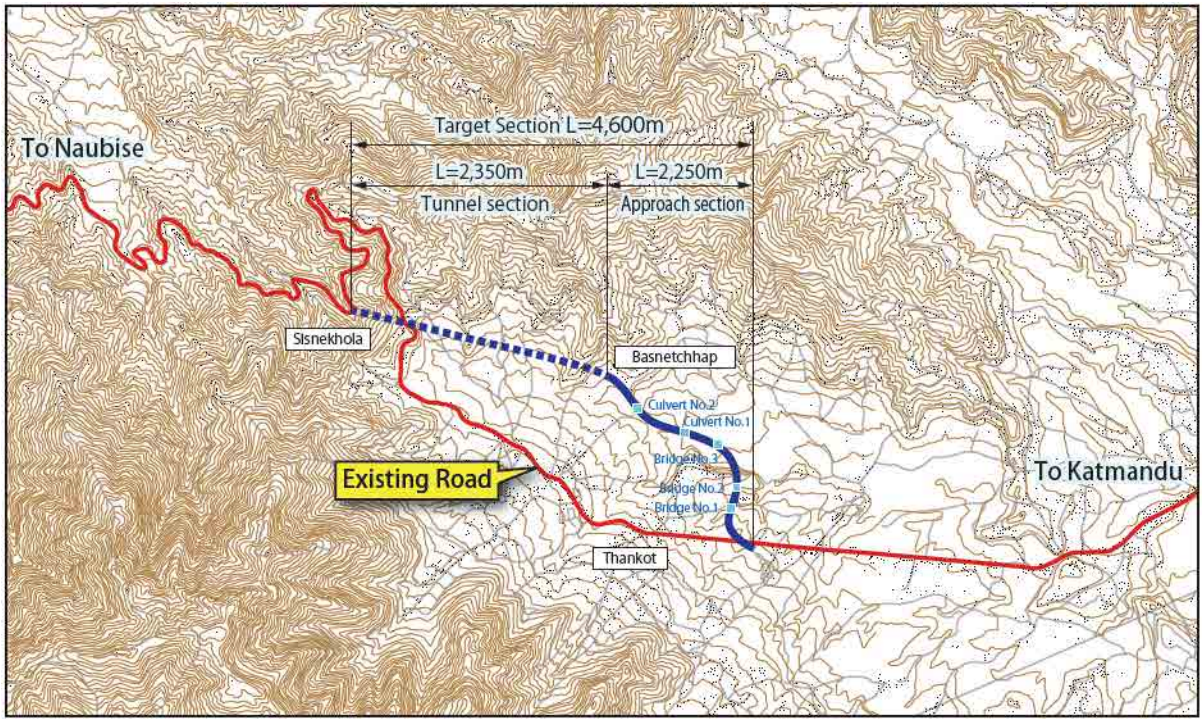
Chapter 1 Introduction

1.1 Current Transport Conditions

1.1.1 Location of the Study Area

Location of the study area is the section with approximately 22km between Kalanki intersection located on a ring road in the Kathmandu Valley and Naubise. The Figure 1-1 shows the location of the Project Road.



Source: JICA Study Team

Figure 1-1 Location of the Project Road

1.2 Background of the Study

In Nepal, road transportation has a predominant role, because it is the only means for public transportation except for the limited air service to some parts of the nation. Therefore, road infrastructure serves as a backbone for overall socio-economic development. The first long distance road to link Kathmandu with the Terai was taken up in 1953 with Indian assistance. This 115km Tribhuvan Road between Thankot and Bhainse was opened to traffic in 1956. Nepal faces various challenges for transport development due to its rugged topography, fragile geology, numerous river crossings etc. Nepal has a hilly terrain symbolized by its change of altitude from 100m to 8,848m over a short stretch of less than 200km. The steep ground slopes and the young fragile mountains create severe problems during construction and the operation of the roads. Flash floods generated by intensive rainfalls are quite common. This has triggered many landslide, that washed out road stretches and many bridges at regular intervals in the past.

Since Nepal is a landlocked country, foreign trade has to be conducted via both adjacent countries, India and China. The city of Kathmandu is located in the valley surrounded by 800~1,500m mountains, only two international corridors are available, namely, one is from India to the western Kathmandu via the Prithvi Highway, and the other is from China to the northeastern Kathmandu via the Arniko Highway. Regarding the latter road, it crosses over Himalaya Mountains and landslides have often occurred in rainy seasons, therefore the trade volume is limited.

Currently, Sindhuli Road financed by Japanese assistance will be inaugurated in 2015. Although it can be the second route from India, it runs through mountainous areas and its 4.75m road width is too narrow for large-sized buses and trucks to pass each other.

From the above consideration, it is advantageous that the route from India to the western Kathmandu via the Prithvi Highway is the most reliable corridor for foreign trade. This route, however, also has the steep gradient and sharp curve and the road alignment is not appropriate for logistics distribution. Especially, those steep gradient and sharp curve sections are located along the road between Thankot and Naubise of Tribhuvan Highway.

Improvement of this steep and sharp curving road to the appropriate alignment enables large-sized vehicles to run smoothly and reduces the traffic accident and traffic congestion. It will make trade between Nepal and India more active and contribute the economic growth of Nepal since Tribhuvan Highway between Thankot and Naubise is the main entry point to Kathmandu Valley.

1.3 Purpose of the Study

The Purpose of the study is to gather information on existing road conditions, and environmental and social consideration for the section between Kalanki intersection and Naubise as the intersection along the Tribhuvan Highway. And also the study should reveal the future policy for the new road improvement in this section from viewpoints of necessity and validity.

1.4 Validity of the Project

1.4.1 Validity of Japanese ODA Assistance

The government of Japan established the ODA assistance policy to the country of Nepal in April, 2012. It places great importance for a sustainable and balanced economic development that includes social infrastructure and legal institutions for the national economic growth. This project has validities with the above policy to correct the weakness in the social infrastructure condition in Nepal.

1.4.2 Validity of Development Strategy between Japan and Nepal

Nepal falls under the LDC category and therefore, has a problem of economic disparity. Japan recognizes that the government of Nepal's main concern is for the future economic growth of the country. Japan will work on development of socio-economic infrastructure for Nepal in order to enhance the Nepalese economic strength. The development strategies between Japan and Nepal will conform to this policy and this project is considered to be of great significance in this aspect.

1.5 Review of Previous Reports

1.5.1 Feasibility Study on the Construction of Kathmandu–Naubise Road (2001 JICA)

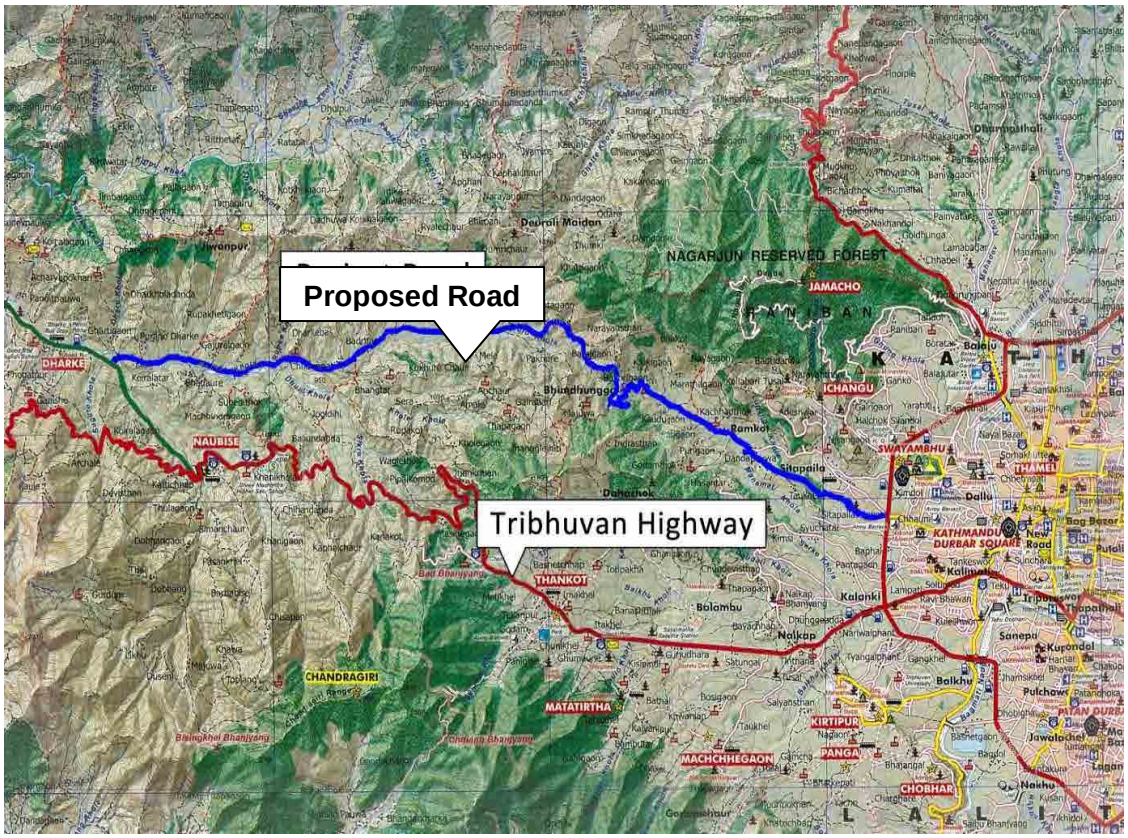
(1) Background

Currently there are two highways connecting Kathmandu with Terai Plain, namely Tribhuvan Highway and Prithivi Highway. Regarding the section between Kathmandu and Naubise, this part of the Tribhuvan Highway is the sole corridor linking Kathmandu with other areas of Nepal and has the most important role in Nepal road network from socio-economic and national security viewpoints. However, the existing road in this section has many problems like steep longitudinal grade (over 10%), weak prevention against disaster and many traffic accidents due to poor alignment.

The traffic volume of the section has reached its traffic capacity already, and improvement of this section by widening of the existing road to 4-lane road or construction of alternate road is required to accommodate future traffic of this section. Since the existing road traverses extremely fragile and steep terrain area, it is considered that widening of the existing road is practically impossible and construction of another alternate road is the most feasible solution for the improvement.

During the recent decade, the Department of Roads (DOR), Ministry of Physical Planning and Works of His Majesty's Government of Nepal (HMG/N), conducted a series of master-plan and pre-feasibility studies on future road improvement. Construction of an alternate road for the Kathmandu-Naubise section has been highlighted as a top priority project and technical assistance was requested from the Japanese Government to carry out a feasibility study for the construction of the Kathmandu – Naubise Alternate Road.

(2) Location



Source: JICA Study Team

Figure 1-2 Location of the Proposed Road (Kathmandu–Naubise Road (2001 JICA))

(3) Route Selection

In the beginning, Study team identified several conceivable routes for each section by using the 1:10,000 scale topographical map and screened out the alternatives by using Land Use Map, Hazard Map, Slope Gradient Map and Soil Production Map prepared by satellite's remote sensing data and field investigation. Except pass crossing section, only one route was selected for each section. For pass crossing section, three alternatives – long tunnel route, short tunnel route and no tunnel route – were remained.

For the justification of the Project to construct a new alternate road in Kathmandu – Naubise Section, further comparison with other alternatives, which are 4-lane improvements of the existing Tribhuvan Highway, was conducted. The current condition of the existing Tribhuvan Highway is shown as below:

Nos. of Lanes	:	2 lanes
Vertical Grade	:	Maximum is 11%, average of Nagdhunga Pass Crossing is 5.7%
Horizontal Curvature	:	Minimum is 20m

Hazard Potential : 66% of whole stretch of the road has potentiality of failure:
(110 nos of slope failures, 3 nos of debris flows and 1 no of huge land slide)

(4) Summary

Table 1-1 Summary of Proposed Road

Classification	
Road Classification Annual Average Daily Traffic Pavement Surface	National Highway 3,900 veh (2010 A.D.), 5,340 veh (2010 A.D.)* Asphalt Concrete
Road Network	
Beginning Point Ending Point Total Length	Ring Road (about 1km North of Kalanki Intersection) On Prithivi Highway at Gharke 21.4 km
Alignment	
Minimum Curve Radius Maximum Vertical Grade	60 m (55 m at hairpin bends) 5 %
Cross Section	
Lane Width Formation Width Paved Shoulder Width Side Ditch Top Width	7 m (2x3.5m) 12 m 3 m (2x1.5m) 1 m
Major Structures	
Tunnel Length Major Bridge at Dharke	0.7 km 50m

Note: Traffic volume in 2020 A.D. is with Kathmandu-Terai Road assumed to be implemented.
Source: Feasibility Study on the Construction of Kathmandu–Naubise Road (2001 JICA)

(5) Estimated Cost

Construction Cost	38.7 million US$
Engineering Cost	6.9 million US$
Contingency	3.9 million US$
Tax and Duty	4.5 million US$
Administration Cost	0.5 million US$
Land Acquisition and Compensation Cost	2.4 million US$
Total Cost	56.9 million US$

(6) Economic Evaluation

EIRR : 18.1%

NPV : 19.17 million US$

BCR : 1.57

Capital Cost Stream (Unit: million US$):

2001	2002	2003	2004	2005	2006
0.43	1.71	13.23	19.65	14.66	0.30

Economic Benefit (Unit: million US$):

	2010	2020
VOC saving	10.24	8.76
Travel Time Cost Saving	1.92	1.53
Total Benefit	12.16	10.29

Note 1: The above Cost Benefit Flow shows on Annex-1.

Note 2: 18.1 % of EIRR for this Project is much higher than 8% of minimum IRR in Nepal that is indicated by World Bank.

(7) Conclusion

- This Project is assessed as technically feasible with scope of construction of a 2 lane paved road in a total length of 21.4 km including a 705m highway tunnel.
- The Project is assessed as economically feasible with EIRR of 18.1 %, NPV of 19.1 million US$ and B/C ratio of 1.57 with the assumption of Kathmandu – Terai Alternate Road opening in the year 2016.
- The existing Tribhuvan Highway, especially Thankot-Naubise Section, is considered to potentially have a high risk for disaster area. Improvement of alignment, improvement of disaster prevention and possibility of 4-lane widening of the existing road were studied. These study results indicate that widening of the existing road is practically impossible and construction of a new alternative road is more advantageous.
- Traffic volume of the Project Road in the year 2010 and 2020 are expected to be about 3,900 vehicle/day and 5,340 vehicle/day, respectively. Traffic volume in the year 2020 is estimated under an assumption that Kathmandu – Terai Alternate Road is opened.
- It is strongly recommended that new truck terminal near the beginning of the Project Road is constructed in order to secure efficient operation of the Project Road and improvement of traffic condition of Kathmandu.

1.5.2 Feasibility Study of Tunnel Roads (2013 DOR)

(1) Background

In accordance with the budgetary provisions during current Financial Year 20168/069 the Department of Roads (DOR) has initiated basic works with a view to select a Feasible Tunnel Road Alignment linking Nagdhunga with Naubise of Tribhuwan Highway. It is desired to start the construction works at the earliest possible. The consultants have collected the following documents prior to field visit in order to select the appropriate Tunnel Road Alignment considering the existing Roads in the concerned localities:

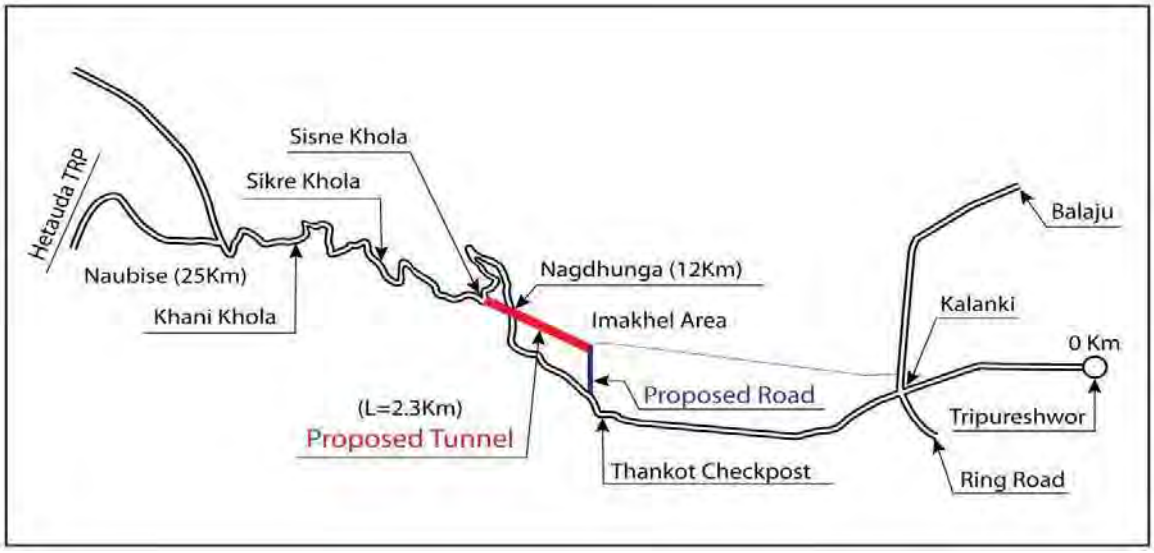
- Village and District Development Area Map
- Geological Map of the Project Area

- Hydrological and Meteorological Date
- Hazard Map/Mountain Risk Engineering
- Road Network Map
- Topographical Map of scale 1:25000 of Thankot Area
- Aerial Photo
- Technical Manual for Design and Construction of Road Tunnels – Civil Elements
- Lecture Notes on Tunnel Engineering – Division of Geotechnical and Transportation Engineering, AIT, Bangkok.

Accordingly the Draft Final Report Volume-I, for Nagdhunga-Naubise Tunnel Road and Volume-II, for Tokha-Gurje Tunnel Road were submitted on January 15, 2013 after desk study of various International Standards, Manuals and Specifications, Code of Practices, Construction Methodology as reported by Construction Contractors for Tunnel works under construction in Nepal, etc. and inspection and surveys (Topographical, Geological and 2D ERT) of the Tunnel Road in the field.

(2) Location

Location of the study area is the section with approximately 22km long between Kalanki intersection located on a ring road in the Kathmandu Valley and Naubise.



Source: Feasibility Study of Tunnel Roads (2013 DOR)

Figure 1-3 Location of the Proposed Road (Tunnel Roads (2013 DOR))

(3) Route Selection

A series of desk studies were carried out on Tunnel Road Engineering before mobilization of staff to the field. The selection for an appropriate Tunnel Road alignment the basic and the most important criteria in accordance with priority are considered as

a) Gradient: preferred Maximum of 4%

b) Gradient of Max.6% can be allowed for smaller Tunnel lengths.

c) Geological Topography & Seismic effects should permit economical method of construction

d) Hydrological water management must be safer and cheaper

e) Sociologically the tunnel must not interfere with historical/mythological places

f) Environment friendly transport / Traffic Management.

Walkthrough survey was conducted at different sections of the proposed Tunnel alignment and several existing information like topography of the area, Geological/hydrological observation, environmental and social impact observation and present traffic information were collected to confirm the tentative tunnel alignment in the field.

Three options were considered during the field visit for Nagdhunga – Naubise tunnel road.

a) Direct Tunnel Road Alignment (Continuous Tunnel from Nagdhunga to Naubise)

Option -1: Totipakha / Thankot – Naubise

Option-2: Imakhel 1/ Thankot – Naubise

b) Small Tunnel Road Alignment (Shorter length of Tunnels at scattered places):

Option -3: Tunnel – 1: Imakhel / Thankot – Sisne Khola

Tunnel – 2: Sisne Khola – Sikre Khola

Tunnel – 3: Sikre Khola – Khani Khola (straight) and Sikre Khola – Khani Khola (Curve)

Table 1-2 Direct Tunnel Alignment Options

Option	Tunnel	Inlet	Elevation (m)	Outlet	Elevation (m)	Distance (m)	Elevation Differenc (m)	Grade (%)
Opt-1	Tunnel-1	Totipakha (Thankot)	1380	Naubise	940	7,700	440	5.71
Opt-2	Tunnel-1	Imakhel (Thankot)	1400	Naubise	940	7,050	460	6.52
Opt-3	Tunnel-1	Imakhel (Thankot)	1389	Sisne Khola	1306	2300	82	3.6
	Tunnel-2	Sisne Khola	1300	Sikre Khola	1200	1700	100	5.88
	Tunnel-3	Sikre Khola	1120	Khani Khola	1019	1750	101	5.77
	Tunnel-3 Curve	Sikre Khola	1120	Khani Khola	1019	1800	101	5.61

Source: Feasibility Study of Tunnel Roads (2013 DOR)

Considering all of the options described above table, Imakhel to Sisne Khola tunnel road with a length of 2.3 km and grade 3.6% (Opt-3 Tunnel-1) is technically viable with an approach road of 1.1km length and is recommended for further feasibility study.

(4) Preliminary Design Conditions

For the feasibility study, the following design conditions are considered for civil works of the proposed Imakhel-Sisne Khola Tunnel Road. These are taken as per present condition of the existing site.

1) Design Speed – 60 kmph
2) Design daily volume as per Nagdhunga Police Post, Different Months of 2012
   7,579 vehicle/day (include motorcycle)
   6,497 vehicle/day (without motorcycle)
3) Width of Road
   Pavement Width : 0.5+3.5+3.5+0.5=8.0 (m)
   Footpath : 0.75m both sides
4) Vertical : 4.75 m
5) Additional allowance against future overlay
   Carriageway portion : +200 mm
   Shoulder : +50 mm

(5) Estimated Cost

Table 1-3 Estimated Cost

Item No.	Description	Amount (NRs.)	Remarks
A	Approach Road	712,840,000.00	
B	Tunnel		
1	EARTHWORKS	800,721,182.14	
2	STONE MASONARY WORKS	92,864,335.64	
3	CONCRETE WORKS	835,089,372.02	
4	FORM WORKS	66,009,463.04	
5	REINFORCEMENT STEEL WORK	302,690,665.60	
6	PAVEMENT WORKS	75,600,890.09	
7	CAMPS	500,000.00	
8	DAYWORKS	500,000.00	
9	MISCELLANEOUS	1,445,690,976.00	
	Sub-Total of Item B	3,619,666,884.52	For tunnel
	Risk Management (@2% of Item B)	72,393,337.69	
	Total	**4,404,900,222.21**	(A+B)
	VAT(@13%)	**572,637,028.89**	of (A+B)
	Grand Total	**4,977,537,251.10**	
	Annual Operation and Maintenance Cost (@5% of Item B)	**180,983,344.23**	During construction and maintenance period upto Defects Liability Period (DLP)

Source: Feasibility Study of Tunnel Roads (2013 DOR)

(6) Economic Evaluation Results

NPV (NRs. Million) : 3,113.01
IRR (%) : 19.65
BCR : 1.38

Capital Cost Stream (Unit: million NRS):

2014	2015	2016
1,215.75	2,836.76	201.63

Economic Benefit (Unit: million NRS):

	2020	2030
VOC saving	2,279.45	4,697.11
Travel Time Cost Saving	1169.07	379.63
Total Benefit	2,468.52	5,076.74

Note 1: The above Cost Benefit Flow shows on Annex-1.

Note 2: 19.65 % of EIRR for this Project is much higher than 8% of minimum IRR in Nepal that is indicated by World Bank.

(7) Conclusion

- The Nagdhunga – Naubise section of the Existing TRP considered being the most critical section in the present Road network linking Kathmandu with Terai in terms of traffic volume and capacity. The traffic in this section has already reached beyond its traffic capacity. Construction of an alternative road is urgently required.
- Possibility of a Tunnel linking Nagdhunga to Naubise is Technically not feasible because it has a grade of 5.7% (Totipakha – Naubise Section) and required criteria for a Tunnel is Max 4% of Grade. Hence, to ease the traffic constraints and economize the construction works a shorter tunnel linking Imakhel to Sisne Khola has been studied for feasibility.
- Considering the Geological mapping and 2D – Electrical Resistivity Tomography (ERT) reports, Imakhel – Sisne Khola Tunnel Road of 2.3 km length at a gradient of 3.6% can be constructed without any further risks for transport system.
- The field survey and interviews with vehicle operators reveal that they prefer to pay Toll equivalent to the price of fuel savings for using an alternative route for the same origin and destination.
- Hence, it is recommended that this Imakhel – Sisne Khola Tunnel Road (2.3 km long with a Grade of 3.6%) should be constructed in order to maintain convenient transport system for light and heavy vehicles to and from Kathmandu.

Chapter 2 Present and Future Transportation

2.1 Current Transport Conditions

2.1.1 Objectives of the Traffic Study

The traffic volume and composition of current and future traffic are important pre-requisites for road and geometric design and economic appraisal works. The main objective of the traffic count study at Nagdhunga is to establish the basic traffic indicators for base year of 2014. The specific objectives of the traffic study are to find out the following parameters of present traffic flow:

- Peak and off peak hour traffic volume,
- Traffic volume at week day and weekend day.
- Traffic volume inbound and outbound.
- Traffic share by each vehicle type.
- Traffic share by heavy vehicle and light vehicle.

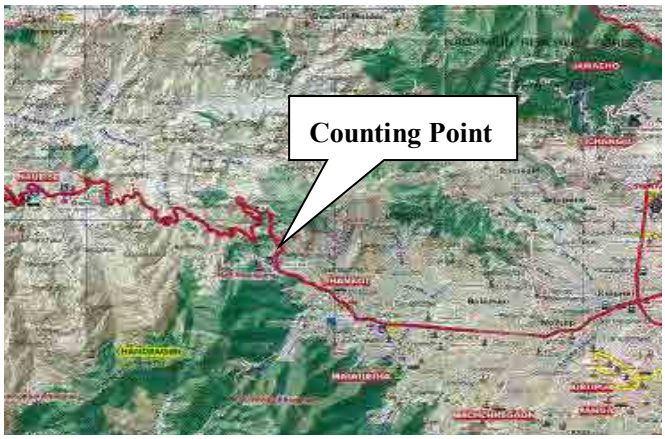
Based on these parameters, the study is aimed at determining the future travel demand along the proposed route.

2.1.2 Methodology of Traffic Survey and Counting

Manual traffic count method, the most reliable one was chosen in this survey. Classified traffic count was carried out as per the usual practice adopted by Department of Roads (DOR). Twenty four hour continuous count was prolonged for two days. Friday (7th Feb, 2014) and Saturday (8th Feb, 2014) were selected for sampling to represent the working and non-working days in Nepal. Saturday is observed as a holiday in Nepal. The brief methodology is described in the preceding sub-chapters:

- **Preparation phase**: The experienced team consisting of two persons for each traffic direction with the change of working shift of 8 hours per day was formed. The field team was led by a civil engineer to coordinate and compile the field data. A brief orientation on the traffic count method was organized during the preparation phase of the survey. The team was provided with the necessary safety gears. The traffic police station at Nagdhunga was contacted for the necessary assistance during traffic survey.
- **Traffic count:** Traffic movement unit (the number of vehicle) was recorded as per five dash method. Traffic count was organized to start from the 6:00 AM. Two persons for each direction were stationed at the convenient place for easy visibility of the traffic stream. Each half an hour count was recorded separately. Eight hour traffic counting shift was managed for reliability and ease for the survey team.
- **Report preparation phase**: After the completion of field survey, the data was compiled

and computer entry was performed. The data in spread sheet was further analyzed for determining necessary parameters. The field data of the survey is attached in the annex of the report.



Source: JICA Study Team

Figure 2-1 Location of Traffic Counting (Nagdhunga)

2.1.3 Vehicle Types

Table 2-1 gives the vehicle types used in the traffic count and classification survey in counting stations. The vehicle types are classified and adopted by Department of Roads (DOR).

Table 2-1 Vehicle Classification Adopted in Traffic Count and Classification Survey

Vehicle Type	Vehicle Characteristics
Multi-Axle Truck	Standard / heavy trucks, trailers/articulated. (≥3 axles)
Heavy Truck	Standard / heavy trucks, trailers/articulated. (2 axles)
Light Truck	Mid-sized trucks with single rear-axle (usually 4-wheeled,<8 tons GVW)
Large Bus	Buses having seating capacity of 35-50 seats
Mini-bus	Medium size buses having seating capacity of 20-35 seats.
Micro-bus	Small buses and vans having seating capacity of 10-15 seats.
Car / Taxi	Passenger car, taxis and vans (≤ 5 seats).
Utility Vehicles	Pickups or 4-wheeled vehicles with single/twin cabin and load compartment (open/hooded), Light freight vehicles
Motorcycle	Motorised two wheelers such as scooters and motorcycles
Power Tiller	Motorised four wheel vehicles used for carrying goods and mainly driven by hands and not steering.

Source: JICA Study Team

The following types of vehicles were not recorded during the survey; hence these categories in the data analysis table were omitted.

i. Non-Motorized types: Bicycle, Rickshaw and Animal Cart
ii. Tractor
iii. Auto-rickshaw

Table 2-2 Traffic Count Data Analysis

TRAFFIC COUNT SURVEY FOR 2014			
Result of Classified Manual Vehicle Count			
Start Date :	7 Feb, 2014	Location :	Nagdhunga
Road Link :	H0214	Station :	Nagdhunga
Road Name :	Tribhuvan Highway (Nagdhunga section)	Station No. :	74
DOR Seasonal Factor at TRP - Thankot (H0215) for February:	0.94	Surveyed by :	Fulbright Consultancy
		Supervised by:	M.K.Manandhar

Date	Start Time	Motorised Vehicles																				Total		
		Truck						Bus						Car/Taxi		MC		Utility Vehicles		Power Tiller				
		Multi-axle Truck		Heavy		Light		Big		Mini		Micro												
		a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a+b
7th Feb 2014	6:00 - 18:00	409	360	511	511	99	114	265	261	225	182	430	190	707	498	944	681	142	65	0	3	3732	2865	6597
	18:00 - 6:00	257	219	357	343	39	66	279	293	13	38	20	112	219	253	154	153	34	106	0	0	1372	1583	2955
	Day 1 Sub Total	**666**	**579**	**868**	**854**	**138**	**180**	**544**	**554**	**238**	**220**	**450**	**302**	**926**	**751**	**1098**	**834**	**176**	**171**	**0**	**3**	5104	4448	**9552**
8th Feb 2014	6:00 - 18:00	243	207	501	472	113	85	220	179	234	183	376	270	749	507	1015	765	175	78	0	0	3626	2746	6372
	18:00 - 6:00	138	404	219	349	18	63	245	398	23	25	26	167	97	447	82	375	41	154	0	0	889	2382	3271
	Day 2 Sub Total	**381**	**611**	**720**	**821**	**131**	**148**	**465**	**577**	**257**	**208**	**402**	**437**	**846**	**954**	**1097**	**1140**	**216**	**232**	**0**	**0**	4515	5128	**9643**
Total		**1047**	**1190**	**1588**	**1675**	**269**	**328**	**1009**	**1131**	**495**	**428**	**852**	**739**	**1772**	**1705**	**2195**	**1974**	**392**	**403**	**0**	**3**	**9619**	**9576**	**19195**
Grand Total (a+b)		**2237**		**3263**		**597**		**2140**		**923**		**1591**		**3477**		**4169**		**795**		**3**		**19195**		
Average Daily Traffic (ADT)		1119		1632		299		1070		462		796		1739		2085		398		2		9598		
Composition (%)		11.65%		17.00%		3.11%		11.15%		4.81%		8.29%		18.11%		21.72%		4.14%		0.02%		99.99%		
Total ADT excl. MC & Rickshaws		1119		1632		299		1070		462		796		1739				398		2		7513		
Composition excl. MC, rickshaws (%)		14.89%		21.72%		3.97%		14.24%		6.14%		10.59%		23.14%				5.29%		0.02%		100.00%		
Average Annual Daily Traffic (AADT)		1051		1534		281		1006		434		748		1634		1959		374		1		**9022**		
AADT excl. MC, Rickshaws		1051		1534		281		1006		434		748		1634				374		1		**7062**		
PCU Factors		4		3		1.5		3		2.5		1.5		1		0.5		1		1.5				
AADT in PCUs		4206		4601		421		3017		1085		1122		1634		980		374		2		**17441**		
% in PCU		24.11%		26.38%		2.41%		17.30%		6.22%		6.43%		9.37%		5.62%		2.14%		0.01%		100.00%		
AADT in PCUs excl. MC & Rickshaws		4206		4601		421		3017		1085		1122		1634		0		374		2		**16461**		

Note : **Direction a:** **Thankot to Naubise (Outbound)**
Direction b: **Naubise to Thankot (Inbound)**

Source: JICA Study Team

2.1.4 A Traffic Count Data Analysis

Traffic count survey conducted for two days have been analyzed and summarized in the Table 2-2. The basic parameters of the result are described in the Table 2-3 and 2-4.

Table 2-3 Traffic Volume on 7 Feb.

	Outbound	Inbound	Total
Day	2,788	2,184	4,972
Night	1,218	1,430	2,648
Total	4,006	3,614	7,620

Table 2-4 Traffic Volume on 8 Feb.

	Outbound	Inbound	Total
Day	2,611	1,981	4,592
Night	807	2,007	2,814
Total	3,418	3,988	7,406

Note 1: The above figures are No. of vehicles excluding motor-cycles.
Note 2: Outbound means vehicle from Kathmandu and inbound means vehicle to Kathmandu.
Source: JICA Study Team

(1) Average Traffic Volume

Traffic volume for the study area of the Tribhuvan Highway can be presented as:

- Average traffic volume excluding MC (motor cycle) is 7,513 vehicles per day.
- Average traffic volume including MC (motor cycle) is 9,596 vehicles per day.

According to Table 2.3 and 2.4, there are not much different for the traffic volume at working and non-working days in the study corridor.

(2) Share of Day and Night Time Traffic

Traffic volume study at Nagdhunga shows the remarkable high traffic volume at night as a National Highway. It means that the project road is a very important corridor since quite a number of vehicles drive through even at night.

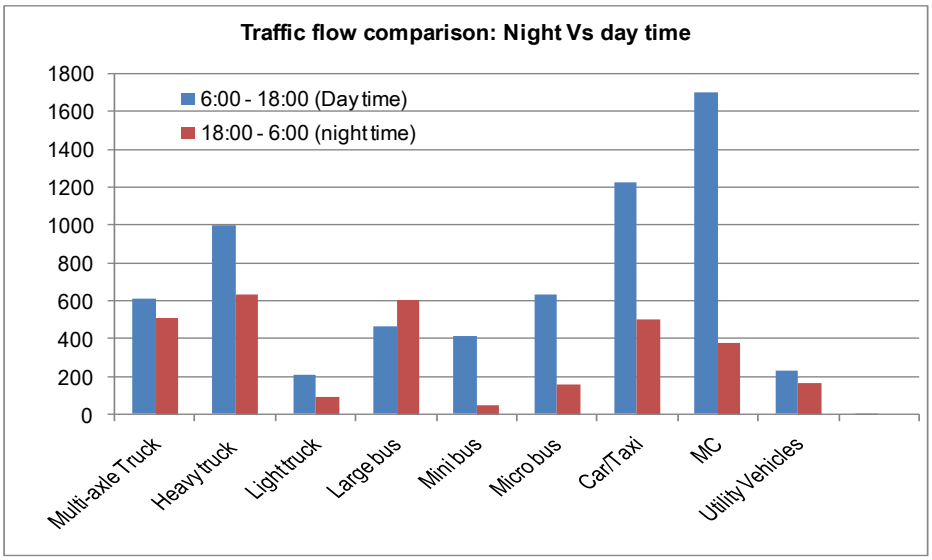
Hourly traffic volume distribution for day and night time category is shown in the Figure 2.2 according to Table 2.3 and 2.4.

<7 Feb. 2014>

Ratio of day and night = 7,620 / 4,972 = 1.53

<8 Feb. 2014>

Ratio of day and night = 7,406 / 4,592 = 1.61



Source: JICA Study Team

Figure 2-2 Traffic Share during Day and Night Time

(3) Traffic Share between Heavy and Light Vehicles

In general, passenger cars and mini buses are considered as light vehicles. Other categories of motorized vehicles can be considered as heavy vehicles. The ratio of these types of vehicles is shown in the Table 2-5.

Table 2-5 Traffic Share between Heavy and Light Vehicles

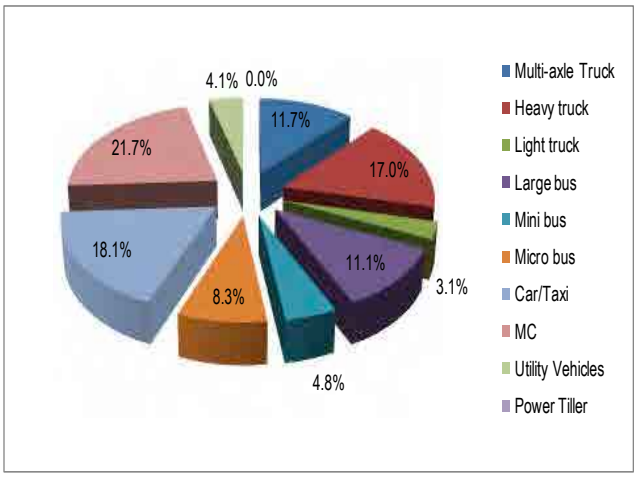
No. of vehicles during day time 12hours	Outbound		Inbound		Average	
	Heavy	Light	Heavy	Light	Heavy	Light
	1,185	1,603	1,132	1,052	2,317	2,655
Total	2,788		2,184		4,972	
Ratio of heavy vehicle	42.5%		51.8%		46.6%	

Note 1: The above figures are No. of vehicles.
Source: JICA Study Team

As shown in Table 2-5, the ratio of heavy vehicle is so big that the project road is regarded as the important logistics corridor. It seems that the surveyed road is the main entry to the Kathmandu Valley.

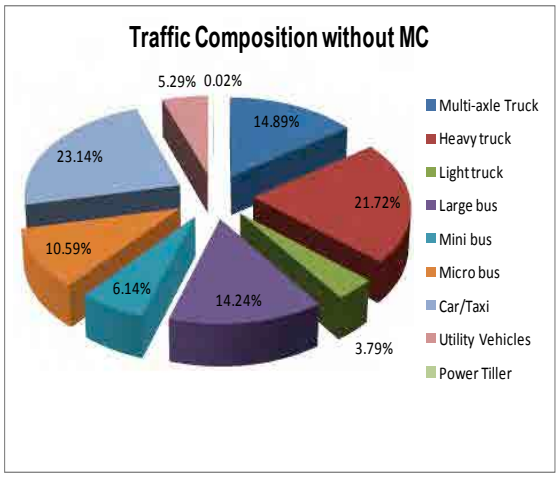
(4) Traffic composition

The traffic composition for the Nagdhunga section of Tribhuvan rajpath (TRP) of traffic with and without the consideration of MC is shown in the Figure 2-3 and 2-4 respectively. They are shown on ADT (Average Daily Traffic) base.



Source: JICA Study Team

Figure 2-3 Traffic Composition with MC



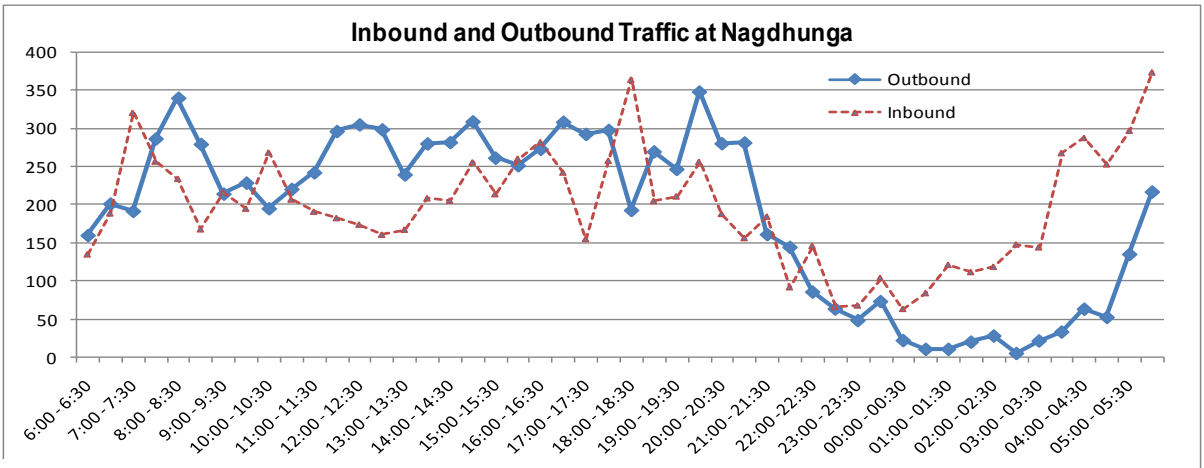
Source: JICA Study Team

Figure 2-4 Traffic Composition without MC

The percentage of heavy vehicle in the traffic stream is about 40%. The ratio of motorcycle (MC) in the traffic stream is about 22%. The share of passenger car/taxi is about 18 % at study section of the highway. MC are very common means of personalized mode for short and medium distance movement. Many studies have shown the percentage of MC in urban streets is about 65%. However, this percentage is also increasing along highways for short distance travel.

(5) Ratio of Inbound and Outbound Traffic

The traffic volume inbound to Kathmandu and outbound from Kathmandu has more or less equal share in the traffic stream. However, for the freight traffic, inbound and outbound for Kathmandu has greater difference in terms of tonnage. Most of the trucks (freight traffic) outbound from Kathmandu are empty. On the other side the inbound trucks are fully loaded with commodities. This scenario should be considered for the design of pavement structure and other facilities along the highway. The details of this fact can be studied by conducting axle load survey. The pattern of inbound and outbound traffic is presented in the Figure 2-5 below.



