IX

STRUCTURAL MEASURE DESIGN AND COST ESTIMATE

IX. Structural Measures Design

9.1 Selected Sites for Implementing Preventive Structural Measures

In addition to the Marsyangdi Power House site, ten locations along the N-M highway were selected to perform Feasibility Study on the basis of the Inventory Survey results as well as the joint inspection consisting of Counterparts and JICA Study members. Table 9.1 lists the selected sites, while Figure 9.1 shows the locations of the selected sites.

Table 9.1 Selected Sites for Feasibility Study

Site No.	Location	Site No	Location
1	11 km + 500	6	23km+930
2	21 km + 200	7	23km+960
3	21 km + 560	8	24km+235
4	21 km + 610	9	30km+690
5	23 km + 510	10	34km+200

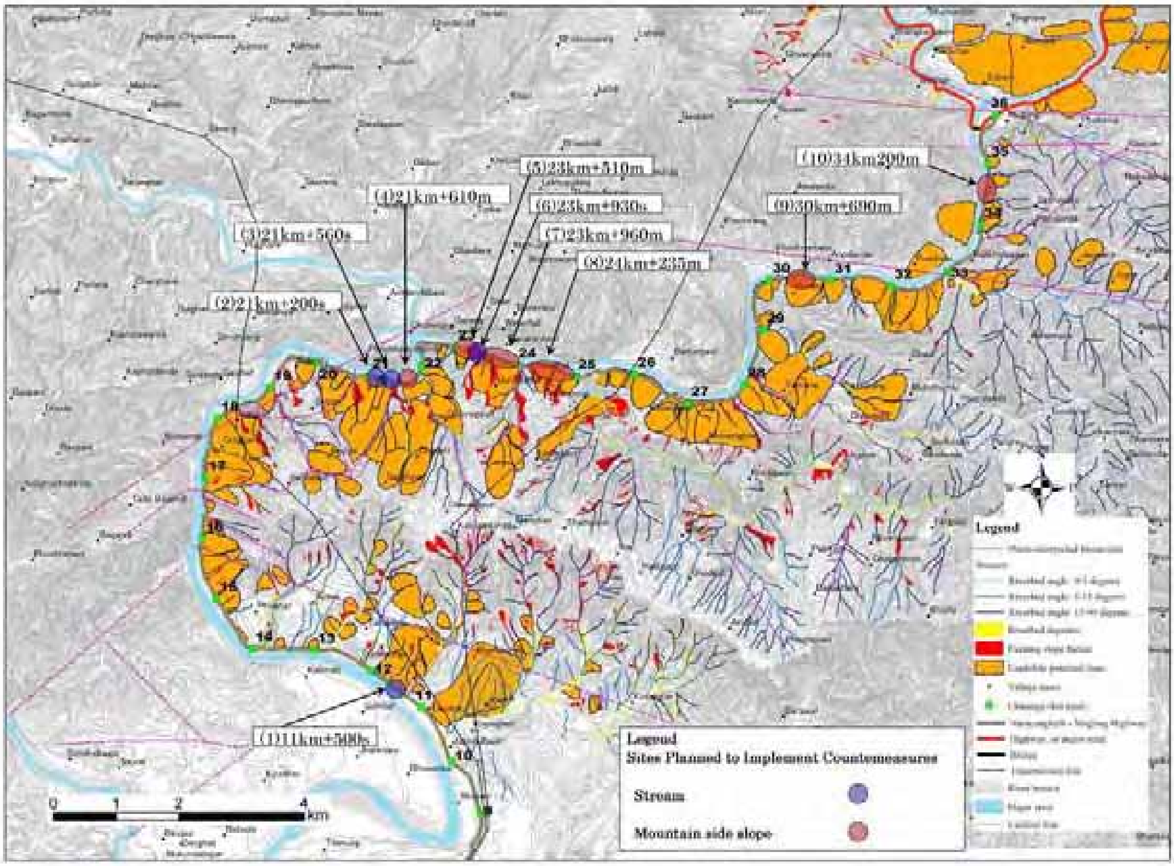

Figure 9.1 Locations of the Selected Sites for the Feasibility Study

9.2 Target Setting

(1) Determination of Structural Measure Level

The size or scale of structural countermeasures is generally classified into several levels taking the following factors into consideration:

a) Importance of the objects to be protected by the proposed structural countermeasures.

b) Hazard or possibility of the road disasters to be considered.

c) Cost-effectiveness of the structural countermeasures to be proposed.

Since 2003 water-induced disasters on the NM Highway, many different kinds of countermeasures were implemented during 2004 and 2006. These implemented countermeasures experienced the 2006 rainfall that was the same as the 2003 rainfall and have effectively insured the safe passage of vehicle along the highway without large-scale landslide occurrence except for some small debris flows and shallow slope failures.

Taking account of the above-mentioned facts and the effectiveness of the implemented structural measures, the structural measure levels (or sizes) were set as follows

(2) Level I

Structural measures of Level I, as permanent measures, are implemented to cope with the following large-scale, potential hazards such as landslide, slope failure and associated debris flow:

a) Large-scale potential hazards that may be triggered by the 2003 rainfall or bigger

b) Large-scale potential hazards those possibly become unstable due to the instability of local, high-level hazards.

(3) Level II

Structural measures of Level II, compared with those of Level I, are small I size and low in safety. They are implemented to maintain the present conditions or maintain the present conditions not to become worse aiming at the following hazards:

a) In the cause of a high-level hazard, the road disaster can be mitigated to a minimum even during a rainstorm same as the 2003 or 2006 rainfalls.

b) In the case of a large-scale potential hazard, the present stability or condition of the large-scale hazard can be maintained by preventing the occurrence of high-level hazards.

c) As additional measures, they are implemented to maintain the existing measures that were installed after the 2003 disaster.

9.3 Design of Structural Measures

(1) Selection of Structural Countermeasures

The option of structural countermeasures was based mainly on causes of damage, mechanism of disaster occurrence and accessibility to the selected sites. For a comparative purpose, the structural countermeasures for each selected location in Level I and Level II are summarized in Table 9.2.

Table 9.2 Structural Measures for Each Location in Level I and Level II

Location	Disaster Type	Structural Countermeasures	
		Level I	**Level II**
11km+500	SF+DF	• Shotcrete crib work • Gabion check dam work	• Bioengineering work*[2)] • wicker work • Gabion check dam work
21km+200	SF(+DF)	• Rock shed work	• Catch wall work • Rock fall protection fence
21km+560	DF	• Removal of deposits • Shotcrete crib work • Sabo dam*[1)]	• Removal of deposits
21km+610 (LS-1)	SL	• Horizontal drain holes • Anchor work	• Horizontal drain holes*[3)]
23km+510 (LS-2)	SL+SF	• Horizontal drain holes • Shotcrete crib work • Anchor work	• Shotcrete crib work • Rock bolt work • Seed-mud spraying work
23km+930	DF	• Gabion mat work • Removal of deposits • Concrete crib work	• Gabion mat work • Removal of deposits
23km+960 (LS-3)	SL	• Horizontal drain holes • Shotcrete crib work • Anchor work	• Shotcrete crib work • Rock bolt work • Seed-mud spraying work
24km+235 (LS-4)	SL+DF	• Horizontal drain holes • Shotcrete crib work	• Horizontal drain holes
30km+690	SF	• Shotcrete crib work • Anchor work	• Shotcrete crib work • Seed-mud spraying work
34km+200	RF	• Shotcrete crib work • Rock bolt work	• Rock fall protection net • Cutting work

Notes: 1) SF- Slope failure, DF-Debris flow, SL- Landslide, Slide, RF- Rock fall
2) Planned or under construction by DWIDP in *1) 21km+560 (Sabo dam), *2) 11km+500 (Check dam), *3) 21km+610 (Horizontal drain holes work), *4) 23km+510 (Horizontal drain holes work).

In addition, the selected structural countermeasures included as follows:

a) Methods generally used in Nepal, such as horizontal drain holes work, sabo dam, gabion, and so on

b) In the cases of a little or no effect for disaster prevention, typical methods in Japan were introduced as new ones, such as concrete crib work, rock fall prevention net and fence, and so on.

Structural countermeasures subjected to the feasibility study are those that were selected as Level II at each selected location. These structural countermeasures were preliminarily designed in the feasibility study.

The following briefly described the causes of disasters, the mechanism of occurrence, and selection and layout of structural countermeasures for each selected locations:

(2) 11km+500 Site (Slope Failure + Debris Flow)

As shown in Figure 9.2, the type of hazard in this site is mainly due to progress of gully erosion, shallow slope failure and associated debris flow along the marginal parts of cultivated land which consists mainly of loose terrace deposits. These hazards are small in size, however, if in progress, will cause a gradual loss of the cultivated land and endless maintenance of the road.

