BASIC DESIGN STUDY REPORT
ON
THE PROJECT
FOR
URGENT REHABILITATION OF
SINDHULI ROAD (SECTION IV)
IN
THE KINGDOM OF NEPAL

FEBRUARY 2003

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.

PREFACE

In response to a request from His Majesty's Government of Nepal, the Government of Japan decided to conduct a basic design study on the Project for Urgent Rehabilitation of Sindhuli Road (Section IV) and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Kingdom of Nepal a study team from November 20 to December 4, 2002.

The team held discussions with the officials concerned of the Government of Nepal, and conducted a field study at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to the Kingdom of Nepal in order to discuss a draft basic design and as this result, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of His Majesty's Government of Nepal for their close cooperation extended to the teams.

February, 2003

Takao Kawakami
President
Japan International Cooperation Agency

February, 2003

LETTER OF TRANSMITTAL

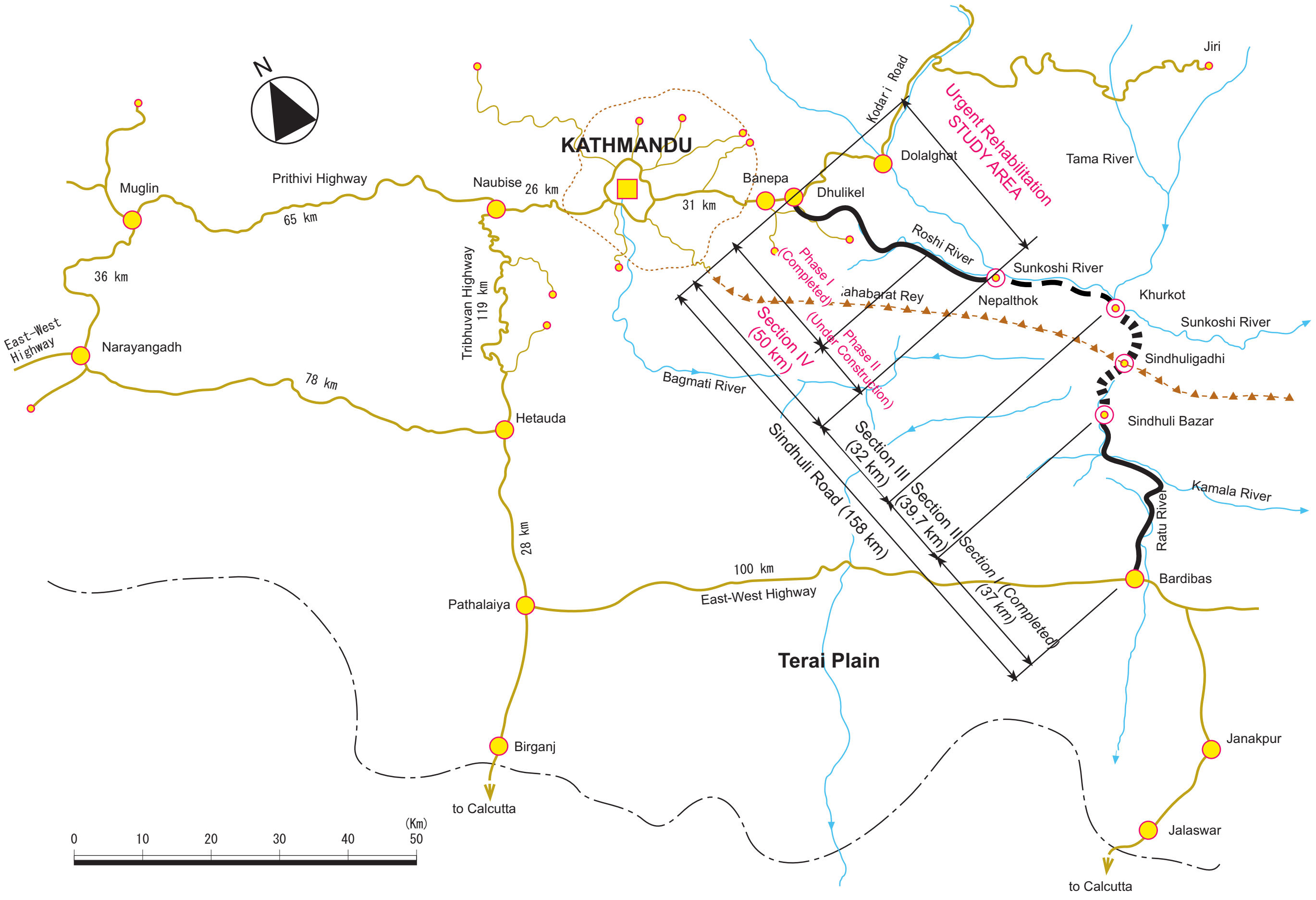
We are pleased to submit to you the basic design study report on the Project for Urgent Rehabilitation of Sindhuli Road (Section IV) in the Kingdom of Nepal.

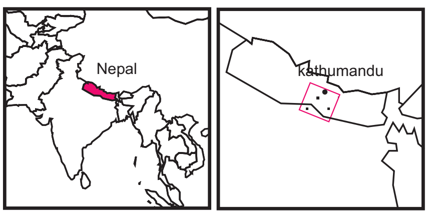
This study was conducted by Nippon Koei Co., Ltd. under a contract to JICA, during the period from November, 2002 to February, 2003. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of the Kingdom of Nepal and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

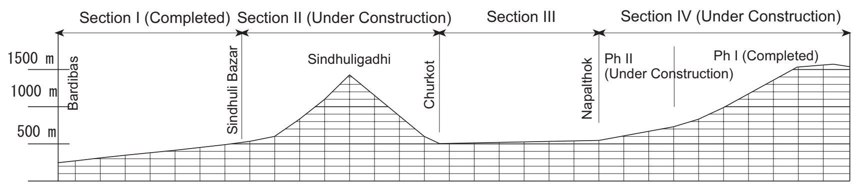
Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours,

Yoshihisa YAMASHITA
Project manager,
Basic design study team on the Project for
Urgent Rehabilitation of Sindhuli Road (Section IV)
Nippon Koei Co., Ltd.







Road Profile

Basic Design Study on the Project for Urgent Rehabilitation of Sindhuli Road (Setion IV)	Location Map

Condition of Damaged Section 1

① [No.2] STA.00+370—00+455：

Embankment washed away

② [No.10] STA.03+370—03+730：

Embankment washed away

③ [No.12] STA.04+245—04+360：

Embankment washed away

④ [No.13] STA.05+075—05+135：

Overturning of revetment

⑤ [No.14] STA.05+190—05+205：

Scour of wall foundation

⑥ [No.36] STA.11+489—11+577：

Embankment washed away

(Arrow：Water Flow Direction)

Condition of Damaged Section 2

⑦ [No.16] STA.05+300－05+461：Embankment washed away

⑧ [No.17] STA.05+500－05+560：Overturning of revetment

⑨ [No.18] STA.06+065－06+206：Embankment washed away

⑩ [No.24] STA.07+625－08+000：Embankment washed away

(Arrow：Water Flow Direction)

Condition of Damaged Section 3

⑪ [No.41] STA.13+262：Slope failure due to scouring

⑫ [No.44] STA.14+885－14+925：

Erosion of riverbank

（Temporary work was done by DOR）

⑬ [No.50] STA.18+558－18+581：

Embankment washed away

（Temporary work was done by DOR）

⑭ [No.65] STA.21+015－21+056：

Embankment washed away

⑮ [No.66] STA.22+915：

Slope failure due to scouring

(Arrow：Water Flow Direction)

LIST OF TABLES

Table 2-1 State of Section IV Project as of July 20, 2002 2-1
Table 2-2 Types and Number of Damage along Section IV 2-3
Table 2-3 Party in charge and progress of Restoration 2-4
Table 2-4 Available Daily Rainfall Records 2-15
Table 2-5 Thiessen Polygon Sets and Their Weights 2-15
Table 2-6 Evaluation Parameters and Standard Value of Probability Distribution Model 2-16
Table 2-7 Probable Average Precipitation over the Target River Basin 2-16
Table 2-8 Return Period of the Recent Torrential Rainfall Event 2-17
Table 2-9 Rainfall Intensity of Target River Basin 2-18
Table 2-10 Coefficient of Storage Function Method 2-18
Table 2-11 Comparison and Summary of Results 2-19
Table 3-1 Damaged sections to be restored under this project 3-2
Table 3-2 Comparison between Original design and situation after this flood 3-4
Table 3-3 Comparison of 1/50 Probable Flood Peak 3-13
Table 3-4 Relationship between d_{60} and coefficient of roughness 3-14
Table 3-5 Estimated High Water Level 3-15
Table 3-6 Estimated Maximum Scouring Depth (without foot protection) 3-18
Table 3-7 Design Velocity for Foot Protection 3-20
Table 3-8 Parameters of Foot Protection Structures 3-24
Table 3-9 Comparison of design between original plan and this study 3-31
Table 3-10 Staffing for Pre-Construction Stage 3-50
Table 3-11 Staffing for Construction Stage 3-50
Table 3-12 Quality Control Tests Plan 3-51
Table 3-13 Procurement of Major Construction Materials 3-52
Table 3-14 Procurement of Major Construction Equipment 3-52
Table 3-15 Tentative Implementation Schedule 3-52
Table 3-16 Maintenance Works for Sindhuli Road Section IV 3-54
Table 4-1 Travel times before and after opening of Section IV 4-1

LIST OF FIGURES

Figure 2-1 State of Section IV Project as of July 20, 2002 2-2
Figure 2-2 Completed works of Section IV Phase 2 Project till July 20, 2002 2-2
Figure 2-3 Location of Damaged sections (1/4) 2-10
Figure 2-4 Location of Damaged sections (2/4) 2-11
Figure 2-5 Location of Damaged sections (3/4) 2-12
Figure 2-6 Location of Damaged sections (4/4) 2-13
Figure 2-7 Attainable Works along Section IV Phase 2 Project 2-14
Figure 3-1 Damaged Section to be Restored Under This Project........ 3-3
Figure 3-2 Types of Damages 3-6
Figure 3-3 Types of Damages (Photo 1/2) 3-7
Figure 3-4 Types of Damages (Photo 2/2) 3-8
Figure 3-5 2.5 dimension riverbed fluctuation analysis (at beginning)........ 3-10
Figure 3-6 2.5 dimension riverbed fluctuation analysis (after 24hours) 3-10
Figure 3-7 2.5 dimension riverbed fluctuation analysis (after 48hours) 3-11
Figure 3-8 2.5 dimension riverbed fluctuation analysis (after 72hours) 3-11
Figure 3-9 Proportions of Hmax and Hd........ 3-17
Figure 3-10 Calculation result of 2.5-dimension riverbed fluctuation analysis 3-18
Figure 3-11 Design policy for Embedment level with foot protection........ 3-19
Figure 3-12 Typical cross section of Foot Protection Structure........ 3-24
Figure 3-13 Countermeasure for slope failure due to scouring around Sta.13+300........ 3-28
Figure 3-14 Countermeasures for slope failure due to scouring around STA.22+900........ 3-29

SUMMARY

The Kingdom of Nepal is a landlocked country, bordered on the north by China and on the east, west and south by India. The population in 2000 was estimated to be 20.3 million. The country is divided into three topographical regions: the Mountain Region, the Hill Region and Terai Plain, and also comprises of 75 Districts. The Districts are regrouped into five Development Regions divided by south-north borders.