(Source: JICA Study Team)

Figure 2-5 Inbound and Outbound Traffic at Nagdhunga

(6) ADT and AADT (Annual Average Daily Traffic)

Average daily traffic or ADT, and sometimes also mean daily traffic, is the average number of vehicles two-way passing a specific point in a 24-hour period. ADT is not as highly referred to as the engineering standard of AADT which is the standard measurement for vehicle traffic load on a section of road. Annual average daily traffic, abbreviated AADT, is a measure used primarily in transport planning and transport engineering. It is the total volume of vehicle traffic of a highway or road for a year divided by 365 days. AADT is a useful and simple measurement of how busy the road is.

Traffic volume fluctuates yearly, especially between dry and rainy season in Nepal. It has higher volume in dry season but lower volume in rainy season. According to DOR, traffic volume of AADT in February shall be 94% of ADT. Table 2-6 shows the seasonal variation factor at Thankot given by DOR.

Table: 2-6 Seasonal Variation Factors

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Thankot	0.97	0.94	0.96	0.95	0.95	0.99	1.09	1.07	1.97	1.10	1.05	1.00

2.1.5 Peak Hour Traffic

The traffic volume distribution for twenty-four hour is shown in the Figure 2-6 and 2-7 below. Peak hour traffic in terms of No. of vehicles per hour for both directions is calculated separately. However, MC is not included in the No. of vehicles.

(1) Peak Hour Traffic of Inbound to Kathmandu

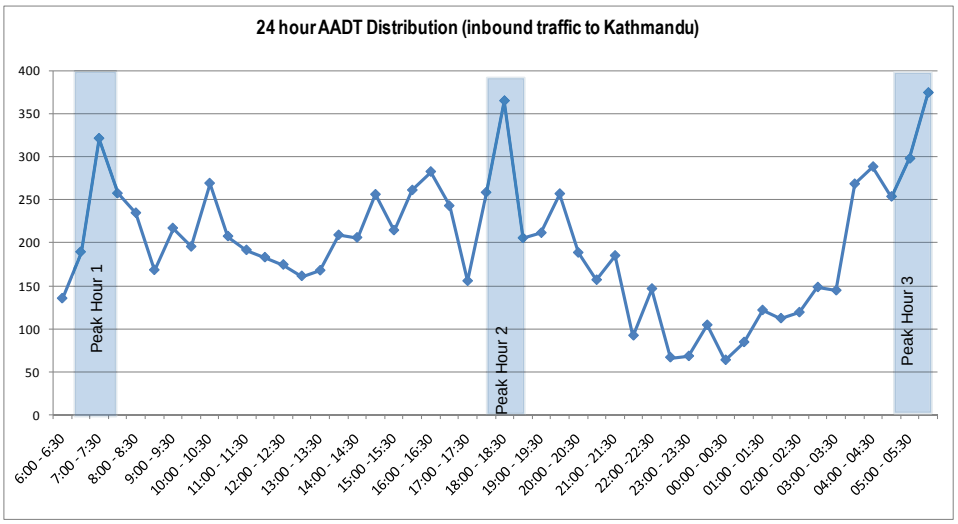
Traffic volume after the evening peak 18:00 is continuously decreasing till the early morning, i.e. 01:00 AM. The inbound traffic peak hour can easily be pointed out as:

- **Peak Hour - 1:** this peak hour duration is 7:00 – 8:00 AM. This peak period is mainly caused by the inbound passenger night buses to the capital city from various parts of the country. Peak hour volume is 379 vehicles.
- **Peak Hour - 2:** this peak hour duration is 17:30 – 18:30 PM. This peak period is mainly caused by the inbound passenger buses (long route day buses) to the capital city from various cities in the country. Peak hour traffic is 580 vehicles.
- **Peak Hour - 3:** this peak hour duration is 5:00 – 6:00 AM. This peak period is mainly caused by the inbound passenger night buses as well as trucks to the capital city from various origins in the country. Peak hour traffic is 476 vehicles.

Peak Hour Traffic of Outbound Vehicles from Kathmandu

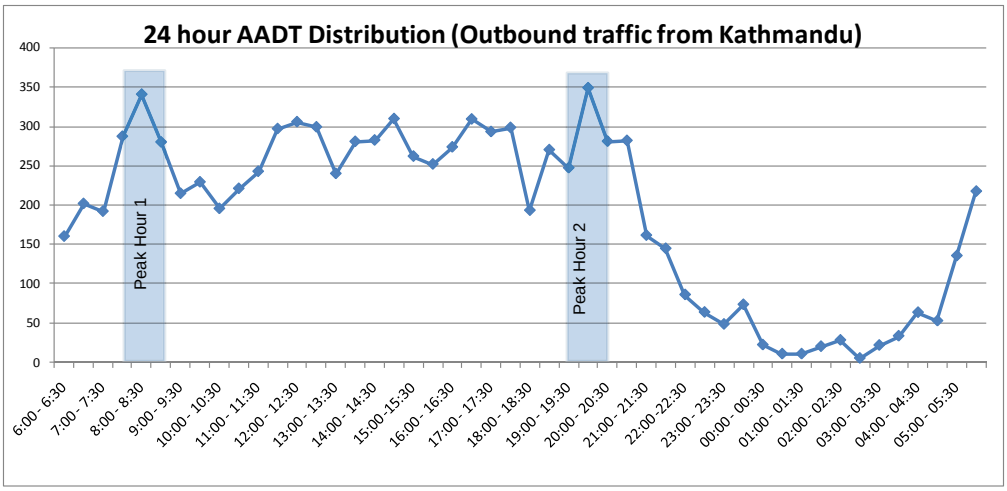
The traffic volume of outbound vehicles is also varying greatly during night and day. The Peak hours for outbound traffic are relatively late in the morning and evening than the inbound traffic. There are two peak hours for our bound traffic in the morning and one in the evening.

- **Peak hour - 1:** this peak hour duration is 7:30 – 8:30 AM. This peak period is mainly caused by the departure of long route as well as medium route passenger buses from Kathmandu. The private vehicles traffic is also relatively high during this peak hour. Peak hour volume is 631 vehicles.
- **Peak hour - 2:** this peak hour duration is 19:30 – 20:30 AM. This peak period is mainly caused by the departure of long route night buses and freight traffic from Kathmandu. The private vehicles traffic is relatively low during this peak hour in the outbound direction. Peak hour volume is 423 vehicles.



Source: JICA Study Team

Figure 2-6 Vehicle Distribution (inbound to Kathmandu)



Source: JICA Study Team

Figure 2-7 Vehicle Distribution (outbound traffic)

2.1.6 Past Record of Traffic Counting at Nagdhunga

Table 2-7 shows the traffic counting data at Nagdhunga from 2007 till 2014. The year of 2011 was the highest traffic volume in accordance with a national economic growth.

Table 2-7 Traffic Counting Data

(Unit: No. of Vehicle)

	2007	2008	2009	2010	2011	2012	2014
ADT (Annual Daily Traffic) with MC	5,582	6,861	6,479	8,020	9,773	7,899	9,022
ADT (Annual Daily Traffic) w/o MC	4,891	5,682	5,379	6,280	8,668	6,653	7,062

Source: DOR

2.1.7 Traffic Accidents along Thankot Road

Table 2-8 shows the annual traffic accidents between Kalanki to Naubise in 2013/14. As shown the table, section between Kalanki – Jhyple Khoka is much more accidents than section between Jhyple Kola – Naubise due to heavy traffic volume.

Table 2-8 Annual Traffic Accidents between Kalanki to Naubise in 2013/14

	No Vehicle Accident	Death					Injured				
		Men	Women	Boy	Girl	Total	Men	Women	Boy	Girl	Total
Kalanki – Jhyple Khoka	355	4	2	2		8	75	23	26	21	145
Jhyple Khola – Naubise	2		1			1	5				5
Total	357	4	3	2		9	80	23	26	21	150

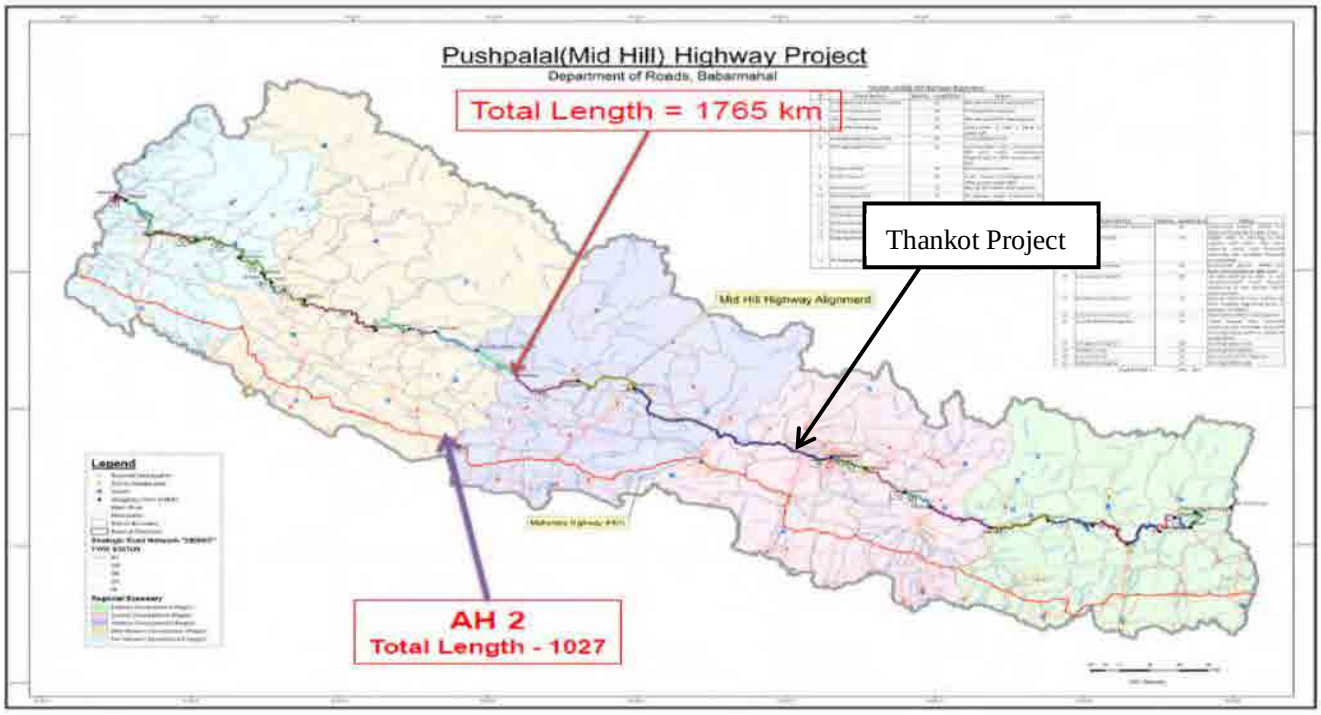
* Jhyple Khola is located 3.2 km from Nagdhunga toward Naubise.
Source: Nepal Traffic Police Headquarter Office, Singhadurbar

2.2 Positioning of the Thankot Road as a part of Road Network

2.2.1 Thankot Road to be one of the Section of Mid-Hill Highway

The project Thankot road is one of the section of the Mid-Hill Highway with a length of 1,765km. Mid-Hill highway a link road between Chiyabhanjyang of Panchathar in the east and Jhulaghat of Baitadi in the far-west. The highway connects 24 hilly districts and 215 villages of the country. The highway contributes to development of various sectors, including tourism, hydropower and agriculture in the region.

The government has a plan to establish 10 model cities along the highway. Phidim (in Panchthar district), Basantapur (Terhathum), Khurkot (Sindhuli), Baireni Galchhi (Dhading), Dumre (Tanahun), Burtibang (Baglung), Chaurjahari (Rukum), Rakam (Dailekh), Sanfebagar (Achham) and Patan (Baitadi) have been selected as locations to set up model towns. Figure 2-8 shows Mid-Hill Highway.

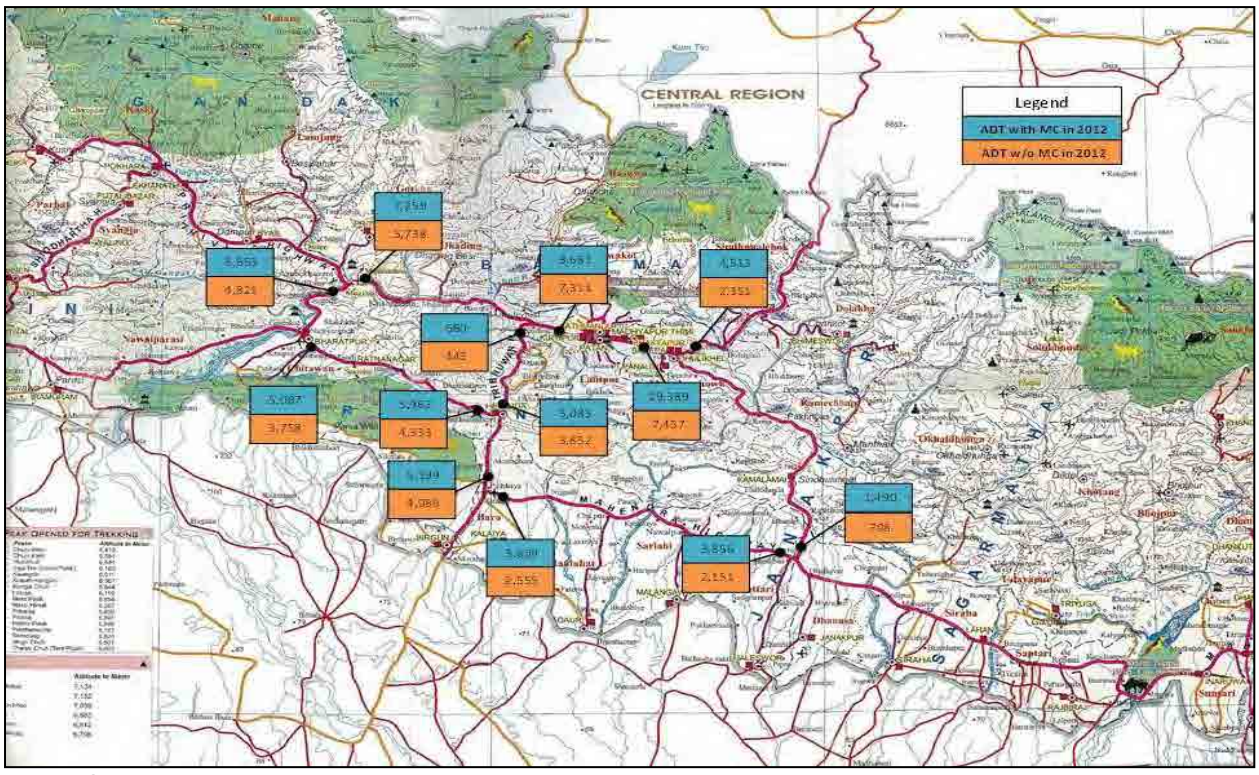


Source: DOR

Figure 2-8 Location of Thankot Project and Mid-Hill Highway

2.2.2 Traffic Volume on Major Roads around Kathmandu

Figure 2-9 shows traffic volume on major roads around Kathmandu in 2012.



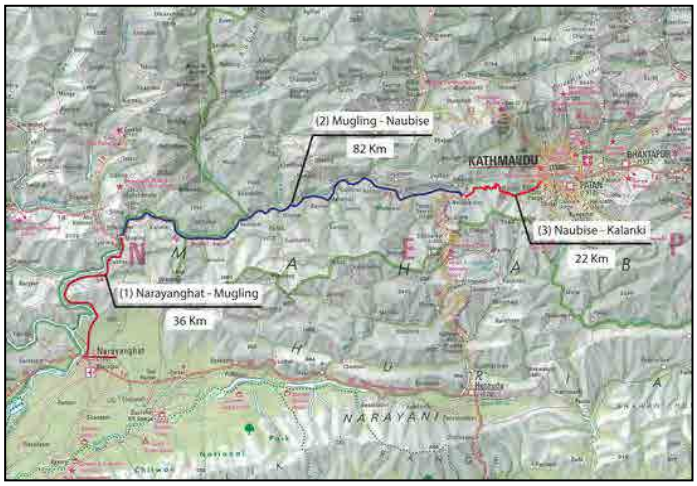
Source: DOR

Figure 2-9 Traffic Volume on Major Roads around Kathmandu

2.3 Road Development Projects around Kathmandu

2.3.1 Improvement of Narayanghat, Mugling, Kathmandu Road conducted by World Bank

The 36km Narayanghat - Mugling section of the road would be upgraded in the 1 phase under financial assistance worth 33 billion NRs. from the World Bank. The width of the road will be expanded to 8.5 m in 3 years. As the 2 phase, 82km Mugling – Naubise and the 3 phase Naubise – Kathmandu roads would be upgraded. These roads are being expanded to develop them into a major trade route linking Nepal and India.



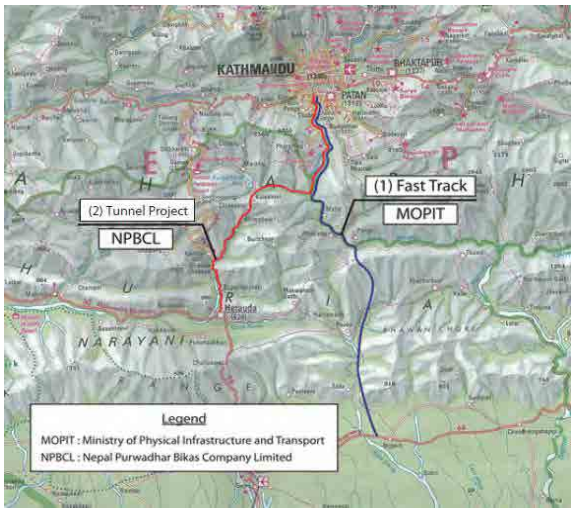
Source: JICA Study Team

Figure 2-10 Narayanghat - Kathmandu Project

2.3.2 North - South Corridor Project

(1) Fast Track carried out by MOPIT

The name of this project is generally called "Kathmandu – Terai Fast Track". Government of Nepal has initiated track opening works for the Kathmandu Terai fast track connecting Kathmandu to East-West Highway along the bank of Bagmati River from outer Ring Road to Nijgard. The total length of the highway is 76 km including tunnels section across the steep mountain. Nepal Army has taken the initiation to open the preliminary track of the highway. Basically, an annuity model is a form of carrying out infrastructure projects, in which a developer is awarded the contract to undertake the project and the cost of building the road is paid to the developer on a yearly basis after the projects starts commercial operations. In annuity projects, developers get paid for what it invested on installment basis including its interest rate and profit margin.



Source: JICA Study Team

Figure 2-11 Fast Track Projects

(2) Tunnel Project carried out by NPBCL

The name of this project is generally called "Kathmandu Hetauda Tunnel Highway". The project is being developed by Nepal Purwadhar Bikash Company Ltd (NPBCL). The development plan of this project is the first BOOT Highway of Nepal going to be developed by

Public-Private and People's - Participation, 4P model. The approximate length of the highway is about 59 km starting from Balkhu Ring Road (Kathmandu) to Hetauda including 3 tunnels (0.3km, 3.5km and 0.9 km) and a total of 15 bridges.

A total of Rs. 10 billion 50 lakhs will be collected from founder shareholders, Rs. 6 billion 50 lakhs will be collected from general shareholders, and the company is preparing to borrow Rs. 17 billion from banks.

2.3.3 Sitapaila - Dharke Road Project

The exsisting road is fair weather with a total length of 23km but proposed length of road is about 35km. It will serve as an alternative route for the existing Prithivi Highway. The alignment passes through unstable slopes At different places. The alignment requires considerable improvement in road geometry, slope stabilization, retaining structures and drainages, major bridge and possible tunnel.

Source: JICA Study Team

Figure 2-12 Sitapaila - Dharke Road Project

Since existing road is not wide enough to bear heavy traffic, the project shall assist in solving this program. At the same time, it also provides an alternative route to enter the Kathmandu valley.

The services provided by the consultants include:

1) Feasibility study for stretch of the road from Kathmandu to Dharke.

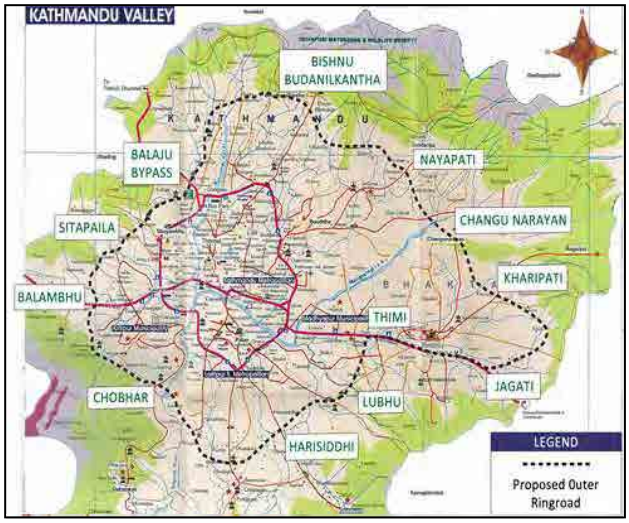
2) Detailed engineering survey and design for preferred alignment including preparation of BID document.

These studies are progressing from support from Kuwait fund grant with allocation of approximately US$ 875,000.

2.3.4 Outer Ring Road Project

The concept of an additional road within the periphery of Kathmandu Valley, known as the Outer Ring Road had been proposed since a decade ago following rapid urbanization and increase in population in the old and new settlements outside the present Ring Road within the Kathmandu Valley.

The Government with the view to construct the Outer Ring Road, formed the Outer Ring



Source: JICA Study Team

Figure 2-13 Outer Ring Road Project

Road Development Project (ORRDP) under the Department of Urban Development and Building Construction (DUDBC).

The Outer Ring Road scheme which is 71.93 km in total length has planned to construct a 50 meter Right-of-way road with 2 high-speed lanes for each direction and two slow-speed lanes (service lanes) for each direction, and an additional lane as shoulder/ parking lane and a cycle lane for each direction. In addition, there would be green belts and footpaths on both sides. The high-speed lanes will be separated by a 2 meter wide median divider. The high-speed and slow-speed lanes are separated by a 1 meter wide lane divider. The design speed for the high-speed lane would be 80 km/hour and 40 km/hour for slow-speed lane.

With a vision to construct the Outer Ring Road as early as possible, the ORRDP has been working swiftly in the past years. Different studies are been conducted, such as, the Study on Technical Viability of the Alignment, Study on Possible Intersection Development, Model Land Re-Adjustment Plan, Townscape in the Proposed Outer Ring Road Area, and presently the EIA/SIA for the entire road corridor has been proposed.

2.4 Traffic Demand Forecast along Thankot Road

2.3.1 Traffic Forecast

Any transport project justification in terms of economic or financial parameters should be based on the traffic volume in the design year. The anticipated design year traffic volume is estimated after the determination of growth rate. The traffic growth rate is based on function of economic as well as population trends in the project areas.

Traffic forecast for this section of Tribhuvan Highway should be mainly guided by the economic growth and population growth of the region. Due to the limitation to the extent of this study, traffic forecast is done on the basis of elasticity approach. Traffic growth rates, compared from the similar studies, are also basis for the traffic forecast in this study. Traffic forecast is mainly associated with the determination of traffic growth rate for passenger and freight traffic in the future.

2.3.2 Traffic Growth along the Existing Highway

For the prediction of traffic volume along the Nagdhunga section of Tribhuvan Highway, extrapolated traffic growth based on elasticity-principle has been used that is common transport forecast methodology in Nepal. Elasticity relates traffic growth with various economic parameters such as Gross Domestic Product, population, etc. This approach for forecasting was preferred over that, based on analysis of historical traffic-growth, owing to sensitivity of the traffic figures.

Growth-rate for trucks (freight traffic) per year in percentage was determined as follows:

$$r_f = G * E \text{ .....(i)}$$

Where,

r_f = Growth rate for freight traffic per year in percentage,

G = Growth rate of GDP, and

E = Income elasticity of transport demand.

Similarly, growth-rate for passenger-transport is calculated by using the following relation :

$$r_p = [\{(1+p)*(1+I*E)\}-1]*100 \text{ .....(ii)}$$

Where,

r_p = Growth rate of passenger traffic per year in percentage,

p = Population growth rate in percentage,

I = Per capita growth rate in percentage,

E = Income elasticity of transport demand.

(1) Traffic Growth Rate for Freight Traffic

Income elasticity of transport demand applicable for developing countries ranges from 1.5 to 2. The elasticity applicable for passenger transport is higher than that of freight –transport. All the economic parameters adopted for traffic growth analysis is based on GON (Government of Nepal) projections and fine-tuned based on latest trend.

The demand of freight traffic mainly depends on the production in the factory or agriculture and its consumption in the market. Hence the growth rate of the freight traffic was calculated by the multiplication of GDP growth rate and the income elasticity of the transport. Table 2.8 shows traffic growth-rate used for this Study.

(2) Traffic Growth Rate for Passenger Traffic

The growth rate of Passenger car and motorcycle is calculated with the help of population growth rate, per-capita income and income elasticity. Similarly, Growth rate of the passenger transport (Buses) is taken as the function of income elasticity, population growth rate and per capita income. Further, the growth rate of was calculated for the duration of five years. The values of GDP, Population and per-capita income growth rate were taken from the World Bank projection, Nepal Bureau Statistics, DOR Twenty Year Plan and so on.

Table 2-9 Traffic Growth Rate

Period	Freight Traffic			Passenger Traffic					
	Truck/Mini-truck			Pop. growth (%/yr)	Per Capita Income-growth (%/yr)	Car/Utility/Vans		Bus/Mini Bus	
	GDP growth (%/yr)	Elasticity	Traffic Growth (%/yr)			Income-elasticity	Traffic Growth (%/yr)	Income-elasticity	Traffic Growth (%/yr)
2006~ 2010	4.4%	1.5	6.6%	2.2%	2.9%	2.0	8.2%	1.6	7.0%
2011~ 2015	4.3%	1.3	5.6%	1.5%	3.2%	1.8	7.3%	1.5	6.3%
2016~ 2020	4.4%	1.0	4.4%	1.8%	2.4%	1.7	6.0%	1.4	5.2%
2021~ 2025	4.9%	1.0	4.9%	1.7%	2.5%	1.6	5.8%	1.3	5.1%
2026~ 2030	5.5%	1.0	5.5%	1.7%	2.5%	1.5	5.6%	1.2	4.8%
2031~ 2035	6.0%	1.0	6.0%	1.7%	2.5%	1.5	5.6%	1.2	4.8%

Source: Calculated by JICA Study Team

(3) Future Demand Forecast

It is worthwhile to note that when growth-analysis is solely based on previous trend. The traffic growth-rate in Table 2-9 is also justifiable as it more closely reflects the DOR Twenty-Year Plan, World Bank and other similar studies. GDP growth is expected to increase after the political stabilization in the country and hence the economic growth as well. The results of the traffic forecast, using the Traffic Growth Rate of Table 2-9, is shown in Table 2-10 below:

Table 2-10 Result of Traffic Forecast

(unit: AADT)

Vehicle Types		2014	2015	2020	2025	2030	2035
Freight traffic	Multi-axle truck	1,051	1,120	1,388	1,763	2,304	3,083
	Heavy truck	1,534	1,635	2,026	2,573	3,363	4,500
	Light truck	281	299	371	471	616	824
	Utility vehicle	374	399	494	627	820	1,097
Passenfer traffic	Large bus	1,006	1,070	1,381	1,768	2,235	2,826
	Mini bus	434	462	596	763	964	1,219
	microbus	748	795	1,027	1,314	1,662	2,101
	Car/Taxi	1,634	1,753	2,343	3,110	4,079	5,349
Total		7,062	7,533	9,626	12,389	16,043	20,999

Source: Calculated by JICA Study Team

Chapter 3 Natural and Social Conditions

3.1 Climate

3.1.1 Climate Conditions in Nepal

The temperature and precipitation patterns are highly dependent on the altitude. Although it's a small country, Nepal has five climatic zones.

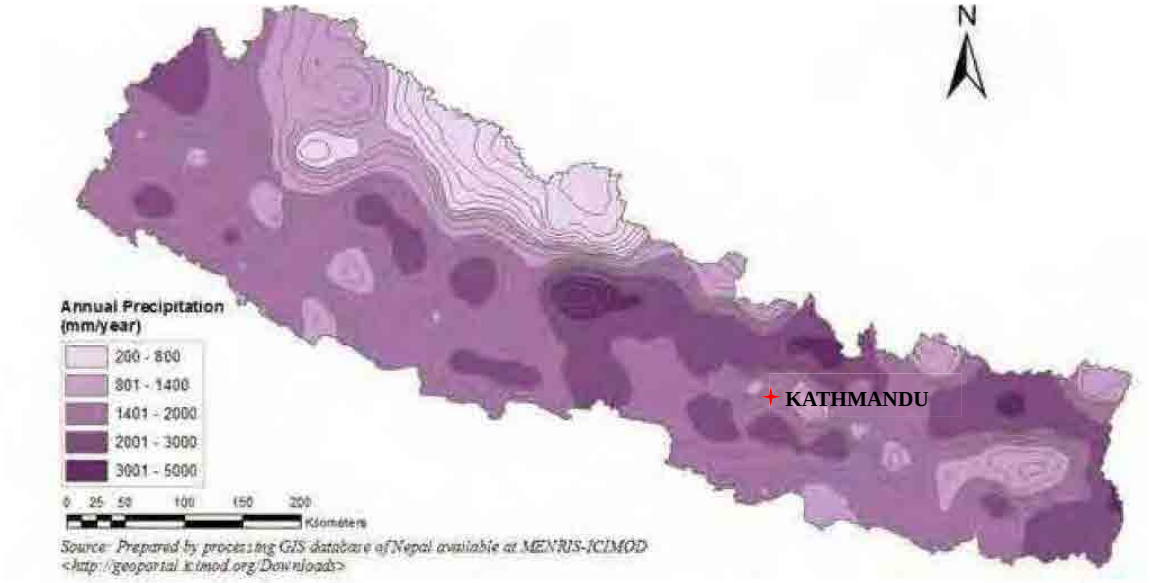
Table 3-1 The Climate at Kathmandu Airport

Altitude	Climatic Zone
Below 1,200 m	Tropical and subtropical zone
1,200 – 2,400 m	Cool, temperate zone
2,400 – 3,600 m	Cold zone
3,600 – 4,400 m	Sub-arctic zone
Above 4,400 m	Arctic zone

Source: Profile on Environmental and Social Considerations in Nepal, January 2013, Japan International Cooperation Agency

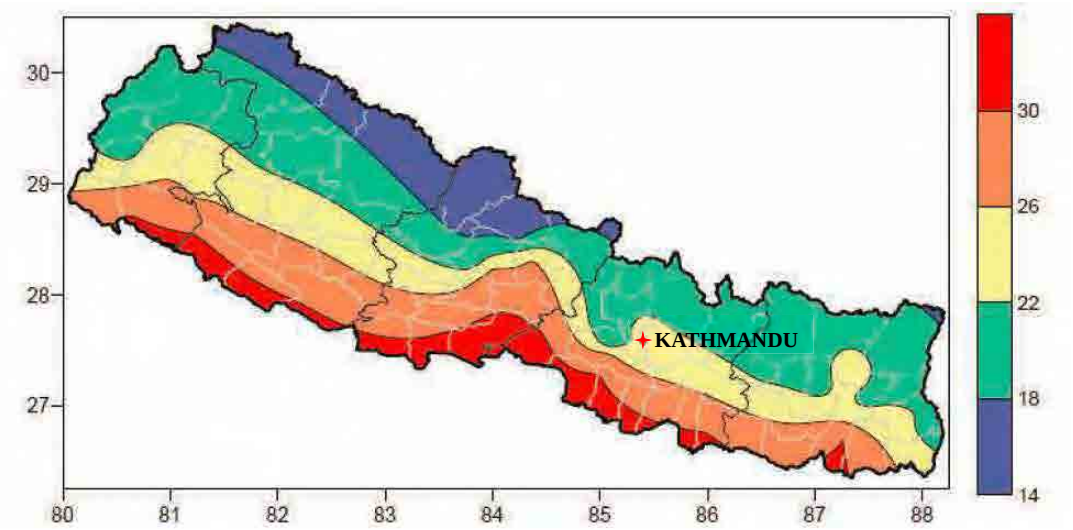
Generally, the temperature in the country decreases from south to north as the altitude increases.

The annual rainfall distribution in Nepal is also influenced by the changes in altitude. In addition to these effects, the amount of rainfall also generally decreases from east to west during the summer monsoon from June to September. Eastern Nepal receives approximately 2,500mm of rainfall annually; the Kathmandu area, about 1,420mm; and western Nepal, only about 1,000mm.



Source: "State of water: Nepal" http://www.wepa-db.net/policies/state/nepal/overview.htm (Accessed on 20 November 2012), cited in Profile on Environmental and Social Considerations in Nepal, January 2013, Japan International Cooperation Agency

Figure 3-1 Annual Precipitation Pattern in Nepal



Source: Nepal Health Research Council. 2009. "Situation Analysis of Environmental Health in Nepal 2009." http://www.nhrc.org.np/reports/Situation%20Report.pdf (Accessed on 27 December 2012), cited in Profile on Environmental and Social Considerations in Nepal, January 2013, Japan International Cooperation Agency

Figure 3-2 Mean Annual Temperature

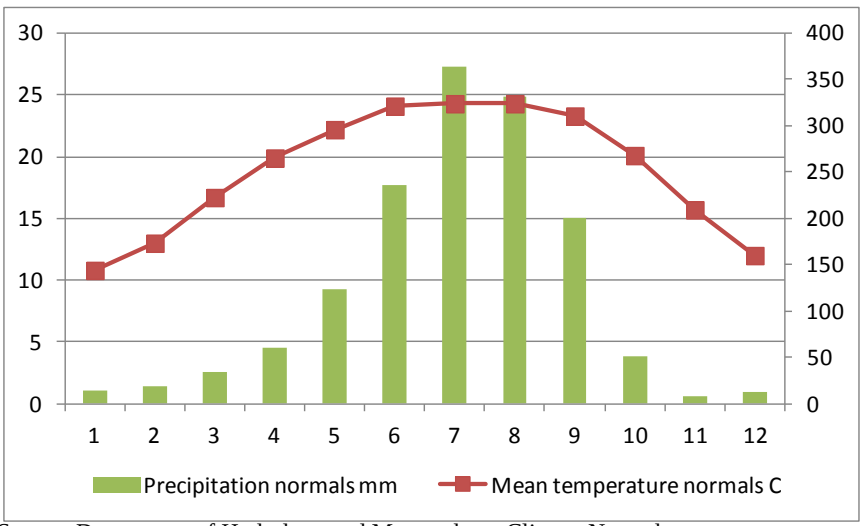
3.1.2 Climate Conditions in the Study Area

The temperature in the Kathmandu area is moderate throughout the year, but its rainfall shows clear dry and wet season. During the wet season between May and September, nearly 90% of the yearly precipitation is observed.

Table 3-2 Mean Temperature and Precipitation at Kathmandu Airport

Month	1	2	3	4	5	6	7	8	9	10	11	12	
Mean temperature normals C	10.8	13	16.7	19.9	22.2	24.1	24.3	24.3	23.3	20.1	15.7	12	Average 18.9
Precipitation normals mm	14.4	18.7	34.2	61.0	123.6	236.3	363.4	330.8	199.8	51.2	8.3	13.2	Total 1,454.9

Source: Department of Hydrology and Meteorology, Climate Normals.
http://www.dhm.gov.np/uploads/climatic/880251189NORMAL%20FILE.pdf (Retrieved 2014 March 10)



Source: Department of Hydrology and Meteorology, Climate Normals.
http://www.dhm.gov.np/uploads/climatic/880251189NORMAL%20FILE.pdf (Retrieved 2014 March 10)

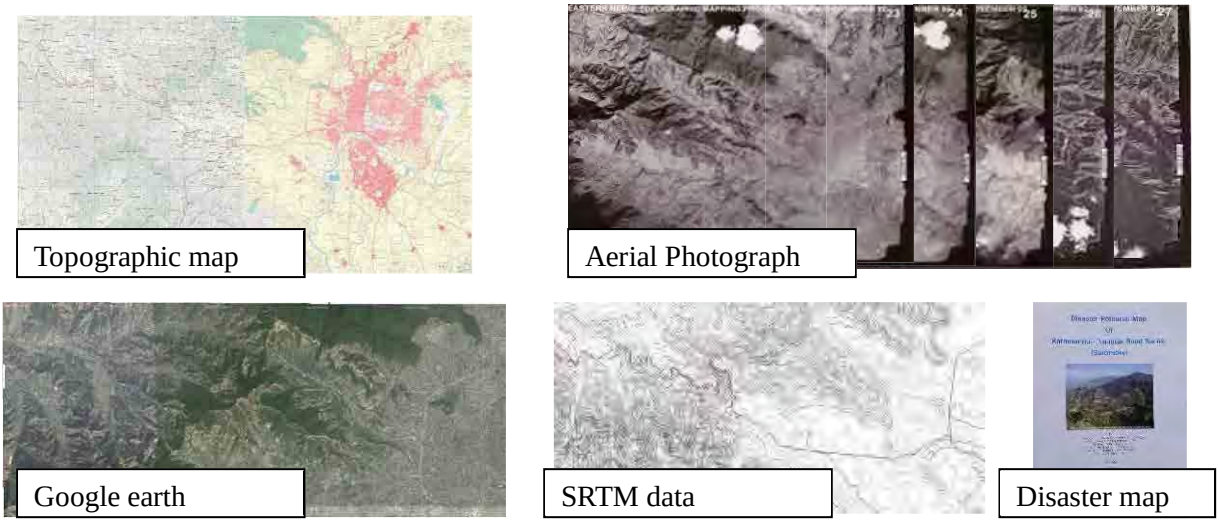
Figure 3-3 Mean Temperature and Precipitation at Kathmandu Airport

3.2 Topography

3.2.1 Field Survey and Data Collection

The Study Team has so far collected the following material from various departments, internet sources, through site reconnaissance and other available sources:

i) Topographic map (scale 1:25,000) (DOS)
ii) Aerial Photograph (scale 1:50,000) (DOS)
iii) Google earth (Google)
iv) SRTM data (NASA)
v) Disaster Potential Map of Kathmandu-Naubise road Sector (Summary) (DWIDP)
vi) Field survey



Source: as noted above

Figure 3-4 Collected Materials for Topographical Analysis

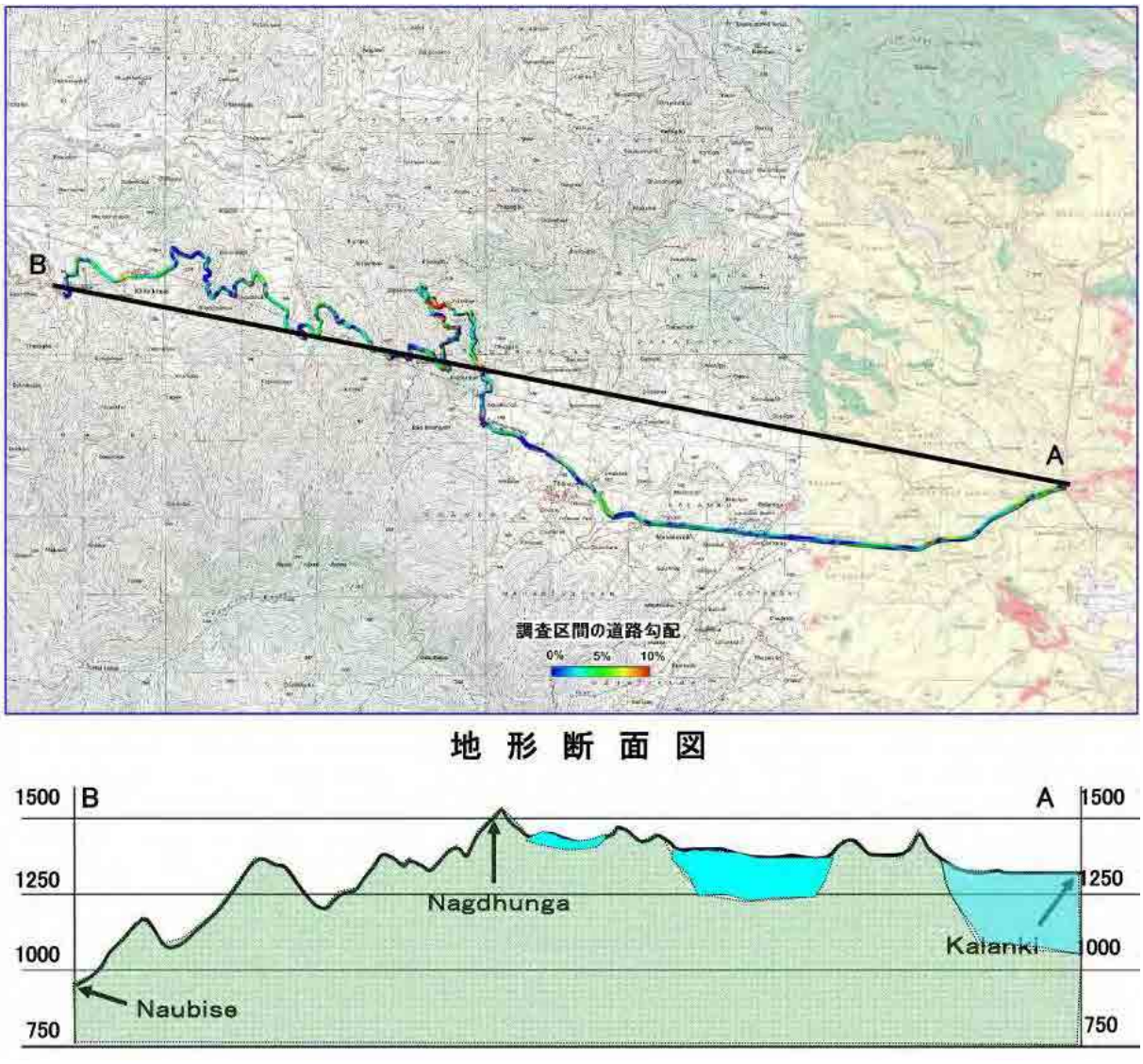
3.2.2 General Topography of Study Area

Topographic map and schematic profile of the Study Area is shown in Figure 3-5.

