Chapter 6

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CHAPTER 6
GEOLOGICAL INVESTIGATIONS

6.1 Background

Geological information is the primary factor required while implementing projects of engineering constructions. Hence, it is essential to conduct geological investigation for evaluating ground condition for the construction of major infrastructures like highways, canals, dams etc. Actually the investigation to be conducted is engineering geology for the interpretation of the results of interaction between geological parameters and the components of infrastructures to be constructed. This will facilitate design engineers for selecting ground parameters more reliably and confidently while designing the structures. This report presents the results of engineering geological study carried out for the detail design study of the Kathmandu-Naubise-Mugling Highway.

The Kathmandu-Mugling-Narayanghat Highway is an existing road required to upgrade to accommodate the traffic growth plying along the road. This highway is serving as one of the most reliable highways linking the capital city of Nepal the Kathmandu to southern plain land and to Birgunj the border city with India which owns more than 50% share of import-export business of the country.

6.2 Introduction

Kathmandu-Naubise-Mugling Highway is the road through which almost all the heavy vehicles coming from southern border of the country enter Kathmandu. Strategically this road is very important since, this is the only road along which all the supply for Kathmandu is transported. Hence, obviously this is very heavily trafficked and need to be improved in terms of easy and smooth driving in view of increasing number of heavily loaded vehicles plying on the road every day. The topography of Nepal varies widely from south to north within a very short distance. Nepal is a rectangular shaped country being the north-south side the shorter one. Average distance in north south direction of the country is about 200km whereas the east-west distance is more than 800km. Hence, the relief is very high while going from south to north. The highest mountain of the world, Sagarmath (Mount Everest, 8848m) lies in the northern boundary of Nepal whereas the lowest altitude to the southernmost part of the country is less than 100m at some places making the southern border strip of the country a plain land almost throughout the east-west direction. This is the reason why construction of roads along north-south direction is always difficult task in the country. Moreover, the Nepalese mountain ranges are very fragile in nature. Construction of highways and canals especially in the north south direction reveals most of the fragility of mountainous terrain. The topography of the Kathmandu-Naubise-Mugling Highway although is mainly aligned in east west direction but the corridor also reflects the fragility in various forms throughout its alignment.

Majority of the hills and/or mountain ranges in Nepal are aligned along the longitudinal direction of the country that is in east-west direction. Aerial distance from Kathmandu to Hetauda is less than 40 Kilometers whereas the road distance from Kathmandu to Hetauda via Mugling and Narayanghat is 227 km. Within the 40km distance there are at least three hill ranges to be crossed which made the construction of high speed expressways through these hills a big

challenge. This is the reason of nonexistent of any short and high speed roads from Kathmandu to Hetauda and south despite its nearness. All the heavy vehicles travelling from Hetauda to Kathmandu take the detour Narayanghat and Mugling following relatively wider and easier road to drive. The existence of east to west flowing river valleys of Trisuli River and its tributary facilitated the construction of Kathmandu-Mugling-Pokhara Highway on their banks.

Figure 6-1 Comparative distance from Kathamdnu to Hetauda straight and detour

Considering the number of vehicles travelling along the Nagdhunga-Mugling Road a four lane road is essentially required. However, it is either difficult from topographical/geological point of view or very costly to make a four lane road throughout. Hence, two different bypasses were proposed for detail design at suitable sections in order to avoid steep and high slope cutting. The two bypasses are Sisne Khola to Dharke 11.2 Km and Bishaltar to Phisling 15.3 Km. In the following paragraphs engineering geological characteristics of all the road sections including the bypasses are described.

6.3 Geology

Nepal is a mountainous country belonging to the Himalayan mountain range. Himalayan mountain range or Himalayan arc is the name given to the relatively young mountain chain located in between the Indian Shield to the south and thick pile of Tibetan sedimentary rock sequence to the north. In a strict sense Himalayas denotes the mountain range extending from Pamir in the west to Bramhaputra River in the east for about 2400km which terminates in a sharp (almost 90 degree) bend towards both end.

For the sake of convenience for geological study and understanding following Ganser (1964), the Himalayas is transversely divided into five divisions as Punjab Himalaya, Kumaon Himalaya, Nepal Himalaya, Sikkim and Bhutan Himalaya and NEFA Himalaya. Among these the segment consisting of 800km out of 2400km of the Himalayan mountain chain occupying almost the middle part lies in Nepal Himalaya.

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6.3.1 Geology of Nepal Himalaya:

Physiographically Nepal is located in the southern lap of the Himalayas extending from Mahakali River in the west to Mechi River in the east. The Nepal Himalaya also houses 8 out of 14 peaks exceeding 8000m including the highest peak of the world the Sagarmatha (Mount Everest).

Longitudinally Nepal Himalaya has been divided into 4, 5, or 6 divisions by various authors for their convenience depending upon the knowledge they acquire from their study on the subject. Stöcklin and Bhattarai (1981) who used aerial photo interpretation techniques extensively to study the geology of central Nepal (inclusive of the project area) suggested 3 fold divisions namely the Higher Himalayas, the Lesser Himalayas and the Sub-Himalayas. Their study excluded the southern plain land of Nepal, the Terai and the northern fossil bearing rock sequence of Tibetan Tethys Zone.

For the purpose of this study, 5 fold longitudinal divisions of the Nepal Himalayas are adapted. For description of geology and nomenclature purpose the names suggested by Stöcklin and Bhattarai, 1981 are adapted as far as practicable. The longitudinal divisions of the Nepal Himalaya from south to north are:

- Terai Indo-Gangetic Plain
- Churia Range or Sub-Himalaya
- Mahabharat or Lesser Himalaya
- Higher Himalaya
- Tibetan Tethys Zone (Inner Himalaya)

Terai or Indogangetic plain composed of quaternary sediments is separated from the Sub-Himalayan sedimentary rocks in the north by Himalayan Frontal Thrust (HFT). The Sub-Himalayan rocks are separated from that of low grade meta-sedimentary rocks of Lesser Himalaya by main boundary thrust (MBT) and the Lesser Himalayan rocks are separated from high grade metamorphic rocks of Higher Himalayas by main central thrust (MCT). Lastly, the high grade metamorphic rocks of Higher Himalaya are separated from locally metamorphosed and fossil bearing sedimentary rocks along the South Tibetan Detachment Fault System (STDFS).

The project area falls in the Central Nepal which was geologically mapped by various authors in the past and has published their results. Except the rocks of the upper part of Kathmandu Complex the Phulchoki group, none of the other rock sequence contains any fossils. Hence, the geologists have to rely on litho-stratigraphic position for the estimation of the relative age of various rocks. Although, various authors have suggested different litho-stratigraphy of their own but in this report the litho-stratigraphy proposed by Stöcklin and Bhattarai (1981) is adapted. The rock type dominant for a particular litho-stratigraphic unit is taken into consideration while assessing the engineering properties of the rocks of a particular location.

6.3.2 Geomorphology

Nepal is divided into eight primary geomorphic zones on the basis of physiography (Modified after Hagen, 1969). From south to north, they are:

- Terai Plain
- Siwaliks (Chure Range) with Dun Valleys
- Mahabharat Range
- Midlands
- Intra-mountain Valleys (like Kathmandu)
- Fore Himalaya
- Higher Himalaya
- Trans Himalaya and Inner Himalayan valleys

Besides above mentioned main geomorphic zones some other intermittent geomorphic featuress are important to be listed. The secondary geomorphic features can be listed as:

- River Valleys and Terraces
- Flood Plain

The proposed Kathmandu-Naubise-Mugling Highway alignment passes only through some primary and secondary geomorphic divisions described above. They are:

- Mahabharat Range
- Midlands
- Intra-mountain Valleys (like Kathmandu)
- River Valleys and Terraces
- Flood Plains

6.3.3 Geology of the Project Area

The project area of Nagdhunga Mugling Road lies in the rocks of Central Nepal. Stocklin (1980) mapped the area of Central Nepal geologically during the period when Mineral Exploration Project was ongoing in Department of Mines and Geology with the Help of UNDP. Lithostratigraphy was established for the description of different rock types of this area because only exceptionally some rock units were fossiliferous. Hence, for the description of the rocks of the project area the same Lithostratigraphy is used with some modifications applicable for engineering geology purpose.

