No.

The Department of Water Induced
Disaster Prevention, Ministry of
Water Resources
The Department of Roads, Ministry
of Physical Planning and Works
The Republic of Nepal

# THE STUDY
# ON
# DISASTER RISK MANAGEMENT
# FOR
# NARAYANGHARH – MUGLING HIGHWAY

## FINAL REPORT

## Volume II
## Main Report

**February 2009**

**JAPAN INTERNATIONAL COOPERATION AGENCY**

**NIPPON KOEI CO., LTD.**

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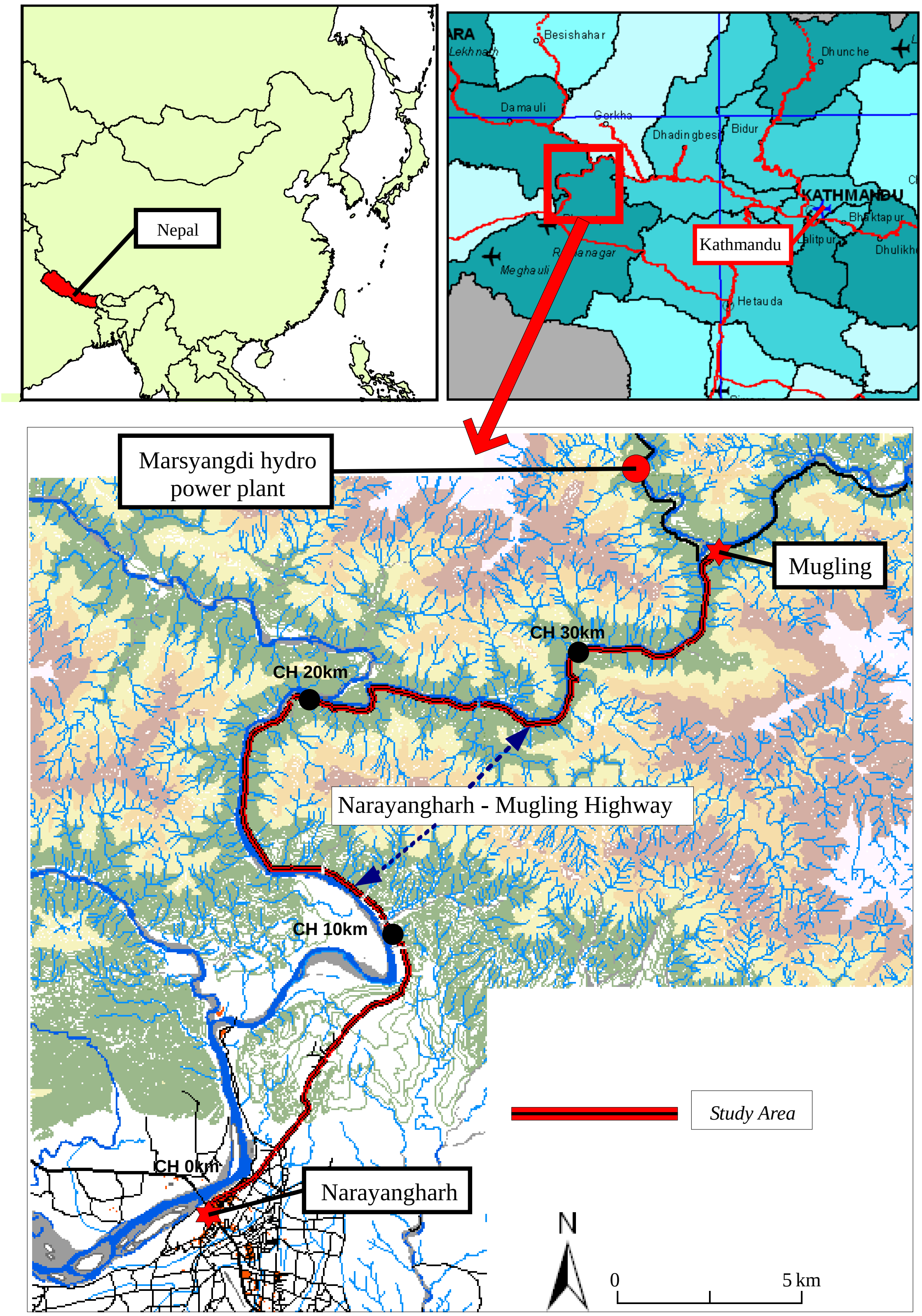
COMPOSITION OF REPORTS

| Volume | Report Name | Language |
|---|---|---|
| Volume I | Summary | English |
| Volume II | Main Report | English |
| Volume III | Data and Drawing | English |
| Volume IV | Technical Guide | English |




**Location Map of the Study Area**

# Definition of Terms for Risk Assessment

| Terms | | Definitions |
|---|---|---|
| **Disturbance** | : | Deformation of the slope and/or road structures or slope collapse which has not reached the road. |
| **Road Closure Disaster [RCD]** | : | A disaster which causes closure of the whole or partial width of the road<br>Deformations and collapses that do not close the road are not necessarily regarded as a RCD but just as a 'Disturbance'. |
| **Loss** | : | Monetary amount of damage caused by a disaster, specifically defined as the sum of the reopening cost, human lives lost, vehicle lost and losses of traffic suspension. |
| **Risk** | : | The total damage characterized by the potential frequency and magnitude of the disaster. Annual total loss is an expression of the risk.<br>The risk is distinguished from the hazard, which could be defined, in the case of this Study, as the overt danger to the road and road users. |
| **Frequency of Road Closure Disasters per Year [FRCD]** | : | The number of RCD occurrences per year for a slope (Nos. of RCD/year) |
| **FRCDp** | : | Potential FRCD |
| **FRCDa** | : | Actual FRCD |
| **Intensity of Road Closure Disasters of a Road Section [IRCD]** | : | Average RCD occurrences per km year for a road section, *i.e.* the total FRCD's for the road section divided by its length (Nos. of RCD/year/km) |
| **IRCDp** | : | Potential IRCD |
| **IRCDa** | : | Actual IRCD |
| **Annual Loss due to RCD [AL]** | : | Annual loss induced by RCD of a slope or a stream (Rs/year) |
| **ALp** | : | Potential AL |
| **ALa** | : | Actual AL |
| **Intensity of Annual Loss of a Road Section [IAL]** | : | Intensity of annual loss of per unit length per year (Rs/year/km) |
| **IALp** | : | Potential IAL |
| **IALa** | : | Actual IAL |
| **Chainage** | : | A point in the road represented by kilometer posts + displacement from the kilometer post in meters from starting point of a road section, as CH xx km + xxx m. |

# Acronyms/Abbreviations

| | |
|---|---|
| AADT | Average Annual Daily Traffic |
| ACLoV | Average Cancellation Loss of Vehicles |
| ADB | Asian Development Bank |
| ADLoV | Average Detour Loss of Vehicles |
| ADPC | Asian Disaster Preparedness Center |
| ADRC | Asian Disaster Reduction Center |
| ALE | Average Life Expectancy at birth |
| ALp | Potential Annual Loss of a site |
| ANHD | Average Numbers of Human Deaths per RCD |
| ANVL | Average Numbers of Vehicles Loss per RCD |
| AR | Automatic Rain gauge |
| ARMP | Annual Road Maintenance Plan |
| ARR | Assistant Resident Representative |
| ASLoV | Average traffic Suspension Loss of Vehicles |
| ATP | Average Traffic Persons of a vehicle |
| AVS | Average Vehicle Speed |
| AWLoV | Average Waiting Loss of Vehicles |
| BCR | Benefit Cost Ratio |
| C | Cost |
| CARE | Cooperative for American Relief Everywhere (NGO) |
| CBS | Central Bureau of Statistics |
| CDMA | Code division multiple access |
| CDO | Chief District Officer |
| CEM | Coefficient of Effectiveness of Structural Measure Effectiveness for FRCDp |
| CH | Chainage |
| CP | Cancellation Percentage |
| C/P | Counterpart(s) or Counterpart Organization(s) |
| CPoWTP150 | Cancellation percentage of Willingness to Pay equal to over than Rs 150 |
| CPoWTP300 | Cancellation percentage of Willingness to Pay equal to over than Rs 300 |
| CPoWTP<150 | Cancellation Percentage of Willingness to Pay under than Rs 150 instead of waiting |
| DAL | Decrease in Annual loss due to structural measure |
| DALy | Decrease in Annual Loss due to structural measure of y year |
| DDC | District Development Committee |
| DDO | District Development Office |
| DG | Director General |
| DDG | Deputy Director General |
| DEM | Digital Elevation Model |

| | |
|---|---|
| DF | Debris Flow |
| DFID | Department for International Development |
| DF/R | Draft Final Report |
| DHM | Department of Hydrology and Meteorology, Ministry of Environment, Science and Technology |
| DP | Detour Percentage |
| DPdNH | Detour Percentage divert to Naubise or Hetauda |
| DPdPB | Detour Percentage divert to Pokhara or Butawal |
| DPO | District Police Office |
| DMG | Department of Mines and Geology, Ministry of Industry Commerce and Supplies |
| DMSPP | Disaster Mitigation Support Program Project |
| DoLIDAR | Department of Local Infrastructure Development and Agriculture Road, Ministry of Local Development |
| DOR | Department of Roads, Ministry of Physical Planning and Works |
| DOS | Department of Survey, Ministry of Land Reform and Management |
| DPTC | Disaster Prevention Training Center |
| DR | Discount Rate |
| DRO | District Road Office |
| DTM | Department of Transport Management, Ministry of Labor and Transport Management |
| DWIDP | Department of Water Induced Disaster Prevention, Ministry of Water Resources |
| EIA | Environmental Impact Assessment |
| EIRR | Economic Internal Rate of Return |
| ENPV | Economic Net Present Value |
| E/R | Evaluation Report |
| EU | European Union |
| FCR | Fixed Cost for Reopening of a RCD |
| F/R | Final Report |
| FRCD | Frequency of Road Closure Disaster of a site |
| FRCDa | Actual Frequency of Road Closure Disaster of a site |
| FRCDabm | Actual Frequency of RCD of a site before structural measure is installed |
| FRCDp | Potential Frequency of Road Closure Disaster of a site |
| FRCDpom | Potential Frequency of Road Closure Disaster of a site without structural measure |
| FRCDpwm | Potential Frequency of Road Closure Disaster with structural measure |
| FS | Frequency Score for FRCDp |
| F/S | Feasibility Study |
| FTP | File Thrasher Protocol |
| GDP | Gross Domestic Product |

| | |
|---|---|
| GIS | Geographic Information System |
| GON | Government of Nepal |
| GPS | Global Positioning System |
| GTZ | Technical Cooperation of the Federal Republic of Germany |
| GWHa | Actual Gross Working Hours |
| HLLp | Potential Value of Human Lives Loss of a RCD |
| IALp | Potential Intensity of Annual Loss of a section |
| INGO | International Non-Governmental Organization |
| IC/R | Inception Report |
| ICIMOD | Integrated Centre for Integrated Mountain Development |
| IEE | Initial Environmental Evaluation |
| IRCD | Intensity of Road Closure Disaster |
| IRCDp | Potential Intensity of Road Closure Disaster of a section |
| IRCS | International Red Cross Society |
| IT/R | Interim Report |
| JICA | Japan International Cooperation Agency |
| LF | Lobar Force |
| Lp | Potential Loss of a RCD |
| LRCpoF | Potential Length of Road Closure section of Full width of a RCD |
| LRCpoP | Potential Length of Road Closure section of Partial width of a RCD |
| LS | Length of Section |
| LTSp | Potential Losses of Traffic Suspension of a RCD |
| LWS | Lutheran World Services |
| MBT | Main Boundary Thrust |
| MCT | Main Central Thrust |
| MFT | Main Frontal Thrust |
| M/M | Minutes of Meeting |
| M-N | Mugling-Narayangharh |
| MNWIDPP | Mugling-Narayangharh Water Induced Disaster Prevention Project |
| MOEST | Ministry of Environment Science and Technology |
| MOFSC | Ministry of Forests and Soil Conservation |
| MOHA | Ministry of Home Affairs |
| MOIC | Ministry of Information and Communication |
| MOLD | Ministry of Local Development |
| MOLT | Ministry of Labour and Transport Management |
| MOPPW | Ministry of Physical Planning and Works |
| MOWR | Ministry of Water Recourses |
| M/P | Master Plan |
| MSL | Mean Sea Level |
| NAR | Non Automatic Rain Gauge |

| | |
|---|---|
| NCDp | Numbers of Predicted Closure Days of the whole width of the road on the survey site per RCD |
| NCDpV | Numbers of predicted Closure Days of a Vehicle |
| NCHpV | Numbers of predicted Closure Hours of a Vehicle |
| NDRA | The Natural Disaster Relief Act |
| NEA | Nepal Electric Authority |
| NGIIP | National Geographic Information Infrastructure Program |
| NGO | Non Government Organization |
| NK | Nippon Koei Co., Ltd. |
| N-M | Narayangharh-Mugling |
| Nos. | Numbers |
| NORAD | Norwegian Agency for Development Cooperation |
| NPC | National Planning Commission |
| NPO | Nonprofit Organization |
| NWP | Non-Waiting Percentage |
| O-D | Origin – Destination |
| PDM | Project Design Matrix |
| PIP | Priority Investment Plan |
| PM | Project Manager |
| PMED | Planning Monitoring and Evaluation Division |
| POP | Population |
| PP | Pilot Project(s) |
| PPD | Policy and Planning Division |
| PR/R | Progress Report |
| PVC | Poly-Vinyl Chloride |
| Q/N | Questionnaire |
| RCD | Road Closure Disaster |
| RCDp | Potential Road Closure Disaster |
| RCp | Potential Reopening Cost of a RCD |
| RF | Rock Fall |
| RRN | Rural Reconstruction Nepal, NGO |
| RRR | Risk Reduction Ratio |
| Rs | (Nepalese) Rupee |
| RSL | Road Section Length |
| S/C | Steering Committee |
| SCF | Save the Children Found |
| SDC | Swiss Development Corporation |
| SF | Slope Failure |
| SL | Slide or Landslide |
| SPM | Suspended Particulate Matter |

| | |
|---|---|
| SRN | Strategic Road Network |
| S/W | Scope of Work |
| TA | Technical Assistance |
| TCR | Travel Conversion Ratio |
| The Study | The Study on the Disaster Risk Management for Narayangharh – Mugling Highway |
| The Team | The JICA Study Team |
| TOR | Terms of Reference |
| TSDC | Transport Sector Development Project |
| UCLp | Unit Potential Losses due to Cancellation of trip per vehicle per RCD |
| UDL | Unit Detour Loss |
| UDLdNH | Unit Detour Loss of a Vehicle when divert to Naubise or Hetauda |
| UDLdPB | Unit Detour Loss of a Vehicle when divert to Pokhara or Butawal |
| UHL | Unit Value of Human Lives Loss |
| ULTS | Unit Loss of Traffic Suspension of a vehicle |
| UMN | United Mission to Nepal |
| UNDP | United Nations Development Program |
| URCpMoF | Unit Reopening Cost per one mater length of Full width road closure |
| URCpMoP | Unit Reopening Cost per one mater length of Partial width road closure |
| U.S. | United State of America |
| USAIDM-N | United States Agency for International Development Mission to Nepal |
| UVOC | Unit Vehicle Operation Cost per km per vehicle |
| UVL | Unit Value of Vehicle Loss |
| UVTT | Unit Value of Traffic Time of a vehicle |
| UWL | Unit Waiting Loss of a vehicle |
| VDC | Village Development Committee |
| VLp | Potential value of Vehicle Loss of a RCD |
| VOC | Vehicle Operation Cost |
| WB | World Bank |
| WFP | World Food Programme |
| W/G | Working Group (comprising of the C/P) |
| WH | Waiting Hours |
| WP | Waiting Percentage |
| W/S | Workshop |
| WTP | Willingness To Pay |
| y | Year from countermeasure installation |

# Measurement Units

**Area**

| | | |
|---|---|---|
| $cm^2$ | = | Square-centimeters (1.0 cm x 1.0 cm) |
| $m^2$ | = | Square-meters (1.0 m x 1.0 m) |
| $km^2$ | = | Square-kilometers (1.0 km x 1.0 km) |
| ha | = | Hectares (10,000 $m^2$) |

**Volume**

| | | |
|---|---|---|
| $cm^3$ | = | Cubic-centimeters (1.0 cm x 1.0 cm x 1.0 cm or 1.0 milliliter) |
| $m^3$ | = | Cubic-meters (1.0 m x 1.0 m x 1.0 m or 1.0 kiloliter ) |
| L | = | Liter (1,000 $cm^3$) |
| mL | = | milliliter (1/1,000 L) |

**Length**

| | | |
|---|---|---|
| mm | = | Millimeters |
| cm | = | Centimeters (cm = 10 mm) |
| m | = | Meters (m = 100 cm) |
| km | = | Kilometers (Km = 1,000 m) |

**Weight**

| | | |
|---|---|---|
| g | = | Grams |
| kg | = | Kilograms (1,000 g) |
| ton | = | Metric tone (1,000 kg) |

**Currency**

| | | |
|---|---|---|
| Rs | = | Nepalese rupee |

**Time**

| | | |
|---|---|---|
| s | = | Second |
| min | = | Minutes (60 s) |
| hr | = | Hours (60 min) |

# THE STUDY
# ON
# DISASTER MANAGEMENT
# FOR
# NARAYANGHARH –MUGULING HIGHWAY

## FINAL REPORT
## Volume II: MAIN REPORT

## Table of Contents

# List of Figures

## List of Tables

The figures and the tables in the report which their references are not described were prepared by the JICA Study Team.

