CHAPTER 9

PRELIMINARY DESIGN OF TUNNEL

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9.1 GEOLOGICAL CONDITION

9.1.1 Geological Survey

In order to confirm the geological condition of Nagdhunga tunnel, following investigations has been carried out.

- Geological survey
- Aerial photo interpretation
- Electrical Resistivity Tomography
- Seismic prospecting exploration (Changed into Microtremor Array Measurement)
- Drilling survey

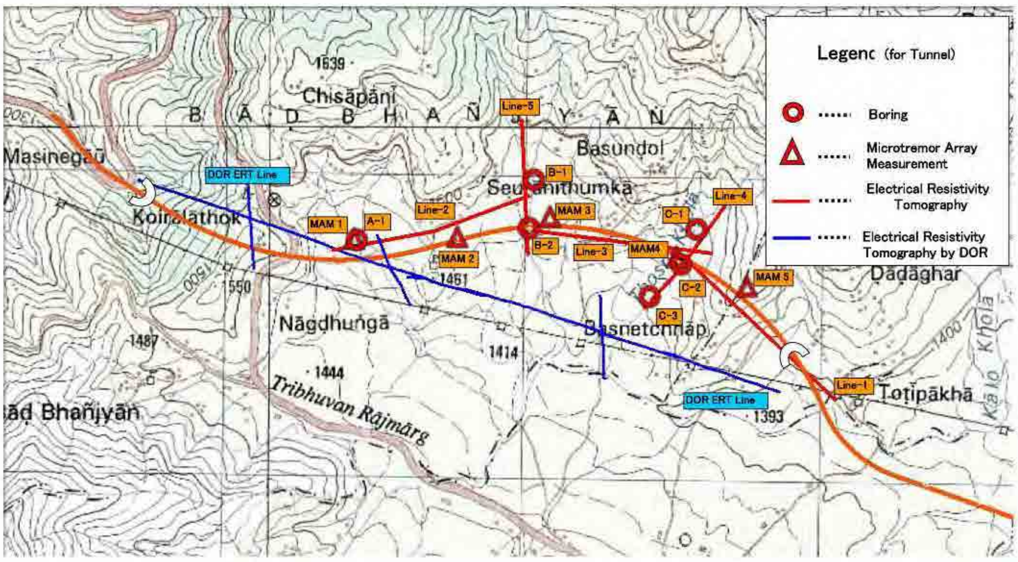


FIGURE 9.1-1 LOCATION MAP OF GEOLOGICAL SURVEY

TABLE 9.1-1 SURVEYED AMOUNT LIST

No.	Item or Work	ID No.	Planned	Achieved
1	Microtremor Array Measurement (MAM)	MAM 1	1.0	1.0
		MAM 2	1.0	1.0
		MAM 3	1.0	1.0
		MAM 4	1.0	1.0
		MAM 5	1.0	1.0
		Total	5.0	5.0
2	Electrical Resistivity Tomography (ERT)	ERT-1	750m	710m
		ERT-2	550m	710m
		ERT-3	800m	710m
		ERT-4	300m	470m
		ERT-5	300m	470m
		Total	2700m	3070m
3	Boring	A1	50m	75m
		B1	60m	55m
		B2	70m	70m
		C1	50m	50m
		C2	50m	60m
		C3	50m	32m
		Total	330m	342m

1) Geological survey was carried out in the range of 12km^2 around the tunnel planned route.

2) The geology of the study area consists of interbedded sandstone and phyllite of the Paleozoic, where many cracks develop as well as thinly developed bedding planes.

3) Survey results are shown in **Figure 9.1-2**.

4) Aerial photo interpretation was carried out by stereoscopic interpretation with scale of 1: 50,000, using the black-and-white photo, taken on 1 November 1992. Results have been reflected on the geological mapping and surface geological survey results.

5) Electrical Resistivity Tomography prospecting has been done along the planned survey lines which cross the original tunnel alignment. And because the seismic prospecting exploration along the tunnel alignment could not be carried out due to the difficulty to obtain permission, ERT was additionally carried out along the tunnel longitudinal alignment. It should be noted that DOR had carried out several surveys for the feasibility study in the vicinity of the project tunnel (in Feb. 2013) and the results of this study are also reflected in the report. The survey results are shown in **Figure 9.1-3**.

6) Seismic refraction exploration was planned to be carried out along the tunnel alignment but because of the availability of dynamite required by the survey was difficult, it was changed to Microtremor Array Measurement (MAM). The survey results are shown in **Figure 9.1-4**.

7) Boring survey was conducted in order to confirm the depth and the properties of the bedrock in the valley areas which cross the tunnel alignment. The boring results obtained are reflected in the photos in **Figure 9.1-5**.

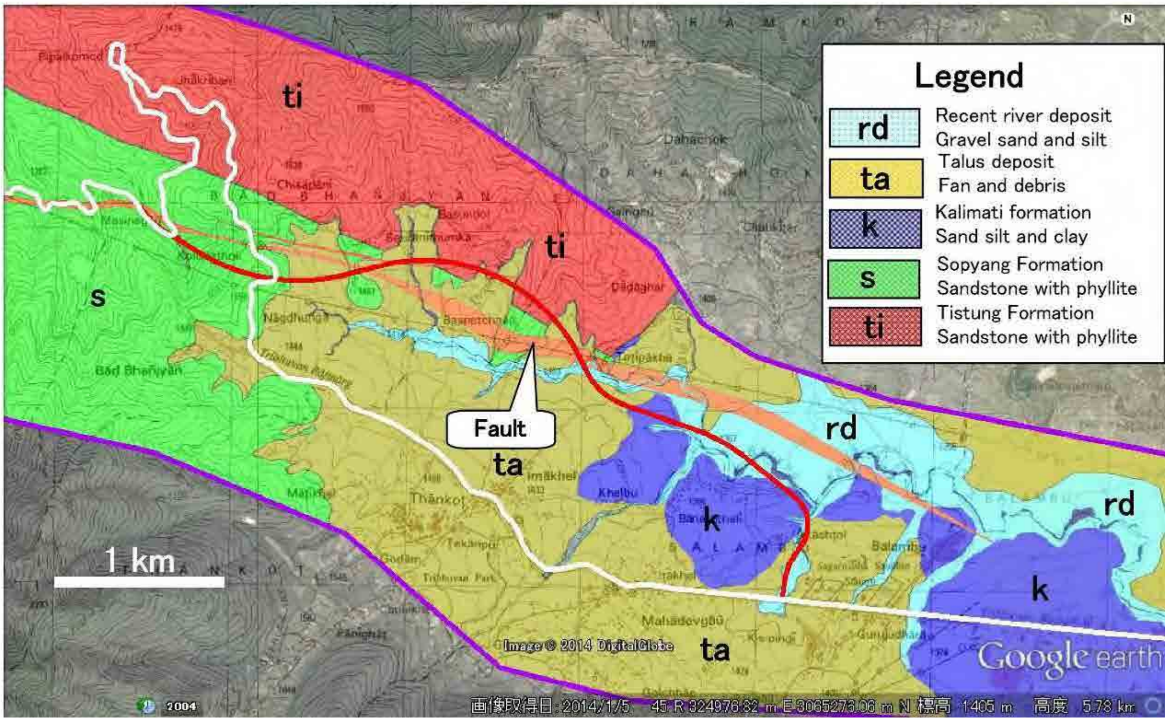


FIGURE 9.1-2 GEOLOGICAL MAP OF SURVEYED AREA

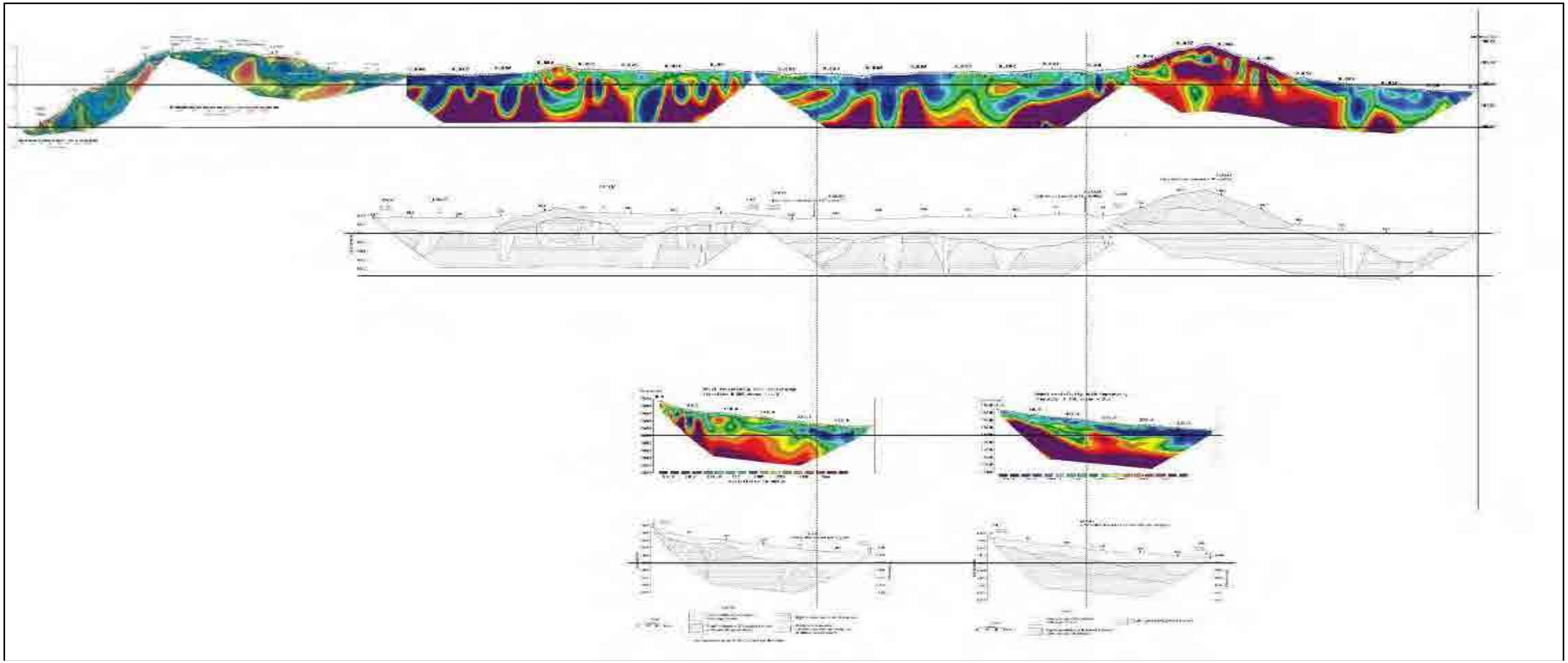


FIGURE 9.1-3 INTERPRETED RESULTS OF ERT

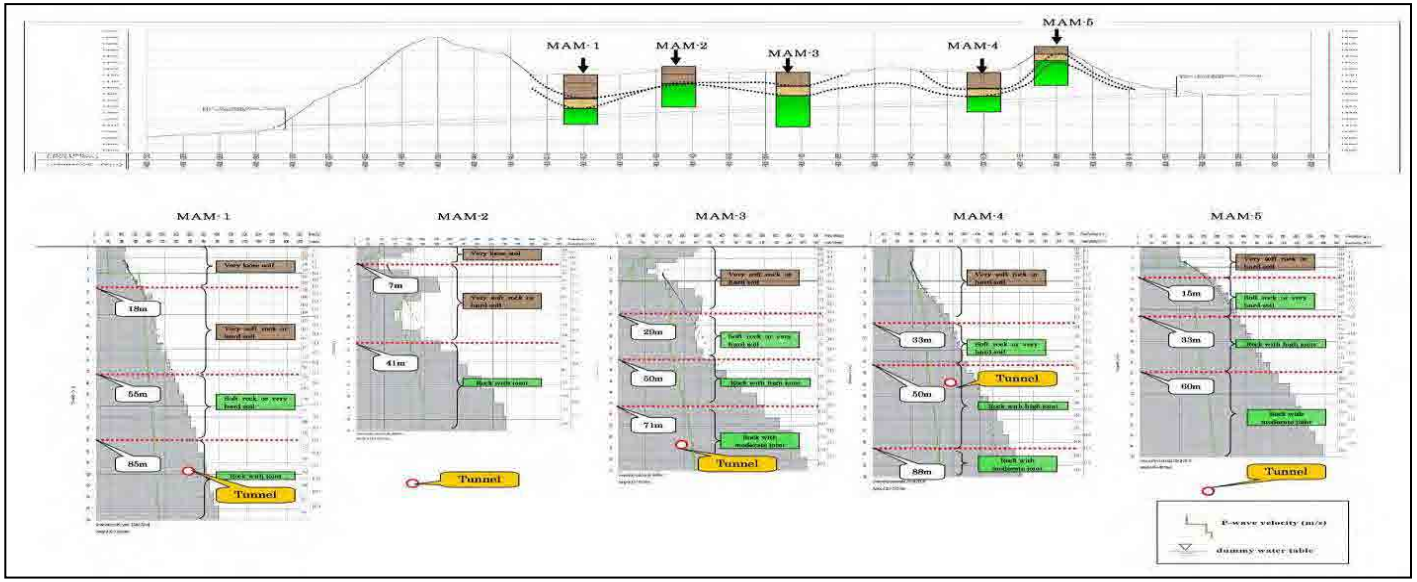


FIGURE 9.1-4 INTERPRETED RESULTS OF MAM

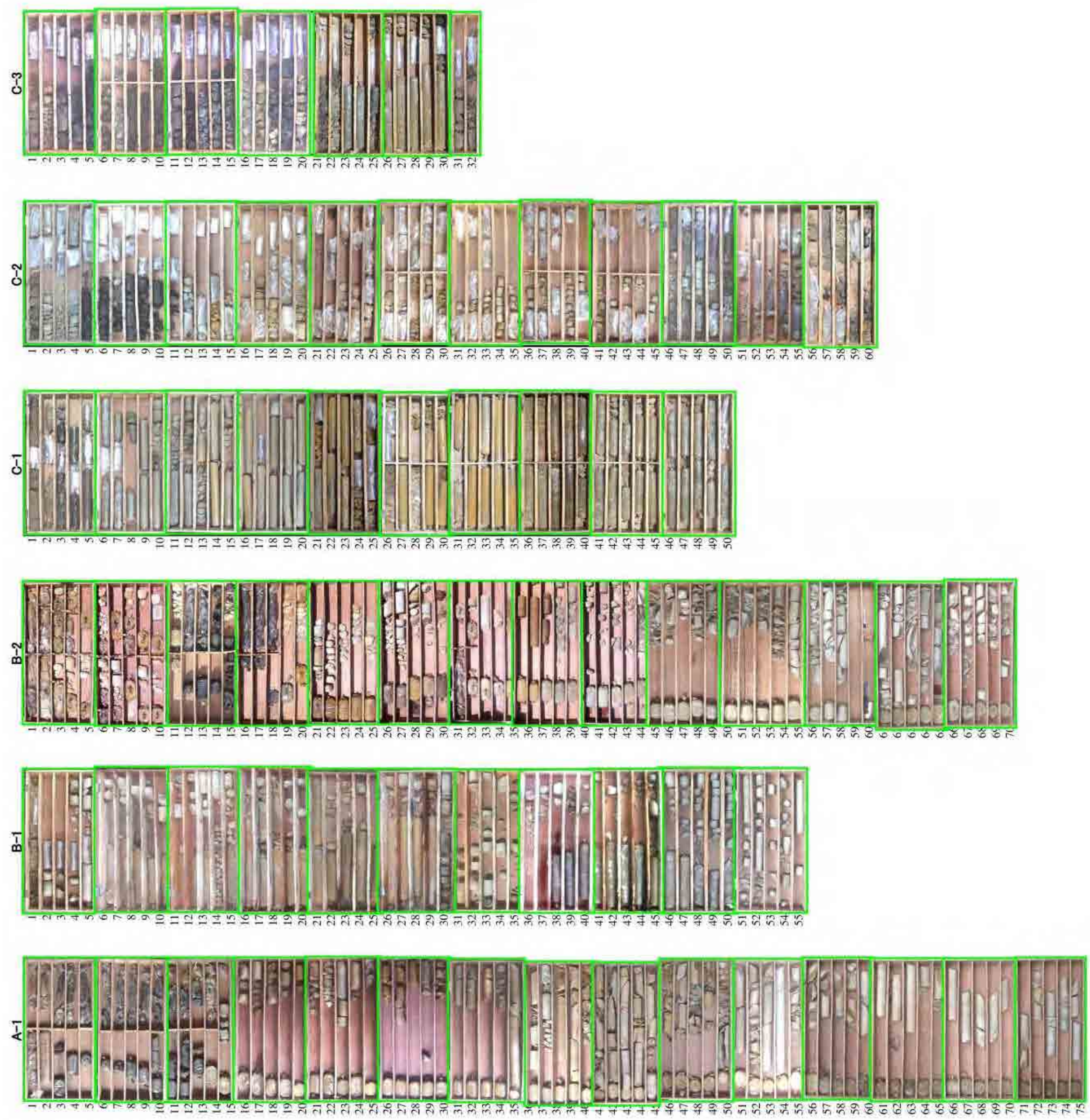


FIGURE 9.1-5 BORING CORES PHOTOS

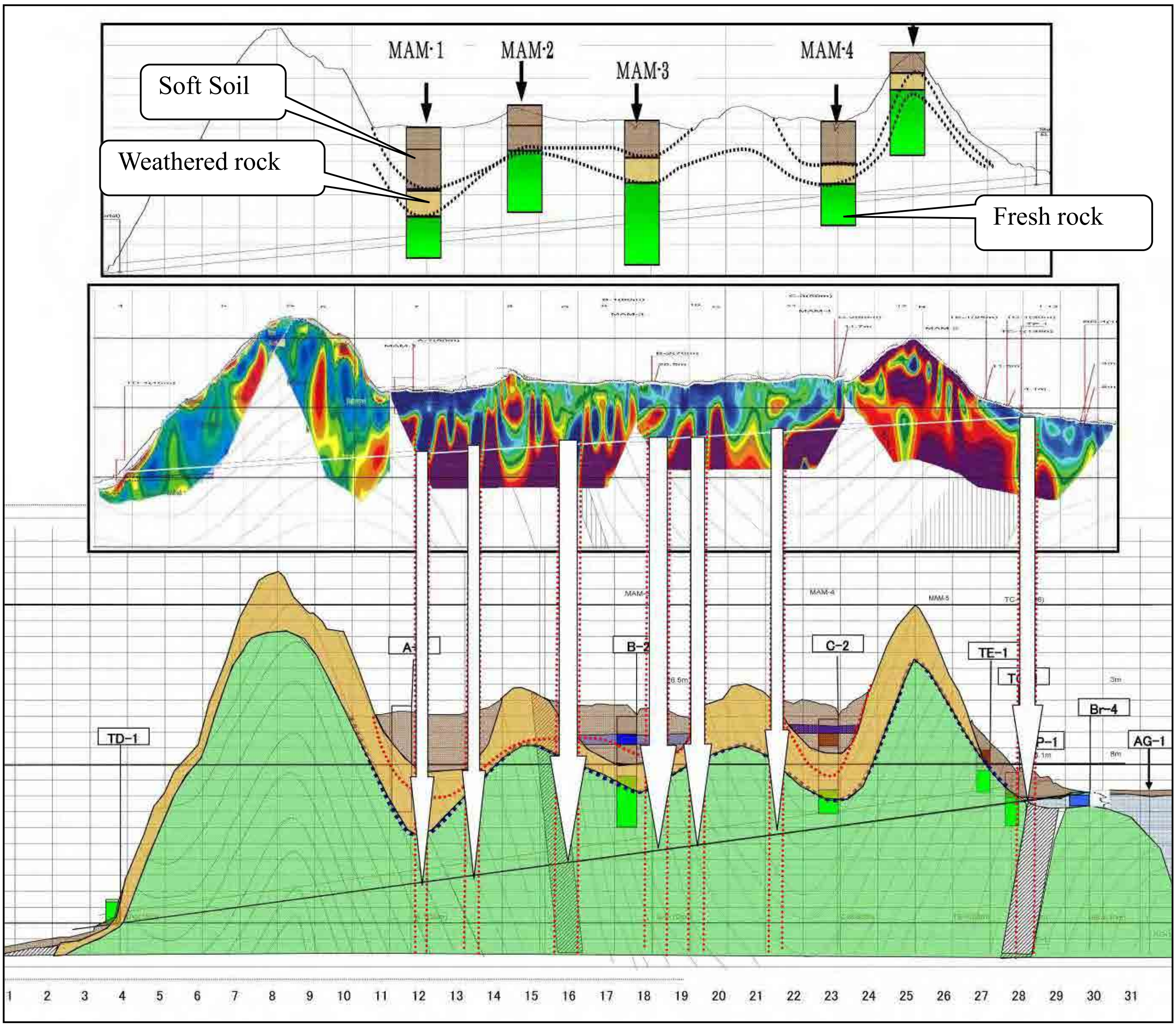


FIGURE 9.1-6 INTERPRETATION OF RESULTS OF MAM, ERT AND BORING

9.1.2 Summary of geological survey on Nagdhunga Tunnel

- The Nagdhunga tunnel is mostly planned in the direction of east and west, starting from Basnetchhap as eastern portal and passes under the Sisne khola to Nagdhunga pass and reaches to the west side portal, and is 2450 m long.
- The geology of this section is Sopyang formation of Paleozoic era.
- Sopyang formation is the thin alternation of sandstones and phyllites.
- The thickness of each sand stone layer is 5 to 30 cm and phyllites are 1 to 5 cm thick, and many cracks develop due to repeated small foldings.
- There are three wide valleys along the tunnel alignment.
- These valleys are filled up with the sediment of talus and clays which deposited when Katmandu basin had been a lake.
- The thickness of the sediments are 20 to 40 m.
- The weathering layer of bedrock is 30 to 40 m from the surface, and below the weathered rock fresh and hard rock with fractures are confirmed by boring.

- Although the groundwater level is assumed to be about 30-40m from surface in a mountain part, about 5-10m from surface are confirmed in the valley area.
- In the west side portal area a little weathered alternations of sandstone and phyllite are exposed, Relationship of excavation slope and bedding planes of the strata shows that slopes to be cut are rather stable because the strata dip into the slope.
- In the east side portal, talus sedimentary layers are thick, and also cohesive soil is distributed over the lower part of a talus cone.
- Longitudinal geological profile is shown in the attached drawing sheets.

FIGURE 9.1-7 FEATURES OF BEDROCK WITH MANY CRACK

9.2 KEY POINTS FOR TUNNELING FROM THE VIEWPOINTS OF GEOTECHNICAL CONDITION

Issues particularly important for the implementation of Nagdhunga Tunnel are summarized as follows;

- It is of great importance in designing the tunnel support pattern and method of tunneling of Nagdhunga Tunnel to maintain the groundwater level as much as possible to the present level, where habitants are using surface water flow and groundwater, and houses near eastern portal shall be maintained safely during tunneling. When shortage of water is triggered it will induce serious difficulty in the implementation of the project.
- Slopes surrounding tunnel portals shall be maintained stable permanently and stream waters shall be adequately managed not to harm the tunnel.
- In the planning of tunneling method it must be reflected that there distributes to some extent hard massive sandstones which may be very difficult for mechanical excavation method without using heavy breaker or some other auxiliary method.
- Another point of importance is that tunneling method and support design shall be adequate to cope with fault zones to be encountered during tunneling although the exact location and nature of the fault zones are not identified yet.

All of the above issues are to be reflected in the design of tunnel support and method of excavation for Nagdhunga Tunnel.

Necessary auxiliary methods and measures and their cost thereof are considered in the design, method of tunneling and cost analysis.

9.3 ENGINEERING APPROACH

9.3.1 Design Standards

There is no design standard for tunnels included in the Nepal Standards. All design standards for road tunnels in developed countries are quite similar.

Japan is the one of the most experienced countries in tunneling in the world, and as the geology and geotechnical condition of Japan is very similar to that of Nepal, the present study for tunneling for the Nagdhunga Pass Project is based upon the experiences in Japan and the design of the tunnel is based on the Standard of NEXCO (Nippon Expressway Company, former Japan Highway Corporation), which is applied to all the highway tunnels and most of national road tunnels in Japan, most of which have been constructed by NATM. Because NATM is applied for most of the tunnels worldwide Nagdhunga Tunnel is to be constructed by NATM.

NATM is first established in Austria, which utilizes shotcrete and rockbolts as major supporting system generally in hard rock mass with measurement of deformation of tunnel walls to evaluate whether the tunnel is stable or not. And if not, additional support measures are applied accordingly.

However, Japanese contractors have applied the method generally in very poor ground and during constructing so many tunnels in difficult ground, Japanese contractors have advanced the method by themselves and innovated various kinds of auxiliary methods and specific equipment for supporting the poor ground.

Result of Data Collection Survey shows that the proposed width of the road in tunnel is 2 x 3.5m lanes with 2.5m wide lane for emergency parking at east bound direction and 0.5m wide shoulders on both sides; a walk way for maintenance of the facilities, 75cm wide and 2.0m high, is required at one side.

No side walk is designed because for the safety of the traffic; non-motorized traffic, such as pedestrians, bicycles, hand cart and animal traction carts, or agricultural tractors are not allowed to enter the tunnel. Thus, the total width of the tunnel is about 12 m and the height is about 7 m.

Tunnel design shall follow the above dimensions and clearance in height for the traffic is determined as 5.0m which is the standard for Asian Highways.

9.3.2 Rock classification method and Standard Support Patterns of the tunnel

(1) Rock classification system and standard support patterns in Japan

Table 9.3.2-1 shows the rock mass classification system of NEXCO and **Table 9.3.2-2** shows the standard support pattern for two lane tunnel.

TABLE 9.3-1 ROCK MASS CLASSIFICATION SYSTEM (NEXCO)

Rock class	Condition of rock mass	RQD	Stability of face	convergence
B	Rock is fresh and hard. Discontinuous planes are stable and the possibility of loosening due to tunnel excavation is very small.	60 to 90	The strength is significantly higher than the expected load and only occasional local spalling of rock fragment may occur.	Convergence of tunnels is negligible.
C I	Rock is partly weathered or altered. Discontinuous planes are generally relatively stable	20 to 70	The strength is higher than the expected load and the loosening is expected to be local.	Convergence of tunnels is usually within the elastic range.
C II	Rock is partly weathered or altered and fractured.	20 to 70	Strength is not significantly higher than the expected load, but is sufficient to limit the elastic deformation. Rock chunks along slippery discontinuous planes tend to spall. Often requires fore-polling.	Convergence stops to increase before the tunnel face has advanced a distance of 2 D, where D is the tunnel diameter. Convergence of tunnels does not exceed 50 mm.

Rock class	Condition of rock mass	RQD	Stability of face	convergence
D I	Rock is significantly weathered and softened or sheared.	< 20	Partial plastic displacement and elastic deformation could occur. Or even if the strength is high enough to limit the elastic deformation, significant loosening of ground along slippery discontinuous planes could occur. Requires fore-pilings.	Where the strength is small and the invert concrete is not placed at an early stage, the convergence could reach 30 to 60 mm and does not stop to increase even if the tunnel face has advanced more than 2 D
D Ⅱ	Rock is completely weathered and partly softened to soil, or heavily sheared. Talus deposits and soil are included in this class.	< 20	The strength is low compared to the expected load and large plastic deformation as well as elastic displacement could occur. In addition to the low strength, significant loosening of ground along slippery discontinuous planes and large displacement could occur.	Convergence of tunnels could reach as large as 60 to 200 mm and does not stop to increase even if the tunnel face has advanced more than 2 D, if the invert concrete is not placed at an early stage
E	Ground such as faults, fractured zones and large talus deposit.		Squeezing occurs and generates occasional collapse in face area.	Large deformation could reach to 400mm.

TABLE 9.3-2 STANDARD SUPPORT PATTERNS FOR TWO-LANES TRAFFIC TUNNELS (NEXCO)

<table>
<tr><th rowspan="3">Ground class</th><th rowspan="3">Support pattern</th><th rowspan="3">Cut per advance (m)</th><th colspan="4">Rock bolts</th><th>Shotcrete</th><th colspan="2">Steel rib</th><th colspan="2">Lining thickness (cm)</th><th rowspan="3">Allowable deformation (cm)</th><th rowspan="3">Excava-tion method</th></tr>
<tr><th rowspan="2">Length (m)</th><th colspan="2">Spacing</th><th rowspan="2">Construc-tion range</th><th rowspan="2">Thickness (cm)</th><th rowspan="2">Upper half size</th><th rowspan="2">Lower half size</th><th rowspan="2">Arch & wall</th><th rowspan="2">Invert</th></tr>
<tr><th>Periph-eral (m)</th><th>Longitu-dinal (m)</th></tr>
<tr><td>B</td><td>B-a</td><td>2.0</td><td>3.0</td><td>1.5</td><td>2.0</td><td>Upper half 120°</td><td>5</td><td>-</td><td>-</td><td>30</td><td>0</td><td>0</td><td rowspan="7">Full face with micro bench or top heading cut</td></tr>
<tr><td>C I</td><td>C I-a</td><td>1.5</td><td>3.0</td><td>1.5</td><td>1.5</td><td>Upper half</td><td>10</td><td>-</td><td>-</td><td>30</td><td>(40)</td><td>0</td></tr>
<tr><td rowspan="2">C II</td><td>C II-a</td><td rowspan="2">1.2</td><td rowspan="2">3.0</td><td>1.5</td><td>1.2</td><td rowspan="2">Upper and lower halves</td><td rowspan="2">10</td><td>-</td><td>-</td><td rowspan="2">30</td><td rowspan="2">(40)</td><td rowspan="2">0</td></tr>
<tr><td>C II-b</td><td>1.5</td><td>1.2</td><td>H125</td><td>-</td></tr>
<tr><td rowspan="2">D I</td><td>D I-a</td><td>1.0</td><td>3.0</td><td rowspan="2">1.2</td><td rowspan="2">1.0</td><td rowspan="2">Upper and lower halves</td><td rowspan="2">15</td><td rowspan="2">H125</td><td rowspan="2">H125</td><td rowspan="2">30</td><td rowspan="2">45</td><td rowspan="2">0</td></tr>
<tr><td>D I-b</td><td>1.0</td><td>4.0</td></tr>
<tr><td>D II</td><td>D II-a</td><td>1.0 or less</td><td>4.0</td><td>1.2</td><td>1.0 or less</td><td>Upper and lower halves</td><td>20</td><td>H150</td><td>H150</td><td>30</td><td>50</td><td>10</td></tr>
</table>

The support patterns are divided into a and b as shown below.
a: Standard support pattern generally used for all rock types
b: Support pattern used in the initial design only when the tunnel excavation is expected to result in a larger displacement in clay stone, black schist, mudstone, shale, tuff, or other rock types.
Note that the values in ( ) for the invert are applied to tertiary mudstone, tuff, serpentinite, and other ground rocks, weathered crystalline schist, and sulfuric soil.

9.4 CROSS SECTION AND SUPPORT PATTERNS OF THE TUNNEL

9.4.1 Tunnel cross section

Cross section of the tunnel is so designed as to meet the requirement to provide two 3.5m wide lanes and one 2.5m wide lane for emergency parking in the east bound direction. Height of the construction gauge for the traffic is 5.0m.

After walk out survey and examining the geological condition on various outcrops, tunnel types and support designs are preliminarily determined. Then after getting information on geotechnical and hydrological condition through field investigations, support patterns (and Tunnel types) and length of distribution of each pattern is defined finally and is reflected in the longitudinal tunnel profile.

Tunnel types are classified into 3 types in this study to reflect the geotechnical condition of the tunnel so far encountered and are classified as CⅡ, DⅠ and DⅡ. Cross sections of each tunnel type are shown in the Sheets NO. 10 to 12 of the Preliminary Design Drawings.

Type CⅡ is to be applied to the ground where rock mass is significantly fractured or sheared. The type of rock is the alternation of thin slate and sandstone. This type of ground is expected to develop in the area beneath the ridges and near western portal area and is supposed to share about 60% of the total tunnel length.

Type DⅠ is to be applied to the ground where rock mass is heavily sheared or weathered or to the CⅡ ground where valley deposits distribute over the rock mass in thin coverage. This type of ground is supposed to be encountered under the valley at two locations, at Thosne Khola and west of it, beneath the small ridge at Chisapani where existence of fault zone is anticipated and in the near portal area where overburden is small. This type of ground is supposed to be of about 35% of the total tunnel length.

Type DⅡ is to be applied to the ground where rock mass is totally weathered and overburden is very small as in the area of both portals. This may occupy about 5% of the total tunnel length.

It is a general requirement for the tunnel to provide emergency parking areas when the tunnel is very long. As for the Nagdhunga Tunnel there is a emergency parking lane in the east bound direction. However, in the west bound direction emergency parking zones shall be provided. In this study 2 numbers of emergency parking zones are designed at about 800m apart and is named Type CⅡ-L.

9.4.2 SUPPORT PATTERNS (See Sheets NO. 13 to 16 of the Preliminary Design Drawings)

Referring to the standard support pattern in **Table 9.4-1**, support patterns for the Nagdhunga Tunnel are designed.

- Support Pattern CⅡ corresponds to Tunnel Type CⅡ. It consists of 10cm thick shotcrete, 3m long rockbolts at spacing 1.5m peripherally and 1.2m longitudinally. Secondary concrete lining is 30cm thick. Due to the fractured nature of the rock mass shotcreting for the excavated face area is sometimes required.
- Support Pattern DⅠ is applied to tunnel class DⅠ. It consists of 15cm thick shotcrete, 3m long rockbolts at spacing 1.2m peripherally and 1.0m longitudinally. Thickness of lining concrete is 30cm. The Pattern requires face shotcrete 3 to 5cm thick to stabilize the excavated face.
- When the rock mass in the invert is very weak and is likely to be deteriorated the support requires extra H-shaped steel arch (H125) and 45cm thick invert concrete and is named Support Pattern DⅠ-a. Pattern DⅠ-a requires also an auxiliary method such as fore-poling and face shotcrete.
- Depending on the rate of ingress of groundwater under the valley area, chemical injection with long span fore-piling may be required instead of fore-poling to maintain the groundwater level. When tunneling encounters fault zones same measures may be required. This support pattern is named as Pattern DⅠ-b.
- Support Pattern DⅡ corresponds to tunnel Type DⅡ. It consists of 20cm thick shotcrete and rockbolts of 4m long at spacing 1.2m peripherally and 0.75m to 1.0m longitudinally depending on the stability of the excavated face. It requires steel arch sets of 150H for the

temporary support of the weight of the above ground. Fore-poling by 3m long rockbolts are generally required. Secondary lining concrete is 35cm thick in arch and 50cm thick in invert.

- In eastern portal area the support pattern requires heavy auxiliary method such as long span fore-piling with chemical injection to maintain the groundwater level (this support pattern is named Support Pattern D Ⅱ -a). On the contrary, in the western portal area portal slope is to be widely cut and fractured but fresh rock mass of C Ⅱ class is expected to appear in a short distance from the portal.
- For the portal zones lining concrete shall be steel-reinforced in order to sustain the non-uniform overburden loads acting on it permanently.
- Western tunnel entrance is to be of reinforced concrete structure of 80cm thick and eastern tunnel entrance will be more rigid structure to cope with the ground pressure acting on it.

As for the emergency parking zones with which the cross sectional area is very large, the parking zones shall be designed in Detail Design stage to locate them in the area of better geotechnical condition.

Table 9.4-1 shows a list of support patterns.

TABLE 9.4-1 LIST OF SUPPORT PATTERNS

Support Pattern	Excavation area m2	Advance per cycle	Applicable geological condition	Excavation method	Auxiliary method	Rock bolt	Shotcrete thickness	Steel-rib	Lining thickness
C Ⅱ	89.16	1.2m	Thinly bedded fractured rock mass Alt. of Sst&shale	Micro bench mechanical		3m long, 1.5m(p), 1.2m(l),	10cm		30cm
D Ⅰ	91.26	1.0m	Highly fractured and weathered rock mass (+ Fault zone)	Ditto		3m long, 1.2m(p),1.0m(l)	15cm		30cm
D Ⅰ -a	101.97	1.0m	Heavily fractured, weathered rock	Ditto	Fore-poling 3m long	Same as above	15cm	125H	30cm(arch) 45cm(inv.)
D Ⅰ -b	101.97	1.0m	Ditto with groundwater (under the valleys)	Ditto	Fore-piling (12m) with chemical injection	Same as above	15c	125H	30cm(arch) 45cm(inv.)
D Ⅱ	105.06	0.75-1.0m	Highly weathered rock mass with thin rock cover	Ditto	Fore-poling 3m long	4m long, 1.2m(p) 0.75-1.0m(l)	20cm	150H	35cm(arch) 50cm(inv.) Steel reinforced
D Ⅱ -a	105.06	0.75-1.0m	Ditto with groundwater (eastern portal area)	Ditto	Fore-piling (12m) with chemical injection	Same as above	20cm	150H	35cm(arch) 50cm(inv.) Steel reinforced

Note: (p) means peripheral, (l) means longitudinal

Important notice on water proofing by chemical injection

In the design chemical injection is intended to be used with AGF in tunnel in order to minimize the lowering of groundwater level. However, our intention is not to make the tunnel perfectly watertight but to reduce the water inflow into the tunnel. Thus tunnel is not designed as watertight tunnel.
When geological structure is taken into consideration, that the strike of the strata is generally sub-parallel to the tunnel axis and dip of the strata is considerably high to the north or to the south due to occasional folding and that permeability of the rock mass across the bedding planes in thin alternation of slates and sandstones is generally low because slates are impermeable and sandstones are permeable and groundwater passes in the fissures of sandstone layers, area of the chemical injection to be carried out with AGF may possibly be limited to along the arch periphery of the tunnel. This shall be further studied in detailed design study.
During tunneling whenever groundwater inflows from the excavated side walls through shotcrete chemical injection shall be done to reduce the rate of inflow.
Groundwater inflow from the face area if any can be accepted because groundwater comes from far front of the face and when tunnel periphery is closed all the way after the completion of tunneling groundwater cannot enter into the tunnel and groundwater level may recover gradually.

9.4.3 Longitudinal profile of the tunnel

Longitudinal profile of the tunnel including geotechnical condition and distribution of type of support are shown in the **Sheet NO. 9 of the Preliminary Design Drawings**.

9.5 METHOD OF TUNNELING

9.5.1 Geology, geotechnical and hydrological condition of the tunnel

(1) Geology and geotechnical condition

Tunnel ground to be excavated mainly consists of thin alternation of sandstone and shale. Their geotechnical condition seems to be of poor nature and are classified into CⅡ, DⅠ and DⅡ. To some extent it is anticipated that considerably thick hard sandstones occasionally appear in the excavation face area beneath the ridge areas and in the selection of tunneling method it is taken into account. Because the bedding planes of the strata are sub-parallel to the tunnel axis cares shall be taken to the stability of excavated side walls.

(2) Hydrological condition

With regard to hydrological condition of the tunnel ground, groundwater may infiltrate into the tunnel where rock mass is sheared or near the portal area and under the Thosne Khola where tunnel is covered by basement rock with thin cover and water-bearing unconsolidated sediments develop above the basement rock.

Surface water flows and groundwater are widely utilized in the eastern portal and valley areas not only for agricultural use but also for domestic use and decrease in groundwater level due to tunneling may induce serious problem. Necessary measures are designed to preserve the groundwater level as much as possible in this study.

9.5.2 Excavation method of tunneling

(1) Method of tunneling

There are two methods of tunneling, Drill & Blasting and mechanical excavation. Drill & Blasting method is generally applied in hard rock mass and when the rock mass is fractured significant overbreaks occur and heavier support is required compared to mechanical excavation.

Geology of the Nagdhunga Tunnel consists mainly of thin bedded alternation of shale and sandstone with many cracks in it and is generally classified as poor rock mass. Thus, the tunnel shall be excavated mechanically by Road-Header (see **Figure 9.5-1 and TABLE 9.5-2**).

- Mechanical excavation has a great merit when it comes to excavate soft rock or hard rock of poor nature where many planes of discontinuities develop. Overbreaks are much smaller, support patterns are lighter and the rock mass surrounding the tunnel remains more intact after excavation than D&B. However, when the rock mass is hard and intact it cannot excavate the rock mass economically. In Nagdhunga Tunnel occasionally road-header may encounter hard massive sandstone and utilization of giant breaker may be required in such a case.

FIGURE 9.5-1 ROAD-HEADER AS TUNNELING MACHINE

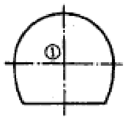
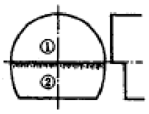
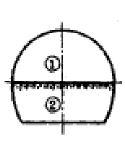
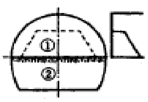
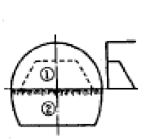
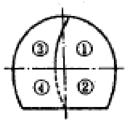
TABLE 9.5-1 COMPARISON OF EXCAVATION METHOD

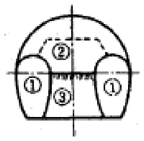
Tunneling Method		Drill & Blasting		Mechanical	
Features		➢ This method is generally applied in hard rock mass and soft rock mass. ➢ In order to use explosives, it is necessary to exercise caution in the application of this method. ➢ Noises and vibrations generated by blasting method is not small. ➢ Overbreaks is large and ground is likely to be loose.		➢ This method is generally applied in middle hard rock mass, soft rock mass and sand/soil layer. ➢ Noise and vibration generated by tunnel excavation is small. ➢ Overbreaks and loose of ground is small.	
Evaluation Indexes	Applicability	➢ Geology of Nagdhunga Tunnel is mainly of thin bedded alternation of shale and sandstone with many cracks, and it is possible to apply Drill & Blasting method. But excessive overbreaks and loose of ground will be occurred.	△	➢ Geology of Nagdhunga Tunnel is mainly of thin bedded alternation of shale and sandstone with many cracks, and it is possible to apply Mechanical method. It is possible to excavate effectively because loose of ground and overbreaks are small.	○
	Environmental	➢ It is necessary to consider the countermeasures of noises and vibrations reduction for residents around west tunnel portal.	△	➢ Noises and vibrations generated by tunnel excavation is small.	○
	Safety	➢ Safety measures for application of explosives are needed.	△	➢ Necessity safety measures for Mechanical method are less than that for Drill & Blasting method.	○
Total Evaluation		△		○	

(2) Excavation method

Tunnel excavation method is classified as shown in エラー! 参照元が見つかりません。. Depending upon the geotechnical condition excavation face area is sometimes divided into sections and when geotechnical condition is of extremely poor center diaphragm method or side drift method are employed. However, geotechnical condition of the Nagdhunga Tunnel is deemed to be of poor nature, not extremely poor, and owing to the merit of mechanical excavation, excavation shall be done by nearly full face excavation method. It is called micro-bench method (it is named *full face method with auxiliary bench cut* in the Table), which leaves the lower bench by few meters from the upper bench excavation face. The lower half section is excavated simultaneously or continuously with the excavation of upper half section. This method can maintain the stability of the face more easily than full face excavation.

TABLE 9.5-2 CLASSIFICATION AND CHARACTERISTICS OF STANDARD EXCAVATION METHOD

Excavation Method		Division of Section of Heading	Applicable Ground Condition	Advantages	Disadvantages
Full Face Method			Common excavation method for small section tunnel Very stable ground for large section tunnel (A=30m^2) Fairly stable ground for medium section tunnel (A>50m^2) Unfit for good grounds interspersed with poor ground that may require the change of the excavation method	Labor saving by mechanized construction Construction Management including safety control is easy because of the single-face excavation.	Full tunnel length cannot necessarily be excavated by full face alone. Auxiliary bench cut will be adopted as required. Fragment rocks from the top of the tunnel may fall down with increased energy & additional safety measure are required.
Full Face Method with Auxiliary Bench Cut		 Bench length = 2~4m	Comparatively stable ground, but difficult using the Full Face Method. Full-face excavation is made difficult during construction. Presence of some poor ground in fairly good ground.	Labor saving due to mechanized construction Construction management including safety control is easy because of the single-face excavation.	Difficult to switch to other excavation method when the face does not stand up.
Bench Cut Method	Long Bench Cut	 Bench length>50m	Ground is fairly stable, but Full-face excavation is difficult.	Alternate excavation of top heading and lower bench reduces equipments and manpower needs.	Alternate excavation system elongates the construction period.
	Short Bench Cut	 D < Bench length≤ 50m	Applicable to various ground such as softly ground, swelling ground, and medium to hard rock ground. (The most fundamental and popular method.)	Adaptable to change in the ground condition.	Parallel excavation makes difficult the balancing of cycle time for top heading and bench.
	Mini Bench Cut	 Bench length <D.	Deformation control of the excavated inner section is more urgently required than in the case of the Short Bench Cut. Squeezing ground that require an early closure of the excavated section	Easy to make early closure of the invert.	Scaffolding is required for the top heading excavation. Selection for construction machine tends to be limited for top heading
Center Diaphragm Method		 One method is to provide a diaphragm only to	Ground of shallow overburden where ground surface settlement is required to be kept at a minimum. Comparatively poor ground condition for a large section tunnel.	Face stability is secured by dividing into small sections. Ground Surface settlement can be significantly reduced. Divided sections of heading are larger than	Displacement or settlement during the removal of the diaphragm shall be checked. Time for diaphragm removal is added to the construction period. The adoption of a special

Excavation Method	Division of Section of Heading	Applicable Ground Condition	Advantages	Disadvantages
	the top heading, while the other is to provide both a top heading and a bench.		those used in the Side Drift Method, and larger machines can be used.	auxiliary method in the tunnel is difficult.
Side Drift Method		Bearing capacity of the ground is not sufficient for adopting the Bench Cut Method. Ground of shallow overburden where ground surface settlement is required to be kept at a minimum.	Ground surface settlement can be reduced. Temporary diaphragms can be more easily removed than those of center diaphragm method.	Small machines have to be used for drift excavation.

Tunnel excavation is designed to be commenced from both portals. Excavation from the western portal is in ascending direction. This eases the excavation by providing natural drainage downward towards the portal. On the contrary excavation from the eastern portal is in descending direction and drainage of groundwater shall be done by pumping.

9.5.3 Sequence of Tunneling

Figure 9.5-2 shows the overall flow chart of procedure of micro bench-cut excavation and **Figure 9.5-3** illustrates the sequence of excavation.