According to the above-mentioned Lithostratigraphy, the area is occupied partly by Phulchowki and Bhimphedi Groups of Kathmandu Complex and Upper and Lower Nawakot Groups of Nawakot Complex of Lesser Himalayas. The rock sequences of the Lesser Himalayas are broadly divided into the low grade metamorphic autochthonous body of Nawakot Complex and comparatively high grade metamorphic rocks forming Nappe structures of Kathmandu complex separated by Mahabharat Thrust (MT).

The Lithostratigraphy of Central Nepal as suggested by Stocklin and Bhattarai (1981) is as presented in the Table 6-1 below;

Table 6-1: Lithostratigraphy of the Project Area Stocklin and Bhattarai (1981)

	Name of the Unit	Main Lithology	Approximate Thickness (m)	Age
KATHMANDU COMPLEX				
	PHULCHOWKI GROUP			
	Godavari Limestone	Limestone, Dolomite	300	Devonian
	Chitlang Formation	Calcareous Slate	1000	Silurian
	Chandragiri Limestone	Limestone	2000	Cambrian-Ordovician
	Sopyang Formation	Calcareous Slate and Phyllite	200	? Cambrian
	Tistung Formation	Meta-sandstone and Phyllite	3000	Early Cambrian to late Precambrian
	UNCONFORMITY			
	BHIMPHEDI GROUP			
	Markhu Formation	Marble, Schist	1000	Early Cambrian to late Precambrian
	Kulekhani Formation	Quartzite and Schist	2000	Precambrian
	Chisapani Quartzite	Quartzite	400	
	Kalitar Formation Jurikhet Conglomerate Pandrang Quartzite Bhimsen Dolomite Lower Schist Member	Schist (partly garnetiferous), Quartzite,Dolomite and Conglomerate	2000	
	Bhainse Dovan Marble	Marble and Schist	800	
	Raduwa Formation	Garnetiferous Schist	1000	
	MAHABHARAT THRUST			
NAWAKOT COMPLEX	UPPER NAWAKOT GROUP			
	Robang Phyllite with Dunga Quartzite	Phyllite and Quartzite	200-1000	Paleozoic
	Malekhu Limestone	Thin platy yellowish limestone and dolomite	Up to 200	
	Benighat Slate with Jhiku Carbonate beds	Slate and Carbonate	500-3000	

	Name of the Unit	**Main Lithology**	**Approximate Thickness (m)**	**Age**
	UNCONFORMITY			
	LOWER NAWAKOT GROUP			
	Dhading Dolomite	Stromatolitic Dolomite	500-1000	Late Precambrian
	Nourpul Formation	Various proportion of Phyllite, quartzite and Dolomite	800	Late Precambrian
	Dandagaon Formation	Phyllite		Late Precambrian
	Fagfog Quartzite	Quartzite	400	Late Precambrian
	Kunchha Formation	Gritty phyllite and quartzite	3000+	Late Precambrian

For the purpose of engineering geological description of the rocks and soils of project area following Table 6-2 is presented.

Table 6-2: Stratigraphy of the Project Area

	Name of the Unit	**Main Lithology**	**Approximate Thickness (m)**	**Age**
QUATERNARY DEPOSITS	Alluvial Soil	Mainly river deposits containing boulder to sand and silt sized material rounded to semi-rounded in shape	Variable thickness up to 100m	Recent
	Colluvial Soil	Mainly the soil derived form slope wash, talus and landslides containing boulder to sand and silt sized material with or without some clay angular, in shape.	Variable thickness sometimes exceeding 50m	
	Alluvial Fan Deposit	Mainly containing rounded to angular shaped boulder to sand and silt sized material	Variable thickness up to 50m and more	
KATHMANDU COMPLEX	PHULCHOKI GROUP			
	Godavari Limestone	Limestone, Dolomite	300	Devonian
	Chitlang Formation	Calcareous Slate	1000	Silurian

	Name of the Unit	Main Lithology	Approximate Thickness (m)	Age
	Chandragiri Limestone	Limestone	2000	Cambrian-Ordovician
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	UNCONFORMITY			
	BHIMPHEDI GROUP			
	Markhu Formation	Marbleand Schist	1000	Early Cambrian to late Precambrian
	Kulekhani Formation	Quartziteand Schist	2000	Precambrian
	Chisapani Quartzite	Quartzite	400	
	Kalitar Formation Jurikhet Conglomerate Pandrang Quartzite Bhimsen Dolomite Lower Schist Member	Schist (partly garnetiferous), Quartzite, Dolomite and Conglomerate	2000	
	Bhainse Dovan Marble	Marble and Schist	800	
	Raduwa Formation	Garnetiferous Schist	1000	
	MAHABHARAT THRUST			
NAWAKOT COMPLEX	UPPER NAWAKOT GROUP			
	Robang Phyllite with Dunga Quartzite	Phyllite and Quartzite	200-1000	Paleozoic
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	Dandagaon Formation	Phyllite		Late Precambrian
	Fagfog Quartzite	Quartzite	400	Late Precambrian
	Kunchha Formation	Gritty phyllite and quartzite	3000+	Late Precambrian

As revealed by the lithostratigraphy presented in the table above, besides the quaternary soil deposits mainly appearing on the surface there are rock of Kathmandu Complex and Nawakot Complex. The rocks of Kathmandu Complex are divided into Phulchoki Group and Bhimphedi Group and they are separated by thrust or unconformity. In the following paragraphs, the type and nature of the rocks and soils observed are described in detail.

Quaternary Deposits

The Quaternary Deposits appear in the area in the form of alluvial deposits, colluvial deposits and/or mixed types of deposits like alluvial fan and debris flow deposit appearing side by side with the alluvial deposits. Short descriptions of separate units of Quaternary soils are given below;

Fig. 6-2a Alluvial Terraces on Trisuli Riverbanks at Ghyalchok

Fig. 6-2b Alluvial Terrace Deposit Bishaltar

Alluvial Soil: The alluvial soils are appearing mainly along the riverbanks on either side of the river at different heights. The alluvial soils are mainly composed of boulder to sand sized particles mostly in segregated form. Individual layers of coarse sand and gravels are well revealed in the alluvial terrace deposits. There are several big alluvial terraces on the banks of Trisuli River (Figure 2a and 2b) and its tributaries and significant length of the road is aligned through these terraces. Further, the alternatives proposed for Prithvi Highway is envisaged to align additional road length in the alluvial terraces of Trishuli River and its tributaries. Almost all

the area occupied by alluvial terrace deposits is actively used for agricultural purposes in the project area.

Colluvial Soil: The colluvial soils are appearing mainly on the hill slopes or at the foot of a hill in slope wash and talus form. They are also derived from landslides. The colluvial soils mainly consist of silt to boulder size particles with angular clasts. Depending upon the nature of parent rock types the soil also contains minor quantity of clays. Mostly the land use of area occupied by colluvial soils was found to be either cultivation or forest land. Hence, many villages on the hill slopes of the project area are located on top of colluvial soil deposits because of agricultural reason. Because the colluvial soils in mosty contain fertile soils and the water source is nearby. Figure 3a and 3b below are some glimpses of colluvial soil.