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of the Study

In Nepal, a lot of disasters have occurred due to adverse natural conditions such as steep topography, fragile geology, heavy rainfalls during monsoon season, and earthquakes that occur intermittently. The roads in the mountainous areas are prone to frequent traffic blockade due to slope disasters. Narayangharh-Mugling Highway (hereafter referred to as “N-M Highway”), which is approximately 36 km, had been subjected to more than 20 serious failures such as slides and heavy debris flows that washout bridges. Severe damages have occurred along this road section due to heavy rains on 30th July 2003. This disaster affected the domestic industry and the logistics due to damaged roads which became impassable for a long duration. It also degraded the operation rates (40-50%) near Marsyangdi Power Plant at Ruwa Khola, 4 km west of Mugling. The N-M Highway is regarded as the most important road section connecting Kathmandu with India. Therefore, any traffic interruption paralyzes logistics, and cause catastrophic damage to the economy causing supply shortage and inflation in Nepal. It is noted that additional sabo facilities in Marsyangdi Power Plant are vital for the sustainable supply.

Well organized investigation and consequent preparation of basic plans is absolutely necessary for defining medium to long-term policy against slope disasters. The Government of Nepal (hereafter referred to as “GON”) had requested assistance from the Government of Japan for carrying out study on the technical issues.

In response to the request from the GON for the technical cooperation, the Government of Japan decided to conduct “The Study on Disaster Risk Management for Narayangharh-Mugling Highway” (hereafter referred to as “the Study”). Accordingly, the Japan International Cooperation Agency (hereinafter referred to as “JICA”), the official agency responsible for the implementation of the technical cooperation programs of the Government of Japan, dispatched a preliminary study team to Nepal and agreed to the related Scope of Work (S/W) and Minutes of Meeting (M/M) held on 31st January, 2007. It was decided that the Study be conducted from July 2007 to February 2009, in accordance the S/W and the M/M.

## 1.2 Objectives/ Activities/ Outputs of the Study

The objectives of the Study are as shown in Figure 1.2.1:

1) To formulate the basic strategy on disaster risk management for the N-M Highway and to confirm the validity of the corresponding disaster management project for the target area

2) To transfer the technology to the responsible and implementing counterpart organizations (hereinafter referred to as "the C/P") which are the Department of Water Induced Disaster Prevention, Ministry of Water Resources (hereafter referred to as "DWIDP") and the Department of Roads, Ministry of Physical Planning and Works (hereafter referred to as "DOR")

3) To formulate structural measures for Marsyangdi Hydro Power Plant in Ruwa River

The major activities and specific outputs of the Study are:

(I) To prepare a hazard map and assess the risks of the water-induced disaster on N-M Highway, and Ruwa River/Marsyangdi hydro power house

(II) To prepare the basic strategy for the water-induced disaster management for N-M Highway

(III) To implement the Feasibility Study (hereinafter referred to as F/S) for basic strategies of the water-induced disaster management for N-M Highway and structural measure for Ruwa River/Marsyangdi hydro power house

(IV) To execute pilot projects to confirm the appropriateness of disaster management procedure

(V) To transfer technology and knowledge of disaster management to the C/P, related organizations and communities

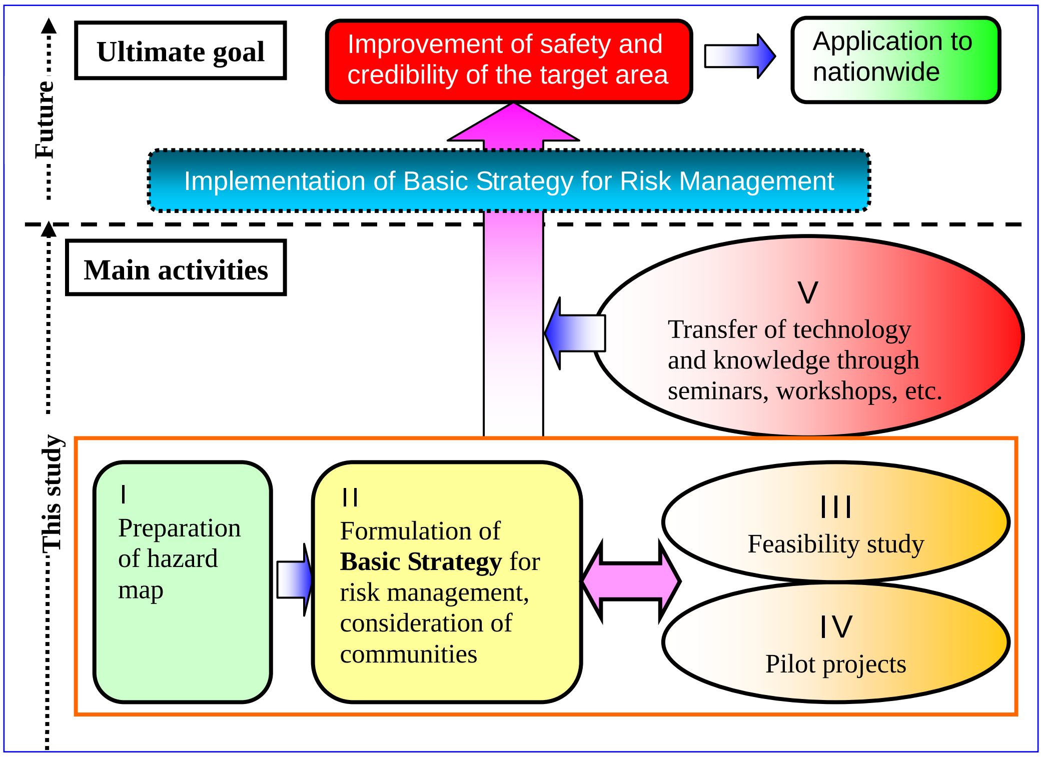



**Figure 1.2.1 Relationship between this Study and the Ultimate Goal**

The results that will be obtained from this study can be applied to other important road sections/areas which are potentially affected by water-induced disasters such as the N-M Highway and neighboring areas and Ruwa River.

## 1.3 Study Area

The Study covers the following areas (Refer to the location map in the first page of this study):

(a) The N-M Highway and neighboring area (Road length: around 36 km, Residents in the vicinity: around 23,000)

(b) The Ruwa River basin beside the Marsyangdi Hydro Power Plant (Attachment area: around 2.69 km2, Residents in the vicinity: around 2,500)

## 1.4 Implementation Framework

In accordance with the M/M on S/W of the Study dated 31st January 2007, the implementing organization established composed of JICA Headquarters and Nepal Office as the client, the DWIDP and the DOR as the Nepali C/Ps, and the JICA Study Team (hereafter referred to as "the Team"). Structure of implementation framework is shown in Figure 1.4.1.

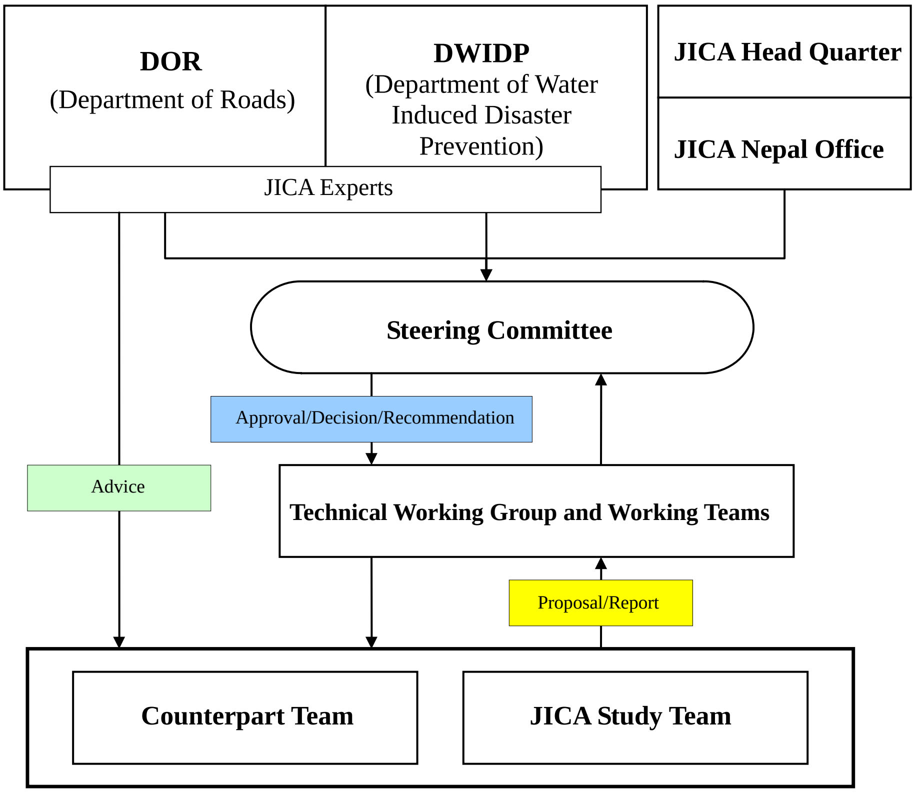



**Figure 1.4.1 Implementation Framework of the Study**

The Steering Committee (hereafter referred to as "the S/C") was set up to manage the implementation of the Study in accordance with the M/M. Additionally technical working groups (TW/G) or working teams for specific tasks are formulated to execute required tasks.

### 1.4.1 Steering Committee

The S/C has been set up to provide the Study with managerial instructions, evaluations reports, and other related information.

The 1st S/C meeting was held on 9th August 2007 to approve the plan of operation of the Study in accordance with the Inception Report. Meeting regarding the progress report was held on 4th November 2007 however, the chairperson was not available during said date. Hence, the official 2nd S/C was held on 27th November 2008 to discuss sustainable implementation of basic strategy.

The S/C was chaired by the Secretary of the Ministry of Water Resources. The organization listed in Table 1.4.1 below has been designated by the GON. In addition to the committee members, the Nepali side invited the related donor agencies as observers, such as the World Bank and Asian Development Bank during the committee's meetings.

**Table 1.4.1 Members of the Steering Committee**

| Name | Position | Organization |
|---|---|---|
| Shankar Prasad Koirala | Chairman | Secretary, MOWR |
| Narayan Prasad Bhattarai | Vice-Chairman | DG, DWIDP |
| Ramesh Raj Bista | Vice-Chairman | DDG, DOR |
| Shiv Chandra Jha | Member | DMD, NEA |
| Ramesh Tuladhar | Member | Sabo Section Chief, DWIDP |
| Shanumukesh Amatya | Member (Successor for Mr. Tuladhar) | Landslide Section Chief, DWIDP |
| Selecting | Observer | World Bank |
| Nogendra Sapkota | Observer | Social Environment Officer, ADB |
| Yusuke Tsumori | Observer | ARR, JICA/Nepal |

### 1.4.2 Counterpart Team

C/P Team assigned five engineers to conduct the study jointly with the Team as shown in the Table 1.4.2.

**Table 1.4.2 Members of C/P Team**

| Name | Position | Present Status |
|---|---|---|
| Ramesh Tuladhar | Team Leader | Superintending Hydrogeologist, DWIDP |
| Shanumukesh Amatya | Team Leader (Successor for Mr. Tuladhar) | Engineering Geologist, DWIDP |
| Shree Kamal Dwivedi | Member | Engineering Geologist, DWIDP |
| Bed Kantha Yogol | Member | Engineer, DRO |
| Rajendra Raj Sharma | Member | Chief DOR, DRO |

### 1.4.3 Technical Working Group

On the initiative of the C/P, a (TW/G) composed of nine engineers was proposed to be set up, in view of the objectives of the Study. The TW/G aims to assist the S/C in organizing regular coordination meetings with the Team, and support the smooth implementation of the Study. The TW/G was composed of designated representatives from DWIDP, DOR, and related organizations.

The 1st TW/G meeting was held on 10th August 2007with engineers of head office of DWIDP and DOR.

The 2nd TW/G meeting was held on 13 September 2007 mainly with engineers of Mugling-Narayangharh Water Induced Disaster Prevention Project (hereinafter described as "MNWIDPP") and District Road Office (DRO) Bharatpur, Chitwan. The participants can be considered members of TW/G who are shown in the Table 1.4.3.

**Table 1.4.3 Members of Technical Working Group**

| Name | Position | Present Status |
|---|---|---|
| Ramesh Tuladhar | Team Leader | Sabo Chief, DWIDP |
| Shanumukesh Amatya | Team Leader (Successor for Mr. Tuladhar) | Landslide Section Chief, DWIDP |
| Shree Kamal Dwivedi | Member | Engineering Geologist, DWIDP |
| Saroj Pandit | Member | PM, MNWIDPP |
| Yogendra Mishara | Member | Engineer, MNWIDP |
| Basanta Raj Paudel | Member | Engineer, MNWIDP |
| Krishna Raj Pathak | Member | Engineer, MNWIDP |
| Rajendra Raj Sharma | Member | Chief DOR, DRO |
| Uma Kant | Member | Engineer, DOR, DRO |

From May 2008, Working Teams for establishment of the basic strategy programs has been formulated as shown in Table 1.4.4.

