7.4 Alternative Route Study

7.4.1 General

Alternative route study is conducted on the topographic map with a scale of 1/10,000 which has been prepared by the Study Team along the corridor selected in the Initial Route Study, and the optimum route of Sindhuli Road is selected through study of alternative routes.

Topographic map with a scale of 1/2,000 is prepared for the use of the preliminary design of this Project, based on the above optimum route selected.

Site reconnaissance was carried out to identify the following control factors in route selection:

- Geological and topographic conditions
    - . Possible landslide area
    - . Talus deposit area
    - . Degraded slope area
    - . Fault and Thrust area
    - . Very steep slope area
- Engineering control factors
    - . Desirable location of long span bridge
    - . Desirable location of crossing point at Sindhuli Garhi
- Socio-economic control factors
    - . Present landuse pattern
    - . Location of houses and public facilities
    - . Accessibility to the village

7.4.2 Alternative Route Study

Alternative routes studied on the map (1/10,000) are illustrated in Fig. 7.5, and the summary of alternative routes are presented in Table 7.4.

(1) Section I (Bardibas - Sindhuli Bazar): 37 km

No major alternative route is considered in this section, since the main subject to be done under the Project is to improve the existing road between Bardibas and Sindhuli Bazar.

(2) Section II-1 (Sindhuli Bazar - Khurkot)

Three conceivable alterantive routes are considered in this section, namely Alternatives II-1a, II-1b and II-1c. Alterantive II-1(a) is selected to conduct sectional comparison of Route II-1a.

Alterantive II-1a: 39 km

This route, starting from Sindhuli Bazar (EL. 530), follows the existing small track along the right bank of Gwangu Khola and ascends the southern slope of the Mahabhrat Range up to the lowest point nearby Sindhuli Garhi. After Sindhuli Garhi, the route goes down making loops on the hillside of right side Andheri Khola Valley. The alignment crosses over Andheri Khola and finally reaches Khurkot at the bank of Sun Kosi River.

Topography and geological condition in the right side slope of Andheri Khola Valley is more favourable than the left side.

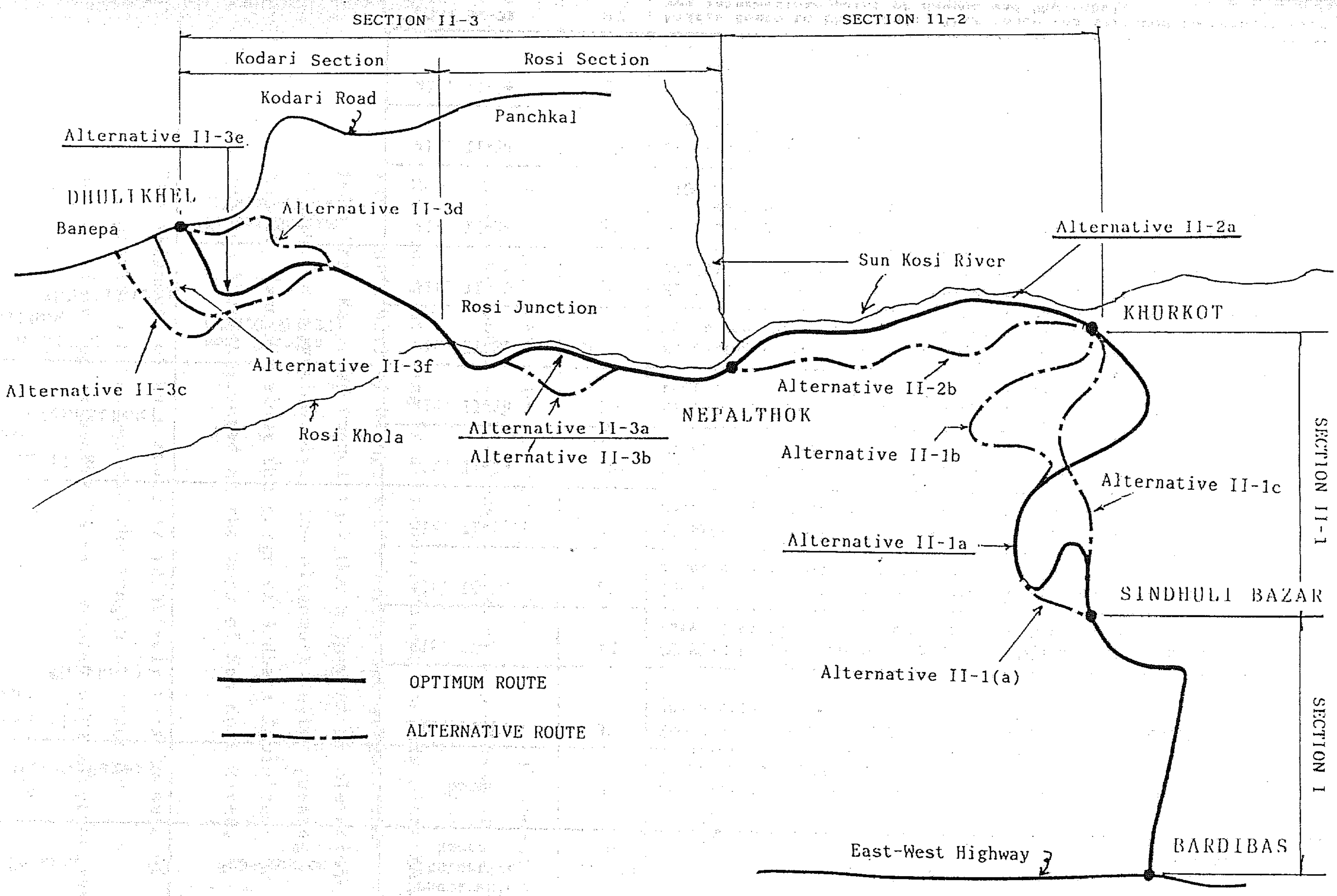


Fig. 7.5 Layout of Alternative Routes in Section I and II

Table 7.4 Summary of Alternative Routes

Section	Sub-Section	Conceivable Alternative Route	Length (km)	Preliminary Examination
Section I (Bardibas-S.Bazar)	-	None	37	Proposed route passes along the existing road which is under construction by DOR.
Section II-1 (S.Bazar -Khurkot)	-	Alt. II-1a	39	New Route: This route is the most reliable and possible route among three alternatives.
		Alt. II-1b	41	COMMTEC Route: The section between Sindhuli Garhi and Khurkot is very difficult due to land slide and topography.
		Alt. II-1c	26	Tunnel Route: This route is the shortest one, however, the construction cost of tunnel (2,000 m) is quite large.
		Alt. II-1(a)	37	Alternative New Route: This route was proposed to shorten Alt. II-1a route by provision of loops between STA5 and STA10.
Section II-2 (Khurkot -Nepalthok)	-	Alt. II-2a	30	Riverside Route: The route passes through left bank of Sun Kosi River. Alignment of road is fair.
		Alt. II-2b	53	Hillside Route: This route was selected taking into account Sun Kosi No.2 Dam Project, shifting the alignment toward hillside.
Section II-3 (Nepalthok -Dhulikhel)	Rosi Section (STA.0-STA.20)	Alt. II-3a	23	Riverside Route: The route passes through left bank of Rosi River. Countermeasures for landslide are required.
		Alt. II-3b	26	Hillside Route: The route was selected to avoid landslides by shifting alignment toward hillside, resulting in bad alignment.
	Kodari Section (STA.20-STA.47)	Alt. II-3c	27	Banepa Route: The route was selected to connect with Banepa. The alignment of road is fair and short by provision of short tunnel (100 m).
		Alt. II-3d	25	Eastern Route of Dhulikhel Hill: This route was selected aiming at shortest route to Dhulikehl. Topography is very steep.
		Alt. II-3e	26	Southern Route of Dhulikhel Hill: This route was selected to connected with Dhulikhel passing on southern slope of D. Hill. The alignment is not fair.
		Alt. II-3f	27	Middle Route to Dhulikhel: This route was selected to connect with the intermediate point of Banepa and Dhulikhel.

Alternative II-1b: 41 km

This route is more or less the same route as proposed by the Italian Consultant, COMTEC, in its study of "NEPAL ROAD FEASIBILITY STUDY" in 1973. The route is selected aiming at passing through the village of Ruapkhot.

Starting from Sindhuli Bazar, the alignment of Alternative II-1b follows the same route of alterantive II-1a up to Sindhuli Garhi. After Sindhuli Garhi, the alignment heads toward north-west and ascends the northern hillside of the Mahabhrat Range so as to avoid the very intricated area of the drainage basin of the Andheri Khola. The route turns eastwards and go downhill making loops on the irregular left bank of Andheri Khola and reaches Khurkot.

This route has to pass through many dangerous and difficult stretches due to landslides and steep topography.

Alternative II-1c: 26 km

This route was selected aiming at the shortest alignment by providing tunnel with a length of 2,000 m approximately.

The route, starting from Sindhuli Bazar, ascends along the right side hill of Gwangu Khola Valley and crosses the Mahabhrat Range by tunnel in 2,000 m long at an elevation of 1,000 m approximately. The alignment, after passing tunnel, descends along the gorge of Andheri Khola and reaches Khurkot located at the bank of Sun Kosi River.

The alignment of this route is relatively fair because of the provision of tunnel and the length of route is shortened by approximately 18 km compared with Alternatives II-1a and II-1b.

(3) <u>Section II-2 (Khurkot - Nepalthok)</u>

Two alternative routes are considered in this section, namely Alternative II-2a and Alternative II-2b.

<u>Alternative II-2a: 30 km</u>

This route is selected aiming at the economy in construction and maintenance cost from the engineering viewpoint.

From Khurkot, the route runs along the left bank of Sun Kosi River, passing through the villages such as Ratmate Bazar, Jhanga Jholi and Dumja, and reaches Nepalthok.

There are 8 major tributaries to be crossed over by bridges. Nigauli Khola, Arubote Khola and Ghyampe Khola requires large bridge with a length more than 100 m.

<u>Alterantive II-2b: 53 km</u>

This route is planned taking into consideration the Sun Kosi No.2 Dam Project proposed in the "Master Plan Study on Sun Kosi River Water Resource Development".

The alignment is shifted toward hillside in order to keep the elevation of EL 600 m, considering the highest water level of reservoir of No.2 Dam at EL 575 m. As the result, the horizontal alignment become considerably worse and route length between Khurkot and Nepalthok increases by 20 km or so, comparing to the riverside route, namely Alternative II-1b.

The existing villages are mostly located at the river bed of Sun Kosi river, the accessibility from the Project Road to villages is very inconvenient since the alignment runs through hillside apart far from the villages.

(4) Section II-3 (Nepalthok - Dhuhkhel)

This section is divided into two sections, namely Rosi section and Kodari section, for easy understanding in route study.

a. Rosi Section (Nepalthok - Confluence of Dabcha Khola)

Alternative II-3a: 23 km

The route, starting from Nepalthok, ascends gradually along the left bank of Rosi Khola up to the confluence of Dabcha Khola.

The right bank of Rosi Khola is not recommended since the slope on the right bank is seriously damaged due to erosion and collapse caused by movement of Main Boundary Thrust (MBT).

In between Nepalthok and the confluence of Dabcha Khola, there are five major tributaries which the route has to cross over by provision of large bridges.

Alternative II-3b: 26 km

The route is selected to avoid the existing large landslides developed nearby Mangaltar.

The alignment follows the same route of Alternative II-3a up to the confluence of Dabcha Khola with the exception of the above extremely difficult section nearby Mangaltar.