Fig. 6-3a Colluviums soil erosion in Galchhi Area

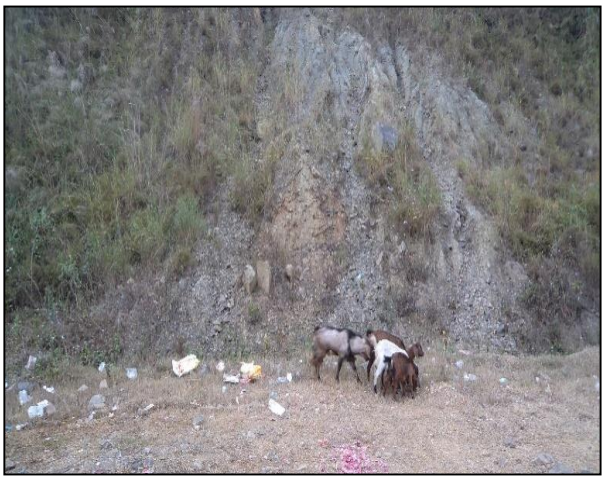
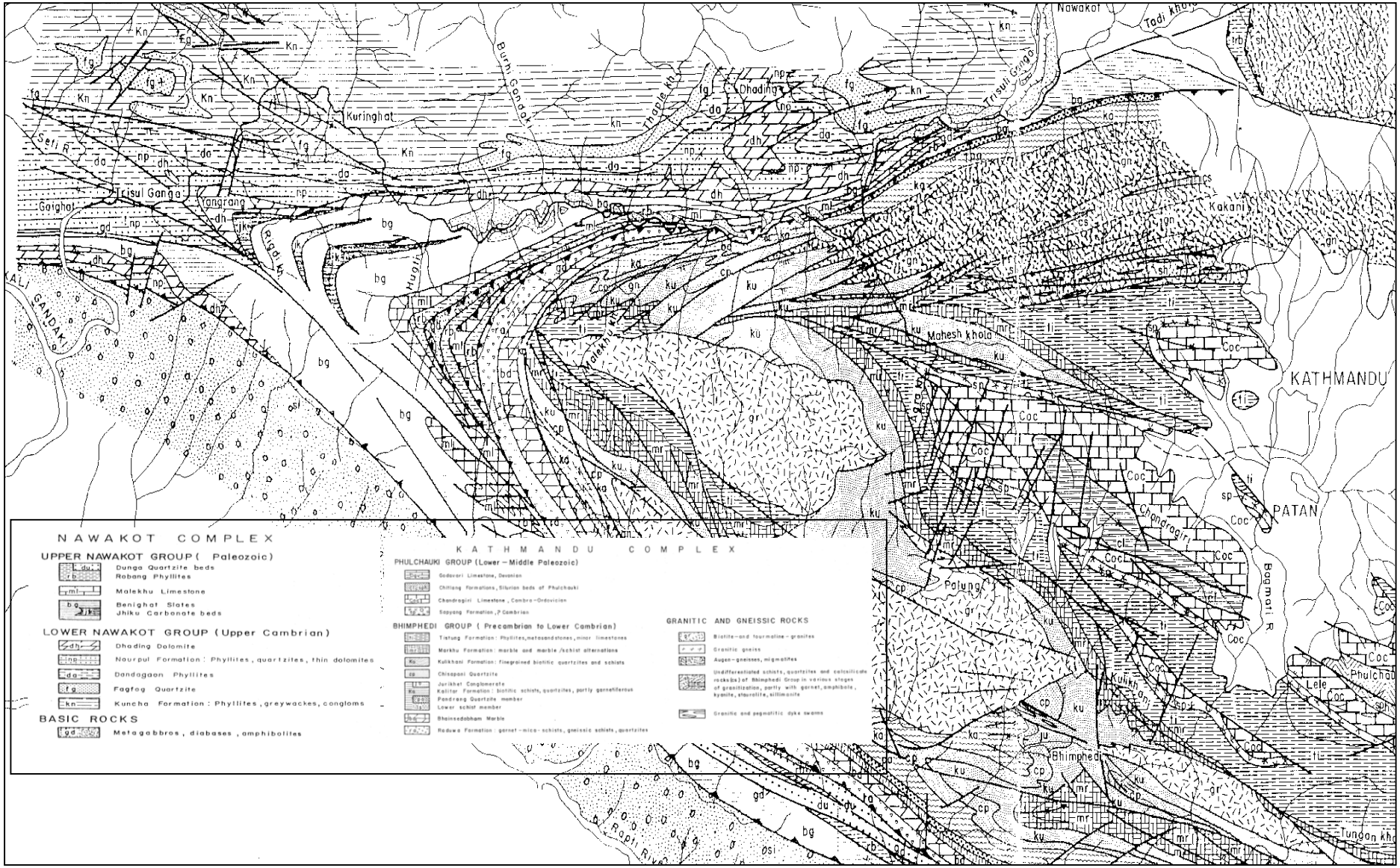


Fig 6-3b Colluviums derived from old landslide at cable car area

Alluvial Fan Deposit: The alluvial fan deposit is mainly appearing at the end of the flow of a torrential stream. The end of the flow is either Trishuli River or its major tributaries. They are consisting of silt to boulder size material with semi-angular to semi-rounded clasts. Significant size of alluvial fan deposits are appearing in the vicinity of Naubise and Dharke in the project area. The soil developed over the alluvial fan is being extensively used for various purposes as in brick production and agricultural purposes as revealed in Figure 6-4 below.

Fig. 6-4 Active alluvial fan made by Mahesh Khola at Dhunibesi area

Figure 7-5 Geological map of Project Area Modified after Stocklin and Bhattarai (1977)



Upper Nawakot Group

There are only three members of Upper Nawakot Group namely Benighat Slates, Malekhu Limestone and Robang Formation. Although the rocks of Benighat Slates and Malekhu Limestone are appearing in significant quantity in the road section from Naubise to Mugling but the rocks of Robang Formations are intensely fractured and crushed due to the effect of Mahabharat thrust. In the following paragraphs short description of individual units of Upper Nawakot Group are given.

Benighat Slate with Jhiku carbonates: As revealed from the lithostratigraphy presented in Table 1 above, the Benighat Slate with Jhiku carbonates member is the lowermost or the oldest member of the Upper Nawakot Group of Nawakot Complex. Particularly characteristic of the Benighat Slates are black "carbonaceous" slates containing much graphitic matter, occurring as intercalated zones up to several tens of metres thick. Generally the Benighat Slate is black slate with or without the intercalations of fine grained carbonates in the form of dolomite and/or limestone. Sometimes high CaO containing limestones are also observed. For the high grade limestone Jogimara is famous which is located along the Prithvi Highway from where high grade limestone is still being mined and used in cement industries.

In the project area the Benighat Slate appear extensively from Benighat at the confluence of Trishuli and Budhigandaki Rivers to Jogimara. The upper boundary of the Benighat Slate is sometime occupied by Malekhu Limestone or sliced by Mahabharat Thrust whereas the lower boundary was having both faulted as well as an unconformable contact with Dhading Dolomite. Outcrops of Benighat Slates are mostly sheared, highly fractured or tightly folded in the area of proposed project.

Fig. 4a Faulted contact of Benighat slate (brown) and Dhading Dolomite

Fig. 4b Features revealing unconformity on top of Benighat Slate near Budhigandaki and Trishuli River confluence

Malekhu Limestone*:* The Malekhu Limestone gets its name from the Malekhu Khola area where typical outcrop of this rock is appearing. This is an excellent marker horizon, containing thin-platy, yellow, dense, siliceous limestone beds with pale-green sericitic partings in the lowermost and uppermost parts, and darker, more thickly bedded dolomites in the middle part. This rock unit is mainly appearing in the area of Malekhu Khola Bazar at the confluence of Malekhu Khola and Trishuli River.

Robang Formation: The characteristically chlorite-rich Robang Formation is composed predominantly of phyllite in the lower part, and white Dunga Quartzite beds become more important in the upper part, where they attain great thickness. Associated with both the phyllites and quartzites are chloritic and amphibolitic metadiabases. The rocks of Robang Formation are sliced by Mahabharat Thrust in the project area restricting the appearance of typical outcrops.

Dhading Dolomite: The Dhading Dolomite is the youngest member of the Lower Nawakot Group of Nawakot Complex. In the project area the Dhading Dolomite is appearing in the form of highly fractured, tightly folded and typically stromatolite bearing dolomite on the right bank slope of Trishuli River near Mauwa Khola area.

The Dhading Dolomite is making faulted upper contact with Benighat Slate as well as the lower Nourpul Formations. However, the unconformable contact was also observed with Benighat Slate elsewhere. The faulted contact between Dhading Dolomite and the Norpul Formation is marked in the topography by a trench like feature with the appearance of crushed and sheared dolomite, fault gauge and tight folding. This fault crosses the existing road at about Km 65+600 and Km 12+200 at Bishaltar-Fisling diversion.

Figure 5a Typical outcrop of Stromatolite bearing Dhading Dolomite

Figure 5b Dhading dolomite outcrop near Mauwa Khola

Nourpul Formation: Nourpul Formation is a mixed lithological rock units consisting of quartzite, dolomite and phyllite. In the proposed project area this formation is revealing more dolomite and quartzite than phyllites. Although, the dominant rock type is grey in colour but pink quartzite and pink dolomites appear frequently specially in the upper part of the formation. In the upper part of the Nourpul Formation white quartzite beds are also appearing which is named as Purbesi Quartzite. The Purebesi Quartzite is white to purplish quartzite having a fractured to blocky nature occasionally with ripple marks and wavy bedding planes.