**Table 1.4.4 Staff for Establishment of Basic Strategy Programs**

| Program | Study Team | DWIDP | DOR |
|---|---|---|---|
| Road Maintenance | M. Eto<br>M. Mori | | B. Subedi, ＋α |
| Quick Response | M. Eto<br>M. Mori | | B. Subedi, ＋α |
| Sabo Facility Maintenance | M. Eto<br>M. Mori<br>P. Yang<br>J. Kitagawa | R. Tuladher<br>(S. Amatya)<br>S. Pandit<br>K.R. Pattack, ＋α | |
| District Disaster Management by Stack holder partnership<br>- Road Early Information System<br>- Disaster Mitigation Activities in Communities (pilot project in Kabilash Village) | M. Eto<br>M. Mori<br>H. Ono<br>Y. Numata<br>T. Matuo | R. Tuladhar<br>(S. Amatya)<br>K. Dwivedi<br>K. R. Pathak, ＋α | B.Yogol<br>R.R.Sharma<br>B.Chapagain<br>District Road Office engineer |
| Preparation of Technical Guide | M. Eto<br>M. Mori<br>P. Yang<br>J. Kitagawa | R. Tuladhar<br>(S. Amatya)<br>S.Pandit<br>K.R.Pathak, ＋α | B.Yogol<br>R.R.Sharma<br>B.Chapagain,<br>＋α |

### 1.4.4 Study Team

The Team, composed of 12 engineers as shown in Table 1.4.5, implemented the Study in accordance with the plan of operation outlined in the IC/R.

**Table 1.4.5 List of JICA Study Team Members**

| Position/Specialties | | Role assignment |
|---|---|---|
| Masatoshi ETO<br><br>Team leader/ control of soil erosion and rivers |  | 1. General management of the Study<br>2. Coordination with the C/P and related organization<br>3. Basic policy and plans of operation<br>4. Management of local contractors<br>5. Technical seminars and workshops<br>6. General evaluation and recommendation<br>7. Preparation of reports |
| Takashi SUGIMOTO<br><br>Co-team leader / control of soil erosion and rivers |  | 1. Proxy for the leader<br>2. General management of the Study<br>3. Coordination with the C/P and related organization<br>4. Basic policy and plans of operation<br>5. Management of local contractors<br>6. Technical seminars and workshops<br>7. General evaluation and recommendation<br>8. Preparation of reports |
| Mikihiro MORI<br><br>Road (disaster) management |  | 1. Formulation of basic policy<br>2. Plan of pilot projects<br>3. Monitoring and evaluation of slides<br>4. Implementation of pilot projects |
| Kenichi TANAKA<br><br>Geology |  | 1. Topological and geological surveys<br>2. Field reconnaissance of slides<br>3. Preparation of a comprehensive hazard map<br>4. Management of geological survey |
| Hiroyuki ONO<br><br>Social/economy |  | 1. Data collection and analysis of social condition, land use, etc.<br>2. Risk assessment<br>3. Feasibility study<br>4. Selection of pilot project sites<br>5. Plan of pilot projects<br>6. Evaluation of pilot projects |
| Takeshi KUWANO<br><br>Environmental/social consideration |  | 1. Review on environmental/social situation<br>2. Feasibility study<br>3. Preparation for stakeholder meeting |
| Khadananda LAMSAL<br><br>Hydrology |  | 1. Collection and analysis of meteorological data<br>2. Analysis of relationship between rainfall and disasters<br>3. Preparation of criteria for alert and traffic control |
| Puchai YANG<br><br>Cost estimation |  | 1. Cost estimation<br>2. Feasibility study<br>3.Technical advice |

| | | |
|---|---|---|
| Satoru NODA<br><br>Project coordinator |  | 1. Project coordination<br>2. Assistance of members |
| Yusuke NUMATA<br><br>Disaster Information management |  | 1. Preparation of road early information system<br>2. Preparation of early warning/ evacuation system |
| Tamaki MATSUO<br><br>Disaster management<br>Environmental/Social Consideration |  | 1. Preparation and facilitation of the pilot project of disaster management in Kabilash Village |
| Junichi KITAGAWA<br><br>Structural countermeasure works |  | 1. Technical advice for structural measures<br>2. Preparation of technical guide |

## 1.5 Progress of the Study

### 1.5.1 Phasing of the Study

The Study has been implemented for around 20 months, form 5th July 2007 to 27th February 2009. Progress schedule and specific work items related to the Study are shown in Table 1.5.1.

**Table 1.5.1 Phasing of the Study**

| Phase | Major Study Theme | Period |
|---|---|---|
| Phase I | - Risk assessment for the target area,<br>- Geological survey,<br>- Formulation of Basic Strategy | July 2007 – November 2007 |
| Phase II | - Implementation of Feasibility Study (F/S),<br>- Pilot projects, and monitoring of slopes | December 2007 – June 2008 |
| Phase III | - Execution Pilot project<br>- Monitoring and evaluation in the monsoon season | July 2008 – November 2008 |

### 1.5.2 Specific Work Items and Progress

Progress schedule and specific work items on the project are shown in Table 1.5.2.

## Table 1.5.2 Study Items and Progress

| Schedule | 2007 | | | | | | 2008 | | | | | | | | | | | | 2009 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 |
| Year | First Year | | | | | | | | | Second Year | | | | | | | | | | |
| Phase | Phase I | | | | | Phase II | | | | | | | Phase III | | | | | | | |
| Activities | □ | ■ | ■ | ■ | | | ■ | ■ | | | ■ | ■ | | ■ | | | ■ | ▣ | | |
| Items | | 1st Field Work | | | | | 2nd Field Work | | | | 3rd Field Work | | | | | | 4th Field Work | | | |
| Report: Inception Report (IC/R) | | ■ | | | | | | | | | | | | | | | | | | |
| Report: Progress Report (P/R) | | | | ■ | | | | | | | | | | | | | | | | |
| Report: interim report (IT/R) | | | | | | | | ■ | | | | | | | | | | | | |
| Report: Draft Final Report (DF/R) | | | | | | | | | | | | ■ | | | | | | | | |
| Report: Evaluation Report (E/R) | | | | | | | | | | | | | | | | | ■ | | | |
| Report: Final Report (F/R) | | | | | | | | | | | | | | | | | | | | ■ |
| **Phase I** | | | | | | | | | | | | | | | | | | | | |
| 1st Work in Japan | | | | | | | | | | | | | | | | | | | | |
| 【1】 Data collection and analysis in Japan | □ | | | | | | | | | | | | | | | | | | | |
| 【2】 Review of policies; preparation of the work plan and methodology | □ | | | | | | | | | | | | | | | | | | | |
| 【3】 Preparation of the Inception Report (IC/R) | □ | | | | | | | | | | | | | | | | | | | |
| 1st Field Work | | | | | | | | | | | | | | | | | | | | |
| 【4】 Meeting on the Inception Report | | ■ | | | | | | | | | | | | | | | | | | |
| 【5】 Data collection | | ■ | | | | | | | | | | | | | | | | | | |
| 【6】 Field reconnaissance | | ■ | ■ | | | | | | | | | | | | | | | | | |
| 【7】 Geological survey | | | ■ | ■ | | | | | | | | | | | | | | | | |
| 【8】 Review of existing plans and studies, organizations, and legal systems | | | ■ | | | | | | | | | | | | | | | | | |
| 【9】 Analysis of relationship between rainfall and disasters | | | ■ | | | | | | | | | | | | | | | | | |
| 【10】 Definition of words on slope disasters | | ■ | | | | | | | | | | | | | | | | | | |
| 【11】 Analysis of data and information | | ■ | | | | | | | | | | | | | | | | | | |
| 【12】 Technical advice on structural measures | | ■ | ■ | | | | | | | | | | | | | | | | | |
| 【13】 Disaster risk assessment in the study area | | ■ | ■ | | | | | | | | | | | | | | | | | |
| 【14】 Formulation of a comprehensive hazard map | | ■ | ■ | | | | | | | | | | | | | | | | | |
| 【15】 Concept formulation of the disaster risk management | | | ■ | | | | | | | | | | | | | | | | | |
| 【16】 Formulation of Basic Strategy | | | ■ | ■ | | | | | | | | | | | | | | | | |
| 【17】 Preparation for pilot projects and monitoring of slides | | | ■ | ■ | | | | | | | | | | | | | | | | |
| 【18】 Preparation/explanation/discussion of the Progress Report (P/R) | | | | ■ | | | | | | | | | | | | | | | | |
| **Phase II** | | | | | | | | | | | | | | | | | | | | |
| 2nd Field Work | | | | | | | | | | | | | | | | | | | | |
| 【19】 Selection of the sites | | | | | | | ■ | | | | | | | | | | | | | |
| 【20】 Implementation of feasibility study (F/S) | | | | | | | ■ | ■ | | | ■ | ■ | | | | | | | | |
| 【21】 Preparation/explanation/discussion of the interim report (IT/R) | | | | | | | | ■ | | | | | | | | | | | | |
| 3rd Field Work | | | | | | | | | | | | | | | | | | | | |
| 【22】 Pilot project and monitoring of slides | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| 【23】 Technical advice on structural measures | | | | | | | | | | | ■ | ■ | | | | | ■ | | | |
| 【24】 Preparation/explanation/discussion of the Draft Final Report (DF/R) | | | | | | | | | | | | ■ | | | | | | | | |
| **Phase III** | | | | | | | | | | | | | | | | | | | | |
| 4th Field Work | | | | | | | | | | | | | | | | | | | | |
| 【25】 Evaluation for pilot project and monitoring of slides | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | | | |
| 【26】 Technical advice on structural measures | | | | | | | | | | | | | | | | | ■ | | | |
| 【27】 Preparation/explanation/discussion of Evaluation Report (E/R) | | | | | | | | | | | | | | | | | ■ | | | |
| 2nd Work in Japan | | | | | | | | | | | | | | | | | | | | |
| 【28】 Preparation/submission of the Final Report (F/R) | | | | | | | | | | | | | | | | | | ▣ | | |

■ Field work □ 1st Work in Japan ▣ 2nd Work in Japan

## 1.6 Main Events in the Field Work

Main events in the field work were as follows.

1) 1st steering committee meeting
2) 1st technical working group meeting
3) Joint inspection for risk assessment
4) 1st seminar/workshop
5) 2nd technical working group meeting
6) Meeting on the progress report
7) 2nd seminar/workshop
8) 1st Chitwan district disaster management partnership committee
9) 3rd seminar/workshop for pilot project
10) 2nd Chitwan district disaster management partnership committee
11) Advisory committee
12) 2nd Steering committee meeting
13) Reporting session

Through these events, discussion on the study policy and study results, decision of policy, or technical transfer was carried out. Outline of these events are shown in the Table 1.6.1.

**Table 1.6.1 Outline of Events in the Field Work**

| Event/ Date | Venue/Outline |
|---|---|
| **Phase I** | |
| 1st Steering committee meeting<br>9th August 2007 | At Secretary's Office, MOWR<br>1. Explanation of plan of operation<br>2. Recommendation and Discussion by members<br>N.P.Bhattarai, R.R.Bista, N.Sapkota, S.C. Jha<br>3. Decision: Approval of objective, |
| 1st Technical Working group meeting<br>10th August 2007 | At meeting room, DWIDP, Pulchwok<br>1. Explanation of methodology of the study and definition of terminology related with landslide<br>2. Discussion on the method of the Study<br>3. Understanding of the methodology and terminology |
| Joint inspection for risk assessment<br>Late August 2007<br>Joint assessment survey and inspection for high risk sites<br>12th September 2007 | Risk assessments for 305 sites (134 mountainside slopes, 78 crossing streams, and 93 river side slopes) on the N-M Highway<br>At N-M Highway<br>1. Inspection for ten selected sites for implementing preventive measures<br>2. Discussion in the field<br>3. Selection for 10 sites structural measure should be planed<br>-11km+500 (Khare khola) and 12km+600(Das Khola) was canceled because of additional sabo dam is constructing. |

| Event/ Date | Venue/Outline |
|---|---|
| 1st seminar/ workshop<br>13th September, 2007 | At the Meeting Room of Global Hotel, Bharatpur<br>-Presentation and discussion on following subjects<br>a) General issues on landslide in Nepal<br>b) Outline of the Study<br>c) Relationship between debris flow and rainfall<br>d) Plan of pilot project |
| 2nd technical working group meeting<br>13th September, 2007 | Discussion on following subjects and approval<br>1. Sites for preventive countermeasure; agreed as the decision in the field<br>2. Policy on the pilot project; agree generally as planned by the Team |
| Meeting on Progress Report<br>6th November, 2007 | Reported by the Team on the progress of the study and given recommendation and requirement by the chairman and members. |
| **Phase II** | |
| 2nd Seminar/ Workshop<br>22nd February, 2008 | Held in 2nd at Hotel Himalaya's Seminar Hall.<br>- Sessions in the seminar<br>Session I: Opening<br>Session II: System and Activities on Sediment-Related Disasters<br>Session III: Risk Evaluation for Slope Hazard in N-M Highway<br>Session IV: Basic Strategy on Disaster Risk Management |
| 1st Chitwan district disaster management partnership committee<br>9th June 2008 | Discussion on<br>- road early warning system on N-M highway<br>- disaster management activities in Kabilash Village |
| Seminar/workshop for pilot projects<br>26th June 2008 | Held in Royal Century the Business Hotel Narayangharh<br>- road early warning system on N-M Highway<br>- disaster management activities in Kabilash Village |
| **Phase III** | |
| 2nd Chitwan district disaster management partnership committee<br>20th November, 2008 | Held in Royal Century the Business Hotel Narayangharh<br>- road early warning system on N-M Highway<br>- disaster management activities in Kabilash Village |
| Advisory committee<br>24th November, 2008 | At meeting room, DWIDP<br>- road early warning system on N-M Highway<br>- disaster management activities in Kabilash Village |
| 2nd Steering committee meeting 27th November, 2008 | At meeting room, MOWR<br>- Discussion of the outline and the results for pilot projects<br>- Acceptance of Draft Final Report |
| Reporting Session<br>28th November, 2008 | At meeting room, DWIDP<br>- Reporting of the results for the project |

Minutes of meeting (M/M) of S/C meeting and participant list of meetings/ seminars are attached in the Volume III DATA AND DROWING 1.

# CHAPTER 2

# OVERVIEW OF SLOPE DISASTERS ON NARAYANGHARH – MUGLING HIGHWAY

## 2.1 Natural Conditions Related to Slope Disaster in the Study Area

### 2.1.1 Topography and Geology

Nepal is located in the southern lap of relatively young mountain chain in the Himalayas. The Himalaya is represented by the mountain chain from Indus River in the west to the Bramhaputra River in the east covering total length of about 2400 km.

According to Ganser (1964), the Himalaya is transversely divided into five divisions as Punjab Himalayas, Kumaon Himalayas, Nepal Himalayas, Sikkim and Bhutan Himalayas and North East Frontier and Assam (NEFA) Himalayas.

Out of 2400 km of the Himalayas, Nepal Himalayas occupy the central one-third parts (about 800 km) of the total length extending from Mahakali River in the west to Mechi River in the east. More than 14 peaks exceeding 8000 m including the highest peak of the world, the Mt. Everest belongs to the Nepal Himalayas.

Longitudinally, the Nepal Himalayas have been divided into four, five or six divisions by various authors for their convenience depending on the knowledge they acquire form their study on the subject.

According to Ganser (1964), and Upreti and Le Fort (1999), the Nepal Himalayans can be divided into several geological/topographical zones.

Figure 2.1.1 below shows subdivisions of the Nepal Himalayas considered by Ganser (1964), and Figure 2.1.2 below shows a geological cross section of the Nepal Himalayas presented by Upreti and Le Fort (1999).