The route in the section nearby Mangaltar ascends up to the center of village of Maugaltar and desends on intricated hillside of Roshi Khola with a steep gradient of 8% or so.

b. <u>Kodari Section (Confluence of Dabcha Khola - Kodari Road)</u>

Four (4) conceivable alternatives are considered in this section as follows:

<u>Alternative II-3c: 27 km</u>

The Alternative II-3c is selected to aim at connecting the Project Road with Banepa on Kodari Road.

The route, starting from the confluence of Dabcha Khola, ascends gradually along the right side bank of Dabcha Khola and proceeds on easy and cultivated area up to Buchakot.

From Buchakot, the alignment follows the existing old track with a 2 to 3 m width on north side slope of Banskarka Hill, and reaches the village of Phaskot.

The road, turning toward west-south direction, passes through cultivated land along Surhi Khola and crosses the Thakurichab Hill by providing a short tunnel with a 100 m in length. After the tunnel the route turns toward north and finally reaches Banepa on Kodari Road.

<u>Alternative II-3d: 25 km</u>

The Alternative II-3d is selected aiming at the direct connection of the route to Dhulikhel town in accordance with the policy of MMG/N.

The route follows the same route of Alternative II-3c up to Phaskot. After Phaskot, the route passes on very steep eastern slope of Dhulikhel Hill and reaches Dhulikhel town on Kodari Road.

This route is the shortest route to Dhulikhel from Paskot, however, it would require large construction and maintenance costs for slope protection work due to unstable and very steep eastern slope of Dhuilkhel Hill.

Alternative II-3e: 26 km

This route was selected as an alternative of Route II-3d to avoid the very steep eastern slope of Dhulikhel Hill. The route passes on favourable southern slope of Dhulikhel Hill and connects with Kodari Road at western end of Dhulikhel town.

The horizontal alignment is not so good comparing with the other alternatives (II-3c, II-3d and II-3f), however, construction cost would be smallest among them because of the favourable terrain.

Alternative II-3f: 27 km

This route is selected for its good alignment as originally expected, and connecting Kodari Road in between Banepa and Dhuikhel town.

The route folows the same alignment of Alternative II-3c up to Thakurichab Hill. After the tunnel, the route passes through paddy rield and reaches the intermediate point between Banepa and Dhulikhel on Kodari Road.

Since the alignment passes through well developed paddy fields on the western slope of Dhulikhel Hill, land aquisition and compensation for the paddy fields might be difficult.

7.4.3 Evaluation of Alternative Routes

(1) Evaluation Method

Alternative routes are evaluated from engineering and socio-economic point of view.

Since the influence area of the Project Road is relatively small, it can be assumed that there would be no great difference in traffic volume in each alternative route.

Based on the above assumption, the route comparison is made employing the criteria presented in Table 7.5 which has been established by the Study Team making reference to similar road projects in under developing countries.

The route which scores the highest mark is regarded as the optimum route of Sindhuli Road.

Table 7.5 Criteria for the Evaluation of Alternative Route

Items	Marks by Classification		
	Good	Fair	Poor
A. Engineering Viewpoint			
A-1 Construction cost	A	B	C
A-2 Maintenance cost	A	B	C
A-3 Route length	A	B	C
A-4 Route alignment	A	B	C
A-5 Ease of construction	A	B	C
B. Socio-economic Viewpoint			
B-1 Insentive to local community	A	B	C
B-2 Accessibility to village	A	B	C
B-3 Enhancement of land use pattern	A	B	C
B-4 Technology transfer	A	B	C

Note: Classes A, B and C gets the marks 3, 2 and 1 respectively for the evaluation.

(2) Evaluation of Alternative Routes

Section I (Bardibas - Sindhuli Bazar)

No alternative route is considered in the Section I.

Section II-1 (Sindhuli Bazar - Khurkot)

The construction cost as well as route length of Alternative II-1b is higher and longer than those of Alternative II-1a. In addition, Alternative II-1b route has to pass through many landslide areas, which will result in large maintenance cost.

Alternative II-1c is the shortest route among three althernatives, however, the construction cost is quite large comparing to another alterantives mainly due to the provision of long tunnel (2,000 m in length approx.). In addition, long tunnel may have maintenance problems for facilities of lighting, communication for emergency case and ventilation. These facilities have to be operated and maintained all the time for 24 hours.

Alternative II-1(a) is advantageous in respect of route length by provision of loops, however, its construction cost would be larger than that of Alternative II-1a.

Summarizing the above, Alterantive II-1a is the most advantageous among four (4) alternatives and is recommended as the optimum route in this section.

Section II-2 (Khurkot - Nepalthok)

In Section II-2 between Nabughat and Nepathok, Alternative II-2a is advantageous in every aspects, lower construction and maintenance cost, shorter route length, better alignment, easy accessibility to the villages, more impact on local economy and social activities, so on.

It was confirmed in the Minutes of Discussion signed on March, 25, 1987 that the alignment design in the section between Khurkot and Nepalthok needs not consider the Sun Kosi No.2 Dam Scheme planned in the "Master Plan Study on the Kosi River Water Resources Development".

Section II-3 (Nepalthok - Kodari Road)

A. Rosi Section (Nepalthok - Confluence of Dabcha Khola)

Alternative II-3a is advantageous in respect of routes length and alignment remarkably, while the construction cost is a little bit larger than alternative II-3b. Therefore, alternative II-3a is recommended as the optimum route in this section.

B. Kodari Section (Confluence of Dabcha Khola - Kodari Road)

Alternative II-3e was selected by HMG/N as the optimum route of the Project Road in this section.

The result of evaluation for each alternative route are presented in Appendix 7.4.1

7.4.4 Selection of the Optimum Route

The summary of optimum route of Sindhuli Road selected through the above alternative study is shown in Table 7.6 below:

Table 7.6 Optimum Route of Sindhuli Road Project

Section	Optimum Route	Length
Section I (Bardibas - Sindhuli Bazar)	Existing Road	37 km
Section II-1 (Sindhuli Bazar - Khurkot)	Alternative II-1a	39 km
Section II-2 (Khurkot - Nepalthok)	Alternative II-2a	30 km
Section II-3 (Nepalthok - Dhulikhel)		
Rosi Section	Alternative II-3b	23 km
Kodari Section	Alternative II-3e	26 km
Total Project Length		155 km

7.4.5 Corridor along the Optimum Route

The corridor of the Project Road is determined on the topographic map of 1/10,000 along the optimum route selected above with 200-300 m in width.

The topographic map with a scale 1/2,000 is prepared by the Study Team along the optimum route for the alignment design of the Project Road.

7.5 Alternatives Bridge Study

7.5.1 General

The purposes of alterantive bridge study are to establish the general concepts in bridge planning and to determine the preliminary type and dimension of major bridges through study of characteristics of the river flows and on the basis of the data collected during the site investigations.

7.5.2 General Concepts in Bridge Planning

The following are general concept adopted in bridge planning to determine bridge location and type.

(1) Bridge site selection

The characteristic of the existing river in the study area is very primitive without providing erosion control works and sabo works. Thus, the bridge site shall be selected at the section of river bank or river bed stable stastically in order to minimize the river training works. The section at bends, isthmus or confluent of a river is not preferable to be as a bridge site from hydraulic viewpoint.

(2) Establishment of bridge planning criteria appropriate under a primitive river

In order to provide enough bridge opening for a primitive river, the bridge planning criteria for determining of minimum span length, total bridge length, free board etc. shall be established fully taking into consideration not only run off peak but also length of drifting logs, grain size of boulders, local scouring depth, etc.

(3) Major elements of bridge type selection

Bridge type shall be selected taking into account of the following major elements.

- Less construction cost
- Less maintenance cost
- Maximum usage of local materials
- Less construction period
- Easy construction

7.5.3 Hydrography in the Study Area

(1) Hydrographic survey

Hydrographic surveys are conducted at respective rivers for the following five items:

- cross sectional survey
- flood mark survey by visual observation
- floating debris survey by visual observation
- river channel stability survey by visual observation
- river bed material survey by geological observation

(2) Preliminary hydrological study

On the basis of meteo-hydrological data collected through Ministry of Water Resources, preliminary hydrological study is conducted to seize the characteristics of hydrological condition and to estimate magnitude of peak run off and flood water level rough in order. Probable value at any desired return period is calculated with a series of the annual maximum rainfall data by Peason Type III method and rainfall intensity curve is established by Mononobe's Equation.

7.5.4 Bridge Planning Criteria

Based on the data collected through hydrographic survey and hydrological study, the following criteria for bridge has been established mainly from hydraulic viewpoint.

(1) Proposed river width

River characteristics in Sections I and II are quite different with regard to river gradient, type of river deposit and flood velocity as summarized below.

Section	River Gradient (%)	Type of river deposit	Grading (mm)	Velocity (m/sec)
I	2-0.5	Coursesand & gravel	0.6 - 200	2 - 3
II	6-3	Gravel & boulders	200 - 4000	3 - 6

Under such, some of river width in Section I can be reduced by providing man-made river guide banks since it is very shallow flood water level and wide flood area without stable river training measures.

In this case, the following formula are applied to estimate desirable width between the banks, but its flood velocity should be less than 3 m/sec.

$$B = 1.2 - 1.6 Q \quad 3/4$$

where, B: width between the banks (m)
Q: Peak run off (m^3/sec.)

However, river width in Section II is preferable to be defined as present channel width or flood area width as measured by cross section survey, since the river in Section II are too primitive to redcuce the river width.

(2) Minimum span length required

Minimum span length required is determined by one of the following factors based on the hydrographic survey results.

1) Peak run off discharge

Minimum span length required due to peak run off discharge is estimated by following formula which is stipulated in Standard on River Control and River Facilities published by Japan River Association.

$$L = 20 + 0.005\ Q$$

where, L: Standard minimum span length (meter)
Q: Peak run off discharge (m^3/sec.)

In case that peak run off discharge is less than 500 m^3/sec and the safety is confirmed technically, minimum span length required can be reduced up to 15 meter.

2) Length of drifting logs

Minimum span length required due to length of drifting logs is preferable to be four times of the length but not less than two to three times of maximum length of drifting logs based on empirical formula.

3) Grain size of boulders

Minimum span length required due to the size of boulders is more than five to six times of the maximum diameter of boulders based on theoretical formula.

(3) Local scouring depth at piers

Local scouring depth will severely affect the stability of piers with spread footing and depends on pier shape in plan, pier width, depth of peak run off, river bed materials etc. In this regard, about 1.8 to 2.1 m of local scouring depth at river piers (except river pier at Rosi Khola) has been estimated by Andru's or Laursen's experimental formula.

Minimum cover on a footing of river pier should be more than 2 m except the river pier at Rosi Khola.

(4) Free board

Free board, the clearance between the high water level and the bottom of girders, will be determined by size or scale of drifting logs. For the study, minimum free board shall be determined to be more than 2 m (two meter) which is about a half of diameter of observed drifitng logs.

(5) Sediment deposition

All of the river bed in the Study area have risen upward due to sediment deposition in general. A certain allowance for sediment depositon shall be estimated to cope with enough bridge openings in future.

Sediment deposition at the river in Sections I and II have been generated by traction caused by rainfall erosion of terrace deposite and generated by debris flow caused by landslide etc. respectively.

Under such, sediment deposition at bridge sites for the duration of 50 years are estimated approximately at 10 - 20 cm depth in Section I and 50 - 80 cm depth in Section II in accordance with Technical Standards for River and Sabo Works, Ministry of Construction, Japan.

7.5.5 Conceivable Bridge Alternatives

In the light of hydraulic factors and bridge planning criteria as described in the previous sub-section, conceivable bridge alternatives structurally divided into superstructure, substructure and foundation are studied hereunder.

(1) Superstructure

Taking into consideration of span length required, possible construction method at the proposed site, construction cost viewpoint, etc., conceivable alternatives of superstructure are selected among the various alternatives and are depicted with applicable span length on Fig. 7.6.