In general individual rock beds of Nourpul formation are hard and blocky in nature with the appearance of occasional shearing. Upper contact of the Nourpul Formation is a faulted contact with Dhading Dolomite whereas the lower contact is a transitional contact with the Dandagaon Formation.

Interbedded quartzite and phyllite with wavy bedding plane of Nourpul Formation

Rock outcrops of Nourpul Formation near Mauwa Khola

Dandagaon Formation: The rocks of Dandagaon Formation are mainly consisting of thinly foliated phyllites or rather schist. The rock is mostly appearing in moderately weathered to fresh form on the surface. They are highly contorted. Folding within the beds can be observed frequently. The outcrops of Dandagaon Formation are mainly appearing in the area of Phisling on both the banks of Trishuli River.

The upper contact between the Purebesi Quartzite member of the Nourpul Formation and the Dandagaon Formation although abrupt is a normal contact. Whereas the lower contact with Fagfog quartzite is faulted bringing the rocks of Dandagaon formation directly against Kunchha Formation in Phisling area.

Microfolding in Dandagaon Phyllite near Phisline

Trishuli River and the rocks of Dandagaon Formation

Fagfog Quartzite: The rocks of Fagfog Quartzite Formation are not appearing in the project area. Fagfog Quartzite is mainly characterized by white quartzite with frequent ripple marks. When weathered the appearance is brownish at the surface. The strength of the quartzite can be considered strong to very strong. The upper as well as the lower contact of Fagfog Quartzite with Dandagaon and Kunchha Formations respectively are transitional contacts in general but due to the displacement by faulting in Phisling area the quartzite of Fagfog Quartzite Formaiton is abruptly terminated and the rocks of Dandagaon Formation comes in direct contact with Kunchha Formation.

Kunchha Formation: The rocks of Kunchha Formation are extensively appearing from Phisling to the end of the road at Mugling. This rock type is mainly characterized by repeatedly occurring alternating bands of bluish to greenish gritty phyllite and gritty quartzite. Gritty nature is the typical character of the rocks of Kunchha Formation. Sometimes the rocks of Kunchha Formation also include conglomerates. However, the conglomerate of Kunchha Formation was not observed within the proposed project area. The strength of the rock is significantly variable. The fresh gritty quartzite sometime is strong to very strong whereas the phyllite component is weak to very weak. Basic intrusive rocks were also observed commonly in the phyllites and quartzite of kunchha Formation. In the project area the basic intrusive rocks were mainly encountered from Manakamana gate to Mugling section of the road alignment.

The rocks of Nawakot Complex is overlain by the rocks of Kathamandu complex by a thrusted contact. The thrust separating the Nawakot Complex and Kathmandu Complex named as Mahabharat Thrust and is appearing near Galchi area. The proposed Nagdhunga Mugling road crosses the Mahabharat Thrust at Km. 26+550 at the confluence of Chiraundi Khola with Trishuli River.

Kathmandu Complex

The rocks of the Kathmandu Complex tectonically overlie the Nawakot Complex along the Mahabharat Thrust (MT). The MT is considered to be the southern extension of the Main Central Thrust (MCT) as a result of Nappe structure as postulated by Hagen (1969). The Kathmandu Complex is subdivided into the Precambrian Bhimphedi Group consisting of relatively high-grade meta-sediments, and the Phulchauki Group of un-metamorphic or weakly metamorphosed sediments containing fossils of Early-Middle Palaeozoic age (Stöcklin 1980). In addition, the Kathmandu Complex includes the intrusive granites and gneissic rocks. The Bhimphedi Group is subdivided into six formations, viz. Raduwa Formation, Bhainse Dovan Marble, Kalitar Formation, Chisapani Quartzite, Kulekhani Formation, and Markhu Formation. Similarly, the Phulchauki Group is further divided into five formations - Tistung Formation, Sopyang Formation, Chandragiri Limestone, Chitlang Formation, and Godavari Limestone. Mainly the rock sequences of the Kathmandu Complex are limestones, dolomites, schists, phyllites, quartzites etc.

Bhimphedi Group

Bhimphedi Group consists of high grade metamorphic rocks of the Kathmandu Complex. They range from the rocks of locally gneissic appearing schist containing Raduwa Formation to coarsely crystalline marble the Bhainse Dovan Marble. Also the rock of Bhimphedi Group is intruded by leucocratic granite in two different phases. However, the granite does not outcrop along proposed Nagdhunga Mugling road. Detail description of the rock units are as given below.

***Raduwa Formation*:** The Bhimphedi Group begins with the Raduwa Formation, consisting of coarsely crystalline, strongly garnetiferous two-mica schist with one major and several minor quartzite intercalations. Amphibole and pyroxene minerals are frequently present toward the bottom and the rock changes to chlorite schist towards the base (MT). intensely crushed and fractured slices of Raduwa Formation is appearing in between Malekhu and Gajuri markets.

BhainseDovan Marble: The BhainseDovan Marble is essentially a coarsely crystalline, well bedded to massive, mica containing limestone (including phlogopite in fine dispersion). It consists of mica in the basal part and the top parts as parting and thin intercalations. The Bhainse Dovan Marble is mainly observed in a sliced by Mahabharat Thrust along the Naubise Mugling road at about Km 46+700

Kalitar Formation: Dark green-grey biotite-and two-mica schists with ill differentiated intercalations of impure, strongly micaceous quartzite are the main lithotypes of the Kalitar Formation. Bedding is often obliterated by discordant schistosities. Garnet and amphibole minerals are common in the lower part, but usually they disappear at higher sections. The Kalitar Formation is exposed at Baireni area at Km 33+700.

Chisapani Quartzite: The Chisapani Quartzite, an important marker, is a white, fine-grained, thin to thick-bedded orthoquartzite showing strong cross bedding. The Chisapani Quartzite is not appearing in the along the proposed road section.

Kulekhani Formation: The Kulekhani Formation is a well-developed alternation of fine-grained biotitic schist and impure, strongly micaceous quartzite, of dark and light green-grey colour. The Kulekhani Formation is mainly appearing for considerably long section of the road from Naubise to Galchi. In Gulchi area it is appearing in sliced or lenticular form before the confluence of Mahesh Khola and Trishuli River.

Markhu Formation: The rock of Markhu Formation consists of schists, quartzites, and marble in varying proportions. Marble is the distinctive lithotype; it is coarse to medium-grained and makes up about fifty percent of the total rock volume in the type area. The formation changes from almost pure, massive marble bodies to schist and quartzite with subordinate thin, impure marble bands. The Markhu Formation is displayed mainly in the area of 18-19 Km.

Phulchauki Group

Rocks of Phulchoki Group are the only fossil bearing rock of Central Nepal. They are differentiated among five formations namely Tistung Formation, Sopyang Formation, Chandragiri Limestone, Chitlang Formation, and Gowdawari Marble from bottom to top. The main characteristic of this group of rocks are the decreased amount of carbonate content from top to the bottom.

Tistung Formation: The Phulchauki Group starts with the Tistung Formation, a fine-clastic sequence of meta-sandstones, siltstones, phyllites, and slates. Distinct colour banding (green, pink, yellow, violet etc.) appears, and intense purple weathering colour is characteristic. Some of sandstone has distinctly calcareous cement, and impure limestone intercalations are occasionally found. The Tistung Formation is mainly displayed in Nagdhunga area and west. The rocks of Tistung Formation are highly to moderately weathered highly fractured sheared and frequently faulted and folded. Significant length of road in Nagdhunga to Naubise and from Sisne Khola to Dharke are aligned in the rocks of Tisutng Formation

Sopyang Formation: The Sopyang Formation is a transitional zone between the fine-grained clastic Tistung deposits and the thick Chandragiri Limestone; dark argillaceous and marly slates and subordinate argillaceous limestones are characteristic of the rocks of Sopyang Formation. Similar to Tistung Formation the rocks of Sopyang Formation are outcropped mainly along Nagdhunga to Naubise and Sisne Dharke section of the proposed road project. The rocks appearing along the road alignment are highly to completely weathered sometimes behaving as soil because of its engineering property.