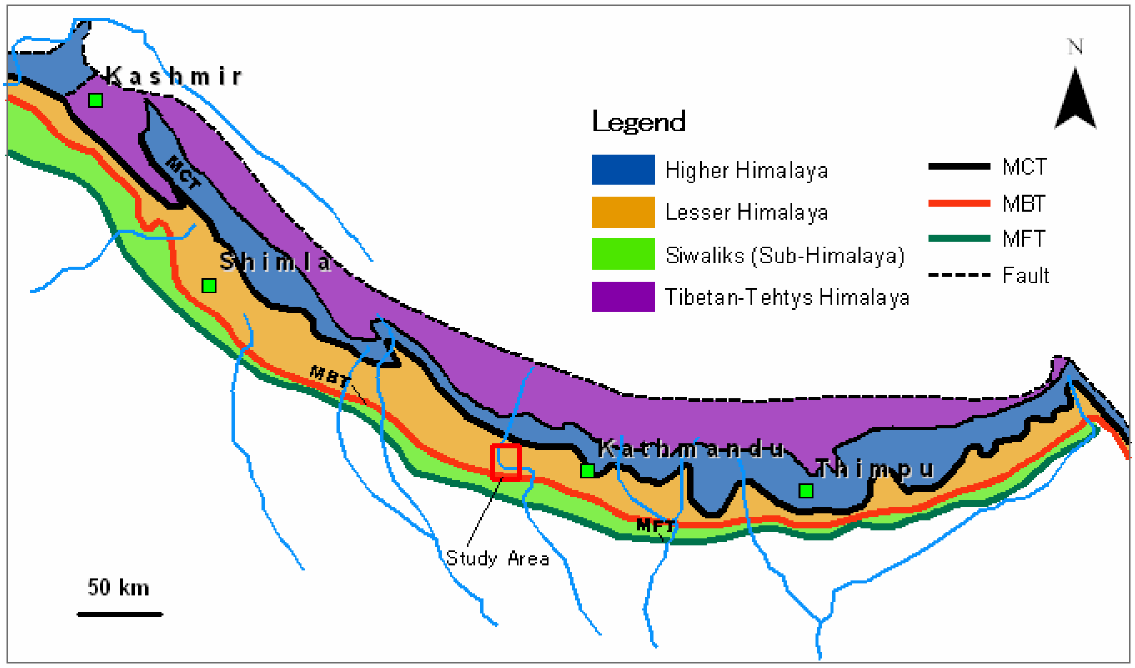



**Figure 2.1.1 Subdivision of the Himalaya (modified after Genser 1964)**

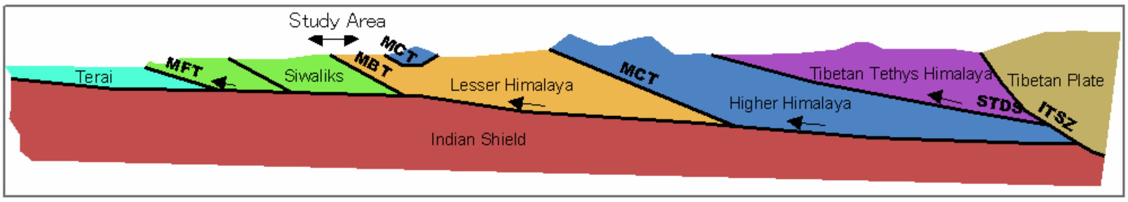



**Figure 2.1.2 Generalized cross section of the Himalaya (modified after Dahal 2005)**

As shown in Figure 2.1.1 and Figure 2.1.2 above, the Nepal Himalayas has been divided into several geological zones, and each zone is considered to be bounded by a major thrust fault.

From the north to the south, the South Tibetan Detachment Fault Systems (STDS) bounds the Tibetan Tethys Himalayas and the Higher Himalyas. The Main Central Thrust (MCT) bounds the Higher Himalayas and the Lesser Himalayas. The Main Boundary Thrust (MBT) bounds the Lesser Himalaya and the Siwaliks (the Sub-Himalaya). The Main Frontal Thrust (MFT) bounds the Siwaliks and the Terai plain.

**(1) Target Road Section**

The N-M Highway, a length of 36 km, is located in a mountain range between Narayangharh and Mugling.

Of the whole section of the N-M Highway, a section of CH[1] (Chainage: distance (km) from Narayangharh) 0 to 10 (about 10 km) is located on flat/ very gentle slope of Dun Formation and the Siwalik Zone where as remaining 26 km section (CH 10 to 36) mostly located in a mountainous zone of the Lesser Himalaya.

Therefore slope disasters along the highway have occurred almost along the section of CH 10 to 26. This Study particularly targeted the section of CH 10 to 36 because there are high potential of slope disasters for the highway.

**(2) Topography with Chainage**

The highway is at the left side slope of the valley surrounded by the Trishuli River and at an elevation of approximately 250 m. Relative heights from the highway to the ridges vary with a minimum of about 750 m.

Topographically, the section of CH 10 km to 36 km can be roughly divided into two sections, CH 10 km to 14 km and CH 14 km to 36 km. Section CH 10 km to 14 km is located in the Siwalik Zone mentioned above. Along this section, the Trishuli River runs toward east to south east. Natural slopes along the road face from south to southwest. Within this section, there are three major branches of the Trishuli River, i.e. Das Khola at CH 12+600 m, Khahare Khola at CH 11+300 m, and Jugedhi Khola at CH 10+300 m.

Meanwhile, section CH 14 km to 36 km is located in the Lesser Himalayan Zone. Along this section, the axis of the Trishuli River winds north to south or east to west, and flows to the Siwalik Zone. Based on the Trishuli River meandering, natural disaster/cut slopes along the road generally face north or west. At CH 25+500, the Trishuli River meets the Rigdi Khola, the largest watershed in the Study Area..

Figure 2.1.3 is a map showing slope gradients along the highway. Generally natural slopes along the highway have angles of 30 degrees and more as shown in Figure 2.1.4.

[1] Refer to the location map in the opening page or Figure 2.3.1

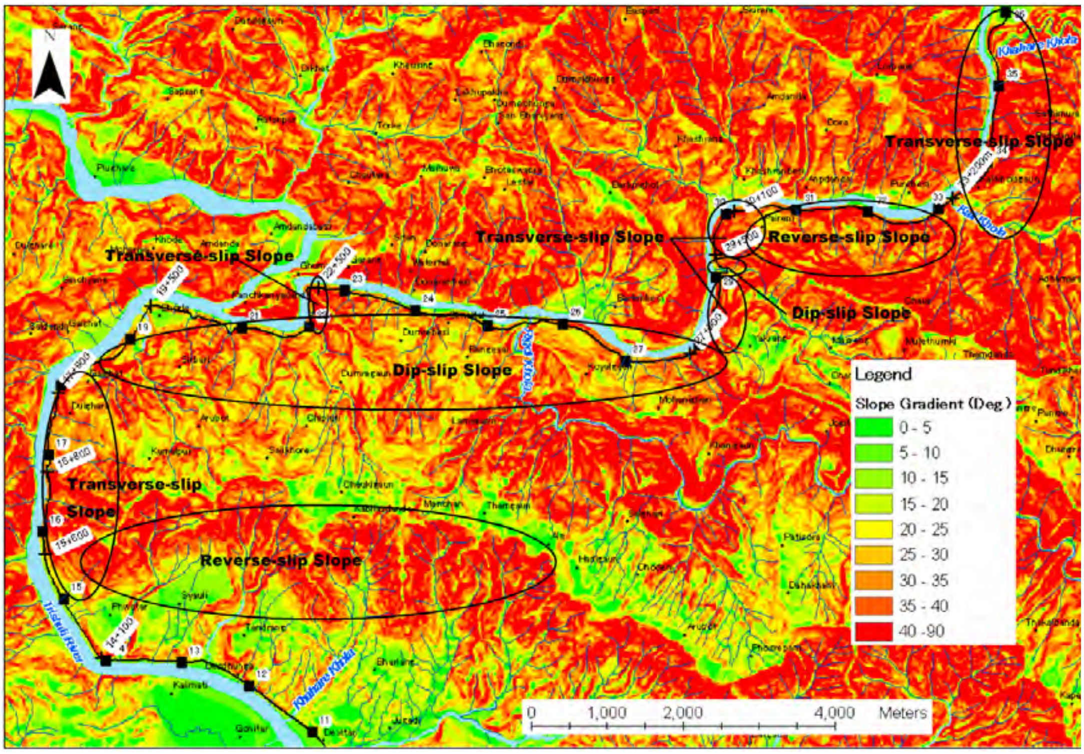



**Figure 2.1.3 Slope Gradient Map for CH 11 to CH 36**

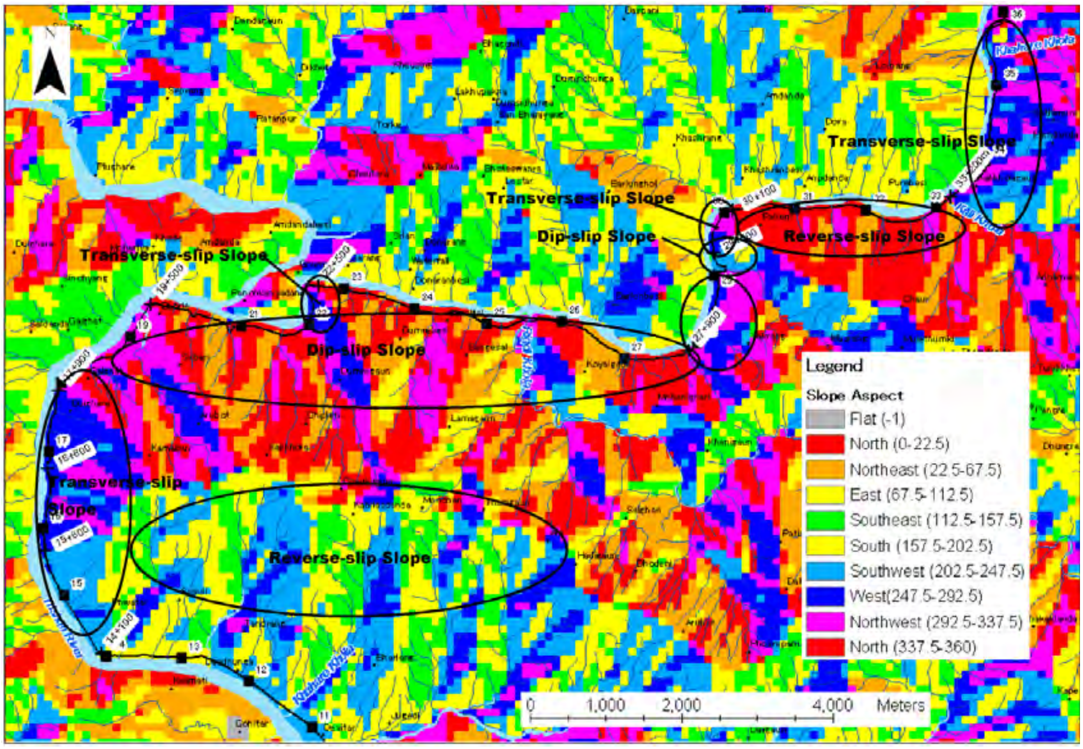



**Figure 2.1.4 Slope Aspect Map for CH 11 to CH 36**

**(3) Geology with Chainage**

Bedrock found in the Study area comprises of rocks of the Lesser Himalayan Zone and the Siwalik Zone as mentioned above.

The Lesser Himalayan Zone and the Siwalik Zone are bounded by the MBT. Within the study area, the MBT seems to cross at about CH 14+500 of the highway.

Figure 2.1.5 shows a generalized geological map for the section of CH 10 to 36 of the highway.

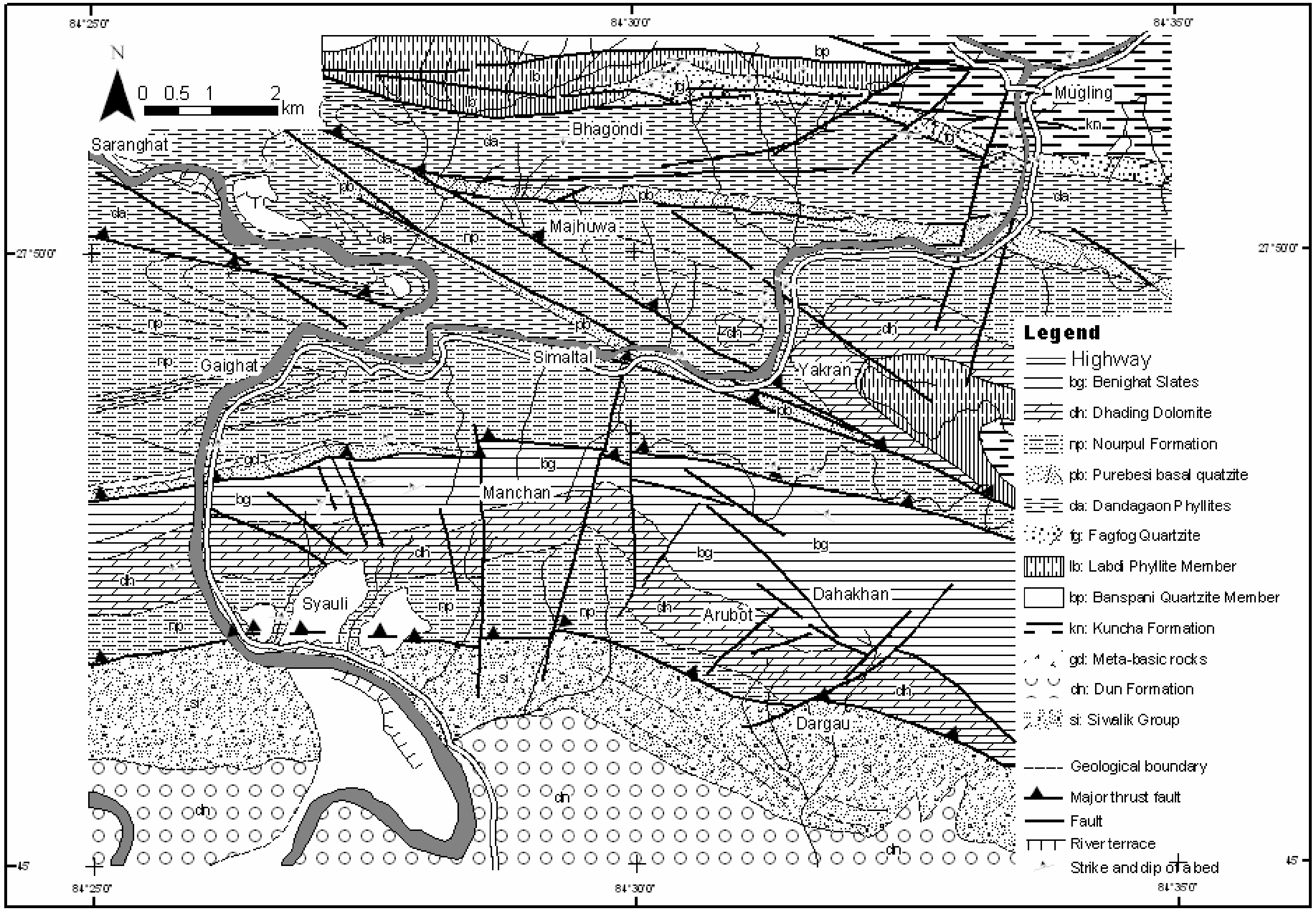
Table 2.1.1 shows strata and rocks of each zone.