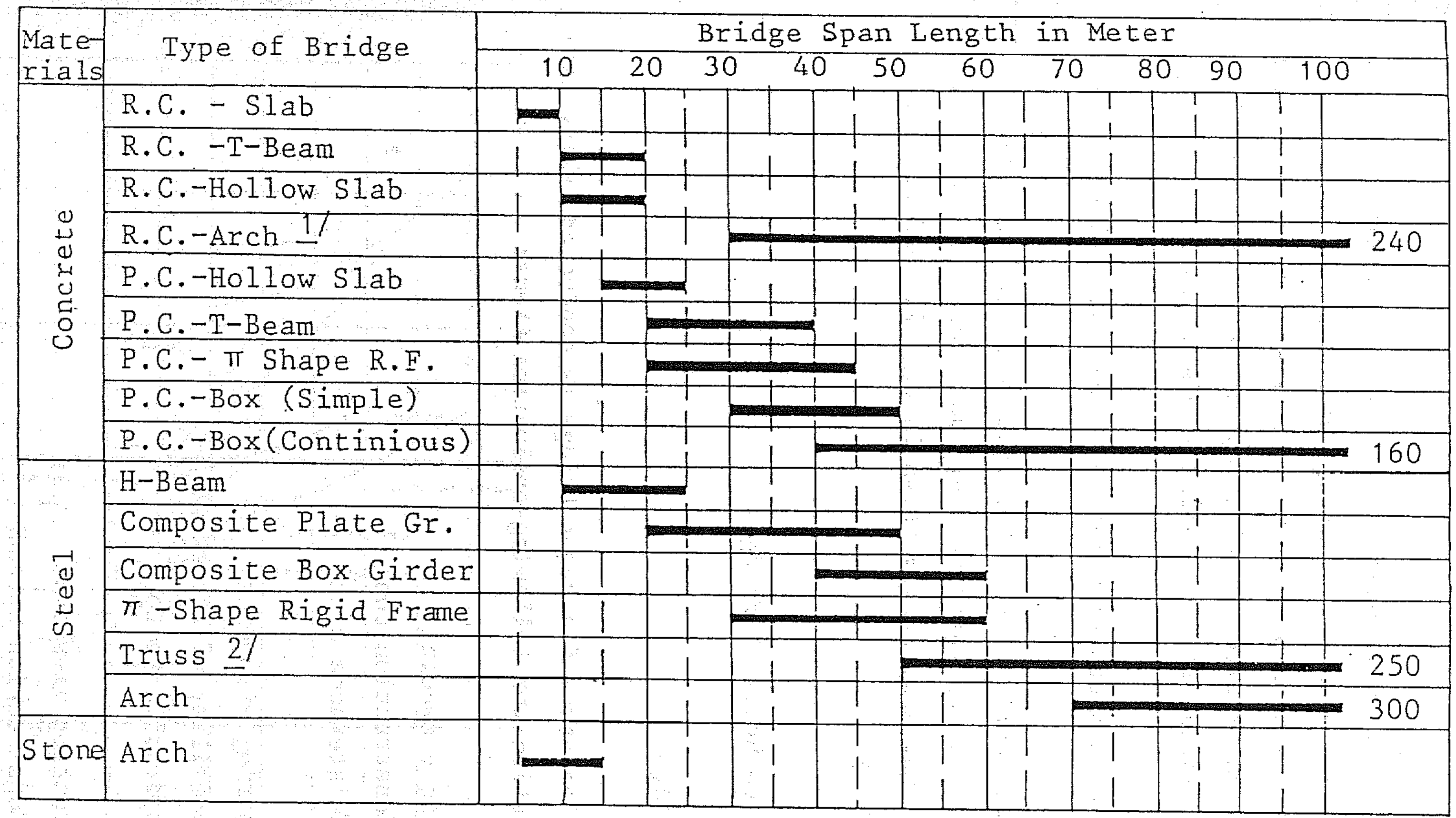
(2) Substructure

1) Abutments

Among the standard type of abutments, gravity or invert-T type is recommneded from the view point of economy and ease in construction.

2) Piers

All the piers proposed in the Project Road have been planned at the location in a river. Thus, wall type (rectangle with semicircular noses as a pier shape in plan) or circular column type is recommended from hydraulic view point.



Note: 1/ In case of contilever election method applied, prestress is required.

2/ Continious type is advantageous in case span less length more than 80m.

Fig. 7.6 Conceivable Alternatives of Superstructure

(3) Foundation

Based on the visual observation at the respective bridge site from geological viewpoint, spread footing, open caisson and shinso pile (a kind of cast-in-situ R.C. pile) depending on required bearing capacity and local scouring depth estimated are recommended in the Study.

(4) Approximate construction cost of conceivable alternatives

For the selection of possible type of superstructure, cost comparison of superstructure by span length and height are estimated and graphically shown in Fig. 7.7 and Fig. 7.8 respectively.

7.5.6 Comparative Study of Bridges

(1) Major Bridge

Comparative study for major bridge is conducted taking into cnosideration the following evaluation items:

- Economic viewpoint
  - Construction cost
  - Maintenance cost

- Engineering viewpoint
  - Stability of structure
  - Hydraulic factors

- Construction viewpoint
  - Construction method
  - Construction period

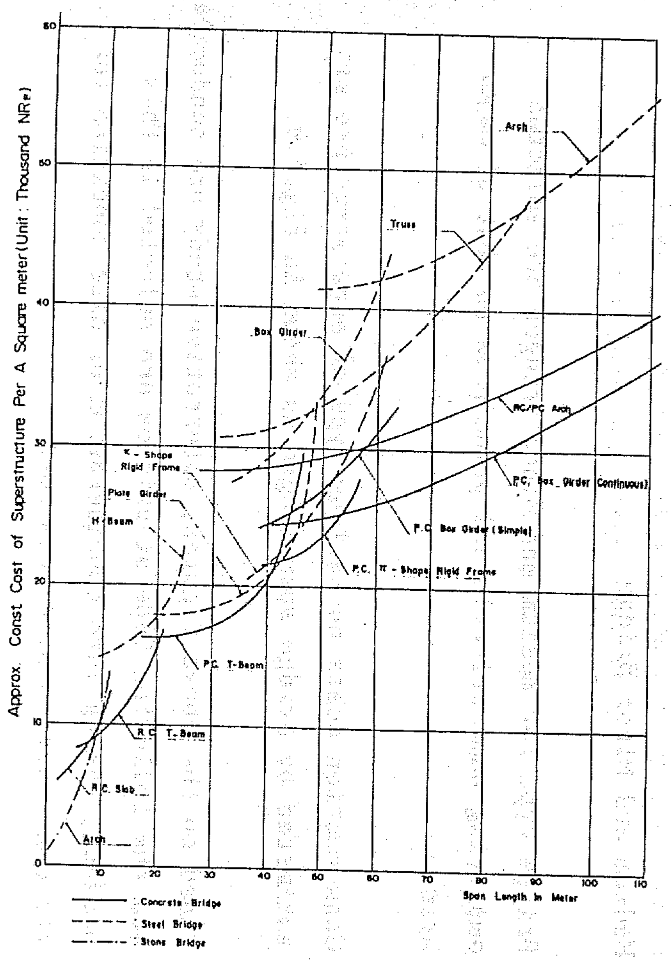


Fig. 7.7 Approx. Construction Cost of Conceivable Type of Superstructure by Span Length

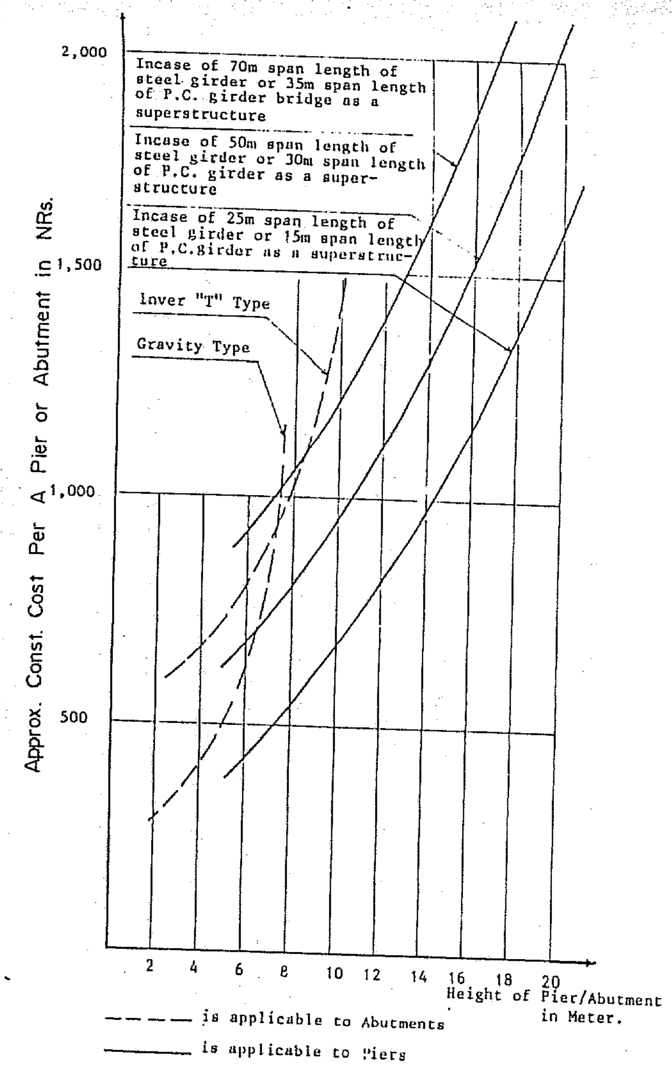


Fig. 7.8 Approx. Construction Cost of Piers and Abutments by Hight

The availability of materials, especially steel bridge, are examined carefully taking into considerartion of the site conditions including weather, topographic conditions, accessibility, economy in construction and maintenance costs and constructions period to be required.

As the result it is concluded that the steel bridge by weather coat processing is advantageous to the major bridges, especially those in Sections II-1 and II-2 where the construction of access road is extremely difficult due to steep topography of Mahabarhat Range and Sun Kosi River.

The unpainted COR-TEN steel bridge by weather coat processing has developed recently in Japan as maintenance free bridge from rusting. The material cost is more or less the same of ordinary material if maintenance cost is considered.

Table 7.7 to Table 7.10 show the summary of comparative study for major bridges in the Project.

(2) Medium and Minor Bridge

Bridge type for medium and minor bridges are selected employing same criteria and principles as that of major bridge.

Construction costs on various type of superstructure are estimated by bridge span length as shown in Fig.7.9.

Based on the above figures, alternative study are conducted and the following type of bridges are selected in this project, taking into consideration of site condition for the construction of access road.

Span Length (L)	Type of Superstructure
(1) Minor Bridge	
5 < L < 10 m	- RC Slab (Sec. I & II)
10 < L < 15 m	- RC T Beam (Sec. I & II)
15 < L < 20 m	- Steel H Beam (Sec. II)
(2) Medium Bridge	
20 < L < 35 m	- PC T Beam (Sec. I)
20 < L < 45 m	- Steel Simple girder (Sec. II)

Medium and minor bridges to be constructed in mountainous terrain requires widening of carriageway due to sharp horizontal curvature. Since curve bridge as well as skewed bridge are technically difficult because of steep topography and not advantageous economically, streight bridge with widening adjusted by the slab are applied in principle to this project.

The medium and minor bridges are planned to be single bridge without pier in the watercourse, since most of bridges cross over very steep watercourses which contain drifting logs and large boulders.