The national economy of Nepal depends heavily on the agricultural sector, which amounts to about 40 percent of the Gross Domestic Product and contains about 80 percent of the economically active population. The Terai Plain is the main agricultural production area.

The road sub-sector has a leading role in the national transport system in Nepal. The development of road network started in 1950, with the network expanding to a length of 15,857 km by 2002. However, the service level of the road network is insufficient as 70 percent of roads have been unpaved and 14 Districts still have no vehicular roadways at all. In order to achieve the National Plan and reduce the national traffic cost, the expansion of the road network and maintaining and improving existing roads is one of the main challenges for Nepal.

Although Prithivi Highway is a main transport route, it is still at risk of periodic partial or full closure to traffic due to landslides and/or bank erosion in the rainy season, such as an event that occurred in July 1993 stopping completely the traffic to and from Kathmandu for 20 days. The Prithivi Highway is a roundabout way traversing about 200 km to the west of Kathmandu for traffic traveling between Kathmandu and the Eastern Region of Nepal.

Taking into account the condition of the present road network linking Kathmandu and the Terai Plain, His Majesty's Government of Nepal (HMG/N) recognized the necessity of a second life line connecting Kathmandu and the Terai Plain, and thus formulated the Sindhuli Road Construction Project. This Project has been planned to connect Bardibas on the East-West Highway with Dhulikel located on the Kodari Road 31 km east of Kathmandu. The Project road is divided into four sections: Section I: Bardibas to Sindhuli Bazar with a total length of 37 km, Section II: Sindhuli Bazar to Khurkot with a total length of 40 km, Section III: Khurkot to Nepalthok with a total length of about 32 km and Section IV: Nepalthok to Dhulikel with a total length of 50 km.

The construction of Sinduli Road is being conducted by Japanese Grant Aid commencing in 1996. The construction of Section IV (Nepalthok – Dhulikhel) of the Project, consisting of the construction of 50 km of road and procurement of maintenance equipment for the project road, was started in 1997. The construction of Section IV Phase 2 is now in progress.

In the year 2002, incessant rain from July 21st to 23rd caused flooding and landslides in different parts of the Kingdom of Nepal, causing a number of casualties and heavily damaging public and private

properties. Newspapers reported that almost two-thirds of the districts in the country had been affected by this incessant rain resulting in widespread floods and landslides. The floods and landslides also disrupted vehicle movements on major highways and other important roads in the country.

Unfortunately, during that period, the heavy rain severely damaged Section IV. The damage was mainly due to flooding and scouring of riverbanks and slope failures in cut slopes along the road alignment.

A preliminary cost estimate for restoration of the damaged sections of the road suggests that the allocated budget for Section IV Phase 2 of the Project could not allow completion of the Project.

Being a high priority, HMG/N intends to complete the Project by the end of its 10th Plan (2003-2008), despite the difficulties arising from the disaster. HMG/N therefore requested from the GOJ a further grant aid for the Urgent Rehabilitation of Sindhuli Road Construction Project (Section IV Dhulikel - Nepalthok) in September 2002. In response to the request, the GOJ decided to conduct a basic design study for the Urgent Rehabilitation of Sindhuli Road Construction Project (Section IV Dhulikhel - Nepalthok).

Based on the above background, Japan International Cooperation Agency (JICA) dispatched basic design study team during the period between November 20 and December 4, 2002. The study team had discussions with HMG/N officials regarding the contents of the urgent rehabilitation of Section IV and the scope of works to be implemented under the Japanese Grant Aid Program and carried out the field survey including site investigation and so on. Basic agreements were then signed and exchanged.

After returning to Japan, based on the results of the field surveys, the study team carried out the basic design based on the restoration policy, and prepared a draft basic design report containing the contents of the Urgent Rehabilitation of Section IV, implementation program, scope of works to be done by HMG/N and so on.

JICA dispatched a mission to explain the draft report to HMG/N during the period between February 6 and February 13, 2003. HMG/N issued a letter of agreement with the contents of the draft basic design report.

This Project will cover the following sites.

- Damaged sites from the recent disaster along Section IV Phase 2 Project and portions of road section that remained incomplete because of budgetary issues.
- The portion of Section IV Phase 1 Project which was completed and handed over to HMG/N but susceptible to obstruction of traffic flow due to the expansion of damages caused by the recent disaster and incomplete sites due to technical reasons from HMG/N side.

In the other handed over portion damaged from the recent disaster, including Section I, HMG/N will conduct their restoration works.

The damaged sections to be restored under this project are listed in the table below.

Damaged section		Length(m)	Description
①	00+370－00+455	85	Embankment washed away
②	03+370－03+730	360	Embankment washed away
③	04+245－04+360	115	Embankment washed away
④	05+075－05+135	60	Overturning of revetment
⑤	05+190－05+205	15	Scour of wall foundation
⑥	05+300－05+461	161	Embankment washed away
⑦	05+500－05+560	60	Overturning of revetment
⑧	06+065－06+206	141	Embankment washed away
⑨	07+625－08+000	375	Embankment washed away
⑩	11+489－11+577	88	Embankment washed away
⑪	13+262	—	Slope failure due to scouring
⑫	14+885－14+925	—	Erosion of riverbank
⑬	18+558－18+581	23	Embankment washed away
⑭	21+015－21+056	41	Embankment washed away
⑮	22+915	—	Slope failure due to scouring

The design of the restoration works was basically carried out as per the original design criteria for the basic design study of section IV in 1996. However, because it was judged that the damage in the July 2002 flood was mainly caused by a complicated and unforeseen hydrological mechanism triggered by prolonged, heavy and incessant rain, the design was done with consideration of those hydrological conditions.

Restoration Policy	Description
Horizontal Alignment	Along the damaged area, the horizontal alignment will be moved up the mountain side as far as the right of way allows for the purpose of reducing the impact of the Roshi River current on revetment structures.
Vertical Alignment and DBSD	Along the damaged sections lying below H.W.L.+ freeboard subject to high runoff, the vertical alignment will be moved up to reduce the erosive impact of surface water and overtopping river flow. For stretches not subject to high runoff flowing over it and/or the move-up of the alignment force to destroy the existing structures, only DBSD (Double Bituminous Surface Dressing) will be applied to protect the road surface rather than moving the alignment.
Cross Section	Embedment level： 2.0 m in conjunction with foot protection works Boulder and rubble are used for backfilling material to lower the residual water level. In two sections having damaged high slope under the road, compound wall, crib works and earth nailing will be applied.
Drainage works	Pipe culverts used as cross drainage will be moved up to prevent them from being flooded. Pipe culverts will be oriented to point down stream to some degree.
Foot Protection	As a countermeasure to suction, foot protection structures will be applied. ・For sections with design flow velocity 7 m/s: weight 13.8 t, height 1.2m per concrete block ・Design flow velocity 6 m/s: weight 10.3 t, height 0.9 m per concrete block ・Design flow velocity 5 m/s: weight 6.9 t, height 0.6 m per concrete block

For the implementation of the Project of Urgent Rehabilitation under the Japanese Grant Aid Scheme, the tendering and the construction will be commenced after Exchange of Notes between the GOJ and HMG/N. The implementation period of the Project is estimated to be 4 months for the pre-construction and 16 months for the construction work.

The beneficiary population for the Sindhuli Road Project is estimated to be about 5.54 million. This is equivalent to the estimated total population of the area along the Sindhuli Road and the eastern area of Kathmandu valley.

The direct effect of the public opening of Section IV is to reduce the travel time between Dhulikel and Nepalthok and to enable passage of vehicles throughout the year. A bus service of 2–4 buses an hour (1 direction, 32 buses per 12 hour, November 2002), has been operated on the partially open section between Dhulikel and Bhakundebesi, and is now an important means of travel for local inhabitants. After opening of the whole of Section IV, it is anticipated that a similar bus service will be operated between Bhakundebesi and Dhulikel.

In addition to the above, the opening of Sindhuli Road Section IV is expected to:

- expand the sphere of the market economy, encouraging cash crop plantations in areas where market accessibility is expected to be improved due to opening of the project road;
- secure the supply of essential provisions such as salt, rice and oil, to the hilly areas; the supply is unstable at present using such means as porters or animals due to luck of vehicular access;
- reduce the burden of labour on women and children in the transportation of materials such as agriculture products, fuel, feed for domestic animals, and so on;
- enable development in the areas neighboring the project road with the opening of access roads and bridges connecting to the former in the long term;
- enhance the welfare of rural people with the opening of hospitals and public facilities in areas where none of these facilities currently exist.

As mentioned above, the Sindhuli Road Construction Project will produce great positive impact on the nation and will enhance the supply of basic human needs to the surrounding areas. Therefore, it is recommendable that the Project for Urgent Rehabilitation of Section IV, which will promote the early connection of the whole of the Sindhuli Road, should be implemented under the Japanese Grant Aid Scheme. However, in order to ensure the permanent usage and maintenance of the Sindhuli Road, it is recommended that HMG/N should undertake the following works:

- Maintain the slope protection along the Sindhuli Road in good condition by taking necessary measurers, such as prohibition of illegal quarrying of gravel and sand.
- Promote the quarrying of river gravel, sand and boulder on the upstream side of causeways
- Take necessary measures to remove sedimentary sand and gravel of islands/bars in the Roshi River to secure an adequate sectional area for river flow requirements.