**Table 2.1.1 Strata and Rocks in Study Area**

| **Group / Formation** | | **Lithology** | **Engineering property** |
|---|---|---|---|
| dn | Dun Formation | Molassic sediments | Loose, unconsolidated |
| si | Siwalik Group (Neogene) | Molassic sandstone, mudstones, conglomerates | Soft-medium hard rocks |
| **Nawakot Complex** | | | |
| **Upper Nawakot Group** (Upper Paleozoic) | | | |
| bg | Benighat Slates | Dark blue-gray argillaceous slates and phylliets, black carbonaceous slates | Medium-hard rock Well-foliated |
| **Lower Nawakot Group** (Upper Precambrian – Lower Paleozoic) | | | |
| dh | Dhading Dolomite | Light blue-grey dolomite, dense stromatolitic; alga, echinoderms (Lower Paleozoic) | Hard rock, massive, often forming steep cliffs and the Karst |
| np | Nourpul Formation | Phyllites and alternation of phyllite / quartzite and phyllite / dolomite; colour-banding. | Medium – hard rock |
| pb | Purebesi Quartzite Memebr | Strongly ripplemarked orthoquartzite | Hard rock, sometime massive, forming steep cliffs |
| da | Dandagaon Phyllites | Dark green grey phyllites, some calc phyllites, rare thin limestones and quartzite | Medium – hard rock, well foliated |
| fg | Fagfog Quartzite | White orhtoquartzite, ripplemarked, with phyllite interzones. | Hard rock, forming steep cliffs, often massive |
| kn | Kuncha Formation | Phyllites, phyllitic quartzites, greywackes, conglomerates, rare basic (amphibolitic) layers. | Medium – hard rock |

"Group/ Formation" by Photo-geological Map of Part of Central Nepal (1982)

Along the southern section of CH 10 to 14, road slope geology comprises of sedimentary rocks of the Siwalik Group, and the quaternary terrace/talus deposits. Rocks of the Siwalik Group are distributed in the NE-SW direction, dipping towards northwest, and showing monocline structure.




(Modified after Stöcklin and Bhattarai, 1980 and 1982)

**Figure 2.1.5 Generalized Geological Map for CH 11 – CH 36**

Quaternary terrace and talus deposits are distributed on hilly land formed of the Siwalik Group, in and around Phwatar, Syauli, Tandran, Divitar.

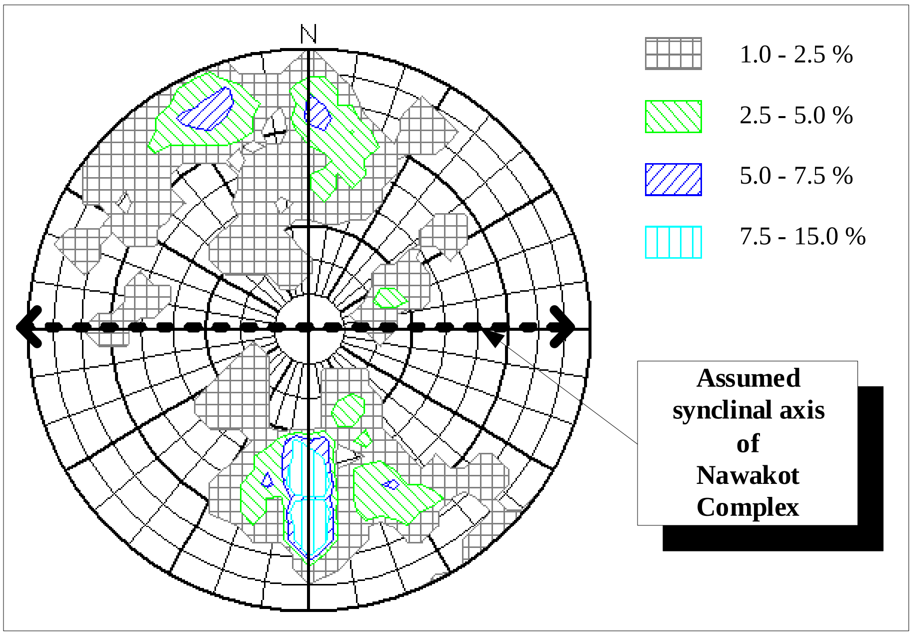
Along a northern section of CH 14 – 36, road slope geology comprises of the Lesser Himalayan meta-sedimentary rocks of the Precambrian – Upper Paleozoic. Those Lesser Himalayan rocks are a part of the Nawakot Complex.

The rocks of the Nawakot Complex expose along road cut-slopes between CH 16 – 36 and as well as riverbeds. The Nawakot Complex is covered by the Quaternary terrace deposits and talus deposits along a section of CH 14 – 16. The bedrocks expose on the upper half of mountain slopes along this 2 km section.

Strata of the Nawakot Complex is generally distributed in a direction of E-W and dipping north with angles of 45 – 75 degrees along a section of CH 14 – 27.

Nearby CH 27, strata of the Nawakot Complex dip toward north with low angles. Around CH 28+500 m, strata of the complex show horizontal bedding planes. Form CH 28+500 m to CH 36, the Nawakot Complex dips toward south with moderate – high angles of 50 – 80 degrees.

Therefore a syncline is assumed through the Nawakot Complex. Its synclinal axis is also assumed in a direction of E-W (See Figure 2.1.6).




(Schmidt net; lower hemisphere projection)

**Figure 2.1.6 Contour Map of bedding planes of the Nawakot Complex**

At around CH 20, the complex is covered by the Quaternary terrace deposits.

The Nawakot Complex is basically classified into the Lower Nawakot Group and the Upper Nawakoto Group. Of the two groups, the following strata and rocks are distributed within the section of CH 10 – 36.

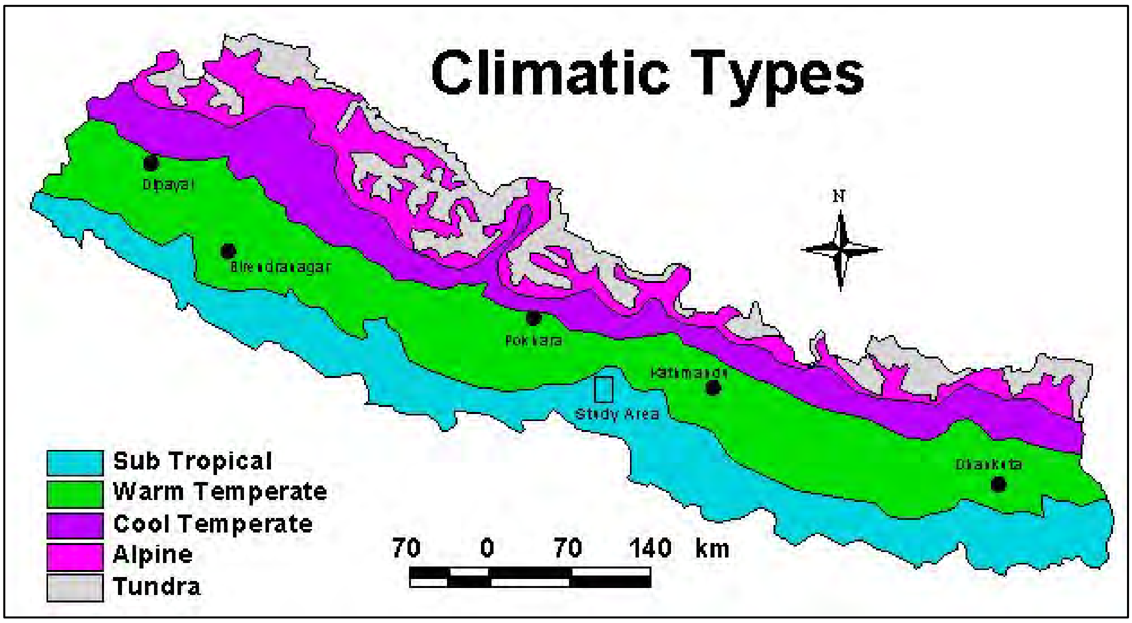
**Table 2.1.2 General Geology of Road Slopes (CH 10 – CH 36)**

| Chainage | Length | Geology |
|---|---|---|
| CH 10 – 14 | 4.00 km | Siwalik Group, Terrace deposits |
| CH 14 – 16 | 2.00 km | Quaternary unconsolidated sediments, Nourpul Formation |
| CH 16 – 16+400 m | 0.40 km | Dhading Dolomites |
| CH 16+400 m – 16+700 m | 0.30 km | Benighat Slate |
| CH 16+700 m – 16+800 m | 0.10 km | Purebesi Quartzite Member |
| CH 16+800 m – 18+600 m | 1.80 km | Nourpul Formation |
| CH 18+600 m – 20+300 m | 1.70 km | Quaternary terrace deposits, Nourpul Formation |
| CH 20+300 m – 33+100 m | 12.8 km | Nourpul Formation |
| CH 33+100 m – 34+350 m | 1.25 km | Purebesi Quartzite Member |
| CH 34+350 m – 34+500 m | 0.15 km | Dandagaon Phyllites |
| CH 34+500 m – 35+900 m | 1.40 km | Kuncha Formation |
| CH 35+900 m – 36 | 0.10 km | Quaternary terrace deposits |

### 2.1.2 Climate

**(1) Climates in Nepal**

Climate is the collected weather patterns of an area. The climate of Nepal differs drastically in different places and seasons, it has cosmopolitan climates. In general, Nepal has cold and dry winter, hot and dry summer, and heavy monsoon periods. Globally most of the regions have four seasons, however, Nepal has six, they are: Spring or Vasant (Mid-March to Mid-May), Summer or Grishma (Mid-May to Mid-July), Monsoon or Varsa (Mid-July to Mid-September), Autumn or Sharad (Mid-September to Mid-November), Hemant (Mid-November to Mid-January) and Shishir (Mid-January to Mid-March). Further, Nepal has mainly five types of climates which are determined based on altitude ranges (Figure 2.1.7). The climates found in Nepal are as mentioned below:




(Modified by materials in Home Page in Department of Hydrology and Meteorology)

**Figure 2.1.7 Climatic Types in Nepal**

**Tundra Climate:** This climate is found in the Himalayan region which falls above 5000 m from the mean sea level (MSL). The temperature in winter is quite less than the freezing point, while in summer it is slightly less than the freezing point. No vegetation is found in this climate.

**Alpine Climate:** This climate is prevailed in higher hilly region which falls in the range of 3300-5000 m from the MSL. The temperature in winter is less than the freezing point but in summer it ranges from 5-15 $^{o}$C. Alpine forests are found in this climate.

**Cool Temperate Climate:** This climate is found in central hilly region between 2100-3300 m from the MSL. In winter, temperature is less than freezing point while in summer it ranges from 15-20 $^{o}$C. Coniferous forests are found in this climate.

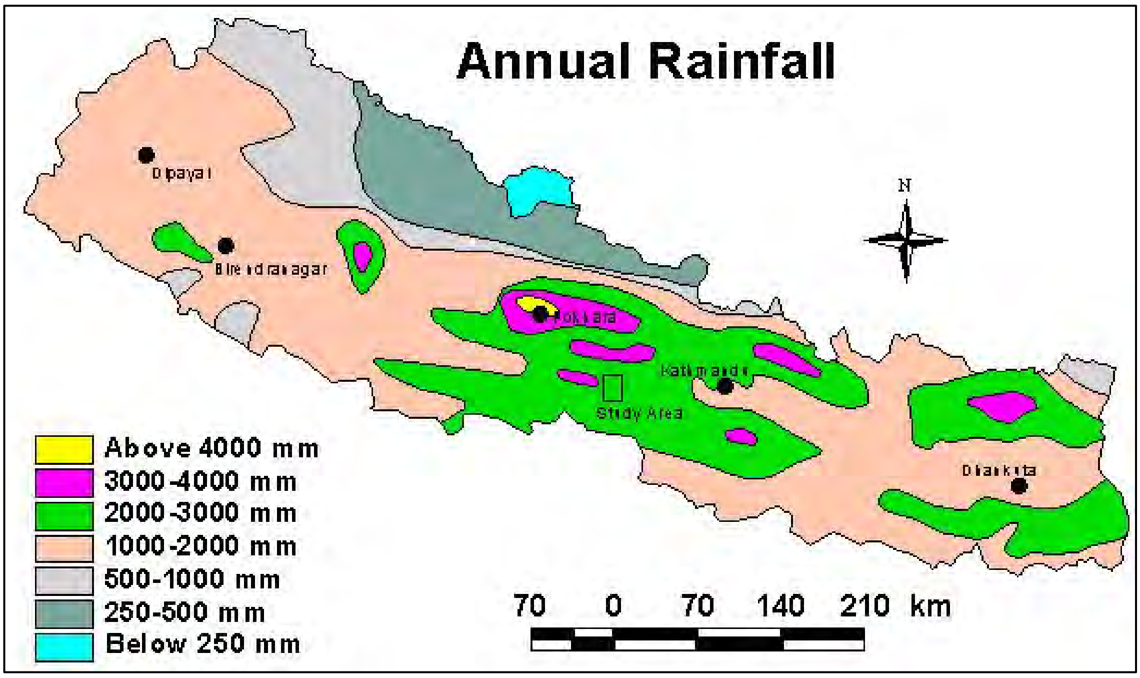
**Warm Temperate Climate:** This climate is found in lower hilly region and in the valley which ranges from 900-2100 m from MSL. In winter, temperature ranges from 0-18 $^{o}$C while in summer it ranges from 17-30 $^{o}$C. Deciduous forests are found in this climate.

**Sub-Tropical Climate:** This climate is found in the Mahabharat hills and Terai which ranges below 900 m from the MSL. The temperature in winter ranges from 6-25 $^{o}$C, while in summer it is 25-40 $^{o}$C. Evergreen forests are found in this climate.

**(2) Annual Rainfall Distribution in Nepal**

Rainfall in Nepal is primarily affected by the summer monsoon developed over the Bay of Bengal. Therefore, high rainfall, about 80% of total annual rainfall, receives during the summer monsoon period between June and September. The remaining period receives about 20% of total annual rainfall. In Nepal, rainfall has wide temporal and spatial variability. Several pocket areas in Nepal receive high rainfall more than 3000 mm in a year. Such high annual rainfall receiving areas lies close to Num in eastern Nepal, Gumthang in Central Nepal and Pokhara in western Nepal. The highest rainfall receiving area is Pokhara with more than 4000 mm rainfall in a year.

The topographic effect as well as windward and leeward effect in rainfall is quite significant in Nepal. This is illustrated by the annual rainfalls observed in Pokhara and Mustang areas. Pokhara area lies in windward side. So it has annual rainfall more than 3000 mm whereas Mustang area lies in leeward side which receives annual rainfall less than 250 mm.




(Modified by materials in Home Page in Department of Hydrology and Meteorology)

**Figure 2.1.8 Annual Rainfall in Nepal**

**(3) Climate in Narayangharh-Mugling Highway**

Elevation of the adjoining areas along the highway ranges from 200-900 m from the MSL, therefore, sub-tropical climate prevails within the vicinity of the highway. In winter, temperature ranges from 6-25oC in the surrounding areas of the highway. Meanwhile, in summer, temperature at the southernmost and depressed part of the highway (i.e Narayangharh and surrounding areas) rises considerably high while at the areas lying on elevated places on the northernmost part of the highway are with fair climate. Moreover in summer, temperature ranges from 25-40 oC in the surrounding areas of the highway. Green forests prevail throughout the highway. For reference purposes, the monthly maximum temperature and daily rainfall recorded at Bharatpur station during 2002-06 were analyzed. A highest maximum temperature of 41.2oC was recorded in May, 2004. It was found that April, May and June are the hottest months with average maximum temperature of 37.8 oC, 39.3 oC and 38.6 oC, respectively. The mean annual rainfall in the area is about 2650 mm.