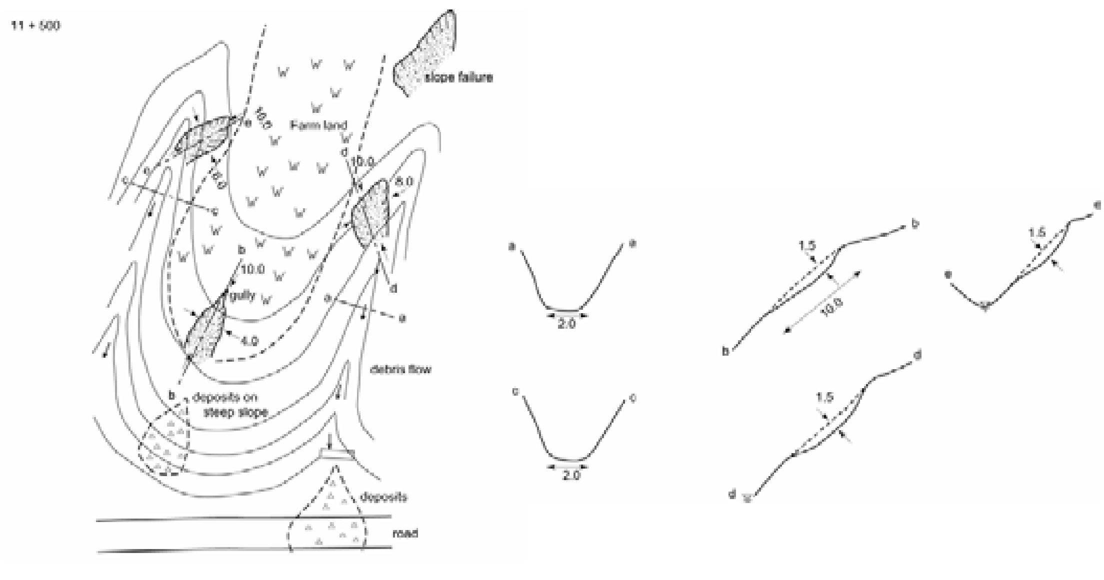

Figure 9.2 Sketch and schematic sections on 11km+500 Site

Accordingly, as preventive measures, bio-engineering method with wicker work was proposed to prevent further surface erosion, and gabion check dam work on the stream, about 1.5 m high and 4.0 wide, was planned to control streambed and bank erosion and simultaneously prevent debris material from moving onto the road.

(3) 21km+200 site (Landslide + Debris Flow)

Small slope failure is distributed on the upper steep and unstable slopes along a potential landslide-block margin. The slope failure was transferred into debris flows and deposited onto the road (Figure 9.3).

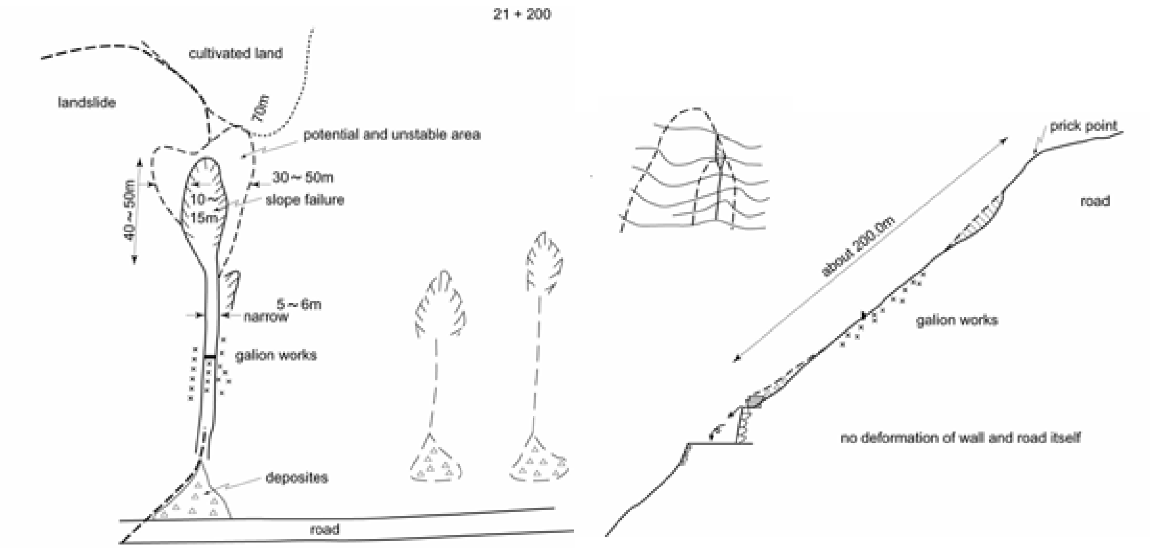

Figure 9.3 Sketch and Schematic Section on 21km+200 Site

Stabilization or complete removal of unstable materials in the source area of debris flow was very difficult and also feasible economically because of land use and difficult access. Therefore, a combination of rock fall protection fence and concrete retaining wall was planned to mitigate the direct hit of debris flow materials and hence protect traffic safety from debris flow.

In addition, during the Study, 6 gabion check dams, about 1.5 m to 2.0 m high, were constructed by DWIDP at upstream of the proposed location for concrete retaining wall. These dams are beneficial to reducing debris flow energy, hence protecting the proposed structures and the road from debris flow.

(4) 21km+560 Site (Debris Flow)

Slope failures are widespread from the road to headstreams and a great amount of debris flow material is produced (Figure 9.4). Five existing sabo dams are effectively preventing discharge of debris flow material. The road thus did not suffer serious damage in the 2006 heavy rain. However, these sabo dams are almost fully filled with deposits due to the 2006 heavy rainfall and can not cope with further deposits for next heavy rain.

Accordingly, the recovery of sabo-dam function by removal of unstable deposits behind these sabo dams was proposed to cope with the further debris flow.

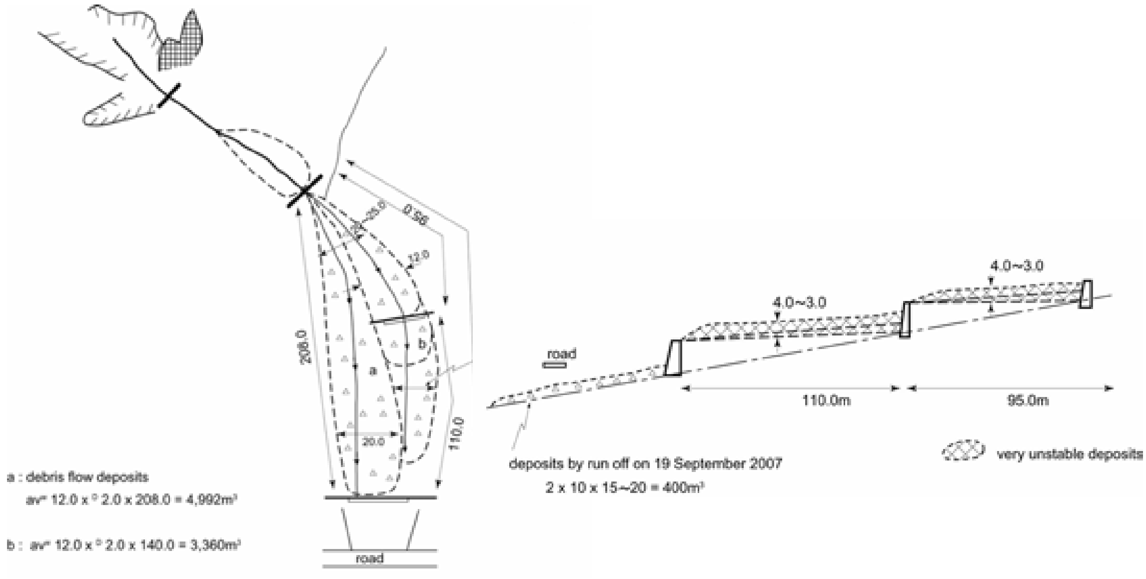

Figure 9.4 Sketch and Schematic Section on 21km+560 Site

(5) 21km+610 Site (Landslide)

The present hazard is a small landslide, a part of large landslide block. The road is located at the foot of the landslide. Several cracks on the retaining wall on the maintain side of the road and settlement of the road surface were observed at field inspection. The strain measurement results show a displacement at depth of about 6.0 m below the ground surface, almost same as the assumed sliding surface by borehole investigation. Therefore, the small landslide block was probably active due mainly to high groundwater level (Figure 9.5)

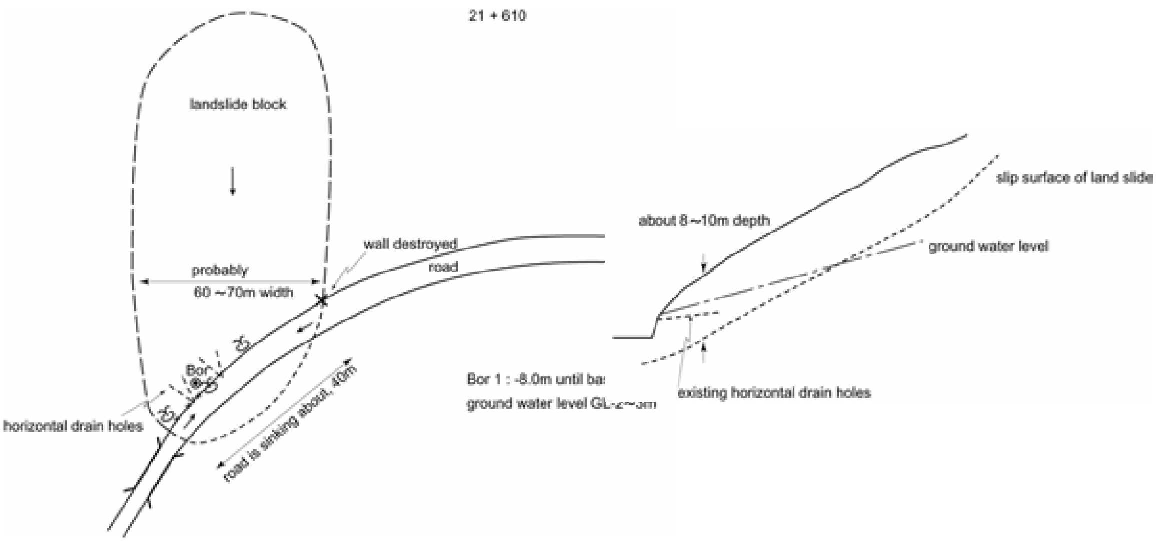

Figure 9.5 Sketch and Schematic Section on 21km+610 Site

The existing horizontal drain holes work is effectively discharging groundwater from landslide area; however the work could not cover the whole landslide area. Accordingly, additional horizontal drain holes work were proposed to control the rise of groundwater level, especially during a heavy rainfall, so that the long-term stability could be secured.