BASIC DESIGN STUDY REPORT
ON
THE PROJECT
FOR
URGENT REHABILITATION OF
SINDHULI ROAD (SECTION IV)
IN
THE KINGDOM OF NEPAL

Contents

Preface
Letter of Transmittal
Location Map and Photo
List of Tables and Figures
Summary

CHAPTER 1 BACKGROUND OF THE PROJECT 1-1

CHAPTER 2 DAMAGES CAUSED BY INCESSANT RAIN ON JULY 2002 2-1

2.1. State of Section IV Project before the Event 2-1
2.2. Contents of the Damages and Restoration Works 2-3
2.2.1. Damaged Sections 2-3
2.2.2. Modified Scope of Works for Section IV Phase 2 Project 2-3
2.3. Verification of Recent Flood Event 2-14
2.3.1. Verification of Recent Flood Event 2-14
2.3.2. Validation of Estimated Flood 2-20

CHAPTER 3 CONTENS OF THE PROJECT 3-1

3.1. Basic Concept of the Project 3-1
3.1.1. Objectives of the Sindhuli Road Construction Project 3-1
3.1.2. Objective of the Project 3-1
3.1.3. Description of the Project 3-1
3.2. Basic Design of the Requested Japanese Assistance 3-4
3.2.1. Assumed Causes of the Failures 3-4
3.2.2. Restoration Policy 3-12
3.2.3. Design Policy of Revetment Works 3-12
3.2.4. Basic Plan 3-26
3.2.5. Comparison between design details of this project and the original plan of Section IV 3-29

3.2.6. Basic Design Drawing 3-32
3.2.7. Construction Plan 3-48
3.3. Obligations of Recipient Country 3-53
3.4. Operation and Maintenance Plan 3-54

CHAPTER 4 PROJECT EVALUATION AND RECOMMENDATIONS 4-1

4.1. Project Effects 4-1
4.2. Recommendations 4-2

Appendices

Appendices 1 Member List of the Study Team
Appendices 2 Study Schedule
Appendices 3 List of Parties Concerned in the Recipient Country
Appendices 4 Minutes of Discussion
Appendices 5 Tentative Cost Estimation Born by the HMG/N
Appendices 6 Engineering Supporting Data

CHAPTER 1

BACKGROUND OF THE PROJECT

CHAPTER 1 BACKGROUND OF THE PROJECT

The Kingdom of Nepal, a landlocked country, heavily depends on the road network as a vertical means of transportation and a lifeline for its economic development

The development of the national road network in Nepal started from 1950. Since then, Nepal has developed a network of 15,857 km of roads across the country. To date, 14 out of the 75 districts of Nepal are still deprived of roads and 70 percent of the existing road network is unpaved.

In order to achieve the objectives set forth by the ninth five-year plan and reduce the transportation costs within the country, the expansion of the road network and the maintenance and improvement of the existing roads are the main issues related to transport development in Nepal.

Presently, there are the two transport routes (Tribhuvan Highway and Prithivi Highway) connecting Kathmandu with Terai Plain. These two highways which meet at Naubise, 26km west of Kathmandu, have been largely used for imports from India and agricultural products from Terai. However, the Prithvi Highway has been used as the better alternative route because of its two-lane width and acceptable alignment (not winding).

Although, Prithivi Highway is the main life-line of the country, linking Kathmandu to other parts of the nation, it is still vulnerable to disruption of traffic due to landslides and/or bank erosion during the rainy season. A water induced disaster in July 1993 and a huge landslide at Krishnebhir are two examples of past events that have completely stopped traffic to and from the Kathmandu for several days. For traffic between Kathmandu and the mid and eastern development regions of Nepal, it is an extra 200km traveling towards the west of Kathmandu, if the Prithvi Highway were used.

Considering the above points, His Majesty's Government of Nepal (HMG/N) recognized the necessity of a second road life-line linking Kathmandu and Terai Plain and has formulated the Sindhuli Road Construction Project. This Project has been planned to link Bardibas, at mid-regional development zone along the East-West Highway, with Dhulikel along the Kodari Highway located 31 km east of Kathmandu. The Project road is divided into four sections: Section I: Bardibas to Sindhuli Bazar with a total length of 37 km, Section II: Sindhuli Bazar to Khurkot with a total length of 39 km length, Section III: Khurkot to Nepalthok with a total length of about 32km and Section IV: Nepalthok to Dhulikel with a total length of 50 km.

In response to a request from HMG/N, the Government of Japan (GOJ) decided to conduct a Feasibility Study (F/S) for the Project. Japan International Cooperation Agency (JICA) carried out the F/S during the period between 1986 and 1988. The Final Report concluded that the Project was both economically and technically feasible; however, implementation of the Project has not materialized due to the budgetary reasons and a political impasse between Nepal and India.

Despite these constraints, HMG/N has persistently given high priority to the implementation of the Project and thus requested the GOJ for grant aid assistance for the following components of the Project:

- Review of the Feasibility Study
- Construction of bridges and its approach roads in Section I
- Procurement of construction equipment and materials for Section II, Section III and Section IV
- Procurement of consulting services for the Project

In response to the request from HMG/N, the GOJ decided to conduct a study to formule practical and realistic restoration schemes and implementation programs based on the review of the previous Feasibility Study (F/S), entitled the Aftercare Study. JICA carried out the Aftercare Study during the period between 1992 and 1993. The final report of the Aftercare Study recommended an optimum development scheme minimizing initial construction costs by introducing a staged construction concept. Based on the recommendation of the Aftercare Study, the GOJ conducted basic design studies for the Project for Construction of Sindhuli Road (Section I: Bardibas - Sindhuli Bazar), the Project for Construction of Sindhuli Road (Section IV: Nepalthok - Dhulikel) and the Project for Construction of Sindhuli Road (Section II: Sindhuli Bazar - Khurkot)

The construction of Section I, consisting of the construction of 9 bridges, 17 causeways and procurement of maintenance equipment for the project road, was implemented during 1996 to 1998.

Similarly, the construction of Section IV, consisting of the construction of 50km of road and procurement of maintenance equipment for the project road, was started in 1997. Section II, consisting of the construction of 39km of road, was started in 2000.

In the year 2002, incessant rain from July 21st to 23rd caused flooding and landslides in different parts of the Kingdom of Nepal, causing a number of casualties and heavily damaging public and private properties. Newspapers reported that almost two-thirds of the districts in the country had been affected by this incessant rain resulting in widespread floods and landslides.

The floods and landslides also disrupted vehicle movements on major highways and other important roads in the country.

Unfortunately, during that period, the heavy rain severely damaged Section IV (Nepalthok – Dhulikel) of the Project. The damage was mainly due to flooding and scouring of riverbanks and slope failures in cut slopes along the road alignment.

The defect liability period of the portion of road from Dhulikel (STA.50+080) to STA.15+000 of Phase-1 under Section IV was completed on May 2002. The Departments of Roads (DOR) has also taken over the road up to STA. 7+900, a portion of Phase-2 (Section IV) and opened to the public up to STA. 9+525 from July 2002. While for the rest of Phase-2, construction has been underway and the DOR have scheduled to conduct the Taking-Over Inspection by November 2002. However, because of this natural disaster, the Project is compelled to postpone the Taking-Over Inspection for some months.

The incessant rain caused unforeseen floods and riverbed-scour of the Rosi River, debris flow from tributary rivers and slope failures in hill areas have occurred at many places from STA. 0+000 at Nepalthok to STA. 21+000 near the Laskot Khola Causeway in the Section IV. In addition, the landslides on the opposite bank of the road have formed a huge fan in the river course, which might have caused higher flood levels and deeper scour than before as a result of a reduction in the capacity of some river-sections. Floods and excessive bed scour have damaged and collapsed many bank protection structures along the Rosi River. Particularly, serious damages and collapse have occurred at the river bends and in its vicinity, from STA. 0+000 at Nepalthok to STA. 8+000 at Dalabeshi.

A preliminary cost estimate for restoration of the damaged sections of the road suggests that the allocated budget for Section IV Phase 2 of the Project could not allow completion of the Project.

Being a high priority, HMG/N intends to complete the Project by the end of its 10th Plan (2003-2008) according to “20 YEAR ROAD PLAN, 2002” by the Department of Roads (DOR), Ministry of Physical Planning and works (MOPPW). HMG/N therefore requested from the GOJ a further grant aid for the Urgent Rehabilitation of Sindhuli Road Construction Project (Section IV Dhulikel - Nepalthok) in September 2002. In response to the request, the GOJ decided to conduct a basic design study for the Urgent Rehabilitation of Sindhuli Road Construction Project (Section IV Dhulikel - Nepalthok).

CHAPTER 2

DAMAGES CAUSED BY

INCESSANT RAIN ON JULY 2002

CHAPTER 2 DAMAGES CAUSED BY INCESSANT RAIN ON JULY 2002

2.1. State of Section IV Project before the Event

The state of Section IV project as of July 20, 2002 at various location and the responsible parties are summarized in Table 2-1 and Figure 2-1

Table 2-1 State of Section IV Project as of July 20, 2002

Section	Progress of Projects	Traffic for Public	Responsibilities
STA.00+000 to STA.10+000	Under construction in Phase 2	Not opened	Contractor
STA.10+000 to STA.15+000	Under construction in Phase 2	Opened	Contractor except for maintenance of pavement and securing traffic safety measures borne by DOR
STA.15+000 to STA.18+700	Completion of construction and defects liability in Phase 1 and under construction in Phase 2	Opened	Contractor except for maintenance of pavement, drainage and securing traffic safety measures borne by DOR
STA.18+700 to STA.50+000	Completion of construction and defects liability in Phase 1	Opened	DOR

Since responsible parties and progress of projects are different in each section as mentioned in Table 2-1, it is necessary to deal with each section classified, as follows, by different measures for restoration works.