Chandragiri Limestone: The Chandragiri Limestone is the most prominent unit of the Group, over 2000 m thick and of massive appearance, though well bedded, partly flaggy, in closer view. Argillaceous (micaceous) partings are common, especially in the more thinly bedded lowermost and uppermost parts. A band of white laminated quartzite is interbedded in the upper third of the limestone. Above this, green and pink argillaceous limestone beds displaying wave-marks contain frequent echinoderm fragments. The Chandragiri Limestone makes up most of the Chandragiri Hills. The rocks of Chandragiri Limestone will not be encountered by the proposed road alignment from Nagdhunga to Mugling.

Chitlang Formation: The Chitlang Formation consists mainly of dark violet-coloured slates. A white quartzite is interbedded in the lower part and some beds of argillaceous limestone with wave marks in the upper. The Chitlang Formation forms the upper part of the southern face of the Chandragiri Range. Similar to Chandragiri Limestone the rocks of Chitlang Formation also are not appearing along the proposed road alignment.

Godavari Limestone: The Godavari Limestone is the youngest rock of the Kathmandu Complex. It occupies the core of the Phulchauki syncline and, in fact, the very core of the entire Mahabharat synclinorium. The lower part consists of well-bedded green and purple argillaceous limestone with wave marks, many layers crowded with crinoidal fragments. The main part of the formation, above these crinoidal limestones, is a massive, coarsely crystalline dolomite of white to light brown colour. The Godavari Limestone makes up the summit of the Phulchoki Range. Similar to above two formations the rocks of Godavari Limestone also does not appear along the proposed road alignment.

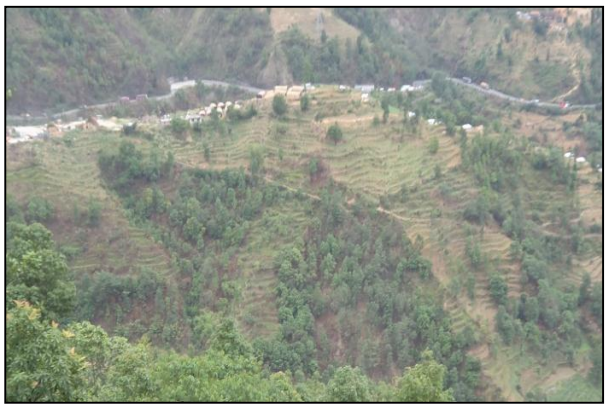
6.4 Geology of the Proposed Road Alignment

Geologically the proposed road is aligned such that it starts in the rocks of Phulchoki Group of Kathmandu Complex, highly weathered sedimentary rocks of Sopyang Formation at Nagdhunga. Structurally starting point is located in the rocks of northern flank of Mahabharat Synclinorium. It continues with the Midlands composed of meta-sediments of Sopyang and Tistung Formations at Nagdhunga area. Although, a tunnel is proposed to be constructed in near future below Nagdhunga up to Sisne Khola Km 3+200 but the starting point of the proposed highway is considered as Nagdhunga at this stage of the study. Construction of the tunnel is expected to improve the traffic flow slightly from Naubise to Kathmandu near Nagdhunga which will by-pass the last lap of the hair pin bend and high gradient section of the road in and around Piplaamod Km 1+650.

Figure 2: Sisne Khola area the exit point of proposed tunnel below Nagdhunga.

Figure 3: Sharp bends on the existing road at Khatripauwa

Failed gabion wall down slope of the road at Jhyaple Khola



Sisne Khola Dharke road is aligned through old landslide at north of Chyaudanda

Nagdhunga To Sisne Khola

There are sharp bends, narrow road sections and high gradient at several locations in this road section. Attempts had been made to widen the road at couple of locations but widening of the road in this section was found to be very difficult. The rock types encountered in this road section is mainly highly weathered and fractured meta-sandstones and phyllites of Tistung and Sopyang Formations of Phulchoki Groups of Kathmandu Complex. Although at some places strong cores of rock beds of meta-sandstone are present but generally the entire 3200m of the road from Nagdhunga to Sisne Khola is weak to very weak at surface. The bedding plane of the rock is varying considerably mainly due to tight folding nature of the rock. There are three sets of discontinuities observed including bedding plane. The discontinuity planes are generally rough and up to 5mm opening at surface. However these opening are expected to be tight inside the slope.

Sisne Khola To Naubise

From Sisne Khola to Naubise the existing road section passes through very rugged and dissected topography consisting of the rocks of Sopyang Formation and Tistung Formations composed of soft sedimentary sequence. The road in this section runs along steep downhill grade frequently encountering very sharp hair pin bends, deeply incised gullies and narrow hilly spurs. After several attempts of road widening some section of the road are made wide enough but still there are several places to be improved. Generally the rocks exposed along the hillside

of the road but the steep topography and the fragile nature of the rock made it vulnerable for road widening at several places. At some places serious nature of slope failure were encountered and were stabilized by using rock anchors as in Km 4+450.

Outcrops of highly to completely weathered rocks of Sopyang Formation at Km 5+950

Some length of road from Nagdhunga to Naubise passes through rolling terrain Km 6+400

Naubise to Galchi

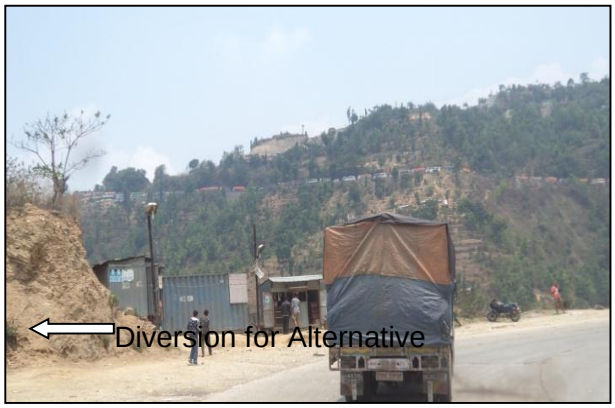
The road section from Naubise to Galchhi area is a part of Prithvi Hiighway and is aligned along the valley of Naubise Khola and Mahesh Khola on their left banks. The terrain is comparatively easier except at some places for road construction than the section from Nagdhunga to Naubise. However, improvement of the road alignment to avoid steep grade and sharp and blind curves are still required. At Galchhi Mahesh Khola meets the snow fed Trishuli River coming from north and the road from Galchhi onward is also aligned along the left bank of Trishuli River. At Galchhi almost the north to south flowing Trishuli River changes its course and flows toward west up to Mugling.

As shown in the geological map the road from Naubise to Galchi passes through alluvial and colluviums soils derived from fluvial action and slope wash respectively deposited along the river banks and also through moderately weathered to fresh rocks of Sopyang Formation (at naubise) Tistung Formation, Markhu Formation Kulikhani Formation and associated intrusive rock mainly the augen gneiss. Except at few locations as in Km 16+600 to 16+900 the road construction will not be very difficult in terms of road widening, slope cut and stabilization because, majority of the slope falls in low to medium landslide hazard zone.

Sisne Khola to Dharke (Alternative)

An alternative alignment of the road for 11km is proposed from Sisne Khola to Dharke to avoid the widening of the road in high landslide hazard zone where deeply incised gullies and difficult terrain of Sisne Khola to Naubise. The alternative alignment diverts from about 600m west of Sisne Khola along the existing road and meets only at Dharke after several loops over the hills and valleys including about 150m long tunnel through Waglethok spur. The rocks to be encountered along the alternative alignment are of Sopyang, Tistung, Kulikhani and Markhu Formations. Generally, the rocks are highly to moderately weathered and sometimes completely weathered behaving like soil. Moreover, the entire slope from Sisne Khola to about Km 4+000 lies in high landslide hazard zone. All the above factors and high degree of

weathering and intense fracturing made the area almost similar to the terrain of the existing road alignment from Nagdhunga to Naubise. Hence, the nature of cut slope and the problem to be faced along this road will be very similar to that of Nagdhunga to Naubise road in terms of slope stabilization. However, the length of the difficult section is reduced considerably.



Diversion point for the alternative alignment section

Terrain through which the new alignment is proposed

Galchi To Benighat

From Galchhi to Benighat the road is aligned mainly along the big terraces of Trishuli River and its tributaries. Except the requirement for the correction of steeper gradient and for sharp curves at some places like in Chiraundi Khola bridge site, Gajuri, and Malekhu bends etc. not major slope cut will be required. However, diversion of some of the road section might be required due to social causes as existence of densely populated area and/or market place as in Malekhu. From geological point of view the area from Galchhi to Benighat is influenced by almost east west running Mahabharat thrust. Repeated appearances of rock units of various formations are expected due to the presence of thrust. Repeatedly appearing rock types are mainly slates, limestone, dolomite, quartzite and some gneisses of Bhimphedi and Upper Nawakot Groups. The Trishuli River flows mostly in east-west direction in this area which is also attributed to the influence of thrust. Although the area is influenced by Mahabharat Thrust, not any evidence of neo-tectonic movement is visible. Hence, due to the dormant nature of the thrust not any major problem is anticipated to Benighat.

