 24**). The terrain in general is moist to wet.

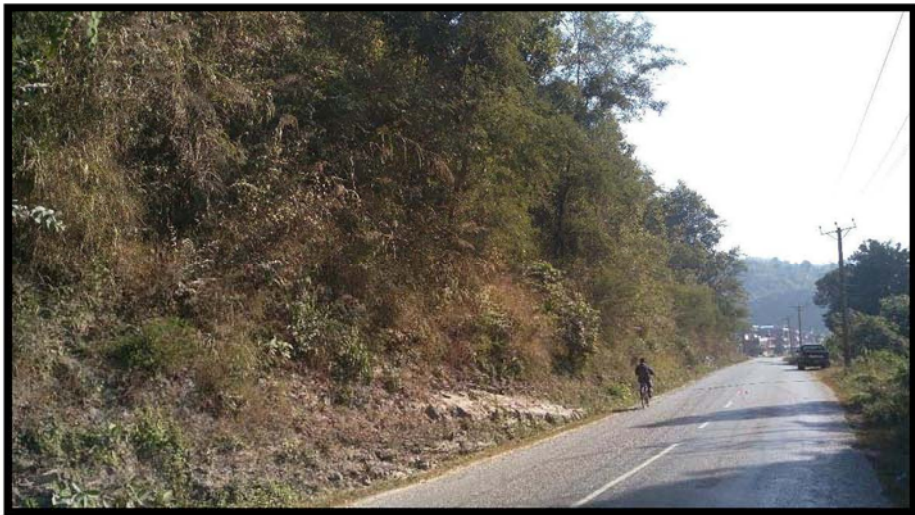


Photo 23: Exposure of rock overlain by thick to medium thick slope scree material in between
59+700 to 59+725



Photo 24: Spring area at Ch 59+925

60+900 to 61+675

The alignment passes through the alluvial terrain of Kumle Khola after crossing the alignment passes through the terrain consisting thick sequence of undifferentiated lake deposits overlying

61+675 to 67+250

The alignment passes through the flat lying terrace consisting very thick to thick slightly to moderately cemented silty/sandy gravel. The area is built up area and passes through Khairanitar, Dulegauda, Thati, Bel Chautara.

67+250 to 69+550

The alignment passes through moderate to gentle hill slope and terrace consisting medium thick to thin colluvial deposit covering the massive to foliated quartzite and phyllite. The terrain however also consists of thick sequence of Pokhara valley sediments consisting moderately to slightly cemented silty/sandy gravel (**Photo 25**). The exposed rock though are limited to the road cut section and upper reached of the hill are slightly weathered, jointed and fractured (**Photo 26**).

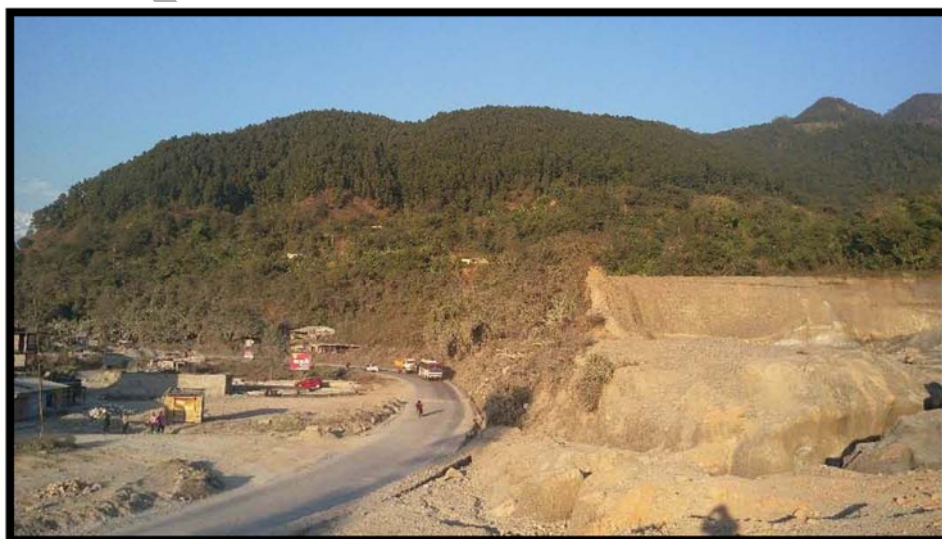


Photo 25: The thick sequence of Pokhara Valley deposit consisting consolidated sediments 67+725 to 68+225

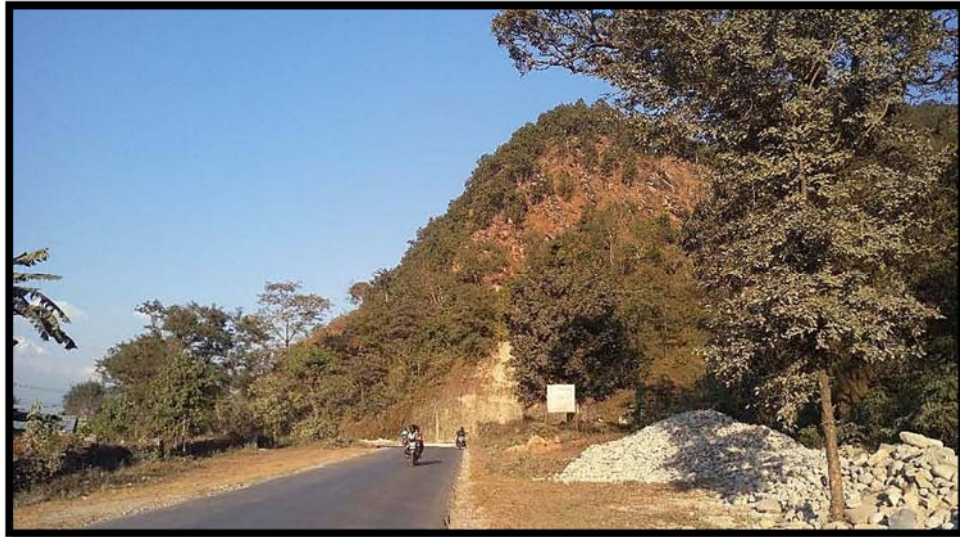


Photo 26: Rock exposure along the upper reaches of hill slope from Ch 69+000

69+550 to 71+550

The alignment passes through the terrain consisting thick sequence of Pokhara valley sediments with brief exposure of phyllite and quartzite at places with no major threats to stability. An isolated hillock consisting slightly to moderately cemented boulder, gravel sand and slit mix and resembles conglomerated is exposed just crossing bridge over Kotre Khola towards Pokhara valley (**Photo 27:**)

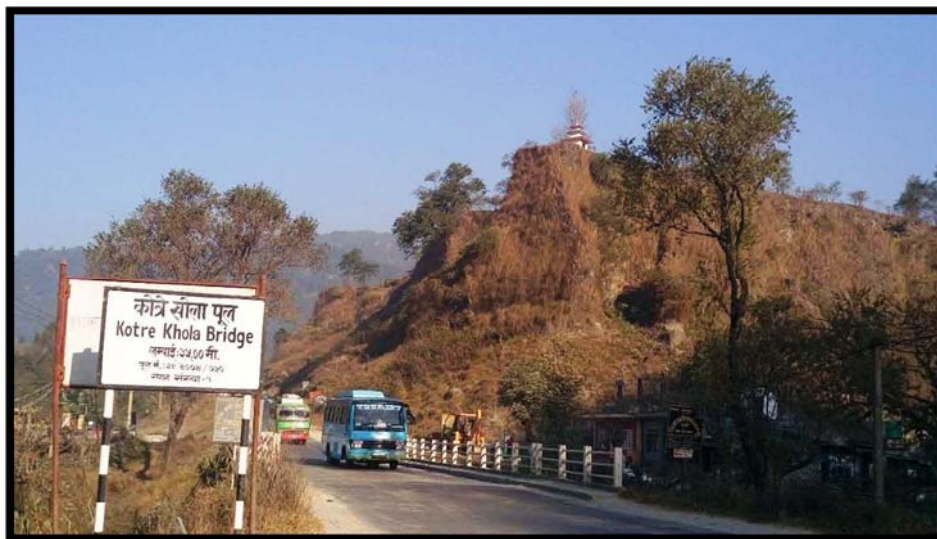


Photo 27: An isolated hillock consisting thick sequence of consolidated sand/silt, gravel from 70+600
Ch 71+550 to 72+375

The alignment passes through an isolated hillock consisting massive, jointed, fractured quartzitic rockmass (**Photo 28**). The hill slope is covered by thin to slope scree material and is densely vegetated. At places the exposure forms a near vertical cliff with sign of block failure especially in an area around Lame Aahale.

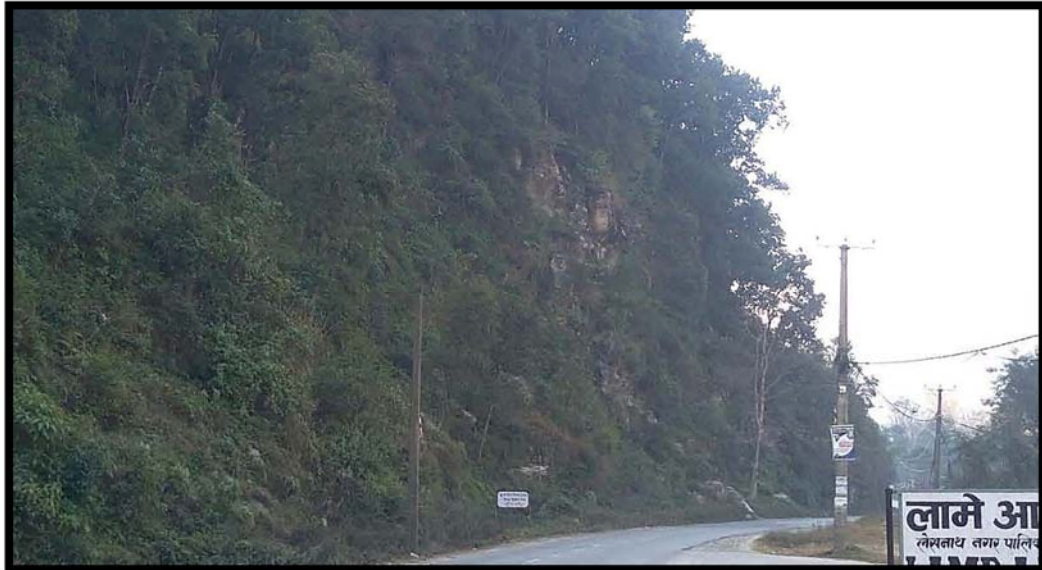


Photo 28: The jointed and fractured rockmass forming a vertical cliff around Lame Aahale (Ch 72+050)

Ch 72+375 to 88+596

The alignment passes through the upper terrace consisting Pokhara valley sediments consisting slightly to moderately cemented silty/sandy gravel, limestone schist, gneiss and granite are the main constituent. The bridge over Seti River Ch 88+596 marks the end of this stretch.

5.4 Conclusions and Recommendations

Geologically, the road alignment passes on the rocks of Nuwakot Group and Kunchha Group consisting Phyllites, Metasandstone, Slate, Dolomite, Quartzite. The exposed rock is slightly to moderately weathered and completely weathered and is jointed and fractured at places. Joints are non-persistent to persistent and are open with infilling of sandy silty/clay material at places. Mostly the rocks are covered by thin to thick slope scree to colluvial-residual materials.

Mugling to Dumre stretch of the alignment passes through river valley of Marsyangdi and the stretch of alignment from Khrenitar to Gagangauda passes through river valley of Seti. Rest of the alignment passes through the moderate to gentle hill slope, foot hill and valley floor within the Lesser Himalaya.

Approximately 45% of the road alignment passes through bazaar and built up area, consisting alluvial-colluvial, colluvial-residual and debris flow deposits, 9% through forest area consisting thin to medium thick slope scree material along with colluvial to residual deposits, 39% through rural and cultivated area consisting thick to medium thick silty/clay about 2% of the alignment through barren land including river, kholchhi etc. and 5% alignment passes through rocky area consisting rocks of Nuwakot Group and Kunchha Group.

Majority of the alignment passes through the terrace like Abu Khaireni, Eekle Phat, Satrasaya Phat up to Dumre, consisting colluvial-alluvial deposits while the terraces between Khairenitar to Pokhara consists of alluvial-debris flow deposits.

The major rocky terrain includes the stretch between Mugling to Abu Khaireni (Ch 0+000 to Ch 6+800), Bimalnagar area (Ch 20+800 to Ch 21+250) and Chhirkine Bhanjyang to Ghasi Kuwa (Ch 30+950 to Ch 21+725). However, the stretch between Ghasi Kuwa to Damauli, Chapaghat to Jamune Bhanjyang, Niure to Rittheponi, area around Seretar, Chuhene Muda, Lame Aahale consists few to brief exposure of rocks.

The hydrological condition of road alignment is almost dry except the stretch at Dabtar-Dhaikaitar (Ch 9+150 to Ch 9+900), Chirkeni Bhyangyang-Ghasikuwa (Ch36+375 to Ch37+525) the area around Mauri Bazar and Ritthevani (Ch 59+875 to Ch 59+975) are wet to dripping.

In general, the Mugling-Damauli-Pokhara road alignment lies in high-low to medium hazard zone, of the total length less than 1% of the alignment passes through high hazard area and includes the active rockfall/landslide in between Mugling-Abukhaireni, the slumping of road edge around Niure-Rithevani.

About 10% of the alignment passes through medium hard zone where uphill slope excavation during widening can induce slope failure involving colluvial, alluvial, residual and slope scree material, the alignment between Ch 8+850 to Ch 9+975, Ch42+725 to Ch 48+125, Ch 53+175 to Ch 53+375, 59+700 to Ch60+900 and Ch 71+500 to Ch72+375 are identified as the terrain with possibility of instabilities induced during hill ward excavation. The instabilities will be of shallow depth and can be treated with minor engineering means involving retaining and breast wall, masonry wall etc. and bioengineering. The instabilities in the rocky terrain can be corrected by proper slope trimming, shotcreting and construction of retaining and breast wall.

Rock weathering, precipitation, groundwater, under cutting of slope for road construction, poor surface water management and gully erosion are the main cause of instability. At moments most of the cut slopes are in stable conditions.

For Reference Only

6. ROAD SAFETY

The responsibility of DoR at the project level MoPIT will continue to have the overall responsibility on road safety in its role as line agency. Home Ministry (Traffic Police Service – TPS) is responsible for enforcement and involved in surveillance, control, post-crash response management and legal proceedings resulting from road crashes. Health Ministry as well as Ministry of Education also has some role to play to deliver better road safety outcomes (contributing to develop safer users) in the country.

Road safety is thus a shared responsibility among various agencies. Activities related to delivering road safety are carried out by several government and non-government agencies. Coordination among these agencies is vital for ensuring better outcomes. The National Road Safety Council (NRSC) established by the Government within MoPIT, as the Secretariat, is the body for general decisions, strategic planning related to road safety improvement and reduction of traffic accidents. The Road Safety Secretariat at MoPIT performs day to day activities related to coordination.

While the above described arrangement represents a commonly practiced institutional framework for managing road safety and has worked well in many countries of the world, this has not been the case in Nepal. The resource allocation needed for proper functioning of the institution is very weak currently. It is not able to deliver road safety outcomes as required to meet the global target of reducing road deaths by 50% by 2020. This is evident by the absence of computerised crash database and road safety information management system with the Government. The absence of proper crash investigation and crash database system is a major obstacle for any meaningful monitoring of the progress on achieving road safety target committed internationally by the nation. Other obstacles are lack of dedicated safety engineers and support personnel for NRSC secretariat and road safety specialists in the country as a whole. Establishment of NRSC with adequate resources was recommended in the Road Safety Action Plan in 2013 and in the ongoing Road Safety Support Project (RSSP) funded by the World Bank.

The existing funding framework also appears to be very weak. It is understood that there is a separate line item in the road operation and maintenance budget dedicated to road safety. But the meagre budget which can be used for road safety studies and retrofit should compete with the overall road operation budget. Road safety improvement works usually get the least priority in the overall road operation and maintenance needs. It, thus, becomes even more important that most essential road safety treatment works be attended during the project implementation phase as there would not be enough fund with the Department for safety retrofits once the road is taken over by its Maintenance Division. There is therefore an ample of opportunities in the country to improve road safety. Nepal is one of the worst performers in the world by the number of traffic accidents in relation to vehicle ownership and vehicles-kilometres travelled.

In its commitment to improve road safety and in accordance with the call of United Nations Decade of Action on Road Safety, Government of Federal Republic of Nepal has also completed its draft Road Safety Strategy in 2013. The plan has been adopted by the Government as its policy document on road safety. Interestingly, the strategy has not set any specific target to reduce death and number of crashes (say by 10% every year or halve its road death and serious injuries). The proposed road safety audit and implementation of the measures to address road safety issues identified by the audit is expected to support the delivery of the Government's commitment on implementing road safety action plan for the overall improvement of road safety and save innocent lives in the country.

6.1 Documents Reviewed

Road safety measures for MP Road Upgrade Project are guided by a number of legislative acts, regulations, national standards, codes and manuals of the Federal Republic of Nepal. Some of the key guiding publications relevant to road safety works are included in Table 6.4.1 below. There is also a manual of its own on road safety process to be applied in undertaking road safety audit and identifying treatment measures in Nepal. The manual was developed in 1997 and has not been revised since then. Asian Development Bank (ADB) has also developed its own operational tool kit to be used as a guiding document in undertaking audit of roads funded by the Bank. Austroads Guide to Road Safety Part 6: Road Safety Audit provides internationally recognised best practice guide and the process recommended by the Guide has therefore been used where they are relevant. Other useful guides for references include Guide to Road Safety Part 9: Roadside Hazard Management, Guide to Road Safety Part 8: Treatment of Crash Locations, Effectiveness of Road Safety Engineering Treatments: Austroads Research Report AP-R422-12 etc. which can be used for

There are a number of acts, rules and regulation to manage road safety in Nepal. In mid to late 1990s, a lot work was done by DoR in the field of road safety. Road Safety Notes were developed. Traffic Sign Manual was published. Road Safety Audit Manual was also developed for use in the country. However, over time, road safety audit practice in the design of road was not actively pursued. It is only in recent times, with the adoption of Road Safety Action Plan and funding agencies' commitment to build safer roads, road safety tasks have become mandatory in many large-scale road projects funded by these agencies.

Table 6.1: Relevant Reference Materials for Road Safety Audit

Title of Publications	Key contents
Road Safety Action Plan (2013 - 2020) February, 2013	Contains various actions committed by the government for implementation in line with country's commitment on UN Decade of Action on Road Safety
Status Paper Traffic Safety 2013	Describes the status of road safety works and outcomes
Nepal Road Standards 2070, July 2013	Specifies road standards to be adopted for project roads
Nepal Bridge Standards 2067	Contains standard to be adopted for bridge
Standard Superstructure Drawings for Road Bridges, 2015	Contains design details and drawings for road bridges of various span length (modular)
Road Safety Note 2: Designing Safer Side Drains, November 1996	Contains guidelines for making road side drains more forgiving
Road Safety Note 5: Delineation Measures, March 1996	Contains guidelines on the selection of delineation measures to guide traffic through bends etc.
Road Safety Note 6: Safety Barriers, July 1997	Contains guidelines for the selection of appropriate type of safety barriers and their details
Road Safety Note 7: Safety at Bridge, July 1997	Contains basis guide on how to make approaches to bridges safer.
Road Safety Note 8: Identifying and Treating Accident, June 1997	Contains guidelines for the selection of types of treatments for key crash types
Road Network Data, 2014	Provides information on road network in the country
Road Users' Guide (in Nepali), May 1999	This guide provides basic rules and regulations, code of conduct while using public roads
Traffic Sign Manual Vol 1 of 2, August 1997	Provides description of various types of road signs used in the country.
Traffic Sign Poster, Not dated	traffic signs for convenient reference
Briefing Note - LRN Road Safety, Not dated	Describes specific road safety tasks for local road network managed by DoLIDAR

Title of Publications	Key contents
Sector wide Road Programme and Priority Investment Plan, 2013	List of roads with priority and investment plan
Motor Vehicle and Transport Management Act, 1993	Basic act for managing transport in the country. Safety issues are not adequately addressed by the existing act.
Motor Vehicle and Transport Management Regulations, 1997	Basic regulations/ code for transport management. Safety issues are not adequately addressed by the existing regulations
Public Roads Act, 1974	Act regarding the management and operation and control of public roads
Local Self Governance Act, 1999	As per LSGA, local governments (City councils) are obliged to manage urban roads. However, strategic urban roads are still being managed by DoR
Roads Board Regulations, 2004	Describes funding
ADB Road Safety Audit Tool Kit, 2003	This is a road safety audit manual to be used un undertaking road safety audit of roads funded by ADB.
Road Safety Guidelines for Asia and Pacific Regions, 1996	Contains ADB's policies and guidelines on road safety matters
Austroads Guide to Road Safety Part 6, 2009	Contains best international practice on road safety audit at various stages of planning and design
Austroads Guide to Road Safety Part 9, 2008	Contains recommendations on best practice roadside hazard management measures
Austroads Guide to Road Safety Part 8, 2009	Contains recommendations on remedial /treatment measures for various types of crashes
Austroads Research Report AP-R422-12, 2012	Contains information on the effectiveness of road safety engineering treatments to reduce crashes

6.2 Road Use Management Strategy

Improvement in road infrastructure in isolation incorporating road safety measures in the design, will not reduce road deaths and serious injuries. Road use culture and understanding of the community in using roads properly plays an important role in getting the maximum benefits out of the enhanced road safety measures in project roads. Access management and speed management are two main components of any road use management strategy. Both components of this strategy are found to be quite inadequate in the country for any improvement in road safety outcomes.

Posted speed limits are usually 10km/hr less than the design speed (for high speed environment of 70km/h and over) unless operating speed models are developed specifically. Sections with 60km/h design speed are proposed to have the same posted speed limit as the design speed (in rural sections). However, at rural township and bazar area, a reduced speed limit of 50km/h (10km less than the design speed), if service roads are provided. Sharper bends such as hair pin types will have posted speed limit of 15km/hr, 5 km/hr less than the design speed.

The adopted design speed of 40 km/h for 2-lane sections means that the posted speed limit would also be 40 km/h. Any collision with the pedestrians at this speed is usually to be fatal. Safe system approach recommends the implementation of reduced speed limit in high pedestrian activity area. However, any speed less than 30 km/hr is not desirable for any long section of this road because of its significance. Therefore, reduced posted speed limit of 30 km/h is recommended for two lane roads for bazar area only (without service roads). For four lane roads with service roads, 50km/hr speed limit is recommended. Development and implementation of right speed management strategy together with access management strategy could be the forward plan of action to make this road safer for all users.

The current practice of speed limit signing is not adequate. Without the end of speed limit sign or repeater sign it will be difficult to enforce speed limit and issue speeding fines. Hence there is a need to review this speed signing practice in the country, not just for MP Road.

Current speed signing practice in Nepal does not conform to international practice. A significant overhaul is needed for speed zoning practice, repeater signing practice and speed limit signing practice. It is recommended that sections of road be divided into appropriate speed zone and speed limit sign be installed at each zone. This recommendation would require changes in Nepal Road Rules (Motor Vehicle and Transport Management Regulations) and Road Signing Standards. A suitable best speed limit signing practice used somewhere can be used until such time Nepal Road Rules or Speed Management Strategy would not be available.

Operating intersections at any speed higher than 40km/hr is a major safety concern for the rural section of the roads with severely restricted visibility (sharp bends). As regular speed limit review is not practiced in Nepal, a lower posted speed limit at the very onset may need to be established. The detailed design and estimate of MP Road allows provision for regular speed limit signing.

The second issue of safety concern, which has been observed in the road design and management practice in Nepal, is the number of accesses to, and egress from, the main road. Vehicles have been seen reversed from driveways to the main road. With the improvement of road and increase in traffic, this practice should stop for safety reason.

In terms of accesses, other than driveways, consideration must be given to implementing all kinds of available and possible measures to reduce the number of accesses to and egresses from the main road involving right turning. All driveways should be accessed using left turning maneuver only. This could have been delivered at planning and design level by developing and implementing appropriate road network strategy (long term) and by developing and implementing access rationalization and control strategy at operational level. At this stage, it appears to be highly desirable to reduce the number of right turn accesses and egresses. Where this is not possible at least simple BAR type of treatment should be provided and the same has been suggested accordingly.

Almost all existing intersections along the road are poorly designed and are substandard. The angle of intersection is acute and grade along minor road is unacceptably high with some exceptions. This is addressed by providing detailed layout and design of each major intersection. Type design drawings do not solve this problem. It is proposed that the successful contractor, after completing construction layout survey, develops details of each major intersection specific to the site using the typical drawings provided in the detailed design report.

6.2.1 Speed Management and Control

Detailed section wise list of recommended posted speed limits can be suggested following the development of speed management and control strategy for the road towards the completion of detailed design, construction through pre-opening stages audit process. While the speed management and control strategy should be based on the nature of development along the road corridors, land use, highlights on initial safety concerns (due to lack of crash data), discussion and agreement with the client, it is recommended as a guide that the following speed limits (See Table 6.5.1) be considered and signposted for the following typical sections and situations (speed zoning) along the NB Road. Locations of speed zones can be suggested following the development of speed management and control strategy towards the completion of detailed design, construction through pre-opening stage audit processes. The speed management strategy should also consider speed enforcement measures.

Table 6.2: Recommended Maximum Posted Speed Limits

SN	Chainage		Length (m)	Total Width (m)	Speed Limit (Km/h)
	From	To			
1	0+000	3+700	3700	900	60
2	3+700	3+900	200	9.00	30
3	3+900	6+770	2,800	12.00	60
4	6+700	8+050	1,350	18.5	40 (30)
5	8+050	23+400	15,350	18.00	60
6	23+400	23+950	550	42.5	40 (30)
7	23+950	40+430	16,480	12.00	60
8	40+430	41+400	970	42.50	40
9	41+400	61+700	20,700	12.00	60
10	61+700	66+740	5,040	46.20	60
11	66+740	70+210	3,470	23.00	60
12	70+210	70+510	300	46.20	60 (30)
13	70+510	74+600	4,090	23.00	60
14	74+600	76+940	2,340	46.20	60 (30)
15	76+940	77+010	70	23.0	30
16	77+010	83+920	6,910	46.2	60 (30)
17	83+920	84+570	650	23.00	40
18	84+570	88+583	4,013	46.20	60(30)

Note1: Figure in parenthesis are for service roads)

Note 2: Localized reduced speeds (e.g. at sharp bends and narrow bridges) are not shown

Following the development of speed management and control strategy for the road corridor, the same could be used to inform the posted speed limits appropriate to the road and traffic environment of each section. For example, speed limit should be reduced at sections where pedestrian activity is significant. Suggested sign posted speed limits, in absence of formal speed limit review process in Nepal, are shown in Table 6.5.1. Various speed reducing devices (horizontal and vertical displacement) are considered along the "urbanized" sections to enforce reduced speed limit as the motorists tend to drive much faster than it would be safe for the road and traffic environment in built up areas.

Repeater speed limit signs are recommended for erection where speed zones are long. Repeater signs are also provided when new stream of traffic enters into the main road (e.g. after turning from side roads).

The strategy should also identify sections of road where cluster of speed related crashes are established. In absence of detailed crash data which would have allowed establish these clusters, specific locations for speed enforcement could not be recommended. These operational level project components are proposed for consideration soon after the upgraded road is open for traffic. Following measures are recommended for implementation in order to enforce posted speed limits on sections where clusters of speed related crashes are found.

- Radar Guns
- P2P Cameras
- Automated Number Plate Recognition (ANPR) Cameras;
- Other traffic surveillance cameras and detection devices

In future, these cameras can also be linked to the computers at District Police Offices and speeding fines as per Nepal Road Rules (Vehicle and Transport Management Act/ Vehicle Transport Management Regulations) can be imposed to offenders. Police in plain clothes should patrol the road

at random with radar guns to bring speeding offenders in control. Patrolling should be more frequent when the new road is opened to traffic.

6.2.2 Access Rationalisation and Control

The expected operating speed will not be achieved along the MP Road in absence of access rationalization and control (ARC) strategy. Designing MP road with too frequent accesses to, and egresses from, minor roads and driveways to abutting properties at 60km/h for four lane sections and improving tight bends suitable for national highway with the hope to achieve this speed does not make sense. The desired operating speed cannot be achieved due to operational difficulties typical for mixed mode environment. Also, this speed should not be permitted in the expected operating environment of MP Road along bazar area unless frontage roads are implemented and local and through traffic and fast and slow moving traffic are segregated. Urban arterial roads without enforcement of speed limit and without proper access rationalization and control strategy will lead to more fatal and serious injury crashes.

Various methods of ARC strategy are available around the world. In Nepal this concept is relatively new. The strategy is not implemented in most instances. Previous attempts to do so along the ring road of Kathmandu Valley had mixed success. Without proper planning, the implementation of ARC gets significant community resistance.

In brownfield road design and construction environment, especially along heavily built up ribbon development sections of MP Road, any proposals to build interchanges or other forms of flyovers / grade separation may not be worth considering. These expensive systems for ARC are difficult to justify technically, socially, environmentally or economically.

Only low cost ARC strategy is therefore suggested for the development and implementation for MP Road at this stage. The strategy involves the provision of implementing pedestrian intrusion at any location on main road, separation of local and through traffic by NJ RCC barrier with simple merge and diverge lanes at strategic locations and closure of access and properly designed limited numbers of at-grade intersections. This strategy together with the speed management and control strategy is considered to be an acceptable solution for desired road safety outcomes and hence implemented in the detailed design.

Speed management and access management are closely related. The decision on the number and nature of accesses / egresses (intersections with main road) should be based on the desirable speed environment.

An indicative proposal on rationalizing and /or controlling direct access to, and egress from, MP Road has been suggested as a part of the safety review study (Refer Table 6.5.2) during the detailed design process. The proposal has significant impact on the number and types of intersections, service road - main road merge and diverge facilities as well as the provision of U-turn facilities along the road corridor. The proposal is based on the safety concerns, discussions and agreements with the client, in principle, on the possibility of direct access closure but the community has not been consulted as yet. All other intersections and driveways will be exclusively Left In and Left out (LILO) operation. Vehicles wishing to go right should turn left, merge with the main traffic, move to right turn or U-turn slots, make U-turns using gaps in the main traffic and move ahead.

Table 6.3: Major Intersections with direct Access to MP Road

S. No.	Tentative Chainage	Location (Town)	Location		Type of Intersections	Remarks
			Coordinate X	Coordinate Y		
1	6+975	Abu Khaireni	553022.99	3086972.26	3 Way	Way to Gorkha
2	23+550	Dumer Bazar	540543.31	3093737.56	3 Way	Way to Lamjung
3	40+875	Damauli Bazar	526547.79	3095272.297	4 Way staggered	Way to CDO office
4	70+000	Kotre	508259.14	3107951.178	3 Way staggered	Bazar
5	73+665	GaganGauda	509237.32	3111249.87		Bazar
6	79+525	Talchowk	505830.18	3115897.50	3 Way	Talchowk
7	81+150	Lekhnath Chowk	505078.96	3117249.02	3 Way	Budi Bazar
8	87+200	Amar Singh Chowk	500299.17	3120579.33	4 Way	Amar Singh Chowk
9	87+830	Buddha Chowk	499698.88	3120704.06	4 Way	Way to Ram Ghat

Note 1: When the service roads have terminating ends on any or both sides close to the intersections, traffic will be required to go to the end, make U-turn and enter into main road.

At-grade intersections are proposed to provide direct accesses to and from all "sub-arterial" and "collector/ distributor or district" roads. Properly designed intersections are provided to make turning movement safe. Where frontage roads are provided, direct accesses to and from local roads and driveways and abutting properties into the main road are closed. Indirect accesses to, and egress from, these roads to main road are managed by providing merge and diverge lanes, turn outs (cul-de sac at terminating ends) at service roads and U-turns along the main road at strategic locations. Locations of these access management and control features are to be identified during the construction stage road safety audit. These locations would require confirmation following the consultation with the local people as closing and rationalizing any accesses could have significant resistance that needs to be managed by the Project during implementation.

It is proposed that the contractor (s) be required to produce shop drawings of intersections and other safety treatment devices based on their locational suitability, functionality and acceptability by the community for prior approval of the Engineer and Project. The design layout should use typical designs developed in the detailed design stage and should be done once the detailed construction survey and setting out of roads are completed by the contractor.

Uncontrolled crossing movements across the road with 8 lanes (including 4 lanes of frontage roads) are not to be permitted for safety reasons. Regulation controlled or sign controlled intersections do not work in Nepal as most drivers do not know road rules and/or understand road signs. Those who know also tend to ignore these rules and signs. If crossing through 8 lanes needs to be allowed (to be determined on the basis of community resistance), it is strongly recommended to allow only after installing traffic lights or Traffic Police's presence to direct traffic in turn.

6.3 Roadside Environment

In accordance with the "Safe System Approach" in road safety management in the country adopted by the Government of Nepal in its Road Safety Action Plan 2013-2020, road safety managers are expected not to blame road users for deaths due to their mistakes they do on roads. Safe System principles clearly state that no one should die on roads because of their mistakes. Roadside

environment should be developed in such a way that it is forgiving to users' mistakes. There needs to be a paradigm shift in the traditional thinking of road engineers in delivering road infrastructure.

A number of specific safety issues that could make roadside non-forgiving have been identified and potential recommendations for their amelioration have been made in the design. Chainage wise identification of any road side objects (natural or manmade) within the clear zone has been left for construction stage. Suggestion has been made about the width of clear zone. For low volume roads (ADT <5000 veh/day: motorcycles are not considered in capacity analysis) and low speed environment (equal to or less than 60km/h) there should be no hazardous objects left on the road side at a minimum distance of 4m from the edge of carriage way. Absence of hazards closer to roads allows motorists to recover their vehicles safely before these hit hazardous objects or end up in deep falls and/ or trapped by deep side drains. Mention has been made and a number of actions recommended regarding trees, other roadside objects such as street lighting poles, utility poles, traffic sign posts, sections of road with steep embankment slopes, open side drains with steep slope, culvert head walls parallel to the road and non-traversable head wall perpendicular to the road without identifying the exact locations of these non-forgiving sections in detail.

Frangible posts with retro-reflective delineation have been proposed at the section of road with substandard curve. Advance warning sign notifying sharp bend /substandard curve is also proposed.

Roadside hazard management involves removal of the hazard in the first place. However, if the removal is not feasible or cost prohibitive, these hazardous objects need to be made as safe as possible so that severity of injury would be less. If impact absorbing or slip base poles cannot be used, protection using crash barrier is proposed. The last level of protection is to make the presence of road hazard prominent by using hazard markers.

Safety measures that are proposed in the design at fill higher than 2 m should not invite new hazard on roads. Concrete side barriers' end could be fatal for errant vehicles if these ends are not protected. Concrete end should be fitted with crash cushion barrier so that severity of injury can be reduced. Locally made water filled plastic containers with the shape similar to that of barriers can be attached to the end of concrete barrier to replace high cost crash cushion barrier. A cheaper solution would be sand bag although not same outcome could be expected.

It should be noted that any sections of road with fill height less than 3 m with side slope steeper than 1:4 should also be treated as road side hazards because these are not traversable or non-recoverable. Errant vehicles can roll over before the proposed road side barriers' location or hit the cushion barrier and experience roll over which can be fatal. In order to make such transition sections more forgiving, consideration should be given to implement protection measures. A vertical drop in the valley side over 3 m with or without river below must be protected by concrete barriers or gabion barriers to fully contain errant vehicle within roadway.

A temporary low cost option could be the combined use of frangible posts with delineation and audio tactile edge line marking (if technology is available in the country). This measure does not prevent /run away or roll over but may reduce the likelihood of these type of crashes.

Open drains on constrained section are also road side hazard. It is proposed to either cover it as in the case of pedestrian connection or to replace it by concrete pipes. Please see Section 6.7 for specific safety measures for road side drains. Following is the summary of measures that are incorporated in the design of MP Road in relation to reducing the effect of, or eliminating, road side hazard.

- A clear zone of 4m width is recommended to be maintained between the edge of the through travelled way (lane) and any potential hazardous objects. For this purpose, following measures

are implemented in the design. These measures are intended to make road side forgiving to errant vehicles

- o Reduce inherent hazard /eliminate hazards that would make vehicles errant (e.g., use of tight curve)
- o Remove all objects hazardous to errant vehicles
- o Protect all objects hazardous to errant vehicles by guard rail or crash cushion or similar so that level of damage/injury can be reduced.

Example of objects to be removed or protected include:

- o Trees of girth greater than 10 cm
- o Utility (Electrical / telecommunication) poles
- o Property / Boundary walls
- o Treatment of roadside objects provided for safety (such as guide posts, roadside barriers)
- o Other roadside manmade structures such as public taps, buildings within clear zones
- o Road side shopping stalls
- o Not forgiving (deep open) roadside drains with step back slope
- o Broken down vehicles / Parked vehicles

In managing roadside environment for better road safety outcomes, the first attempt should be to reduce inherent hazards with safe elements built in the design, next in the order is to remove hazard permanently from roadside and third priority is to protect them for reduced severity (for example, do not provide tight curve not compatible with the likely operating speed, cut trees and install hazard marker on trees in case trees cannot be removed.

The two illustrations below (Figure 6.6.1 and 6.6.2) demonstrate typical examples of unforgiving road side environment along MP Road which require the installation of continuous RCC or gabion (rigid or semi rigid) road side barriers.



Photo 6.1: This could be typical candidate section for continuous RCC roadside crash barrier. Potential run off crash can trigger mass casualties due to large depth of drop on river side. Use of confidence block can guide the vehicles but cannot stop errant vehicles from Road widening is possible by cutting hill slope.



Photo 6.2: Road in Nepal is not just for transport. This is also a place for washing and cleaning. On the right steep fall calls for installing RCC crash barrier. Widening is possible by cutting hill side. On the right, side drains should be covered and water spout should be managed to satisfy both safety and drainage

Each site is different and nature of hazard also varies widely. It is therefore proposed that these be identified towards the end of the construction and treated accordingly. These safety measures do not add to the project cost in any significant way and are best identified during the pre-opening road safety audit.

6.4 Side Drains

One of the hazardous elements/ structures road engineers overlook in hilly and mountainous terrain is unforgiving road side drains. Side drains become unforgiving due to the shape of side drains provided to cater for surface run off and steep forward slope to reduce the width of roadway. This is usually justified by the likely reduction in construction cost in many projects. However, if engineers allow the potential costs due to crashes (damages in the property, hospital cost, loss in productivity, blockade of roads due to damaged vehicle occupying lanes) over the life of the road an additional cost for the provision of shallow drains or drains with cover which do not trap vehicles in it, can most likely be justified.

Taking into consideration of this reality, the following safety measures have been incorporated in finalizing the design and estimate of the proposed MP Road Upgrade.

- Where open drain section is chosen along non-built-up area, side drains with flat slope (1:4) on road side and vertical wall on the hill side are proposed;
- Preference is given to RCC over RRM construction;
- Drain bottom equal to the width of shovel are made flat to ease cleaning;
- For drain section along built up areas, rectangular RCC channel as recommended by NRSN#2 is adopted;
- In order to keep the drain shallow enough and forgiving, cross drainage structures are provided more frequently than that on natural creeks/ *kholis* only. Nepal Road Safety Note (NRSN) #2 recommends cross-drainage structures at spacing not more than 100m. This is probably over generous (depends on rainfall etc.). For the proposed road, it is suggested not to increase the spacing between cross drainage over 300m;

- Where irrigation channel and side drains are to be combined, side drains are designed to carry irrigation water. Covered drain is recommended to make road side forgiving in this case;
- Recommendations of Nepal Road Safety Notes #2: Designing Safer Drains are followed for other details;
- Recommendations of Austroads Guide to Road Safety Part 9: Roadside Hazard Management are also incorporated in some instances as these constitute best international practice of managing road side hazards;
- RRM drains may not be cheaper than RCC drains if life cycle cost is considered in the decision. RCC drains are provided for this reason. Results of the analysis of life cycle cost including crash cost can potentially justify RCC drains.
- Open side drains become more costly than covered drains (especially along the sections where debris are brought from hill slopes (minor land slide etc.) and deposited on side drains and clog them. With no timely maintenance, water flows from the pavement and the whole road is damaged, which is expensive to rebuild. Surface water is also a safety issue. It is difficult to buy the logic that the cover drains are not to be preferred because they are not clogged and are not cleaned. This applies equally to open side drains and chances of clogging are more for open drains than for closed drains.

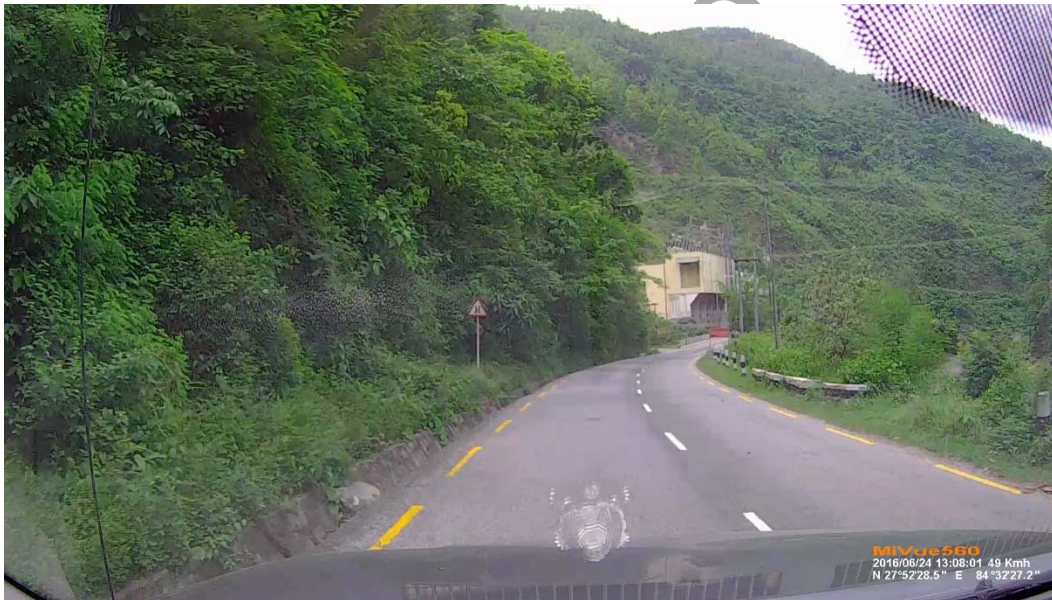


Photo 6.3: Drain on the left is too deep and is a roadside hazard. Not maintained grass shoulder on the right obstructs drainage of carriage way.



Photo 6.4: Multiple safety problems (a) Deep drain on left is road side hazard (b) Deep drop on the right is highly hazardous (c) Pedestrian Intrusion on road at blind spot (d) No center line marking on blind turn (e) Narrow shoulder

6.5 Delineation Measures

In spite of rigorous safety treatment measures identified by road safety review and used in the design, it is to be recognized that some of the existing hazards cannot be treated fully and some new hazards may be created during the construction itself. This means that road side environment cannot be made fully forgiving in real practice. Examples of safety hazards include tight curves provided to negotiate with the contour at the end of steep descents, side slopes steeper than 1:3, vertical drop more than 1m deep on the valley side, culvert head walls and end walls, bridge parapet walls, crash barriers' end treatments and so on. In such cases, road users should be warned of the existence of hazard so they can take necessary precaution measures to avoid colliding with these hazards.

Some of the potential delineation measures associated issues, which are relevant to MP Road, are listed below.

- Each horizontal curve on the valley side has been provided with delineation measures on the outer edge of the road (except on those where crash barriers are provided which will have its own delineation);
- The common practice in Nepal is to use RCC delineation posts which itself represent hazards for road users as these are rigid. When hit by run-off vehicles, it could be fatal;
- The current delineation practice involves providing one reflector plate facing the traffic attached to RCC delineator posts;
- A better and cheaper alternative is the use of frangible plastic poles which yields at its footing on hit and bounces back to its vertical position following the hit. Possibility of manufacturing such poles by the local plastic industry is being explored and if the industry is willing to manufacture, RCC posts shown currently in the design are proposed to be replaced by frangible poles. These poles comply with best international practice of making road side more forgiving. The cost of frangible plastic poles is expected to be lower than that of the RCC posts and hence a switch over during the construction phase is possible;
- The standard practice is to have red reflector paint on the side facing traffic and white reflector plate on the reverse. In Nepal, the practice is to have reflector paint plate only on the traffic side. This small change with added nominal cost is implemented to comply with international best practice;

- In terms of required level of retro-reflectivity, please refer to Nepal Road Specifications and highlight in the project document specification that that this requirement must be complied with. Ordinary industry grade paint should not be accepted for reflector plates;
- CAM (Chevron Alignment Markers) are provided at curves as shown in Nepal Road Safety Notes;
- Provision is made in the estimate and design to delineate center and edge lines correctly;
- Reflective road studs (Cat's eyes) are not recommended for road conditions in Nepal;
- In case frangible plastic delineation posts would not be available, RRM or plum concrete confidence blocks or RCC delineator posts can be used;
- Recommendations of Nepal Road Safety Notes #5: Delineation Measures are implemented for developing details of RCC poles, their installation spacing and use of other delineation measures
- For best international practice of managing roadside delineation and making roadside more forgiving, Austroads Guide to Road Safety Part 9: Roadside Hazard Management or similar other guides can be referred by the engineers responsible for construction supervision.

There are numerous sections along MP Road which require delineation measures. These are shown in the detailed design (see Plans and Profiles). In fact, these delineation measures are very common to all roads located along mountainous terrain. Three typical example sections of MP Road are illustrated in Photos 6.6.1 and 6.6.2.



Photo 6.5: Delineation measures in the form Chevron Alignment Markers (CAMs) on the approach of the bridge is missing. Concrete posts or other simple delineation should be introduced on the near approach both sides to guide traffic to reduce the likelihood of vehicles hitting the bridge hand rails. Intersection approach and culvert head wall needs improvement. There is no terminal treatment on the W-Beam Guard Rail.



Photo 6.6: Another example of potential site for delineation measures on either side of the curve and either ends of high fills above waterway. When the road will be widened and culvert extended or replaced, its parapet wall must be raised to the standard height of RCC barrier with hazard markers on both ends.



Photo 6.7: This is a typical section of PM Road where the fill slope can be made recoverable (1:4 or flatter). In this section, frangible delineation posts will be advantage to guide traffic along the bend. On the left, deep side drain is a safety concern.

6.6 Intersections

Intersection crashes constitute significant proportion of total road crashes. This is mainly due to many conflicting movements at intersections, absence of knowledge of motorists on priority rules (e.g., giving way to traffic on major roads), lack of signs, poor visibility, and improper layout and design. The existing practice of providing standard layout and design for intersections should be backed up by the provision in the contract document to require contractors to develop and submit customized shop drawings to fit the site for approval. Guidance provided below can help make intersection design along MP Road safer.

- Each intersection, especially along hill road, is unique. Each should be treated and design audited for its safe operation individually. While a type design provides concept, it does not help implementation. Design of intersections specific to each location is not undertaken at this stage. Allowance has been made for the development of shop drawing for each intersection by the contractor. These drawings will be approved by the supervising engineer before the intersections are constructed;
- While undertaking design, designers have made sure that the minor road approaches have given way or stop sign (if the visibility of approaching vehicles and pedestrians is good give way sign is suggested and if it is poor a stop sign is suggested at the approaches of minor intersections). Also, stop line or yield line on the pavement is provided on the pavement of the minor road to reinforce the message. Gravel or earthen road are sealed at least up to 30m from the main road. Although not suggested in the design, it is strongly recommended that the Project consider a trial of "mud trap" at the approaches of each unsealed roads to prevent dust on main roads;
- Intersection ahead warning signs are provided at major road;
- It is further recommended that the approval of new accesses from hidden spot would not be issued and that existing accesses in such locations be closed as far as possible. This is not the design issue but existing operational issue. Safety will be improved by employing proper access rationalization and control strategy along the project road corridor. Hidden access roads and hidden driveways are signed where unavoidable.;
- Existing accesses to private properties encroaching road (such as staircase in bazaar area protruding on roads) are removed in the proposed design;
- Existing obstructions (vegetation, tress, bushes/hedges, houses, poles Chautara etc.) are removed to provide clear line of sight within the sight triangle. Where not feasible, hazard markers and appropriate warning signs are provided;
- Some movements (e.g., acute right turn or left turn access to main roads from minor roads or from main road to minor roads) have been banned where the design requires so and traffic signs are proposed to communicate it to road users;
- Pedestrian crossings are marked along all approaches (Pedestrian crossings are not proposed where sight triangle is not clear). Although not provided in the design, it is strongly recommended that solar lights be provided at least at all zebra crossings and at intersections to improve night time safety;
- The design of each intersection is not contemplated in the scope of work of consulting service. Type designs are suggested. Special provision in the conditions of contract has been made whereby the successful contractors would require to develop "shop" drawings based on the type designs and get these approved by the supervising authority;
- DOR Traffic Sign Manual has been referred for sign layout at intersections and for complying with its requirements.

Depending on the specific locational circumstances (two lane road, four lane road with or without service roads), configurations (e.g., angle of intersecting roads), number of minor roads meeting the major road (MP Road), volume of turning traffic, one of the following types of intersections have been considered. Type designs of some of the major intersections are provided which should be fully developed by the contractor during the construction:

- Basic Left Turn (BaL) Treatment on Major Road;
- Basic Left Turn (BaL) on Minor Road;
- Basic Right Turn (BaR) Treatment on Major Road;
- Basic Right Turn (BaR) Treatment on Minor Road

- Multi-lane Undivided Road with No Specific Right (MNR) Turn Treatment;
- Auxiliary Left Turn (AuL) Treatment on Major Road;
- Auxiliary Left Turn (AuL) Treatment on Minor Road;
- Auxiliary Right (AuR) Turn Treatment on Major Road;
- Auxiliary Right (AuR) Turn Treatment on Minor Road;
- Channelized Right Turn Treatment with Short (ChRS) Turn Slot;
- Channelized Right (ChR) Turn Treatment on Major Road;
- Channelized Right (ChR) Turn Treatment on Minor Road;
- Channelized Left (ChL) Turn Treatment on Major Road with or without High Angle Entry;
- Channelized Left (ChL) Turn Treatment on Minor Road with or without High Angle Entry;
- Right-Left Staggered T-Intersection (RLST) Treatment;
- Left-Right Staggered T-Intersection (LRST) Treatment;
- Single Right Turn Ban (SRTB) Treatment;
- Double Right Turn Ban (DRTB) Treatment;
- Double Right Turn Ban reinforced with Right Turn Ban Sign (DRTBS);
- Seagull Treatment with Two Stage Right (STTSR) Turning Treatment from Major and Minor Roads;
- Offset Right Turn Lanes (ORTL) Treatment; and
- Two Way Right Turn Lanes (TWRTL) (also called Median Turning Lanes) Treatment



Figure 6.1: A Typical Section of PM Road requiring access rationalisation and intersection improvement (realignment of minor road)

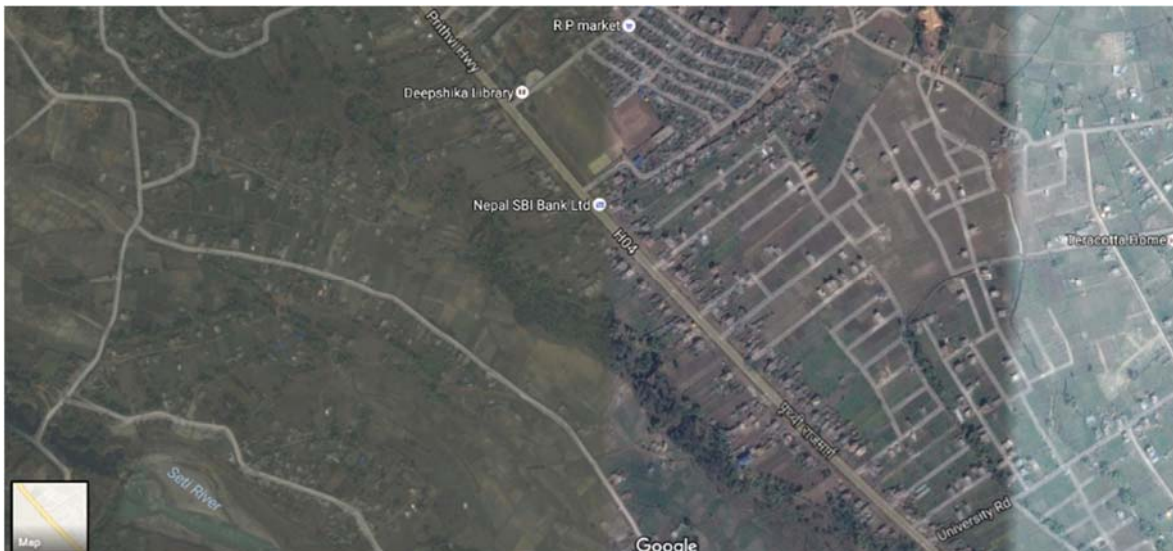


Figure 6.2: Accesses to Minor Roads must be rationalized for road safety (Lekha Nath Nagar Palika)

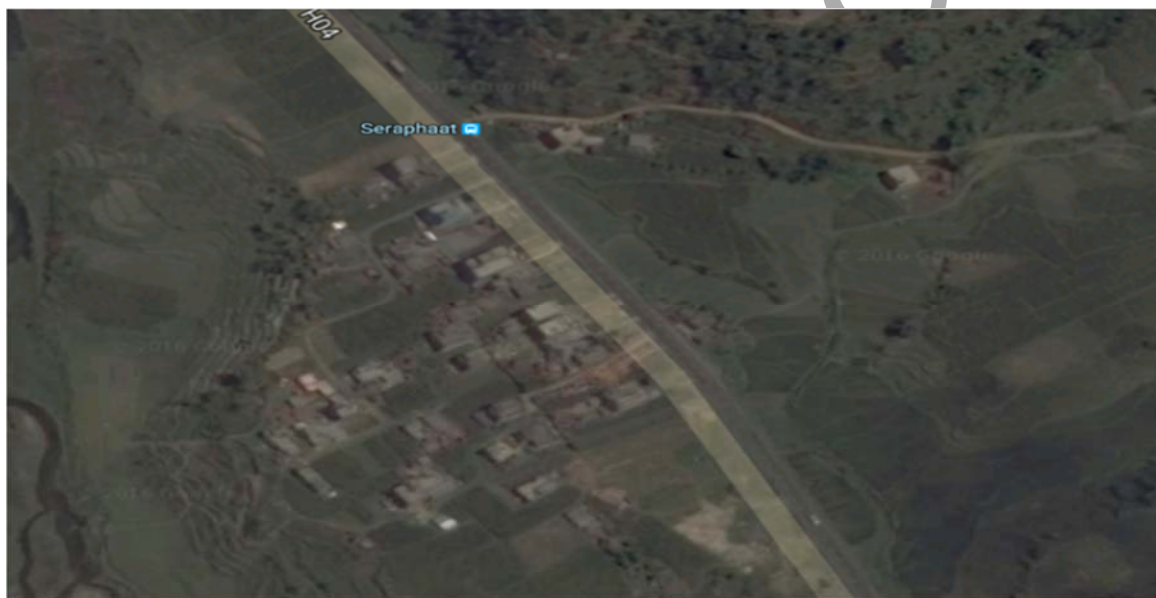
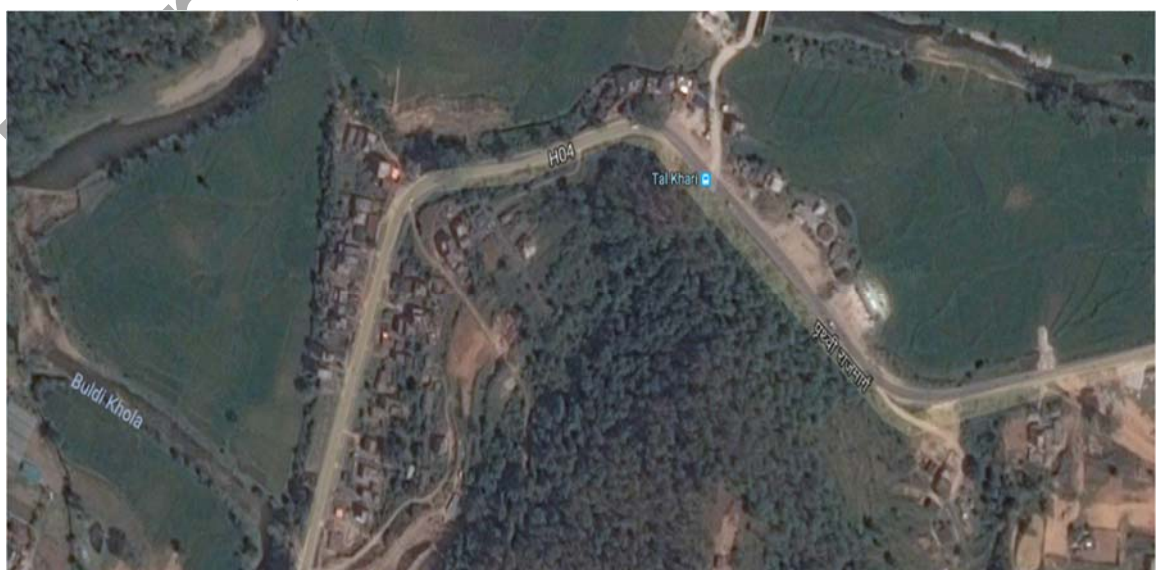


Figure 6.3: MP Road passing through a typical rural settlement (Sera Phant)



6.7 Roadside Barriers

Anecdotal evidence suggests that bulk of road deaths on low volume hill roads in Nepal with low posted speed limit occur due to run off the road (ROR) type of crashes. Errant vehicles can run off to the left or to the right. Run off to the left often ends up with roll over along the steep drop or downhill resulting in multiple fatalities or to the side drains or hit cut slopes causing significant damage to the vehicles and serious injuries. Run off to the right may also cause side swipes or head on collisions with the oncoming traffic. On hill roads, head on collisions during aggressive overtaking along the sections of road with restricted visibility are also found to be very common.