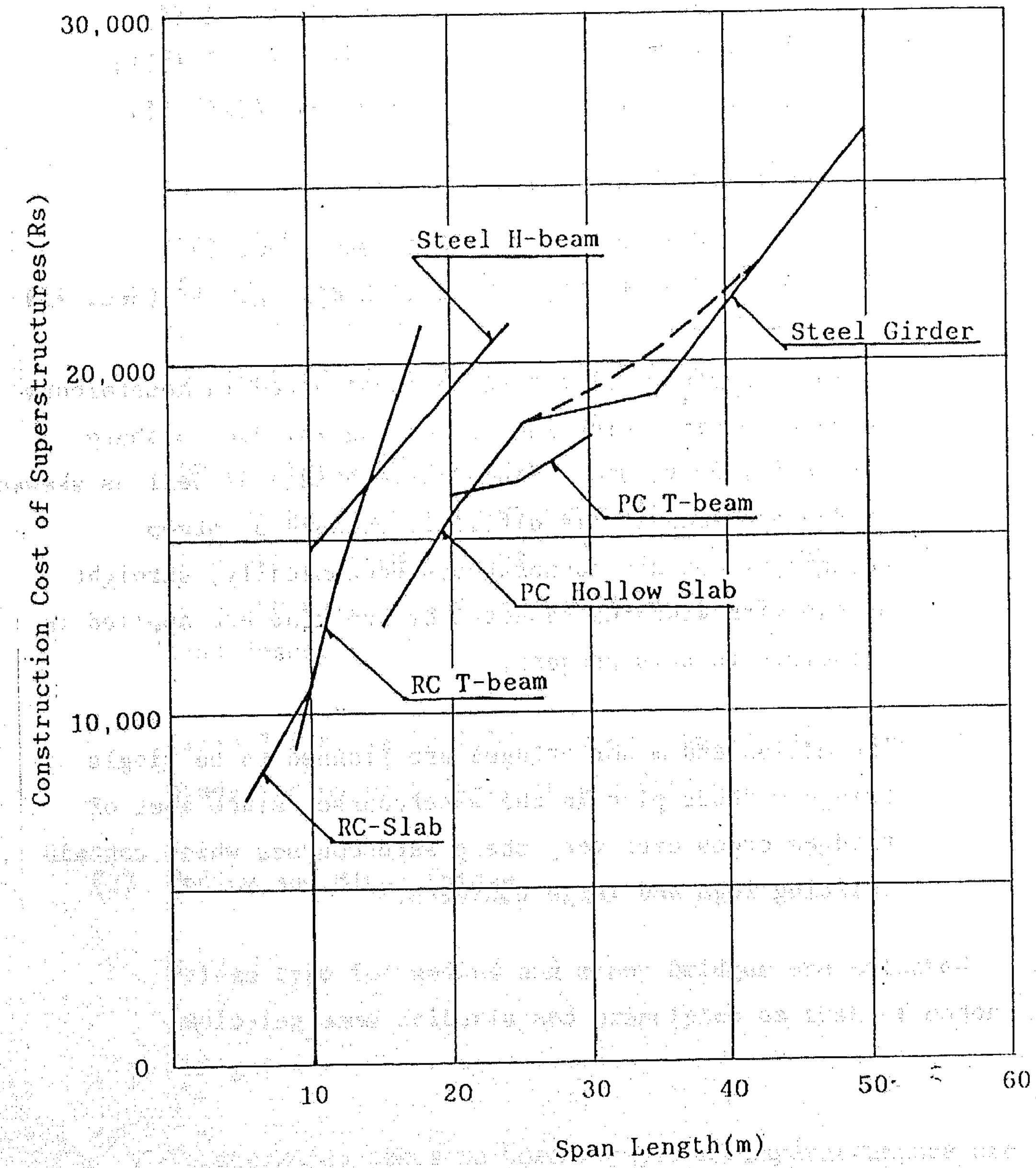


Fig. 7.9 Approx. Construction Cost of Superstructure of Medium and Minor Bridges

Table 7.7 Comperative Study of Bridge Type Under Section I

Name of Bridge	Station	Alternatives	Total Bridge Length (in Meter)	Span Arrangement	Type of Bridge	Approx. Const. Cost (Thousand NRs.)	Approx. Const. Period (in Month)	Maintenance	Recommendation	Prevailing Reasons of Bridge Selection
Bhogate Khola	7 + 550	Alt. - A	105.m	27.5 + 50 + 27.5	R.C. Arch	30,700	18.M	Excellent	Not recommendable	Economic and Constructional view point
		Alt. - B		3 x 35.0	P.C. T. Beam	27,000	10.M	Good	Recommendable	
Kare-Kare Khola	7 + 950	Alt. - A	50.m	10.0 + 30 + 10.0	R.C.Arch.	10,300	10.M	Excellent	Recommendable	Hydraulic and structural stability view point
		Alt. - B		2 x 25.0	P.C. Simple Gr.	10,200	9.M	Good	Not recommendable	
Ratu Khola	12 + 400	Alt. - A	200.m	8 x 25.0	P.C. Simple Gr.	35,600	23.M	Fair	Recommendable	Economic and maintenance view point
		Alt. - B		6 x 33.3	P.C. Simple Gr.	37,300	20.M	Good	Not recommendable	
Shindhuse Khola	28 + 050	Alt. - A	75.m	3 x 25.0	P.C. Simple Gr.	13,700	13.M	Good	Recommendable	Economic and maintenance view point
		Alt. - B		3 x 25.0	Steel Girder	14,500	12.M	Poor	Not recommendable	
Kamala Khola	28 + 750	Alt. - A	165.m	30.0+3x35+30.0	P.C.Simple Gr.	32,500	20.M	Good	Recommendable	Economic and maintenance view point
		Alt. - B		4 x 41.25	Steel Girder	35,600	18.M	Poor	Not recommendable	
Phittang Khola	32 + 250	Alt. - A	60.m	3 x 20.0	P.C.Simple Gr.	11,000	12.M	Good	Recommendable	Economic and maintenance view point
		Alt. - B		3 x 20.0	Stell Girder	11,600	10.M	Poor	Not recommendable	
Buka Khola	34 + 200	Alt. - A	60.m	2 x 30.0	P.C.Simple Gr.	11,000	12.M	Good	Recommendable	Economic and maintenance view point
		Alt. - B		2 x 30.0	Steel Girder	12,000	10.M	Poor	Not recommendable	
Gadeuli Khola	34 + 950	Alt. - A	60.m	2 x 30.0	P.C.Simple Gr.	12,000	13.M	Good	Not recommendable	Maintenance and structural stability view point
		Alt. - B		17.5 + 25.0 + 17.5	P.C.π Shape Rigid Frame	13,500	12.M	Excellent	Recommendable	

Table 7.8 Comperative Study of Bridge Type Under Section II-1

Name of Bridge	Station	Alternatives	Total Bridge Length (in Meter)	Span Arrangement	Type of Bridge	Approx. Const. Cost (Thousand NRs.)	Approx. Const. Period (in Month)	Maintenance	Recommendation	Prevailing Reasons of Bridge Selection
Gwangu Khola	7 + 800	Alt. - A	70.m	2 x 35.0	P.C.Simple Gr.	14,900	14.M	Good	Recommendable	Maintenace view point
		Alt. - B		2 x 35.0	Steel Girder	14,900	11.M	Poor	Not recommendable	
Ardleri Khola	37 + 650	Alt. - A	120.m	4 x 30.0	P.C.Simple Gr.	21,600	15.M	Good	Recommendable	Economic and maintenance view point
		Alt. - B		4 x 30.0	Steel Girder	23,000	13.M	Poor	Not recommendable	

Table 7.9 Comperative Study of Bridge Type Under Section II-2

Name of Bridge	Station	Alternatives	Total Bridge Length (in Meter)	Span Arrangement	Type of Bridge	Approx. Const. Cost (Thousand NRs.)	Approx. Const. Period (in Month)	Maintenance	Recommendation	Prevailing Reasons of Bridge Selection
Nigauli Khola	5 + 300	Alt. - A	130.m	4 x 32.5	P.C.Simple Gr.	23,000	18.M	Good	Recommendable	Hydraulic and maintenance view point
		Alt. - B		4 x 32.5	Steel Girder	25,800	14.M	Poor	Not recommendable	
Arubote Khola	10 + 700	Alt. - A	105.m	3 x 35.0	P.C.Simple Gr.	20,800	15.M	Good	Recommendable	Economic and maintenance view point
		Alt. - B		3 x 35.0	Steel Girder	20,900	12.M	Poor	Not recommendable	
Khahare Khola	12 + 250	Alt. - A	50.m	50.0	R.C.Arch	12,000	11.M	Excellent	Recommendable	Structural stability and maintenance view point
		Alt. - B		50.0	P.C. π Shape Rigid Frame	11,700	11.M	Good	Not recommendable	
Bhote Khola	16 + 700	Alt. - A	75.m	3 x 25.0	P.C.Simple Gr.	13,400	13.M	Good	Recommendable	Economic and maintenance view point
		Alt. - B		3 x 25.0	Steel Girder	15,400	9.M	Poor	Not recommendable	
Gangate Khola	19 + 700	Alt. - A	90.m	2 x 30.0+30.0	P.C.Simple Gr.	16,900	14.5M	Good	Recommendable	Economic and maintenance view point
		Alt. - B		2 x 30.0+30.0	Steel Girder	18,000	13.M	Poor	Not recommendable	
Dhamile Khola	21 + 550	Alt. - A	70.m	2 x 35.0	P.C.Simple Gr.	13,800	12.M	Good	Recommendable	Economic and maintenance view point
		Alt. - B		2 x 35.0	Steel Girder	13,700	9.M	Poor	Not recommendable	
Sandi Khola	24 + 350	Alt. - A	70.m	2 x 35.0	P.C.Simple Gr.	13,400	11.M	Good	Recommendable	Economic and maintenance view point
		Alt. - B		2 x 35.0	Steel Girder	13,400	9.M	Poor	Not Recommendable	
Ghayampe Khola	32 + 900	Alt. - A	210.m	7 x 30.0	P.C.Simple Gr.	36,400	20.M	Good	Recommendable	Economic and maintenance view point
		Alt. - B		6 x 35.0	Steel Girder	40,400	17.M	Poor	Not recommendable	

Table 7.10 Comperative Study of Bridge Type Under Section II-3

Name of Bridge	Station	Alternatives	Total Bridge Length (in Meter)	Span Arrangement	Type of Bridge	Approx. Const. Cost (Thousand NRs.)	Approx. Const. Period (in Month)	Maintenance	Recommendation	Prevailing Reasons of Bridge Selection
Mamti Khola	1 + 250	Alt. - A	120.m	4 x 30.0	P.C.Simple Gr.	21,600	15.M	Good	Recommendable	Economic and maintenance view point
		Alt. - B		4 x 30.0	Steel Girder	23,000	13.M	Poor	Not recommendable	
Bhyakure Khola	7 + 200	Alt. - A	120.m	4 x 30.0	P.C.Simple Gr.	21,600	15.M	Good	Recommendable	Economic and maintenance view point
		Alt. - B		4 x 30.0	Steel Girder	23,000	13.M	Poor	Not recommendable	
Daune Khola	11 + 150	Alt. - A	50.m	50.0	R.C.Arch	12,100	11.M	Excellent	Recommendable	Structural stability and maintenance view point
		Alt. - B		50.0	P.C. π Shapte Rigid Frame	11,600	12.M	Good	Not recommendable	
Narke Khola	13 + 600	Alt. - A	70.m	70.0	R.C.Arch	19,400	13.M	Excellent	Recommendable	Economic and Structural stability view point
		Alt. - B		70.0	Steel Truss	24,100	8.M	Good	Not recommendable	
Roshi Khola	18 + 950	Alt. - A	90.m	3 x 30.0	P.C.Simple Gr.	22,800	23.M	Good	Not recommendable	Hydraulic and maintenance view point
		Alt. - B		3 x 30.0	Steel Girder	23,800	22.M	Poor	Not recommendable	
		Alt. - C		2 x 45.0	P.C. Box Contineous Girder	23,000	24.M	Excellent	Recommendable	

CHAPTER 8 ENGINEERING SURVEY AND ANALYSIS

8.1 General

In this chapter, a comprehensive analysis related to engineering aspects for the Project Road was made.