Benighat To Hugdi Khola

From Benighat to Hugdi Khola the existing road is aligned not only through the alluvial terraces of Trisuli River and its tributaries but also through the steep rock slopes vulnerable to landslides. The road passes through Bishaltar, Charaundi, Krishnabhir, Majhimtar, up to Hugdi Khola. The famous landslide of Krishnabhir is anticipated to be the most problematic area while constructing road in this section. The landslide in the area of Krishnabhir occurred on 21 August 2000 AD and for about 4-5 years it was a big chaos for the road users of Prithvi Highway especially during the rainy seasons. Big amount of resources and techniques were spent to make the road usable again.

The rock types appearing in the entire road section from Benighat to Hugdi Khola is the Benighat Slate Formation of Upper Nawakot Group dipping inside the hills. The rocks are highly fractured and frequently sheared. Although overall dipping of the rock is southerly or inside the hill but due to folding nature of the rock and changing direction of road alignment at places dip plane

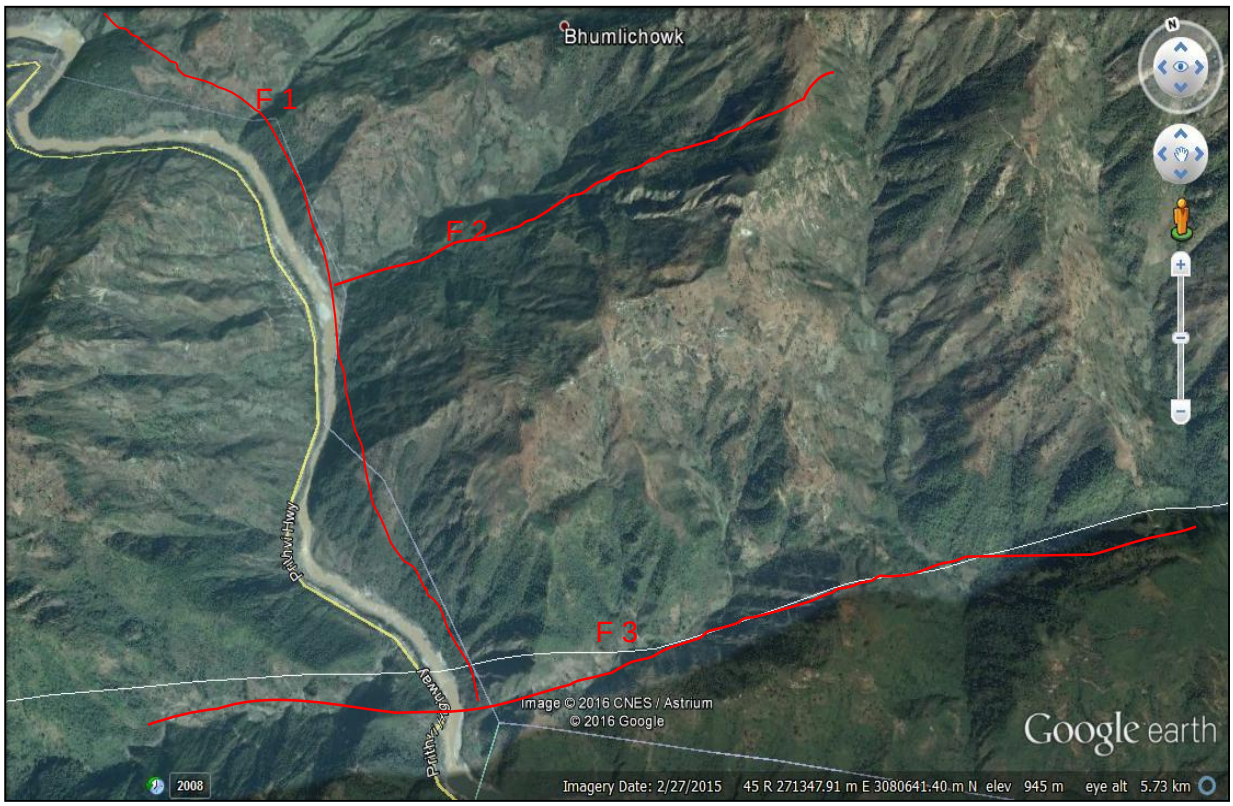
of the bedrock daylight at some places. Moreover, the Mahabharat Thrust (MT) running in almost east-west direction is located on top of the Krishnabhir making the area more vulnerable. One of the main causes of occurrence of Krishnabhir landslide is the presence of thick pile of loose rock and soil deposit on top of the slope together with the occurrence of highly fractured, sheared and highly weathered nature of the bedrock due to the influence of MT.

Except Krishnabhir, the narrow section of the road where widening might be a problem are Benighat area and the selected section between Bishaltar and Charaundi due to steep topography and fragile nature of rock/soil.

Hugdi Khola to Chumlingtar

The road section from Hugdi Khola to Chumlingtar is one of the most challenging section of road widening and construction of new roads. The famous Jogimara landslide (Rock fall) is located in this section of the road. The road alignment passes through very rugged topography and complex geological arrangements in steep slope. The rock types appearing in this area are dolomite, quartzites, phyllites and grit-stone or gritty phyllite and meta-sandstones of Lower Nawakot group of rocks. However, toward the Hudgi Khola area the rocks are black slates and some limestone and/or dolomite. At least three different faults are dissecting the area such as the Khani Khola fault at Phisling running along Khani Khola F2, the Trishuli fault running almost along the Trishuli River from near Mauwa Khola to Phisling and beyond F1 and a fault running almost east west direction from Ghyalchok crossing Trishuli River near Mauwa Khola confluence and beyond F3.

Tectonically the area is very complex and the rock dip in different directions. However, the regional trend of the bedrock is dipping at high angle toward north or south with little deviation to east or west. Although active large scale mass movement was not observed in this area but evidence of old landslides and creeping slope were observed at some places. Since the famous Jogimara landslide is located in this section of the road it will be necessary to make sure not to reactivate the slide while widening the road. Previously in Jogimara area there was stone quarry just above the road level and the attitude of discontinuities and slope direction was configured such that rock fall occurred in the direction of road causing many accidents. At present that particular quarry is shut and no problem is faced due to rock fall in this area. The road was also shifted slightly toward the valley side and a high wall was constructed at hill side keeping room to trap the falling material and to enhance the road safety. Although, the old quarry was stopped but new quarries are emerging at higher elevation at different locations threatening the safety of the road in the long run.



Faults mapped in the area of Hugdi Khola to Chumlingtar Area

There is a sharp bend appearing at Chumlingtar area which can be avoided if a 400m road tunnel is constructed across the spur on which the bend is made. The bedrock to be encountered in this section of the road is mainly gritty quartzite and phyllite of Kunchha Formation.

Chumlingtar to Manakamana Cable Car

The road section from Chumlingtar to Manakamana Cable Car is aligned either through the river terraces of Chumlingtar and Kurintar made by Trishuli River and its tributaries or through the colluvial deposit consisting of talus material as Lewatar. As of present situation any significant problem of road construction is not anticipated in this area. The rock types to be encountered are mainly gritty phyllite and quartzite of Kunchha Formation belonging to Lower Nawakot group.

Bishaltar to Phisling

In view of the existence of several landslide area like Krishnabhir and Jogimara and other problematic zones along the existing road of Prithvi Highway from Benighat to Kurintar an alternative alignment was proposed along the right bank of Trisuli River. The alternative is proposed from Bishaltar from about Km 53+000 to divert and cross Trishuli River from Bishaltar to enter Ghyalchok. In Ghyalchok area the proposed alternative alignment passes mostly along the wide alluvial terraces of Trishuli River and its tributaries up to about Hugdi Khola confluence on the opposite bank of the Hugdi Khola and Trishuli River confluence. Although there are some sections where the road is anticipated to be carved in bedrock mainly weathered slate of Lower Nawakot Complex the Benighat Slate Formation but majority of the road length will be constructed in alluvial terrace deposit consisting of sand, gravel boulders and pebbles mixed with some silt material. The alternative alignment of the road is expected to be far better in terms

of stability than the existing one up to the opposite bank of Hugdi Khola confluence because there are wider terraces and the landslide like Krishnabhir can be avoided. Moreover, there is already a vehicle track open for a significant length of the proposed road in this section.