Likelihood of crashes of run off to the right types (head on and side swipe) can be reduced by proper center line marking and by providing road signs (warning and regulatory) prohibiting aggressive overtaking. Additional measures such as rumble strips or audio-tactile line marking (ATLM) are also common overseas. Potential safety measures related to line marking and road signs practiced in Nepal are listed in the technical notes listed in Section 6.3. General guidance on the use of road side barriers to prevent "run off to the left" type of crashes is provided below. These guidelines are adopted in the design of MP Road as far as possible.

- Where to provide what type of roadside barriers?
 - o Nepal Road Safety Note #6 has been followed for the general guidance on the selection of types of barriers;
 - o The selection of the type of barriers for strategic low volume MP Road to the height of fill or depth of drop along the valley side is based on engineering judgment and potential risk levels associated with not providing appropriate type of barriers. Cost is a major consideration but not at the expense of allowing risk potential likely to cause mass casualties or deaths. Following rules of thumb are implemented as a guide (warning: use this rule with caution!) in the design of MP Road:
- 15km/hr, special considerations are made (delineation - chevron marking, reflector may have to be combined with the barrier);
- All road side barrier ends are fitted with red retro-reflective roadside hazard markers (at a minimum);
- Although not implemented in the design, it is proposed that the connection from semi rigid to rigid barriers (generally at approaches to bridge) be designed with special consideration as provided in the NRSN #6 (Page 12); and
- It is important for the Department to know that steel beam barriers for locations with sharp bends tighter than 40m are to be factory pre-curved.

6.8 Safety of Vulnerable Users Group

- ✓ Pedestrians and motorcyclists are two dominant groups of vulnerable users of any rural hill roads in Nepal (cycling is not practiced due to high grade). MP Road is an exception. Due to gentle grade along most of the sections of MP Road local people use cycles to get from Sections with fill slope steeper than 1:4 (V:H) and height of fill or drop of existing ground slope ≤ 2 :
- ❖ In case if the valley side retaining wall is of RRM, use RRM or plum concrete continuous wall (allow for surface drain/ construction joints); but do not use short blocks like those used currently on many hill roads. These do not work as crash barriers but as confidence block to delineate motorists (Details as per NRSN #6);
- ❖ In case if the valley side retaining wall is of gabion, extend gabion wall to build roadside barriers on top of it (also to be continuous) (Details as per NRSN #6);
- ❖ In case if there are no retaining walls, use one of those types (RRM or Plum Concrete) or RCC or steel beam depending on the available width for barrier construction;

- ❖ In each case, standard hazard markers are to be provided on the face of barriers approaching traffic.

- ✓ Sections with drop depth >2m but ≤4m:

As above, but suggested to provide additional strength to road side barriers made of RRM or Plum concrete (e.g. dowel bars - discuss with structural engineer for ways to provide measures to resist impact load. Failure in containing vehicles within the road may have the catastrophic risk of mass casualties. Also, need to provide hazard markers (at minimum) or impact absorbing measures on the face of these barriers approaching traffic);

- ✓ Sections with drop depth >4m:

Provide RCC road crash barrier (details as per NRSN#6). Failure in containment of vehicles on road can result in mass casualties especially along the river. Hence highest level of protection is needed along these sections. Provide hazard markers or crash cushion on the face of the barriers fronting approaching traffic;

- ✓ Sections with restricted width and valley drop depth ≥3m:

Provide W-Beam crash barrier with appropriate terminal treatment (See details in RSRN#6). Use of steel W-Beam barrier is limited because damaged W-Beam elements may themselves work as roadside hazards if these are not restored timely (which is the common case in Nepal).

- The continuous road side barriers are provided ensuring they do not obstruct drainage of pavement surface;
- Appropriate deflection zone as per best practice W-Beam installation requirement is provided;

For sections with sharp curve (design speed less than or equal to their rural settlements to nearby bazar. Apart from this, recreational cycling is also becoming popular in Nepal. There are possibilities of increase in bicycle traffic and therefore bicycle safety also must be considered for this road. Children who use roads to access schools are exposed to crash risks. Their behavior on roads is highly unpredictable. Many rural roads are places for children to play. Motorcyclists are also at significant risks on rural roads in Nepal due to steep grade and sharp bends. Motorcyclists generally tend to drive at speed higher than it could be safe at sharp bends and zigzag roads with reversing curves and they tend to lose control more frequently than four wheel vehicles. Motorcyclists are also at greater risks as they tend to overtake slow moving four wheel vehicles aggressively. Motorcycle users are of lower age group and this is another contributing factor to expose them at high risks.

Following safety measures have been recommended for implementation along PM Road to improve pedestrians' cyclists' and motorcyclists' (collectively called vulnerable users group -VUG - in road safety literature) safety.

- Foot paths are provided on either side of road on bazaar/ settlements/ townships located along the project roads;
- Pedestrian (zebra) crossings are provided generously (even if people are not used to use it and they cross roads anywhere they like. Training road users for proper use of roads and of zebra crossing is the responsibility of the government agencies who are managing roads);
- Typical locations for zebra crossings include indented bus bays, bazaar area, settlements, schools and community facilities. Zebra crossings are provided frequently as shown in the plan, the location of which can be changed during construction phase following the consultation with the community;
- Thermo plastic paint (thickness of paint 4mm) is used for marking zebra crossing (in fact all road painting will use this type of paint). This requirement has been specifically mentioned /highlighted in the specification, so the paint lasts longer. Roads in Nepal have too much of sand and dust which

abrade paint quickly and there is no practice of repainting on time, hence the reason for thicker paint than normally provided overseas;

- Warning signs that says (pedestrian crossing ahead) and pedestrian crossing sign with high level of retro-reflectivity have been provided at each crossing. All road crossings in towns are wombat type (raised platform with saw teeth) with warning signs for motorists about the hump and requirement to reduce speed;
- There should also be stop line on either lane (on intermediate lane, it will be continuous across the road). The stop line should be at least 2 m ahead of crossings. This has been reflected in typical design for the pedestrian crossing;
- DOR Traffic Sign Manual Volume 1 has been used extensively for preparing type design and installation drawings;
- Blind spots are avoided in installing zebra crossings as far as possible. Where unavoidable, additional warning measures (e.g., flashing yellow lights with pedestrian crossing ahead sign, highly reflectorized red warning signs and other devices as appropriate are provided (at a distance sufficient ahead of crossings to enable motorists to stop their vehicles);
- Speeds are limited to 20Km/hr on bazaar area and 40 Km/hr along all rural settlements/ townships and these locations are signed properly;
- "Under-run" in the opening /gap between guard rail and ground will be trialed (so that motorcyclists who lose control and hit W-beam barriers are not shredded by sharp edge) at selected locations. This should be done in consultation with the District Office;
- "Road is slippery" or "skid surface" warning signs are installed at sharp bends to warn motorcyclists of potential danger of corner cutting at high speed.



Photo 6.8: Children walk along the narrow shoulder that could expose them to risk



Photo 6.9: A Typical "Under Run" metal bar proposed for trial along MP Road. Also shown is the double center line marking indicating overtaking is prohibited (because it is not safe due to restricted visibility and unsafe sight distance. Also shown is the edge line (delineation measure)

6.9 Culverts and Bridges

The existing road construction practice in Nepal involves providing head wall and end wall for pipe culverts and return wall/ wing wall with small return kerb/ parapet wall at slab culverts. RCC box culverts are rarely used even though the streams/ *kholsis* bring a lot of damaging boulder /debris which hit on RRM walls, primarily probably due to their higher initial costs. Most of these structures are not built road safety friendly.

Observations on existing approaches to bridges suggest that even the basic safety features are not implemented in most sites. Apart from serious pedestrian safety concern on existing bridges due to the absence of footpath (e.g., in Mugling Bridge), guide walls, hazard markers and CAMs are not seen as required by NRSN #7. Although these technical notes were available for the designers and DoR division engineers since mid-1990s, basic safety measures specified in these Department approved Notes are not followed in practice.

Bridges closer to Mugling Damauli, Dumre, Khaireni and Pokhara Bazaar areas and other townships with high pedestrian activity should get priority for the provision of footpaths.

Following safety measures have been considered in the design of MP Road to make culverts and bridges forgiving and user friendly.

- The common practice in Nepal is to provide parapet walls on culvert ends (head wall/ end wall), which themselves are hazard to traffic (roadside hazards) and puts road users at risk. Where safety risks are considered to be high, water filled plastic containers are proposed to prevent head on hit on concrete parapet;
- Hazard markers (see details of Traffic Sign Manual for hazard marker) with high retro-reflectivity are provided, at a minimum, at all parapet;
- Traversable culvert ends (it could be cheaper!) with generously flat side slopes are proposed such that errant vehicles can recover back to road safely. Traversable culvert ends with grating are popular safety treatments at intersections and driveways in rural roads;
- RRM guide walls with CAMs (see NRSN #5) are provided at the interface between approach road and slab culvert (minor bridge/ slab bridge),

- Delineation measures and roadside barriers as per above Notes are provided generously along the entire section of the road requiring such measures;
- NRSN #7 has been followed to produce standard drawings for bridge approaches;
- While not considered in the proposed design, it is highly recommended that, if the fund allows, footpath in the existing bridge be provided as far as possible. A separate foot bridge parallel to the existing bridge should be considered by the Department at a later stage if footpath cannot be added in the proposed Project due to cost constraints.

6.10 Road Signs and Marking

The existing road construction and maintenance practice in Nepal largely ignores the importance of installing traffic signs and providing line marking and other road markings. These are often treated as auxiliary "cosmetic" items by many practitioners and policy makers. This is probably because their contribution on improving road safety is often underestimated. Lack of awareness of road users about the importance of following the messages given by signs and line marking is another contributing factor for attaching low importance in the provision of these road furniture. Questions are often asked why should the road authority waste money on items that are just standing there and no one follows them. This attitude needs to be changed if government safety commitments to international community are to be met. Large scale awareness, education, enforcement campaigns should follow the provision of engineering measures.

Following basic guidelines have been provided. No special considerations or recommendations beyond DoR Traffic Sign Manual have been made in terms of the provision of new signage or use of new technologies.

- DOR traffic sign manual are followed at this stage in the preparation of design. If some important signs are missing and do require department's approval for installation, these can be done later during construction, if not in the final estimate. There are typical layout of signs and line marking for intersections as well. These recommendations can be used later to reproduce type design drawings for the project road;
- Reference are made to sign identifier in the plan as per DOR Traffic Sign Manual (e.g., A19 for no left turn sign, B46 for sharp bend, C24 for advance direction sign, D9 for single lane bridge, F11 for edge marking prohibiting parking and stopping along the road and so on);
- Lump sum or per kilometer rate for road signing and marking has not been used in the estimate and Bills of Quantities (BoQ). BOQ number of signs by types, kilometres of line marking of specific type and number of pedestrian crossings etc. are provided as far as possible;
- Level of retro reflectivity required for each sign/ colour as per national /international practice in the estimate and specification is specified so that ordinary signs are not erected by the contractor;
- Specification of work items require that the certificate of manufacturer on retro-reflectivity be submitted by the contractor.

6.11 Non-road based Safety Measures

Following pillars of road safety management are targeted together with the upgrade of road infrastructure (delivery of safer roads and road side environment). These measures currently stand as recommendations. These recommendations are of immense value if DOR would like to get very high safety benefits with low cost (value for money non-infrastructure solutions to safety problems). The below discussion together with the example scope of works for upcoming safety tasks for the Project is included in this report as the Project can use it in formulating TOR for the construction supervision (project management) services.

6.11.1 Safer Users

Together with the improvement of roads and road side environment it is essential to change the behaviour of road users so that they can use the upgraded roads safely. Training on how to use roads safely to the road users as well as to Traffic Police to enforce the road use rules to the community (e.g., drivers, passengers, pedestrians) by enforcement agencies is very important to deliver good road safety outcomes. For this purpose, the scope of services should include the followings project activities.

The scope of services comprises the development of awareness campaigns and also establishes in-country expertise for further road safety campaigns. The safety awareness campaign for the project roads should take into consideration safety-issues related to high-speed traffic, safe driving along tight bends with restricted visibility, understanding of road rules and line marking and the likely implication to both the road-users and roadside communities. The target-groups would therefore be (i) road-users and drivers of all types of vehicles and (ii) roadside communities. Suggested campaigns should include (but are not limited to):

- **Safe road rules:** Educating drivers about the correct use /behaviour while driving on project roads. It should consist of design of materials to be used in program and the actual education should be conducted to all road-users through joint collaboration with DoR Traffic Police and the consultants.
- **Awareness Campaign for Heavy Vehicles (Truck and Bus drivers):** The main message behind this campaign should be to underscore the importance of observing safe-driving habits with special consideration given to pedestrians and non-motorised vehicles on mixed traffic road sections. This campaign should be conducted at truck and bus operator's depots and should include preparation of brochures and stickers and lectures at transport operator's depots with the assistance of DoTM, DoR and Traffic Police.
- **Pedestrian Awareness Campaign:** This campaign should use posters and literature related to increased danger from heavy-vehicles and safe pedestrian behaviour when walking by heavily trafficked roads. This program should be conducted in schools along the project roads: Activities should include preparation of posters and other literature, conduct lectures at schools and so on with the assistance of DoR and Traffic Police. Short video clips capturing various aspects of road safety should be produced by the communication / media specialist to be engaged in the construction supervision team.
- **Publicity through Public Media:** The Project should produce a documentary on public media highlighting the following issues pertaining to the Project roads, including code of driving behaviour on high speed/ four lane roads. Motorists in Nepal do not follow the rules for lane changing. For newspaper publicity, a set of road safety advertisements/information should be designed and placed in national and regional papers, radio and TV. A number of video clips should be produced for training contractors' supervisory personnel in managing road traffic during construction.
- **Formation of Community Road Safety Action Groups (CoRSAG):** In order to implement sustained community road safety Social Development/ Community Development Specialists to be included in the consultants' team for supervision/ project management should mobilize local community and form permanent Community Action Groups along the road corridors. These groups should be provided with the basic knowledge on several aspects of road safety (e.g., effects on their safety by over-speeding, overloading , overcrowding, overtaking from the wrong side, overtaking along the sections of road with reduced visibility, parking illegally, drink driving) who will then conduct regular community level meetings at community halls. It is suggested to have one community action group for each township and rural settlements. Films should be shown in the evenings to attract villagers to attend road safety awareness events and Transport and Road Use Management Regulations (Nepal Road Rules) where road safety related advertisements, talk programs would

be included. Community Action Groups are expected to work as a vigilante group and support Traffic Police to enforce road rules along the project road corridors.

- Capacity Strengthening of Local Police Stations and District Police Offices: Radar guns, breathalyzers, desk top computers and tablets should be supplied to all local police stations and all district offices as a part of the Project. Radar guns are beneficial to control speeding by issuing speeding fines. Police should be trained to use radar guns and breathalyzers as well as how to stop vehicles safely to undertake on-road drink driving tests. Current on-road test practice is very unsafe and also creates congestion on roads. Police should also be trained on how to attend crash scenes, undertake crash investigation and complete crash report forms properly. World Bank funded Road Safety Support Project has created Nepal Road Crash Database System. It is also developing new form for web based data collection using tablets/ smart phones and for transferring these data to central servers. Web based crash data collection and electronic transfer of collected data are expected to significantly reduce the cases of under reporting crashes.

In order to educate road users on the right use of roads and raise awareness about road safety, the strengthened institutions and established community action groups require the use of a variety of road safety education and awareness materials. In the past, Department of Roads Project Offices built roads and handed these roads over to the District Maintenance Division. There has been less attention given on how the roads built and maintained by the Department should be operated safely and efficiently. One of the ongoing operational activities of the DOR Division Offices should be the management of road safety activity after the MP Road is widened to four lanes/ two lanes.

Examples of road safety awareness materials to be produced for project roads may include the followings:

- road safety leaflets (5 types) aiming at school children, school teachers, motorbike riders, cyclists, pedestrians and public transport users making people aware of crash risks and promoting road safety and road safety measures. Each leaflet can be two sides of an A-4 sheet with 2 folds, can be printed 10,000 copies in colour;
- banners (5 Nos) aimed at road traffic and the community to promote road safety measures. Can be printed 2 * 50 pieces (1 by 4 meter);
- road safety (flex) hoarding board (one type) aiming at traffic users and community, making them aware of a 'black spot'. Can be printed 60 pieces (1 by 1.5 meter);
- road safety reflecting sticker (one type) to be used by e.g. motorcyclists to be visible in the dark. 15,000 may be printed;
- 1 - 30-minutes documentary aimed at school children and members of the local community to make them aware of road crash risks and possible safety measures. Messages should be in line with the content of the leaflets. 100 -200 DVDs may be made for wide distribution; and
- 4 - 30-second radio spots / jingles aimed at people in the community to promote road safety measures. Messages should be in line with the content of the leaflets.

Quantities estimated above are indicative only and can be changed as per budget allocation.

The video documentary should contain the following elements:

- Changes along the project road corridors in the last 10 - 20 years through interviews, archive footage and animations/ infographics (fast growing ribbon development and increase in road traffic) and how this relates to road safety risks along the project road corridors;
- An overview of road safety risks (including issues causing risk), especially for pedestrians, motorbike riders and public transport users and the potential impact of these risks.
- Key tips for individuals to reduce the risk of being involved in a road accident.

6.11.2 Safer Vehicles

While the system of certifying road worthiness of vehicles to ply on roads in Nepal falls under the jurisdiction of DoTM, DoR as the agency responsible agency for the delivery and maintenance of safer roads and roadside environment, it is recommended that the MP Road Project in its project documents include the following features in the Road Upgrade Project components:

- Heavy Vehicle Inspections Sites /Stations: Bypass lanes with appropriate facilities to check overloading and necessary measures to direct heavy vehicles (buses and trucks) through that lane should be included in the Project.
- Rest Areas: Keeping in mind the nature of vehicle fleet (aged) in the country, it is recommended that the consideration be given to establish rest areas along the upgraded MP Road. This will not only facilitate regular safety check of the vehicles but also assists in reducing serious fatal crashes resulting from fatigue.
- Training to Traffic Police to operate these facilities should also be incorporated in the Project. It is not just adequate to build the road. Weak enforcement on prevention of overloading of trucks and overcrowding of long distance route buses are potentially two main contributing factors of road crashes. With upgraded roads, bus and truck entrepreneurs will be tempted to carry overloads and this should be discouraged through appropriate check systems on the project roads.

It should be noted that overloading or overcrowding of vehicles and fatigue from long night time drives are major contributing factors to road crashes in Nepal resulting in mass casualties. Overloading also contributes to road pavement damages significantly. DoR may wish to play a key role in addressing these issues on every upgraded road including MP Road.

6.11.3 Safer Speeds

Speed management and control strategy developed for MP Road corridor to manage speed and reduce speeding related crashes should be implemented as soon as the road is opened to traffic after its upgrade. The strategy should inform the posted speed limit for each section of road appropriate to the road and traffic environment of each section. Where pedestrian activity is significant speed limit should be reduced and sign posted. Various speed reducing devices (horizontal and vertical displacement) should be considered to enforce reduced speed limit

Repeater speed limit signs should be erected where the speed zones are long.

The speed management strategy should also identify sections of road where clusters of speed related crashes are established. Following measures may be considered by the Project for implementation.

- Radar Guns
- P2P Cameras
- Automated Number Plate Recognition (ANPR) System

These technologies are no more expensive. These cameras can be linked to the computer at District Police Offices as recommended in the Speed management and control strategy.

6.12 Post-Crash Response

It is recommended to include at least one post-crash response station on MP Section of Prithvi Highway which should be equipped with tow trucks, other devices / facilities for removing disabled vehicles and ambulance with first aid/ emergency medical facilities (or telephone facilities linked to nearby hospitals). The station should be located in such a way that the post-crash response units can reach the crash scenes within the golden hour. The **golden hour** (also known as **golden time**) refers to a time period lasting for one **hour**, or less, following traumatic injury being sustained by a casualty or medical

emergency, during which there is the highest likelihood that prompt medical treatment will prevent death.

Actual location of post-crash management should be determined in consultation with relevant medical professionals or national trauma centre.

6.13 Project Benefits Monitoring and Safety Indicators

Following the opening of new roads and improvement of existing roads, which result in higher driving speed, more local people along the road corridors are likely to be killed or seriously injured or traumatized due to higher exposure to crashes and crash scenes. Children, women and other vulnerable peoples are likely to be at greater risks than other affluent members of society who use cars. It is therefore important to monitor the social impact of project roads. This is the only way to measure the project benefits (or dis-benefits) of improved roads.

It is generally assumed for granted that improvement in roads results in improved road safety. This might not be the case in many rural roads and in fact, in many cases, opposite may be true.

It is therefore recommended that the opportunity to include additional social indicators in the Social Action Plan be explored for the project roads. These indicators can be used in subsequent Project Benefits Monitoring and Evaluation works.

While the best international practice is to include indicators, which relate number of fatalities or serious injuries or crash costs with vehicle ownership, population, driving license holders, vehicle-kilometer travelled (VKT, which is a measure of exposure to crash risk), consideration of such indicators for the subject MP Road is not realistic due to many reasons including the unavailability of base line data. However, simple road safety indicators such as below can be included which can be monitored after the road is opened to traffic against the base line data collected before the project;

- Level of awareness of local people on road safety;
- Number of people exposed to road crash risk;
- Number of people (by children, women, low income local people) killed and injured on roads;
- Number of bread winners of the family killed and seriously injured on roads resulting in loss of income in the family and its impact on well-being;
- Number of people seriously injured resulting in permanent disabilities;
- Number of families impacted by road crash;
- Others as determined by Social Specialist.

Road safety is totally ignored thus far in the objective evaluation of social impacts in road projects in Nepal and it will be a good start if some simple indicators could be included in the subject project roads. The new proposed practice helps deliver expected outcomes from Nepal Road Safety Action Plan. It is fully consistent with the high priority given by ADB on improving safety on roads built by its support.

6.14 Road Safety Measures: Cost Estimate

It was proposed to allocate 10% of the total construction cost for introducing various road safety measures during the feasibility stage cost estimate preparation. This margin does not include the cost of items such as intersections, turnouts, median strip, NJ barriers on either sides, covered drains, street lights, continuous metallic fencing along the median strips on four lane roads with medians in the last segment of MP Road. but includes items such as RCC/ steel beam barriers along high fill slope and steep side slope or hill slope, Audio Tactile Line Marking (ATLM), Wide Centre Line Treatment (WCLT with or without ATLM), line marking (lane, simple edge line no stopping/ parking edge, traffic signs (additional), mid-block pedestrian crossings (raised wombat type), clear zones, crash cushion barriers

at each terminal of rigid barriers fronting traffic, pedestrian caging, refuge island and other work items required for safety interventions.

Proposal for allocation 10% of the total project cost for implementing various road safety measures (including on education, awareness, enforcement and behavioural change programs and not just infrastructure improvement program) is very much consistent with the Government's endorsed Road Safety Action Plan which clearly outlines the following strategy in this regard:

"To ensure funds for road-safety interventions, seek endorsement from the Ministry of Finance and the National Planning Commission to recognise the principle of the first-year of returns as a basis for investment decision. Seek these agencies endorsement also to utilise the Roads Board Fund or to set a policy to mandatorily set aside a fixed portion (e.g. 10%) of the total cost of road-constructions to mobilise budget for road-safety interventions".

It is expected that the 10% of the project fund for MP Road should be adequate to additional measures for road safety improvements. Detailed breakdown of estimates of the safety interventions are undertaken together and integrated with the overall project cost estimate, specifications and contract documentations.

6.15 Normal Design Domain, Extended Design Domain and Design Exceptions

In many international road design standards, there are three different ranges of design parameters that can be employed by a designer to make his/her design more context sensitive. A Context Sensitive Design (CSD) seeks to deliver a design that combines good engineering practice with the natural and built environment. Many roads in Nepal are designed without due consideration of natural and built environment in order to satisfy the design parameters under Normal Design Domain (NDD).

Design parameters from Nepal Road Standards generally apply to unconstrained environment of road design. Such a design environment is known as "greenfield environment" and is characterized by open field with complete freedom in the selection of design parameters such as road widths, grade or curves. These are "generous" NDD design values. In mountainous environment and in the projects involving widening / upgrade of existing roads, a designer will have little or no freedom in the selection of generous design parameters since such a selection would be cost prohibitive. In these circumstances, less favorable design parameters than "ideal" can be suggested under what is called "Extended Design Domain (EDD)". These are called EDD design parameters. Design parameters selected under EDD would generally be less safe or less efficient but usually less expensive than those selected under NDD.

These design parameters can be selected either under Normal Design Domain (NDD) or Extended Design Domain (EDD)" or rarely under Design Exceptions. The cost differential between upgrading a road to a level within the Normal Design Domain compared to a level within the EDD is likely to be high in these cases. In contrast, the relative cost differential between providing a road that conforms to the Normal Design Domain, compared to the EDD, is likely to be relatively less for a new road (i.e. at a 'green field' site). Application of EDD design parameters for MP Road is expected to give great cost saving and less environmentally disastrous as the EDD parameters may need less disturbance on natural environment. Austroads (2016)² recommendation in this regard is as follows:

- Assessment of existing roads;
- Improving the standard of existing roads in constrained situations;
- Duplication of carriage way in constrained situations

² Guide to road Design Part 2: Design Considerations, Austroads

Selection of less favorable design parameters (EDD values) for MP Road than NDD values provided in Nepal Road Standards is well within the internationally accepted best practice.

The use of design parameters even less favorable than under EDD regime is also allowed. But these values cannot be justified on engineering grounds. Use of such values is considered as a “Design Exception (DE)”. Use of such values, while possible, is to be justified by all constraints, criteria and risks and approved by chief executive officer or delegated authorities. In all cases, the designer must demonstrate that safety risks are identified and mitigating measures suggested (e.g. reduced speed at sharp bends). DE can be used only as an interim solution for addressing funding shortfall for limited time.

The design speed for MP Road is 60km/hr for four lane sections and 40km/hr for two lane sections. This means the posted speed limits must not be higher than 60km/hr for four lane section and 40km/hr for two lane sections. This does not reflect the prevailing speed even in the current road environment. Most motorists are driving faster along sections other than with tight bends, narrow bridges, with bazar /township and poor pavement surfaces. Better speed limit compliance can be expected under the suggested speed management and control strategy (if implemented). Research overseas shows that the actual operating speed is generally 5-6 km/hr higher than the posted speed limit (Certainly not so in Nepal). There is a need of strong enforcement of posted speed limit in the country in order to improve road safety. And under this better compliance as in overseas may be expected.

NDD values for cross sectional elements even for 100km/hr speed limit for two lane – two way roads are³:

- Lane width 3.25m (In situations with more than one lane in a single direction, the lane width is the same for all lanes);
- Sealed shoulder width: 1.75m (In situations with an auxiliary lane, a shoulder width of 1.0 m is often satisfactory. This width should be increased in areas of restricted visibility (e.g. around curves) and in the merge area at the end of the lane);
- Wide Centre Line Treatment (proposed to separate traffic in opposing direction: 1.0 m;
- Total Seal Width: 11.0m

It is to be noted that these dimensions of cross sections should only be used on roads in cuttings, or low embankments or where the batter slope does not exceed 1V:4H (desirably 1V:6H) – i.e. recoverable for cars. If roadside barriers are used, additional verge width should be applied when needed to accommodate the barrier. It is also to be mentioned that cheaper option of continuously wide shoulder for breakdown or parking vehicles would be to provide vehicle breakdown bays where terrain allows to do so without touching hill slope. Plenty of such places are available along the road.

For 40km/hr rural sections of road WCLT as narrow as 0.5 m can be made. Hence the total seal width can be reduced to 10.5 m.

With EDD values, these cross-section elements would be 3.25m, 1.25m, 1.0m and 10.0m for 100/90 km/hr roads and 9.5m for 40km/hr road (WCLT width = 0.5m).

Research has shown that wide lanes encourage motorists to go faster. Also, motorcyclists tend to pass slow moving vehicles using the spare width available even against oncoming vehicles. Narrow lane could be safer than wide lane in many situations. Narrow lanes force road users to slow down and make use of passing lanes to overtake slow moving vehicles. Better safety outcomes can be expected

³ Wide Centre Line Treatment – Interim Advice, Technical Note 155, Queensland Department of Transport and Main Roads, 2015

with awareness campaigns implemented on the road side about what can be done and what cannot be done in WCLT sections where overtaking allowed or banned.

At tight sections with vertical rocky cliff or unstable hill slope, it is better not to touch them for widening MP Road by a few metres that does not serve any meaningful purpose. As it can be seen there are no safety compromises with these EDD values of design parameters.

DE report can be prepared in support of the values of the cross-section elements which are lower than EDD values. Design by Exception can be employed for such sections of roads where significant savings in initial and maintenance cost can be achieved without compromising road safety.

With the option of pipe covered drain and manholes at regular intervals, quality and vandal proof grating cover and drivable RCC gutters, there will be no or little need of touching the hill slope for road widening in rural steep mountain sections.

Similar EDD design parameters can be applied for other geometric elements and save money as well as environment.

It is believed that PM Road can be delivered in a more cost effective and environment friendly manner with this innovative design approach than by conventional approach. The ongoing design is still needed and is useful for completing the formal budgeting and tendering process. However, the actual construction stage design can apply suggested approach.

This does not mean that EDD values should be applied for all sections of roads. The design should always be started with NDD values. EDD values are to be applied only if there are constraints (physical, manmade, funding) in the project delivery, saving is substantial and safety of road users is not compromised.

The above approach is recommended for consideration by the Department in light of the traffic management and environmental management disaster that is being experienced in the widening of Mugling – Narayangadh Road. There are opportunities for improved delivery of road construction projects in Nepal through careful planning, programming and procuring project management (construction supervision) services.

6.16 Road Safety Measures: Selected Engineering Treatments

In previous sections, review of the existing situations along MP Road and potential treatment measures that could be considered in the design were made. This section provides specific details of road safety measures that are included in the design to reduce some of the main types of crashes. Although detailed crash data by types and their contributing factors are not available in Nepal, anecdotal evidence suggests the following four are the dominant types of crashes in rural roads in Nepal generally and along the MP Road specifically.

- head on;
- run off the road (to the left or to the right);
- hit pedestrians; and
- intersection crashes

The proposal involving the development of short sections of service roads (up to 250m) may not offer adequate transitioning between service roads and shoulders. Operational deficiencies need to be addressed at these interfaces carefully. There could be conflicts between pedestrians using footpath transitioning to shoulder and vehicles transition from service roads to main roads if these are not managed properly.

Various elements of cross-section which play important role in ensuring better road safety outcomes include:

6.20.1 Median Treatments

Median treatments are effective road safety treatments **to reduce head on crashes**. Raised median treatments are provided along the following sections.

- 23+400 to 23+950 (550m)
- 40+430 to 41+400 (700m)
- 41+400 to 61+700(20300m)
- 61+700 to 66+740 (5180m)
- 66+740 to 88+583 (21843m)

The proposal of providing 4m wide central reserve in the design (including 0.5m of kerb "shy away" width on either side) is highly desirable from both safety and operational efficiency perspectives. It supports the safe access and pedestrian crossing management. This space is beneficial and can be used for a number of purposes: (i) to create central reserve to prevent head on collision (ii) to prevent crashes resulting from head light glare from opposing traffic (iii) to accommodate right turning lanes (waiting lanes at intersections with minor roads (at grade) and avoid mainly straight rear end and right - through head on or rear end crashes, (iv) to provide pedestrian refuge and construct safety fencing for double stage crossing to reduce pedestrian hit crashes, (v) to accommodate essential underground utility services including storm water drainage pipes connected to gutters (vi) to provide place for street light poles, (vii) to provide median fencing for preventing people from crossing at unspecified locations to list a few.

While it is usually desirable to have a slightly wider median (5.0m wide is the desirable range for raised median), a 4m wide median (including kerb shy away width of 0.5 m on each side) is an acceptable solution for the low speed environment of MP Road. At intersections, where right turns lanes are to be provided, the desirable 2 m wide residual raised median strip is to be compromised by the provision of double line to separate opposing traffic or by a narrow strip of residual raised median. Essential traffic signs are to be located somewhere else.

Where there would be a right turn pocket lane, the width of median strip would be only 1m. It is recommended as a matter of safety consideration of pedestrian to allow enough space for pedestrian refugee / safety caging (see below) for proposed double stage crossings. A five-metre wide median is possible at the expense of the wide shoulder. These may be considered during construction. Some sections where pedestrian flow is low, a 4m wide median at median block and with residual median width of 0.5 m is considered to be adequate.

Figure 6.4 shows an early version of typical cross-section with 4m (0.5m+3.0m+0.5m) wide median strip for four laning section of road with service road (Total Width: 40.5m). It shows just the concept. These are detailed out and included in Volume 3 of the Draft Report. Typical sections with 5m wide and 2 m wide median strips around the intersection area are also included in Volume 3: Drawings.

If access and driveways are managed properly and local traffic are separated with through traffic by implementing enforcement and safety education measures, these sections of road are expected to operate fairly safely. Engineering measures for access and intersection rationalisation are discussed earlier and details given later.

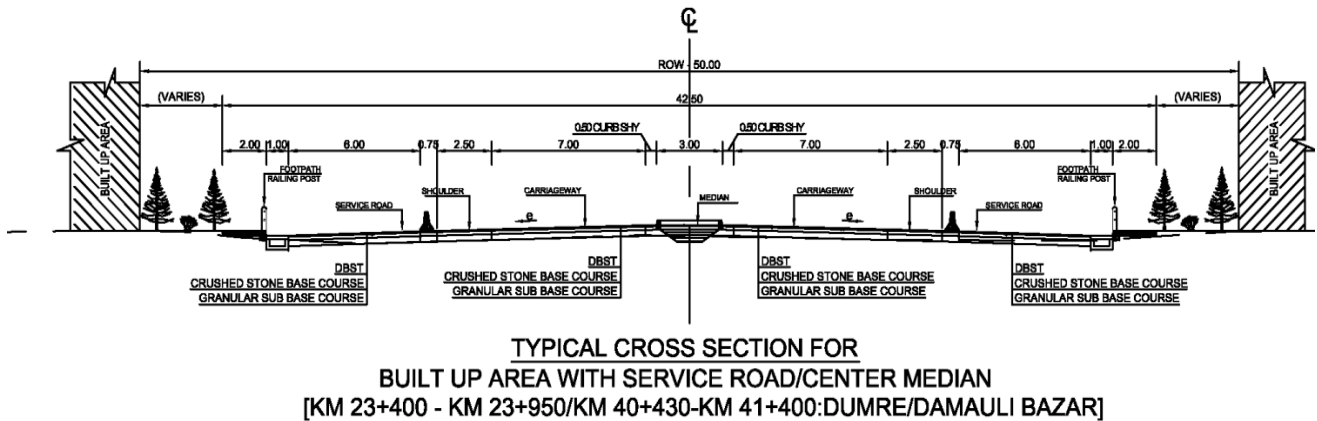
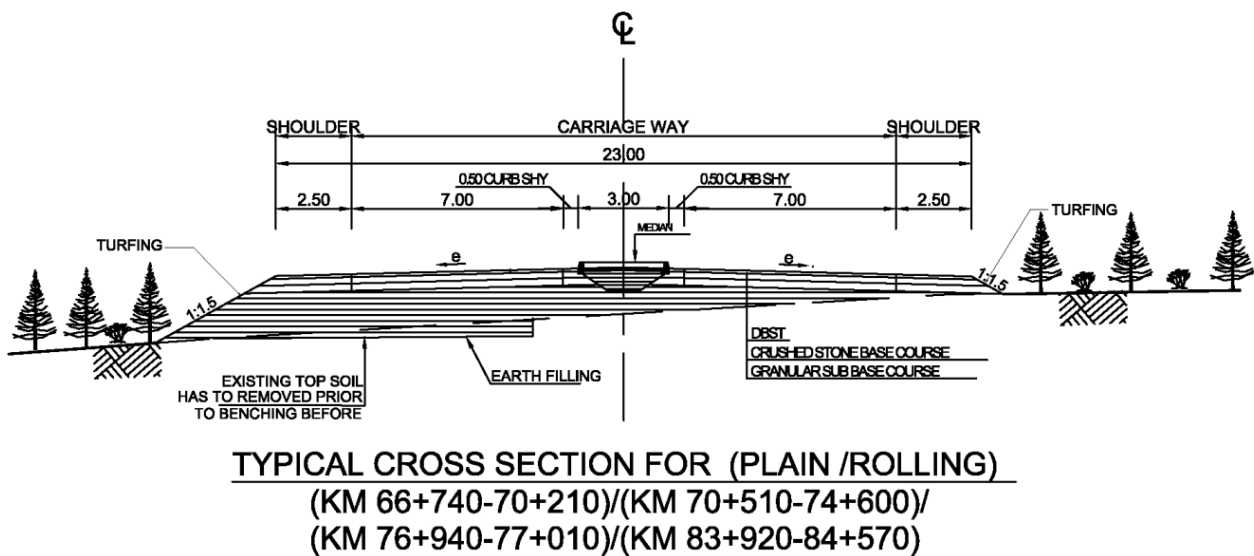


Figure 6.4: Typical X-Section of Four Lane Road in Built-up Areas



Typical X-Sections for roads with the total width of 23 m section (without NJ Barrier, service Road and Footpath here)

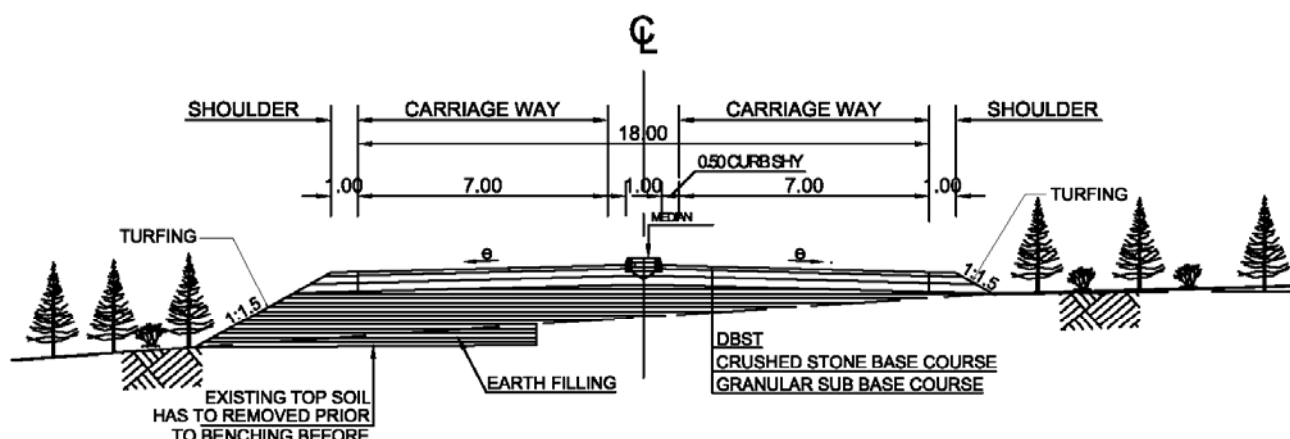
Figure 6.5: Typical X-Section of Four Lane Road without Service Road and Footpath

The next section of four lane road has the reserved total width of 23.0m. Figure 6.5 shows typical cross-section fitted in this available total width. The section also has 4 m wide median strip (0.5m+3.0m+0.5m) with two traffic lanes in each direction as in the first section as well as generously wide shoulders (2.5m). These sections do not have service road though. Absence of connecting service roads and footpath is a safety concern, which should be addressed carefully by providing safe transition sections. Shoulder should be connected to footpath and vehicles from service road should be prohibited to spill on to shoulder by providing physical road closure measures.

A management plan (development control comprising of at least building level specification, conceptual storm water drainage system, future service road provision) of the reserve land between the edge of the road and end of development width is very much essential to preserve the space in favor of better road safety outcomes and should be considered where opportunities exist.

The remaining sections of the MP Road are without service roads and footpaths. Initial sections (from Mugling) have been proposed to have only two lanes with or without Centre Space (CS). Some other

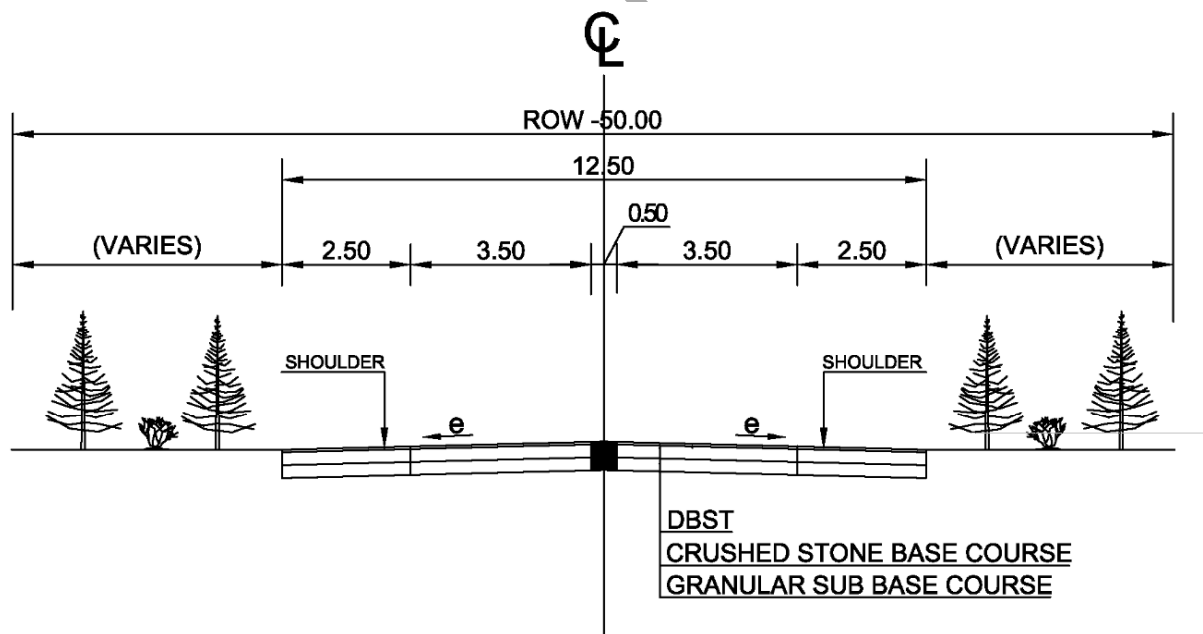
sections without service road and footpath have been proposed to have four lanes. Initial 8 m section is proposed to have two lanes.



TYPICAL CROSS SECTION FOR (PLAIN/ROLLING)
ABUKHAIRENI - DUMRE (KM 8+250 - KM 23+400)
DUMRE - DAMAULI (KM 23+950- KM 40+430)
DAMAULI - KHAIRENITAR (KM 41+400- KM 61+700)

Typical four lane cross section with 1.0m CS

Figure 6.6: Typical X-Section of Four Lane Road without Service Road and Footpath



TYPICAL CROSS SECTION FOR
ABUKHAIRENI BAZAR (KM 3+900 - KM 6+770)

Typical two lane cross section with 0.5 m CS

Figure 6.7: Typical X-Section of Two Lane Road without Service Road and Footpath

Following minor adjustments are proposed from safety considerations. The proposed changes conform to the EDD and DE practices described briefly above.

(1) From 0+000 to 3+700: Reduce lane width to 3.25m and implement 0.5m wide WCLT. This is expected to reduce the likelihood of head-on collisions. This will also reduce likelihood of run off road crashes resulting from overtaking at no-passing or no-overtaking sections. Further narrow lanes are safer than wider lanes as these discourages speeding, as demonstrated by research. Also, explore the implementation of 2+1 treatments (Note: Experience has shown that a properly designed rural road with 2+1 treatment can serve traffic (ADT) of up to 20,000 vehicles.

(2) From 3+700 to 3+900: Reduce lane width to 3.25m and implement 0.5m wide WCLT for reason as above. Consider, in consultation with NEA, exploring semi bridge option on the river side to accommodate at least 2 m wide footpath and 0.5m curb shy on both sides. Discontinuity of footpath is unsafe for pedestrians. Until that time, implement reduced speed limit by installing posted speed limit sign with 30km/h.

(3) From 3+900 to 6+700: Consider reducing width of lane to 3.25m and shoulder to 1.0m; Implement 2+1 treatment using the spare width obtained this way; Adjust dimension accordingly. Where terrain allows consider implementing breakdown bays.

(4) From 6+700 to 8+050: As in 3, foot path remains as proposed

(5) From 8+050 to 23+500, from 750 to 40+300 and from 41+000 to 61+320: consider reducing lane width to 3.25m and implement 1m wide WCLT at widened CS and 1.75m wide shoulder (total width remaining unchanged). Consider the provision of vehicle breakdown bays where terrain is favorable

(6) From 66+500 to 69+800, from 70+150 to 74+250, from 76+580 to 76+640 and from 83+880 to 84+460: Consider reducing lane width to 3.25m and correspondingly increase the width of the median. This recommendation would allow implementing RT pocket lanes for right turn as well as U turn movements yet leaving wide residual median for safety. This is optional / desirable as 3m wide median with curb shy on either side can also accommodate RT lane but without residual raised median.

(7) For remaining sections with four lane and 40.5m total road width, consideration can be given similarly to 23m wide sections, to reduce the lane width to 3.25 m and increase the median (4m without curb shy and 5m with curb shy)

In Nepal, the level of compliance with the rules related to lane discipline is quite poor. Meaning of double solid centre lines is not known to many motorists and motorcyclists. These rules are often ignored even by those who know. The replacement of worn out centre line marking does not necessarily become the priority of road agencies. In absence of these treatments, aggressive overtaking in front of opposing vehicles could be a more regular phenomenon, which can potentially lead to fatal head on crashes.

It is therefore suggested that the DOR consider trialing Wide Centre Line Treatment (WCLT) with Audio Tactile Line Marking (ATLM), which can be implemented with and without fencing barriers. These treatments can be implemented using the centre space proposed in the design without any additional width. Minor adjustments proposed above in relation to the elements of cross section can be used to provide WCLT as wide as 1m along some sections and 0.5m along highly constrained sections of MP Road. (See details later). WCLT with ATLM has been proven to be very effective to reduce head on collisions along narrow two lane roads. WCLTs (with or without ATLMs) have been proved to be very effective in **reducing head on crashes** in two lane roads. ATLM on road edges are very useful in reducing likelihood of **run off road crashes**

6.16.1 Footpath

A two-metre wide footpath has been proposed for pedestrian safety, which is considered to be adequate to ensure pedestrian safety along built up areas. Unauthorized use of footpath by vendors

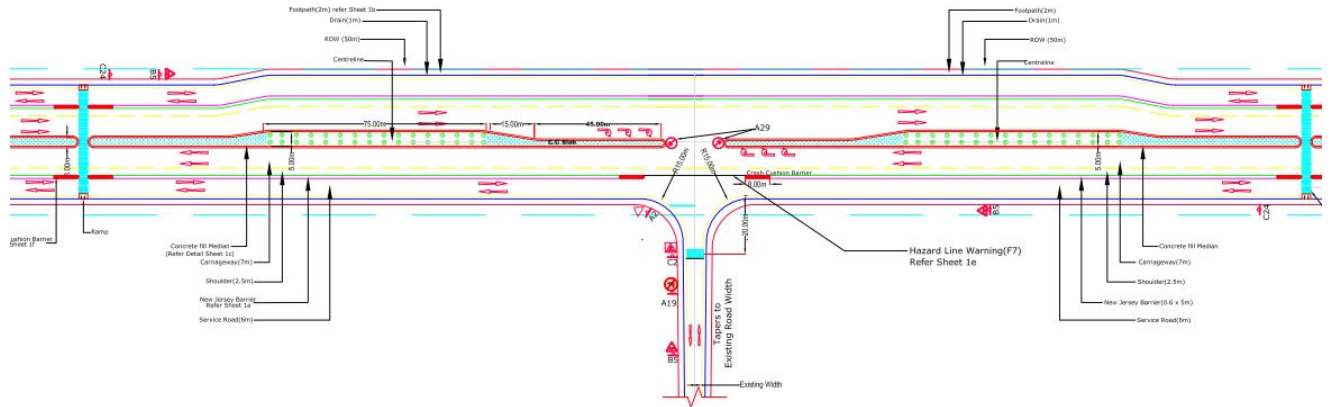
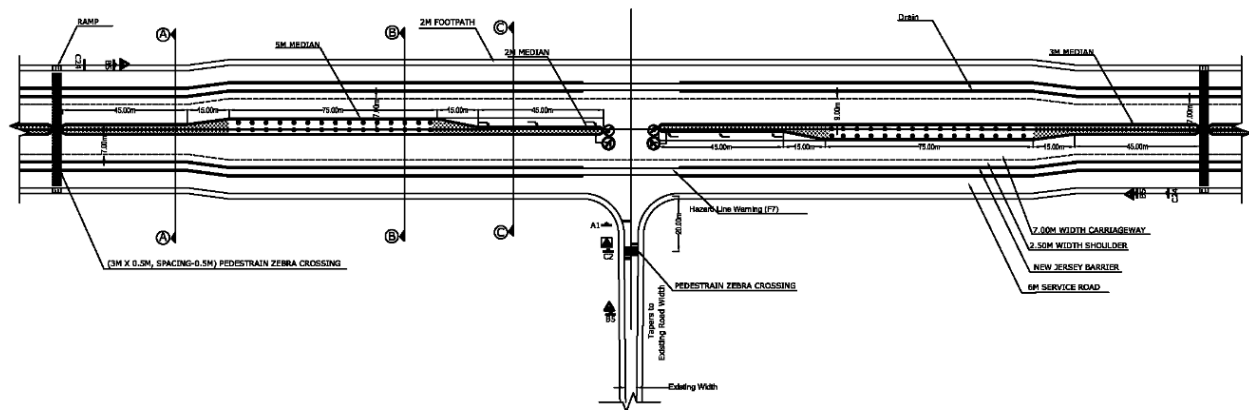


Figure 6.9: Typical At-grade Intersection for BLT Road (Three Way)



TYPICAL THREE WAY INTERSECTION
CASE-1: CENTRAL MEDIAN OPEN

Typical At-grade Intersection for MP road Road (Three Way)

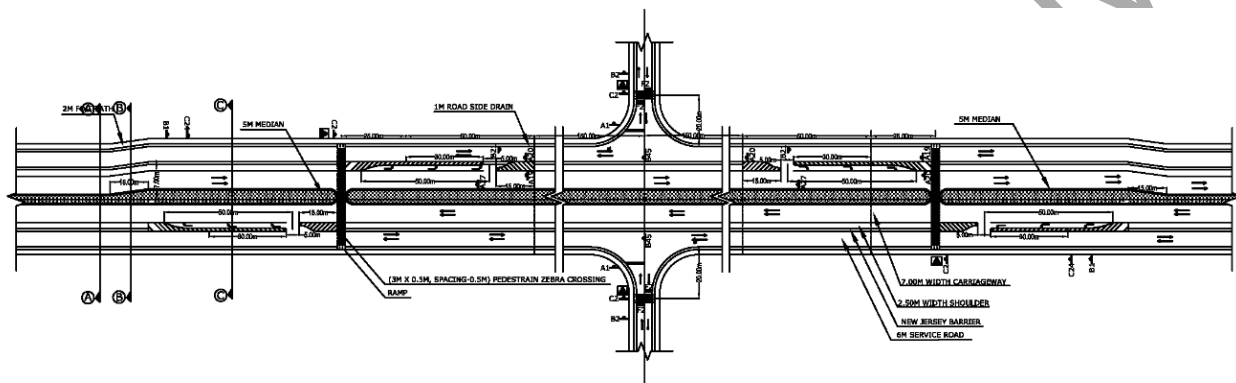


Figure 6.10: Artistic Impression of a Typical T-Intersection demonstrating the Use of additional RT and LT Lanes (applies manly at built-up sections)

6.16.3 Intersections with Closed Medians

Designs of intersections with medians closed are also developed which would be implemented along the selected sections of MP Road with raised medians. Detailed drawings of these type of intersections are included in Volume 3 of this report. Both types of intersections (medians closed and medians open) can apply equally to four way or three way intersections with sealed service roads or graded earthen service roads or even without service roads with minor changes in the design. The decision on which type design to be used is not just a technical; it might be determined by the level of resistance from the community. Other situations remaining identical, it is recommended to prefer the design option with median closed.

By closing medians at intersections, many **crashes related to right turning movements** can be reduced. Other intersection related crashes are also reduced.



Typical Four Way Intersection
Case-2: Central Median Closed

Figure 6.11: Typical At-grade Intersection for MP Road (fourWay-with central median closed)

6.16.4 Intersections with Basic Right (BaR) Turn & Basic Left (BaL) Turn Treatments

Design of intersections such as those presented above for built up environment may be expensive and at times would not be suitable for rural roads. In these situations, intersection development can be started from the very basic type and gradually upgraded to higher standards (such as AUL, AUR, CHL, CHR etc. See Section 6.9) as the turning traffic volume increases.

BaR and BaL are simple and low cost road safety treatments at intersections to **reduce intersection related crashes**. Generally, these treatments are used overseas at intersections along rural roads where traffic is light and turning movements are low. These treatments are recommended at all intersections along rural sections of the MP Road and at selected intersections (with "unimportant" road) along semi-urban sections. These treatments are useful to reduce the likelihood of rear end and right-through and left-through type of crashes. Both BaL and BaR treatments are either completely contained within the shoulder (if it is wide) or are implemented with the provision of additional roadway width.