Engineering surveys including geological and soil/materials survey, hydrological survey, seismic survey and topographical survey were undertaken by the Study Team along the proposed route shown on the map with a scale of 1/10,000.

8.2 Geological and Soil/Materials Surveys

8.2.1 General

The purpose of the survey is to obtain the necessary data for the preliminary design and construction cost estimation for bridge, structure, pavement and embankment.

The geological investigation and materials survey were conducted in the Section I between Bardibas and Sindhuli Bazar, and Section II between Sindhuli Bazar and Dhulikhel during March and June, 1987 respectively. The work was tendered and entrusted to a local consultant, namely SILT Consultant (P.) Ltd. and carried out under the supervision of the Study team accompanied by counterpart engineer of DOR.

All the result obtained from the above investigation and survey including the result of laboratory tests are presented in Vol. II Appendices and Vol. III Drawings.

8.2.2 Geological Characteristics

Geological observation was conducted along the Project route in February 1987.

The project area stretches from Bardibas on the E-W Highway over Dhulikhel on the Kodari Road, passing through the outermost of the Terai Plain in the north, the Siwalik Hills, the Mahabharat Range and the southern part of the mid-land zone, geologically classified into the Kathmandu Group and Nuwakot Group as shown in Fig. 8.1.

The Terai Plain is composed of the Gangetic alluvium deposit. The Siwalik Hills forms the front of Himalayan Range bounded by the Mahabharat Range, namely, Lesser Himalaya, with a distinctively large fault zone, referred to as the Main Boundary Thrust (MBT). Geological formations of the Siwalik are composed of Molasse-like thick sediments in the age of Tertiary.

The Mahabharat Range is the south front of the great overthrust nappes and the breaker against the Siwaliks, and it forms a large syncline. Geological formation of this Range is of metamorphosed sedimentary facies, called the Kathmandu Group belonging to Precambrian-Devonian. This group is consisting of sandstone, sandy semi-schist, quartzite, slate, phillite, biotite schist, crystalline limestone and their alternation. These rocks are generally bluish or greyish dark colour, except for white quartzite or highly siliceous sandstone. Some of quartzite, crystalline limestone and sandstone are fairly hard, whereas others are moderately hard. Schist and quartzite are developed in the south and north areas of Sindhuli Garhi.

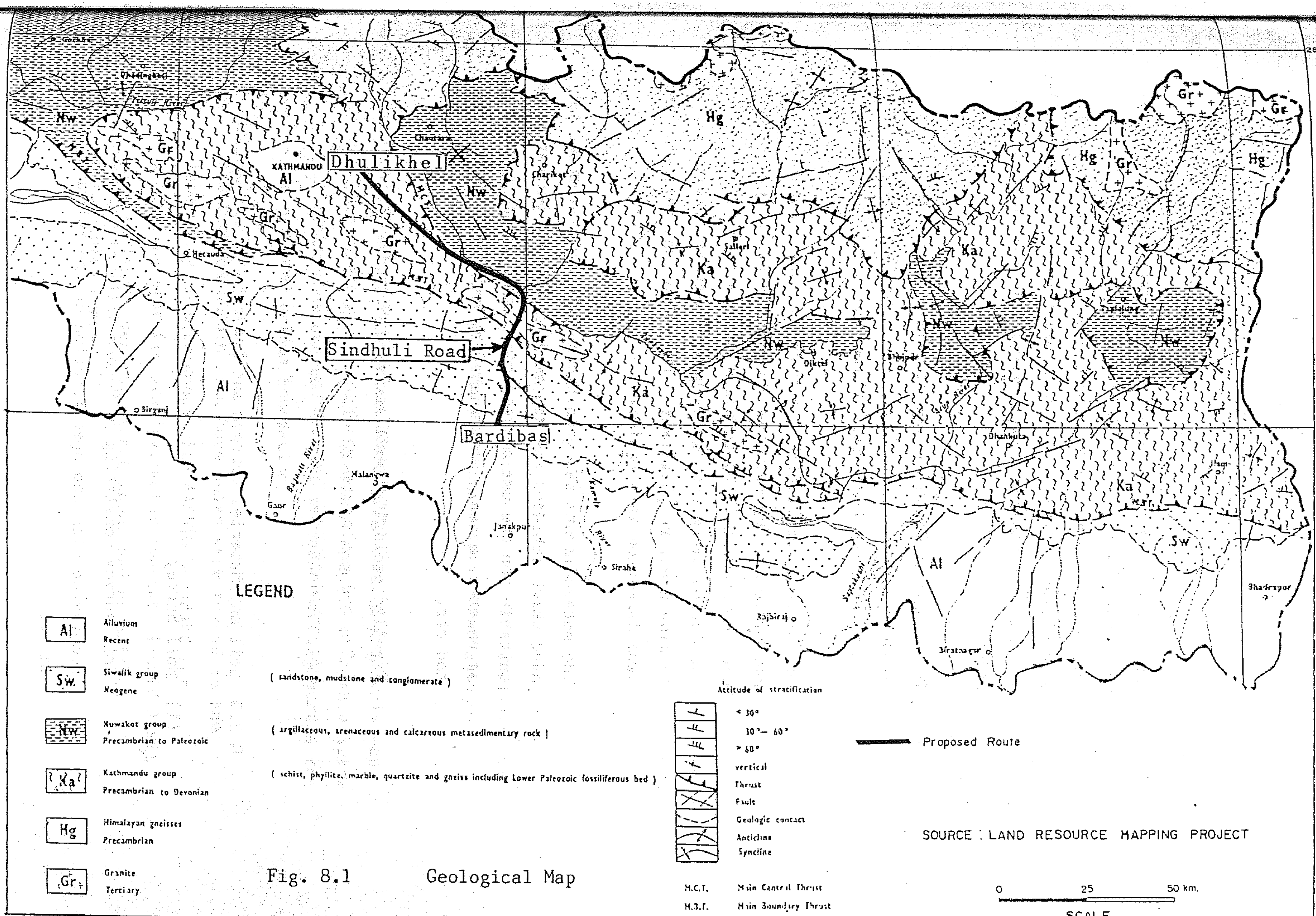


Fig. 8.1 Geological Map

The geology, where the project area embraces Dhulikhel on the Kodari Road and its vicinity, is dominated with metasediments, called Nuwakot Group, belonging to upper precambrian - Paleozoic. This formation is a quite similar to that of Kathmandu Group, except for only chronological order.

The groups of Kathmandu and Nuwakot are bounded in the north by a large fault line, named the Main Central Thrust (MCF). The Sun Kosi river flows down along MCF.

The beddings of Siwaliks, Mahabharat Range, Kathmandu Group and Nuwakot Group show the strikes directing from about north-northwest (NNW) to south-southeast (SSE). The boundaries among each group hold the thrust plains and folding axes, respectively. They also runs following the same direction in parallel.

The metasediments and granitic rocks fairly or moderately hard which embedded and deposited in the project area are suitable for the use of road construction such as concrete aggregates, masonry works, grading and surfacing materials and etc.

Detailed geological conditions are described in Appendix 8.2.1 and geological profiles along the project road are presented in Vol. III Drawings.

8.2.3 Soil and Material Surveys and Laboratory Test Results

(1) Soil Survey

Soil survey consisting of 9-core drilling was conducted in accordance with the specification at the following bridge sites:

Reference No.	Station	Name of Bridge	Boring Site	Estimated Bore Depth
MB - 1	18+950	Rosi	Left bank	L=20 m
MB - 2	34+950	Gadeuli	Right bank	L=20 m
MB - 3	34+200	Buka	Left bank	L=20 m
MB - 4	32+250	Phitting	Right bank	L=20 m
MB - 5	28+750	Kamala	Center of River	L=20 m
MB - 6	28+050	Sindhuse	Right bank	L=20 m
MB - 7	12+400	Ratu	Center of River	L=20 m
MB - 8	7+950	Karekare	Left bank	L=20 m
MB = 9	7+550	Bhogate	Left bank	L=20 m
	Total: 9 places			L=180 meters

The core drilling was carried out to confirm the rock (or soil) surface and engineering properties of subsurface geology of the proposed structure site. The drilling was performed near the abutment and/or pier of the major bridges.

The Standard Penetration Test (STP) at 2 m intervals was conducted to estimate the bearing capacity of strata below the river bank and to find the reliable bearing strata for the proposed bridge foundation.

The samples obtain from bore holes were tested in the laboratory in accordance with AASHTO Standard for gradation, specific gravity, water content, liquid limit, plastic limit, density direct shear and unconfined compression tests.

(2) Material Survey

Material survey was conducted to confirm the availability of materials to be used for concrete structure, embankment and pavement of the proposed road.

The survey consists of 18-auger borings and 12-test pits, and samples taken were tested in the laboratory for compaction, CBR, abrasion of coarse aggregate and absorption of fine aggregate, in addition to the tests specified in the geological investigation stated above.

(3) Laboratory Test

The summary and detail of laboratory test results are presented in Appendix 8.2.2.

8.2.4 Evaluation of Subgrade

The superficial strata along the proposed route are roughly classified as follows:

Section	Classification					Total
	Rock (km)	Rock/ Moderately weathered rock (km)	Weathered rock (km)	Sand/ Gravel (km)	Common Soil (km)	(km)
I	-	-	26	9	2	37
II-1	5	16	9	2	7	39
II-2	-	11	9	2	13	35
II-3	1	29	2	4	10	46
Total	6 (4%)	56 (36%)	46 (29%)	17 (11%)	32 (20%)	157 (100%)

Rock, moderately weathered rock and sand/gravel are judged to be superior subgrade not only in cut portion but also in embankment. Weathered rock and most common soil are also judged to superior subgrade in cut portion because most of the common soils are compact decomposed rocks and N-values of them are more than 30. However those weathered rocks and common soil are doubtful in their superiority as subgrade when they are used for a embankment material. Therefore, the properties of those materials as a subgrade were examined by laboratory testing.

The laboratory test results are assessed by the AASHTO Standard as shown in Appendix 8.2.3. About 30% of the tested samples show the CBR-value less than 4% and about 60% of them show the CBR-value less than 8%. The following CBR Values are assumed in cut and embankment sections:

- Cut section: 15% for all meterials

- Embankment section:

  . 15% for rock moderately weathered rock and sand/gravel material

  . 8% for weathered rock and common soil (decomposed rock)

  . 2% for common soil (clayey alluvial deposits)

All of those samples were taken from the alluvial deposits which compose the flat topography. At the vicinity of the alluvial deposite, the fresh or moderately weathered rock or the riverbed deposits of sand and gravel materials are distributed abundantly and they will be superior subgrade materials.