(6) 23km+510 Site (Slope Failure)

Because shallow and small collapses have occurred on the toe part of potential landslide blocks, due mainly to local weathering, bedding, joints, crack, springs, etc. These shallow collapses, generally ranging in size from 1.0 to 2.0 m in depth and from 2.0 to 3.0 m in length, if in progress, could lead to instability of the potential landslide block.

Accordingly, shotcrete crib work (300×300, 2,000×2,000) with rock bolt work was proposed to protect further toe collapse of the potential landslide slope from weathering, spring, jointing and cracking, thereby maintaining the stability of the landslide block.

(7) 23km+930 site (Debris Flow)

The toe collapses of a large-scale landslide are still much active, due chiefly to river flow erosion, and simultaneously the toe collapses is the main source of debris flow material (Figure 9.6).

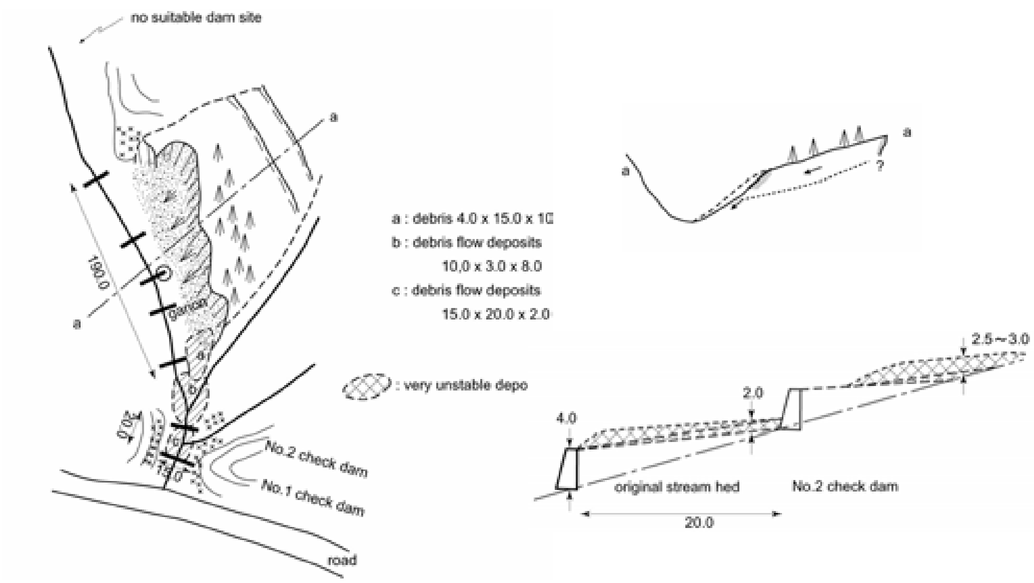

Figure 9.6 Sketch and Schematic Section on 23km+930 Site

Accordingly, gabion mat work was proposed to protect the toe collapses of the potential landslide. Also the functional recovery of sabo dams near the road by removing the unstable deposits was proposed to catch further debris flow deposits.

(8) 23km+960 Site (Slope Failure)

The present hazard in this site (LS-3), geologically and topographically similar to that in km 23+510 site, is some small and shallow collapses on a foot slope of a potential landslide block (Figure 1.7).

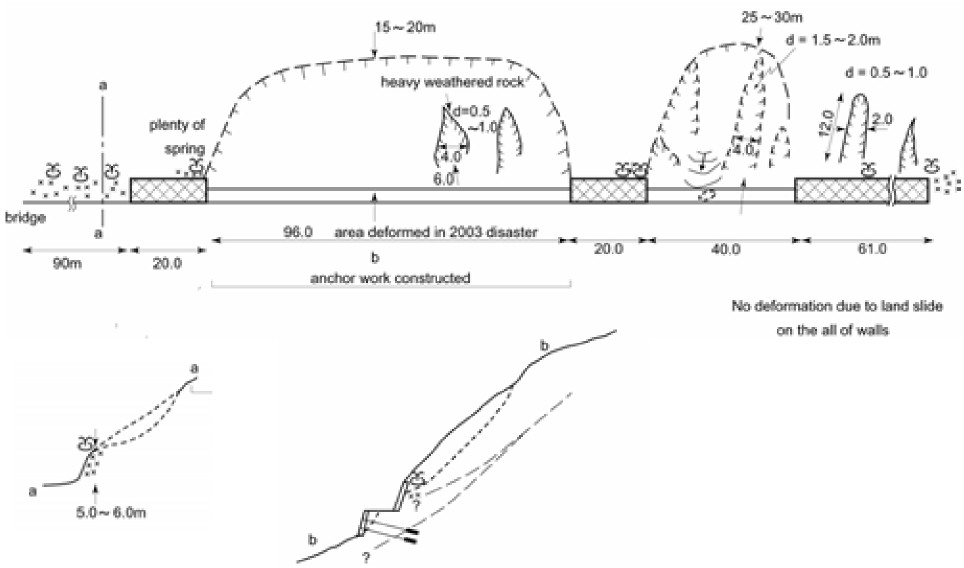

Figure 9.7 Sketch and Schematic Section on 23km+960 Site

Similarly, shotcrete crib work (300×300, 2,000×2,000) with rock bolt work was thus proposed to protect further toe collapse of landslide block from weathering, spring, jointing and cracking, thereby maintaining the stability of landslide block.

(9) 24km+235 Site (Slope Failure + Debris Flow)

The present hazard in this site (LS-4) is geologically and topographically similar to that in the 23km+510 and 23km+960 sites, but more stable because of good vegetation cover on the foot slope. In addition, springs were widespread in the site and underground level would be high. Therefore, horizontal drain holes work was proposed to decrease surface water and groundwater infiltrated through ground cracks in order to improve the stability of unstable slope.

(10) 30km+690 Site (Slope Failure)

Several small slope failures were observed on the foot of a large landslide block along the road in this site. The small slope failures, about 0.5 m to 1.0 m deep, are due mainly to local weathering, bedding, joints, crack, springs, etc., similar to those in the locations 23km+510 and 23km+960.

Therefore, shotcrete crib work (200×200@1.2m) was proposed to protect the foot failure of the landslide slope.

(11) 34km+200 Site (Rock Fall + Slope Failure)

In this site, small-scale slope failures or rock falls, about 1 m^3, frequently occur on steep slope of cracked and jointed rocks on the hillside of the road. The fallen rock blocks falls down onto the road and have a considerable threat on the traffic safety.

As a structural measures, rock fall protection net (cover-type) was proposed to cope with individual rock fall block and small-scale slope failure. In addition, big cracked bedrocks were removed by cutting.

1.4 Implementation Plan

A Feasibility Study for Narayangharh-Mugling Road has been done within the Maintenance and Development Project (MDP), Sector Wide Road Programme and Priority Plan Study, which is financed by the World Bank. However, an agreement to finance for the implementation of the Maintenance and Development Project has been not yet reached between the Government of Nepal and the World Bank.

Therefore, implementation plan for structural measures in this feasibility study will be formulated, taking no account of the above-mentioned Maintenance and Development Project.

(1) Available Technology and Equipment in Nepal

Table 9.3 lists the selected sites together with the proposed works for each site. In addition, the site No. 1 (11km+500) has been planned to be implemented as pilot project.

Table 9.3 Selected Sites and Proposed Structural Measures for Each Location

Site No.	Location	Works	Remarks
1	11km+500	・ Bio-engineering/wicker work ・ Gabion check dam work	Pilot project
2	21km+200	・ Catch wall＋Rock fall protection fence	
3	21km+560	・ Removal of deposits	No structure
4	21km+610	・ Horizontal drain holes work	LS-1
5	23km+510	・ Shotcrete crib work with rock bolt ・ Seed-mud spraying work	LS-2
6	23km+930	・ Gabion mat work ・ Removal of deposits	
7	23km+960	・ Shotcrete crib work with rock bolt ・ Seed-mud spraying work	LS-3
8	24km+235	・ Horizontal drain holes work	LS-4
9	30km+690	・ Shotcrete crib work	
10	34km+200	・ Rock fall prevention net work	
11	Ruwa Khola	・ Revetment type guide concrete wall ・ Removal of deposits	

As shown in Table 9.3 above, the major work items proposed in the Study can be carried out by local contractors in terms of available technology and equipment and recent experience. The exception to this is as follows:

(a) Shotcrete crib work,

(b) Shotcrete crib work with rock bolt work, and

(c) Rock fall protection net work

The former two works will require experienced contractors for the purpose of guarantee of quality and functions for the works. Execution of shotcrete cribs will be done with spraying equipment and the installation of rock bolt will be needed drilling equipment, such as auger drilling and leg hammer drilling. Some local contractors have certain experience in the construction of shotcrete crib work under the supervision of international consultants.

Rock fall prevention net work is the preferred solution to mitigate the damage of rock fall, especially in mountainous countries like Nepal. Its application will provide the opportunity to expand the base of contractor experience in country.