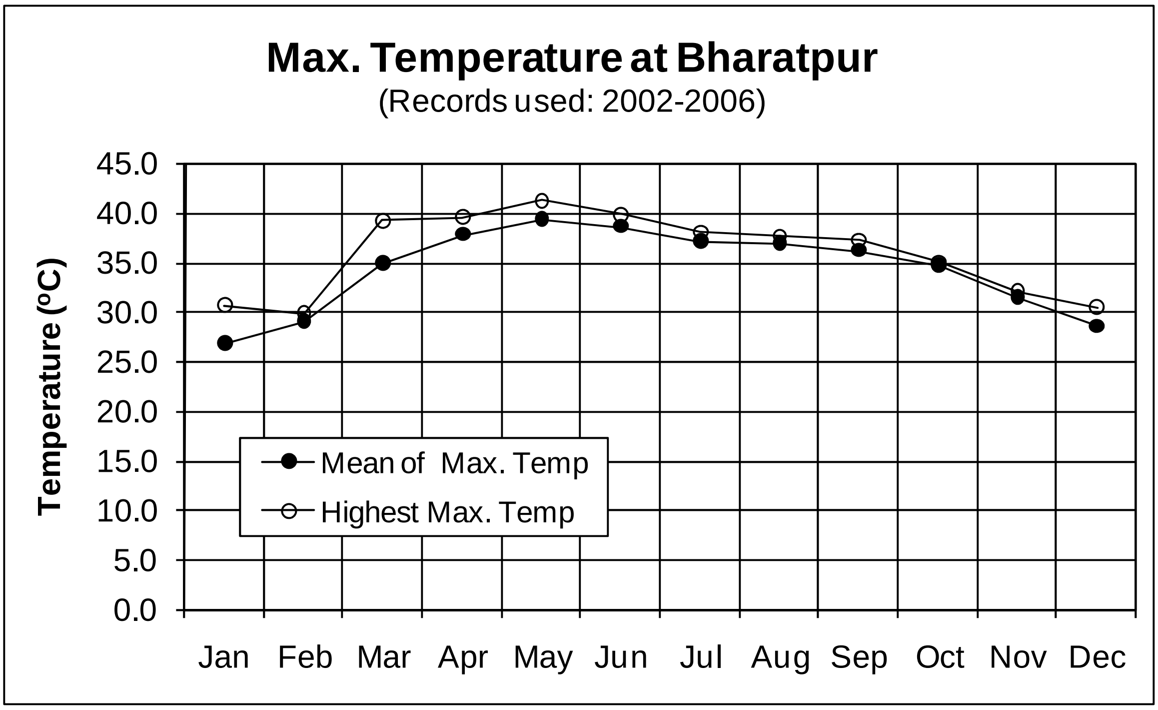



**Figure 2.1.9 Maximum Air Temperature of Bharatpur Station**

## 2.2 Social and Natural Condition

The social conditions in each VDCs are studied to formulate practical approaches for the slope disasters management.

### 2.2.1 Outline of the Study Area

#### (1) Location of the Study Area

The Study area is composed of the Kabilash, Darechok, Dahakhani and Chandi Bhanjyang VDCs and Bharatpur Municipality in Chitwan district. Most areas along the Nayarangharh-Mugling Highway which are prone to disaster, include Kabilash VDC that stretches between the sections CH 10 km to 26 km of the highway. Thus studies on social conditions are mainly concentrated in the Kabilash VDC. Its location is highlighted in the map.

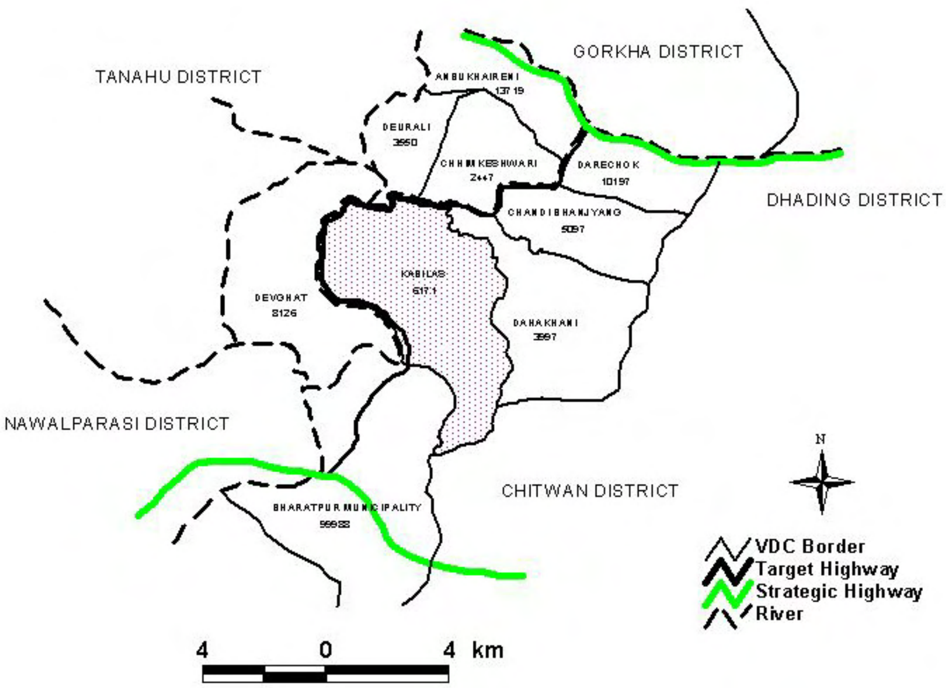



**Figure 2.2.1 Location of Study Area**

##### (a) Kabilash VDC

The Kabilash VDC is one of the major landslides and debris flow disasters prone village along the N-M Highway. The total area of Kabilash VDC is approximately 62 $km^2$. The Kabilash VDC is bounded by the Trishuli river in the north and west; Bharatpur Municipality and Jutpani VDC in the south; and Dahakhani VDC in the east.

### (b) Dahakhani VDC

The total area of Darechok VDC is about 39 km$^2$. The boundary of the VDC is Kabilash VDC in the west.

### (c) Chandi Bhanjyang VDC

The total area of Chandi Bhanjyang VDC is about 48 km$^2$. The VDC is bounded by Dahakhani and Shaktikhor VDCs in the south.

### (d) Darechok VDC

The total area of Darechok VDC is about 39 km$^2$. The boundary of the VDC is Trishushuli River in the west; Chandi Chandibanjyang VDCs in the south; Saktikhor and Gorka District in the north.

## (2) Population

According to the Central Bureau of Statistics (CBS) of 2003, the total number of households in the Kabilash, Darechok, Dahakhani and Chandi Bhanjyang VDCs were 985, 1648, 589 and 813, respectively as shown in Table 2.2.1.

**Table 2.2.1 Household and Population in the Study Area**

| VDC | Household | Population | | |
|---|---|---|---|---|
| | | Male | Female | Total |
| Kabilash | 985 | 2767 | 2748 | 5513 |
| Dahakhani | 589 | 1807 | 1764 | 3571 |
| Chandi Bhanjyang | 813 | 2279 | 2274 | 4553 |
| Darechok | 1648 | 4790 | 4319 | 9109 |
| Total | 4035 | 11641 | 11105 | 22746 |

Source: CBS2003

## (3) Economic Condition

### (a) Sources of Income

In the study area, only 24 % of total households have been engaged in some sorts of economic activities where as 76 % of households are depended on traditional agriculture farming for their livelihood in the study area as shown in Table 2.2.2.

**Table2.2.2 Economic Activities in the Study Area**

| VDC | Household Nos. | | | Type of Economic Activity | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | Having Economic Activity | Not having Economic Activity | Manufacture | Trade | Transport | Servic | Other | Total |
| Kabilash | 985 | 326 | 659 | 11 | 89 | 2 | 3 | 221 | 326 |
| Dahakhani | 589 | 17 | 572 | 1 | 6 | 0 | 8 | 2 | 17 |
| Chandi Bhanjyang | 813 | 83 | 730 | o | 53 | 0 | 20 | 10 | 83 |
| Darechok | 1648 | 549 | 1099 | 11 | 339 | 14 | 111 | 74 | 549 |
| Total | 4035 | 975 | 3060 | 23 | 487 | 16 | 142 | 307 | 975 |

Source: CBS2003

Rain-fed agriculture is being practiced in the Study area due to lack of irrigation facilities. Similarly, method of raising livestock is conventional using available local breeds which seem less productive. Therefore, income generated from the agricultural production and raising livestock is not enough to maintain the livelihood. Hence, it is common for the youths in the area to leave their village and seek opportunities either to other domestic cities or overseas, working as unskilled labors in order to support the families.

**(b) Income**

Due to steep geographical condition, the cultivated area is very limited. Therefore, income from agricultural sources is insignificant and is difficult to sustain for a period of six months. The estimated average annual incomes of households in four VDCs is shown in Table 2.2.3

**Table 2.2.3 Estimated Annual Income per Households in Study Areas**

| VDC | Total Households | Estimated Average Annual Income (NRs) |
|---|---|---|
| Kabilash | 985 | 18000 |
| Dahakhani | 589 | 12000 |
| Chandi Bhanjyang | 813 | 15000 |
| Darechok | 1648 | 25000 |
| Total | 4035 | (average) 17500 |

Source: CBS2003

**(4) Agriculture Condition**

**(a) Cultivated Land and Irrigation Status**

Total cultivated land of the Study areas is estimated as 1326 hectare with only 108.8 hectares (8.2 percent) under irrigation. Table 2.2.4 shows the estimated cultivated land and irrigation status in four VDCs.

**Table 2.2.4 Estimated Cultivated Land and Irrigation Status in Study Areas**

| VDC | Estimated Cultivated Land (ha) | Irrigated Area (ha) | Irrigation Method | Percent of Irrigation Available | Irrigation Available Wards |
|---|---|---|---|---|---|
| Kabilash | 68.0 | 61.2 | Small Irrigation | 90 | 1, 2, 4, 5, 6 and 7 (2, 4, 5 and 6 are affected from water disaster) |
| Dahakhani | 510.0 | 6.8 | Small Irrigation | 2 | 7,3 and 9 |
| Chandi Bhanjyang | 278.8 | 27.2 | Small Irrigation | 10 | 3 |
| Darechok | 476.0 | 13.6 | Pipe | 3 | 9 and 2 |
| Total | 1326.0 | 108.8 | | 8.2 | |

Source: Field Survey, September, 2007

**(b) Cropping Pattern and Yield Rates**

The yearly cropping pattern of the study areas is presented in Table 2.2.5.

**Table 2.2.5 Cropping Pattern in the Study Area**

| Crops | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monsoon Paddy | | | | | | | ■ | ■ | ■ | ■ | ■ | |
| Spring Paddy | | | ■ | ■ | ■ | ■ | | | | | | |
| Monsoon Maize | | | | | ■ | ■ | ■ | ■ | | | | |
| Spring Maize | | | ■ | ■ | ■ | ■ | | | | | | |
| Wheat | ■ | ■ | ■ | ■ | | | | | | | | ■ |
| Mustard | ■ | ■ | | | | | | | | ■ | ■ | ■ |
| Pulses | ■ | ■ | ■ | ■ | | | | | | | | ■ |
| Vegetables | ■ | ■ | ■ | ■ | ■ | | | | ■ | ■ | ■ | ■ |

Source: Field Survey, September, 2007

The following Table 2.2.6 shows the cropped areas and their productivity in four VDCs.

**Table 2.2.6 Estimated Cropped Areas and Yield Rates**

| Crops | Kabilash | | | Dahakhani | | | Chandi Bhanjyang | | | Darechok | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area (ha) | Yield Rate (mt/ha) | No.of House | Area (ha) | Yield Rate (mt/ha) | No.of House | Area (ha) | Yield Rate (mt/ha) | No.of House | Area (ha) | Yield Rate (mt/ha) | No.of House |
| Paddy | 61.2 | 2.0 | 325 | 6.8 | 0.9 | 200 | 54.4 | 1.5 | 60 | 13.6 | 1.0 | 85 |
| Wheat | 68.0 | 1.0 | 380 | 2.7 | 0.6 | 250 | 23.8 | 0.6 | 125 | - | - | - |
| Maize | 204.0 | 1.0 | 680 | 510.0 | 1.0 | 540 | 200.0 | 1.0 | 650 | 476.0 | 0.5 | 120 |
| Millet | 15.7 | 0.5 | 620 | 346.8 | 0.5 | 550 | 102.0 | 0.4 | 700 | 272.0 | 0.3 | 950 |
| Pulses | 15.7 | 0.5 | 870 | 34.0 | 0.2 | 500 | 12.6 | 0.3 | 90 | 13.6 | 0.2 | 800 |
| Vegetable | 12.0 | | 200 | 25.0 | | 150 | 5.0 | | 50 | 10.0 | | 300 |

Source: Field Survey, September, 2007

### (5) Drinking Water Situation

About 83.0 percent of the households obtain drinking water from pipes linked to water sources. The remaning 17 .0 percent obtain water directly from other sources such as wells, river etc. Table 2.2.7 shows status of households using pipe water and other sources.

**Table 2.2.7 Drinking Water Situation**

| VDC | % Households Using Pipe Water | % Households Using Others Sources (Wells, River etc) | Estimated Time of walking Distance (Minutes) |
|---|---|---|---|
| Kabilash | 70 | 30 | 20 |
| Dahakhani | 97 | 3 | 10 |
| Chandi Bhanjyang | 90 | 10 | 30 |
| Darechok | 75 | 25 | 10 |
| Total | 83 | 17 | 17 |

Source: Field Survey- September, 2007

### (6) Education

#### (a) Literacy Status

In the study area, only 46.6 % of the population can read and write. Moreover, male has higher literacy rate of 59 % while female with 41 %.

**Table 2.2.8 Literacy Status in the Study Area**

| S. N. | VDC | Population of School Age | | | Can't Read and Write | | | Can Read Only | | | Can Read and Write | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Male | Female | Total | Male | Female | Total | Male | Female | Total | Male | Female | Total |
| 1 | Kabilas | 2342 | 2364 | 4706 | 861 | 1290 | 2151 | 308 | 301 | 609 | 1164 | 764 | 1928 |
| 2 | Dahakhani | 1500 | 1396 | 2896 | 638 | 885 | 1523 | 230 | 186 | 416 | 614 | 310 | 924 |
| 3 | Darechok | 4125 | 3708 | 7833 | 1056 | 1455 | 2511 | 102 | 104 | 206 | 2944 | 2148 | 5092 |
| 4 | Chandi Bhanjyang | 1859 | 1989 | 3848 | 1217 | 1474 | 2691 | 47 | 49 | 96 | 585 | 455 | 1040 |
| Total | | 9826 | 9457 | 19283 | 3772 | 5104 | 8876 | 687 | 640 | 1327 | 5307 | 3677 | 8984 |

Source: CBS 2003

### (b) Educational and other Service Institutions Available in Study Areas

Education and service institutions are important for uplifting the socio-economic conditions. These are also essential in rendering institutional services during planning and implementation of development programs in above study areas. Table 2.2.9 shows about educational and service institutions in 4 VDCs.