- Between STA.00+000 and STA.15+000: Section to be restored by the Phase-2 Project
- Between STA.15+000 and STA.18+700: Section to be restored by the Phase-2 project or DOR
- Between STA.18+700 and STA.50+000: Section to be restored by DOR

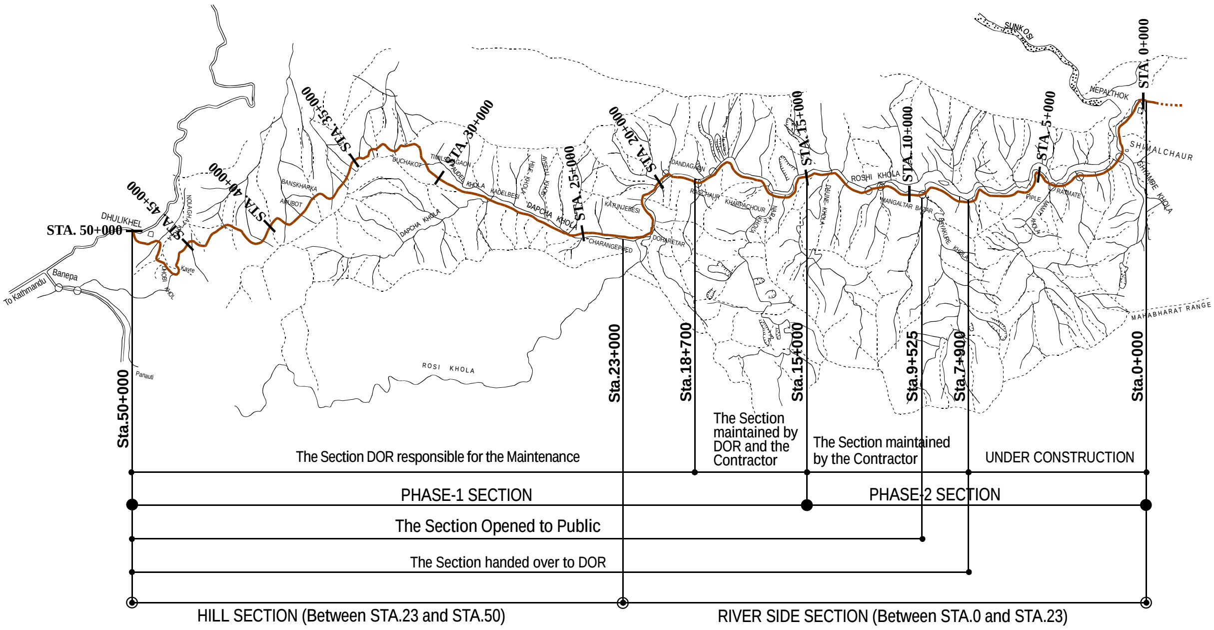


Figure 2-1 State of Section IV Project as of July 20, 2002

The direct cost as of July 20, 2002 had reached 97.1% of total contract price. Works completed till July 20, 2002 is shown in Figure 2-2.

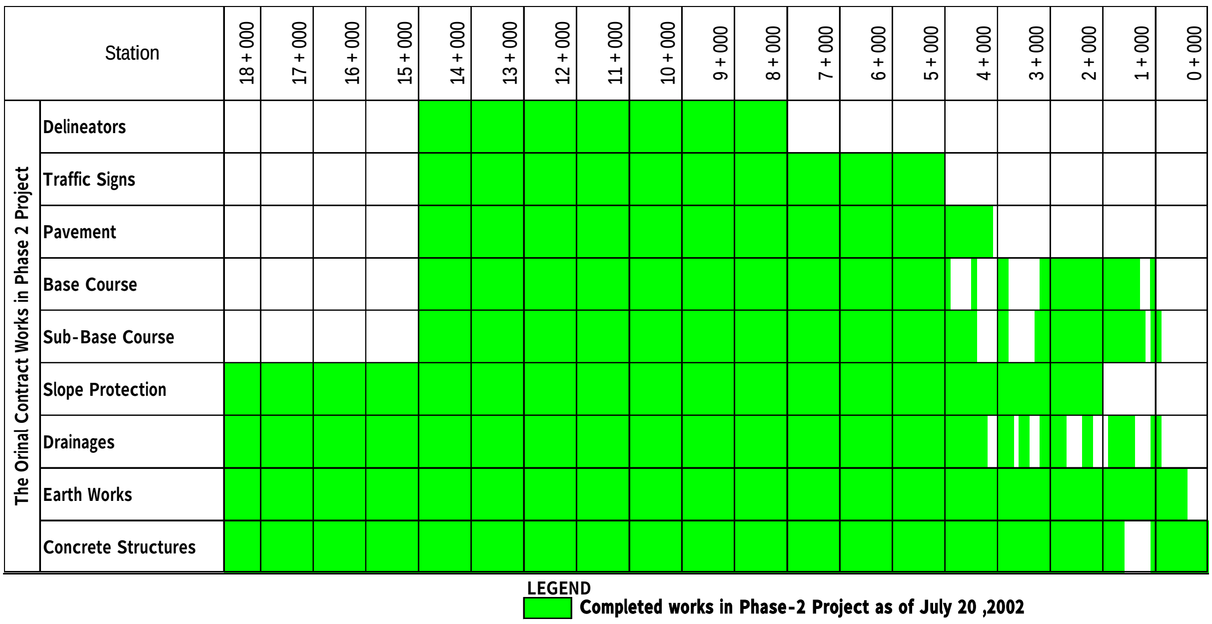


Figure 2-2 Completed works of Section IV Phase 2 Project till July 20, 2002

2.2. Contents of the Damages and Restoration Works

2.2.1. Damaged Sections

Damages in Section IV can be divided broadly into two categories, namely hillside and riverside. In hillside category, for the alignment of road between STA. 23 and STA. 50, damages are mainly due to landslide and slope failure, along with settlement of wall structures at several points.

On the other hand, in the Roshi river portion of the road between STA. 0 and STA. 23, the causes of damages are mainly from scouring and washing away of road structure by flooding, avalanche debris and landslides.

Table 2-2 shows the types and number of damage along Section IV.

Table 2-2 Types and Number of Damage along Section IV

Station		Description of Damages	Number of damages	
Roshi River section	STA.00+000 — STA.23+000	Washing away of Revetment structures	17	66
		Settlement of road surface	6	
		Landslide and slope failure	17	
		Debris flow	6	
		Others	20	
Mountainous Section	STA.23+000 — STA.50+000	Landslide	72	
		slope failure		
		Settlement of wall structure		
Total			138	

2.2.2. Modified Scope of Works for Section IV Phase 2 Project

(1) Party in charge and progress of restoration

After the incessant rain in July, 2002, the DOR in HMG/N and the Contractor conducted temporary and permanent restoration works in order to prevent the expansion of damage and disruption of traffic flow. However the HMG/N could not conduct restoration works at several damaged sites such as around STA. 21+030 and STA. 22+900 in the Phase 1 project because of their scale and size. Table 2-3 describes their station and a description of damages along the party-in-charge of the restoration works and their progress. Figure 2-3 to Figure 2-6 describes the location of damages.

Table 2-3 Party in charge and progress of Restoration

No.	Damaged section	Length (m)	Description of Damages	Party in charge	
				Phase-2 PJT	DOR
1	00+320—00+355	25	Slope failure due to scouring	○	
2	00+370—00+455	85	Embankment washed away	Unattainable for Phase-2 and DOR	
3	00+645—00+680	35	Landslide	○	
4	00+642—00+652	10	Overturning of revetment	○	
5	00+690—00+720	30	Settlement of road surface	●	
6	00+997—01+009	12	Settlement of road surface	●	
7	01+175—01+550	—	Debris deposition at causeway	●	
8	01+550—01+757	207	Damage on side ditch	○	
9	03+050—03+096	—	Debris deposition at causeway	●	
10	03+370—03+730	360	Embankment washed away	Unattainable for Phase-2 and DOR	
11	03+915—03+972	—	Debris deposition at causeway	●	
12	04+245—04+360	115	Embankment washed away	Unattainable for Phase-2 and DOR	
13	05+075—05+135	60	Overturning of revetment	Unattainable for Phase-2 and DOR	
14	05+190—05+205	15	Scour of wall foundation	Unattainable for Phase-2 and DOR	
15	05+245—05+269	24	Fallen rocks	●	
16	05+300—05+461	161	Embankment washed away	Unattainable for Phase-2 and DOR	
17	05+500—05+560	60	Overturning of revetment	Unattainable for Phase-2 and DOR	
18	06+065—06+206	141	Embankment washed away	Unattainable for Phase-2 and DOR	
19	06+273—06+283	10	Landslide	●	
20	06+500—06+586	86	Landslide	●	
21	06+715—06+750	35	Slope failure	●	
22	07+475—07+500	25	Rock failure	●	
23	07+560—07+574	14	Settlement of road surface	●	
24	07+625—08+000	375	Embankment washed away	Unattainable for Phase-2 and DOR	
25	08+180—08+490	—	Contractor's facilities washed away	●	
26	09+160—09+190	30	Landslide	●	
27	09+269—09+330	31	Landslide	●	
28	09+643—09+757	—	Debris deposition at causeway	●	
29	09+775—09+881	106	Erosion of road surface	○	
30	10+064—10+116	42	Debris deposition at causeway	●	
31	10+425	—	Damage of pipe culvert	●	
32	10+445—10+445	—	Settlement of road shoulder	●	
33	10+855—10+885	30	Slope failure	●	
34	11+096—11+226	130	Debris deposition at causeway	●	