It is thus recommended that the above-mentioned works be assigned an experienced foreign involvement, either by the prequalification process as a part of international competitive bidding ensuring the relevant experience, or by the use of specialist sub-contractors.

(2) Contract Packaging and Implementation Organization

As stated before, certain works have been recommended for international competitive bidding (ICB) mainly for technical reasons. Accordingly, the works is suggested to be divided into two packages for contract, as shown in Table 9.4.

Table 9.4 Arrangement of Selected Sites for Implementation

Package	Location	Works	Cost (mill.Rs)	Implementation organization
1	21km+200	・ Catch wall + Protection fence	1.04	DWIDP (LCP)
	21km+610	・ Horizontal drain holes	6.48	
	23km+930	・ Gabion mat + Removal of deposit	1.82	
	24km+235	・ Horizontal drain holes work	2.00	
	Ruwa Khola	・ Guide concrete wall	18.37	
		Sub-total	**29.71**	
2	23km+510	・ Crib with rock bolt + Vegetation	29.63	DOR (ICP/LCP)
	23km+960	・ Crib with rock bolt + Vegetation	142.05	
	30km+690	・ Crib work + Vegetation	13.70	
	34km+200	・ Rock fall prevention net	6.98	
		Sub-total	**192.36**	
		Total	**222.07**	

It is proposed that the Package I is carried out by local contractors and the Package II is done under International Competitive Bidding (LCB) and Local Competitive Bidding (LCB) for the procurement of engineering works.

(3) Construction Procedures

Most of the proposed works are common in Nepal. Local contractors have much experience in implementing them under the management of DWIDP or DOR. Therefore, construction procedures will focus on crib work and rock fall protection net work, as shown in Figures 9.8 to 9.10.

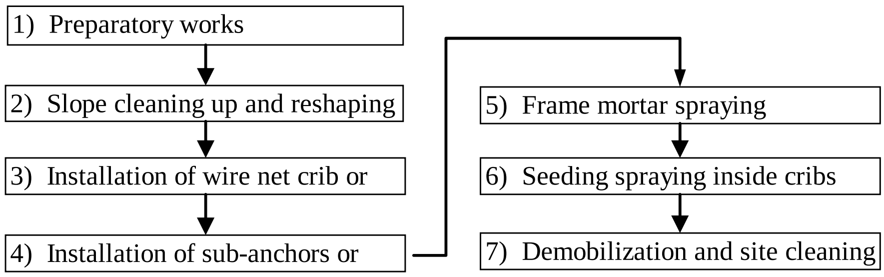

Figure 9.8 Procedure of Shotcrete Crib Work Construction

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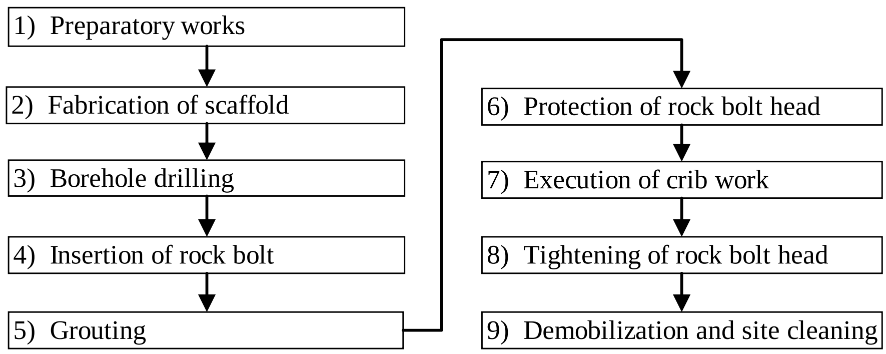

Figure 9.9 Procedure of Shotcrete Crib Work with Rock Bolt Construction

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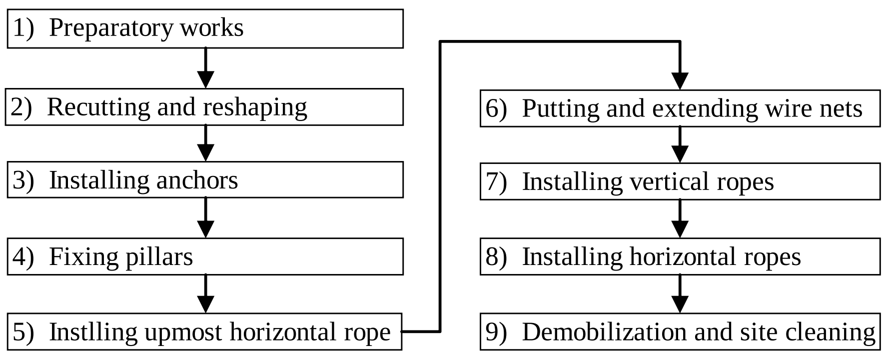


Figure 9.10 Procedure of Rock Fall protection Net Work Construction

(4) Construction Schedule

Figures 9.11 and 9.12 show the overall construction schedule for Package I and Package II, respectively.

For the purpose of construction quality guarantee, construction of works will begin after rainy season (after September) and terminate before next rainy season (before July).

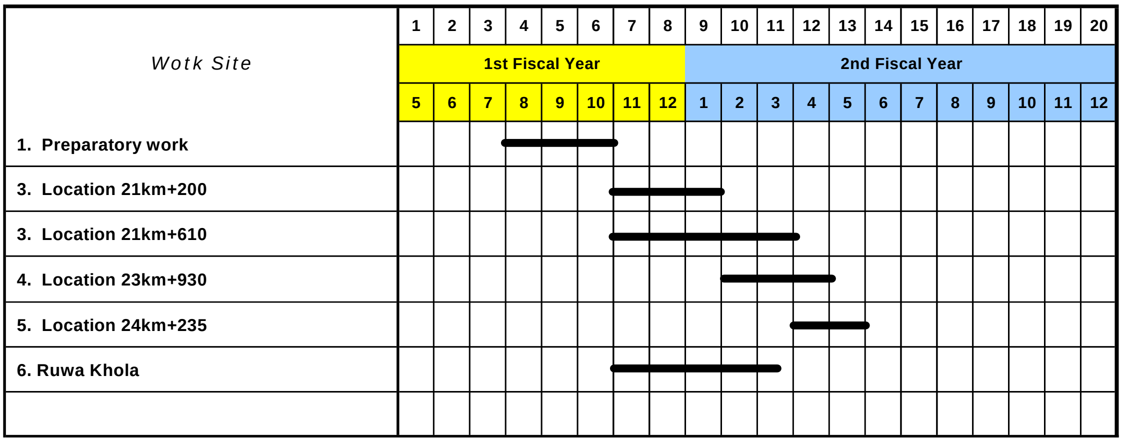


Figure 9.11 Overall Construction Schedule for Package I

In implementing the Package I, conditions of construction is considered as follows:

(a) Three parties shall carry out the construction of the all works in the Package, namely, the first party for Locations 21km+200 and 23km+930, the second party for others.

(b) Drilling for installing horizontal drain holes is assumed to be 5m/day.

Similarly, conditions of construction for the Package II is considered as follows:

(a) Two parties shall carry out the construction of the all works in the Package, namely, the first party for Location 23km+510, and the second party for other locations.

(b) Location 23km+960 shall be implemented in another fiscal year after the completion of the other locations.

(c) The drilling method used for installing rock bolts is assumed to be leg hammer drilling. For Location 23km+510, 5 leg hammer drillings shall be used with a working speed of 2 rock bolts per day, whereas, for Location 23km+960, 10 leg hammer drillings shall be used with a working speed of 3 rock bolts per day because of experience.

(d) During drilling for rock bolts and inserting of rock bolts, installation of wire net frames and mortar spraying shall be carried out simultaneously in the separate working areas.