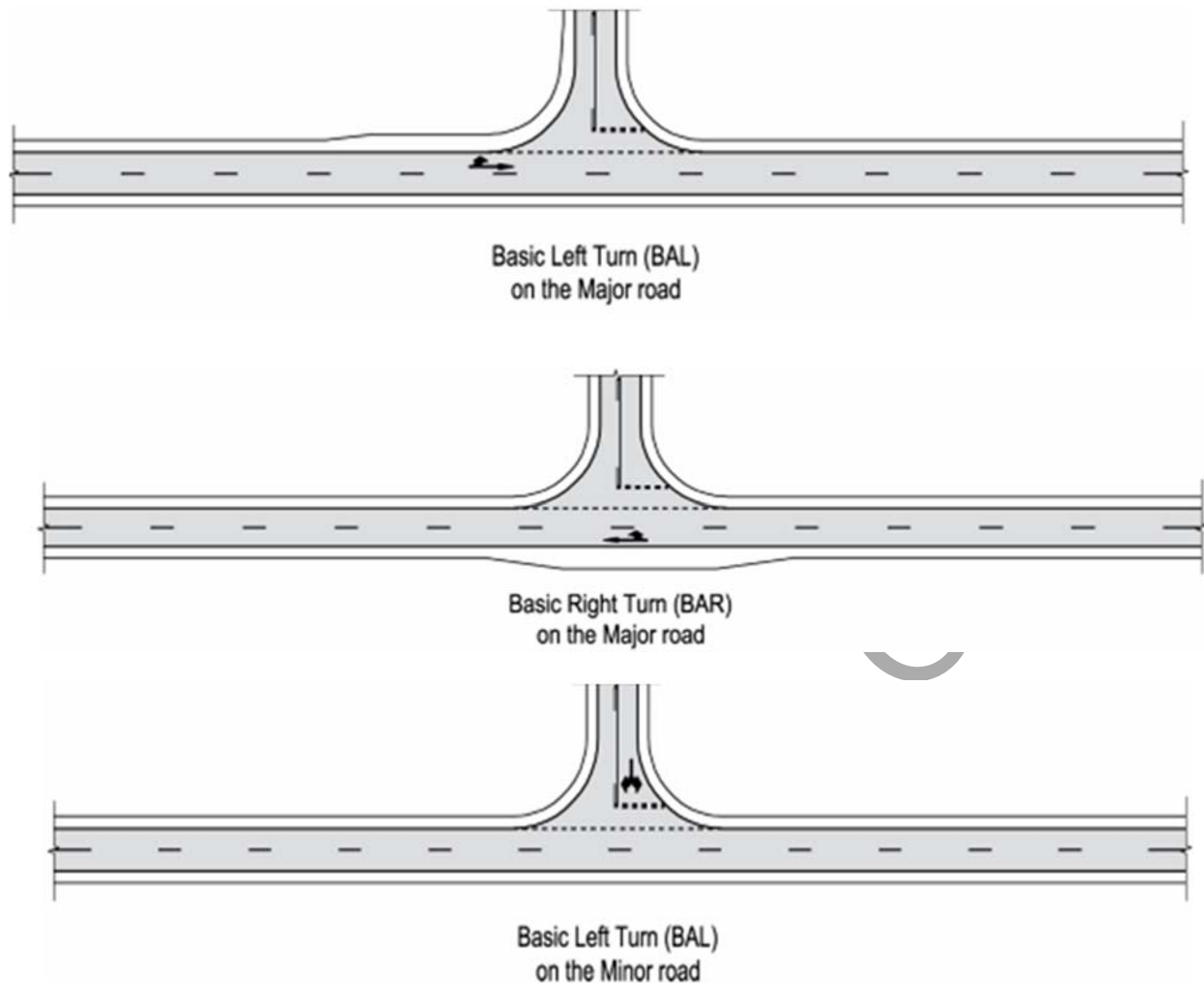


Figure 6.12: Basic Right Turn and Basic Left Turn Treatments (Conceptual)

(Source Austroads, 2008)

6.16.5 Roadside Barriers

Single sided reinforced concrete barriers (NJ barriers) (Figure 6.13) are proposed on road side with deep vertical drop **to reduce run off road crashes**. Symmetrical double sided NJ RCC barriers are also proposed to separate service road traffic from main through traffic. These barriers also deter pedestrian intrusion into main road from everywhere. These barriers need to have enough holes on the bottom to allow surface run of disperse on the service road before these get drained to kerb and channel at the end of service road. Details of RCC and other forms of road side barriers can be found in Nepal Road Safety Note.



Figure 6.13: RCC Barriers for Valley side

6.16.6 Wide Centre Line Treatments

Approximately 8km section of MP Road which is currently single / intermediate laned, will be retained as two lane road at this stage. Half of the 2-lane section road has highly constrained width where narrow WCLT (0.5m wide) is proposed. The remaining half of the two lane sections can have 1m wide WCLT.

WCLTs and ATLMs separately or in combination are expected to reduce many crashes mainly head on and runoff road types significantly.



Figure 6.14: Illustration of a Typical Wide Centre Line Treatment (WCLT) with ATLM markings
(Source: Technical Note 155, QDTMR, Nov 2015)

For Reference

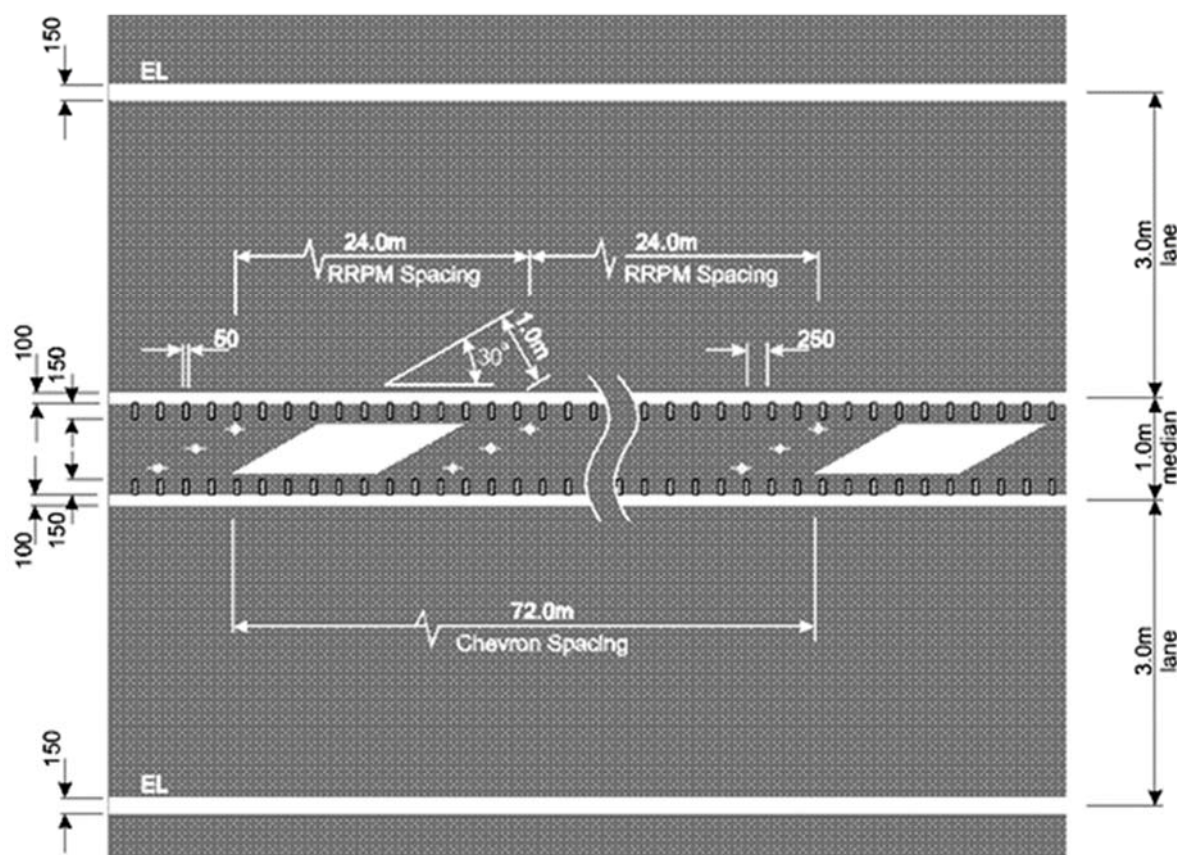


Figure 6.15: WCLT Details

(Source: Technical Note 155, QDTMR, Nov 2015)

Note: Reduce 1m wide median to 0.5m in constrained environment (Design Exceptions: for lower speed environment of MP Road it is considered totally acceptable)

6.16.7 Overtaking Lane Treatment

Many crashes in Nepal's hill roads occur when making aggressive overtaking. Slow moving trucks are required to be overtaken by fast moving vehicles. Drivers behind slow moving vehicle do not wait for safe overtaking section with adequate visibility. Overcorrection many times leads to run off road crashes and many times collide with oncoming vehicles head on. In order to address this safety problem, either slow lane treatment or overtaking lane treatment is provided.

Where site situation allows and where there is a risk of long "platooning" behind a slow-moving vehicle (truck, bus, tractor, motorcycle), a third lane needs to be added for reducing aggressive passing using the opposing lane. Slow moving lane is generally provided at climbing section where loaded heavy vehicles slow down significantly. The locations can be identified at detailed design stage audit process following the agreement with the Project for trial and details can also be developed then.

The concept of passing (also called overtaking) lane treatment is similar to slow lane treatment but not specifically provided at slow sections. Passing lanes are provided when the volume of traffic is relatively high and passing opportunities are rare due to low or risky gaps available in oncoming traffic or become risky due to restricted visibility conditions prevalent along the road. When percent time spent following is high, motorists lose patience and start taking risky overtaking opportunities. Passing lanes can be provided with or without median fencing. In the MP Road, median fencing is not proposed because of the maintenance issue.



Figure 6.16: Illustration of Combination of WCLT and Passing Lane Treatment

(Source: QDTMR, 2015)

(Note that shoulders are not as wide as proposed in MP Road Design)



Figure 6.17: Special Sign indicating overtaking banned (An alternative is to use Nepal Traffic Sign Manual's overtaking prohibited sign with supplementary plate)

6.16.8 Two Plus One Lane Treatment

Two Plus One Lane Treatment is a relatively new concept introduced in Sweden, Finland and other European countries for low to medium volume roads. Research has shown that a two-lane road with two plus one safety treatment (See below) can be used for roads with ADT of up to 20,000 vehicles per day. MP Road even in the last section closer to Pokhara is not expected to have over 20,000 vehicles in a day. DOR may reconsider four laning and go for two plus one treatment in the interim if the fund would not be adequate for four laning.

Two adjacent passing lanes in the middle can be raised or rumble stripped (may not be safe for motorcyclists) for Nepal situation, where drivers do not care and cross double lines, WCLT or painted "ghost" island. This treatment is proposed for consideration by the DOR on trial.

It is to be noted that in overtaking lane treatment, vehicles on completion of overtaking merge right whereas in 2+1 treatments they merge left.



Figure 6.18: Example of 2+1 Treatment without Median Fencing



Figure 6.19: Example of 2+1 Treatment with Median Fencing

6.16.9 Miscellaneous Road Safety Treatments

A number of other road safety treatment measures have been proposed for consideration by the Project for built up areas. These include:

- (a) Vandal proof fencing to prevent jay walking (enough height so people can't jump over it (See Figure 6.20). Crash cushion with hazard marker should be placed at the end of fencing. Details will be as shown in the drawings. Details of fencing should be developed in such a way as to remove some

panels to create median cross overs to be used by tow trucks or emergency response vehicles (ambulance, emergency vehicles) in case of road crashes.



Figure 6.20: Vandal Proof Median Fencing

(b) Raised Zebra Crossing are provided at rural townships and bazar area to reduce pedestrian cashes (Figures 6.21 and 6.22)

(c) Two Stage Crossings: Where children and aged people cross, two stage crossings with safety cage as shown in Figure 6.23 are proposed MP Road.

(d) Indented Bus Bays or Yellow Bus Boxes: Where land is available indented bus bays are provided. In four lane roads yellow box bays can indicate dedicated bus stops shown in Figure 6.24

Indented bus-bays should be located on the far side of intersections such that zebra crossings should be behind the stopped bus (bus stops should be located behind pedestrian crossings). In case of built up areas with 2.5 m wide hard shoulder, yellow boxes can replace indented bus bays designated for long haul (inter-city) bus services. Local buses should run (where frontage roads exist) and stop on frontage roads only. These buses should not be allowed to drop off or pick up passengers on main road. Details are included in Volume 3 of the report.

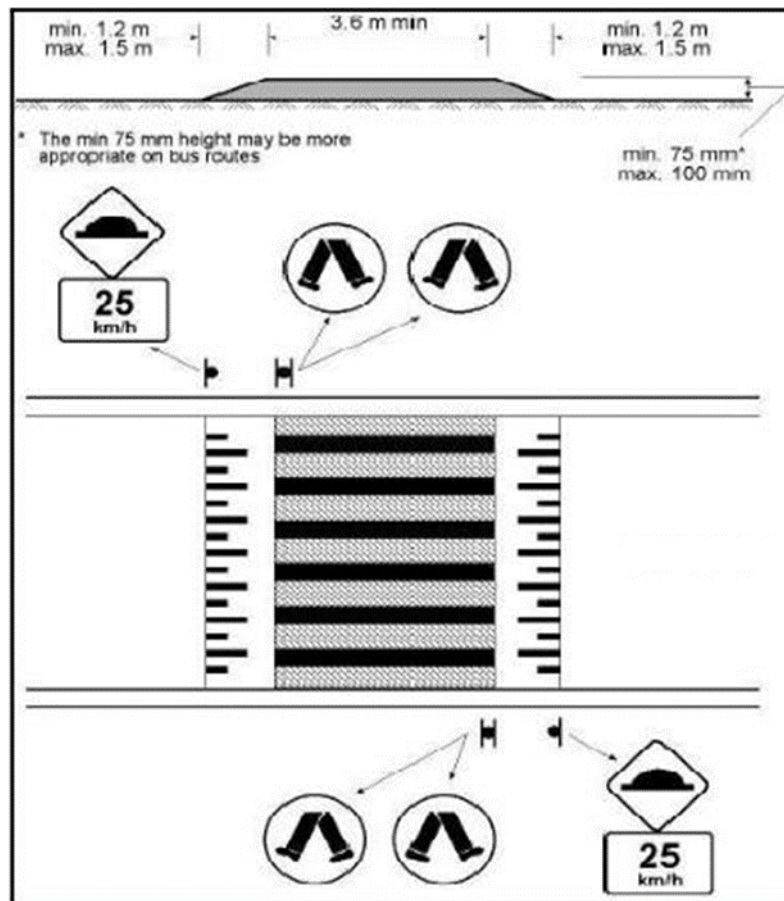


Figure 6.21: Details of Raised Zebra Crossings



Figure 6.22: Raised Pedestrian Crossings



Figure 6.23: Two stage Crossings with Safety Cage



Figure 6.24: Yellow Bus Box at Bus Stops

6.16.10 Safety Treatments in Rural Urban Environment Transition

(a) Gateway Treatment: Many motorists do not realize the presence of new and reduced speed limit signs before the start of rural township and they continue drive with the same speed as in rural sections of the road. This puts pedestrians on the township at greater risks. A combination of physical, visual and perceptual features has been found to be of great effect in achieving reduction in speed within the township from as high as 100 km/hr to 50 km/hr. These combined speed-reducing features, collectively called gateway treatment, are proposed to introduce in the MP Road to effectively reduce from the proposed speed at rural sections of 60 km/hr to 40 km/hr speed at bazar / township areas along the MP Road.

The concept is explained in Figure 6.25 with the example of Pinch Point Gateway Treatment. Here the width of road is narrowed with curb extension and central ghost island to create physical cues. Change in the colour of pavement aids to the motorists' perception that they are approaching to different unusual speed environment and with large speed limit sign, motorists can not miss the speed limit sign.

Jigsaw marking and other forms of treatments like welcoming gate can further make the entrance to rural township or market zone from rural environment more prominent.

(b) "2 to 4" Safety Treatments: These are simple transitional arrangements for safe movement of vehicles from two lane sections of roads to four lane sections (Flaring).

(c) "4 to 2" Safety Treatments: These are simple transitional arrangements for safe movement of vehicles from four lane sections of roads to two lane sections (Narrowing). It can be designed either as give way merge or "zipped merge".

(d) Other transitional treatments These include service road to without service road transition and footpath to shoulder treatments.



Figure 6.25: Gateway Treatment

The items and total quantities provisioned for road safety measures for Mugling Pokhara is given in Table below. The item wise detail quantity calculations for each location/site are depicted in Cost Estimate Volume.

Summarized Quantity of Road Furniture and Traffic Safety Measures

6.01	Supply and erect Traffic Signs in place including required size of steel tubes, steel plates, cement concrete, painting, writing and supporting steel angles, nuts and bolts etc. all complete, as per Drawings.	Unit	Quantity
a.	Single post	nr	1658
b.	Double or more posts	nr	94
6.02	Supply and place Road Marker (RCC Kilometer post) including excavation, concrete back filling, painting and writing etc. all complete as per Drawings.		-
a.	Standard Kilometer stone.	nr	71.00
b.	Standard 5th Kilometer stone.	nr	17.00
6.03	Supply and fix in place precast RCC delineator post with reflective paint including foundation preparation, concrete back filling, painting and erection etc., all complete as per drawings	nr	12250
6.04	Supply and fix in place precast concrete Kerb Stone with M20/20 concrete grade including foundation preparation, back filling, painting and erection etc., all complete as per Drawings.	m	203873
6.05	Providing and installation of precast RCC New Jercey block with reflective paint in line and level oner prepared level surface etc., all complete as per the specification and drawing.	m	6080
6.06	Road Marking with hot applied thermoplastic compound with reflectorising glass beads on bituminous surface as specified in Traffic Sign Manual and as per the drawings.	Sq m	5,625.00

6.07	Provide and erect "W" metal beam crash barrier comprising of 3 mm thick corrugated sheet metal beam rail, 700 mm above road/ground level, fixed on ISMC series channel vertical post, 150 mm x 75 mm x 5 mm spaced at 2 m c/c, 1.8 m high of which 1.1 m shall be below ground/road level. All steel parts and fitment shall be galvanised by hot dip process	m	87167
6.08	Providing and laying 60mm thick interlocking concrete block using stone dust/sand bed on 75mm thick compacted granular sub base in a footpath including stone dust filled in between the blocks etc., all complete as per the drawings and specification	Sq m	86413
6.09	Providing and installing of 75mm - Φ GI pipe railing and precast RCC railing post including foundation excavation and preparation, concrete back filling, painting and erection etc., all complete as per specification and drawing.	m	43206

6.20.12 Selected Readings on Road Safety Measures

Nepal Road Safety Action Plan (2013 - 2020)

(http://www.dor.gov.np/documents/RSAP_english.pdf)

Nepal Road Safety Notes

(<https://www.dor.gov.np/publications/>)

Nepal Traffic Sign Manual

(<https://www.dor.gov.np/publications/>)

Guide to Road Design, Part 1 to Part 8

(<https://www.onlinepublications.austroads.com.au/collections/agrd/guides>)

Guide to Road Safety, Part 1- Part 9

(<https://www.onlinepublications.austroads.com.au/items/AGRS>)

Guide to Traffic Management, Part 1 - Part 13

(<https://www.onlinepublications.austroads.com.au/collections/agtmguides>)

Achieving Safe System Speeds on Urban Arterial Roads: Compendium of Good Practice,

(<https://www.onlinepublications.austroads.com.au/items/AP-R514-16>)

Safety of Disadvantaged Road Users

(<https://www.onlinepublications.austroads.com.au/items/AP-R516-16#>)

Safe System Roads for Local Government

(<https://www.onlinepublications.austroads.com.au/items/AP-R518-16>)

Application of European 2+1 Roadway Design National Cooperative Highway Research Program, RESEARCH RESULTS DIGESTs

(http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_275.pdf)

Cost Effective Safety Improvements for Two-Lane Rural Roads

(<http://www.lib.washington.edu/msd/norestriction/b60952015.pdf>)

Safe System Assessment Framework

(<https://www.onlinepublications.austroads.com.au/items/AP-R509-16>)

Wide Centre Line Treatment – Interim Advice, Technical Note 155, November 2015

<http://www.tmr.qld.gov.au/-/media/busind/techstdpubs/Technical-notes/Road-design/TN155.pdf?la=en>

Figure 6.26: Layout of 3-Way Intersection, T-Junction (Median open)



Figure 6.27: Layout of 3-Way Intersection, T-Junction (Median closed)

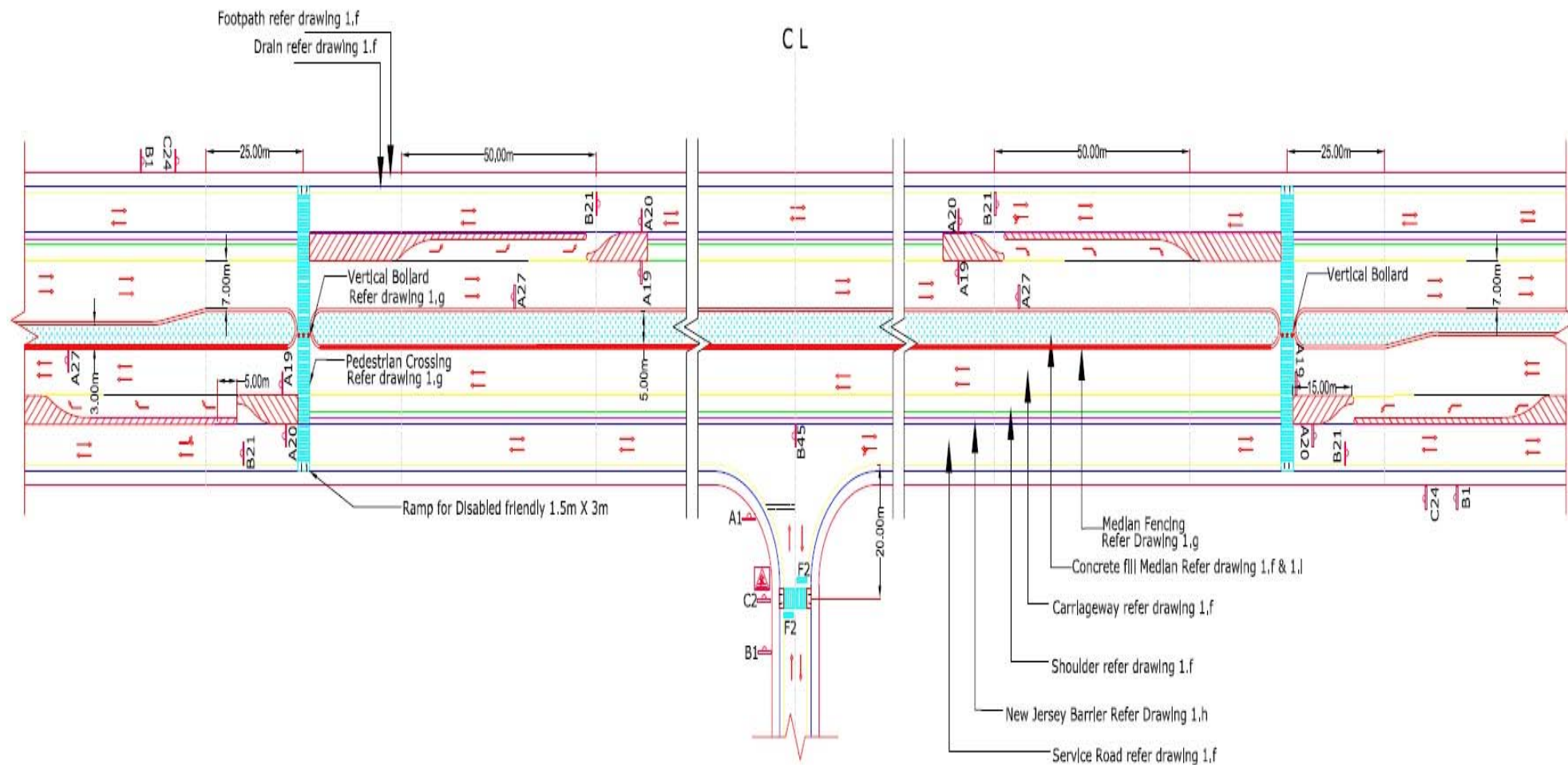
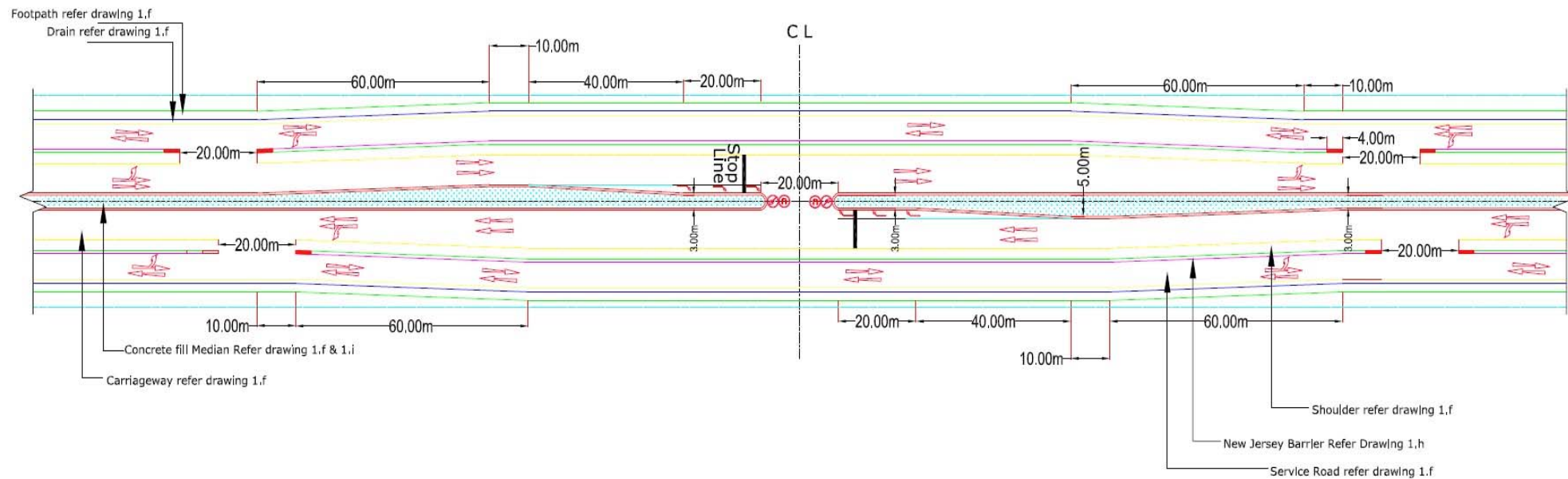


Figure 6.28: Layout of U-Turn



7. ALIGNMENT DESIGN

7.1 Introduction

After submission of the feasibility study and its presentation and interaction in DOR, client instructed the consultant to carry the detailed design report of Option III; which was the most economically viable optional among three other options proposed by the consultant in the feasibility study. The consultant started finalizing detailed design work of Option III with some revision on consultant's proposal in FS as per instruction of client in presentation. It was maximization of 4 laning in Mugling Damauli section, therefore In rocky area and Marshyangdi-powerhouse section of Mugling-Abukhaireni. Section, double lane has been proposed in Option III. The revised option of feasibility study is given below:

Option I: Double lane from Mugling - Damauli section and 4 lanes in the Damauli - Pokhara Section with service lane in major settlement area and Bazar area.

Option II: 4 lane design from Mugling - Pokhara with service lane in major settlement area and Bazar area.

Option III: Double lane in all roads Corridor from Mugling to Abukhaireni(0+000 to 8+250km), 4 lanes Abukhaireni to Khairenitar, 4 lanes with service road from Khairenitar to Pokhara. Service lane in major settlements and Bazar area.

Thus during the economic evaluation of the preliminary design of above mentioned options the most economic option is Option III, the EIRR of this option is most economical viable among three with EIRR 20.33% where as for other two options EIRR is also more than 12% with 16.74 and 12.64% respectively, but highest rate of return is 20.33 %EIRR is obtained from option III.

The Consultant discussed with client about the feature of Option III alignment, design standards, technology and risk mitigation measures with the DOR.

The Consultant had also discussed with the Client about alignment of the road section which will be designed as per the geometric standard specified for various class of roads as per NRS 2070 for 4-laning of Mugling-Pokhara road.

7.2 Geometric Design Standards

The geometrical design standards for horizontal and vertical alignment design are related to function of road, volume of traffic and type of terrain, with additional procedures for the recognition and appropriate treatment of potential hazards.

The geometric design of the road is carried out to provide safe and smooth movement of vehicles operating at design speed and minimum disturbance to landscape. Furthermore the geometric design of road depends on the class of road adopted for the candidate road as specified in NRS 2070. For the Upgrading of the Mugling-Pokhara road to 4 lanes the geometric design standards hill and rolling section has been adopted as Class II and III as per NRS 2070 (Detailed has been given in Table 2.9, of chapter 2). Hence the geometric design standard for this road generally has been followed as for the Class II and III road as under NRS 2070. Reference to AASHTO "A policy on Geometric Design of Highway and Streets" 2001 and Overseas Road Note 6 "A Guide to Geometric Design" published by TRRL 1988 has been made as required.

For traffic signs and road markings, DoR's Traffic Signs Manual 2007 has been followed.

7.2.1 General

Design speed is a speed established to determine the various geometric design features of the Road. The design speed should be a logical one with respect to the functional classification of Highway, anticipated speed, topography, the adjacent land use, and any planned improvements for the facility, including future projects on adjacent roads and segments.

Overall geometric design of a road is a function of design speed. Design speed is decided based on the importance of the road (road class) and the type of terrain. The sight distance, radius of horizontal curve, super elevation, extra widening of pavement, length of horizontal curve and the length of vertical curve (summit and valley) depend on the design speed, which in turn depends on class of road and nature of terrain. According to the design standard NRS 2070 and AHDS, for different class of road, design speed has been specified in chapter-2.

7.2.2 Design speed

Accordingly, the adopted design speed for geometric design of this road for plane and hill sections is tabulated below.

S. No.	Road	Length (Km)	Terrain	Design Speed (Km/hr.)	Road Classification
1	Mugling-Abukhaireni (0+000 to 8+250)	8.250	Hill and difficult section	40km/hr.	NRS
2	Abukhaireni (8+250 to 88+583 km)	98.46	hill / rolling	60km/hr	NRS

NB: In difficult sections and prohibitive areas the specified standard might need to be relaxed for short sections. In these cases signs would be erected warning of substandard sections

7.2.3 Design Criteria

Table 7.1: Geometric Criteria for Mugling-Pokhara road

SN	Design Parameters	Adopted		Remarks
		Double lane from Mugling to Abu khairani(km 0+00 to 8+250km)	Four lane from(Km8+250 to 88+583	
1	Minimum Radius of Horizontal Curves, m	50	80	
2	Length of Transition curve, m	35	40	
3	Extra widening (m)	0.9	1.2	
4	Maximum Gradients%	7	7	
5	Minimum length of vertical curve in (m)	29	94	
6	Maximum(critical) Length, m	300	300	
7	Super Elevation (%) (max)	7	7	
8	Camber (%)	3	2.5	

7.2.4 Adopted Cross-section

At present the existing road width in the Mugling-Pokhara is two lane road widths varied from 6 to 10 m.

It was intended to upgrade Mugling-Pokhara road from double lane to four lanes. There are five adopted cross –section for the upgrading one in double lane and four type of cross sections in hilly and rural sections, Market area .

- In double lane section ,total road width of 9m, 7m and 12.5 meter has been adopted

- From Mugling to Marshyangdi Power house (MPH) (3.7km), MPH area (0.200km) and MPH to Abukhaireni (2.870km) respectively. Where as in Abu khaireni Bazar main carriageway is 7m adding median(0,5), shoulder(2.5/25m in either side),footpath(2m/2m) and drain(1/1m)total road width becomes18.5 m , **total double lane=8.250km**

Cross section features adopted for in 4 lanes from Abu khaireni to Bijayapur seti Bridge start are summarized under.

A, Rural and forest area, Abukhareni-Dumre (15.15km), Dumre-Damauli-Bazar (16.48km) and Damauli-Dulegauda (20.300km). Total road width=18m and total km=51.930.		
Formation Width	:	Total= 4x3.5+2x0.5 (kerb shyness)+1 (Median)+2x1.0 (shoulder) = 18m
Service lane	:	-
Shoulders	:	Paved 1.0 m both side
Pavement Camber	:	2.6 % on either sides from centre
B Bazar area,Dumre Bazar(550m) and Damauli Bazar(970m) .Total road width=42.5m and total km=1.520 km		
Formation Width	:	Total= 4x3.5+2x0.5 (kerb shyness)+1 (Median)+2x2.5.0 (shoulder)+NJ Barrier(0.75/.75m) + service road (6m/6m)+footpath (2/2m)+ drain in bothside (1/1m)= 42.5 m
Shoulders	:	Paved 2.5m both side,
Pavement Camber	:	2.5% on either sides from centre
C. Bazar area, Dulegauda, Belchautara and Thati Bazar (5.040 km), Gagangauda-Sainik basti (2.34km), Kotrebazar (300 m). Bhandarik - Bijayapur (6.910km) and Bijayapur (84+570 to 88+583) to start of seti bridge (4.013km), Total road width=46.5m and total km=18.603 km		
Formation Width	:	Total= 4x3.5+2x0.5 (kerb shyness)+3 (Median)+2x2.5.0 +2X0.60 (shoulder+curbshy)+ service road+ curbshy (6m/6m+2X0.60)+footpath (2/2m)+ drain in bothside (2.4/2.4m)= 46.2 m
Service road	:	6m/6m both side
Shoulders	:	Paved 2.5/2.5m) both side
Pavement Camber	:	2.6 % on either sides from centre
D. Rural area,Thati-Kotre Bazar (3.470km), Kotre-Gagangauda (4.090km) and Bijayapur (650m) Total road width=23.0m and total km=8.210 km		
Formation Width	:	Total= 4x3.5+2x0.5 (kerb shyness)+3m (Median)+2x2.5.0 (shoulder)= 23.0m
Shoulders	:	Paved 2.5m both side,
Pavement Camber	:	2.5% on either sides from centre

Typical cross section of project road showing road features like drains, retaining structures, etc. are given in **Figure 6.1, Figure 6.2 and 6.3**

The design drawings showing plans, longitudinal profiles and cross sections, that completely define the road geometry of the project road, are submitted under **Volume IC (Drawings)**.

7.2.5 Camber and Super-elevation

Super elevation has been provided at the curves to avoid overturning of the vehicles and provide comfortable playing of the vehicles. The maximum super elevation adopted is 7 %. Values adopted for super elevations of the carriageway in Mugling-Pokhara road are maximum 7% and cross slope or Camber is 2.5%.

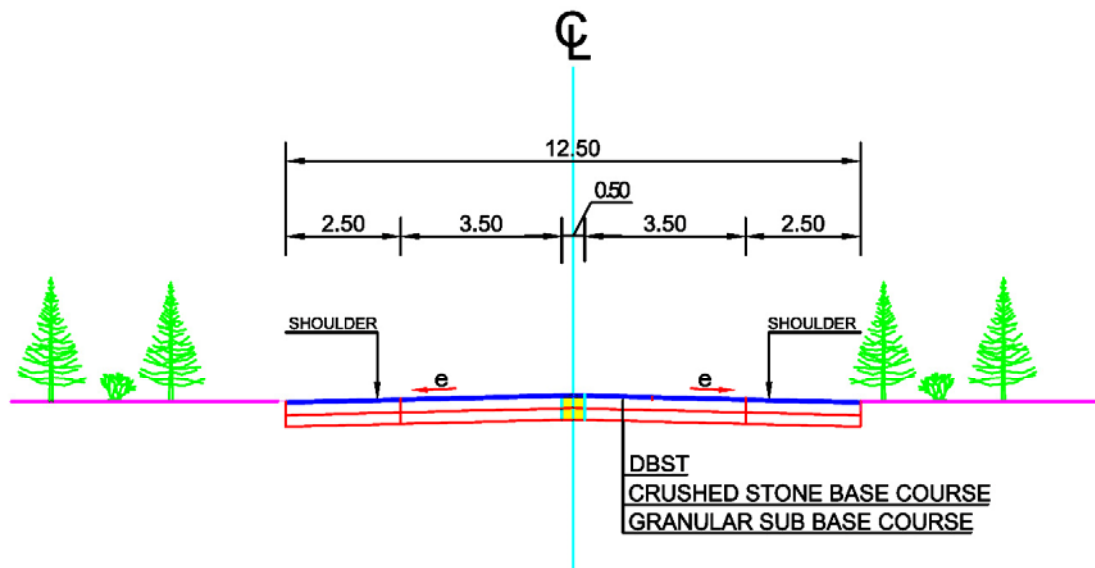
7.2.6 Sight Distance

For safety it is necessary that sight distance of adequate length should be available to permit drivers enough time and distance to control their vehicles.

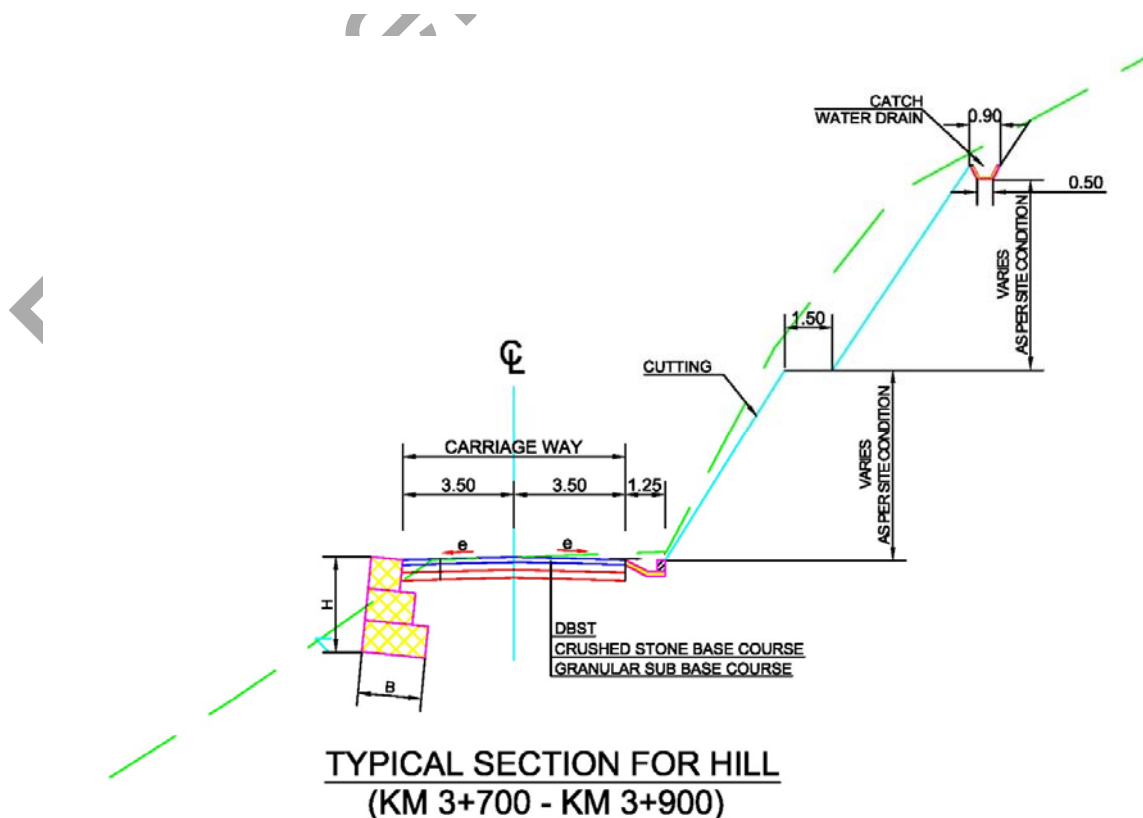
As Per NRS 2070, stopping distance for various speeds is given in the table below.

Speed, km/h	20	30	40	60	80	100	120
Stopping Distance, m	20	30	50	80	130	190	260

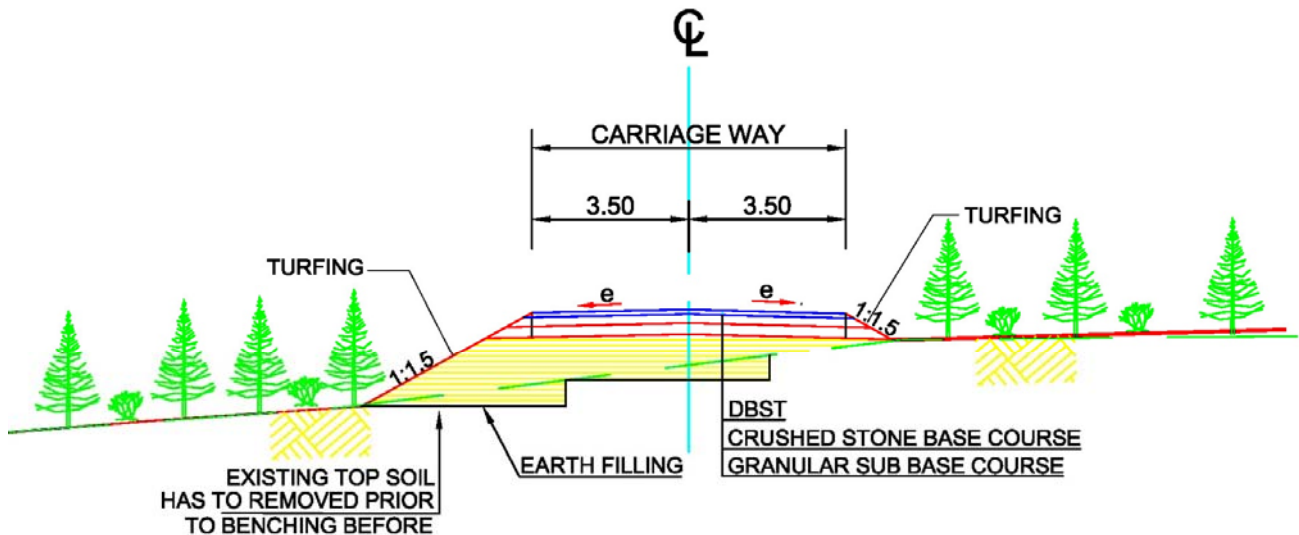
As design speed in this road is 60km /hr, minimum sight distance is as per table is 80m.



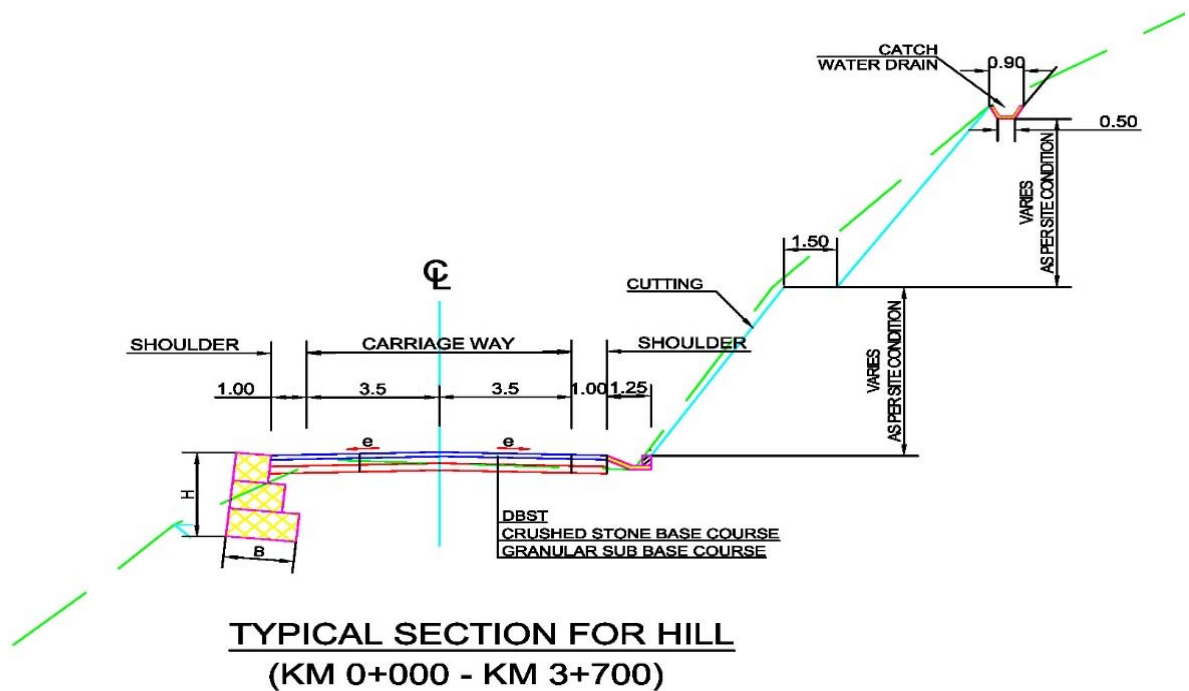
**TYPICAL CROSS SECTION FOR
(KM 3+900 - KM 6+770)**



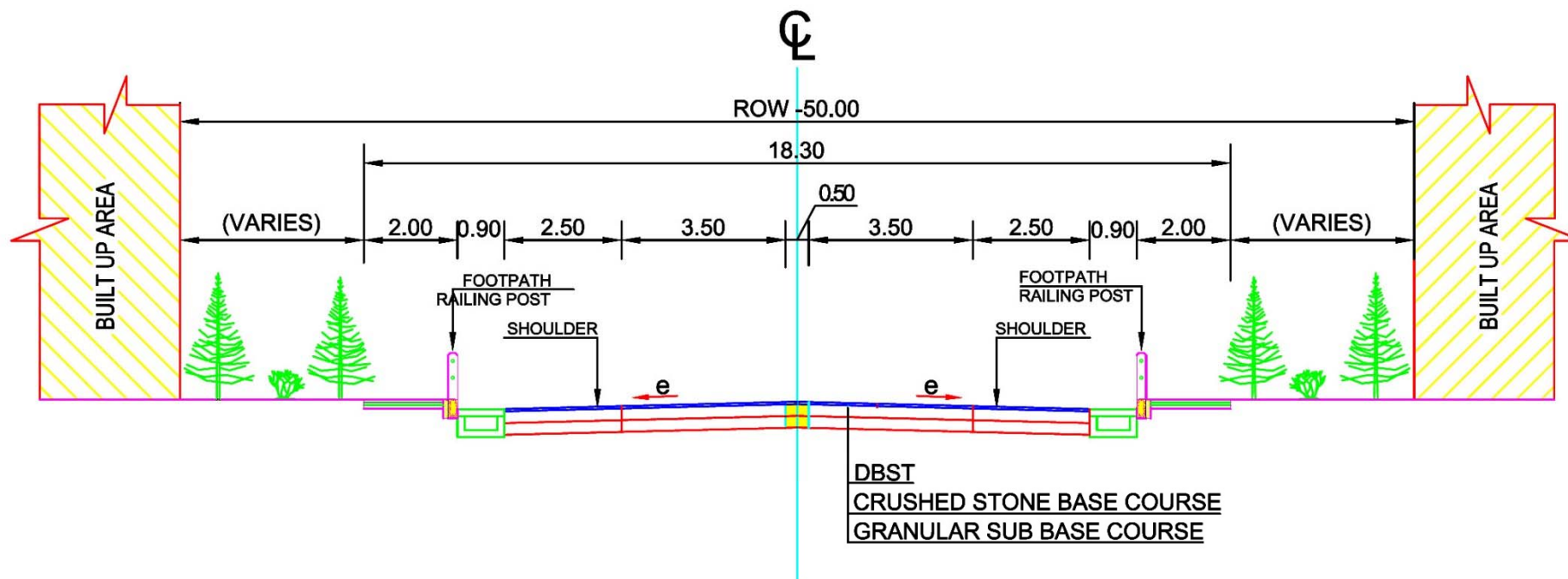
**TYPICAL SECTION FOR HILL
(KM 3+700 - KM 3+900)**



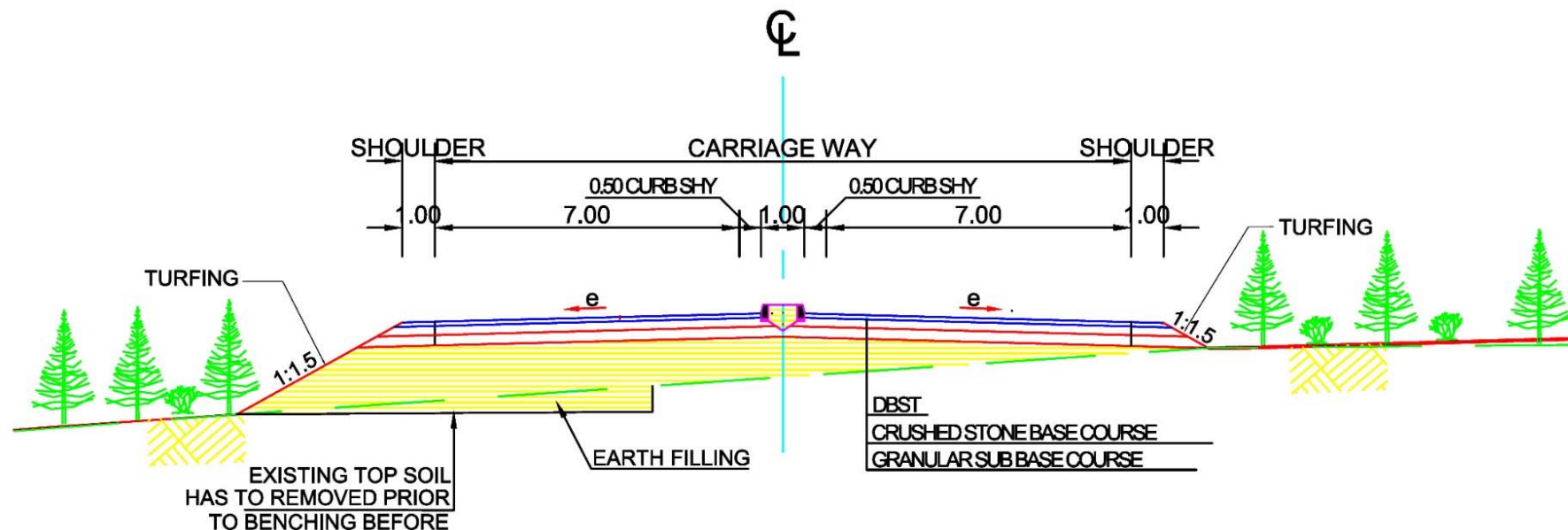
TYPICAL CROSS SECTION FOR (PLAIN /ROLLING)
(KM 3+700 - KM 3+900)



TYPICAL SECTION FOR HILL
(KM 0+000 - KM 3+700)



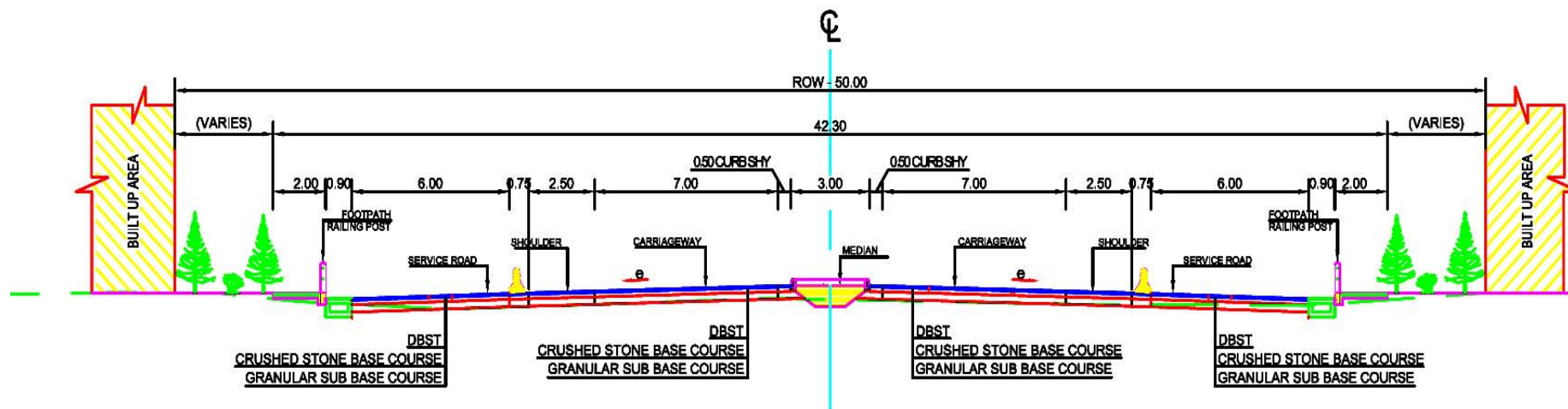
TYPICAL CROSS SECTION FOR ABUKHAIRENI BAZAR (KM 6+770 - KM 8+240)



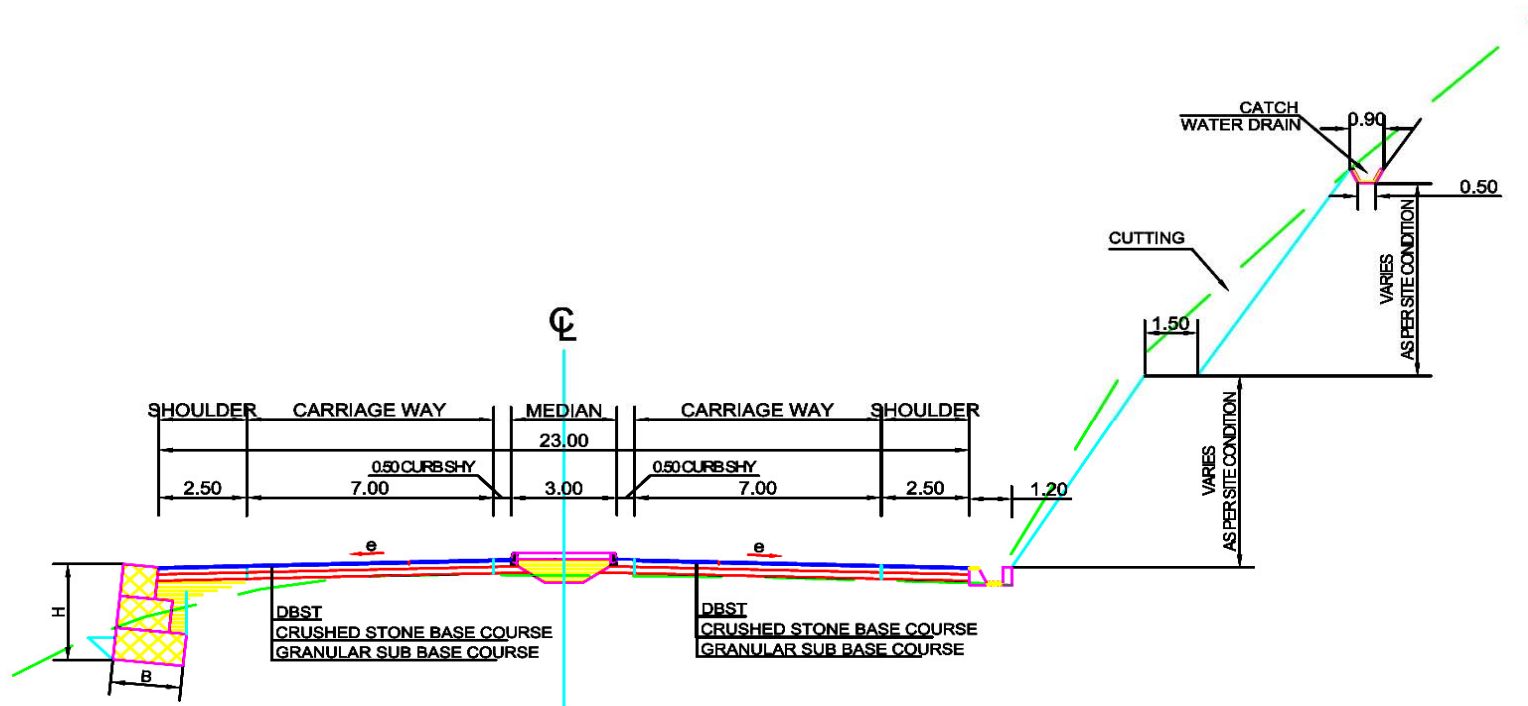
TYPICAL CROSS SECTION FOR (PLAIN/ROLLING)
ABUKHAIRENI - DUMRE (KM 8+240 - KM 23+400)
DUMRE - DAMAULI (KM 23+940 - KM 40+300)
DAMAULI - KHAIRENITAR (KM 41+400 - KM 62+930)



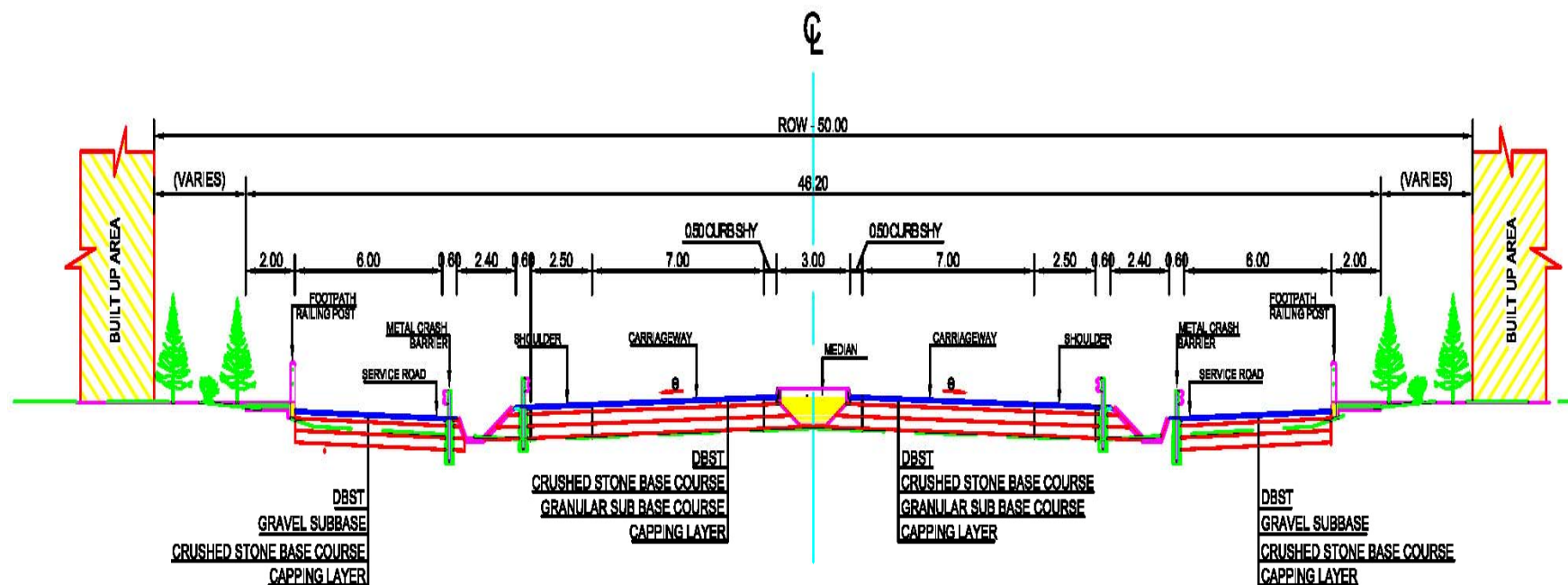
ABUKHAIRENI - DUMRE (KM 8+240 - KM 23+400)
DUMRE - DAMAULI (KM 23+940- KM 40+300)
DAMAULI - KHAIRENITAR (KM 41+400- KM 62+930)



**TYPICAL CROSS SECTION FOR
BUILT UP AREA WITH SERVICE ROAD/CENTER MEDIAN
[KM 23+400 - KM 23+940/KM 40+300/KM 41+000:DUMRE/DAMAULI BAZAR]**



TYPICAL CROSS SECTION FOR HILL
(KM 66+740-70+210)/(KM 70+510-75+590)/(KM 83+930-84+570)



TYPICAL CROSS SECTION FOR
BUILT UP AREA WITH SERVICE ROAD/CENTER MEDIAN
KHAIRENITAR - THATI BAZAR [KM 62+930 - KM 66+740]
KOTRE BAZAR [KM 70+210 - KM 70+510]
GAGANGAUNDA - SAINIK BASTI [KM 74+590 - KM 76+450]
BHANDARIK - KALIKA CHOK [KM 76+510 - KM 83+930]
BIJAYAPUR - SETI BRIDGE [KM 84+570 - KM 88+590]

7.2.7 K Value

The minimum K value adopted for design of Vertical and Summit curve are as tabulated below for the road section.