No.	Damaged section	Length (m)	Description of Damages	Party in charge	
				Phase-2 PJT	DOR
35	11+500－11+540	40	Landslide	●	
36	11+489－11+577	88	Embankment washed away	Unattainable for Phase-2 and DOR	
37	11+627－11+636	9	Depression of road surface	●	
38	12+464－12+479	15	Depression of road surface	●	
39	12+900	—	Rock failure	●	
40	13+130	—	Collapse of revetment at Daune Br. A1	●	
41	13+262	—	Slope failure due to scouring	Unattainable for Phase-2 and DOR	
42	13+475	—	Overturning of revetment around foundation of existing suspension Br.	○	
43	13+663－13+935	272	Settlement of road surface	●	
44	14+885－14+925	40	Erosion of riverbank	Unattainable for Phase-2 and DOR (Temporary revetment work have only been conducted by DOR)	
45	15+630	—	Settlement of road surface around Narake Br. A1	●	
46	15+690	—	Overturning of revetment around Narake Br. A2	●	
47	16+010	—	Erosion of road shoulder	●	
48a	16+262	—	Damage of irrigation canal	●	
48b	16+710－16+725	15	Scour of wall foundation	○	
49	16+780－16+950	170	Settlement of road surface	●	
50	18+558－18+581	23	Embankment washed away	Unattainable for Phase-2 and DOR (Temporary revetment work have only been conducted by DOR)	
51	18+620－18+787	167	Settlement of road surface	●	
52	18+695 & 18+725	—	Damage of pipe culvert	●	
53	18+970	—	Debris deposition at causeway		●Removal of Debris
54	19+730－19+740	10	Scour of wall foundation	○	
55	19+754－19+799	45	Damage of wall, Rock collapse		△(Removal of Debris)
56	19+800－19+804	—	Damage of wall, Rock collapse		△(Removal of Debris)
57	19+970	—	Damage of irrigation canal	○	
58	20+010	—	Damage of retaining wall on cut slope	●	
59	20+010	—	Damage of pipe culvert	●	
60	20+350	—	Erosion of slope failure around Roshi Br.	●	
61	20+410	—	Erosion of revetment around Roshi Br.	●	

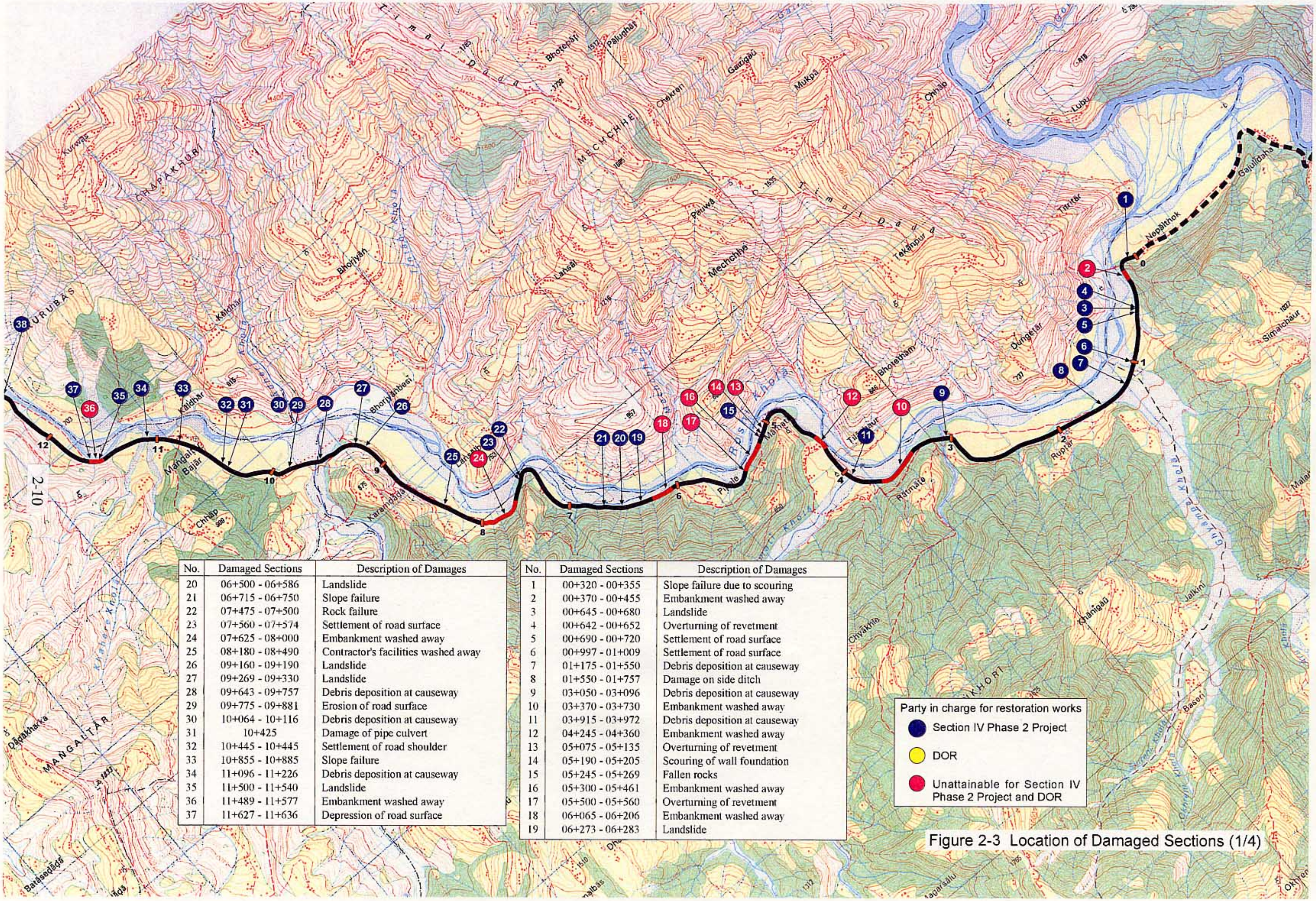
No.	Damaged section	Length (m)	Description of Damages	Party in charge	
				Phase-2 PJT	DOR
62	20+485	—	Damage of irrigation canal	●	
63	20+925	—	Erosion of road shoulder	●	
64	21+020−21+030	—	Damage of side ditch	●	
65	21+015−21+056	41	Embankment washed away	Unattainable for Phase-2 and DOR	
66	22+915	—	Slope Failure due to scouring	Unattainable for Phase-2 and DOR	
67	23+600	—	Settlement of road surface	○	
68	23+675	—	Fallen rocks		●Removal of Debris
69	23+800	—	Settlement of road surface	○	
70	23+950	—	Slope failure		●Removal of Debris
71	26+000	—	Slope failure		●Removal of Debris
72	26+600	—	Settlement of road surface		○
73	26+650	—	Slope failure		●Removal of Debris
74	27+300	—	Slope failure		●Removal of Debris
75	27+775	—	Slope failure		●Removal of Debris
76	27+800	—	Slope failure		●Removal of Debris
77	30+950	—	Slope failure		●Removal of Debris
78	32+250	—	Slope failure		●Removal of Debris
79	32+400	—	Scour of wall foundation	○	
80	32+450	—	Slope failure		●Removal of Debris
81	32+650	—	Slope failure		●Removal of Debris
82	32+675	—	Slope failure		●Removal of Debris
83	33+025	—	Slope failure		●Removal of Debris
84	33+050	—	Slope failure		●Removal of Debris
85	33+200	—	Slope failure		●Removal of Debris
86	33+330	—	Slope failure		●Removal of Debris

No.	Damaged section	Length (m)	Description of Damages	Party in charge	
				Phase-2 PJT	DOR
87	33+800	—	Slope failure		●Removal of Debris
88	33+825	—	Slope failure		●Removal of Debris
89	34+325	—	Slope failure		●Removal of Debris
90	34+600	—	Scour of wall foundation		△
91	35+075	—	Slope failure		●Removal of Debris
92	35+125	—	Slope failure		●Removal of Debris
93	35+325	—	Landslide		●Removal of Debris
94	35+350	—	Slope failure		●Removal of Debris
95	35+700	—	Slope failure		●Removal of Debris
96	36+400	—	Slope failure		●Removal of Debris
97	36+650	—	Slope failure		●Removal of Debris
98	36+750	—	Scour of wall foundation		△
99	37+075	—	Erosion of slope		△
100	37+075	—	Slope failure		●Removal of Debris
101	37+425	—	Slope failure		●Removal of Debris
102	37+475	—	Landslide		●Removal of Debris
103	38+700	—	Landslide		●Removal of Debris
104	38+775	—	Slope failure		●Removal of Debris
105	38+800	—	Landslide		●Removal of Debris
106	39+050	—	Slope failure		●Removal of Debris
107	39+300	—	Slope failure		●Removal of Debris
108	39+350	—	Collapse of Embankment slope		△
109	39+400	—	Slope failure		●Removal of Debris
110	39+475	—	Slope failure		●Removal of Debris

No.	Damaged section	Length (m)	Description of Damages	Party in charge	
				Phase-2 PJT	DOR
111	39+600	—	Slope failure		●Removal of Debris
112	39+750	—	Slope failure		●Removal of Debris
113	39+800	—	Landslide		●Removal of Debris
114	40+000	—	Slope failure		●Removal of Debris
115	40+975	—	Erosion of road shoulder		△
116	41+325	—	Slope failure		●Removal of Debris
117	41+475	—	Scour of wall foundation		△
118	41+475	—	Slope failure		●Removal of Debris
119	41+750	—	Movement of wall		●Removal of Debris
120	41+750	—	Slope failure		●Removal of Debris
121	41+775	—	Slope failure		●Removal of Debris
122	42+750	—	Settlement of wall foundation		△
123	43+450	—	Slope failure		●Removal of Debris
124	44+100	—	Slope failure		●Removal of Debris
125	44+150	—	Landslide		●Removal of Debris
126	44+175	—	Landslide		●Removal of Debris
127	44+925	—	Slope failure		●Removal of Debris
128	45+100	—	Settlement of wall foundation		△
129	45+350	—	Slope failure		●Removal of Debris
130	45+400	—	Slope failure		●Removal of Debris
131	45+700	—	Slope failure		●Removal of Debris
132	45+825	—	Slope failure		●Removal of Debris
133	45+875	—	Slope failure		●Removal of Debris
134	46+125	—	Slope failure		●Removal of Debris

No.	Damaged section	Length (m)	Description of Damages	Party in charge	
				Phase-2 PJT	DOR
135	46+150	—	Slope failure		●Removal of Debris
136	46+475	—	Slope failure		●Removal of Debris
137	46+650	—	Slope failure		●Removal of Debris
138	46+850	—	Slope failure		●Removal of Debris