Both the topographical and geological situation on both banks of Trishuli River is equally difficult after the Hugdi Khola confluence to Phisling area. Steep slopes, narrow gorge of Trishuli River, dissected topography due to the complex geological features and traverse by faults and highly fractured steeply dipping bedrocks of Dandagaon and Kunchha Formation of Lower Nawakot Complex make the area quite complex. Moreover, the area lies in high landslide hazard zone. Possibility of triggering of new landslides or reactivation of the old ones is very likely effect of slope excavation in this area. From geological point of view it can be concluded that the road section in between Hugdi Khola confluence to Kurintar the problems to be faced while constructing road will be similar to that of the widening of existing road. Hence, while designing supports for the cut slopes in this section of the road keen assessment is done and considerable quantity of slope support measures are provided.

Manakamana Cable Car to Mugling

The road section from Manakamana Cable Car to Mugling will be quite challenging for widening of the road. There are steep and rugged topography on both banks of Trishuli River. The entire section of the road for 1700m from about Km 78+350 to Km 80+050 is old landslide and falls at high landslide hazard zone. The road alignment is located almost at the toe part of the landslide. However, the narrow Trishuli River in this area must have washed away almost all the debris brought by the landslide and left steep rocky slopes at several places. Hence, during the construction of the road in this area several cantilever bridges were introduced to make room for the existing road. Moreover, the location of Cable Car facility, growing urbanization, occurrence of complex landslide etc. needs to be negotiated delicately while widening the road in this area. Geologically the areas consist of the rocks of Kunchha Formation the gritty quartzite and chlorite schist in association of irregularly appearing several basic intrusive rock bodies. In this area the rocks are strong, brittle and fractured to blocky.

6.5 Investigation of Construction Material

Investigation of the naturally occurring construction material like sand, gravel and aggregates was conducted. Besides the naturally occurring construction material samples from crusher and screening plants were collected. It was found that sufficient quantity of construction material of suitable quality can be found in the vicinity of the road alignment. Table below shows location of the construction material site together with available quantity and distance from the road.

Construction Material Sites and Estimated Volume						
S. No	**ID**	**Location**	**Name of the Place**	**Available Quantity (m^3)**	**Distance/Reference**	**Remarks**
1	CM 1	Trishuli River at Galchi-Trishuli Road	Keureni	238000	4/22+600	River bed/Crusher
2	CM 2	Dharke	Dharke	As per Demand	0.2/6+100	Crusher
3	CM 3	Jabang Khola	Jabang Khola	288000	2/66+100	Quarry
4	CM 4	Malekhu Khola	Malekhu	45000	1.5/43+400	River bed
5	CM 5	Trishuli River at Bishaltar	Siurenitar	42000	2/51+300	

Construction Material Sites and Estimated Volume						
S. No	**ID**	**Location**	**Name of the Place**	**Available Quantity (m^3)**	**Distance/Reference**	**Remarks**
6	CM 6	Agra Khola	Mahadev Besi	As per Demand	2/11+200	River bed + Quarry
7	CM 7					
8	CM 8	Marsyangdi River	Anbu Khaireni	84000	11/82+400	River bed
9	CM 9	Trishuli River	Charaundi	90000	0.3/55+500	River Bed
10	CM 10	Trishuli River	Malekhu	74000	1/42+300	River Bed

6.6 Conclusions

From the geological mapping of different phases, following conclusions were drawn relevant to Tribhuvan Highway, Prithvi Highway and other two alternative alignments.

- The road from Nagdhunga to Mugling is considered to be the lifeline of Kathmandu Valley because this is the only road to connect to the southern border of Nepal via Narayanghat, Hetauda and Birgunj. The other road the Tribhuvan Highway via Palung and Bhainse is full of hair pin bends at several locations before reaching Hetauda.
- The first 12 kilometer of the existing road alignment of the Tribhuvan Highway from Nagdhunga to Naubise passes through the steep and very fragile topography. Geologically the area is composed of slightly metamorphosed to un-metamorphosed sedimentary rocks, deeply weathered and highly fractured in most of the sections. The road was blocked time and again in the past especially during the rainy season mainly because of slope failure and/or vehicle breakdown in narrow section of the road. Widening of the entire section of this road is very difficult hence, an alternative alignment was explored.
- An alternative alignment to divert from Km 3+975 is proposed to meet the existing road again at Dharke Km 2+250 (PRM). Although the hilly part of the alignment is quite similar to the existing alignment but the road section through the hilly section is only for about 4 Km and it is expected that while constructing new road many problems faced in the existing road will be corrected.
- The road section from Naubise to Galchhi Km 22+300 is comparatively easier than the previous TRP section of the road. The road is aligned mainly along the left bank of Mahesh Khola and its tributaries.
- The road section from Galchhi Km 22+300 to Bishaltar Km 33+300 the road passes through several market places located on the alluvial terraces deposited by Trishuli River and its tributaries and through steep hill slopes. Although some rock fall or landslide problems are anticipated while widening the road but it is anticipated that those landslides/rock falls can be managed by providing appropriate slope stabilization techniques.

- The road section from Bishaltar Km 33+300 to Hugdi Khola Km 62+100 is mainly aligned through the steep terrain and week geological formations of sheared and fractured black slate. The notorious Krishnabhir landslide is located in this part of the road. Widening of the existing road as well as construction of new road in certain area is anticipated to be very difficult. There is a possibility of triggering new landslide like Krishnabhir or reactivation of old and dormant landslide as well. Hence, widening of the road in this section should be avoided as far as practicable.
- An alternative road alignment was proposed from Bishaltar Km 33+300 of the existing road to meet again at Phisling Km 68+500 to avoid the problematic area like Krishnabhir and Jogimara. In this alignment the road section from Bishaltar to Hugdi Khola confluence will be a better alignment in terms of topography and geology but from Hugdi Khola onward to Phisling there will not be any significant difference from geological point of view from the existing alignment rather it may be more problematic.
- The road section from Phisling Km 68+500 to Manakamana Cable Car Km 78+300 the road is proposed mainly along the alluvial or colluvial terraces above Trishuli River. Not any major problem is anticipated in this section of the road while widening the road. However, there is a sharp bend in Chumlingtar which needs to be corrected in terms of visibility distance. One of the method could be construction of a short tunnel to avoid the loop.
- The road section from Manakamana Cable Car Km 78+300 to the end of the road at Mugling Km 82+410 is anticipated to be among the most difficult section of road widening or construction. Steep topography, old landslide terrain and narrow river gorge at valley side will be quite challenging. Moreover, an active landslide was also mapped in the area of Km 78+400.
- Site specific support measures should be provided in the road section whenever steep and/or higher cut slope exceeding 7m. Although the approximate location of the support measures in the slope is shown in the drawing it can vary by few meters in the field condition while installing.
- The proposed short tunnel in the package 6 is expected to be driven through highly weathered, fractured and sheared metasandstone and phyllite of Tistung and Sopyang Formation. The tunnel excavation is expected to be a soft tunneling.

6.7 Recommendations

Following general recommendations are made for the safe construction and operation of the Nagdhunga Naubise to Mugling road on the basis of the geological studies carried out and the conclusions drawn above.

- While widening of the existing road or constructing new alternatives the cut/fill slope exceeding 5m in soil or highly to completely weathered rock without proper support should be avoided. Whenever cut slope is made suitable drainage should provided to drain out slope water.
- Whenever there is cut slope in steep rock slopes constant supervision of a geologist/geotechnical engineer will be required during excavation of the slope as well as during installation of support measures

6.8 Landslide Hazard Mapping

A landslide hazard map of the proposed road alignment corridors is prepared by evaluating the slope parameters as slope angle, geological parameters, geodynamics as the existing landslides and geo-hydrology of the project area. The additional parameters considered were slope aspect and the nearness to the geological structures like fault and/or thrust and water body. All those parameters were evaluated in totality while preparing the map. While assessing for the hazard level visual assessment of individual slope unit was conducted in the field and also the topographical maps prepared by the department of survey and recent Google images were also consulted to validate the visual evaluation of the slope. The existing individual landslide area irrespective of whether active or not was put into high hazard category while defining the slope.