A. Four lane sections		
K Value, For Design Speed 60km/hr.	:	94m for Vertical Curve
	:	42m/% for Summit Curve
B. Double sections		
K Value, For Design Speed 40km/hr.	:	29 m for Vertical Curve
	:	17 for Summit Curve

It is based on the design speeds provided as per NRS 2070.

7.2.8 Gradient

Gradient is one of the most important considerations in designing of roads especially in mountainous and steep terrain. Roads once constructed to a given profile are difficult to be upgraded to flatter gradient at a subsequent stage without great loss to the initial investment. Vehicle operation cost is directly related with the longitudinal gradients, and so it is recommended to adopt their values as small as possible.

Table 7.2: Adopted Gradients

S.No	Design Standard	Double	Four lane
		Value	
1	Maximum gradient	7%	7%
2	Minimum longitudinal gradients for longitudinal drainage purpose	0.5%	0.5%

7.2.9 Barriers

Guard Rails and safety barriers are provisioned in places where serious damage to vehicle and people may occur when an out of control vehicle may leave the roadway or hit other objects based on road safety study. As per NRS 2070 Road edge barriers are provided near the edge of the road with steep slopes (more than 1:4) or there is a drop of more than 3m or on the outer edge of sharp horizontal curves to protect the vehicles from falling off.

Steel beam barriers, Gabion and masonry barriers are used for road barrier in this project road. The W metal beam crash Barrier has been provided in for safety in major and minor bridges section and curve where the radius is below 60m. In major bridges the length of W- beam metal crash barrier is 300m in each bridges whereas in minor bridges length is 200m in each bridges. In Mugling-Abukahairani section also steel beam barrier (6570m) has been proposed in downstream river side in vertical steep portion. Thus total length of W Metal Beam barrier in Major & minor bridges 87167 m. Similarly, New Jersey Concrete Barrier has been provided in the settlement and market area as a safety Barrier, the total length of NJ barrier is 3040 m. The other types of gabion or masonry barrier are used during implementation as per site condition and safety consideration. The detailed location of all type of Barrier is given in summary of cost estimate as well as Drawing volume.

7.2.10 Summary of the Geometric Design Criteria

The summarized geometric design criteria for horizontal and vertical geometry are tabulated below for the upgrading of the Mugling-Pokhara road to Double lane and four lanes.

SN	Design Parameters	Design standard adopted in Mugling – Pokhara road		Remarks
		Double lane (from km0+000 to 8+500)	4-lane from (km 8+500 to km 88+583)	
1	Terrain	Hill and steep	Hill and Rolling	
2	Road Class Identified as per NRS 2070	Class III	Class II	NRS 2070
3	No of lanes	2.00	4.00	
4	Design Speed	40km/hr.	60km/hr.	NRS
5	Carriageway Width, m/lane	3.50	3.50	NRS
6	Shoulder Width (m) on either side	1 to 2.5 varies as per site situation	2x0.75	NRS
7	Median (m)	0.5	3.0	NRS
8	Kerb shy near median	0	0.5	
7	Formation Width (m)	9m to 12m	Varies from 18, 23, 42.5 and 46.2 as per site situation.	NRS
8	Drain Width	1.25	1.25	NRS
9	Right of way, m (Total)	50.0	50.0	NRS
10	Sight Distance			
10.a	Stopping Distance, m	50	80	NRS
10.b	Overtaking Distance, m	60	135	NRS
11	Horizontal Alignment			
11.a	Minimum Radius of Horizontal Curves	50	80	Calculated for e=0.70 and f=0.14
11.b	Length of Transition curve, m	35	40	NRS
11.c	Extra widening ,m	0.9	1.2	NRS
12	Vertical Alignment			
12.a	Maximum Gradients%	7	7	NRS
12.b	Maximum(critical) Length, m	300	300	NRS
12.c	Minimum Value of K** for summit curves, m/%	29	94	NRS
12.d	Minimum Value of K** for valley curves, m/%	17	42	NRS
13	Super Elevation (%) (max)	7	7	NRS
14	Camber (%)	2.5	2.5	NRS
15	Shoulder slope (%)	3	3	
15	Minimum culvert size (mm dia.)	900	900	NRS

7.3 Geometric Design of Alignment

Geometric design of the road has been carried out adopting the design given **Table 7.3**.

7.3.1 Horizontal Alignment

The new road (horizontal) alignment has been designed to follow the existing one as much as possible with minor modifications like easing sharp bends and realigning short sections to connect new major bridges under design. Major deviation has not been made keeping the improved road within the existing RoW by compromising the standards. The minimum standards required to be adopted for design of horizontal curve are given in **Table 7.3** below.

Table 7.3: Geometric Design Standards for Horizontal Alignment

Design Parameters	Double lane	4-lane	Reference
Minimum horizontal curve radius (m)	50	80	NRS
Minimum Length of transition Curve, m	40	35	IRC:52-2001
Extrawidening, m	1.2	NA	NRS
Super Elevation (%) (max)	7	7	NRS
Pavement and Shoulder Slope (%)	2.5	2.5	NRS

However, in few short stretches of Highway as tabulated below, the existing curvature is less than adopted minimum at few unavoidable locations (refer Table below) like bridge point to manoeuvre the alignment to fit the existing bridge, and settlement.

Table 7.4: Minimum Horizontal Design Standards could not be provided in Sections

IP No	Easting	Northing	Transition length	R	BC of Simple Curve	MC	EC of Simple Curve
(no)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
100	545128.2	3091278	0	35	17365.05	17396.18	17427.3
101	545085.3	3091375	0	35	17459.37	17484.79	17510.21
102	545162.2	3091420	0	45	17537.76	17564.68	17591.6
103	545148	3091509	0	45	17621.91	17647.43	17672.94
124	542950.8	3092029	0	45	20081.42	20108.89	20136.35
149	540158.8	3094232	46	45	24311.65	24320.91	24330.16
164	539132.9	3094968	46	45	25920.47	25937.91	25955.35
185	536926.4	3095439	0	35	28536.73	28552.61	28568.49
186	536887.8	3095424	0	35	28580.78	28592.52	28604.26
213	534717.6	3096304	0	45	31450.12	31464.77	31479.41
215	534640.1	3096349	0	45	31542.08	31561.14	31580.19
216	534591.6	3096357	0	45	31583.78	31606.71	31629.64
248	530911.9	3096402	0	30	35483.71	35517.17	35550.63
249	530900.3	3096543	0	30	35584.04	35614.29	35644.53
250	530831.6	3096503	0	35	35654.24	35673.99	35693.74
251	530714.9	3096583	0	30	35736.07	35772.05	35808.02
258	530392.9	3096246	0	30	36297.38	36314.87	36332.36
259	530338.4	3096235	0	30	36349.16	36366.05	36382.93
287	526134	3095670	0	45	41750.56	41781.06	41811.56
288	525731.1	3095542	0	45	42176.55	42196.54	42216.52
291	525269.8	3095538	0	45	42706.58	42720.94	42735.3
297	524821.1	3095652	0	45	43267.59	43293.47	43319.35
298	524748.3	3095654	0	45	43329.84	43358.47	43387.1
393	510169.8	3100613	0	45	60843.6	60869.8	60895.99

7.3.2 Vertical Alignment

The Asian Highway Standard and Nepal Road Standards 2070 were adhered to the based on adopted class of road in different terrain. The design level of the new road has been fixed with minimum 0.30m above the existing road top surface taking in due account of drainage and hydrological aspects in the project road. The vertical alignment of the road has been designed for smooth transition at bridge locations as recommended by the hydrologist. Maximum 5.0% longitudinal gradient has been provided

for the approaches to bridges. For smooth vertical curve transition the following standard are adopted as tabulated below.

Table 7.5: Geometric Design Standards for Vertical Alignment

Design Parameters	Double lane	4-lane	Reference
Maximum gradient (%)	5%	7%	NRS
Minimum Value of K for summit curves, m/%	29	94	NRS
Minimum Value of K for valley curves, m/%	17	42	NRS

For connecting the approaches with design road profile and bridge ends vertical curves have been inserted using minimum K values as specified as far as possible. However, in few bridge locations K value is adjusted below the minimum specified.

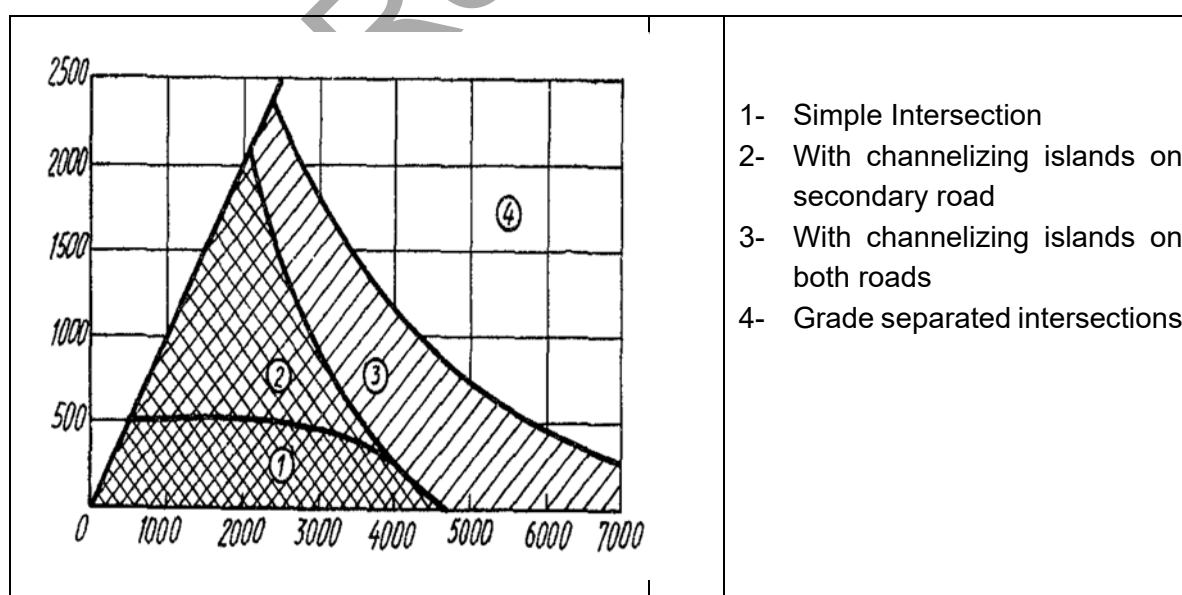
Table 7.6: Minimum Vertical Design Standards could not be provided in Sections

Chainage	Elevation	Length	Valley(V)/ Summit(s)	LVC	Algebraic Difference A	k=L/A	K Reqd	OK/ Not
0+103.72	260.61	20	V	20	0.45	2.23	6	NA
1+878.25	255.253	40	V	40	6.88	5.81	6	NA
17+400.51	396.2	45	V	45	7.53	5.98	6	NA
36+375.00	382.241	20	S	20	7.85	2.55	4	NA
51+398.58	523.558	35	V	35	7.00	5.00	6	NA
67+623.77	511.35	20	S	20	5.02	3.98	4	NA

7.4 Design of Road road Crossing

7.4.1 Road Junction Design

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.



The widening of an existing 2-lane road to a 4-lane road is substantially complicated by the necessary accommodation of existing junctions.

For road safety reasons junctions at-grade are undesirable because of the need for right 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.

For at-grade existing cross-roads, a right-left stagger has generally been introduced to minimize vehicle path crossing movements and thereby maximize road safety for this type of junction.

At minor T-junctions, right turning movements from the main carriageway have been catered for by the introduction of a locally widened central reserve in conjunction with an offside queuing lane for turning traffic. For traffic turning right from the side road, the locally widened central reserve is extended beyond the junction to provide a queuing lane within the central reserve. This will allow vehicles turning right from the side road, to wait for a gap in the traffic flow, before joining the main carriageway traffic.

For increased safety, SMVT lanes and/or service lanes along the main highway, which need to cross a side road, have been aligned to take SMVT traffic further away from the junction of main and side roads, thereby reducing the concentration of crossing movements at any given location and improving potential SMVT flow where otherwise queuing side road traffic would block the side road and prevent SMVT from crossing.

Where junctions with the main carriageway occur within, or close to, urban areas, but are not with major roads, large roundabouts have been provided for, as an in-between measure that will cater for traffic in the shorter term. Such locations will require regular monitoring of classified traffic volumes in order that junction upgrading may be carried out as and when necessary, and in a timely and orderly manner

For grade separated intersections, with cattle underpass animal underpass structures are selected as per the site suitability. Vertical clearances at underpasses shall not be less the specified below.

Pedestrian and Cattle Underpass	2.5 - 3.0m	IRC:SP:84-2014
Animal Underpass(Crossing)	4.5m	IRC:SP:84-2014

Wherever existing slab/box culverts and bridges having a vertical clearance of more than 2m, these can be used in dry season for pedestrian and cattle crossing in rural settlements and forest sections by providing necessary flooring.

Mugling-Pokhara road has been connected many villages and settlement areas. During the up grading, the all the junction has to improve for the free flow of high speed vehicle and access from the village road and service road has to be provided in main 4-lane Carriage way. The junction has to be designed as per road safety consideration. The detailed of the number of junction in this road has been provided in the Road safety chapter 5 (Table 5.2 and 5.3). There are 10 no of major junction out of 10 there are 4 way Junction and 6 no of 3 way junction Similarly direct access to and from local road and drive way into main road are closed. Indirect accesses to, and from these roads to main road are managed by providing merge and diverge lanes, turn outs at service roads and U-turns along the main road at strategic locations . This concept and design has been detailed out Chapter 6 .There are 75 locations along this road where provision of U-turn has been considered and designed. The detailed list of U-turn and its location has been provided in drawing Volumes. The typical junction designed in this road for safe and safety purpose for the road user and traffic has been given in below:

7.4.2 Market Areas

There are number of settlements along the highway section. It has been noted that due to development and construction of roads, the growing settlement has encroachment on the right of way of the road and further compounded after improvement and upgrading. Lack of footpath, crossing structures, adequate provision of traffic signage to facilitate two ways traffic along the sections of the service road passing through the settlements can aggravate the conflicts between the pedestrians and vehicles as well as between vehicles themselves. Hence the Covered side drains, service lane for slow moving vehicle in urban area are proposed in the market areas to be forgiving to the pedestrians and facilitate them to access the adjacent properties. Similarly Cover slabs of the side drains are installed at a higher level than the carriageway in order to separate them from the carriageway to protect the pedestrians. Furthermore provision of footpaths has to be made on the sides of service lane. Width of the footpath depends on the volume of anticipated pedestrian traffic. But a minimum width of 2.0 m is required.

There are 8 locations of service road provided in the settlement areas and market centres in design which is given below:

Table 7.7: Summary of service road

S.N o	Location	From	To	Length (M)
1	Abukhaireni	6+770	8+250	1480
2	Dumre Bazar	23+400	23+950	250
3	Damauli Bazar	40+430	41+400	970
4	Khairanitar, Dhulegaunda, Belchautara and Thati Bazar	61+700	66+740	5040
5	Kotre Bazar	70+210	70+510	300
6	Gagangauda - Sainik Basti	74+600	76+940	2340
7	Bhandarik, Okhale, Talchok, Lakhanchok, Sundar Bazar, Budhi Baazar, Kalika Chok, Bijayapur	77+010	83+920	6910
8	Bijayapur - Start of Seta Bridge	84+570	88+583	4013
Total length of market area foot path provided length				21303

7.4.3 Services/Access Roads and Restriction of Direct Access

Access to the Road shall be partially controlled. Intersection has been considered for major feeder road, minor feeder road, district roads. Intersection with the village road and other minor roads subject to a minimum distance of 3km from nearest intersection in 4-lane section. In certain localities where existing accesses to the road are numerous, direct access to the 4-lane highway has been restricted for reasons of road safety.

In such situations, where side road traffic is light, the design has attempted to "collect" emerging traffic and guide it to a single access or junction, via a Service Lane, along which traffic may travel (in both directions) until a suitable junction with the main carriageway is reached. A possible alternative solution would be to block access to the national highway from minor side roads, and encourage side road users to re-route their journey to access the highway at a larger alternative junction. This may be inconvenient for a minority of road users, but would provide a safer and less expensive alternative solution to this specific problem. Further study of this possible solution will be carried out at during the implementation of project.

Also, for similar road safety reasons, where two side roads join the existing main highway within a relatively short distance of each other, the proposed design, wherever possible, re-aligns one of the side roads so that it joins up with the second side road before the second side road reaches the proximity of the main highway. In so doing the number of junctions with the proposed main highway is

reduced and as a consequence the probability of occurrence of accidents along the proposed highway is also reduced.

It is essential for safety reasons to control access on to the widened and improved highway. The design provision must be taken in account of the access to approach at junction for other SRN roads and village road with adequate signage and delineation measures. Access from properties should not be allowed at bends, and access from schools, hospitals and other institutions needs to be designed with proper attention to safety.

As per IRC: SP: 84 2014, Median openings shall not be spaced closer than 2km in rural section. In built up area, median opening shall be provided as per site requirement and the spacing between two medians opening in built up area shall not be less than 500m. The length of median opening shall be 18 to 20m.

7.4.4 SWVT lanes

The service lane on both side of main four lane highway is provisioned for movement of Slow Moving Vehicular Traffic. The width of service lane is taken 6.00m. The service lane has been provided especially in market area and settlement area. In Mugling Pokhara road in all together 21.303 km in 8 major markets and settlement which is give above Table 7.7.

7.4.5 Approach to Narrow Bridges

Along the exiting alignment being widened to 4 lane standards, there are some narrow / single lane bridges. As the road carriageway is being widened to 2 lanes on either side, the new bridges being constructed on one side are 2 lanes but the existing bridge on the other side is only single lane. From traffic point of view it is not a concern for number of years as the traffic volume is low but it is a safety concern. In these sections the approach road shall be narrowed from 100 before the bridge and Narrow Bridge Ahead warning signs placed. After the traffic increases the single lane bridges shall have to be replaced.

7.4.6 Road Furniture and Ancillary Works

Road furniture has been provided in the form of road signs, crash barriers, road markings, delineators, foot paths, covered side drains.

Table 7.8: Summary of the road furniture and Ancillary works

W beam Crash barrier (Rm)	Road marking (sqm)	Delineator post(No)	Footpath (m2) in 21.303km of service road 2m wide (sqm).	Cover side drain (m)	Tick type drain	Precast kerb Stone (m)	NJ concrete Barrier (m)
87167	89591	12250	86413	3040	58610	203873	3040

Medians been provided as per road safety requirements In Mugling –Pokhara road sufficient traffic signs and road sign has been provided In the design there are 1658 no of single post and 94 no of double or more posts has been proposed for the erection of different type of traffic sign post. Summary of the road furniture and Ancillary works are given above in Table 7.8 and Detailed in summary of quantities.

7.4.7 Relocation of Utilities

For the up grading of the road from two lane to 4- lane ,all the utilities within the Right of Way (50m) or corridor of Impact has to cleared or removed and relocated. The consultant has counted all the existing public utilities such as Electric poles, Telephone poles water supply system, And Public Water Supply and, Bus shades etc. within the Line of Influence. It has been also understood that Nepal

Telecom and NCELL has buried their optical fibre cable within the road shoulder/ beneath the drain in the existing road corridor. This matter has been discussed with the client and NT and Ncell Authority has promised the relocation of their cables will be done by themselves. The list of public utilities to be relocated is given in Table 7.9 below.

Table 7.9: Detail of public utilities to be relocated

S.No.	Electric Pole		Telecom Pole (NO)		Electric Transformer (no)		Water supply Pipe line (location)		Construction of passenger shade (No)
	Left	right	Left	right	Left	right	Left	right	
	2293	1401	381	284	63	33	47	11	38
Total	3694		665		96		58		

The cost of the relocation of all these activities has been put in the Provision Sum in the cost estimate and BOQ. All other details and their locations are given in Annex-3.1

7.5 Land Acquisition

7.5.1 Objectives

Land acquisition is required to carry out the project works without any obstruction when contracts have been awarded. Normally land along the alignment belongs to the local public and the government etc. Once the land is acquired and boundary pillars erected, there is no confusion about the land ownership.

7.5.2 RoW and Acquisition Width

As per the GoN regulations for the East West Highway, the right of way is 50m (25m on either side of the centreline). Project road falls under National Highway category, but it is felt that 25m on either side of the road or ROW will be sufficient for improving the Mugling-Pokhara road to 4- lane.

7.5.3 Guidelines for Acquisition of Land

Guidelines for land acquisition have been issued by the GoN under the Land Acquisition, Resettlement and Rehabilitation Policy for Infrastructure Development Project (BS 2071). Same are followed for the project.

7.5.4 Preparation of LA Plans

Land ownership maps are collected from the land revenue department and digitized for working on computer. Similarly status of ROW clearance has been collected from District Roads Office of Butwal. On these centreline of the road is marked, requirement of Line of Influence in the cadastral map road widening to acquire is shown.

7.6 Engineering Drawings

The drawings are prepared with sufficient details for bidding and execution of works in appropriate size, scale and format as defined in ToR and acceptable to PD, ADB / DoR. Detailed Engineering Drawings, consisting of key plan, alignment plan & profile, and cross-sections have been prepared on A3 size paper at appropriate scales. Drawings have been prepared in SOFTWEL and then exported to AutoCAD for labelling and text editing and printing. Drawings are presented in Volume 3C.

7.6.1 Preparation of Engineering Drawings

The following drawings are prepared to complete the design study:

- Locality Map showing the location of the works in relation to region/district /municipality / VDC commonly (1:250,000)
- Site plan of the road alignments in topographic maps (1:50,000)
- Index plan of road alignment in district maps (1:125,000)
- Regional geological map of the region (1:250,000)
- Land use maps of the road corridor (1:50,000)
- Location map showing linkage of road, the road width surrounding road network, survey and design status of the complete road, intersection points, benchmarks and other reference points.
- Road plan (1:500),
- Road profile (horizontal 1:1,000 and vertical 1:200)
- Road cross sections (1:100) at required interval
- Plan and profile containing details of geometry viz. horizontal alignment with coordinates of IP, deflection angle, IP to IP distances, Chainage of IP, curve data etc.
- Plans, profiles and cross sections of structural sites (suitable scales)
- Material sources maps (1:25,000)
- 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), hairpin bend
- Maps showing key environmental aspects (in suitable scale)

The drawings have been systematically catalogued contract wise so that future scrutiny becomes convenient.

7.6.2 Plan Drawings

Plans have been prepared showing road design features such as centreline, edge of pavement, cut slope and embankment, toe line, drain details, horizontal curve details, etc. The existing road and all roadside features (natural and man-made) and details of the natural topography, existing infrastructure and other land features etc. have been shown. The Plan has been prepared in two different sets. One is prepared on 1:500 scale with 0.2 contour interval as master copy and on 1:2000 scale with 0.5m contour interval for bidding purpose.

7.6.3 Profile Drawings

On the profile drawings, the existing ground elevations along the centreline of the designed horizontal alignment and the designed grade lines with vertical curves have been shown in detail. The levels of both natural and design surfaces along the road centreline have been shown, generally at 20m intervals. The Profile drawings are prepared in two different sets. One is prepared on 500H: 100 V scale as master copy and on 2000H: 400V scale for bidding purpose.

7.6.4 Cross-section Drawings

Cross-section Drawings is prepared at 10m interval in 1:100 scale with details of existing and designed elements.

8. TRAFFIC STUDIES AND ANALYSIS

8.1 Introduction

This chapter describes the traffic analysis that was conducted for the detail design of the widening of the Mugling- Pokhara section of the Prithvi Rajpath (highway or PRM) from its existing intermediate lane cross-section.

Three day, 24 hours, classified counts were conducted in April 2016 at the following four locations lying within the project road.

- Mugling Bridge West (H0405), just west from the approach
- Musi Khola Bridge west (H0409), west from Damauli
- Talchowk (H0411), about 500 m west from the PRM⁴/ Talchowk junction
- Bijayapur Khola Bridge (H0412), just east from the bridge

As there are no competing roads that would significantly influence traffic demand in this project road, no origination- destination (OD) surveys were conducted.

Axle-load data for commercial vehicles were mostly taken from the 2005 axle-load survey conducted at Talchowk, PRM under a World Bank aided Road Maintenance & Development Project (RMDP).

8.2 Desk Study

In order to collect the background information on the project roads and fine tune the traffic forecast analysis, the following documents were collected and reviewed.

- DoR annual traffic counts in 2014/15 at Mugling West (H0405) and Pokhara East (H0411) including the historical counts.
- National Population and Housing Census 2011; GoN NPC Central Bureau of statistics; February 2014; Kathmandu, Nepal
- Statistical Year Book 2014; GoN NPC Central Bureau of Statistics; Kathmandu, Nepal

8.3 Methodology

8.3.1 Traffic Count

Amongst the four count locations, Mugling Bridge West and Talchowk also coincide with the DoR permanent count stations to enable a consistent comparison of the traffic growth. All the counts along the project roads were segregated into the following vehicle class.

- | | | |
|---------------------|--------------------|----------------|
| ➤ Multi-axle trucks | ➤ Heavy truck | ➤ Light truck |
| ➤ Bus | ➤ Mini-bus | ➤ Micro-bus |
| ➤ Car, van and taxi | ➤ Four-wheel drive | ➤ Farm tractor |
| ➤ Motor-cycle | ➤ Power-tiller | ➤ Rickshaws |
| ➤ Bullock carts | ➤ Bicycles | |

The corresponding average daily traffic (ADT) generated from the counts was adjusted to average annual daily traffic (AADT) by multiplying with the DoR seasonable variation factor most appropriate for the count station considered. Though the DoR's seasonal variation factors were developed during the nineties and the trend of traffic has changed since then, the existing factors were still used as there was no updated seasonable factor data.

8.3.2 Sectors Assumed and Design Option Adopted for the Detail Design

For traffic forecast analysis, the project road was divided into the following four homogenous sections for refinement and consistency with the varying traffic levels.

- Section A: Mugling - Abukhaireni section (KM 0+000 ~KM 6+700)
- Section B: Abukhaireni - Damauli (KM 6+700 ~ KM 40+300)
- Section C: Damauli – Bijayapur (KM 40+300 ~KM 83+880)

⁴ PRM= Prithvi Rajmarg

- Section D: Bijayapur– Prithvi Chowk (KM 83+880 -KM 88+197)

The last section is highly urbanised and depicts the urban extent of Pokhara City. During the feasibility study of this project road, three options were investigated for upgrading this road which were as follows.

Option 1: Two lane (7 m) carriageway from Mugling to Damauli (KM 0+000- KM 40+300) and four lane (14 m) divided carriageway from Damauli to Prithvi Chowk, Pokhara (KM 40+300 –KM 88+197)

Option 2: Four lane (14 m) divided carriageway with service roads throughout

Option 3: Two lane (7 m) carriageway from Mugling to Abukhaireni (KM 0+000- KM 8+050) and four lane (14 m) divided carriageway with 6 m wide service roads on both sides at the market areas such as Dumre, Damauli, Khairenitari- Thati, Kotre, Gagangauda- Sainik Basti, Bhandarik- Bijayapur, Bijayapur- start of Seti Bridge

Amongst these three options, widening of the project road under Option 3 was chosen for detailed design following discussion with DoR. The subsequent sections thus pertain to Option 3 only.

8.3.3 Traffic Growth

The growth rate of the normal traffic involved (i) a review of historical traffic growth at Mugling West and Pokhara East stations lying within the project road; (ii) extrapolation of the growth-rate based on elasticity of transport demand with respect to gross domestic product (GDP) or per capita income (PCI) through regression analysis; (iii) extrapolation of the growth-rate based on elasticity of transport demand with respect to petroleum consumption and (iv) review of the elasticity factors and growth-rate adopted in other road projects. Taking all the above data into consideration, the final growth-rate to adopt for traffic growth rate was determined.

To extrapolate the growth-rate based on elasticity, the GDP, PCI and vehicle registration data in Nepal were compiled. The elasticity of transport demand was calculated through regression analysis using GDP figures for the freight vehicles and the PCI figures for passengers and private vehicles. The elasticity of transport demand with respect to a parameter (e.g. GDP, travel-time savings or travel cost, etc.) is the change in the transport demand for a corresponding change in that parameter. In simple terms, an elasticity factor of -0.50 for transport demand with respect to travel cost signifies that for every 1% increase in the cost of travel, there will be a 0.5% decrease in the travel demand based on the arc-elasticity method. There are various methods adopted for calculating the elasticity factors (e.g. log arc elasticity, mid-point arc elasticity, etc.) and the value resulting from different method varies nominally.

The growth in vehicle registrations was taken as proxy for traffic growth and compared with the GDP/PCI growth observed in Nepal over the years. There is certain distortion in this assumption as the vehicle registrations in Nepal is the cumulative total of vehicle registered without accounting for those that are either scrapped or not plying. But there are no national statistics on vehicle-travel along the road networks of Nepal. Therefore, this anomaly was ignored and the following formula was adopted to derive the future growth-rates for different time periods.

For passenger and private vehicles, $G = E \times \{(1 + G_p) \times (1 + G_{pci}) - 1\}$

Where, E= elasticity of transport demand; G_p = population growth-rate

G_{pci} = per-capita income growth-rate & G= traffic growth-rate

For freight vehicles, $G = E \times G_{GDP}$

Where, E= elasticity of transport demand;

G_{GDP} = gross domestic product growth-rate & G= freight vehicle growth-rate

The elasticity factor of vehicle travel with respect to petroleum consumption in Nepal was also calculated through liner regression from the historical data on diesel and petrol consumptions and vehicle travel. Though the official statistics on vehicle travel is not available, an estimate was made from the limited surveys such as the 2001 Truck Travel Survey conducted under the former Maintenance Rehabilitation and Coordination Unit under DoR and the 2007 Road-User Satisfaction Survey. The following formula was used to calculate vehicle growth by this method.

For commercial vehicles, $G = E \times G_d$

Where, E= elasticity of transport demand;

G_d = growth in diesel consumption & G= traffic growth-rate

For private and small vehicles, $G = E \times G_d$

Where, E= elasticity of transport demand;

G_d = growth in petrol consumption & G= traffic growth-rate

The population, GDP, PCI data were taken from the statistics published by the GoN Central Bureau of Statistics, Nepal Rastriya Bank (central reserve bank of Nepal) and the Ministry of Finance. The calculated elasticity factors were compared with the corresponding factors used in other road projects to ensure consistency. In general, the correlation between the vehicle registration with GDP or PCI was stronger than based on the correlation between vehicle travel and petroleum consumptions with some exception.

Based on the above review, the final growth-rate applicable was adopted mostly from the calculation of growth-rate based on elasticity of transport demand with respect to GDP/PCI with some adjustment.

8.3.4 Traffic Mix Reassignment

Traffic mix is not expected to change significantly after the project road is upgraded as mainly the mobility will improve along a highway and traffic along the highway section has already evolved fully. Some of the non-motorised transport plying along this road is likely to shift to motorised vehicles but these changes are envisaged to be limited to the urban or the rural settlement areas and not extend throughout the network. This project proposes to provide dual median-divided carriageway and 6 m service lanes on both sides at all the urbanised or rural settlements. It is assumed that the traffic mix at the main carriageway and service-lanes will mirror the traffic mix that currently existing along the undivided road throughout the route.

Though traffic mix tends to gradually vary over time, such effects were ignored and the mix was assumed to remain constant throughout the design period to simplify the analysis.

8.3.5 Traffic Forecast Analysis

The future traffic forecast involved extrapolation of the normal, diverted, induced and generated traffic components and their summation to arrive at the final forecast over the design life of the pavement of the project-highway i.e. ten years (year 2030) and subsequent periods (15 and 20 years). For the Mugling - Pokhara Road, the construction period was assumed to be three years with the road opening from 2019 onwards.

Normal Traffic

The normal traffic represents that component of the traffic that exists whether the project-road is upgraded or not. The traffic growth-rate that was adopted for this project road was applied to the 2016 AADT at the various sections derived from the counts in order to forecast the future traffic.

Diverted Traffic

The diverted traffic results from traffic diverting from other routes to the project-road. This traffic results when there are competing routes along the project-road and the diversion is assumed to be in proportion to the travel-time savings, which, is logical based on the travel behaviour. Commuter will take the route that is the quickest unless the cost of travel along the route in question is not very high. However, there is no likelihood of any diversion of traffic to the project road and therefore diverted traffic was ignored for the analysis.

Generated Traffic

The generated traffic results after the improvement of the road due to reduction in the cost of travel. It reflects the additional trips that occur apart from the normal traffic due to shorter travel time or cheaper cost of travel following a road upgrade.

Generated traffic are generally based on the price elasticity of transport demand. Price elasticity of transport demand is the change in transport demand with a change in the price of travel. For passenger vehicles, the fare reflects the cost of travel while it is the time cost and fuel cost for private vehicles. To simplify the analysis, the elasticity of transport demand with respect to travel-time savings was taken to be analogous to the price elasticity of transport demand. This is logical since the transport demand tend to increase with decrease in the travel time, which, in turn usually trigger a reduction in the cost of travel.

For this project road section, an elasticity of transport demand for generated traffic based on the average of values of -0.2 and a factor of -0.5 adopted globally (De Corla- Souza et al, 1999). The actual traffic generated was the product of the average elasticity of transport demand calculated and the travel-time savings that results after the project-highway section is upgraded. Table 8.1 shows the elasticity factor and speed characteristics that were adopted for the project road.

Table 8.1: Elasticity Factor, Speed Adopted for Generated Traffic

Adopted Elasticity Factor	Travel Speed Assumed (kph)		Estimated Saving in Travel Time
	Before Upgrade*	After Upgrade**	
-0.35	50	80	38%

Note: *Based on observation

**Based on design speed proposed

50% of the total generated traffic was assumed to develop at the time that the upgraded road opens in 2019 while the whole of the total generated traffic was assumed to evolve one year after the upgraded road opens. The generated traffic was assumed to grow at the same rate as that adopted for normal traffic during the different time blocks.

Induced Traffic

Induced traffic is that component of the traffic that results following new economic opportunities that emerge after a road improves. This component is different from the generated traffic but it is often difficult to assess this component of the traffic in Nepal owing to lack of data and the fact that some portion of this component is already included in the generated traffic. Therefore, induced traffic was not considered for the project road owing to this difficulty and to avoid double counting.

8.3.6 Design Load Analysis for Pavement Design

Pavement design was based on the calculation of the total number of equivalent standard axles (ESA) of 8.16 MT envisaged to ply over the project road over the design life of its pavement which is assumed

to be ten years. The ESA for commercial vehicles at the project roads were adopted mostly from the axle survey data observed at Talchowk in PRM in 2005 under RMDP⁵ with some adjustments.

The following steps were adopted to calculate the ESA of commercial vehicles during the axle-load survey at Talchowk in 2005.

1. The weights of the individual axle of all the commercial vehicles surveyed in one direction were converted into ESA using the following formula.

$$\text{Equivalent standard of the individual axle} = \left(\frac{\text{Weight of axle in kg}}{8160} \right)^{4.5}$$

2. The weight of the individual axles in ESA in one direction were added to derive the ESA of each vehicle sample and the average of all the samples was taken to derive the average ESA for that vehicle class in the direction concerned.
3. Similarly, the average ESA for other vehicle class and other direction was also calculated adopting the process in step 1 and 2.

The pavement design load for the project road section was calculated based on the following steps.

1. The ESA for each vehicle class in each direction was multiplied with its 2019 directional traffic forecast to obtain the 2019 daily standard axles per direction for that vehicle class. The direction split derived from the traffic count survey was adopted to divide the total traffic in two directions.
2. The 2019 daily standard axles for each vehicle class by direction was multiplied with 365 to derive the 2019 annual standard axles for that vehicle class. In this manner the 2019 annual standard axle for each vehicle class in each direction was calculated.
3. The annual standard axles in each direction per vehicle class were multiplied by the following channelization factor based on IRC⁶ standard.

Road Section	Cross Section	Channelization Factor
Mugling – Abukhaireni (KM 0+000~ KM 8+050)	Two lane	0.75
Abukhaireni- Damauli (KM 8+050 ~ 40+300)	Four lane	0.40
Damauli – Bijayapur (KM 40+300~ 83+880)	Four lane	0.40
Bijayapur- Start of Seti Bridge (KM 83+880~ 88+197)	Four lane	0.40
Service roads at the market areas (Dumre, Damauli, Khairenitar- Thati, Kotre, Gagangauda- Sainik Basti, Bhandarik- Bijayapur, Bijayapur –Start of Seti Bridge)	Intermediate lane (6 m)	0.88

It was assumed the local traffic will be equally distributed to both sides of the service roads.

4. The adjusted annual standard axle per all vehicle class in both directions was added to derive the adjusted 2019 annual axle loads.
5. In this manner, the adjusted annual standard axles per a vehicle class in each subsequent year were projected adopting the normal traffic growth-rate and added to get the adjusted annual

⁵ Road Maintenance and Development Project, Institutional Strengthening Component; "Traffic, Axle-load, Road Roughness Survey and Surface Distress Index Surveys; GoN DoR/ World Bank; 2005

⁶IRC= Indian Road Congress

standard axles for each subsequent year. The total of all the adjusted annual standard loads spanning different time horizon (5 – 20 years) was thus calculated to derive the design loads.

8.4 Traffic Forecasts

8.4.1 Review of the Historical Growth-rate

A review of the historical traffic counts at the DoR permanent stations (Mugling West and Pokhara East) which were also adopted for the primary counts in 2016 was conducted to assess the traffic growth trend. The yearly traffic growth over the years however at both stations is very erratic and unrealistic to use to establish the traffic growth rates. This erratic pattern has been observed throughout the strategic road network of Nepal and it is likely that various external factors that also trigger the traffic growth following continuous upgradation of various road links that have not been rationalised.

Owing to this trend, it was deemed more scientific to project traffic at different period following a smooth growth trend. Table 8.2 shows the traffic-growth observed at the two stations together with the adjusted traffic calculated based on this trend analysis.

Table 8.2 Traffic Growth Observed at the Project Road

Year	Trucks		Buses		Cars + 4WD		All Four-wheel Vehicles		Motorcycles	
	AADT (vpd)	AADT Trend Value	AADT (vpd)	AADT Trend Value	AADT (vpd)	AADT Trend Value	AADT (vpd)	AADT Trend Value	AADT (vpd)	AADT Trend Value
Mugling West (H0405)										
1998	267	324	230	279	85	99				
1999	389	333	290	304	146	113				
2000	382	343	409	332	142	128				
2001	371	353	403	362	121	145				
2002	377	364	349	394	151	165				
2003	382	375	439	430	181	187				
2004	386	386	525	469	206	212	1264	1187	1489	1371
2005	370	397	464	511	212	240	1177	1284	1447	1527
2006	353	409	404	557	220	272	1091	1388	1406	1701
2007	336	421	568	608	230	309	1229	1501	1543	1894
2008	348	433	587	663	404	350	1484	1624	1934	2110
2009	682	446	1510	723	865	397	3379	1756	4239	2350
2010	525	459	838	788	505	451	2116	1899	2819	2617
2011	495	473	890	859	569	511	2177	2053	2960	2915
2012	460	487	942	937	633	580	2228	2221	3093	3247
2013	546	501	992	1022	692	658	2403	2401	3342	3616
2014	412	516	1000	1114	640	746	2274	2597	3713	4028
Annual Growth		2.9%		9.1%		13.4%		8.1%		11.4%
Pokhara (H0411)										
1998	209	288	281	285	224	95				
1999	522	311	434	317	165	112				
2000	526	335	439	353	124	133				
2001	335	362	229	392	50	158				

Year	Trucks		Buses		Cars + 4WD		All Four-wheel Vehicles		Motorcycles	
	AADT (vpd)	AADT Trend Value	AADT (vpd)	AADT Trend Value	AADT (vpd)	AADT Trend Value	AADT (vpd)	AADT Trend Value	AADT (vpd)	AADT Trend Value
2002	363	391	427	437	113	187				
2003	391	422	453	486	176	221				
2004	421	455	999	541	515	261	2,139	1367	3,735	2314
2005	307	491	459	602	302	309	1,247	1546	2,527	2614
2006	313	530	440	670	365	366	1,272	1748	2,236	2954
2007	456	572	570	746	277	433	1,433	1977	2,079	3337
2008	1,083	618	1,183	830	831	513	3,474	2236	5,163	3770
2009	658	667	991	924	467	607	2,315	2529	3,314	4259
2010	1,349	720	1,361	1028	796	719	3,915	2860	6,278	4812
2011	622	777	946	1144	848	850	2,811	3234	5,212	5436
2012	674	839	876	1273	900	1007	2,831	3657	5,270	6141
2013	757	905	1,111	1417	951	1192	3,164	4135	5,641	6938
2014	1,346	977	2,765	1577	2,370	1410	7,011	4677	11,453	7839
Annual Growth		8.0%		11.3%		18.3%		13.1%		13.0%

Source: Consultant's analysis based on the DoR annual counts.

Table 8.2 shows that despite adjustment to the traffic to follow a smooth growth-trend, the adjusted growth-rate generated was still high for bus and cars in both stations. Therefore, some adjustment was made to derive the traffic growth-rate to apply on the project road as discussed below.

8.4.2 Traffic Growth-rate Extrapolated from the Elasticity Method

The GDP and PCI growth-rate were adopted for calculating traffic growth-rates over different time periods. These economic growth-rate were generated based on linear regression of GDP and PCI data over time derived from the national account data published annually by GoN Central Bureau of Statistics Table 8.3 shows the GDP and PCI growth-rate that was adopted for calculating traffic growth-rates over different time periods. These economic growth-rates were generated based on linear regression of GDP and PCI data over time derived from the national account data published annually by GoN Central Bureau of Statistics.

Table 8.3: GDP/PCI Growth-rates Generated

Period	GDP Growth/year	PCI Growth/year
2012-2014	4.1%	2.7%
2015- 2019	4.1%	2.6%
2020- 2024	4.2%	2.8%
2025- 2029	4.2%	2.8%
2030- 2034	3.9%	2.5%
2035- 2039	3.7%	2.2%

Source: Consultant's estimate based on government/donor forecasts.

Table 8.4 and Table 8.5 illustrate the elasticity of transport demand and traffic growth-rates that was generated from liner regression of vehicle registrations with respect to GDP/PCI or the elasticity of transport demand with respect to fuel consumption over the years.

Table 8.4: Elasticity of Vehicle Registrations with respect to GDP/PCI Growth

Year	HT	LT	B	MB	MiB	C	4WD	TRA	UV	MC
2015~ 2017	1.79	NA	2.28	1.84	1.07	2.60	2.60	2.36	8.16	5.29
2018 ~ 2022	1.77	NA	2.27	1.68	1.03	2.52	2.52	2.25	7.81	5.17
2023~ 2027	1.70	NA	2.27	1.54	1.00	2.44	2.44	2.16	7.55	5.06
2028~ 2032	1.63	NA	2.27	1.42	0.96	2.36	2.36	2.08	7.34	4.96
2033~ 2037	1.57	NA	2.27	1.31	0.93	2.30	2.30	2.00	7.17	4.88
R ² =	0.99	NA	0.98	0.93	0.74	0.96	0.96	0.97	0.99	0.98

Table 8.5: Elasticity of Vehicle Travel with respect to Petroleum Consumptions

Year	HT	LT	B	MB	MiB	C	4WD	TRA	UV	MC
2012 ~ 2014	0.66	0.66	NA	2.16	1.81	0.91	0.91	1.11	NA	0.98
2015~ 2019	1.01	1.01	NA	1.31	1.38	1.10	1.10	1.05	NA	1.06
2020 ~ 2024	0.95	0.95	NA	1.43	1.45	1.06	1.06	1.01	NA	1.03
2025~ 2029	0.91	0.91	NA	1.52	1.51	1.04	1.04	0.98	NA	1.02
2030~ 2034	0.88	0.88	NA	1.59	1.55	1.02	1.02	0.96	NA	1.00
2035~ 2039	0.86	0.86	NA	1.65	1.59	1.00	1.00	0.94	NA	0.99
R ² =	0.92	0.92		0.92	0.85	0.90	0.90	0.87		0.96

Note: HT= heavy truck; LT= light truck; B= bus; MB= minibus; MiB= microbus; C=car; 4WD= four wheel drive; TRA= farm tractor; UV= utility vehicle; MC= motorcycle

The elasticity factor of transport demand for normal traffic used in various road projects ranged from 1.1 to 1.4 for freight vehicles; 1.2 to 1.6 for bus; 0.8 to 1.8 for cars and 0.8 to 2 for motor-cycles. Based on the current trend, the elasticity of transport demand should be more for private vehicles compared to that for passenger and freight vehicles. Though the calculated elasticity factors in Table 8.4 and Table 8.5 reflect this trend, the calculated factors are higher than that used in other projects.

Table 8.5 shows the traffic growth-rate generated based on linear regression with respect to GDP/PCI or petroleum consumption over the years.

Table 8.6: Generated Traffic Growth based on Different Parameters

Based on GDP/PCI Growth

Period	HT	LT	B	MB	MiB	C	4WD	TRA	UV	MC
2015~2019	7.2%	cannot predict	9.2%	31.5 %	4.3%	10.5 %	10.5 %	9.7%	32.7%	21.3 %
2020 ~ 2024	7.0%	cannot predict	9.1%	31.8 %	4.2%	6.8%	6.8%	9.5%	32.5%	21.0 %
2025 ~ 2029	6.8%	cannot predict	9.0%	31.2 %	4.1%	6.8%	6.8%	9.1%	31.9%	21.0 %
2030 ~ 2034	6.3%	cannot predict	8.4%	28.1 %	3.8%	6.2%	6.2%	8.1%	29.8%	19.7 %
2035 ~ 2039	5.7%	cannot predict	7.6%	26.1 %	3.4%	5.4%	5.4%	7.4%	27.1%	18.0 %
Based on petroleum consumptions										
2011 ~ 2014	12.7 %	12.7%	cannot predict	41.7 %	35.1 %	23.5 %	23.5 %	21.5 %	cannot predict	75.4 %
2015~2019	19.5 %	19.5%	cannot predict	25.3 %	26.7 %	24.1 %	24.1 %	20.4 %	cannot predict	23.3 %
2020 ~ 2024	18.4 %	18.4%	cannot predict	27.7 %	28.1 %	23.3 %	23.3 %	19.6 %	cannot predict	22.7 %
2025 ~ 2029	17.6 %	17.6%	cannot predict	29.5 %	29.2 %	22.8 %	22.8 %	19.0 %	cannot predict	22.3 %
2030 ~ 2034	17.0 %	17.0%	cannot predict	30.8 %	30.0 %	22.3 %	22.3 %	18.5 %	cannot predict	22.0 %
2035 ~ 2039	16.6 %	16.6%	cannot predict	31.9 %	30.7 %	22.0 %	22.0 %	18.1 %	cannot predict	21.8 %

Source: Consultant's estimate, 2015

The final traffic growth-rate adopted for the traffic forecast analysis was the average of the adjusted historical traffic growth-rate observed along the project road (refer to Table 8.2) and the growth-rate derived from elasticity method with respect to GDP/ PCI growth. Table 8.7 shows the final traffic growth-rates adopted for this study.

Table 8.7: Traffic Growth-rate Adopted for the Traffic Forecasts

Period	MaT	HT	LT	B	MB	MiB	C	4WD	TRA	UV
2016~ 2020	6.3%	6.3%	6.3%	6.9%	6.9%	6.7%	10.8%	10.8%	7.8%	17.3%
2021 ~ 2025	5.5%	5.5%	5.5%	5.4%	5.4%	4.2%	7.0%	7.0%	7.6%	17.2%
2026 ~ 2030	4.3%	4.3%	4.3%	4.3%	4.3%	4.1%	7.0%	7.0%	7.3%	16.9%
2031 ~ 2035	4.0%	4.0%	4.0%	4.0%	4.0%	3.8%	6.3%	6.3%	6.5%	15.8%
2036 ~ 2040	3.6%	3.6%	3.6%	3.6%	3.6%	3.4%	5.5%	5.5%	6.0%	14.4%
Period	MC	3-wh	PT	RICK	BUC	BC				
2016~ 2020	14.6%	6.2%	7.8%	2.5%	2.50%	14.6%				
2021 ~ 2025	13.0%	2.9%	7.6%	2.5%	2.50%	13.0%				
2026 ~ 2030	11.6%	2.9%	7.3%	1.5%	1.50%	11.6%				
2031 ~ 2035	9.8%	2.7%	6.5%	1.0%	1.00%	9.8%				
2036 ~ 2040	9.0%	2.4%	6.0%	0.0%	0.00%	9.0%				

Source: Consultant's estimate, 2016

8.4.3 2016 Existing Traffic

Table 8.8 and Table 8.9 show the 2016 traffic in vpd and PCU/day, respectively, at the four sections based on the traffic counts taken for the detail design of this project road.

Table 8.8: 2016 AADT in vpd Based on the Counts at the Project Road (vpd)

Vehicle	Section A Mugling- Abukhaireni (KM 0+000~ KM 8+050)	Section B Abukhaireni- Damauli (KM 8+050 ~ KM 40+300)		Section C Damauli ~ Bijayapur (KM 40+300 ~KM 83+880)		Section D Bijayapur ~ Prithvi Chowk (KM 83+880 ~ KM 88+197)	
	Undivided Two Lane	Undivided/ Main CWY	Service Roads at Dumre Bazar (KM 23+500~ 23+750)	Undivided/ Main CWY	Service Roads at Market Areas (Damauli, Khairanitar- Thati, Kotre, Gagangauda- Sainik Basti, Bhandarik- Bijayapur)	Undivided/ Main CWY	Service Roads
MaT	410	269	27	190	10	253	38
HT	232	273	27	667	33	517	78
LT	116	106	11	69	3	258	39
B	377	321	32	465	23	389	58
MB	525	430	43	581	29	1,208	181
MiB	486	410	41	402	20	456	68
C, Ta, V	794	782	78	1,253	63	2,949	442
4WD	542	454	45	261	13	475	71
TRA	20	101	10	125	6	95	14
UV	366	224	22	281	14	634	95
MC	1,559	1,840	184	3,423	171	9,749	1,462
3WH	1	-	-	1	0	6	1
PT	1	17	2	30	2	39	6
RICK	14	-	-	2	2	11	11
BC	56	51	51	100	100	240	240
Total	5,501	5,278	574	7,850	489	17,278	2,805
Total MVs	5,430	5,227	523	7,748	387	17,026	2,554

CWY= carriageway; MaT= multi-axle truck; HT= heavy truck; LT= light truck; B= bus; MB= minibus; MiB= microbus; C=car; V=van; Ta= taxi; 3WH =three wheeler; 4WD= four wheel drive; UV=utility vehicle; TRA= farm tractor; PT= power-tiller; RICK= rickshaw; BuC= bullock-cart; BC= bicycle; MVs= motorised vehicles

Source: Consultant's analysis based on the traffic counts, 2016

Table 8.9: 2016 AADT in PCU/day Based on the Counts at the Project Road

Vehicle	Section A Mugling- Abukhaireni (KM 0+000~ KM 8+050)	Section B Abukhaireni- Damauli (KM 8+050 ~ KM 40+300)		Section C Damauli ~ Bijayapur (KM 40+300 ~KM 83+880)		Section D Bijayapur ~ Prithvi Chowk (KM 83+880 ~ KM 88+197)	
	Undivided Two Lane	Undivided/ Main CWY	Service Roads at Dumre Bazar (KM 23+500~ 23+750)	Undivided/ Main CWY	Service Roads at Market Areas (Damauli, Khairanitar- Thati, Kotre, Gagangauda- Sainik Basti, Bhandarik- Bijayapur)	Undivided/ Main CWY	Service Roads
MaT	1,640	1,076	108	760	38	1,011	152
HT	696	819	82	2,001	100	1,552	233
LT	174	159	16	104	5	386	58
B	1,131	963	96	1,395	70	1,166	175
MB	1,313	1,075	108	1,453	73	3,020	453

Vehicle	Section A Mugling- Abukhaireni (KM 0+000~ KM 8+050)	Section B Abukhaireni- Damauli (KM 8+050 ~ KM 40+300)		Section C Damauli ~ Bijayapur (KM 40+300 ~KM 83+880)		Section D Bijayapur ~ Prithvi Chowk (KM 83+880 ~ KM 88+197)	
	Undivided Two Lane	Undivided/ Main CWY	Service Roads at Dumre Bazar (KM 23+500~ 23+750)	Undivided/ Main CWY	Service Roads at Market Areas (Damauli, Khairanitar- Thati, Kotre, Gagangauda- Sainik Basti, Bhandarik- Bijayapur)	Undivided/ Main CWY	Service Roads
MiB	608	513	51	503	25	570	86
C, Ta, V	794	782	78	1,253	63	2,949	442
4WD	542	454	45	261	13	475	71
TRA	59	303	30	375	19	286	43
UV	366	224	22	281	14	634	95
MC	780	920	92	1,712	86	4,874	731
3WH	1	-	-	1	0	6	1
PT	3	51	5	90	5	116	17
RICK	22	-	-	3	3	16	16
BC	28	26	26	50	50	120	120
Total	8,156	7,364	759	10,240	562	17,181	2,693
Total MVs	8,107	7,339	734	10,187	509	17,045	2,557

PCU= passenger car unit

Source: Consultant's analysis based on the traffic counts, 2016

100% of the total traffic was assumed for the main carriageway without deducting the local traffic using the service lane in order to be conservative. The traffic projection at the main carriageway where it applies is therefore the same as the corresponding traffic that prevails at the undivided carriageway section (rural section) of the project road. Motorised traffic along the service roads was assumed to be distributed as follows but all the non-motorised traffic was assumed to use the service roads only.