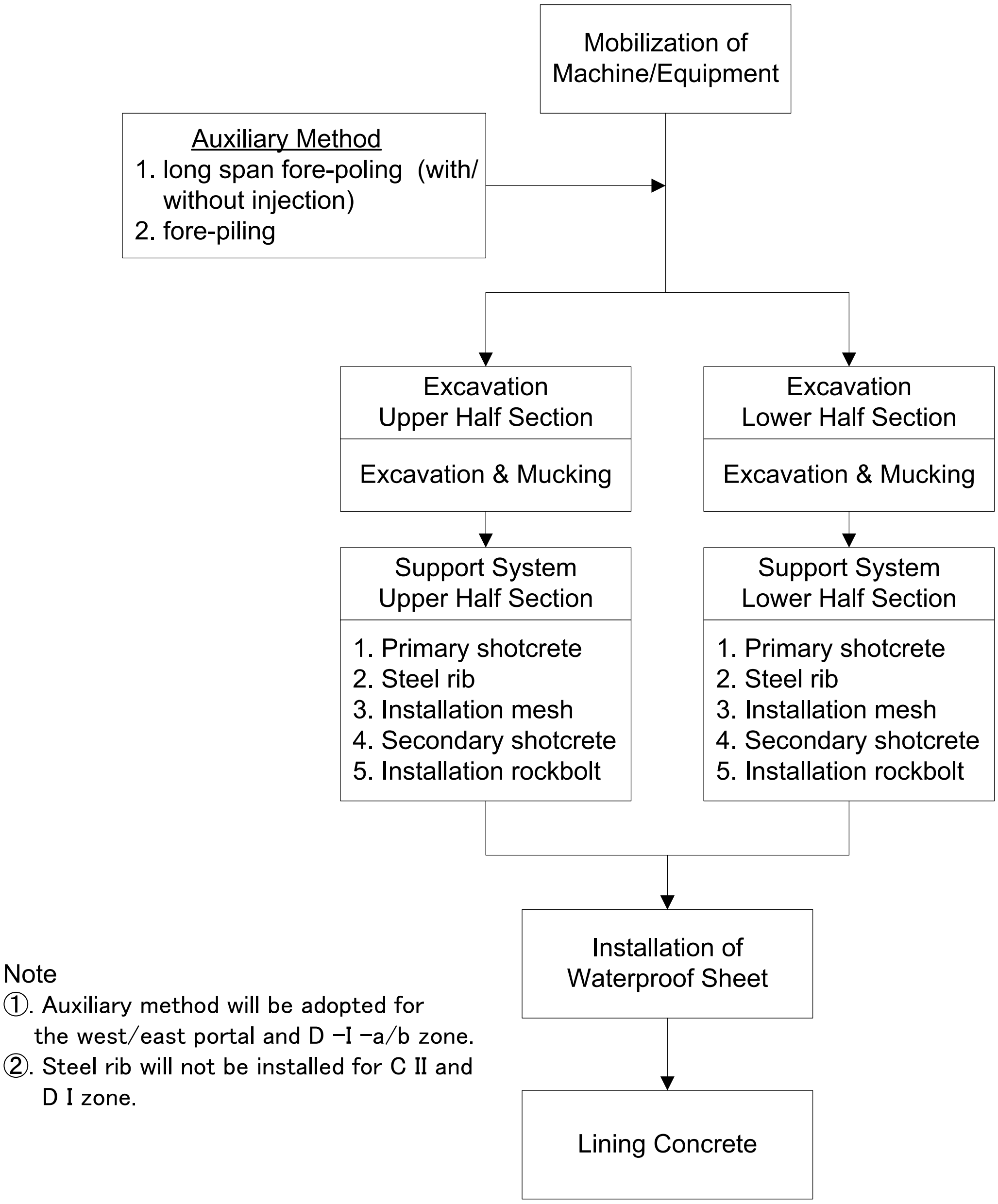


FIGURE 9.5-2 PROCEDURES OF MICRO BENCH-CUT EXCAVATION

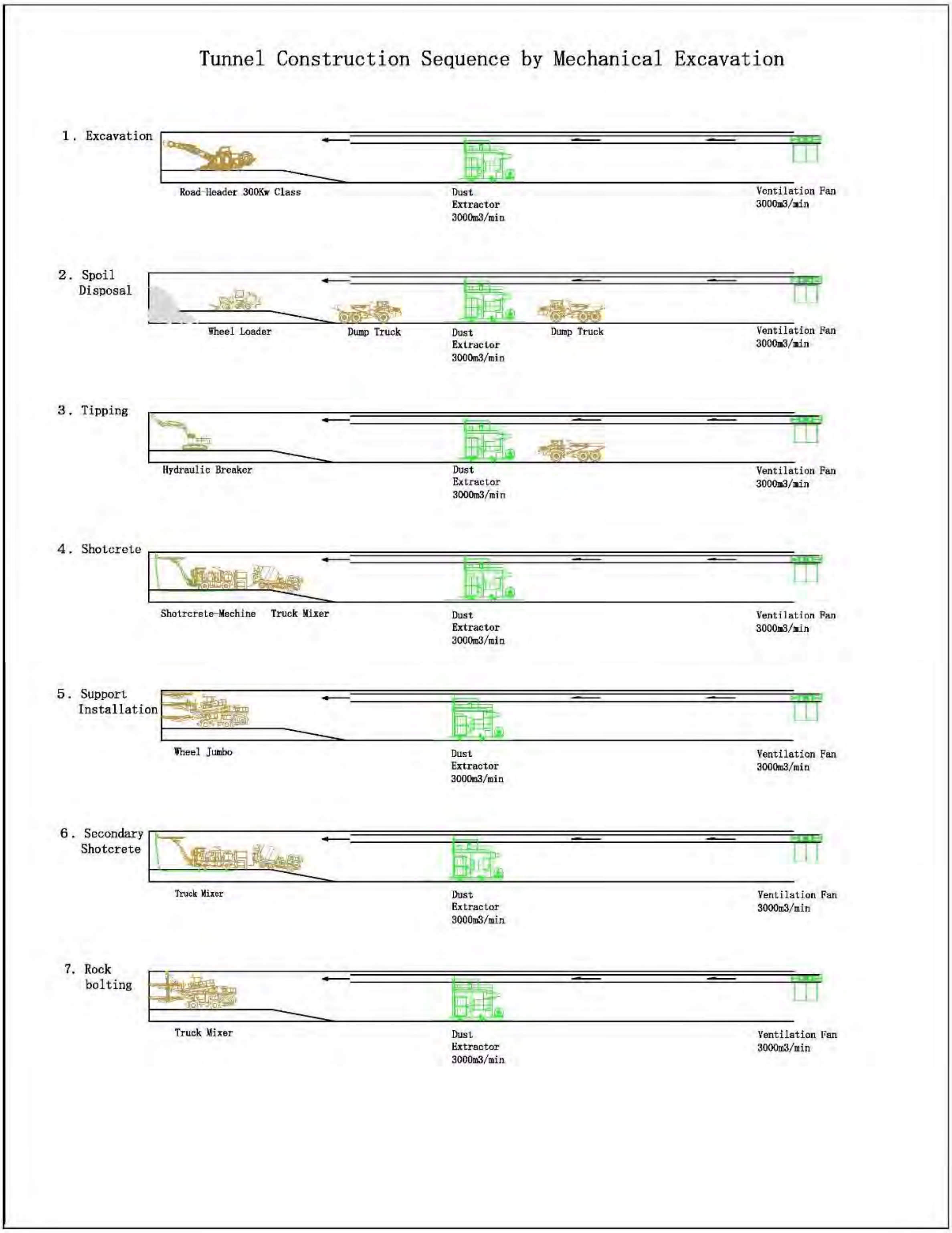


FIGURE 9.5-3 SEQUENCE OF MECHANICAL EXCAVATION

(1) Tunnel excavation and support installation

Excavation from western portal

After finishing mobilization and preparation work at western portal area, which include construction of water channel along small valleys at both sides of the tunnel and along a valley in front of the tunnel, preparation of temporary yards at both sides of the tunnel and installation of temporary facilities start. During this period slope in front of the portal shall be cut and protected by shotcrete and rockbolts or by free-flame and provide yards for tunneling operation.

Portal excavation then starts. First 17.5m long section is to be excavated by applying DⅡ Support Pattern with fore-poling. Fore-poling, 3m long, is constructed at first from the portal slope and mechanical excavation starts at upper half section by the length of 0.75m to 1.0m and immediately after excavation primary shotcrete is applied to stabilize the excavated surface. Steel support, H150, is installed then and secondary shotcrete is carried out. Rockbolts are drilled and fixed and mechanical excavation continues in lower half section and supports are installed continuously. Then next cycle fore-piling is constructed and upper-half excavation starts.

Thin shotcreting may be required for the excavation face area to stabilize the poor rock mass. Tunneling continues till 17.5m long from the portal and then tunneling continues by applying Support Pattern CⅡ towards eastern portal.

Whenever fore-poling or fore-piling is required it is executed before commencement of next cycle excavation utilizing the H-steel support as a guidance. Fore-poling is 3m long and is executed in every excavation cycle where required by designated support pattern. On the contrary fore-piling is 12m long and after execution of fore-poling tunnel is excavated by 9m long continuously through applying designed support. After excavation of 9m is completed next fore-piling starts.

Fore-piling is generally installed in arch section with injection of cement material to reinforce the area surrounding fore-piling. However, when it is required to provide water-tight zone around the whole tunnel periphery fore-piling is installed with chemical injection to all the periphery of tunnel including invert.

When mechanical excavation encounters hard sandstones giant breaker is to be used or several holes are drilled by drilling jumbo to ease the mechanical excavation.

Excavation from eastern portal

In the eastern portal area construction activity can be started independently from tunneling in western portal. Gentle slope is to be cut till about 8m coverage above the tunnel is ensured. During the open cut activity existing village road shall be diverted. As for the groundwater treatment in the portal area to minimize the groundwater level shall be referred to 9.7.1 (2).

After finishing preparatory work tunnel excavation starts. Support Pattern DⅡ shall be applied till the zones where chemical injection from surface has been carried out. Afterwards tunneling continues by applying DⅡ-a Pattern which accompanies installation of fore-piling with chemical injection to establish watertight structure. Tunneling in descending gradient is scheduled to continue till about 520m from the portal. When tunneling from western portal delays tunneling from eastern portal should be continued to further west.

(2) Lining Concrete

Secondary lining concrete, to be commenced from both portals, follows the excavation about several hundred meters to thousand meters apart. Behind the lining concrete water-proofing sheets are fixed in order to prevent the groundwater entering into the tunnel through joints and cracks of the lining concrete.

In portal area where non-uniform overburden loads acting permanently lining concrete shall be reinforced by steel bars but in other section steel reinforcement is not required. Arch shaped steel-form is to be used for secondary lining concrete.

(3) Muck Disposal

Excavated material is loaded onto the dump trucks by shovel and is transported inside the tunnel till portal area. Muck then shall be transported by dump-cars to the spoil disposal area. In western portal muck is transported by dump truck to the disposal area in the valley in front of portal. In the eastern portal muck will be transported by dump cars to the temporary storage yards within the ROW area in approach road.

(4) Observation and Measurement

Observation and measurement is the key monitoring activity in NATM to confirm the stability of the tunnel.

Observation of geotechnical condition of the excavated face and condition of already supported tunnel are to be carried out as a daily activity and are to be recorded on the sheets and stored for later review.

Measurement of the rate of deformation of the tunnel is to be carried out once a day at the face area to confirm the adequacy of the support installed. If deformation rate of tunnel is larger than expected then additional support is installed to confine the deformation. With the progress of tunnel measurement behind the face area is to be done once a week or once a month and when deformation is confirmed to have finished measurement is no more required there.

Measurement is generally done by electro-optical distance measuring instrument. It measures the deformation of the tunnel by measuring the displacement of the monitoring pins fixed on the shotcrete. Results of measurements are recorded in the data sheets and are analyzed after each measurement whether tunnel is getting stability or not and are stored for later review.

Figure 9.5-4 shows the flow chart of observation and measurement.

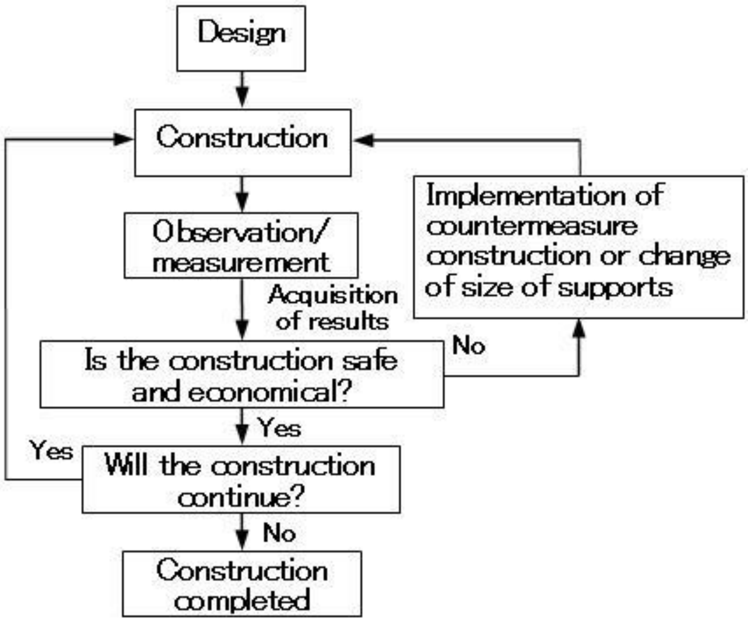


FIGURE 9.5-4 FLOWCHART OF OBSERVATION AND MEASUREMENT

(5) Preservation of Groundwater Level

Along the tunnel alignment surface water flow and groundwater are utilized for various purpose by inhabitants. Especially in the eastern portal area and Thosne Khola area tunnel passes in thin rock cover and preservation of groundwater level shall be very important.

To preserve the groundwater level in the eastern portal area as much as possible, about 100m long section of the tunnel from the portal is designed to be watertight. Chemical injection from the surface ground or by the use of long- span fore-piling shall be done for this section of the tunnel.

As for Thosne Khola area about 200m long tunnel section will be excavated using long span fore-piling with chemical injection.

Whenever significant water ingress from the shotcrete surface is observed additional chemical injection shall be carried out by drilling holes for injection.

(6) Drainage Inside the Tunnel

The tunnel is descending to the west and parts of the eastern approach road descends to the tunnel. Thus it is important to manage the rainfall water adequately. Drainage system shall have enough capacity for the future climate change also. Some of the rainfall water from the approach road shall be drained off before entering into the tunnel adequately.

In the tunnel at both sides of the bottom of tunnel shall be equipped with U-shaped water channel other than center drain. Water from the tunnel then shall be gathered at outside the western portal into water storage tank and then discharged to the drainage system to be provided in the valley in front of the tunnel or used for other purposes.

Details of drainage system shall be suitably studied and designed in Detail Design Stage.

9.6 AUXILIAR METHODS

Some of the auxiliary methods are already explained and being designed in the support patterns such as fore-poling and fore-piling in Type DⅠ-a and b and Type DⅡ and DⅡ-a.

When tunneling encounters very poor ground where excavation face is very difficult to self-supporting, shotcreting for the face and rock-bolting for the face are required. Support pattern DⅡ requires long span fore-piling with or without chemical injection depending on the rate of ingress of groundwater. When tunneling encounters fault zones extra auxiliary measures such as injection grouting to improve the strength of the poor ground is required. These auxiliary measures shall be selected adequately in accordance with the nature of the ground encountered during tunneling.

FIGURE 9.6-1 LONG SPAN FORE-PILING IN DIFFICULT GROUND

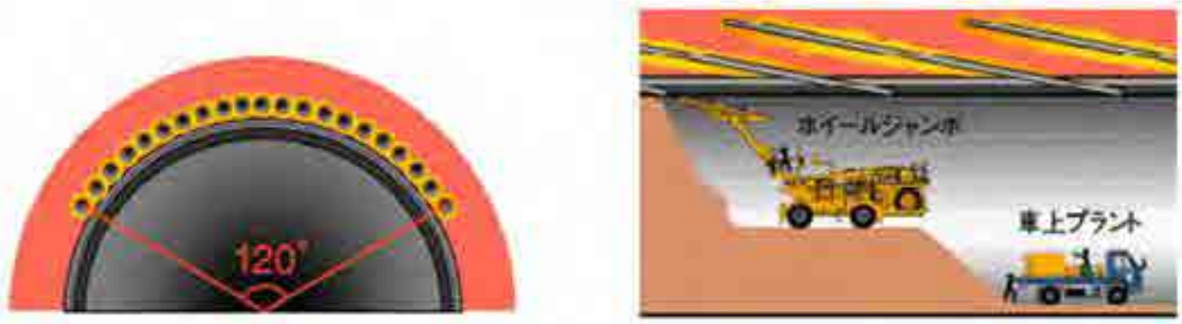


FIGURE 9.6-2 IMAGE OF EXECUTION OF LONG SPAN FORE-PILING

Figure 9.6-1 and **Figure 9.6-2** shows the schematic view of long span fore-piling. **Figure 9.6-3** shows the procedure of typical long span fore-piling, named AGF (All Ground Fastening).

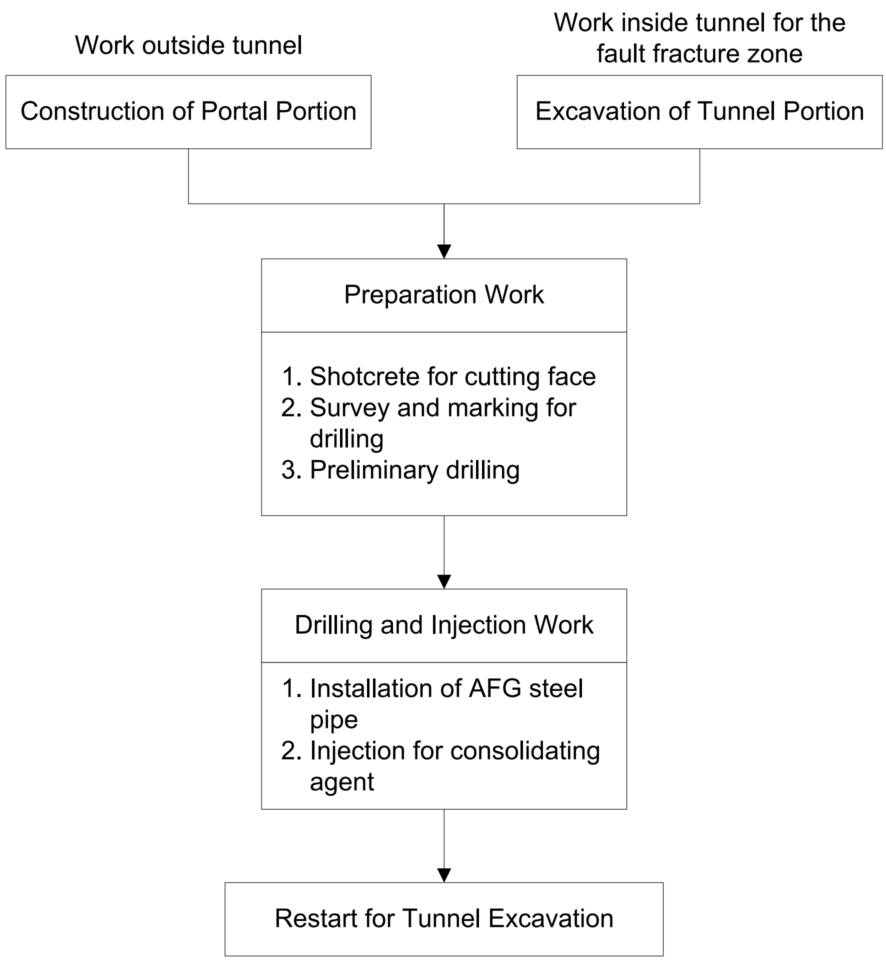


FIGURE 9.6-3 PROCEDURE OF AGF

9.7 DESIGN OF TUNNEL PORTALS

Tunnel portal shall be located where slope is stable and natural drainage system is not harmful for the structure. Preservation of natural environment is also required. Considering these issues tunnel portals are fixed.

9.7.1 Eastern portal

Eastern portal is located in a very gentle slope where several houses exist and land is used for agriculture. To reduce numbers of houses to be demolished or affected by tunneling as much as possible, portal is fixed in the foot of the slope. Construction of the portal requires cutting of the gentle slope to some extent. Cut slopes are protected permanently by shotcrete and rockbolts or other slope protection measures and decorated by terraced flowers or grasses.

(1) Protection of houses near tunnel portal in eastern portal area

There are several houses near the tunnel portal. However, nearest house to the portal situates at about 60m apart from the tunnel portal. Adequate slope protection is designed at the portal area and tunnel excavation is to be done mechanically houses are not affected by tunnel construction activities.

At No.2 + 700 there are two houses which are about 35m from the periphery of the tunnel. Mechanical tunnel excavation at this distance has no influence to the stability of the houses and very small level of vibration and noises are felt by the inhabitants.

Thus tunnel excavation as well as open cut excavation at the eastern portal area may not be a harmful activities to the houses and residents.

(2) Treatment of groundwater at eastern portal area

Basic concept of the design (see Sheet NO. 21 of the Preliminary Design Drawings)

To minimize lowering of groundwater level at eastern portal area series of chemical injection is designed. Objective of the chemical injection is to minimize the lowering of groundwater level but not to get perfect watertight structures in the area.

In this concept and for the ease of open cut excavation in the area, groundwater level is to be lowered to some extent along the slope above and east of tunnel.

- Open cut from No.2 + 880 to the east shall use gravity dewatering pumping well to lower the groundwater level by about 3m.
- Zones from No.2 + 790 to No.2 + 880 shall be grouted by chemical injection from the surface to the depth 3m deeper than finished grade of tunnel and road.
- Dimension of chemical injection is determined by the hypothesis that groundwater level may be lowered by about 3m from the existing one through dewatering by gravity well pump and dewatering by the weep holes in the retaining wall in the future.

Sequence of chemical injection is as following;

- Chemical injection from the surface at No.2 + 790 to No.2 + 820 where open cut of the slope for tunnel portal starts.
- Chemical injection area is extended from here to both sides to cover the open cut excavation of north and south walls.
- Chemical injection continues till No.2 + 880
- After completion of chemical injection works, open cut excavation starts from several locations, from tunnel portal area and from east of it.

Longitudinal cross section and profile of the area for chemical injection from the surface is shown in the **Sheet NO. 21 of the Preliminary Design Drawings**.

In the commencement of portal excavation long span fore-piling is to be carried out with chemical injection. **Figure 9.7-1** shows the typical example of the method.

Tunnel entrance structure will be similar to that shown in **Figure 9.7-2**.

(3) Drainage of the surface water

The small stream at southwest of the tunnel portal flowing to southeast shall be reconstructed into new water channel in order not to inundate into the portal area during heavy rainfall. On the cut slope in portal area water channels are designed to drain the rainfall to the outside of the structure.

Rainfall waters from the approach road is designed to be drained by the water channels along both sides of the road and are led to the underground water tank in the tunnel entrance and then drained to western portal area through water channels fixed at both sides of the tunnel.

FIGURE 9.7-1 TYPICAL EXAMPLE OF PORTAL EXCAVATION USING LONG SPAN FORE-PILING

FIGURE 9.7-2 TUNNEL ENTRANCE STRUCTURE

9.7.2 Western portal

(1) Slope stability

Western portal situates in the foot of cut slope beneath the moderately steep slope. Cut slope shall be protected by shotcrete and rockbolts or by free-flame for permanent stability. Thus required width of space is provided for the working space for tunneling. Tunnel is to be connected to the existing road which is to be partially relocated.

Strikes of the strata in the slope in front of the tunnel are sub-parallel to the tunnel axis with high dip angles, slope is generally stable here. However, the slopes at both sides of the tunnel are rather instable due to the strikes of the strata which requires adequate protection measures during construction.

While the rock mass in the tunnel portal area is deemed to be of Class CⅡ owing to the slope cut, excavation of the portal area, 17.5m long, is designed to be constructed by D-Ⅱ pattern.

(2) Drainage system

In the small valleys at both sides of the tunnel which are scheduled to be used as temporary construction yard for installation of temporary facilities and stock yard, water channels are designed and led to the valley in front of portal where continuous channels, composed of 2m diameter corrugate pipes, are designed which have enough capacity for the future climate change (see **Sheet App.10 of the Preliminary Design Drawings**). Tunnel portal and new road shall be protected by debris flow from these two small valleys and debris flow prevention dams are designed accordingly.

Entrance structure of the tunnel may be similar to that shown in **Figure 9.7-3**.

FIGURE 9.7-3 TUNNEL ENTRANCE STRUCTURE

9.8 TEMPORARY FACILITIES AND EQUIPMENT NECESSARY FOR TUNNEL CONSTRUCTION

Major temporary facilities consist of water treatment plant for contaminated water from the tunnel, concrete batching plant for shotcrete and lining concrete, diesel generators for electric supply, air compressors for shotcrete and other activities, ventilation fan and dust collector to keep inside the tunnel clean and temporary houses for office and labor camps and so on. Detail is shown in the **Table 15.5.3-1 in Chapter 15**.

9.9 FACILITIES NECESSARY FOR INSIDE AND OUTSIDE TUNNEL

9.9.1 General

Those mentioned below are facilities to be installed for the road tunnel (inside and outside) to secure the safe and smooth traffic flow.

- Ventilation Facilities
- Lighting Facilities
- Emergency Facilities
- Others

(1) Facilities for the Inside of Tunnel

The facilities to be installed inside of tunnel are shown on **Table 9.9-1**.

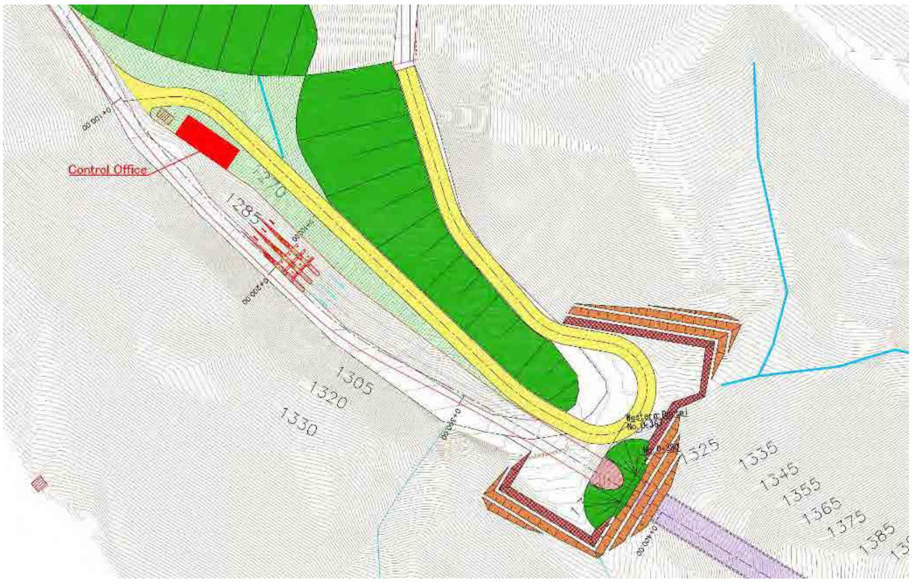
TABLE 9.9-1 FACILITIES TO BE INSTALLED TUNNEL INSIDE

Facilities	Name of Equipment
Tunnel Ventilation	Jet fan, CO meter, VI meter, AV meter
Tunnel Lighting	Interior Lighting, Entrance Lighting, Emergency Lighting
Emergency Facilities	Emergency Telephone, Push Button Alarm, Fire Detector, Fire Extinguisher, Fire Hydrant, Evacuation guide panel, Hydrant, leaky coaxial cable, CC TV Camera, etc.

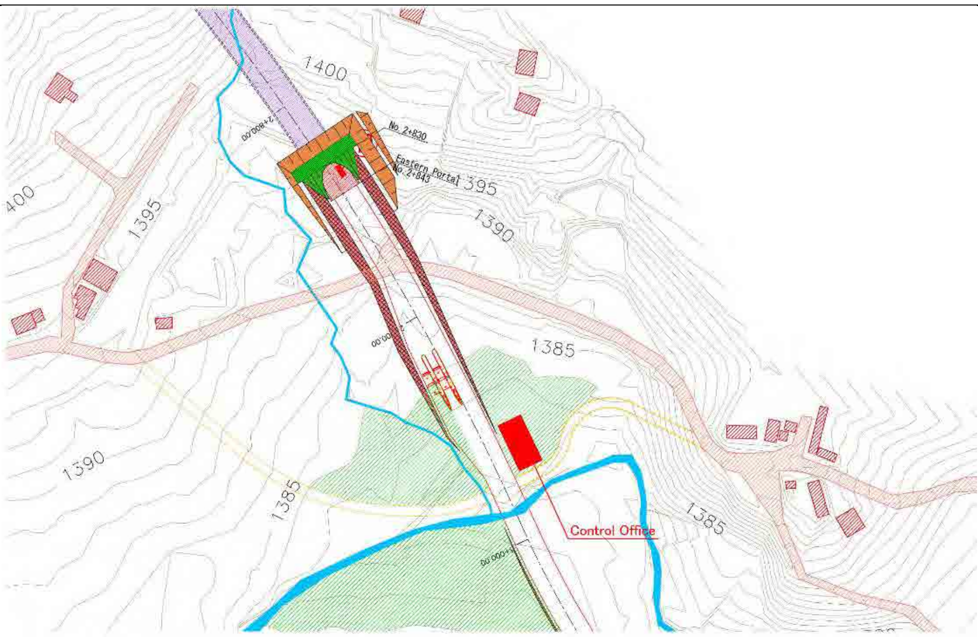
(2) Facilities for the Outside of Tunnel

Control Office will be constructed at West and East Portal Sites shown in **Figure 9.9-1**.

Control Office	**Detail of the Control Office**
Control Office-1 (West Portal Side)	**Sub-control Office** Office Area: 390m^2 **Function:** - Administration building for toll-collection-related staffs - Administration building for emergency staffs (support for main control office) - Parking area of emergency vehicles **Facilities:** -Building ✓ Sub-Monitoring room and control room ✓ Equipment room ✓ Toll management room ✓ Staff room (Multiuse room) ✓ Others (Toilet, Kitchen, Nap room) -Parking space (2 lots)
Control Office-2 (East Portal Side)	**Main Control Office** Office Area: 300m^2 **Function:** - Administration building for tunnel operation, monitoring, and maintenance staffs (installation of related facilities) - Administration building for toll-collection-related staffs - Parking area of tunnel maintenance vehicles and emergency vehicles **Facilities:** -Building ✓ Main-Monitoring and Main-Control room ✓ Equipment room (Control panel etc..) ✓ Toll management room ✓ Staff room (Multiuse room) ✓ Others (Toilet, Kitchen, Nap room) -Parking space (10 lots)



Control Office-1 (West Portal Side)



Control Office-2 (East Portal Side)

FIGURE 9.9-1 LOCATION MAP OF CONTROL OFFICE

The facilities to be installed outside of tunnel are shown on **Table 9.9-2**.

TABLE 9.9-2 FACILITIES TO BE INSTALLED TUNNEL OUTSIDE

Facilities	Name of Equipment
Tunnel Ventilation	Local control panel
Tunnel Lighting	Lighting outside the Tunnel Entrance, Local control panel, etc.
Emergency Facilities	Local control panel, Water supply Pump, Water tank, Pump panel, Information board at tunnel entrance, Outside hydrant, Emergency Telephone, Wireless terminal box, etc.
Others	Electrical room, Management office, Power supply system, Back up generator, UPS Tunnel facilities remote control system, Remote monitoring system, Transmission system, , Building Facilities

9.9.2 Ventilation Facilities

(1) Purpose of Ventilation

The ventilation system is very much necessary to secure the safe and comfortable driving inside tunnel; also it shall contribute for the better circumstance for the superintendants that are used to manage the tunnel maintenance work. For that purpose, the important factor is to alleviate the harmful substances from the emission of vehicles, which may cause the instinctive dislike, and to make the good visual field.

(2) Design Criteria

It is recommendable to apply “Japan Road Tunnel Ventilation Standard on 2001” for Nagdhunga Tunnel, in consideration of environment criteria and social conditions in Nepal.

(3) Design Conditions

The design conditions is described as mentioned below. It is considered upon the basis of “Japan Road Tunnel Ventilation Standard on 2001” and some factor is added in taking account of environment/social situation in Nepal.

- Length of Tunnel: 2,450m
- Longitudinal gradient: ＋3.22%（rising gradient from West to East）
- Tunnel altitude: average altitude is 1,340m
- Cross section of tunnel: 72.3m^2
- Hydraulic diameter: 8.5m
- Traffic conditions: Two way traffic
- Designed velocity inside tunnel: 40km/h
- Expected traffic volume and mix rate of big-sized car

Year 2020：Traffic volume = 7,400 unit/day, Mix rate of big-sized car = 55.4%

Year 2025：Traffic volume = 8,100 unit/day, Mix rate of big-sized car = 55.6%

Year 2030：Traffic volume = 9,500 unit/day, Mix rate of big-sized car = 55.8%

Year 2035：Traffic volume = 8,100 unit/day, Mix rate of big-sized car = 49.4%

The factors used for making Design Conditions are shown on the **Table 9.9-3**.

TABLE 9.9-3 FUTURE TRAFFIC VOLUME
(WITH SINDHULI RD: 2025, FAST TRACK RD: 2031)

Future traffic volume (with Sindhuli Rd : 2025, Fast Track Rd. : 2031) ①=②+③ (veh/day)

Year	2020			2025			2030			2035		
Direction	Eastbound	Westbound	Total	Eastbound	Westbound	Total	Eastbound	Westbound	Total	Eastbound	Westbound	Total
Passenger Car	1,100	1,300	2,400	1,400	1,400	2,800	1,500	1,700	3,200	1,500	1,700	3,200
Micro Bus	500	700	1,200	500	700	1,200	600	900	1,500	600	900	1,500
Mini Bus	300	400	700	300	500	800	400	500	900	300	500	800
Large Bus	900	1,000	1,900	1,000	1,100	2,100	1,200	1,400	2,600	1,100	1,300	2,400
Light Truck	600	200	800	600	200	800	700	200	900	600	200	800
Heavy truck	1,200	1,800	3,000	1,300	1,900	3,200	1,600	2,100	3,700	1,000	1,400	2,400
Total	4,600	5,400	10,000	5,100	5,800	10,900	6,000	6,800	12,800	5,100	6,000	11,100
% Large	45.7%	51.9%	49.0%	45.1%	51.7%	48.6%	46.7%	51.5%	49.2%	41.2%	45.0%	43.2%

Number of Vehicles on Tunnel Section ② (veh/day)

Year	2020			2025			2030			2035		
Direction	Eastbound	Westbound	Total	Eastbound	Westbound	Total	Eastbound	Westbound	Total	Eastbound	Westbound	Total
Passenger Car	900	900	1,800	1,100	1,000	2,100	1,200	1,200	2,400	1,200	1,200	2,400
Micro Bus	400	500	900	400	500	900	500	600	1,100	500	600	1,100
Mini Bus	0	0	0	0	0	0	0	0	0	0	0	0
Large Bus	800	800	1,600	900	900	1,800	1,100	1,100	2,200	1,000	1,000	2,000
Light Truck	500	100	600	500	100	600	600	100	700	500	100	600
Heavy truck	1,100	1,400	2,500	1,200	1,500	2,700	1,400	1,700	3,100	900	1,100	2,000
Total	3,700	3,700	7,400	4,100	4,000	8,100	4,800	4,700	9,500	4,100	4,000	8,100
% Large	51.4%	59.5%	55.4%	51.2%	60.0%	55.6%	52.1%	59.6%	55.8%	46.3%	52.5%	49.4%

Number of Vehicle on Existing road ③ (veh/day)

Year	2020			2025			2030			2035		
Direction	Eastbound	Westbound	Total	Eastbound	Westbound	Total	Eastbound	Westbound	Total	Eastbound	Westbound	Total
Passenger Car	200	400	600	300	400	700	300	500	800	300	500	800
Micro Bus	100	200	300	100	200	300	100	300	400	100	300	400
Mini Bus	300	400	700	300	500	800	400	500	900	300	500	800
Large Bus	100	200	300	100	200	300	100	300	400	100	300	400
Light Truck	100	100	200	100	100	200	100	100	200	100	100	200
Heavy truck	100	400	500	100	400	500	200	400	600	100	300	400
Total	900	1,700	2,600	1,000	1,800	2,800	1,200	2,100	3,300	1,000	2,000	3,000
% Large	22.2%	35.3%	30.8%	20.0%	33.3%	28.6%	25.0%	33.3%	30.3%	20.0%	30.0%	26.7%

(4) Type of Ventilation System

There are several types of ventilation system i.e. longitudinal ventilation system, semi-transverse ventilation system, transverse ventilation system and a combination of these types. Longitudinal ventilation system, which is typified by the jet fan, is the most economical and widespread system. Use of jet fans in particular is effective in terms of low running cost, providing ventilation even if vehicles are queuing in the tunnel and removal of smoke in the event of a fire.

(5) Required Air Volume

Required air volume in the tunnel and number of ventilation (jet fan) is calculated based upon the factors described below.

1) Traffic volume per hour

The factor of calculation of ventilation system is dependent upon the time zone of peak hour for the “traffic volume per hour” through the year.

The traffic volume per hour is calculated as follows;

Traffic volume per hour = 9,500 unit/day × K = 9,500 ×10% = 950 vehicles/hr

K = 7~15% in general, so 10 % is adopted for Nagdhunga Tunnel

9,500 unit/day = Traffic volume of Year 2030 (see 9.8.2-(3)), which contains Mix rate of big sized car, γL=55.8%

2) Design value of Co and visibility

Acceptable environment design value of pollutants in the tunnel are shown in the **Table 9.9-4** below.

TABLE 9.9-4 DESIGN VALUES FOR CO AND VISIBILITY

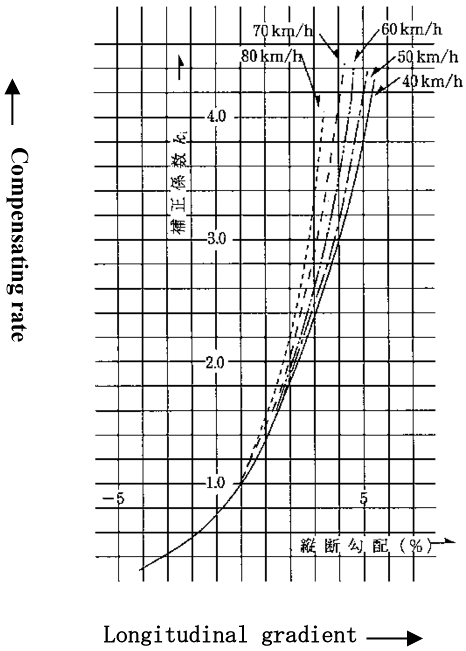
Item	Design Velocity	CO	Visibility Transmissions (beam length: 100 m)
Design Criteria	Above 80km/hr	100ppm	50%
	Below 60km/hr		40%
Nagdhunga tunnel	40km/h	100ppm	40%

3) Basic emission factor, speed & gradient factor and altitude factor

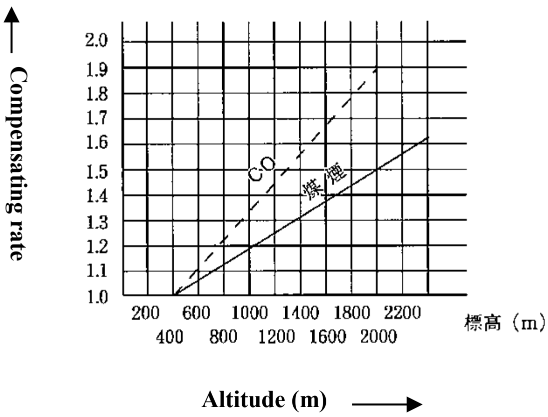
Table 9.9-5 indicates the basic-emission factor, speed and graduation compensating rate and altitude compensating rate.

TABLE 9.9-5 BASIC EMISSION FACTORS

Cars	Particle matter (opacity)		CO
	Average (m^2/km)	Standard valuation (m^2/km)	Average (m^3/km)
Big-sized car	5.1	2.3	0.007
Normal size car	0.5	0.7	



Speed & Gradient compensation factor for PM



Altitude compensation factor for PM&CO

FIGURE 9.9-2 SPEED & GRADIENT COMPENSATION FACTOR AND ALTITUDE COMPENSATION FACTOR

4) Required air volume and number of jet fan

The number of jet fans calculated by the figure of CO and visibility are shown on **Table 9.9-6**.

TABLE 9.9-6 REQUIRED AIR VOLUME AND NUMBER OF JET FAN

year	Traffic (no/hr/h)	Mix rate of Big-sized car (%)	Required air volume (m3/s)		Number of Jet Fan (unit)	
			CO	Visibility	CO	Visibility
2020	740	55.4	54	353	3	17
2025	810	55.6	58	388	3	21
2030	950	55.8	69	456	4	28
2035	810	49.4	58	353	3	17

The maximum number of jet fan shall be adopted; therefore, the number of jet fans shall be twenty-eight (28) units in case of Nagdhunga Tunnel in consideration of 2030. Jet fan shall be "JFX-1250" and those will be set at a distance of 160 m from the tunnel portal and at intervals of 160 m in the tunnel.

It is considered that the traffic volume in Nagdhunga Tunnel will be reduced after 2030, because the traffic will be diverted to the other new road, which is expected to construct by that time.

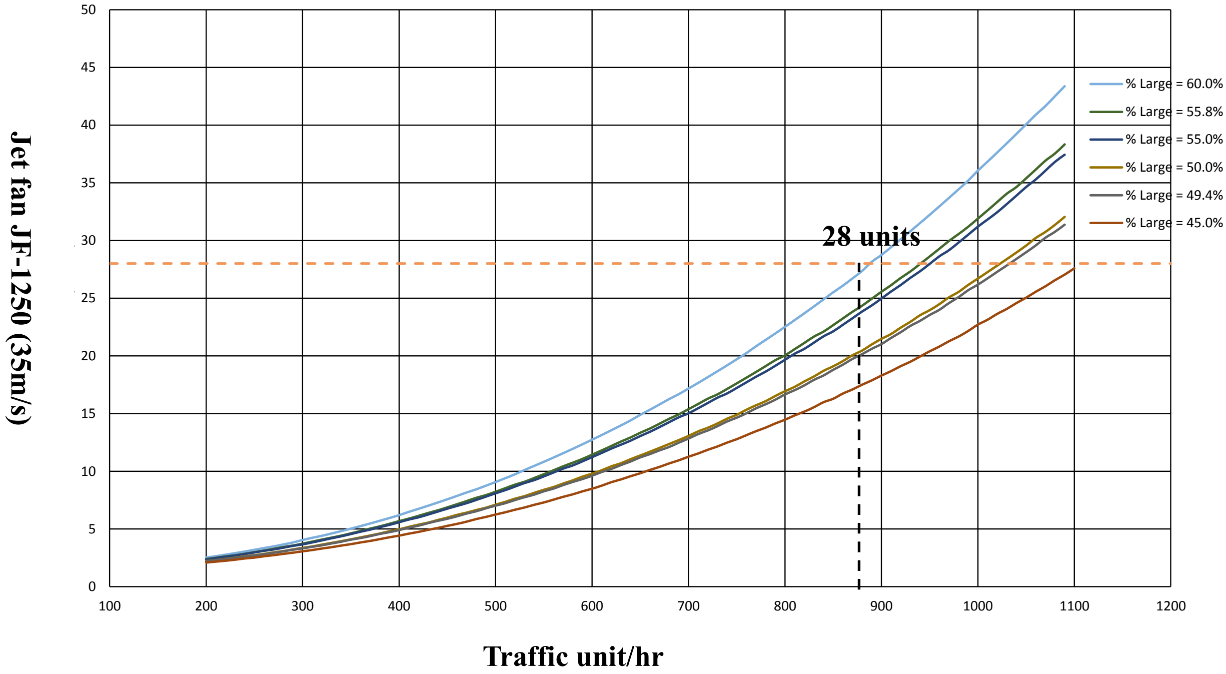


FIGURE 9.9-3 CORRELATION DIAGRAM FOR TRAFFIC VOLUME AND NUMBER OF JET FAN

5) Specification of jet fan

Standard specification of selected jet fan (JFX-1250) is described on **Table 9.9-7**.

TABLE 9.9-7 STANDARDS SPECIFICATION OF JET FAN (JFX-1250)

Specification		JFX-1250
Jet Fan	Diameter of Fan (mm)	1250
	Average Wind Speed (m/s)	More than 35
	Efficiency (%)	More than 75
	Noise (dB(A)	Less than 95
	Length (mm)	4250
	Diameter (mm)	1450

	Specification	JFX-1250
	Flow rate (m^3/s)	More than 43
	Air flow area (m^2)	1.23
	Blow direction	Both Side
Motor	Type	Three phase induction, drip proof type
	Voltage (V)	400
	Motor Power (kW)	Less than 50

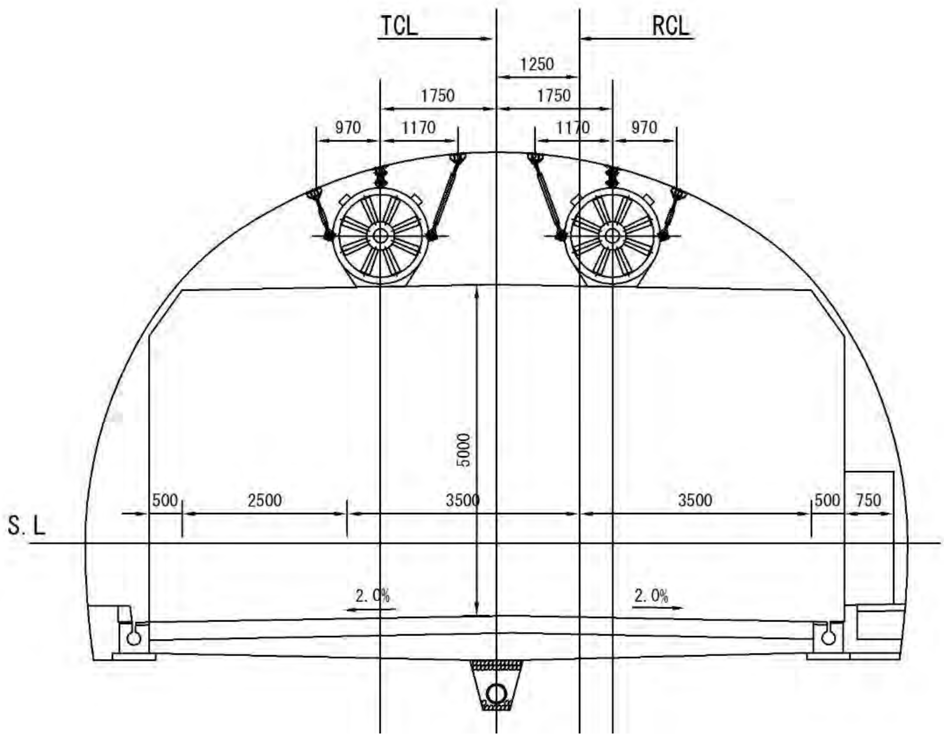


FIGURE 9.9-4 INSTALLATION OF JET FAN

PHOTO 9.9-1 JET FANS INSIDE TUNNEL

(6) Operation of Ventilation for 24 hours（Estimation for 2030）

The 28 units of jet fan shall be installed against the traffic volume per hour at the time of peak hour. The operation frequency of 24 hours on someday of 2030 is estimated on **Table 9.9-8**.

However, the 0～11 units of jet fans may be enough with maneuvering the jet fans in opposite current or vice versa when the traffic flow is not busy. In this case, the accumulated electric energy for one day shall be 5,850 kWh.

TABLE 9.9-8 OPERATION FREQUENCY OF 24 HOURS (IN CASE 2030)

Direction	*East bound*		*West bound*		*Total (East + West)*		*Nos. of JFX-1250*	
Time	*Traffic [veh/h]*	*Large size [%]*	*Traffic [veh/h]*	*Large size [%]*	*Traffic [veh/h]*	*Large size [%]*	*Ventilation Direction*	
							East bound	*West bound*
7	270	77.4	182	44.8	452	64.3	9	15
8	198	70.6	325	41.2	523	52.3	9	8
9	238	56.0	365	44.0	603	48.8	10	8
10	319	47.9	283	42.7	602	45.5	9	11
11	295	35.6	266	42.9	561	39.1	7	7
12	233	40.8	304	47.2	537	44.4	8	5
13	227	43.4	323	50.3	550	47.4	8	5
14	240	36.1	281	51.0	521	44.1	7	5
15	310	37.1	283	51.6	593	44.0	8	8
16	262	33.3	313	59.1	575	47.3	9	5
17	270	33.8	270	60.4	540	47.1	8	5
18	283	22.0	304	69.2	587	46.4	9	3
19	237	34.1	241	81.7	478	58.1	8	4
20	186	46.2	226	91.0	412	70.8	9	4
21	102	36.4	264	94.6	366	78.4	9	0
22	64	35.7	138	90.4	202	73.1	5	1
23	92	53.0	91	89.9	183	71.4	3	2
0	44	48.9	26	81.9	70	61.1	2	2
1	49	61.7	16	96.1	65	70.3	2	2
2	57	70.9	7	27.2	64	66.2	1	3
3	71	65.6	4	75.9	75	66.2	1	3
4	168	86.2	20	69.9	188	84.4	2	9
5	297	97.6	50	83.6	347	95.6	10	24
6	287	95.3	117	67.1	404	87.1	11	22

9.9.3 Tunnel Lighting Facilities

The lighting of the tunnel is very important for securing traffic safety inside the tunnel.

(1) Lighting Composition

Tunnel lighting is composed of Primary Lighting, Entrance Lighting, Back Up Lighting (in case of power cut), and Approach Lighting.

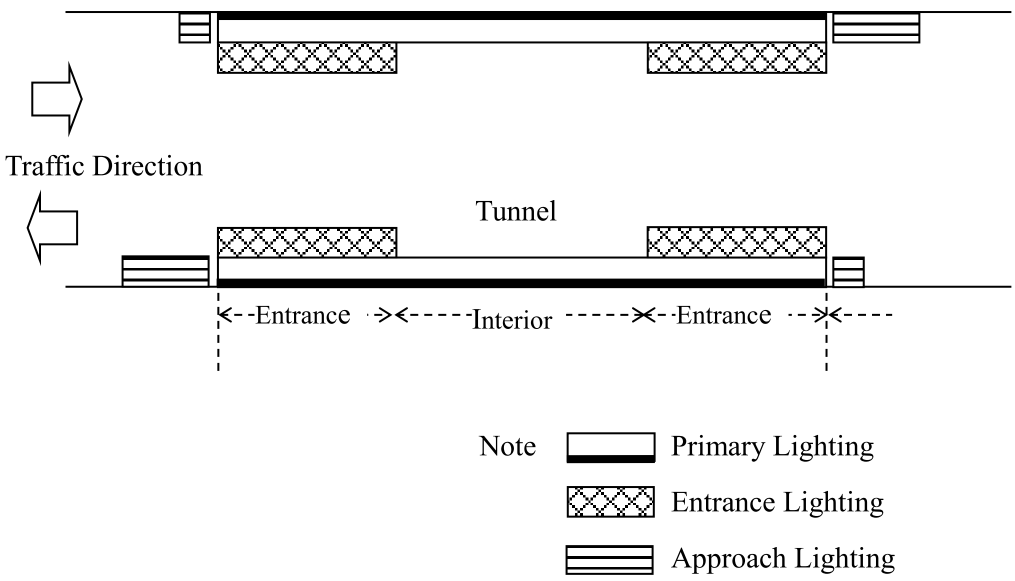


FIGURE 9.9-5 COMPOSITION OF TUNNEL LIGHTING

(2) Light Source

The following factors shall be considered for the selection of lighting sources.

- High efficiency with long life
- Accommodating against to high temperature, durability and humidity
- Appropriate luminescent color
- High luminous flux to meet the required high lighting level
- Easy maintenance
- Low running cost

1) Interior Lighting

Basic lighting levels are determined by the visual distance for the safety driving and not feeling discomfort under the certain velocity, and it shall be provided whole length of the tunnel.

2) Entrance Lighting

Entrance lighting is provided to adjust the difference between the brightness outside tunnel and relatively dark area inside tunnel, especially it happens in day time. Therefore, the lighting at entrance area shall be more luminous than inside of tunnel, so that the driver shall be able to adopt the difference of brightness.

3) Emergency Lighting during Power failure

In case of a sudden loss of power, emergency lighting is required to prevent visual obscuration for the drivers already running in the tunnel. Power shall be supplied from the UPS immediately as uninterruptible power source, and subsequently it shall be connected to the back-up generator.

4) Lighting outside the Tunnel Entrance

The street ramp at the exit of tunnel shall be installed adequately to guide the drivers coming up from the tunnel, especially in nighttime. No street ramp at the exit road may cause the constriction of the visual field of drivers, and may lead the accidents. This street ramp may be applicable with the same type of street ramp used in Kathmandu City.

5) Selection of Light Source

LED lighting is used in common against the conventional light fixtures, because the overall cost is less in respect of durability and power consumption. Therefore, it is recommended to use LED lightings.