By above arrangement the entire project area was categorized into three hazard level as **Low Hazard** (LH) **Medium Hazard** (MH) and **High Hazard** (HH). The high hazard slope is such that any time a landslide can be initiated. The slope is already full of landslide or the slope angle is greater than 50 degrees or the rock/soil is highly to completely weathered or the slope is always moist or all or some combinations of abovementioned conditions exist. Similarly the medium hazard is assigned to the slope unit which is although lesser than 50 degree slope angle but toe cutting potential is there or it is moist and is without vegetation. The low hazard category is assigned to the slope which is lesser in slope angle than 15 degrees; landslide in the slope does not exist, and are mostly the cultivated or vegetation covered slopes.

6.8.1 Active Landslide Area

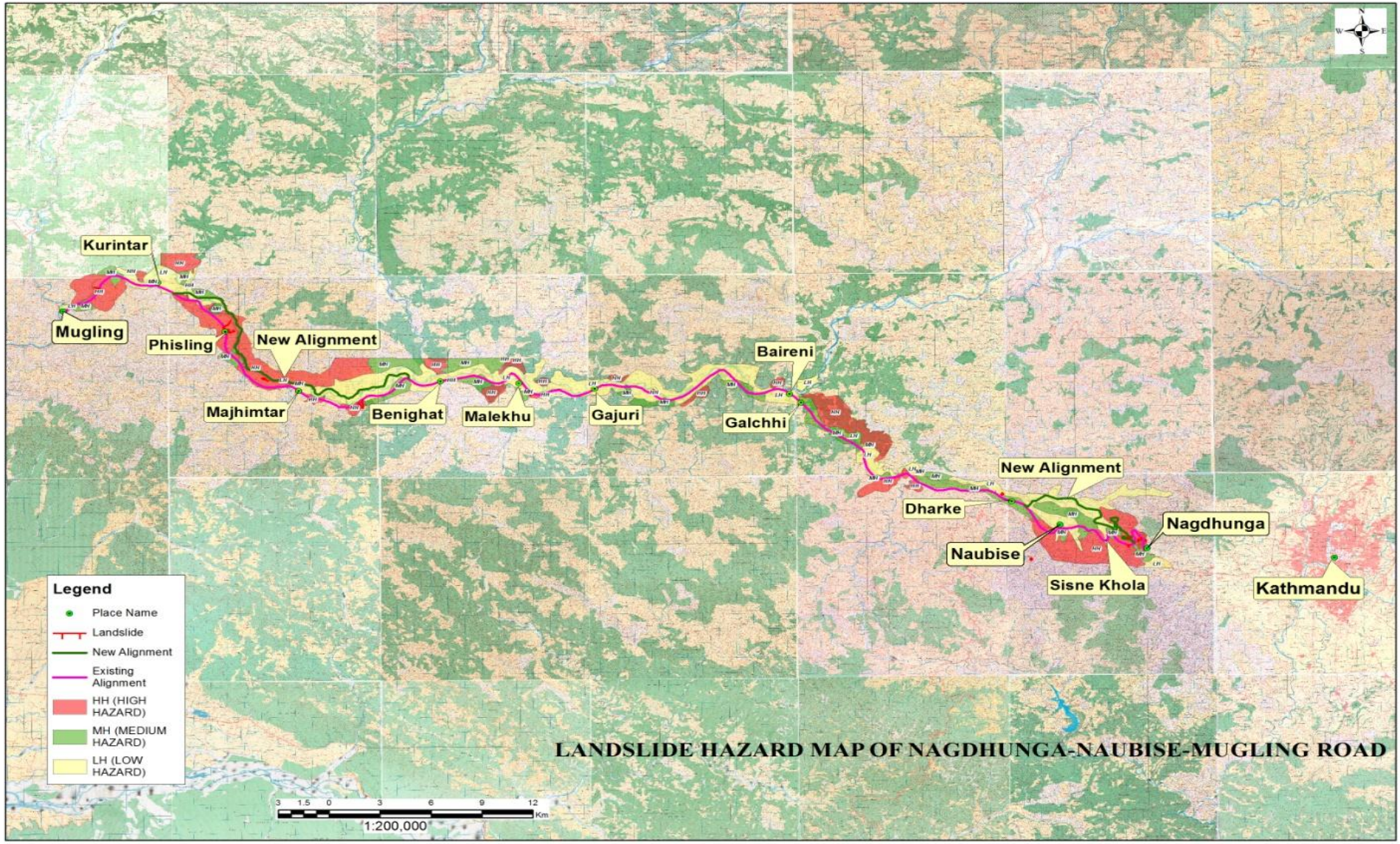
Areas of active landslides were identified during the walk over survey of the proposed road alignments of all the alternatives of the Nagdhunga Mugling road. Although, the status of landslide in almost all the unit slopes encountered by the road alignment were indicated in landslide hazard map, however area of existing active landslides and/or old landslides which were previously stabilized by various means are listed in the Table 7-3 presented below. As per the tabulated data the TRP section of the road from Nagdhunga to Naubise, consists of at least 6 locations of either active or previously stabilized landslides. Similarly along the PRM section of the highway from Naubise to Mugling there are either high potential of landslide or the slope has already failed and stabilized at 6 locations including Krishnabhir and Jogimara,.

On the other hand the proposed new alternative alignment from Sisne Khola to Dharke section consists of two locations where there are two potential sites for active landslide. At these locations scars of old landslides can be seen. Along the proposed new alternative alignment from Benighat to Kurintar active landslides were neither observed nor viewed any sites of old landslide. However, considering the morphology of the area topographical features and geology of the alignment it can be concluded that landslides can be initiated at many locations while constructing road along this alignment.

Table 6-3: Active landslide areas in the proposed road alignment

From	To	Distance (m)	Name of the Place	Remarks
Nagdhunga Naubise				
0+050	0+200	150	Nagdhunga	Hillside Active L/S
2+250	2+400	150	Jhakribas	

From	To	Distance (m)	Name of the Place	Remarks
2+790	2+830	40	Jhyaple Khola	Vally side L/S
3+950	4+075	125	Khatri pauwa	Hillside Active L/S
4+125	4+175	50	Khatri pauwa	
4+400	4+650	250	West of Khatripauwa	Stabilized L/S
Total		**765**		
Naubise Mugling				
13+350	13+550	200	Koiralagaon	Potential L/S
16+625	16+925	300	Eklephant	Deep Rock cut
42+540	42+600	60	Malekhu	
57+050	58+050	1000	Krisnabhir	Stabilized L/S still potential
66+800	66+925	125	Jogimara	Potential rock fall zone
69+000	69+200	200	Fisling	Slow and Active L/S
79+550	80+050	500	Mugling	
Total		**2035**		
Sisne Khola Dharke				
0+050	0+200	150	Chayudanda	Bedrock dip out of slope
0+450	0+740	290		Old L/S and Potential
1+100	1+500	400	Waglethok	Old landslide downslope
1+500	2+500	1000	Below Piplaamod	Deep cut in highly to completely weathered slope
3+200	3+800	600	Waglethok	
3+800	4+000	200	Waglethok	Potential landslide zone
Total		**2640**		
Bishaltar Phisling				
2+620	2+680	60	Dhobadighat	Steep soil slope
4+820	5+200	380	Chuwatar	Steep slope toe erosion by Trishuli River
7+260	8+820	1560	Jyamirghat	Steep unstable slope toe erosion by Trishuli River
9+780	10+820	1040	Thumka	Steep rocky slope
11+240	14+600	3360	Hulintar	Steep rocky slope fragile


Kurintar
Mugling
Phisling
New Alignment
Majhimtar
Benighat
Malekhu
Gajuri
Baireni
Galchhi
New Alignment
Dharke
Nagdhunga
Naubise
Sisne Khola
Kathmandu
Legend
Place Name
Landslide
New Alignment
Existing Alignment
HH (HIGH HAZARD)
MH (MEDIUM HAZARD)
LH (LOW HAZARD)
3 1.5 0 3 6 9 12
Km
1:200,000
LANDSLIDE HAZARD MAP OF NAGDHUNGA-NAUBISE-MUGLING ROAD