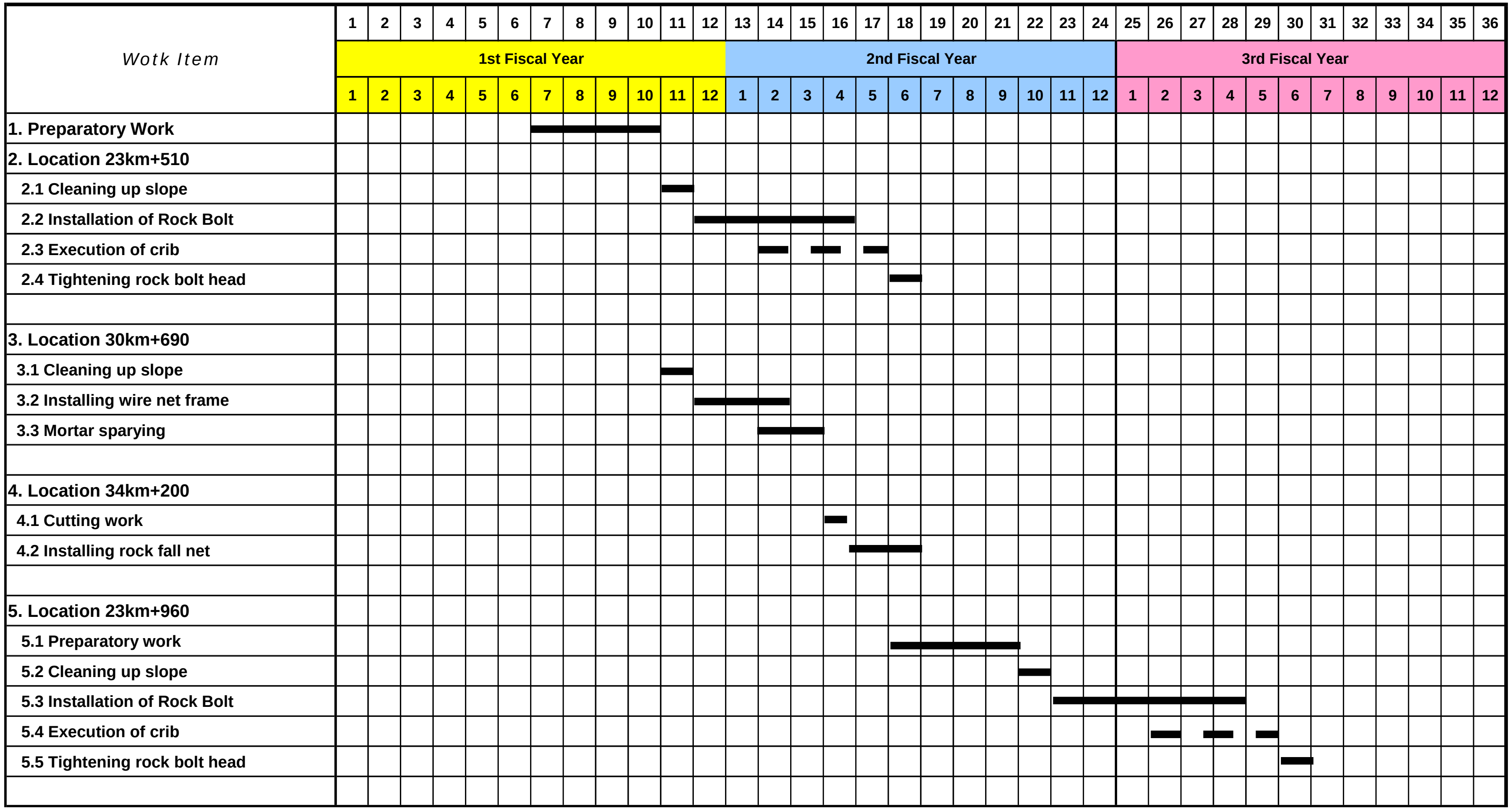


Figure 9.12 Overall Construction Schedule for Package II

1.5 Project Cost Estimation

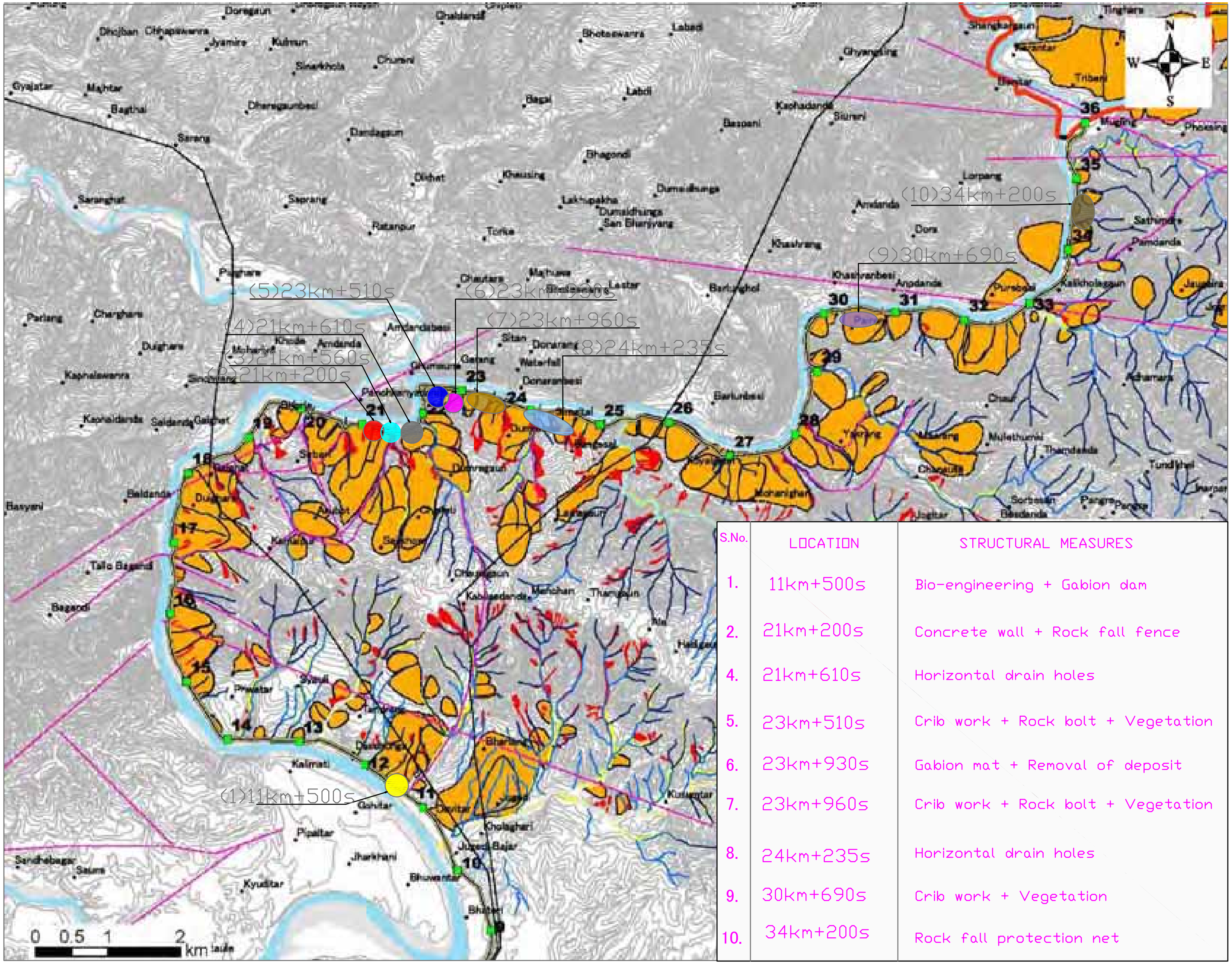
The work quantities for the designed structural countermeasures were calculated on the basis of the layout of the structures. Table 9.5 summarizes the work quantities and construction cost.

Table 9.5 Summary of Work Quantity together with Construction Cost

Location	Structural Measures		Cost (NRs)
11km+500	Bio-engineering (Wicker) work	67.0m	21,094.0
	Gabion check dam work	11.88 m^3	21,146.0
	×1.13（13%VAT）		**47,731.0**
21km+200	Concrete retaining wall work	113.39 m^3	527,859.0
	Rock fall protection fence work	22.0m	377,663.0
	Demolishing of existing wall work	19.5m	13,934.0
	×1.13（13%VAT）		**1,038,985.0**
21km+560	Removal of deposits	10,350 m3	—
	×1.13（13%VAT）		—
21km+610 (LS-1)	Horizontal drain holes work	486.0m	5,728,880.0
	×1.13（13%VAT）		**6,473,634.0**
23km+510 (LS-2)	Shotcrete crib work	4196.6 m2	14,318,696.0
	Rock bolt work	3671.50m	5,398,327.0
	Seed-mud spraying work	3032.06 m2	6,506,910.0
	×1.13（13%VAT）		**29,633,044.0**
23km+930	Gabion mat work	825.69 m3	1,607,117.0
	Removal of deposits	2,730m3	—
	×1.13（13%VAT）		1,816,042.0
23km+960 (LS-3)	Shotcrete crib work	20269.72 m2	68,930,851.0
	Rock bolt work	17734.5m	26,000,153.0
	Seed-mud spraying work	14644.87 m2	30,774,324.0
	×1.13（13%VAT）		**142,047,020.0**
24km+235 (LS-4)	Horizontal drain holes work	150.0m	1,770,488.0
	×1.13（13%VAT）		**2,000,651.0**
30km+690	Shotcrete crib work	2433.94 m2	8,466,350.0
	Seed-mud Spraying work	1690.24 m2	3,660,422.0
	×1.13（13%VAT）		**13,703,252.0**
34km+200	Rock fall protection net work	4150.0m2	6,180,463.0
	×1.13（13%VAT）		6,983,923.0
Total			**203,744,282.0**
Ruwa Khola	Revetment type guide concrete wall work	2842.8m3	16,251,029.0
	×1.13（13%VAT）		**18,363,663.0**

Note: Cost-Construction Cost

LOCATION MAP



S.No.	LOCATION	STRUCTURAL MEASURES
1.	11km+500s	Bio-engineering + Gabion dam
2.	21km+200s	Concrete wall + Rock fall fence
4.	21km+610s	Horizontal drain holes
5.	23km+510s	Crib work + Rock bolt + Vegetation
6.	23km+930s	Gabion mat + Removal of deposit
7.	23km+960s	Crib work + Rock bolt + Vegetation
8.	24km+235s	Horizontal drain holes
9.	30km+690s	Crib work + Vegetation
10.	34km+200s	Rock fall protection net

THE DEPARTMENT OF WATER INDUCED DISASTER PREVENTION AND TEH DEPARTMENT OF ROADS THE GOVERNMENT OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY
NIPPON KOEI CO., LTD. (NK)

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01			RECOMMENDED BY	
			APPROVED BY	