Interior Lighting(LED)		
Back Up Lighting (lighting system in case of power cut)		
Entrance lighting		
Lighting outside the Tunnel Entrance		

PHOTO 9.9-2 TUNNEL LIGHTING (LED)

9.9.4 Tunnel Emergency Facilities

(1) General

Tunnel Emergency Facility is the equipment and devices to prevent the accidents caused by the fire inside of tunnel. Counter disaster measures for tunnel are divided into two objectives, which are:

- Prevention of accident
- Minimization of damage from accident

Prevention measures are basically composed of education of tunnel users such as i) to learn the potential of accident in tunnel, ii) cooperation to the tunnel administrators with using the emergency services, and iii) provision of a comprehensive safety and surveillance control system. Counter disaster measures will be carried out not only by the staff of the tunnel management office, but also by the tunnel users themselves. Therefore, public involvement is very important.

(2) Classification of Tunnel and Installation of Emergency Facilities

The tunnel length of 2,450m with daily traffic of 9,500 (as of 2030) is classified for "Class A" tunnel as depicted on **Figure 9.9-6**, which is specified on "Japanese Road Tunnel Safety Standard".

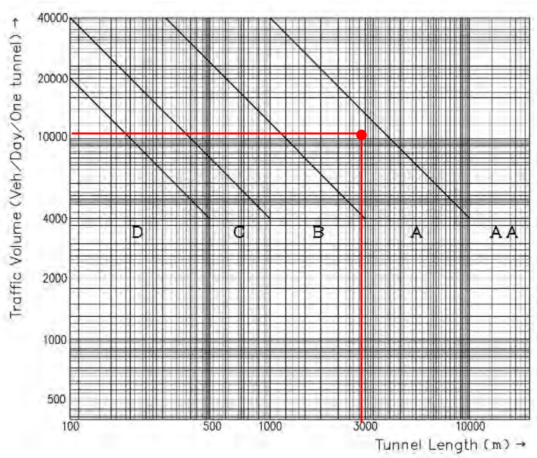


FIGURE 9.9-6 CLASSIFICATION OF TUNNEL

The class A tunnel requires provision of emergency facilities, as shown on **Table 9.9-9**.

TABLE 9.9-9 INSTALLATION STANDARD OF EMERGENCY FACILITIES

Facilities \ Classfication of tunnel		AA	A	B	C	D	Remarks
Information and Alarm Facility	Emergency Telephone	○	○	○	○		
	Push Button Alarm	○	○	○	○		
	Fire Detector	○	△				To be provided in Class A tunnel with Ventilation System or Water sprinkler system.
	Emergency Information board	○	○	○	○		Information board at tunnel entrance
Fire Fighting Facility	Fire Extinguisher	○	○	○			
	Fire Hydrant	○	○				
Evacuation Guide Facility	Guide Board	○	○	○			
	Smoke removal system or Evacuation route	○	△				Ventilation system shall be used for smoke removal. Evacuation tunnel shall be provided for Class A tunnel, 3000m or more in length, bidirectional traffic and longitudinal ventilation system.
Other Emergency Facilities	Hydrant	○	△				To be provided in Class A tunnel with Fire hydrant.
	Radio communication support System	○	△				To be provided in Class A tunnel 3000m or more in length. Required and recommended for tunnel Operation and Maintenance.
	Radio Rebroadcast System	○	△				To be provided in Class A tunnel 3000m or more in length. Required and recommended for tunnel Operation and Maintenance.
	Loud Speaker System	○	△				To be provided in Class A tunnel 3000m or more in length. Class A tunnel with evacuation passage.
	Water sprinkler system	○	△				To be provided in Class A tunnel 3000m or more in length.
	Monitor System	○	△				To be provided in Class A tunnel with Water sprinkler system.

Note : ○ : Mandatory(standard) △ : Recommended

(3) Type of Emergency Facilities

Following emergency facilities will be planed based on “Japanese Road Tunnel Safety Standard”.

Provision of TV cameras to monitor the traffic conditions inside the tunnel is not required by the Japanese Standard. However, this can enable visual monitoring of traffics for obtaining prompt and reliable information of traffic condition inside and outside the tunnel. Therefore, it is decided to facilitate TV cameras in Nagdhunga Tunnel.

TABLE 9.9-10 EMERGENCY FACILITIES

Safety System	Contents	Detail
Information and Alarm Facility	Emergency Telephone	
	Push Button Alarm	
	Fire Detector	
	Emergency Information board	Information board at tunnel entrance
Fire Fighting Facility	Fire Extinguisher	Portable fire extinguisher
	Fire Hydrant	
Evacuation Guide Facility	Guide Board	Evacuation guide panel(LED)
	Smoke removal system	Ventilation System
Other Emergency Facilities	Hydrant	
	Radio communication support System	Wireless Radio System
	Radio Rebroadcast System	
	Monitor System	CCD TV Monitoring System

1) Emergency Telephone

Emergency Telephones will be set at both entrances and at intervals of 200 m in the tunnel.

Emergency Telephone on wall	Emergency Telephone at entrance	Emergency Telephone Box
		

2) Push Button Alarm

Push button alarm system will be set 1.2 to 1.5m above road surface and at intervals of 50 m. This alarm system will connect with the emergency telephone and fire fighting system.

Push Button Alarm with Extinguisher & Fire Hydrant


3) Fire Detector

Fire Detector will be set in the tunnel for automatic detection of fire and at intervals of 50 m. The tunnel entrance information board, lighting system, fire fighting facilities and ventilation system will be operated automatically or receiving a signal from an automatic fire detector.

Fire Detector	
	

4) Emergency Information board

Emergency alarm system will include both visual signals and audible alarm. Flashing lights instructions given by loudspeaker will be effective for aiding evacuation of user.

The information boards must have sufficient communication ability to inform users of conditions inside the tunnel. Information boards shall be set at appropriate locations to avoid any disturbance to fire fighting and/or evacuation of users.

Information board at entrance	Control panel
	

5) Extinguishers

Extinguishers shall be set at intervals of 50m.

6) Fire Hydrants

Setting interval of Fire hydrants is the same as extinguishers, 50m.

Extinguisher & Fire Hydrant

7) Guide Boards

Guide boards are illuminated signs to inform the location of Tunnel portal to road users. Guide board shall be set at t intervals of 200m.

Guide Board (LED)

8) Smoke removal system

The tunnel ventilation system shall be used both as a Smoke removal and tunnel ventilation. Jet fan will act to extract smoke in the event of fire in the tunnel.

Smoke removal system (Jet Fans)

9) Hydrants

Hydrants shall be set at intervals of 200m in the tunnel inside the fire hydrant box. Outdoor Hydrants for use outside the tunnel shall be set at both tunnel entrances.

Outdoor Hydrant


10) Wireless Radio System

Coaxial cable shall be set under the tunnel lighting system or the tunnel center wall to allow for use of radios by tunnel staff and the emergency services.

Wireless terminal box	Coaxial cable
	

11) Radio Re-broadcasting System

Radio re-broadcasting system is secure radio broadcast in tunnel using lead antenna at tunnel entrance. When an emergency occurs in the tunnel, the system shall be used to transmit emergency information radio signals to car users in the tunnel.

Guide Wire for AM Radio


AM aerial wire	Radio Receiving Panel
	

12) Monitor System

The monitor camera system is designed based on the tunnel plan and profile, focal length of cameras, and the size of objectives. Camera shall be installed at 2.8m above road surface, and those shall be installed at Emergency Parking Bay and 150～200m intervals of tunnel.

Arrangement of tunnel equipment is shown in the **Sheet NO.22 of the Preliminary Design Drawings**.

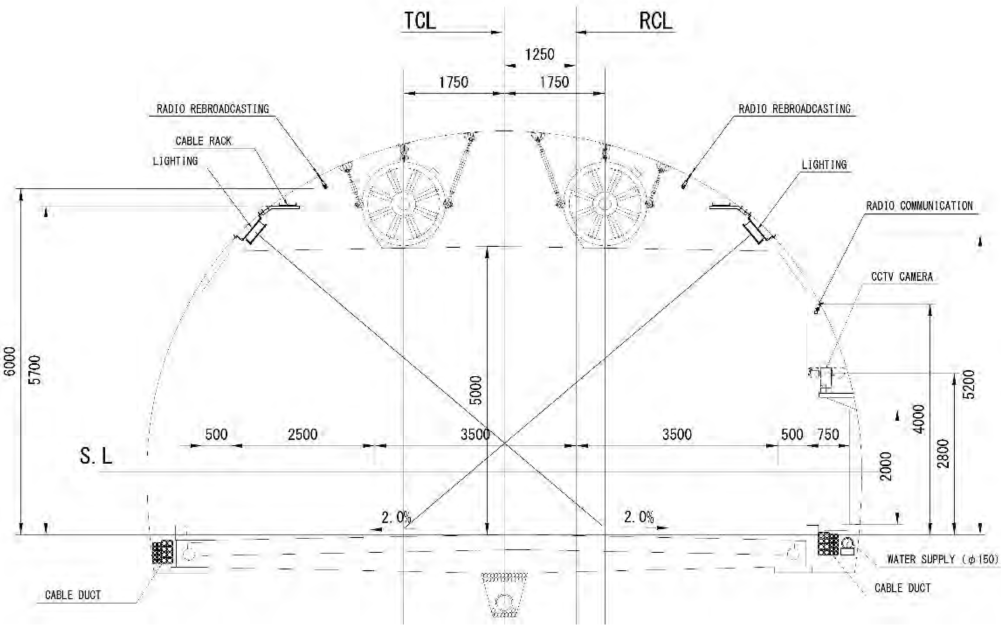


FIGURE 9.9-7 INSTALLATION OF CABLE, WATER SUPPLY, CCTV CAMERA, ETC.

9.9.5 Power Supply System

(1) General

This section is summarizing power supply and back-up system. The back-up system will cover the lighting, 4 units of ventilation fan, water supply and others, which is required minimum function to secure the safe and adequate driving.

(2) Design condition

- Frequency: 50Hz
- Location of Power Supply System: East Electrical room
  West Electrical room

(3) Design Load

The following table shows loads of each system.

TABLE 9.9-11 LIST OF LOADS AT EAST ELECTRICAL ROOM

	Total Load (kVA)	Capacity of Transformer (kVA)
Ventilation 1	523.2	750
Ventilation 2 & Power	431.6	750
Lighting & Others	202.0	300
Total	1156.8	1,800

TABLE 9.9-12 LIST OF LOADS AT WEST ELECTRICAL ROOM

	Total Load (kVA)	Capacity of Transformer (kVA)
Ventilation 1	523.2	750
Ventilation 2	392.4	750
Lighting & Others	202.0	300
Total	1117.6	1,800

TABLE 9.9-13 LIST OF LOAD FOR EAST ELECTRICAL ROOM

Application	Source / Voltage	Capacity	
		kW	kVA
Jet Fan-1	AC 3φ3W 415V	50	65.4
Jet Fan-2	AC 3φ3W 415V	50	65.4
Jet Fan-3	AC 3φ3W 415V	50	65.4
Jet Fan-4	AC 3φ3W 415V	50	65.4
Jet Fan-5	AC 3φ3W 415V	50	65.4
Jet Fan-6	AC 3φ3W 415V	50	65.4
Jet Fan-7	AC 3φ3W 415V	50	65.4
Jet Fan-8	AC 3φ3W 415V	50	65.4
Sub-total			**523.2**
Jet Fan-9	AC 3φ3W 415V	50	65.4
Jet Fan-10	AC 3φ3W 415V	50	65.4
Jet Fan-11	AC 3φ3W 415V	50	65.4
Jet Fan-12	AC 3φ3W 415V	50	65.4

Application	Source / Voltage	Capacity	
		kW	kVA
Jet Fan-13	AC/GC 3φ3W 415V	50	65.4
Jet Fan-14	AC/GC 3φ3W 415V	50	65.4
Fire Fighting Pump	AC/GC 3φ3W 415V	30	39.2
Spare	AC 3φ3W 415V		-
Sub-total			**431.6**
Lighting control	AC 3φ3W 415V		1.0
Entrance Lighting -1	AC 3φ3W 415V		13.0
Entrance Lighting -2	AC 3φ3W 415V		12.5
Entrance Lighting -3	AC 3φ3W 415V		12.0
Entrance Lighting -4	AC 3φ3W 415V		11.5
Interior Lighting -1	AC 3φ3W 415V		5.0
Entrance Lighting -5	AC 3φ3W 415V		13.0
Entrance Lighting -6	AC 3φ3W 415V		12.5
Entrance Lighting -7	AC 3φ3W 415V		12.0
Entrance Lighting -8	AC 3φ3W 415V		11.5
Interior Lighting -2	AC 3φ3W 415V		5.0
Interior Lighting -3	AC 3φ3W 415V		5.0
Lighting outside TN -1	AC 3φ3W 415V		0.5
Lighting outside TN -2	AC 3φ3W 415V		0.5
Spare	AC 3φ3W 415V		-
Spare	AC 3φ3W 415V		-
Sub-total	**AC 3φ3W 415V**		**115.0**
Interior Lighting -4	AC/GC 3φ3W 415V		2.0
Guide Board -1	AC/GC 3φ3W 415V		2.0
Guide Board -2	AC/GC 3φ3W 415V		1.0
Spare	AC/GC 3φ3W 415V		-
Sub-total	**AC/GC 3φ3W 415V**		**4.0**
Interior Lighting -5	INV 3φ3W 415V		2.0
Interior Lighting -6	INV 3φ3W 415V		2.0
Emergency Information board	INV 3φ3W 415V		2.5
Others	INV 3φ3W 415V		6.0
Spare	INV 3φ3W 415V		-
Sub-total	**INV 3φ3W 415V**		**12.5**
CCTV Camera in TN	INV 1φ2W 210V		2.5

Application	Source / Voltage	Capacity	
		kW	kVA
CCTV Camera outside TN	INV 1φ2W 210V		0.5
Spare	INV 1φ2W 210V		-
Spare	INV 1φ2W 210V		-
Subtotal	**INV 1φ2W 210V**		**3.0**
Control Panel -1	INV 1φ2W 105V		2.5
Control Panel -2	INV 1φ2W 105V		2.0
Control Panel -3	INV 1φ2W 105V		1.5
Control Panel -4	INV 1φ2W 105V		1.0
Control Panel -5	INV 1φ2W 105V		0.5
Control Panel -6	INV 1φ2W 105V		1.0
Spare	INV 1φ2W 105V		-
Subtotal	**INV 1φ2W 105V**		**8.5**
Power -1	AC/GC 3φ3W 210V		5.0
Power -2	AC/GC 3φ3W 210V		5.0
Power -3	AC/GC 3φ3W 210V		3.5
Power -4	AC/GC 3φ3W 210V		5.0
Power -5	AC/GC 3φ3W 210V		25.0
Power -6	AC/GC 3φ3W 210V		3.5
Power -7	AC/GC 3φ3W 210V		1.0
Spare	AC/GC 3φ3W 210V		-
Subtotal	**AC/GC 3φ3W 210V**		**48.0**
Panel -1	AC/GC 1φ2W 105V		1.0
Panel -2	AC/GC 1φ2W 105V		1.0
Panel -3	AC/GC 1φ2W 105V		1.0
Panel -4	AC/GC 1φ2W 105V		1.0
Panel -5	AC/GC 1φ2W 105V		1.0
Panel -6	AC/GC 1φ2W 105V		1.0
Panel -7	AC/GC 1φ2W 105V		1.0
Panel -8	AC/GC 1φ2W 105V		2.0
Panel -9	AC/GC 1φ2W 105V		2.0
Spare	AC/GC 1φ2W 105V		-
Subtotal	**AC/GC 1φ2W 105V**		**11.0**
Total			**202.0**

TABLE 9.9-14 LIST OF LOAD FOR WEST ELECTRICAL ROOM

Application	Source / Voltage	Capacity	
		kW	kVA
Jet Fan-1	AC 3φ3W 415V	50	65.4
Jet Fan-2	AC 3φ3W 415V	50	65.4
Jet Fan-3	AC 3φ3W 415V	50	65.4
Jet Fan-4	AC 3φ3W 415V	50	65.4
Jet Fan-5	AC 3φ3W 415V	50	65.4
Jet Fan-6	AC 3φ3W 415V	50	65.4
Jet Fan-7	AC 3φ3W 415V	50	65.4
Jet Fan-8	AC 3φ3W 415V	50	65.4
Sub-total			**523.2**
Jet Fan-9	AC 3φ3W 415V	50	65.4
Jet Fan-10	AC 3φ3W 415V	50	65.4
Jet Fan-11	AC 3φ3W 415V	50	65.4
Jet Fan-12	AC 3φ3W 415V	50	65.4
Jet Fan-13	AC/GC 3φ3W 415V	50	65.4
Jet Fan-14	AC/GC 3φ3W 415V	50	65.4
Spare	AC 3φ3W 415V		-
Spare	AC 3φ3W 415V		-
Sub-total			**392.4**
Lighting control	AC 3φ3W 415V		1.0
Entrance Lighting -1	AC 3φ3W 415V		13.0
Entrance Lighting -2	AC 3φ3W 415V		12.5
Entrance Lighting -3	AC 3φ3W 415V		12.0
Entrance Lighting -4	AC 3φ3W 415V		11.5
Interior Lighting -1	AC 3φ3W 415V		5.0
Entrance Lighting -5	AC 3φ3W 415V		13.0
Entrance Lighting -6	AC 3φ3W 415V		12.5
Entrance Lighting -7	AC 3φ3W 415V		12.0
Entrance Lighting -8	AC 3φ3W 415V		11.5
Interior Lighting -2	AC 3φ3W 415V		5.0
Interior Lighting -3	AC 3φ3W 415V		5.0
Lighting outside TN -1	AC 3φ3W 415V		0.5
Lighting outside TN -2	AC 3φ3W 415V		0.5
Spare	AC 3φ3W 415V		-
Spare	AC 3φ3W 415V		-

Application	Source / Voltage	Capacity	
		kW	kVA
Subtotal	**AC 3φ3W 415V**		**115.0**
Interior Lighting -4	AC/GC 3φ3W 415V		2.0
Guide Board -1	AC/GC 3φ3W 415V		2.0
Guide Board -2	AC/GC 3φ3W 415V		1.0
Spare	AC/GC 3φ3W 415V		-
Subtotal	**AC/GC 3φ3W 415V**		**4.0**
Interior Lighting -5	INV 3φ3W 415V		2.0
Interior Lighting -6	INV 3φ3W 415V		2.0
Emergency Information board	INV 3φ3W 415V		2.5
Others	INV 3φ3W 415V		6.0
Spare	INV 3φ3W 415V		-
Subtotal	**INV 3φ3W 415V**		**12.5**
CCTV Camera in TN	INV 1φ2W 210V		2.5
CCTV Camera outside TN	INV 1φ2W 210V		0.5
Spare	INV 1φ2W 210V		-
Spare	INV 1φ2W 210V		-
Subtotal	**INV 1φ2W 210V**		**3.0**
Control Panel -1	INV 1φ2W 105V		2.5
Control Panel -2	INV 1φ2W 105V		2.0
Control Panel -3	INV 1φ2W 105V		1.5
Control Panel -4	INV 1φ2W 105V		1.0
Control Panel -5	INV 1φ2W 105V		0.5
Control Panel -6	INV 1φ2W 105V		1.0
Spare	INV 1φ2W 105V		-
Subtotal	**INV 1φ2W 105V**		**8.5**
Power -1	AC/GC 3φ3W 210V		5.0
Power -2	AC/GC 3φ3W 210V		5.0
Power -3	AC/GC 3φ3W 210V		3.5
Power -4	AC/GC 3φ3W 210V		5.0
Power -5	AC/GC 3φ3W 210V		25.0
Power -6	AC/GC 3φ3W 210V		3.5
Power -7	AC/GC 3φ3W 210V		1.0
Spare	AC/GC 3φ3W 210V		-
Subtotal	**AC/GC 3φ3W 210V**		**48.0**

Application	Source / Voltage	Capacity	
		kW	kVA
Panel -1	AC/GC 1φ2W 105V		1.0
Panel -2	AC/GC 1φ2W 105V		1.0
Panel -3	AC/GC 1φ2W 105V		1.0
Panel -4	AC/GC 1φ2W 105V		1.0
Panel -5	AC/GC 1φ2W 105V		1.0
Panel -6	AC/GC 1φ2W 105V		1.0
Panel -7	AC/GC 1φ2W 105V		1.0
Panel -8	AC/GC 1φ2W 105V		2.0
Panel -9	AC/GC 1φ2W 105V		2.0
Spare	AC/GC 1φ2W 105V		-
Subtotal	**AC/GC 1φ2W 105V**		**11.0**
Total			**202.0**

Total load demand in MW shows below.

<u>2MW (East Electrical Room:1MW, West Electrical Room:1MW)</u>

1.Ventilation Jet-fan 28 unit* 50kW =1,400kW
2. Tunnel Lighting =300kW
3. Others =less than 300kW
Total 2,000kW

(4) Transformer Capacity

Transformer capacity of each Electrical room is as follows:

1) East Electrical room

- Ventilation Transformer No.1: 750kVA
- Ventilation Transformer No.2: 750kVA
- Transformer for Lighting: 300kVA

2) West Electrical room

- Ventilation Transformer No.1: 750kVA
- Ventilation Transformer No.2: 750kVA
- Transformer for Lighting: 300kVA

(5) Un-Interruptible Power Supply System

Un-Interruptible Power Supply System shall be installed for the following systems which need electricity all the time.

- Tunnel Information Board
- CCTV System
- Safety system control panel

- Remote control system

Capacity of Battery is as follows:

1) East Electrical room

- UPS: 30kVA

2) West Electrical room

- UPS: 30kVA

(6) Back Up Generator

Capacity of back-up generator is as follows:

1) East Electrical room

- Generator Capacity: 300kVA

2) West Electrical room

- Generator Capacity: 300kVA

The back-up generator system can provide the minimum functions of tunnel lighting, emergency facilities' operation in case of power cut. The back-up generator will be installed for 300 kVA at each Electrical room.

The planed back-up system will cover the quarter of lighting (only one side, alternating on and off), 4 units of jet-fan, fire hydrant, CCTV camera and control systems, which is required minimum function to secure the safe and adequate driving. Based on the estimation of ventilation, 4 units of jet-fan will handle 14hours operation in year 2030.

Un-Interruptible Power Supply System shall be also needed to maintain the minimum functions of tunnel lighting and emergency facility's operation during unstable condition of back-up system after just power cut (approximately 10 minutes).

9.10 DISPOSAL AREAS OF EXCAVATED MATERIAL

For shortening the construction period, the tunnel excavation is planned to excavate from the east and west portals. Excavated material of about 52,000 cubic meters comes out from the eastern portal and about 176,000 cubic meters from the western portal.

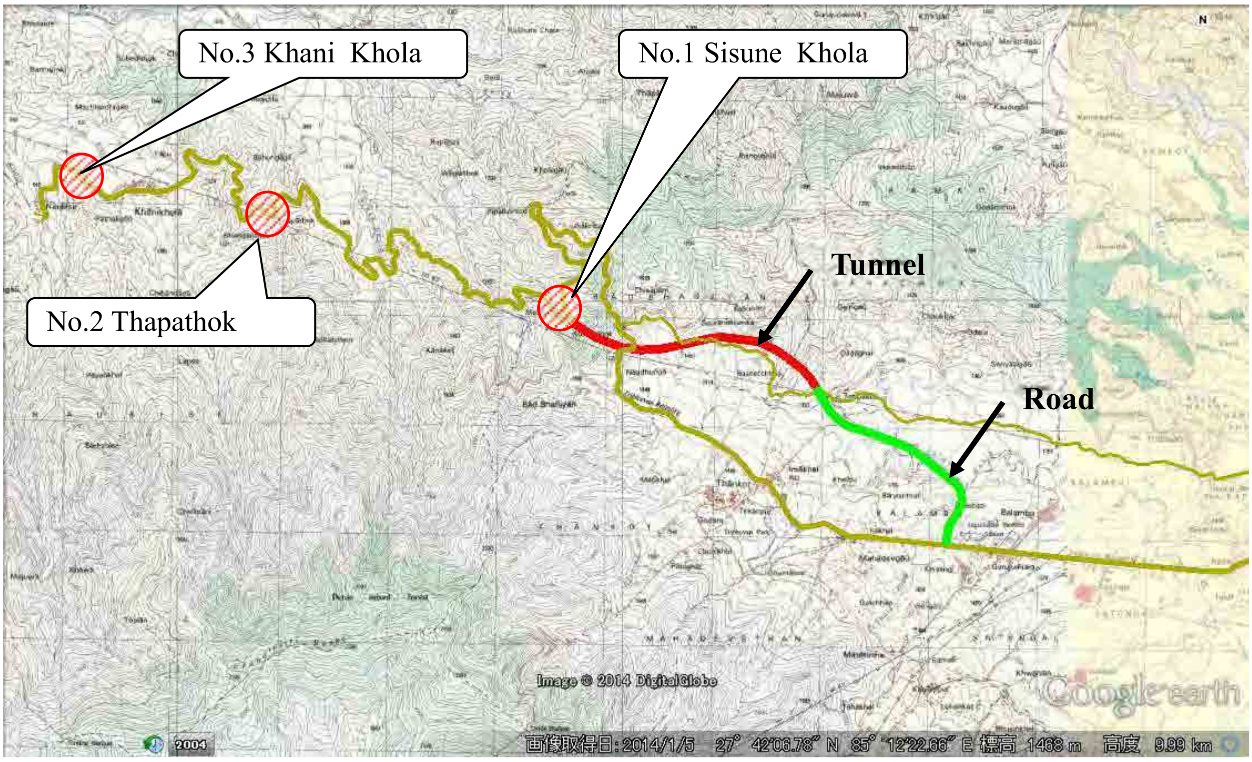


FIGURE 9.10-1 LOCATION MAP OF DISPOSAL AREA

Excavated material out of the eastern portal is planned to be used as fill material for road. Excavated material from western portal is about 176,000 cubic meters and after reviewing several conditions as below listed Sisune Khola valley was selected as spoil disposal site among the three candidate sites shown in the **Figure 9.10-1**.

1. Disposal site shall be close to the tunnel portal for the economy of transportation
2. Disposal site that can contribute to the improvement of the road
3. Disposal site becomes a meaningful place for local residents and road users
4. Compensation for agricultural land is less

Three candidate sites shown in **Table 9.10-1** were compared from above points of view.

TABLE 9.10-1 COMPARISON OF DISPOSAL SITE

No.	Place	Distance	Volume	Feature	Comparison
1	Sisune khoka	100m	300,000	• Close to the tunnel • Secure the land required for the road improvement • Installation of tunnel management facility • Effective use of the tunnel drainage	◎
2	Thapathok	5.3km	140,000	• Substantially horizontal land can be used • Current road can be shortened by 150m • Shortage in capacity	△
3	Khanikhola	8.3km	125,000	Nice view, agricultural products gather from near village, useful for such as Road Station • 5 houses • Shortage in capacity	△

9.11 PLANNING OF POWER TRANSMISSION SUPPLY FACILITY

9.11.1 Identification of NEA grid Substation for Power Supply to the Tunnel

For Power supply to the tunnel operation the nearest located Nepal Electricity Authority (NEA) Grid Substation is 132/11kV Substation at Matatirtha.

NEA has already started construction of 60 MW Trishuli 3A, 38 MW Trishuli 3B, 14.6 MW Upper Sanjen, 42.5MW Sanjen , 111MW Rasuagadhi, 5MW Tadi khola, 4.2 MW Tharpek, 102 MW Upper Trisuli -2 and 5 MW Upper Mailung-A are some other projects being considered connected to the National Grid.

A new 220/132/33kv Substation is being built nearby Upper Trishuli 3B HEP which acts a Hub for the evacuation of Hydro Electric Power generated in Trishuli 3B Hub 220/132kV Substation Project in the Trishuli region. This Substation will be connected with 220 /132kV Matatirtha S/S in Kathmandu by 220 kV double Circuit Distribution line which is in construction stage.

The existing space at 132/11 kV substation at Matatirtha is congested and to house the 220/132kV substation the substation area has to be extended and accordingly NEA has initiated the land acquisition procedure for its extension and for this NEA has published public notice to acquire the required land, on 26 September 2014 and the whole Project work of expansion is expected to be complete within 2016.

With this extension of Matatirtha Substation area, it is easier to plan the route alignment for the outgoing 11kV feeders from the Matatirtha substation, compared to the present condition. But still the problem of fast urbanization causes public grievances for Distribution line alignment. Because of this extension of Substation area in Matatirtha, Distribution line outlet from this Substation to Tribhuvan Highway has been easily possible through cable trenching.

A 22 MVA, 132/11kV, 3 Phase Transformer is installed in Matatirtha Substation to supply the local feeders.

For 11kV Power Supply to Tunnel Operation a separate reliable and dedicated 11kV double circuit transmission System is required and accordingly two separate 11kV feeders are planned from 132/11kVMata Tirtha Substation to the east control room located at tunnel portal and from here by 11kVcable laid on the cable tray anchored on the one side of the tunnel the 11kV Power will be fade to the west control room located at tunnel out let portal.

i) Principally it is possible to have dedicated Power Supply system for the tunnel operation as the ventilation fans and light loads should be fed without any frequent Power outage are vital for movement of vehicles inside the tunnels. For obtaining dedicated 11kV double circuit Distribution line for tunnel operation necessary procedure and applications will be submitted as per NEA Electricity Act at the tunnel construction time.

At Matatirtha Substation 11kV VCBs of ABB Italy made are installed for supply to local feeders and its panel drawings are shown **Figure 9.11-1**.

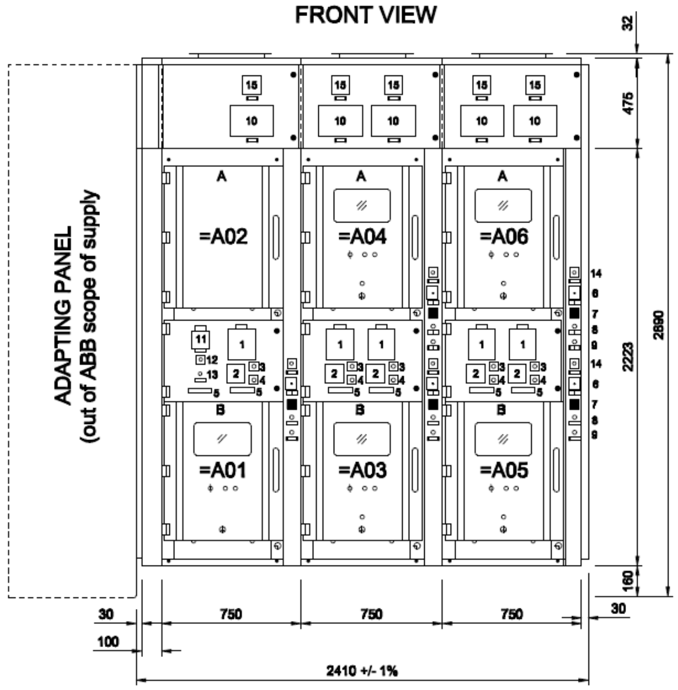


FIGURE 9.11-1 PANEL DRAWING AT MATATIRTHA SUBSTATION

For Power supply to tunnel operations two VCBs of the same make is proposed to install by extending the 11kV bus and by doing so no adaptation panel will be required.

9.11.2 Power Supply to Tunnel Operation

To supply Power to the tunnel, two control rooms one near to the west wide tunnel portal (West Control Room) and another near the east side tunnel portal (East Control Room) are planned.

Basically the tunnel length is 2.45KM long and have jet-fans for ventilation and lights among other facilities. For supply of power to these facilities, an estimated total of 3600 KVA, 11/4.0 kV is required. Two 750KVA, 11/0.4kV and one 300KVA, 11/0.4kV transformers are planned to be installed at the west side control room. Similarly, two750KVA, 11/0.4kV and one 300KVA, 11/0.4kV transformers are planned for installation at the east side control room.

The basic concept to design two control room each of them housing 2x750 kVA transformers and 300kVA transformers of voltage 11/0.4kV at each tunnel portal is that, the one set of ventilation and light loads is fed from east control room and other set of ventilation and light loads is fed from west control room and doing so it minimizes the voltage loss in 400Volt cables, as the length of cable will be halved.

9.11.3 Transformer Capacity

Transformer capacity of each Electrical room is as follows:

(1) East Electrical room

- Ventilation Transformer No.1: 750kVA
- Ventilation Transformer No.2: 750kVA
- Transformer for Lighting: 300kVA

(2) West Electrical room

- Ventilation Transformer No.1: 750kVA
- Ventilation Transformer No.2: 750kVA
- Transformer for Lighting: 300kVA

9.11.4 Un-Interruptible Power Supply System

Un-Interruptible Power Supply System shall be installed for the following systems which need electricity all the time.

- Tunnel Information Board
- CCTV System
- Safety system control panel
- Remote control system

Capacity of Battery is as follows:

(1) East Electrical room

- UPS: 30kVA

(2) West Electrical room

- UPS: 30kVA

9.11.5 Selection of 11kV Cable size for Power Supply

Calculation for 11kV Cable size :

Total Transformer Capacity

East Control room 1800KVA
West Control room 1800KVA
Total load 3600 KVA
Current (I) =236.195675Amps
XLPE Cable size for 3600 KVA shall be
a) 240Sq.mm(resistance =0.1618Ohm/km) or
b) 300 Sq.mm size (resistance= 0,1302Ohm/KM)
Voltage drop =199.7268 V
Receiving end voltage =10654.06 V

240Sq.mm (resistance =0.1618Ohm/km) Aluminum Cable can be selected but for safe margin Aluminum cable is preferably 300 Sq.mm is selected.

Hence two Nos. of 300 Sq.mm, Aluminum Cable are selected for two 11kV Distribution line circuits to be tapped to feed each of the 2x750 kVA and 300 KVA ,11/0.4kV transformers located at east and west control rooms for tunnel operation.

9.11.6 11kV Power supply feeder from 132/11kV Matatirtha Substation to East and West Control rooms for Tunnel operation.

Matatirtha Substation is located near to densely populated area of Thankot a lot of congested houses are seen and the roads are narrow and the no free space available to locate the 11kV Distribution line poles. Moreover the NEA has constructed cable trench for outgoing 11kV distribution feeders from this substation and the cable duct is full and no space is left for new cables in it. For future outgoing Distribution line feeder a new Distribution line route alignment or cable duct route is to be planned.

An extensive site survey to identify a viable 11kV outgoing Distribution line feeder alignment from this 132/11kV substation to Naghdhunga Power supply system was conducted. The information of upgrading program of 132/11kV Substation to accommodate the 220/132kV substation in the same substation premises with extension of the substation area and the progress of land acquisition was collected.

The 132/11kV Matatirtha Substaion is seen in the Google map. The proposed extended substation area is shown in **Figure 9.11-3** and the boundary line is shown in red. The land acquisition to extend the substation is under process.

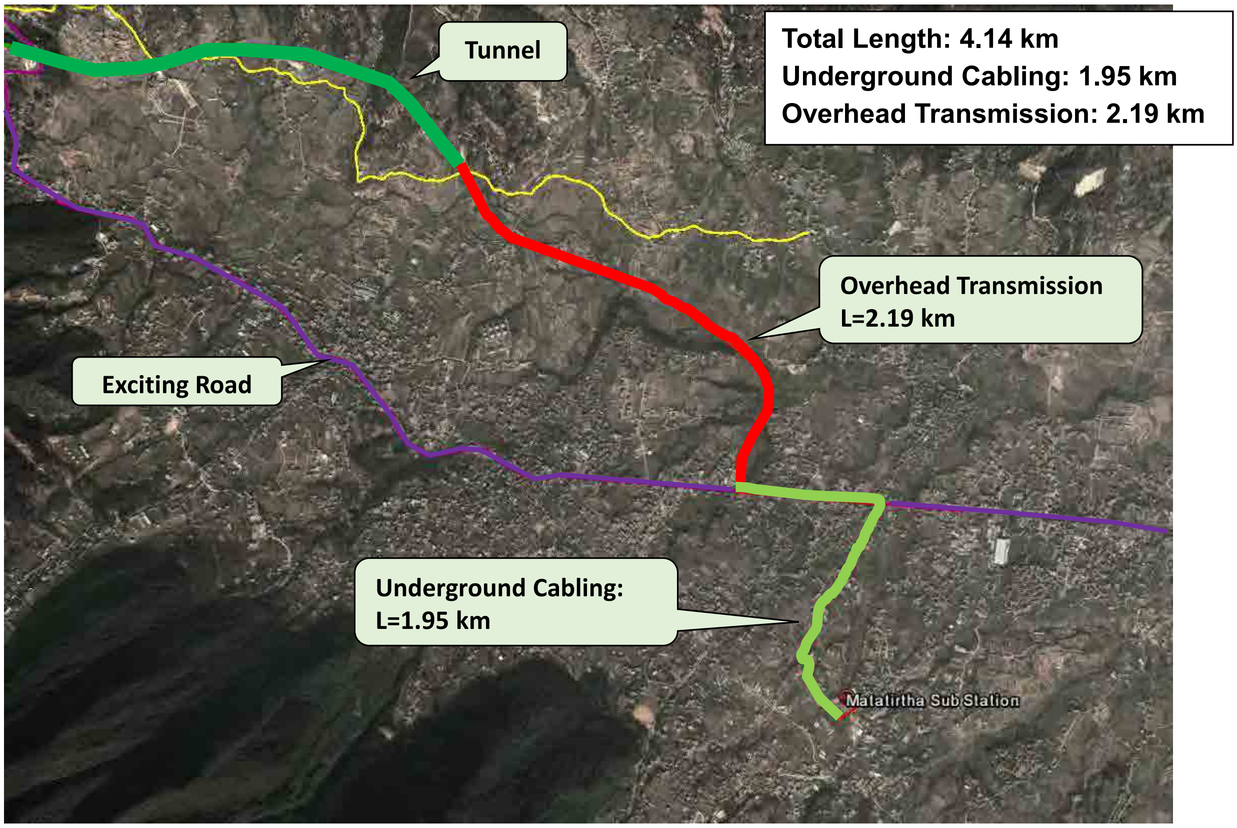


FIGURE 9.11-2 ENTIRE DISTRIBUTION LINE FROM MATATIRTHA SUBSTATION TO TUNNEL EAST PORTAL

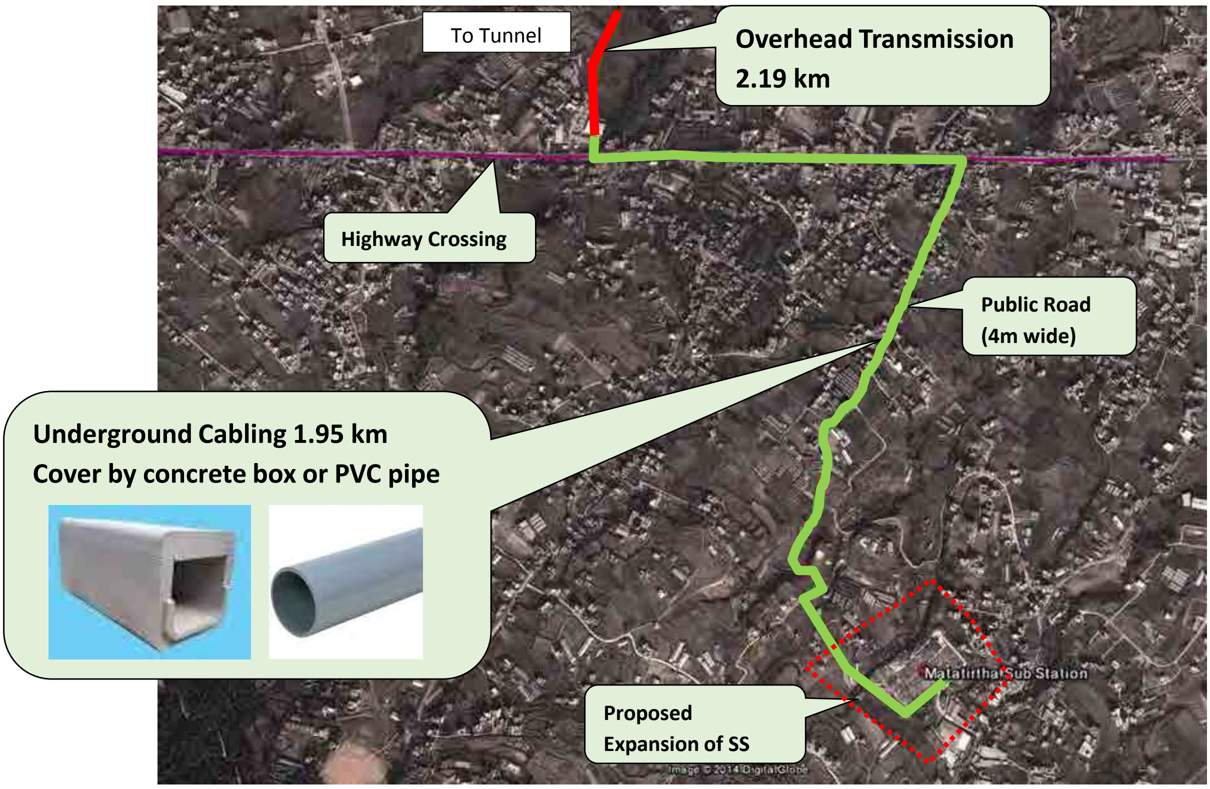


FIGURE 9.11-3 DISTRIBUTION LINE FROM MATATIRTHA SUBSTATION TO HIGHWAY CROSSING POINT

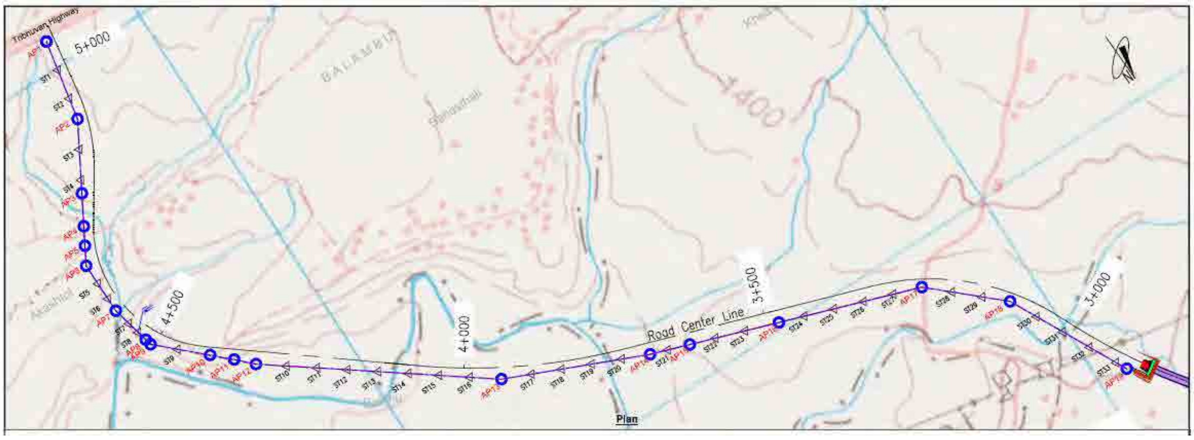


FIGURE 9.11-4 DISTRIBUTION LINE FROM HIGHWAY CROSSING POINT TO TUNNEL EAST PORTAL (WITH TOWER LOCATION)

9.11.7 Transformers

To supply 11kV to the 2x750 and 300KVA Transformers installed in the

a) East control room

b) West control room

The following measures shall be taken

1) From 132/11kV Matatirtha Substation two outgoing 300Sq.mm, 3 core aluminum, armored cables for 11kV double circuit Distribution line feeder shown in green color in the Google map will be buried in cable duct of 1.95Km long
The path of the 11kV cable duct 1.95 Km long is shown in the Google map and is described as follows

a) The 11kV cable duct starts from Matatirtha Substation

b) passes through a narrow road between the houses in both sides

c) reaches to a point near to the highway from where it follows parallel to the road

d) and it crosses the road

2) After crossing the road the each of the two cables will be connected to its relevant 11kV circuit of overhead Distribution line circuit. The double circuit Distribution line is 2.19 KM long and follows along the approach road to the tunnel portal where the east control room is located. The route map is attached.

3) Both circuits of the 11kV Distribution line shall be connected to 11kV bus in east control by respective cables. To supply to the west control room from the 11kV bus located in easrt control room an outgoing nearly 2.35 KM long, 240Sq.mm, 3core, armored Aluminum cable will be laid in the cable rack anchored on one side of the tunnel wall and then after passing out from the tunnel the cable will be connected to 11kV bus of east control room to supply power to 2x750 and 300 KVA transformers located here to supply Power to the tunnel operation.

4) SLD

A SLD for Power supply containing all the equipments from the interconnection Substation to the control rooms located at Tunnel inlet and out let portals

9.11.8 Brief description of the VCBs in the SLD

a) From 132/11kV Matairtha Substation for double circuit 11kV outgoing Distribution line feeder following arrangements are necessary:

1) 3core, 300sq.mm, Armored, Aluminum cable for each of the outgoing feeders for tunnel operation

2) 2Nos of VCBs of 1250 A rating for the outgoing feeders to be installed at Matatirtha Substation

3) 2 Nos. of VCBs of 1250 A rating for the outgoing feeders to be installed at East Control room
4) One sectionalizing VCB of 1250 A to be installed at East control room 11kv bus
5) 11kV double circuit overhead Distribution line
6) 3 Nos. of VCBs of 630 A for protection of the distribution transformers for east control room
7) 3 Nos. of VCBs of 630 A for protection of the distribution transformers for west control room
8) Estimation

9.11.9 Cost Estimation

Based on the equipments shown in the SLD and the design philosophy described above the cost estimation is prepared and attached herewith.

The Bill of quantities for Power Supply to Tunnel operation prepared includes basically following costs

a) The cost of the equipments to be incurred at the NEA interconnecting substation at 132/11kV Matatirtha Substation ,
b) The cost of 11kV cables laid on the cable trench from Matatirtha substation to the road crossing , HDPE Pipes and joints pipes for 11kV cables installation works,
c) Cost of civil works of cable trench ,
d) Cost of overhead 11kV double circuit Distribution line starting from the end point of cable trench and following the approach road to tunnel portal ,
e) Cost of equipments to be installed in east and west control rooms
f) Cost of 11kV cable to be laid at the cable rack on tunnel side wall for supply of Power to west control room from east control room
g) The cost of the backup 300KVA diesel engine considered in the design is not included in the BOQ as the information received is the diesel engines used in construction will be utilized for operation time of tunnel to save cost.

The BOQ is prepared and attached herewith revel that for Power Supply to the tunnel operation at least a fund of USD 1,499 thousands is required.

The Summary Table of the Cost breakdown is shown in the **Table 9.11-1**.

TABLE 9.11-1 COST ESTIMATION OF THE ELECTRICAL WORKS FOR POWER SUPPLY TO TUNNEL VENTILATION AND LIGHTING

Item No	Description	Totals US$
1	11kV ABB Italy made Vacuum Circuit Breakers (VCB)	171,800
2	Other VCBs	146,880
3	Distribution Transformers	204,975
4	11kV double circuit Distribution line	204,564
5	Air Circuit Breakers (ACBs)	19,217
6	Aluminum Cable, HDPE Pipes and Pipe Joints (from Matathirtha SS to East Control Room)	252,252
6.2	HDPE Pipes 140mm 5 inches diameter 6kg/sq.cm	63,063
6.3	HDPE Pipe Joints	7,453
7	Aluminum Cable, HDPE Pipes and Pipe Joints (from East Control Room to West Control Room)	131,576
8	Civil works of cable trench (from Matathirtha SS to Highway Crossing)	107,388
9	11kV Cabling works on cable racks installed on left side wall of the tunnel for supply of Power to west control room from east control room . from East Control Room to West Control Room.	30,030
10	Others	160,000
	Total Costs	1,499,198

Refer to **Annex 9.11-1** for details of the Cost Estimation.

9.12 FACILITIES NECESSARY FOR TUNNEL O & M

(1) Tunnel Management Office

Safe operation of a tunnel require the creation of a Tunnel Management Office, thorough discussion of this can be found in **Section 14.2**.

(2) Toll Collection Facility

In order to secure the tunnel O & M cost, toll collection facilities was designed.

1) Required Toll Booth Number

In accordance with traffic demand forecast (see section 5.2), the required toll booth was calculated. Toll Booth will be installed at each tunnel entry point to check dangerous car, over weight car and etc.

TABLE 9.12-1 PEAK HOUR TRAFFIC VOLUME AT TUNNEL SECTION

	AADT 2030 (a)	Peak hour (b)	Peak Traffic Volume(c= a × b)
Eastbound	5,000 veh /day	6.3 %	315 veh/hr
Westbound	4,800 veh/day	6.3 %	302 veh/hr

In Japan, the average service time at toll gate is 8 second in case of flat rate. But study team assumed the average service time at toll gate is 10 second for this project. **Table 9.12-2** shows the required toll booth, service time and average waiting vehicle at gate. As peak traffic volume is 302 ~ 315, the minimum required toll gate is two (2) booths for average one waiting vehicle level. The study team recommended three (3) booths for eastbound (west-side) considering one spare booth.

TABLE 9.12-2 SERVICE TIME, AVERAGE WAITING VEHICLE AT TOLL GATE AND NO. OF TOLL GATE

Service Time / Ave. Waiting Vehicle at Toll Gate / No. of toll gate	6 sec		8 sec		10 sec		14 sec		18 sec		20 sec	
	1.0	3.0	1.0	3.0	1.0	3.0	1.0	3.0	1.0	3.0	1.0	3.0
1	300	450	230	340	180	270	130	190	100	150	90	140
2	850	1,040	640	780	510	620	360	440	280	350	250	310
3	1,420	1,630	1,070	1,230	850	980	610	700	480	550	430	490
4	2,000	2,230	1,500	1,670	1,200	1,340	860	960	670	740	600	670
5	2,590	2,830	1,940	2,120	1,550	1,700	1,110	1,210	860	940	780	850
6	3,180	3,430	2,380	2,570	1,910	2,060	1,360	1,470	1,060	1,140	950	1,030
7	3,770	4,020	2,830	3,020	2,260	2,410	1,620	1,720	1,260	1,340	1,130	1,210
8	4,360	4,630	3,270	3,470	2,620	2,780	1,870	1,980	1,450	1,540	1,310	1,390
9	4,960	5,220	3,720	3,920	2,980	3,130	2,130	2,240	1,650	1,740	1,490	1,570
10	5,560	5,820	4,170	4,370	3,330	3,490	2,380	2,490	1,850	1,940	1,670	1,750
11	6,150	6,420	4,610	4,820	3,690	3,850	2,640	2,750	2,050	2,140	1,850	1,930
12	6,740	7,020	5,050	5,270	4,040	4,210	2,890	3,010	2,250	2,340	2,020	2,110
13	7,340	7,620	5,510	5,720	4,400	4,570	3,150	3,270	2,450	2,540	2,200	2,290
14	7,940	8,220	5,954	6,170	4,760	4,930	3,400	3,520	2,650	2,740	2,380	2,470
15	8,530	8,820	6,400	6,620	5,120	5,290	3,660	3,780	2,840	2,940	2,560	2,650

Source: NEXCO EAST Highway Design Manual, 2005

2) Toll Booth Layout

Figure 9.12-1 shows the toll booth layout for this project.