The Topography of the study area is divided into two distinct parts with Nagdhunga Pass in the middle; gentle topography of the Kathmandu Valley in the east and mountainous topography of Naubise side at the west. The topography at the Kathmandu valley is composed of lowland alluvial fan and has gentle slops with its elevation in the range between 1,500m and 1,300m.

The topography at the Naubise side varies from 1,500m to 900m and is composed of many valleys developed as the result of continuous progress of erosion of the mountains. Traces of landslides and slope collapse can be seen at several locations. In the vicinity of Khanikhola, a wide gentle slope formed from the deposit of the mass debris flow that filled up the valley can be observed.

This characteristic of the topography has been directly reflected in the alignment of the existing road. The alignment at the valley side is tangential with relatively flat vertical grade, while at the Naubise side, due to existence of unstable mountains, the road has numerous sharp horizontal curved and steep vertical grades reaching more than 10%.



Source: JICA Study Team

Figure 3-5 Topography Map of Study Area and Profile

Photos shown below indicate the typical case of topography found in the study area.

Thankot: Gentle slope

Kathmandu valley

Nagdhunga Pass: Steep slope

Jhyaple khola Collapse

Sisne Khola Road and Cliffs

Naubise Even road

Source: JICA Study Team

Photos 3-1 Typical Case of Topography found in the Study Area

3.2.3 Consideration Needed for Construction of Tunnel and Road

(1) Roads

- Kalanki intersection ~ Nagdhunga Pass

The entire area has a gentle grade and no particular consideration is required for the planning of a road in regards to the topography.

-Nagdhunga ~ Naubise

The existing road runs along steep hillside where rivers such as Sisne Khola, Khatripauwa, Sikre Khola etc, is accelerating erosion of the slopes. There are many locations where traces of slope failure can be identified. Several locations where mountains have steep slopes (more than 45%), cutting mountains in terrace shape for cultivation use and deforestation are some of the cuases than can be considered for slope failures.

If a new road is to be constructed, then it is inevitable to plan on the upper side of the existing road. As such, provision of bridges, slope protection and measures against slope failures will be required. Figure 3-6 shows the landslide and collapse distribution map of the Study Area.

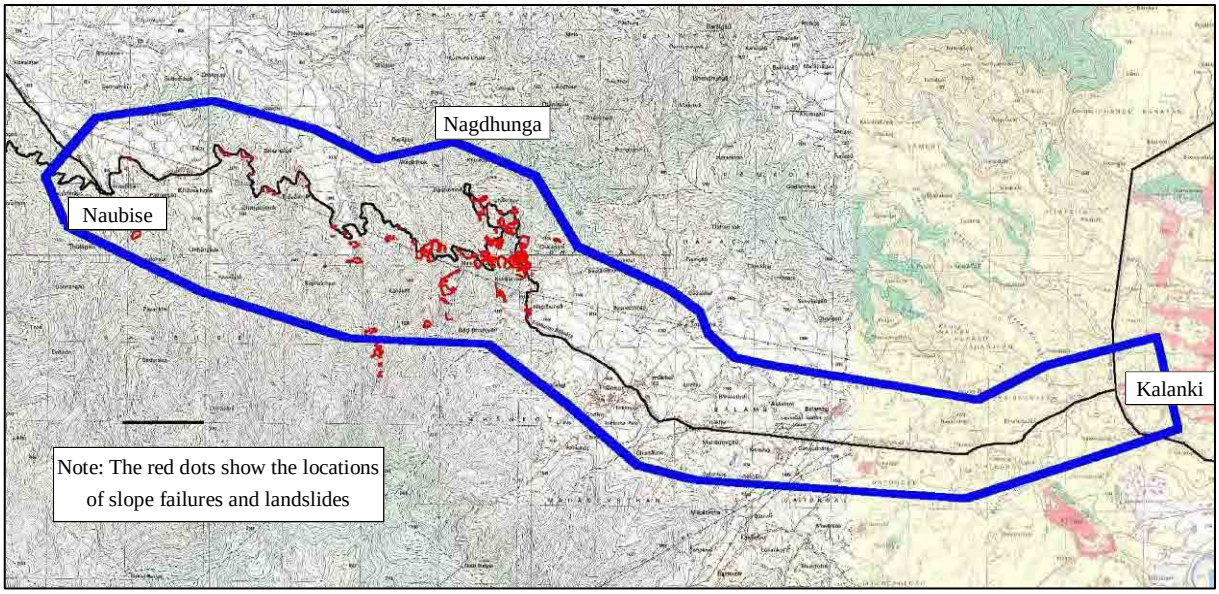


Figure 3-6 Landslides and Collapses in the Study Area

As can be understood from the figure above, landslides are concentrated on the western slopes of Nagdhunga Pass as far as up to Naubise.

(2) Tunnel

Considerations needed for excavation during construction of tunnel, with respect to the topographic conditions are;

- Secure safety from collapse, debris flow, and spring water at the tunnel portal
- Ensure that the tunnel is perpendicular with the topography
- Avoid locations with possible faults

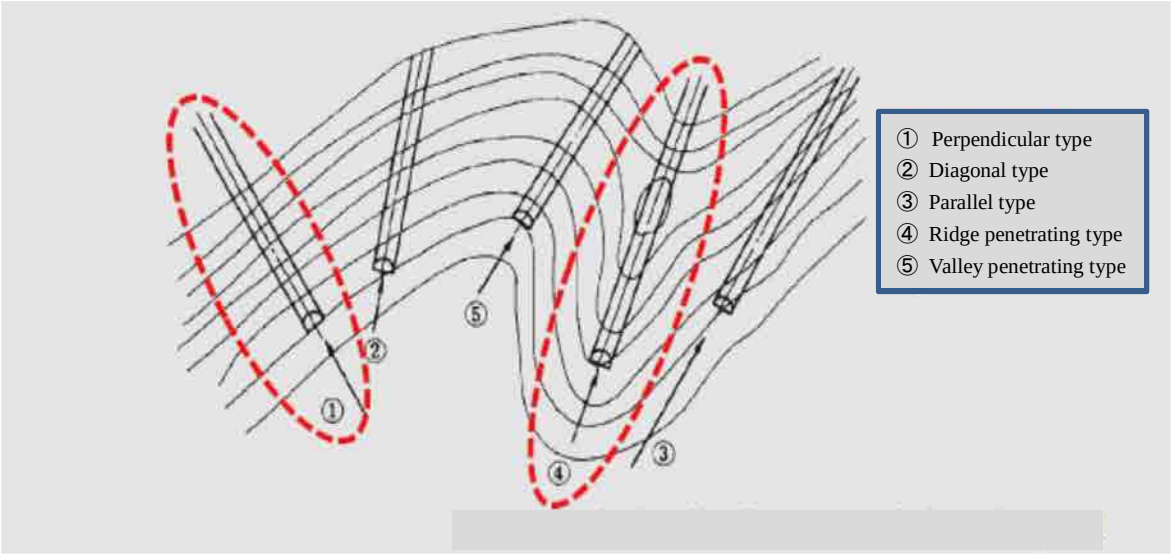
Drilling for geotechnical investigation is being carried out at three locations near the entry portals of the tunnels of the proposed routes in the Kathmandu Valley side. Boring points are shown in Figure 3-7 as TA1, TB1, TC1 and TE1. From the results of the drilling at TA1, the geology of the entry portal is judged to have a thick layer of soft clay, with abundant spring water. However, as entry portal at TB1, TC1 and TE1 are almost perpendicular to the slope of the hill, it can be expected that the distribution of rock bed can be found in relatively shallow depth. The exits of the tunnels for all proposed routes lie in the same area near the ridge of Sisne Khola, which is sandwiched between two streams.

Debris flow has occurred in the past at this valley. After this debris flow, 5 number of Sabo dams (Masonry and concrete including gabions). However, these Sabo dams reservoirs are already filled by sediment. Therefore, measures against debris flow may be required at this area.

Source: JICA Study Team

Figure 3-7 Alternative Route and Boring Point

The center axis line of a tunnel must as far as possible be close to perpendicular with the topography as illustrated by numbers 1 and 4 in Figure 3-8. This requirement is considered to be met for the portals of all the routes.



Source: Tunnel guideline (Central Nippon Expressway, Japan)

Figure 3-8 Topographic Selection and Tunnel Wellhead

3.3 Geological Features

3.3.1 Field Survey and Data Collection

Materials and data collected are as follows.

i) United Nations Mineral Exploration Technical Report. (Scan data) (DOS)

ii) Geological map of the Kathmandu and Central Mahabharat range (scale 1:250,000) (DMG)

iii) Photogeological map of part of Central Nepal (scale, 1:100,000) (DMG)

iv) Geological map of part of Chitwan, Dhading and Makawanpur district (scale, 1:50,000) (DMG)

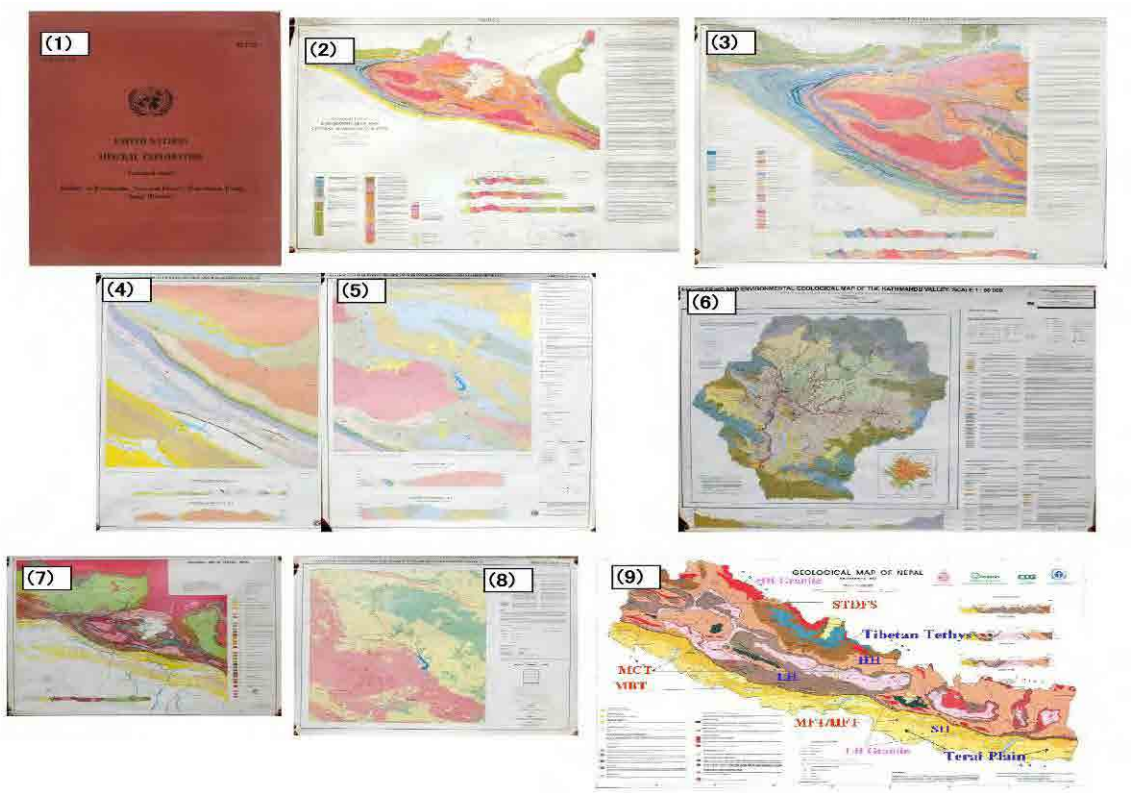
v) Geological map of part of Dhading, Makawanpur, Kathmandu and Lalitpur district (scale, 1:50,000) (DMG)

vi) Engineering and environmental geological map of Kathmandu valley (scale, 1:50,000) (DMG)

vii) Geological map of Central Nepal (scale, 1:250,000) (DMG)

viii) Landslide Hazard Zonation Map of Part of Makawanpur, Dhading and Kathmandu Districts (scale,1:50,000) (DMG)

ix) Geological Map of Nepal(scale, 1:1,000,000) (DMG)

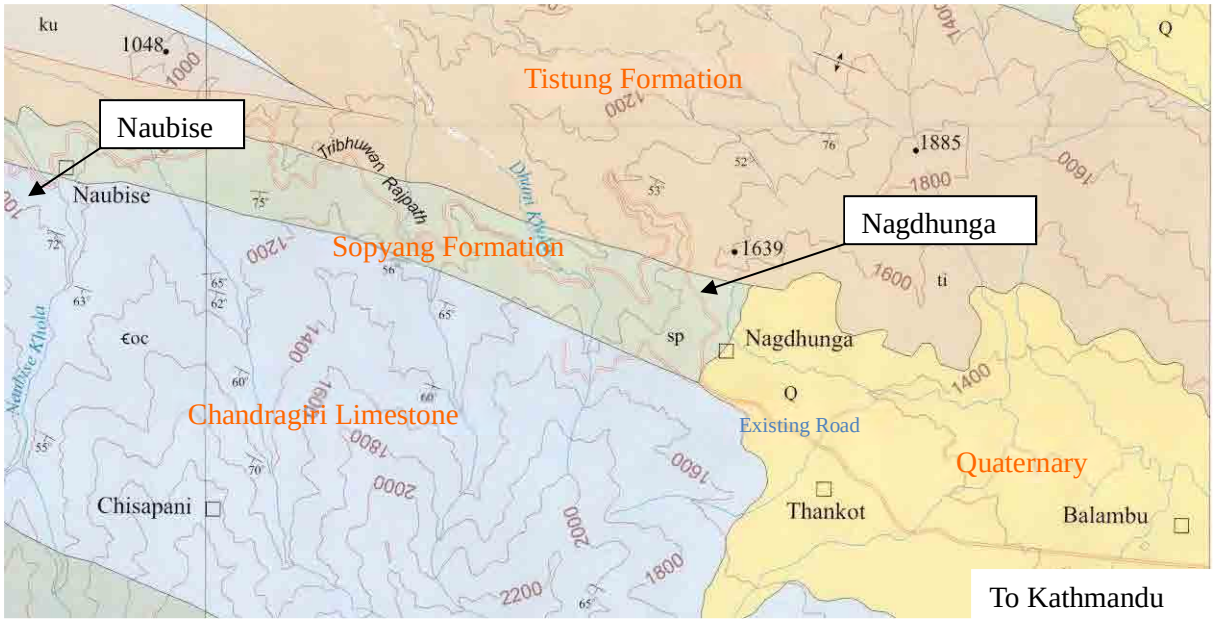


Source: as noted above

Figure 3-9 Collected Materials for Geological Survey

3.3.2 Geological Outline

The outline of the geological condition of the Study Area is discussed briefly hereunder, based on the results of field survey and the material collected. Figure 3-10 illustrates the geographical map of the Study Area.



After Geological map of part of Dhading, Makawanpur, Kathmandu and Laritpur Districts 2007

Figure 3-10 Geological Map of Study Area

The characteristics of geology distributed in the study area are as follows:

i) Quaternary – Recent (salf, klm)

(Alluvial, Colluvial and Lacustrine) Deposits, clay, silt, sandy and gravel and conglomerates.

ii) Phulchoki Group(Lower Paleozoic)

- Chandragiri Limestone(eoc):

Light fine-crystalline, partly siliceous, medium to thick bedded, massive limestone with micaceous seams having sands and phyllites at places, white quartzite in upper part, top part impure argillaceous, colored, wavy limestone containing Late Ordovician echinoderm.

-Sopyang formation(sp):

Dark argillaceous and marly slates, thin limestone, calc phyllites.

-Tistung formation (ti):

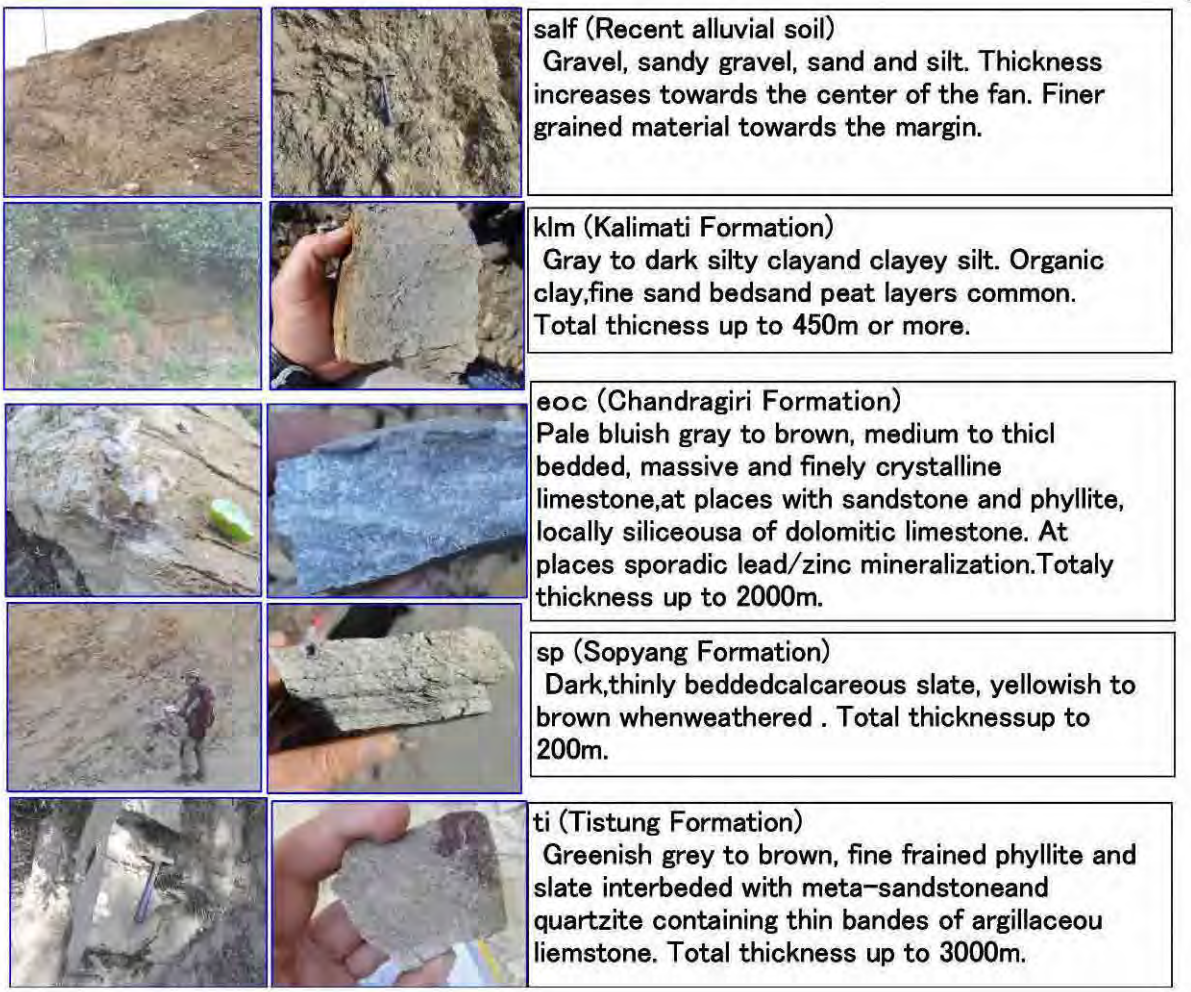
Metasandstones, siltstones, phyllites, slates, sandstone(with ripplemarks) sandy limestones, clay cracks, worm tracks, intense purple-weathering colour, pebble beds near base, underlain by fine biotite schist.

(Description of the geology, is according to information provided in the above map)

Among these, clay, silt, and gravel belonging to Quaternary are distributed from Kalanki at Kathmandu side to Thankot. In areas where road improvement and tunnel are planned, bedrock such as Tistung formation and Sopyang formation are distributed. Sopyang formation consists of alternating layers of thin sandstone and phyllite. The surface is formed of weathered red or gray soil. On the other hand, Tistung formation is distributed on the northern side of Nagdhunga and contains characteristically a layer of massive sandstone. Weathered gray or whitish grey soil is observed at the surface.

In addition, on the south side of the study area, Chandragiri Limestone is widely distributed, forming high mountains.

The major formations confirmed around the Study Area are compiled in the pictures in Figure 3-11 below.



Source: JICA Study Team

Figure 3-11 Rocks Explanation at Study Areas

3.3.3 Geological Considerations During Construction of Road and Tunnel

(1) Roads

- Kalanki intersection ~ Nagdhunga Pass

The section between Kalanki to Satungal area is relatively flat and the layers of Quaternary clay and silt are distributed. Also, the area is accumulated by alluvial fan deposits composed of gravel. However, there is no particular consideration required for construction of a road.

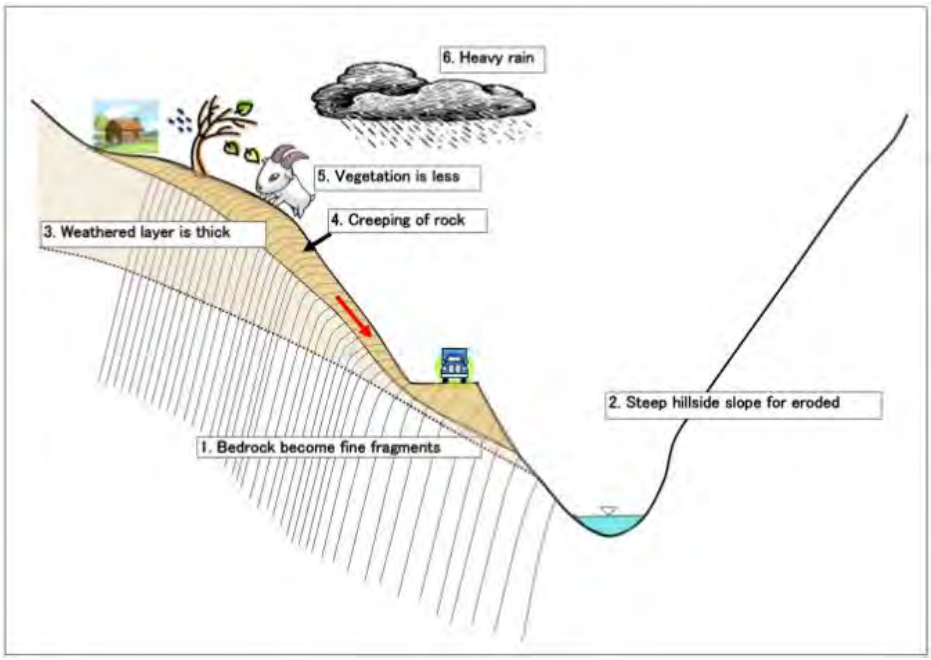
-Nagdhunga ~ Naubise

In the section between Nagdhunda and Naubise, the north side of Nagdhunga pass, is mostly distributed by an inter-bedded phyllite including thick layer (1-2m) sandstone and Sapuyong formation.

These formations are shown in Figure 3-12. As shown in the figure, these formations have;

i) Many cracks,
ii) Steep topography,
iii) Highly weathered surface layer,
iv) Loose and unstable rocks on the surface,
v) Poor vegetation to prevent erosion and collapse, and
vi) Susceptibility to slope failure during heavy rain

Therefore, it is desirable to avoid cutting of slopes in order to or during construction of new roads including widening of the existing road. If cutting is unavoidable, then proper measures should be taken.



Source: JICA Study Team

Figure 3-12 Collapse and Failure Characteristics of Study Areas

(2) Tunnel

- Considerations of the tunnel excavation from the geological conditions

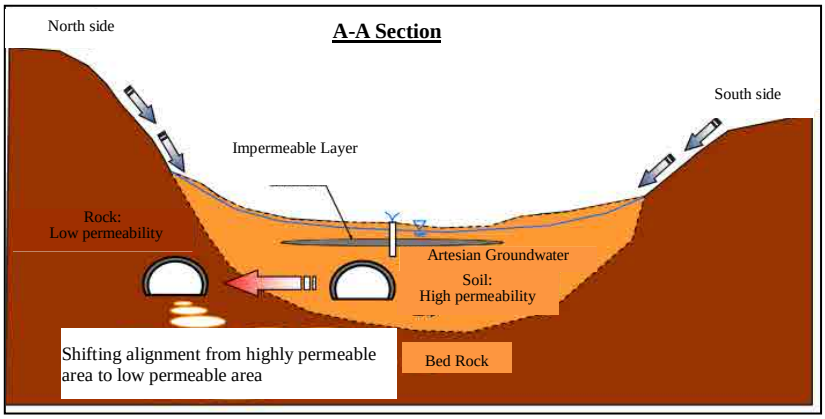
  - Secure safety from collapse, debris flow, and spring water at the tunnel portal
  - Avoid locations with possible faults

Drilling for geo-technical investigation is on-going at the entry portals of tunnels of the proposed routes at Kathmandu Valley side. These locations, TA1, TB1 and TC1 are shown in Figure 3-13. From the results of the drilling here, the followings were observed:

i) The road bed layer is deeper than 25m
ii) Spring water from the underground water (refer to Photos 3-2)

From above, it can be judged that the location for provision of entry portal of a tunnel including the tunnel section should be in such location where the distribution of basement rock can be confirmed, probably at the edge of the basin.

The route and the tunnel section runs in the major axis direction of the Kathmandu Valley. There are reports that one of the faults in the Kathmandu Valley extends in the same direction as the tunnel. However, to verify this, a more detailed geological survey should be conducted in the future.



Source: JICA Study Team

Figure 3-13 Layout of Tunnel near Basin

Source: JICA Study Team

Photos 3-2 Spring Water from Boreholes

3.4 Hydrology

3.4.1 Hydraulic and Hydro-geological Conditions in NEPAL

(1) General Hydro-meteorological conditions in Nepal

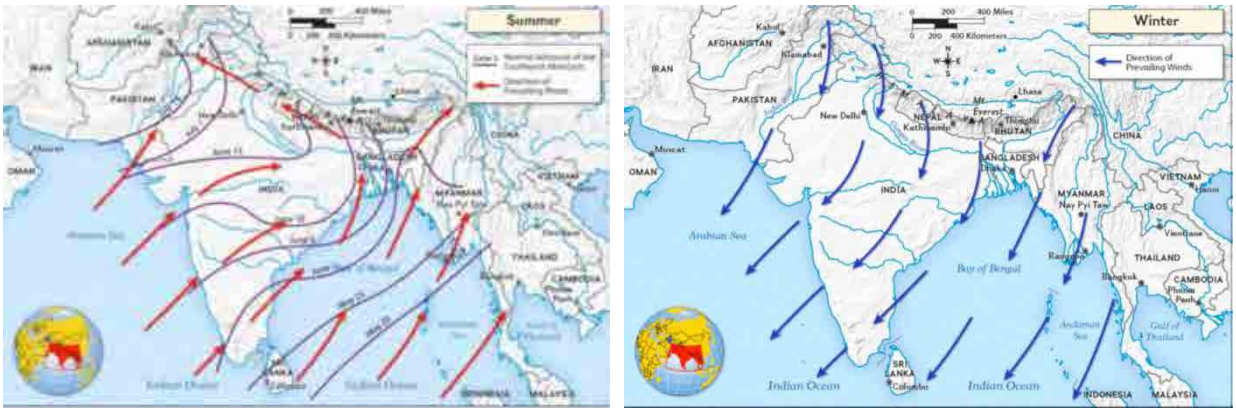
Nepal is situated between China and India on the global map measuring 800km in the east-west direction along the Himalayas and 150-250m across the north-south direction. Its lowest point is 59m in the south and the highest point is 8,848m in the north above mean sea level. That means the topography of Nepal has a very sharp relief leading to unusually high inter-variability of climate and hydrology in space and time.

Climate of Nepal ranges from tropical in the southern plains through eight climate zones through alpine to Nival (or the perpetual snow) in the northern Himalayas. Maximum and minimum temperatures, thus, across the country goes well over 40 degrees on the Celsius scale to perennially well below freezing.

Rainfall in Nepal is mainly due to two kinds of monsoon - the summer monsoon originating from the Bay of Bengal and the winter monsoon originating from the Mediterranean Sea (See Figure 3-14). Intensity and pattern of rainfall distribution are highly variable due to rain-shadowing of the monsoon by the mountains. During summer season, most of the precipitation occurs due to the summer monsoon wind flowing from the Bay of Bengal and proceeds westwards. The winter rain is usually brought by the winter monsoon originating from the Mediterranean Sea and traverses eastwards.

Summer season monsoon rain usually begins in the second week of May and lasts until the end of September. It usually moves to the north and westward guided by the mountain range (the Chure, Mahabharat and the Himalayas) producing differential precipitation even over relatively smaller region. Maximum annual precipitation of 2,200-2,500mm has been recorded in the Terai and Shiwaliks range. An annual precipitation of 1,500-2,500mm has been recorded in the Mahabharata range and less than 1,000mm in the Himalayan range, majority of which is in the form of snow.

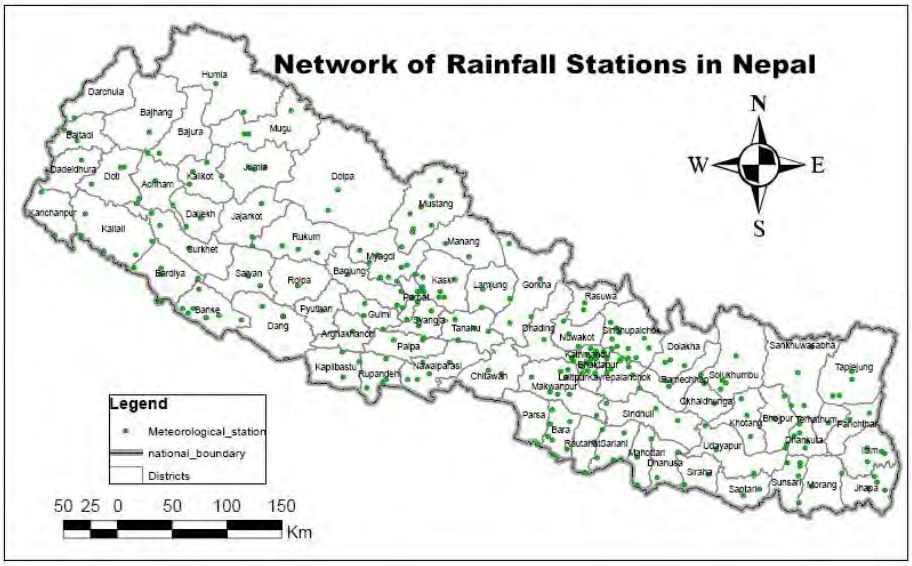
The months between October to May are generally dry. Winter monsoon originating from the Mediterranean Sea and travelling eastward occasionally brings rain during this period. The winter monsoon naturally has more influence in the western part of Nepal than the eastern part of the country. Precipitation in the form of hail has been recorded during February and March.



Source: Natural Geographic

Figure 3-14 Nepal and the Monsoon of South Asia

Department of Hydrology and Meteorology (DHM), a Nepalese Government agency, maintains a network of rain gauge stations throughout the country, which include more than 400 rain gauge stations across the country as shown in Figure 3-15**.** DHM collects and manage the rainfall data, which the department itself publishes and makes available to the users on demand. While some of the gauging stations maintain relatively reliable and longer historical records, others may not be so well maintained. Available data at such stations may have interrupted time series, or it may be available for a limited period of time and sometimes lacking coherence. As in any hydrological and watershed studies elsewhere in the world, data acquisition and manipulation is often a challenging task in Nepal. Nonetheless, positive side is that at least some data are available which is far superior to black box type of numerical models generating synthetic data. And even that be the case, an expert hydrologist will find the measured data extremely helpful in deriving the model parameters that will be a closer representation of the study area. Such grab data can also prove useful in deriving the model parameters by regional correlation.



Source: DHM, Nepal

Figure 3-15 Network of Rain Gauge Stations in Nepal

(2) General characteristics of Nepalese rivers and river basins

Almost all of the Nepalese Rivers are part of the greater Ganges River Basin. They are mostly in one of the three categories based on their origin - namely rivers originating from the Himalayas, from the Mahabharat range or from the Churia ranges - and drain through the Southern Plains, finally merging into the Ganges River. Steep slope of the rivers in the mountainous area combined with the high spatial and temporal inter-variability in terms of rainfall intensity and pattern produces high flash floods. Both the flood flows and their sediment carrying ability are thus highly variable in Nepalese rivers. Records kept at and analysis performed by the DHM show that the 24-hour maximum rainfall and the range and standard deviation of the consequent peak flows are very high.

River basins in the Nepalese mountains are drained by dense network of small streams or rivulets draining into tributaries which then feed into the major rivers. Both the watershed and the streams in the mountainous region have steep slope and a fragile geological condition leading into rapid run-off. In the process, large amount of sediment is deposited daily due to the continuous erosion of riverbank leading to periodic change in the course of many rivers. This, at times has caused heavy flooding adjacent to the river and considerable erosion of the river banks. Understanding and addressing this problem is crucial to prevent the damages to physical infrastructures and to the human life. A good understanding of potential flooding issues is also very important for future infrastructure planning. Flood events are more frequent in the Terai regions of Nepal, but it is equally affecting the intermountain valleys where flash floods can be very high in an otherwise dry looking streams.

(3) Hydrological characteristics of Nepalese rivers

Based on an average annual rainfall of about 1,400mm, Nepalese rivers have been estimated to be draining 174 billion cubic meters of water per year as surface run-off. This number reaches 200 billion cubic meters per annum when run-off from the Tibetan catchments that drains through the Nepalese rivers are added. Due to high concentration and intensity of precipitation during the monsoon period, about 72% of the total run-off is instantaneous, while the rest is conserved as snow and ground water which drain into the rivers as dry season flow.

According to the geological periods of formations, Nepalese rivers can be grouped as:

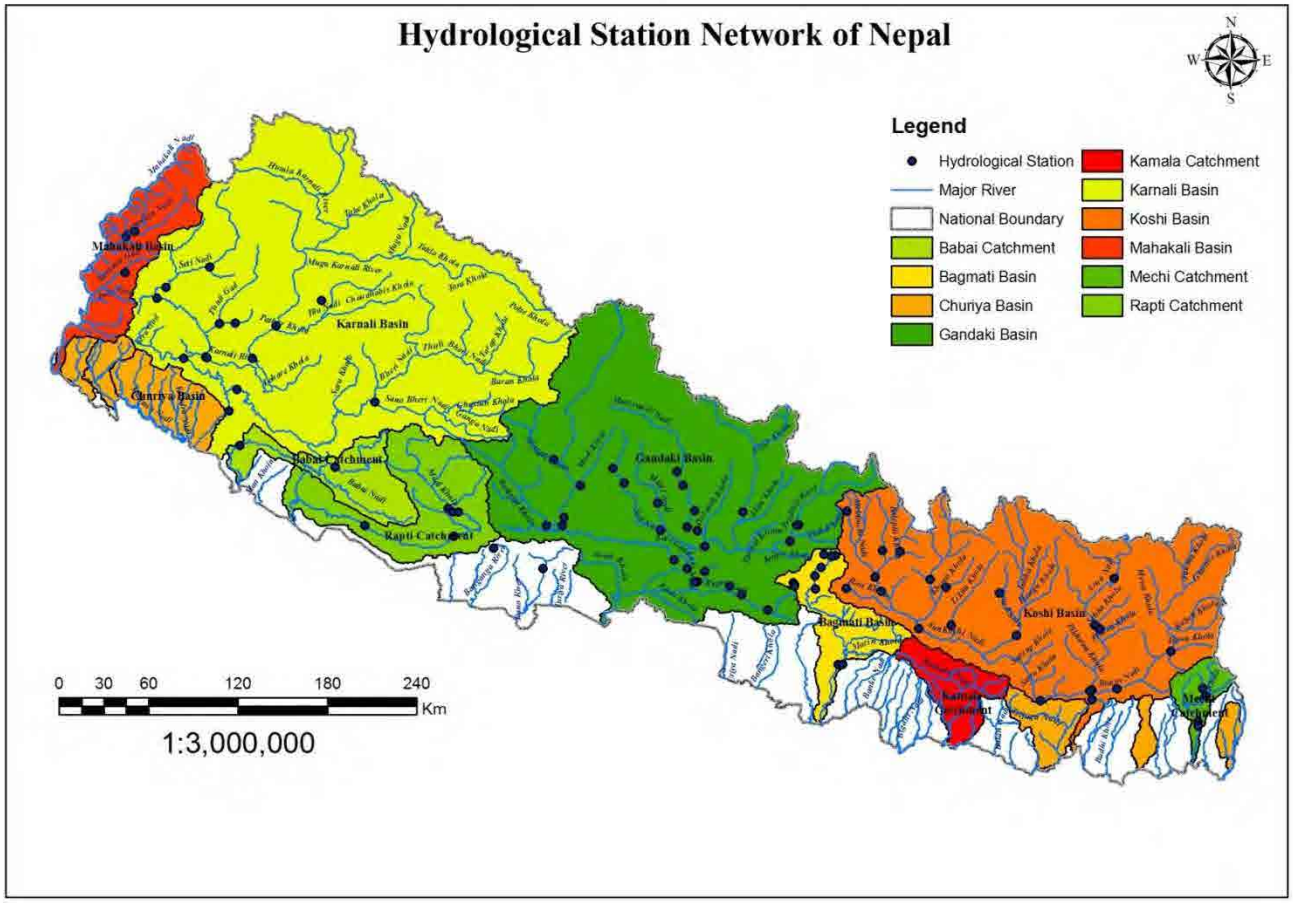
- Very young post Churiya (rivers coming from Churiya which numbers quite alot)
- Young post Mahabharata (Kankai, Kamala, Bagmati, Tinau, Babai)
- Old pre-Himalayas (Koshi, Gandaki, Karnali)

About 6,000 large and small rivers have been identified in Nepal. These rivers are grouped into four basins and two boundary rivers (see Figure 3-16):

- Koshi River Basin [Indrawati, Bhotekoshi, Tamakoshi, Dudhkoshi, Likhu, Arun and Tamor]
- Gandaki River Basin [Kali Gandaki, Seti, Madi, Marshyangdi, Daraundhi, Trishuli and Budhi Gandaki]
- Karnali River Basin [Seti, Budhi Ganga, Humla Karnali, Mugu Karnali, Tila, Thuli Bheri, Sani Bheri]
- Southern Rivers [Babai, West Rapti, Tinau, East Rapti, Bagmati, Kamala, Kankai]
- Mahakali River Basin (Western Boundary) [Chameliya, Surnaya, Rangoon, Khuti Yankti (India), Dhouli Ganga (India), Gori Ganga (India), Sarju (India), Ladhiya]
- Mechi River Basin (Eastern Boundary) [No tributaries]

All the major rivers originate in the Himalaya or the Tibetan Plateau. These river basins are partly snow or glacier fed. During the monsoon, these rivers receive abundant runoff due to heavy rainfall and the effects of snowmelt factor become rather insignificant proportionally. Rivers originating southwards from the Mahabharata range and flowing towards the Terai belt through the Siwalik Hills are categorized as southern rivers and they depend entirely on rainfall for their runoff. Depending on the altitude, some catchments may be influenced by monsoon and some by snow melt. For the catchments below 3,000m, there is no significant contribution from snowmelt where as for the catchments above 5,000m, snow melt feeds the stream flow. Catchments lying between 3,000 to 5,000m are influenced by both monsoon and snowmelt.

Most of the major rivers have been equipped with hydrometric stations by DHM. It maintains the record of more than 100 flow gauge stations across the country. Maximum instantaneous flood data have been collected for these stations (see Figure 3-16). WECS and DHM have also estimated floods of different frequency for some rivers at their gauging locations.