- Dumre Bazar (KM 23+500~ 23+750) within Section B 10%
- Market areas (Damauli, Khairanitar- Thati, Kotre, Gagangauda- Sainik Basti and Bhandarik- Bijayapur) within Section C (KM 40+300 ~KM 83+880) 5%
- Bijayapur- Start of Seti Bridge (KM 84+460 -KM 88+197) of Section D 15%

8.4.4 Traffic Forecast at the Road-opening

Based on a three-year construction period, the project road is expected to open in the year 2020 after its upgradation. The following sections show the traffic projection during the road opening for different sections of the project road.

Traffic at the Undivided and Main Carriageway Segment during Road Opening

Table 8.10 and Table 8.11 show the traffic forecast in vpd at Section A to D.

Table 8.10: 2019 AADT during Road Opening in vpd at Section A & B

Vehicle	Section A: Mugling- Abukhaireni (KM 0+000~ 8+050)			Section B: Abukhaireni- Damauli (KM 8+050 ~40+300) Undivided Road Segment and Main Carriageway at Dumre Bazar (KM 23+500 ~ 23+750)		
	Normal	Generated	Total	Normal	Generated	Total
MaT	493	37	530	323	24	347
HT	279	21	300	328	25	352
LT	139	10	150	127	10	137
B	460	34	493	392	29	420
MB	641	47	687	525	39	563
MiB	590	43	634	498	37	535
C	1,079	71	1,150	1,062	70	1,133
4WD	737	48	785	617	41	657
TRA	25	2	26	126	9	136
UV	592	33	624	362	20	382
MC	2,348	139	2,486	2,770	165	2,935
3WH	1	0	2	-	0	-
PT	1	0	1	21	2	23
RICK	16	1	16	-	0	-
BC	61	3	64	55	3	58
Total=	7,460	489	7,948	7,206	473	7,678
MV=	7,383	485	7,868	7,151	470	7,620

Source: Consultant's analysis

Table 8.11: 2019 AADT during Road Opening in vpd at Section C & D

Vehicle	Section C Damauli ~ Bijayapur (KM 40+300 ~83+880) (Undivided segment and main carriageway at the market areas (Damauli, Khairenitar- Thati, Kotre, Gagangauda- Sainik Basti, Bhandarik- Bijayapur)			Section D Main Carriageway -Bijayapur ~ Start of Seti Bridge (KM 83+880 ~88+197)		
	Normal	Generated	Total	Normal	Generated	Total
MaT	228	17	246	304	24	328
HT	801	61	863	622	49	671
LT	83	6	89	309	24	334
B	567	42	610	474	36	510
MB	709	53	762	1,474	113	1,587
MiB	488	36	525	554	43	597
C	1,702	114	1,816	4,005	275	4,281
4WD	355	24	378	646	44	690
TRA	157	11	168	119	9	128
UV	454	26	480	1,024	59	1,083
MC	5,153	311	5,464	14,676	911	15,586
3WH	1	0	1	7	1	7

Vehicle	Section C Damauli ~ Bijayapur (KM 40+300 ~83+880) (Undivided segment and main carriageway at the market areas (Damauli, Khairenitar- Thati, Kotre, Gagangauda- Sainik Basti, Bhandarik- Bijayapur)			Section D Main Carriageway -Bijayapur ~ Start of Seti Bridge (KM 83+880 ~88+197)		
	Normal	Generated	Total	Normal	Generated	Total
PT	38	3	40	48	4	52
RICK	2	0	2	12	1	12
BC	108	5	113	259	13	272
Total=	10,846	710	11,557	24,532	1,606	26,138
MV=	10,736	705	11,442	24,262	1,592	25,854

Source: Consultant's analysis

Similarly, Table 8.12 and

Table 8.13 show the corresponding traffic forecast during road opening in PCUs/day at Section A to D.

Table 8.12: 2019 AADT during Road Opening in PCU/d at Section A & B

Vehicle	Section A: Mugling- Abukhaireni (KM 0+000~ 8+050)			Section B: Abukhaireni- Damauli (KM 8+050 ~40+300) Undivided Road Segment and Main Carriageway at Dumre Bazar (KM 23+500 ~ 23+750)		
	Normal	Generated	Total	Normal	Generated	Total
MaT	1,970	148	2,120	1,293	97	1,388
HT	837	63	900	984	74	1,056
LT	209	16	225	191	14	206
B	1,379	101	1,479	1,175	86	1,260
MB	1,601	117	1,718	1,312	97	1,408
MiB	738	54	793	622	46	669
C	1,079	71	1,150	1,062	70	1,133
4WD	737	48	785	617	41	657
TRA	74	5	78	379	27	408
UV	592	33	624	362	20	382
MC	1,174	69	1,243	1,385	83	1,468
3WH	1	0	2	-	-	-
PT	3	0	3	64	5	69
RICK	23	1	24	-	-	-
BC	30	2	32	27	2	29
Total=	10,448	728	11,175	9,473	661	10,131
MV=	10,394	725	11,119	9,446	659	10,102

Source: Consultant's analysis

Table 8.13: 2019 AADT during Road Opening in PCU/d at Section C & D

Vehicle	Section C Damauli ~ Bijayapur (KM 40+300 ~83+880) Undivided segment and main carriageway at the market areas (Damauli, Khairanitar- Thati, Kotre, Gagangauda- Sainik Basti, Bhandarik- Bijayapur)			Section D Main Carriageway -Bijayapur ~ Start of Seti Bridge (KM 83+880 ~88+197)		
	Normal	Generated	Total	Normal	Generated	Total
MaT	913	70	984	1,214	96	1,310
HT	2,404	184	2,589	1,865	147	2,012
LT	124	10	134	464	37	501
B	1,702	127	1,830	1,422	109	1,531
MB	1,772	132	1,905	3,684	282	3,966
MiB	610	46	656	693	53	746
C	1,702	114	1,816	4,005	275	4,281
4WD	355	24	378	646	44	690
TRA	470	34	504	358	27	385
UV	454	26	480	1,024	59	1,083
MC	2,576	155	2,732	7,338	455	7,793
3WH	1	0	1	7	1	7
PT	113	8	120	145	11	156
RICK	3	0	3	17	1	18
BC	54	2	57	129	7	136
Total=	13,253	931	14,188	23,012	1,604	24,616
MV=	13,196	928	14,129	22,865	1,596	24,462

Source: Consultant's estimate.

Service Lanes Traffic at Road Opening

The traffic projection at the service roads during road opening in the year 2020 at all the sections in both vpd and PCUs/day is given in Table 8.14 to Table 8.15

Table 8.14: Service Roads 2019 AADT at Road Opening at Section B

Vehicle	Dumre Bazar (KM 23+500~ 23+750) within Section B: Abukhaireni- Damauli in vpd			Dumre Bazar (KM 23+500~ 23+750) within Section B: Abukhaireni- Damauli in PCU/day		
	Normal	Generated	Total	Normal	Generated	Total
MaT	32	2	35	129	10	140
HT	33	2	35	98	7	105
LT	13	1	14	19	1	21
B	39	3	42	117	9	126
MB	52	4	56	131	10	140
MiB	50	4	53	62	5	66
C	106	7	113	106	7	113
4WD	62	4	66	62	4	66

Vehicle	Dumre Bazar (KM 23+500~ 23+750) within Section B: Abukhaireni- Damauli in vpd			Dumre Bazar (KM 23+500~ 23+750) within Section B: Abukhaireni- Damauli in PCU/day		
	Normal	Generated	Total	Normal	Generated	Total
TRA	13	1	14	38	3	42
UV	36	2	38	36	2	38
MC	277	17	294	138	8	147
3WH	-	0	-	-	-	-
PT	2	0	2	6	0	6
RICK	-	0	-	-	-	-
BC	55	3	58	27	2	29
Total=	770	50	820	972	67	1,039
MV=	715	47	762	945	66	1,010

Source: Consultant's analysis.

Table 8.15: Service Roads 2019 AADT in vpd at Road Opening: Section C & D

Vehicle	Market areas (Damauli, Khairenitara- Thati, Kotre, Gagangauda- Sainik Basti, Bhandarik- Bijayapur) within Section C: Damauli ~ Bijayapur (KM 40+300 ~83+880)			Bijayapur ~ Start of Seti Bridge (KM 84+460 ~88+197)		
	Normal	Generated	Total	Normal	Generated	Total
MaT	11	1	12	46	4	49
HT	40	3	43	93	7	101
LT	4	0	4	46	4	50
B	28	2	30	71	5	77
MB	35	3	38	221	17	238
MiB	24	2	26	83	6	90
C	85	6	91	601	41	642
4WD	18	1	19	97	7	104
TRA	8	1	8	18	1	19
UV	23	1	24	154	9	163
MC	258	15	273	2,201	137	2,338
3WH	0	0	-	1	0	1
PT	2	0	2	7	1	8
RICK	2	0	2	12	1	12
BC	108	5	113	259	13	272
Total=	647	40	685	3,910	253	4,163
MV=	537	35	570	3,639	239	3,878

Source: Consultant's analysis

Table 8.16: Service Roads 2019 AADT in PCU/day at Road Opening: Section C & D

Vehicle	Market areas (Damauli, Khairanitar- Thati, Kotre, Gagangauda- Sainik Basti, Bhandarik- Bijayapur) within Section C: Damauli ~ Bijayapur (KM 40+300 ~83+880)			Bijayapur ~ Start of Seti Bridge (KM 84+460 ~88+197)		
	Normal	Generated	Total	Normal	Generated	Total
MaT	46	3	48	182	14	197
HT	120	9	129	280	22	302
LT	6	0	6	70	5	75
B	85	6	90	213	16	230
MB	89	7	95	553	42	595
MiB	31	2	33	104	8	112
C	85	6	91	601	41	642
4WD	18	1	19	97	7	104
TRA	23	2	24	54	4	58
UV	23	1	24	154	9	163
MC	129	8	137	1,101	68	1,169
3WH	0	0	-	1	0	1
PT	6	0	6	22	2	23
RICK	3	0	3	17	1	18
BC	54	2	57	129	7	136
Total=	717	49	761	3,577	247	3,824
MV=	660	46	701	3,430	240	3,669

Source: Consultant's estimate.

8.4.5 Future Traffic Forecasts

Forecast at the Undivided and Main Carriageways Segments in vpd

Based on the extrapolation of the normal and generated traffic, the future traffic forecasts in vpd at the undivided and main carriageway segments of all the sections is shown in Table 8.17 to Table 8.18.

Table 8.17: Future Traffic Forecast at the Undivided/Main CWY (vpd): Section A & B

Vehicle	Section A: Mugling- Abukhaireni (KM 0+000~ 8+050)			Section B: Abukhaireni- Damauli (KM 8+050 ~40+300) Undivided Road Segment and Main Carriageway at Dumre Bazar (KM 23+500 ~ 23+750)		
	2029	2034	2039	2029	2034	2039
MaT	927	1,131	1,354	608	742	888
HT	525	641	767	617	753	901
LT	262	320	383	240	292	350
B	860	1,049	1,257	733	894	1,072
MB	1,198	1,461	1,751	982	1,198	1,436
MiB	1,037	1,255	1,493	875	1,060	1,260
C	2,456	3,360	4,428	2,420	3,312	4,364
4WD	1,677	2,295	3,025	1,405	1,923	2,534
TRA	57	79	107	296	409	549
UV	3,145	6,615	13,106	1,925	4,049	8,023
MC	8,486	13,794	21,387	10,021	16,289	25,255

Vehicle	Section A: Mugling- Abukhaireni (KM 0+000~ 8+050)			Section B: Abukhaireni- Damauli (KM 8+050 ~40+300) Undivided Road Segment and Main Carriageway at Dumre Bazar (KM 23+500 ~ 23+750)		
	2029	2034	2039	2029	2034	2039
3WH	2	3	3	-	-	-
PT	3	4	5	50	69	92
RICK	21	22	22	-	-	-
BC	82	87	88	74	78	79
Total=	20,738	32,115	49,175	20,245	31,066	46,803
MVs=	20,635	32,006	49,064	20,172	30,988	46,724

Source: Consultant's analysis, 2016.

Table 8.18: Future Traffic Forecast at the Main CWY (vpd): Section C & D

Vehicle	Section C Damauli ~ Bijayapur (KM 40+300 ~83+880) (Undivided segment and main carriageway at the market areas (Damauli, Khairenitar- Thati, Kotre, Gagangauda- Sainik Basti, Bhandarik- Bijayapur)			Section D Main Carriageway - Bijayapur ~ Start of Seti Bridge (KM 83+880 ~88+197)		
	2029	2034	2039	2029	2034	2039
MaT	431	526	629	575	702	840
HT	1,512	1,845	2,208	1,177	1,436	1,719
LT	156	191	228	586	715	856
B	1,063	1,297	1,555	892	1,087	1,304
MB	1,328	1,620	1,942	2,772	3,381	4,053
MiB	859	1,041	1,237	979	1,185	1,409
C	3,882	5,312	7,000	9,165	12,540	16,525
4WD	809	1,107	1,458	1,477	2,021	2,664
TRA	367	507	680	281	388	521
UV	2,417	5,085	10,074	5,466	11,499	22,783
MC	18,661	30,333	47,030	53,292	86,625	134,312
3WH	2	2	2	10	12	13
PT	88	122	163	114	157	211
RICK	3	3	3	15	16	16
BC	145	154	155	350	370	374
Total=	31,724	49,142	74,367	77,152	122,135	187,600
MVs=	31,576	48,985	74,209	76,787	121,749	187,210

Source: Consultant's analysis, 2016.

Forecast at the Main CWYs in PCUs/day

The future traffic forecast at the main carriageway in terms of PCUs for all the five sections is given in Table 8.19 and Table 8.20.

Table 8.19: Future Traffic Forecast at the Undivided/Main CWY (PCU/day): Sec A & B

Vehicle	Section A: Mugling- Abukhaireni (KM 0+000~ 8+050)			Section B: Abukhaireni- Damauli (KM 8+050 ~40+300) Undivided Road Segment and Main Carriageway at Dumre Bazar (KM 23+500 ~ 23+750)		
	2029	2034	2039	2029	2034	2039
MaT	3,709	4,525	5,416	2,432	2,967	3,551
HT	1,575	1,922	2,300	1,851	2,259	2,703
LT	393	480	574	359	438	525
B	2,579	3,146	3,771	2,199	2,682	3,215
MB	2,994	3,652	4,378	2,455	2,994	3,589
MiB	1,296	1,569	1,866	1,094	1,325	1,575
C	2,456	3,360	4,428	2,420	3,312	4,364
4WD	1,677	2,295	3,025	1,405	1,923	2,534
TRA	172	238	320	888	1,227	1,647
UV	3,145	6,615	13,106	1,925	4,049	8,023
MC	4,243	6,897	10,693	5,010	8,144	12,628
3WH	2	3	3	-	-	-
PT	8	11	15	149	207	277
RICK	32	33	34	-	-	-
BC	41	44	44	37	39	39
Total=	24,322	34,790	49,972	22,225	31,566	44,671
MVs=	24,250	34,713	49,894	22,188	31,527	44,632

Source: Consultant's analysis, 2016.

Table 8.20: Future Traffic Forecast at the Main CWY (PCUs): Section C & D

Vehicle	Section C Damauli ~ Bijayapur (KM 40+300 ~83+880) (Undivided segment and main carriageway at the market areas (Damauli, Khairenitara- Thati, Kotre, Gagangauda- Sainik Basti, Bhandarik- Bijayapur))			Section D Main Carriageway -Bijayapur ~ Start of Seti Bridge (KM 83+880 ~88+197)		
	2029	2034	2039	2029	2034	2039
MaT	1,723	2,102	2,516	2,300	2,806	3,359
HT	4,536	5,535	6,624	3,532	4,309	5,157
LT	235	286	343	879	1,073	1,284
B	3,190	3,890	4,664	2,675	3,262	3,911
MB	3,321	4,051	4,856	6,929	8,452	10,132
MiB	1,074	1,301	1,547	1,224	1,482	1,762
C	3,882	5,312	7,000	9,165	12,540	16,525
4WD	809	1,107	1,458	1,477	2,021	2,664
TRA	1,100	1,520	2,041	842	1,164	1,563
UV	2,417	5,085	10,074	5,466	11,499	22,783
MC	9,330	15,166	23,515	26,646	43,313	67,156
3WH	2	2	2	10	12	13
PT	264	365	490	341	472	633
RICK	4	5	5	22	24	24
BC	73	77	78	175	185	187
Total=	31,960	45,803	65,212	61,685	92,614	137,153
MVs=	31,883	45,722	65,130	61,488	92,405	136,942

Source: Consultant's analysis, 2016

Traffic Forecast at the Service Roads

The corresponding future traffic at the service roads in all the four sections under various options in vpd and PCUs/ day is given in Table 8.21 to Table 8.23.

Table 8.21: Future Traffic Forecast at the Service Roads within Section B

Vehicle	Dumre Bazar (KM 23+500~ 23+750) within Section B: Abukhaireni- Damauli in vpd			Dumre Bazar (KM 23+500~ 23+750) within Section B: Abukhaireni- Damauli in PCU/day		
	2029	2034	2039	2029	2034	2039
MaT	61	74	89	243	296	355
HT	62	75	90	185	226	270
LT	24	29	35	36	44	52
B	73	89	107	220	268	322
MB	98	120	144	246	299	359
MiB	88	106	126	109	133	158
C	242	331	436	242	331	436
4WD	141	192	253	141	192	253
TRA	30	41	55	89	123	165
UV	193	405	802	193	405	802
MC	1,002	1,629	2,526	501	815	1,263
3WH	-	-	-	-	-	-
PT	5	7	9	15	21	28
RICK	-	-	-	-	-	-
BC	74	78	79	37	39	39
Total=	2,091	3,177	4,751	2,256	3,192	4,503
MVs=	2,017	3,099	4,673	2,219	3,153	4,463

Source: Consultant's analysis, 2016.

Table 8.22: Future Traffic Forecast at the Service Lanes in vpd at Section C & D

Vehicle	Market areas (Damauli, Khairenitar- Thati, Kotre, Gagangauda- Sainik Basti, Bhandarik- Bijayapur) within Section C: Damauli ~ Bijayapur (KM 40+300 ~83+880)			Section D: Bijayapur ~ Start of Seti Bridge (KM 84+460 ~88+197)		
	2029	2034	2039	2029	2034	2039
MaT	22	26	31	86	105	126
HT	76	92	110	177	215	258
LT	8	10	11	88	107	128
B	53	65	78	134	163	196
MB	66	81	97	416	507	608
MiB	43	52	62	147	178	211
C	194	265	350	1,375	1,881	2,479
4WD	40	55	73	222	303	400
TRA	18	25	34	42	58	78
UV	121	254	503	820	1,725	3,418
MC	932	1,516	2,350	7,994	12,995	20,148
3WH	0	0	0	2	2	2
PT	4	6	8	17	24	32
RICK	3	3	3	16	16	17
BC	145	154	155	350	369	373
Total=	1,726	2,604	3,866	11,884	18,650	28,474
MVs=	1,578	2,448	3,708	11,519	18,264	28,084

Source: Consultant's analysis, 2016.

Table 8.23: Future Traffic Forecast at the Service Roads in PCU/d at Section C & D

Vehicle	Market areas (Damauli, Khairenitar- Thati, Kotre, Gagangauda- Sainik Basti, Bhandarik- Bijayapur) within Section C: Damauli ~ Bijayapur (KM 40+300 ~83+880)			Bijayapur ~ Start of Seti Bridge (KM 84+460 ~88+197)		
	2029	2034	2039	2029	2034	2039
MaT	86	105	126	345	421	504
HT	227	277	331	530	646	774
LT	12	14	17	132	161	193
B	159	194	233	401	489	587
MB	166	202	243	1,040	1,268	1,520
MiB	54	65	77	184	222	264
C	194	265	350	1,375	1,881	2,479
4WD	40	55	73	222	303	400
TRA	55	76	102	126	175	234
UV	121	254	503	820	1,725	3,418
MC	466	758	1,175	3,997	6,497	10,074
3WH	0	0	0	2	2	2
PT	13	18	24	51	71	95
RICK	4	5	5	23	25	25
BC	73	77	78	175	185	187
Total=	1,670	2,366	3,337	9,422	14,071	20,755
MVs=	1,593	2,285	3,254	9,224	13,862	20,543

Source: Consultant's analysis, 2016.

Based on the 20 year forecast above, a capacity assessment was also done to evaluate the adequacy of the cross-section proposed under Design Option 3 and the traffic operation that is expected in the long term period.

Table 8.24: Lane Required, Future Traffic Operation

Section		Undivided Segment/ Main CWY	Service Roads
A	Mugling- Abukhaireni (KM 0+000~ 8+050)	By the year 2029, traffic to operate at capacity (LOS ⁷ E), four lane carriageway required beyond the year 2029.	Not applicable
B	Abukhaireni- Damauli (KM 8+050 ~40+300)		Traffic operation at design capacity (LOS B) till the year 2039.
C	Damauli ~ Bijayapur (KM 40+300 ~83+880)	Traffic to operate at design capacity (LOS B) till the year 2034 but will be constrained (LOS C/D) along the four-lane carriageway by the year 2039.	
D	Bijayapur ~ Start of Seti Bridge (KM 83+800 ~88+197)	Traffic operation begin to be slightly constrained (LOS C) along the four-lane carriageway by the end of the year 2029.	Traffic to operate at LOS D by the year 2039. Service roads to be expanded to two lanes (7 m) beyond the year 2039.

Source: Consultant's analysis, 2016.

Traffic operation at design capacity (which is roughly 45% of the theoretical capacity of the road), accords a high degree of freedom for vehicles to move with little interference. Traffic operation at LOS C still offering relative freedom of movements but there are moderate friction in movements sometimes. At LOS D, congestion starts to build up but traffic operation is still unsaturated.

8.5 Design Loading for the Pavement Design

8.5.1 Pavement Design Load at the Undivided/ Main Carriageway

The ESA for the commercial vehicles at the Mugling – Pokhara Highway was based on the 2005 axle-load survey conducted under RMDP. The ESA values for some of the vehicles such as microbus, tractor, utility vehicles and power-tillers in both directions that were missing in the above axle-load survey were taken from other sources. Table 8.25 shows the ESA factors derived from the RMDP axle-load survey above for use in this project road.

Table 8.25: Vehicle ESA Adopted for the Project Road

Vehicle	Unloaded Direction (West to East)	Loaded Direction (East to West)
Multi-axle truck	2.464	0.092
Heavy truck	3.959	0.904
Light truck	0.226	0.093
Bus	0.238	0.145
Mini-bus	0.022	0.002
Micro-Bus	0.010	0.010
Car, van, taxi	0.000	0.000
Four-wheel drive	0.010	0.010
Farm tractors	0.041	0.010
Utility Vehicle	0.010	0.040
Three wheeler	0.000	0.000
Power-tiller	0.000	0.000

⁷ LOS= Level of service

Source: Axle-load Surveys; GoN DoR RMDP Institutional Strengthening Component (IDA Credit 3293-NP); January 2005.

As already discussed, 100% of the traffic was considered to ply along the main carriageway where service roads are provided within Section B to D. Therefore, the pavement design load pertaining to the main carriageway will be applicable for the undivided (rural) segment of the project road. The ten year pavement design load over the project road is given in Table 8.26 and Table 8.27.

Table 8.26: Ten Year Design Load at all the Sections of the Project Road

Vehicle	Section A: Mugling- Abukhaireni (KM 0+000~ 8+050)	Undivided & Main CWY Segments within Section B: Abukhaireni- Damauli (KM8+050 ~40+300)	Undivided & Main CWY Segments within Section C: Damauli ~ Bijayapur (KM 40+300 ~83+880)	Undivided/ Main CWY within Section D Bijayapur ~ Start of Seti Bridge (KM 83+880 ~88+197)
Multi-axle truck	2,633,190	967,602	570,433	1,012,747
Heavy truck	2,853,526	1,948,169	4,490,671	3,765,393
Light truck	90,537	44,224	27,012	117,197
Bus	357,822	166,538	239,581	208,511
Mini-bus	32,107	14,163	19,021	43,447
Micro-Bus	23,280	10,484	10,293	11,726
Car, taxi, van	-	-	-	-
Four-wheel drive	33,481	14,958	8,609	15,729
Farm tractor	2,978	8,062	9,808	8,539
Utility-vehicle	115,123	37,940	52,517	99,236
Motor-cycle	-	-	-	-
Three wheeler	-	-	-	-
Power-tiller	54	1,302	2,404	3,234
Total=	6,142,099	3,213,441	5,430,349	5,285,760
Traffic Level	T6	T5	T5	T5

Source: Consultant's analysis, 2016.

8.5.2 Pavement Design Load at the Service Roads

Table 8.27 shows the ten year pavement design load at the service lanes in Section B to D.

Table 8.27: Ten Year Design Load at the Service Roads in Section C & D

Vehicle	Dumre Bazar (KM 23+500 ~ 23+750) within Section B	Market areas (Damauli, Khairanitar- Thati, Kotre, Gagangauda- Sainik Basti, Bhandarik- Bijayapur) within Section C	Bijayapur ~ Start of Seti Bridge (KM 84+460 ~ 88+197) within Section D
Multi-axle truck	106,322	31,348	167,122
Heavy truck	214,327	246,787	621,358
Light truck	4,865	1,484	19,340
Bus	18,322	13,167	34,408
Mini-bus	1,558	1,045	7,170
Micro-Bus	1,153	566	1,935
Car, taxi, van	-	-	-
Four-wheel drive	1,646	473	2,596
Farm tractor	887	539	1,409
Utility-vehicle	4,174	2,887	16,375
Motor-cycle	-	-	-
Three wheeler	-	-	-
Power-tiller	143	132	534
Total=	353,397	298,429	872,245
Traffic Level	T2	T2	T3

Source: Consultant's analysis, 2016.

8.6 Conclusions and Recommendations

This chapter has enumerated the twenty year traffic forecast and the corresponding pavement design load for the Mugling –Pokhara section of PRM. The twenty year traffic forecast both in terms of vpd and PCU/day for the Mugling –Pokhara Road under all the design options in given in Table 8.17 Table 8.20.

Based on the traffic analysis, the it is recommended to upgrade the Mugling- Abukhaireni section (KM 0+000 –KM 8+050) from the two-lane to four-lane median divided carriageway beyond the year 2029. In addition, widening of the four-lane main carriageway along the Bijayapur- start of Seti Bridge (KM 83+880 – KM 88+197) to six lanes should be revisited beyond the year 2029.

9. DETAILED PAVEMENT DESIGN

9.1 Pavement Design

9.1.1 Design Criteria for Road Width

Existing Road Width

The existing width of the pavement (carriageway and paved shoulder) varies from 6m to 8m for the most part except for market places. At market places and settlement areas such as Abu Khaireni, Dumre, Damauli and others, the pavement width range from 9 to 10m. A 3m to 3.5m service road on both the sides exist at Khairenitar, Dhulegauda, Gagangauda, and Khairenitar (km 60.4).

Formation Width Requirement for a Four Lane Highway

It is understood that the Department of Roads now desires to upgrade the Mugling Pokhara road with a double lane and four lanes. The initial 8 km odd length would be of double lane while the remaining of a four lane. Details with tentative chainages are elaborated below.

The 4 lane highway would start after Abu Khaireni Bazaar(km 8+420) and pass through Dumre (km 29+350), Damauli (km 40+300), Khairenitar (km 61+300), Dhulegauda (km 66+500), Kotre (km 70+120), Gagangauda (km 74+600), Sanik Basti (km 76+450), Bandarik (km 76+950) Talchowk, Argachowk, Budi Bazaar, Bijayapur (km 83+920), Pokhara Industrial Area, Amarsingh Chowk and end at left bank abutment of Seti Bridge (km 88+595).

The total formation width including a 14m carriageway width, foot paths, service roads and road side drains would be about 41m. In areas without service roads, the formation width is envisaged to be only 23m.

Service roads will be provided only in the following sections:

- Dumre Bazaar (km 23+420 to km 23+950)
- Khairenitar-Dhulegauda-Belchautara-Thati Bazaar (km 61+320 to km 66+500)
- Kotre Bazaar (km 70+120 to km 70+500)
- Gagangauda-Sanik Basti (km 74+600 to km 76+450)
- Bhandarik-Okale-Talchowk-Lakhan Chowk-Sundar Bazaar-Budi Bazar-Kalika Chowk-Bijayapur (km 76+500 to km 83+920)
- Bijayapur-Amarsingh Chowk-Seti Bridge (km 84+500 to km 88+595)

Formation Requirement for a Two Lane

Double lane road is proposed from Mugling to Abu Khaireni (km 8+240).

The standard road formation width for a two lane would consist of 7m of carriageway with 2.5m shoulders on either side and a median of 0.5m. Thus the total road width between shoulder breakpoints would be 12.5m. The above, however, could be relaxed for the first four km from Mugling to Marsyangdi Power House **so as to accommodate 9m or even 7m should construction of 12m be assessed to be too challenging. At this stretch the pavement width would vary from 7m to 12.5m.**

At market areas, the carriageway width is expected to be widened to have a 14m width with 0.5m median, footpath and shoulder. The formation widths at various sections from Mugling (km 0) to Abu Khaireni (km 8+420) are as follows:

- km 0 to km 3+900 (Marsyangdi Power House): Pavement width ranging from 7m to 9m. Shoulder of 1m will be provided where possible, except at km 0 where the road will have to be widened to accommodate turning radius and visibility when approaching the new bridge at Mugling.

- km 3+900 (Marsyangdi Power House) to km 6+700 (Abu Khaireni): Carriageway width of 7m with 2.5m shoulders on either side and a 0.5m median totaling 12.5m
- km 6+770 to km 8+420 (Abu Khaireni Bazaar): Carriageway width of 7m with 2.5m shoulders and 2m foot path on either side and a 0.5m median totaling 16.5m

9.1.2 Existing Pavement Condition from Mugling to Abu Khaireni

This part of the road section is planned as a double lane road. The existing pavement condition is generally smooth. The road which was completed under Chinese grant aid in 1972 was later upgraded and widened by DoR in 1992 and the total carriageway width inclusive of shoulders range from 7m to 9m.

Massive rocky cliffs flank on the hill side till Ruwa Khola which will make widening prohibitively expensive and difficult to construct especially if thoroughfare is to be maintained. Across Ruwa Khola, the Marsyangdi Power House infrastructure severely limits the potential for any carriageway extension.

Pits dug to assess the pavement condition reveal that base course consist of emulsion stabilized base course (EAM) of a thickness ranging from 130 to 150mm with a granular sub base of 150mm to 160mm thickness. The EAM course is sealed with DBST.

9.1.3 Existing Pavement Condition from Abu Khaireni to Seti Bridge

The road stretch from Abu Khaireni to Kumle Khola (km 60+925) near Khairenitar was upgraded and widened by DoR and Marsyangdi Hydropower Project in the mid-1990s. The pavement structure and their surface condition are as tabulated below in Table 9.1 (a) and Table 9.2 (b).

Table 9.1(a): Findings from Pit Excavation from Damauli to Kumle Khola

Chainage (km)	Pavement Condition	Pavement Thickness (mm)	Remarks
59+700 (Kumle Khola)	Good	380 comprising of 160mm base and 200mm Sub base	Reasonable DBST riding surface with localized depressions
56	Good	140 all base course and sub base could not be found. Sub grade of clayey silt material with granular material	Reasonable DBST riding surface with perceptible depressions within 200m towards Damauli
45+250	Good	490 comprising of 170mm granular base	Sub base include old Chinese construction
42+450 (Damauli)	Undulating, depressed	390 comprising of 170mm granular base	old spring area, sub base could include old Chinese capping layer
40+400 (Damauli)	Good	496 comprising of 170mm granular base	Old problematic area. Sub base includes old Chinese construction

Table 9.1(b): Findings from Pit Excavation from Abu Khaireni to Km 37Just after Ghansikuwa)

Chainage (km)	Pavement Condition	Total Pavement Thickness (mm)	Remarks
37	Good	456. 170mm granular base	Rocky hill side
33+200	Good	396. 160mm granular base course	Sub base includes old Chinese construction
29+500	Poor	380mm. Base course 170mm	Longitudinal cracks, shoving, rutting

Chainage (km)	Pavement Condition	Total Pavement Thickness (mm)	Remarks
23+950 (Dumre)	Poor	270mm. Base course 170mm	Heavily cracked and undulating bend. Weathered rock on hill side
21+620 (Bimal Nagar)	Good	420mm. Base 170mm	Rocky Cliff on hillside
16+820 (Satrasaye Phat)	Good	330mm. EAM Base 130mm	Marsyangdi Hydropower Construction
15+820 (Baradhi Khola)	Good	310mm. EAM Base 150mm	Marsyangdi Hydropower Construction
13+320 (Markhi Chowk)	Good	310mm. EAM Base 150mm	Marsyangdi Hydropower Construction
Abu Khaireni Bazaar (km 8+400)	Good	400mm. EAM Base 150mm	DoR Construction
Abu Khaireni Bazaar (km 6+770)	Good	360mm. EAM Base 150mm	DoR Construction

Pavement condition between Abu Khaireni and Damauli is generally good but the pavement do show signs of distress at sporadic stretches, most noticeably at bends where there are substantial map cracking and undulations, probably due to high moisture content of the sub grade particularly in the monsoon. Pavement subsidence was also noticed at a minimum of two locations but these are attributed to slope failures rather than problems sole restricted to the pavement structure.

EAM base course structure construction by Marsyangdi Hydropower Project is only till Andhi Khola (km 17+425) which lies west of Satrasaye Phat. The base course there after all the way to Kumle Khola consists of semi processed or processed granular material.

Apart from periodic DBST resealing, the pavement structure after Kumle Khola apparently has never been upgraded or strengthened intervened by DoR since 1972, except at very few locations mostly in stretches between Kotre (km 70+500) and Seti Bridge (km 88+197) .

After the bridge over Kumle Khola, the road ascends to Khairenitar. It then ascends and descends at several locations passing through Dhulegauda, Kotre, Gagangauda, Talchowk, Sainik Basti, Budi Bazaar, and Bijayapur all the way to Amarsingh Chowk and Seti Bridge.

The pavement surface in the Kumle Khola Khairenitar stretch is relatively better than that in the remaining sections, where rampant map cracking and undulations can be seen. Recent repairs or surface sealing have cracks (probably reflection cracks) arising out of a combination of inadequate drainage, pavement structural capacity and poor construction practices. Details from pit examinations are given below in Table 9.1 (c).

Table 9.1(c): Findings from Pit Excavation from Khairenitar to Pokhara Seti Bridge

Chainage (km)	Pavement Condition	Pavement Thickness (mm)	Remarks
61+320 (Khairenitar)	DBST surface good	250 comprising of 100mm granular base and 150mm Sub base	Reasonable DBST riding surface with localized depressions
Dhulegauda (62+400) at Khairenitar end	DBST surface Poor. Cracked and undulating.	200 comprising of 80mm base course	Area prone to pavement flooding. Flat terrain, beginning of bazaar.
Dhulegauda (64+500)	Poor. No outlet for drainage	230 comprising of 80mm granular base	Main road lower than service road. Flat terrain

Chainage (km)	Pavement Condition	Pavement Thickness (mm)	Remarks
Dhulegauda (65+800)	Poor, cracked surface	230 comprising of 80mm granular base	No outlet for storm water. Flat terrain
Dhulegauda (66+300)	Poor, cracked surface	230 comprising of 80mm granular base	No outlet for storm water. Flat terrain
Dhulegauda (67+400) Kotre end	Poor, cracked, undulating	310 comprising of 100mm granular base	Road descends. Outlet for storm water possible
68+500	Poor, cracked, undulating	260 comprising of 100mm granular base	Roadside drains exist on rocky hillside
Kotre Bazaar (70+500)	Poor, cracked, undulating	320 comprising of granular base less than 100mm	Good subgrade
Majuwa (71+300)	Poor, cracked, undulating	270 comprising of 100mm granular base	Predominantly round, weathered aggregates
78+600	Poor, cracked, undulating	230 comprising of 100mm granular base	High moisture content, sub grade fine with gravel. Earthen drains
Gagangauda (74+400)	Poor, cracked, undulating	200 max. comprising of max 100mm granular base	High moisture content (12%)
Sainik Basti (76+300)	Fair	360. comprising of 160mm granular base	Rare good stretch
Talchowk (81)	Fair with longitudinal crack	380mm comprising of 130 base	Subgrade black clayey silt
Argau Chowk (82+100)	Poor and corrugated	320mm max. comprising of 120 base	Earthen side drains, DoR repaired section
Budi Bazaar	Poor and corrugated	300mm max. comprising of 100 base	Earthen side drains, DoR repaired section

Table 9.1(d): Findings from Pit Excavation from Khairenitar to Seti Bridge (contd.)

Chainage (km)	Pavement Condition	Pavement Thickness (mm)	Remarks
Bijayapur/Chauthe (85+300)	Poor and cracked	370mm max. comprising of 120 base	Original Chinese Construction/
Industrial Area (86+600)	Fair with minor cracks	250mm max. comprising of 100 base	DoR repaired section
km 87+200	Cracked AC surface	Ac 40mm, base 100mm, Sub base 100mm	100m from Welcome Gate Pokhara side

Most of the stretches from Khairenitar to Pokhara consist of Chinese pavement structure in which the base course is in between 80mm to 100mm. DoR has over the years partially reconstructed some parts of the road but even there the old base course was replaced but rarely exceeding 100 or 120mm.

No pits were excavated after km 87+200 (100m after Pokhara Welcome Gate). The pavement after this point consists mostly of premix carpet or Asphalt Concrete (from Amarsingh Chowk to Sarada Petrol Pump).

9.2 Design Methodology and Reference Literature

9.2.1 Design Methodology

The methodology adopted in the structural design for this road is based on the California Bearing Ratio (CBR).

The design process broadly involved the following:

- a) Estimate on the amount of traffic and subsequently the cumulative number of equivalent standard axles of 8.16t for a pavement design life of 10, 15 and 20 years (ESA_{10} , ESA_{15} and ESA_{20}) as applicable. Lane factor used are 0.75 and 0.4 respectively for a double lane and four lane roads.
- b) Assessment of the CBR of the sub grade over which the pavement and hard shoulder is proposed to be laid. Both DCP and soaked CBR were considered to arrive at the design CBR of the sub grade.
- c) Assessment of the existing pavement thickness of sub base/base layers and its condition. Pit samples were taken for the purpose to measure the layer thickness/gradation of base and sub base and moisture content of subgrade if required.
- d) 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
- e) Selection of most economical combination of pavement materials (bound or unbound) and layer thickness (sub base, base and wearing course) for a design life of 15 years. Bituminous top layer shall consist of either DBST or Asphalt Concrete.

9.2.2 Standards and Literature

Standards and literature referred for pavement design were:

- Pavement Design Guidelines, Government of Nepal, Ministry of Physical Infrastructure and Transport, Department of Roads, 2014 Kathmandu
- Overseas Road Note 31, TRL Limited, Crowthorne, Berkshire United Kingdom
- From Web: CE742LeC_21_IRC_Pavement Design.pdf
- An Examination of Options for Maintenance or Rehabilitating the Arniko Highway, Roughton and Partners, January 1993

In addition to the above, reference has been made to appropriate text books as required. In the design presented herein is largely based on TRL Road Note 31.

9.2.3 Traffic, Design Loads and Sub Grade CBR

Traffic and Design Load

Recent traffic counts reveal that the design load along the whole stretch of road from Mugling to Pokhara does not vary substantially. Table 9.2 lists the traffic for a four, two and service lanes for various design periods.

Table 9.2: Pavement Design Loads along Mugling to Pokhara

FOUR LANE OPTION

Road Section	Traffic Level Range (msa)/TRL	Design Period	Remarks
Mugling to Abu Khaireni (km 8+400)	3.28 msa/T5	10	Traffic between Abu Khaireni and Damauli Decreases slightly but is taken as 3.26 msa (T5). Traffic between Damauli and Bijayapur slightly higher at 5.42 msa while that from Bijayapur to Prithvi Chowk Pokhara is 5.24 msa. Design value of 5.42 (T5) adopted for the stretch from Damauli to Prithivi Chowk.
Abu Khaireni/ Markhi Chowk/ Satrasaye Phat//Damauli East (km 40+300)	3.21 msa/T5	10	
Damauli Bazaar/Damauli West/ Bijayapur/Seti Bridge	5.42 msa/T5	10	
TWO LANE OPTION			
Mugling to Abu Khaireni (km 8+400)	6.14 msa/T6	10	Traffic after Abu Khaireni to Damauli decreases slightly from 6.14 to 6.03 msa but is taken as 6.14 msa (T6). Traffic between Damauli and Bijayapur slightly higher at 10.16 msa while that from Bijayapur to Prithivi Chowk Pokhara is 9.9 msa. Design value of 9.9 msa` (T6) adopted.
Abu Khaireni/Markhi Chowk/Satrasaye Phat/ Damauli (km 40+300)	6.03 msa/T5	10	
Damauli West/ Khairenitar/Bijayapur	10.16 msa/T7	10	
Bijayapur to Seti Bridge	9.9 msa/T6	10	
SERVICIE LANE			
Mugling to Abu Khaireni	0.18 msa/T1	10	Traffic for service lane much higher at the Pokhara end compared with the Mugling end. For Abu Khaireni, T2 taken as little traffic may be diverted there.
Abu Khaireni to Damauli	0.35 msa/T2	10	
Damauli West to Bijayapur	0.30 msa/T2	10	
Bijayapur West to Prithvi Chowk	0.872 msa/T3	10	

It can be reasonably concluded that the ten year pavement design for a 4 lane Mugling Pokhara road could be designed for a TRL Traffic Level of T5 while such TRL traffic level would be T6 for a two lane road. The service lanes shall be designed for the traffic level of T2 for whole stretch except for Bijayapur Seti Bridge Section which is taken as T3.

CBR of Sub Grade

All the structural pavement design will be based on the CBR value of the sub grade. The Mugling Pokhara road has been divided in homogenous section. Based on the findings from DCP and laboratory soaked tests, the CBR adopted are as follows.

The sub grade along the Pokhara Mugling road varies according to its chainage. For the first 9km till Markhi Chowk (km 12), the lab soaked CBR is in the range of 14 -22 (S4 to S5 as per TRL). The soaked CBR for rest of the alignment vary from 5.2 to 12.1 (S3 and S4 as per TRL). Hence, it can generally be concluded that till km 12, the pavement could be designed with TRL value of S4 while a value of S3 could be adopted for the remaining section if the design is wholly to be based on soaked CBR.

There are however stretches which are relatively weaker that have been assessed from its high moisture content, finer soil matrix of predominantly clayey silt or silt in which the gravel content is less than 10%. These stretches indicate (and is enforced by the DCP tests) that the soaked CBR value for these stretches would be in between 5 and 7 corresponding to a CBR range of S3. Hence, the design CBR proposed for the entire road from Mugling to Pokhara is as follows:

- km 0 (Mugling) to km 8+400 (end of Abu Khaireni Bazaar) : Design CBR value of 14 or S4 as per TRL Road Note 31

- km 8+400 to km 17.4 (Satrasaye Phat end: Design CBR value not exceeding 7 or S3 as per TRL Road Note 31
- km 17.4 (Satrasaye Phat) to Khairenitar (km 62): Design CBR value in between 5 and 7 or S3 according to TRL Road Note 31
- km 62 (Khairenitar) to km 70+500 (Kotre): Design CBR value not to exceed 7 or S3 as per TRL Road Note 31
- km 70+500 (Kotre) to km 88+197 (Seti Bridge): Design CBR value not less than 5 and 7 i.e. S3 according to TRL Road Note 31

The design load (ESA) for 10 years and the CBR values proposed for various sections of road for a two lane and four lane options are summarized in Table 6.3. The values proposed in Table 9.3 reflect:

- The Client desire to have a double lane road till Abu Khaireni and widening at Abu Khaireni Bazaar
- The Client's desire to have a 14m wide carriageway after Abu Khaireni Bazaar all the way to Pokhara (Seti Bridge) with foot paths, medians and service roads at selected spots. From a pavement design perspective, this stretch of the road has been considered as a double lane road.

The CBR value of S3 (5 to 7) may look a bit conservative for some stretch and sections such as Abu Khaireni to Markhi Chowk, Bimal Nagar to Dumre and for some locations from Dumre to Damauli. But these stretches are relatively small with the presence of some very wet areas. Hence from a design and construction perspective, a uniform CBR value has been taken, particularly for a robust pavement design and ease of construction.

Table 9.3: Summary of Design Loads and Sub Grade CBR

Road Section	Design Loads (ESA) in msa		Soaked CBR	Design Loads (ESA) in msa for Service Roads	
	ESA ₁₀ for 2 Lane Road	ESA ₁₀ for 4 Lane Road		Design Load (ESA ₁₀)	Sub Grade Level (TRL)
Mugling to Abu Khaireni Bazaar (km 0 to km 8+400)	6.14 (T6)	3.28 (T5)	14 (S4)	T2	S4
Abu Khaireni (km 8+400) to Bijayapur (km 83+920)	6.14 (T6)	3.28 (T5)	5- 7 (S3)	T2	S3
Bijayapur (km 83+920) to Seti Bridge (km 88+197)	6.14 (T6)	5.4 (T5)	5- 7 (S3)	T3	S3

9.3 Pavement Structural Design

9.3.1 Preliminary Design

Pavement structural design is based on TRL Road Note 31. Guidelines based on DoR Pavement Guidelines are based on specific values of CBR. There is limited number of soaked laboratory tests which could be prone to errors. Secondly, the CBR values are seen to vary from 5.2 to 22 which could pose problems during construction even if these specific values are adopted. Hence, CBR range values, shown in Table 6.3, based on TRL have been taken. It not only considers the limited soaked laboratory tests but also allows for a homogenous design over a longer stretch which is favorable during construction.

The scope of the use of Asphalt Concrete has been limited for the stretch from Mugling to Km 3+900. After km 3+900, all the road surface irrespective of 2 or 4 lane capacity will be sealed with DBST using

20/14mm and 14/10mm aggregates with 80/100 bitumen. It is recommended to use VG 30 for AC construction.

The thickness of base and sub base for two lane, four lane and service road where applicable under this feasibility studies are shown in Table 6.4 to Table 6.6. The design is for the following options:

- with granular base/sub base with DBST (Chart 1 of TRL Road Note 31)
- with structural surface with granular base/sub base (Chart 5 of TRL Road Note 31)
- with structural Design as per Pavement Design Guidelines of DoR, 2014

Road structures with composite, bituminous or cemented road base have not been considered owing to the costs.

It may also be mentioned that Pavement Design Guidelines of DoR, 2014 is considered only for the road section from Mugling (km 0) to km 3+900 because all the stretches thereafter is to be sealed with DBST. The rationales for this recommendation are:

- The road in between Dhulegauda (km 62+200) and Seti Bridge (km 88+197) show severe pavement distress and an AC surface that cracks would be difficult and expensive to repair. It is recommended to upgrade the road using thick granular layers and proper drainage to counter the moisture ingress, observe the performance of the road for corrugation and undulations along the carriageway and to lay AC at a subsequent stage. DBST is a better sealant for road surface, less expensive and hence preferred.
- In between Abu Khaireni and Dhulegauda, the road will have to be widened across existing paddy fields which would wet during the monsoon. The older pavement would probably have a higher Modulus of Resilient than the widened part which could lead to subsidence and longitudinal cracks, for which AC is more susceptible and more expensive to repair.
- At the current traffic level of T5, TRL Road Note 31 does not justify the use of AC and it would be too expensive.

Table 6.4 and 6.5 shows the various possibilities of pavement structure for main carriageway and service roads from TRL Road Note 31 while Table 6.6 shows the pavement structure from DoR Pavement Design Guidelines 2014. The section splits from Mugling to km 3+900, km 3+900 to end of Abu Khaireni Bazaar (km 8+400) for a double lane road and 14m carriageway width thereafter are based on the Client's desire after the Consultant's submission of the Feasibility Report.

Table 9.4: Pavement Design Based on TRL Road Note 31

Road Section and Design Parameters (Traffic and CBR)	Lane Capacity & Pavement Structure	Layer Thickness (mm)
With Granular Road Base (Chart 1 TRL Road Note 31)		
Mugling (0+000) to Abu Khaireni (km 3+900) T5/S4	Double Lane with Carriageway Width 7 to 9m with shoulder width of 1m on either side possible Base Sub Base Surface: DBST	200 mm 250 mm
Km 3+900 to Abu Khaireni (km 8+400) T5/S4	Double Lane with Carriageway Width 7 with 2.5m shoulders on either side with 0.5m median totaling 12.5m.	

Road Section and Design Parameters (Traffic and CBR)	Lane Capacity & Pavement Structure	Layer Thickness (mm)
	At Abu Khaireni Bazaar, 2m wide foot path would be added on either side totaling a total formation width of 16.5 with a 7m carriageway Base Sub Base Surface: DBST	200 mm 250 mm 14/20mm and 10/14mm aggregates
Abu Khaireni (km 8+400 to Damauli East (km 40+300) T5/S3	Four Lane with Carriageway of 14m with median, foot path and service roads at selected locations Base Sub Base Surface: DBST	200 mm 325 mm 14/20mm and 10/14mm aggregates
Damauli West to Khairenitar (km 40+300 to km 65) T5/S3	Four Lane with Carriageway of 14m with median, foot path and service roads at selected locations Base Sub Base Surface: DBST	200 mm 325 mm 14/20mm and 10/14mm aggregates
Khairenitar to Pokhara (km 65 to km 88+595) T5/S3	Four Lane with Carriageway of 14m with central drains in lieu of median and at selected locations , foot path and at service roads Base Sub Base Surface: DBST	200 mm 325 mm 14/20mm and 10/14mm aggregates
With Granular Road Base and Semi Structural Surface (Chart 3 TRL Road Note 31)		
This option has been discarded after the submission of Feasibility Report because of AC layer on top		

Chart 5 of TRL with granular base and structural surface with 100mm AC is not applicable and is uneconomical for a four lane road.

Table 9.5: Pavement Design for Service Roads Based on TRL Road Note 31

Road Section and Design Parameters	Pavement Structure	Layer Thickness (mm)
With Granular Road Base (Chart 1 TRL Road Note 31)		
Dumre Bazaar (km 23+410 to km 23+950) T2/S4	Base Sub Base Surface: DBST	150 mm 175 mm 14/20mm and 10/14mm aggregates
Damauli Bazaar (km 40+300 to km 41) T2/S3	Base Sub Base Surface: DBST	150 mm 200 mm 14/20mm and 10/14mm aggregates
Khairenitar (km 61+320) to Thati Bazaar (km 66+500) T2/S3	Base Sub Base Surface: DBST	150 mm 200 mm 14/20mm and 10/14mm aggregates

Road Section and Design Parameters	Pavement Structure	Layer Thickness (mm)
Kotre Bazaar (km 70+120 to km 70+500) T2/S3	Base Sub Base Surface: DBST	150 mm 200 mm 14/20mm and 10/14mm aggregates
Gagangauda (km 76+400) to Sainik Basti (km 76+450) T2/S3	Base Sub Base Surface: DBST	150 mm 200 mm 14/20mm and 10/14mm aggregates
Bhandarik (km 76+500) to Bijayapur (km 83+920) T2/S3	Base Sub Base Surface: DBST	150 mm 200 mm 14/20mm and 10/14mm aggregates
Bijayapur (km 83+920) to Seti Bridge (km 88+595) T3/S3	Base Sub Base Surface: DBST	200 mm 225 mm 14/20mm and 10/14mm aggregates
With Granular Road Base and Semi Structural Surface (Chart 3 TRL Road Note 31)		
Not applicable as it results in higher costs		
With Granular Road Base and Structural Surface (Chart 5 TRL Road Note 31)		
Not applicable as it results in higher costs		

Table 9.6: Pavement & Service Road Design Based on DoR Pavement Design Guidelines

Road Section and Design Parameters (Traffic in msa and CBR %)	Pavement Structure	Layer Thickness (mm)
For a Four Lane Road		
DoR Pavement Design Guidelines uses AC for binder and wearing course. The use of AC has been ruled out except from km 0+000 (Mugling) to km 3+900 and that too for a double lane road and hence has been ruled out.		
For a Two Lane Road		
Mugling (km 0+000) to km 3+900) with Traffic 6.14 msa and CBR of 14%	Sub Base Granular Base HDM Base Wearing Course: AC	210* 150 50 50
All the other sections from km 3+900 to Seti Bridge (km 88+197) would have to use AC for wearing and binder course and as such has been ruled out.		
For Service Lanes		
At Dumre Bazaar (km 23+410 to km 23+950), Traffic 1 msa and CBR of 14%	Sub Base Granular Base Wearing Course: DBST in lieu of PC	150* 150 14/20mm and 10/14mm aggregates
Damauli Bazaar (km 40+300 to km 41), Traffic 1 msa and CBR of 7%	Sub Base Granular Base Wearing Course: DBST in lieu of PC	210* 150 14/20mm and 10/14mm aggregates
Khairanitar (km 61+320) to Thati Bazaar (km 66+500), Traffic 1 msa and CBR of 6%	Sub Base Granular Base Wearing Course: DBST in lieu of PC	250* 150 14/20mm and 10/14mm aggregates
Kotre Bazaar (km 70+120 to km 70+500), Traffic 1 msa and CBR 7%	Sub Base Granular Base Wearing Course: DBST in lieu of PC	210* 150 14/20mm and 10/14mm aggregates

Road Section and Design Parameters (Traffic in msa and CBR %)	Pavement Structure	Layer Thickness (mm)
Gagangauda (km 76+400) to Sanik Basti (km 76+450) Traffic 1 msa and CBR 5%	Sub Base Granular Base Wearing Course: DBST in lieu of PC	280* 150 14/20mm and 10/14mm aggregates
Bhandarik (km 76+500) to Bijayapur (km 83+920), Traffic 1msa, CBR 5%	Sub Base Granular Base Wearing Course: DBST in lieu of PC	280* 150 14/20mm and 10/14mm aggregates
Bijayapur (km 83+920) to Seti Bridge (km 88+595), Traffic 1msa, CBR 5%	Sub Base Granular Base Wearing Course: DBST in lieu of PC	280* 150 14/20mm and 10/14mm aggregates

* Note: DoR Pavement Guidelines does not provide details on traffic less than 1 msa and CBR value in excess of 10

9.3.2 Final Pavement Structure

The final pavement structure and their respective thickness for main carriageway and service roads are shown in Table 9.4, Table 9.5 and Table 9.6. Any widening would also have the same thickness in addition to new granular fill to a depth as described in Chapter 9.4.

Pavement thickness for service roads from DoR Pavement Design Guidelines is generally comparable with those proposed by TRL Road Note 31; hence TRL Road Note 31 has been followed.

The stretch of two lane road from Mugling to km 3+900 has been proposed to by TRL method to have a sub base of 200mm, base course of 250mm with DBST.