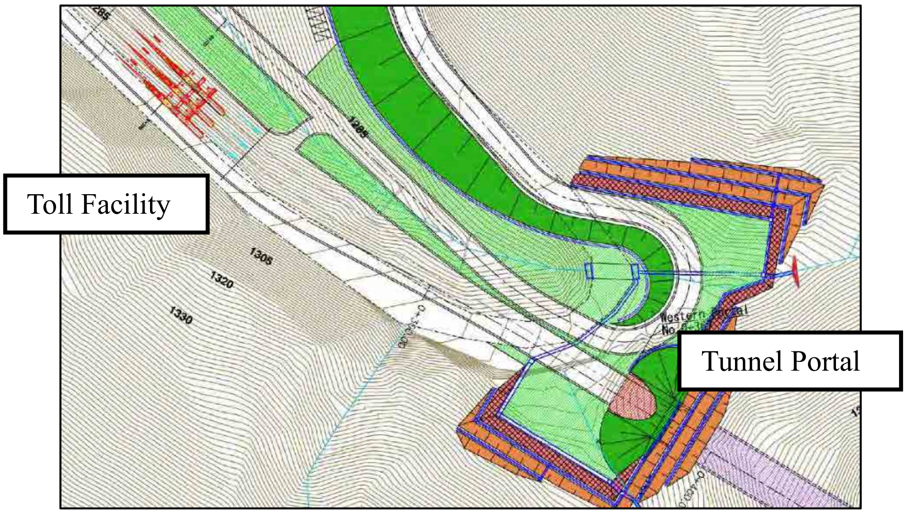


FIGURE 9.12-1 (1) TOLL BOOTH LAYOUT AT WESTSIDE

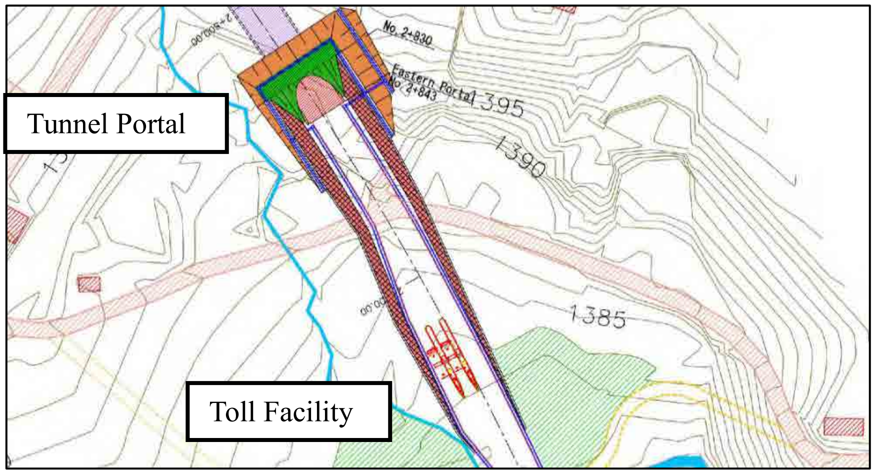


FIGURE 9.12-1 (2) TOLL BOOTH LAYOUT AT EASTSIDE

General outline of toll facilities

- 3 lane@3.0m (West Side), 2 lane@3.0m (East side)
- 3 simple booth (West Side), 2 simple booth (East side)
- Information sign & pavement-marking
- Roof
- Lighting

9.13 DISPOSAL AREA DEVELOPMENT PLAN (MICHI-NO EKI[1])

9.13.1 Objective

The expected volume from excavation of tunnel is approximately 176,000 m2. The JICA-assisted Data Collection Survey proposed three locations as candidates for disposing the excavated soil. It further proposed several method such as, use of space for control office of the tunnel, to improve existing road alignment at hair-pin curves if required and to provide a "Michi-no-Eki".

The objective for the plan of Michi-no-Eki is to promote the road service facility for the safe

1 Michi-No-Eki is a facility developed in Japan, which literally means "road station", provided on National Highways and arterial roads for the purpose to integrate parking area, rest rooms (toilets), information facilities and community facilities provided by local governments.

driving and comfortable service for road users such as truck, tourist bus and private vehicles, and contributing tourism promotion and local economy.

9.13.2 Existing Rest Facilities along Tribhuvan Highway

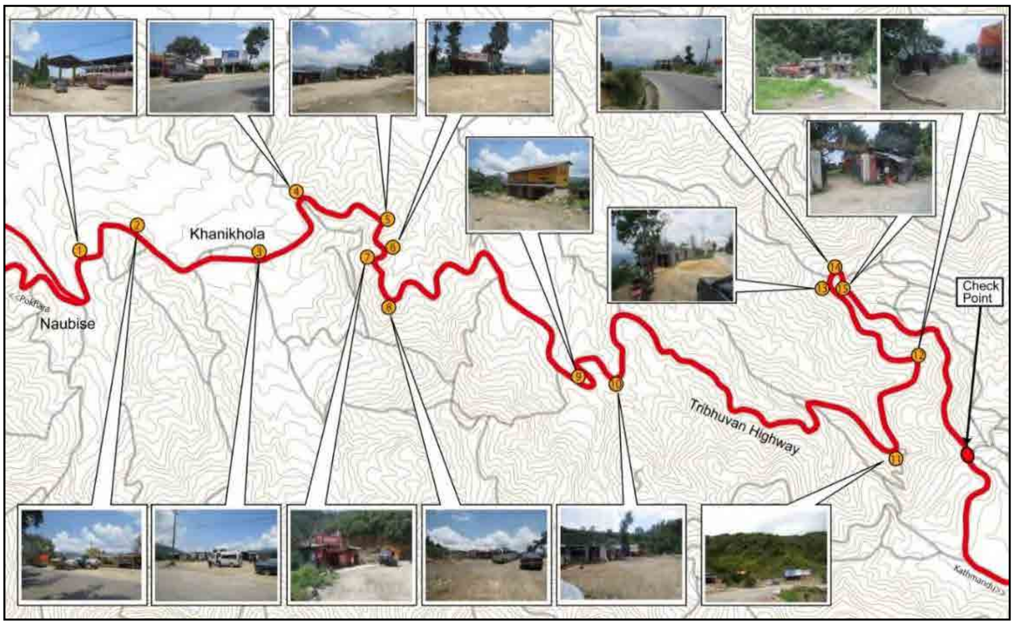
(1) Location of Existing Rest Facilities

The JICA Survey Team carried out the existing rest facilities survey along Tribhuvan Highway between Naubise and Nagdhunga Pass. Sixteen (16) rest facilities are located as shown in **Figure 9.13-1**.

These rest facilities expect No.1 are illegally operated by the private companies. DOR has ordered to these facilities to move out of ROW of DOR. Car drivers, truck drivers and tourist buses are using these illegal rest facilities, it is understood that there are high demands for rest facilities.

(2) Average Distance between Rest Facilities

The average distance between rest facilities is shown in **Table 9.13-1**. The average distance is approximately 0.82 km.



Source: JICA Survey Team

FIGURE 9.13-1 LOCATION OF EXISTING REST FACILITIES ALONG TRIBHUVAN HIGHWAY

TABLE 9.13-1 AVERAGE DISTANCE BETWEEN EXISTING REST FACILITIES

Location	No.	Distance (km)		Note
		between point	from base point	
Westside from West Portal	1	0.62	8.80	Legal
	2	0.85	8.18	Illegal
	3	0.47	7.33	Illegal
	4	0.58	6.86	Illegal
	5	0.25	6.28	Illegal
	6	0.10	6.03	Illegal
	7	0.26	5.93	Illegal
	8	2.16	5.67	Illegal
	9	0.54	3.51	Illegal
	10	2.97	2.97	Illegal
	11	0.00	0.00	Illegal

Location	No.	Distance (km)		Note
		between point	from base point	
Eastside from West Portal	12	0.74	0.74	Illegal
	13	0.81	1.55	Illegal
	14	0.06	1.61	Illegal
	15	0.16	1.77	Illegal
	16	1.79	3.56	Check Point (Naagdhunga), Legal
Average		0.82	-	

Source: JICA Survey Team

(3) Typical Type of Existing Rest Facilities

The existing rest facilities have various problems as follows;

1) Parking space is provided very close to the existing road and not paved, thus in very bad condition.

2) Toilets are provided at most rest facilities, however, they are very dirty and unhealthy.

3) Some stores are doing business.

4) There is no stores which sell local products.

Parking space and situation

Toilet situation

Multiple shop facilities

Shops sells some snacks, drinks and fruits

PHOTO 9.13-1 TYPICAL FACILITIES IN THE AREA

9.13.3 Tourism Spots and Local Products

(1) Tourism Spots

This project provides vital access to the famous tourism spots which are located in Kathmandu, Pokhara, Chitwan National Park and others. Therefore, this Michi-no-Eki will be utilized by local and foreign tourists.

1) Kathmandu

Kathmandu tourist sports are Patan area, Bhaktapur area and Thamel area where many tourists are visiting.

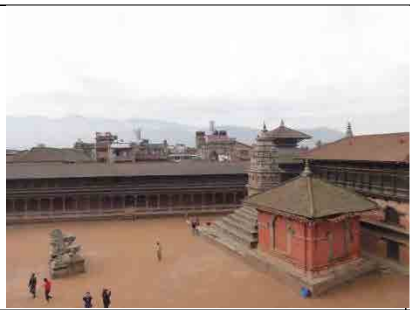
		
Patan Area	Bhaktapur Area	Thamel Area

PHOTO 9.13-2 TOURISM SPORTS IN KATHMANDU

2) Pokhara

Pokhara is very famous lakeside resort in Nepal. Many tourists enjoy trekking in and around Pokhara.

		
Source: http://www.explorehimalaya.com/	Source: http://www.nepallinktravel.com/	Source: http://www.pokharapalacehotel.com/
Lakeside	Temple	Trekking Mountain

PHOTO 9.13-3 TOURISM SPORTS IN POKHARA

3) Chitwan National Park

This park is located in south central Nepal. Tourist can enjoy safari wildlife tour.

	
Park Tour	Wild Animals

Source: Department of National Parks and Wildlife Conservation

PHOTO 9.13-4 TOURISM SPORTS IN CHITWAN NATIONAL PARK

(2) Local Products in Project Area

Major local products are paddy rice, maize, wheat, tomato and mushroom etc, in project area and shown in **Table 9.13-2**. These products are basically provided for their consumption and are not for sale. Michi-no-Eki can provide opportunities to sell local products and farmers will bi inspired to produce more to sell products at Michi-no-Eki for their additional income.

TABLE 9.13-2 LOCAL PRODUCTS

District	VCD[2]s	Major Agricultural Products
Kathmandu	Mahadevsthan	Paddy Rice, Maize, Wheat, Tomato, Mushroom and Cauliflower
	Balambu	Paddy Rice, Maize, Wheat and cauliflower
	Dahachowk	Paddy Rice, Maize, Wheat, Tomato and Mushroom
	Thankot	Paddy Rice, Maize, Wheat, Tomato and Mushroom
	Baad Bhanjyang	Paddy Rice, Maize, Wheat, Potato and Tomato
Dhanding	Naubise	Paddy Rice, Maize, Wheat, Potato, Tomato, Cauliflower and Cabbage

Source: JICA Survey Team

9.13.4 Candidate Locations of Disposal Area and Rest Facilities

Candidate locations of disposal area/rest facilities are shown in **Figure 9.13-1**.

Alternative-1: Located adjacent to the West Portal of a tunnel, thus excavated material can be disposed at the cheapest cost. About 150,000 – 200,000 cubic meters of excavated material can be disposed.

Alternative-2: Located at about 3.00 km away from the West Portal, and about 150,000 – 200,000 cubic meters of excavated material can be disposed.

Alternative-3: Located at about 0.00 km away from the West Portal, and not advantageous as a disposal area. This site is located near Naubise, thus convenient for people to sell local products.

Source: JICA Survey Team

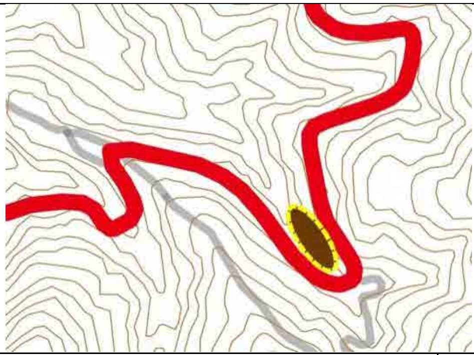
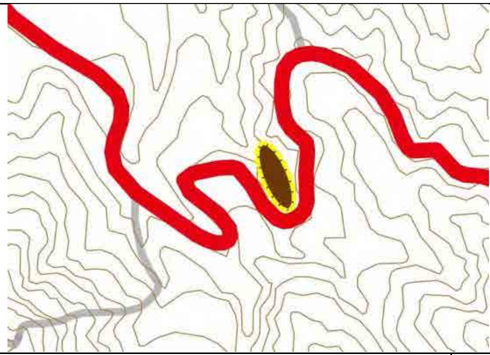
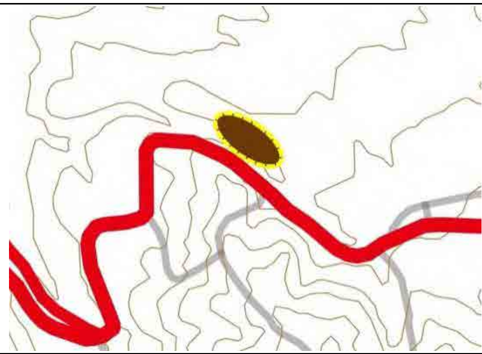
FIGURE 9.13-2 PROJECT SITE

9.13.5 Comparing with the Disposal Area

Three candidate locations are compared from the viewpoint of 1) Site Condition, 2) Filling Cost 3) Environment Impact and 4) Impact on Tunnel Project and shown in **Table 9.13-3**.

2 Village Development Committee: VDC is the lower administrative part of its local development ministry. Each district has several VDCs, similar to municipalities but with greater public-government interaction and administration.

TABLE 9.13-3 COMPARISON OF DISPOSAL AREA

Evaluation Item	Alternative-1		Alternative-2		Alternative-3	
Location						
Site Condition	• This site is located adjacent to West Portal of a Tunnel. • About 150,000 – 200,000 cubic meters of excavated material can be disposal	A	• This site located at about 3.00 km away from the West Portal of a Tunnel. • About 150,000 – 200,000 cubic meters of excavated material can be disposal	B	• This site located at about 8.00 km away from the West Portal of a Tunnel. • This site located near Naubise.	C
Filling Cost	Landfill is near, cost is cheap.	A	Landfill is middle, Cost is expensive.	B	Landfill is far, Cost is more expensive.	C
Environment Impact	• Firm land • Stream	B	• Firm land • Stream	B	• Firm land and residencies	C
Effect on Tunnel Project	• Transfer length of evacuated material is shortest for disposal area.	A	• Transfer length of evacuated material is 3.00 km away from the West Portal of a Tunnel is high cost.	B	• Transfer length of evacuated material is 3.00 km away from the West Portal of a Tunnel is highest cost of alternative.	C
Total Evaluation	**Recommendation**	1	**Not Recommendation**	2	**Not Recommendation**	3

Notes: Evaluation of compatibility, A: Good, B: Tolerable
Source: JICA Survey Team

9.13.6 Layout of Typical Michi-no-Eki

(1) Estimation of Demand of Parking Lots on Michi-no-Eki

The parking area will be arranged in each zones like car, mini bus, large bus and truck, and then the large truck will be parked at the Michi-no-Eki not to make a traffic jam with other vehicle. Therefore, estimation of demand of parking lot on Michi-no-Eki is calculated as followings;

1) Calculation Condition

Demand of parking lots is resolved based on 1) target interval of Michi-no-Eki, 2) design daily volume and 3) utilization factor. In principle, it is calculated by traffic classifications in older to calculation items are shown in **Table 9.13-4**.

TABLE 9.13-4 CALCULATION ITEMS

Items		Figure	Remarks
Target Interval of Roadside Station (L)		**10**	**km**
Design Daily Volume (N)	Small Vehicles	4,824	Year 2025
	Large Vehicles	6,045	
Stop Ratio at Michi-no-Eki (S)	Small Vehicles	0.007	
	Large Vehicles	0.008	
Peak Hour Ratio (P)	Small Vehicles	0.08	
	Large Vehicles	0.08	
Parking Occupy Ratio (O)	Small Vehicles	0.25	
	Large Vehicles	0.20	

Source: Design Guidelines of Road (Chubu Regional Development Bureau in Japan, 2014)

2) Calculation for Demand of Parking Spaces

Formulation of demand of parking spaces and calculation formula is shown in below.

$$N = L\,(km) \times S \times P \times O \qquad (1)$$

Where,

N – Demand of Parking Spaces
L – Target Interval of Michi-no-Eki
S – Stopping Ratio at Michi-no-Eki,
P – Peak Hour Ratio
O – Parking Occupy Ratio

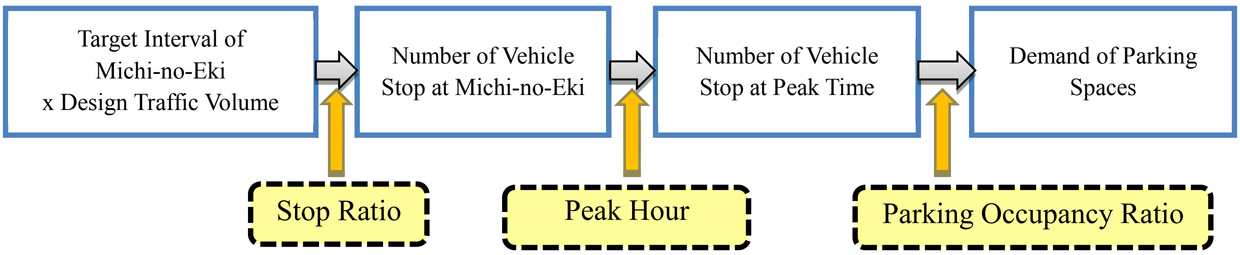


FIGURE 9.13-3 FORMULATION OF DEMAND OF PARKING SPACE

3) Result of Number of Parking Spaces

Result of number of parking spaces at proposed Michi-no-Eki are shown in below,

- Small Vehicles: 7 (nos)
- Large Vehicles: 10 (nos)

Although parking spaces were calculated based on above formula, sufficient land required of large vehicles parking lots cannot be secured in this area consideration for driveway. Thus, large vehicles parking lots are planned depending on available land required.

(2) Infrastructure Plan for Custom Facility

The plan for the infrastructure of the Michi-no-Eki will be designed based on the analysis of present condition in terms of 1) water supply facility, 2) sewage facility, 3) energy and electric power facility and 4) communication facility. Table 9.13.6-2 shows the present condition and plan strategy for the infrastructure plan.

TABLE 9.13-5 PRESENT CONDITION AND PLAN STRATEGY FOR INFRASTRUCTURE PLAN

Infrastructure	Present Condition	Plan Strategy
1) Water supply facility	• Water supply facility is not existing in the project area because of disposal area.	• The facility of water supply will be used, according to constructing water tank. • New deep well in the site will be developed if necessary.
2) Sewage facility	• Sewage disposal system by discharging to stream. • Sanitary sewage disposal system by direct stream.	• The sewage facility and sanitary sewage system by septic tank will be constructed for public toilet and restaurant.
3) Energy and electric power facility	• Middle-voltage line on the mountain • Fire power supply by propane gas and charcoal	• The existing high-voltage line in the site will be used by a lead-in cable from the Tunnel. • The existing system for fire power supply will be used.

(3) General Layout of Facilities

1) Basic Concept for Facilities at the Michi-no-Eki

General layout of some facilities at the Michi-no-Eki is considered by basic concepts as shown in below;

- From a hygiene standpoint, the public toilet and the restaurant should be separated buildings.
- The public toilet and the restaurant will be applied water place, they should be located at grand floor. And, water tank has to locate between building of toilet and restaurant.
- The septic tank should be constructed in the Michi-no-Eki for sanitary environment.
- The management office and the information center are located restaurant in a corner.
- The trash cans should be located at various places in the Michi-no-Eki.
- The shop facility will be located at 2nd floor within same building of the restaurant, which will sell some snacks, drinks and local productions.

2) General Layout of Facility

The layout of general and typical facilities is shown in **Table 9.13-6** and **Figure 9.13-4** to **Figure 9.13-5**. A compact style facility will be made an appeal of “Festivity” and “Amenity” to the road user without felling of pressure, and will be also made an appeal of “Landmark”. The total area of site will be estimated at 4,650 m^2, which is comprised of parking area at 471.5 m^2, plaza area at 442 m^2, building area at 329 m^2 and green area at 290 m^2.

TABLE 9.13-6 VALUE OF PROPOSED FACILITIES

Items	Units	Value	Contents
Plaza area	m^2	442 m^2	Including pedestrian aisle
Toilet	Male	32.5 m^2 (6.5m x 5.0m)	Washstand: 3 pieces Urinal: 6 pieces Water closet: 3 pieces
	Female	32.5 m^2 (6.5m x 5.0m)	Washstand: 3 pieces Water closet: 8 pieces
	Access Aisle	7.5 m^2 (1.5m x 5.0m)	-
	Total	78 m^2 (13.0m x 6.0m)	-
Restaurant (1F)	Restaurant	154 m^2 (11.0m x 14.0m)	Table: 9 sets
	Kitchen	40 m^2 (4.0m x 10.0m)	Wash place, cooking table, shelf, refrigerator, etc
	Total	194 m^2	-
Managem ent Office and Information Center (1F)	m^2	16 m^2 (4.0m x 4.0m)	Working table, PC, shelf, etc
Shop (2F)	m^2	135 m^2 (15.0m x 9.0m)	Shelf, casher, table
Parking	Small and Middle	25 nos (5.0m x 2.3m)	-
	Large	8 nos (15.0m x 2.3m)	-
	Total	552.0 m^2	-
Green Area	m^2	290 m^2	-
Others	m^2	116.25 m^2	Water tank, septic tank, dump yard

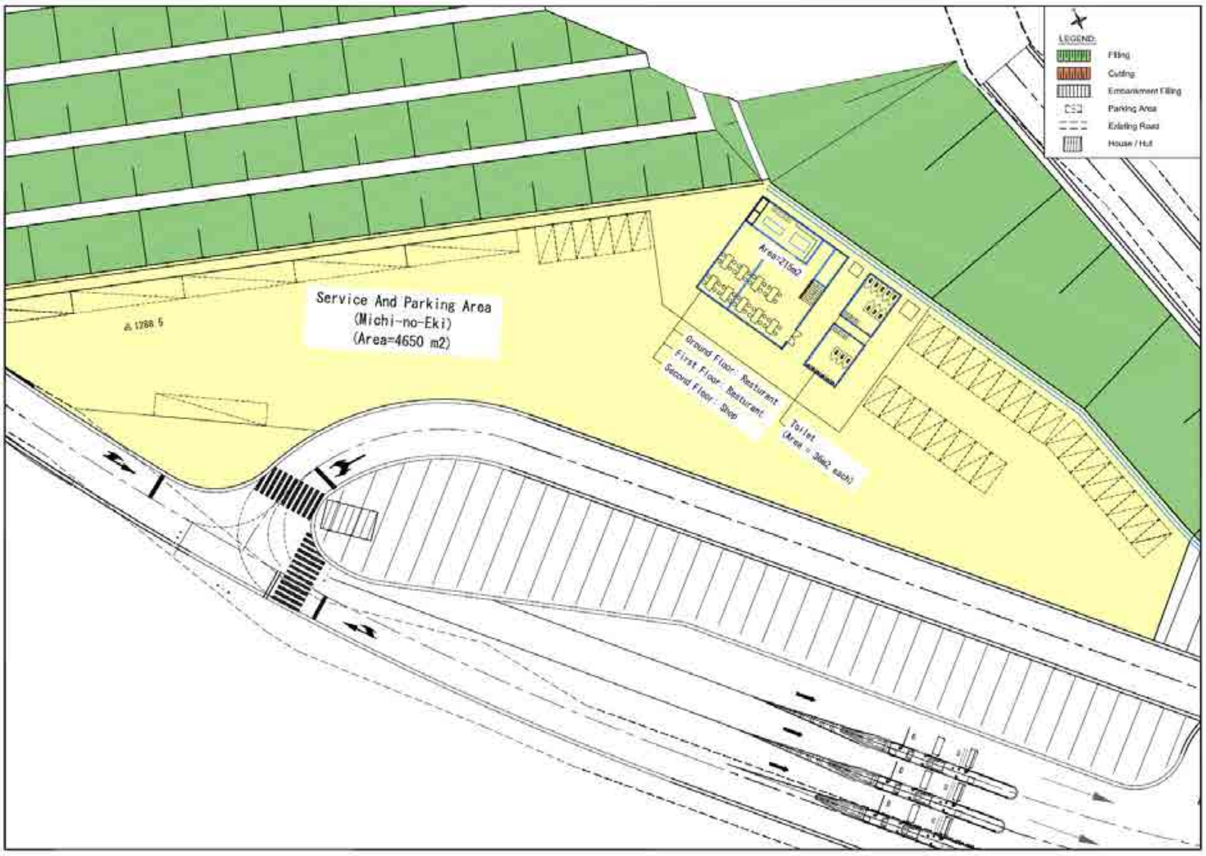
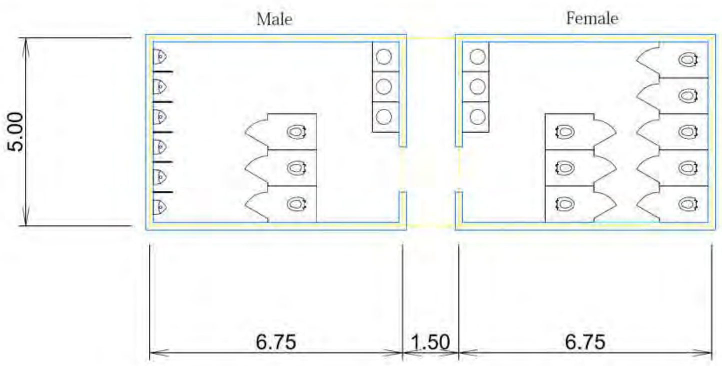
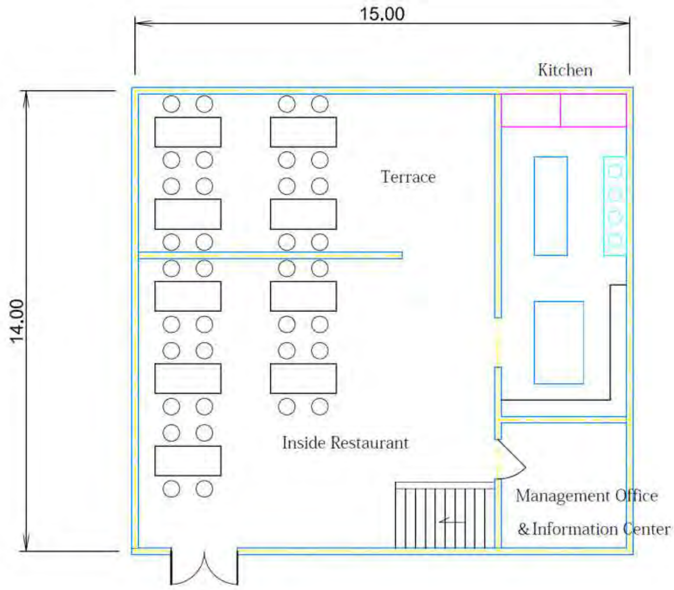


FIGURE 9.13-4 LAYOUT OF THE MICHI-NO-EKI IN THIS PROJECT



Toilet



Restaurant, the Information Center and the Management Office

Shop

FIGURE 9.13-5 LAYOUT OF FACILITIES

9.13.7 Operation and Maintenance for the Michi-no-Eki

Scheme of administrative organization for the Michi-no-Eki and part of O&M is considered as followings;

1) Based on the new regulation of MoPIT, DOR will be submitted the application document to MoPIT which are permitted for bidding and sub-contract under DOR.
2) After submission the application document, MoPIT will judge this document and accept for undertaking the bidding and selection private company under DOR.
3) DOR-PMU will conduct the bidding for private company to operate the rest facility depending on fair evaluation.
4) Private company will operate and maintain the rest facility (Restaurant, Toilet, Shop). And, revenue collected from the facility will be used for the O&M of the facility. However, maintenance of parking space, drive way, information facility and beautification of Michi-no-Eki will be responsibility of Tunnel Management Office.
5) Tunnel Management Office and private company should tie-up to operate and maintenance of Michi-no-Eki.

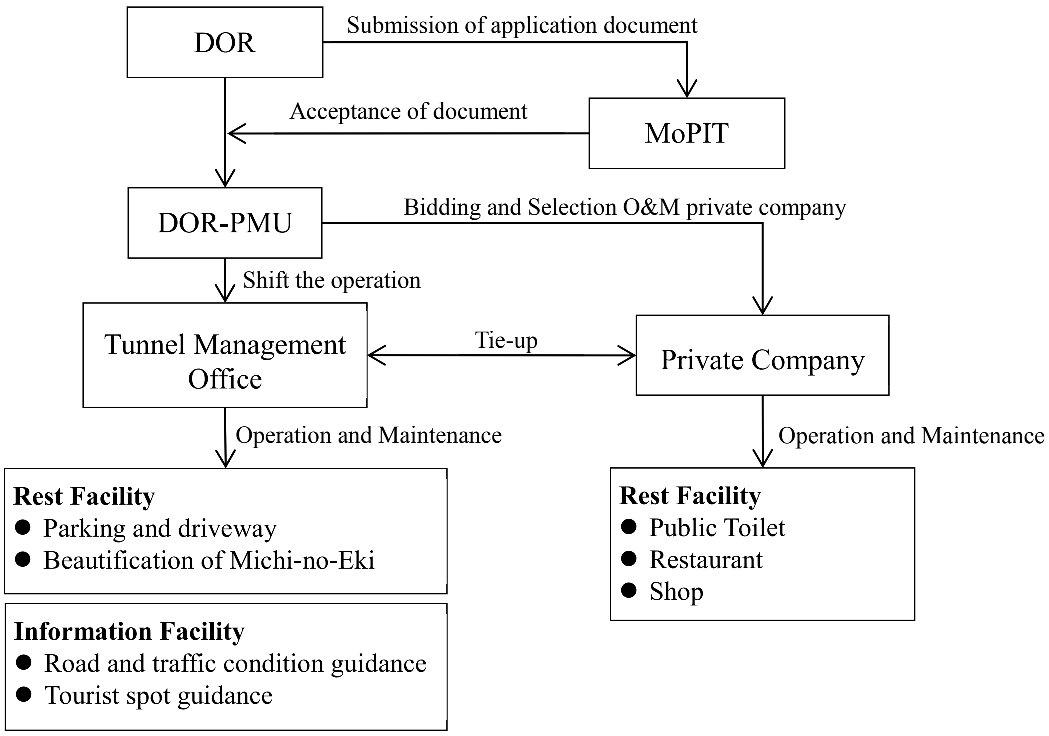


FIGURE 9.13-6 SCHEME OF CONFIGURATION FOR ADMINISTRATIVE ORGANIZATION FOR THE MICHI-NO-EKI

9.13.8 Project Cost Estimate

The project cost for the construction of the Michi-no-Eki is shown in **Table 9.13-7**. The project of a typical the Michi-no-Eki was estimated at 36.3 million Rupees.

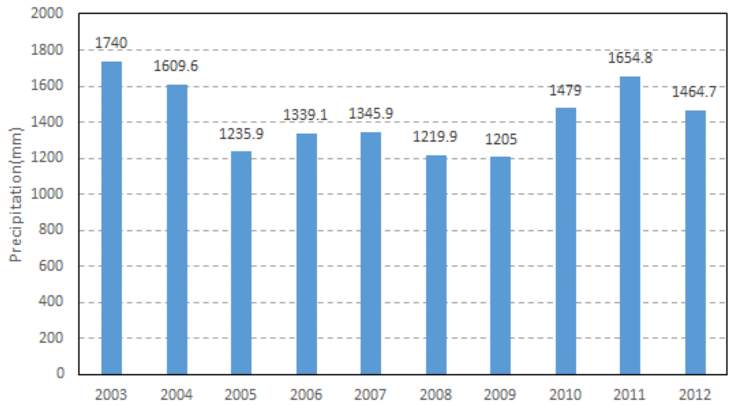
TABLE 9.13-7 PROJECT COST ESTIMATE

No.	Major Item	Cost (Million Rs)
1	Construction Cost	34.5
2	Maintenance Cost (1 year)	1.8
Total		36.3

9.14 POSSIBILITY OF LOWERING OF GROUNDWATER LEVEL

9.14.1 Climate Conditions in the Study Area

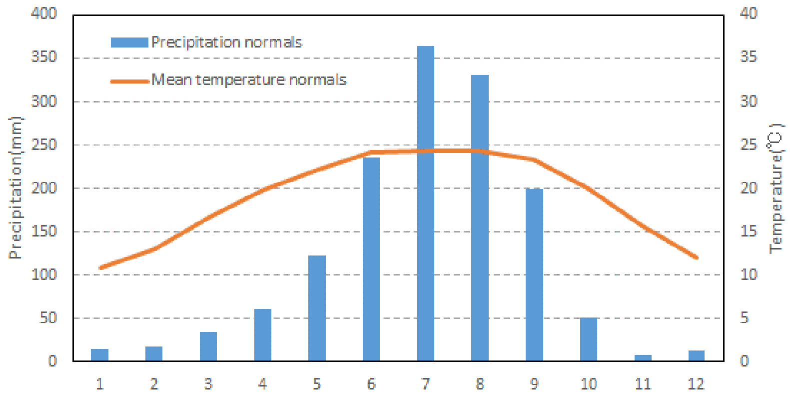
There is a rainfall of about 1400mm per year in Kathmandu. Rainy season and dry season are clearly separated. During the rainy season between May and September nearly 90% of the annual precipitation is observed. Precipitation since June of this year follows that of the normal year.



Source : Department of Hydrology and Meteorology

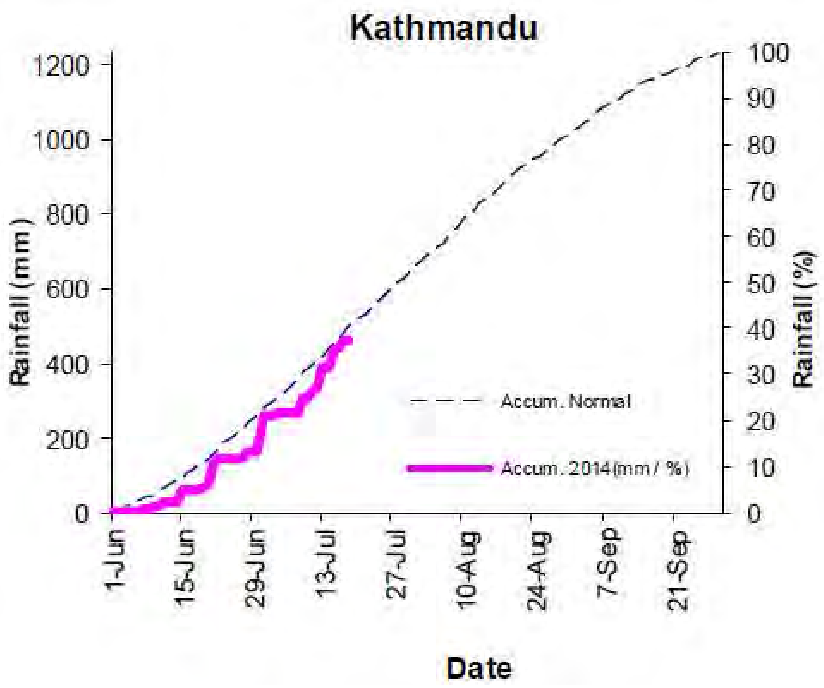
FIGURE 9.14-1 ANNUAL RAINFALL

Month	1	2	3	4	5	6	7	8	9	10	11	12
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
Mean temperature normals (℃)	10.8	13.0	16.7	19.9	22.2	24.1	24.3	24.3	23.3	20.1	15.7	12.0



Source : Department of Hydrology and Meteorology

FIGURE 9.14-2 MONTHLY RAINFALL



http://www.dhm.gov.np/uploads/climatic/1002508489Monsoon Monitoring 18july2014.pdf

FIGURE 9.14-3 CUMULATIVE RAINFALL FROM JUNE 1, 2014

9.14.2 Water Usage in the Study Area

(1) Hydrological investigation results

Hydrological investigation was carried out in the end of July. Water quality and quantity are shown in the **APP NO. 11-a of the Preliminary Design Drawing Sheets**. Because it was carried out during the rainy season, the flow rate was higher relatively.

There are many intake pipes from the stream. They have been used as agricultural water and domestic water. Utilization of many wells has been confirmed in the tunnel route near the top of the valley.（see **NO. 11-b of the Preliminary Design Drawing Sheets**）

PH and EC of wells are shown in **NO.11-c and NO.11-d of the Preliminary Design Drawing Sheets** respectively.

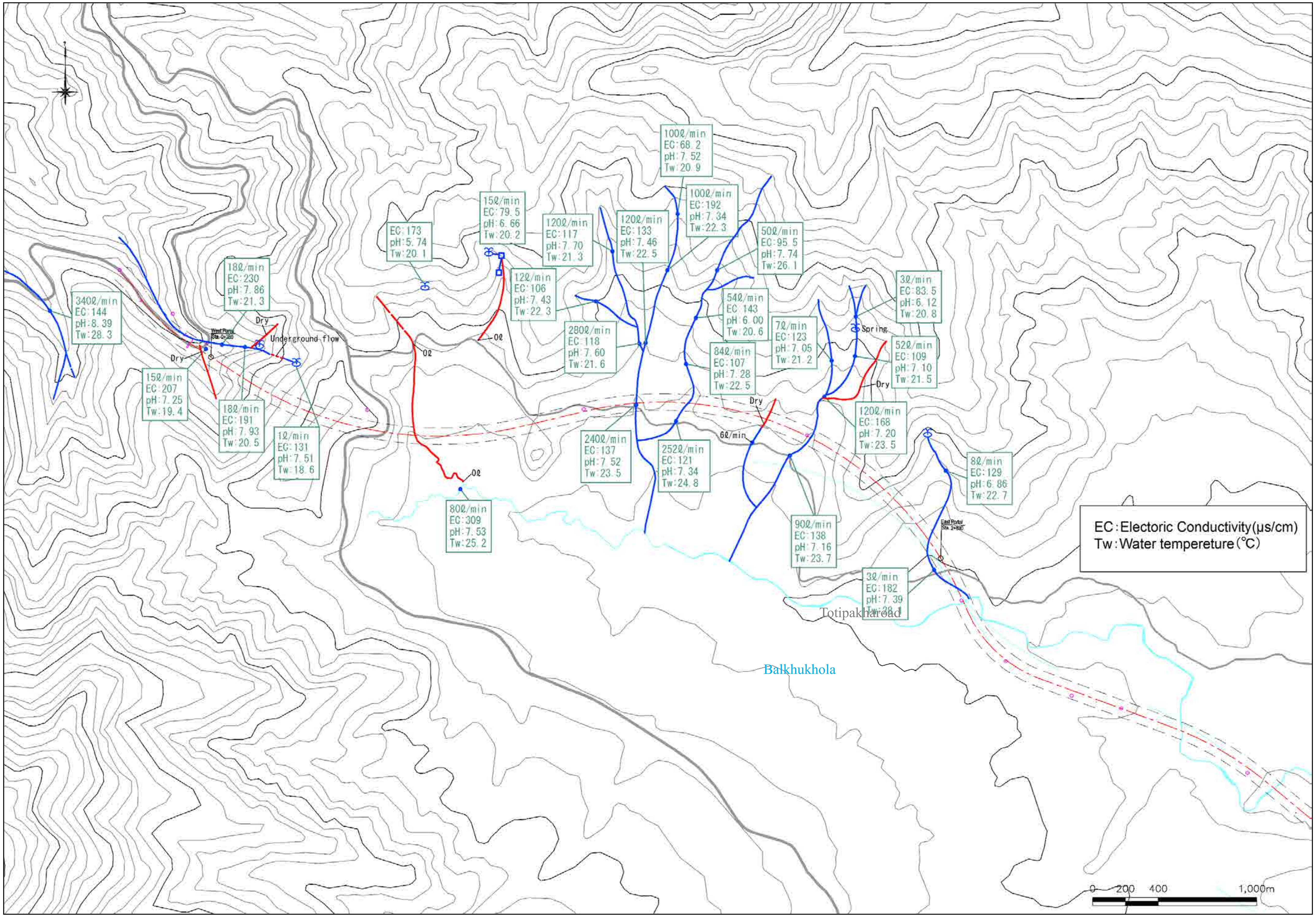
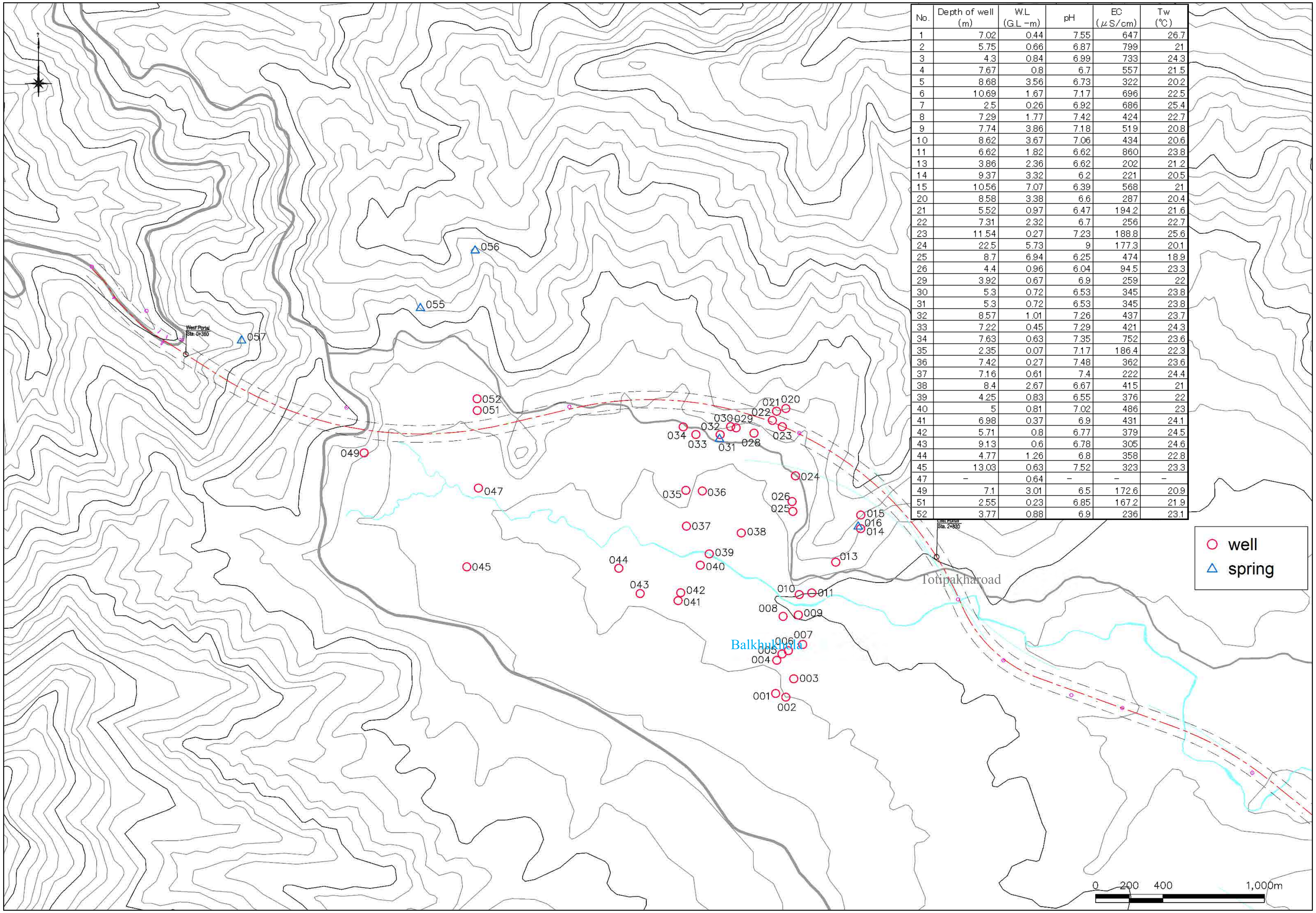


FIGURE 9.14-4 HYDROLOGICAL EXPLORATION RESULTS



No.	Depth of well (m)	W.L (G.L −m)	pH	EC (μS/cm)	Tw (℃)
1	7.02	0.44	7.55	647	26.7
2	5.75	0.66	6.87	799	21
3	4.3	0.84	6.99	733	24.3
4	7.67	0.8	6.7	557	21.5
5	8.68	3.56	6.73	322	20.2
6	10.69	1.67	7.17	696	22.5
7	2.5	0.26	6.92	686	25.4
8	7.29	1.77	7.42	424	22.7
9	7.74	3.86	7.18	519	20.8
10	8.62	3.67	7.06	434	20.6
11	6.62	1.82	6.62	860	23.8
13	3.86	2.36	6.62	202	21.2
14	9.37	3.32	6.2	221	20.5
15	10.56	7.07	6.39	568	21
20	8.58	3.38	6.6	287	20.4
21	5.52	0.97	6.47	194.2	21.6
22	7.31	2.32	6.7	256	22.7
23	11.54	0.27	7.23	188.8	25.6
24	22.5	5.73	9	177.3	20.1
25	8.7	6.94	6.25	474	18.9
26	4.4	0.96	6.04	94.5	23.3
29	3.92	0.67	6.9	259	22
30	5.3	0.72	6.53	345	23.8
31	5.3	0.72	6.53	345	23.8
32	8.57	1.01	7.26	437	23.7
33	7.22	0.45	7.29	421	24.3
34	7.63	0.63	7.35	752	23.6
35	2.35	0.07	7.17	186.4	22.3
36	7.42	0.27	7.48	362	23.6
37	7.16	0.61	7.4	222	24.4
38	8.4	2.67	6.67	415	21
39	4.25	0.83	6.55	376	22
40	5	0.81	7.02	486	23
41	6.98	0.37	6.9	431	24.1
42	5.71	0.8	6.77	379	24.5
43	9.13	0.6	6.78	305	24.6
44	4.77	1.26	6.8	358	22.8
45	13.03	0.63	7.52	323	23.3
47	−	0.64	−	−	−
49	7.1	3.01	6.5	172.6	20.9
51	2.55	0.23	6.85	167.2	21.9
52	3.77	0.88	6.9	236	23.1

FIGURE 9.14-5 WATER SOURCE LOCATION MAP

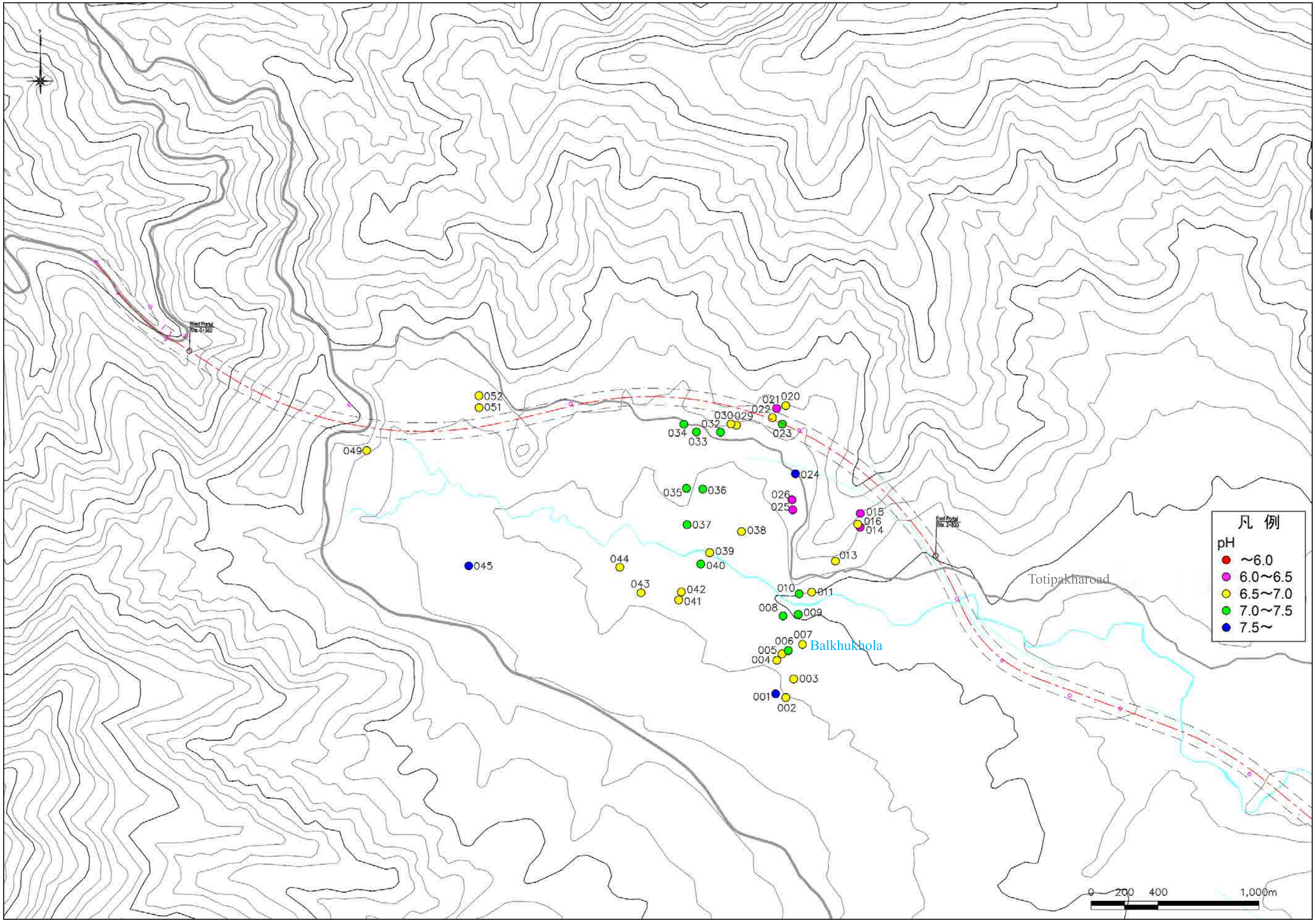


FIGURE 9.14-6 WATER QUALITY OF THE WELL (PH)