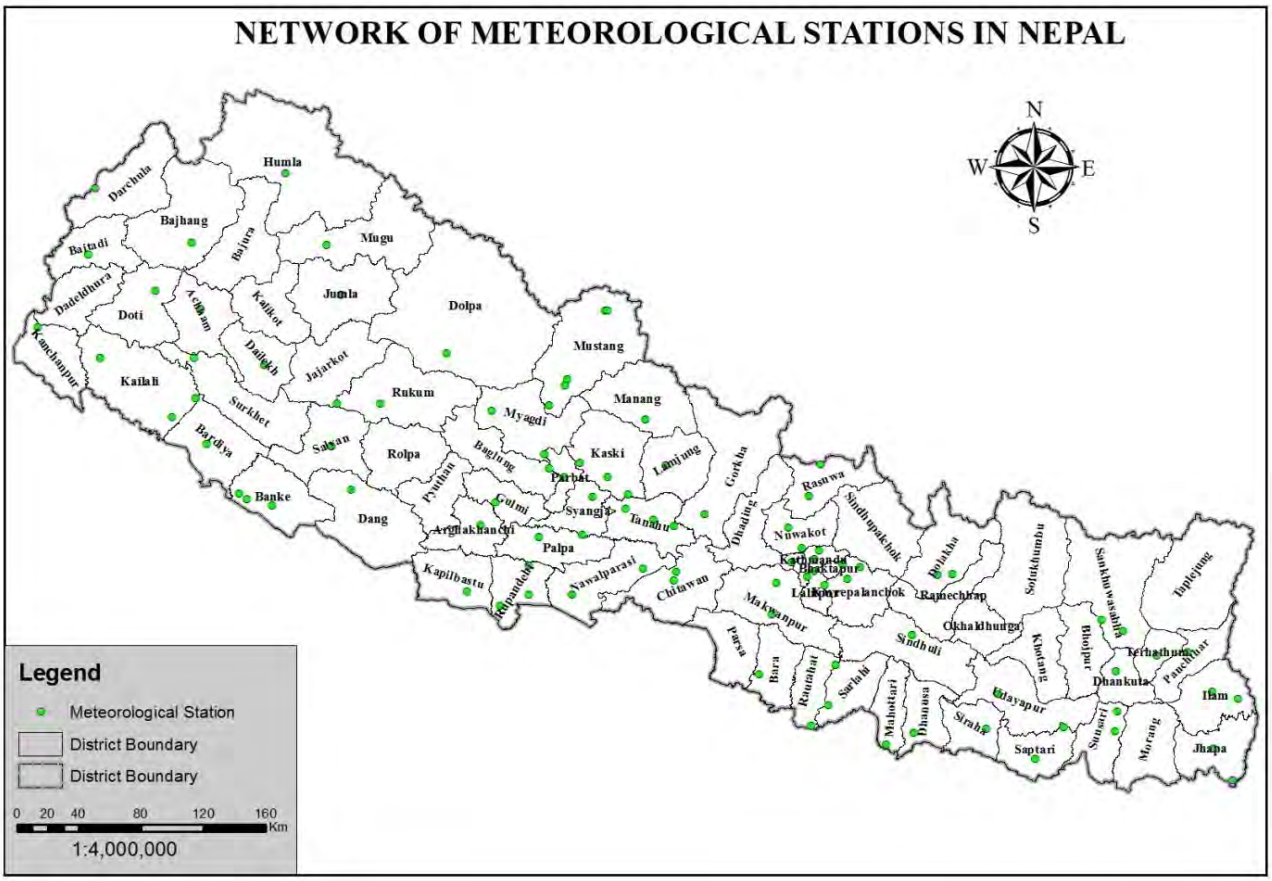


Source: DHM, Nepal

Figure 3-16 Hydrometric Stations, River Networks and Major River Basins in Nepal

(4) Meteorological weather stations in Nepal

DHM maintains a network of 68 climatic stations and 22 agro-meteorological stations across the country. A few of them belong to the mid- 1950's but most of them have recording periods beginning in early to late 1970's or much later. Figure 3-17 shows the meteorological stations in Nepal. Most of the stations are under DHM and equipped with personal computer systems connected through network for database management as well as for hydrological and meteorological modeling. DHM publishes the data on annual basis and are made available to users through published reports, bulletins, and also through computer media outputs such as hard copies or diskettes.



Source: DHM, Nepal

Figure 3-17 Network of Meteorological Stations in Nepal

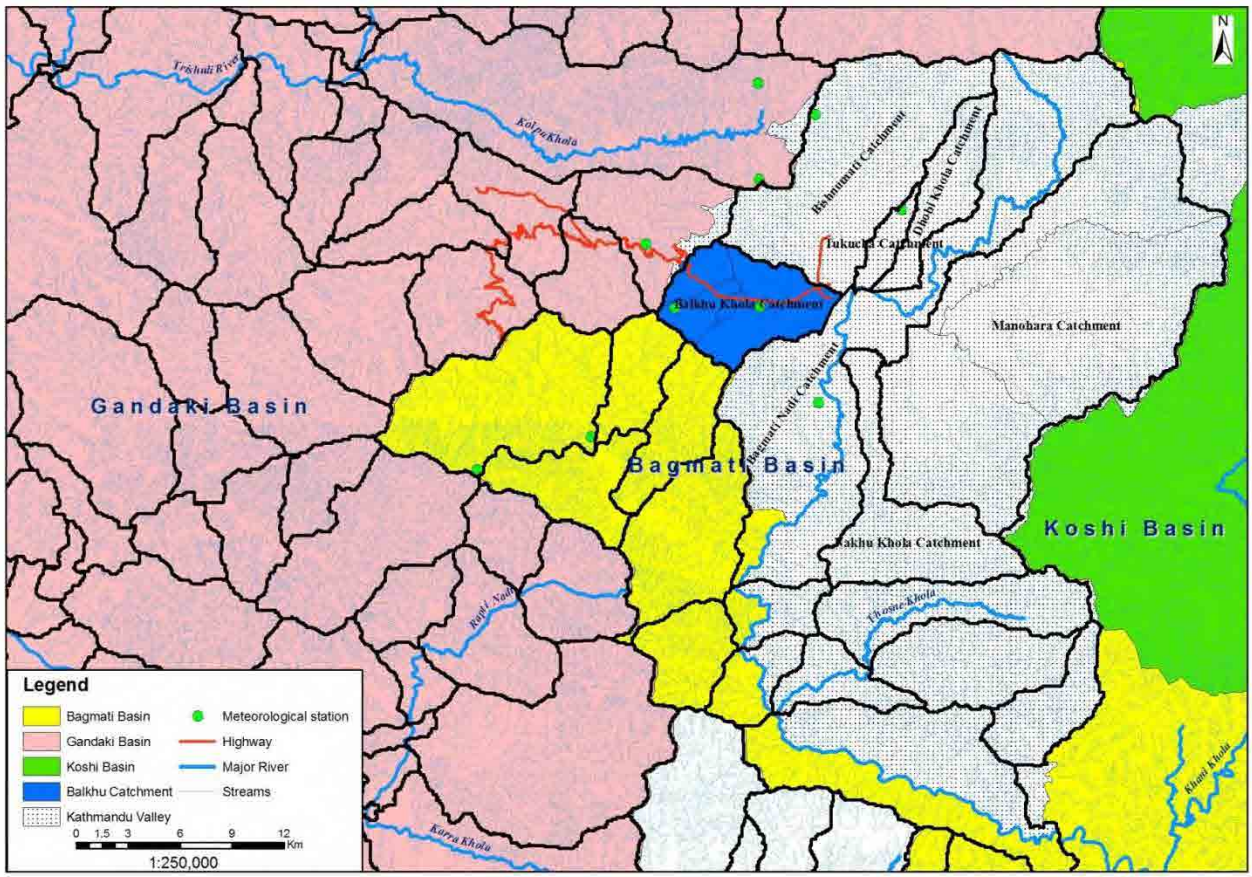
3.4.2 Hydraulic and Hydro-geological Conditions in the Study Area

Figure 3-15 shows the catchment of whole Kathmandu valley with the rivers and their respective catchment areas. The study area lies in the western part of the Kathmandu valley in the Balkhu Khola river basin in its upper part. Figure 3-18 shows the map of the river basin with the existing highway - namely the Tribhuvan highway, rain gauge stations and the network of rivers. Majority of the study area falls within the Balkhu Khola river basin (within Kathmandu valley) and only a small portion lies outside and adjacent to Kathmandu valley. Study area falling outside the Kathmandu valley that has the proposed tunnel outlet is mountainous, has steep slope and a very thin settlement. Part of the study area falling within the Kathmandu valley is also mountainous with steep slope and sparse settlement; but it becomes milder in slope, with rolling ground, and denser in settlement as it moves towards the city center.

(1) River basins in the study area

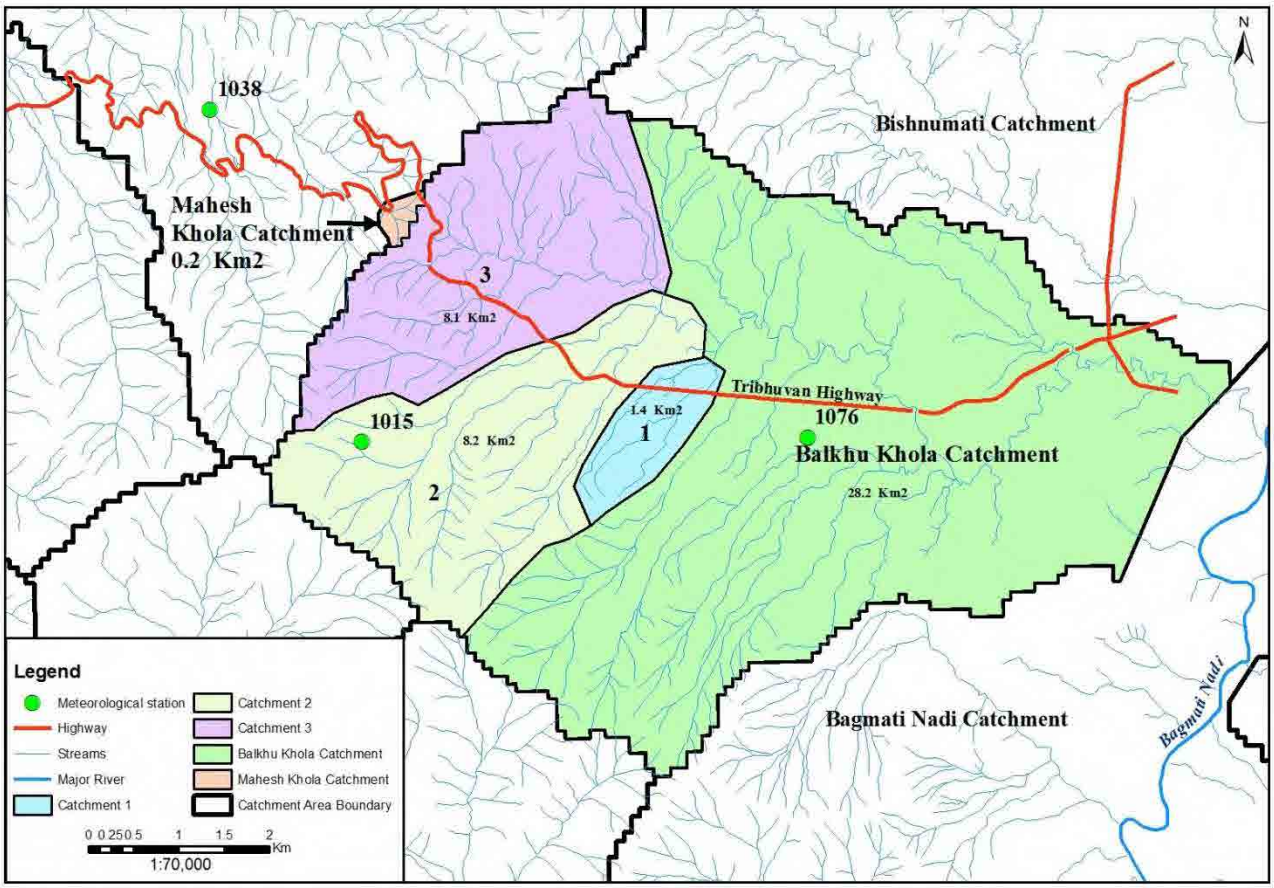
Two major river basins can be considered in the study area for the hydraulic and hydrologic analysis see Figure 3-19). One of them is the Balkhu Khola river basin (in Kathmandu valley) and the other one is a small tributary river basin feeding into the Mahesh Khola (outside and adjacent to Kathmandu valley). The Balkhu Khola River goes a long way beyond the study area

collecting inflows from few tributaries until it drains into the Bagmati River. Thus only a portion of the Balkhu Khola river basin, as indicated in Figure 3-19, actually lies within the study area. However, for this study purpose, the portion of the river basin will be called as Balkhu Khola river basin since the tributaries does not have a name and the locals simply call them as "Khola" meaning 'small river' in Nepalese language. Similarly, the other river basin (outside and adjacent to Kathmandu valley) that is a small tributary feeding into the Mahesh Khola will be called as Mahesh Khola river basin for this study purpose. Both the catchments, besides the rainy season have very small flow to almost dry conditions, do not have flow gauging stations installed on them at present. Hence synthetic flows of different return periods needs to be estimated for those river basins based on the rainfall data.



Source: JICA Study Team

Figure 3-18 Watersheds of Kathmandu Valley and its Vicinity



Source: JICA Study Team

Figure 3-19 Balkhu Khola River Basin

1) The Balkhu Khola river basin

The Balku Khola has two major tributaries. One of them originates at Macchegaun area in the south-western part of the valley and the other one originates at Balambu area in the western part of the valley and joins together at Salyanthan (near Naikap) area draining into the Bagmati River near the Ring Road at Balkhu. Total catchment area of this river basin is 28 km^2 at its confluence with the Bagmati River. This river basin is partially mountainous and has steep slope (maximum 45%) towards the outer side of the basin and the settlement is rather sparse. Highest point in the river basin is 1,530m above the mean sea level. But as it moves towards further down towards the city, topography becomes a lot milder in slope (average slope 1%-3%), with some undulations and the population becomes progressively denser. The lowest point is around 1384m above mean sea level (See Photos 3-3). The urban development along the banks of the river is seen to be rapid especially from at Tinthana, Naikap and Satungal areas that falls along the ring road and way to Thankot (See Photo 3-4). Based on the current growth and visual inspection of the area, it seems an obvious conclusion that there is rapid growth of settlement and construction. That means increasing portion of the

watershed is going to be paved, thus sealing the ground that will lead to an increased surface flow into the river. It could become a matter of concern especially in the rainy season for the design and safety of hydraulic structures. Present hydrological condition will no longer be valid for the future built up scenario and needs to be dually considered for high flow computations.

Source: JICA Study Team

Photos 3-3 Balkhu Khola River Basin

According to one study conducted by Full Bright Consultancy in 2007, Balkhu Khola has been recorded to inundate 5 to 20m strip of land during annual flood events and about 15 to 30m strip of land during the occasional high flood events. The Balkhu Chowk and vicinity of Dipendra Hospital near Satungal could become severely affected in case of occurrence of rare high flood inundating lateral distance of up to 50m from the river banks. Some heavy engineering works have been done to train the river at several locations along this river.

2) The Mahesh Khola river basin

Catchment area of the part of the Mahesh Khola river basin lying within the study area is 0.2km^2. The terrain is highly mountainous with thick vegetation and almost negligible to very sparse habitation. Highest and lowest point of the river basin is 1,530m and 1,333m above the mean sea level. Average elevation of this river basin is 1,428m above the mean sea level with an average slope of 53%. Outlet of the proposed tunnel will be opening into this river basin joining the Tribhuvan highway. There are also only a couple of tributaries that does not flow beyond the rainy season. The river basin is drained mostly through gully flow, and crosses over the existing Tribhuvan highway over a causeway. A check-dam has been built upstream of the causeway to reduce the velocity of the flow down the slope. Based on how the tunnel is connected to the existing highway, some structures may be needed to control the flow running down the hill. And hence a hydrologic analysis will be needed to compute the maximum flow concentrating at that point for the adequate and efficient design of the hydraulic structures required at the outlet of the tunnel.

Source: JICA Study Team

Photo 3-4 Balkhu Khola River Basin with Increasing Urbanization

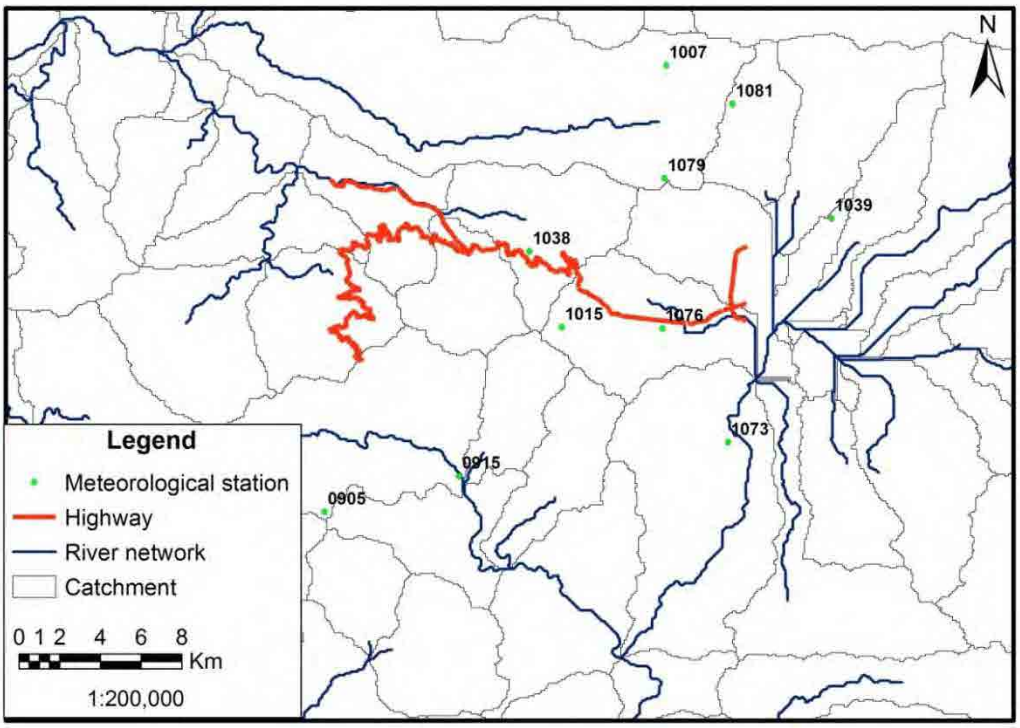
(2) Rain gauge stations within the study area

Table 3-3 shows the details of the rain gauges located in the study area (See Figure 3-20). Historical time series of the rainfall data for individual rain gauges stations are presented in the subsequent tables and figures. While some of the stations have time series records starting in 1971, others are as recent as the year 2000. Historical data shows that more than 80 percent of the rainfall was concentrated in the summer/rainy season. Historical time series will be useful for the statistical analysis of rainfall to determine the design floods in the streams and river crossings in the project area. It will also be needed for calculation of water inflow into the channel and calculation of the hydraulic grade lines of groundwater for determining the hydraulic and hydrological impacts in the study area.

Table 3-3 Rain Gauge Stations in and around the Study Area

Station name	Station ID	District	Latitude	Longitude	Altitude	Aspect	NMS Estd.
Daman	0905	Makwanpur	27.60	85.08	2314	North	May-71
Markhu gaun	0915	Makwanpur	27.62	85.15	1530	East	Dec-71
Nuwakot	1004	Nuwakot	27.92	85.17	1003	West	Nov-71
Kakani	1007	Nuwakot	27.80	85.25	2064	East	Dec-71
Thankot	1015	Kathmandu	27.68	85.20	1630	South-east	Sep-66
Dhunibesi	1038	Dhading	27.72	85.18	1085	West	Apr-71
Panipokhari (Kathmandu)	1039	Kathmandu	27.73	85.33	1335	North-east	Jul-73
Khokana	1073	Lalitpur	27.63	85.28	1212	North-east	Aug-91
Naikap	1076	Kathmandu	27.68	85.25	1520	North	Jun-96
Nagarjun	1079	Kathmandu	27.75	85.25	1690	West	Jun-97
Jetpurphedhi	1081	Kathmandu	27.78	85.28	1320	East	May-00

Source: Full Bright Consultancy, 2007, Report "*Study of Flood Prone Regions of Rivers in the Kathmandu Valley*"



Source: JICA Study Team

Figure 3-20 Rain Gauge Stations in and around the Study Area

(3) Rainfall data in the study area

Historical time series of rainfall data collected for the stations are available at DHM. Some of the rain gauges have historical records beginning from 1971 where as the others may have available records of 10 years beginning from the year 2000. The rainfall data were collected from the rain gauge stations available within and around the study area. The 24 hours maximum rainfall data collected from different rain gauge stations within Kathmandu valley from year 1981 to 2000 has been presented in Table 3-4 and plotted in Figure 3-20.

Table 3-4 24 Hours Maximum Rainfall (mm) for Different Stations in Kathmandu Valley

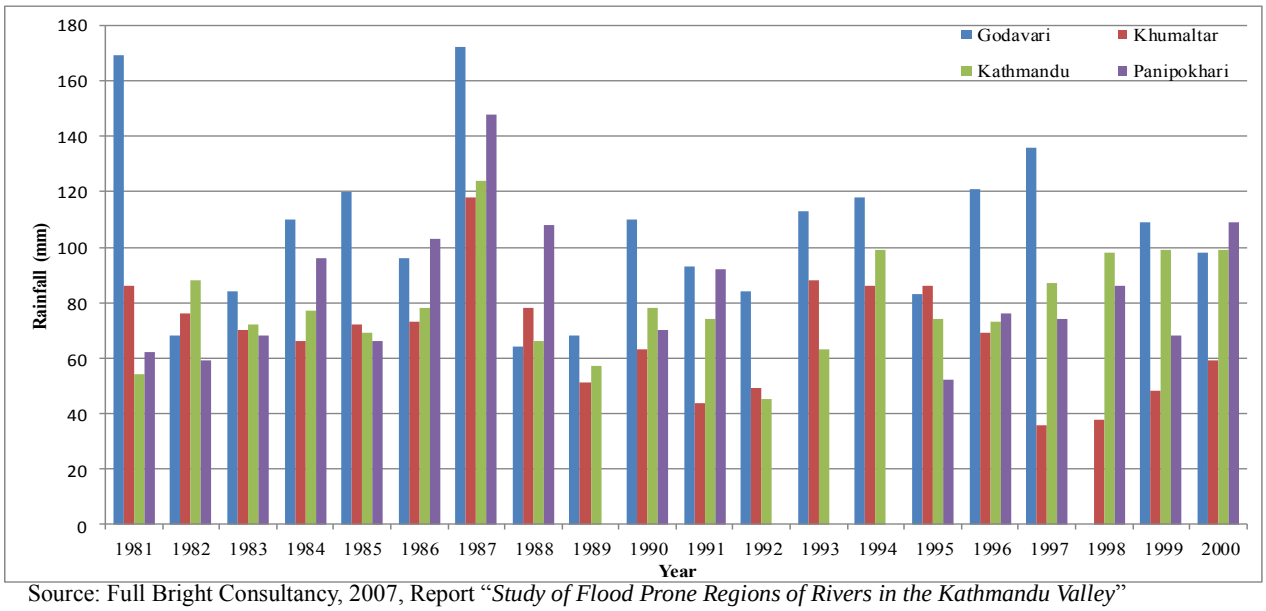
Year	Govadavi	Khumaltar	Kathmandu Airport	Panipokhari
1981	169	86	54	62
1982	68	76	88	59
1983	84	70	72	68
1984	110	66	77	96
1985	120	72	69	66
1986	96	73	78	103
1987	172	118	124	148
1988	64	78	66	108
1989	68	51	57	N/A
1990	110	63	78	70
1991	93	44	74	92
1992	84	49	45	N/A
1993	113	88	63	N/A
1994	118	86	99	N/A
1995	83	86	74	52

1996	121	69	73	76
1997	136	36	87	74
1998	N/A	38	98	86
1999	109	48	99	68
2000	98	59	99	109

Note: NA = Not Available

Source: Full Bright Consultancy, 2007, Report "*Study of Flood Prone Regions of Rivers in the Kathmandu Valley*"

Based on the available 24 hours maximum rainfall for different rainfall stations for a period between 1981 to 2000 presented in Table 3-4, frequency analysis was been done by Gumbel Extreme Value distribution. The result of this frequency analysis is presented in Table 3-5.



Source: Full Bright Consultancy, 2007, Report "*Study of Flood Prone Regions of Rivers in the Kathmandu Valley*"

Figure 3-21 24 Hours Maximum Rainfall for Different Stations in Kathmandu Valley

Table 3-5 Frequency Analysis of the Rainfall Data using Gumbel's Extreme Value Distribution

Return Period	Godavari	Khumaltar	Kathmandu Airport	Panipokhari
2	101.152	64.484	75.624	79.495
5	127.796	82.322	92.17	101.376
10	145.437	94.133	103.125	115.864
20	162.359	105.461	113.633	129.76
50	184.261	120.125	127.234	147.748
100	200.674	131.114	137.427	161.227

Source: Full Bright Consultancy, 2007, Report "*Study of Flood Prone Regions of Rivers in the Kathmandu Valley*"

(4) Hydro-geology of Kathmandu valley and its surrounding areas

The inherently fragile and geologically young and active Himalayan Mountains of Nepal are characterized by high relief, high intensity monsoon rainfall and earthquake tremors which are the main sources of water-induced disaster problems in the form of landslides, debris flow, soil

erosion and floods. Large scale deforestation, unplanned land use systems and construction of physical infrastructure in the region without ample consideration of the environmental consequences has contributed to the possibilities of such disaster. Losses caused by these natural disasters are on the rise aided by rapid population growth and infrastructure development. Most affected in these areas are primarily the marginal poor who live densely along the flood plains of river. At the same time, the condition is worsened due to increasing interference to the natural regime of rivers, especially in the urban and densely populated areas.

The Kathmandu Valley is an intermontane valley that occupies an approximate catchment area of 625km^2. The major rivers traversing the valley are Bagmati, Bishnumati and Manahara. Apart from these major rivers, other rivers like Dhobi Khola, Tukucha, Samakhusi, Kodku (Karmanasa), Balkhu, Nakkhu, Mahadev, Hanumante, Karmanasa are also flowing through the valley. The drainage pattern inside the Kathmandu valley is centripetal and hence all the rivers flow towards the valley center to conjoin with Bagmati River that eventually drains out of the valley through the Chovar gorge.

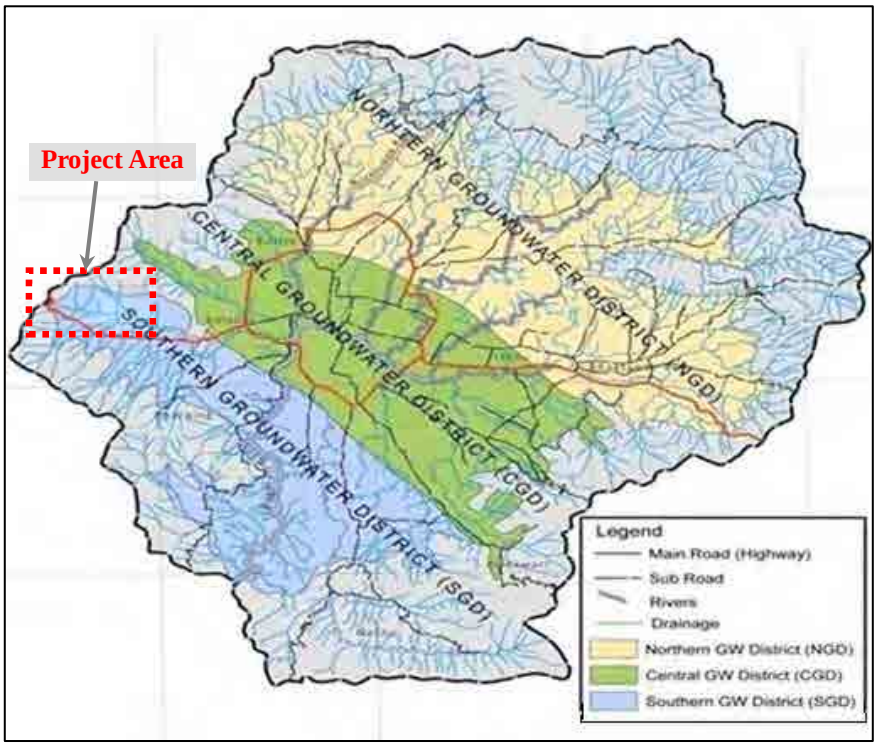
The Kathmandu basin is surrounded by mountains ranging in altitude up to 3,000m. The hills are of low altitude in the eastern and western part while the northern and southern part of the valley is having high hills (Shivapuri and Mahabharat Lekh). The average altitude of the valley floor is 1,340m, the minimum being around 1,200m at the southern margin of the valley. The rocks are exposed around the Kathmandu valley (Basement Rocks) and the valley portion is consisting of basin-filled Sediments (overlying the basement rocks).

Kathmandu valley lies on the Kathmandu Complex that is consisting of metamorphic rocks overlain by the fossiliferous Tibetan Tethys sediments. The valley floor is basically filled with the sediments derived from the surrounding mountainous regions. The maximum thickness of the basin filled sediments is around 650m. Many drill core data suggests that more than 300m thick muddy and sandy sediments are extensively distributed under the basin. Alluvial fan and recent flood plain deposits are basically associated with the rivers flowing through the valley while the colluviums are distributed along the margins of the valley. Geomorphologically, the Kathmandu valley and surrounding mountainous parts can be subdivided into hill and hill slopes, rock outcrop, terraces, flood plain and riverbed. Hill and hill slopes can be observed in the periphery of the valley while the rock outcrops can be observed in some of the areas within the valley. The terraces are widely distributed in the basin with flat to gentle topography. There are different levels of terraces in the valley. The terraces that are distributed around the central part of the valley are having height of 20m to 50m from the present riverbed. The terraces, which are distributed further outwards from the center of the valley, are situated at the higher ground with the height ranging from 50m to 80m. Similarly, the terraces that are distributed along the fringe of the valley near the hilly parts are much higher reaching up to 160m from the present riverbed.

The average annual precipitation in the valley is around 1,600mm. The rainwater is drained through a number of rivers, streams and rivulets that discharges to the Bagmati River. The occasional torrential rains within the valley have caused flooding problems in the core areas of the city causing loss of life, and damage to private properties, especially to areas in close proximity to the rivers. The floods and inundation problem along the river banks is common during high intensity and long duration precipitation. The fear of damage due to flood have also been prominent because of rapid growth of settlement in the flood plains. Natural soil that could have infiltrated more water is getting sealed due to urban grown and paved areas. It thus reduces the time of concentration and increased the overland contribution into the rivers. Excessive deforestation in the hills surrounding the valley combined with climatic changes further contributes to the high floods in the region. The flood situation within Kathmandu Valley is not very favorable to the urban dwellers and any further planned development will necessitate the study that there is a need to take steps for the protections of river regimes to control the effects due to rivers flooding.

(5) Groundwater Conditions in Kathmandu Valley

Groundwater condition for Kathmandu Valley has classified the entire Kathmandu Valley into 3 hydro-geological divisions based on the hydrologic formation of various characteristics including river deposits.



Source: Dr. Jha, Hydrological Study of Kathmandu MRT Railway

Figure 3-22 Groundwater Divisions of Kathmandu Valley

1) Northern Division

The northern groundwater division has a relatively good recharge capacity and is generally composed of unconsolidated highly permeable materials and coarse sediments are inter-bedded with fine impermeable sediments and forms the main aquifer in the valley. However, extraction of groundwater is difficult in mountainous areas and the mountain ranges surrounding the valley also provide very little possibility for groundwater recharge because of their high relief. The slope is steep and much of the rainwater quickly turns into surface runoff and joins the nearest tributaries. According to the sedimentary development, the area suitable for recharging aquifers is located mainly in the northern part of the valley and along the rivers.

2) Central Division

The central groundwater division mainly comprises of impermeable stiff black clay along with lignite deposits and underlying layer of unconsolidated coarse sediment deposits of low permeability. The old urban core of Kathmandu Valley lies over this region. This area is categorized to have low recharge capacity due to thick impermeable layers.

3) Southern Division

The geologic formations of the southern groundwater division consist primarily of thick impermeable clay and low permeable basal gravel. The aquifer in the southern area is known to be less developed compared to the northern and central divisions. Recharge is restricted to the areas along the gravel fans near the hillside.

The Project Area lies within the Southern division, which lies on the far-western part of the valley. The groundwater is encountered at a very high level, and the local people are depended excessively on the groundwater for their water needs.

3.4.3 Hydraulic and Hydrologic Impacts in the Study Area due to Tunnel Route

Placement of underground tunnels below the peizometric level of groundwater may induce the steady state rise of the groundwater table upstream of a shallow tunnel due to the obstruction of groundwater flow in the direction normal to the tunnel axis (Mannos and Kavvadas, Johnson). Such rise of groundwater table can be very significant at times, up to the point of even reversing the prevailing hydraulic gradients. Rising of shallow groundwater table can become a significant hazard for the structures in urban area and can affect adversely the root systems of the vegetation causing disturbance to the local ecosystem. The types of structures considered to be at risk by rising groundwater table include basements, foundations of buildings and any other underground structures. Besides, there can be appreciable reduction of bearing capacity of shallow foundation, significant settlements of poorly compacted fills, increased loads on retaining systems, increased need for drainage and instabilities in temporary excavations.

From the environmental perspective, it is possible that the rising groundwater table can cause the propagation of contaminants contained in the previously unsaturated zone and can pollute the groundwater systems. When the rising groundwater table reaches the surface, it can increase the risk of flooding and can pose increased risk of pollution of surface water resources. Rising groundwater table can affect the efficiency of highway drainage system in the area of influence.

The proposed tunnel lies in the outskirts of urban center but it can pose risk to the rapid urbanization along the hill slope. It is therefore necessary to consider the aftermaths of tunnel construction and investigate the effects of such tunnel on groundwater. Kathmandu valley has good data on groundwater but the outskirts of the city may not have enough data. Therefore it is necessary to incorporate some measurements of the hydraulic grade line in the future geophysical studies.

The already increasing urbanization in the area will likely experience even more rapid development due to the construction of the proposed tunnel. As pointed out earlier, this will result in changed hydrological and hydraulic characteristics of the watershed. This needs to be dually considered and numerically evaluated for the design of hydraulic structures in the proposed route as well on the existing river training works along the river. Conveyance capacity of the existing trained river sections has to be sufficient to allow the anticipated increased flow in the river or else flooding of the local area can take place affecting the normal life as well the engineering structures. A detailed study of these proposed possibilities should be incorporated in further studies.

3.5 Ecosystem, Conservation Area and Pollution

3.5.1 Ecosystem

(1) Land Use and Vegetation in the Project Area

The Project Area is located at the western fringe of Kathmandu Valley. Although the Area is still considered 'Rural' in the Capital Area, every corner of accessible land is strongly modified for human use, except the national forests on steep slopes.

Land use in the Project Area is mainly defined by its location.

Road side: Commercial businesses, mechanic workshops, schools, other public and private services and transportation services, and residences.

Valley area: Brick yards and kilns which operate during dry months, commercial agriculture with greenhouse structures, subsistence farming, and suburban residential development.

Hill and mountain area: Community forests used by local residents for various daily necessities, private forest lands, residences, subsistence farming.

Source: JICA Study Team

Photo 3-5 The Project Area (East Side)

The vegetation of the subtropical belt (1,000-2,000m altitude) of eastern Nepal is *Schima wallichii - Castanopsis indica - Castanopsis tribuloides* forest, mainly consisted of oak trees and camellia trees. The major associates are *Engelhardtia spicata, Acer oblongum, Pyrus pashia, Eurya acuminata, Myrica esculenta* etc.[1]

In the Project Area, *Pinus roxburghii* and *Alnus nepalensi*s are the most common tree species.

(2) Protected trees

The Nepal Gazette 2058/9/16/2001 lists the following tree species, mainly useful for commercial purposes, as Protected Trees, and requires a Cabinet approval to cut down.

[1] Source: http://www.nhm.ac.uk/research-curation/research/projects/nepal/flora.html

Occurrence of these trees to be affected by the Project shall be identified in the EIA survey.

Table 3-6 Protected Tree Species in Nepal

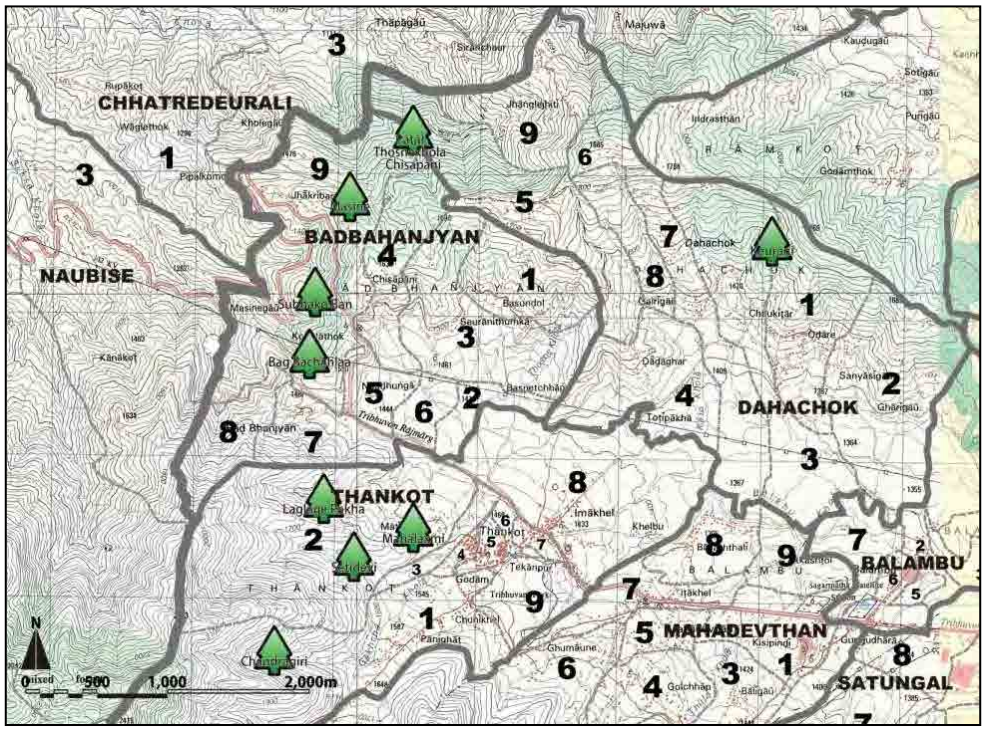
	Local Name	Academic Name	IUCN
1	Champ	*Michelia champaca*	
2	Khayer	*Acacia catechu*	
3	Sal	*Shorea robusta*	
4	Simal	*Bombax ceiba*	
5	Satisal	*Dalbergia latifolia*	VU
6	Bijaya sal	*Pterocarpus marsupium*	VU
7	Okhar	*Juglans regia*	NT

VU: Vulnerable
NT: Near threatened
Source: Nepal Gazette 2058/9/16/2001

(3) National Forests

Forested areas in the Project Area are owned nationally. In those forests, community forest users' group are registered and allowed to harvest fuels and animal feeders, but they are not allowed to cut trees.

Exact locations and boundaries of those forests shall be identified in the EIA survey.



Source: District Forest Office

Figure 3-23 Names and General Locations of Community Forests in the Project Area

3.5.2 Conservation Area

The protected areas in Nepal include ten national parks, three wildlife reserves, one hunting reserve, six conservation areas, and eleven buffer zones covering an area of 31,029.67km^2 that is 21.08% of the total area of the country.

Five types of protected areas—national park, wildlife reserve, hunting reserve, conservation area and buffer zone—were defined under the Nepal National Parks and Wildlife Conservation Act, 1973 with the objective of conserving biodiversity (in situ) and the natural environment of various forest types.

The Project Area does not include any Protected Areas.

Table 3-7 Type of Protected Areas in Nepal

Type of Protected Areas	Description
National Park	An area set aside for the conservation, management, and utilization of flora, fauna, and scenery along with the natural environment.
Wildlife Reserve	An area set aside for the conservation and management of wildlife resources and their habitats.
Hunting Reserve	An area set aside for the management of wildlife by allowing hunters to hunt them.
Conservation Area	An area to be managed according to an integrated plan for the conservation of the natural environment and balanced utilization of natural resources.
Buffer Zone	A peripheral area of a national park or reserve prescribed under section 3 a in order to provide facilities to use forest resources on a regular and beneficial basis for local people.

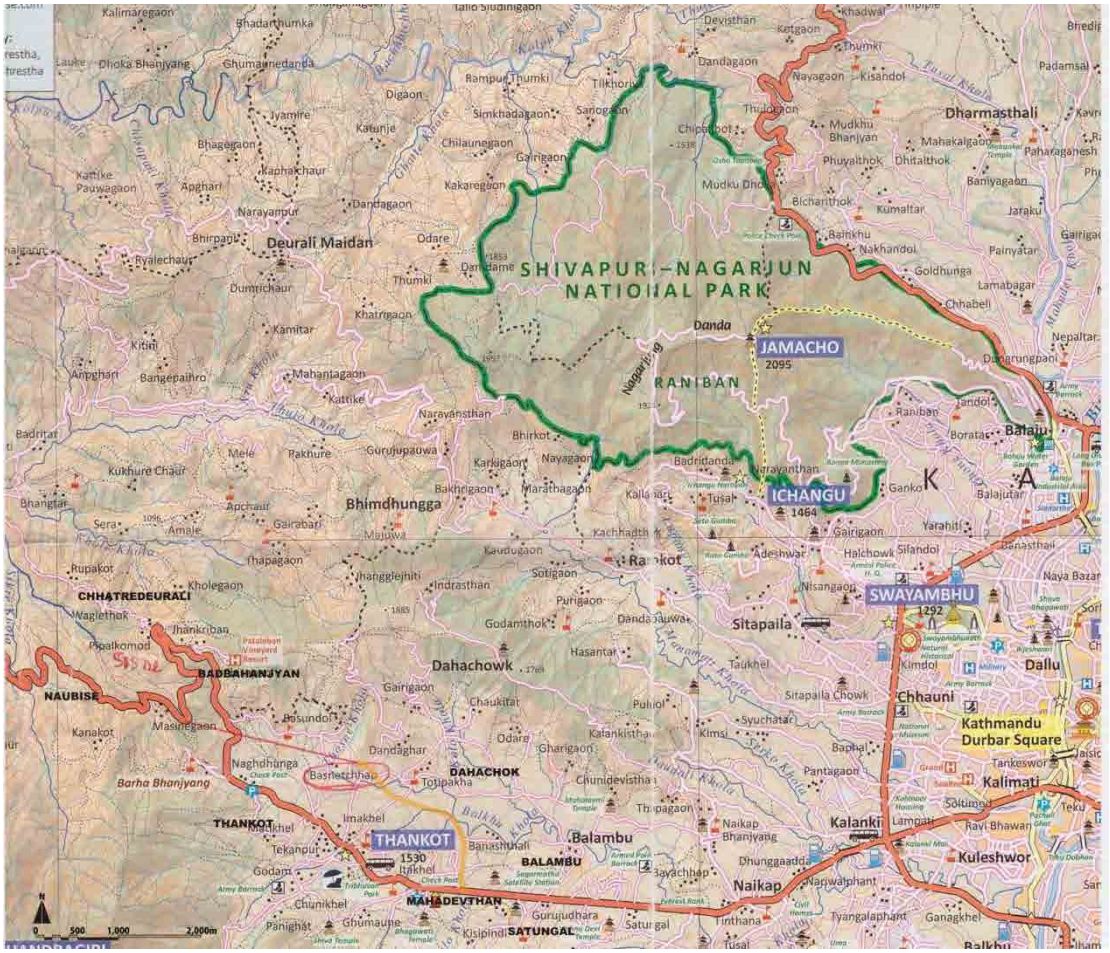
Source: Nepal National Parks and Wildlife Conservation Act (NPWCA), 1973, cited in Profile on Environmental and Social Considerations in Nepal, January 2013, Japan International Cooperation Agency

The nearest protected area to the Project Area is the Shivapuri Nagarjun National Park. The major part of the Park lies on the northern watershed mountain and hill area. In 2009, forest area located at the west of Kathmandu Valley was designated as the extension of the Park. The south western border of the Park, the extended part, is located about 2km north east of the Project Area.