**Table 2.2.9 Educational and other Service Institutions Available in Study Areas**

| VDC | Schools | Health Posts | Animal Health Posts | NGOs/ Private Services Institutions |
|---|---|---|---|---|
| Kabilash | 12 | 1 | - | NGOs (Practical Action, Red Cross) |
| Dahakhani | 8 | 1 | - | - |
| Chandi Bhanjyang | 13 | 2 | - | - |
| Darechok | 15 | 2 | 1 | 1Finance Institution |
| Total | 48 | 6 | 1 | 3 |

Source: VDC Profiles and Field Survey- September, 2007

## (7) Environmental Condition

Environmental condition in adjoining villages along the N-M Highway has degraded. Natural disasters like landslides, floods and debris flows occur frequently during rainy seasons. Fragile geology is the main reason that affect environmental situation in the Study area. The social and economic conditions of the people in the areas are also affecting the environmental degradation and induce water disasters. Poverty is realized as the primary cause while lack of awareness and education are secondary factors in affecting the current environmental condition. Similarly, deforestation and excessive grazing are the main reasons that cause slope disasters.

### (a) Deforestation

People are clearing forests for cultivation to produce more to meet their family's yearly food requirements, and are cutting trees intensively for fuel wood. Therefore, deforestation is one of the key factors for slope disasters.

### (b) Haphazard and Over Grazing

Cattle, sheep and goats are found almost in each household. People let their cattle, sheep and goats graze haphazardly and freely without any control regardless of carrying capacity of the forests. As a result, forest area has been reducing and damaging day by day. This is also one of the major reasons of natural disasters made by human activities.

**(c) Migration and Land Encroachment**

People migrating from neighboring districts in Kabilash VDC is in increasing trend. Among them, majority are settling illegally along the road sides of N-M Highway and upper hill areas. Migrants are clearing the forests to settle their houses and cultivating slope lands which are government lands. Due to this, the risk of slope disasters has increased in study areas. Therefore, to reduce the risk of slope disasters the local government should have policy to check the settlements in slope and forest areas. Further, the local government should formulate effective policy to shift the settlements from risky areas which is very challenging.

### (8) Heritage and Monuments to be protected in Study Areas

There are few monuments and heritage in study areas. These are as follows:

**Table 2.2.10 Heritage and Monuments to be Protected in Study Areas**

| VDC | Types | Location | Number |
|---|---|---|---|
| Kabilash | 1. Gadhi Buddhist<br>2. Japanese Remberance | Ward No -7<br>Ward No- 1 | 1<br>1 |
| Dahakhani | 1. Temple<br>2. Gadhi | Ward No -5 | 1 |
| Chandi Bhanjyang | 1. Gadhi<br>2. Temple | Tundikhel<br>Ichha Kamana Mandir | 1<br>1 |
| Darechok | 1. Temple<br>2. Gumba | Wards-3,9,4 | 4 |
| Total | | | 9 |

Source: Field Survey- September, 2007

## 2.2.2 Social Condition of Kabilash Village

### (1) Administrative Structure of Village

Kabilash VDC represented by a Chairman, a Vice- Chairman, and nine Ward Chair Persons (one from each ward) and 36 Ward Members (four from each ward). The VDC is entrusted with powers, functions and responsibilities within the village development area:

(a) Relating to planning, administration and finance

(b) Relating to development

(c) Miscellaneous

Currently, there is absence of elected VDC Chairperson. Therefore, VDC Secretary who is an employee of Ministry of Local Government is responsible to carry out the administrative and development works. Political and administrative Charts of Kabilash VDC are presented as given below in the Figure 2.2.2 and 2.2.3.

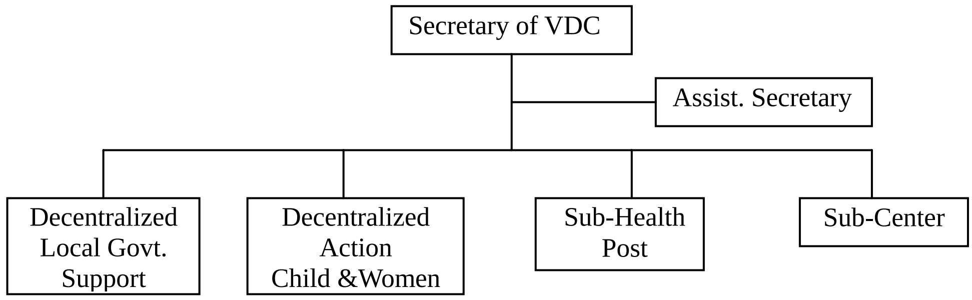



**Figure 2.2.2 Administrative Chart of Kabilash VDC**

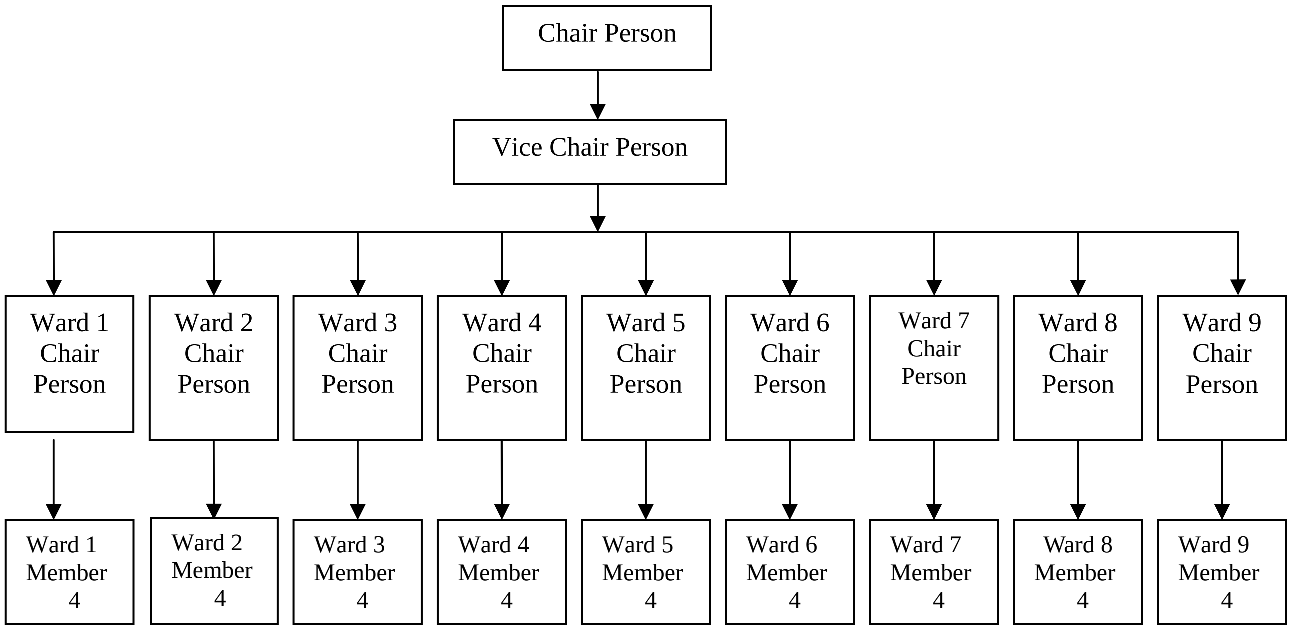



**Figure 2.2.3 Political Organization of Kabilash VDC**

The development projects completed by Kabilash VDC in 2006/2007 include construction of primary school buildings, procurement of electric posts, provision of trail roads, drinking water and small scale irrigation system. These projects were implemented under the financial assistance of District Development Committee of Chitwan. The total estimated budget of VDC in 2007/2008 is Rs 2,265,000.

**(2) Land Use**

The land-use pattern in Kabilash is presented in the following figure. Most of the land areas are covered with forests.

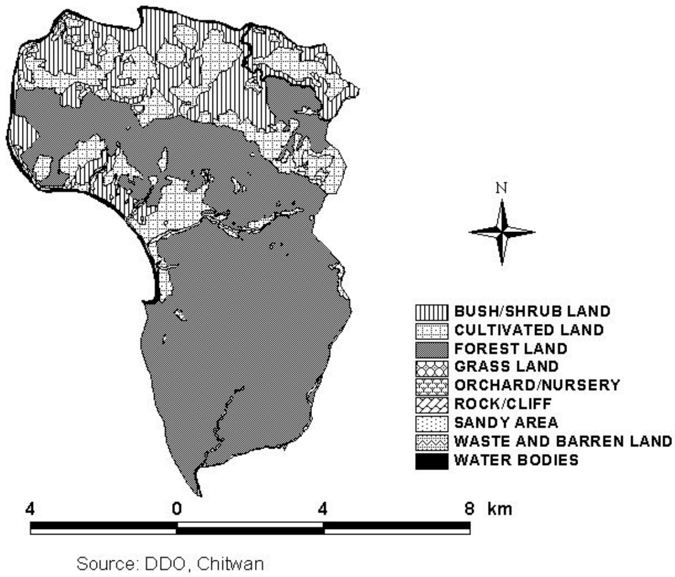



**Figure 2.2.4 Land-use Map of Kabilash VDC**

### (3) Disaster Prone Areas in the Kabilash Village

Disasters prone areas in Kabilash are in wards 1, 6, 8 and 9 (Figure 2.2.5). In 2003 and 2006, disasters occurred in these wards, with many lives and properties lost due to landslides and debris flows. Therefore, much attention should be paid on these areas concerning disasters risk management.

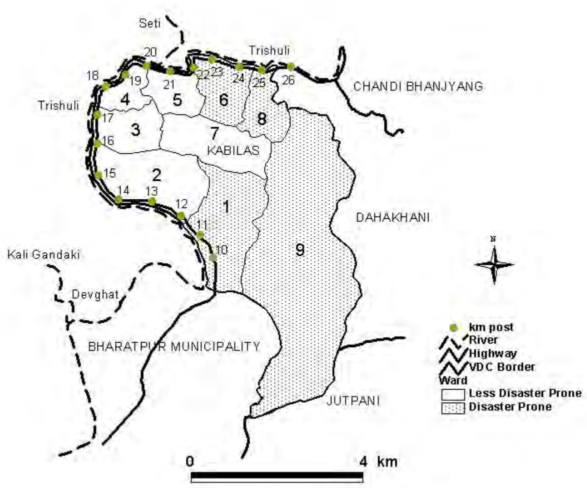



**Figure 2.2.5 Disasters Risk Areas of Kabilash Village**

### (4) Organizations Involved in Disaster Management in Kabilash Village

Disasters management programs from various organizations are being launched in the Kabilash VDC through local community group or through school students. Some of the organizations involved in the disasters management and their on-going programs in the

Kabilash VDC are briefly discussed.

**(a) Forests Committees**

In the past, 6 forests committees were formed in the VDC to conserve and manage the forests. Among them only 3 forests committees are active at present. The forests committees have been requesting to the Government to handover these forests to local community management. Still no any decision has been taken in this connection.

**(b) Climate Change Impact Disaster Management Group and Practical Action (INGO)**

Some energetic youths of the VDC have formed the group in the VDC. The group had made some studies on the causes of deforestation in the VDC and concluded that poverty is the main cause of deforestation as they found, people have been cutting timbers to earn money by selling them in local markets and to use them as fuel by themselves. Therefore, the group is launching some income generation programs including goats keeping in the VDC since 2004 to raise the income level of the people to support on the conservation of the forests. The group is also making some check dams in the streams in the VDC with people participation.

**(c) Red Cross**

Red Cross organized Disaster Risk Reduction Training to Kabilash High School students of classes above grade six. The training was organized to teach some preventive and safeguard measures from the landslides, debris flows and earthquake disasters to the students.

**(d) Mugling Narayangharh Water Induced Disaster Prevention Project (MNWIDPP):**

The MNWIDPP has been carrying out major landslides and debris flows prevention works in the catchments of the cross streams along the M-N Highway. The project has emphasized on non-structural and structural measures for slope disasters prevention. Similarly, the project has been focusing on immediate and long-term countermeasure works for slope stabilization.

### 2.2.3 Disaster Management in National Level

The detail on this content is described in “Volume III DATA AND DRAWING”. The outline on the content is mentioned in this section.

**(1) Institutional Arrangements for Natural Disaster Relief**

In general, Nepal is highly prone to various types of disasters with major ones induced by water. Each year after occurrence of disasters, approximately a thousand people are killed, about one hundred were lost and thousands of families are demoralized. In addition, properties worth millions are ruined. To cope with such natural calamity, a disaster management system has been formulated in the national level.

The Natural Disaster Relief Act (NDRA) has been established to constitute the organizational structure through which the various activities of disaster management are being carried out effectively and efficiently.

**(2) National Action Plan on Disaster Management**

The major programs on disaster preparedness, response, reconstruction, and mitigation action plan have been formulated in 2001 as follows.

1) Measures related Geological, Hydrological and Metrological Hazard Assessment
   Executing organization**:** MOFSC, TU, DWIDP, and DMG
2) Awareness Raising Programs
   Executing organization**:** MOIC and MOHA
3) Training/Rehearsals/Simulations
   Executing organization**:** NRCS, MOHA, Local NGOs
4) Disaster Management Information System
   Executing organization**:** MOIC, NA, Police, INGOs, NGOs
5) National Land Use and Cover Plan
   Executing organization: MOFSC, MOWR
6) Policy on Disaster Reduction Measures
   Executing organization: MOFSC, MOWR
7) Promotion of Regional and Sub-regional Cooperation between Countries exposed to same Natural Hazards
   Executing organization: MOFA, MOWR, and MOI
8) Establishment of Documentation Centre on Disaster Management
   Executing organization: MOFA, MOWR, and MOI

**(3) Activity of DWIDP on Sediment- Related Disaster**

Water Induced Disaster Prevention Technical Centre (DPTC) was established in 1991. Eventually, it became the DWIDP in February 2000 under the Ministry of Water Resources as the lead agency. The Government of Japan through JICA has been assisting to promote the capacity of Government of Nepal and the communities to cope with water induced disasters.

The Disaster Mitigation Support Program Project (DMSP) through JICA cooperation was an attempt to manage these water induced disasters in a comprehensive manner with community involvement through model mitigation works.

The three major activities in DWIDP that contribute to mitigation and reduction of water induced disaster in Nepal. (Source: DWIDP, an Introduction)

(a) Technology Development Work
(b) Training, Study and Introduction Work
(c) Water Induced Disaster Mitigation Work

Activities mentioned in the former clause are carried out by human resources of total 231 which are shown in the Table 2.2.11. (Source: DWIDP, an Introduction)

**Table 2.2.11 Manpower of DWIDP**

| Unit | GI | GII | GIII | NG I | NGII | NC | Total |
|---|---|---|---|---|---|---|---|
| Department | 3 | 7 | 24 | 29 | 2 | 5 | 70 |
| Division | - | 7 | 22 | 58 | 9 | 30 | 126 |
| Subdivision | - | - | 5 | 10 | 10 | 10 | 35 |
| | 3 | 14 | 51 | 148 | 21 | 45 | 231 |

G: Gazetted, NG: Non-Gazetted, NC: Non-classified

**(4) Activities for Road Maintenance Work of Work of Division Road Office (DRO), Bharatpur, Chitwan**

**(a) Organization of Division Office Bharatpur, Chitwan**

DRO, Bharatpur is responsible for disaster management and maintenance of strategic roads in Chitwan and Dhading districts of Nepal. These roads comprise 186 km national highways and 23 km feeder roads. In addition to this, the office is also involved in construction of major bridges in said two districts.