THE STUDY ON DISASTER RISK MANAGEMENT FOR NARAYANGHARH-MULING HIGHWAY

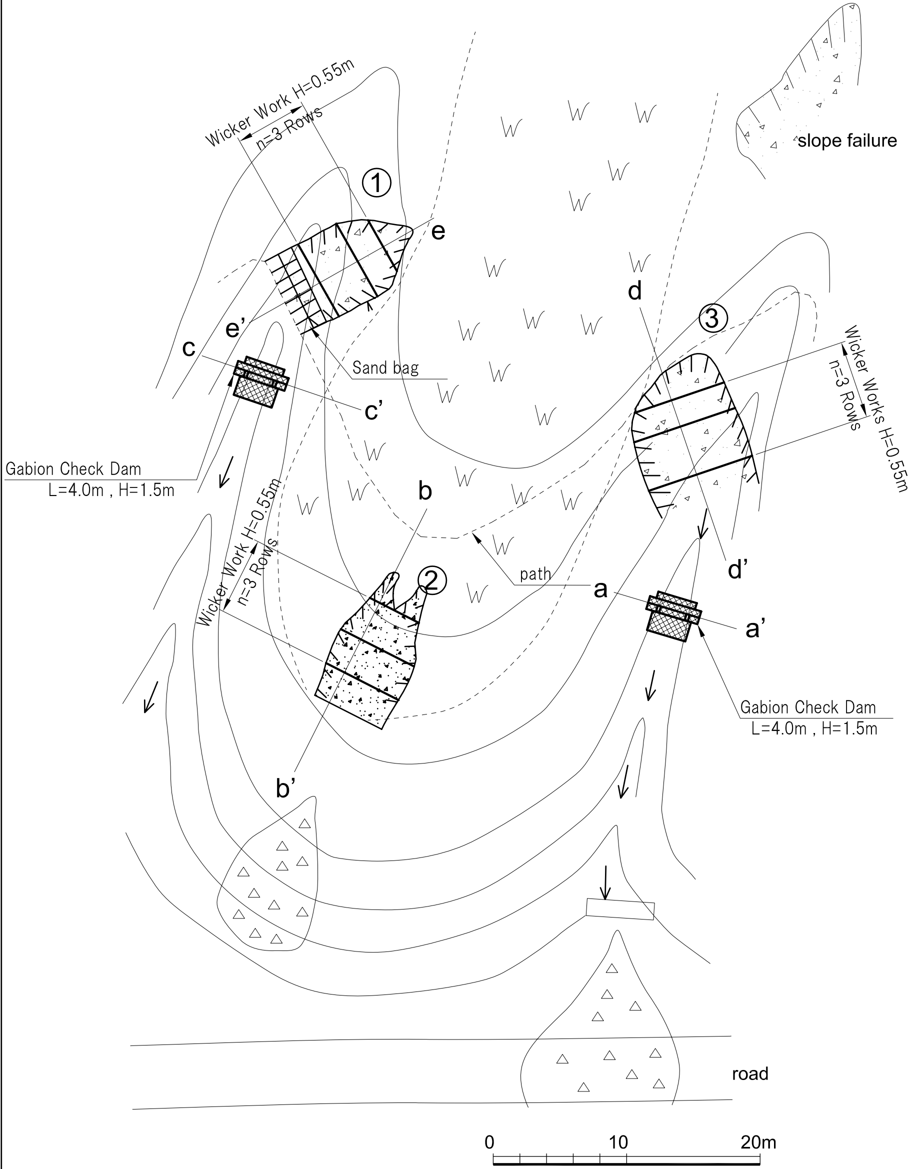
SCALE

DATE: FEBRUARY 2008

DWG. NO.: LOC01-01

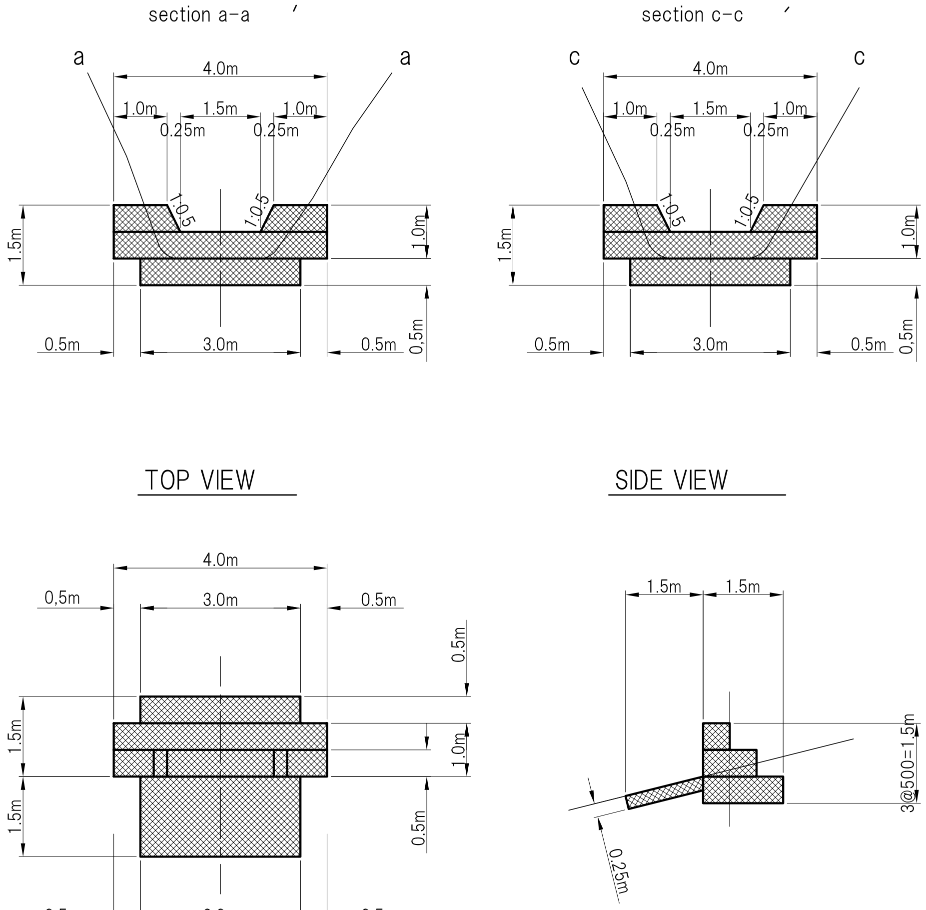
BIO-ENGINEERING AND GABION CHECK DAM WORKS IN 11KM.+500 SITE

PLAN S=1:400



GABION CHECK DAM WORKS S=1:100

SECTION



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WICKER WORK

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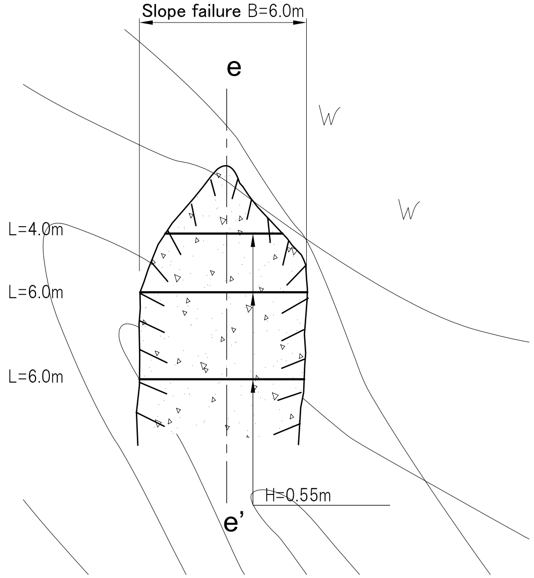
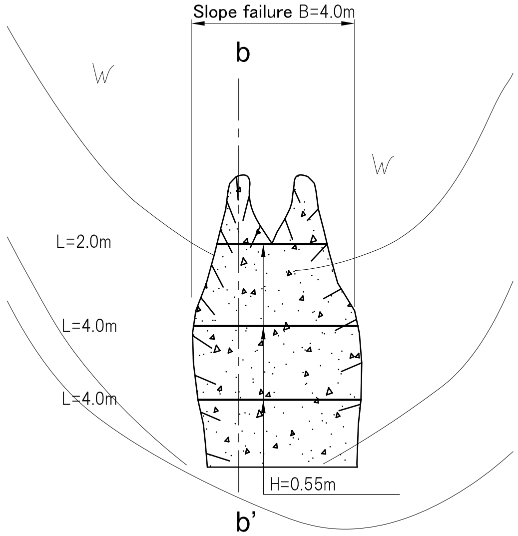
STRUCTURE ARRANGEMENT DRAWINGS

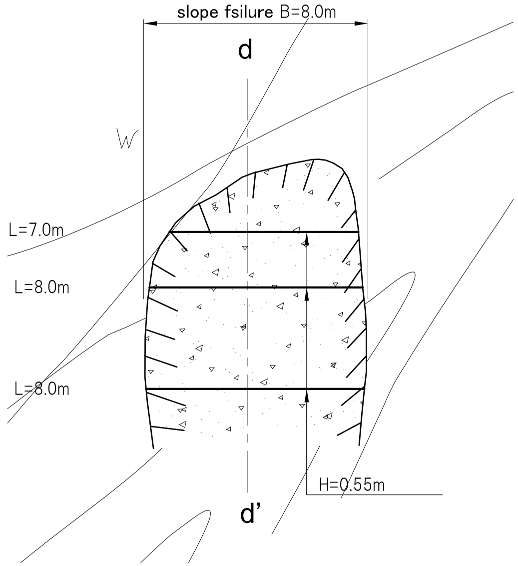
AREA ⅠPLAN



AREA ⅡPLAN



AREA ⅢPLAN



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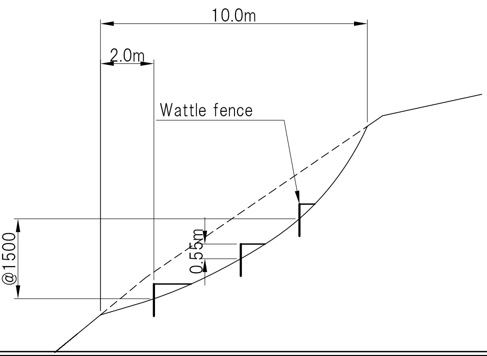