Table 3-8 Shivapuri Nagarjun National Park

Site Name	Established year	Region	Area (km^2)
Shivapuri Nagarjun National Park	2002 Extension 2009	Highlands Hills - Centre	159

Source: Shivapuri Nagarjun National Park, Department of National Parks and Wildlife Conservation, Ministry of Forests and Soil Conservation, http://www.dnpwc.gov.np/index.php/page/10 (retrieved on April 28, 2014)



Source: Nepa Maps, Around Kathmandu Valley, Touring Map 700 Series 1:60.000, NR751, Himalayan MapHouse

Figure 3-24 Location of South-West Part of Shivapuri Nagarjun NP

Shivapuri Nagarjun National Park lies in a transition zone between subtropical and temperate climates. The vegetation consists of a variety of natural forest types including pine, oak, rhododendron etc, depending on altitude and aspect.

Recorded wildlife in the park includes mammalian species such as Himalayan Black bear, leopard, jungle cat, and rhesus monkey. The park is also home to 177 species of birds, including at least 9 threatened species, 102 species of butterflies with a number of rare and endangered species, and 129 species of mushroom.

Shivapuri is one of the main sources of drinking water for Kathmandu Valley. Everyday about 30 million liters of water is tapped from rivers such as the Bagmati and the Vishunumati as well as from several other smaller streams.[2]

[2] Source: Shivapuri Nagarjun National Park, Department of National Parks and Wildlife Conservation, Ministry of Forests and Soil Conservation, http://www.dnpwc.gov.np/index.php/page/10 (retrieved on April 28, 2014)

3.5.3 Rare and Endangered Species

During the interviews with MOSTE, MOFSC, Department of Forests, Kathmandu District Forest Office, and Forest Ranger Points in Kathmandu District, potential occurrence of endangered species in the Project Area was denied except Simal trees (***Bombax ceiba***), which is located a few places along the existing highway, but not in the work areas of the Project.

Red List of Nepal (IUCN, 2012), CITES-List of Animals and Plants in Nepal (CITES, 2012), and the National Parks and Wildlife Conservation Act, 1973, either do not include information of habitat locations for the listed species, or states that Kathmandu Valley is included in the habitats of mammals such as Himalayan Black Bear, Eurasian Otter, Himalayan Serow, Asiatic Golden Cat, Large Indian Civet, and Leopard. During the field survey of the EIA Study of the Project, in future phase, it is expected to clarify the occurrence or non-occurrence of those listed species in the Project Area.

3.5.4 Pollution

The Project Area is tranquil and rural atmosphere in general.

The area near the existing highway, however, is receiving air pollution, noise and vibration mainly caused by traffic passing-by. Dust around earthen roads is also severe in dry season.

The waters in the small rivers in the Project Area smell of sewer and no fish has been recognized during the field observation. Since the Project Area is located at the fringe of the Kathmandu Valley, all the streams in the Area have quite small catchment area, and surface water resource is scarce in the Area.

As of 2014, neither MOSTE nor DOR/GESU have a unit and equipment for periodical monitoring of ambient environment. During an interview with GESU on March 2014, it was not clear whether private consultants are equipped with sufficient instrument to monitor the environment periodically.

Table 3-9 Existing Causes of Pollution in the Project Area

Air pollution	* Exhaust gas from vehicles * Dust caused by vehicles on earthen road * Soot and other gas emission from brick kilns * Smoke caused by burning of plant residues for fertilizer
Noise and Vibration	* Noise and vibration by running heavy vehicles * Noise of vehicle horns
Water pollution	* Residential waste water runoff * Direct water use at rivers * Random littering of solid wastes and garbage into rivers (Industrial waste water runoff is not evident yet) (Potential runoff of agriculture fertilizer is not confirmed)
Wastes	* Random littering of solid wastes and garbage

Source: JICA Study Team

3.6 Social Environment

3.6.1 Local governance system and the Project Affected Area

Nepal's 5 development Regions are subdivided into 14 administrative Zones and then 75 Districts.

A District is governed by District Development Committee (administrative function), District Chief District Officer (law enforcement), and District Court.

A District is consisted of Village Development Committees, or VDCs. One VDC is in most cases consisted of 9 Wards.

Municipalities are the area with relatively large accumulation of population, and are designated as 'Municipality' by the government. As of 2011, there are 99 municipalities in Nepal including 41 newly declared and waiting for approval in July 2011. In Kathmandu District, Kathmandu Metropolitan City and Kirtipur are designated as Municipality.[3] There is no Municipality in Dhading District.

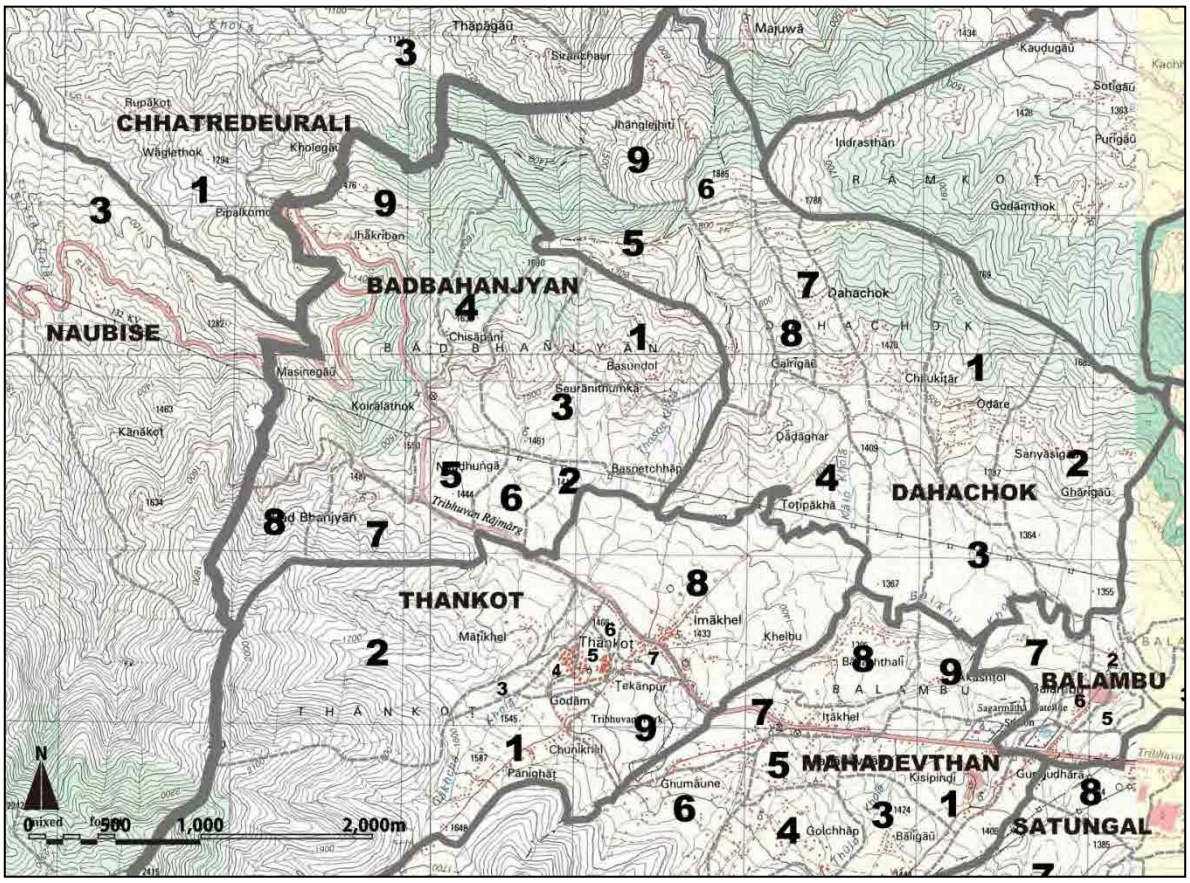
The Project Area includes lands in 7 VDCs in 2 Districts, as summarized in the following Table.

Table 3-10 The VDCs in the Project Area

Region	Zone	District	VDC
Central	Bagmati	Kathmandu	Balambu
			Mahadevsthan
			Dahachok
			Thankot
			Baad Bhanjyang
		Dhading	Naubise
			Chhatre Dyaurali

Source: JICA Study Team

[3] Bhaktapur and Madhyapur Thimi are 2 municipalities in Bhaktapur District. Lalitpur Sub-Metropolitan City is a municipality in Lalitpur District.



The boundaries of VDCs and wards are under confirmation and subject to future change
Source: JICA Study Team

Figure 3-25 Location of VDCs and Wards

3.6.2 Population

(1) Population

The information of Ward-wise number of population and households in the Project Area was collected from the National Population Census 2011.

There is possibility that the number in the following table does not include population and households who are renting rooms and houses. In the EIA Census Survey, it is necessary to include those renters as stakeholder of the Project.

Table 3-11 Population and Households in the Project Area (2011 Census)

District	VDC	Male	Female	Total Population	Household
Kathmandu	Balambu	3,625	3,698	7,323	1,734
	Mahadevsthan	7,731	7,783	15,514	3,731
	Dahachok	1,991	2,045	4,036	878
	Thankot	6,106	5,941	12,047	2,820
	Baad Bhanjyang	1,873	1,906	3,779	817
Dhading	Naubise	7,203	7,350	14,553	3,184
	Chhatre Dyaurali	3,665	4,022	7,687	1,655

Source: Village Development Committee & Demographic Profile of Nepal, Mega Publication & Research Centre

(2) Household

Multiple source, including DOR/GESU confirmed that the definition of a household in Nepal is "a group of people who share one cooking stove."

Also local consultants advised the JICA Study Team that in houses with large floor area and multiple stories, one story is occupied by one household, usually the owner's household on the top floor and tenants occupying other floors.

(3) Mother Tongue

In the National Population and Housing Census 2011, 124 languages are listed as mother tongue.

In the preparation of interviews and public meetings, it is important to select proper languages for the Project Area.

Table 3-12 Mother Tongue in National Level

Mother Tongue	Population	Ratio
Total	26,494,504	100.0%
Nepali	11,826,953	44.6%
Maithili	3,092,530	11.7%
Bhojpuri	1,584,958	6.0%
Tharu	1,529,875	5.8%
Tamang	1,353,311	5.1%
Other (119 languages)	7,106,877	26.8%

Source: National Population and Housing Census 2011 (Table 21), Volume 01, Central Bureau of Statistics, November 2012

(4) Literacy Status

Literacy status at District level is shown in Table 3-13.

In the preparation of interviews and public meetings, it is important to recognize that there shall be many stakeholders who can not read nor write, and that female stakeholders need more attention so that they equally understand about the Project and impact they may be affected.

Table 3-13 Literacy Status at District Level

District	Sex	Population aged 5 years & above	Population who			
			Can read & write	Can read only	Can't read and write	Not stated
Kathmandu	Total	1,632,640	1,408,199	25,606	198,225	340
	%	100.0%	86.3%	1.6%	12.1%	0.0%
	Male	853,486	786,704	11,471	55,116	195
	%	100.0%	92.2%	1.3%	6.5%	0.0%
	Female	779,154	621,495	14,135	143,109	145
	%	100.0%	79.8%	1.8%	18.4%	0.0%
Dhading	Total	305,985	192,337	7,745	105,681	222
	%	100.0%	62.9%	2.5%	34.5%	0.1%
	Male	142,433	101,240	3,765	37,348	80
	%	100.0%	71.1%	2.6%	26.2%	0.1%
	Female	163,552	91,097	3,980	68,333	142
	%	100.0%	55.7%	2.4%	41.8%	0.1%

Source: Village Development Committee & Demographic Profile of Nepal, Mega Publication & Research Centre

3.6.3 Religion, Culture and Community

(1) Population by Religion

District level population by religion is shown in Table 3-14.

In the preparation of interviews and public meetings, it is important to recognize holidays and festivals of each religion located in the Project Area.

In the basic design of the Project, it is important to identify various places or facilities which are important for each religion, and to avoid negative impacts on such places and activities related to the facilities.

Table 3-14 District-Level Population by Religion

	Total	Hindu	Buddhism	Islam	Kirat	Christianity	Prakriti	Bon	Jainism	Bahal	Sikhism	Undefined
Kathmandu	1,744,240	1,395,538	268,473	21,866	13,379	40,592	898	214	829	55	63	2,327
	100.0%	80.0%	15.4%	1.3%	0.8%	2.3%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%
Dhading	336067	243384	69113	1034	26	21243	817	3	2	45	0	400
	100.0%	72.4%	20.6%	0.3%	0.0%	6.3%	0.2%	0.0%	0.0%	0.0%	0.0%	0.1%

Source: Village Development Committee & Demographic Profile of Nepal, Mega Publication & Research Centre

		
Cremation site	Hindu temple	Washing spring

Source: JICA Study Team

Photos 3-6 Example of Places and Facilities Related to Religion in the Project Area

Although the rivers in the Project Area is rather small, Hindu temples, in addition to the cremation sites, are located in various places, and related washing sites are also observed.

These facilities are strongly related to each other, and to the rivers. It is assumed that the body of the deceased is burned at the cremation site and the remaining ash is scattered to the river. Any modification or construction works nearby shall require well-advanced communication with the local communities.

(2) Religiously Protected Tree

Although there is no legal base, *Ficus religiosa* and *Ficus benghalensis*, local name Pipal tree and Bor tree, respectively, are religiously important tree both for Hindus and Buddhists. Many examples are seen in Kathmandu Valley where large tree is left in the center of major road because it was decided not to cut down the tree despite of the urgent need of expansion of the road.

Source: JICA Study Team

Photo 3-7 *Ficus religiosa*

(3) Cultural Heritage and Landscape

There are historical places and religious facilities with local importance in the Project Area. In the later phase of the Project, further inquiry of local resources and assessment of significance of indirect impacts need to be conducted.

There is no significant landscape that must be conserved or protected in the Project Area.

3.6.4 Livelihood, Minimum Wage and Poverty Line

(1) Livelihood

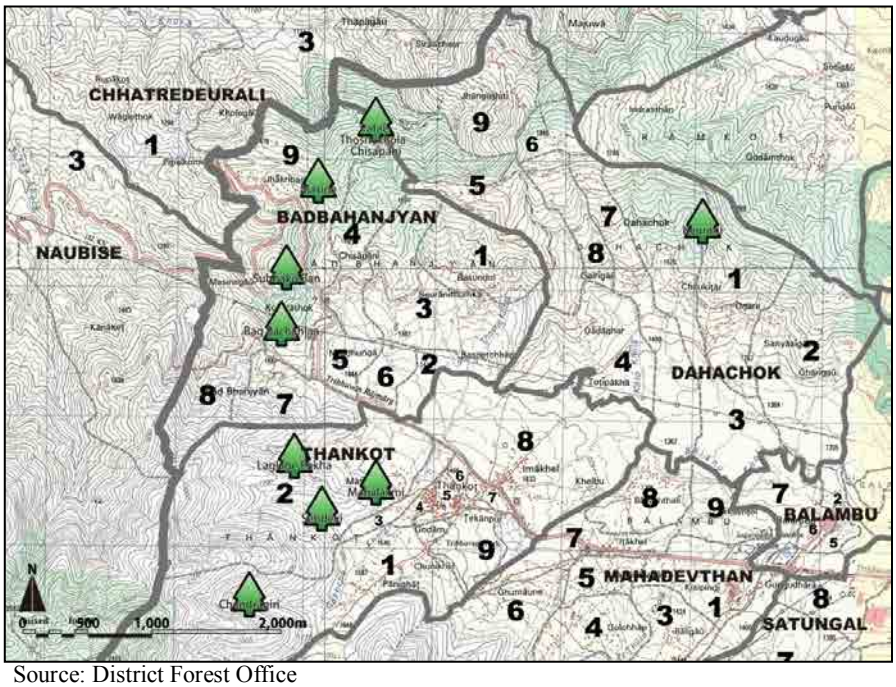
Inventory of the local resources was conducted during the Study. In the Project Area, besides agriculture field for subsistence farming, poultry farming, pig farming, flower cultivation, mushroom farming, greenhouse structures for tomato farming were popular commercial farming activities.

In manufacturing sector, there are brick kilns, cloth and textile factories and saw mills.

Along the section of existing highway that are to be bypassed by the new road, there are many small shops and eateries that are frequented mainly by vehicle drivers.

Forested areas in the Project Area are owned nationally. In these forests, community forest users' group, consisted of local residents, are registered and allowed to harvest fuels and animal feeders, but they are not allowed to cut down trees.

Exact locations and boundaries of those forests shall be identified in the EIA survey.



Source: District Forest Office

Figure 3-26 Names and General Locations of Community Forests in the Project Area

(2) Minimum Wage

The monthly Basic Wage in Nepal is NRs. 5,100 in 2013. In addition, monthly Dearness Allowance is NRs. 2,900.

In every 2 year interval Minimum Wage is fixed by the government on the recommendation of the Minimum Remuneration Committee.[4]

(3) Poverty Line

According to the Poverty review in Nepal 2010/11, excerpts of the Nepal Living Standards Survey (NLSS-III, 2010-11), the poverty line in Nepal is defined and calculated as follows.

Table 3-15 Poverty Line in Nepal 2010/2011

		National Average	Urban-Kathmandu	Urban - Hill
Food	A minimum caloric requirement of 2,220 Kcal per day per person	NRs. 11,929	NRs. 14,610	NRs. 11,805
Non-Food		NRs. 7,332	NRs. 26,323	NRs. 7,772
Total		NRs. 19,261	NRs. 40,933	NRs. 19,577

Source: Poverty in Nepal 2010/11, http://cbs.gov.np/wp-content/uploads/2012/02/Statistical_Report_Vol1.pdf

The food cost in urban Kathmandu is 20 % more than that of national average. Non-food expense in urban Kathmandu is 3.6 times of national average.

3.6.5 Public and Commercial Infrastructure

(1) Energy and Telecommunication

There are high voltage transmission lines and pylons in the Project Area. Any impacts need to be avoided or minimized by design and construction management. The contact office regarding pre-construction coordination shall be Mr. Kasendra Yadap, Division Chief, Kathmandu Grid Division, Grid Operation Department at Minbhawan Sub Station, Nepal Electricity Authority.

Currently, Nepal Electricity Authority operates a sub station in Matatirtha. The Authority has a plan to construct underground transmission line between Matatirtha and Nagdhunga, but as of April 2014, no time table for the construction is decided yet.

Nepal Oil Corporation fuel storage tanks and Nepal Telecom Sagarmatha Satellite Station are also located within the Project Area.

(2) Water Supply

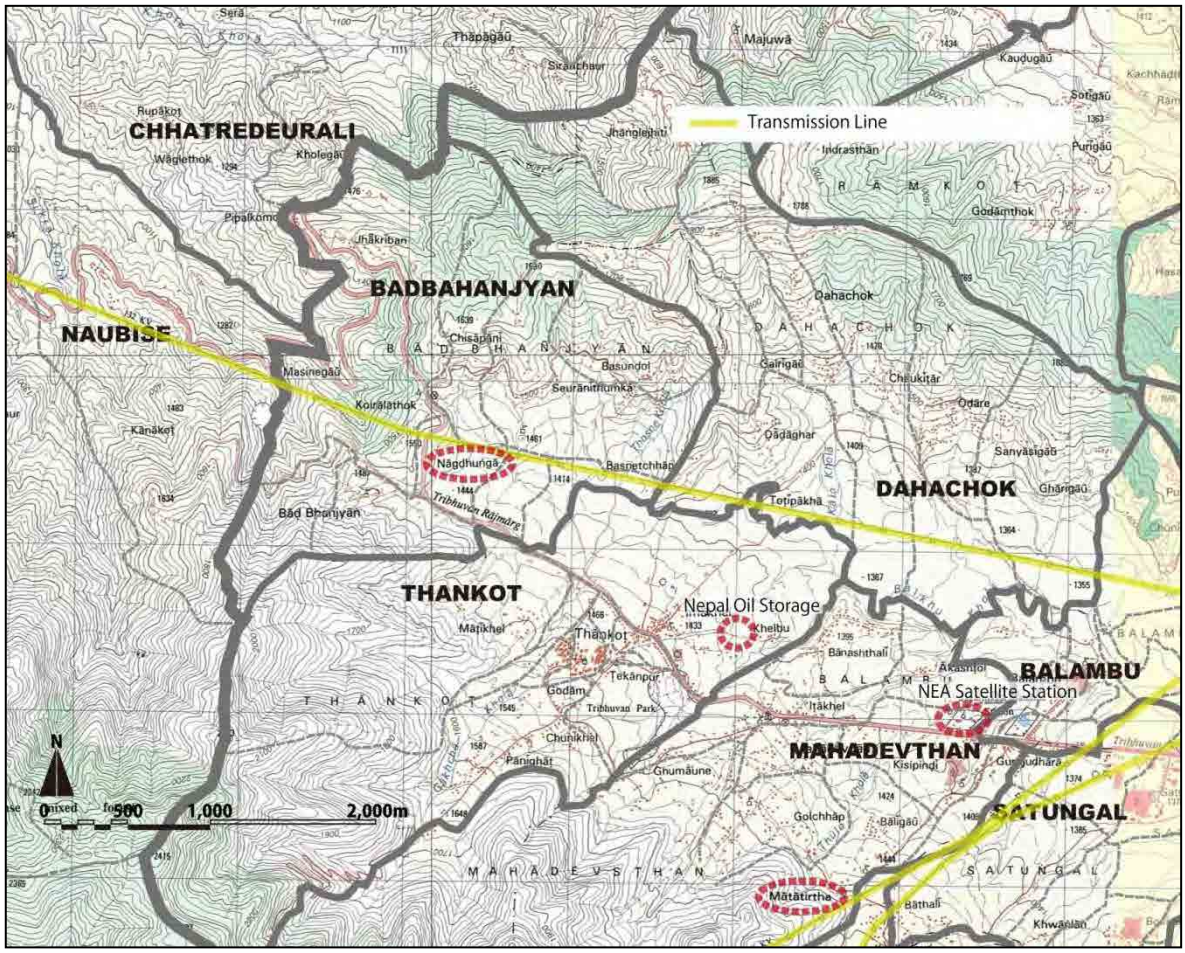
A list of drinking water supply schemes in the Project Area was obtained by literature survey, but, during the field reconnaissance survey, no information of such schemes were heard from

[4] Source : Invest Nepal, Ministry of Industry, http://www.investnepal.gov.np/portal/index.php?p1=content&p2=8 [Retrieved April 15, 2014]

the residents interviewed.

On the other hand, smaller, more private water pipes, a few water taps and many water wells were observed during the field reconnaissance survey.

Drinking and irrigation water supply system need further study in the later phase of the Project.



Source: JICA Study Team

Figure 3-27 Location of Existing Transmission Lines, Oil Storage and Satellite Station

Table 3-16 Drinking Water Supply Schemes in the Project Area

District	VDC	Ward	Service Operator	Scheme Name	HH	Population
Kathmandu	Dahachok	3	KA	Ransure Khola	89	509
	Thankot	8,9	KA	Thankot (Hirjol)	175	947
Dhading	Naubise	4	SKSSL	Jugedi	163	953
	Chhatre Dyaurali	1	NRCS-DHAD	Kukhure chour	95	641
		3	SKSSL	Amale	130	755

Source: Village Development Committee & Demographic Profile of Nepal, Mega Publication & Research Centre

Source: JICA Study Team

Photos 3-8 Example of Water Supply Facilities

(3) Schools

Schools in the following Table were recognized in the Project Area, north side of the existing Highway, during the field reconnaissance survey.

Table 3-17 Schools Located in the Project Area

Shira Montessori Home
Rhododendron International Higher Secondary Boarding School
Chandragiri Boarding School
Glory Montessori School
Banasthali Primary School
Dibya Netra community school
Bhim Higher Secondary School
Manamohan Medical College (Proposed, under-construction)

Source: JICA Study Team

(4) Roads

An earthen road network is developed in the Project Area and used by pedestrians and vehicles. A paved District Road runs east-west from Nagdhunga to Kalanki on the lower slope of the northern hill.

Those roads shall cross with the proposed road. Since the proposed road is wide and will receive large volume of traffic, mainly of heavy vehicles, existing movement of local residents

shall be interfered by the Project, and may cause increase of traffic accidents.

(5) Rivers

Major rivers in the Project Area are the east-bound Bhanjyang Khola and the west-bound Sisnekhola. Also, surface water is used to irrigate agriculture fields by small irrigation ditches.

River condition at the potential soil disposal site needs further survey.

River area is not strictly defined in Nepal. The location of boundary of river and private land need the Cadastral Survey. If river area is registered in cadastral plan and cadastral map, the land is owned by the government and no purchase is necessary for road project.

3.6.6 Vulnerable Groups

In very complicated and religion-related social structure in Nepal, following multi-angle definition is necessary to sort out vulnerable groups in the Project Area.

Identification of vulnerable project-affected-people (PAPs) need to wait for the Census Survey of the Project in later phase. The necessity of assistance program for vulnerable PAPs need to be based on comprehensive understandings of the particular PAP's situation. One may be a Dalit, but if wealthy, he/she shall not be a program target. A woman in higher Caste may be living without male partner and may be facing many difficulties in daily life.

Table 3-18 Multi-Angle Definition of Vulnerable Groups

Angles	Vulnerable Groups
Caste Group	'Dalit' in Table 3-19
Indigenous Group	'Endangered' to 'Disadvantaged' Indigenous groups in Table 3-20
Gender Group	Female-headed household Young female Widows living without support from family
Economically Underprivileged Group	Ex-Kamlari/Kamalari/Kamaiya (bonded laborer) Elderly household without support from family Children without adult support (orphans) People with disabilities (differently-abled) Child laborer Household under poverty line
Educationally Underprivileged Group	Illiterate persons People who do not understand/speak Nepali
Religious Group	Non-Hindus

Source: JICA Study Team

Table 3-19 Scheduled Castes of Dalit Community

A) Hill Dalit	1. Gandharba (Gaine) 2. Pariyar (Damai, Dargee, Suchikar, Nagarchee, Dholee, Hudke) 3. Badi 4. Bishwokarma (Kami, Lohar, Sunar, Od, Chunanra, Parki, Tamata) 5. Mijar (Sarki, Charmakar, Bhool) 6.Pode (Deula,Pujari,Jalari) 7.Chyame (Kuchikar,Chyamkhal)

B) Terai Dalit	8. Kalar 9. Kakaihiya 10. Kori 11. Khatik 12. Khatwe (Mandal, Khang) 13. Chamar (Ram, Mochi, Harijan, Ravidas) 14. Chidimar 15. Dom (Marik) 16. Tatma (Tanti, Das) 17. Dushadh (Paswan, Hajara) 18. Dhobi (Rajak) Hindu 19. Pasi 20. Bantar 21. Mushar 22. Mestar (Halkhor) 23. Sarbhang (Sarbariya) 24. Natuwa 25. Dhandi 26. Dharikar/ Dhankar

Source: National Dalit Commission, http://www.ndc.gov.np/caste-schedul-12-en.html (Retrieved 2014/05/03)

National Foundation for Upliftment of Aadibasi/Janjati Act, 2058(2002) lists 59 ethnic groups as indigenous in Nepal.

According to the ESMF (p. 154) and National Foundation for Indigenous Nationalities (NEFIN) (2004), the 59 groups are classified into 5 groups depending on their general status in the society. It was also confirmed in the interview with DOR/GESU that although the Newar and the Thakali are indigenous groups, they may not be the target group for additional assistance from the Project because, in many cases, people who belong to those groups are in advanced position in Nepal society.

Table 3-20 Indigenous Groups in Nepal by General Social Status

5. Endangered Groups	Bankariya, Kusunda, Kushbadia, Raute, Surel, Hayu, Raji, Kisan, Lepcha, Meche
4. Highly Marginalized Groups	Santhal, Jhangad, Chepang, Thami, Majhi, Bote, Dhanuk (Rajbansi), Lhomi (Singsawa), Thudamba, Siyar (Chumba), Baramu, Danuwar
3. Marginalized Groups	Sunuwar, Tharu, Tamang, Bhujel, Kumal, Rajbansi (Koch), Gangai, Dhimal, Bhote, Darai, Tajpuria, Pahari, Dhokpya (Topkegola), Dolpo, Free, Magal, Larke (Nupriba), Lhopa, Dura, Walung
2. Disadvantaged Groups	Jirel, Tangbe (Tangbetani), Hyolmo, Limbu, Yakkha, Rai, Chhantyal, Magar, Chhairotan, Tingaunle Thakali, Bahragaunle, Byansi, Gurung, Marphali Thakali, Sherpa.
1. Advanced Groups	Newar, Thakali

Source: National Foundation for Upliftment of Aadibasi/Janjati Act, 2058(2002), ESMF (Table 8.1)

In the Population Census 2011, among 122 names of the Caste/ethnic group found in Kathmandu and Dhading Districts, following 40 groups, or about 570,000 persons, belong to disadvantaged to endangered indigenous groups. According to the interview with DOR/GESU, there is no particular area in the Project Area where specific indigenous group is located.

Table 3-21 District-Level Population by Indigenous Caste/Ethnic Group

Vulnerability	Caste/ethnic Group	Kathmandu District	Dhading District	*Caste*	Vulnerability	Caste/ethnic Group	Kathmandu District	Dhading District	*Caste*
5	Raji (Rajhi)	21			3	Kumal	1,461	4,624	Non-Dalit
5	Hayu	54		Non-Dalit	3	Lhopa	48		
5	Kusunda	13			3	Pahari	657		
5	Lepcha	42			3	Rajbansi	814	19	
5	Meche	51			3	Sunuwar (sunuar)	3,760	39	Non-Dalit
4	Chepang/Praja	532	14,492	Non-Dalit	3	Tajpuriya	179		
4	Danuwar	998	969		3	Tamang	192,311	74,239	
4	Dhanuk	1,770	23		3	Tharu	18,478	282	Non-Dalit
4	Jhangad/Dhagar	117			3	Topkegola	35		
4	Lhomi	80			3	Walung	14		
4	Majhi	4,215	535		2	Byasi/Sauka	26		
4	Satar/Santhal	149			2	Chhantyal/Chhantel	819		
4	Thami	724			2	Gurung	45,784	18,632	Non-Dalit
3	Bhote	1,781	29	Non-Dalit	2	Hyolmo	1,698		
3	Darai	153	818		2	Janajati Others	168		
3	Dhimal	793			2	Jirel	484	20	
3	Dolpo	48			2	Limbu	11,149	99	
3	Dura	219			2	Magar	70,083	28,644	Non-Dalit
3	Gangai	24			2	Rai	39,762	2,211	

The number in 'Vulnerability' cullum corresponds the number in Table 3-20.
Source: National Population and Housing Census 2011

3.6.7 Issues related to Land

(1) Ownership

Land ownership information can be obtained from Land Revenue Office, Kathmandu District in Kalanki.

General land tenure composition, i.e. owner, tenant, caretaker, in the two districts were not obtained by literature survey.

(2) Market

During the survey periods in Kathmandu, information about land parcels for sale was located in the newspapers and the internet web pages. In Nepal, however, there is no licence to evaluate real estate or to be an agent or broker for real estate sales. Land and house can be traded between the owner and the buyer directly. No governmental office is monitoring real estate sales.

Table 3-22 Samples of Advertized Land Prices in the Project Area

Source	NRs./Aana	NRs./m^2	Location
Land Price in Classified Advertisement, April 2014	500,000	15,725	Swarswatisthan height, Thankot (Residential)
	375,000	11,794	Thankot (Residential)
	700,000	22,015	Balambu, Behind the Nepal Telecom Station (Residential)

1 Aana = 31.79 m^2
Source: http://www.nepalhomesearch.com/ (Retrieved on April 18, 2014)

(3) Price

District Land Revenue Office, Department of Land Reform and Management, Ministry of Land Reform and Management conducts survey and issues the Minimum Land Price

Evaluation Booklet every year. The land price is set according to the type of access road and VDC. The set price is used for determination of property tax and referred in land acquisition for public works.

Table 3-23 The Minimum Land Price in the Project Area

VDCs	Category of Land (Both sides of the road of the VDCs)	Price per Aana NRs.	Per m^2 NRs.
Balambu	1. Main Tribhuvan Highway	320,000.00	10,064
	2. Black topped sub- road	170,000.00	5,347
	3. Earthen Road	100,000.00	3,145
	4. Trail only	88,000.00	2,768
	5. Other (Out from road touch)	32,000.00	1,006
Mahadevthan	1. Main Tribhuvan Highway	320,000.00	10,064
	2. Black topped sub-road	170,000.00	5,347
	3. Earthen Road	100,000.00	3,145
	4. Trail only	44,000.00	1,384
	5. Other (Out from road touch)	32,000.00	1,006
Dahachok	1. Black- topped Road	100,000.00	3,145
	2. Earthen Road	60,000.00	1,887
	3. Trail only	42,000.00	1,321
	4. Other (Out from road touch)	22,000.00	692
Thankot	1. Main Tribhuvan Highway	320,000.00	10,064
	2. Black topped sub-road	170,000.00	5,347
	3. Earthen Road	100,000.00	3,145
	4. Trail only	44,000.00	1,384
	5. Other (out from road touch)	32,000.00	1,006
Badbhanjyang	1. Main Tribhuvan Highway	170,000.00	5,347
	2. Black topped sub- road	60,000.00	1,887
	3. Earthen Road	30,000.00	944
	4. Trail only	15,000.00	472
	5. Other (Out from road touch)	10,000.00	315

1 Aana = 31.79 m^2, NRs.

Source: Lowest land price evaluation booklet, Land Revenue Office, Kalanki, Kathmandu, Department of Land Reform and Management, Ministry of Land Reform and Management, 2013/2014

For the purpose of determining the amount of compensation, the District Compensation Determination Committee (CDC) shall conduct interview survey with related offices and local leaders to obtain information related to recent transaction.

During the field survey, the JICA Study Team tried to obtain the information of the decision of CDC regarding recent compensation price, but such information was not accessible to the Team.

Therefore, as the market price of the land in the Project Area, the JICA Study Team decided to refer the Feasibility Study of Tunnel Roads (Nagdhunga-Naubise Tunnel Road), DOR, 2013, and use the same amount to estimate the project cost.

Table 3-24 Land Price for Estimation of the Project Cost

Source	NRs./m^2	Location
Unit Price used in the DOR F/S Report 2013 (p. 83)	**9,430**	Between Imakhel and Sisne Khola

Source: Feasibility Study of Tunnel Roads (Nagdhunga-Naubise Tunnel Road), DOR, 2013

(4) Public land

The location and size of public land can not be obtained until the Cadastral Plan and Cadastral Map are obtained from Kathmandu District Surveyor's Office in Kalanki.

Information of the possibility of land parcels own by DOR in the Project Area was not obtained during the Study.

Publicly owned land can be used for road construction without payment of the price. If the land is owned by other office, such as Ministry of Forest and Soil Conservation (MOFSC), DOR shall negotiate the transfer of land registration with MOFSC.

3.6.8 Issues Related to Land Use

(1) Land use plan

There is no land use planning at District level in Nepal.

Department of Local Infrastructure Development and Agricultural Roads (DOLIDAR) publish District Transportation Master Plan (DTMP) on its website, and the Plans for Kathmandu and Dhading Districts are available.

(2) Land use change

There is no governmental procedure necessary for land use change of privately owned land, either residential or agricultural land, and only the consent of the owner is necessary. It is desirable, however, to obtain agreement of the neighbouring owners regarding the change in preparation of the Project.

For the tree cutting and land use change in National Forest, the Project Owner must apply to MOFSC for the Project, as well as to compensate according to the number of trees cut for the Project.

3.6.9 Issues Related to Residency, Structures and Businesses

(1) Registration of residents

In Nepal, there are Voter's Registration and issuance of Citizen Certificate. But there is no mandate registration of residents.

Therefore, the information regarding the residents, including tenants and family members working abroad, is only available with the Census Survey in the EIA phase of the Project.

(2) Types of housing structures

The JICA Study Team tried to obtain standard unit cost for structures that may be used as reference in determining compensation price. Such information may be available at E-bidding

Section, DUDBC, Ministry of Urban Development, Babarmahal Kathmandu. The contact person was Mr. Prakrina Tuladhar, Phone: 9851 049004. During the Study period, the information was under preparation at Ministry and was not yet provided to the Department.

Similar information may be obtained from District Technical Office.

In a statistics reference, types of housing structures are classified as shown in Table 3-25.

Table 3-25 Types of Housing Structures

Foundation	Mud bonded bricks/stones Cement bonded bricks/stones RCC with pillar Wooden pillar Other
Outer wall	Mud bonded bricks/stones Cement bonded bricks/stones Wood/planks Bamboo Unbaked Others
Roof	Thatch straw Galvanized iron Tittle/slate RCC Wood planks Mud Others

Source: Village Development Committee & Demographic Profile of Nepal, Mega Publication & Research Centre

(3) Ownership and tenancy of structures

In District level, there are more households who are renting their housing than those who own one.

Table 3-26 Households by Ownership of House/Housing Unit in Use

District	Owned	Rented	Institutional	Others	Total
Kathmandu	171,828	255,444	4,675	3,597	435,544
	39.5%	58.6%	1.1%	0.8%	100.0%
Dhading	67,706	5,224	235	677	73,842
	91.7%	7.1%	0.3%	0.9%	100.0%

Source: Village Development Committee & Demographic Profile of Nepal, Mega Publication & Research Centre

Average tenant rate in the Project Area is not yet obtained.

Resettlement Action Plan Narayanghat – Mugling Road (Chitwan District section), Nepal – India Trade and Transport Facilitation Project, January 2013, provides NRs. 10000 (Per HH) as rental stipend equivalent of 3 months for tenants who have to relocate.

(4) Policy of Public Housing Supply

In Nepal, there is no public housing policy and project yet. Therefore, resettlement compensation is made in cash, rather than provision of resettlement housing.

(5) Business Licences

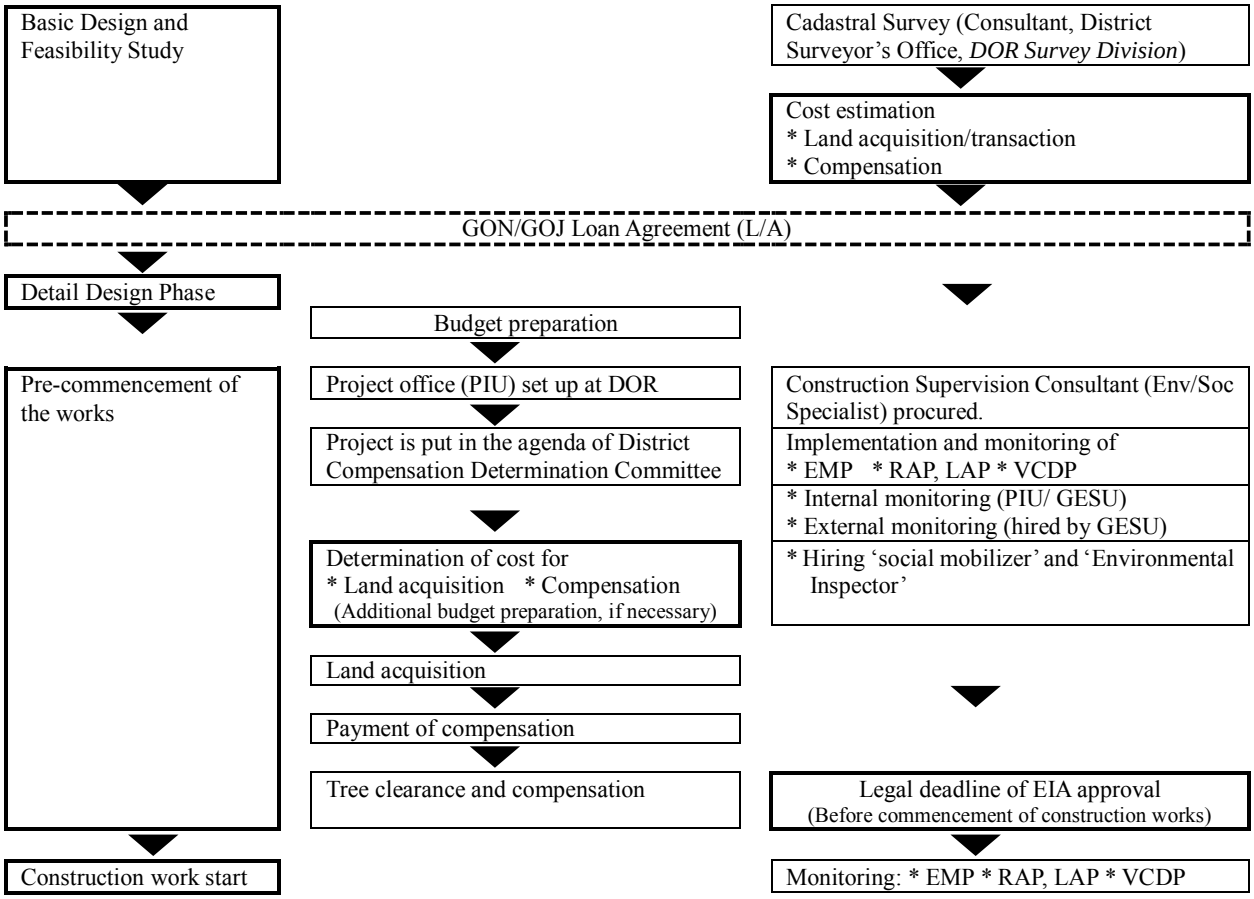
Business license is issued by Ministry of Industry. In the Project Area, however, there are many small shop stalls and mobile kiosks that are unlikely licensed.