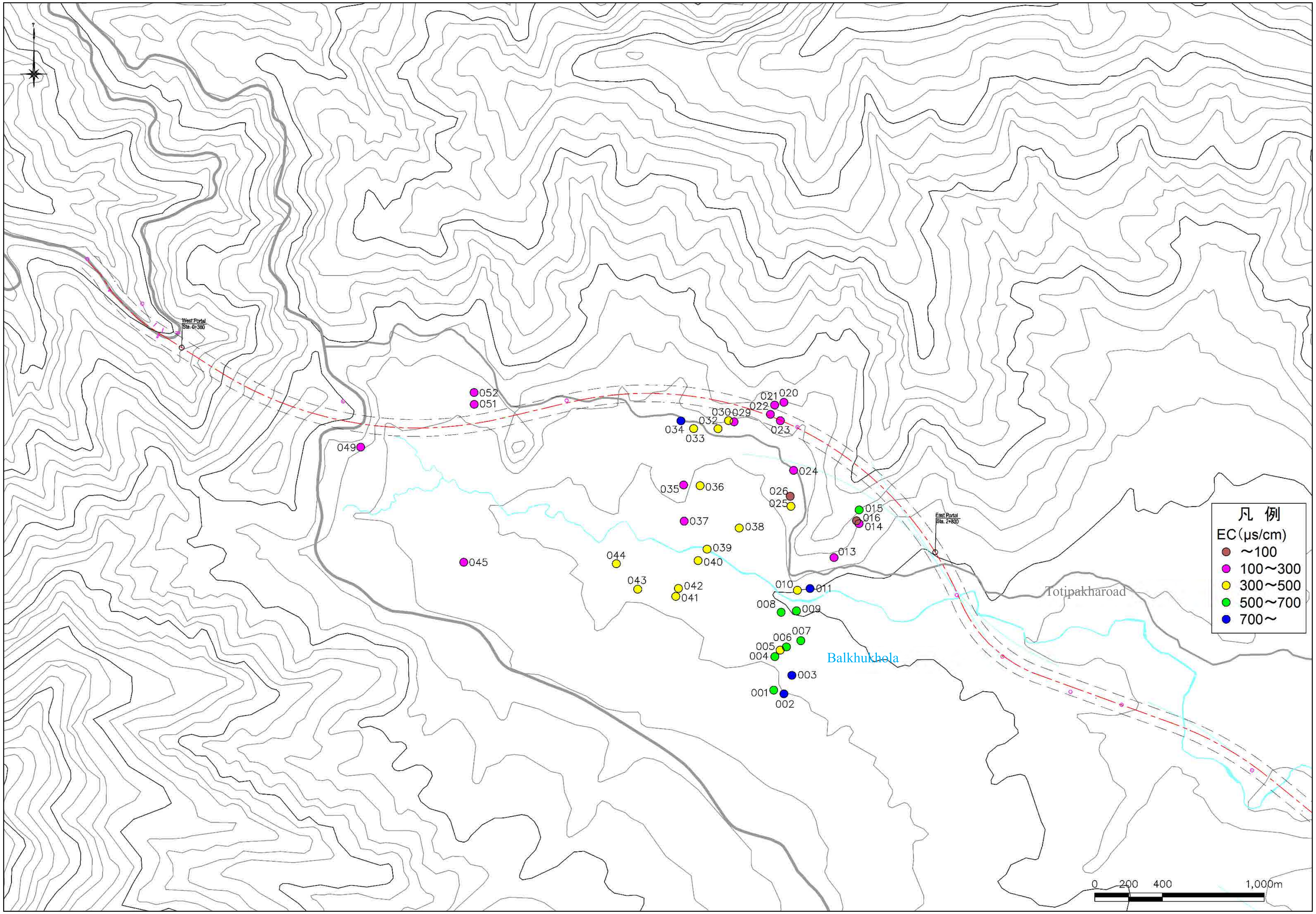


FIGURE 9.14-7 WATER QUALITY OF THE WELL (EC)

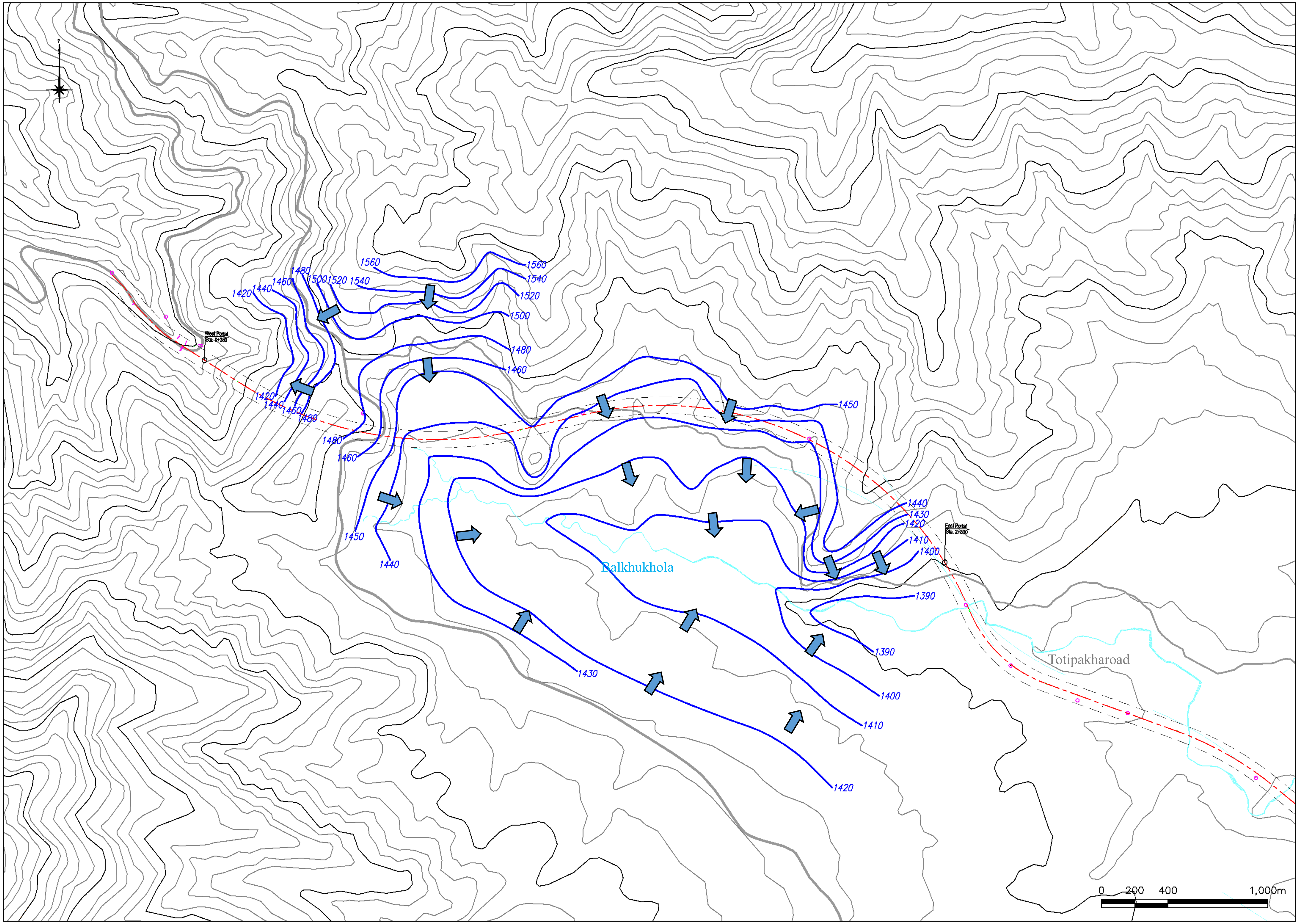


FIGURE 9.14-8 GROUNDWATER LEVEL CONTOUR MAP

(2) Water usage of each basin

Tentatively water basins are divided into 5 locations as is shown in **Figure 9.14-9**.

FIGURE 9.14-9 BASIN CLASSIFICATION

1) A area

【Drinking water】

Drinking water is from well water or spring water.

【Agricultural water】

Due to the utilization of water for domestic use in the upstream area, water does not flow through the streams. Therefore, paddy field is small.

2) B area

【Drinking water】

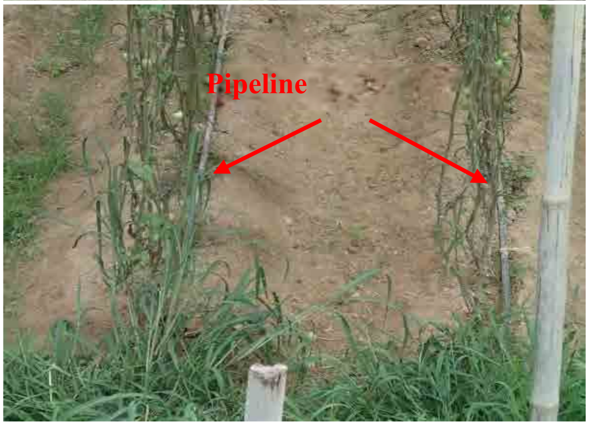
Drinking water is often from wells until near 100m upstream from the Totipakha Road. In the higher locations upstream of it, drinking water is from water of stream.

【Agricultural water】

Tomato cultivation is a thriving place. Tomato cultivation makes use of the water of the stream. There are a lot of paddy fields, there is a water use of the stream.

【Water use of other】

There is a large pond upstream, it is used as a venue for training fish farm.



3) C area

【Drinking water】

Residents of this watershed are using spring water or stream. There is information that has water conveyance from afar.

【Agricultural water】

There is water in the stream, paddies irrigated area is wide.

4) **D area**

【Drinking water】

They are using the spring water in the upstream of the stream.

【Agricultural water】

Stream water can be seen only after rainfalls. There is a paddy field on the downstream side of the Totipakha road, They are irrigated with rainfall.

5) **E area**

【Drinking water】

The use of the spring water.

【Agricultural water】

Not farmland.

9.14.3 Study of Groundwater Lowering Range

(1) Hydrological Method of Takahashi

A rough estimation of groundwater lowering due to tunnel excavation was done by using Takahashi's method which is one of Hydrological methods. The catchment area of the tunnel approximates the shape and size of the basin with the flow path length comparable to the tunnel length. This method consists of empirical rules. Hydrological method is represented by the average permeability around the shape of the basin.

$$Kt = R^2/6H \quad (Kt\text{: Average permeability})$$

$$R = A/2L$$

R：Average basin width

A：Basin area (m^2)

L：Flow pass length (m)

H：Relative elevation difference (m)

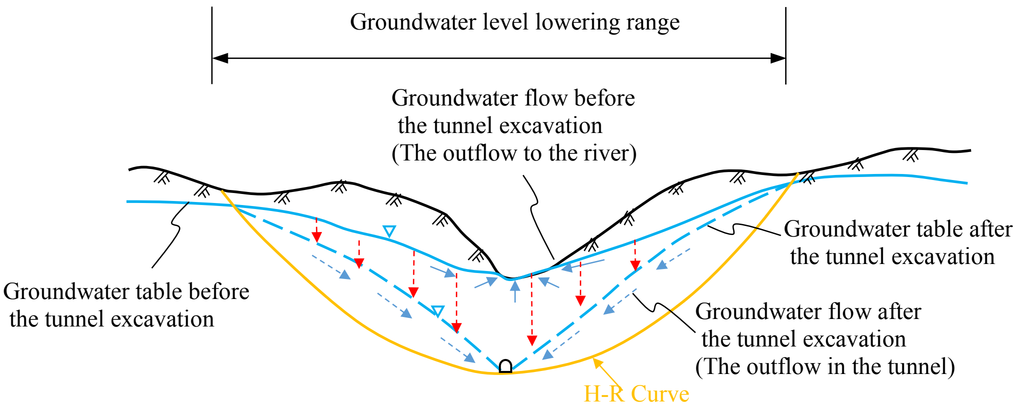


FIGURE 9.14-10 CONCEPT OF GROUNDWATER LOWERING RANGE BY HYDROLOGICAL METHODS

(2) Groundwater lowing range of the tunnel due to hydrological methods

The groundwater lowing range was studied in two representative basin close to the tunnel.

A basin : Kt = 76.2 (L=865m A=253,788m^2 H=47.1m)

B basin : Kt = 82.1 (L=955m A=433,418m^2 H=104.5m)

As is shown in the drawing (**APP NO. 11-d of Preliminary Design Drawing Sheets Preliminary Design Drawing Sheets**) that area of the groundwater lowering are very wide. However, the model is a very simplified model and actual geological condition in the area differs very much from the model. Geological structure is sub-parallel to the tunnel axis and bedding planes of the strata are sub-vertical dipping north or south due to minor foldings. Strata consist of alternation of sandstones and slates where slates are generally impervious. Thus groundwater may infiltrate from the sandstone layers vertically and migration of groundwater in lateral direction which cut the bedding planes hardly occurs. Moreover, as are shown in the **App. 9c and 9d of the Preliminary Design Drawings**, there develop impervious clay layers which limit the movement of the groundwater surrounding the tunnel. Thus order of lowering of groundwater level due to tunnel excavation is supposed to be not so large. The matter shall be further studied in Detail Design Stage because it relates to the manner and quantity of chemical injection during tunneling which significantly affects the tunnel cost and construction time.

9.14.4 The drought management consideration by groundwater lowering

There is a possibility that the groundwater level is lowered by the tunnel excavation. Therefore, it may be necessary to consider beforehand about the drought management. There are permanent measures and emergency measures for drought management.

(1) Measures for drinking water

Water trucks may be used in emergency cases.

As for permanent measures there are several ways;

① Headrace from a nearby stream

→ It is very difficult to design any headrace because there is little water in a nearby stream.

② Development of a new well

→ There is a possibility near Balkhukhola or the opposite bank of the Balkhukhola. It requires pumping up systems and piping systems to distribute the water to wide spread area where inhabitants live.

③ Horizontal boring to the mountain

→ It is very difficult to determine where to make drilling as well as it may affect the present water use.

The potential is a new well development in the second.

It may be possible to newly develop wells but it should be studied and prepared before construction starts.

(2) Measures for Agricultural water

Flow rate of the stream is less when there is no rainfall. Therefore, paddy irrigation relies on rainfall. It is possible that the flow rate of the stream is reduced by the tunnel excavation. But paddy irrigation may be possible. However, it should be noted that there is a spring water in the paddy fields of the downstream side of the Totipakharoad.

There is an item of some permanent measures.

① Development of a new well---unrealistic

② Pond Construction---very difficult

③ Crop substitution compensation

④ Compensation in money

⑤ Alternate site compensation

It is necessary to examine the measures in accordance with the situation.

(3) PROPOSAL OF PERIODIC OBSERVATION

Periodic monitoring of wells are necessary during construction in order to grasp the lowering of groundwater by tunnel excavation. Periodic observations measure water level, flow rate and water quality. Periodically monitoring points are shown in the **APP NO. 11-d of Preliminary Design Drawing Sheets**. Monitoring shall be done for wells at the left bank of the river.

9.15 PROJECT RISKS AND OTHER ISSUES TO BE STUDIED FURTHER

9.15.1 PROJECT RISKS

(1) Construction risks

1) Tunneling is an underground activity where complete geotechnical conditions generally are not foreseen at the design stage. Moreover, due to the difficulty to carry out seismic refraction survey and the lack of proper equipment for exploration drilling, condition of rock mass and distribution of classes of tunnel types may differ from the supposition in our current design and international design team shall carry out above investigations in their early stage of detail design to make it clearer.

2) It is anticipated that surface water flows in the valley areas and groundwater level are lowered by tunneling to some extent. Groundwater being extracted from wells and surface water are utilized for domestic use and agricultural use and significant shortage of water may cause serious problem for the implementation of the project. Groundwater monitoring shall be continued throughout the detail design stage and construction stage and adequate measures against water shortage when it occurs shall be studied during detail design stage.

3) To minimize construction risks the prequalification of contractors should focus on their technical capabilities in handling similar works. Especially their experience of tunneling in difficult ground with employment of particular auxiliary methods shall be carefully considered.

4) The implementation of the project requires substantial land acquisition and resettlement. On some recent infrastructure projects in Nepal delays in completing resettlement has led to delays in project implementation.

(2) Operation Risks

Characteristics of drivers' driving manners and vehicle characteristics are as follows;

(a) Drivers try to overtake slow moving vehicles, even using space of an opposite direction lane. If this kind of driving is practiced inside the tunnel, there is a high risk of fatal traffic accident.

(b) There are many old trucks and they often stop on the road due to breakdown of vehicle. Breakdown vehicles are particularly observed at up-grade sections. Currently they stop at a shoulder or at an emergency bay.

(c) High rate of old model of vehicles causes high rate gas emission which affects visibility and high contents of CO, NOx, etc. inside a tunnel.

Tunnel cross section and facilities were planned and designed in due consideration of above drivers' and vehicles' characteristics.

During the detailed design, the following should be considered;

1) To cope with (a) and (b) above, study lane width and shoulder width

This Study :	Upgrade direction	3.5m + 2.5m (shoulder) = 6.0m
	Downgrade direction	3.5m + 0.5m (shoulder) = 4.0m

Possible Alternatives to be studied during the detailed design are;

- To specify 2.5m shoulder as a climbing lane and all trucks shall utilize a climbing lane.
- To widen a climbing lane to 3.0m instead of 2.5m (tunnel cross section is to be widened by 0.5m or use carriageway width of 3.25m).
- To install flexible plastic poles at a center line to avoid vehicle to use the opposite lane.

2) To cope with (c) above, review ventilation system

This Study :	In due consideration of present vehicle condition, number of jet fans, visibility meters, CO meters, etc. were planned.
Detailed Design :	Review number of jet fans, etc., carefully in due consideration of vehicle conditions.

3) To operate a tunnel safely, one of the most important issues is to educate the drivers prior to opening of a tunnel. Under the Capacity Development Program, the Traffic Safety Campaign is planned. This campaign should be continuously implemented even after a tunnel opened to traffic by the Tunnel Management Office.

4) Timely implementation of maintenance work such as pavement markings, cleaning of lighting facilities, etc., shall be implemented regularly and whenever identified as necessary. Tolls are collected from tunnel users, thus, Tunnel Management Office must provide high quality of tunnel facilities.

9.15.2 Important issues to be further studied in DD stage

(1) Prevention of lowering of groundwater level

In the preliminary design of the tunnel chemical injection is designed in type D1-b and D2-a by utilizing the AGF method for all the surrounding periphery of the tunnel as well as additional chemical injection from the shotcrete surface where water inflows are observed after excavation.

However, when the geological condition is taken into account that strikes of the strata are sub-parallel to the tunnel axis and dips are generally in high angle to the north or to the south depending on minor folds, groundwater may perforate into the fissures in the sandstones in vertical direction and due to the thin alternation of sandstone and shale in which shale is impervious groundwater may not migrate to lateral direction across the bedding planes.

If this is the case then waterproofing by chemical injection may be OK to be carried out along the periphery of the tunnel arch instead of along all the periphery of the tunnel. It may reduce the construction cost and time drastically.

It is strongly recommended to the DD designers to further study on this point after getting results of seismic refraction survey and drilling surveys. Seismic survey may reveal the depth of the debris above the rock mass. Some of drilling surveys shall be done in short length in the rock perpendicular to the tunnel axis to confirm the strikes of the rock to be sub-parallel to tunnel axis. Thus, adequate hydrological model can be established and proper chemical injection design can be recommended.

Schematic geologic and hydrologic model is shown in **APP. NO. 9-c and 9-d of Preliminary Design Drawing Sheets**.

(2) Ground treatment at the eastern portal area

Chemical injection from the surface is designed at eastern portal area in order to minimize the lowering of groundwater level here. Along the tunnel and road axis talus deposits distribute above the weathered rock mass. Groundwater is supposed to be trapped in weathered rock mass as pressurized groundwater in the area from the drilling result of TC1 which was carried out at the Data Collection Survey stage. However, in the talus deposit groundwater was hardly detected during auger drilling survey in portal area, which may imply that talus deposits contain high amount of very small particles.

It is recommended in DD stage to excavate a pit near the portal to ensure whether talus deposit is impervious or not and if lower part of talus deposit contains groundwater. If groundwater is supposed to be accumulated and trapped only in the uppermost weathered part of the rock mass, then total length of the chemical injection treatment from the surface can be significantly reduced. The treatment may target the zones from the lower part of talus deposits to weathered rock mass till 3m coverage of treated zones are obtained beneath the tunnel base.

(3) Review of longitudinal geological profile of the tunnel

Due to the difficulty in carrying out seismic survey, dynamites are strictly controlled by the army, and lack of adequate equipment for core drilling there are uncertainties in longitudinal geological profile. Thus in the preliminary design tunnel is designed based on supposition that rock mass may be somewhat inferior than is seen in outcrops. In DD stage seismic survey shall be carried out in very early stage and core drilling shall be carried out equipped with adequate double core tubes to make the longitudinal geological profile more accurate.

(4) Monitoring of groundwater level and preparation of adequate measures for water shortage

Wells and springs to be monitored during construction stage are shown in **APP. NO. 11-d of Preliminary Design Drawing Sheets**. There are 52 numbers of wells and springs in the figure but only the left bank ones of the Ghate Khola shall be monitored. Groundwater level may be lowered to some extent during tunneling due to the water inflow from sandstones, however, owing to the chemical injection accompanied with AGF rate of ingress of groundwater is deemed to be small and after completion of the tunnel construction groundwater level is expected to recover to the original level.

However, during monitoring of groundwater level when significant lowering of groundwater level occurs and it affects domestic water use significantly adequate measures shall be taken to mitigate the situation. DD designers are recommended to prepare adequate temporary water supply measures to be adopted in case of significant water shortage occurrence.

(5) Review of alignment in western portal outlet in view of traffic safety

In the preliminary design road to the western direction is descending by 3.22% in the tunnel till 0+200 followed by about 6.3% from here on to the west and meets a signal location where relocated existing road intersects with the new road.

For the safety of traffic following two points shall be further studied in DD stage.

First one is traffic safety at signal location. New road including tunnel is of very high graded road with much better pavement than is now and traffic is supposed to descend the new road in fairly high speed. However, most of vehicles are of very old ones and most of the drivers has no experience with signaling it is very doubtful whether vehicles can stop properly at the signal. This is also the case for vehicles from existing road.

Second one is that in the vicinity of tunnel outlet vehicles from existing road may occasionally plunge into the new road due to very small descending curve with gradient of 5%.

Due to the short duration for the preliminary study our team only could follow the selected alignment. Above two issues may not be adequately resolved without shifting the tunnel portal and alignment to some other location, which requires additional topographical survey and geological investigations.

(6) Requirement of emergency escape measures

According to Japanese Standards, provision of an evacuation tunnel or escape shelter or similar measures is mandatory for tunnels longer than 3.0km. The length of Nagdhunga Tunnel is 2.5km and fundamentally does not require such provisions. However, the GON requested the Survey Team to conduct a study on the evacuation method as considering the present condition of vehicles and driving manner of Nepal, provision of such facility is inevitable. They said they became aware of the need after observing such facility in one of the tunnels being constructed in Japan during the visit study to Japan in August. In addition GON said provision of such measure also necessitates from the fact that Nagdhunga Tunnel- potentially being the first highway tunnel in the history of Nepal- will hopefully be a model project for other similar projects, such measure are desirable to be undertaken. Following the request from the GON, the Survey Team conducted a study of different methods as shown in **Table 9.15-1**. The Survey Team recommended **Case-4** and suggests further study in the detailed design stage.

9.15.3 Important issues to Construction stage

(1) Flexible Action for Change Order

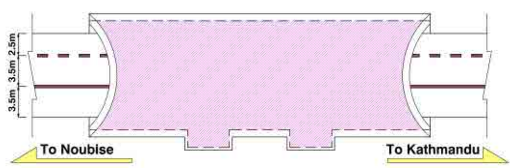
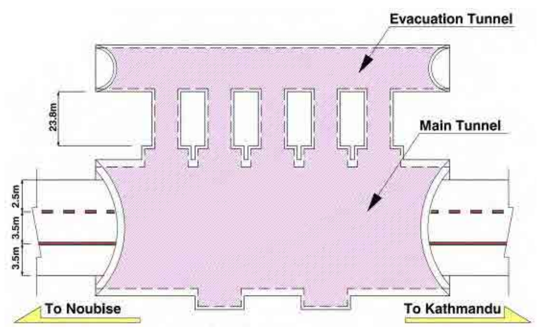
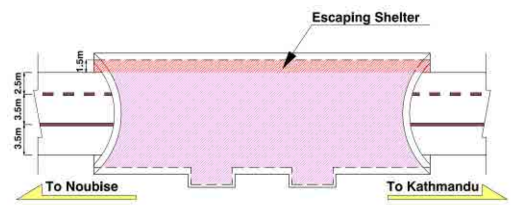
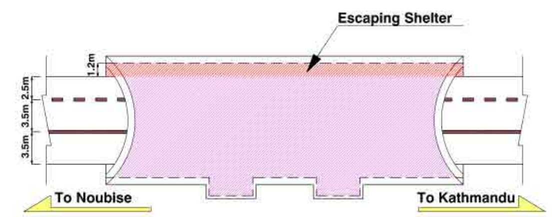
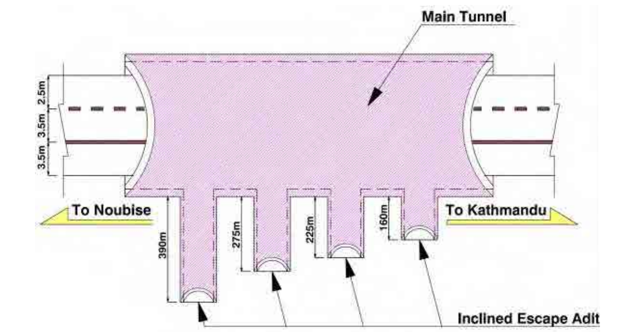
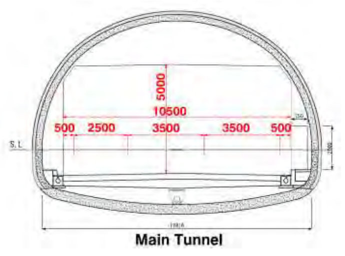
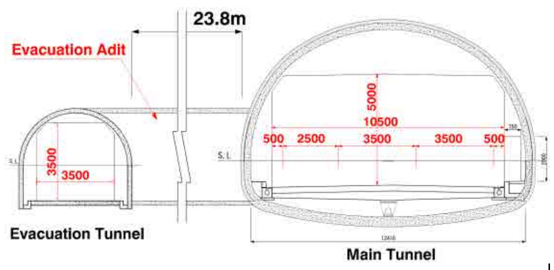
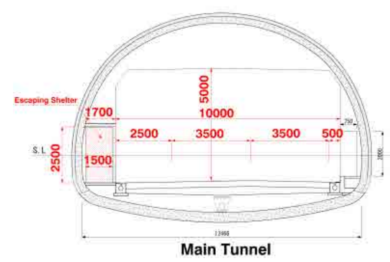
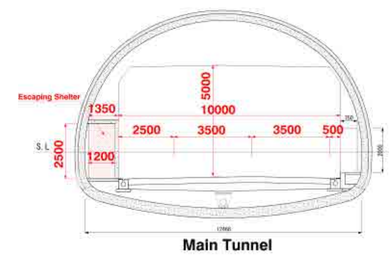
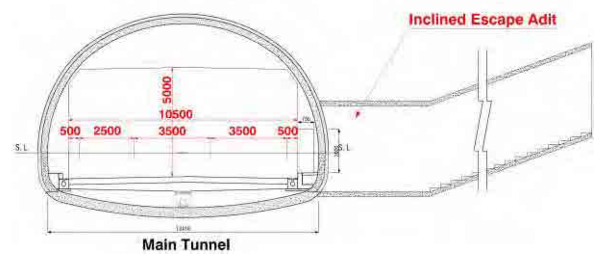
Tunnel construction methods highly depend on the geological conditions, accordingly construction cost varies drastically. Even though detailed geological survey is undertaken, it is impossible to reveal exact geological condition and it can only be known during construction. It is also true that it is quite difficult and unrealistic to stop tunneling work during construction and it should be continued.

In view of above, one of the most important considerations on tunnel construction is that the Government can approve change order(s) based on the recommendations of the Consultant as soon as the unexpected geological conditions are found. The contract of tunnel project should clearly specify the above conditions so that the bidders can be able to bid based on the fare price without taking account of changes of geological condition.

There will be plus or minus change orders. In anticipation of plus change orders, GON shall prepare sufficient budget for the Project with the anticipation of change orders. Price contingency and physical contingency should be included in the annual budget. In case that the allocated budget for the Project is found to be insufficient, DOR shall realign the budget of other projects in order for this tunnel project to be continued even under unexpected geological conditions.

Above these project risks and issues were summarized in **Section 17.6** with other risks.

TABLE 9.15-1 NAGDHUNGA TUNNEL OPTION COMPARISON

Case	**Case-1** **Main Tunnel (Base Plan)** (Road Width=0.5m+2.5m+3.5m+3.5m+0.5m)	**Case-2** **Main Tunnel (Base Plan)** **+Evacuation Tunnel** (Road Width =0.5m+2.5m+3.5m+3.5m+0.5m)	**Case-3** **Main Tunnel (0.5m Expansion)** **+Escaping Shelter(W=1.5m)** (Road Width=2.5m+3.5m+3.5m+0.5m)	**Case-4** **Main Tunnel (Base Plan)** **+Escaping Shelter(W=1.2m)** (Road Width=2.5m+3.5m+3.5m+0.5m)	**Case-5** **Main Tunnel (Base Plan)** **+Inclined Escape Adit** (Road Width=0.5m+2.5m+3.5m+3.5m+0.5m)
Plan					
Cross Section					
Safety Facilities Concept	➢ In case of happening the vehicle trouble, emergency parking bay can be utilized.	➢ In case of happening the vehicle trouble, emergency parking bay can be utilized. ➢ In case of happening serious traffic accidents like fire accident, escape of tunnel users and passing the evacuation vehicles are possible by utilizing evacuation tunnel.	➢ In case of happening the vehicle trouble, emergency parking bay can be utilized. ➢ In case of happening serious traffic accidents like fire accident, escape of tunnel users is possible by utilizing escaping shelter.(Adult two people can run in parallel)	➢ In case of happening the vehicle trouble, emergency parking bay can be utilized. ➢ In case of happening serious traffic accidents like fire accident, escape of tunnel users is possible by utilizing escaping shelter.(A adult and a child can run in parallel)	➢ In case of happening the vehicle trouble, emergency parking bay can be utilized. ➢ In case of happening serious traffic accidents like fire accident, escape of tunnel users is possible by utilizing inclined escape adit.(Evacuation vehicle can not pass)
Main Tunnel Cross Sectional Area	Main Tunnel: 89.25m^2	Main Tunnel: 89.25m^2 Evacuation Tunnel: 19.56m^2 Total: 108.81m^2	Main Tunnel: 95.17m^2	Main Tunnel: 89.58m^2	Main Tunnel: 89.25m^2 Inclined Escape Adit: 19.56m^2 Total: 108.81m^2
	(Base Case)	(+19.23m^2) or (1.21)	(+5.92m^2) or (1.07)	+0.29m^2) or (1.01)	(+19.23m^2) or (1.21)
Cost (2014 Price) (Without VAT)	Main Tunnel: 10,626 Million JPY	Main Tunnel: 10,626 Million JPY Evacuation Tunnel: 3,349 Million JPY Total: 13,975 Million JPY	Main Tunnel: 12,860 Million JPY Escaping Shelter: 123 Million JPY Total: 12,983 Million JPY	Main Tunnel: 10,626 Million JPY Escaping Shelter: 99 Million JPY Total: 10,725 Million JPY	Main Tunnel: 10,626 Million JPY Inclined Escape Adit: 4,179 Million JPY Total: 14,805 Million JPY
	(Base Case)	(3,349 Million JPY) or (1.32)	(+2,357 Million JPY) or (1.22)	(+99 Million JPY) or (1.01)	(4,179 Million JPY) or (1.39)
Construction Period	43.0 months (Base Case)	43.0 months (+0.0 month)	44.0 months (+1.0 month)	43.0 months (+0.0 month)	43.0 months (+0.0 month)
Other	– No safety measures are yet considered.	– Evacuation tunnel L=2.45km, H=3.5m, width=3.5m, 5 adits 500m interval – Emergency vehicle for rescue and fire fighting can pass Evacuation Tunnel. – In case of another 2-lane tunnel required, Evacuation Tunnel can be utilized as a part of additional Main Tunnel.	– Escaping Shelter width of 1.5m provided.	– Minimum Escaping Shelter width of 1.2m provided.	– 4 Inclined Escape Adits are provided.
Recommendation				**Recommended**	

CHAPTER 10

PRELIMINARY DESIGN OF APPROACH ROAD

CHAPTER 10
PRELIMINARY DESIGN OF APPROACH ROAD

10.1 GEOLOGICAL INVESTIGATON UNDERTAKEN

10.1.1 Survey Area

The geological investigation was carried out for the selected alignment of part of Tribhuvan Highway as shown in **Figure 10.1-1**. The road length for the survey is approximately 4.6km.

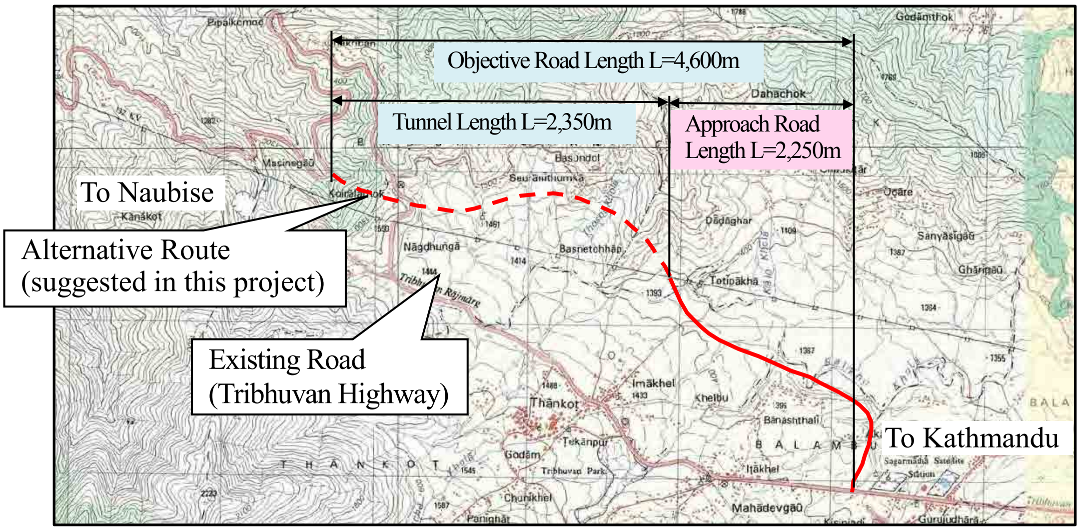


FIGURE 10.1-1 LOCATION MAP OF THE SURVEY AREA

(1) Geological Setting

As **Figure 10.1-1** shows, the investigation area is located in a wide valley of Balkhu Khola, which is one of tributaries of Bagmati River. This valley is underlain by basement rocks of Lower Paleozoic age. These basement rocks correspond stratigraphically to Phulchauki Group, and divided into three formations, namely Tistung Formation, Sopyang Formation and Chandragiri Limestone in ascending order.

The valley of Balkhu Khola composes the western part of Kathmandu Basin, and is filled with Quaternary fluvio-lacusrtine sediments. The basal part of the basin-fill sediments consists of lower Pleistocene lacustrine clays of Kalimati Formation. At the surface of the valley, Kalimati Formation is overlain by unconsolidated sediments of talus deposit and recent river deposit.

The geological map of the survey area is shown in **Figure 10.1-2**.

Lithological characteristics of the Lower Paleozoic basement rocks and the overlying Quaternary sediments are as follows;

[Phulchauki Group (Lower Paleozoic)]

1) **Tistung Formation:** The formation consists essentially of slates, phyllites, and meta-sandstone, being considered to be of early Cambrian age. The lower part of the formation consists of dark phyllites with fine biotite, which disappears or becomes inconspicuous at upper part. Sericite and chlorite are the dominant metamorphic minerals.

2) **The Sopyang Formation:** This formation is a transitional zone between the fine-grained clastic rocks of the Tistung Formation and the thick Chandragiri Limestone. It consists of softly weathered phyllitic slates, argillaceous limestone of black color. Worm tracks on the bedding planes of slate have been reported

3) **Chandragiri Limestone:** Limestone is the most prominent formation of the Phulchauki

Group. It consists of wellbedded to massive weathered limestone. In the lower part, the limestone is more thinly bedded to more argillaceous. The formation contains conodonts and echinoderms indicating Middle Cambrian and Middle-Late Ordovician age.

[Quaternary]

1） **Kalimati Formation:** The Kalimati Formation (or Kalimati Clay) is mainly composed of thick black lacustrine clay, which is rich in organic matter, diatoms, plant fossils and natural gases.

2） **Talus deposits:** In foothill slopes, unconsolidated clay, silt and sand to boulders of variable thickness compose the inhomogeneous deposits.

3） **River deposits:** The recent alluvial sediments, which are composed of sand, gravel to boulder, and distributed in flood plains and lower alluvial terraces.

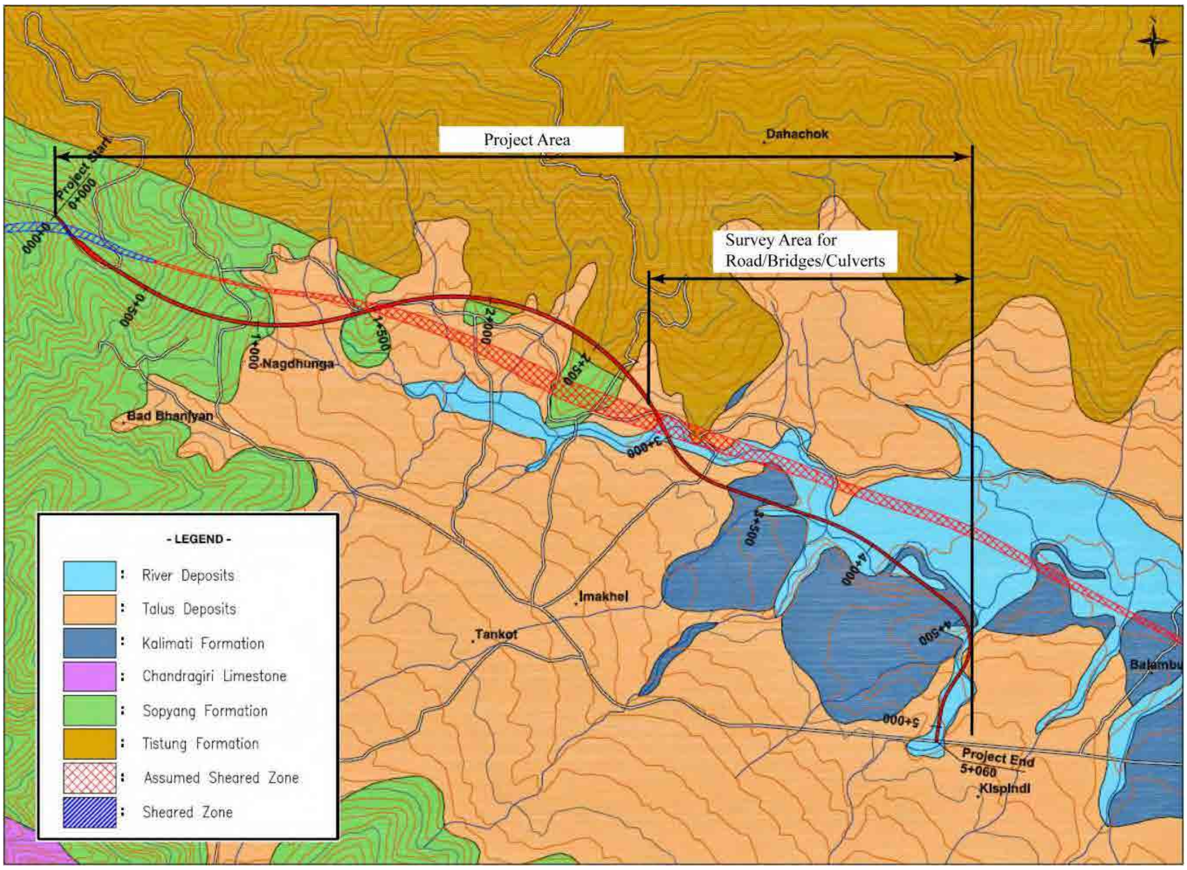


FIGURE 10.1-2 GEOLOGICAL MAP OF STUDY AREA

Focusing on the study area for an approach road and bridges/culverts, the area is relatively flat and Quaternary clay and silt is distributed. Also, the area is accumulated by alluvial fan deposits composed of gravel. The detail of Quaternary feature (salf, klm) is shown in **Figure 10.1-3**.

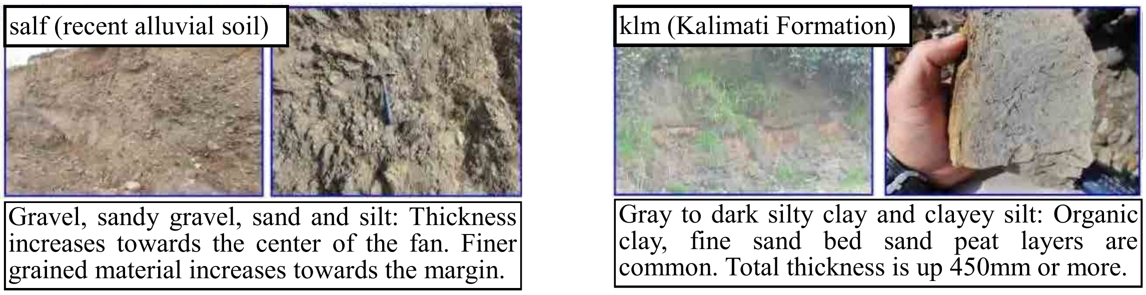


FIGURE 10.1-3 LOCATION MAP OF STUDY/SURVEY AREA

(2) Objective of the Geotechnical Investigation

The objective of the investigation was to determine the geotechnical properties of the sediments which are distributed along the planned route of the approach road. Rotary drillings and the standard penetration tests (SPT) were carried out to identify the characteristics of the ground as the foundation of bridges and culverts. Soil samples for laboratory tests were obtained from drilling cores. Also test-pits and auger-borings had were carried out to obtain the samples of laboratory tests to analyze soil parameters as materials and foundations for the road construction.

(3) Scope of Work

Items and quantities of the geological investigation are shown in **Table 10.1-1**. Also, the locations of each investigation are indicated as follows;

1) Locations of borings for bridges/culverts: shown in **Figure 10.1-4**.

2) Locations of test-pits and auger-borings: shown in **Figure 10.1-5**.

Each geological investigation and laboratory tests were conducted in accordance with the relevant ASTM standard or equivalent standards shown in **Table 10.1-1**.

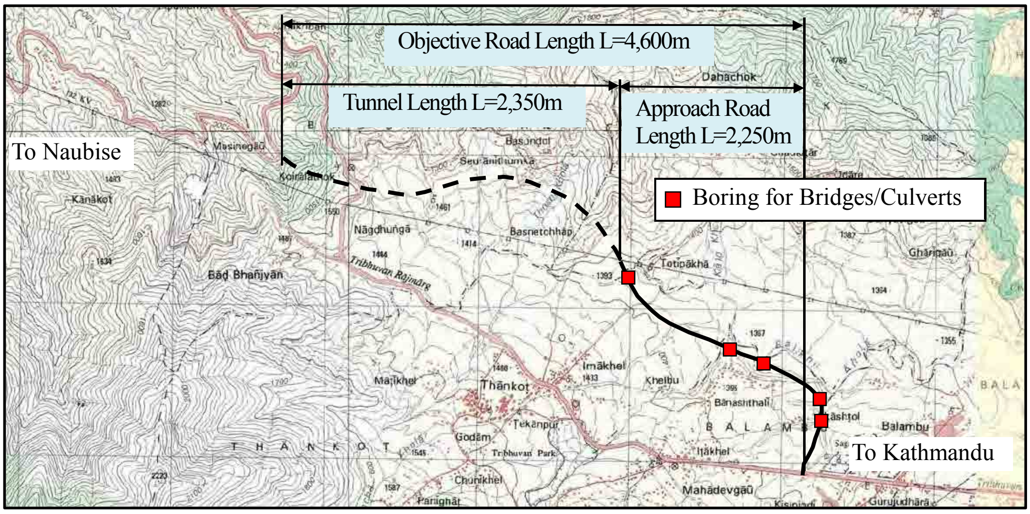


FIGURE 10.1-4 BORING LOCATIONS FOR BRIDGES/CULVERTS

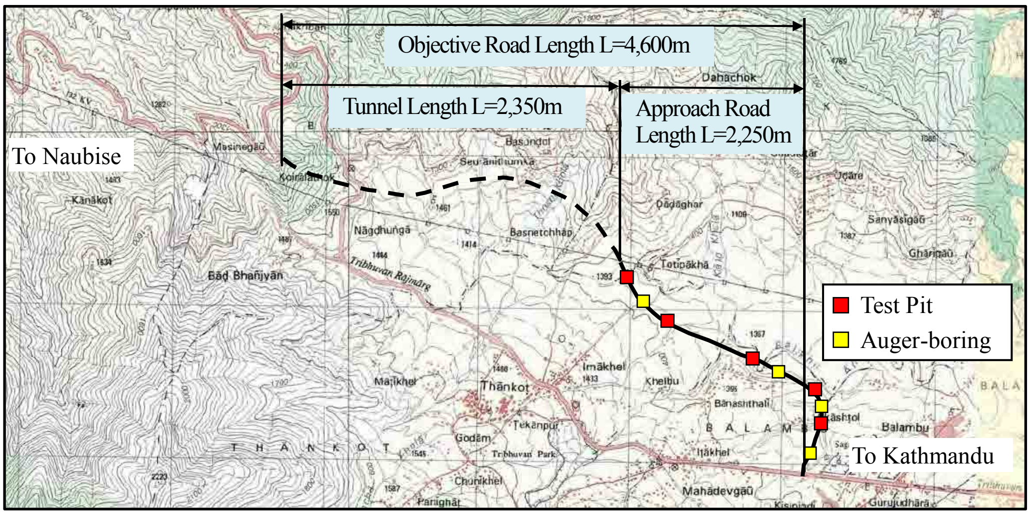


FIGURE 10.1-5 LOCATIONS OF TEST-PITS AND AUGER-BORINGS

TABLE 10.1-1 INVESTIGATION/TEST ITEMS AND QUANTITIES

Investigation/Test for the Bridge /Culvert Site					
Particulars			Qty	Unit	Applied Method
1.	Drilling (5BHs)		70	meter	ASTM D5434-03 / D2113-08
2.	Standard Penetration Test (SPT)		70	each	ASTM D1586-11
3.	Laboratory Test				
	1)	Specific gravity	5	sample	ASTM D854-14
	2)	Natural Moisture Content	5	sample	ASTM D2216-10
	3)	Grain size Distribution	5	sample	ASTM D422-63(2007)e1 / D2217-85(1998)
	4)	Soil Classification	5	sample	ASTM D2487-11
	5)	Atterberg limit	5	sample	ASTM D4318-10e1

Investigation /Test for the Approach Road Site					
Particulars			Qty	Unit	Applied Method
1.	Test Pit		5	pit	Excavation at 1.0 x 1.5 x 2.0m
2.	Auger Boring		14	point	ASTM D1452-09
3.	Laboratory Test				
	1)	Specific gravity	10	sample	ASTM D854-14
	2)	Natural moisture content	10	sample	ASTM D2216-10
	3)	Grain size distribution	10	sample	ASTM D2217-85(1998) / D421-85(2002)
	4)	Soil classification	10	sample	ASTM D2487-11
	5)	Atterberg limit	10	sample	ASTM D4318-10e1
	6)	Moisture-density relation	5	sample	ASTM D698-12e1
	7)	CBR	5	sample	D1883-99

Note; - Atterberg limit (Liquid limit and Plastic limit) of soil test was conducted only for cohesive soil.
- CBR test was conducted with samples obtained in the test pits.

10.1.2 Method of Investigation

(1) Rotary Drilling

Rotary drillings were carried out on the site of planned sites for bridges and culverts. As the investigated area is covered with unconsolidated sediments, mud drilling or rotary drilling without injecting water had been performed, and the standard penetration test (SPT) according to ASTM D-1586, at intervals of 1 meter (depth) in the borehole.

Drilled cores and SPT samples were placed in core boxes in a systematic manner for the logging. Photographs of core boxes of each borehole were taken and combined continuously in the sheets. Drilling logs and photographs of cores are included in the Final Report.