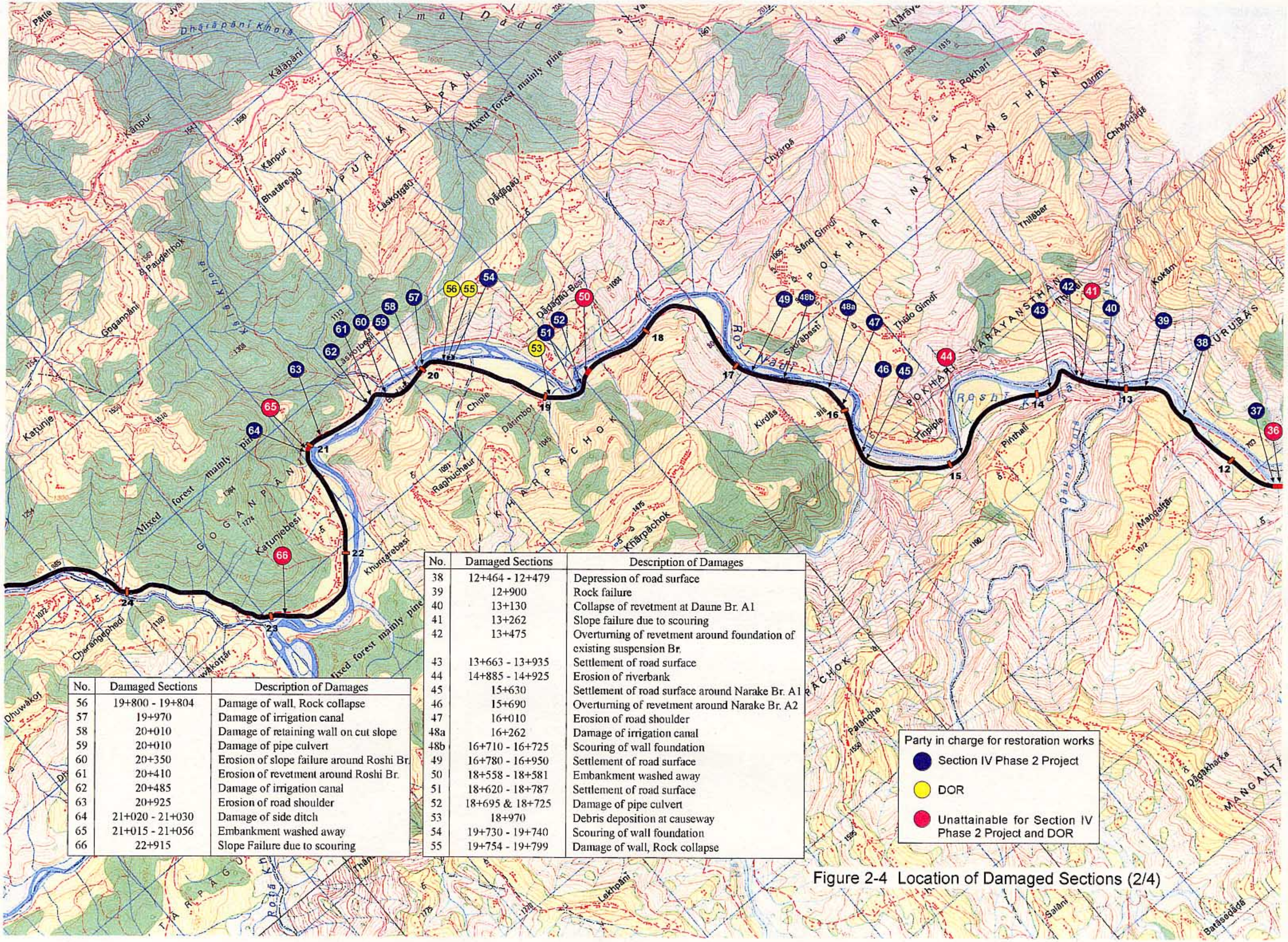
LEGEND：●Completed ○Planned △Planned in the future



No.	Damaged Sections	Description of Damages
1	00+320 - 00+355	Slope failure due to scouring
2	00+370 - 00+455	Embankment washed away
3	00+645 - 00+680	Landslide
4	00+642 - 00+652	Overturning of revetment
5	00+690 - 00+720	Settlement of road surface
6	00+997 - 01+009	Settlement of road surface
7	01+175 - 01+550	Debris deposition at causeway
8	01+550 - 01+757	Damage on side ditch
9	03+050 - 03+096	Debris deposition at causeway
10	03+370 - 03+730	Embankment washed away
11	03+915 - 03+972	Debris deposition at causeway
12	04+245 - 04+360	Embankment washed away
13	05+075 - 05+135	Overturning of revetment
14	05+190 - 05+205	Scouring of wall foundation
15	05+245 - 05+269	Fallen rocks
16	05+300 - 05+461	Embankment washed away
17	05+500 - 05+560	Overturning of revetment
18	06+065 - 06+206	Embankment washed away
19	06+273 - 06+283	Landslide

No.	Damaged Sections	Description of Damages
20	06+500 - 06+586	Landslide
21	06+715 - 06+750	Slope failure
22	07+475 - 07+500	Rock failure
23	07+560 - 07+574	Settlement of road surface
24	07+625 - 08+000	Embankment washed away
25	08+180 - 08+490	Contractor's facilities washed away
26	09+160 - 09+190	Landslide
27	09+269 - 09+330	Landslide
28	09+643 - 09+757	Debris deposition at causeway
29	09+775 - 09+881	Erosion of road surface
30	10+064 - 10+116	Debris deposition at causeway
31	10+425	Damage of pipe culvert
32	10+445 - 10+445	Settlement of road shoulder
33	10+855 - 10+885	Slope failure
34	11+096 - 11+226	Debris deposition at causeway
35	11+500 - 11+540	Landslide
36	11+489 - 11+577	Embankment washed away
37	11+627 - 11+636	Depression of road surface

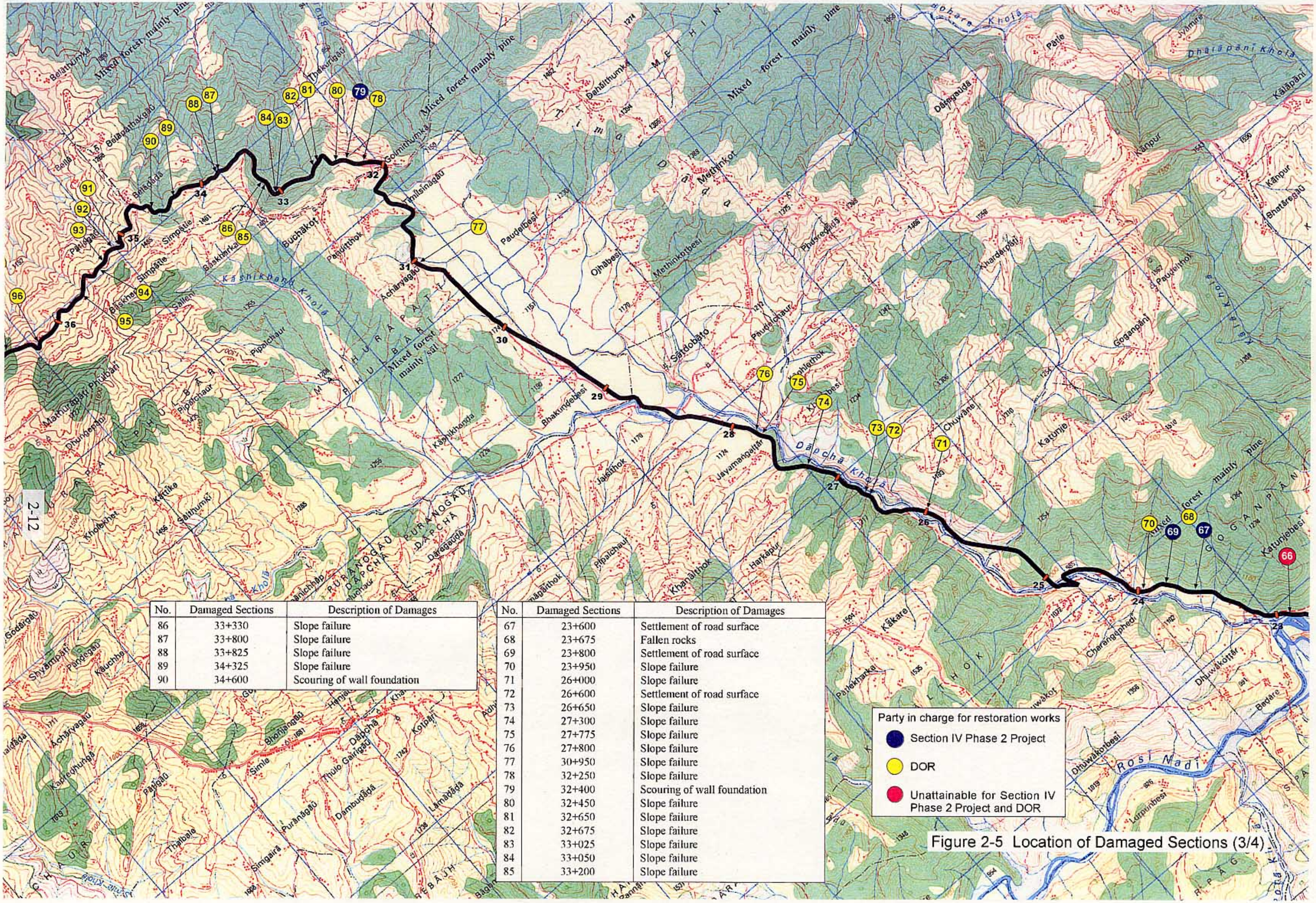
Figure 2-3 Location of Damaged Sections (1/4)



No.	Damaged Sections	Description of Damages
56	19+800 - 19+804	Damage of wall, Rock collapse
57	19+970	Damage of irrigation canal
58	20+010	Damage of retaining wall on cut slope
59	20+010	Damage of pipe culvert
60	20+350	Erosion of slope failure around Roshi Br.
61	20+410	Erosion of revetment around Roshi Br.
62	20+485	Damage of irrigation canal
63	20+925	Erosion of road shoulder
64	21+020 - 21+030	Damage of side ditch
65	21+015 - 21+056	Embankment washed away
66	22+915	Slope Failure due to scouring