Based on the considerations mentioned above, the design CBR values of subgrade are, provisinally but conservatively, determined for this feasibility study as follows:

	Design CBR Value
- Section I	15%
- Section II	8%

8.2.5 Aggregate Materials

As the sources of aggregate for base course, surface course and concrete, the following materials were investigated and tested:

- Sand and gravel materials of Ratu, Kamala, Gwangu, Sunkosi and Rosi rivers and their tributaries along the proposed route

- Granite and rocks and Kathmandu group formation in Mahabharat range along the proposed route

Laboratory test results are summarized as shown below:

Sample		Specific Gravity	Absorption (%)	Abrasion (%)
Sandstone (Bujhakot)	0.9 m	2.63	4.8	75.6
	1.8 m	2.62	3.8	53.1
Gneiss (Katunje)	0.9 m	2.60	4.5	64.3
	1.8 m	2.62	4.5	45.9
Sand/Gravel (Sindhuli Madi)	0.9 m	2.61	3.6	60.0
	1.8 m	2.58	3.6	48.8
Sand/Gravel (Bhiman)	0.9 m	2.65	1.7	39.3
	1.8 m	2.66	1.7	30.2

According to these results, the materials except the sand and gravel material of the deeper bed at Bhiman are judged suitable for the aggregate.

The sand and gravel materials of the Ratu and Kamala rivers are sound, durable, round and well-graded with some cobbles and boulders, which are distributed abundantly along the proposed route between STA.0 and STA.29 in Section I. These are available for the aggregates source for the most part of the Section I.

The sand and gravel material of the Gwangu river are also sound, durable, round and well-graded with comparatively much boulders. These materials are distributed abundantly from Sindhuli Bazar (STA.0 to STA.4 in Section II-1). In the further upstream, the boulders materials of 2 m maximum size are distributed along the route. Both the sand/gravel materials and the boulder materials are originated mainly from granite and qualitatively suitable for the aggregates sources for the part of Section I and Section II-1.

Granite, quartzite, limestone and schistose sandstone are distributed between STA.16 and STA.30 in the Section II-1. These rocks are available for the aggregates although unsuitable micaschist and weathered rocks are intercalated. Disadvantages in use of these materials are the rugged topography and a comparatively minor quantity of requirement to develop quarries.

Sand and gravel materials are distributed abundantly in the Sun Kosi river along the route. These materials are also sound, durable, round and well-graded suitable for the aggregates for whole Section II-2. These materials are also advantageous for the latter half of Section II-1 because of its easy collectability though the hauling distance is considerably long.

Sand and gravel materials are distributed abundantly in the Rosi river along the route between STA.0 and STA.21. The quality of these materials is almost same as that of the Sun Kosi river materials except for difference in boulder content. These materials shall be used for the aggregates in the lower half of the Section II-3.

The schistose sandstone is distributed along the route between STA.30 and STA.38 in the Section II-3. The fresh sandstone which alternates with the weathered rock is judged suitable for the aggregates in the upper half of Section II-3. The Similar sandstone is distributed along the Kathmandu-Kodari road at vicinity of Dhulikhel. This material is also judged available for the aggregates in the section.

8.2.6 Embankment and Cut Slopes

(1) Embankment Slope

Materials excavated from cut sections shall be used in principle for embankment materials in view of economy. The rock, moderately weathered rock, weathered rock and common soil obtained from the cut sections will be used for the embankment materials. Mixture of sand, gravel and/or boulder are available for embankment materials at some stretch where the sand and gravel materials are distributed nearly such as most of Seciton I, the part of Section II-1, most of Section II-2 and a part of Section II-3.

Embankment heights shall be, at highest, not more than 15 m in principle except in most of the Section II-1 where the embankment is obliged to be constructed on steep slopes and in the access portion to some bridges.

Hazardous embankment foundation are not developed in the route except some prospective sliding areas.

The excavated common soil and weathered rock are found to have the index properties same as those of the similar materials used in the existing road and to have natural moisture content. Thereby, the shear strength of these materials are estimated to be similar to those of the existing road, though the test result shows very low values.

The slope of embankment is provisionally determined taking the above conditions into consideration as follows:

- common soil and weathered rock:
  1 V: 1.5 H for embankment height up to 5 m
  1 V: 1.8 H for embankment height exceeding 5 m

- hard rock, moderately weathered rock and sand/gravel:
  1 V: 1.5 H without limit of embankment height

In order to attain the stability for the high embankment, berm with a 1.5 m wide shall be provided at every 5 m embankment height.

Since the common soil and weathered rock are very susceptive to be eroded, slope protection work and drainage system on slope surface shall be provided sufficiently.

(2) Cut Slope

The cut slopes are recommended for various strata as follows:

- rock and moderately weathered rock:
  1 V to 0.5 H without limitation of height

- common soil and weathered rock:
  1 V: 1.0 H for height not more than 10 m
  1 V: 1.2 H for height more than 10 m

Berm with a 2.0 m wide shall be provided at every 7 m in cut height. Where the cut slope height exceeds 10 m, then stone masonry with a 7.0 m in height is adopted depending on geological condition.

This recommendation can be generally adopted for the massive rock and homogeneous soil strata. However, the sedimentary rocks in this region are generally metamorphosed by the tectonic movement.

8.2.7 Foundation Analysis

(1) Bhogate Bridge (Boring No. MB9)

The siltstone of lower Siwalik Formation out-crops at both river banks. It is overlaid by the river bed deposit of sand/gravel of 2 m thick at the center of the river. This layer has the SPT values (N-value) of more than 50 and thereby can be a bearing bed for the bridge foundation.

(2) Karekare Bridge (Boring No. MB8)

The same siltstone as the Bhogate bridge is distributed with overburden of the sand and gravel deposits of 1.7 m thick. The N-value of this layer was measured at more than 50, though the penetration amounting 15 cm against 50 blows is larger than that of the Bhogate (10 cm). Thereby this layer also is judged a suitable bearing bed for the foundation of the bridge.

(3) Ratu Bridge (Boring No. MB7)

The center of the river course, consists of the riverbed deposit of the sand/gravel materials with boulders of 8 m thick, the sand layer of 6 m thick and the claystone of the lower Siwalik Formation. Both riverbed deposits are very dense and have the N-value more than 50. The foundation of the bridge can be set on any of them.

(4) Shinduse Bridge (Boring No. MB6)

The siltstones of the lower Siwalik Formation are found to be overlaid with 1.8 m thick of the top soil and riverbed deposits of sand and gravel. These siltstones have the N-values more than 50 and, thereby, are judged to be suitable bearing beds for the foundation of the bridge.

(5) Kamala Bridge (Boring No. MB5)

The center of the river course is overlaid with the dense sand and gravel deposit of 11 m thick and the sand deposit of 2 m thick. N-values of the sand and gravel deposit, sand deposit and siltstone were measured at more than 50. The sandstone of the upper Siwalik Formation outcrops at the left bank and the siltstones of the lower Siwalik Formation outcrops at the right bank. These strata may be a suitable bearing bed for the bridge foundation.

(6) Phitting Bridge (Boring No. MB4)

The river bed consists of the heavily weathered conglomerate of 2 m thick, the heavily weathered sandstone, and the sandstones with silt of the upper Siwalik Formation. The heavily weathered conglomerate and sandstone shows N-values of 44 and the sandstones with silt shows N-values more than 50. These layer are available for the bearing beds of the bridge foundation. The upper sandstone however is not recommended for the bearing beds because of high erodability of the heavily weathered strata.

(7) Buka Bridge (Boring No. MB3)

Buka river consists of the dense sand deposit of 6 m thick and the conglomerate with sandstones of the upper Siwalik Formation. The sand deposit have N-values ranging 33 to 39 and the upper Siwalik Formation N-values more than 50. The conglomerate is recommended for the bearing bed of the bridge foundation.

(8) Gadeuli Bridge (Boring No. MB2)

The river bed is overlaid with the deposits of mixture of silt, sand, gravel, cobble and boulder. The riverbed deposits have a thickness of 7.5 m and N-values more than 50. The Siwalik Formation below the deposits has also the N-values more than 50. The Strata of Siwalik Formation is recommended for the bearing bed of the bridge foundation because of the high N-value.

(9) Rosi Bridge (Boring No. MB1)

The riverbed deposits of mixture of sand, gravel, cobble and boulder of 9 m thick are overlaid on the hard meta-sandstone. The N-values of the riverbed deposits is more than 50 and no-penetration was measured in the meta sandstone. The riverbed deposits is suitable for a bearing bed of the bridge foundation.

(10) Other Major Bridges

The geological conditions at the major bridge sites seemed to be quite similar to those at the bridge sites where the investigations were carried out by core borings. Accordingly, the similar foundations to those designed based on the investigation by boring were provisionally adopted for the other major bridges.

8.3 Hydrological Study

8.3.1 General

Hydrological study was carried out to furnish hydraulic data for the design of the bridges and drainage structures.

Prior to hydrological study, the field survey was conducted about the following items;

- Cross section survey of the river channel at proposed bridge site
- Flood mark survey to identify the flood water level
- Floating debris survey to determine the minimum span length and depth of free board
- River channel stability survey for forecasting the movement of river bed either upward or downward
- River bed materials survey to assume subsurface condition and to estimate local scouring depth

8.3.2 Review of Hydrological Records

The meteorohydrological data recorded in and around the Study area were collected through Ministry of Water Resources. These data comprises;

. Climatological Records of Nepal, 1971-1982 Volume I
. Climatological Records of Nepal, 1971-1975 Volume II
. Special Supplement Kathmandu Valley
. Surface Water Records of Nepal, 1965-1975

In addition, rainfall data recorded at Kathmandu Indian Embassy were collected for further analysis, since rainfall