Geological survey include approach road, was performed in a range of 1 km or more left and right. Geological map is shown in **Figure 10.1-2**.

Before the implementation of rotary drilling, geological mapping and aerial photograph interpretation with scale of 1: 50,000 had been performed to analyze the geological structure of the basin-fill sediments.

(2) Standard Penetration Test (SPT)

The standard penetration test (SPT), according to ASTM D-1586, had been carried out at intervals of 1 meter depth in the borehole, until N-value of 300 or more (SPT blow count 50 or more/5 cm) is confirmed. The soil classification, tone of color, mixed matters, etc. of the soil samples which obtained by "Raymond-sampler" were recorded.

(3) Test-pit and Auger-boring

The subgrade investigation of the low embankment section by test-pit and auger-boring had been carried out. The test-pits and the auger-borings were performed alternately at about 500-meter interval.

Size of the test-pits were 1.5m in length, 1m in width and 2m in depth in principle, and the soil samples for the laboratory tests, such as CBR tests, were obtained.

The auger-boring had been drilled until 2 meter depth, and the soil samples for the laboratory tests were also obtained.

(4) Laboratory Test of Soil Samples

The laboratory test of soil samples according to the standards indicated in **Table 10.1-1**. And in addition to the above mentioned items, CBR (California Bearing Ratio) test had been carried out with samples obtained in the test pits.

1) **Specific Gravity (ASTM D854-14):** The test methods cover the determination of the specific gravity of soil solids that pass the 4.75-mm (No. 4) sieve, by means of a water pycnometer. When the soil contains particles larger than the 4.75-mm sieve, Test Method C127 shall be used for the soil solids retained on the 4.75-mm sieve and these test methods shall be used for the soil solids passing the 4.75-mm sieve.

2) **Natural Moisture Content (ASTM D2216-10):** The test methods cover the laboratory determination of the water (moisture) content by mass of soil, rock, and similar materials where the reduction in mass by drying is due to loss of water except.

3) **Grain Size Distribution (D421-85(2002)):** The test method covers the quantitative determination of the distribution of particle sizes in soils. The distribution of particle sizes larger than 75 μm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 75 μm is determined by a sedimentation process, using a hydrometer to secure the necessary data.

   Grain Size Distribution (ASTM D2217-85(1998)): The practice covers the wet preparation of soil samples as received from the field for particle-size analysis and determination of soil constants. Procedure A provides for drying the field sample at a temperature not exceeding 140°F (60°C), making a wet separation on the No. 10 (2.00-mm) sieve, or No. 40 (425-[mu]m) sieve, or both, as needed, and finally drying at a temperature not exceeding 140°F. Procedure B provides that the sample shall be kept at moisture content equal to or greater than the natural water content. The procedure to be used should be indicated in the specification for the material being tested. If no procedure is specified, the provisions of Procedure B shall govern.

4) **Soil Classification (ASTM D2487-11):** This practice describes a system for classifying mineral and organo-mineral soils for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit, and plasticity index and shall be used when precise classification is required.

5) **Atterberg Limit (ASTM D4318-10e1):** The liquid and plastic limits of a soil and its water content can be used to express its relative consistency or liquidity index. In addition, the plasticity index and the percentage finer than 2-μm particle size can be used to determine its activity number. The test methods cover the determination of the liquid limit, plastic limit, and the plasticity index of soils. Two methods for preparing test specimens are provided as follows:

   - *Wet preparation method,*
   - *Dry preparation method,*

   In the case that no method was specified, the wet preparation method was used.

6) **Moisture-density Relation (ASTM D698-12e1):** The test methods cover laboratory compaction methods used to determine the relationship between molding water content and dry unit weight of soils (compaction curve) compacted in a 4 or 6-in. (101.6 or 152.4-mm) diameter mold with a 5.50-lbf (24.5-N) rammer dropped from a height of 12.0 in. (305 mm) producing a compactive effort of 12 400 ft-lbf/ft3 (600 kN-m/m^3).

7) **Moisture-Density Relation (ASTM D698-12e1):** The test methods cover laboratory compaction methods used to determine the relationship between molding water content and dry unit weight of soils (compaction curve) compacted in a 4 or 6-in. (101.6 or 152.4-mm) diameter mold with a 5.50-lbf (24.5-N) rammer dropped from a height of 12.0 in. (305 mm) producing a compactive effort of 12 400 ft-lbf/ft3 (600 kN-m/m^3).

8) **CBR (ASTM D1883-99):** This test method covers the determination of the CBR (California Bearing Ratio) of pavement subgrade, subbase, and base/course materials from laboratory compacted specimens. The test method is primarily intended for but not limited to, evaluating the strength of cohesive materials having maximum particle sizes less than 3/4 in. (19 mm).

10.1.3 Result of Investigation

(1) General

Achieved quantity of the rotary drillings, test-pits and auger-borings are summarized in **Table 10.1-2**. And based on observation of the drilling cores and soil samples which were obtained by SPT, test-pits and auger-borings, the geological structure of the basin-fill sediments along the approach road were analyzed.

As **Figure 10.1-6** shows, the geological profile is proposed as the results of analysis.

TABLE 10.1-2 LIST OF SURVEYED AMOUNT

No.	Item of work	ID No.	Planned	Achieved
1	Rotary Drilling (Bridge site)	Br-1	20m	21m
		Br-2	20m	18m
		Br-3	20m	10m
		Br-4	20m	10m
		Br-5	10m	11m
		Total	90m	70m
2	Test Pit	TP-1	2.0m	2.0m
		TP-2	2.0m	2.0m
		TP-3	2.0m	1.5m
		TP-4	2.0m	2.0m
		TP-5	2.0m	2.0m
		Total	10.0m	9.5m
3	Auger Boring	AG-1	2.0m	2.0m
		AG-2	2.0m	2.0m
		AG-3	2.0m	2.0m
		AG-4	2.0m	2.0m
		Total	8.0m	8.0m

(2) Result of Rotary Drilling and SPT on Bridge /Culvert Sites

5(five) rotary drillings were performed to confirm the geotechnical properties of foundations for bridges and culverts. Results of the geological logging, N-Value and photographs of the core boxes are summarized in logging sheets, and included in the Appendix.

(3) Result of Laboratory Test of the Soil Samples

Result of the laboratory tests on the samples obtained by rotary drillings, test-pits and auger-borings are summarized in **Table 10.1-3**, **Table 10.1-4** and **Table 10.1-5**.

The samples of rotary drilling are composed of black organic clay, correspond to Kalimati Formation, and are classified into ML. The samples of the auger-borings are mainly composed of grey clay, silt and sand of the river deposits, and classified into CL-ML. The samples of test-pit TP-1, TP-2, TP-4 and TP-5 are composed of black clay of Kalimati Formation, and classified mainly into ML, while the sample of TP-3 is sandy silt with gravel of talus deposits, and classified into CL.

TABLE 10.1-3 SUMMERY SHEET OF LABORATORY TEST ON BRIDGE DRILLING SAMPLES

S.No.	Bore Hole	Depth (m)	Laboratory Test Results							Remarks
			NMC (%)	Moist Bulk Density (g/cc)	Sp.Gr.	LL (%)	PL (%)	PI	Soil Classification	
1	BR-1	4.5(SPT-5)	26.18	2.16	2.568	22	NP	NP	ML	
2	BR-2	11.5(SPT-12)	43.10	1.77	2.524	36	26	10	ML	
3	BR-3	5.5(SPT-6)	39.95	1.81	2.493	36	29	7	ML	
4	BR-4	7.5(SPT-8)	27.01	2.06	2.601	32	25	7	ML	
5	BR-5	6.5(SPT-7)	31.81	1.99	2.579	34	25	9	ML	

TABLE 10.1-4 SUMMERY SHEET OF LABORATORY TESTS ON AUGER BORING SAMPLES

S.No.	Bore Hole	Depth (m)	Laboratory Test Results						Remarks
			NMC (%)	Sp.Gr.	LL (%)	PL (%)	PI	Soil Classification	
1	AG-1	0.00 - 0.35	23.01	2.695	23	17	6	CL-ML	
2	AG-2	0.30 - 0.75	27.74	2.685	27	22	5	CL-ML	
3	AG-3	0.60 - 0.10	23.81	2.624	22	NP	NP	ML	
4	AG-4	1.70 - 2.00	25.83	2.557	24	NP	NP	ML	
5	AG-4 (A)	2.00	23.97	2.579	23	16	7	CL-ML	

TABLE 10.1-5 SUMMERY SHEET OF LABORATORY TESTS ON TEST PIT SAMPLES

S.No.	Bore Hole	Depth (m)	Laboratory Test Results									Remarks
			NMC (%)	Sp.Gr.	OMC (%)	MDD (g/cc)	CBR (%)	LL (%)	PL (%)	PI	Soil Classification	
1	TP-1	2m down	21.03	2.579	11.70	1.95	7.10	22	NP	NP	ML	
2	TP-2	2 m	44.51	2.535	16.70	1.71	4.70	34	27	7	ML	
3	TP-3	1.5 m	21.60	2.557	7.90	2.10	10.30	28	20	8	CL	
4	TP-4	2m down	31.45	2.514	12.00	1.75	7.00	22	NP	NP	ML	
5	TP-5	2m down	31.20	2.535	15.90	1.82	6.30	29	22	7	CL	

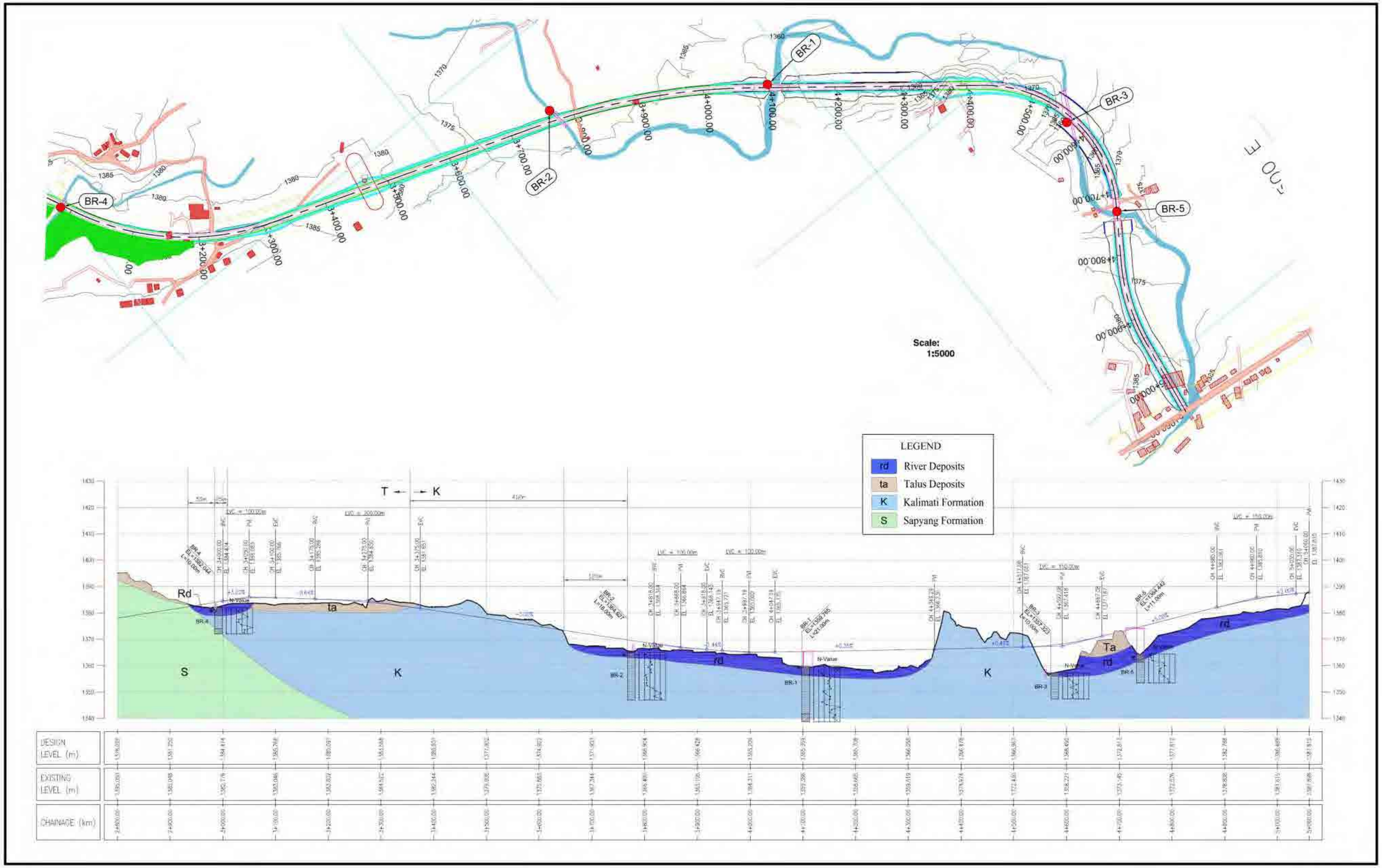


FIGURE 10.1-6 GEOLOGICAL PROFILE ALONG THE APPROACH ROAD

10.2 DESIGN STANDARDS (ROAD AND BRIDGE)

10.2.1 Design Standards (Road)

The standards applied for the design of approach roads are;

- Nepal Road Standards, 2070
- AASHTO Guide for Design of Pavement Structures 1993" (AASHTO Guide)
- Road Structure Guidelines, Japan Association of Roads, February 2004
- Other equivalent guidelines

The criteria to be applied for the design of the objective road are summarized in **Table 10.2-1**. These criteria have been determined after reviewing the criteria adopted during the Data Collection Survey. In addition to the Standards of Nepal, actual figures applied in other projects were also referred in establishing these criteria.

TABLE 10.2-1 PROPOSED DESIGN CRITERIA FOR HIGHWAY DESIGN

SN	Items		Parameters	Reference	Remarks
1	Highway Classification		National Highway Class II		
2	Design Speed (km/h)		60.0		5000-20000 PCU/day
	Cross section	No of lanes	2.0		
		Formation Width (m)	12.0		
		Lane Width (m)	7.0		
		Hard Shoulder (Paved) (m)	2.0		
		Soft Shoulder (Earthern) (m)	1.0		
		Camber/ Crossfall (%)	2.5		
		Slope of Earthwork			
		Fill	V:H = 1:1.8	JRA	
		Cut	V:H = 1:0.8 to 1.8	JRA	
3	Sight Distance	Stopping Sight Distance (m)	65	NRS	
4	Overtaking	Overtaking Distance (m)	300		
5	Horizontal Alignment	**Minimum Radius of Horizontal Curve (m)**			
		Desirable Minimum (m)	150		
		Absolute Minimum (m)	100		
		Unavoidable condition (m)	90		
		Maximum superelevation (%)	6		
		Minimum Length of Transitonal Curve (m)	50	JRA	
6	Vertical Alignment	Maximum Average vertical grade (%) section	4	NRS	
		Maximum Average vertical grade (%) in limited length	6	NRS	
		Critical Length of grade (m)			
		For less than equal maximum average	No limit	NRS	
		For greater than maximum average	210	NRS	
		Minimum Radius of Vertical Curve (m)			
		Crest / Summit Curve	1000		
		Sag / Valley Curve (m)	1200		

Source: JICA Survey Team

10.2.2 Design Standards (Bridge and Culvert)

(1) Review of Design Standard

Nepal Road Standards (NRS 2027) contained the standard design for various kinds of bridges and culverts in Nepal published in 1988. However, this is too old to adopt to design bridge and culvert in Nepal now. Department of Road (DOR) has formulated these standards with a view to establish a common procedure for design and construction of road, bridge and culvert in Nepal. It is called "NBS (Nepal Bridge Standards) -2067 (2010)".

However, the above standard is not practical enough for design all kinds of bridges and culverts at the construction site, therefore, IRC (Indian Roads Congress), AASHTO (Standard Specifications for Highway Bridges) and Japanese Standard shall be applied for the items not covered by the above NBS 2067.

(2) Classification of Bridge and Culvert

Classification of bridge and culvert shall be as follows:

- Culvert : Length up to 6m
- Minor Bridge : When length ≤ 50m (with span ≤ 25m)
- Major Bridge : When span > 25m or length >50m (with smaller spans)
- Special Bridge : Bridge that require special design considerations, whose construction features (e.g. concrete girder bridges with >50m span, steel truss >100m span, arch bridges, suspension bridges, cable-stayed bridges and other non-standard bridges).

(3) Design Life and Design Discharge

All permanent bridges and culverts shall be designed for a design line of minimum 50 years. Traffic projections shall be made for a period 30 years.

All permanent bridges shall be designed for a discharge of 100 years return period and culverts shall be designed for a discharge of 50 years. For the calculation of design discharge empirical formulas especially developed for other catchments shall not be used.

(4) Loadings

All permanent road bridges and culverts in Nepal shall be designed per IRC loadings or AASHTO loadings. All design shall be carried out in accordance to IRC standards for bridge and culvert unless otherwise specified in the project documents. There are various kinds of loadings for bridge such as dead load, live load, impact friction, pre-stress, creep and shrinkage of concrete, dynamic water pressure, earth pressure, buoyancy, wind load, thermal effects and seismic force are considered in design of bridges and culverts.

Live load is applied HS 20-44 (AASHTO) for this important artery road.

(5) Carriageway and Foot path

All bridges in Highways and Urban Roads shall be designed with a minimum carriageway width of 7.5m.

Footpaths shall be provided on all bridges located at settlement areas or on areas of high movement of pedestrian traffic. They should be separated from the vehicular traffic by safety curbs (in rural areas) and by raised footpath or curbs (in urban areas).The width of the footpath should be decided according to projection of pedestrian traffic, however, a minimum clear width (excluding the width of railings) of 1.0 m footpaths to be provided, where necessary.

(6) Clearances

1) Vertical Clearance

The vertical clearance of structures shall be:

- For all roads not less than 4.75m for through structures.
- Overhead wires, poles etc. shall be at least 7.0m above the highest point of the road surface.
- For culvert, clearance shall be more than the highest water level.

2) Horizontal or Lateral Clearance

The horizontal clearance is the clear width available for the passage of vehicles. For culverts, the full roadway width as well as width of shoulders shall be carried through.

(7) Minimum Free Board

In case of bridges over water bodies, the free board from the design HFL (Highest Flood Level) with afflux to the lowest point of bridge superstructure shall not be less than 1.0m. The minimum freeboard shall be as shown on the following **Table 10.2-2**.

TABLE 10.2-2 MINIMUM FREE BOARD

Discharge (m^3/sec)	Minimum Free Board (mm)
Less than 200	1,000
201-500	1,200
501-2,000	1,500
2,001-5,000	2,000
5,000 and above	More than 2,000mm (depending on the reliability of the available data for the calculation of discharge)

Source: Nepal Bridge Standards- 2067, DOR

(8) Seismic Force

According to IRC (Indian Roads Congress), the horizontal seismic coefficient is calculated by the following formula:

$$kh = \alpha\beta\lambda$$

Where, kh = horizontal sesmic coefficient

α= 0.08 (Zone V) : coefficient depends upon the location

β= 1.0 to 1.5 : coefficient depands upon the soil condition (and standard penetration test)

λ= 1.5 : coefficient depends upon the importance of bridge

According to NRS-2067, the horizontal seismic coefficient is 0.15 for the important bridge.

(9) Other Facilities and Utilities to be Provided

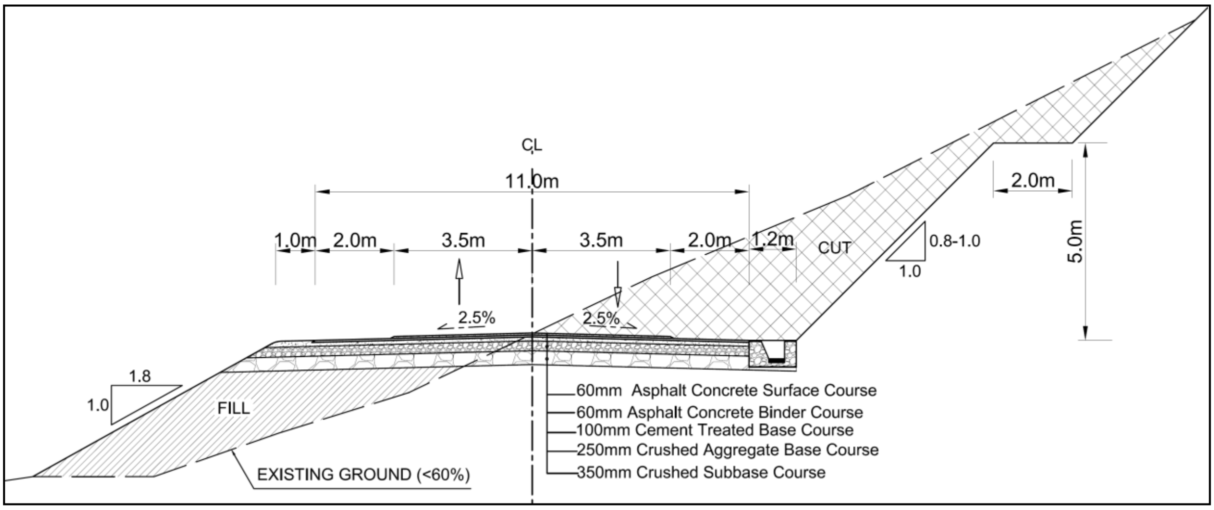
All bridges shall be designed taking into consideration the provision of the following facilities and carrying utilities:

- Curbs and safety curbs (bridge barriers)
- Carriageway drainages
- Railings
- Utilities (electricity, water, telephone and other cables)

10.3 TYPICAL CROSS-SECTIONS

10.3.1 Typical Cross Section (Road)

The proposed typical cross section for the approach road is shown in **Figure 10.3-1**.



Source: JICA Survey Team

FIGURE 10.3-1 TYPICAL CROSS SECTION OF APPROACH ROAD

1) Number of Lanes

The number of lanes on the approach road will be 2 lanes. The width of the lanes will be 3.5m as required by the NRS.

2) Shoulder

The cross section consists of two types of shoulders. A hard shoulder, which will have similar pavement as the lanes will be 2.0m wide. This width is the recommended width in the NRS. The wide shoulder has been applied in order to secure space for traffic in cases of emergency parking or vehicle break down.

On the other hand a 1.0m wide soft shoulder, which will not have a metallic pavement, will be provided on each side of the carriageway. The edge of the shoulder will be rounded in order to prevent from possible erosion.

3) Pavement Structure

Asphalt pavement is proposed for the approach. The pavement will have two layers of 60mm thick asphalt concrete for surface course and binder course. The base course will also have two layers. The upper layer will be cement treated with a thickness of 100mm, and the 250mm thick crushed stone will be provided for the bottom layer. The subbase will be 350mm thick where crushed stones will be applied. This pavement composition is derived from the calculation method discussed in Section 10.4.

4) Drainage Facilities

At cut sections, side ditch will be provided in the soft shoulder to facilitate drainage safely. At high fill section, drainage facility (side ditch) will be provided at the slope toe to facilitate drainage from both the surface and the fill slope runoff.

As the land use along the approach road in the Kathmandu Valley side is mostly cultivated land, it is necessary to ensure that the flow of water is not interrupted. For this purpose, provision of pipe culverts (diameter 900mm) every 200m interval is recommended.

5) Cross fall

Cross fall of camber of 2.5% is adopted based on the requirement for asphalt pavement as mentioned in the NRS.

6) Right-of-Way

The ROW for the proposed approach road is 50m (25m at each side from the centreline at) as according to the standards of Nepal.

(1) Fill and Cut slopes

A slope of 1:1.8 is applied for fill sections and 1:0.8-1.0 for cut sections. Where fill height exceeds 5m, gentler slope will be considered. A berm, 2m wide, is provided in such sections and the top of the slope will be rounded to prevent from erosion. Provision of guard rails will be considered for section where the fill height exceeds 3m. The slopes will be provided with adequate vegetation.

For cut slopes, although the standard slope is 1:1, the slope of 1:0.8 will be applied in case of rocks. As in fill, cut sections will also be provided with a 2m wide berm where the cut height exceeds 5m. The slope face will be provided with proper vegetation. In case of weathered rocks, the slope face will be protected by applying shotcrete.

10.3.2 Ancillary Facilities

1) Pavement Markings

In order to encourage safe operation of traffic and to reduce traffic accidents, road markings will be provided on approach roads. The types of pavement markings and its details are recommended as mentioned in **Table 10.3-1**.

TABLE 10.3-1 TYPES OF RECOMMENDED PAVEMENT MARKINGS

Item	Line Type/Colour	Dimension	Remarks
Centerline	Broken / White	15cm	
Sideline (Shoulder)	Solid / White	15cm	
Travelled lane	Broken/White	15cm	Transition section
Stop Line	Short Broken / White	40cm	
Yield line (Road)	Short Broken / White	15cm	Yield Intersections
Yield line	Short Broken / White	40cm	Roundabouts
Cross walks	Solid / White	3m x 0.4m	Intersections
Directional Arrows	Solid / White	Varies	Straight, Left/ Right Turn
Zebras	Solid / White	40cm	45 degrees

Source: JICA Survey Team

2) Sign Posts

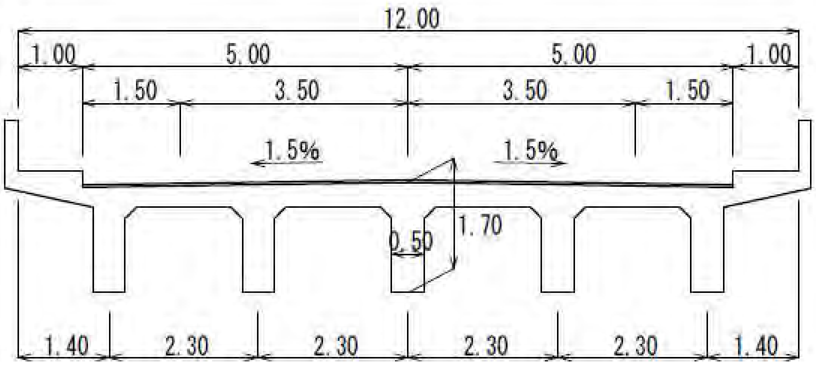
Regulatory signs and informatory signs (informatory signs are limited to bus stop sign) will be provided on the approach roads based on the requirements of Nepal. The provision of such road signs are expected to control, alert and inform the drivers and secure the safety and efficiency of roads.

3) Traffic Lights and Traffic Signals

Approach road section will be provided adequately with Traffic lights. Traffic signals will be provided at intersections at the start point and end point of the approach

10.3.3 Typical Cross Section（Bridge）

The typical cross section applied for bridges on the approach road is shown in **Figure 10.3-2**. As shown in figure, the carriageway of the bridge is designed for the same width as the approach road to secure smooth and safe traffic flow. A 1.5m shoulders 1.5m wide and sidewalks 1m wide are provided at both sides of the bridge. As for the structure, the bridge is planned to be reinforced concrete.

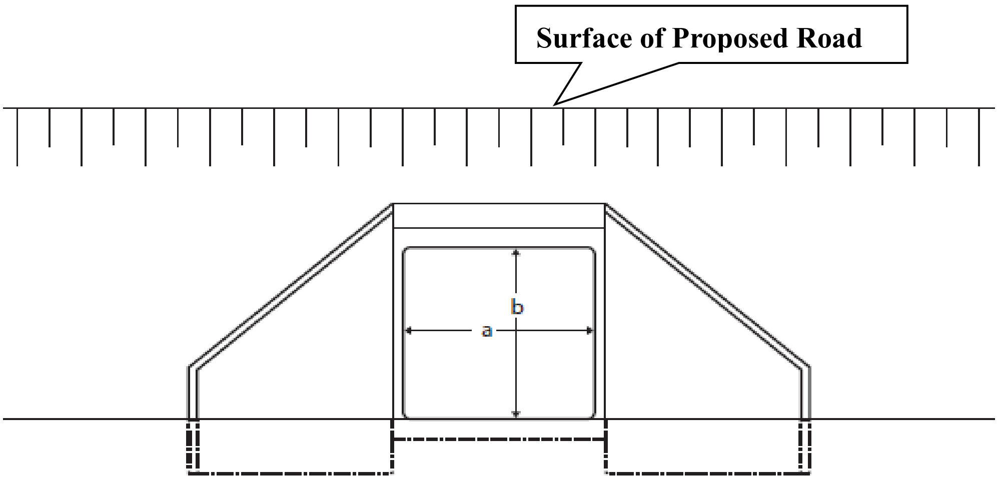


Source: JICA Study Team

FIGURE 10.3-2 TYPICAL BRIDGE CROSS SECTION

10.3.4 Typical Cross Section（Culvert）

The typical cross section of a culvert to be applied to the approach road is shown in **Figure 10.3-3**. The size of the barrel, 'a' and 'b' shown in the figure depends upon volume of the maximum water flow.



Source: JICA Study Team
Note: Detailed dimensions of each culvert is shown in 10.6.6 Dimension of Culverts

FIGURE 10.3-3 TYPICAL CULVERT CROSS SECTION

10.4 PAVEMENT DESIGN

10.4.1 General

This section describes pavement design for the project approach road section. The pavement design based on the following;

a) The results and findings of the sub-grade characteristics over which the road is to built;
b) The traffic load anticipated to traverse the proposed road alignments over the selected design life; and
c) The type of pavement to be adopted based on the technical advantages.

10.4.2 Pavement Design Standards

The pavement design is in accordance with the "Guide for Design of Pavement Structures, 1993" by the American Association of State Highway and Transportation Officials and in reference also to Pavement Design Guideline (Flexible Pavement) by Planning, Monitoring and Evaluation UNIT, DOR.

10.4.3 Technical Approach

The design parameters used in the pavement design includes time constrains, traffic, design serviceability loss, reliability, sub-grade strength and material properties for pavement structure design.

Following are major design condition;

(1) Design period

10 years

It is assumed that the design life of pavement consummates the 20-year design period before rehabilitation is performed.

(2) Traffic

The structural design of the pavement is based on fatigue loads. Fatigue loading is taken as the cumulative number of passes of an Equivalent Standard Axle load (ESAL) of 8,300kgs (18kips) per axle, to which the pavement structure will be subjected throughout its design life.

10.4.4 Recommended Pavement Structures

(1) Pavement Structure

The recommended pavement structure for the main carriageway is as below;

No	Thickness	Pavement Structure
1	60mm	Asphalt Concrete Surface Course
2	60mm	Asphalt Concrete Binder Course
3	100mm	Cement Treated Base Course
4	250mm	Crushed Aggregate Base Course
5	350mm	Crushed Sub-Base Course

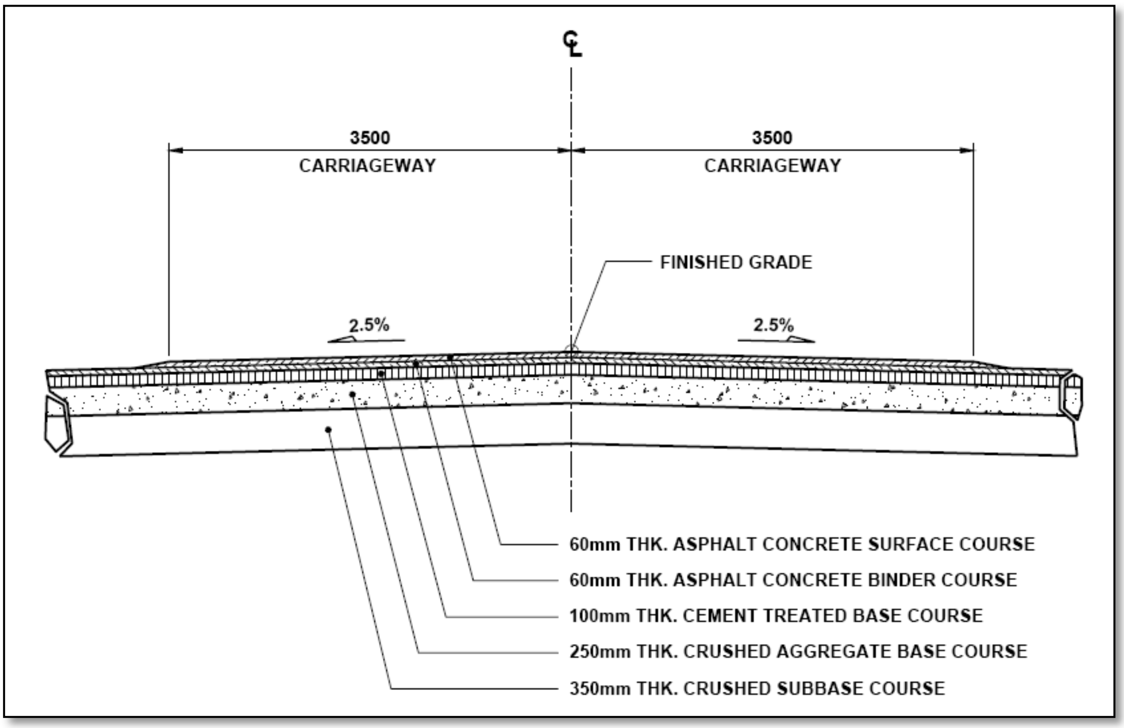


FIGURE 10.4-1 PAVEMENT STRUCTURE OF MAIN CARRIAGEWAY

TABLE 10.4-1 TRAFFIC VOLUME AND COMMUTATIVE EQUIVALENT STANDARD AXLE LOAD (ESAL) (W18KIPS)

【Design Period : 20 years】

Project Title: Nagdhunga Tunnel Project

Year				Total	Large V/Total	Large V	Class 1	Class 2	Class 3	Class 4	Class 5		Total
			Vehicle Type				Cars	Micro Bus	Large Bus	Light Truck	Heavy Truck		
			Traffic Volume in 2021 *	6,300	37%	2,300	1,300	600	1,700	400	2,300		
			Load Equivalence Factor (LEF)**			-	0.0002	0.0004	1.1005	1.5720	4.5370		
			Grouth Rate*	4.50%			0.03	0.030	0.06	0.045	0.045		
	2021	1	Open				0.26	0.24	1,870.85	628.80	10,435.10		12,935.25
1	2022	2					0.27	0.25	1,983.10	657.10	10,904.68		13,545.39
2	2023	3					0.28	0.25	2,102.09	686.67	11,395.39		14,184.67
3	2024	4					0.28	0.26	2,228.21	717.57	11,908.18		14,854.51
4	2025	5					0.29	0.27	2,361.91	749.86	12,444.05		15,556.37
5	2026	6					0.30	0.28	2,503.62	783.60	13,004.03		16,291.83
6	2027	7					0.31	0.29	2,653.84	818.86	13,589.21		17,062.51
7	2028	8					0.32	0.30	2,813.07	855.71	14,200.73		17,870.12
8	2029	9					0.33	0.30	2,981.85	894.22	14,839.76		18,716.46
9	2030	10					0.34	0.31	3,160.76	934.46	15,507.55		19,603.42
10	2031	11					0.35	0.32	3,350.41	976.51	16,205.39		20,532.98
11	2032	12					0.36	0.33	3,551.43	1,020.45	16,934.63		21,507.21
12	2033	13					0.37	0.34	3,764.52	1,066.37	17,696.69		22,528.29
13	2034	14					0.38	0.35	3,990.39	1,114.36	18,493.04		23,598.52
14	2035	15					0.39	0.36	4,229.81	1,164.50	19,325.23		24,720.30
15	2036	16					0.41	0.37	4,483.60	1,216.91	20,194.87		25,896.15
16	2037	17					0.42	0.39	4,752.62	1,271.67	21,103.63		27,128.72
17	2038	18					0.43	0.40	5,037.77	1,328.89	22,053.30		28,420.79
18	2039	19					0.44	0.41	5,340.04	1,388.69	23,045.70		29,775.28
19	2040	20	in 20 years				0.46	0.42	5,660.44	1,451.18	24,082.75		31,195.26
Cummulative ESAL													415,924.04

one lane lane adjustment coefficient

415,924.04 × 365days × 0.5 × 1.0 = 75,906,138 (Design ESAL)

* Based on Traffic Demand Forecast

** Source:Study Team

TABLE 10.4-2 FLEXIBLE PAVEMENT DESIGN

Design Standard: Guide for Design of Pavement Structures, 1993, American Association of State Highway and Transportation Officials

Design Case: **2021 to 2040 (20 years)**

Project Title: Nagdhunga Tunnel

1. Calcuation of Structural Number

(1) Basic Formula

The formula shown below is applied for flexible pavement design in accordance with AASHTO design guideline.
Design Condition is shown in Table 1.
Structural Number is computed to accommodate the basic formula.

$$\log_{10}(W_{18}) = Z_R \times S_0 + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}(\Delta PSI/(4.2-1.5))}{0.40 + 1094/(SN+1)^{5.19}} + 2.32 \times \log_{10}(MR) - 8.07$$

(2) Design Condition

Design Condition		Index	Value	Grounds	Remarks
	Design Period		20	2017 ~2040(20 Years)	Design life of pavement of initial pavement structure
1. Traffic	Design ESAL	W18	75,906,138		
2. Level of Reliability	Reliability	R(%)	80	Principal Arterial (AASHTO)	The possibility to satisfy road user during design period. Stronger pavement structure is required in accordance with Value.
	Standard Normal Deviate	ZR	-0.841	Value corresponding to R=80%	Corresponding to R
	Overall Standard Deviation	S0	0.45	Average of Flexible Pavement	Variation of reliability according to regional traffic difference
3. Serviceabiity	Initial Serviceability Index	P0	4.2	Standard of AASHTO	5: Perfect 0: Inperfect
	Terminal Serviceability Index	P1	2.5	Standard of AASHTO	Serviceability expected at the end of design period
	Present Serviceability Index	ΔPSI	1.7	PSI = P0- Pt	
4. Pavement Support Layer	CBR(%)	CBR	7		
	Resilient Modulus	MR	10,500	MR=1,500×CBR	Soil Subgrade Strength

(3) Computation of SN

1. Left side of Basic Formula	log10(W18)	7.880
2. Value of Righ side of Basi Formula		7.880
3. SN Value required	SN	5.537

2. Pavement Structure

1(inch)=2.540(cm)

Pavement Structure		Layer Coefficient (a)	Thickness D (cm)	Thickness d (inch)	Drainage Coeffient (m)	Structural Number SN=a×m×D1	Remarks
Asphalt Concrete Surface	new	0.390	**6.00**	2.362	-	0.921	
Asphalt Concrete Binder	new	0.390	**6.00**	2.362	-	0.921	
Cement Treated Base	new	0.230	**10.00**	3.937	1.0	0.906	Cement treated base course
Crushed Aggregate Base	new	0.140	**25.00**	9.843	1.0	1.378	Crushed aggregate,CBR>20
Crushed sub-base	new	0.110	**35.00**	13.780	1.0	1.516	Crushed aggregate
Evaluation	Required SN			5.537	<	5.642	OK

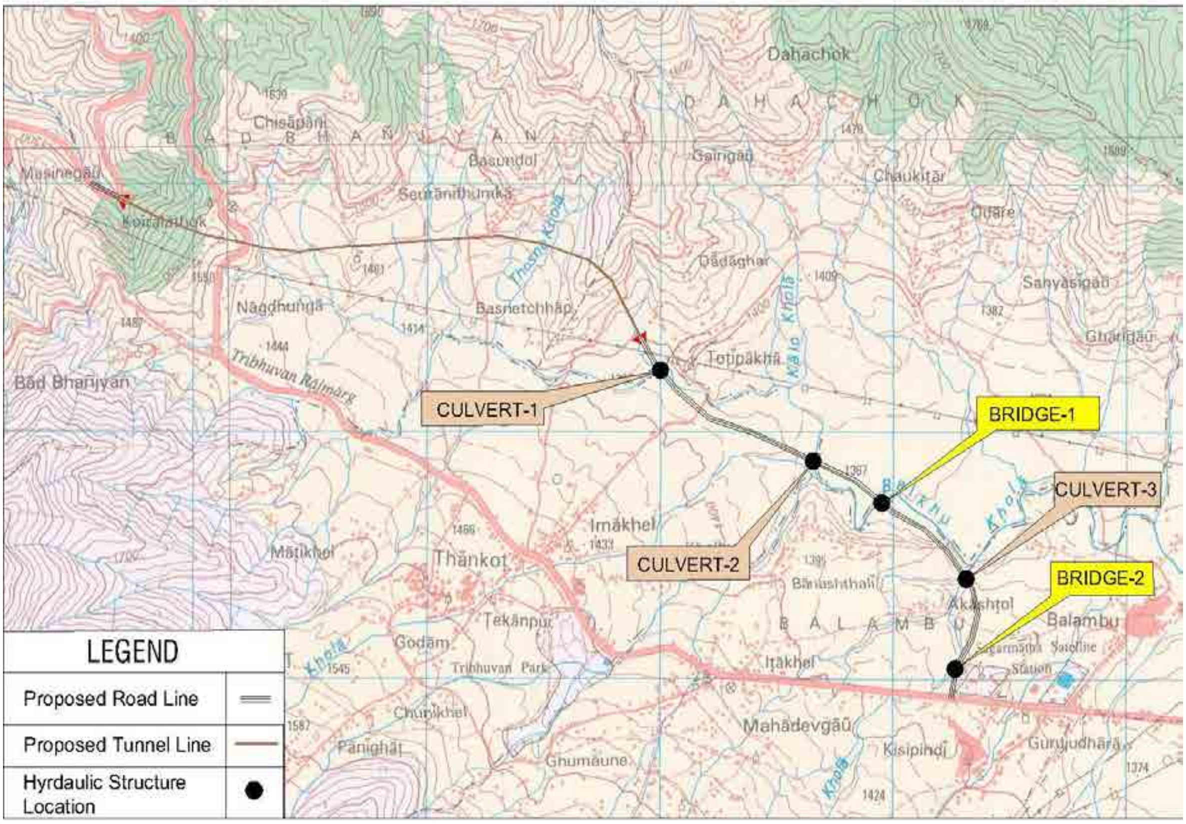
W18 : Predicted number of 18-kip equivalent single axle load applications
ZR : Standard normal deviate
S0 : Combined standard error of the traffic prediction and performance prediction)
MR : Resilient modulus (psi)
D : Layer thickness(inches)
m : Layer drainage coeficient
SN is equal to the structural number indicative of the total pavement thickness required.

$SN = a1D1 + a2D2m2 + a3D3m3$

10.5 BRIDGE DESIGN

10.5.1 Location of Bridge and Culverts

The location of the proposed cross drainage structures such as bridges and culverts along the proposed approach road is shown in **Figure 10.5-1**. The east side approach road will require two bridges and three culverts to span water channels or rivers.



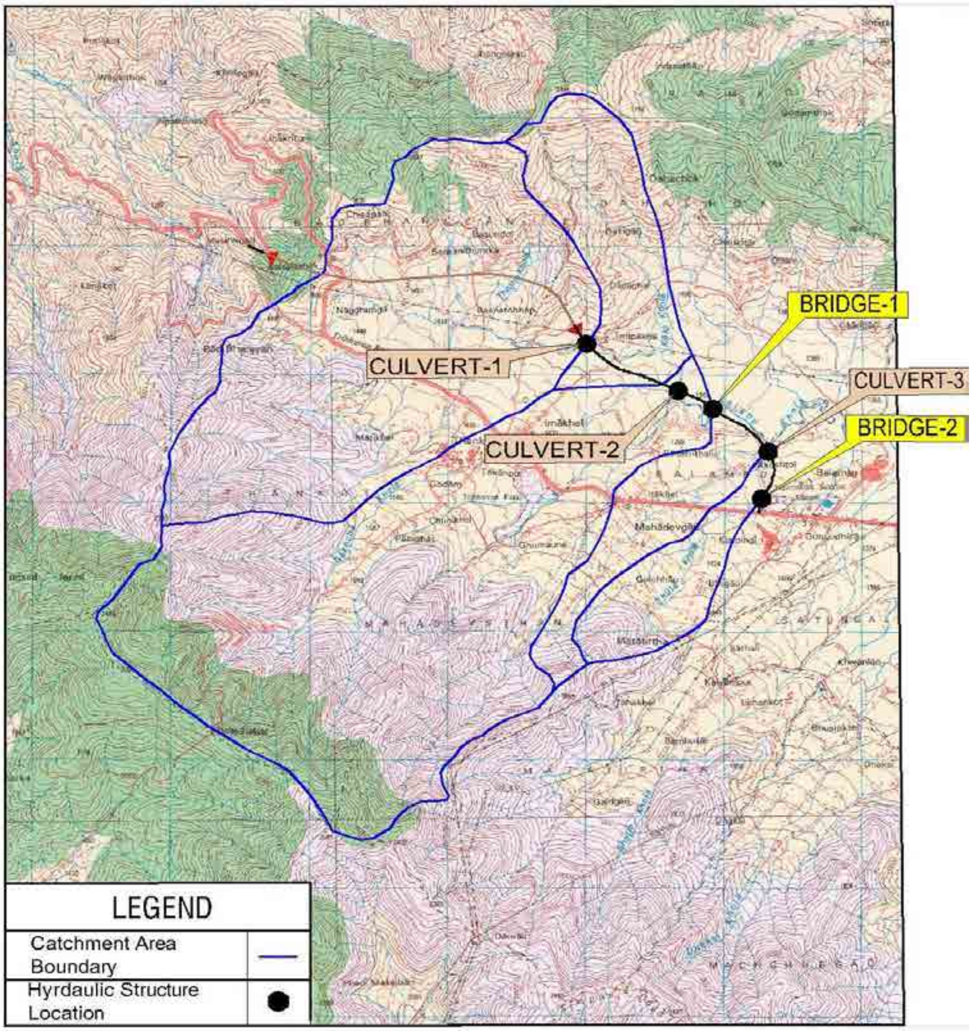
Source: JICA Study Team

FIGURE 10.5-1 LOCATION OF BRIDGES AND CULVERTS

10.5.2 Hydrological Study

The watershed map comprising the catchment basins and sub-basins corresponding to the proposed route and location for the proposed cross drainage structures are shown in **Figure 10.5-2**. All the basins and sub-basins lie below the Mahabharat range of mountains, therefore, none of the rivers have contribution of melting snow in their flow. They have a very low flow during the dry season and high flood during monsoon. In the upper areas of the catchment, the average gradient is quite high but decreases significantly where the small tributaries meet to form the Balkhu khola.

In the present sites, the road geometric requirement has become the dominant parameter in deciding the sizes of the cross drainage structure, both in span and height rather than that of hydrological requirements. Therefore, in this case the road geometric requirement is the main deciding factor rather than the hydrological consideration for the height and width of bridges and culverts.



Source: JICA Study Team

FIGURE 10.5-2 AREAS OF CATCHMENT BASINS AND SUB-BASINS

10.5.3 Discharge Estimation

For the present phase of the study, discharge in the streams where cross drainage structures are required, has been calculated using two methods, namely, WECS/DHM method and Rational Method. The former is a local empirical formula widely used in Nepal. Brief description of each method is given below.

(1) Water and Energy Commission Secretariat (WECS/DHM) Method

The WECS/DHM method, based on flood frequency analysis, is recommended for the context of Nepal after performing few case studies. In this method, the most significant independent variable is the area of the basin below 3,000m elevation. This area represents the portion of the basin that is influenced by monsoon precipitation. The results of this method are not applicable to basins located entirely above 3,000m elevation. Also, even if the proportion of a basin lying below 3,000m is very small, the results of this method will not be particularly reliable.

As per the recommendation of the Water and Energy Commission Secretariat / Department of Hydrology and Meteorology (WECS/DHM) of Nepal, the flood flows of any river of catchment area A (km^2) lying below 3,000m elevation are given by:

Instantaneous Peak flood for a return period of 2 years, $\mathbf{Q_2 = 1.8767\ (A + 1)^{0.8783}}$
Instantaneous Peak flood for a return period of 100 years, $\mathbf{Q_{100} = 14.63\ (A + 1)^{0.7342}}$

The flood flow for any other return period, T years, can be found as:

$$Q_T = \exp(\ln Q_2 + s\sigma)$$

Where, A = area below 3,000m elevation

σ = standard deviation of natural logarithms of annual floods = ln (Q_{100} / Q_2) / 2.326

s = Standardised normal variate from a particular return period

= 0, 0.842, 1.282, 1.645, 2.054, 2.326, and 2.576 for T = 2, 5, 10, 20, 50, 100, and 200 years, respectively.

(2) Rational Method

The design intensity of rainfall corresponding to the time of concentration is determined from IDF curve. The time of concentration is determined using Kirpich equation. Most of the catchment area lies in hilly terrain and covered by vegetation. So the average coefficient of runoff is taken as 0.4 for the application of Rational method.

$$Q_t = \frac{C * I_{Ct} * A}{3.6}$$

Where, Q_t = discharge at return period t years in m^3/s

C = Average Runoff coefficient

I_{ct}= Intensity of rainfall corresponds to t years return period in mm/hr

A = Catchment area in sq. Km

(3) Results of the Estimated Discharge

In Nepal, for the design of major bridge, 100 year return period flood value is taken as the design discharge and for the culverts 50 year return period flood is taken as the design discharge. Therefore, for all the basins, 50 year and 100 year return period flood has been computed and presented in the following **Table 10.5-1**.

TABLE 10.5-1 RESULTS OF ESTIMATED DISCHARGE

Hydrologic element	Basin area (km^2)	100 years return period flood (m^3/s)		50 years return period flood (m^3/s)		Recommended Design Discharge (m^3/s)
		WECS method	Rational	WECS method	Rational	
Bridge-1	15.03	112.24	146.88	92.50	131.08	146.88
Bridge-2	0.65	21.50	9.72	16.99	8.59	9.72

Source: JICA Study Team

The discharge calculated using Rational Formula has been recommended because this method takes into account the rainfall data in the vicinity/or of the watershed. Also it considers the runoff coefficient accounting for all differences between the rainfall intensity and the flood peak which gives a more reliable result.