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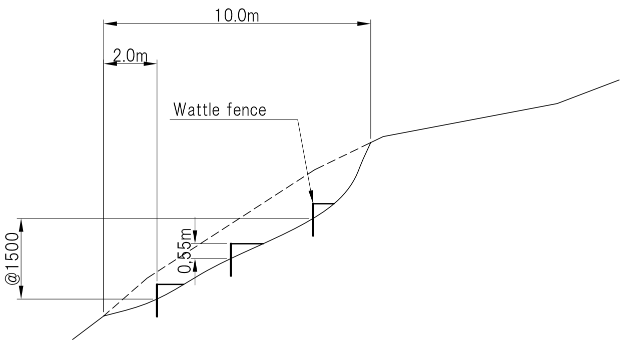
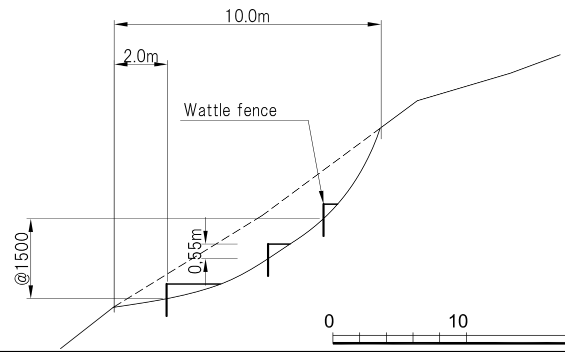


d-dsection



0 10 20m

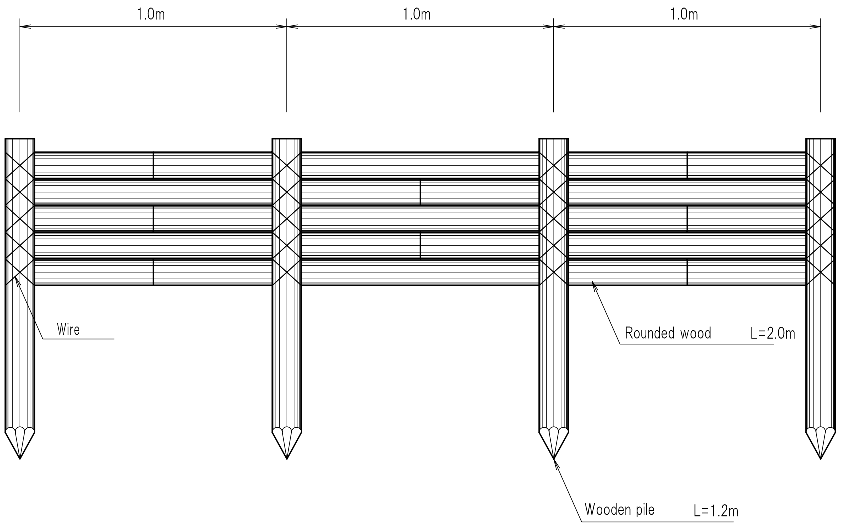
THE DEPARTMENT OF WATER INDUCED DISASTER PREVENTION AND TEH DEPARTMENT OF ROADS THE GOVERNMENT OF NEPAL	JAPAN INTERNATIONAL COOPERATION AGENCY JICA NIPPON KOEI CO., LTD. (NK)	04			DESIGNED BY		THE STUDY ON DISASTER RISK MANAGEMENT FOR NARAYANGHARH-MULING HIGHWAY		SCALE
		03			DRAWN BY				
		02			ASSISTED BY			DATE FEBRUARY 2008	DWG. NO. SO1-02
		01			RECOMMENDED BY				
		REV.	DATE	DESCRIPTION	APPROVED BY				

DETAIL OF WICKER WORK

S=1:20

WOOD PILE TYPE FOR SOIL AREA

FRONT VIEW



SIDE VIEW

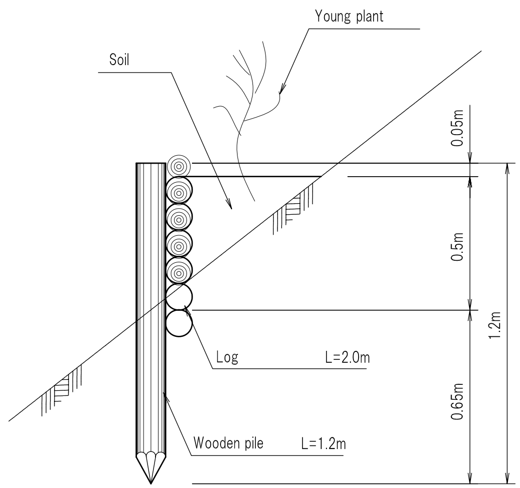


Table of Materials (per 1m)

Material	Dimensions	Units	Quantity	Remarks
Wooden Pile	ϕ 0.11m,L1.2m	Nos.	2	
Rounded Wood	ϕ 0.11m,L1.2m	Nos.	2.5	
Steel Wire		Kg	1.24	
Soil		m		

THE DEPARTMENT OF WATER INDUCED DISASTER PREVENTION AND TEH DEPARTMENT OF ROADS THE GOVERNMENT OF NEPAL

JAPAN INTERNATIONAL COOPERATION AGENCY
JICA NIPPON KOEI CO., LTD. (NK)