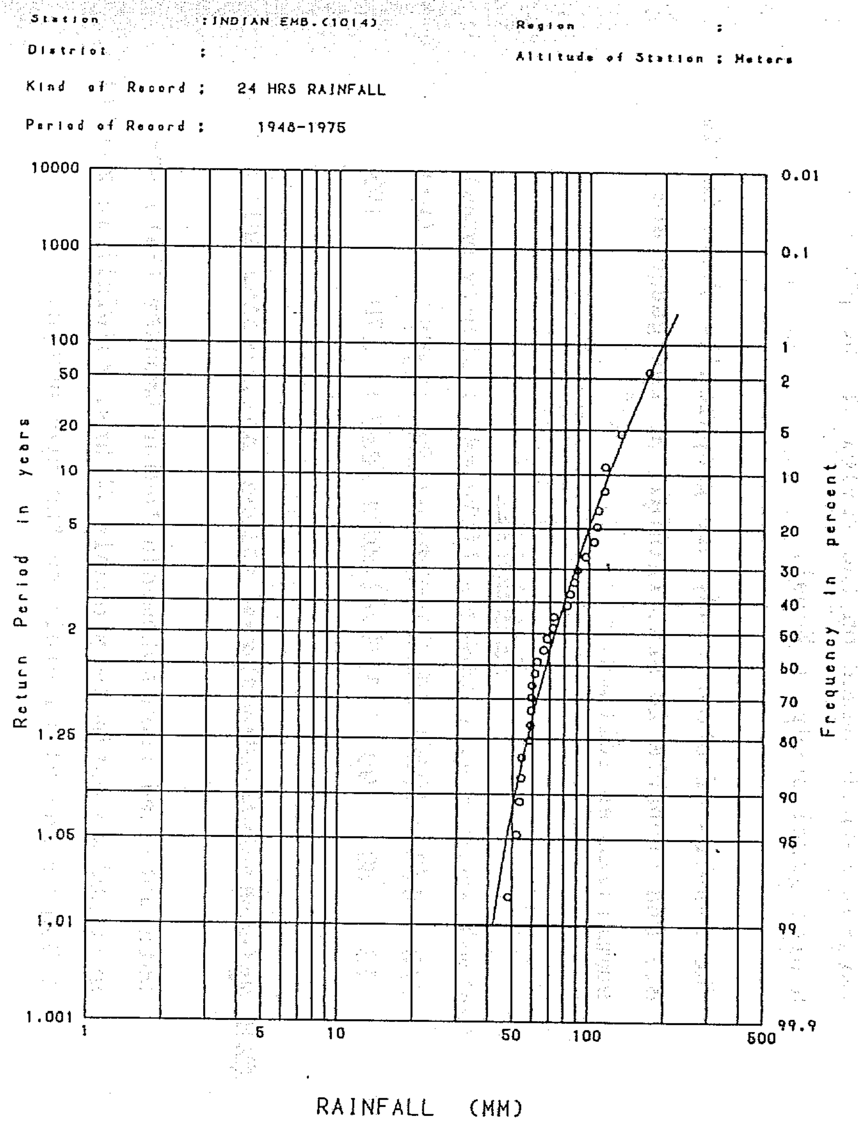


Fig. 8.2 Frequency Curve

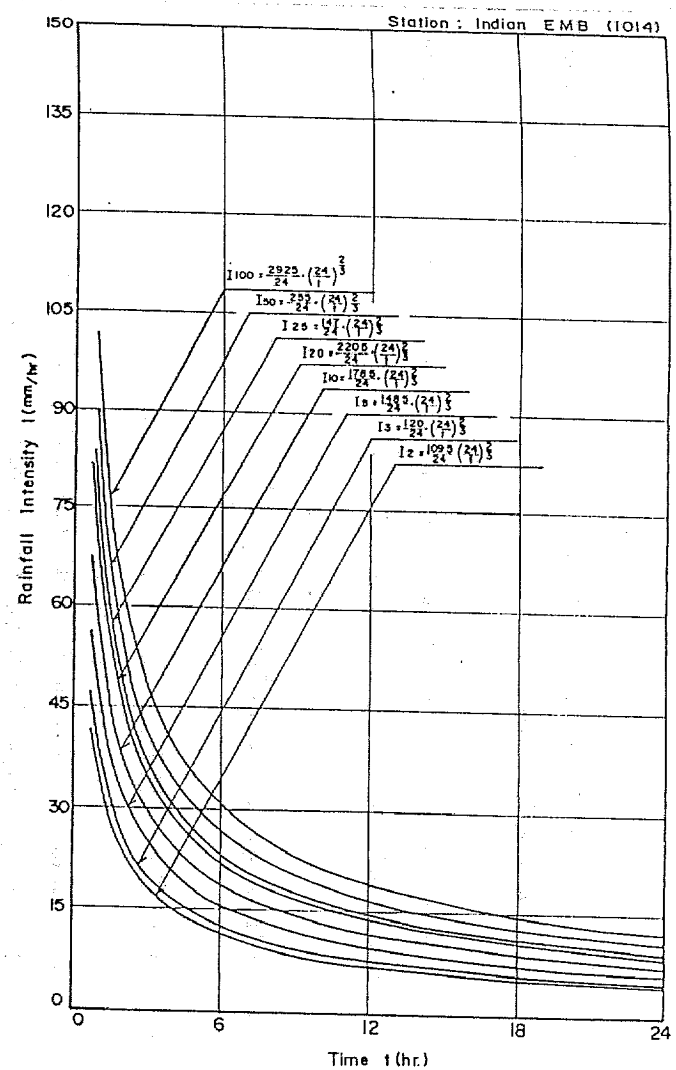


Fig. 8.3 Rainfall Intensity Curve

and runoff data available were very limited and almost none in the Study area.

The hydrological study was conducted in accordance with the procedure as shown in Appendix 8.3.1.

8.3.3 Hydrological Calculation

(1) Frequency Study

The annual maximum 24 hrs. rainfall data measured during the period from 1948 to 1977, were plotted on probability paper by Hazen method of plotting position. And probable value (X) at any desired return period (T) was calculated with a series of the annual maximum data (X) by Peason.

Type III method might be with the most fitness among various methods based on the review of the previous hydrological study in Nepal.

The results of above study are graphically shown in Fig. 8.2 and probable 24 hrs. rainfall at the gauge are summarized as follows.

Probability

(Unit: mm)

1/2	1/3	1/5	1/10	1/20	1/25	1/50	1/100
73	80	99	119	140	147	170	195

(2) Rainfall Intensity Curve

Data obtained from Kathmandu Indian Embassy (KIE) was utilized to estimate probable 24 hrs. rainfall in zone of 1,350 mm annual rainfall on the hyetograph.

However, the Project Road passes several zone of average annual rainfall ranging from 1,000 mm to 2,500 mm. Thus, probable 24 hrs. rainfall estimated is adjusted to convert into the 24 hrs. rainfall in the Study area by multiplying 1.5 of factor estimated by the following equation.

$$(R_{24})_{SA} = \frac{(Rannual)_{SA}}{(Rannual)_{KIE}} (R_{24})_{KIE}$$

where, $(R_{24})_{SA}$: Probable 24 hrs. rainfall in the Study area

$(R_{24})_{KIE}$: Probable 24 hrs. rainfall at KIE

$(Rannual)_{SA}$: Annual rainfall in the Studfy area (2000)

$(Rannual)_{KIE}$: Annual rainfall at KIE (1350)

On the adjusted probable 24 hrs. rainfall, rainfall intensity curve of the Study area was established by Mononobe's Equation, which is generally applied in mountainous countries and one of Sherman's type equation as follow.

$$Rt = \frac{R_{24}}{24} \left(\frac{24}{t}\right)^{\frac{2}{3}}$$

where, Rt : Rainfall intensity in t hours (mm/hr)

R_{24}: 24 hours rainfall (mm)

t : Lag time (hr)

The calculation results is given as shown in Fig. 8.3.

(3) River and Basin Characteristics

River characteristics related to the Project road is broadly divided into two categories, i.e., one is the river in Section I located in Siwalik hills which has gentle river slope and coursesand and gravel as river deposit, and the other is the river in Section II located in Mahabharat range which has steep river slope and gravel and boulders as river deposit.

The catchment areas of respective river are identified as shown on Appendix 8.3.2 and basin characteristics such as river length, basin slope etc. are summarized in Appendix 8.3.3.

(4) Estimate of Flood Runoff Peak

Since individual catchment area in the Study area are relatively small, flood runoff peak at the proposed sites is estimated by menas of rational formula as shown in below.

$$Qp = 1/3.6 \cdot f \cdot Rf \cdot A$$

where, Qp: Flood runoff peak (m^3/s)

f : Runoff coefficient (= 0.7)

Rf: Rainfall intensity (mm/hr)

A : Catchment area (km^2)

Lag time in equation of Rt is estimated by following formula.

$t = ti + tf$

where, t : Lag time (hr)
ti: Inflow time (hr)
tf: Flowing fluid time (hr)

Inflow time (ti) Mountainous Area (t = 0.5 hr)
Mountainous Area with steep slope (t = 0.33 hr)

Flowing fluid time (tf) Kraven's formula /1 (tf = L/v)

if $i > 1/100$, then $v = 3.5$ m/s
if $1/100 < i < 1/200$, then $v = 3.0$ m/s
if $i < 1/200$, then $v = 2.1$ m/s

i: Basin slope
v: Flow velocity
L: River length

The calculation results are shown in Appendix 8.3.4.

8.3.4 Design Returned Period

The following return periods are adopted in the Project for design of the bridges, culverts and highway drainage:

a. Major bridges : 100 years
b. Medium and minor bridges: 50 years
c. Culvert : 20 years
d. Roadside ditches : 10 years

8.3.5 Hydraulic Calculations

Flood level and velocity are estimated by means of Manning formula as shown below:

$$V = \frac{1}{n} R^{2/3} I^{1/2}$$

where: V = velocity of flow in m/sec.

R = hydraulic mean depth in metres

I = hydraulic gradient

n = Mannings Roughness Factor

Mannings roughness factor is adopted as follows:

(a) Natural water course, n = 0.035

(b) Riprap lined section, n = 0.025

(c) Concrete lined section, n = 0.014

The calculation results on flood runoff peak, flood level and velocity at propoosed major bridge sites are presented in Table 8.1.

Table 8.1 The Summary Results of Hydraulic Calculation

Basin No.	Name of River	Catchment Area (km2)	Runoff Peak (1/100) m3/sec.	Runoff Peak (1/50) m3/sec.	Estimated Velocity (m/sec.)	Height of 1/ Flood Level (m)
1.	Bhogate	5.4	199	177	4.5	3.1
2.	Karekare	5.2	157	140	3.4	1.8
3.	Ratu 2/	42.4	960	855	3.5	1.4
4.	Bhiman 2/ 3/	3.9	130	116	3.3	1.5
5.	Sukha 2/ 3/	2.1	74	66	2.6	1.2
6.	Sindhure	2.1	80	71	2.5	1.0
7.	Kamala	142.8	2,857	2,546	4.1	4.9
8.	Phitting	7.4	246	219	3.2	2.9
9.	Buka	13.4	406	362	2.8	3.5
10.	Gadeuli	31.6	779	694	5.1	3.9
11.	Gwang	12.9	418	372	6.6	1.8
12.	Ardleri	20.7	390	334	4.8	1.2
13.	Nigauli	21.0	405	347	6.2	1.7
14.	Arubote	17.3	301	258	4.9	1.8
15.	Kharare	4.4	108	93	4.8	1.0
16.	Bhote	16.9	267	229	4.8	1.6
17.	Gangate	19.2	343	294	4.5	2.2
18.	Dhamile	28.7	500	429	6.3	2.5
19.	Sandi	7.4	170	146	6.4	1.6
20.	Ghyampe	14.8	332	285	7.8	2.0
21.	Mamti	17.0	319	274	4.9	1.5
22.	Bhayakure	22.3	442	379	4.9	2.1
23.	Daune	10.5	213	183	6.5	1.8
24.	Narke	18.1	343	294	8.4	2.9
25.	Roshi	410.7	3,258	2,794	7.9	8.4

Note: 1/ Height of flood level measures from the lowest point of river bed.

2/ Estimated velocity and flood level are calculated under the condition of providing man-made river banks.

3/ Due to providing man-made banks, these bridges are categorized under medium bridge.

8.4 Seismic Analysis

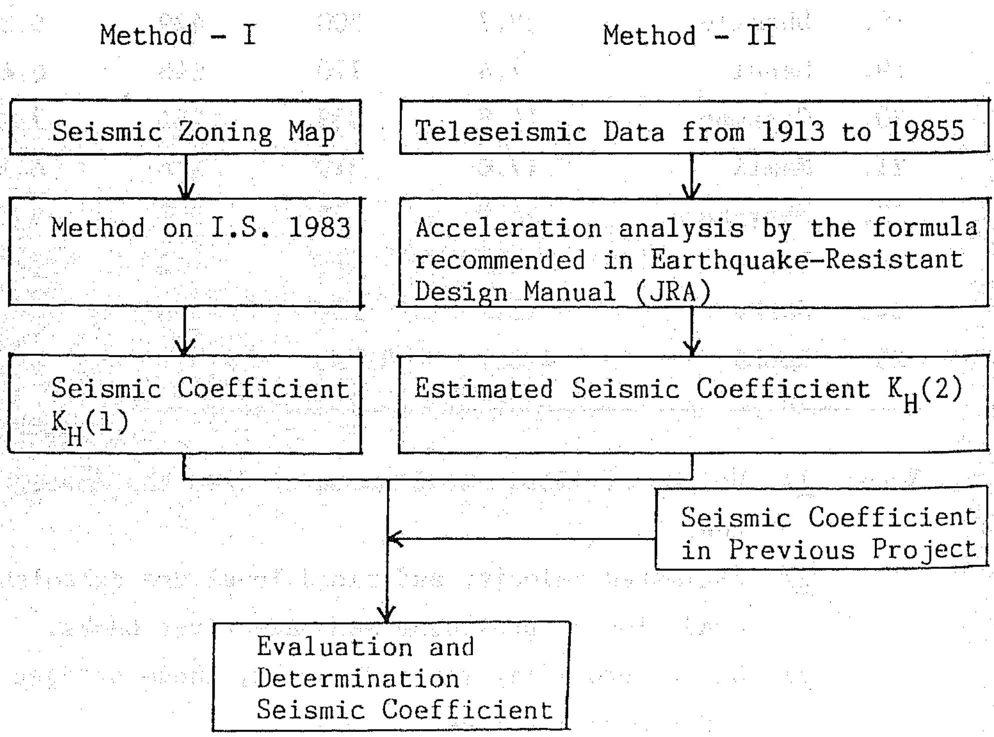
8.4.1 General

The Study area is located in a high-seismicity of the world and earthquake damages in Nepal have been observed in the past few decades. Earthquake-resistant design is therefore required for all the bridges and other structures. Taking into the consideration of magnitude of strucutres, seismic coefficient method is recommended as earthquake-resistant design. In order to establish seismic coefficient, seismic data have been collected through the various government agencies concerned and the date of which obtained are:

1) Seismic Zoning Map in India prepared by Kaila, Guar and Narain, and

2) Teleseismic Data from 1913 to 1985 collected by Department of Mining and Geology.