Therefore, the information regarding the businesses, including information on workers, is only available with the Census Survey in the EIA phase of the Project.

3.6.10 System and Procedure of Land Acquisition and Compensation

(1) Project Phases and Land Acquisition Procedure

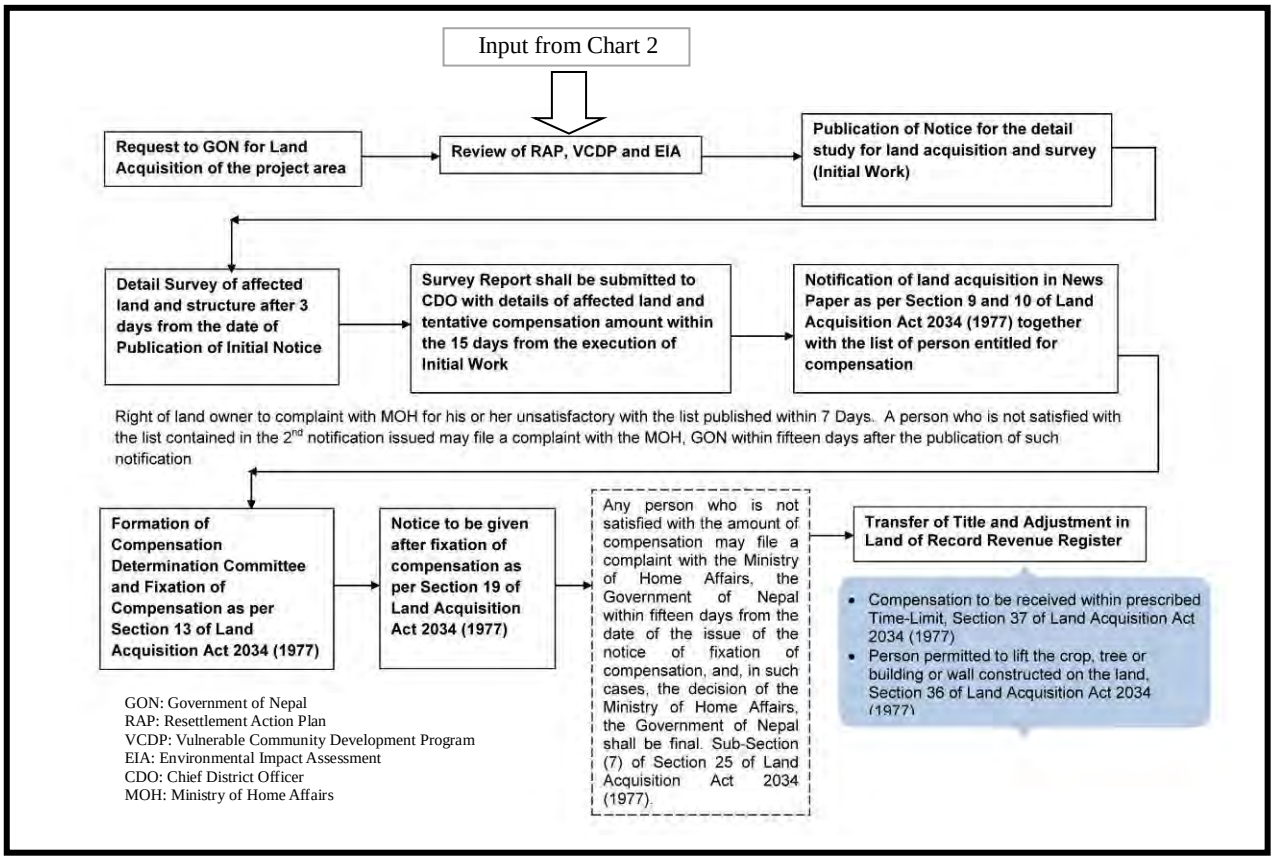
According to the Land Acquisition Act and the Land Acquisition Management Guideline for Public Road 2003(2059) (Ministry of Physical Planning and Works, Department of Road), the procedure shall follow the steps described in the following charts.



GON: Government of Nepal, GOJ: Government of Japan, EMP: Environmental Management Plan,
RAP: Resettlement Action Plan, LAP: Land Acquisition Plan, VCDP: Vulnerable Community Development Plan

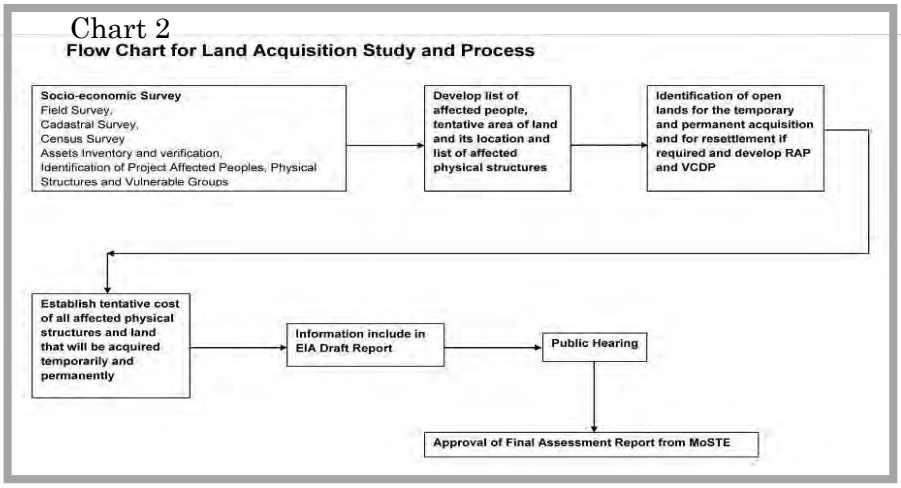
Source: JICA Study Team

Figure 3-28 Land Acquisition Procedure and Project Activities



Source: JICA Study Team

Figure 3-29 Detailed Land Acquisition Procedure (1)



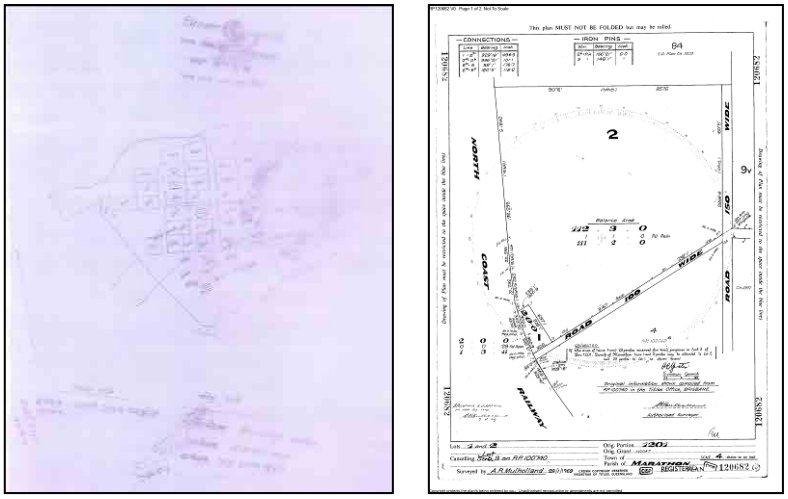
Source: JICA Study Team

Figure 3-30 Detailed Land Acquisition Procedure (2)

(2) Cadastral Survey

Cadastral Survey shall be conducted during the Feasibility Phase, together with EIA survey and basic design, to determine the list of parcels for land acquisition.

The Cadastral Survey shall be followed by the Asset Survey and the Census Survey to determine the list of other assets for compensation and the list of Project Affected Persons.



Source: Kathmandu District Surveyor's Office at Kalanki

Figure 3-31 Image Sample of Cadastral Plan (Left) and Cadastral Map (Right)

1	**Cadastral Survey**, starting with obtaining copies of **cadastral plan** for the project area
2	Selecting land parcels for acquisition
3	Obtaining copies of **cadastral map** for parcels for acquisition, accompanied by the information of owners, including the locations of governmentally owned land
4	**Ownership Survey**, including preparation of the List of Land Owners, inquiry for absentee owners, and survey of recent transfer of ownership by inheritance or purchase
5	**Property Boundary Survey**, accompanied by the owners of each land parcels, to determine exact locations of land parcels and the area for acquisition
6	**Asset Survey** and **Census Survey**

Source: Kathmandu District Surveyor's Office at Kalanki

Figure 3-32 Steps to Determine the Areas for Land Acquisition

Cadastral Plan and Cadastral Map shall be obtained from Kathmandu District Surveyor's Office in Kalanki for charge.

The local consultants, procured by the JICA Consultant, shall conduct the surveys with assistance from the Project Implementation Unit nominated by DOR.

(3) Cost Estimation by Compensation Determination Committee

As shown in Figure 3-28, the Compensation Cost shall be estimated in the F/S phase, and then determined by the Compensation Determination Committee in later phase.

The price of land, structure and other assets as well as any other assistances for project affected people shall be decided and approved by the Compensation Determination Committee, consisted of four members, namely, the District Chief Officer, District Development Committee representative, District Land Revenue Office representative, and Project Implementation Office representative from DOR.

(4) Tree Clearance and Compensation

According to the Nepal Forest Guidelines 2006, which is not yet obtained by the Team, the Project Owner is responsible to plant 25 saplings for one cutting of tree of 10 cm diameter or larger. The land for reforestation shall be provided by the District Forest Office. The Project Owner, also, is responsible for maintenance of the reforested area for five years after the forestation.

According to the interview to DOR/GESU, DOR regularly chose cash compensation instead.

The National Forest land that falls in ROW of a national road shall be transferred from MOFSC to MOPIT without charge.

The cut timber and other assets shall be the property of the District Forest Office.

The responsible institution for tree clearance activities on National Forest land shall be nominated by the District Forest Office. Sample cases in road projects shall be studied later in this Study.

In case the trees are owned privately, regular asset survey and compensation measures shall be applied.

3.6.11 Work Safety

Work safety regulations or guidelines in Nepal was not obtained during the Study.

Chapter 4 Road Profile

4.1 Profile of the Study Road (Existing Road)

4.1.1 Road Network System

The Study Road is a section of the Tribhuvan Highway, which is a part of Mid-hill Highway and is one of the major trunk roads in the road network system of Nepal. The national road system in Nepal divides all the roads in three separate but interrelated systems. Individual roads in each system are then grouped under various classifications and sub-classifications. The three road systems are as follows:

(1) Strategic Road Network

The strategic road network comprises of National Highways, Feeder and Postal Roads.

1) National Highway

These are the main roads connecting East to West, South to North and those roads joining the main north-south valleys of the Nation. It also includes the roads that connect the Regional Headquarters with these main roads. National Highways directly serve the greater proportion of long distance travel. They normally provide a consistently higher level of service (in terms of future development) and serve the inter-community mobility (regional interest) and cross border traffic, fulfilling the functions required for a balanced and well-managed national road system.

2) Feeder Roads

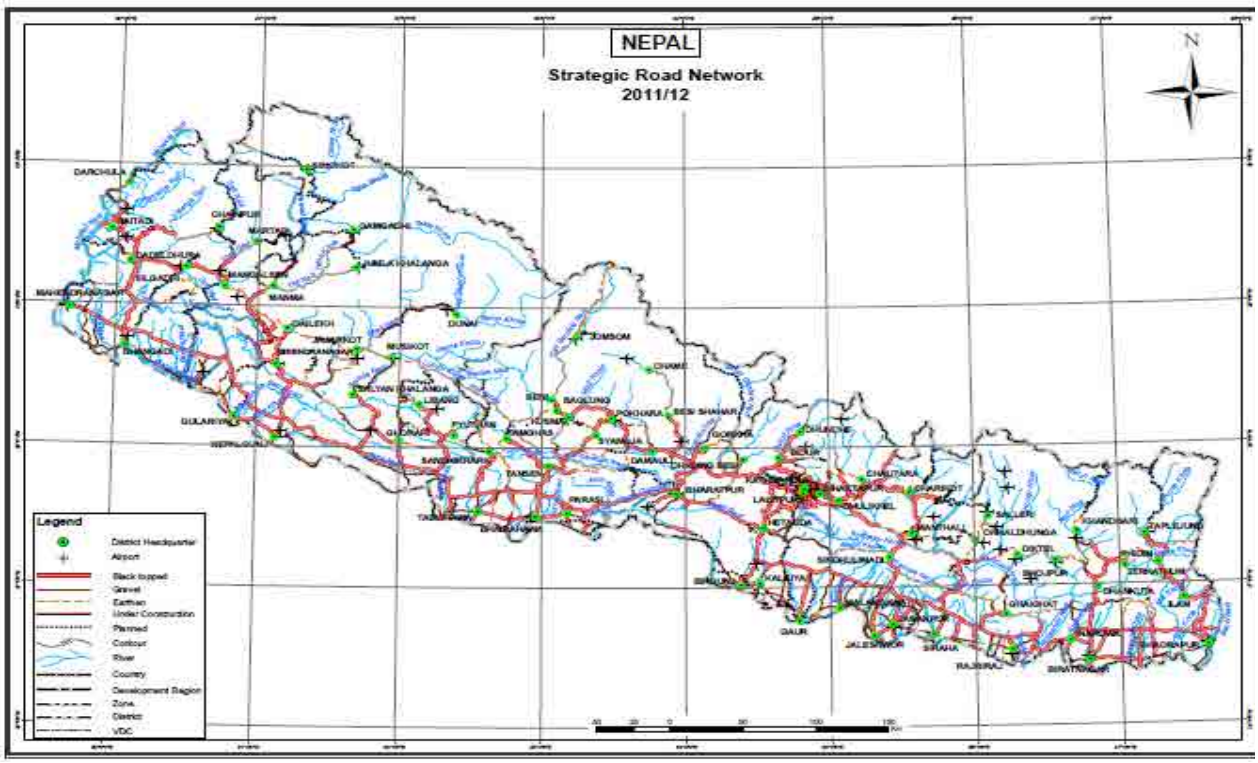
Feeder roads are important roads of a more localised nature than National Highways and are of secondary importance in the road system hierarchy. They are sub-classified into Feeder Roads (Major) and Feeder Roads (Minor). Feeder Roads fulfil the principal functions of collection and distribution and human and social liaison required for a balanced and well-managed national road system. Feeder roads connect District Headquarters, Major economic centers, and Tourism centers to National Highways and other Feeder Roads and serve the community's wide interest.

With an aim to further balance the national road system investment and decentralization of road responsibilities, the feeder roads are further divided into four sub-groups based on traffic density, agriculture development, infrastructure and strategic support, and community strengthening as follows;

i) Multi-purpose Roads, ii) Agriculture Roads, iii) Project Specific Roads, and iv) Social Roads

3) Postal Roads

The remains of former road network used extensively for communications within the country comprise the Postal Roads. These roads are principally located along the Indian Border in the Terai. They command a high political priority as they continue to provide links between the East-West Highway and the Border. However, as the network develops, these roads will be progressively upgraded to Feeder Roads.



Source: DOR

Figure 4-1 Strategic Road Network in Nepal

(2) Local Road System

Local road system is comprised of District Roads, Agriculture Roads, Village Roads, and Mule Tracks/Main Trails/Village Trails

1) District Roads

These are roads connecting groups of villages within a District to the Central Road System. They command the top priority in the Local Road System

2) Agriculture Roads

Agriculture Roads serve specific areas of agricultural importance within a District and connect these areas to District Roads or the Central Road System.

3) Village Roads

These are short, non-through roads connecting isolated villages to District Roads or directly to the Central Road System.

4) Mule Tracks/Main Trails/Village Trails

These are small roads preserved to fulfill the collection and distribution function as well as human and social liaison functions at the local level.

(3) Urban Road System

Municipal Roads and City Development Roads comprise the Urban Road System.

1) Municipal Road

Municipal Roads are roads and streets within a municipal boundary, excluding the Central Road System. They provide access to residential, business, government and industrial establishments within the municipality and thus enable the local distribution of goods, assist business activity and are the primary means of social interaction. It is most important for Municipal Roads to be developed and designed within a land-use planning framework for the Municipality.

2) City Development Roads

The roads that provide short access connections within to a residential and industrial estates of a municipality comprise the City Development Roads. The networks connect with Municipal Roads or Urban Links of the Central Road System and are secondary elements within the Urban Road System hierarchy.

4.1.2 Road Network

There are three types of road network in Nepal, i) strategic road network (SRN), ii) urban road network (URN), and iii) local road network (LRN).

National Highways and Feeder Roads comprise the SRN. These roads are the primary roads in the national road system hierarchy and act as the principal collection and distribution elements and thus form the essential backbone of the system. The National Highways and Feeder Roads fulfil this important function in the national road system of Nepal. In order to highlight the importance of these roads they have been additionally grouped under the heading, the Strategic Road Network. The Strategic Road Network was defined by DOR/MRCU and approved by the Government in 1994.

According to the Statistics of SRN 2011/12, the SRN has a total length of about 11,636km and consists of 3 main east west corridors and several north south corridors. The east west corridors are: (i) East West Highway (EWH), (ii) Postal Roads, and (iii) Mid-Hill East-West Corridor (MHC). The overall management from construction to maintenance of MHC lie under the responsibility of DOR. District Development Committees (DDC) and Department of Local Infrastructure Development and Agricultural Roads (DOLIDAR) are responsible for the URNs and LRNs respectively.

EWH, which is a part of Asian Highway 2 runs from far east to far west in the Terai region of the country and is approx. 1,027km long. This serves as the main artery of SRN where heavy traffic plies day and night. Postal roads (roads designated for transporting mails) along the Indian border in the south run in parallel with EWH. MHC, which is approx. 1776km (including portions of existing national highways) as of 2011/12 is a series of feeder roads that link mid hill districts and provide routes to the main centers in the hills, including Kathmandu and Pokhara.

4.1.3 Classification of Roads

There are many types of road classifications in Nepal. Different agencies use different classifications. However, the NRS 2070 classifies the roads in Nepal into two types, as follows:

(1) Administrative Classification

Administrative classification of roads is intended for assigning national importance and level of government responsibility for overall management and methods of financing. This consists of the following four roads.

1) National Highways

Also represented by the letter "H", National Highways are the main arterials passing through the length and breadth of the country. They emphasize the mobility function and allow long-distance travel with higher speeds while connecting the abutting community.

2) Feeder Roads

Feeder roads connect District Headquarters, Major economic centers, and Tourism centers to National Highways and other Feeder Roads and serve the community's wide interest. As such, these roads are equivalent to collector roads in the AASHTO Classification. They are designated by letter "F" followed by 3-digit number.

3) District Roads

As afore-mentioned, District Roads are important roads within a district serving areas of production and markets, and inter-connecting or connecting with main highways.

4) Urban Roads

Urban Roads are the roads serving within the urban municipalities.

(2) Functional Classification

This type of classification is used for assigning various geometric and technical parameters for design. Roads are categorized into Class-I to Class IV in accordance with the average daily traffic (ADT) expressed in terms of passenger car unit (PCU). Table 4-1 shows the range of PCU for each class.

Table 4-1 Classification of Roads

Classification	ADT in terms of PCU in 20 years perspective period	Remarks
Class-I	More than 20,000	Expressways
Class-II	5000 – 20,000	
Class-III	2,000 -5,000	
Class-IV	Less than 5,000	
Note: There are no expressways till date in Nepal, although the government of Nepal is undertaking several studies for the construction of such road in the future. One of them is the Kathmandu – Kulekhani-Hetauda Fast Track.		

Source: Nepal Roads Standard 2070

4.1.4 Role of the Study Road

The study road lies in Tribhuvan Highway, which presently is a part of one of the only two highways connecting the capital city Kathmandu with the neighboring countries. The Tribhuvan Highway connects Kathmandu with Raxaul on the Indian Border. It also serves in combination with the Prithivi Highway to connect the capital with the country's most tourist-attracted city, Pokhara. It further combines with the East-west Highway in the Terai region to connect with other entry points on the Indian Border. All vehicles coming into and going out from Kathmandu to Indian border or other parts of the country ply on this road, making it the most important road not only as an economic corridor but also as the arterial for the tourism sector.

The Sindhuli Road (also known as the BP Road), connecting the capital city Kathmandu with the eastern Terai and the border with India, is being constructed under the grant aid scheme of Japan. The completion of the last section (approx. 36.8 km) of the approx. 160km long Sindhuli Road is expected in March next year. After completion, this will be the second trunk road to connect the capital with the eastern region of Nepal. However, it has been estimated in the PIP that this road will only divert about 500 hundred vehicles per day and concluded that under the present condition, this road will have a limited role in bringing large traffics from the Indian Border. On the other hand, the current traffic volume on the existing road is about 7600 vehicles per day and is expected to constantly increase in the future. As such, the Study Road is expected to function as the life line of the Kathmandu Valley until another alternative route has been provided.

It is also worthy to note that the provision of tunnel on Thankot-Naubise section has been regarded as one of the priority projects for the development of the Asian Highway and providing linkage to the Asian Highway and intermodal connections.

Therefore, from above, the Study Road is expected to play the following roles:

i) To ensure reliable, safe and faster access between Kathmandu and the Terai region

including the border with India and contribute in enhancing the economic and social activities,

ii) To ensure reliable, safe and faster access between Kathmandu and Pokhara and help promote the tourism sector,

iii) To reduce travelling cost and vehicle operating cost particularly for the Kathmandu bound traffics,

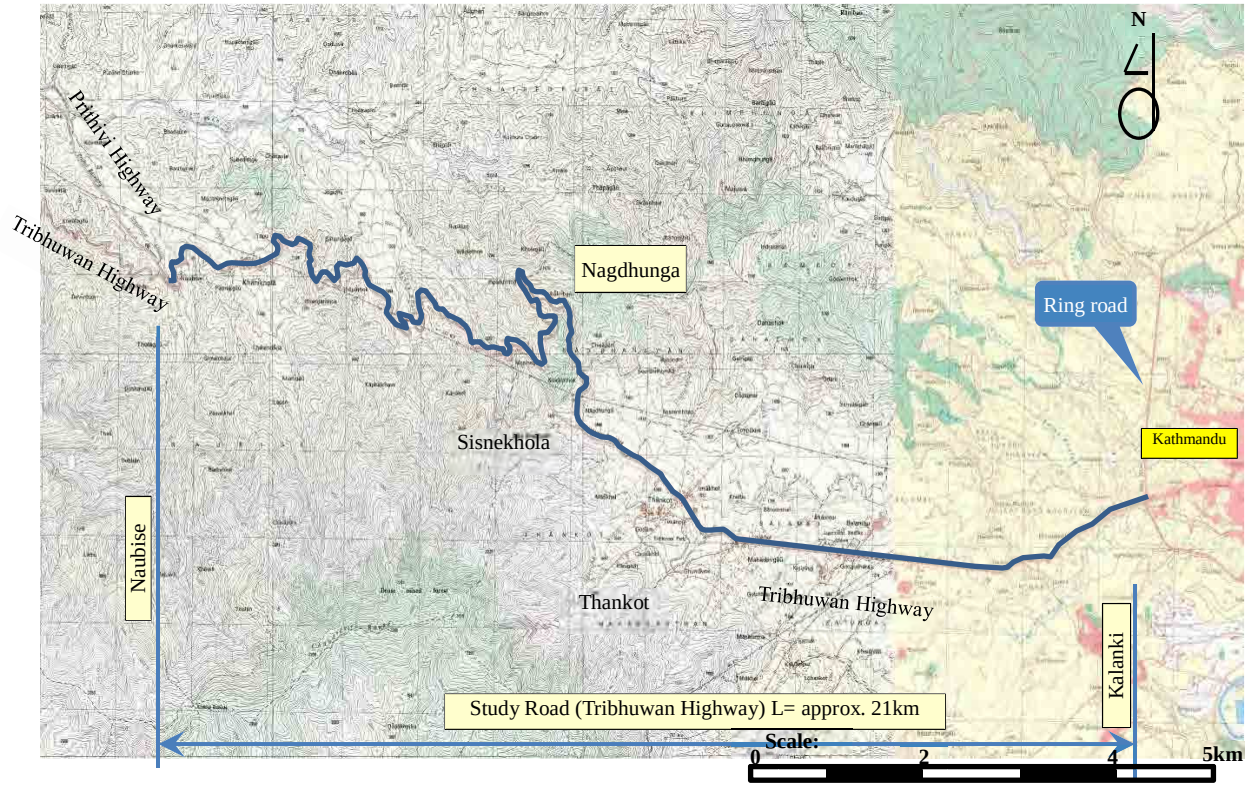
iv) To improve social and economic activities of the areas along the study road, and

v) To function as the model project for other similar successive projects.

4.1.5 Present Road Condition

(1) Location of Study Area

The study area is located on the western side of Kathmandu Valley. The study road commences from the intersection with the existing Ring Road at Kalanki in Kathmandu District and ends at Naubise in Dhading District. The topography from Kalanki to Thankot (about 7km) is a rolling plain and beyond Thankot it is mountainous. The elevation near Kalanki, the beginning point of this project, is about 1,300m. It gets higher as it approaches to the west end of Kathmandu Valley and reaches the highest point at the Nagdhunga pass crossing, where the elevation is about 1,500m. The road then takes a serpentine alignment along the mountain and downgrades all the way up to Naubise, where the elevation is about 950m. Figure 4-2 shows the location of the study area.



Source: JICA Study Team

Figure 4-2 Location of Study Area

(2) Topography and Geology

The schematic drawing of the topography and geology of the study area (Kalanki to Naubise) is presented in Figure 4-3. As can be understood from the geological plan and profile drawings, the geological distribution along the existing road can be largely classified into two areas.

1) Topography and Geology along Existing Road

Kalanki to Nagdhunda Pass Section

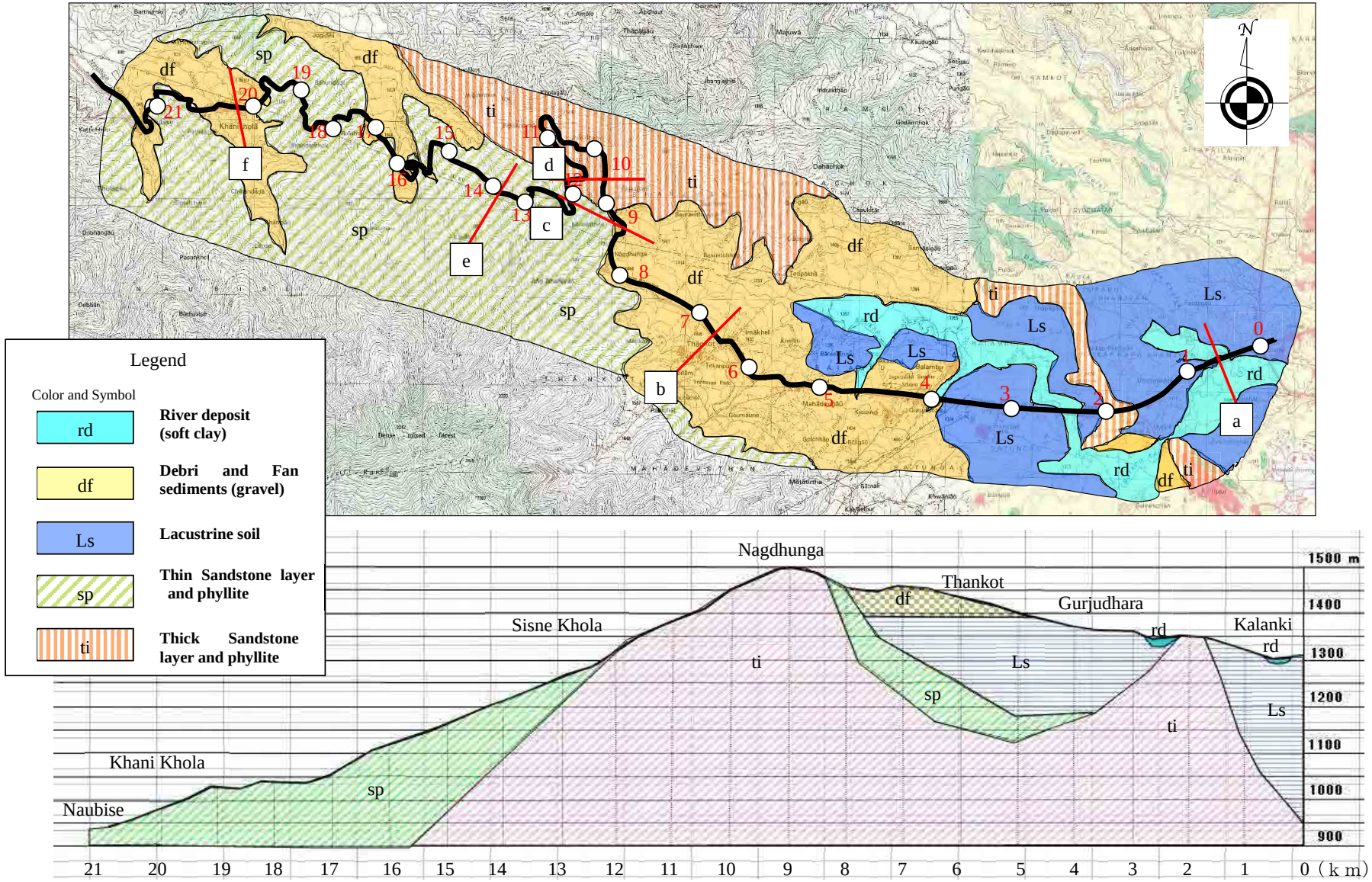
- River sediment (clay) accumulated along a river
- lacustrine sediments(Sand , silt , clay mainly) deposited in the Kathmandu Valley
- Fan deposits and debris flow deposits accumulated in the foothills of the eastern mountains mainly gravels.

Nagdhunga Pass to Naubise Section

- Sandstone , phyllite as bedrock
- Debris flow deposits

The profile of the existing road is as shown in the cross section. On the other hand, the typical geological cross sections at 6 different locations along the road was studied and prepared, as shown in Figure 4-4 (a) to (f). The locations of cross section are indicated by the red line on the plan. It can be understood from these figures that from Kalanki to Nagdhunga Pass, the road has been constructed in a relatively flat topography, which is assumed to be formed from the debris flow deposits from the surrounding mountains or/and the accumulated lacustrine of the Kathmandu basin.

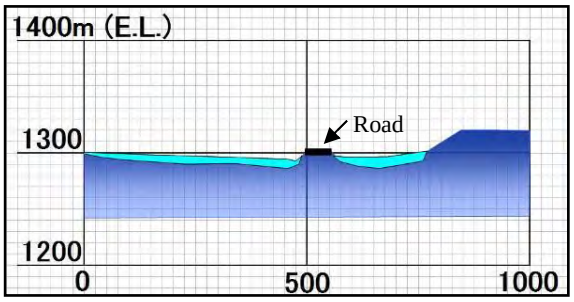
However, from Nagdhunga Pass to Naubise, the road has been constructed on a eroded slope of a steep mountain.



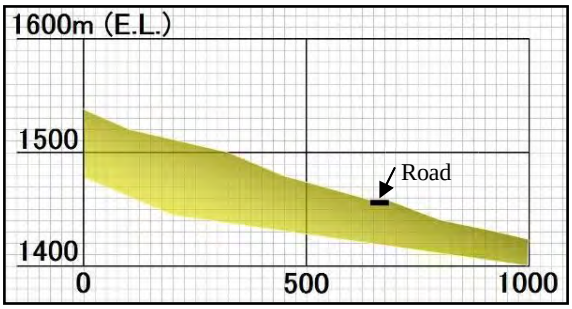
Source: JICA Study Team

Figure 4-3 Geological Map and Profile around Study Area

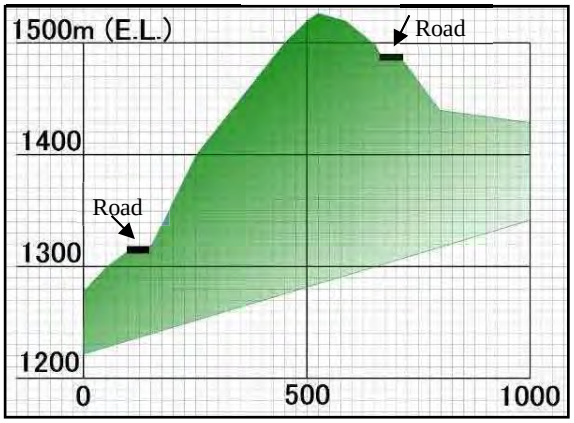
a (0km+500)



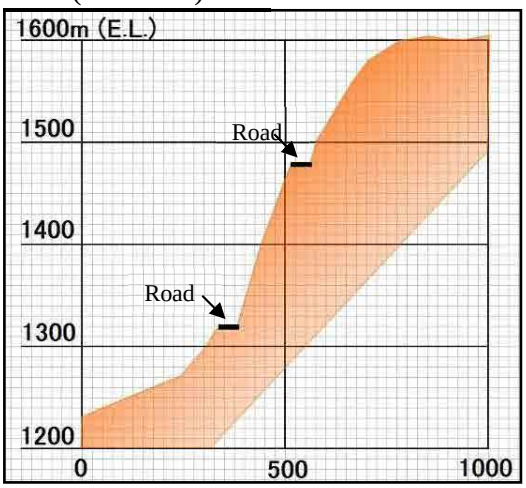
b (6km+800)



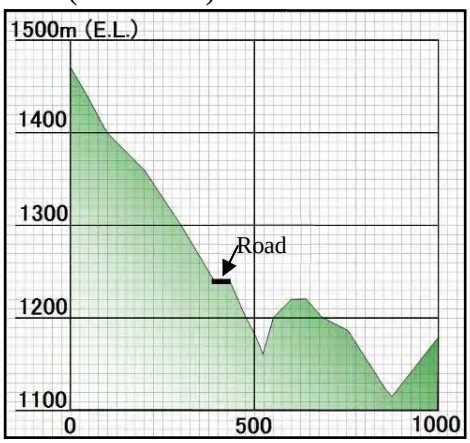
c (8km+500)



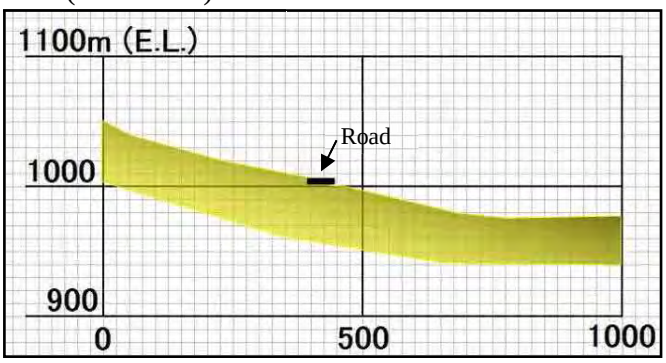
d (9km+700)



e (13km+700)



f (20km+200)



Source: JICA Study Team

Figure 4-4 Schematic Cross Sections of the Study Road

2) Slope Condition

The unstable slopes observed along the existing roads are indicated in Figure 4-5. Landslides and collapse including unstable slopes were confirmed altogether at 61 locations. These locations are indicated in an interval of every kilometer in Figure 4-6. According to this, unstable slopes are found to be concentrated within a section of 9km ~ 13km, with 10 or more unstable spots within a stretch of a kilometer. This section corresponds to the steep slope portion of the west side from Nagdhunga Pass.

On the other hand, the percentage of unstable spots in terms of road length is illustrated in Figure 4-7. The most unstable slope, which occupies 90% in a kilometer stretch was found from 9km to 10km section, which is also the area that corresponds to the steep slope portion of the west side from Nagdhunga Pass. The next unstable section is within 12 to 14km stretch where the percentage is about 50. Some of these unstable areas are shown in pictures below.

Landslide at Nagdhunga Pass

Erosion prevention work of the valley

Rock anchor (retaining wall)

Deformed Gabion

Collapse of the road shoulder

Source: JICA Study Team

Photos 4-1 Various Unstable Slopes at Study Road

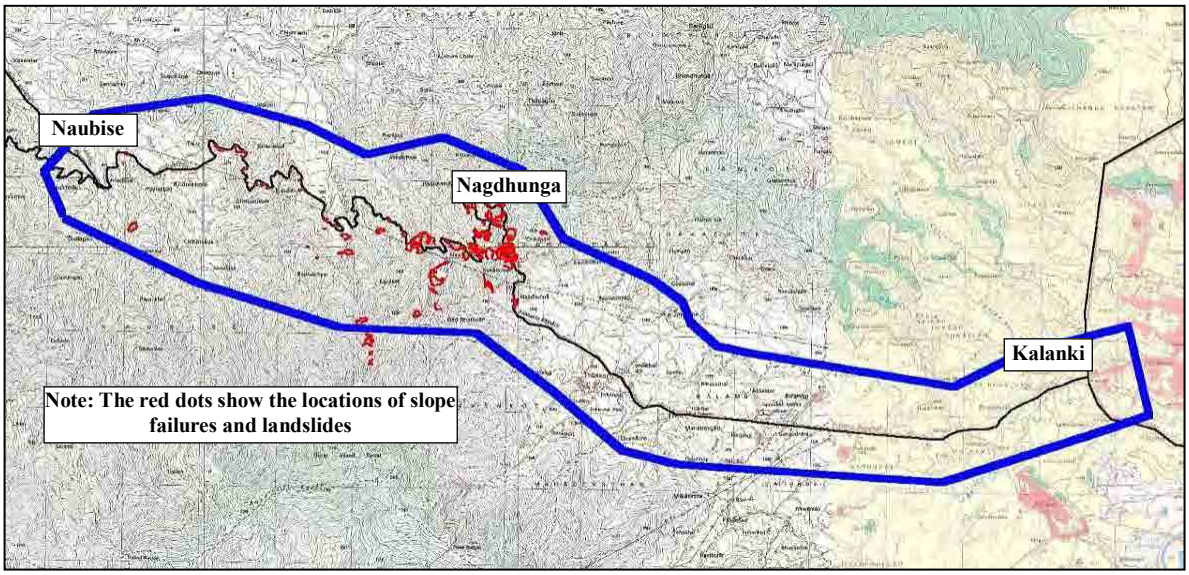


Figure 4-5 Landslides and Collapses in the Study Area

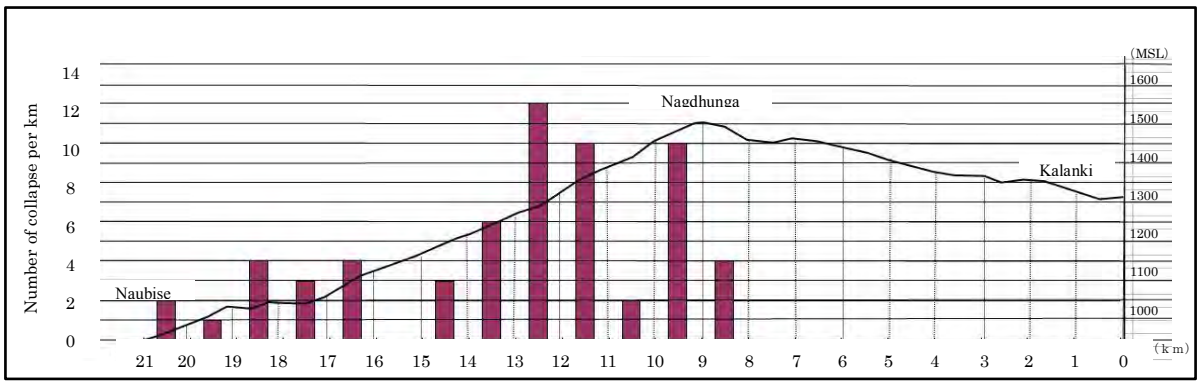


Figure 4-6 Number of Every 1km of Landslides and Collapses

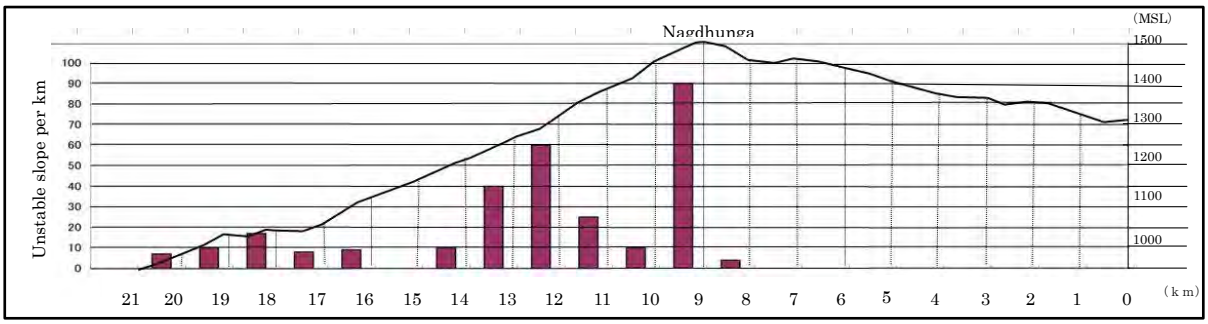


Figure 4-7 Length as a Percentage of 1km Each Landslides and Collapses

3) Debris Flow

Debris flow risk streams surveyed along the road is shown in Figure 4-8 and in Photos 4-2. According to hearing conducted with the locals and concerned authorities, occurrence of debris flow in the past was confirmed in these streams. There are several sabo dams provided for flow prevention measures.