No.	Damaged Sections	Description of Damages
38	12+464 - 12+479	Depression of road surface
39	12+900	Rock failure
40	13+130	Collapse of revetment at Daune Br. A1
41	13+262	Slope failure due to scouring
42	13+475	Overturning of revetment around foundation of existing suspension Br.
43	13+663 - 13+935	Settlement of road surface
44	14+885 - 14+925	Erosion of riverbank
45	15+630	Settlement of road surface around Narake Br. A1
46	15+690	Overturning of revetment around Narake Br. A2
47	16+010	Erosion of road shoulder
48a	16+262	Damage of irrigation canal
48b	16+710 - 16+725	Scouring of wall foundation
49	16+780 - 16+950	Settlement of road surface
50	18+558 - 18+581	Embankment washed away
51	18+620 - 18+787	Settlement of road surface
52	18+695 & 18+725	Damage of pipe culvert
53	18+970	Debris deposition at causeway
54	19+730 - 19+740	Scouring of wall foundation
55	19+754 - 19+799	Damage of wall, Rock collapse

Figure 2-4 Location of Damaged Sections (2/4)



No.	Damaged Sections	Description of Damages
86	33+330	Slope failure
87	33+800	Slope failure
88	33+825	Slope failure
89	34+325	Slope failure
90	34+600	Scouring of wall foundation

No.	Damaged Sections	Description of Damages
67	23+600	Settlement of road surface
68	23+675	Fallen rocks
69	23+800	Settlement of road surface
70	23+950	Slope failure
71	26+000	Slope failure
72	26+600	Settlement of road surface
73	26+650	Slope failure
74	27+300	Slope failure
75	27+775	Slope failure
76	27+800	Slope failure
77	30+950	Slope failure
78	32+250	Slope failure
79	32+400	Scouring of wall foundation
80	32+450	Slope failure
81	32+650	Slope failure
82	32+675	Slope failure
83	33+025	Slope failure
84	33+050	Slope failure
85	33+200	Slope failure

Figure 2-5 Location of Damaged Sections (3/4)

No.	Damaged Sections	Description of Damages
116	41+325	Slope failure
117	41+475	Scouring of wall foundation
118	41+475	Slope failure
119	41+750	Movement of wall
120	41+750	Slope failure
121	41+775	Slope failure
122	42+750	Settlement of wall foundation
123	43+450	Slope failure
124	44+100	Slope failure
125	44+150	Landslide
126	44+175	Landslide
127	44+925	Slope failure
128	45+100	Settlement of wall foundation
129	45+350	Slope failure
130	45+400	Slope failure
131	45+700	Slope failure
132	45+825	Slope failure
133	45+875	Slope failure
134	46+125	Slope failure
135	46+150	Slope failure
136	46+475	Slope failure
137	46+650	Slope failure
138	46+850	Slope failure

No.	Damaged Sections	Description of Damages
91	35+075	Slope failure
92	35+125	Slope failure
93	35+325	Landslide
94	35+350	Slope failure
95	35+700	Slope failure
96	36+400	Slope failure
97	36+650	Slope failure
98	36+750	Scouring of wall foundation
99	37+075	Erosion of slope
100	37+075	Slope failure
101	37+425	Slope failure
102	37+475	Landslide
103	38+700	Landslide
104	38+775	Slope failure
105	38+800	Landslide
106	39+050	Slope failure
107	39+300	Slope failure
108	39+350	Collapse of Embankment slope
109	39+400	Slope failure
110	39+475	Slope failure
111	39+600	Slope failure
112	39+750	Slope failure
113	39+800	Landslide
114	40+000	Slope failure
115	40+975	Erosion of road shoulder

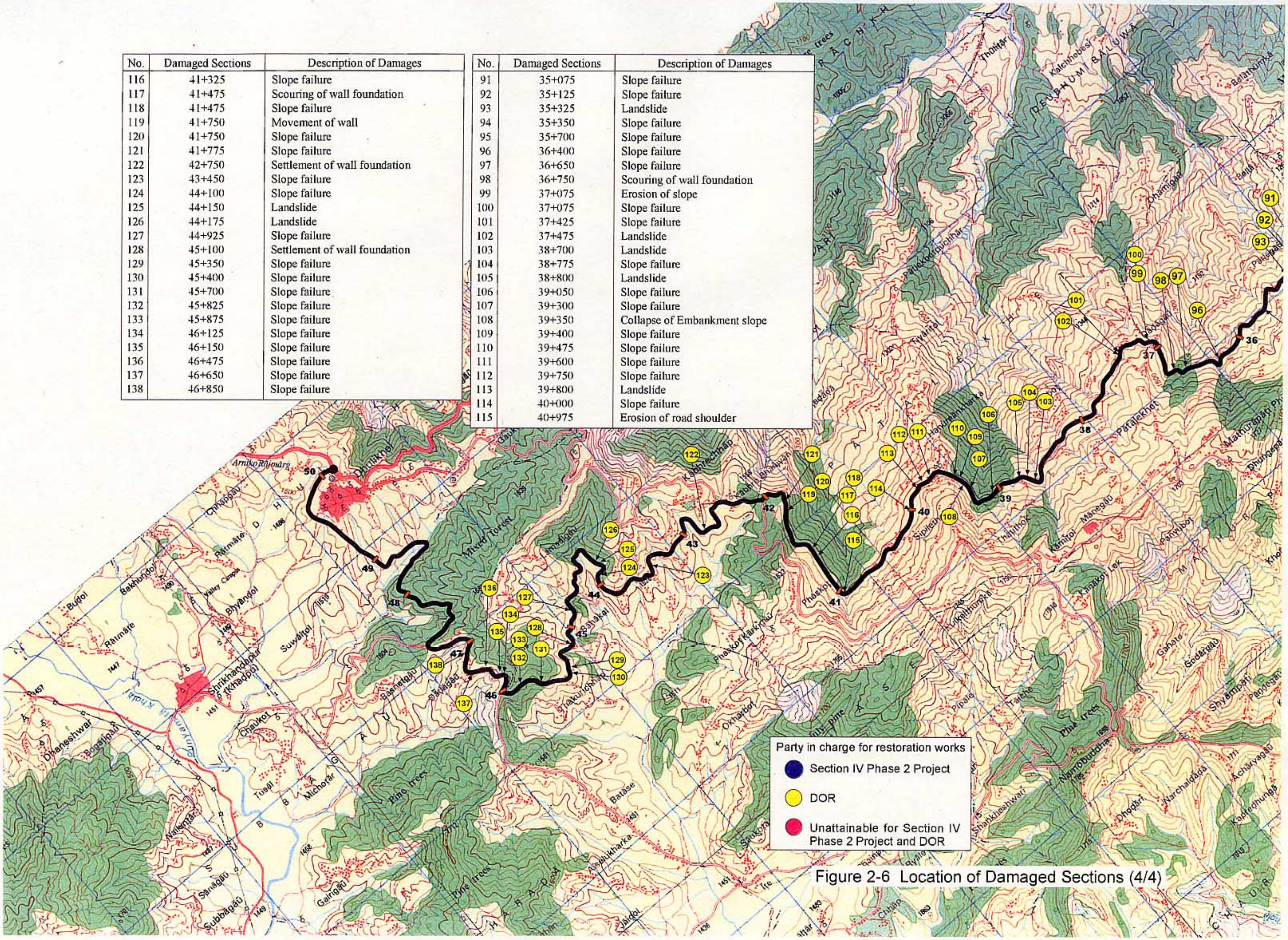


Figure 2-6 Location of Damaged Sections (4/4)

(2) Attainable restoration works in Section IV Phase 2 Project

The break down of works at Section IV Phase2 Project, that can be achieved by a total sum of the direct cost available to the project from the remainder of direct costs as of July 2002 and Contractor’s insurance, is illustrated in Figure 2-7 below.

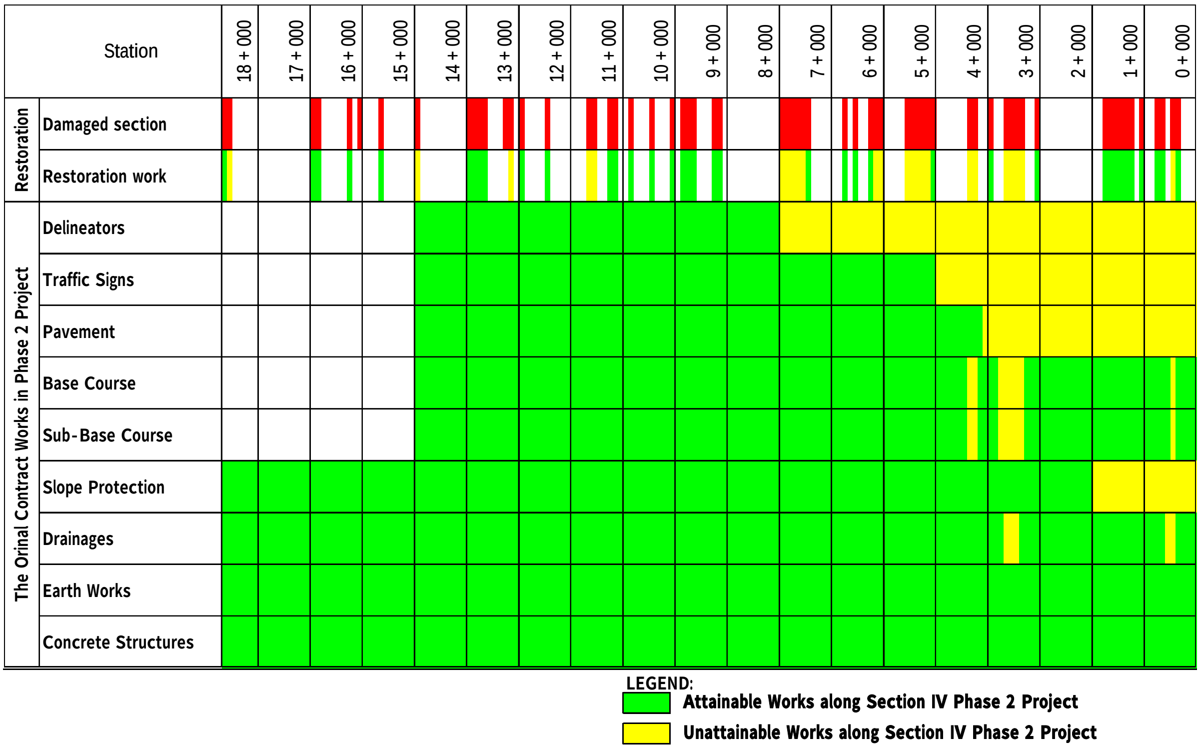


Figure 2-7 Attainable Works along Section IV Phase 2 Project

2.3. Verification of Recent Flood Event

2.3.1. Verification of Recent Flood Event

(1) General

The target area for this urgent rehabilitation project lies along the Roshi River in the stretch between the Dapcha River confluence and Nepalthok. The catchments areas vary from 400 km2 to 560 km2. A 50-year return period discharge was selected as the design flood level for the target area of the Road Project in the previous design report. The flood Study was carried out using the instantaneous flood peak discharge of the Roshi River at the Panauti runoff gauging station with catchments area of 87 km2, this being the only available data in the target area. Since the Panauti runoff gauging station had already been closed, observed data on the recent flood event of July 2002 was unavailable. Therefore, the estimation of the recent flood event was sought using rainfall runoff relationship of the basin.