The analysis flow which was established based on reviewing the available data is shown hereunder.



8.4.2 Seismicity

The seismic zone as well as distribution map of earthquake epicenters is depicted based on teleseismic data in Nepal Himalayas for the period from 1913 to 1985 as shown in Fig. 8.4 and Fig. 8.5. Among these earthquakes, the shallow earthquakes with more or less 5 of magnitude within 20 km distance from the site or the earthquake with more than 8 of magnitude at approximate 110 km distance from the site might cause serious damages for the proposed strucutres.

1) Method - I: ISI 1983

According to the map of seismic zoning by Kaila, Gaur and Narain as shown in Fig. 8.5, the Project Road falls under Zone V with IX of intensity in Modified Mercalli Scale of expected earthquakes. Maximum acceleration assigned to MM intensity IX ranges from 0.206 g to 0.441 g. In accordance with the method on ISI, 0.10 of horizontal seismic coefficient was assigned in Zone V since the geological condition in the Study is classified into Soil type II (medium).

2) Method - II: Earthquake-Resistant Design Manual (JRA)

Based on the teleseismic data and the distribution map of earthquake epicenters depicted on Fig. 8.4, the maximum accelerations in the Study area due to individual earthquake occured within approximately 200 km of radius from the gravity center of the Project Road are calculated by the following regression formula recommended in Earthquake-Resistant Design Manual (published by Japan Road Association).

$$Amax = 24.5 \times 10^{0.333 M} \times (d + 10)^{-0.924}$$

where, Amax: Maximum acceleration (gal)
M: Magnitude in richter Scale
d: Distance from epicenter (km)

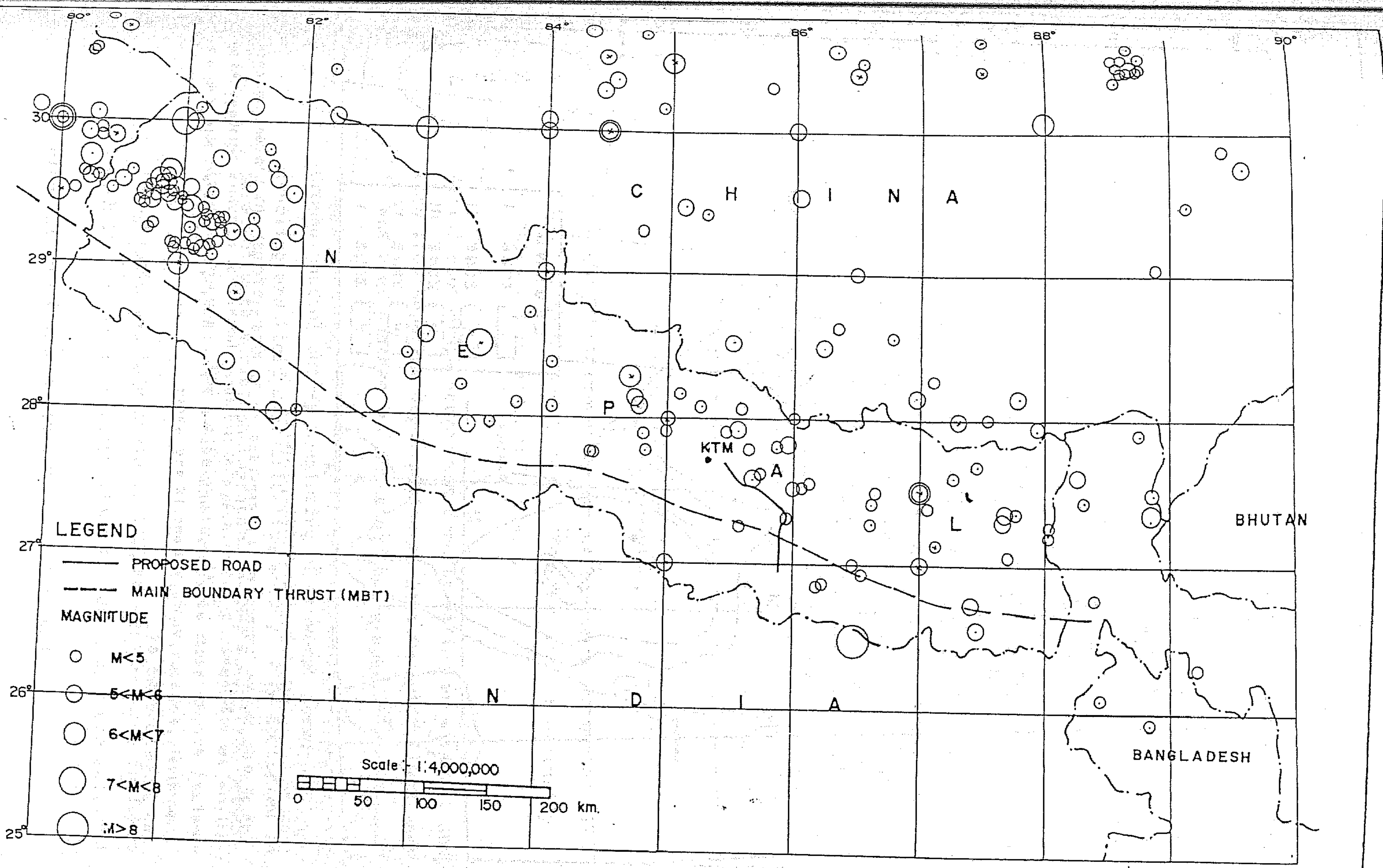
Calculation results are summarized as follows:

Acceleration (gal)	Frequency	Remarks
A < 0.8	-	-
0.8 < A < 2.5	-	-
2.5 < A < 8.0	30	-
8.0 < A < 25.0	44	-
25.0 < A < 80.0	9	-
80.0 < A < 250.0	1	Amax = 182.8 gal

Above results gives 0.186 g of acceleration as the most servere value among the past earthquake records.

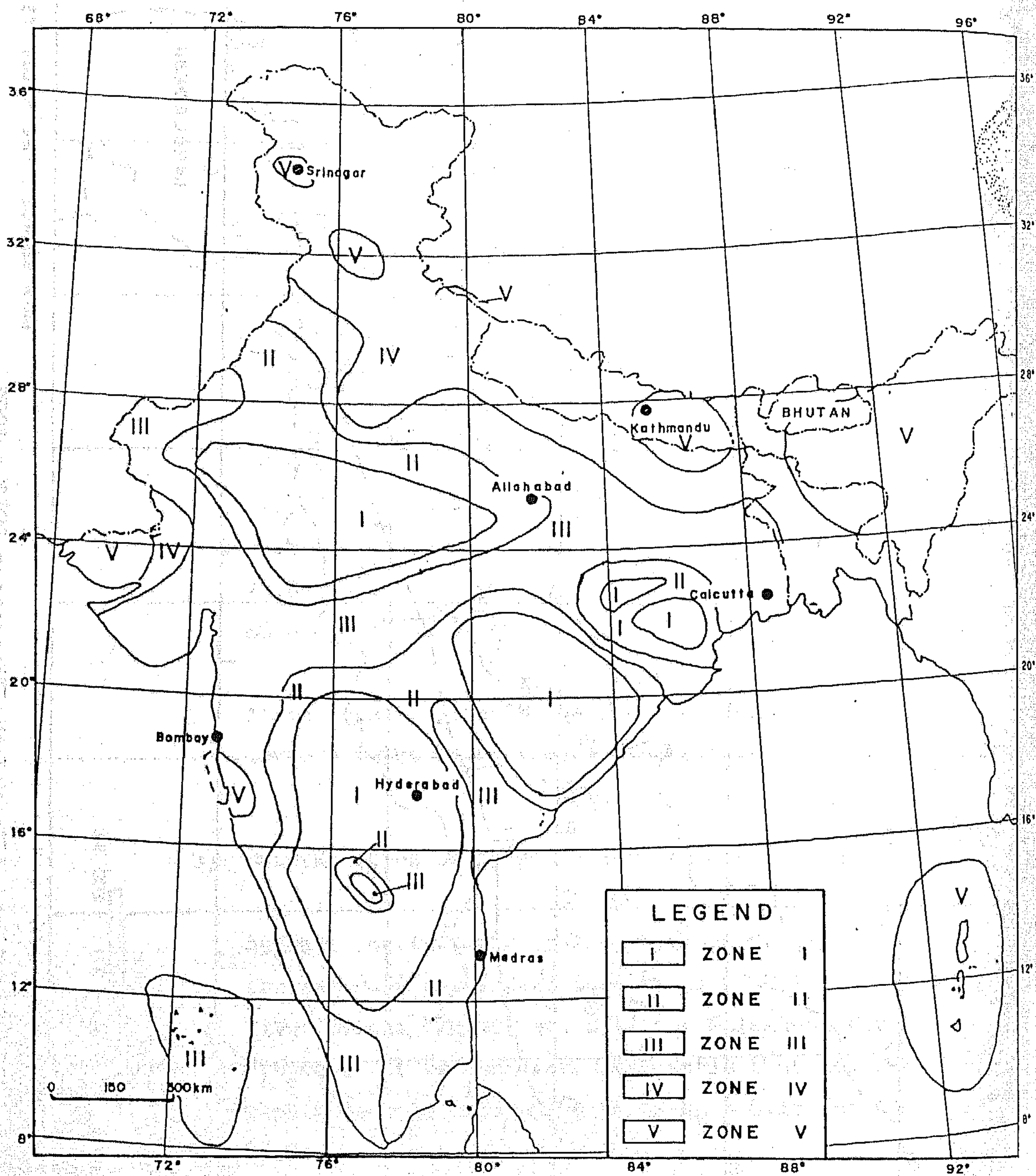
3) Determination of proposed seismic coefficient

Seismic coefficients in the previous projects are applied 0.20 for Kodari Road Project, 0.15 for Karnali River Bridge Project and 0.12 for Kulekhani Dam Project. It is therefore reasonable that seismic coefficient is determined to be k_H = 0.18 for the Study.



DATA SOURCE : THE STUDY TEAM

Fig. 8.4 Distribution Map of Earthquake Epicenters 1913 - 1985



Taken from:
KAILA, K.L., GAUR, V.K., AND NARAIN, H. (1972):
Map of India showing seismic zones, appended to IS 1893 – 1970 (ISI 1971), Indian standerd criteria for earthquake resistant design of structures. Intensities of future earthquakes on Modified Mercalli scale associated with seismic zones I, II, III, IV, and V as per this map are respectively, V or less, VI, VII, VIII and IX and above
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Fig. 8.5 Map of Seismic Zones in India