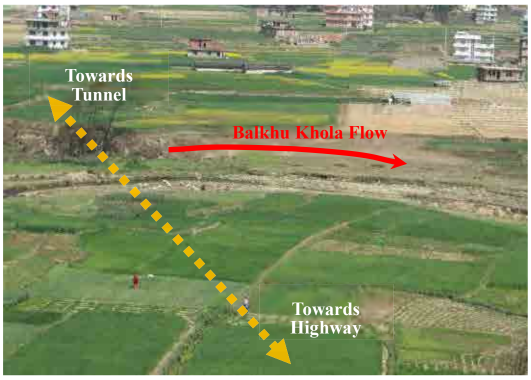
10.5.4 Proposed Bridge-1

The proposed bridge site for Bridge-1 is over the main Balkhu Khola. The proposed bridge axis lies in the meander of the stream. The river is shallow during the dry period with very little flow but at the time of flood, the river spreads laterally and linear waterway reaches almost 20m, inundating the nearby flood plain, which in dry season is used for cultivation. The lateral spread of the flood is more prominent on the right bank than on the left as the elevation of right bank is lower than that of the left bank.

In addition, river bank cutting is also prevalent in this river near the bridge site. The bridge axis, being in the meander of the river, needs special protection as the concave banks are prone to erosion. Bridge of about 20m has been proposed at this site and associated river training works are also needed for the safe passage of flood. According to the local people, the rise in water level is about 2.5m from the bed level, during flood. Hence the proposed deck level should be well above this elevation including adequate room for freeboard.

The stream section of the Bridge-1 site is shown in **Photo 10.5-1**.

(a) Proposed Bridge Site



(b) Bird's Eye View

PHOTO 10.5-1 PROPOSED BRIDGE SITE FOR BRIDGE-1

(1) Span of Bridge-1

Length of bridge span is estimated by using the following formula:

$$L= 20 + 0.005Q$$

Where, L= minimum span length (m)
Q= maximum discharge (m^3/s)

In the case of less than 500 m^3/s discharge, the above 'L' shall be reduced to 15.0m.

According to the above formula, the result of the span length for the Bridge-1 is estimated as follows:

$$L= 15 + 0.005 \times 147 \quad = \text{approximately } 16\text{m}$$

Therefore, the length of span for the Bridge -1 is designed for minimum 16.0m and it should take allowance to be 20.0m as safe length.

(2) Height of Bridge-1

The hydrological study is concentrated in estimating the approximate High Flood Levels (HFL) at the stream crossings for the judgment of bridge deck levels. However, there are no gauging stations in any of the streams within the Project Area. In the absence of flood data of the rivers the flood determination has been estimated by empirical methods and Rational Method only.

High Flood Level (HFL) was estimated by inquiring the knowledgeable local people at the site. In Bridge-1, where the rise in water level is about 2.5m from the bed level during serious flood according to the local people.

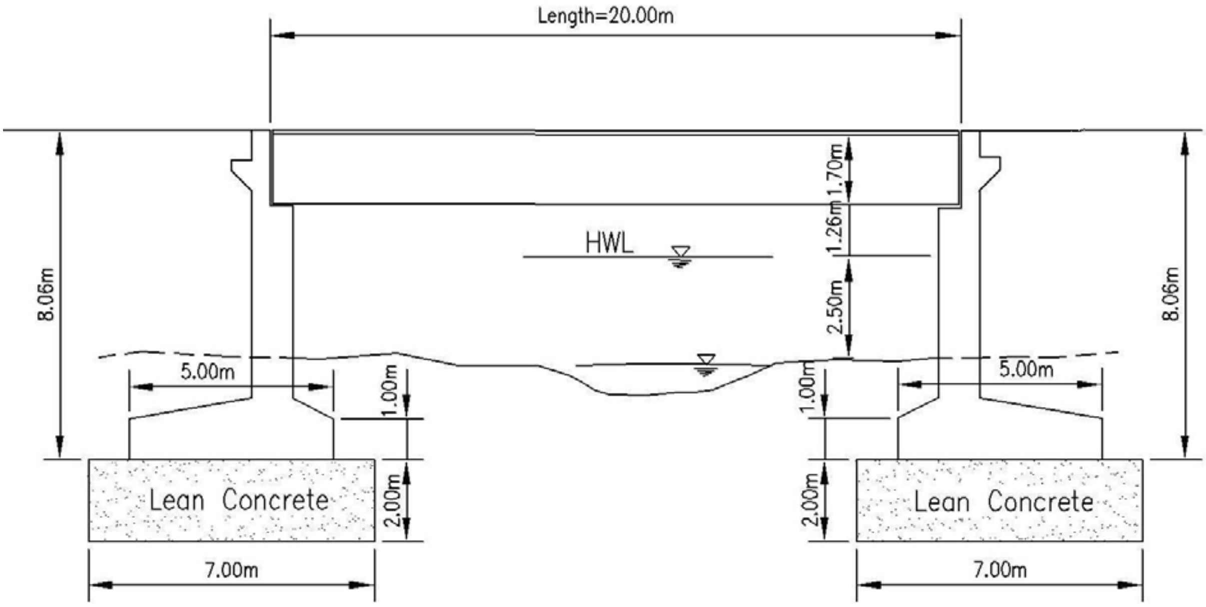
(3) Foundation of Bridge-1

According to the boring examination at the location of the Bridge-1, clayey and sandy gravel as a top soil covers this area with a thickness of 3.5m. Silt clay is found from 3.5m up to 15.0m below the ground level. N value of 20 and over 20 is seen at the 3.5m below the existing ground level.

Therefore, as a support layer of the bridge, the bottom of structure shall be 3.5m deep from the existing level. In this case, however, short piles are not suitable for the bridge. Instead of adoption of pile foundation, lean concrete with a thickness of 2.0m can be most applicable as a foundation for Bridge-1.

(4) Dimension of Bridge-1

Schematic side view of the bridge-1 is shown in **Figure 10.5-3**.



Source: JICA Study Team

FIGURE 10.5-3 SCHEMATIC SIDE VIEW OF THE BRIDGE-1

10.5.5 Proposed Bridge-2

The proposed bridge-2 is over a small tributary of Balkhu Khola. The stream is in a deep gorge of about 5m. At this site, in the dry season, the waterway of the stream is narrow, about 2 m only and the depth of water is shallow. Moreover, a lot of vegetation covers the drainage line of the stream and also on the adjacent terraces many trees are present as seen in **Photo 10.5-2**. On the right bank of the stream has been used for farming and on the left bank there is a stone paved road.

As per the local residents of the area, during monsoon season the water level in the stream rises to about 2m from the stream bed level. However, discharge water of Bridge-2 is very little due to small area of catchment according to **Table 10.5-1**. In this case the road geometric requirement is the main deciding factor rather than the hydrological consideration for the height and width of this bridge.

Besides the above, in order to accommodate the existing local road and small stream with the provision of extension, the span of bridge is divided into 2 spans, one in 15m and another is 20 m. Therefore, span of Bridge-2 is 35m.

PHOTO 10.5-2 PROPOSED BRIDGE-2

(1) Span of Bridge-2

As described above, discharge water of Bridge-2 is too small to apply the empirical formula which is applied for Bridge-1. Span of Bridge-2 is decided by geometrical profile, but it has to be considered for the existing local road and the alignment of proposed approach road intersect near by the small stream.

In order to accommodate both the local road and small stream under the bridges, 2 spans of the bridge should be proposed. One span is for the existing road and the other span is for the small stream. Thus the total length of Bridge2 becomes 35 m in 2 spans.

(2) Height of Bridge-2

Due to the small stream under the Bridge-2, the height of the bridge is not decided by the Highest Flood Level. But there was another factor to be considered is road finish level and gradient of the proposed road. Road gradient is 5.0% increasing order and the difference between two ends is almost 1.75 m.

Therefore, it has to be considered to maintain the height of bridge is 7.7m in lower abutment, 8.7m in center pier and 9.7m in higher abutment respectively as shown in **Figure 10.5-4**.

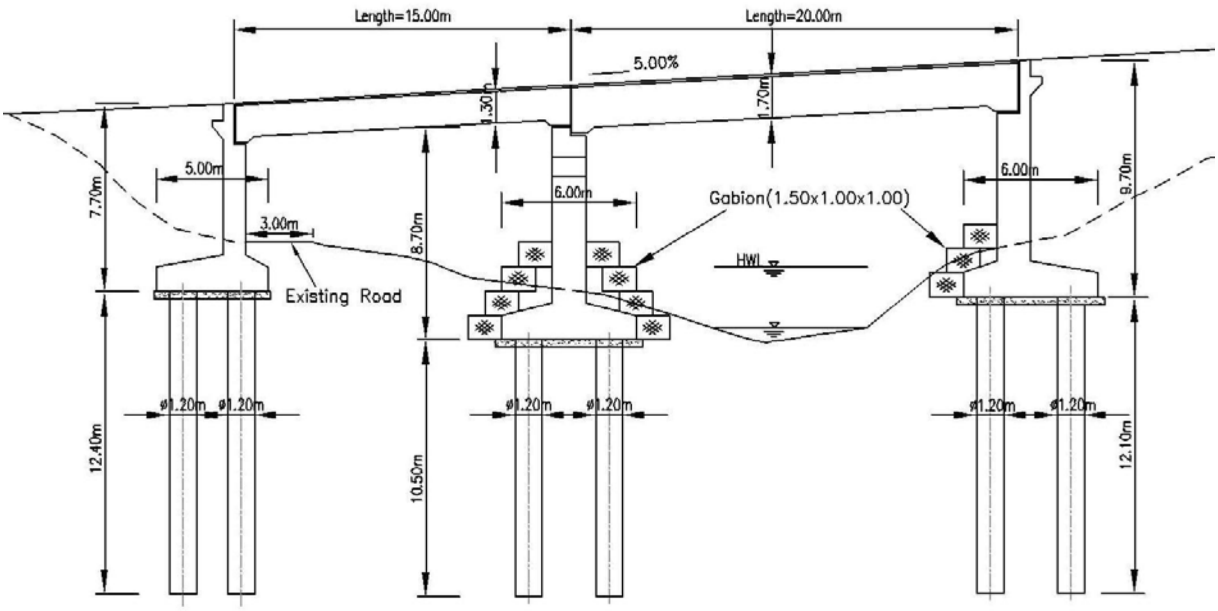
(3) Foundation of Bridge-2

According to the boring examination at the location of the Bridge-2, clayey gravel and grey fine sand as a top soil covers this area with a thickness of 9.0m. Black clay is found from 9.0m upto 11.0m. Soft layer with N value of less than 20 is seen at the 6.0m below the existing ground level. However, N value of 38 is seen at the 11m below the ground level.

Therefore, as a support layer of the bridge, the bottom of the structure shall be 11.0m from the existing level. In this case pile foundation should be applied. The piles with a length of 10.5m to 12.4m can be applied for Bridge-2.

(4) Dimension of Bridge-2

The length of Bridge-2 is 35 m and divided in to two span; 15 m and 20 m respectively. The height of bridge is different in two ends because of road alignment and its gradient. Overall height at centre pier is 8.7 m. The depth of pile is different from 10.5 m to 12.4 m as shown below. Schematic side view of the bridge-2 is shown in **Figure 10.5-4**.



Source: JICA Study Team

FIGURE 10.5-4 SCHEMATIC SIDE VIEW OF THE BRIDGE-2

10.6 CULVERT DESIGN

10.6.1 Discharge Estimation

According to **10.5.2 Hydrological Examination and Figure 10.5-4**, discharge in the streams where cross drainage structures are required, has been calculated using two methods, namely, WECS/DHM method and Rational Method. The former is a local empirical formula widely used in Nepal. Brief description of both methods are given **10.5.3 Discharge Estimation**.

In Nepal, for the design of major bridge, 100 year return period flood value is taken as the design discharge and for the culverts 50 year return period flood is taken as the design discharge. Therefore, for all the basins, 50 year return period flood has been computed and presented in the following **Table 10.6-1**.

TABLE 10.6-1 RESULTS OF ESTIMATED DISCHARGE

Hydrologic element	Basin area (km^2)	100 years return period flood (m^3/s)		50 years return period flood (m^3/s)		Recommended Design Discharge (m^3/s)
		WECS method	Rational	WECS method	Rational	
Culvert-1	5.65	58.83	71.08	47.77	63.44	63.44
Culvert-2	7.20	68.61	84.19	55.91	75.14	75.14
Culvert-3	0.72	21.81	10.52	17.31	9.39	9.39

Source: JICA Study Team

The discharge calculated using Rational Formula has been recommended because this method takes into account the rainfall data in the vicinity/or of the watershed. Also it considers the runoff coefficient accounting for all differences between the rainfall intensity and the flood peak which gives a more reliable result.

10.6.2 Proposed Culvert-1

This stream is also one of the tributaries of Balkhu Khola. The proposed section is about 3m wide and the stream has a low flow during dry season. The stream is extremely polluted with stagnant heaps of garbage in the waterway. Either banks are used for cultivation. It is suggested to keep the HFL at least 1.5m above the current bed level at the proposed site.

PHOTO 10.6-1 PROPOSED CULVERT-1

10.6.3 Proposed Culvert-2

The stream is one of the tributaries of Balkhu Khola draining from the north of the watershed of Balkhu Khola. A little upstream of the proposed culvert site, there exists a slab culvert of about 5m length and having an opening of approximately 2m depth. Just upstream of the bridge site the stream takes a sharp curved path and also the stream has been heavily channelized to approximately 50-60m upstream.

At this section of the stream, the flood has not exceeded the banks, according to the local residents. However, the increasing trend of channelizing the stream into a narrower width and encroachment of the nearby lands filled with increased surface flow due to rapid urbanization could significantly raise the water levels in the stream during flood time. Therefore the design level should be adequately high such that passage of flood is safe. Consequently, high flood level, at least 2m higher from the current stream bed level is suggested for this stream. Also, standard freeboard height should be provided for the culvert.

PHOTO 10.6-2 PROPOSED CULVERT-2

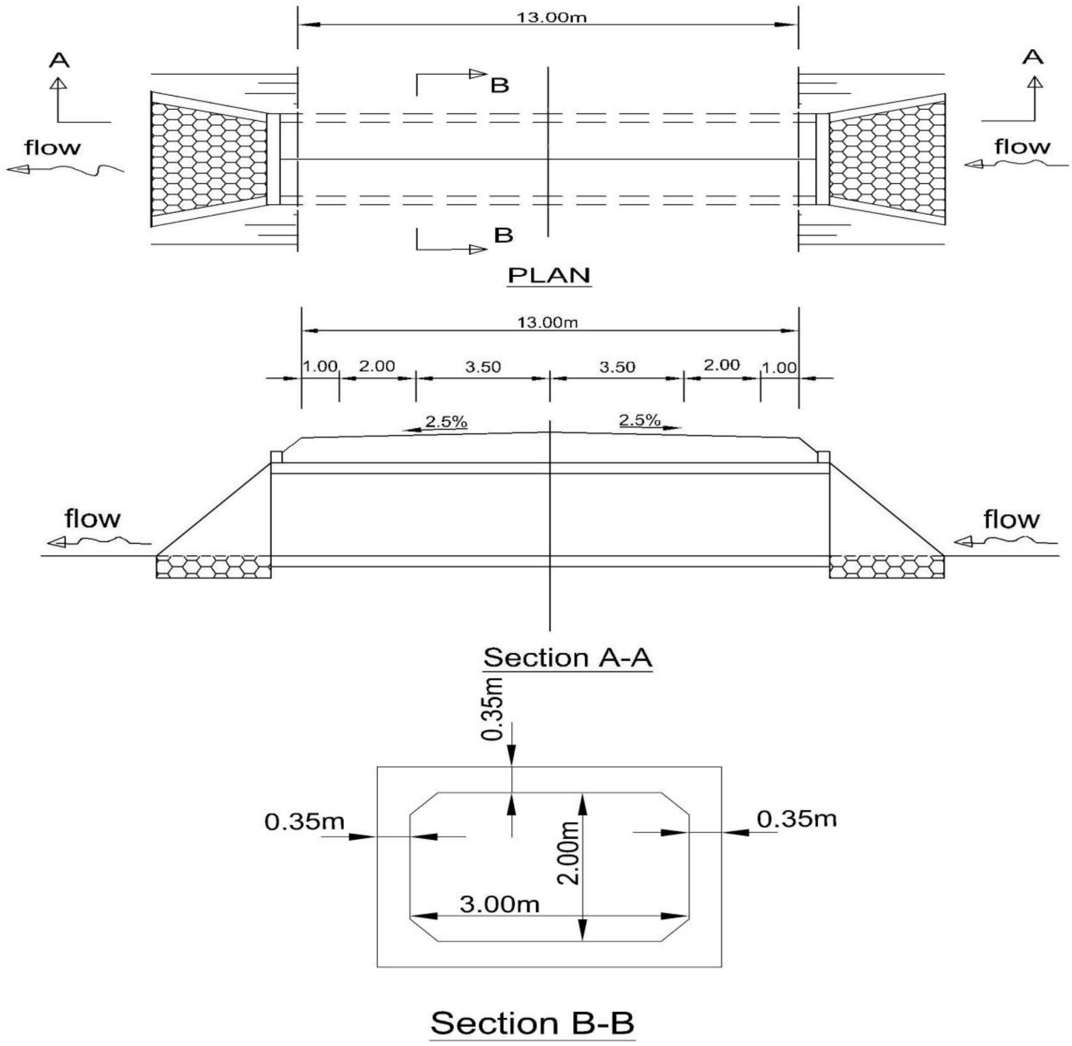
10.6.4 Proposed Culvert-3

The proposed Culvert-3 is located nearby Bridge-2 only 200m away downstream. Therefore, the stream flows continuously from the Bridge-2 to Culvert-3. The depression is about 2m deep and 3m wide. A lot of bushes cover the drainage line of the stream and also on the adjacent terraces many bushes are present as seen in **Photo 10.6-3**.

PHOTO 10.6-3 PROPOSED CULVERT-3

10.6.5 Dimension of Culverts

According to the **Table 10.6-1** and geometric requirement, size of each culvert are finalized as shown in **Figure 10.6-1**.



Source: JICA Study Team

FIGURE 10.6-1 SCHEMATIC SIDEVIEW OF EACH CULVERT

10.7 INTERSECTION DESIGN

To secure traffic safety and efficient vehicle operation, it is important to identify where intersection need to be properly controlled. This Study shall thus identify the critical intersections along the study road, determine the intersection type and propose a plan to be adopted.

10.7.1 Identification of Intersections

The approach road crosses or meets with existing roads at several locations. However, following locations as shown in **Figure 10.7-1** and listed below are identified as intersections to be selected for the design.

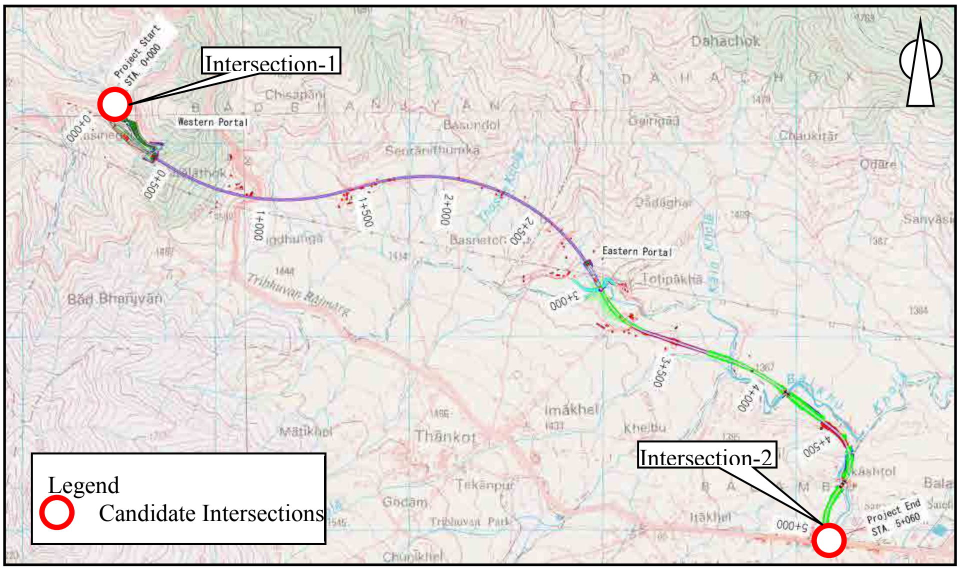
- The beginning point of the approach road
- The end point of the approach road

Although there are other locations where existing roads do cross with the approach road, these existing roads are district roads or community roads, where traffic volume is extremely low compared to the approach road. Therefore, design of intersection at these locations is not required and traffic flow here are planned to be controlled by providing stop lines and appropriate road signs and other facilities.

10.7.2 Design Conditions

Following conditions apply to the design of intersections.

- At-grade cross intersections will be applied considering the traffic volume and land use,
- The target year for intersection design will be 2020.
- Target vehicles for intersection at location 1 is SU-12 as classified by AASHTO, which are equivalent to trucks and buses in Nepal,
- Target vehicles for intersection at location 2 is WB-19 as classified by AASHTO, which is equivalent to semi-trailers,



Source:JICA Study Team

FIGURE 10.7-1 LOCATION OF INTERSECTION

10.7.3 Type of Control System

Types of control system that may be applied for any intersection are as follows;

i) Non-signalized (Stop sign),

ii) Signalized,

iii) Roundabout, and

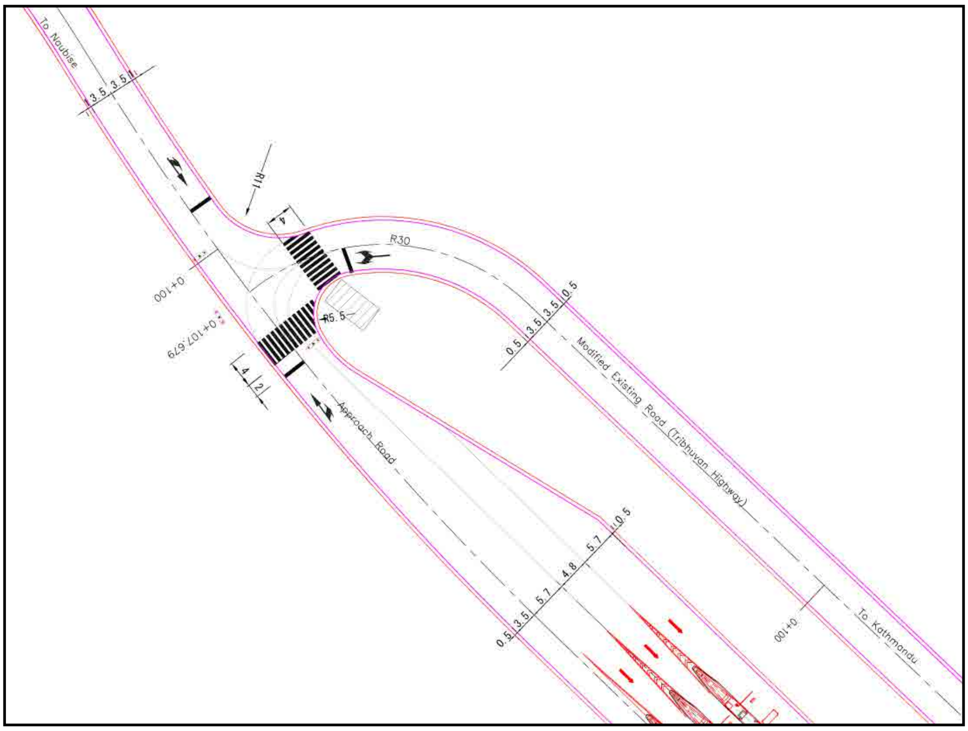
iv) Signalized roundabout

However, the types of control system to be applied for the selected intersections will be signalized intersection due to following reasons;

- In general, non-signalized intersections are applied where traffic volume is less than 1000 vehicles. As given in Chapter 5, the estimated traffic volume in year 2020 along the approach road and the existing road are approx. 7,300 and 2,500 respectively.
- Roundabout is efficient when traffic volumes are low and are equal on all the legs (roads). Also, it is considered not effective on high standard highways. In addition, the topographic condition and the land use at the above locations are not favorable for provision of a roundabout.
- Same thing can be said for signalized roundabout as mentioned for roundabout.

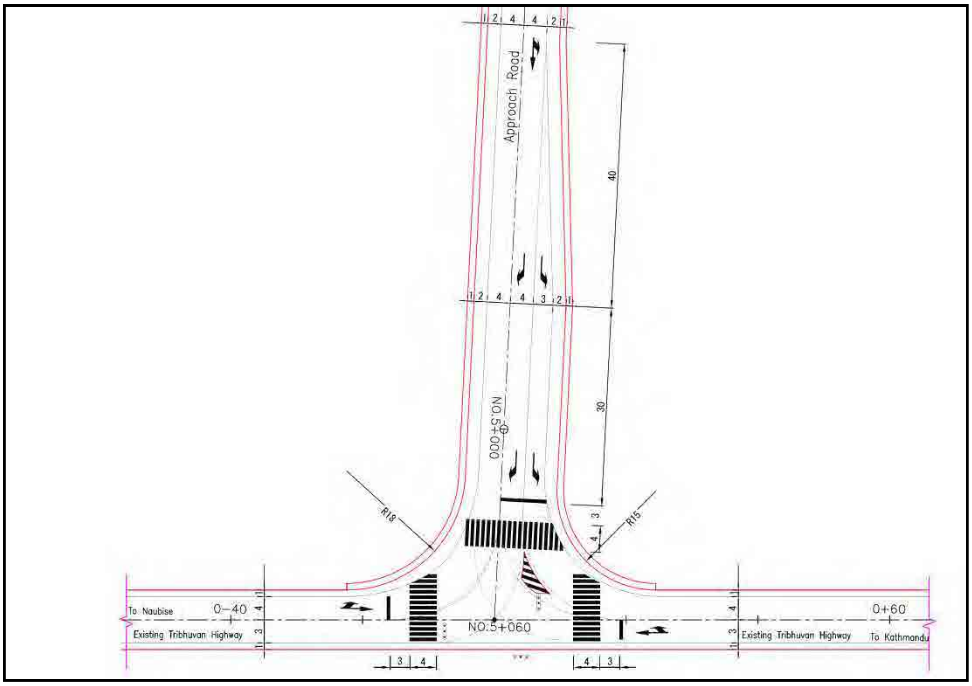
10.7.4 Design of Intersections

The plan of Intersection-1 and Intersection-2 are shown in **Figure 10.7-2** and **Figure 10.7-3** respectively. Both the intersections are planned to be signal controlled. Turn-exclusive lanes have been provided at Intersection-2 for securing safe and smooth traffic flow from approach road to the existing road. It has not been designed at Intersection-1 as the major stream of traffic here is expected on the approach road, which will go straight and take no turns.



Source: JICA Study Team

FIGURE 10.7-2 PLAN OF INTERSECTION-1



Source: JICA Study Team

FIGURE 10.7-3 PLAN OF INTERSECTION-2

10.8 SLOPE PROTECTION DESIGN

There are sections where the approach road sees embankment and cut height that reaches up to 10 meters. For this height, it is judged that provision of vegetation is sufficient to protect the slopes and no special slope protection measures are required. Particularly, the cut section is limited to a highland near the end of the approach road. The topography here is not as rugged as in the mountains nearby. The geological condition is also fair as the earth here is not made of withered and fractured rocks but is made of alternating layer of clay or silt and sand. However, in order to protect the slopes, following measures have been undertaken in association with provision of vegetation on the slopes.

<u>Fill Slopes</u>

i) Soil from tunnel excavation has been planned to be used for fill material of the approach road. The material consists of rock and sandy soil and is considered to be suitable for filling material. (Soil from the nearby mountains should not be used for fill material. Particularly, the top layer of the area is composed of Kalimati, literally meaning black soil formed by sediments of lake. Kathmandu Valley used to be a lake in the past).

ii) The fill slopes 1:1.8 or gentler are applied.

iii) Berms are provided for fill height exceeding 5 meters.

<u>Cut Slopes</u>

i) The cut slope of 1:0.8 to 1.0 is applied.

ii) Berms are provided when the height exceeds 5 meters.

10.9 DRAINAGE DESIGN

As described in section 10.3, open ditch will be constructed for both cut section and embankment section. Road surface water move to both side of the open ditch then discharge to river or stream shown in **Figure 10.9-1**. Surface water volume at road section will calculate the open ditch size / pipe culvert size which will be determined in the detailed design stage.

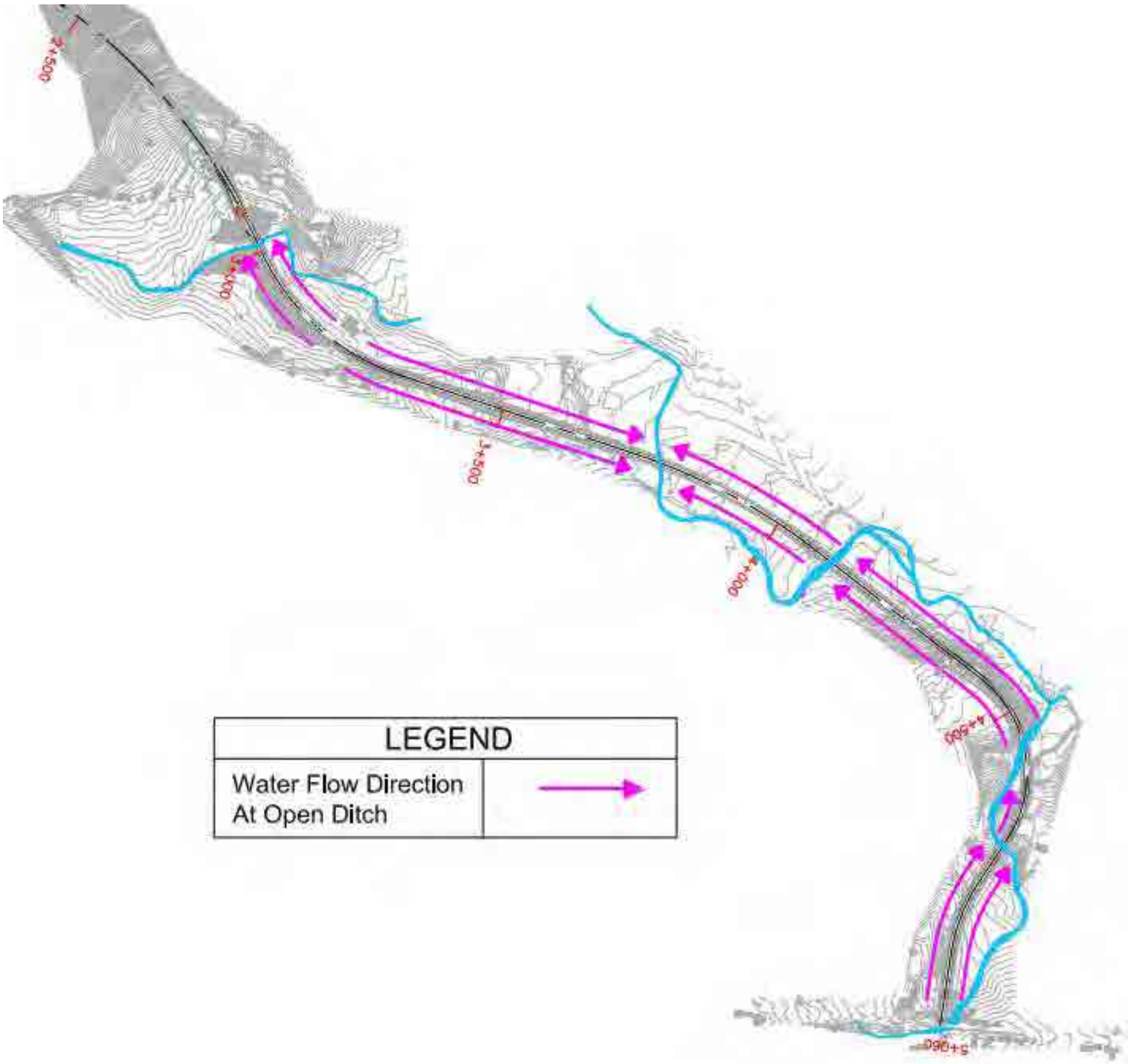


FIGURE 10.9-1 DRAINAGE DESIGN CONCEPT AT APPROACH ROAD SECTION

CHAPTER 11

PROJECT COST ESTIMATE

CHAPTER 11
PROJECT COST ESTIMATE

11.1 COST ESTIMATE METHODOLOGY

The cost estimation is implemented through the software “JICA Civil Engineering Estimation System”, which is known as “Seki-san Taro”, especially for the cost estimation of tunnel.

The auxiliary method of tunnel, such as “fore-poling method” and “long span fore-piling method” (otherwise better known as All Ground Fastening Method = AGF) is adopted in this Nagdhunga Tunnel to overcome the water seepage and go through the unconsolidated geological conditions. Then, the cost is calculated based upon the estimation manual issued by Geofronte Institute of Japanese scientific association. AGF is prevailing in Japan for the geological conditions like Nagdhunga Tunnel, and Geofronte Institute has extensive background in the tunneling field of Japan.

As mentioned in **Chapter 9**, the Project will be required the AGF, developed by Japan. If AGF were not adopted, construction period will become longer and it may occur the collapse during excavation. Totally the construction cost, adopted AGF method by Japan will be lower than that in other countries. Due to above reason, cost estimate assumed that major construction source is from Japan or Nepal.

The source of unit price of construction material and rental fee for the construction machine are mainly extracted from various publications issued by public organizations in Japan and Nepal. Also some data from private companies in Japan and Nepal are referred as the prevailing prices.

The sources of unit price are summarized on the **Table 11.1-1**.

TABLE 11.1-1 SOURCE OF UNIT PRICE AND MACHINE RENTAL FEE

No	Publications/Quotation	Issued Organization	Country
1	Construction Price List	General Incorporated Foundation: Investigation Committee for Construction Price	Japan
2	Estimation Book	General Incorporated Foundation: Economic Research Association	Japan
3	Construction Machine Rental Fee List	General Incorporated Foundation: Nihon Kensetsu Machine Construction Association	Japan
		Ministry of Land, Infrastructure, Transport and Tourism of Japanese Government	Japan
4	Price List	Prevailing Price through Estimation Software Maker	Japan
5	Construction Cost and Marine/Inland Transportation Cost	Various private companies in Japan	Japan
6	Method of Construction and Estimation for Auxiliary Method	Umbrella Method Sectional Committee, Geofronte Institute	Japan
7	Rental Machine List	Department of Road of Ministry of Physical Infrastructure and Transport of Nepal Government	Nepal
8	Kathmandu District Wage Rate and Construction Material Rate	District Technical Office Babarmahal, Kathmandu, Nepal Government	Nepal
9	Price of Fuel	Nepal Oil Corporation	Nepal
10	Construction Rental Fee and Construction Material Cost	Several Construction and Rental Company (private company)	Nepal

Source: JICA Survey Team

11.2 CIVIL WORK COST

The total cost is estimated as 10.792 Billion NPR or 11.87 Billion Japanese Yen equivalent, including “Tunnel Work” and “Approach Road and Others”.

The tunnel is planned to be driven and lined from west side and east side in consideration of work efficiency and to shorten the construction period, so the tunnel cost is estimated in two (2) ways “West Portal Side” and “East Portal Side”.

The summary of civil work cost is shown on **Table 11.2-1**. The cost does not include VAT, and the indirect cost is added to each direct cost proportionally; therefore the cost and unit rate that will be described from now are combined cost or rate of direct/indirect work, unless otherwise noted.

The conversion rate is; NPR 1 = JPY 1.1

TABLE 11.2-1 SUMMARY OF CIVIL WORK COST

item	unit	Quantity	Unit Price		Cost		Total
			Foreign	Local	Foreign	Local	
			yen	NPR	yen	NPR	yen
Tunnel Construction	set	1			8,810,751,000	1,640,984,000	10,615,833,400
Approach Road Construction	set	1			30,002,000	238,988,000	292,888,800
Bridge Construction	set	1			0	405,015,000	445,516,500
Toll Facility Construction	set	1			0	25,000,000	27,500,000
Control Office Construction	set	1			120,000,000	36,000,000	159,600,000
Disposal Area Development	set	1			85,000,000	77,300,000	170,030,000
Transmission Line	set	1			0	146,000,000	160,600,000
Total					9,045,753,000	2,569,287,000	11,871,968,700

Source: JICA Survey Team

11.2.1 Tunnel Construction Cost

(1) General

The tunnel length is 2,450m, and it is estimated as 10.615 Billion Japanese Yen equivalent. The tunnel consists of six (6) different “Class of Ground”; those are “C II”, “D I”, “D I –a”, “D I –b”, “D II” and “D II –a”, according to ground classification criteria of NEXCO (Nippon Expressway Company; former Japan Highway Corporation), and enumerated from solid (hard) to relatively soft or friable conditions. The “Class of Ground” is depicted briefly on **Figure 11.2-1**.

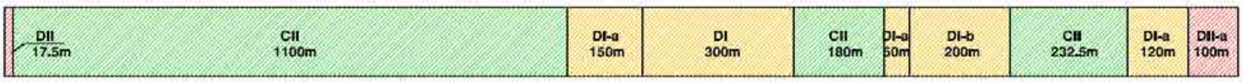


FIGURE 11.2-1 CLASS OF GROUND OF NAGDHUNGA TUNNEL

Therefore, the cost is estimated according to the Class of Ground. The summary of construction of tunnel (including excavation and lining) per meter and other factors per meter along the class of ground is shown above on **Table 11.2-2**. This cost does not include Tunnel Facilities, just for the excavation, lining and other concerns temporary work and indirect cost only to know simply the unit cost of tunneling work per meter. The “Tunnel Facility” is the facilities to be set after finishing the tunnel excavation and lining works.

TABLE 11.2-2 UNIT COST BY CLASSIFYING OF ROCK CONDITIONS (EXCLUDED VAT)

1	Rock Type		D II	C II	D I	C II	D I -a	C II	D I -b	C II	D I -a	D II -a	Amount	Convert to JPY
2	Distance (m)		17.5	1,100	300	212.5	200	100	200	100	120	100	2,450	
3	Excavation/m	NPR	523,104	189,492	213,880	189,492	392,397	188,768	389,135	188,062	389,298	526,856	NPR 615,418,000.00	¥3,011,357,000
		JPY(¥)	1,540,422	770,267	1,027,294	812,880	1,460,179	914,615	1,233,031	756,974	1,234,262	1,560,795	¥2,365,168,000	
		①. JPY(convert)	2,089,682	969,234	1,251,868	1,011,847	1,872,195	1,112,821	1,641,623	954,439	1,643,026	2,113,994		
4	Auxiliary Method/m	NPR	100,559	0	0	0	100,559	0	55,271	0	100,559	62,196	NPR 51,213,000.00	¥1,103,226,000
		JPY(¥)	401,850	0	0	0	401,850	0	2,768,188	0	401,850	3,601,904	¥1,049,452,000	
		②. JPY(convert)	507,437				507,437		2,826,223		507,437	3,667,210		
5	Pavement/m	NPR	4,066	4,066	4,066	4,066	4,066	4,066	4,066	4,066	4,066	4,066	NPR 99,457,590.00	¥211,524,000
		JPY(¥)	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372	4,372	¥107,093,200	
		④. JPY(convert)	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641	8,641		
6	General Temporary Work/m	NPR	129,148	129,148	129,148	129,148	129,148	129,148	198,126	198,126	198,126	198,126	NPR 352,280,624.00	¥1,481,148,000
		JPY(¥)	376,172	376,172	376,172	376,172	376,172	376,172	740,849	740,849	740,849	740,849	¥1,111,252,853	
		③. JPY(convert)	511,777	511,777	511,777	511,777	511,777	511,777	948,881	948,881	948,881	948,881		
7	Temporary work at Portal/m	NPR	49,591	49,591	49,591	49,591	49,591	49,591	49,775	49,775	49,775	49,775	NPR 121,593,000.00	¥335,431,000
		JPY(¥)	46,576	46,576	46,576	46,576	46,576	46,576	226,665	226,665	226,665	226,665	¥207,758,000	
		③. JPY(convert)	98,646	98,646	98,646	98,646	98,646	98,646	278,929	278,929	278,929	278,929		
8	⑤. Tunnel Direct Work/m	⑤=①+②+③+④	¥3,118,000	¥1,490,000	¥1,772,000	¥1,532,000	¥2,900,000	¥1,633,000	¥5,425,000	¥1,912,000	¥3,108,000	¥6,739,000		¥6,142,686,000
9	Indirect Work/m	NPR	164,490	164,490	164,490	164,490	164,490	164,490	164,490	164,490	164,490	164,490	NPR 403,000,000.00	¥2,661,150,000
		JPY(¥)	913,469	913,469	913,469	913,469	913,469	913,469	913,469	913,469	913,469	913,469	¥2,238,000,000	
		⑥. JPY(convert)	1,086,531	1,086,531	1,086,531	1,086,531	1,086,531	1,086,531	1,086,531	1,086,531	1,086,531	1,086,531		
10	Price Cost for Tunnel/m	⑦=⑤+⑥	¥4,204,531	¥2,576,531	¥2,858,531	¥2,618,531	¥3,986,531	¥2,719,531	¥6,511,531	¥2,998,531	¥4,194,531	¥7,825,531		¥8,803,836,000

Source: JICA Survey Team

(2) Breakdown of Tunnel Construction Cost

The breakdown of tunnel construction cost is shown on **Table 11.2-3**. This is a breakdown of Tunnel Work on the column a) of **Table 11.2-1**.

TABLE 11.2-3 BREAKDOWN OF TUNNEL CONSTRUCTION COST

item	unit	Quantity	Unit Price		Cost		Total
			Foreign	Local	Foreign	Local	
			JPY	NPR	JPY	NPR	JPY
1) Tunnel Work (Excavation and Concrete Lining)	m						
a) DII Type from West Portal (up to 17.5m)	m	17.5	2,259,000	676,000	39,532,500	11,830,000	52,545,500
b) CII Type from West Portal (up to 1,117.5m)	m	1,100	1,130,000	245,000	1,243,000,000	269,500,000	1,539,450,000
c) DI Type from West Portal (up to 1,417.5m)	m	300	1,507,000	276,000	452,100,000	82,800,000	543,180,000
d) CII Type from West Portal (up to 1,630m)	m	212.5	1,192,000	245,000	253,300,000	52,062,500	310,568,750
e) DI-a Type from West Portal (up to 1,830m)	m	200	2,141,000	507,000	428,200,000	101,400,000	539,740,000
f) CII Type from West Portal (up to 1,930m)	m	100	1,341,000	244,000	134,100,000	24,400,000	160,940,000
g) DII-a Type from East Portal (up to 100m)	m	100	2,289,000	681,000	228,900,000	68,100,000	303,810,000
h) DI-a Type from East Portal (up to 220m)	m	120	1,810,000	503,000	217,200,000	60,360,000	283,596,000
i) CII Type from East Portal (up to 320m)	m	100	1,110,000	243,000	111,000,000	24,300,000	137,730,000
j) DI-b Type from East Portal (up to 520m)	m	200	1,808,000	503,000	361,600,000	100,600,000	472,260,000
Total of Excavation and Concrete Lining					3,468,932,500	795,352,500	4,343,820,250
2) Auxiliary Method	m						
a) DII Type from West Portal	m	17.5	589,000	130,000	10,307,500	2,275,000	12,810,000
b) DI-a Type from West Portal	m	200.0	589,000	130,000	117,800,000	26,000,000	146,400,000
c) DI-b Type from East Portal	m	200.0	4,060,000	71,000	812,000,000	14,200,000	827,620,000
d) DI-a Type from East Portal	m	120.0	589,000	130,000	70,680,000	15,600,000	87,840,000
e) DII-a Type from East Portal	m	100.0	5,282,000	80,000	528,200,000	8,000,000	537,000,000
Total of Auliliary Method					1,538,987,500	66,075,000	1,611,670,000
3) Concrete Pavement	m2	24,500	6,410	5,240	157,045,000	128,380,000	298,263,000
Concrete pavement					157,045,000	128,380,000	298,263,000
4) General Temporary Work							
a) At West portal	ls	1			1,064,733,000	321,983,000	1,418,914,300
b) At East portal	ls	1			564,976,000	133,087,000	711,371,700
Total of General Temporary Work					1,629,709,000	455,070,000	2,130,286,000

Source: JICA Survey Team

item	unit	Quantity	Unit Price		Cost		Total
			Foreign	Local	Foreign	Local	
			JPY	NPR	JPY	NPR	JPY
5) Temporary Work at West/East Portal							
a) At West portal							
i) Earth Work for Facility Yard	m3	30,000	740	430	22,200,000	12,900,000	36,390,000
ii) Slope Protection	ls	1			5,019,000	16,357,000	23,011,700
iii) Facilities, drainage system & others	ls	1			0	12,918,000	14,209,800
iv) Sabo-dam	unit	2	199,000	40,608,000	398,000	81,216,000	89,735,600
v) Temporary Deck	m2	360	249,000	1,000	89,640,000	360,000	90,036,000
vi) Others	ls	1			14,666,000	0	14,666,000
Total					131,923,000	123,751,000	268,049,100
b) At East portal							
i) Earth Work for Facility Yard	m3	10,000	650	420	6,500,000	4,200,000	11,120,000
ii) Slope Protection	ls	1			5,019,000	16,357,000	23,011,700
iii) Facilities, drainage system & others	ls	1			0	12,918,000	14,209,800
iv) Soil Improvement	ls	1			73,328,000	0	73,328,000
v) Well point	ls	1			73,328,000	0	73,328,000
vi) Others	ls	1			14,666,000	0	14,666,000
Total					172,841,000	33,475,000	209,663,500
Total of Temporary Work at West/East Portal					304,764,000	157,226,000	477,712,600
6) Tunnel Facility							
a) Ventilation, lighting, monitoring, emergency, CCTV & others	ls	1			1,562,244,000	0	1,562,244,000
b) Vehicles for maintenance and operation	ls	1			146,655,000	0	146,655,000
Total of Tunnel Facility					1,708,899,000	0	1,708,899,000
Grand Total of Tunnel Work					8,808,337,000	1,602,103,500	10,570,650,850

Source: JICA Survey Team

(3) Other Breakdown of Tunnel Work

The auxiliary method is applied for the weathered rock section or to stop water seepage for the section “D II –a”, “D II”, “D I –a” and “D I –b”. The detail cost of auxiliary method is shown on **Table 11.2-4**.

The detail of auxiliary method is described on Chapter 9.6. This is direct cost only, not including indirect cost.

TABLE 11.2-4 COST OF AUXILIARY METHOD (EXCLUDED VAT)

No	Type of Excavation (Class of Ground)	Long span fore-poling with injection for all periphery	Long span fore-poling with injection for all periphery	Fore-piling	① Unit Rate per 1m		② Length	③ = ① × ② Cost for Tunnel Auxiliary Method		Convert to JPY (NPR. 1 = JPY. 1.1)
		N = 67	N = 51	N = 19	NPR	JPY	(m)	NPR	JPY	
1	D II -a	○			62,196	3,601,904	100.00	6,219,600	360,190,400	367,032,000
2	D II			○	100,559	401,850	17.50	1,759,783	7,032,375	8,969,000
3	D I -a			○	100,559	401,850	320.00	32,178,880	128,592,000	163,989,000
4	D I -b		○		55,271	2,768,188	200.00	11,054,200	553,637,600	565,798,000
5	D I	−	−	−			300.00	0	0	0
6	C II	−	−	−			1,512.50	0	0	0
	Total						2,450.00	51,212,463	1,049,452,375	1,105,788,000

Source: JICA Survey Team

1) Tunnel Facility

The cost of tunnel facility is shown on **Table 11.2-5**. The equipment and facility will be imported from Japan. This is the direct cost only not including indirect cost.

As enumerated on **Table 11.2-5**, those are facilities to be set inside tunnel for comfortable and safety driving; such as blowing off emission from the cars by ventilation system, lighting system and emergency system to encounter the fire inside tunnel.

TABLE 11.2-5 COST OF TUNNEL FACILITY

	Item	Specification	Unit	Q'ty	Unit Rate (JPY)	Amount (JPY)
A	Facilities of Operation					
1	**Ventilation System**					
	Jet fan	JF1250 35m/s	Unit	28	15,000,000	420,000,000
	Mesuring devices	CO, VI and AV	ls	1		20,000,000
	Measuring and control system		ls	1		40,000,000
	sub-total					480,000,000
2	**Lighting System**					
	Lighting for tunnel		m	2450	49,800	122,100,000
3	Access & Distribution System of Electrocity					
	Access to electoricity	East portal	ls	1		50,000,000
	Distribution of electricity	West portal	ls	1		30,000,000
	Generator system	East portal	ls	1		36,000,000
	sub-total					116,000,000
4	**Distant Monitoring Control System**					
	Faciliteis of monitoring	East portal	ls	1		36,000,000
5	**Emergency Facility**					
	Water pipe	CIPφ150	m	2450	9,000	22,050,000
	Emergency facility		m	2450	68,000	166,600,000
	sub-total					188,650,000
6	**CCTV Facility**					
	CCTV facility		m	2450	50,000	122,500,000
	Total					**1,065,250,000**

Source: JICA Survey Team

11.2.2 Approach Road and Bridge Cost

The breakdowns of construction cost for Approach Road and Bridge are shown on **Table 11.2-6** and **Table 11.2-7**. The approach road is constructed at the east portal to connect the tunnel and existing National Highway; then, the bridges and culvert are constitutive part of approach road. Some part of excavated material from tunnel shall be used for the embankment of road.

TABLE 11.2-6 COST OF APPROACH ROAD

item	unit	Quantity	Unit Price		Cost		Total
			Foreign	Local	Foreign	Local	
			JPY	NPR	JPY	NPR	JPY
1) Cutting	m^3	79,757	60	470	4,785,420	37,485,790	46,019,789
2) Embankment	m^3	110,974	240	70	26,633,760	7,768,180	35,178,758
3) Pavement	m^2	26,426	0	7,300	0	192,909,800	212,200,780
Total					31,419,180	238,163,770	293,399,327

Source: JICA Survey Team

TABLE 11.2-7 COST OF BRIDGES

item	unit	Quantity	Unit Price		Cost		Total
			Foreign	Local	Foreign	Local	
			JPY	NPR	JPY	NPR	JPY
1) Bridge No.1 (L=35m)	unit	1			0	211,594,000	232,753,400
2) Bridge No.2 (L=18m)	unit	1			0	108,820,000	119,702,000
3) Culvert and others	set	1			0	83,966,000	92,362,600
Total					0	404,380,000	444,818,000

Source: JICA Survey Team

11.2.3 Other Facilities; Toll Facility, Control Office, Disposal Area Development and Power Supply Facility

The breakdowns of cost for other facilities, which will support the tunnel operation are enumerated as below;

- Toll Facility
- Control Office
- Disposal Area Development
- Power Supply Facility

Those facilities will be constructed outside the tunnel. The cost of "Power Supply Facility" was described in **Section 9.11**.