REV.	DATE	DESCRIPTION		
04			DESIGNED BY	
03			DRAWN BY	
02			ASSISTED BY	
01			RECOMMENDED BY	
			APPROVED BY	

THE STUDY ON DISASTER RISK MANAGEMENT FOR NARAYANGHARH-MULING HIGHWAY

SCALE

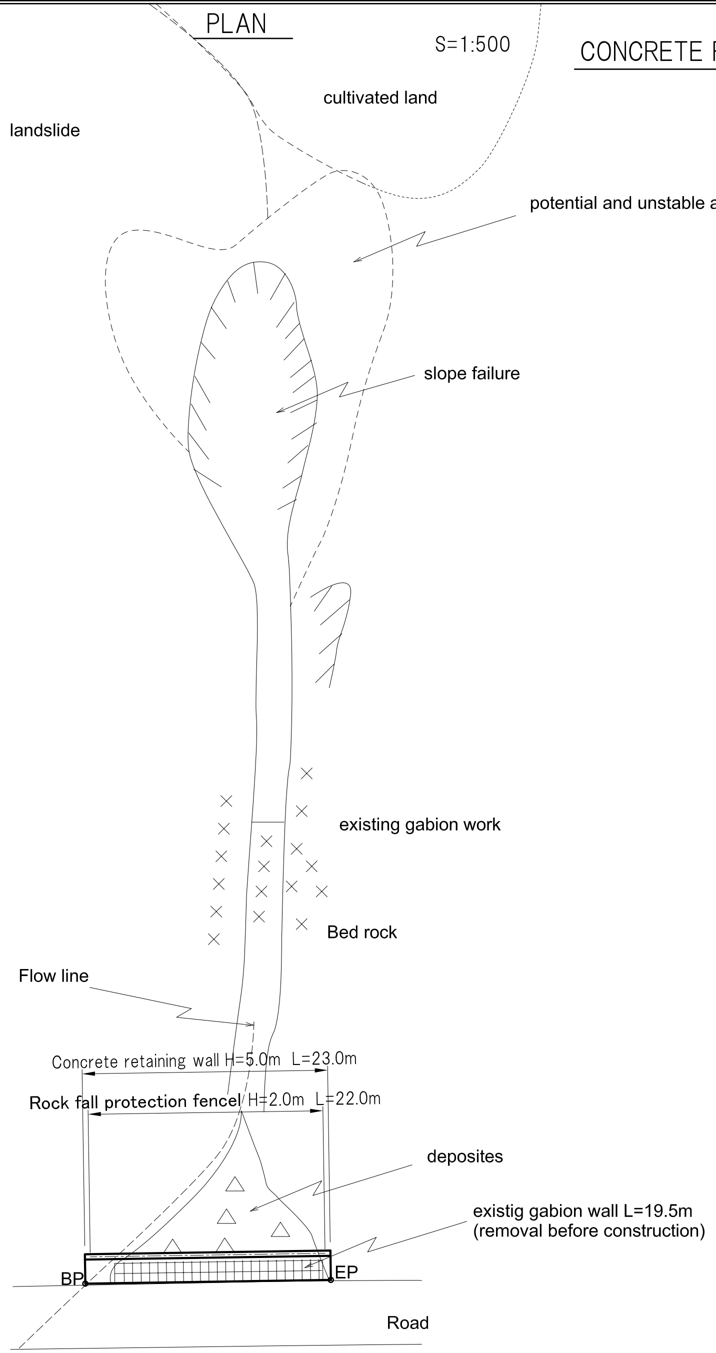
DATE: FEBRUARY 2008

DWG. NO.: SO1-03

CONCRETE RETAINING WALL WITH ROCK FALL PROTECTON FENCE IN 21KM.+200 SITES

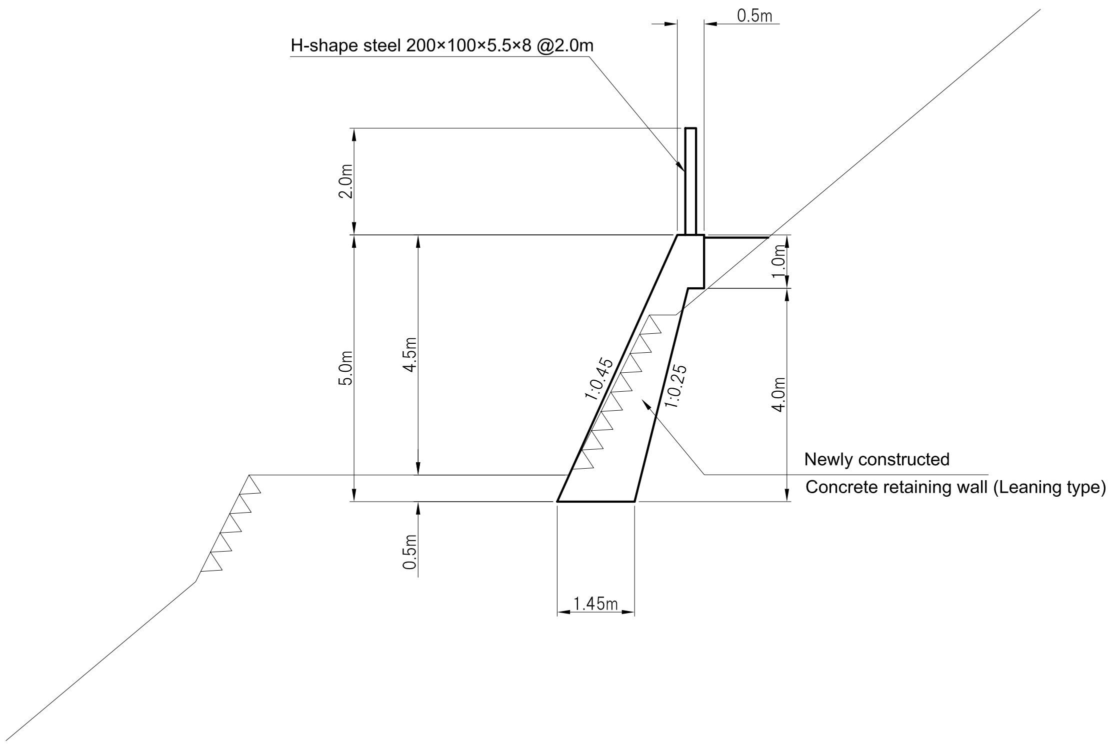
PLAN

S=1:500



CROSS SECTION

S=1:100



NOTE:

1) Foundation level may be modified by the Engineer according to the actual geological condition of foundation ground

2) The begining and the ending points of Concrete Retaining wall are shown in the following table

	X	Y
Begining Point(BP)	29498	38097
Ending Point (EP)	52496	38445

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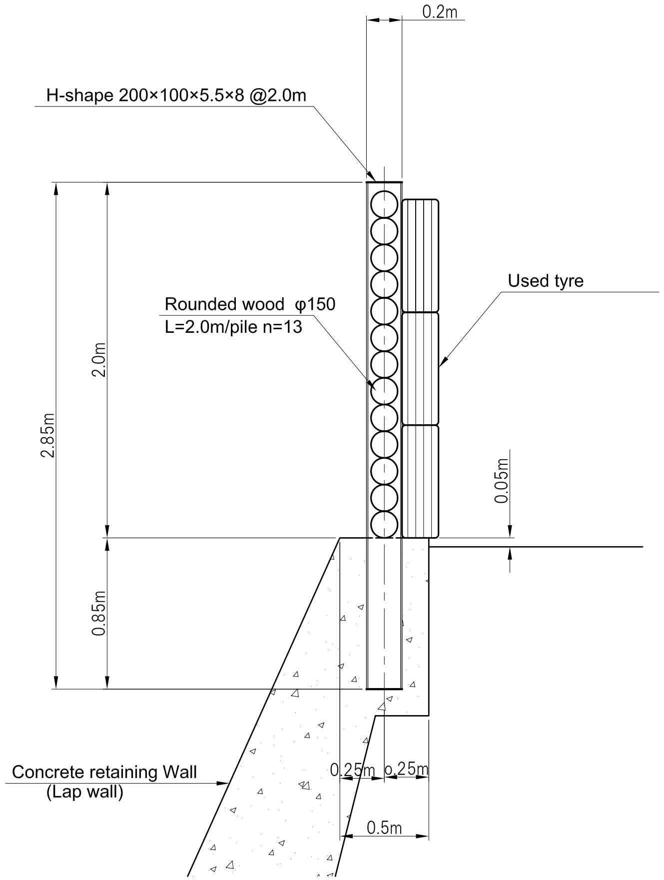
		03		DRAWN BY		
		02		ASSISTED BY		
		01		RECOMMENDED BY	DATE: FEBRUARY 2008	DWG. NO.: SO2-01
		REV.	DATE / DESCRIPTION	APPROVED BY		

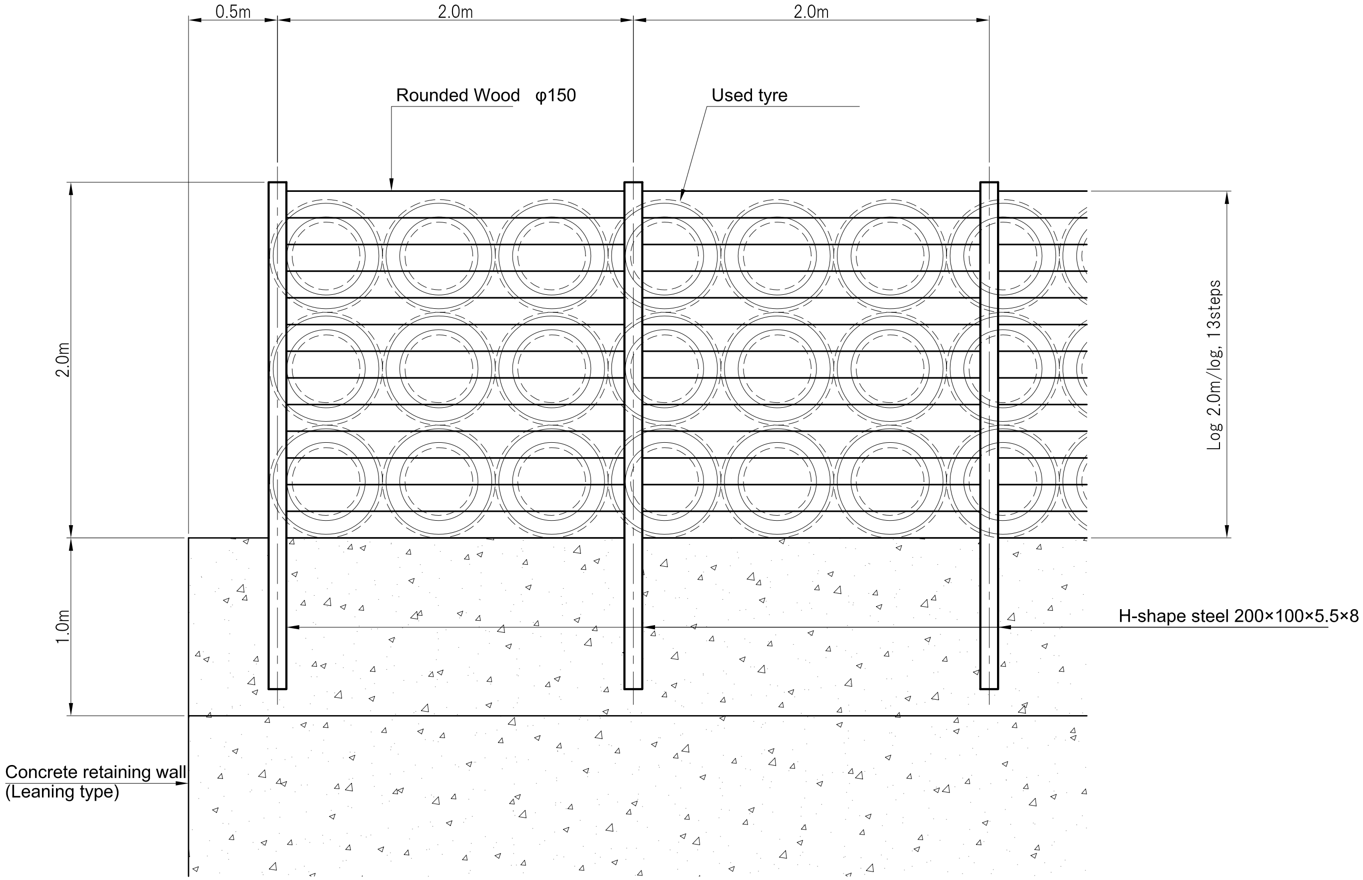
DETAIL OF ROCK FALL PROTECTION FENCE

S=1:30

SIDE VIEW



FRONT VIEW



THE DEPARTMENT OF WATER INDUCED DISASTER PREVENTION AND TEH DEPARTMENT OF ROADS THE GOVERNMENT OF NEPAL	JAPAN INTERNATIONAL COOPERATION AGENCY NIPPON KOEI CO., LTD. (NK)	04			DESIGNED BY	THE STUDY ON DISASTER RISK MANAGEMENT FOR NARAYANGHARH-MULING HIGHWAY	SCALE
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