Table 9.7(a): Pavement Structure from Mugling to Abu Khaireni (km 8+400)

Chainage	Layer Thickness	Remarks
0+000 (Mugling) to 3+900 Double Lane Capacity	Chart 1 of TRL Road Note 31 Base: 200 Sub Base: 250 Surface: DBST	
km 3+900 to km 8+400 (Abu Khaireni Bazaar end)	Base 200 mm Sub Base 250 mm Surface: DBST	Refer to Table 9.4, 9.5 and 9.7(c) for details

Table 9.7(b): Pavement Structure from Abu Khaireni to Seti Bridge (km 88+197)

Chainage	Layer Thickness	Remarks
Abu Khaireni (km 8+400 to Damauli East (km 40+300)	Base Course 200 mm Sub Base 325 mm Surface: DBST	Refer to Table 6.4, 6.5 and 6.7(c) for details. No capping layer.
Damauli West to Khairenitar (km 40+300 to km 65)	Base Course 200 mm Sub Base 325 mm Surface: DBST	Refer to Table 6.4, 6.5 and 6.7(c) for details. No capping layer.
Khairenitar to Seti Bridge (km 65 to km 88+595)	Base Course 200 mm Sub Base 325 mm Capping Layer: 300mm Surface: DBST	Refer to Table 6.4, 6.5 and 6.7(c). Capping layer required from km 62+860 to 66+387 and again from km 70+500 (Kotre) till Seti Bridge.

Table 9.7(c): Pavement Structure for Service Roads

Chainage	Layer Thickness	Remarks
Dumre Bazaar (km 23+410 to km 23+950)	Base:150 mm Sub Base:175 mm Surface: DBST	Refer to Table 6.5 for Details. No capping layer for service roads
Damauli Bazaar (km 40+300 to km 41)	Base:150 mm Sub Base:200 mm Surface: DBST	Refer to Table 6.5 for Details. No capping layer for service roads
Khairnitar (km 61+320) to Thati Bazaar (km 66+500)	Base:150 mm Sub Base:200 mm Surface: DBST	Refer to Table 6.5 for Details. No capping layer for service roads
Kotre Bazaar (km 70+120 to km 70+500)	Base:150 mm Sub Base:200 mm Surface: DBST	Refer to Table 6.5 for Details. No capping layer for service roads
Gagangauda (km 74+400) to Sanik Basti (km 76+450)	Base:150 mm Sub Base:200 mm Surface: DBST	Refer to Table 6.5 for Details. No capping layer for service roads
Bhandarik (km 76+500) to Bijayapur (km 83+920)	Base:150 mm Sub Base:200 mm Surface: DBST	Refer to Table 6.5 for Details. No capping layer for service roads
Bijayapur (km 83+920) to Seti Bridge (km 88+595)	Base:200 mm Sub Base:225 mm Surface: DBST	Refer to Table 6.5 for Details. No capping layer for service roads

The final adopted Pavement thickness layers in design for main carriageway and service lane in Mugling Pokhara has been tabulated below:

Pavement Details in Main Carriageway (Pavement surface=DBST)					
SN	Locations		Capping Layer	Sub Base	Base Course
	From	To	(mm)	(mm)	(mm)
1	0+000	4+000	0	250	200
2	4+000	12+000	0	250	200
3	12+000	18+000	0	325	200
4	18+000	40+000	0	325	200
5	40+000	61+700	0	325	200
6	61+700	88+583	300	325	200

Pavement Details in Service Road (Pavement surface=DBST)					
SN	Locations		Capping Layer	Sub Base	Base Course
	From	To	(mm)	(mm)	(mm)
1	23+400	23+950	0	175	150
2	40+430	41+400	0	200	150
3	61+700	66+740	0	200	150
4	70+210	70+510	0	200	150
5	74+600	76+940	0	200	150
6	77+010	83+920	0	200	150
7	84+570	88+583	0	200	150

9.4 Drainage

9.4.1 General

Much of the pavement distress observed in between Kotre and Pokhara and in the Khairenitar Dhulegauda section could be attributed to poor drainage. The problems are less acute in the Mugling Khairenitar section.

The problem however could acerbate after pavement widening which would result more concentrated surface runoff from the widened pavement.

9.4.2 Roadside Drains

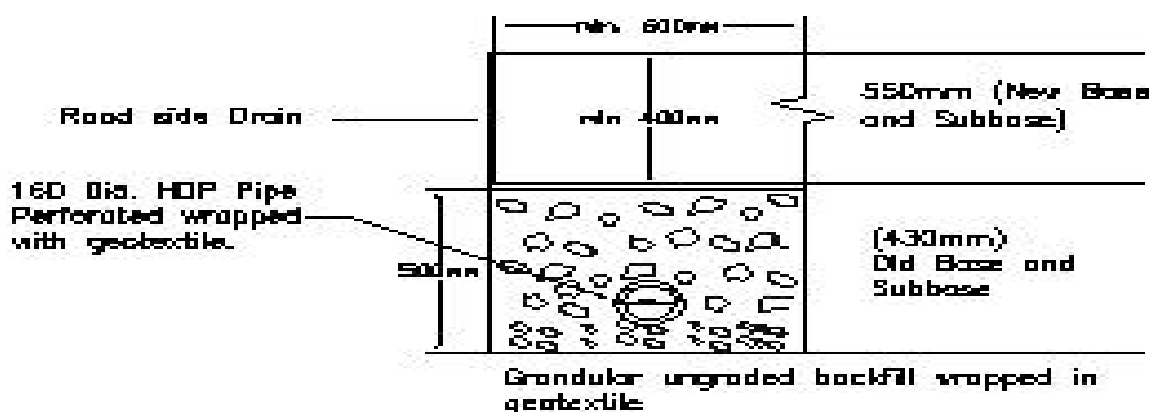
All roadside drains are planned to be lined. For a two lane road and at Abu Khaireni market, the drainage system would essentially consist of two roadside drains. In market areas, these drains would be covered.

In four lane stretches including market areas such as Dumre, Damauli, Khairenitar and Damauli the two roadside drains have been proposed to evacuate storm water. The service roads shall share the same drains as the main pavements thus obviating the necessity of two additional drains in market/built areas at the extreme end of service roads. No drains in the middle of the carriageway.

From Kotre to Seti Bridge, a central drain in addition to the above arrangement would be beneficial. This would require a series of cross drains but would serve to ensure minimum infiltration in the pavement in an area of high intensity rainfall.

9.4.3 Sub Surface Drains

Sub surface drains will be required at areas where natural spring have contributed to pavement undulation and cracking. A typical example is at Damauli some 200m from DoR camp towards Pokhara. Similar distresses were noticed at several bends in between Abu Khaireni and Khairenitar. Sub surface drains are proposed for such areas and preliminary assessment is that a total of 2000m would be required for the entire stretch from Mugling to Pokhara. A typical stretch is laid down below.



9.5 Construction Procedure

9.5.1 General

The pavement would require major widening throughout the stretch from (km 3+900) till Pokhara and limited widening from km 0+000 to km 3+900. Such widening entails construction of new subgrade over the extended portion, building up the road pavement structure till the existing pavement level and then placement of additional layers to cater for the traffic load for the next 10 years.

There is a danger that such widening after construction would result in a longitudinal crack along the extended sections owing to a difference in the Modulus of Resilient value between the old and widened pavement. The next chapter outlines construction procedure to *minimize* such effects.

9.5.2 Construction Procedure for Widening

Pavement / embankment needs to be widened either on one side or both sides of the existing road. Pavement if widened keeping the old pavement intact shall cause differential modulus of resilience between the two (new and old) leading to cracks. So pavement has to be constructed fresh from the subgrade upwards.

Depending upon the road width available / construction requirements, the embankment on one / two sides shall be built upto the subgrade level. Then half of the existing pavement shall be scarified while traffic allowed on other one lane. The existing base / subbase material shall be spread over the whole (old and new) subgrade and compacted. Then the traffic shall be diverted on to the compacted layer and the remaining pavement is scarified and existing base / subbase is spread over the full subgrade (old and new). Any extra material(base / subbase) shall be collected the contractor. This material if found suitable after testing can be reused after engineer's approval. Contractor shall account for the value of this salvaged material by quoting appropriate rates in his bid.

9.6 Conclusion

The upgrading of the Pokhara Mugling Road is to be accomplished by the following:

- I. The pavement may have to be scarified upto subgrade level or as instructed by engineer as per site conditions (limited to 400m for cost estimating purpose)
- II. Capping layer of 300mm is not envisaged for the road stretch from Abu Khaireni to Khairenitar. Capping layer is required from Dhulegauda section (km 62+860 to km 66+387) but not thereafter till Kotre (km 70+500). Capping layer shall however be required from Kotre (70+500) to Seti Bridge (km 88+595)
- III. In certain areas, notably at bends, pavement distress is noticed due to occurrence of natural springs, most of them in between Abu Khaireni (km 8+400) to Khairenitar (km 62+800). Sub surface drains have been proposed for such areas (Chapter 9.4.3). For cost estimate purpose, allocate 2000m.
- IV. Drainage system for two and along four lane stretches without major market/settlement shall have two drains on either side. At major market/settlement areas in between Abu Khaireni and Kotre, it will also have only two drains but of higher discharge capacity
- V. Drainage after Kotre/Majuwa all the way to Pokhara would be better if a drain is placed in the middle to channelize and evacuate the water off the road surface as quickly as possible. Hence in essence this would require three drains, one of them placed along the central median and shall be connected to the roadside drains by a series of cross drains appropriately spaced. This area has high rainfall and such measure would ensure that any standing water does not encroach the level of the proposed capping layer.

10. HYDROLOGY AND DRAINAGE DESIGN

10.1 Introduction

The analysis of the peak rate of runoff, volume of runoff, and time distribution of flow is fundamental to the design of drainage facilities. Errors in the estimates will result in a structure that is either undersized and causes drainage problems or oversized and costs more than necessary. On the other hand, it must be realized that any hydrologic analysis is only an approximation. The relationship between the amount of precipitation on a drainage basin and the amount of runoff from the basin is complex, and too little data are available on the factors influencing the rural and urban rainfall-runoff relationship to expect exact solutions. The solutions proposed for the road are based on the performance of the existing structure over their life, available rainfall data in the vicinity of the project area, rational method of runoff estimation and best professional judgement of the hydrologist. Therefore, these solutions should be considered reasonably good to serve our objectives as outlined below.

10.2 Objective

The main objectives of the hydrological and drainage studies for the project roads are as follows:

- to identify the required formation levels of the roads so that the road embankments are not inundated during peak flooding in the area, where the road runs close to a river or natural drainage channel or is in low lying area in embankment, to assess the cross drainage requirements, and to check required waterway openings through the bridges and culverts;
- to identify the requirements for additional drainage structures and roadside drains in order to keep the road free from water logging during heavy rains; and
- to identify the type and extent of protective measures to be undertaken for structures and road embankments which are vulnerable to river erosion.
- to identify any subsurface drainage requirements in a waterlogged zone.

In the case of Mugling-Pokhara road, which is one of the important strategic highways from the view point of tourism development, the inventory of the existing drainage situation including identification of sections critical from drainage view point is the main basis for new design.

10.3 Project Area Description

The Road starts from Mugling Bazaar, and passes through various towns and settlement areas and ends at Prithvi Chowk of Pokhara city, a major tourist hub of Nepal. This is the vital road link and has strategic importance to boost tourism industry of the country as well as connectivity to western hilly region. The geometric details and other relevant description of the road may be found in other chapters of this report including the road safety chapter. Here, a brief description of the drainage characteristics of the project area is presented.

The alignment follows river valleys of Marsyangdi, Madi and Seti Rivers, which are the major tributaries of the Gandaki River system. Pokhara valley receives the highest rainfall in the entire country and is referred to as the Cherapunji of Nepal. The average annual rainfall at Lumle station, which is directly above the Pokhara valley, is around 4500 mm. The very high rainfall zone extends right up to Khairnitar, whereas the overall alignment should be considered as high rainfall area for the purpose of designing the drainage facilities.

A google image of the road corridor area is shown as Figure 10.1 below.

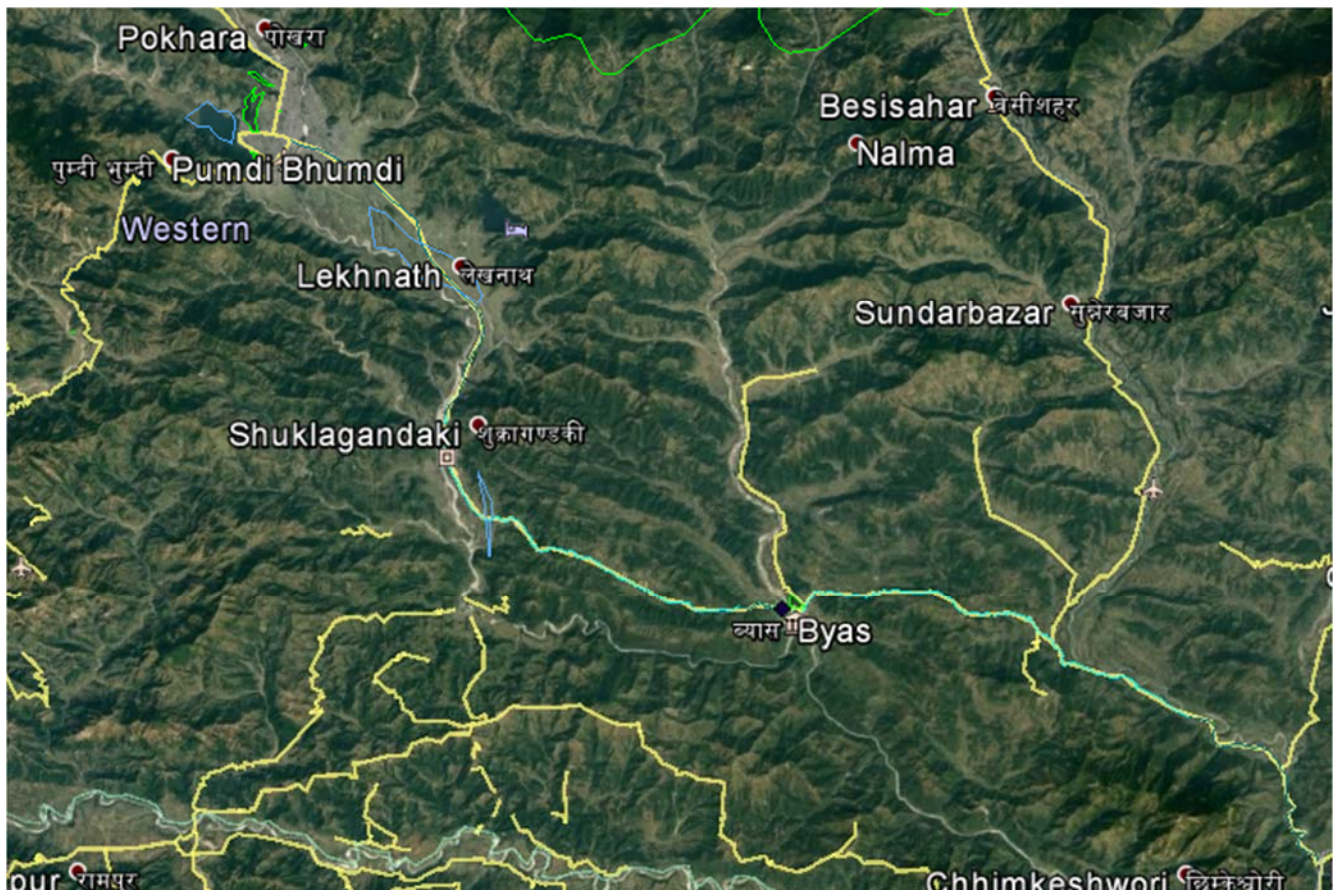


Figure 10.1: The Project Area

10.4 Hydrological Design Criteria

10.4.1 Design Frequency

Design frequency is the return period of flood for which the structure is designed. DOR bridge standards require all permanent bridges to be designed for 100-year return period. Based on best engineering practices and DOR standards, the following design frequencies are selected for the Project Road:

Table 10.2: Proposed Design Frequency

S.N.	Type of Structure	Design Frequency (years)
1	All permanent Bridges (Any cross drain structure with length more than 6.0m)	100
2	Culverts (Any cross drain structure with length less than 6.0m)	50
3	Side Drains	25

Side drains are normally designed for 10 to 15 year return period, however 25 years has been selected for the current road in order to provide more level of confidence in the estimates of design discharge keeping in view the uncertainties inherent in the process and also to address the climate change impacts. Additionally, this road area being in the high rainfall zone, the higher frequency design discharge will also provide for uncertainty of estimates.

10.4.2 DoR Standards for Bridges

Chapter 7 of the Bridge Design Standards of DOR classifies the type of bridges based on total length and spans as follows:

- **Culvert** : Length up to 6 m

- **Minor Bridge** : When length < 50 m (with span < 25 m)
- **Major Bridge** : When span >25 m or length >50 m(with smaller spans)
- **Special Bridge** : Bridges that require special design considerations such as the concrete girder bridges with >50m span, steel trusses > 100m span, arch bridges, suspension bridges, cable-stayed bridges and other nonstandard bridges.

Similarly Ch. 8 of the Standards has the following provision for minimum freeboard for bridges.

Table 10.2: Recommended Freeboard

S.N.	Discharge (m ³ /s)	Minimum Free Board, mm
1	Less than 200	1000
2	201-500	1200
3	501-2000	1500
4	2001-5000	2000
5	5000 and above	More than 2000 (depending on the reliability of the available data for the calculation of discharge)

10.5 Design of Culverts and Road Side Drain

10.5.1 Culverts

10.5.1.1 General

A culvert is a cross drain structure designed to convey surface water across or from the highway right-of-way. Most highway design standards including Nepal Road Standards (NRS) define a culvert as a cross drain structure with span less than 6.0m. Based on its structural form or shape a culvert could be any of the following types:

- I. Pipe Culvert
- II. Box Culvert
- III. Slab Culvert

A blanket policy decision is to dismantle all minor cross drain structures including minor bridges and they will be replaced by a new structure of adequate opening area to pass the design flood. As mentioned above, the weightage has been placed more on the performance of the existing structure than the hydrological estimation while deciding the spans of the culverts and minor bridges. The following sizes of structures are proposed.

- All pipe culverts (which are all less than diameter 1.20m) and all slab culverts of span less than 1.20m replaced by RCC box culvert of size 1.20mx1.20m
- Slab culverts are proposed of the spans: 2.0, 3.0, 3.5, 4.5, 5.0 and 6.0m
- Any cross drain structure with total span length between 6.0m and 25.0m will be replaced by RCC Girder Bridge or RCC Slab Bridge.

The hydraulic design of culverts has been completed using an EXCEL spread sheet using Rational formula for discharge calculation and Manning's equation for flow calculation.

10.5.1.2 Hydraulics of Culvert Design

Hydraulically, based on the conditions of flow a culvert is either inlet control or outlet control.

Inlet Control – Inlet control occurs when the culvert barrel is capable of conveying more flow than the inlet will accept. This typically happens when a culvert is operating on a steep slope. The control section of a culvert is located just inside the entrance. Critical depth occurs at or near this location, and the flow regime immediately downstream is supercritical.

Outlet Control – Outlet control flow occurs when the culvert barrel is not capable of conveying as much flow as the inlet opening will accept. The control section for outlet control flow in a culvert is located at the barrel exit or further downstream. Either subcritical or pressure flow exists in the culvert barrel under these conditions. Most culverts in the Terai with flat slope will fall under this category.

The hydraulic calculations methods of each type of culverts are given in section 7.5.1.4

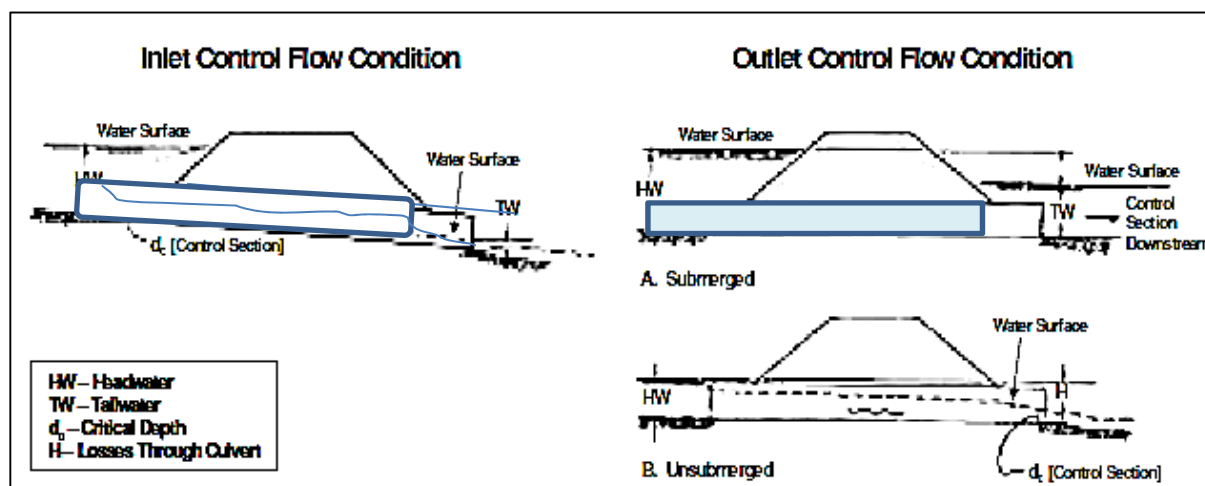


Figure 10.2: Culvert Flow Conditions (adapted from USDOT, 1985)

10.5.1.3 Hydro-meteorological Data, Design Frequency and Design Discharge

As the culverts are normally provided on ephemeral small streams, natural gullies with no flows during dry months and just an appropriate location to serve as a breaking point for the longitudinal road side drain, or as balancing culverts on plain area, none of the culvert locations are gauged and hence have no hydrological data. Therefore, the design discharges are calculated using Rational Formula for which an Intensity-Duration-Frequency (IDF) curve has been developed using the 24-hour extreme rainfall data of a relevant rainfall station for the Project roads as below.

Table 10.3: Rainfall Stations and Data Used

S.N.	Rainfall Station	District	DHM Index No.	Period of Data used
1	Damauli	Tanahu	817	1971-1998
2	Khairanitar	Tanahu	815	1974-1998
3	Pokhara Airport	Kaski	804	1968-1998

The 24-hour rainfall data and the developed IDF curves using the data of Pokhara Airport is given in **Annex 10.1**. This station gives the higher design rainfall value of the three stations and hence has been selected to for a conservative design.

A design frequency of 50-year flood has been selected and the design discharge is calculated using the following steps of calculations.

- Delineate catchment area and measure the area in km^2
- Find the longest flow path and the average slope of the stream
- Using the following Kirchoff's formula (equation 7.1) calculate time of concentration
- Find the 50-year rainfall intensity corresponding to the duration equal to the time of concentration T_c

- Assuming an appropriate value of the runoff coefficient C, find out the design discharge using the rational formula (equation 7.2).

Kirchoff's formula for T_c

$$T_c = .019L^{0.77} S^{-0.385} \text{-----(7.1)}$$

Where, T_c = time of concentration in minutes,

L = longest flow path along the channel in meters

S = average slope of the flow path

Rational Formula for discharge calculation

$$Q = 0.278 * C * I * A \text{-----(7.2)}$$

Where, Q = design discharge in m^3/s

C = runoff coefficient (value lying between 0 to 1 to be judiciously selected)

I = rainfall intensity mm/hour

A = catchment area in km^2

10.5.1.4 Design Procedure

The following design procedure requires the use of inlet and outlet control nomographs. (Annex 10.2), which also require unit conversion because they are in Imperial Units.

Step 1: List design data

Q = discharge (m^3/s) L = culvert length (m)

S = culvert slope (m/m) TW = tailwater depth (m)

V = velocity for trial diameter (m/s) K_e = inlet loss coefficient

HW = allowable headwater depth for the design storm (m) D = pipe diameter (m)

Step 2: Determine trial culvert size by assuming a trial velocity 1.5 to 2.5 m/s and computing the culvert area, $A = Q/V$. Determine the culvert diameter.

Step 3: Find the actual HW for the trial size culvert for both inlet and outlet control.

For inlet control, enter inlet control nomograph with D and Q and find HW/D for the proper entrance type.

Compute HW and, if too large or too small, try another culvert size before computing HW for outlet control.

For outlet control enter the outlet control nomograph with the culvert length, entrance loss coefficient, and trial culvert diameter.

To compute HW, connect the length scale for the type of entrance condition and culvert diameter scale with a straight line, pivot on the turning line, and draw a straight line from the design discharge through the turning point to the head loss scale H. Compute the headwater elevation HW from Equation 7.3.

$$HW = H + h_0 + LS \text{-----}(7.3)$$

where: H =head loss, m

$h_0 = \frac{1}{2}(\text{critical depth} + D)$ or tailwater depth, whichever is greater (maximum = D), m

L = culvert length, m

S = culvert slope, m/m

10.5.2 Summary of Culverts Proposed in the Project Roads

The summary of proposed culverts is given in the following Table and the detailed chainage wise list has been presented as **Annex 10.3 and cross section wise drainage list are given in Table below**

Table 10.4: Summary of Proposed Cross Drain Structures

S.N	Type and Span of CD Structure	Total Number
1	Slab Culvert of 1.2x1.2m	62
2	Slab Culvert of 2.0x2.0m	125
3	Slab Culvert of 3.0x3.0m	85
4	Slab Culvert of 4.0x3m	15
5	Slab Culvert of 5.0x3m	2
10	Slab Culvert of 6.0x3m	5
11	RCCslab, and Box culvert of 7.0 to 17.0m(minor Bridges)	31
	Total	325

Table 10.4(a): Summary of Location and No. of proposed cross drainage in 2-lane and 4-lane section

Road cross sections	Slab culverts					Remarks
	2m span	3m span	4 m span	5m span	6m span	
Double lane						Extend the existing slab culvert or replace with new one as per condition of existing culvert to fit in the section road.
Width of road = 7m	0					
Width of road = 9m	1	6				
Width 12.5m		4	1			
Four lane						
Width 18.5 m	90	65	11	2	3	
Width 23 m	11	5				
Width 43 m			1			
Width 47 m	23	5				
length	3008	1656.5	259	37	149.5	
No	125	85	13	2	5	

Road width of different section	7m	9m	12.5m	18.5m	23m	47
Box culvert 1.2mX1.2m	0	3	1	44	7	7
Existing Pipe culverts of 900mm dia has been proposed to replace with box culvert of 1.2mx1.2m						

10.5.3 Side Drains

10.5.4.1 Design Objective

The primary function of a road side drain ditch is to collect and convey surface water along the highway right-of-way until it can be drained away from the roadbed. The ditches are designed to carry the design runoff and to accommodate excessive storm water flows with minimal highway flooding or damage. The catchment area includes the road surface area and the adjoining hill slope or the adjoining rooftop and footpath area if the houses are adjoining the footpath. The segment length of the drain is from cross drain to cross drain or from summit point to the next cross drain.

10.5.4.2 Design Criteria

The size of the drain is designed such that it is adequate enough to carry the design discharge. However, the shape of the ditch is designed based mainly on the following consideration:

- Safety to road traffic (adopt shallow and wide drain avoiding deep and narrow) if not covered
- Life cycle cost
- Ease of construction
- Ease of maintenance
- Aesthetics

Thus the governing consideration in deciding the drain shape has been to keep the depth less than 35 cms if left uncovered and the back-slope as flat as permitted by the road width available. However, the drains in the 4-lane section of the road will be necessary mostly in the urban and semi-urban areas and hence the type of drain proposed is a precast concrete U-drain fully covered by a grated concrete cover slab.

10.5.4.3 Design Method

The design of the side drain was completed for each of the roads in the following steps:

- Drain segments are limited within 300 meters by installing additional culverts at appropriate locations;
- The drain section shape is decided based on the criteria listed in the previous section;
- Other design data such as start and end chainage of drain, length, catchment area, runoff coefficient, rainfall intensity and the flow area, hydraulic radius, top width, side slopes and longitudinal slopes are filled in the design spread sheet;
- Manning's equation and the continuity equation as follows are used to check the conveyance capacity of the trial drain size:

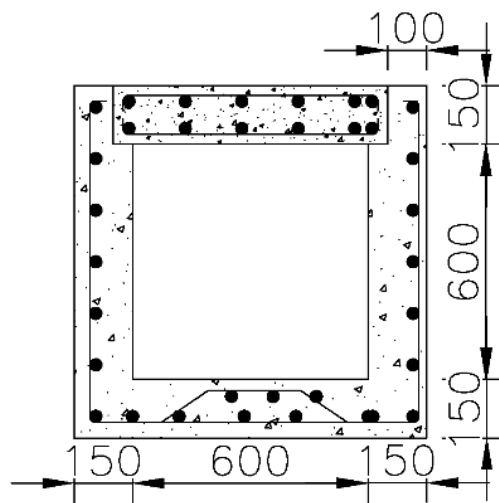
$$V = 1 / nR^{2/3} S^{1/2} \text{ and, } Q = V * A \text{ -----(7.4)}$$

- If the size is inadequate, the depth or bottom width of the drain is adjusted such that the design discharge is safely passed through it.

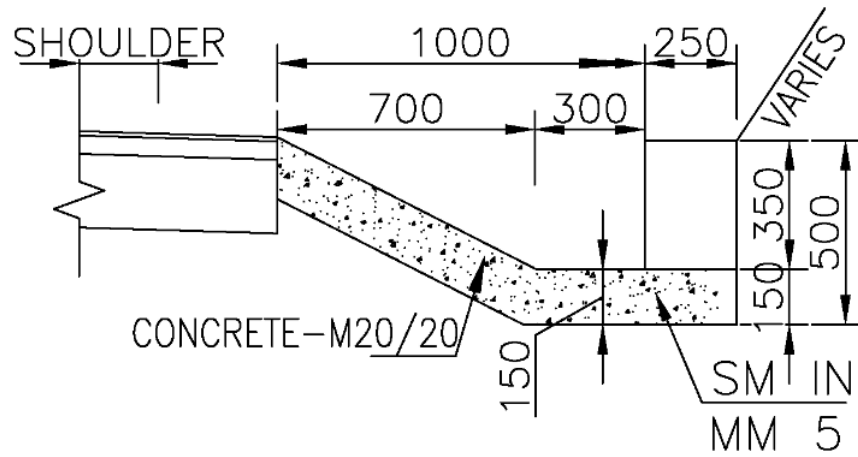
10.5.4.4 Proposed Drain Section

The total length of the highway is divided into the following four sections:

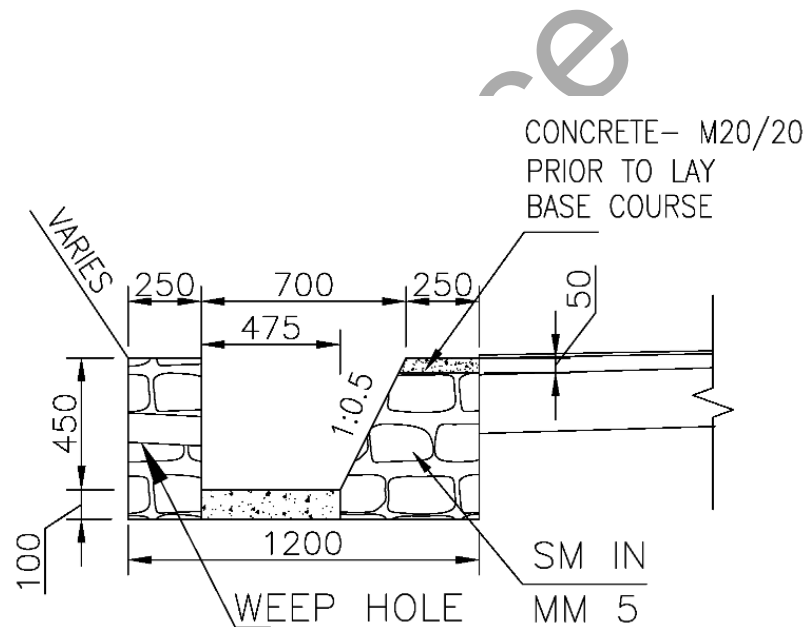
- I. Section running through double lane sections and rural and jungle area B4 type drain is provided in hill side It has vertical in hill side and concrete slope to the road side , the total length of drain is 1250mm. and height 50mm
- II. In settlement area and market area with service lane, footpath M2(rectangular concrete drain of type drain with one meter wide and depth 600mm depth has been provided
- III. In four lanes section from km 61 +700 to 86 +583km with all feature, service road, footpath shoulder 2.5/2.5m, E1 type drain has been proposed after main carriage way to both side to cater all surface water from carriageway and service road.
- IV. In the section from km 70 + 570 to 84+440 where no service road, B1 type drain has been proposed on those sections. The figure and dimension of all type of drain is given below:



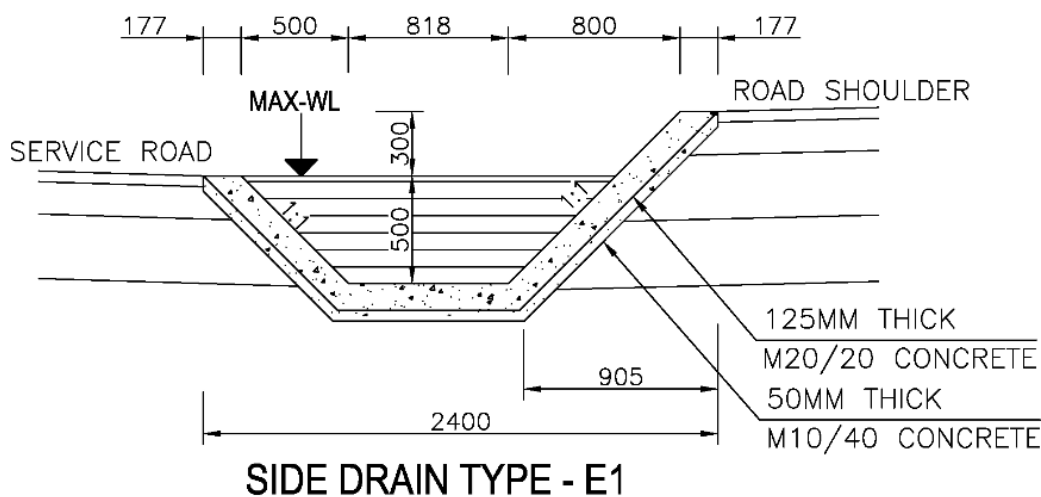
RCC PRECAST DRAIN
TYPE - M2



SIDE DRAIN TYPE - B4



SIDE DRAIN TYPE - B1



Type of drain	Left side (m)	Right side (m)	Total
B4	41060	17550	58610
M2	3040	3040	6080
B1	2430	6540	8970
E1	18680	18680	37360
Total	65210	45810	111,020.00

Figure 10.3: Side Drain Types

As has been repeatedly mentioned in the foregoing sections, the area falls in a high rainfall zone of the country, however with adequate slope and hardly any problem for drainage outfall, the main problem of designing side drain is to provide adequate capacity. The clue has been taken from the existing drains and the sizes are slightly increased to accommodate runoff from the additional impervious surface of the widened road. The drains sections thus designed are shown in the quantity estimation sheet.

10.5.4.5 Quantity of Side Drain Lengths

The quantities of each type of drain are calculated by preparing a schedule of the type of drains provided in each section of the road. Unit price are worked out as per the norms of the GON.

10.5.4 Subsurface Drains

Wherever deemed necessary a subsurface drain with a semi perforated HDPE pipe of size 150mm diameter has been proposed as shown in the following drawing.

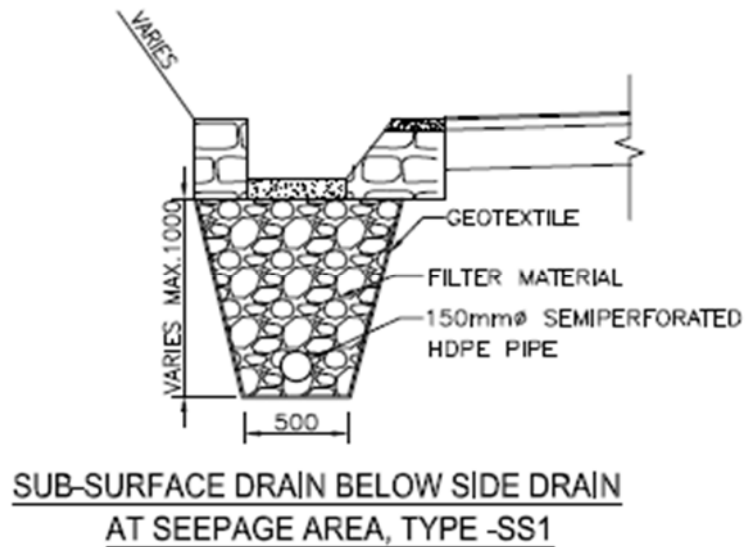


Figure 10.4: Subsurface Drain

10.5.5 Catch Drains

In a steeply sloping areas where landslides are frequent occurrences or the slope stability is a likely issue, catch drains will be provided near the crown of the landslide to divert water away from the unstable area. A trapezoidal masonry drain with 0.50m bottom width, 0.50m depth and 1:1 side slopes is proposed at such critical locations.

10.5.6 Drainage Outfall

Outfall of all culverts will be in a natural drain. If there is no natural drain nearby, it should be in areas where private property is least impacted.

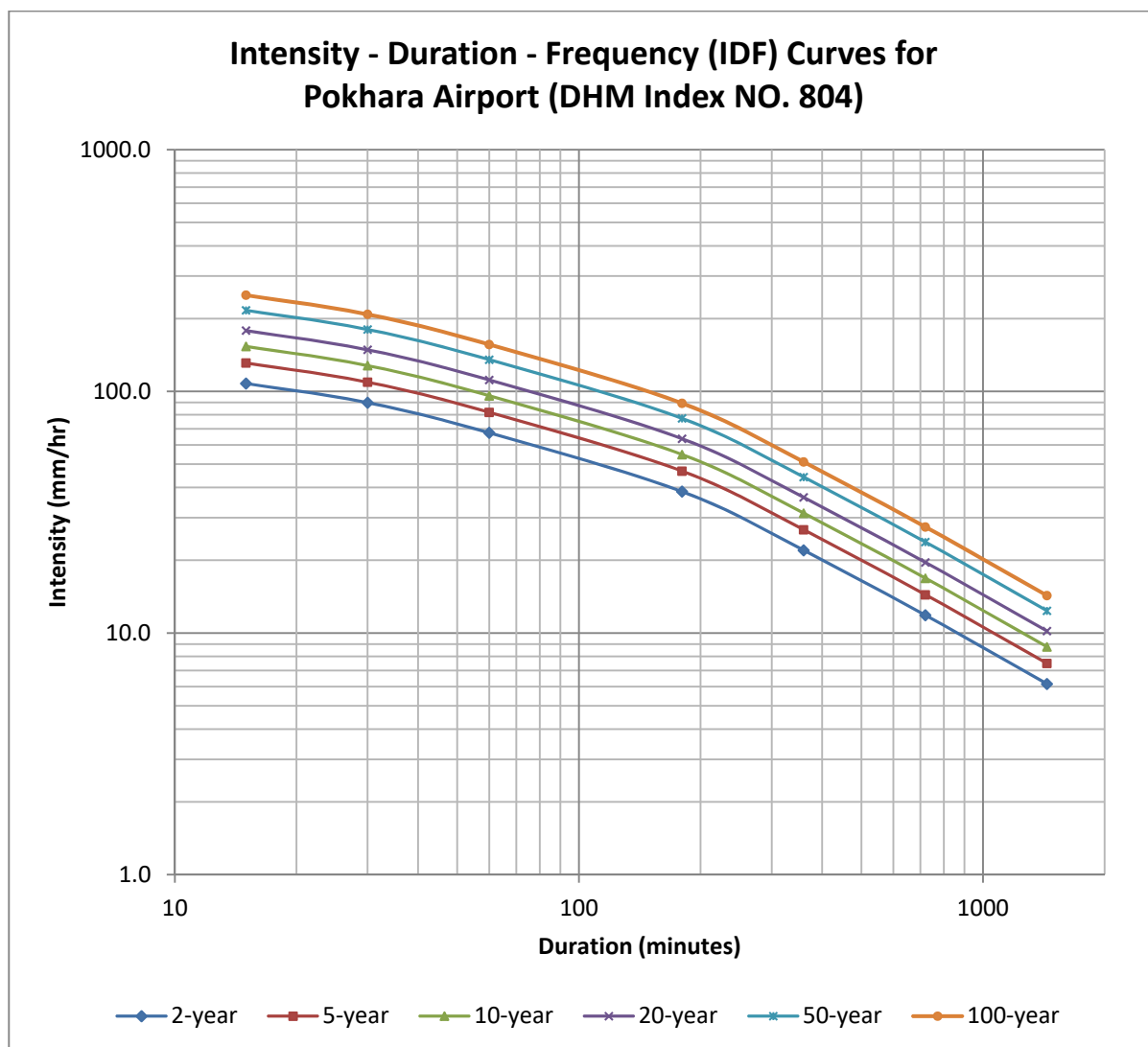
10.5.7 Riverbank Protection Works

At locations where the road runs close to river bank, gabion river protection works are proposed for protecting the road valley slope from possible toe cutting.

ANNEX 10.1

24-h Rainfall Data

station	804	815	817
Name	Pokhara Airport	Khairanitar	Damauli
Year			
1968	87.0		
1969	44.2		
1970	156.0		
1971	101.0	23.5	
1972	158.2	137.0	
1973	173.4	131.5	
1974	204.8	118.4	384.2
1975	171.2	119.3	50.0
1976	181.8	104.3	93.1
1977	204.2	91.6	82.0
1978	188.1	133.3	110.0
1979	277.6	157.6	115.0
1980	159.2	162.7	190.0
1981	168.6	114.2	265.0
1982	164.2	128.5	100.0
1983	169.2	241.9	210.0
1984	171.5	136.2	135.0
1985	235.4	91.1	98.0
1986	143.2	108.0	100.0
1987	196.4	166.0	197.0
1988	186.6	168.0	128.0
1989	168.3	140.7	143.0
1990	157.9	120.0	79.0
1991	167.4	90.9	81.0
1992	148.1	142.5	78.0
1993	145.2	162.2	87.2
1994	199.2	173.3	79.0
1995	228.0	182.0	85.0
1996	168.0	100.1	120.5
1997	179.0	118.5	104.0
1998	173.0	134.0	123.0



11. GEOTECHNICAL INVESTIGATIONS AND SOLUTIONS

11.1 Methodology

Geotechnical studies and investigations are carried out to determine generalize stabilization characteristics of slope, embankment and retaining structure along with the estimation of bearing capacity of soil strata along Mugling-Pokhara section of Prithvi highway.

Within the scope of geotechnical study, for the better results, following stepwise procedures are followed:

- Understanding of the general geology of the project area
- Collection of available soil and slope data in the vicinity of road area
- Verification of cross slope, stability conditions during field visit and with survey data
- Bearing capacity analysis for high retaining structure using DCPT test
- Standard cross slope analysis for embankment and cut slope

11.2 Terrain / Geology

As in the other parts of the Himalaya, geologically Nepal can be divided into the following five major tectonic zones from south to north, each zone characterized by their own lithology, tectonics, structures and history.

1. Terai zone
2. Churia zone/Siwaliks (Sub Himalaya)
3. Midland and Mahabharata zone (Lesser Himalaya)
4. Higher Himalayan zone
5. Tethys zone

The Mugling-Damauli-Pokhara road stretch passes through numerous terraces consisting of recent alluvial materials and along the moderate to gentle hill slope with a few exceptions where the road passes through rocky terrain consisting vertical rocky cliff. The hill slope is either covered with medium thick to thick residual to colluvial deposits or slope scree material, from Khairanitar onwards up to the Seti river bridge the alignment passes through Pokhara valley floor characterized by recent quaternary Pokhara Valley sediments consisting of slightly to moderately cemented silty/sandy gravel

11.3 Geotechnical assessment of alignment

Geological Map of Nepal, 1997 best depicts the regional geology of the alignment. Almost all of the alignment passes through Lesser Himalayan Metasediments belonging to Nuwakot and Kunchha Group. The Nuwakot Group consists of phyllites, sandstones, quartzite and calcareous sandstone along with limestone, dolomite and slates while Kunchha Group consists of phyllites, metasandstone, and quartzite. Beside some part of the alignment especially the alignment near Pokhara Valley passes through quaternary, slightly to moderately cemented fluvial/fluvio-glacial gravels, conglomerates and lacustrine clay deposit.

Dynamic cone penetrometer tests (DCPT) were conducted on a site to classify soil type and to evaluate bearing capacity using correlation with a penetration value on particular location and grouped accordingly.

In general, soil have good bearing capacity and fair to stable nature, except on small stretch around some hilly moist area. The types of soil encountered are classified along with generalize slope are presented in annex 9.

For the design of retaining structures, geotechnical parameters like unit weight of walls, friction factor, unit weight of compacted materials, allowable bearing capacities for different types of soil, type of back fill for retaining walls, values of coefficient for horizontal load due to uniform surcharge etc. are taken from tables given in Mountain Risk Engineering Manual (ICIMOD).

Sufficient drilling works were carried out at major bridges and foundation is fixed based on proper combination of designed load and capacity of underlying soil.

11.4 Design of Slopes/Embankments

11.4.1 Slope Stability

Slope fails because of its material shear strength on the sliding surface is insufficient to resist the actual shear stresses. Factor of safety is a value that is used to examine the stability of slopes. For FoS values greater than 1 means the slope is stable, while values lower than 1 means slope is unstable. In accordance with the shear failure criteria, the factor of safety against slope failure is simply calculated as:

$$\text{FoS} = \tau / \tau_f$$

Where τ is the shear strength of the slope material, which is calculated through Mohr-Coulomb criterion as:

$$\tau = C + \tau_n \tan \phi$$

And τ_f is the shear stress on the sliding surface. It can be calculated as:

$$\tau_f = C_f + \tau_n \tan \phi_f$$

Where the factored shear strength parameters C_f and ϕ_f are:

$$C_f = C / \text{SRF}$$

$$\phi_f = \tan^{-1} (\tan \phi / \text{SRF})$$

Where, SRF is strength reduction factor. This method has been referred to as the 'shear strength reduction method'. To achieve the correct SRF, it is essential to trace the value of FoS that will just cause the slope to fail.

Movement in natural and artificial (man-made) slopes

In all slopes, there exists an inherent tendency to degrade to a more stable form (ultimately towards horizontal) and in this context instability is constructed as the tendency to move, and failure as an actual mass movement (Roy, 2001). The main forces that lead to the instability are both gravity and seepage, while there is resistance towards the failure consequential mainly from a combination of slope geometry or shape and the shear strength of the soil or rock mass itself.

Mass movement can be defined as the result of a shear failure along an internal surface or when there are general decreases in effective stress between particles.

Slides

In this form of movement, the mass remains basically intact while sliding along a definite failure surface. This form consists of two structural sub-divisions:

(a) Rotational slips occur in homogeneous soft rocks or cohesive soils. The movement takes place along the curved shear surface in such a way that the slipping mass slumps down near the top of the

slope and bulges up near the toe (Roy, 2001). Details of this mode of movement can be seen in Figure 11.1.

11.4.2 Slope Stability Analyses

SLOPE/W Model

The stability of the Active sections was evaluated using limit equilibrium methods as implemented in the SLOPE/W software, which is available from GEO-SLOPE International. Ltd. of Calgary, Alberta, Canada (www.geo-slope.com). Analyses were completed for static loading and long-term steady-state seepage conditions. SLOPE/W is a special-purpose computer code designed to analyze the stability of earth slopes using two-dimensional, limit equilibrium methods. With SLOPE/W, the distribution of pore water pressures within the earth mass can be mapped directly from a SEEP/W solution.

Limit Equilibrium Methods in SLOPE/W

Limit equilibrium methods for evaluating slope stability consider the static equilibrium of a soil mass above a potential failure surface. For conventional, two-dimensional methods of analysis; the slide was above an assumed failure surface is first divided into vertical slices, then stresses are evaluated along the sides and base of each slice. The factor of safety against a slope failure (FS_{slope}) is defined as:

$$\text{FoS slope} = \text{shear strength of soil} / \text{shear stress required for equilibrium}$$

Where the strengths and stresses are computed along a defined failure surface located at the base of the vertical slices. The shearing resistance along the potential slip surface is computed, with appropriate Mohr-Coulomb strength parameters, as a function of the effective normal stress.

Spencer's solution procedure (Spencer 1967; USACE 2003; Duncan and Wright 2005), which satisfies all of the conditions of equilibrium for each slice, was used in this study. Spencer's procedure computes FS_{slope} for an assumed failure surface. A search must be made to find the critical slip surface corresponding to the lowest FS_{slope}. Both circular and noncircular potential failure surfaces can be evaluated.

Analysis Approach

The slope stability analyses were performed using SLOPE/W 2007 on the sections of roads. SLOPE/W incorporates various search routines to locate the critical slip surface. For the analyses presented here, "Entrance and Exit" method was employed. The distribution of pore water pressures obtained from the SEEP/W model was used in the analysis.

Selection of Shear Strength Parameters

The stability analyses presented in this report focus on static steady state seepage conditions as well as earthquake or other dynamic loads. For these conditions, soil unit weights and drained strength parameters (c' and ϕ') are needed.

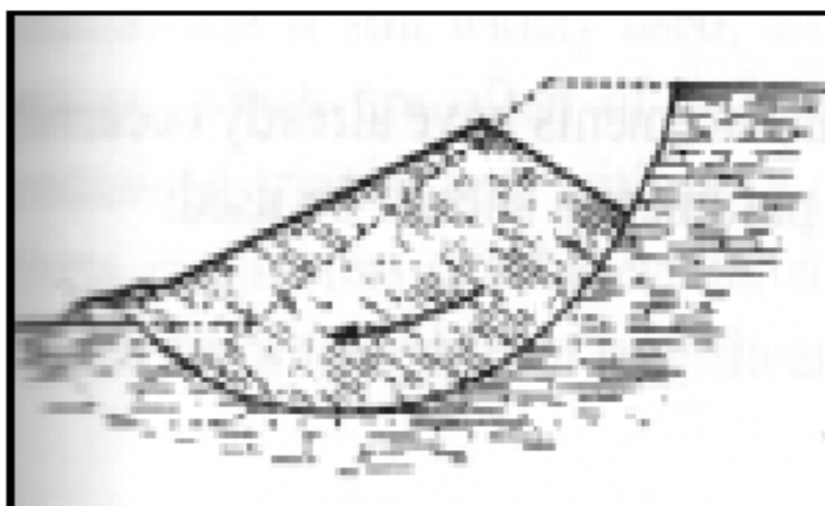


Figure 11.1: Rotational Slide (Roy, 2001)

The drained shear strength parameters used for the clayey and sandy foundation materials were derived using standards, along with consideration given to standard penetration test data and laboratory classification test data. In addition, the strength parameters selected were further refined or confirmed by comparisons with the strength parameters listed in the historical reports. Representative strengths for each horizon were selected using the methodology outlined in the US Army Corps of Engineers, Engineers Manual EM 1110-2-1902 as a guide.

Some critical sections were selected and analyzed based on tested result and provided designed slope with best interpolation.

Soil samples abstracted from field were grouped based on visual classification and tested for shear parameters are as follows;

Table. 11.1 Tested result of Soil sample for Shear Strength Parameters

Chainage, Km	Soil Description	Unit Weight, KN/m ³	Estimated Cohesion of soil, kPa	Angle of Friction, °
9+900	Silty Sand to gravel cobble followed with weathered and fissured rock	20	10	32
23+020	Conglomerates	19	15	32
40+310	Silty Sand to gravel mixed with conglomerates	19	10	32
51+450	Brownish/red Silty Sand Mix. Gravel	19	15	33
84+670	Silty Sand to gravel cobble followed with weathered and fissured rock	20	15	33

Slope Stability of Embankment

Final gradient of filled slope is to be decided according to slope stability that takes into account of the formation and strength of the bearing ground. Slope gradient must be redesigned if there were changes during actual construction (Figure 11.2).

General standard for roadway embankment slope from the ground level is as shown in the figure 11.2. Slope of 1:1.5 for height less than 5m, 1:1.8 for height 5-10 m, 1:2 for height 10-15 m and 1:2.3 for height more than 15 m are required. 1.5 m wide benching terrace should be created with standard 5% outward slope for every 5 m height of embankment.

Standard safety factors for compaction of fill slopes will conform to following provisions given in the Table 11.3 will apply.

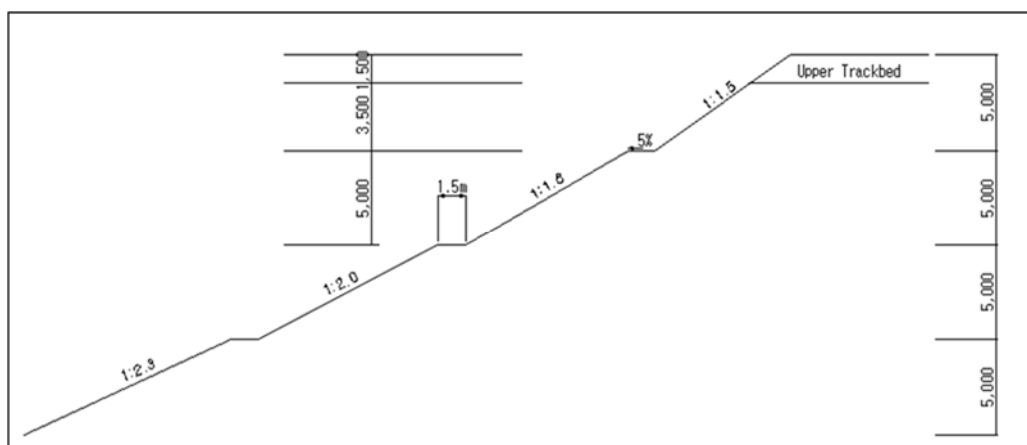


Figure 11.2: Typical output from analysis of embankment slope

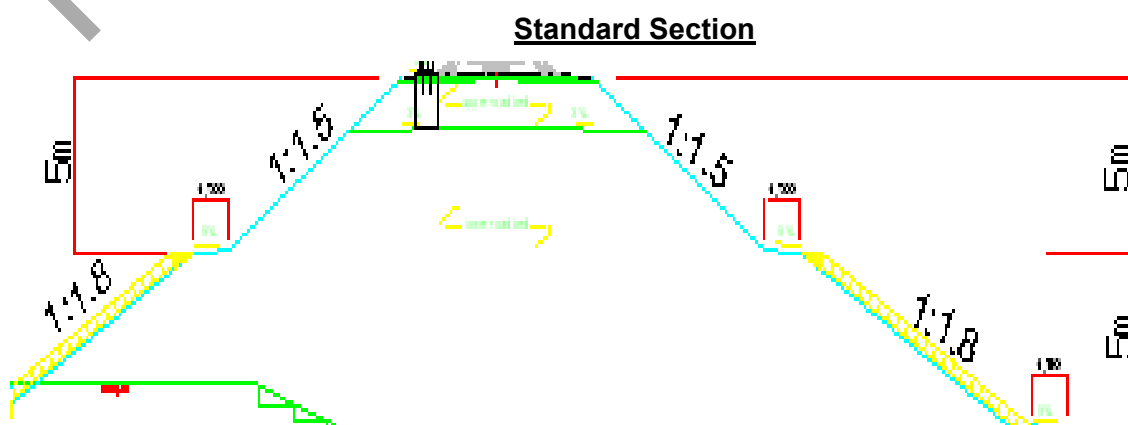
Table 11.2: Shear Strength Parameters for Stability Analysis

Material	Unit Weight, KN/m ³	Cohesion of soil, kPa	Angle of Friction, °
Embankment Soil (valley slope)	19	10	31
Sandy slope soil (hill slope)	19	5	33

Table 11.3: Safety Factor

	Standard Safety Factor	Remarks
Dry season	FS>1.25	· Assume no groundwater exists.
Rainy season	FS>1.15	· There are no special groundwater level conditions for general fill slopes. · On slopes where one side is filled and one side is cut, the safety factor will be analyzed using measured groundwater level or analyzed seepage groundwater level. · Safety factor analysis will take into consideration of the rainfall seepage when there is rainfall seepage.
Earthquake	FS>1.00	· Seismic momentum force acts in horizontal direction from the center of embankment soils. · Groundwater level is the actual measured level or the level determined from seepage analysis.
Short-term	FS>1.00	· In cases of short-term, review safety after one year

Fill slope design should review safety factors for rainy periods when necessary and also meet safety factors during dry periods.