(2) Historical rainfalls

Daily precipitation records in and around the Roshi River Basin have been observed by Department of Hydrology and Meteorology (hereinafter referred to as DHM) since 1947. The data is available for the period from January 1948 to August 2002.

The records from the five rain gauge stations, viz. Godavari, Dhulikel, Nagarkot, Khopasi (Panauti) and Nepalthok, are available for the analysis of the precipitation over the Roshi River Basin. Table 2-4 shows the availability of precipitation data in and around the target river basin of the Project.

Table 2-4 Available Daily Rainfall Records

Gauge station No.	Name	Period
1022	Godavari	Jan.1953 to Aug. 2002
1024	Dhulikel	Jan.1948 to Aug. 2002
1043	Nagarkot	Jan.1971 to Aug. 2002
1049	Khopasi	Jan.1971 to Aug. 2002
1115	Nepalthok	Jan.1948 to Aug. 2002

(3) Precipitation Analysis

1) Average Precipitation in the Roshi River Basin

The daily average precipitation over the river basin was estimated using the Thiessen polygon method. Three patterns of the Thiessen polygons were prepared for estimation since the observations on those stations were started in the different years. The analysis was carried out using observed data from January 1948 to August 2002. The time period for each observed data set for each Thiessen polygon pattern and Thiessen weights are listed in Table 2-5.

Three patterns of the Thiessen polygons are drawn for stations distributed over the runoff contributing area and are shown in Appendix-6.

Table 2-5 Thiessen Polygon Sets and Their Weights

Pattern	Period	Station				
		1022 Godavari	1024 Dhulikel	1043 Nagarkot	1049 Khopasi	1115 Nepalthok
1	Jan.1948 to Dec.1952	-	0.772	-	-	0.278
2	Jan.1953 to Dec.1970	0.172	0.550	-	-	0.278
3	Jan.1971 to Aug.2002	0.098	0.177	0.033	0.417	0.276

2) Frequency Analysis

Several frequency analysis methods such as log-normal distribution (Iwai's method and Moment method), Gumbel distribution, GEV distribution, SQRT-ET distribution, log-Pearson Type III and exponential distribution (Moment method) were used as per new Japanese Criteria for estimating rainfall amount for various return periods.

Selection of the probability distribution model was done in accordance with Japanese Criteria. The evaluation parameters and their standard values used for the selection of distributions are as follows;

Table 2-6 Evaluation Parameters and Standard Value of Probability Distribution Model

Evaluation Items		Standard Value	Level of importance
Fit index	SLSC	blow 0.04	high
	CORX	above 0.99	low
	CORP	above 0.99	low
Stability	JACE	curve evaluation	high

The return period of various precipitation duration predicted by each method is shown in Appendix -6

The SQRT-ET distribution method was adopted in this study for the prediction of return periods based on the above evaluation. In addition, the result based on Gumbel distribution, which was applied to in the original design, was mentioned for reference.

The probable precipitation in the target river basin is listed as follows;

Table 2-7 Probable Average Precipitation over the Target River Basin

Return Period	1-day (mm)		2-days (mm)		3-days (mm)	
	SQRT-ET	Gumbel	SQRT-ET	Gumbel	SQRT-ET	Gumbel
2	71	73	107	111	128	133
5	99	101	152	156	180	185
10	119	119	186	186	220	219
20	140	137	221	215	261	252
30	153	147	242	231	286	271
50	170	159	270	252	318	295
70	181	167	289	266	340	311
100	194	176	310	280	365	327
150	208	186	335	296	393	346
200	229	193	352	307	414	359

3) Analysis of Recent Rainfall Event

The average precipitation of the target river basin during July 2002 is estimated using precipitation data on selected five stations and the Thiessen polygon weights.

In the preliminary study, the maximum flood peak discharge was estimated as the maximum run off rate produced by a 3 day maximum rainfall. In this study also, a 3-day rainfall event was therefore chosen as the design storm for analysis.

The return period of the recent torrential rainfall event is summarized below:

Table 2-8 Return Period of the Recent Torrential Rainfall Event

Duration	Recent Precipitation (mm)	Period	Return Period (years)
3-day	312	21-23rd July	50

As seen from the above table, the return period for recent flood events based on the rainfall records from January 1948 to August 2002 is estimated around 50-years.

(4) Estimation of Flood

The estimation of recent flood was carried out using various standard methods to evaluate the adopted design flood for the project.

1) Estimation of Rainfall Intensity

The rainfall intensity, for various duration of river basin under study, was estimated using frequency analysis. Since hourly precipitation records are not available, the 1-hour duration rainfall intensity was predicted using Kawakami's Equation.

The rainfall intensities for various durations are listed below:

Table 2-9 Rainfall Intensity of Target River Basin

Distribution	Return Period (years)	Rainfall Intensity (mm)			
		1-hour	24-hour	48-hour	72-hour
SQRT-ET	5	17.5	4.4	3.1	2.5
	10	21.0	5.0	3.7	3.1
	20	25.0	6.0	4.4	3.7
	30	26.9	6.7	4.8	4.0
	50	30.0	7.5	5.4	4.4
	100	35.0	8.4	6.1	5.1
	150	38.0	9.1	6.7	5.6
Gumbel	5	18.0	4.3	3.2	2.6
	10	21.0	5.0	3.7	3.1
	20	24.0	5.7	4.2	3.5
	30	26.0	6.2	4.6	3.8
	50	27.7	6.9	5.0	4.1
	100	29.2	7.3	5.3	4.3
	150	30.8	7.7	5.5	4.6

2) Estimation of Flood

Using model hyetograph, prepared with the help of estimated rainfall intensities for various durations, the 50 year return flood period was determined. The storage function method was used for this purpose. The appropriate value of the coefficient of storage function was adopted taking into consideration of topography, geology and the existing vegetation of the basin under study. These are presented in Table 2-10 below.

Table 2-10 Coefficient of Storage Function Method

Item		Mark	Value	Note
Coefficient of Storage Function	proportion	k	40.3	
	exponent	P	0.5	
Primary Runoff Coefficient		f1	0.9	In accordance with Japanese Criteria
Saturated Rainfall Coefficient		Ra	100	
Saturated Runoff Coefficient		f	1.0	

Summary of the result and comparison with previously adopted design floods is presented below in Table 2-11.

Table 2-11 Comparison and Summary of Results

Items	Previous Design (B/D)			This Study	
Method of flood analysis	Using specific flood discharge obtained from Panauti GS.			Storage Function Method	
Data Type	Runoff peak discharge at Panauti GS.(CA=87km^2)			Daily precipitation records in and around the target river basin (CA=560km^2) *Intensity duration frequency (IDF) model. $I_{50} = \frac{39}{t^{0.5} + 0.3}$	
Period	Jan.1964 to Dec. 1985			Jan 1964 to Aug.2002	
Probability Distribution Model	Gumbel method			SQRT-ET Method	
Probable Flood Discharge (m3/s)	Location	CA (km^2)	Q_{50} (m^3/s)	Q_{50}(m^3/s)	
				SQRT-ET	Gumbel
	Dapcha	400km^2	774	977	867
	Narke	446km^2	861	1,086	964
	Daune	465km^2	899	1,130	1,005
	Bhyakure	503km^2	972	1,213	1,079
	Mamuti	536km^2	1,035	1,289	1,148
	Nepalthok	560km^2	1,080	1,344	1,197

From the above analysis, it is seen that the maximum flood discharge of 1,344m^3/s based on SQRT-ET distribution and 1,197 m^3/s based on Gumbel distribution at Nepalthok are about 25% and 10% larger than the design discharge adopted in the original design respectively. However, the accuracy of estimation is suspect since the calibration of parameters using the observed discharge has not been carried out because of non-availability of any observed data on the recent flood event of July 2002. In addition, the selection of probability distributions includes some discrepancy for the prediction of flood discharge.

On the other hand, the flood water levels at the un-damaged road stretches during July 2002 were comparable to the design flood water level. Thus it is important to note that the hydraulic conditions at the damaged road stretches during July 2002 were unprecedented phenomena. These are described in detail in the following chapter.

2.3.2. Validation of Estimated Flood

1) Hydrometeorological Conditions

As discussed earlier flood frequency analysis of a 3-day rainfall shows that the present 3-day incessant rain is comparable to a 50 year return period event, based on the observed data from January 1964 to August 2002.

2) Hydraulic Conditions

Since, significant stretches of road along the target area was not damaged by the recent July 2002 flood, which equals the design flood, hydraulic parameters like high flood level (HFL), velocity of flood and design scour during that period, can be considered to be within the design limit. However, the river hydraulics in the vicinity of the damaged road stretches were as follows:

- Substantial increase in flow velocity and rise in the water level of the river channel thus reducing the river channel section due to debris deposition from tributary or slope failure.
- Increase in flow velocity and rise in water level locally due to development of the shoals at the river bends.
- Rise in water level locally and increased tractive force due to development of turbulent eddy flow triggered by rock mass deposition in the river channel.

The related road structures were designed based an estimated Q_{50} of river. The estimated Q_{50} used for design purposes and the recent peak flood produced by the incessant rain during July 2002 are close to each other. From the above mentioned observation, it can thus be concluded that the damages are mainly due to the abrupt substantial changes in the local morphology of river in the vicinity of the road structures. Such changes must have been developed by adverse conditions, which were beyond the prediction basis made during the design period.