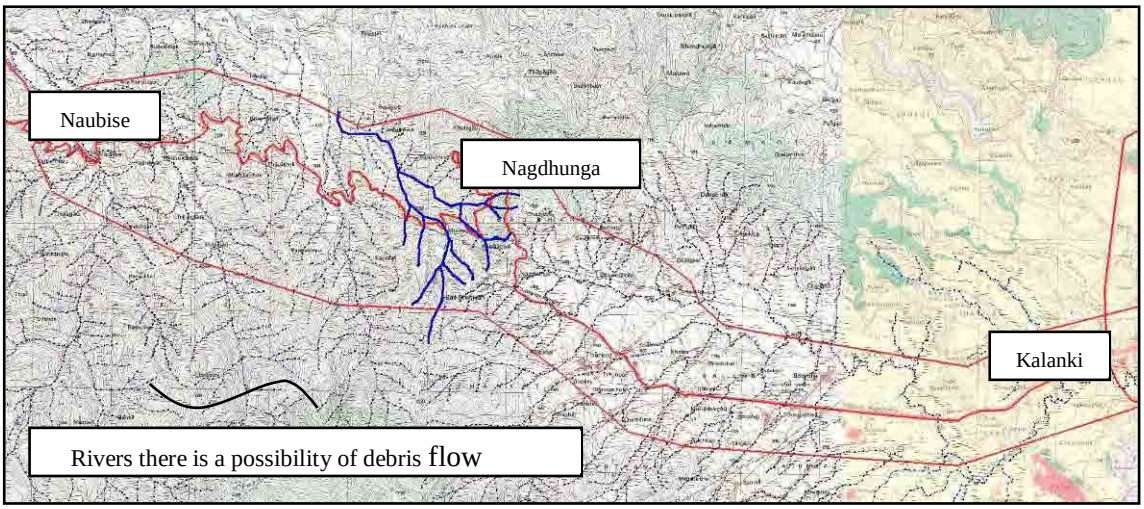


Figure 4-8 Rivers There is a Possibility of Debris Flow Occurrence

Sisnekhola
(west side tunnel portal)

Upper stream of Sisnekhola
(Exising sabo dams)

Near Koiralathok

Photos 4-2 Debris Flow Rivers

(3) Inventory Survey of Existing Road

Inventory survey of the existing road within Kalanki to Naubise (L= approx. 22km) stretch was conducted by the Study Team to gather necessary information on the present condition. During the course, the existing horizontal and vertical alignment, pavement condition, drainage facilities, abutting land use, ancillary facilities and structures including religious facilities were studied. These features are shown schematically in Figure 4-9. In addition to this, the composition of the cross section elements and the condition of slopes, both natural and road slopes were also studied. The findings of the survey are briefly described hereunder.

1) Alignment

Tribhuvan Highway was constructed in the fifties, probably under the then presiding standard. Therefore, it consists of alignment that does not satisfy the requirements of the present standards. As shown in Figure 4-9, most of the curvatures in the section of the study road lie between 100m to 25m. The horizontal alignment from Kalanki to Nagdhunga is generally smooth although there are few curvatures with radius as small as 40m. However, the section beyond consists of consecutive sharp curves including hairpin curves that have a radius of 25 – 50m. The maximum radius of curvature in this section is 100m and the minimum is 25m.

Looking at the vertical grade, the grade from Kalanki to Naghdhunga pass crossing is 4% except for the section immediately before Naghdhunga where the grade is as high as 7%. On the contrary, the vertical grade beyond Naghdhunga is about 6%. The steepest section is between Naghdhunga to Sisnekhola where the vertical grade is between 10% and 6%.

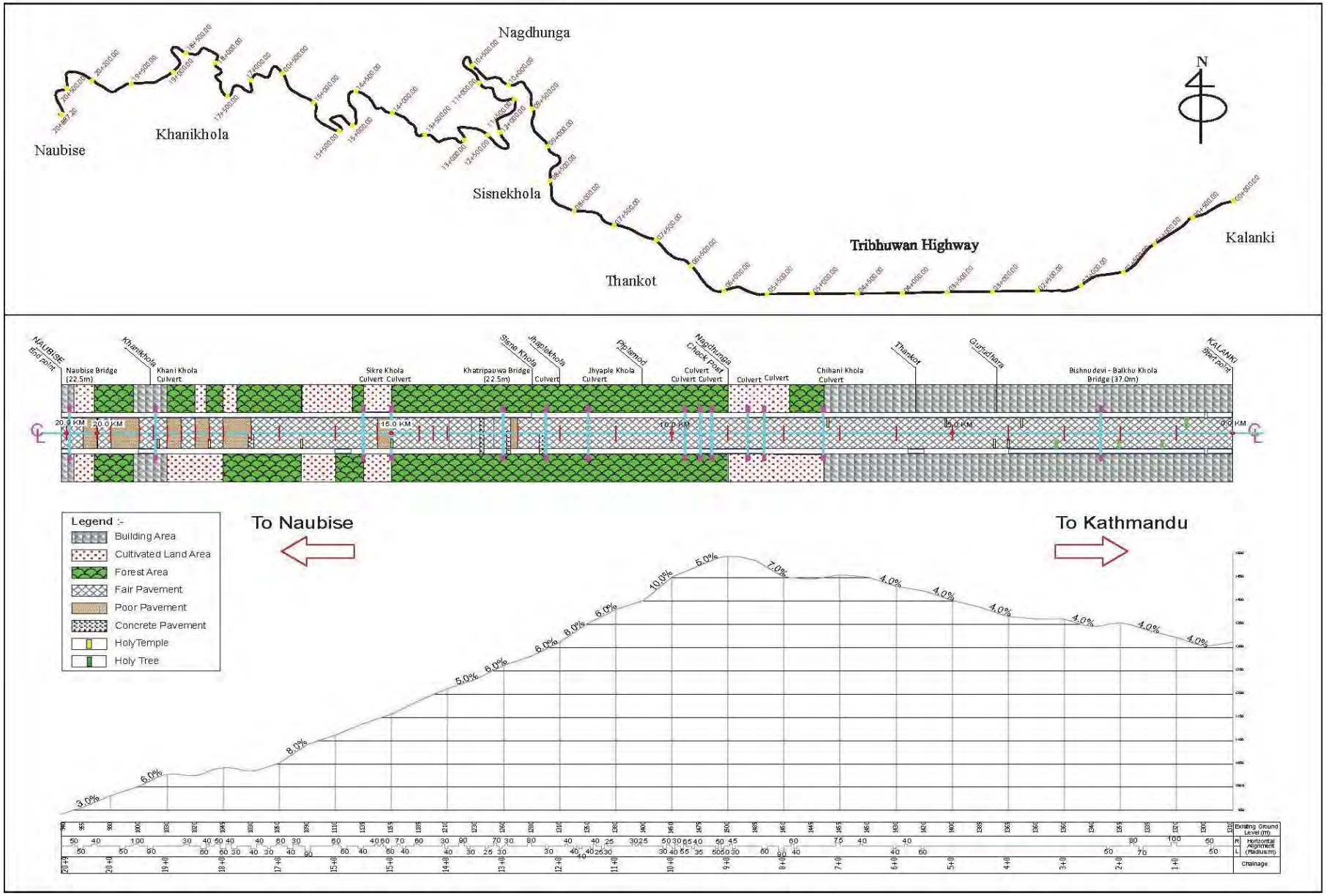
From above, it can be concluded that the Nagdhunga pass crossing is considered to be the most critical section among the Study Road section, as both the horizontal and vertical alignment is poorest among other sections. This combination of sharp horizontal alignment and steep vertical alignment contributes largely in causing difficulty for heavily loaded trucks to attain smooth drive on its way to Kathmandu.

2) Cross section

The study road consists of two lanes (one in each direction), a hard shoulder and an earthen shoulder. In general, the road has a 7.0m wide carriageway with 0.5m of hard shoulder on both sides. The width of the earthen shoulder is not constant. The road is provided with a standard cross-fall 2 – 2.5%. Widening and super-elevation are provided at horizontal curves.

Mounted sidewalks are provided on both sides of the road near kalanki area. However, it is limited to a section of about 400m from the starting point of the Study Road. The width of the sidewalk is not constant and varies from 1.5m to 2.3m. Beyond Kalanki, some areas have road shoulders widely paved that can accommodate the pedestrians. But most of the areas either have a narrow space of earthen shoulder or don't have enough space at all for pedestrians. This is significant particularly along densely built-up area or along the mountain side of the road.

According to the NRS, the Right-of-Way (ROW) of this road is supposed to be 50m; 25m each side, from the centre of the road. However, there is no such place, except the Naghdhunda Pass crossing, where the required ROW is secured. From Kalanki to Thankot, due to rapid urbanization and improper development, the houses are located so near the road that some of the houses are hardly 5m away from the centre of the road. ROW beyond Naghdhunga also does not meet with the present requirement. This is mainly because of the topography – one side of the road has a steep mountain while the other side is a deep valley.



Source: JICA Study Team

Figure 4-9 Schematic Diagram Showing Present Condition of Existing Road

3) Pavement condition

Two types of pavement are found applied on the study road; surface treatment with granular base (STGB) and asphalt mixed with base (AMGB). The former type is provided in the section from Kalanki to Nagdhunga and the latter type is provided from Nagdhunga to Naubise. According to the final report on " Traffic, surface distress and road roughness surveys on Strategic Road Network" published by DOR in fiscal year 2012, the pavement from Kalanki to Nagdhunga (9.11km) is in fair condition. However, the section from Nagdhunga to Naubise (12.55 km) is in poor or bad condition. This was substantiated during the inventory survey. The sections where the pavement is in bad condition, can be identified from the inventory result also, which is shown in Figure 4-9. The most remarkably poor condition of the pavement is prominent along creeks, where the horizontal curves are sharp and vertical grades are higher. The pavement distress at these sections can be attributed to low speed of heavy vehicles and concentration of rain water. According to the DOR, maintenance work for overlay of pavement was conducted along most of the sections within the Study Road.

4) Drainage facilities

Side ditches and cross drainage facilities are found provided on the existing road. Side ditches (typical size of 40cm x 50cm) are provided on both sides of the road in the urban and sub-urban areas, while in the mountainous area, side ditches are appropriately provided on the hill side of the road as it is observed along the hill side. In the urban and sub-urban areas, the ditches are generally covered, while the ditches in the mountainous areas are open. Lack of maintenance is prominent in the urban/sub-urban areas where most of the side ditches are buried and non-functional. Cross-drainage facilities such as bridge, pipe or box culvert are seen to be provided to allow water flow on rivers, streams, or at the creeks and where the rain water is required to be carried across the road. There are several bridges within the objective section of Study as listed in Table 4-2. Where the size of the water channel is small, box or pipe culvert is mostly seen provided. All bridges in the Study section is RC concrete. Pipe culverts are mainly made of concrete while box culverts are made of wet-stone masonry.

Table 4-2 Location of Major Bridges

No.	Station	River/Bridge Name	Bridge Type	Length (m)	District
1	2+350	Bishnudevi Balkhu Khola	PSC Girder	37.0	Kathmandu
2	13+075	Khatripauwa Br.	RC T-Beam	22.5	Kathmandu
3	20+850	Naubise Br.	RC T-Beam	22.5	Dhading

Source: JICA Study Team

5) Land Use

As shown in Figure 4-9, the area from Kalanki to Thankot is densely built-up with houses align at both sides of the road. The areas beyond the road are also used for residential purpose.

Beyond Thankot, there is sudden decrease in the number of houses. Houses are found scattered along the road all the way up to Khanekhola. From Khanekhola to Naubise, the road is again abutted by shops/houses. Where there are no houses and not forested the lands are used for cultivation.

6) Utilities and Other Obstruction Structures

Utilities such as overhead electric poles and cables, overhead telecommunication cables, underground water pipes and underground telecommunication cables etc. exist along the Study Road. The electric poles, which are also used for distribution of telecommunication cables, are significant all the way up to Naghdhunda Pass crossing. These poles are installed within the ROW and will require to be relocated if the road is to be widened.

Water pipes of diameter 50mm to 100mm are installed along the road sides. This was confirmed up to about 3 km from Kalanki.

At several locations, there are several small sized temples and Banyan Trees within the ROW.

Regarding the above utilities, they should be investigated again when the optimum route will be finalized during F/S study.

7) Slopes

Slopes, both natural and road slopes were studied during the inventory survey. Slope failure, debris flow etc, have been confirmed at several locations. The data has been collected and is being compiled for simple analysis of slopes. The result will be reflected in the Final Report.

4.1.6 Issues of Existing Road

From the results of site reconnaissance, hearings and meetings including the inventory survey of the existing road, issues related to the following items were identified.

(1) Right-of-Way

The Study Road is classified as national highway and according to the NRS-2070, it needs to have a ROW of 50m; 25m on each side from the road centre. However, the existing road does not have this ROW width because, in the Kathmandu Valley side (Kalanki to Naghdhunga) too many houses/shops, building etc. exist along the roadside, while outside the Valley (Nagdhunga to Naubise section) the topography is very steep. It is appropriate to mention that at densely built-up areas such as Kalanki, Balkhu, Thankot etc, the minimum distance to abutting houses is just about 5m from the road center as is shown in the pictures below. In this regard, at present situation, the widening of the existing road is deemed very difficult.

Source: JICA Study Team

Photos 4-3 Insufficient (Unsecured) Right-of-Way at Built-up Areas

(2) Geometric Design Criteria

The geometric design criteria of the existing road are not pursuant to the criteria mentioned in NRS-2070. The horizontal curvature and the vertical grade of the road are remarkably poorer than the present standards. This is particularly significant within the Nagdhunga to Sisnekhola section where the geometric criteria are in the most critical state. Inbound (going to Kathmandu) heavy vehicles have a very hard time negotiating with the steep grade and the sharp curves and speed is significantly reduced along this section. Therefore, although some horizontal curves can be improved by cutting the mountains, it is very difficult to improve the vertical grade as it will require new and longer alignment.

Source: JICA Study Team

Photos 4-4 Alignment Condition and Heavy Vehicle Negotiating Steep Grades

(3) Topography and Geology

The topography of the Study Area, particularly within the Nagdhunga to Naubise is very rugged and steep. The existing road runs along the slopes of the mountains where one side is very steep and the other side is very deep. The geology is very complicated and fragile with traces of slope failures and debris flow here and there. Cutting the slopes for construction of roads will further cause these mountains to become unstable and pose frequent risk of collapses and failures. As such, widening of the existing road or new construction in this area is considered to be very difficult and risky.

Source: JICA Study Team

Photos 4-5 Fragile Topography and Rugged Terrain (one-side mountain one-side ridge)

(4) Environment

The Study Road is the only trunk road at present that connects the Indian Border with Kathmandu. All the vehicles, particular those carrying goods from India to Kathmandu ply this road. According to the traffic survey, about 7,600 vehicles, 50% of those trucks use this road. Larger portion of these trucks are old, usually heavily landed with goods and emitting large volume of exhaust smoke. This is significant in the Nagdhunga to Sisnekhole section.

(5) Maintenance

The existing road had under gone pavement overlay recently. Therefore, these sections have relatively fair pavement. However, there are other sections including the structures that have not been addressed timely. The pictures below show examples of such case. The left picture shows the distressed pavement near Khanikhola and the right pictures show the collapse of hand rail of a bridge.

Source: JICA Study Team

Photos 4-6 Fragile Topography and Rugged Terrain (one-side mountain one-side ridge)

(6) Disaster

The fragile geology of the area, particularly the section between Nagdhunga and Naubise poses huge threat to the existing road during rainy season. There had been many traffic closures due to landslide, slope failure or debris flow triggered by torrential rain in the rainy season thereby, severely inflicting the people and the transportation of daily commodities to Kathmandu. In this context, avoiding the area is considered effective than to widen the existing road.

4.2 Review of Design Standards

4.2.1 Vehicle Type

According to the NRS-2070, the maximum dimensions of vehicles to be considered during design of roads are as follows;

Width	: 2.5m
Length	: 18.0m
Height	: 4.75m
Single Axle Load	: 100 kN

Although most of the vehicles, particularly the heavy vehicles like trucks and passenger buses, plying on the highways are manufactured in India, they are different from vehicles in other countries. In this regard, the DOR has in its standard designated WB-15 (AASHTO) as equivalent vehicle type for the above mentioned dimensions to ease the design work. However, the existing road alignment is not sufficient to accommodate this vehicle.

4.2.2 Terrain Classification

The terrain classification based on the NRS-2070 is shown in Table 4-3. According to this standard, the Study Area can be divided into three regions; i) Rolling, ii) Mountainous, and iii) Steep. The stretch between Kalanki to Thankot has a gentle slope and can be classified into plain to rolling terrain. Thankot to Naghdhunga, Khanikhola to Naubise can be classified between rolling and mountainous, while the rest of the section has a slope more than 25% and can be classified between mountainous and steep terrain.

Table 4-3 Classification of Terrain

No.	Terrain Type	Percent Cross Slope	Degree
1	Plain	0 - 10	0° – 5.7°
2	Rolling	Over 10 - 25	Over 5.7° - 14°
3	Mountainous	Over 25 -60	Over 14° - 31°
4	Steep	Over 60	Over 31°
Note: Percent cross slope is given by counting the 1m contours crossed by a 100m long line.			

Source: Nepal Road Standard 2070

4.2.3 Present Available Standards

Standard for road design, known as Nepal Road Standard (NRS) was first introduced by DOR in 1970 with the objectives of achieving consistency in road design and construction. The latest standard NRS-2070 is the second revision of the standard and was published in July 2013. The second revision was done with an aim to cope with the modern technological development. The design criteria for each classification with respect to the terrain type are summarized in Table 4-4. Although in the past, design standards adopted by various agencies and consultants had been used along with the DOR Standard, DOR now generally requires all roads planned and constructed in the rural areas to follow these standards. However, it still allows other standards

to be used where these standards are considered to be insufficient and inappropriate. The major standards in use in such cases are, but not limited to;

i) Nepal Bridge Standards- 2067
ii) Nepal Rural Roads Standards- 2055 1st edition 2069
iii) Road Structure Ordinance of Japan Road Association (JRA), 2004
iv) A Policy on Geometric Design of Highways and Streets, AASHTO, 6th edition, 2011
v) A Guide to Geometric Design, Overseas Road Note, 1988
vi) Standard Specifications and Codes for Road and Bridges
vii) Pavement Design Guidelines (Flexible Pavement), 2013

4.2.4 Design Criteria

(1) Design of Roads

The design criteria for roads according to NRS-2070 are summarized in Table 4-4. This table presents the criteria for all functional classification. However, some criteria are limited to certain speeds only. The design criteria of DOR, particularly those related to the design speed, horizontal and vertical alignment are relatively higher in the context of the study Road. Also, it does not have any criteria of the road slopes. Therefore the design criteria of DOR need to be modified taking other international standards such as AASHTO, JRA etc. into consideration so that more practical criteria can be established. The proposed design criteria for the Study Road will be proposed in Chapter 6.

Table 4-4 Design Criteria for Roads

SN	Design Parameters		Plain	Rolling	Mountain	Steep	Remarks
	Highway Classification		**National Highway (Strategic Road)**				
1	Design Speed (Km/Hr.)	(a) Class I	120.0	100.0	80.0	60.0	> 200000 PCU/day
		(b) Class II	100.0	80.0	60.0	40.0	5000-20000 PCU/day
		(c) Class III	80.0	60.0	40.0	30.0	2000-5000 PCU/day
		(d) Class IV	60.0	40.0	30.0	20.0	<2000 PCU/day
2	Cross Section Elements	Design Vehicle (LxBxH)	16 x 2.5 x 3.8 (WB-15 equivalent)				AASHTO
		No of lane	2.0	2.0	2.0	2.0	
		Formation Width (m)	12.0	12.0	12.0	12.0	
		Lane Width (m)	7.0	7.0	7.0	7.0	
		Outer Shoulder Pavement Width (m)	1.5	1.5	1.5	1.5	
		Outer Shoulder Earthern Width (m)	1.0	1.0	1.0	1.0	
		Camber (%)					
		(a) Concrete Pavment	1.5 – 2				
		(b) Bituminous	2.5				
		(c) Gravel	4.0				
		(d) Earthern	5.0				
3	Stopping Sight Distance	(a) Class I	260	190.0	130.0	80.0	
		(b) Class II	190	130.0	80.0	50.0	
		(c) Class III	130	80.0	50.0	30.0	
		(d) Class IV	80	50.0	30.0	20.0	
4	Overtaking Distance	**Overtaking Distance (m) for Speeds**	**100 km/h**	**80 km/h**	**60 km/h**	**40 km/h**	
		Minimumum Overtaking distance(m)	640	472	300	165	Varies for other speeds
5	Horizontal Alignment	**Minimum Radius of Horizontal Curve (m) for Design Speeds of**	**100 km/h**	**80 km/h**	**60 km/h**	**40 km/h**	
		When no superelevation	870	440	200	70	Varies for other speeds
		When 10% superelevation	370	210	110	40	
		From comfort criteria of passengers	530	340	190	90	
		Superelevation					
		Maximum superelevation	6.0	6.0	6.0	6.0	
		Transition Curve for Radius shown	**100**	**200**	**500**	**1000**	
		Minimum Length of Transitonal Curve (m)	50	70	110	120	Varies for other radii
6	Vertical Alignme	Maximum Average vertical grade (%) section	4	5	6	7	Varies for other radii
		Critical Length of grade (m)	600	450	400	300	
		Minimum K values of Vertical Curve (m) for Design Speeds	**100 km/h**	**80 km/h**	**60 km/h**	**40 km/h**	
		Crest / Summit Curve	427	231	94	29	Varies for other speeds
		Sag / Valley Curve (m)	236	111	42	17	Varies for other speeds

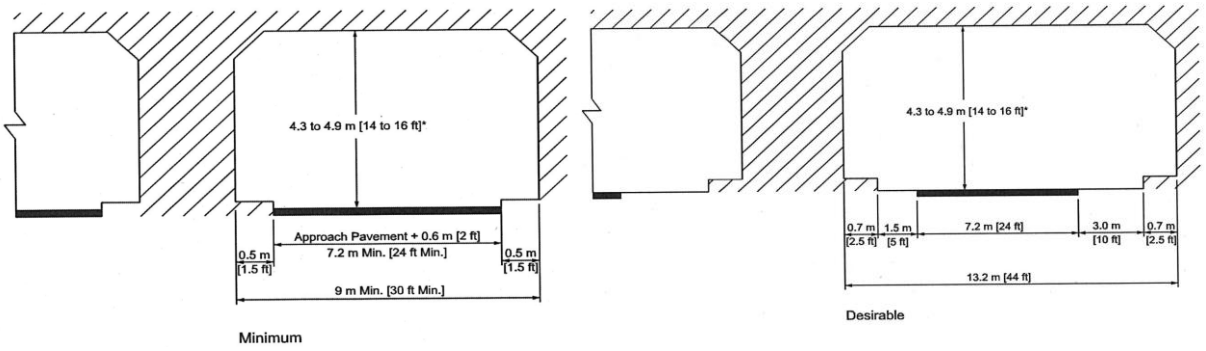
Source: Nepal Road Standard- 2070

(2) Design of Tunnels

It is worth to mention that a proper official standard for the design of tunnels does not exist in Nepal, although there is a provision of general standards in the NRS in Chapter7 Structures. The items mentioned are extracted from the Standard as follows:

a. Tunnels are usually constructed with two lanes. In four lane roads two separate two lane tunnels are constructed.
b. The minimum roadway width between curbs should be at least 0.6m greater than the approach carriageway, but not less than 7.2m.
c. The curb or sidewalk should be 0.5m minimum on either side of the pavement.
d. The total clearance between walls of a two lane tunnel should be a minimum of 9m
e. Minimum vertical clearances inside the tunnels should be 5.0m.
f. As far as possible tunnels should be constructed with straight horizontal alignment which simplifies the construction, reduces the cost and it is easy to provide adequate sight distance on tunnels.
g. Vertical alignment of the tunnel should be decided based on the economic balance between construction costs and operating and maintenance expenses.
h. Maximum gradient of the road in tunnels should be 4% and minimum 0.4%(From drainage consideration)
i. Tunnels of length less than 300m are constructed with one directional gradient and more than 300 m with two way grades with maximum height at the centre.
j. Tunnels of more than 150m length should be provided with artificial ventilation.
k. Maximum speed of air inside the tunnels (without considering the motion of air due to movement of vehicles) from artificial ventilation should be 6m/s.
l. Tunnels of more than 300m length on straight sections or 150m on curved sections of non-urban roads or all tunnels on urban roads should be illuminated with artificial lighting.
m. Illumination of tunnels at the level of carriageway should not be less than:
   - 30 lux at night
   - 400-750 lux during day time near the portals and 30 lux at the middle.
n. Illumination of tunnels should be changed gradually from entrance to the interior so as to provide smooth light adaptation. To achieve this, sometimes the entrance of the tunnel is located on slight horizontal curvature or covered by gratings.

Minimum and desirable clearances for tunnel are shown in Figure 4-10.



Source: Nepal Road Standard - 2070

Figure 4-10 Minimum and Desirable Clearances for Tunnel

The above standard for tunnels however is too general to be applied for the design of tunnel. Also consideration should be given to the fact that Nepal still does not have a road tunnel. Therefore, application of Japanese Standards for the design of tunnel is strongly recommended.

(3) Design of Bridges and Culverts

A standard for the design of bridge used to be included in the NRS but now it is separately and is known as Nepal Bridge Standard -2067. This was formulated three years ago in 2011 with a view to establish a common procedure for design and construction of road bridges in Nepal. This standard basically refers to AASHTO and IRC codes. However, presently this six paged standard consists of only general items and lack lots of other necessary information that is required for the design of bridges. In addition, there is no standard for the design of culverts.

Therefore, for the design of bridges the Nepalese Standards is proposed. However, where this standard does not suffice, the Japanese Standard should be applied, while reference to IRC is also desirable.

(4) Pavement Design

Recently, it is understood that the guideline for the design of pavement has been formulated. However, as this is just published and is not put into normal practice and as is furthermore based on the AASHTO's pavement design guideline, application of AASHTO's pavement guideline is recommended to be applied. However, consideration should be given in referring to the guideline of Nepal also.

Chapter 5 Selection of Optimum Route

5.1 Basic Policy of Route Planning

The main objective of the Study is to establish a route which will not only improve the existing alignment of the Study Area by avoiding sharp and continuous horizontal curves and steep vertical grades but also contribute in decongestion of traffic and reduction of traffic accidents and mitigate effects of road disasters. For this, three methods can be considered; i) provision of a tunnel, ii) provision of a loop bridge, and iii) large sized cut slopes with proper reinforcement. Therefore, the selection of the alternative should be done taking these three methods into consideration.

In regards to this, the following policies govern the selection of the proposed routes for the improvement of the existing Tribhuwan Highway within the Study area.

(1) Assure Mobility by Maintaining the Present Design Criteria

The proposed route is a part of Tribhuwan Highway that emphasizes the mobility function of a road. Although other sections of the highway still have alignment that does not meet the present standards, the proposed route needs provision of proper road geometry in accordance with the present standard of DOR. This is particularly important for this section because this will include a tunnel - first of its kind in Nepal - and as such it will be a model project for other similar road construction projects.

(2) Minimizing Tunnel Length

As aforementioned, this is possibly going to be the first tunnel road in the road network of Nepal. This implies that implementing agency does not have till date any experience on the design and construction of a road tunnel, including its operation and maintenance. Therefore, it is important not only from minimizing the initial and running cost but also from the technical capacity of the implementing agency that the first ever tunnel be as short as possible.

(3) Maximum Utilization of Existing Road

The topography of the Study Area is very fragile. New route that passes along the mountains of the area will require cutting of the existing mountains, which is considered to accelerate possibilities of slope disasters that would contribute in inflating the maintenance cost. Also, new route means new land acquisition, relocation and resettlement of residents affected by the route. Therefore, the proposed routes shall be selected such that existing roads are utilized to the maximum possible extent and both construction and maintenance cost is minimized.

(4) Minimum Adverse Impact on Natural and Social Environment

The proposed routes shall, to the possible extent, be selected to minimize the number of

affected persons and structures to reduce adverse social impact. Public sites and structure including religious temples, cremation spots, holy trees, institutional areas and, reserved forest and historical and cultural heritage sites shall be avoided.

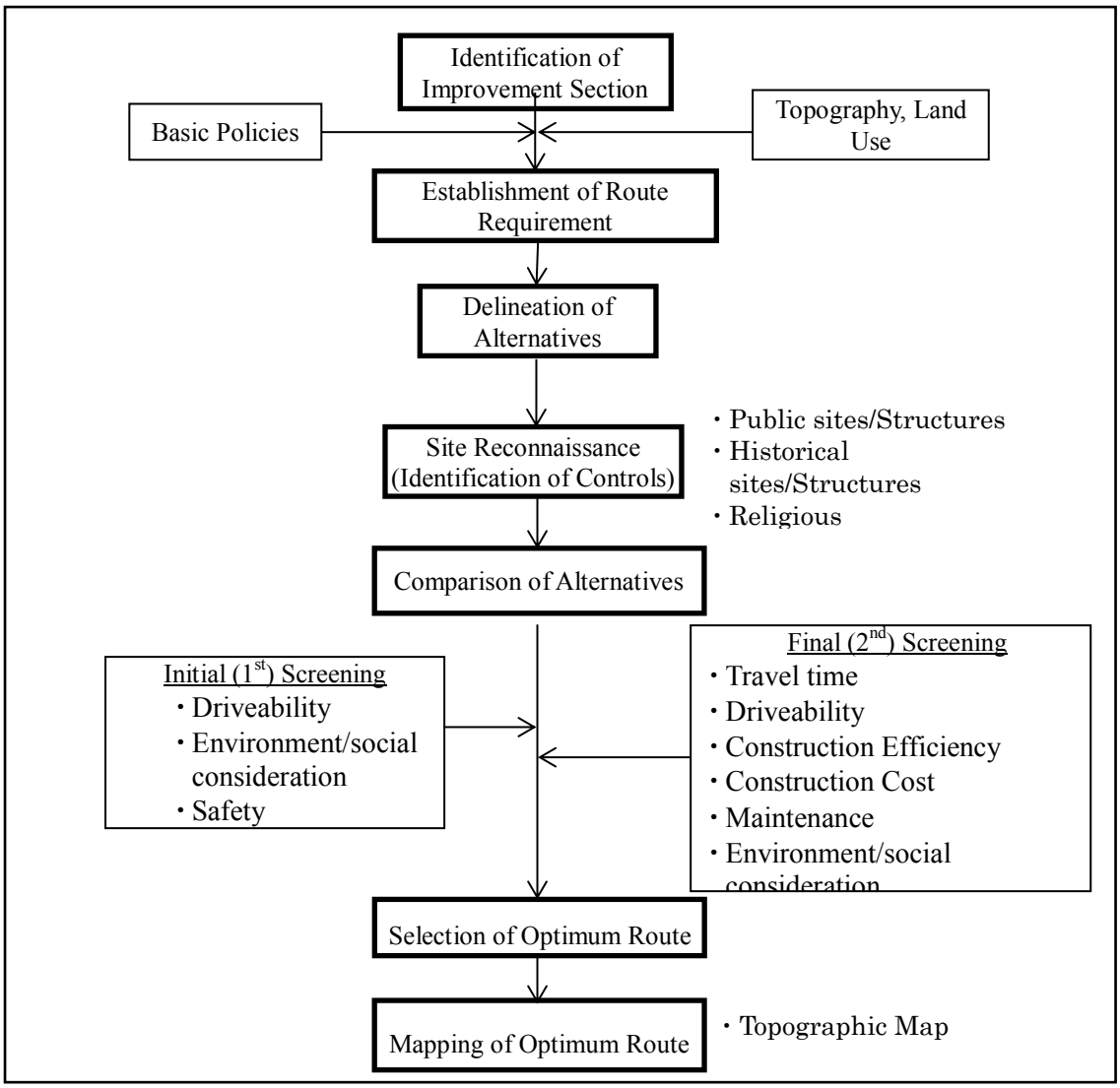
(5) Economic Feasibility

If implemented, the project is going to be the first ever tunnel road project in Nepal. It is a fact that the cost of tunnel is several times higher than the roads, be it in the steep mountains. Therefore, it is important that the project is economically feasible.

5.2 Alternative Route Plans

5.2.1 Procedure of Route Location Selection

The flow of the process for route location selection for the improvement of the existing road within Kalanki to Naubise section is illustrated in Figure 5-1 and explained below.



Source: JICA Study Team

Figure 5-1 Route Location Study Procedure

(1) Identification of Improvement Section

The existing road conditions was thoroughly studied using available topographic maps and other relevant documents as well as through site reconnaissance to understand the existing issues, identify critical sections and find a potential solution that would have the most effective outcome of the improvement.

(2) Establishment of Route Requirements

The route locations are then decided based on the requirements of:

Technical/Engineering: The proposed route should conform to the design requirements stipulated in the NRS in accordance with its functional class.

Operation & Maintenance: the proposed routes shall be such that the operation and maintenance can be readily undertaken by the recipient country in terms of technical and financial aspects.

Topography/Geology: the proposed routes should avoid fragile topography or hazardous areas to minimize project costs. When significant constraints are unavoidable, the routes will require reinforcement by appropriate countermeasures.

Environment: the proposed route should be established such that it has minimal adverse impact on both natural and social environment.

(3) Delineation of Alternatives

Alternatives for the improvement section are then established using available maps. In this study, the only available map with topographic features is the 1:25,000 topographic map, which was compiled from 1:50,000 aerial photography in 1992 and verified in 1994. Google earth satellite images were used to supplement the delineation of the alternatives.

(4) Site Reconnaissance

The established alternatives are then verified on site to check the important control points, constraints related to natural conditions such as topography, geology including existing ground slopes and soil strata formations, hydrology such as streams and river crossings, and existing roads and structures that may affect the established alternatives or be affected by the established routes.

(5) Establishment and Comparison of Alternatives

The alternatives are finalized following modifications from the feedback of the site reconnaissance. These alternatives are then examined and compared based on certain evaluation factors including the requirements mentioned above.

(6) Selection of Optimum Route

The most probable optimum route is then selected based on the criteria established above.

(7) Mapping of Optimum Route

The selected route is then plotted in the topographic map and used in preparing further plans.

5.2.2 Identification of Improvement Section

The objective section of this Study is from Kalanki to Naubise. It is no doubt that the best outcome of the improvement work is attainable if the entire section is improved. But as mentioned in Section 4.1, improvement of the entire section is impractical and very difficult in terms of cost, social and environmental consideration and disaster mitigation.

It is explicit from the road inventory survey that the Nagdhunga to Sisnekhola section has the most crucial alignment, rugged terrain and fragile geology and the existing road is in critical condition. On the other hand, improvement of the existing road from Mugling to Kathmandu, which includes the objective section of the Study, is likely to be undertaken by DOR under the assistance of the World Bank. The DOR, Foreign Cooperation Branch has called for expression of interest (EOI) for the feasibility study and detailed design of improvement under the project name, "Nepal India Regional Trade and Transport Project". Therefore, under proper coordination with this project, the improvement of the existing road can be effectively applied in the Nagdhunga – Sisne Khola section. Following are further justifications for selecting this section for improvement.

i) There are many houses distributed along the existing road from Kalanki to Thankot and widening of the existing road will require large number of resettlement.
ii) This section has consecutive horizontal curves with radius as small as 25m and vertical grades as high as above 10%.
iii) Vehicles coming to Kathmandu, often heavily loaded run between 5km/h-15km/h, emitting large amount of exhaust fumes and excessive noise thus polluting the environment.
iv) Transportation cost and vehicle operating cost is very high.
v) Blocked by the slower vehicles, the faster vehicles have to overtake using the opposite direction lane posing high risks for traffic accidents.
vi) There are many traces of slope failures and debris flow that have occurred in the past causing closure of the road for several days. There are many locations where the slopes are considered to be in vulnerable state even at present.
vii) This section needs to be maintained more often as the pavement here is easily deteriorated; partly due to the fragile geology, partly by flash-flow of water from the mountains and partly by the slower vehicles trying to negotiate the sharp curves.

5.2.3 Establishment of Route Requirements

(1) Engineering Requirements

Some of the basic engineering requirements for the route alignments are presented in Table 5-1. These requirements are basically based on NRS. However, some of the requirements in the NRS is not practical for the kind of topography of the study area and is therefore modified based on other standards such as Japan Road Ordinance and AASHTO.

Table 5-1 Engineering Requirements for Route Location

Administrative and Functional Classification	National Highway Class II	
Design Traffic (ADT)	10,000 -11,000	
Design Vehicle	WB-15 AASHTO	
Design Speed	40 – 60 km/h (40 km/h for Spiral bridge)	
Design Radius	Desirable	150m
	Minimum	100m
	Unavoidable	90m
Vertical Grade	0.5% - 4.0% (tunnel standard applied)	
Right-of –Way Reserve	50 m (25m each side)	

Source: JICA Study Team

(2) Land Access Requirements

The objective road is a national highway that in general, emphasizes the mobility function of a road. However, as this is the only road/access for the alongside community, the proposed route should also provide access appropriately and serve the communities wherever possible.

(3) Environmental and Social Requirements

In identifying the possible route locations for the proposed improvement of the existing road, the following environmental and social requirements were taken into account:

1) Natural Environment

The first half of the Study Road lies inside the Kathmandu Valley, which is basically flat with some rolling terrain as it goes towards the west and reaches the highest point at Naghdhunda Pass crossing. The existing road passes a little higher at the west side of the lowest level of the valley. The area has high mountains both in the north and the south side. This causes rain water to congregate in the valley forming a river.

On contrary, the area Beyond Naghdhunga is surrounded by steep mountains – some are forest and some cultivated land (terrace field). The mountains are geologically very complicated and from the traces of slope failures at several locations, it can be said that these mountains are very fragile.

There is one national park (Tribhuwan National Park) near Thankot but this is far away from the proposed route. Also, there are several community forests (national forests

specially permitted to be used for the particular community for their use as fuel and/or to feed animals) in the Study Area but only one is close to the proposed routes.

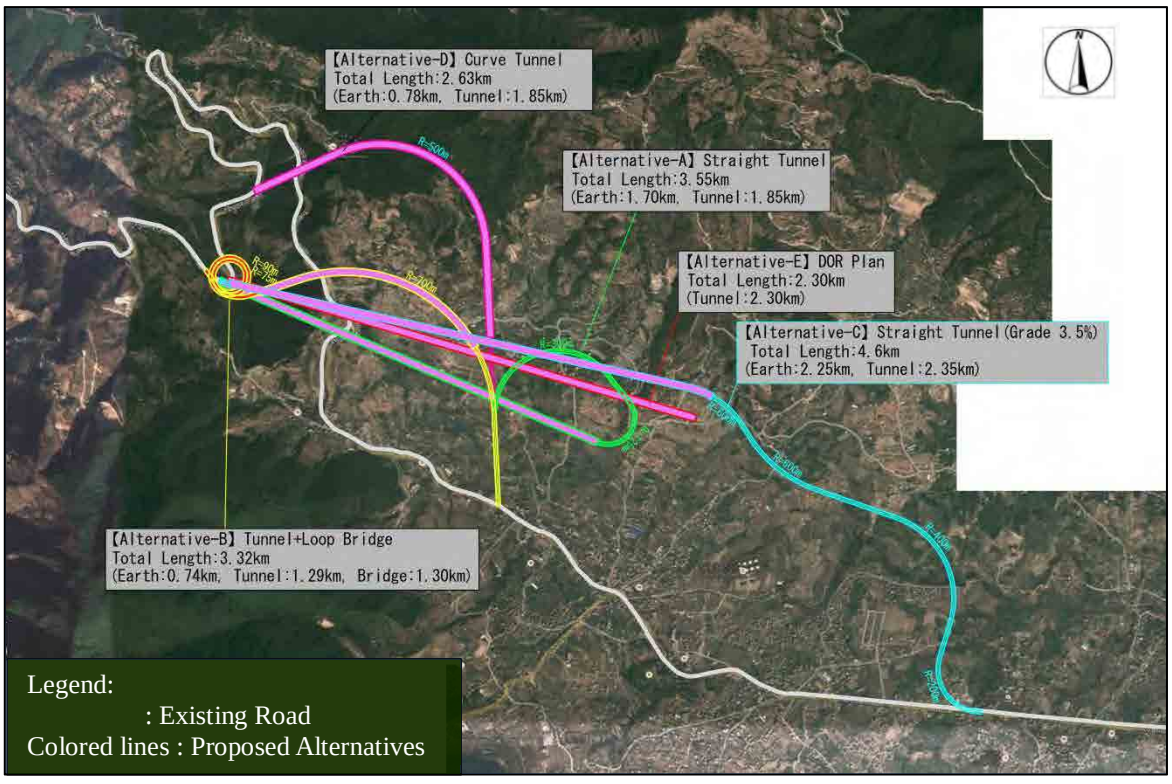
2) Land Use Along Proposed Routes

The following environmental and social concerns of existing land use were taken into account in identifying the proposed routes.