Safety factor will be reduced by 0.1 from the above standard if after analysis strength parameter is found to be not as maximum strength but as residual strength. Safety factor is increased by 0.05 from the above standard if there are fixed structures such as dwelling units or building structures within failure ranges of the slope's upper and lower parts. Separate review is made when there is foundation of a facility within failure range of the slope's upper part. Minimum safety factor of 1.0 is applied when above conditions are applied and checked in duplicate and found the safety factor to be $FS < 1.0$.

Some critical sections were selected and analyzed based on tested result and provided designed slope with best interpolation.

The results of analysis were presented as in following section;

Results of Slope Stability Analysis

Using the strength parameters (c' and ϕ') listed in Table 11.1, configurations were analyzed at various selected cross-sections. Geo-Slope's Slope/W computer program was used for the analysis with pore pressures. Long term (effective stress) steady state seepage conditions were analyzed using Spencer's method. For the Spencer's method analyses, circular failure surfaces with optimization were conducted. The stability analyses focused on the potential for failure along the exterior slope.

Scrutinized parameters of soil elements like composition of soils, soil type, soil strength, permeability, ground - water, the reduction in strength due to the increase of water content, surface water and additional traffic load determine the side slope of excavations and cuttings.

Typical design is presented as follows,

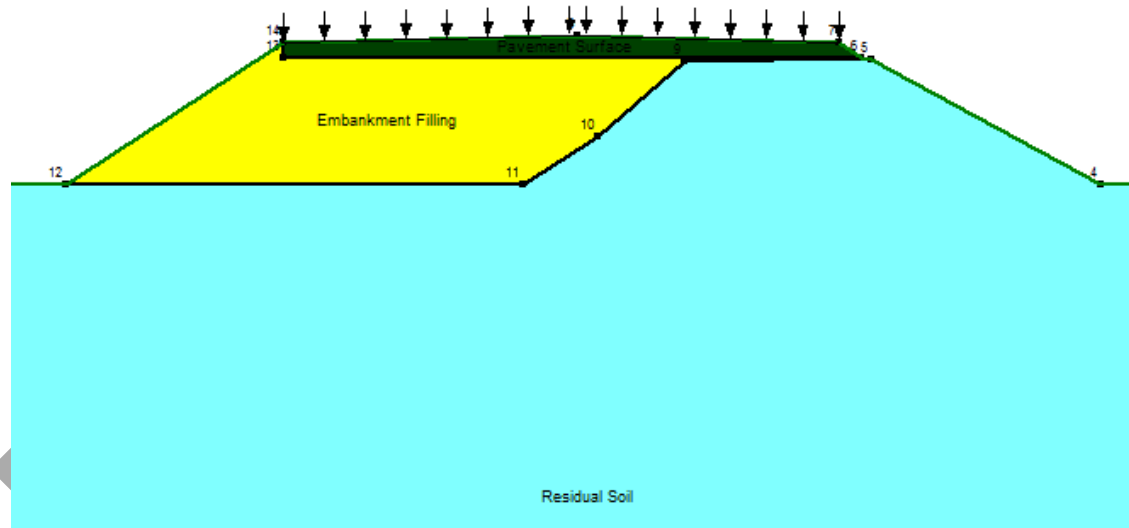


Figure 11.3: Standard design section at Km 51+450

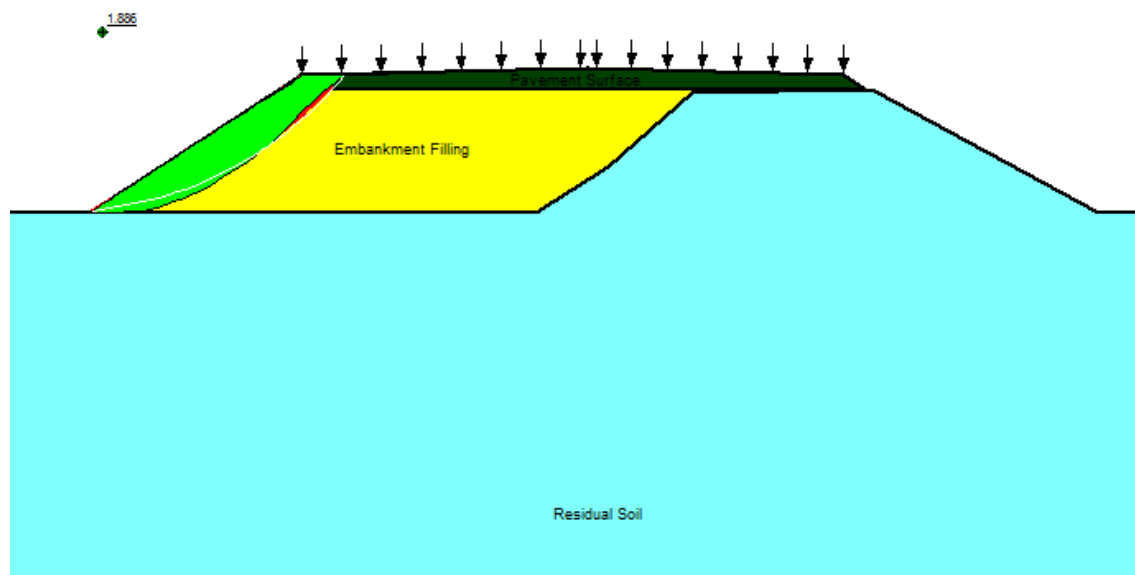


Figure 11.4: Stability Analysis result of Km 51+450 for dry condition

If there is not enough confidence to existing design based on soil parameter, field design may require based on the stability of excavated slope.

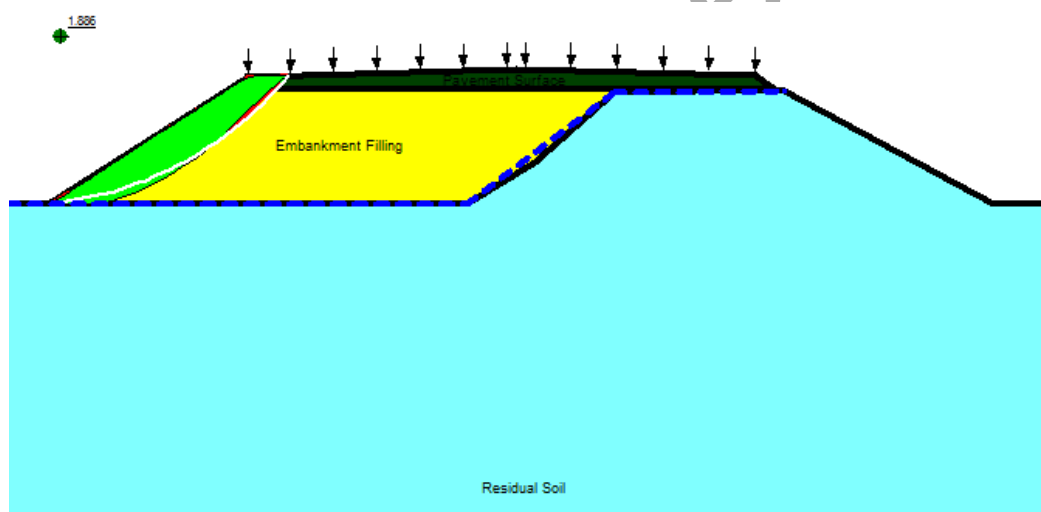


Figure 11.5: Stability Analysis result of Km 51+450 for wet condition

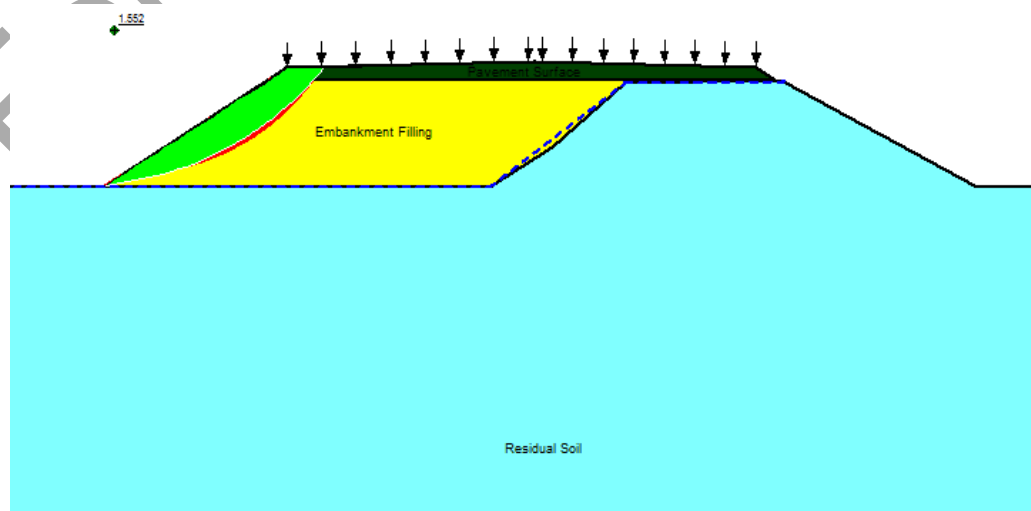


Figure 11.6: Stability Analysis result of Km 51+450 for dry-seismic condition

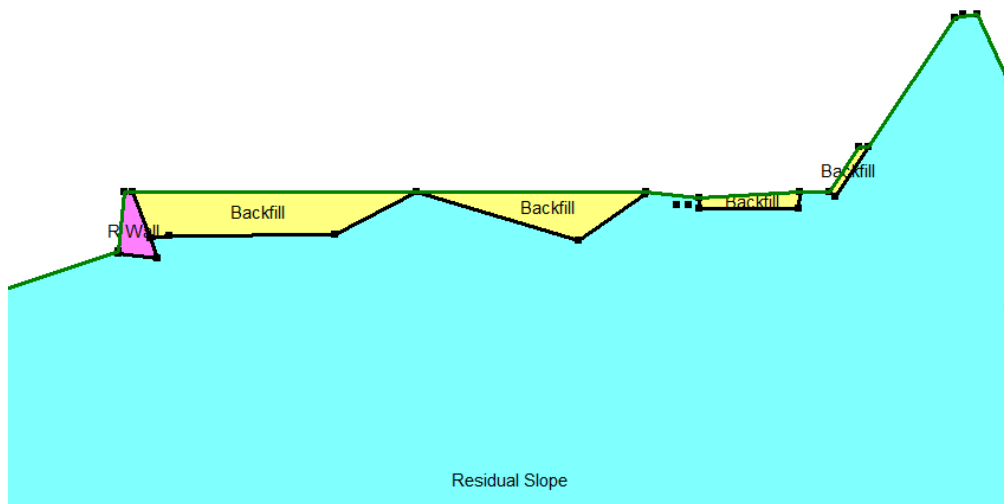


Figure 11.7: Standard design section at Km 84+670

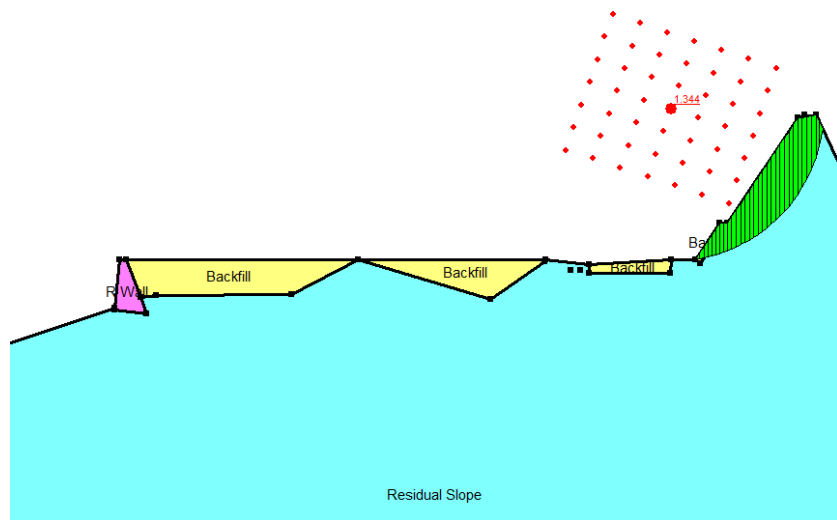


Figure 11.8: Stability Analysis result of Km 84+670 for dry condition

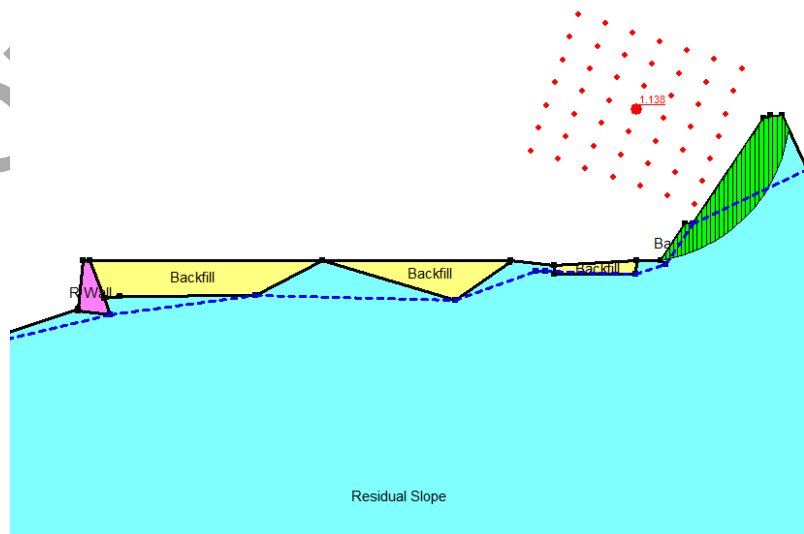


Figure 11.9: Stability Analysis result of Km 84+670 for wet condition

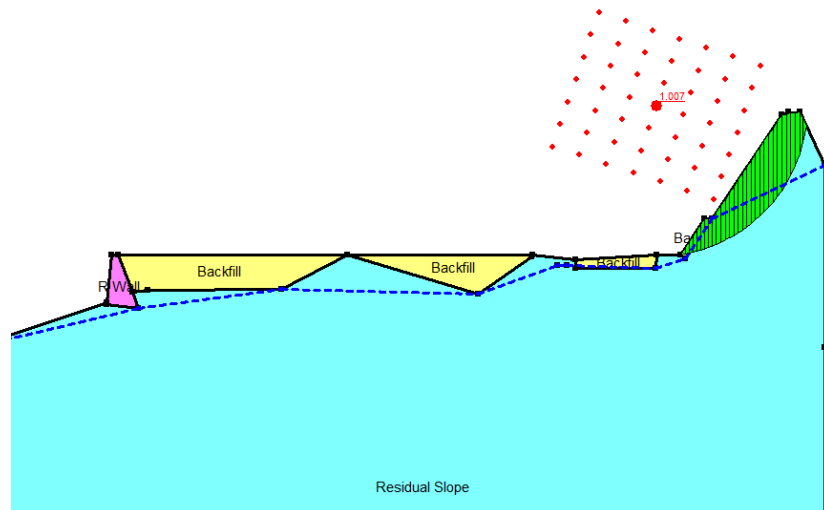


Figure 11.10: Stability Analysis result of Km 84+670 for wet-seismic condition

Analysis Result			
General Condition	Analysis Result	Factor of Safety	Decision
Dry Season	> 1.25	1.25	Stable
Rainy Season	> 1.10	1.10	Stable
Earthquake	> 1.0	1.00	Stable

Proposed and designed cut and embankment slope is stable for designated material.

11.5 Slope Stabilization with Bio Engineering

Bio-engineering is the use of vegetation, either alone or in conjunction with civil engineering structures, to reduce instability and erosion on unstable slopes, cut slopes and embankments. It should be a fundamental part of the design and construction of all roads in rural (and urban) hill areas, mainly because it provides one of the best ways to armour slopes against erosion and can also provide a significant contribution to soil reinforcement and other anti-failure measures. The plantation design for each bio-engineering site is made by taking into consideration many factors, such as; the causes of landslides, erosion, gully formation and slump, together with the slope degree, altitude of the site, the soil type, whether above the road or below the road, and the condition of the bio-engineering site.

It, however, is only an additional tool for slope stabilization and does not replace other civil engineering structures needed for slope protection. The materials and skills required for bio engineering are generally easily available in rural areas of Nepal. The technique, therefore, provides a cost effective and a sustainable solution for stabilization of hill slopes in Nepal. It is an optimal mixture of vegetation and engineering structures, which could be managed effectively, even in remote hilly areas. Vegetation is a very desirable means of providing slope protection for reasons of availability, relatively low cost, appropriateness of installation techniques and compatibility with the rural environment. Although vegetation cannot be designed or built to engineering specification in the conventional sense, it can be selected and arranged on the slope to perform a specific engineering function which will be identified as part of process of bio engineering design. Stabilization of slopes will be most rapidly achieved by planting of grass slips, by the spreading of collected topsoil containing roots and seeds or by sodding with turfs.

Appropriate bio-engineering techniques, along with other environment mitigation measures, have been used in evolving effective and Site Specific Environment Management Action Plans (SSEMAP) for the

project road. The details of these measures are given in the SSEMAP submitted separately. The item wise detail quantity calculations for each location/site are depicted in Cost Estimate Volume.

The items and total quantities and locations proposed for the road is given in **Table 11.3**, The locations proposed for Bioengineering works, details are presented in **Annex.11**

Table 11.4: Proposed Bio-engineering items and Quantities

7	Bio-engineering works	Units	Qty
a.	Slope preparation for bio-engineering works.	sq m	155290
b.	Supply and planting rooted grass slips at spacing of 100 mm in row and 250 mm spacing between two rows.	sq m	139760
c.	Planting single node culm cutting of grass on fill slopes < 45 and embankment slopes in plain areas etc. all complete.	m	19413.75
d.	Supply and planting tree with tree guards as specified.	nr	15530
e.	Brush layering.	m	19413.75
f.	Supply, preparation and planting of live cuttings of selected species fascines of minimum 1 m length to 0.5 m and pegs spaced at 5 cm centres within rows.	m	15530
g.	Supply, Preparation and planting of live cuttings of selected species palisade of minimum 1 m length to 0.5 m into and pegs spaced at 5 cm centres within rows, with 5-20 cm between rows.	m	7766.5
h.	Supply and broadcasting grass seeds @ 25 gms / m ² .	sq m	496850
i.	Supply and laying grass turfing on the various slope with cutting, watering and transportation etc. including in median	sq m	105400
j.	Supply and planting large bamboos.	No	313
k.	Construct live check-dams	Rm	1028
l.	Provide and Laying of 200 mm thick of dry stone rip rap.	Sq m	7539
m.	Supply and planting Median Shrubs	nr	36938

12. BRIDGES, CULVERTS AND OTHER STRUCTURES

12.1 Introduction

The purpose of structural analysis is the verification of overall stability and establishment of action effects on the whole or a part of the structure. These effects include the distribution of internal forces and moments as well as the calculation of stresses, strains, curvatures, rotations and displacements in static or dynamic modes. To carry out analysis, the geometry, boundary conditions and behaviour of the structure will need to be idealized both for global and local behaviour. The structure is idealised by considering it as made up of elements which can be linear, two dimensional or three dimensional.

Since concrete is a heterogeneous material, its properties are not independent of the size of the member. These are also time dependent. For reinforced and pre-stressed concrete elements the structural behaviour depends on the location and amount of steel as well as the state of deformation and cracking of the element, which in turn, depends upon the level of load. In the analysis, appropriate simplified values of properties of constituent materials and properties representing composite action (e.g. bond) are made in order to represent the behaviour of these elements. The range of validity of these simplified properties and the level of accuracy in predicting the structural behaviour by analytical methods, has to be taken into account in the design process.

12.2 Surveys, Studies and Investigation

Surveys for the structure would be done based on the type of structure. As the required structure is the structure need resulting from the road side topography and proposed alignment/standard. Besides this, nature of the surveys is dictated by the type of structure and precision tolerance. Mainly, the survey includes:

- Topography survey;
- Geotechnical survey;
- Material availability survey
- Condition assessment survey;/Inventory Survey

12.3 Design Criteria

12.3.1 Introduction

All bridges/ Culverts shall be designed in accordance with the relevant Codes, Standards and Specifications and Special Publications and Guidelines of the IRC. All construction of bridges /culverts shall conform to Standard Specification for Road and Bridges Works published by Ministry of Physical Planning and Works, Department of Roads-2001. Bridges shall have independent superstructure for each direction of travel unless specified otherwise. Bridges shall be high level bridges unless specified.

The design of sub structure/foundation is to resist worst combination of live, earthquake, impact, temperature; and horizontal forces caused by lateral earth force. Mainly, it consists of following two parts.

The foundation shall be 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 is taken to such depth that it is not affected by scour or protected from it. Apart from this the foundation is safe from the consideration of bearing capacity, settlement, liquefaction, stability and suitability of strata at the founding level. Mainly it is focused on:

12.3.1.1 The Stability analysis:

Stability analysis aims at removing the possibility of failure of foundation by tilting, overturning, uprooting and sliding due to load intensity imposed on soil by foundation being in excess of the ultimate capacity of the soil. The most important aspect of the foundation design is the necessary check for the stability of foundation under various loads imposed on it, which it is to borne. The foundation, should remain stable under all the possible combinations of loading, to which it is likely to be subjected under the most stringent conditions. The stability of foundations should be checked for the following aspects.

i. Check for bearing capacity

The total downward load at the base of footing consists of compression derived from the design, buoyant weight of concrete below ground level (if any) and weight of concrete above ground level.

ii. Check for uplift resistance

In the case of spread foundations (Open Foundation), the resistance to uplift is considered to be provided by the buoyant weight of the foundation and the weight of the soil volume contained in the Inverted T base of the footing with slides making an angle equal to the angle of earth frustum applicable for a particular type of the soil.

iii. Check for side thrust

The Inclined thrust and horizontal forces causes to slide the structure which is resisted by the weight of the structure and overburden over the structure.

iv. Check for over-turning

Stability of the foundation against overturning under the combined action of uplift and horizontal shears may be checked by the following criteria:

The foundation over-turns at the toe;

The weight of the footing acts at the center of the base and

Mainly that part of the earth which stands over the heel causes the stabilizing moment.

v. Check for sliding

In the foundation, the horizontal shear is comparatively small and possibility of sliding is generally negligible. However, resistance to sliding is evaluated assuming that passive earth pressure conditions are developed on vertical projections above the toe of foundations. The friction between bottom of the footing and soil also resist the sliding of footing and can be considered in the stability of foundation against sliding. The coefficient of friction between concrete and soil can be considered between 0.2 and 0.3. However, the frictional force is directly proportional to vertical downward load and as such may not exist under uplift condition.

12.3.2 Structural design of foundation

Structural design of concrete foundation comprises the design of base slab/block. The structural design of different elements of concrete foundation is discussed below. The Toe, Hill and Stem should be designed for maximum bending moments due to side thrust in both transverse and longitudinal direction combined with direct pull (Tension)/ direct down thrust (compression). The Toe and hill thickness is to satisfy the punching stress requirement.

The important provisions applicable for concrete foundations which are necessary and should be considered in the design are explained below:

- a. Footings shall be designed to sustain the applied loads moments and forces and the included reactions and to ensure that any settlement which may occur shall be as nearly uniform possible and the bearing capacity of the soil is not exceeded.
- b. Thickness at the edge of footing in reinforced concrete footing shall not be less than 15cm (5cm lean concrete plus 10cm structural concrete). In case of plain concrete footing thickness at the edge shall not be less than 5cm.
- c. Bending moment. The bending moment at any section shall be determined by passing through the section of a vertical plane which extends completely across the footing and computing the moment of the forces acting over the entire area of the footing on the side of the said plane.

12.3.3 Design Standards

The basis of design of bridges and culverts would be Nepal Bridge Standard -2967. Based on which the Design includes:

- (a) Bridge Loading
- (b) Geometric Standard
- (c) Clearances

Road Bridge Loading: All permanent road bridges in Nepal shall be designed as per IRC loading and all design shall be carried out in accordance to IRC standards for bridges.

12.4 Choice of Structural Form

12.4.1 Bridges

The bridges is categorized when span >6m.

Minor Bridge: When length ≤ 50 m (with span ≤ 25 m)

Major Bridge: When Span >25m or length >50 (with smaller spans)

Special Bridge: Bridge that require special design considerations, whose construction features (e.g. concrete girder bridges with > 50 m span, steel trusses > 100 m span, arch bridges, suspension bridges, cable stayed bridges and other non-standard bridges)

12.4.2 General Introduction - Major and Minor bridges

There are 43 Rivers crossings listed in the Mugling Pokhara MP Sector with 12 major bridges and 31 minor bridges. Out of 12 major bridges, only 8 bridges will be constructed as to cater traffic in upgrading of Mugling-Pokhara road. Trishuli River, Madi Bridge and Seti Bridge are not in the scope of the consultant. Ruwa khola bridge in the ch 3+764, due to Marshyangdi Power house site no addition or extension of existing bridge work has been proposed In eight bridges one new bridge has proposed to improve the curve To cater the four lane traffic following two options were considered: 1) Demolish the existing structure and provide full width 4lane - new bridge; 2) provide a new 2-lane bridge at the side of the existing one, upstream or downstream as appropriate. Demolishing of the existing bridge has to be decided as per condition survey report carried by the consultant. The condition survey report of all major bridges did not show any poor rating of bridge, which need to be replaced with new one (except one bridge at Nala (24+803km) Crack is seen in bridge deck which will be replaced by double bridge with 1.5m gap.) . Hence it was decided to provide a new bridge for the additional two lanes for major bridge.

However for minor bridges and culverts it has been proposed to demolish or add new bridge in downstream or upstream site or extend the existing bridge/ culvert as per the condition of structure

and topography of the alignment of road . The detailed list of existing Minor bridges proposed for upgrading of road has been listed table 12.1 below.

Table 12.1: Proposed Minor Bridge along Mugling

S. No	Location (km)	Bridge Name	Proposed					Recommendation
			Type	Side	No of Span / Cell	Span Arrangement	Abutment Height (m)	
1	1+852	Khowsing Khola	RCC Slab	B/S	1	2x2x7	6	Extension on both side
2	5+180	Slab Bridge	RCC Slab	B/S	1	2x4x7	10	Extension on bothside
3	5+388	Arch Bridge	Inverted U Girder	B/S	1	2x2x12	17	Embankment on top
4	6+904	Adheri Khola-1	RCC Slab	B/S	1	2x7x9	5	Extension on bothside
5	8+265	Khahare Khola	RCC Slab	U/S	1	1x10	8	at 4m Offset from Existing
6	13+115	Rodi Khola (BOX CULVERT)	RCBC	D/S	1	1x33	3	Same type RCBC at 4m offset
7	14+926	Sukhaurea Khola	RCC Slab	B/S	1	2x7x7	4	Extension on bothside
8	15+613	Kundi khola Baradi)	RCC T-Beam	D/S	1	1x16	12	at 4m Offset from Existing
9	17+443	Adheri Khola	Inverted U Girder	B/S	1	2x3x12	17	Embankment on top
10	20+064	Boke Khola	Inverted U Girder	B/S	1	2x2x9	14	Embankment on top
11	22+264	Badh Khola	RCC Slab	B/S	1	2x3x9	6	Extension on bothside
12	22+503	Khahare Khola	RCC Slab	B/S	1	2x19x9	6	Extension on bothside
13	28+573	Sathimure (Chaubise Khola)	RCC Slab	D/S	1	1x10	6	at 4m Offset from Existing
14	37+695	Muse Khola	RCC Slab	D/S	1	1x10	8	at 4m Offset from Existing
15	46+691	Slab Bridge	RCC Slab	B/S	1	2x7x7	6	Extension on bothside
16	47+548	Slab Bridge	RCC Slab	B/S	1	2x7x7	4	Extension on bothside
17	48+219	Slab Bridge	RCC Slab	U/S	1	1x10	6	at 4m Offset from Existing
18	49+355	Saatmure Khola	RCC T-Beam	U/S	1	1x16	6	at 4m Offset from Existing
19	50+611	Thade Khola	RCC T-Beam	U/S	1	1x16	6	at 4m Offset from Existing
20	51+421	Samdi Khola	RCC T-Beam	U/S	1	1x16	6	at 4m Offset from Existing
21	54+206	Slab Bridge	RCC Slab	B/S	1	2x7x8	3	Extension on bothside
22	58+748	Mul Khola	RCC Slab	D/S	1	1x10	6	at 4m Offset from Existing
23	59+270	Phedi Khola	RCC T-Beam	D/S	1	1x16	10	at 4m Offset from Existing
24	66+516	Slab Bridge	RCC Slab	B/S	1	2x8x12	5	Extension on both side
25	66+907	Rudi Khola	RCC Slab	U/S	1	1x10	6	at 4m Offset from Existing
26	67+591	Hadeli Khola	RCC T-Beam	U/S	1	1x16	6	at 4m Offset from Existing

The scope of work includes detailed survey, soil investigation, hydraulic analysis and structural design of the major bridges, whereas for minor bridges/culverts, the consultant has fitted all existing bridges in type design of 10m, 16 and 25 length of superstructure with three categories of abutment of stem height 6m, 8m and 10 including typical appropriate general arrangement.

As the soil investigation work for minor bridges was not in scope of work of the consultant, it is proposed that design review of foundation including soil and hydrology study for the minor crossings will be done by the construction contractors(s) during the implementation period and design of foundation/ abutment will be reviewed and modified accordingly. The General arrangement drawing sample for three types of minor bridges is given in Fig 11.11 below.

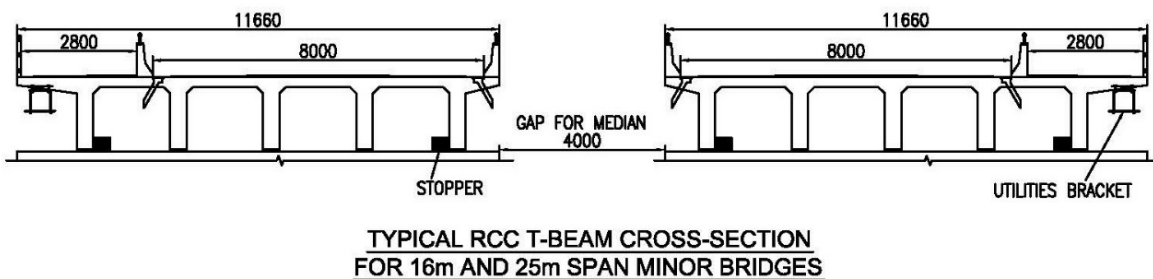
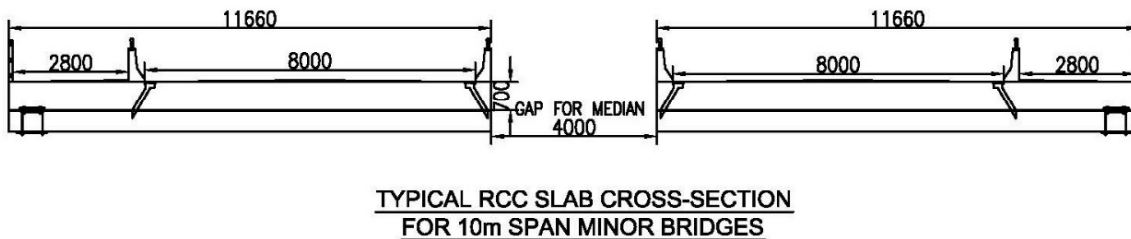
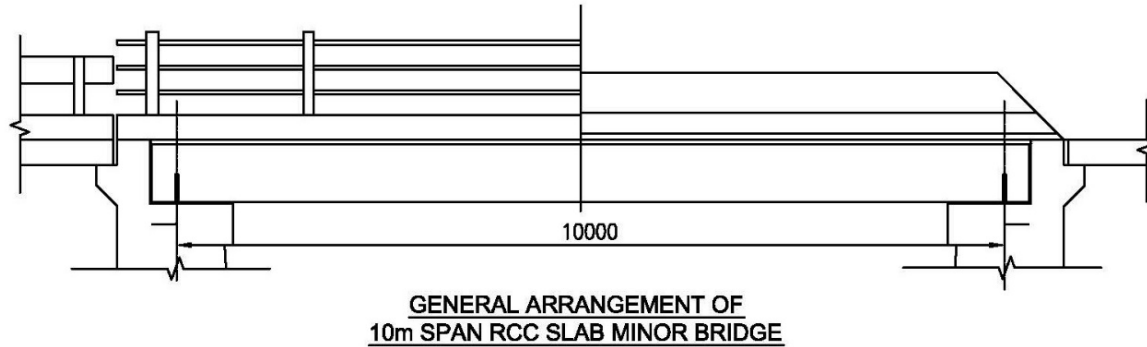


Figure 11.11: Typical cross-section for Minor bridges (RCC slab and RCC T- beam)

12.4.2.1 Choice of New Bridge Types and Span Arrangement

The type of bridges, widths of carriageway and footpaths, construction technologies and other ancillary elements were discussed during project meetings. It was agreed that the bridge width should match the outlines of the road elements. After discussions with the DOR engineers the adopted standard widths of the carriageway and footpaths, as well as the crash barriers are as shown below:

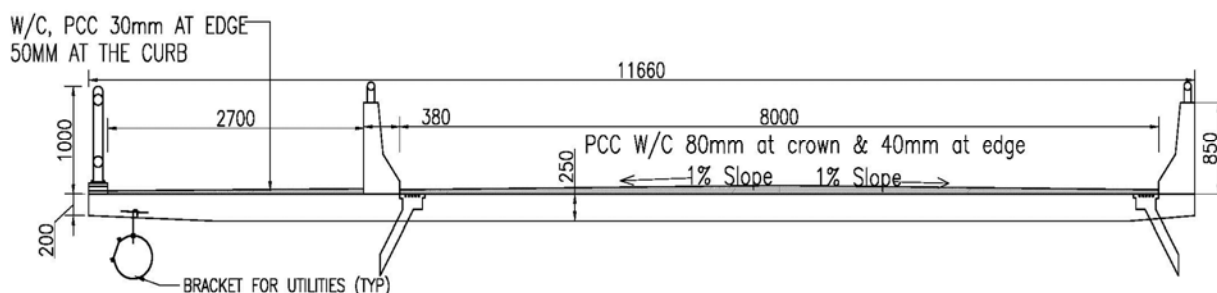


Figure 11.12: Cross Section Widths for the Proposed New Major Bridges

Carriageway width: 7.5 m carriageway + 0.5 m curb shyness width = 8.0 m

Footpaths: 2.75 to 2.8 m clear width (excluding the hand rails) only at the side opposite from the existing bridge

Safety barriers: FHWA approved "F" type New Jersey crash barriers separating the footpath and at the non-footpath side. Base width = 0.38 m

Total width of the bridge deck: 11.66 m

Clear space between the new and existing bridge decks: 4.0 (typical)

As already mentioned above, most of the existing major bridges have through type steel truss deck. It was a general understanding that owing to their maintenance requirements, steel bridges are to be avoided as far as possible. In the existing bridges the depth of the deck from the top surface is in the order of 75 cm to 90 cm. While it is not necessary to keep the deck level of the new bridges same to the existing one, to avoid additional grade and length of the approaches as well as to maintain the aesthetics, it is desirable to keep the level difference as minimum as possible. It meant to provide the depths of the new bridge decks as shallow as possible.

By hydraulic requirements it was necessary to keep the span arrangement similar or compatible to the existing one. It means either to provide abutments and piers in alignment with the existing ones or to keep the spans such that there is least possibility of clogging of waterway by debris. For that purpose as well as to balance the cost of superstructure and substructure, in general, longer spans were preferred. However for the bridges with existing span lengths in the order of 55 to 64 m the spans were divided into suitable lengths keeping the openings sufficiently large to provide unclogged debris flow.

Considering the above matters, for the bridges with span lengths more than 26 m, prestressed concrete (PSC) superstructure was chosen, whereas RCC T-girder decks were found appropriate for smaller bridges with span lengths less than 26 m. The following table shows the existing and new span arrangement and type of bridge selected for the major bridges

The detailed list of the major bridges and its span arrangement is given in Table 11.2.

To have a more efficient way of construction, precast technology is preferred for the Box girder and PSC bridges. One of the major concerns with such method is requirement of heavy lifting or launching equipment. Furthermore, to address the issue of level difference between two bridges the depth of the main load bearing elements (girders) has to be as low as possible. These concerns dictated for the determination of number of girders, their sizes and pre-stressing requirements.

Table 11.2: List of Proposed Major Bridge along Mugling - Pokhara Road

S No.	CHAINAGE (km)	BRIDGE NAME	PROPOSED TYPE	FOUNDATION TYPE	SIDE	No. of Span	SPAN LENGTH (m)	TOTAL LENGTH (no. X span length) (m)	FOOTH PATH at	CARRIAGE WAY WIDTH (m)	REMARKS
1	0+942	DHARAPANI KHOLA	PSC	OPEN	D/S	1	25.00	25.00	B/S	7.50	Benitar/ new construction
2	11+166	KHANI KHOLA	PSC	OPEN	D/S	1	33.20	33.20	O/S	8.00	at 4m offset from ex-bridge
3	24+803	NALA KHOLA	PSC	OPEN	U/S	1	33.20	33.20	O/S	8.00	replace with double bridge with 1.5m gap
4	40+376	BULDI KHOLA	PSC	PILE	D/S	2	24.00	48.00	O/S	8.00	at 4m offset from ex-bridge
5	55+402	MYAGDE KHOLA	PSC	PILE	D/S	1	24.00	24.00	O/S	8.00	at 4m offset from ex-bridge
6	60+932	KUMLE KHOLA	RCC-T BEAM	OPEN	D/S	3	16.54	49.62	O/S	8.00	at 4m offset from ex-bridge
7	70+535	KOTRE KHOLA	PSC	OPEN	D/S	1	35.00	35.00	O/S	8.00	at 4m offset from ex-bridge
8	84+517	BIJAYPUR KHOLA	PSC/RCC-T BEAM	OPEN	U/S	3	16.54+33.20+16.54	66.28	O/S	8.00	at 4m offset from ex-bridge

NOTE: B/S: BOTH SIDE

O/S: ONE SIDE

D/S: DOWN STREAM

U/S: UP STREAM

PSC: PRESTRESSED CONCRETE

RCC: REINFORCED CEMENT CONCRETE

*Proposed width for each bridge with footpath=11.66m

12.4.3 Type of Substructures and Foundations

RCC substructures with suitable shape are proposed. To utilize the limited time it is proposed to adopt similar types of structure for all the bridges as far as possible. Abutments with inverted "T" type retaining structure and piers with circular columns and hammerhead caps have been adopted.

As already mentioned, information on the existing foundation was missing for most of the bridges in the available inventory. Informal sources informed that majority of the bridges have shallow spread footing, which could not be formally verified. Hence the conditions of the existing bridge foundation are largely unknown. In such scenario it was decided to minimize excavation near the existing foundations. Hence bored and cast in situ concrete piles were found appropriate for this purpose. It reduces vibrations in the ground as well as keeps the soil intact at the vicinity. A general observation of the surface soil in the road corridor shows the possibility and suitability of such foundation.

12.4.4 Choice of Soffit level and Freeboard

The Highest Flood Levels for 100 years return period have been determined after detailed hydrological and hydraulic analysis. The minimum freeboard is adopted from the Nepal Bridge Standards. However, as general principle, the soffit level of the existing bridge has been maintained in the new bridge as long as the hydraulic analysis allowed.

The design details for the minor bridges will be put in Annex-11.

The detail design report for 8 Major bridges is prepared and submitted in separate volume.

12.4.5 Culverts

The culvert is categorized when length of crossing structure is up to 6 meter

12.5 Structural Design

Culverts shall be designed with a minimum overall width of new culverts to be same as the roadway width of the approaches. All new culverts shall have following geometry and standards.

Footpath

Footpaths shall be provided and be separated from the vehicular traffic by curb. The width of the footpath shall be 2.5 m on either or both side as the case may be as furnished in the typical cross section.

Curbs and Safety Curbs (Bridge Barriers)

Raised curbs shall be designed as appropriate the height of the safety bridge curb above the carriageway shall be about 500 mm from the safety consideration.

Carriageway Drainage

Transverse and longitudinal drainage of the carriageway shall be managed respectively by providing a suitable cross fall and a camber or gradient. Water flowing down grade on the approach shall be intercepted and not permitted to run to the bridge. The details of deck drains shall be such as to prevent the discharge of drainage water against any portion of the structure and to prevent erosion adjacent to the outlet of the drainage. Overhanging portion of concrete deck shall be provided with drip head or notch, continuous where possible.

Railings

Railings shall be provided along the edges of structures for protection of traffic and pedestrians. The height of the railing shall be of 1.0 m from the top of the footpath or curb surface.

Provision for Utilities

All culverts shall be designed taking into consideration the provision of carrying utilities (electricity, water, telephone, cables etc.) through them wherever required.

12.6 Design Loading for Road Bridge/ Culvert

Live load: IRC 1 lane of 70 R or 1 or 2 lane of class A Whichever governs and Footpath Loading shall be used in design

a) **Load Combination:** As per IRC 6- 2014 Clause: 202.3

b) **Seismicity in General:**

Elastic seismic acceleration method is to be followed:

Horizontal Seismic Force: As per IRC 6 -2014 i.e. for Zone V: 0.27 for Superstructure & 2/3 of Horizontal for Vertical Sub Structure: 0.18 and two third of Horizontal Coefficient for Vertical For Foundation: 1.25 times the forces transmitted by its sub structure

Ductile Detailing as per IRC 112 and Seismic arrester to be provisioned in case of Bearing Failure. The detailed of the culvert provided in MP road has been already provided in Chapter 9.

Design calculation for bridges are provided in separate volumes.

12.7 Retaining Wall

Retaining wall is a structure used to retain backfill and maintain difference in the elevation of the two ground surfaces. Retaining wall may be effectively utilized to tackle the problem of landslide in hill area by stabilizing the fill slopes and cut slopes.

From the initial construction cost considerations, one meter of extra width in filling, requiring retaining walls costs much more than constructing the same width by cutting inside the hill. Similarly the cost of a breast wall is several times more than a non-walled cut slope. However, considering maintenance cost, progressive slope instability and environmental degradation from unprotected heavy excavations, the use of retaining walls on hill roads and terraces becomes essential.

In general, **the choice of wall depends on local resources, local skill, hill slope angle, foundation conditions, slope of backfill, and compatibility of materials and seismicity of the region.** However, the guidelines given in **IS code 14458.1 1998 retaining wall for hill areas** shall be considered for selection of the type of retaining wall to be constructed for the purpose of imparting stability to the slopes in hill area.

- For hilly roads, being of low volume, walls may not be designed for earthquake forces. It is economical to repair failed walls after earthquake. ‘
- Earthquake considerations lead to excessive wall dimensions. High walls may, therefore, be avoided by alternative geometric designs of roads and terraces unless justified by risk analysis. Walls with dip at the base towards hillside will reduce the base width in seismic areas.
- Front battered retaining walls are many times more expensive than back battered walls in steep hilly areas.
- A retaining wall on a thin talus slope may not be able to prevent the failure of entire talus slope during monsoon because of the quick rise of water table above the relatively impervious bed rock.

12.7.1 Types of Road Retaining Walls

Retaining walls are proposed to support:

- road partly on fill when the ground profile is steep
- toe of slope that is likely to fail
- cut slopes that are steep and unstable

The types of road retaining walls proposed to be provided on the project road are described in the following:

12.7.2 Coursed Random Rubble Masonry walls (CRRM)

These types of walls are adopted in steep rocky ground where foundations are shallow and where the less working area and gabion walls are not economical. Stones are easily available in the project area. we have adopted the CRRM walls for height 1.00 to 4.00 m as per site conditions. The CRRM wall is used as minimum as possible to minimize the cost. These types of walls are used mostly in cross-drainage structures.

12.7.3 Gabion Walls (GW)

Gabion walls being eco-friendly are adopted where poor foundation conditions, wet soils, high ground water and slope movement due to creep and landslide where flexible structure is suitable. Gabion walls have the following advantages:

- are cheap as compared to CRRM wall

- are flexible structure
- are free draining structure
- can accommodate settlement without rupture
- can be constructed in short sections
- shape of gabion structures can easily be varied to suit the ground conditions
- are eco-friendly

As far as possible, Gabion Wall is recommended to minimize cost. We have adopted the gabion wall for height 2.0-6.0 m as per site conditions.

12.7.4 Plum Concrete Wall

It is proposed to use plum concrete wall in place of CRRM wall where comparatively stronger wall is required. It can also be used to make strong base for both CRRM and gabion wall. It is recommended to adopt this wall at flooding area where water hits the retaining wall. Plum concrete with 60 % of M20 concrete mix and 40% of stone 150 sizes is adopted.

12.7.5 Skin Wall

Skin wall has uniform thickness from bottom to top which is recommended to retain the slope where top loose soil erosion is likely to occur due to rain which eventually fails and where the active soil pressure is not significant. These types of walls are provided for height up to 3m provided that the slope is self-stable. The skin walls are of following types;

- CRRM
- Dry Stone Masonry Wall
- Composite wall

The choice of skin wall depends on various factors like foundation type, quality of available stone, condition of slope to be retained etc.

12.7.6 Concrete or RCC retaining Wall

There are four common type of Concrete walls used to retain the earth as below.

Gravity Poured Concrete Retaining Walls

Gravity retaining walls depend on their own weight and any soil resting on the concrete in resisting lateral earth forces.

They are generally economical up to 3-4m height for cast concrete structures.

Usually are sufficiently massive to be unreinforced.

Monolithic cast walls are generally formed on site.

Semi-Gravity Retaining Walls

A specialized form of gravity walls is a semi-gravity retaining wall. These have some tension reinforcing steel included so as to minimize the thickness of the wall without requiring extensive reinforcement. They are a blend of the gravity wall and the cantilever wall designs.

Cantilever Retaining Walls

Cantilever retaining walls are constructed of reinforced concrete. They consist of a relatively thin *stem* and a *base slab*. The base is also divided into two parts, the *heel* and *toe*. The heel is the part of the base under the backfill. The toe is the other part of the base.

Use much less concrete than monolithic gravity walls, but require more design and careful construction. Generally economical up to about 8m. in height.

Counterfort Retaining Walls

Counterfort retaining walls are similar to cantilever walls except they have thin vertical concrete webs at regular intervals along the backside of the wall. These webs are known as *counterforts*.

The counterforts tie the slab and base together, and the purpose of them is to reduce the shear forces and bending moments imposed on the wall by the soil. A secondary effect is to increase the weight of the wall from the added concrete.

Can be precast or formed on site.

Counterfort retaining walls are more economical than cantilever walls for heights above 8.0m can be precast or formed on site.

In Mugling Pokhara road, RCC wall has been proposed in many locations and height of wall range from 7m to 12m. The summary of location and length of RCC wall is given in table below .The different type of concrete Retaining walls are given in fig11.2 -The details locations and all details of RCC wall are given in Drawings.

Table No11.3 Location and length of RCC retaining Wall

S.N	Height					
	7m	8m	9m	10m	11m	12m
locations (No)	97	32	22	11	8	10
Length (m)	970	320	220	110	80	100

Typical sections of different types of walls are shown in Figure 12.13 below;

Figure 12.13: Typical Section of Different types of retaining walls

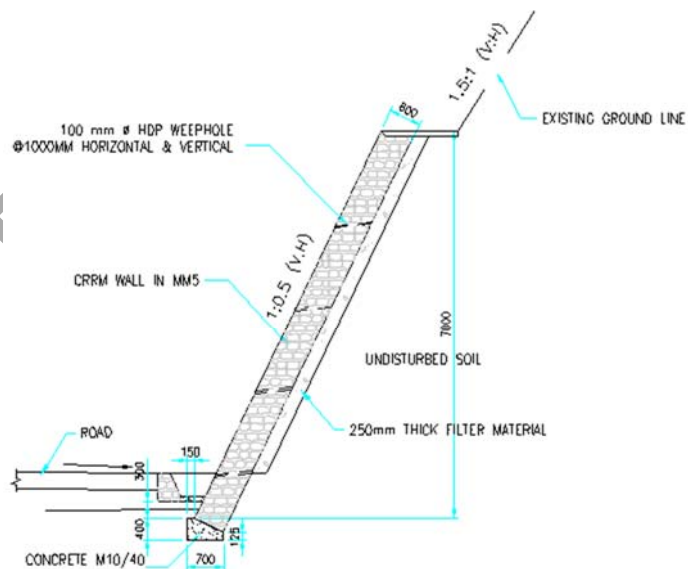
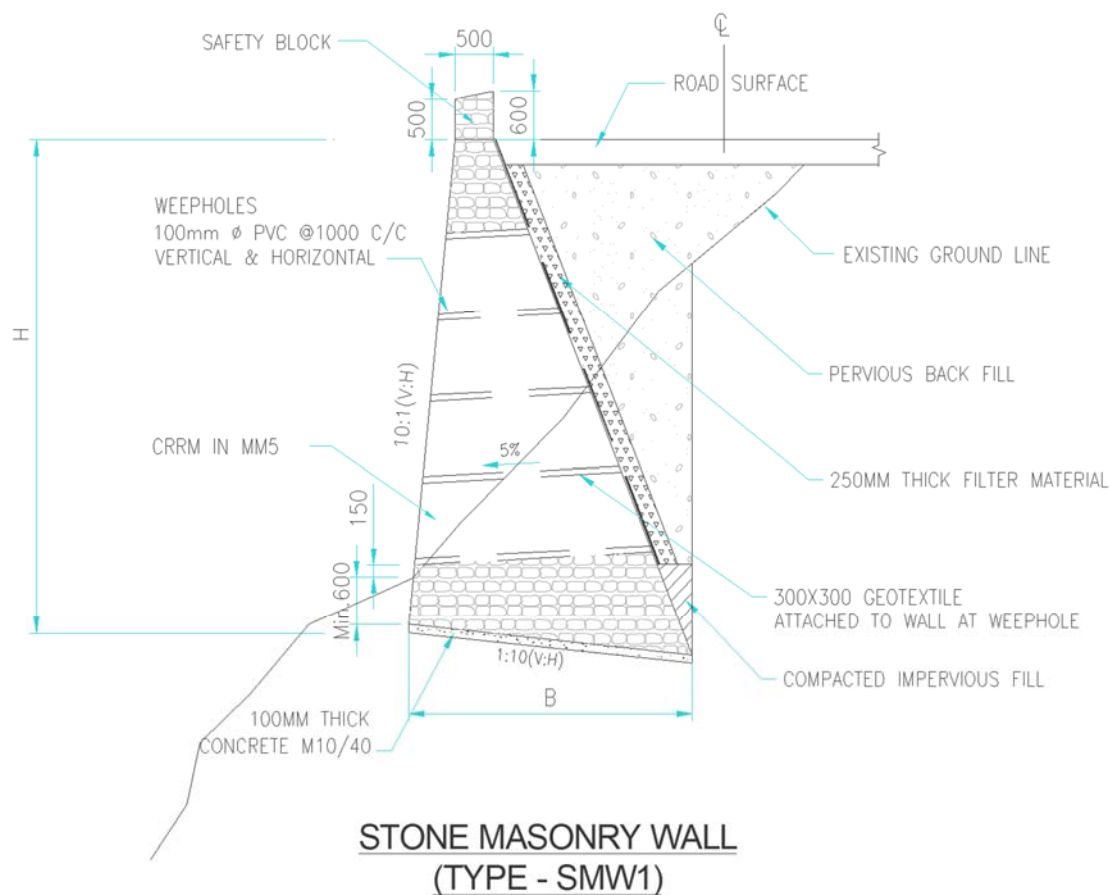
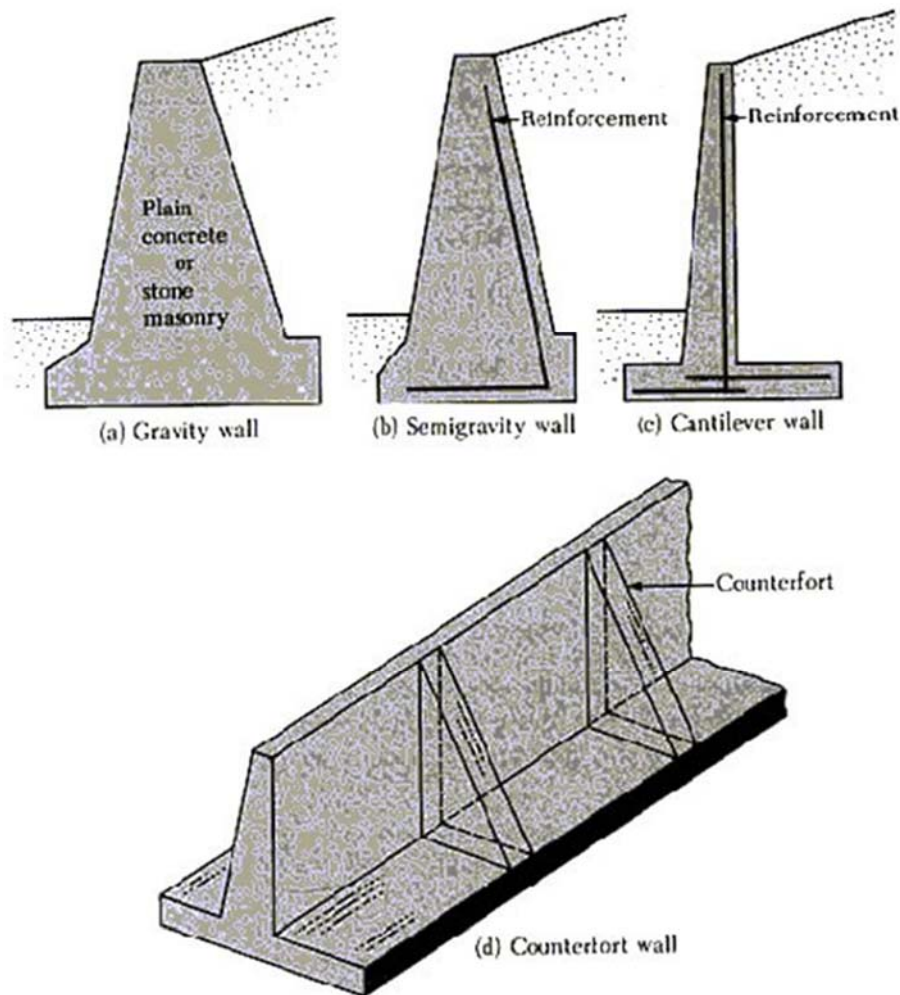


Figure 12.14: Typical Section of Different types of Concrete retaining walls



12.8 Design of Retaining Walls

Road Retaining walls are designed to a standard cross section in the basis of assumed achievable bearing capacities, horizontal or inclined back fill slope, angle of friction of back fill, permeability and drained conditions. Retaining structures like random rubble masonry, dry masonry and gabion walls are designed as gravity walls. Weep holes are provided in random rubble masonry wall to reduce pore water pressure and back of the wall is filled with pervious material for proper drainage. **Figure 12.15** shows the earth pressure forces acting on retaining wall and its stability. For preparation of typical cross section of retaining structures the design parameters are adopted as follows:

Angle of internal friction of back fill, $\phi = 32.0^\circ$

Unit weight of back fill, $\gamma_b = 16.0 \text{ kN/m}^3$

Unit weight of random rubble masonry, $\gamma_m = 24.0 \text{ kN/m}^3$

Unit weight of gabion wall, $\gamma_g = 16.5 \text{ kN/m}^3$

Angle of base inclination = 5.7° (1V:10H)

Active earth pressure is calculated by Coulomb's theory by the equation:

$$P = \frac{1}{2} r h^2 C_a$$

Where, P = active earth pressure

r = bulk density of soil

Ca = coefficient.