(1) Toll Facility

Two (2) toll facilities will be constructed at the east portal and west portal. The toll will be utilized for the maintenance and operation of tunnel.

TABLE 11.2-8 COST OF TOLL CACILITY

item	unit	Quantity	Unit Price		Cost		Total
			Foreign	Local	Foreign	Local	
			JPY	NPR	JPY	NPR	JPY
Toll Facility Construction	unit	5	0	5,000,000	0	25,000,000	27,500,000
Total					0	25,000,000	27,500,000

Source: JICA Survey Team

(2) Control Office

Tunnel control office will be constructed at the east portal and west portal and the traffic conditions will be monitored through CCTV facility.

TABLE 11.2-9 COST OF CONTROL OFFICE

item	unit	Quantity	Unit Price		Cost		Total
			Foreign	Local	Foreign	Local	
			JPY	NPR	JPY	NPR	JPY
Control Office at West Portal	m^2	390	0	52,000	0	20,280,000	22,308,000
Control Office at East Portal	m^2	300	0	52,000	0	15,600,000	17,160,000
Operation and Management Vehicles					120,000,000		120,000,000
Total					120,000,000	35,880,000	159,468,000

Source: JICA Survey Team

(3) Disposal Area Development

The excavated material from tunnel shall be filled in the valley and reclaim the area. The corrugated culvert shall be installed at the bottom of valley for the drainage and the soil will be filled.

Michi-no-Eki, which is very common in Japan as the service area for the passenger of long distance buses is scheduled to construct on the reclaimed area. Michi-no-Eki facilitates the rest room, kiosk, canteen and multipurpose assembly hall for the community.

Table 11.2-10 shows the cost of disposal area development.

TABLE 11.2-10 COST OF DISPOSAL AREA DEVELOPMENT

item	unit	Quantity	Unit Price		Cost		Total
			Foreign	Local	Foreign	Local	
			JPY	NPR	JPY	NPR	JPY
1) Corrugated culvert for disposal area	m	400	73,000	39,000	29,200,000	15,600,000	46,360,000
2) Embankment/Compaction for disposal area	m^3	191,000	290	130	55,390,000	24,830,000	82,703,000
3) Construction of Michi no Eki	set	1			0	36,300,000	39,930,000
Total					84,590,000	76,730,000	168,993,000

Source: JICA Survey Team

11.2.4 Indirect Cost

Indirect cost consists of two categories; one is “Common Temporary Cost” and the other is “Site Management Cost”. The cost of indirect work is quite a big amount, which is about 45% of direct cost, otherwise, equivalent with 2.66 billion of Japanese Yen, so the detail items and cost are explained through the tables below.

The indirect cost does not appear in the items introduced in **Table 11.2-1** “Summary of Civil Work Cost”, but those amounts are distributed to each direct cost proportionally and make up the combined cost.

TABLE 11.2-11 SUMMARY OF INDIRECT COST

Item	①	②	③=①+②×1.1
	JPY	NPR	Corresponding Cost(JPY)
Common Temporary Cost	1,110,688,484	65,000,000	1,182,188,484
Site Management Cost	1,127,630,000	338,382,910	1,499,851,201
Total	2,238,318,484	403,382,910	2,682,039,000

Source: JICA Survey Team

TABLE 11.2-12 COMMON TEMPORARY COST

Items			Q'ty	Unit	① JPY	② NPR	③=①+②×1.1 Corresponding Cost(JPY)
1.Freight Cost	West Side	Machines/Equipments	1	Set	487,360,746	0	487,360,746
		Materials	1	Set	137,285,111	0	137,285,111
		Subtotal of West Side			624,645,857	0	624,645,857
	East Side	Machines/Equipments	1	Set	457,648,446	0	457,648,446
		Materials	1	Set	3,394,181	0	3,394,181
		Subtotal of East Side			461,042,627	0	461,042,627
	Total				1,085,688,484	0	1,085,688,484
2.Preparation Cost	West Side		1	Set	5,900,000	0	5,900,000
	East Side		1	Set	4,100,000	0	4,100,000
	Subtotal				10,000,000	0	10,000,000
3.Facilities Cost for Operation Loss	West Side		1	Set	0	5,900,000	6,490,000
	East Side		1	Set	0	4,100,000	4,510,000
	Subtotal				0	10,000,000	11,000,000
4.Safety Protection Cost	West Side		1	Set	0	11,800,000	12,980,000
	East Side		1	Set	0	8,200,000	9,020,000
	Subtotal				0	20,000,000	22,000,000
5.Servise Charge	West Side		1	Set	0	5,900,000	6,490,000
	East Side		1	Set	0	4,100,000	4,510,000
	Subtotal				0	10,000,000	11,000,000
6.Technical Control Cost	West Side		1	Set	8,850,000	8,850,000	18,585,000
	East Side		1	Set	6,150,000	6,150,000	12,915,000
	Subtotal				15,000,000	15,000,000	31,500,000
7.Maintenance Cost	West Side		1	Set	0	5,900,000	6,490,000
	East Side		1	Set	0	4,100,000	4,510,000
	Subtotal				0	10,000,000	11,000,000
Subtotal	West Side				639,395,857	38,350,000	681,580,857
	East Side				471,292,627	26,650,000	500,607,627
Total					1,110,688,484	65,000,000	**1,182,188,484**

Source: JICA Survey Team

TABLE 11.2-13 SITE MANAGEMENT COST

Items		Q'ty	Unit	① JPY	② NPR	③=①+②×1.1 Corresponding Cost(JPY)
1.Labor Management Cost	East Side	1	set	0	7,515,000	8,266,500
	West Side	1	set	0	4,400,000	4,840,000
	Subtotal			0	11,915,000	13,106,500
2.Cost for Safety Program	East Side	1	set	0	3,006,000	3,306,600
	West Side	1	set	0	1,760,000	1,936,000
	Subtotal			0	4,766,000	5,242,600
3.Premium	East Side	1	set	177,000,000	0	177,000,000
	West Side	1	set	123,000,000	0	123,000,000
	Subtotal			300,000,000	0	300,000,000
4.Salary	East Side	1	set	621,630,000	38,010,000	663,441,000
	West Side	1	set	196,550,000	21,750,000	220,475,000
	Subtotal			818,180,000	59,760,000	883,916,000
5.Stationery Cost	East Side	1	set	0	1,740,000	1,914,000
	West Side	1	set	0	1,400,000	1,540,000
	Subtotal			0	3,140,000	3,454,000
6.Communication & Transportation Cost	East Side	1	set	0	1,340,000	1,474,000
	West Side	1	set	0	640,000	704,000
	Subtotal			0	1,980,000	2,178,000
7.Social Cost	East Side	1	set	0	1,260,000	1,386,000
	West Side	1	set	0	900,000	990,000
	Subtotal			0	2,160,000	2,376,000
8.Compensation Cost	East Side	1	set	0	5,900,000	6,490,000
	West Side	1	set	0	4,100,000	4,510,000
	Subtotal			0	10,000,000	11,000,000
9.Subcontract Management Cost	East Side	1	set	0	5,900,000	6,490,000
	West Side	1	set	0	4,100,000	4,510,000
	Subtotal			0	10,000,000	11,000,000
10.Travelling Overseas Cost	East Side	1	set	5,100,000	20,925,245	28,117,770
	West Side	1	set	4,350,000	9,097,345	14,357,080
	Subtotal			9,450,000	30,022,590	42,474,849
11.Accommodation Cost	East Side	1	set	0	79,379,560	87,317,516
	West Side	1	set	0	38,759,760	42,635,736
	Subtotal			0	118,139,320	129,953,252
12.Vehicle Cost	East Side	1	set	0	50,400,000	55,440,000
	West Side	1	set	0	26,100,000	28,710,000
	Subtotal			0	76,500,000	84,150,000
13.Miscellaneous Cost	East Side	1	set	0	5,900,000	6,490,000
	West Side	1	set	0	4,100,000	4,510,000
	Subtotal			0	10,000,000	11,000,000
Subtotal	East Side			803,730,000	221,275,805	1,047,133,386
	West Side			323,900,000	117,107,105	452,717,816
Total				1,127,630,000	338,382,910	1,499,851,201

Source: JICA Survey Team

11.3 ENGINEERING SERVICES

Engineering costs were estimated and summarized in **Table 11.3-1**.

TABLE 11.3-1 SUMMARY OF ENGINEERING SERVICE COST

Description	Estimated Cost excluding VAT (Million NPR)	Remarks
a) Detailed Engineering Design Cost	253.03	Refer to **Table 11.3-2** and **Table 11.3-3**
b) Tender Assistance for Selection of Contractor	79.66	Refer to **Table 11.3-4** and **Table 11.3-5**
c) Construction Supervision Cost	532.17	Refer to **Table 11.3-6** and **Table 11.3-7**
d) Capacity Development for Tunnel O&M	154.33	Refer to **Table 11.3-8** and **Table 11.3-9**
Total	1,019.19	

Source: JICA Survey Team

TABLE 11.3-2 ENGINEERING COST FOR NAGDHUNGA TUNNEL CONSTRUCTION – DETAILED ENGINEERING DESIGN (12 MONTHS)

Description	Unit	Unit Price (1,000 JPY or NPR)		Quantity	Total (1,000 JPY or NPR)	
A. Professional Staff						
A-1 Remuneration						
1) Professional Staff (A)	M/M	JPY	2,895	57.00	JPY	165,015
2) Professional Staff (B)	M/M	JPY	275	73.00	JPY	20,075
Sub-Total (A-1)					JPY	185,090
A-2 Reimbursable Cost						
1) International Travel Expenses	RT	JPY	364	15.00	JPY	5,460
2) Subsistence Allowance	M/M	JPY	250	57.00	JPY	14,250
3) International Communication	Month	JPY	50	12.00	JPY	600
4) Vehicle Rental (3×12months)	Veh.-Mo.	JPY	220	36.00	JPY	7,920
5) Office Supply/Equipment	Month	JPY	175	12.00	JPY	2,100
6) Printing Cost	Month	JPY	200	12.00	JPY	2,400
7) Topographic Survey	L.S.	JPY	2,400	-	JPY	2,400
8) Geological Survey (Tunnel Section)	L.S.	JPY	18,000	-	JPY	18,000
9) Soils/Geo-technical Investigation (Roads and Bridges)	L.S.	JPY	2,100	-	JPY	2,100
10) Parcellary Survey	L.S.	JPY	4,500	-	JPY	4,500
11) Mechanical/Electricity/Communication	L.S.	JPY	20,000	-	JPY	20,000
Sub-Total (A-2)					JPY	79,730
Sub-Total (A)					JPY	264,820
	(Equivalent to)				**NPR**	**240,745**
B. Supporting Staff						
B-1 Remuneration						
1) Technical Support Staff	M/M	NPR	80	68.00	NPR	5,440
2) Administrative Staff	M/M	NPR	80	36.00	NPR	2,880
Sub-Total (B-1)					NPR	8,320
B-2 Reimbursable Cost						
1) Office Rental (300m²×700NPR/m²)	Month	NPR	210	12.00	NPR	2,520
2) Office Running Cost	Month	NPR	100	12.00	NPR	1,200
3) Local Communication	Month	NPR	20	12.00	NPR	240
Sub-Total (B-2)					NPR	3,960
Sub-Total (B)					**NPR**	**12,280**
Total (A) + (B)					**NPR**	**253,025**
VAT (13%)					**NPR**	**32,893**
Grand Total					**NPR**	**285,919**

Exchange Rate:
1.0 NPR = 1.1 Yen

Source: JICA Survey Team

TABLE 11.3-3 ASSIGNMENT SCHEDULE FOR NAGDHUNGA TUNNEL CONSTRUCTION – DETAILED ENGINEERING DESIGN (12MONTHS)

	Position	1	2	3	4	5	6	7	8	9	10	11	12	Total	
														Foreign	Local
Foreign	1 - Project Manager	1	1	1	1	1	1	1	1	1	1	1	1	12.00	
	1 - Sr. Highway Engineer	1				1	1	1						4.00	
	1 - Sr. Structural Engineer	1				1	1	1	1					5.00	
	1 - Tunnel Planner (Planning)	1	1			1	1	1	1					6.00	
	1 - Tunnel Engineer (Design)					1	1	1	1					4.00	
	1 - Tunnel Engineer (Electrical)						1	1	1					3.00	
	1 - Tunnel Engineer (Communication)						1	1	1					3.00	
	1 - Tunnel Engineer (O & M)										1	1	1	3.00	
	1 - Geologist	1	1	1	1	1								5.00	
	1 - Document Specialist								1	1	1			3.00	
	1 - Specification Writer									1	1	1	1	4.00	
	1 - Sr. Cost Estimator								1	1	1	1	1	5.00	
	Sub-total													**57.00**	
Local Key Staff	1 - Deputy Team Leader	1	1	1	1	1	1	1	1	1	1	1	1		12.00
	1 - Highway Engineer	1				1	1	1	1						5.00
	1 - Structural Engineer	1				1	1	1	1	1					6.00
	1 - Drainage Engineer					1	1	1							3.00
	1 - Geologist	1	1	1	1	1									5.00
	1 - Geodetic Engineer	1	1	1		1	1	1	1	1	1	1	1		11.00
	1 - Specification Writer									1	1	1	1		4.00
	2 - Cost Estimator									2	2	2	2		8.00
	1 - RAP Specialist	1	1	1		1	1	1		1	1	1			9.00
	1 - Asset Assessor	1	1	1	1	1	1	1	1	1	1				10.00
	Sub-total														**73.00**
Local Support Staff	1 - Admin. Officer	1	1	1	1	1	1	1	1	1	1	1	1		12.00
	1 - Secretary/Encoder	1	1	1	1	1	1	1	1	1	1	1	1		12.00
	1 - Janitor	1	1	1	1	1	1	1	1	1	1	1	1		12.00
	3 - Jr. Civil Engineer	1	1	1	1	3	3	3	3	3	3	1	1		24.00
	6 - CAD Operator	2	2	2	2	6	6	6	6	6	2	2	2		44.00
	Sub-total														**104.00**
TOTAL														**57.00**	**177.00**

Source: JICA Survey Team

TABLE 11.3-4 ENGINEERING COST FOR NAGDHUNGA TUNNEL CONSTRUCTION – TENDER ASSISTANCE FOR SELECTIONOF CONTRACT (14 MONTHS)

Description		Unit	Unit Price (1,000 JPY or NPR)		Quantity	Total (1,000 JPY or NPR)	
A.	**Professional Staff**						
A-1	Remuneration						
1)	Professional Staff (A)	M/M	JPY	2,895	20.00	JPY	57,900
2)	Professional Staff (B)	M/M	JPY	275	21.00	JPY	5,775
	Sub-Total (A-1)					JPY	63,675
A-2	Reimbursable Cost						
1)	International Travel Expenses	RT	JPY	364	13.00	JPY	4,732
2)	Subsistence Allowance	M/M	JPY	250	20.00	JPY	5,000
3)	International Communication	Month	JPY	50	11.00	JPY	550
4)	Vehicle Rental (2×7months)	Veh.-Mo.	JPY	220	14.00	JPY	3,080
5)	Office Supply/Equipment	Month	JPY	100	11.00	JPY	1,100
6)	Printing Cost	Month	JPY	200	11.00	JPY	2,200
	Sub-Total (A-2)					JPY	16,662
Sub-Total (A)						JPY	80,337
		(Equivalent to)				**NPR**	**73,034**
B.	**Supporting Staff**						
B-1	Remuneration						
1)	Technical Support Staff	M/M	NPR	80	14.00	NPR	1,120
2)	Administrative Staff	M/M	NPR	80	42.00	NPR	3,360
	Sub-Total (B-1)					NPR	4,480
B-2	Reimbursable Cost						
1)	Office Rental (150m^2×700NPR/m^2)	Month	NPR	105	11.00	NPR	1,155
2)	Office Running Cost	Month	NPR	80	11.00	NPR	880
3)	Local Communication	Month	NPR	10	11.00	NPR	110
	Sub-Total (B-2)					NPR	2,145
Sub-Total (B)						**NPR**	**6,625**
Total (A) + (B)						**NPR**	**79,659**
VAT (13%)						**NPR**	**10,356**
Grand Total						**NPR**	**90,014**

Exchange Rate:
1.0 NPR = 1.1 Yen

Source: JICA Survey Team

TABLE 11.3-5 ASSIGNMENT SCHEDULE FOR NAGDHUNGA TUNNEL CONSTRUCTION – TENDER ASSISTANCE FOR SELECTION OF CONTRACTOR (14 MONTHS)

	Detailed Design	10	11	12	1											Total	
	Tender Assistance	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Foreign	Local
Foreign	1 – Project Manager					1	1			1	1	1		1	1	7.00	
	1 – Tunnel Engineer	1	1					1								3.00	
	1 – Document Specialist	1							1						1	3.00	
	1 – Specification Writer						1	1						1	1	4.00	
	1 – Sr. Cost Estimator		1					1							1	3.00	
	Sub-total															**20.00**	
Local Key Staff	1 – Deputy Project Manager	1	1	1	1	1	1	1	1	1	1	1	1	1	1		14.00
	1 – Specification Writer	1	1				1	1	1					1	1		7.00
	1 – Cost Estimator		1						1					1			3.00
	Sub-total																**24.00**
Local Support Staff	1 – Admin. Officer	1	1	1	1	1	1	1	1	1	1	1	1	1	1		14.00
	1 – Secretary/Encoder	1	1	1	1	1	1	1	1	1	1	1	1	1	1		14.00
	1 – Janitor	1	1	1	1	1	1	1	1	1	1	1	1	1	1		14.00
	1 – CAD Operator	1	1	1	1	1	1	1	1	1	1	1	1	1	1		14.00
	Sub-total																**56.00**
TOTAL																**20.00**	**80.00**

Source: JICA Survey Team

TABLE 11.3-6 ENGINEERING COST FOR NAGDHUNGA TUNNEL CONSTRUCTION – CONSTRUCTION SUPERVISION STAGE (42 MONTHS)

Description		Unit	Unit Price (1,000 JPY or NPR)		Quantity	Total (1,000 JPY or NPR)	
A.	**Professional Staff**						
A-1	Remuneration						
1)	Professional Staff (A)	M/M	JPY	2,895	116.00	JPY	335,820
2)	Professional Staff (B)	M/M	JPY	275	426.00	JPY	117,150
	Sub-Total (A-1)					JPY	452,970
A-2	Reimbursable Cost						
1)	International Travel Expenses	RT	JPY	364	31.00	JPY	11,284
2)	Subsistence Allowance	M/M	JPY	250	116.00	JPY	29,000
3)	International Communication	Month	JPY	50	42.00	JPY	2,100
4)	Vehicle Rental ((2×42months) + 3 months)	Veh.-Mo.	JPY	220	87.00	JPY	19,140
5)	Office Supply/Equipment	Month	JPY	300	42.00	JPY	12,600
6)	Printing Cost	Month	JPY	200	42.00	JPY	8,400
	Sub-Total (A-2)					JPY	82,524
Sub-Total (A)						JPY	535,494
		(Equivalent to)				**NPR**	**486,813**
B.	**Supporting Staff**						
B-1	Remuneration						
1)	Technical Support Staff	M/M	NPR	80	252.00	NPR	20,160
2)	Administrative Staff	M/M	NPR	80	126.00	NPR	10,080
	Sub-Total (B-1)					NPR	30,240
B-2	Reimbursable Cost						
1)	Office Rental (300m²×700NPR/m²)	Month	NPR	210	42.00	NPR	8,820
2)	Office Running Cost	Month	NPR	100	42.00	NPR	4,200
3)	Local Communication	Month	NPR	50	42.00	NPR	2,100
	Sub-Total (B-2)					NPR	15,120
Sub-Total (B)						**NPR**	**45,360**
Total (A) + (B)						**NPR**	**532,173**
VAT (13%)						**NPR**	**69,182**
Grand Total						**NPR**	**601,355**

Exchange Rate:
1.0 NPR = 1.1 Yen

Source: JICA Survey Team

TABLE 11.3-7 ASSIGNMENT SCHEDULE FOR NAGHDUNGA TUNNEL CONSTRUCTION – CONSTRUCTION SUPERVISION STAGE

	Position	Assignment Schedule																																										Defect Liability			Total	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	49	53	54	Foreign	Local
Foreign	1 - Project Manager	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1	39.00	
	1 - Resident Engineer	1	1	1	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1	1				37.00	
	1 - Tunnel Engineer					1	1	1				1	1	1				1	1	1			1	1	1		1	1	1		1	1	1		1	1	1		1	1	1						24.00	
	1 - Sr. Material Engineer				1	1				1	1				1	1				1	1				1	1				1	1				1	1				1	1						16.00	
	Sub-total																																														**116.00**	
Local Key Staff	1 - Deputy Project Manager	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		45.00
	2 - Asst. Resident Engineer	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1					73.00
	1 - Highway Engineer																								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						18.00
	1 - Structural Engineer																								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						18.00
	2 - Material Engineer	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1					73.00
	2 - Quantity Engineer	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1					73.00
	1 - Surveyor	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					42.00
	1 - Laboratory Technician	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					42.00
	1 - Environmental Monitoring Specialist	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					42.00
	Sub-total																																															**426.00**
Local Support Staff	1 - Admin. Officer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					42.00
	1 - Secretary/Encoder	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					42.00
	1 - Janitor	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					42.00
	4 - Inspector	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4					168.00
	2 - CAD Operator	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2					84.00
	Sub-total																																															**378.00**
	TOTAL																																														**116.00**	**804.00**

Source: JICA Survey Team

TABLE 11.3-8 TUNNEL O & M CAPACITY DEVELOPMENT COST FOR NAGDHUNGA TUNNEL (24 MONTHS)

Description		Unit	Unit Price (1,000 JPY or NPR)		Quantity	Total (1,000 JPY or NPR)	
A.	**Professional Staff**						
A-1	Remuneration						
1)	Professional Staff (A)	M/M	JPY	2,895	45.00	JPY	130,275
2)	Professional Staff (B)	M/M	JPY	275	17.00	JPY	4,675
	Sub-Total (A-1)					JPY	134,950
A-2	Reimbursable Cost						
1)	International Travel Expenses	RT	JPY	364	23.00	JPY	8,372
2)	Subsistence Allowance	M/M	JPY	250	32.00	JPY	8,000
3)	International Communication	Month	JPY	50	12.00	JPY	600
4)	Vehicle Rental (2×6months)	Veh.-Mo.	JPY	220	12.00	JPY	2,640
5)	Office Supply/Equipment	Month	JPY	150	12.00	JPY	1,800
6)	Printing Cost	Month	JPY	200	12.00	JPY	2,400
7)	Training in Japan	L.S.	JPY	5,440	-	JPY	5,440
	Sub-Total (A-2)					JPY	29,252
Sub-Total (A)						JPY	164,202
		(Equivalent to)				**NPR**	**149,275**
B.	**Supporting Staff**						
B-1	Remuneration						
1)	Technical Support Staff	M/M	NPR	80	35.00	NPR	2,800
2)	Administrative Staff	M/M	NPR			NPR	-
	Sub-Total (B-1)					NPR	2,800
B-2	Reimbursable Cost						
1)	Office Rental (150m^2×700NPR/m^2)	Month	NPR	105	10.00	NPR	1,050
2)	Office Running Cost	Month	NPR	100	10.00	NPR	1,000
3)	Local Communication	Month	NPR	20	10.00	NPR	200
	Sub-Total (B-2)					NPR	2,250
Sub-Total (B)						**NPR**	**5,050**
Total (A) + (B)						**NPR**	**154,325**
VAT (13%)						**NPR**	**20,062**
Grand Total						**NPR**	**174,387**

Exchange Rate:
1.0 NPR = 1.1Yen

Source: JICA Survey Team

TABLE 11.3-9 TUNNEL O & M CAPACITY DEVELOPMENT ASSIGNMENT SCHEDULE FOR NAGDHUNGA TUNNEL (24 MONTHS)

	Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Man-months	
																										Foreign	Local
Foreign	Team Leader																									9+2 = 11	
Foreign	Tunnel Maintenance (Civil) Specialist																									5+2 = 7	
Foreign	Tunnel Maintenance (Facilities) Specialist																									5+2 = 7	
Foreign	Traffic Monitoring Specialist																									7+2 = 9	
Foreign	Emergency Action Specialist																									5+3 = 8	
Foreign	Safety Campaign Specialist																									1+1 = 2	
Foreign	Coordinator for Training in Japan																									0+1 = 1	
Foreign	**Sub-total**																									**32+13= 45**	
Local Key Sta	Chief Coordinator																										13.00
Local Key Sta	2 - Safety Campaign Assistant																										4.00
Local Key Sta	**Sub-total**																										**17.00**
Local Support Staff	Chief Administrator																										13.00
Local Support Staff	Encoder/Secretary																										12.00
Local Support Staff	CAD Operator																										10.00
Local Support Staff	**Sub-total**																										**35.00**
TOTAL																										**32+13= 45**	**52.00**

Source: JICA Survey Team

11.4 PRELIMINARY ROW, PORTAL SITES OF THE TUNNEL, AND DISPOSAL SITE ACQUISTION COST

During the construction and the operation phases of the Project, the following land areas will be needed.

- Approach Road
- Tunnel Portals
- Soil Disposal Area for excavated soil from the proposed tunnel
- Staging area and other facilities for construction works
- Other auxiliary facilities

Before finishing the Cadastral Survey, Census/Socio Economic Survey, and Replacement Cost Survey, which were done on October 2014, of this JICA Preparatory Survey, it was considered and estimated for expected land acquisition areas and the reference costs, including governmental prices by data collections and interviews to the local key persons, including government officials. The reference data was reviewed and the preliminary land acquisition areas/costs were mentioned at section 11.4 of the Interim Report of this JICA Preparatory Survey.

However, based on the results of the Cadastral Survey, Census/Socio Economic Survey, and Replacement Cost Survey, the actual expected land acquisition areas and the costs are considered and estimated as follows:

11.4.1 Approach Road and the ROW

Along the planned Approach Road, 50 m (25 m on either side of Center Line of the Approach Road) as the ROW will be needed for the Project for the west side (the exit point from the west side of the tunnel to the connection point with the existing Highway on west side) and the east side (the exit point from the east side of the tunnel to the connection point with the existing

Highway on east side).

For the west side of the approach road and the ROW, it will be estimated as approximately 20,000 m^2 (15,000 m^2 in Naubise VDC and 5,000 m^2 in Baadbhanjyang VDC) based on the results of the above latest surveys. However, all of the area is actually belongs to government lands. Therefore, no actual land acquisition cost for compensation will be needed for the area.

For the east side of the approach road and the ROW, it will be estimated as approximately 110,000 m^2 based on the results of the above latest surveys. All of the area is belongs to private lands lies in Mahadevsthan, Balambu, Dahachok and Thankot VDCs. Therefore, the land acquisition cost for compensation will be needed for the approach road and the ROW.

11.4.2 Tunnel Portals

Only the land used for the east and west portal part of the tunnel shall be acquired.

For the tunnel west portal area, which is located in Baad Bhanjyang VDC, it is estimated that the total area will be approximately 12,000 m^2. However, all of the area is actually belongs to government lands. Therefore, no actual land acquisition cost for compensation will be needed for the tunnel west portal site.

For the east portal area, which is located in Dahachok VDC and Thankot VDC, it is estimated that the total area will be approximately 7,700 m^2. All of the area is belongs to private lands. Therefore, the land acquisition cost for compensation will be needed for the tunnel east portal site.

11.4.3 Soil Disposal Site

The proposed soil disposal site is planned at Sisnekhola Area, which flows through Baad Bhanjyan and Naubise VDCs. it is estimated that the total area of the soil disposal site will be approximately 26,200 m^2. The site is located within a 50 m from the centerline of the existing Highway at Naubise VDC, Dhading District. However, the entire site is actually belongings to government lands. Therefore, no actual land acquisition cost for compensation will be needed for the proposed soil disposal site.

11.4.4 Staging area, other facilities for construction works, and other ancillary facilities

It is considered that the staging area, other facilities for construction works, and other ancillary facilities will be utilized on lease base. Therefore, it will not need to consider these land acquisition costs.

11.4.5 Preliminary Estimation of Land Acquisition Cost for the ROW and Soil Disposal Site

There were many possibilities for the land acquisition costs for the above each area/site by this Project. However, the actual land acquisition costs will be necessary for the approach road and the RoW, as well as the tunnel east portal site, after all.

In the final stage of this Preparatory Survey, it will be necessary to consider the land acquisition costs as the replacement costs for the land compensation.

Therefore, the land acquisition costs are estimated based on the results of a current market cost survey (replacement cost survey) of this JICA Preparatory Survey, taking into account of the expected replacement costs for the land compensation. The detailed results, including both each current market cost and government cost, of the affected land parcels and the estimated costs are shown in **Annex 13.4-3.**

According to the replacement cost survey in the affected area, each land unit price had wide ranges, especially for Mahadevestthan VDC, because of the distances from the main roads, and actual land conditions such as undulation, etc. The each land unit price range in each affected VDC is shown in **Table 11.4-1**.

TABLE 11.4-1 LAND UNIT PRICES RANGES OF THE CURRENT MARKET PRICE IN THE PROJECT AFFECTED AREAS

VDC	Area for Necessary Acquisition (m2)	Price Range per ana* (NRs per ana)	Price Range per m2 (NRs per m2)
Mahadevsthan	39,000	600,000 – 1,500,000	18,873.9 – 47,184.6
Balambu	2,000	700,000 – 750,000	22,019.5 – 23,592.3
Dahachok	35,000	700,000 – 800,000	22,019.5 – 25,165.1
Thankot	40,000	600,000 – 800,000	18,873.9 – 25,165.1

Note: 1 ana is equal to 31.79 m2.*
Source: Replacement Cost Survey of this JICA Preparatory Survey, October, 2014

Based on the estimations of the actual each parcel of the necessary private lands, the necessary land acquisition costs for this Project are summarized in **Table 11.4-2**.

TABLE 11.4-2 SUMMARY OF THE ESTIMATION OF LAND ACQUISITION COSTS

S.N.	VDC	Area for Necessary Acquisition (m^2)	Average Unit Price within each VDC (NRs per m^2)*	Necessary Land Cost Total (NRs)
1	Mahadevsthan	39,000	24,236.5	945,225,133
2	Balambu	2,000	21,778.6	43,557,186
3	Dahachok	35,000	22,043.8	771,533,343
4	Thankot	40,000	20,624.0	824,961,196
Total		**116,000**	**-**	**2,585,276,858**

Note: These average unit prices are calculated as references from each actual data by the Replacement Cost Survey.*
Source: Replacement Cost Survey of this JICA Preparatory Survey, October, 2014

11.5 ADMINISTRATIVE COST

Administrative cost of DOR was assumed to be 5.0% of Civil Work Cost.

11.6 SUMMARY OF BASE COST

Project cost was summarized in **Table 11.6-1**.

TABLE 11.6-1 SUMMARY OF BASE COST

Item	Cost (Million NPR in 2014)
1.CONSTRUCTION COST	
Tunnel Construction	9,650.76
Approach Road Construction	266.26
Bridge Construction	405.02
Toll Facility Construction	25.00
Control office Construction/ O&M Vehicles	145.09
Disposal Area Development	154.57
Transmission Line *(refer to Section9.11)*	146.00
Sub-Total	**10,792.70**
2.CONSULTANCY COST	
Detailed Engineering Design Cost	253.03
Tender Assistance for Selection of Contractor	79.66
Construction Supervision Cost	532.17
Tunnel O&M Capacity Development	154.33
Sub-Total	**1,019.19**
3.ROW COST	
Land Acquisition Costs	2,585.28
Others (Structure, Factories, RAP etc.)	151.06
Sub-Total	**2,736.34**
4. ADMINISTRATIVE COST	**539.65**
GROUND TOTAL (1.-4)	**15,087.88**

Note; VAT not included.
Source: JICA Survey Team

CHAPTER 12

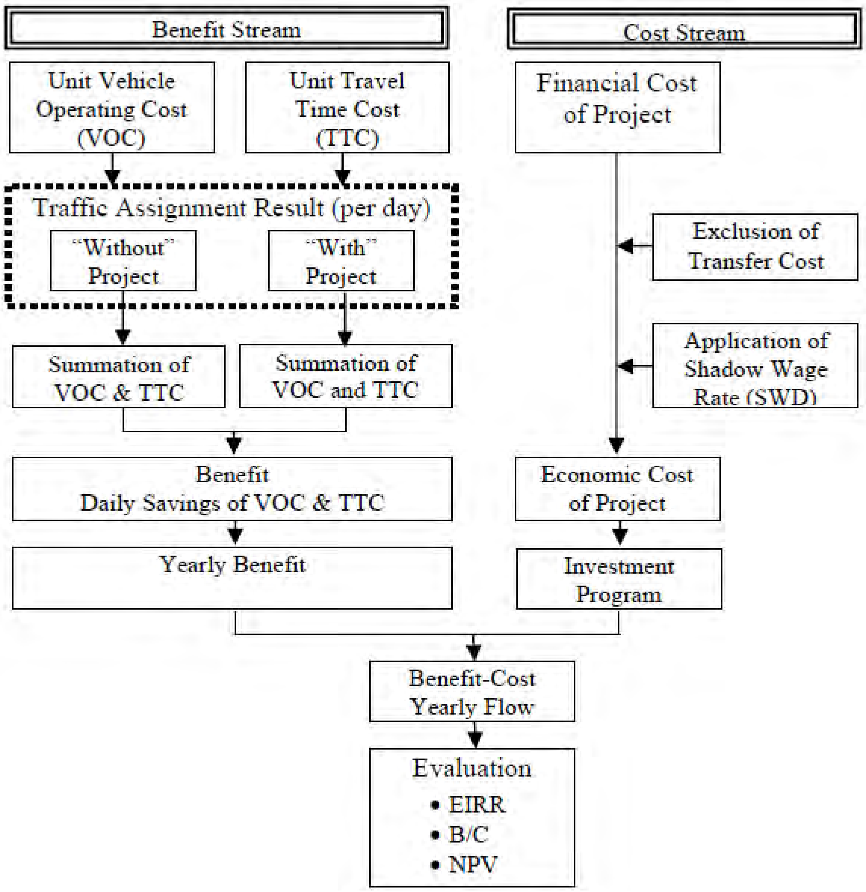
ECONOMIC AND FINANCIAL EVALUATION

CHAPTER 12
ECONOMIC AND FINANCIAL EVALUATION

12.1 ECONOMIC EVALUATION

12.1.1 Methodology

The economic analysis shall be determined whether the construction and operation of the proposed project will be feasible based on the benefits and costs to be derived from the project. The road projects such as Nagdhunga tunnel construction project can play a very important role in strength of the accessibility and economic growth. It is required however, that the project must be economically viable, satisfying the government-prescribed hurdle rates. Annual economic cost and benefits shall be estimated under "With project" and "Without project" case. The difference in economic costs and benefits in both cases shall be attributed to the project and subjected to economic feasibility measurement. The economic feasibility of the project shall be indicated by the Economic Internal Rate of Return (EIRR), Cost Benefit Ratio (CBR), and Net Present Value (NPV) at an assumed discount rate of 12%, which is acceptable social discount rate for economic appraisal of public investment projects in the development bank such as world bank. The hurdle rates for economic feasibility are the following: EIRR > 12%, B/C > 1.0, and NPV > 0. Sensitivity of the project arising from adverse changes in costs and benefits shall be examined to establish the capacity of the project to exhibit economic feasibility under these cases.



Source: JICA Survey Team

FIGURE 12.1-1 WORK FLOW OF ECONOMIC EVALUATION

Economic costs and benefits throughout the project life periods are compared by a discount cash flow analysis. The discount rate (hereinafter referred to as "DR") is at 12%, which is widely used in World Bank project as a social discount rate. For economic evaluation, three indicators are calculated: Economic Internal Rate of Return (hereinafter referred to as "EIRR"), Cost Benefit Ratio (CBR, hereinafter referred to as "B/C") and Net Present Value (hereinafter referred to as "NPV").

In addition, the economic life is assumed to be 30 years from 2022 to 2051, taking into account future rapid growth and changes of socioeconomic conditions. Therefore, the Pro-forma cash flow of a project evaluation will be prepared for 2015-2051. They are defined as **Table 12.1-1**.

TABLE 12.1-1 INDICATORS OF ECONOMIC EVALUATION

No.	Indicators	Calculation Formula or Value
1	Net Present Value (NPV)	$\sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^{t-1}}$ *i=12.0%*
2	Benefit/Cost Ratio (CBR; B/C)	$\frac{\sum_{t=1}^{n} B_t/(1+i)^{t-1}}{\sum_{t=1}^{n} C_t/(1+i)^{t-1}}$ *i=12.0%*
3	Economic Internal Rate of Return (EIRR)	i_0: social discount rate that satisfies the following equation $\sum_{t=1}^{n} \frac{B_t - C_t}{(1+i_0)^{t-1}} = 0$

Source: JICA Survey Team

12.1.2 Economic Cost of the Project

(1) Initial Cost

The project cost must be estimated by shadow price in the cost benefit analysis. This is because market price is distorted by governmental system and policies such as custom duty, and market intervention. The shadow price expresses the real value of the resources. The Project cost of Nagdhunga Tunnel project is estimated in market prices in Chapter 11. It is converted into economic cost and the residual cost after the project life is calculated for economic evaluation, taking the following process.

a) Out of material and equipment cost, import duty and value added tax (VAT) at 13% are deducted.
b) The life year will be considered at 30 years

TABLE 12.1-2 IMPLEMENTATION SCHEDULE AND ECONOMIC COST

(Billion NPR)

	2016	2017	2018	2019	2020	2021	2022	Total
Civil work	0	0	4.32	2.16	2.16	1.62	0.54	10.79
Consulting Service	0.26	0.09	0.13	0.14	0.20	0.11	0.01	0.94
Land Acquisition	0.39	2.35	0	0	0	0	0	2.74
Administration Cost	0.04	0.15	0.27	0.14	0.15	0.13	0.04	0.91
Physical Contingency	0.07	0.28	0.49	0.26	0.27	0.21	0.07	1.65
Total of Economic Cost	***0.76***	***2.87***	***5.21***	***2.70***	***2.78***	***2.07***	***0.66***	***17.03***

Source: JICA Survey Team

(2) Operation and Maintenance Cost

The Operation and Maintenance Cost was estimated. The operation and maintenance cost per year is for tunnel infrastructure and facilities including electricity, tunnel management office running with staff cost, and maintenance work / replacement of parts. As road user fee will be considered for the vehicle passing this tunnel, operation and maintenance cost for toll gate is charged in this study. The operation and maintenance costs of 43.1 NPR required in every year was estimated and shown in **Table 12.1-3**. Regarding the road maintenance such as overlay, 200 million NPR will be expenses per 10 years.

TABLE 12.1-3 OPERATION AND MAINTENANCE COSTS

(million NPR / year)

Items	Economic cost
Electricity Cost	25.0
Tunnel management office running cost including staff cost	13.0
Maintenance work / replacement of parts, etc.	6.0
Toll gate O&M	5.0
Total	49.0

Source: JICA Survey Team

12.1.3 Economic Benefit of the Project

Economic benefits are calculated according to multiplied the estimated traffic volumes and Vehicle Operating Cost (VOC) /Travel Time Cost (TTC) respectively for each case, and the amount of 'without' case minus 'with' case is considered as the benefit provided by the project.

(1) Unit Vehicle Operating Cost (VOC)

The VOC per unit distance is estimated by type of vehicle being composed of the following components; they are a) fuel cost, b) oil cost, c) tire cost, d) spare parts cost, e) depreciation cost, f) capital opportunity cost and g) crew and overhead cost. The type of vehicles is 6 type of vehicles, passenger car, micro-bus, mini-bus, heavy bus, light truck, and heavy truck.

The department of roads use the VOC estimated by HDM-4 in PIP report in 2007. However, unite VOC is not opened in this report. In this study, the VOC is calculated based on road user costs knowledge system by world bank refer to the basic idea of PIP report and interview to certain car owner or truck company for collecting the basic information of operation and maintenance cost for vehicle. And also, due to intended road section is very hard uphill road; the VOC should be considered gradient condition. In term of these aspects, the VOCs depending on the gradient type is estimated. Finally, the VOC estimated was confirmed adequacy by the comparison to the realistic situation from owner of vehicle.

TABLE 12.1-4 UNIT VOC BY SIX VEHICLE TYPES IN 2014

Gradient= 0 NPR/veh-km

Speed (km/hr)	Car	S_Bus	M_Bus	H_Bus	L_Truck	H_Truck
10	26.9	35.8	77.4	135.2	30.7	127.8
20	23.5	29.8	54.8	89.0	26.9	95.1
30	20.2	23.8	32.3	42.7	23.1	62.4
40	19.4	22.6	28.8	36.6	22.2	55.0
50	18.3	21.0	24.3	29.1	20.7	45.0
60	17.5	19.8	21.3	24.3	19.6	38.4

Gradient= 3.2% NPR/veh-km

Speed (km/hr)	Car	S_Bus	M_Bus	H_Bus	L_Truck	H_Truck
10	27.0	36.3	83.9	155.0	32.4	136.7
20	23.7	30.2	59.4	102.0	28.4	101.7
30	20.3	24.1	35.0	48.9	24.4	66.7
40	19.6	23.0	31.2	41.9	23.4	58.9
50	18.5	21.3	26.3	33.3	21.9	48.1
60	17.6	20.0	23.1	27.9	20.7	41.1

Gradient= 7.0% NPR/veh-km

Speed (km/hr)	Car	S_Bus	M_Bus	H_Bus	L_Truck	H_Truck
10	28.0	41.3	105.4	211.5	40.9	182.3
20	24.5	34.4	74.6	139.2	35.9	135.6
30	21.0	27.4	43.9	66.8	30.8	89.0
40	20.3	26.1	39.2	57.3	29.6	78.5
50	19.1	24.2	33.0	45.5	27.6	64.1
60	18.3	22.8	29.0	38.0	26.2	54.8

Source: JICA Survey Team

(2) Unit Travel Time Cost (TTC)

The Travel time cost is the lost cost for travel by vehicle. TTC should be considered for economic analysis of this tunnel construction project. Because the income and price are increasing every year in Nepal, therefore, it is not affordable to ignore this item if considering the economic increasing in Nepal. The Travel Time Cost is normally calculated based on the average labor productivity and income in the country. As DoR don't configure official TTC for road project in Nepal, the Survey Team estimated TTC per vehicle-km based on income level, working time and occupancy from OD survey on roadside by type of vehicle.

Basically, reduction in travel time is the main component in the derivation of the TTC saving. The annual savings was calculated as the difference in travel time between the base road network and with Nagdhunga tunnel project. Due not to collect the latest official income data, the information based on the interview to authorities in Nepal government was used as the average income per income level. The unit TTC of vehicles will also be corresponded to the six (6) vehicle types of estimated such as 1) Passenger Car, 2) Micro-bus, 3) Mini-Bus, 4) Heavy Bus and 5) Light Truck, 6) Heavy truck, which is shown in **Table 12.1-5**.

TABLE 12.1-5 UNIT TRAVEL TIME COST IN 2014

Classification	NPR/veh.-min
Passenger Car	12.2
Micro-bus	22.1
Mini-bus	18.4
Large Bus	58.8
Light truck	3.3
Heavy truck	7.6

Source: JICA Survey Team

(3) Estimation of Economic Benefit (VOC and TTC Saving)

Based on the unit VOC by vehicle type by vehicle speed and the total vehicle-km, VOC saving by year will be estimated. The daily TTC saving by year also will be estimated based on the unit TTC by vehicle type and the total vehicle-hour. **Table 12.1-6**.

TABLE 12.1-6 ECONOMIC BENEFIT

	Economic Benefit (billion NPR / year)		
year	Saving of TTC	Saving of VOC	Total
2020	1.2	1.0	2.2
2025	1.5	1.3	2.8
2030	2.0	1.6	3.6
2035	1.7	1.3	3.0

**2015: Sindhuli road will be in service*
***2031: Fast track road will be in service*
Source: JICA Survey Team

12.1.4 Results of Economic Analysis

The result of economic analysis is shown at **Table 12.1-7**. The economic costs and benefits of the project generated a positive NPV and on EIRR that is higher than the government prescribed hurdle rate (12%). These values indicate that the project is economically viable.

TABLE 12.1-7 RESULT OF ECONOMIC ANALYSIS

No.	Indicators	Result
1	Net Present Value (NPV)	494 Million NPR
2	Benefit/Cost Ratio (CBR; B/C)	1.05
3	Economic Internal Rate of Return (EIRR)	12.5%

**Social discount rate is 12.0%*
Source: JICA Survey Team

12.1.5 Project Sensitivity

The Project Sensitivity to the identified risks is shown in **Table 12.1-8**. Results show that the project is able to hurdle the minimum acceptance criteria of EIRR =12.0%. In order to hurdle the minimum criteria EIRR=12.0%, it is necessary to keep within the 10% down of the benefits or cost increase of 10%.

TABLE 12.1-8 PROJECT SENSITIVITY

	Base	Cost plus 10%	Cost plus 20%
Base	12.5%	11.8%	10.9%
Benefit less 10%	11.7%	10.7%	9.9%
Benefit less 20%	10.5%	9.6%	8.9%

Source: JICA Survey Team

TABLE 12.1-9 ECONOMIC ANALYSIS

(Million NPR)

	year	Constructuon Cost	O&M	Total Cost	Benefit TTC saving	Benefit VOC saving	Total Benefit	Cash Flow
Base year	2014	-	-	-	-	-	-	-
-7	2015	0.0	0.0	0.0	0.0	0.0	0.0	0
-6	2016	759.6	0.0	759.6	0.0	0.0	0.0	-760
-5	2017	2,867.5	0.0	2,867.5	0.0	0.0	0.0	-2,867
-4	2018	5,208.5	0.0	5,208.5	0.0	0.0	0.0	-5,208
-3	2019	2,700.3	0.0	2,700.3	0.0	0.0	0.0	-2,700
-2	2020	2,780.0	0.0	2,780.0	0.0	0.0	0.0	-2,780
-1	2021	2,047.3	0.0	2,047.3	549.2	474.4	1,023.6	-1,024
Open	2022	654.6	49.0	703.6	1,168.2	992.7	2,160.9	1,457.3
1	2023	0.0	49.0	49.0	1,238.1	1,036.7	2,274.8	2,225.8
2	2024	0.0	49.0	49.0	1,312.1	1,082.7	2,394.7	2,345.7
3	2025	0.0	49.0	49.0	1,493.8	1,320.2	2,814.0	2,765.0
4	2026	0.0	49.0	49.0	1,583.1	1,378.7	2,961.8	2,912.8
5	2027	0.0	49.0	49.0	1,677.7	1,439.9	3,117.5	3,068.5
6	2028	0.0	49.0	49.0	1,778.0	1,503.7	3,281.7	3,232.7
7	2029	0.0	49.0	49.0	1,884.3	1,570.3	3,454.6	3,405.6
8	2030	0.0	49.0	49.0	1,996.9	1,639.9	3,636.9	3,587.9
9	2031	0.0	249.0	249.0	1,511.3	1,157.9	2,669.2	2,420.2
10	2032	0.0	49.0	49.0	1,561.3	1,196.7	2,758.0	2,709.0
11	2033	0.0	49.0	49.0	1,612.9	1,236.9	2,849.8	2,800.8
12	2034	0.0	49.0	49.0	1,666.3	1,278.4	2,944.7	2,895.7
13	2035	0.0	49.0	49.0	1,721.4	1,321.3	3,042.7	2,993.7
14	2036	0.0	49.0	49.0	1,779.2	1,365.6	3,144.7	3,095.7
15	2037	0.0	49.0	49.0	1,779.2	1,365.6	3,144.7	3,095.7
16	2038	0.0	49.0	49.0	1,779.2	1,365.6	3,144.7	3,095.7
17	2039	0.0	49.0	49.0	1,779.2	1,365.6	3,144.7	3,095.7
18	2040	0.0	49.0	49.0	1,779.2	1,365.6	3,144.7	3,095.7
19	2041	0.0	249.0	249.0	1,779.2	1,365.6	3,144.7	2,895.7
20	2042	0.0	49.0	49.0	1,779.2	1,365.6	3,144.7	3,095.7
21	2043	0.0	49.0	49.0	1,779.2	1,365.6	3,144.7	3,095.7
22	2044	0.0	49.0	49.0	1,779.2	1,365.6	3,144.7	3,095.7
23	2045	0.0	49.0	49.0	1,779.2	1,365.6	3,144.7	3,095.7
24	2046	0.0	49.0	49.0	1,779.2	1,365.6	3,144.7	3,095.7
25	2047	0.0	49.0	49.0	1,779.2	1,365.6	3,144.7	3,095.7
26	2048	0.0	49.0	49.0	1,779.2	1,365.6	3,144.7	3,095.7
27	2049	0.0	49.0	49.0	1,779.2	1,365.6	3,144.7	3,095.7
28	2050	0.0	49.0	49.0	1,779.2	1,365.6	3,144.7	3,095.7
29	2051	0.0	249.0	249.0	1,779.2	1,365.6	3,144.7	2,895.7
30	2052	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total		17,017.7	2,070.0	19,087.7	51,221.0	40,479.5	91,700.5	72,612.8
NPV	*12%*	10,087.8	220.1	10,307.8	5,934.1	4,867.6	10,801.8	493.9
B/C	*12%*							1.05
EIRR								**12.5%**

Source: JICA Survey Team