- Important government facilities
- Residential houses/buildings/huts
- Commercial stores dealing with daily goods, restaurant
- Institutional/educational facilities
- Undergoing housing development plans
- Religious facilities including communal cremation spots, temples holy trees etc.
- Historical and cultural heritages

5.2.4 Delineation of Alternatives Routes

The proposed alternative shown in Figure 5-2 were delineated using Google satellite image photographed in January, 2014 and with reference to the topographic map of scale 1:25,000.



Source: JICA Study Team

Figure 5-2 Delineation of Proposed Alternative Routes

Alternative-A diverge from the existing road towards the north at Matikhel, about 7.3km from Kalanki and forms a loop before entering the tunnel section near Basnetchhap. The approach to the entrance of the tunnel is earthen, basically fill at the start and then cut until the tunnel. The tunnel section has a straight alignment and its exit is near Sisnekhola. The route meets with the existing road soon after exiting from the tunnel.

Alternative-B diverges from the existing road at the same location as of Alternative-A, follows its alignment and then diverges from it. It then makes a big circular path just before the commencement of the tunnel. The exit portal of the tunnel is near Sisnekhola but the exit is high on the slope. From there the route takes a spiral form to meet with the exiting road below.

Alternative-C diverges towards north-west direction from the existing road at Kisipindi, about 2.5km ahead (towards Kathmandu side) from other routes. It then passes through a communities like Banasthali and Totipakha forming an s-shaped alignment. The entry portal of the tunnel is near Basnetchhap. The tunnel has a straight alignment and its exit is near Sisnekhola, where it meets with the existing road in a similar way as Alternative-A.

Alternative-D diverges from the existing road at the same location as of Alternative-A and B, follows the same alignment and proceeds straight towards the foot of the hill all the way up to the proposed entry portal of the tunnel. Then the tunnel section starts. The first few hundred meters of the tunnel section has a straight alignment but follows a large curvature in the middle and then again follows a straight alignment near the exit portal. The exit of the alignment is at Jhaplekhola. This is the only route that exits here.

Approach road of Alternative-E starts from Thankot and follows the existing feeder road up to the entry portal of the tunnel. The tunnel has a straight alignment and its exit is also at Sisnekhola, where it meets with the existing road in a similar way as Alternative-A and Alternative-C.

5.2.5 Identification of Control Points

Site reconnaissance was conducted for all the proposed alternative routes to determine the existing conditions on ground. The control points for determining alternative route location is shown in Figure 5-3 and identified as follows:

- Built-up areas
- Vital Telecommunication facilities (Sagarmatha Satellite Center)
- Religious Temples/Trees
- National Parks
- Cremation Centers
- Slope Disaster Traces

Source: JICA Study Team

Figure 5-3 Control Points for Route Location Alternatives

5.3 Comparative Study of Alternative Routes

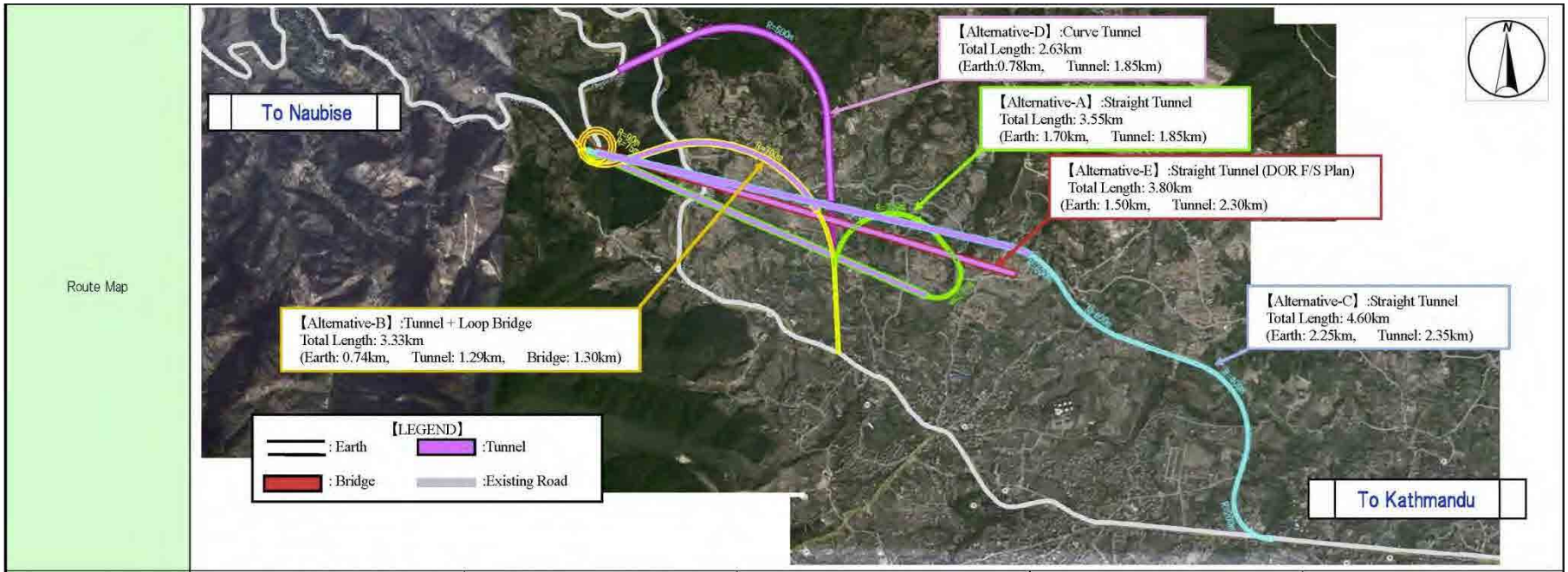
5.3.1 Introduction

The horizontal and vertical alignment from Kalanki to Naubise on Tribhuwan Highway is in poor condition. Constructed in the fifties, the road has many sharp curves and steep vertical grades. These substandard alignments are not only causing difficulty for the vehicles to negotiate smoothly but also contributing to the increase of travel time as well as deadly accidents. It is not an exaggeration to say that almost every day vehicles are seen stranded due to mechanical mal-functioning such as engine heat-up or gear break-down, causing traffic congestion. To alleviate these issues, the potential and effective countermeasure is to provide a tunnel or a combination of tunnel and structures such as a spiral bridge in this section.

5.3.2 Initial Screening

The most important task during the first field work was to determine the optimum route within a short period of time. For this, it was necessary to consider all theoretically possible alternatives and conduct screening of them. As shown in Figure 5-2, the Study Team proposed 5 such alternative routes based on the available maps, documents and information collected thru meetings with JICA and relevant organizations of the GON. These alternatives were checked at the site and screened based on general evaluation factors. The alternative routes that were found inappropriate in the initial screening were dropped out and the remaining alternatives were selected as the potential alternative routes and subjected for a more detailed comparison. The comparison result for the initial screening is summarized in Table 5-2.

Table 5-2 Comparison of Conceivable Alternative Routes (First Screening)



Route Map											
Alternatives		【Alternative-A】:【Straight Tunnel(i=4.0%)】 Minimum acquisition of land, high drivability and construction efficiency. (Tunnel Grade4%)		【Alternative-B】:【Tunnel + Loop Bridge】 Innovative and advanced technology (Tunnle grade 4%)		【Alternative-C】:【Straight Tunnel(i=3.5%)】 High drivability and construction efficiency (Tunnel grade 3.5%)		【Alternative-D】:【Curve Tunnel】 Minimum land acquisition and construction efficiency (Tunnel grade4%)		【Alternative-E】:【DOR F/S Plan】 The proposed plan of DOR in the Feasibility Study (Tunnel grade 3.6%)	
Evaluation Factors	Drivability	■Horizontal alignment of tunnel section is straight but the earthen section is poor. Vertical grade is steeper than Alternative-A..	△	■ Horizontal alignment of the loop bridge section is poorest. Also vertical grade is steepest.	△	■Both horizontal and vertical is superior than other alternatives.	○	■Horizontal alignment of tunnel section is curved and vertical grade is steepest.	△	■ Horizontal alignment and vertical grade is superior to others, but is inferior to Alternative-C.	○
	Environmental and Social Consideration	■ Number of affected houses is minimum.	○	■Similar to Alternative-A.	○	■Number of affected houses is slightly larger than other routes but not as significant as Alternative-E.	△	■Similar to Alternative-A and C.	○	■ Number of affected house is maximum, as it merges with existing road at densely built-up area.	×
	Safety	■No significant problem.	○	■Similar to Alternative-A.	○	■Similar to Alternative-A and B.	○	■Traces of slope failure identified at exit portal of tunnel. ■Poor alignment remains at the exit side of tunnel.	×	■Similar to Alternative-A,B and C.	○
	Cost and Period	■ Excellent in terms of cost and construction period.	○	■Cost highest and longer time required than Alternative-A.	△	■Cost higher and longer time required than Alternative-A.	△	■Similar to Alternative-A .	○	■Similar to Alternative-C .	△
Ranking Evaluation		Environmental and social consideration and safety is superior. Drive comfort is better than Alternative-B.	1	Environmental and social consideration and safety is superior.	3	Drive comfort, safety is most superior. No remarkable impact on social environmental also.	2	Traces of slope failure could be troublesome after construction, also alignment soon after exiting from tunnel is poor and dangerous.	5	Not feasible from perspective of social consideration. (Too many affected houses)	4

Conclusion;

From the 5 alternatives, Alternative-D and Alternative-E is screened out from perspective of safety and consideration. Alternative-A, B and C are selected for detail comparison (Final Screening)

Source: JICA Study Team

5.3.3 Characteristics of Each Alternative Route

The characteristics of the three alternative routes selected for further comparison is briefly discussed in this section.

(1) Engineering Characteristics

1) Alternative-A

The engineering characteristics of Alternative-A are briefly explained hereunder while the plan and profile drawings is shown in Figure 5-4.

- Applied design speed is 60km/h.
- Maximum vertical grade is 4%.
- The stretch is 3.55km long and consists of 1.85km long tunnel section and 1.70km long approach road.
- The approach road diverts from the existing Tribhuvan Highway at Matikhel near Thankot, about 7.3km west from Kalanki Intersection, towards the north and forms a loop shape before entering the tunnel.
- The approach road and the tunnel section at the east side of Nagdhunda runs along the lowest area of the valley.
- The horizontal alignment of the tunnel section is tangent (straight line), while the approach road to the east side tunnel portal is looped shaped formed from two curves (radius 300m and 125m).
- The east side tunnel portal (entry portal) is located in the lowest area of the valley and is about 20m below the existing earth surface.
- The west side tunnel portal (exit portal) is located near Sisnekhola at Naubise side.
- The approach road at this side is very short.

2) Alternative-B

The engineering characteristics of Alternative-B are briefly explained hereunder while the plan and profile drawing is shown in Figure 5-5.

- Applied design speed is 60km/h at approach road and tunnel section and 40km at land bridge section.
- Maximum vertical grade is 4.8%, and the grade of tunnel section is 4%.
- The stretch is 3.32km long and consists of 1.29km long tunnel section, 1.30km long land bridge (Spiral Bridge) and 0.74km long approach road.
- The approach road diverts from the existing Tribhuvan Highway at Matikhel near Thankot, about 7.3km west from Kalanki Intersection (same location of Alternative A) towards the north to the high grounds before entering the tunnel.
- The entire horizontal alignment of the route is curved. The radius of the tunnel

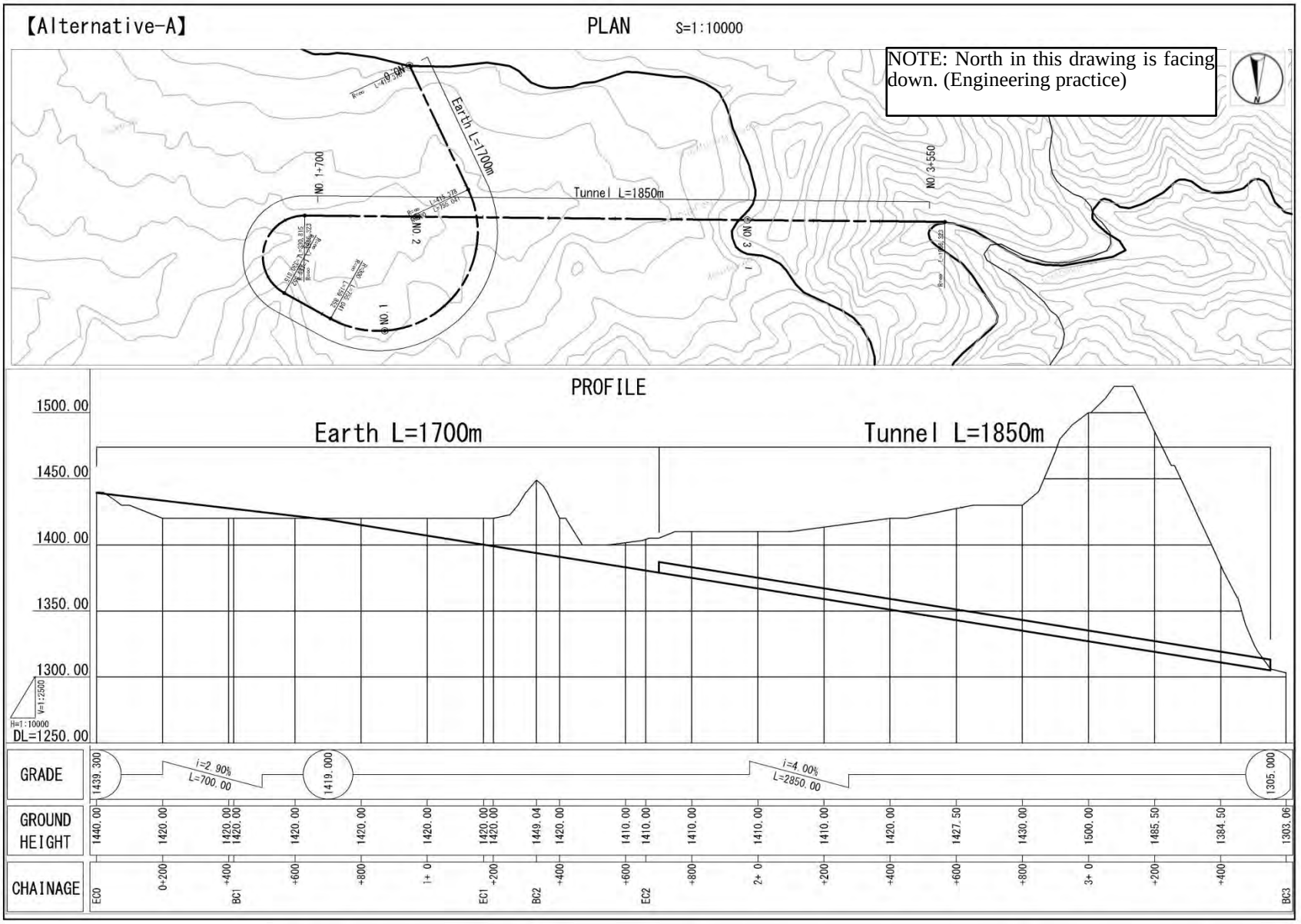
section is 700m. The radius of the spiral bridge is 90m and 75m.

- The east side tunnel portal (entry portal) is located in the high land but the elevation of the proposed tunnel at the portal is about 20m below the existing earth surface.
- The west side tunnel portal (exit portal) is located near Sisnekhola at Naubise side. But the tunnel portal is about 70m higher from the existing road and lies in the west slope of Nagdhunga pass.

3) Alternative-C

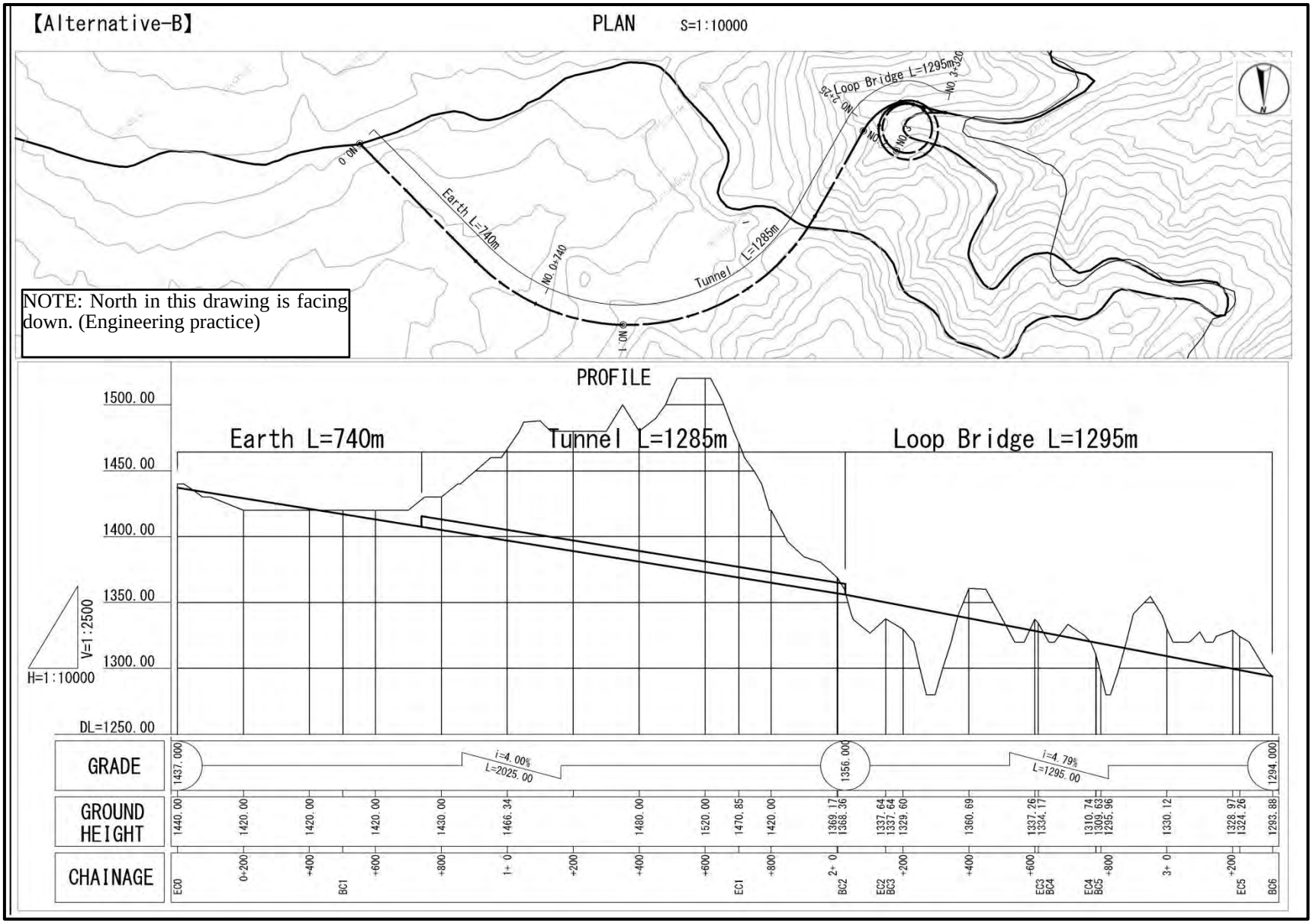
The engineering characteristics of Alternative-C are briefly explained hereunder while the plan and profile drawing is shown in Figure 5-6.

- Applied design speed is 60km/h.
- Maximum vertical grade is 3.5%.
- The stretch is 4.6km long and consists of 2.35km long tunnel section and 2.25km long approach road.
- The approach road diverts towards the north from the existing Tribhuvan Highway at Kisipindi near Sagarmatha Satellite Center, about 4.8km west from Kalanki Intersection. Then it bends left after passing a small community, passes through a cultivated land area and ends at the east side tunnel portal in Basnetchhap.
- In doing so, the route spans over water channels at four locations and intersects with an existing road at one location. Provision of bridges or culverts at these locations is essential.
- The horizontal alignment of the tunnel section is tangent (straight line), while the approach road to the east side tunnel portal is winding (radii 200m, 400m and 600m).
- The east side tunnel portal (entry portal) is located in the high land but the elevation of the proposed tunnel at the portal is about 10m below the existing earth surface.
- The west side tunnel portal (exit portal) is located near Sisnekhola at Naubise side (similar location of Alternative A).



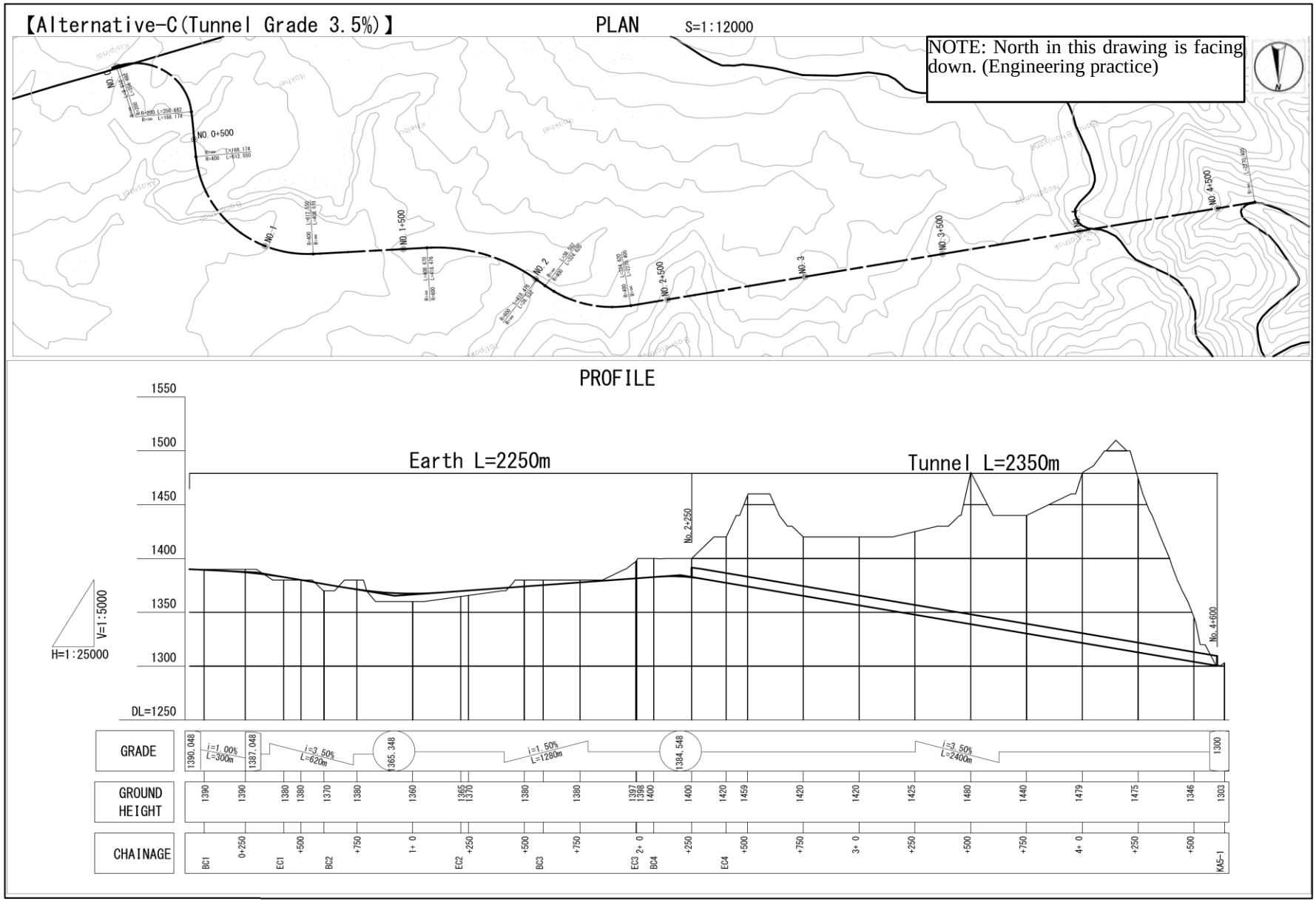
Source: JICA Study Team

Figure 5-3 Plan and Profile of Alternative-A



Source: JICA Study Team

Figure 5-5 Plan and Profile of Alternative-B



Source: JICA Study Team

5-6 Plan and Profile of Alternative-C

(2) Geological Characteristics

1) Alternative-A

The geological characteristics of Alternative-A is schematically illustrated in Figure 5-7 and briefly explained hereunder;

- The route runs along two distinct and alternate soil distribution area; lacustrine soil and bed rock.
- The bigger portion of the route, particularly from the diversion point at existing Tribhuvan Highway up to the Naghdhunga lies in the lacustrine soil (unconsolidated or unsolidified).
- At lacustrine soil area, special support might be required during construction of tunnel
- Running along the lowest point of the valley, there is high risk of water flow during and after construction of tunnel posing potential threat to lowering of groundwater level.

2) Alternative-B

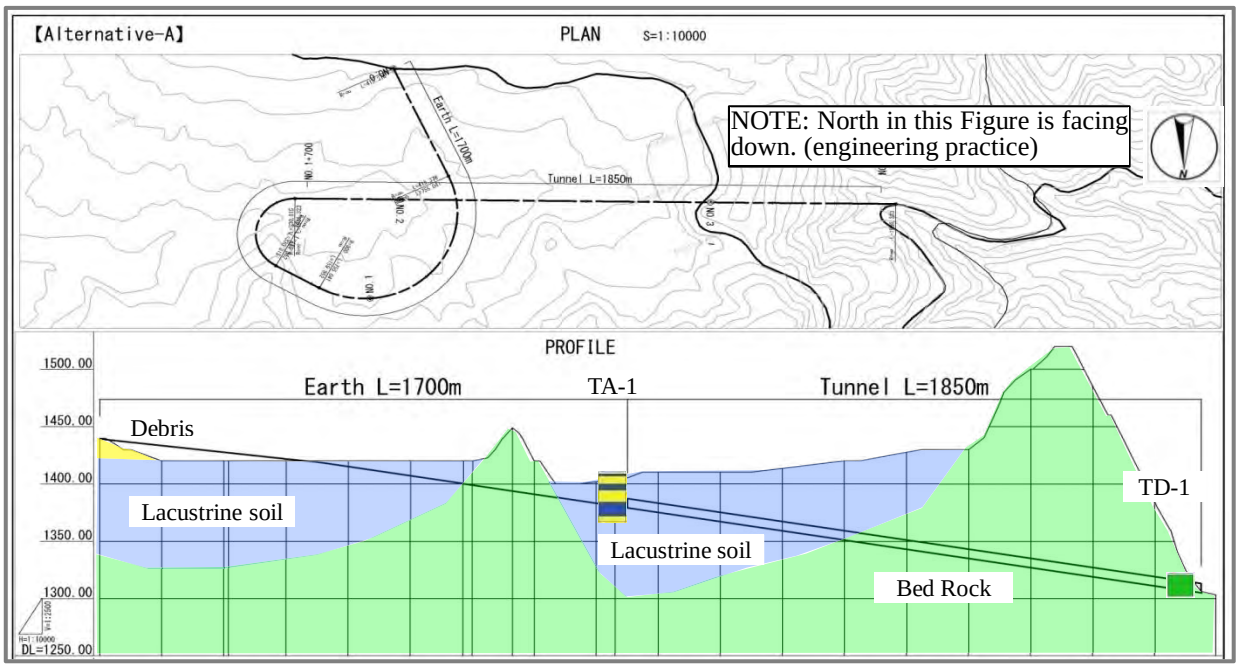
The geological characteristics of Alternative-B is schematically illustrated in Figure 5-8 and briefly explained hereunder;

- The route runs along two distinct soil distribution area; lacustrine soil and bed rock.
- The tunnel section lies in the bed rock.
- Potential effect on groundwater is expected to be very small.
- The west side tunnel portal is located high in the mountain slope and necessitates provision of land bridge (spiral bridge) to connect with the existing road.

3) Alternative-C

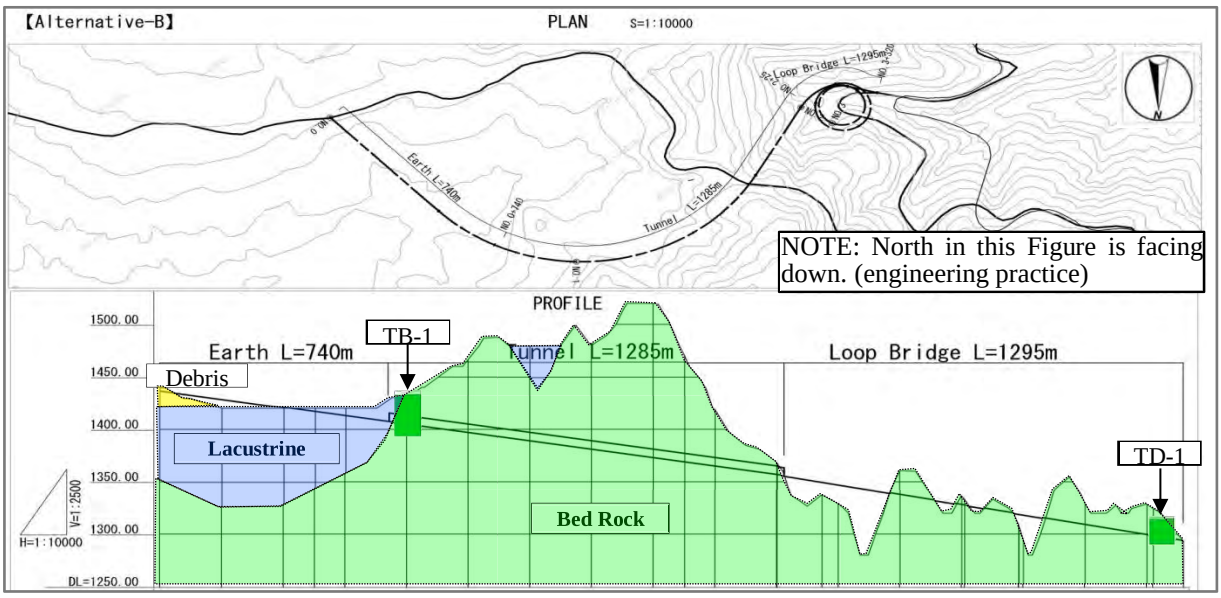
The geological characteristics of Alternative-C is schematically illustrated in Figure 5-9 and briefly explained hereunder;

- The route runs along two distinct soil distribution area; lacustrine soil and bed rock.
- The tunnel section lies in the bed rock.
- Potential effect on groundwater is expected to be minimal.



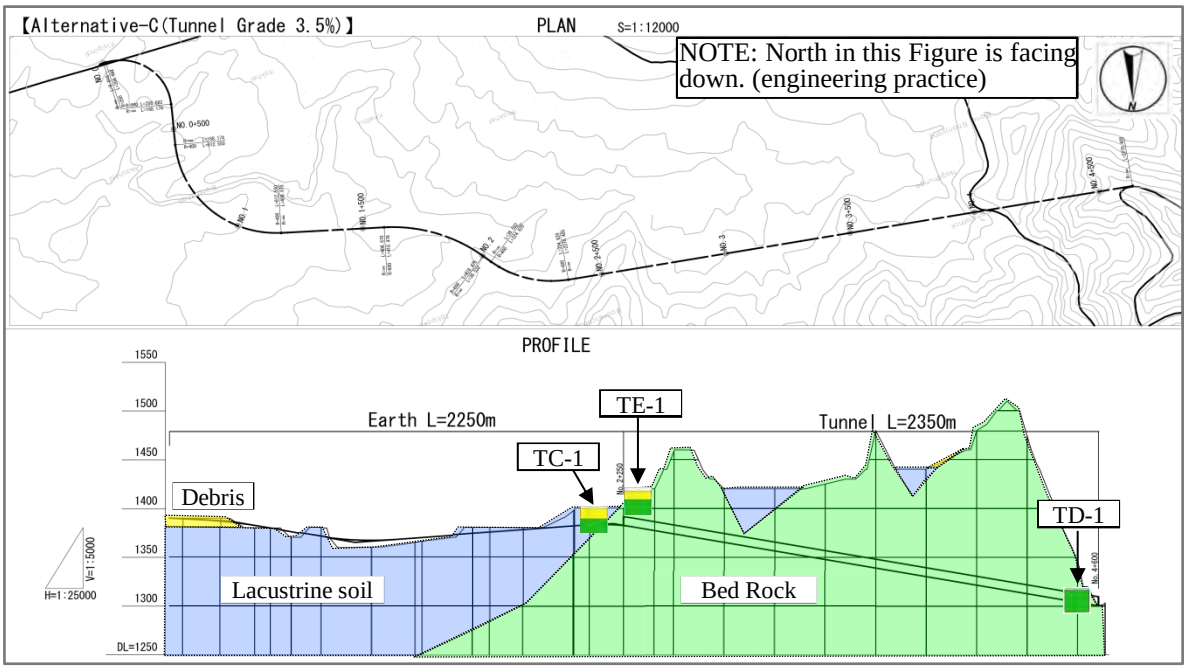
Source: JICA Study Team

Figure 5-7 Geological Characteristics of Alternative-A



Source: JICA Study Team

Figure 5-8 Geological Characteristics of Alternative-B



Source: JICA Study Team

Figure 5-9 Geological Characteristics of Alternative-C

(3) Environmental and Social Considerations

Potential impacts of the alternative routes are estimated and compared between the alternatives. Conservation areas, endangered species, specific settlements of underprivileged group, and regionally significant social infrastructures are not located in the Project Affected Area, and no evaluation was conducted for those topics.

1) Alternative-A

- Area for land acquisition shall be 85,000 m^2.
- Number of residential structures to be demolished is estimated as 20.
- Significance of impacts from spoil soil deposition, assuming proportional to the length of the tunnel, shall be the second among the three alternatives.
- Potential impact on ground water is the highest as described in (2) Geological Characteristics.

2) Alternative-B

- Area for land acquisition shall be 85,000 m^2.
- Number of residential structures to be demolished is estimated as 15.
- Significance of impacts from spoil soil deposition shall be the smallest among the three alternatives.
- Potential impact on ground water is expected to be very small as described in (2) Geological Characteristics.

3) Alternative-C

- Area for land acquisition shall be 120,000 m^2.
- Number of residential structures to be demolished is estimated as 27.
- Significance of impacts from spoil soil deposition shall be the largest among the three alternatives.
- Potential impact on ground water is expected to be minimal, as described in (2) Geological Characteristics.

The characteristics of each alternative route are compared as shown in Table 5-3. In overall evaluation, the Alternative-B scored the minimum impacts on environment and social condition.

When selecting other alternatives, stakeholder agreement and engineering solution shall be necessary to avoid or minimize the negative impacts on the society and environment.

Table 5-3 Potential Environmental and Social Impacts of the Alternative Routes

	Alternative Routes		
	A	B	C
a. Area for land acquisition (m^2)	85,000	85,000	120,000
Rank	1	1	3
b. Number of residential structures to be demolished	20	15	27
Rank	2	1	3
c. Affected conservation areas	0	0	0
d. Affected endangered species	0	0	0
e. Affected indigenous groups	0	0	0
f. Significance of impacts from spoil soil deposition (Assumed proportional to the length of tunnel (m))	1,850	1,285	2,350
Rank	2	1	3
g. Potential impacts on ground water	3	2	1
h. Impacts on social infrastructure	0	0	0
Total Rank Points	8	5	10
Overall Rank	2	1	3

Rank: 1=Best, 2=Second, 3=Third.
Source: JICA Study Team

5.3.4 Evaluation Factors

The 3 alternatives selected from the initial screening are again examined and compared in detail, based on the following evaluation factors:

Travel Time	:	Shorter routes with smooth alignment contribute to high travel time reduction (high vehicle operating cost),
Driving Comfort (safety)	:	Smooth alignment meeting minimum geometric requirement will be better alternative,
Construction Efficiency	:	Sufficient availability of construction yard and easy to construct (especially tunnels are easy to construct upwards) relates to shorter time and cheaper cost,
Maintenance	:	Metal bridges need regular maintenance,
Environment and social consideration	:	Less number of affected houses will have less impact during implementation, and
Cost	:	The shorter and simple structures used, the less expensive is the route

The environmental and social consideration factor in general needs to be given the highest importance as the evaluation factor. However, as there is no significant difference in the number of relocation, other factors such as travel time, driving safety etc. are used for evaluation.

5.3.5 Comparative Study

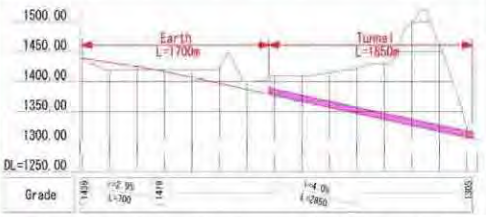
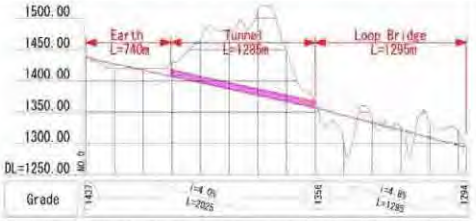
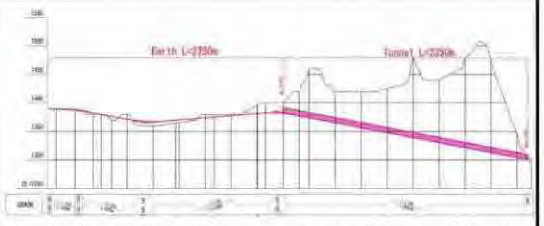
The comparative study for the three alternatives was conducted with respect to the above-mentioned evaluation factors as shown in Table 5-4.

5.3.6 Conclusion

From the result of the comparative study Alternative-C is recommended as optimum as it is superior than or similar to other alternatives in the following manner:

- Reduction of travel time is highest,
- Both horizontal and vertical alignment are smooth meaning high driving comfort,
- Sufficient construction yard available plus upward excavation is possible,
- Maintenance cost is low (Metal bridge of Alternative-B requires regular maintenance), and Number of houses affected is low

Table 5-4 Comparison of Alternative Routes (Final Screening)

		【Alternative-A】:【Straight Tunnel (i=4.0%)】		【Alternative-B】:【Tunnel + Loop Bridge】		【Alternative-C】:【Straight Tunnel (i=3.5%)】	
Alternatives		Alternative with an emphasis on Constructability and Drivability. (Grade of Tunnel section is 4.0%)		Alternative which utilizes advanced technologies.		Alternative with an emphasis on Constructability and Drivability. (Grade of Tunnel section is 3.5%)	
Longitudinal Section							
Evaluation Factors	Time Reduction	■Travel time is reduced by about 14 minutes compared to the existing road use. (Existing Road:about 26 minutes, Alternative Route:about 12 minutes)	△	■Travel time is reduced by about 14 minutes compared to the existing road use. (Existing Road:about 26 minutes, Alternative Route:about 12 minutes)	△	■Travel time is reduced by about 19 minutes compared to the existing road use.(Existing Road:about 26 minutes, Alternative Route:about 7 minutes)	○
	Distance Shortened	■Approx. 1.4km (Existing road 4.95km)		■Approx. 1.6km (Existing road 4.95km)		■Approx. 3.0km (Existing road 7.55km)	
	Drivability	■Drivability(vertical alignment and horizontal alignment) is good.	△	■Loop bridge radius is small. Drivability is inferior.	△	■Drivability is best among the alternatives.	○
	Constructability	■Tunnel excavation from the west portal is possible. Here, construction yard can be easily secured. Transport of excavation soil and drainage discharge is also easy because excavation can be done from the lower side. ■The overburden (surcharge) at the east portal of the tunnel is low ■Effect of groundwater is high as the alignment runs in a valley	○	■Excavation from tunnel exit portal is difficult as it is on high slope. Excavated from the entry portal needs digging in the lower (downward) direction easing difficulty in transporting the excavated soil and drainage discharge. ■Securing construction yard for construction of loop bridge is difficult. ■Effects of groundwater is lowest.	△	■Space for construction yard is readily available at the tunnel entrance side and also at the exit portal. Transport of excavation soil and drainage discharge is also not a big issue as the excavation in the higher (upward) direction is possible. ■The overburden (surcharge) at the starting point of the tunnel is low. ■Effect of groundwater is lowt.	○
	Maintenance	■Maintenance cost is lowest among the alternatives.	○	■Maintenance cost is higher than other alternatives because the metal bridge requires regular painting to avoid rusting.	△	■Maintenance cost is lower than alternative-B.	○
	Environmental and Social Consideration	■Land acquisition area required is about 85,000 m^2. ■Maximum number of house to be relocated is estimated to 20. ■As the tunnel passes along a valley, possibility of lowering of groundwater level of the surrounding area is anticipated.	△	■Land acquisition area required is about 85,000 m^2. ■Maximum number of houses to be relocated is about 15	○	■Site acquisition area is about 120,000 m^2. ■Maximum number of houses to be relocated is about 27. ■Possibility of lowering groundwater level of the surrounding area is anticipated.	△
	Cost (Ratio)	About $ 80 million (1.00)	○	About $ 180 million (2.25)	△	About $ 100 million(1.25)	△
Ranking Evaluation		Construction and maintenance cost is the cheapest, but drivability and time reduction are inferior than alternative-C.	2	Construction cost is the highest. Superior in terms of environmental and social consideration, but constructability and maintenance are inferior than other alternatives.	3	Drivability, constructability and maintenance are better than other alternatives. The construction cost is higher than alternative-A, but there is no large difference.	1

Source: JICA Study Team