Earth pressure coefficient Ca is calculated by following equation

$$Ca = \frac{\cos^2(\phi - \alpha)}{\cos^2 \alpha * \cos(\delta + \alpha)} \left[1 + \left\{ \frac{\sin(\phi + \delta)}{\cos(\alpha - z)} * \frac{\sin(\phi - z)}{\cos(\delta + \alpha)} \right\} \right]$$

Where, α = Angle which the earth face of the wall makes with vertical
 δ = Angle of friction between wall and earth fill
 ϕ = Angle of internal friction
 r = Dry density of earth fill
 z = Slope of the earth fill

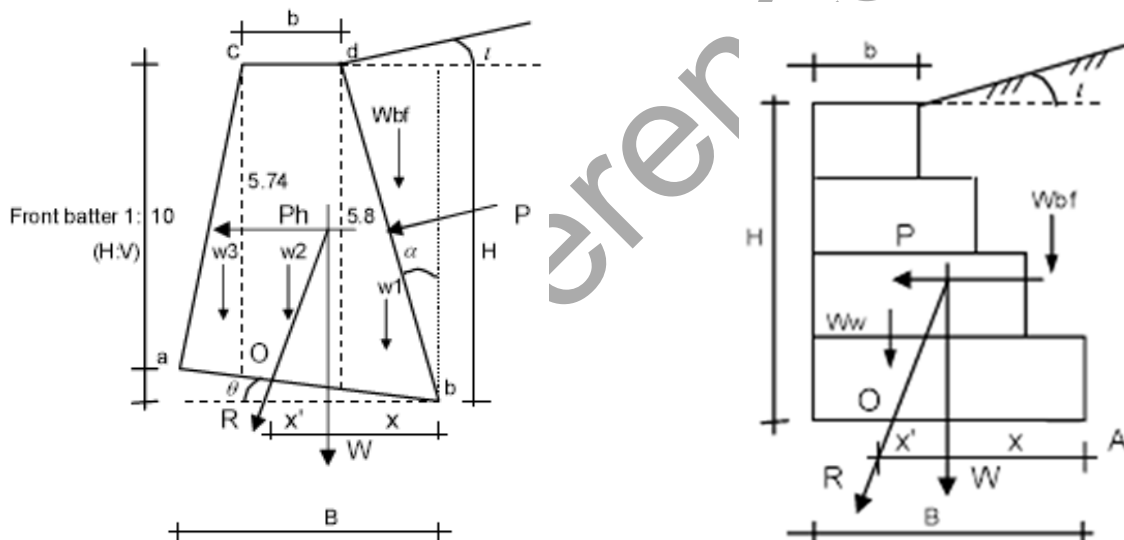
The maximum and minimum pressure at the base of footing is calculated by the following formula:

$$\sigma = P/A \pm M/Z$$

Where, P = total weight of structure A = area of base

M = moment due to external forces Z = section modulus of base

Figure 12.15: Earth Pressure Forces for Stability Analysis of Retaining Walls



Based on the above parameters sample calculations for design of coursed random rubble masonry and gabion walls are provided in **Annex 11.1** and **Annex 11.2** respectively.

Based on the above design, coursed random rubble masonry and gabion walls have been proposed at various locations of the project road. The location of these structures and other details for coursed random rubble masonry and gabion walls are given in **Annex 11.3**

The typical design drawings of retaining walls are provided in **Volume -2C (Drawings)**.

13. SOCIAL AND RESETTLEMENT ISSUES

13.1 General

The road is the part of Prithivi Highway which passes through Chitwan, Tanahun and Kaski districts. The total length of the road is 90 KM and exists between Mugling of Chitwan to Prithivichowk of Pokhara. The road passes through Darechowk VDC of Chitwan district and the road moves a head crossing Trishuli River than Anbu Khaireni municipality and Byas, Suklagandi and Bandipur municipality of Tanahun district. Similarly, the road passes five VDC of Tanahun district namely Manpang, Jayamunebhangyang, Ghanshikuwa and Chhang and ends at Prithivi Chowk of Kaski districts.

13.2 Objective of the study

The objective of the study is to carry socio-economic baseline surveys specifically related to the socio-economic condition of the people, people 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 as follows:

- Analyse the socioeconomic conditions in the project roads;
- Identify the poor and socially vulnerable groups;
- Consultations with the stakeholders about how to involve them in the project activities;
- Assessment of the status of women and deprived/ marginalized group of people for their social empowerment in the future.

13.3 Methodology

The study consisted of both qualitative and quantitative data from primary and secondary sources. The primary data were collected from sample household survey in each of the project roads and 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 conducted in local language i. e. Nepali. The field work for Mugling-Pokhara road section was conducted over a period December 1 to 15, 2015. Altogether 1297 households were interviewed during the course of baseline survey. Besides, Group Interview, Focus Group Discussion (Public Consultation) and Settlement Checklist through Key Informant interviews were also administered. The questionnaire investigated the following main parameters:

- Household profile
- Socio-economic and demographic information
- Health and education
- Family income and expenditure pattern
- Community perceptions of roads upgrading
- Human Trafficking
- Need Assessment
- Gender equality

13.4 Defining Zone of Influence

13.4.1 Direct Impact Area (DIA)

This 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 (Col) in this Report. The area, within which upgrading work is carried out, is referred as formation width (7 m).

13.4.2 Indirect Impact Area (IIA):

In this area, physical and biological environment will probably experience minimal impacts. However, influx of labour from these areas may affect the socio-economic and cultural environment of the project area. The concerned VDCs and areas within 200 m from the centre line of road on either side are referred as Indirect Impact area (IIA) in this study.

13.4.3 Selection of Sample

The zone of influence is defined in terms of impact and benefits of projects. The two categories of impact zone are defined for the baseline study; Direct impact Zone (DIZ) and Indirect Impact Zone (IIZ). The DIZ is defined as corridor of impact i.e. right of way of the roads (25 meter either side from the central line of road) and IIZ is defined as 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. Similarly, the total households in DIZ and IIZ were taken as universe and the twenty percent of households were sampled using purposive but applying random method. It was why purposive that the consultant attempted to cover all types of socio-economic, cultural groups in sample so the different cultural and social background people were also identified with the help of key informants. Thus, it is also a stratified random sample of the respondent, to make representation of each and every type of cultural groups within the settlement, such as major ethnic/caste groups, Dalit, indigenous people; poor families were included in the sample. Sample size of household survey is presented in **Table 13.1** below:

Table 13.1: Sample Size of Road Sections

Road Section	Sample of Surveyed Households
Mugling _Pokhara	1297

Source: Field Survey

13.4.4 Key Survey Findings

The PSA survey of 1,297 household's show a total population of 6,828 of which 50.21 % are male and 49.78 % are female. The average household size found to 5.26, which is higher than the district average of 4.31 (Census survey of 2011).

The project area is dominated by Brahmin, Chhetri, Newar, Gurung, Magar and Dalit. In totality the project influence area consists of 49.50% Indigenous People (IP) and 6.18% Dalit and the rest belong to the ethnicity/castes as mentioned above. The major indigenous people are Newar, Gurung and Magar.

The survey revealed that the major occupations of the inhabitants of the project influence areas are agriculture, non-agriculture labour, trade & business and service. About 12% of the households are living below the poverty line (HH income below 130,500 /year has been considered as below poverty for the study).

Almost all the households during socioeconomic survey and consultations 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, employment creation and so on. Some households and stakeholders assumed the transmission of HIV/AIDs due to influx of the people, human trafficking, loss of agricultural land,

loss of income and social disturbances. During the public consultation, no HIV/AIDS and human trafficking cases registered in 2014.

A. Consultation and Participation

Extensive consultations were held with different stakeholders during socioeconomic survey in the project influence areas. Altogether 4 Consultations/Focus Group Discussions and number of consultations were held at different settlements. The meetings were held with the stakeholders such as farmers, teachers, local politicians, business person, students, service holders to inform them about the project and to get feedback so as to include them in the project activities.

Some of the feedbacks derived from the stakeholders during consultations are as follows: (i) appropriate compensation packages for loss of private property, (ii) rehabilitation of damaged public utilities (iii) the quality of the road should maintain during construction (iv) extensive skill trainings for vegetable, fruit farming as well as for livestock rearing should be provided that helps to get self-employment (v) provision of community involvement/participation in the project activities (vi) employment opportunities during construction, preference should be given to vulnerable people, poor and the women (vii) fair compensation and rehabilitations for the displaced persons.

13.5 Social Issues

13.5.1 Gender

The illiteracy rate of the women has been found as 13.7 % in the project area. The Gender Development Index of the district is higher than the national in average in all project district. It means that the status of women is better in project in project districts.

It has been perceived that the household assets are predominating by the men. However, some changes have been observed in the project areas. Women have more ownership of households' assets particularly the ownership of livestock and ornaments.

Majority of the women have been involved in agricultural activities. They are involved more in cleaning/processing, manuring, seed broadcasting, harvesting, transportation, storing, and marketing than the male. The women mostly spent their time in household chores. They are extensively involved in all household activities like fetching the drinking water, grinding grains, collection of firewood, cooking, cleaning, washing clothes, care of elderly except purchasing the goods.

The important and crucial decisions are made in family consensus and consultation. Women are given authority but not hundred percent in using the household income in different activities. Women have been involved more to take decision in household affairs like ritual/religious ceremonies, education to the children.

The project is expected to ensure employment opportunities to the women during construction and their involvement or participation in other project activities.

13.5.2 Poverty

About 11.8012% of the populations still live below the poverty level. Further the access to basic services like drinking water, education, health, sanitation is very low. Only 1.5% of the population still use open defecation due to lack of private toilets. People used firewood and, LPG gas and Bio-gas for energy and only about 13 % of the populations are illiterate.

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.

13.5.3 Indigenous People

The government of Nepal has classified Indigenous People (IP) in 5 major groups i.e. endangered, highly marginalized, marginalized, disadvantaged and advanced groups. There are more than 51 indigenous /janajati people are living in the project districts. Among the project districts, 48% in Chitwan, 50% in Tanahun, % 43 in Gorkha and 54% in Kaski district is indigenous while about 50% of the total household populations are indigenous in the project influence area.

Similar socioeconomic characteristics in occupation, income source, expenditure pattern, land use, possession of household facilities etc. are found with non-IPs. 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 standard of living.

However, the IP living in the sub-project area were found to be integrated into the mainstream society/culture and have no distinct custom or practices than other non-IP group. This has been proved from the survey findings and analysis of both groups. Similar socioeconomic characteristics in occupation, income source, expenditure pattern, land use, possession of household facilities etc. are found with non-IPs. Again the Social Scientists are in view that the highly marginalized and endangered group identified by NEFIN should be defined as IP. In this sub-project too, no such IPs are found living in the project influence areas.

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 standard of living

13.5.4 Social Risk

The issues on HIV/AIDS and human trafficking were raised and discussed in some community during consultation. This is because there is a high probability of the above issues due to influx of the people from different part of the country and after the mobilization of contractor's team in the project areas. Altogether 39 cases of HIV/AIDS have been recorded in the district where no cases of HIV/AIDS reported in the project area.

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 male in same nature of work. It is expected that the project will review carefully in this matter and will make provision of the appropriate terms and condition to address the above issues while preparing the contract documents. During the public consultation the people focused to implement the programs against of HIV/AIDS and human trafficking.

13.6 Conclusions and Recommendations

The social analysis and consultation with this sub-project have 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 recognised.

In order to address the above issues like gender inequality, poverty, social risks like HIV/AIDS and human trafficking, child labour, the mitigation measures should be incorporated in enhancement measures and livelihood support programs in Resettlement Action Plan under Livelihood Restoration Programs. The project should implement the social development component which includes the

Complimentary Poverty Reduction Program (CPPR) and Gender Equality and Social Inclusion Plan (GESI) through Project Implementation Unit (PIU) during project implementation.

For Reference Only

14. RESETTLEMENT PLAN

14.1 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 to identify measures to mitigate various losses due to the Subproject. The Plan also aims to provide effective guidelines to the GoN for TPPF-2 Implementation Management, to address the identified resettlement impacts as per the Plan and ensure that the households and people affected due to the Subproject are compensated under the prevailing legal norms of GoN in keeping with the ADB, SPS.

The Government of Nepal (GoN) has legally fixed Right of Way (RoW) of 50 meters for the highways 30 meters for feeder roads and 20 meters for the district roads. So, the different subproject roads under the TPPF project for feasibility study have different scope for the land acquisition.

14.2 Objectives of Land Acquisition

The principal objective of this Resettlement Planning document is to plan measures to compensate, rehabilitate and relocate (if applicable) to those who might be displaced due to resettlement impacts to be brought by the Subproject. 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.

The upgrading of the roads and construction of new cutting will require additional land. The land is associated with livelihood so the acquisition of land will definitely affected source of income and livelihood of local people. Most of the houses in road alignment are operating small/medium size of business. The business is based on hotels and tea shops targeting the highway passengers. It was observed that more than 80% houses are operating any types of business in their house which is major sources of income of people. The upgrading and construction of roads requires relocation of structures that significantly affects source of income of local people.

The project has envisaged causing direct impact to the land and other property loss. Of all the properties acquired by the project, land is the most common which are of different qualities from their current and potential use values. Even more significance adverse impact of the project will occur due to acquisition of private residential structures, which will result in the displacement of people from their original place, seriously affecting their earlier livelihood pattern. Loss of cultivated private land is one of the major permanent land losses in this project. The losses of cultivated land have great impact on livelihood of depending people. Based on the finding of resettlement census carried out during the detail design, an estimated number of 860 households have been expected to be directly affected due to acquisition of land for the Subproject

However, the RP may require further updating during the detail survey and implementation phase as information on some of the affected land parcels yet to be updated by conducting land measurement survey for the official record missing land as some affected land parcels were destroyed from the District Land Revenue Office during 10 years Maoist insurgency in Nepal.

14.3 Methodology

Resettlement impact in the Subproject road has been finalized by conducting a detail field survey, and consultations with stakeholder in different field locations. Some of the key stakeholders consulted include local community, family members of displaced households, local key informants, officials of relevant district level agencies like; District Land Survey Office, District Land Revenue Office, District

Agricultural Office, District Forest Office, local political leaders, and representatives of local level institutions etc. The Resettlement Specialist, supported by Resettlement Officer, Cadastral Surveyor and other team members conducted field survey in the Subproject location. One-day orientation was conducted to resettlement team in advance to the fieldwork for making them familiar with the objective and method of detail census survey and to train them on using the information collection tools (census questionnaire and inventories formats, socio-economic questionnaire, and checklists). The team with the guidance and intensive support from the Resettlement Specialist carried out field survey across the corridor of Subproject road to collect information on likely resettlement impacts on different assets and socio-economic information from the displaced households.

14.3.1 Assets Inventory

As part of feasibility study, the inventory survey was also conducted by the survey teams 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 land, houses and other structures, private trees, public properties and common property resources was recorded through walk over survey throughout the road alignment.

Inventories of affected assets and affected households were also prepared with the involvement of Resettlement Specialist, Field Surveyor, Cadastral Surveyors, Field Researcher, Enumerators, representative of District Land Survey Office and other concerned District Level Officials deputed in the field. Displaced households were also participated in the process. However, inventory of some affected land could not be officially verified, because ownership documents/records of such land were destroyed from District Land Revenue Office during 10 years Maoist insurgency. Therefore, inventory of such affected land parcels need to be updated during the implementation after conducting land measurement survey by DLRO in such affected area as discussed in the individual Resettlement Action report of different road section.

14.3.2 Cadastral Survey

The Cadastral Surveyor with the knowledge of engineering design identified upgrading requirements and likely areas of land to be acquired. The team pegged the alignment and impact boundaries and verified the affected land areas, assets and structures. The affected lands and other assets were determined at the site and the cadastral surveyors enumerated and measured other affected assets (e.g. structures, trees etc.) within the premises of affected land parcels. The social survey team then collected the census related information from affected households.

14.3.3 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.

14.3.4 Socio-economic survey

Socio-economic information of the directly project affected households were carried out to assess the key socio-economic indicators of the displaced households like; sources of income and average annual income of the displaced households, vulnerability status of the households, issues related to resettlement impact in the households, and other relevant information and to solicit their

14.3.5 Public Consultation and Participation

While preparing these 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, officials of DLSO and DLRO, team members of TPPF consultant, likely Displaced Persons including the local community and other relevant agencies at Subproject district). The meetings were held with the stakeholders such as farmers, teachers, local politicians, business person, students, and service holders to inform them about the project and to get feedback so as to include them in the project activities. Such consultation and participations with the stakeholders were mainly focused on sharing information and knowledge about the project and its activities for preparing the RP.

14.4 Resettlement Cost

Preliminary cost estimates of land acquisition, structures and rehabilitation were prepared for each sub-project was required for the economic analysis and to estimate the total cost of sub-project road. The right-of-way dimensions ideally required by Door are very high: 50 m (25 m either side of centerline) for highways 30 m (15 m either side) for feeder roads and 20 m (10 m either side) for district roads. Instead, a corridor of impact (Col) was also established for some roads comprising the width required for the road formation, side slopes, side drainage and back slopes necessary to improve the road and maintain safety for pedestrian and residents. The RoW/Col used in each road is shown in Table below and are consistent with other road feasibility studies. The final land requirement will only be determined after the detailed designs are completed. The costs were estimated by computing the additional land or structures to be acquired in the RoW/Col of each road and applying the government compensation rates applicable in each District or rates recently paid on similar road projects and compliance with ADB Guidelines on Involuntary Resettlement and Safeguard Policy Statements (SPS). An additional 10% was added to cover rehabilitation and other costs. The estimated resettlement costs have been summarized in Table. The cost estimation is based on the road design and the actual compensation amount will be mentioned in RP of individual road projects.

Table 14.1: Estimated Resettlement Costs of the Mugling-Pokhara Road

S. No.	Name of Roads	Proposed RoW/Col	Estimated number of structures	Estimated number of land parcels	Total cost
1	Mugling-Pokhara	50	817	133No (12219.33sqm)	1,170,604,123.40
		Total			1,170,604,123.40

15. ENVIRONMENT ASSESSMENT

15.1 Background

The study of environmental aspects of upgrading of Mugling Pokhara Road aims to address the issues of sound and sustainable planning, designing and construction of road structures. Those issues as mentioned in the IEE report are, but not limited to, construction materials and techniques, flood control and cross drainage structures, bio-engineering for slope protection, conservation of aquatic and wildlife species, health and safety of construction workers and the road users etc. This part of the report has primarily been based on the primary and secondary data available from the DOR, field study and the IEE report prepared for the project road.

There are different kinds of environmental interventions proposed during the entire project cycle of the road project and they are: landslide and slope protection, cross drainage structures, minimal removal of forest and vegetation, use of eco-friendly construction materials and techniques, health and safety precaution during construction and operation etc. The intervening measures are either preventive or corrective or the compensatory depending upon the nature of impact and its gravity. These interventions have to be kept in mind during the entire project cycle of the project. The different types of activities as the intervention measures have been suggested in the following table.

Table 15.1: Environmental Activities at Different Phases

SN	Phase of project	Environmental activity	Purpose
1.	Pre-feasibility (new roads only)	Environmental screening	Early check to see what level of environmental assessment is required
2.	Feasibility (new roads and upgrading/rehabilitation/improvement)	Initial Environmental Examination, or, if necessary, scoping followed by EIA	The required level of environmental assessment is carried out.
3.	Detailed survey and design	Review of IEE or EIA (incorporation of recommendation) Environmental Management Plan	To ensure that the project design incorporates the recommendation of the EIA/IEE Avoids or mitigates any potential environmental problems.
4.	Construction or rehabilitation	Monitoring	Checks are made to ensure that the recommendations measures, made in EIA/IEE, are carried out.
5.	Maintenance (the road in operation)	Monitoring	Regular inspections (usually annually) are made to check that the mitigation measures are working satisfactorily.

Moreover this report explains comprehensively about the mitigation measures for the potential impacts envisaged in the IEE report, monitoring of the measures employed in the project, Environmental Management Plan (EMP) and the budgetary arrangement for implementing the EMP.

15.2 The Environmental Mitigation Measures

The environmental mitigation measures have been differentiated into the following three phases:

- Design phase
- Construction phase

- Operation and maintenance phase

15.2.1 Road Design phase

The mitigation measures considered during design or pre-construction phases are of preventive in nature with two basic objectives: (1) avoiding costly mitigation, and (2) awareness among the stakeholders for environment protection while constructing and operating infrastructure services.

Alignment Finalization: Proper selection of appropriate route for the road alignment can be one of the major preventive environmental mitigation measures. The appropriate route selection avoids or minimizes the environmental degradation primarily in terms of loss of flora and fauna, minimum or no slope instability or soil erosion, disruption of water bodies, minimum loss of fertile cultivated land, no loss of valuable personal properties etc. Adequate measures should be taken while surveying to avoid forests, sensitive habitats, cultivable lands and settlements while carrying out alignment section or designing geometrical improvements or widening of road. Since the road is in operation since long time, existing alignment has been followed for upgrading.

Detailed Survey and Design: At this stage, the Social consultants conduct a census survey and assessed the potential impacts and losses on properties and lands, and establish the baseline data for compensation. The detailed survey and design have included all possible preventive measures to avoid or minimize slope instability, disruption of water systems, minimize disturbance to settlements, minimize forest loss, and affecting cultural assets and the aesthetic value of the landscape. The design shall adopt the labour-intensive approach, minimizing/avoiding blasting and use of mechanized method, as far as practical. Bio-engineering can be used for slope stabilization in an environment friendly manner, and plan for using local resources and manpower.

Inclusion of EMP requirements in BoQ: To become effective and verifiable, all provisions mentioned in the EMP should be reflected in the Bill of Quantity (BoQ) explicitly while issuing Tender Document for the Contractors. The contractors must clearly quote these activities in BoQ rate, and provide beforehand any comments in case of opposing these clauses.

15.2.2 Construction phase

Beneficial Impacts: The following impacts have been identified from the IEE report:

- Increased Income and Employment Opportunities
- Enhancement of Technical Skills of locals
- Enhancement of the Local Economy

Adverse Impacts: The adverse impacts have been analyzed categorizing them in compensatory, preventive and the Mitigating measures. Different physical, biological and socio-economic impacts have been given in the following table:

Table 15.2: Adverse Impacts during Construction Phase

SN	Environmental category	Impacts	Types of Mitigation Measures
1	Physical Environment	- Addressing changes in land-use pattern and Loss of land - Coping with slope failure and erosion - Addressing destabilization of slopes - Precautionary measures during slope cutting activities - Avoiding hazards due to unsafe spoil disposal - Avoiding hazards due to water flow diversion - Avoiding hazards originating from Quarry and Borrow pit operations - Addressing Risks associated with stone crushing plants - Addressing issues associated with stockpiling of materials - Avoiding Water Pollution - Avoid Air Pollution - Control of noise pollution - Handling hazardous materials - Avoiding Hazards caused by the use of bitumen	Compensatory, mitigating and preventive
2	Biological Environment	- Clearing of Forest Land and Habitat Damage or Loss - Avoiding Habitat Fragmentation - Control of Illegal Harvest of Forest Products and Poaching of Wildlife	Compensatory, mitigating and preventive
3	Socio-Economic and Cultural Environment	- Loss of properties and productive land - Avoid impacts on indigenous people - Damages to community infrastructure and Quality of Life - Observation of Occupational Health and Safety (OHS) - Avoiding Impacts on Cultural and Historical Properties	Compensatory, mitigating and preventive

15.2.3 Operation and maintenance phase

Beneficial Impacts: The following impacts have been identified from the IEE study report:

- Improved access to services and reduced total transportation cost and time;
- Improved quality of life for the rural population in the project area;
- More efficient and safe road transport system;;
- Improved interstate connectivity to Chitwan, Tanahun and Kaski Districts;
- Connectivity to the Asian Highway network;
- Increase in land value;
- Increase in opportunities of high value crop cultivation and commodities development; and
- Development of tourism

Adverse Impacts: The adverse impacts have been analyzed categorizing them in compensatory, preventive and the Mitigating measures. Different physical, biological and socio-economic impacts have been given in the following table:

Table 15.3: Adverse Impacts during Operation and Maintenance Phase

SN	Environmental category	Impacts	Remarks
1.	Physical Environment	- Slope Instability and Erosion - Control Air, Noise and Water Pollution - Control of Cross-Drainage Outfall and Gullies	mitigating and preventive
2.	Biological Environment	- Depletion of Forest Resources - Collision and Disturbance afflicting vegetation and wildlife	mitigating and preventive
3.	Socio-Economic and Cultural Environment	- Road Safety and Speed Limit Controls - Control of Ribbon Settlement along the Road and the RoW	mitigating and preventive

The mitigation measures for the respective impacts have been summarized in the following table:

Table 15.4: Interventions to Environmental Impacts

SN	Category	Potential problem	Interventions
1.	Slope stability	Landslide and other types of mass instability in the slope	Geological/geo-morphological study conducted to investigate and recommend best available option Civil engineering structures and bio-engineering works Quarrying prohibited in river bed where increased flood discharge velocity can give rise to subsequent damage
		Development of erosion and gulling	Check dam and bio-engineering works used as necessary
2.	Spoil disposal	Road crosses major areas of deep seated instability	Width and surfacing standards relaxed for short lengths as required Minimize spoil by balancing cut and fill wherever possible
		Spoil tipped away from designated area	Safe tipping areas identified and enforced
		Spoil falling or being washed onto farm land	Spoil trap constructed Land owner compensated
3.	Water management	Scour and erosion below unprotected drainage outfall	- Mattresses and check dams and others protection measures constructed as necessary - Cascade constructed, to be as long as necessary
		Disruption of drinking and irrigation water supplies	Measures to resolve these problems incorporated in project work or owner compensated
4.	Land use	House to be removed	House owner compensated
		Loss of agricultural land	Land owner compensated Check impacts are limited to acquired land
		Loss of forest land	Respective Forest users group are compensated for the trees and product lost Check impacts are limited to trees and products

SN	Category	Potential problem	Interventions
5.	Plants and wildlife	Large numbers of trees being removed	Felled trees replaced using same species if appropriate Trees planted where land is available
		Disturbance to wildlife	Damage to wildlife avoided as far as possible Habitat re-created in marginal roadside land
6.	Quarries and Borrow pits	Pollution, disturbance and danger from quarry operation	Construct bund to screen noise and dust Enforce access restriction
		Safety risks from abandoned quarries or borrow pits	Quarries made safe by re-grading slope and installing structures as necessary
		Land seriously disturbed or lost from production	Quarries and borrow areas rehabilitated to productive plantation using bio-engineering Techniques
		Quarries continue to be used by unauthorized persons	Unauthorized quarrying stopped wherever possible working with DDC
7.	Stone crushing plant	Dust and noise pollution	Plant re-sited or compensation arranged if pollution is caused Large earth bunds is constructed and vegetated to reduce hazard
8.	Hazardous materials	Spoils, leaks and injury from any types of hazardous materials (bitumen, cement, paint, explosives, fuels, lubricants etc.)	Check to ensure that storage is good and there is no leakage and loss Check to ensure protective clothing and safety measures are used
		Bleeding bitumen	Appropriate chipping are spread and rolled into the affected areas
9.	Camp operation	Pollution from work and labor camp	Check to ensures that labors are not polluting neighboring areas with sewerage and rubbish disposal
		Labors cut trees for firewood	Kerosene stoves and kerosene provided to laborers
		Land remains damaged after construction	Check to ensure that camp areas are fully restored including re-top soiling and plantation if appropriate
10.	Dust and noise	Dust generated from construction work and construction vehicles	Speed control using speed bump, if water is available, the road surface sprayed on a frequent schedule
		Dust from road with earth and gravel surface	Permanent bumps are installed in villages and bazaars to reduce traffic speed in inhabited areas Bituminous surface is constructed in bazaars with speed controls Dense vegetation planted on roadside
		Noise from large work site	Large earth bunds constructed and vegetated to reduce noise Work scheduled to minimize disturbance
11.	Social issues	Positive impacts of road limited to	Other agencies encouraged to develop activities beneficial to poor and excluded section of society

SN	Category	Potential problem	Interventions
		wealthier section of society	
		Local people excluded from project activities	Designs incorporate the methods within the skills of the locals Contractors encouraged to use the local people wherever possible
		Promises were made to local people during feasibility and planning phase	Checks to ensure that the promises are fulfilled, if they prove to be not possible, reasonable alternatives must be negotiated
		Significant disparities emerges in levels of compensation	Compensation levels rationalized to ensure reasonable parity
12.	Road safety	Faster traffic resulting from new smoother road surface	• Traffic safety measures installed, such as warning signs, delineators and barriers. • Awareness of road safety raised among affected communities • Road safety audits carried out and recommendations • Implemented

15.3 Environmental Management Plan

The Environmental Management Plan (EMP) provides a basis for the implementation of Environmental Protection Measures (EPMs). This includes project monitoring, project management issues and the verification of predicted environmental impacts actually arising from the project implementation, and institutional arrangements for implementation. It also incorporates the estimated budget for implementing the EMP.

The Environmental Protection Measures (EPMs) of this subproject will be implemented during the preconstruction stage, construction stage and operational and maintenance stages of the project. The implementation of the mitigation measures will be the responsibility of the proponent. All preparatory activities related to site clearance and design works will be completed during the preconstruction stages. The proponent will continue its environmental protection activities during the post construction or the operational stage as well.

15.3.1 Environmental Monitoring

Environmental monitoring is an integral part of IEE report and the project as well. The sub-section focuses on baseline, compliance and impact monitoring.

(i) Baseline Monitoring:

Baseline Monitoring is required to compile and maintain the database on environmental conditions prior to the implementation of the project. The primary concern during this stage will be to implement field data collection programs to obtain the baseline conditions, such as scientific and sociological information needed to finalize the design and cost of the mitigation measures. This is especially important if the project is delayed due to unforeseen circumstances. Such data recorded before the project implementation will facilitate the comparison of information obtained in monitoring activities conducted during project construction.

(ii) Compliance Monitoring:

Compliance Monitoring employs a continuous recording of specific environmental quality indicators or pollution levels in order to ensure project compliance with recommended environmental protection standards. Compliance covers the work to be done by the contractor as specified in various contract clauses. Basically, compliance and impact monitoring would be carried out at site.

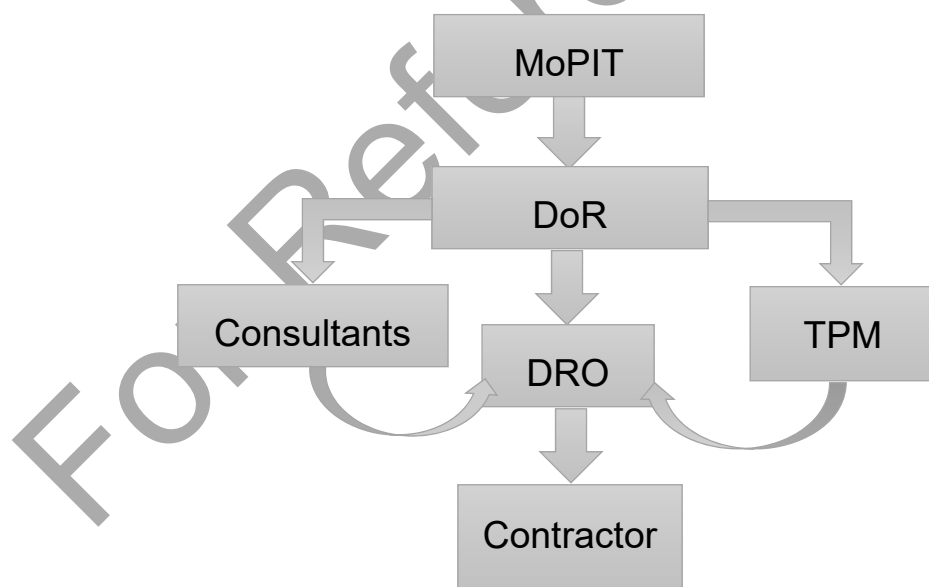
(iii) Impact Monitoring:

Impact Monitoring measures the physical, biological, socio-economic and cultural parameters within the project area during the construction and operation stages in order to detect environmental changes that occurred as a result of project implementation. It involves actual measurement of the impacts of construction activities on the environment, such as water quality samples being taken at regular intervals to assess pollution concentrations in the river from construction work camps, after mitigation steps are taken. Impact monitoring is scientific data collection, analysis interpretation and follow-up of mitigation works. It is designed to assess actual impact vs. predicted impact and the effectiveness of the mitigation measures.

The responsibility of monitoring rests upon the proponent, Department of Roads. The third party monitoring (TPM) has been recommended for the validity of the monitoring report.

15.4 Resources

Institutional and human resources: The Department of Roads will be the authority to execute the environmental and social management plan. Since it is less effective to look after the field level activities from the centre, the Division Road Offices will oversee the respective stretches of the roads, the construction and operation and the monitoring of the interventions. Following institutional set-up has been proposed under DoR for this.



The consultant or the third party monitoring team will work under the specified organizational set up with the professional staff.

Financial resources: The implementation of the project needs execution of construction activities taking care of the recommendations of the EIA report, operation and maintenance of the road and environmental monitoring. The construction and operation and maintenance of the road come under the project cost whereas the environmental protection measures are also a component of the total project cost. The total environmental mitigation cost (including bio-engineering) for the Mugling – Pokhara Road Sub-project has been estimated about NRs. 138,647,401.25

15.5 Bioengineering

Bioengineering is an integral part of the Green Road concept. It uses living vegetation, either alone or in conjunction with civil engineering structures and non-living plant material to reduce shallow-seated instability and erosion on slopes. Positive mechanical and hydrological properties of plants are utilized to control erosion and stabilize the slopes. This is the most effective low-cost measure. It can be applied in the failed zone of slope as a curative means and also for reducing the risks of future slope failure as a preventive measure.

Bioengineering is a sustainable approach where the combination of live and dead plants and plant parts are used as building materials for erosion reduction and upland slope prevention. The combination of vegetative engineering systems and civil engineering systems normally offer the most complete natural and cost effective solution to the variety of instability problems affecting a site.

Under most circumstances, bioengineering can be effectively combined with appropriate and low cost geotechnical applications to provide the most cost-effective, integrated solution to slope stability problems. This is important for a mountainous country like Nepal because, with the steep and dynamic slopes found in the Himalayas, most hill roads are engineered near to the margin of safety. Bio-engineering is the most affordable and effective way of enhancing civil engineering structures to increase stability as far as possible. The vegetative structures are also flexible, being capable of absorbing movement and recovering from damage. In this respect, bio-engineering is simply part of a wise and sustainable asset management since it helps to ensure the life of physical structures, and reduces overall maintenance costs. On roadsides, plants reduce the supply of debris from degrading slopes, which is one of the greatest contributors to road maintenance costs through blocked drains and damaged pavements.

Road bioengineering is totally a labour based approach providing benefits to the local people. It focuses on minimizing the damages to the natural environment as well as reducing the future maintenance costs. The major portion of the cost of the road construction goes toward the payment of wages to the local labour. Road construction approach incorporates social, environmental and technical issues. Due to these facts, it is getting increasingly prioritized by national and international organizations in hill road construction. People's participation is most essential for the success of slope conservation works. The use of local materials motivates local people's participation.

Existing manuals of DoR on bioengineering techniques are used to design such works. Bio-engineering work is proposed for the project road at major slide areas. Total estimated cost for bio-engineering work for the project road is NRs.70,551,435.25

15.6 Climate Change Consideration

Climate change refers to any significant change in the measures of climate lasting for an extended period of time. It includes major changes in climatic parameters like temperature, precipitation, or wind patterns, among other effects, that occur over several decades or longer. The longevity of transportation infrastructure, the long-term nature of climate change, and the potential impacts identified by recent studies warrant serious attention to climate change in planning new or rehabilitated transportation systems.

Climate change may cause more flooding of roads, bridges and airport runways, especially in low land areas as a result of erratic rains. A range of adaptation responses can be employed to reduce risks through redesign or relocation of infrastructure, increased redundancy of critical services, and operational improvements. Roads, bridges, tunnels and railway lines will be vulnerable to increased precipitation, groundwater levels, temperatures and winds.

Higher groundwater levels associated with extreme precipitation will mean an increased risk of landslides on excavated slopes. There is a risk that the bearing capacity of bridge and tunnel foundations, supporting walls and sheet pilings will be reduced by increased groundwater levels. This can be a great problem, especially for foundations on sand. Modern safety installations are significantly more sensitive to temperature increases than older installations and this presents a particular problem. Autonomous adaptation to climate change is important because of the complexity and long lifetime of roads. Furthermore, improved maintenance in the form of cleaning existing road drainage systems can retain drainage capacity corresponding to that of a new installation.

The road transport sector is a key area that contributes to climate change by way of greenhouse gas emissions. However, the transport sector is in turn itself affected by climate change. Whilst, transport systems and infrastructure are designed to withstand typical weather patterns, climate change impacts arising in the near and longer-term can have an impact on the efficiency of transport operations and ability of infrastructure to withstand extreme events.

The feasibilities of project roads have 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. A checklist of climate change hazards for the two types of environments found in Nepal and the potential impacts on SRIP roads are presented in **Table 15.5**.

Mugling - Pokhara project road section falls on rolling, hilly and mountain terrain. Effects of climate change could include the possibility of flash floods/rapids, mud flows in rivers/streams, and an increase in incidence of landslides along the alignment. Other existing roads in the Hilly areas are also susceptible to landslides due to the limited drainage capability and nature of the soil type. For this reason, particular consideration has been given in the feasibility design of road formation and embankment heights and the size of waterways and soffit levels of bridges.

Table 15.5: Road Checklist for Climate Change Effects

Type of Environment	Natural Hazards and Climate Change	Possible Impacts on SRIP Roads
Humid and sub-humid plains, foothills and hill country	- Over 500 mm precipitation per year; - Resilient ecosystems and complex human pastoral and cropping systems; 10-30% projected decrease in water availability in next 40 years; - Projected increase in droughts, heat waves and floods; - Increased erosion of loess-mantled landscapes by wind and water; - Increased gully erosion; - Increased likelihood of landslides on steeper slopes; - Likelihood of decrease in overall agricultural productivity and compromised food production from variability, with rain-fed agriculture yield reduced by 30% or more by 2020;	Terai Roads: - Flash floods/rapids; - Mud flows in streams and rivers; - Increase in landslides along road alignments close to Siwaliks; - Flooding and inundation in plains, especially where the drainage capacity is reduced because of almost flat topography; and - Reduced bearing capacity of soils which become saturated. Hill Roads: - Slope and gully erosion; - Torrential damage/washouts; - Torrents and river action/erosion; - Attenuation of drainage capacity in side drains and culverts due to debris flow; and

Type of Environment	Natural Hazards and Climate Change	Possible Impacts on SRIP Roads
	- Increased incidence of forest and agriculture-based insect infestations; and - Occurrence of earthquake and other geophysical hazards.	Aggravation of unstable areas and increased landslides and landslips.
Mountain ecosystems	- Accelerated glacial melting, rock falls/landslides and glacial lake outburst floods (GLOF), leading to increased debris flows, river bank erosion and floods and more extensive outwash plains and, possibly, more frequent wind erosion in inter-montane valleys; - Enhanced snow melt and fluctuating stream flows may produce seasonal floods and droughts; - Melting of permafrost in some environments; - Faunal and floral species migration; and - Earthquakes, landslides and other geophysical hazards may also occur in these environments.	Hill Roads: - Aggravation to slope instabilities and landslides; - Increase in Slope and gully erosion; - Changes in drainage pattern; - Impacts on land use and topography; and - Attenuation of drainage capacity in side drains and culverts due to debris flow.

To ameliorate the impact on micro-climate due to cutting of trees, compensatory plantation (87313 saplings) at the ratio of 1:25 has been proposed in this road project, which will also help to reduce the level of GHG in the atmosphere. The road improvement design assures that it will be better able to cope with the effects of climate change impacts.

16. RATE ANALYSIS AND COST ESTIMATE

16.1 Introduction

Project execution involves two phases. First phase is construction phase with 42 months and Defect Liability Period (DLP) 12 months of the project. The second phase is the Performance Base Maintenance Contract, which will be start immediately after completion of Phase 1 and it will be continue to 48 months i.e. 4 years. This has been agreed after discussion with DOR and ADB. Project cost shall consist of costs of these two phases, land acquisition / resettlement costs and construction supervision costs.

16.2 Quantities of Works

Quantities of works have been worked out based upon the final design and drawing of various designs produced by the Consultant, and cross-sections and typical details proposed for the road and Bridge works.

Quantities and costs for the major elements i.e. General and Site Facilities, Site Clearance, Earthworks, Pavement Works, Structures, Road Furniture and Traffic Safety Measures, Environmental Mitigation (including Bio-engineering), Day Works and Provisional Sum.

As per the design quantities of major works for the project road are as under;

	Item	Unit	Quantity
I.	a. DBST Surfacing	Sqm.	511,890
	b.PBMW	Km/mon	4252
II.	Proposed		
	Minor bridges = 26 RCC Slab Span 10m = 6 RCC T-Beam 16m = 6 Extension of Inverted U girder 11m = 3 Extension of RCC Slab = 10 Extension of RCBC 33m = 1		
	Major Bridge = 8 Side drain(„M ₂) = 7770m		
	Gabion Walls = 100,789 Cum Plumb concrete work = 66,370 cum Concrete Quantity of Different Grades for wall, slab etc. (M10/40, M15/40,M20/20, M25/20,M35/20) = 106,414 cum		
	Stone Masonry = 63,687 cum Rebar = 3998Mt.		
iii.	Volume of earthworks		
	a. Earthwork in Excavation (Roadway and Foundation)	Cum.	3,812,321

16.3 Analysis of Unit rates

16.3.1 General

Rate Analysis must reflect existing market price, wages of skilled and unskilled labours, and reliable cost estimate and is prepared based on considering the district rate for the labour and material, market price of construction material and norms for the rate analysis of GON. For that purpose, the following relevant items have been duly taken into considerations:

• Standard / special norms of Government of Nepal • Market prices of special materials • Availability of materials • Availability of local construction materials	• Wages of skilled and unskilled labours approved by Concerned District • Construction equipment and their hiring rate • Contractual overhead / profit • Value added tax
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The unit rates of items are based on the approved norms of Department of Roads, Government of Nepal. The norms for items which are not included in the approved norms are taken as per the norms adopted 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 at site always includes transportation cost.

16.3.2 Basic Rates for Labour

The Labour rates for cost estimation are based on the Tanahu and Kaski Districts Rates for fiscal year 2074/2075 which are approved by the District Administration Offices of above 2 districts. The rates are prepared for the contract based on weight average of rate and length of road in each districts.

16.3.2.1 Market Rates for Construction Materials

The rates for cost estimation are based on the Tanahun and Kaski District Rates for fiscal year 2074/2075.ct. In case of the items for which rates are not approved by the District Administration Offices, market rates or approved rates of adjoining districts or the road head are taken after adding the approved transportation charge of Transportation Management Organization of the respective district was added. For locally available materials such as water, firewood etc., the local rates of such items is used in the estimation. Similarly for the construction material rate also averaging is adopted.

16.3.2.2 Rates of Equipment and Collection of Material as per DoR Norms

The equipment rates are taken from the rates of equipment provided by the Mechanical Branch of the Department of Roads. The cost for collection and production of the construction materials likes sand, stones, aggregate, surfacing chips, gravel material and crushed stone base were based on the DoR Norms for respective items. Few rates were also calculated based on the machine/equipment involvement for activity and were already used practice in the earlier DoR projects; and the prevailing rates quoted by the contractor in the road project of the area.

16.3.2.3 Comparison of Rates with On-going Contracts

The basic district rates and the unit rate analysis as mentioned above provide the theoretical prices. Actual prices are generally reflected in the rates in the awarded / on-going contracts in the projects vicinity. Consultants collected rates from on-going contracts in the vicinity and compared with rates obtained from abovementioned methods. After comparison rates of some items were rationalized.

16.4 Construction Cost Estimate

16.3.3 Estimated Cost of Works

Based on the rates and quantities worked out as above the cost estimate is prepared for the following bills of quantities. Engineer's Estimate of the costs of works is prepared and submitted separately.

Table 16.1: Summary of Cost Estimate

Bill No.	Description
1	General Items
2	Site Clearance
3	Earthwork
4	Pavement Works
5	Structures including Major and Minor bridges
6	Road Furniture and Traffic Safety Measures
7	Environmental Mitigation (Including Bio-engineering)
8	Day works
9	Provisional Sum
A	Sub Total
B	VAT @ 13% of (A)
C	Grand Total (Including VAT)
D	Cost per Km

16.3.2 Other Cost

Other project costs are as detailed below.

i. Land Acquisition and Resettlement Cost

The Land Acquisition and Resettlement Cost is NRS: 1,170,604,123.40

ii. Construction Supervision Cost

The Construction Supervision Cost is NRS: 622,120,606.64 (4.5%)

16.3.4 Total Project Cost

The total project cost is depicted below.

Item	Amount (NPR)	
Total Construction Cost of Works	As per Engineer's Estimate	A
Other Cost		
Land Acquisition Cost		B
Construction Supervision Cost		C
Total Project Cost		D=A+B+C

17. PROCUREMENT

17.1 Procurement Approach

17.1.1 Introduction

The choice in relation to procurement lies between:

- Traditional – where design is provided and construction bids are solicited and
- 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 these works, which are neither complex nor extensive.

17.1.2 Contract Packaging

It has been agreed that ICD procedure would be adopted to enhance the contract administration effectively and increase the option of coming more professional international Contractors to achieve the good quality works in time. It is therefore recommended that ICB procedures would be adopted and contract packaging be arranged accordingly for Mugling – Pokhara Road.

17.1.3 Post Qualification

Post qualification, rather than the lengthier and more complex prequalification process, has been successfully adopted as the normal procedure in Nepal for works. It is therefore considered that the “Post Qualification” process should be utilised.

17.1.4 Bidding Process

The bidding process for works has been developed, refined and standardised by the Roads Department, Project Directorate (ADB) over many years. The standardised procedure which has been developed should be adopted: this involves the following –

- Preparation of bidding documents
- Publication of procurement notice
- Issuance of bidding documents
- Pre-tender meeting
- Receipt and opening of tenders
- Analysis of tenders and recommendation for award

17.2 Contract Packaging

17.2.1 Methodology

As outlined above these project works will be procured using the Single Stage – Two Envelope method (post-qualification) based on the Standard Bidding Document of ADB.

For International Competitive Bidding (ICB) procedure, the SBD “Procurement of Works, without Pre-qualification” issued by ADB dated December 2015 shall be used.

The selection of contract packages in relation to these roads is thus based on the desired contract value and geographic considerations.

17.2.2 Salient Features

The Mugling Pokhara Road is 88.853 km long, which starts from Mugling and ends at Pokhara Seti Bridge start point (Km 88+853). The road section with an estimated construction cost of about US \$ - ---- billion shall be proposed to be bid as one ICB Contract lots under One (1) Package.

17.2.3 Contract Packages

The selected contract packages Mugling-Pokhara Road are tabulated below:

Road Name	Package	Lots	Chainage		Length (Km)	Contract ID No	Approx. Contract Value (US \$)
			From	To			
Mugling Pokhara	1						

17.3 Bidding Documents

Bidding Documents have been prepared for each contract in the specified ICB format (see Section 15.2.1 above) as follows:

Part I Bidding Procedures

- 1 Instruction to Bidders
- 2 Bid Data Sheet
- 3 Evaluation and Qualification Criteria
- 4 Bidding Forms
- 5 Eligible Countries

Part II Employer's Requirements

- 6A Summary Descriptions of Works
- 6B Standard Specifications
- 6C Special Provisions
- 6D Drawings
- 6E Personnel Requirements
- 6F Equipment Requirements

Part III Conditions of Contract and Contract Forms

- 7 General Conditions of Contract
- 8 Particular Conditions of Contract
- 9 Contract Forms

17.4 Project Implementation Schedule

The construction period for Mugling-Pokhara Road shall be 42 months, Defect Notification Period shall be 12 months. The proposed schedule is outlined in **Figure 15.1**.

17.5 Project Impact Monitoring Framework

The Project Impact Monitoring Framework is shown in Table 17.1. Likewise the Project Implementation Schedule is shown in Figure 15.1 and the Project Impact Monitoring Schedule is shown in Figure 15.2 respectively.

Table 17.1: Project Impact Monitoring Framework Mugling-Pokhara Road

Design Summary	Performance Indicators / Targets	Monitoring Mechanism	Assumptions and Risks
1 Impact Economic activity in the area of project influence is stimulated and promotes pro-poor economic growth.	Poverty incidence decreases.	Household Income and Expenditure Survey (HIES).	Risks: economic activity stagnates, poor do not benefit from road upgrade.
2 Outcomes (a) Road user costs are reduced and savings passed to users.	Bus fares and freight rates reduced.	Baseline established by detailed design consultant. On construction completion comparison made by supervision consultant. 5 years after construction completion further comparison is made.	Assumption: competitive transport markets.
(b) Road capacity is improved.	Journey time across all vehicle types is improved. Weighted average traffic along road increases.	Traffic speed surveys on construction completion and 5 years after construction completion Annual AADT surveys.	Assumption: construction is completed on schedule and to design. Assumption: transport demand develops as anticipated.
(c) Number of accidents is reduced.	Number of fatal and non-fatal accidents reduced when adjusted for increased vehicle-km travelled on the road.	Accident figures assessed at baseline, construction completion and construction completion + 5 years.	Assumption: detailed design safety features are executed as per design.
3 Outputs (a) Road capacity increased to 5.5 m intermediate lane standard by 2018.	Inspection. VOC excluding travel time costs drops by x percent after upgrade opens.	Project Completion Report (PCR). Direct measurement at baseline, construction completion and construction completion + 5 years.	Risk: construction is delayed.
	Land acquisition and resettlement plan implemented and services relocated to schedule.	Resettlement monitoring by an independent institute. Mid-term review mission.	Risk: land acquisition is delayed.
	Welfare of those resettled re-established to at least the same level as before land acquisition.	Monitoring by an independent institute. Mid-term review mission.	Risk: suitable resettlement land cannot be found.

Design Summary	Performance Indicators / Targets	Monitoring Mechanism	Assumptions and Risks
	Implementation complies with EMP.	Environmental monitoring reports, mid-term review mission and PCR.	Risk: contractor does not comply with requirements.
(b) Safety features implemented.	Inspection.	PCR.	Risk: safety features not fully implemented during construction.
(c) Upgraded road is well maintained.	IRI remains below y.	Pavement condition surveys at construction completion and construction completion + 5 years.	Risks: construction is substandard: overloading occurs: maintenance is not undertaken.

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Figure 15.1: Project Implementation Schedule

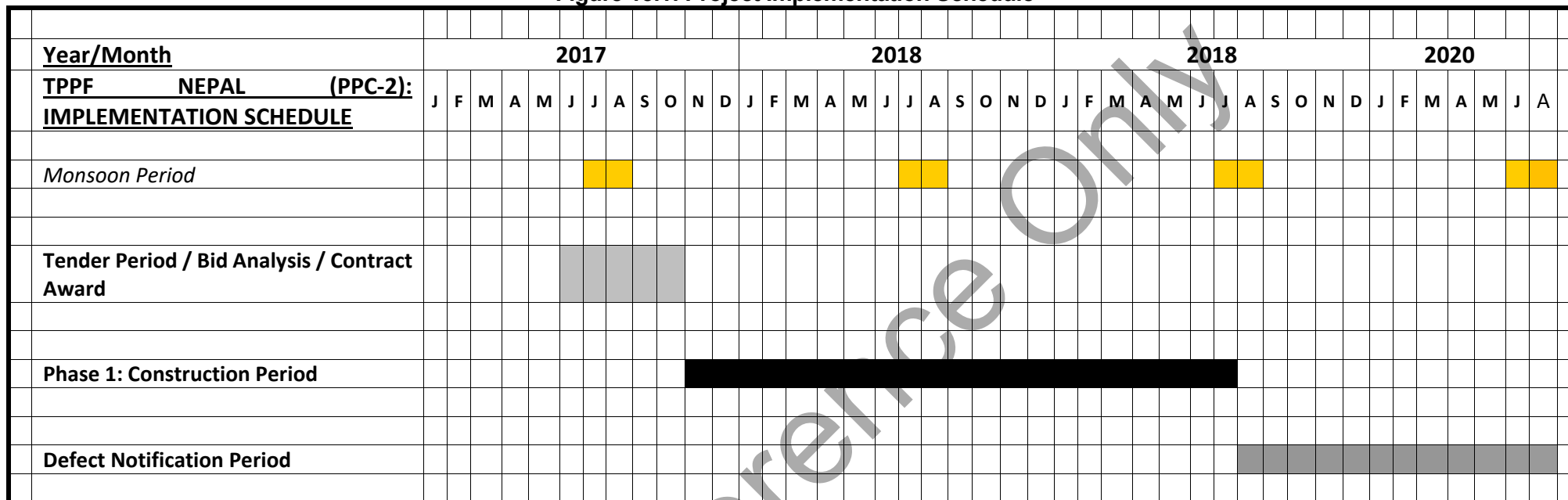
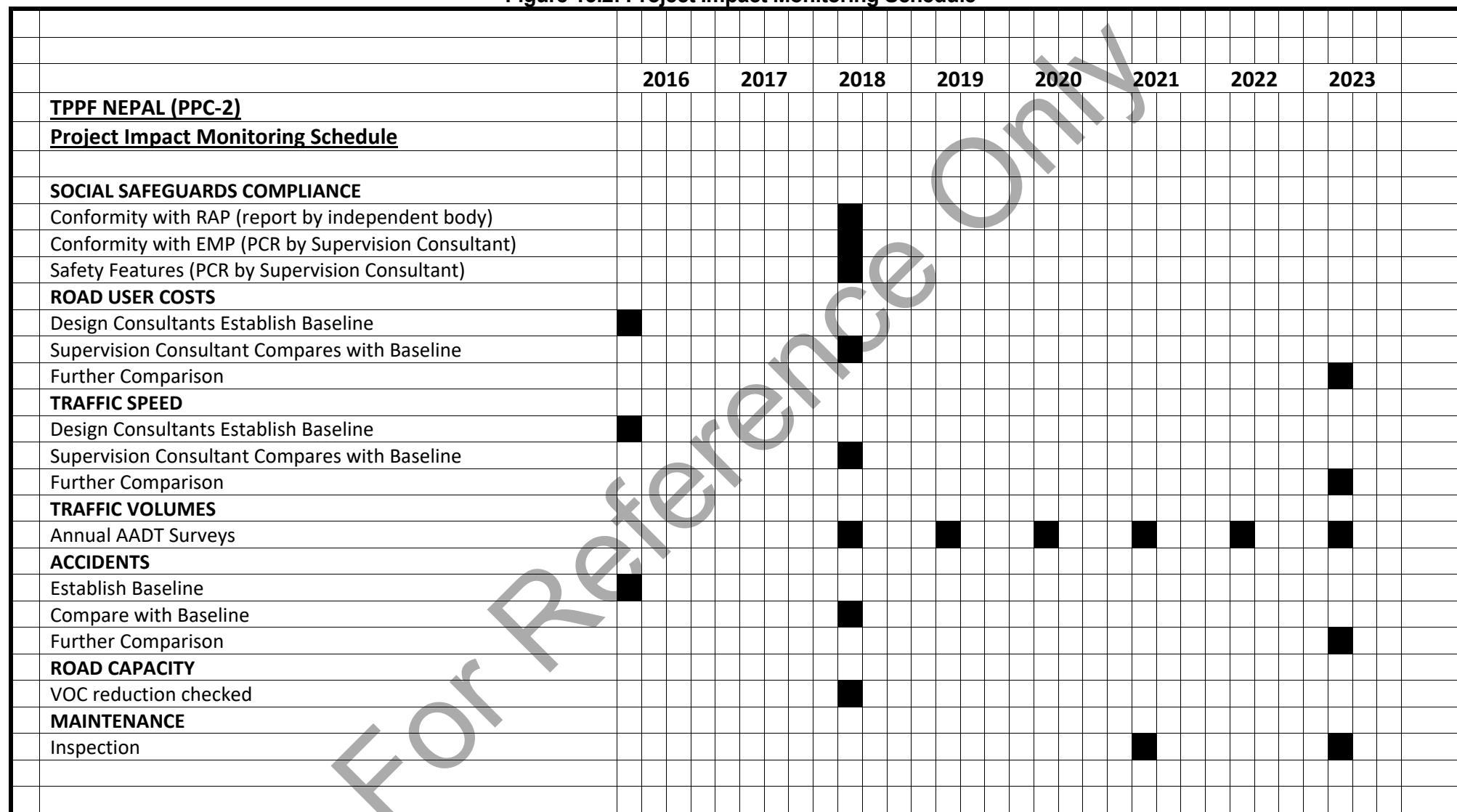


Figure 15.2: Project Impact Monitoring Schedule



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