DOR is responsible to carry out on and off -road works within 25m from the Highway. However, DOR and DWIDP are carrying out their preventive and maintenance works in close collaboration. (Source: Road Division Office, Bharatpur, 2007)

N-M Highway lies under the supervision and maintenance of Division Road Office in Bharatpur, Chitwan district. Under the Technical Section, Division Office, Bharatpur, 4 Engineers, 12 sub Engineers, 5 Driver Operators, 1 Lab Technician and 2 Lab boys have been employed on permanent basis. In addition, 11 Supervisors and 75 Length workers have been deployed on temporary basis. In case of urgent disaster, equipment from other offices such as Hetauda, Janakpur, Naubishe and Gajuri have been used in disaster sites within N-M Highway.

**(b) Routine Maintenance**

Total 75 length workers are employed in Chitwan district and each worker is assigned a section of road and is responsible for the routine maintenance. At the beginning of fiscal year, agreement of each length worker is updated for the period of one year. A site of mechanical office with 3 loader machines is responsible for routine maintenance of N-M Highway. However, considering the nature of urgency, the required number of operators and machines are deployed in site from other Civil Division Offices situated in Hetauda, Janakpur and Bharatpur.

**(c) Response on Urgent Disaster and Reopening**

As mentioned in above (b) in order to response on urgent disaster and reopening considering the nature of urgency, the required number of operators and machines are deployed in disaster sites from the Division offices Hetauda, Janakpur and Bharatpur. Currently, the road maintenance sites are located in Mugling, Naubise and Gajuri. Currently, in Technical Section of the Road Division office, Bharatpur, 4 Engineers, 12 Sub-engineers, 5 Driver Operators, 1 Lab Technicians and 2 Lab boys are working on permanent basis. In addition, 11 Supervisors and 75 Length workers are working as temporary. The manpower is responsible to look after Chitwan and Dhading districts.

**(d) Road Maintenance Expenditure at the Project Office Level**

Budget allocation for N-M Highway for Fiscal Year 2006/2007 is as follows:

**Table 2.2.12 Road Maintenance Expenditure for N-M Highway for Fiscal Year 2006/2007**

| | |
|---|---|
| Routine Maintenance | NRs 606,513.00 |
| Recurrent Maintenance | NRs 460,206.24 |
| Recurrent Major | NRs 1027,564.80 |
| Khahare Bridge Maintenance (Retaining/other structure/plumb concrete works) | NRs 360,877.00 |

Source: DOR

### 2.2.4 Rainfall Feature in the Study Area

The detail on this content is described in "Volume III DATA AND DRAWING". The outline on the content is mentioned in this section.

**(1) Spatial Distribution**

The spatial distribution of rainfall stations in and around study area is prepared (Figure 2.2.6). There is one station at Khahare Khola and other nearby stations from the highway is Devghat and Bharatpur. All these 3 stations lie on the southern part of the highway.

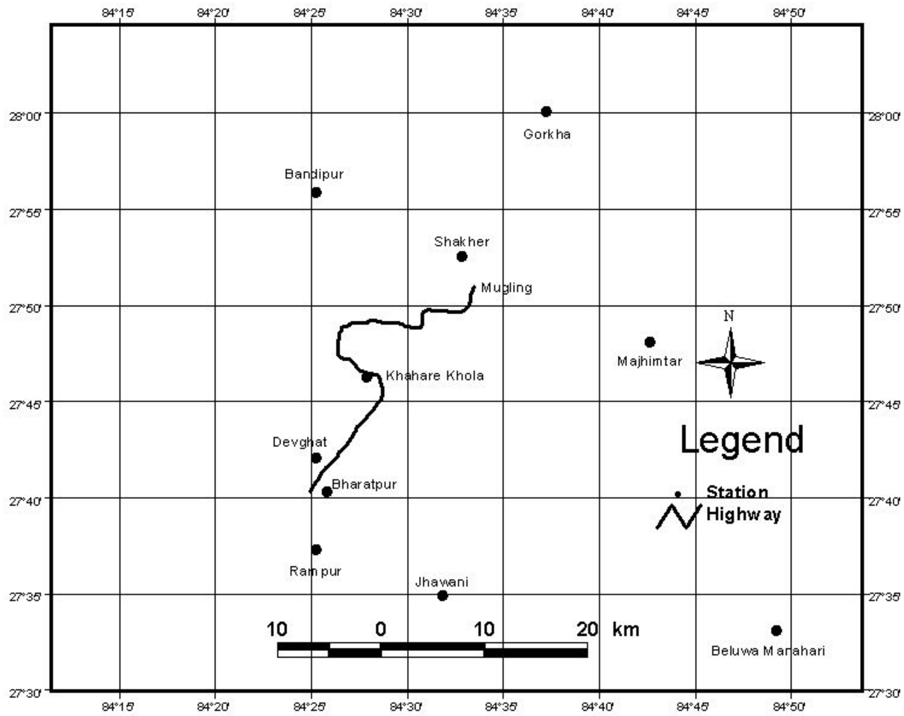



**Figure 2.2.6 Rainfall stations in and around the study area.**

**(2) Operational Conditions and Data Availability**

The stations in the study area are illustrated briefly.

**Khahare Khola Station**: This station was established after 2003 disaster by the Divisional Road Office, Bharatpur at 11 km on N-M Highway. Non-recording rain gauge was installed and daily rainfalls are being measured since 2004. Present operational condition of the station seems satisfactory.

**Devghat Station**: This station is located at downstream of confluence of Kali Gandaki. At this station, both non-recording and recording types of rain gauges are installed by the Department of Hydrology and Meteorology (DHM). The hourly and daily rainfalls are being recorded at this station since 1998. Operational condition of the station at present is satisfactory. Daily rainfalls data of 1998-2006 of this station were made available.

**Bharatpur Station**: The station has non-recording rain gauge and is located in Bharatpur Municipality compound. This station is managed by Department of Hydrology and Meteorology (DHM). Discontinuous daily rainfall records of 2002-06 were made available; however, operational condition of the station seems satisfactory.

**(3) Analysis of 2003 Disaster Rainfall**

The rainfall distribution pattern of 31 July 2003 was studied. The rainfall chart of recording rain gauge of Devghat station showed rain started at 8:45 AM of 30 July and continued until 5:00 AM of 31 July, and the total rainfall amount was 446.2 mm in 20.25 hours (Figure 2.2.7). It showed about 25% of total rainfall (i.e. 114.5 mm) had occurred in the first 10 hours (between 8:45 AM and 18:45 PM), about 50% of total rainfall (i.e. 221.5 mm) had occurred in 12.5 hours (between 8:45 AM and 21:15 PM), and about 75% of total rainfall (i.e. 339.5 mm) had occurred in 14 hours (between 8:45 AM and 22:45 PM). It indicates that in 4 hours period (between 18.45 PM and 22.45 PM) 225.5 mm of rainfall occurred, and it devastated the highway with landslides and debris flows.

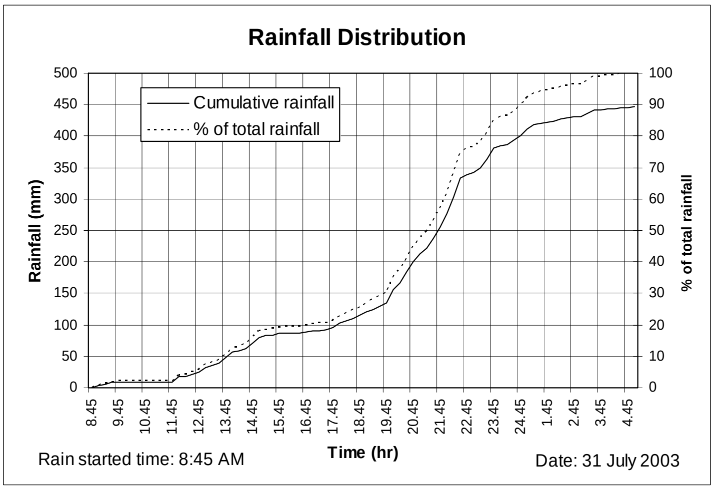



**Figure 2.2.7 Rainfall Distribution on 31 July 2003 at Devghat station**

Similarly, rainfall intensity curve of 2003 disastrous rainfall is developed to use as a reference for getting ideas on devastating intensity of rain and thereby develop the warning system for the possibility of the highway disasters (Figure 2.2.8). The relation used for developing rainfall intensity curve is given below.

$$I = \frac{C}{(t+a)^b} \qquad (1)$$

Where,

| | | |
|---|---|---|
| I | = | Rainfall intensity (mm/hr) |
| t | = | Time duration (min) |
| a, b, C | = | Constants |

From the above analysis, it can be concluded that occurrence of very high intensity rain (i.e. more than 80 mm/hr) after almost 12 hours of continuous rainfall with considerable amount can cause devastating debris flow along the streams crossing the highway.

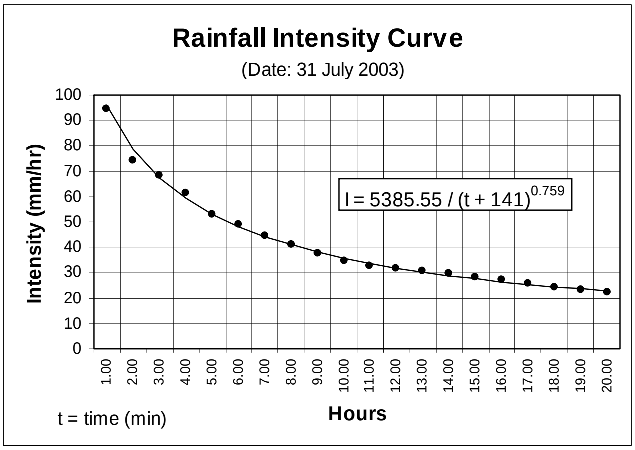



**Figure 2.2.8 Rainfall Intensity Curve for 31 July 2003 (Devghat Station)**

### (4) Daily Rainfall Patterns during Past Disasters

The daily rainfall patterns during 2003, 2006 and 2006 disasters and the pattern of recent heavy rainfall day were analyzed.

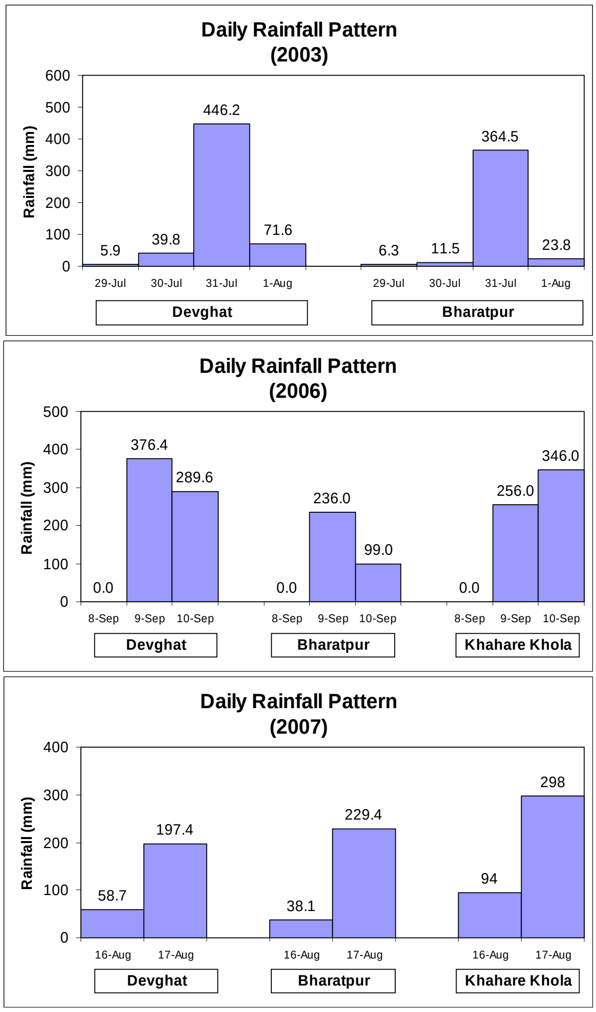



**Figure 2.2.9 Daily Rainfall Pattern during 2006 Disaster**

With analyzing daily rainfall pattern of Devghat stations during 2003 and 2006 disaster, it can be concluded that landslides and debris flow occur on the highway if rainfall continued for 2 days with considerable amount of rainfall on the first day and heavy rainfall of more than 300 mm on the second day. From the inspection of the highway during 2007, it can be concluded that highway is vulnerable to landslides when rainfall continues for 2 days with considerable amount of rainfall on the first day and heavy rainfall of more than 200 mm on the second day.

**(5) Threshold Rainfall Amount Determination for Early Warning**

The accumulated rainfall amounts and intensities have been used for threshold rainfall amount in Japan. However, it is has been pointed out that they do not have enough accuracy for the prediction. In this study, the modified rainfall amounts of 6, 12 and 24-hour half-value, which were estimated using annual maximum daily rainfalls of 1998-2006 during at Devghat station, instead of accumulated rainfall amount for early warning employ for the purpose of increasing the reliability of early warning against the rainfall triggered disasters. The daily rainfall amounts were divided by 24 to convert it to hourly rainfall amounts because H-hour half-value rainfall amounts are estimated based on hourly rainfalls. However, hourly rainfall data on the day of maximum rainfall in 2003 were derived from the rainfall recording chart. The relation used for estimation of T-hour half-value rainfall amounts is as shown in the following equation.

$$RA_{Hhv}(t) = 0.5^{i/H} \times HR(i)$$

Where,

$RA_{Hhv}(t)$ = rainfall amount of H-hour half-value of time ‘t’

i = ‘i' hour before from time ‘t’ (hour)

H = H-hour half-value: Half-value period of hourly rainfall reduction (hour)
H = 6, 12, 24

HR(i) = Hourly rainfall of ‘i +1’ to ‘i' hour before from time ‘t’

The maximum modified rainfall amounts of 6, 12 and 24-hour half-value were computed for the maximum annual daily rainfall days during 1998-2006 at Devghat station. The return periods of 6, 12 and 24-hour half-value rainfall amounts and 24-hour maximum recorded rainfall amounts were analyzed. The return periods of 6, 12 and 24-hour half-value rainfall amounts of 2003 disaster are 85, 58 and 25 years, respectively. Similarly, the return periods of 6, 12 and 24-hour half-value rainfall amounts of 2006 disaster are 4, 5 and 9 years, respectively. The 12-hour half-life rainfall amounts have in-between values of return period for both 2003 and 2006 years among the 6, 12 and 24-hour half-value modified rainfall amounts (Table 2.2.13). As 12-hour half-value modified rainfall has in-between value of return period, it can be used effectively for early warning of disasters which occur due to high intensity rainfall as well as gentle and long duration rainfall. Therefore, 12-hour half-value modified rainfall amount is decided to use as threshold value in early warning for traffic control and residents evacuation on the N-M Highway.

**Table 2.2.13 Return Periods of Each Type of Rainfall Amounts**

| Year | Date | Maximum of 24-hour Rainfall Amount mm (yr) | Maximum of 6-hour half-value Rainfall Amount mm (yr) | Maximum of 12-hour half-value Rainfall Amount mm (yr) | Maximum of 24-hour half-value Rainfall Amount mm (yr) |
|---|---|---|---|---|---|
| 1998 | 5-Jul | 162.3 (1) | 31 (1) | 60.2 (1) | 118.8 (1) |
| 1999 | 25-Aug | 250 (3) | 47.7 (2) | 92.8 (2) | 182.9 (3) |
| 2000 | 24-May | 131 (1) | 25 (1) | 48.6 (1) | 95.9 (1) |
| 2001 | 30-Jul | 224.9 (2) | 42.9 (2) | 83.5 (2) | 164.6 (2) |
| 2002 | 12-Jul | 180.2 (2) | 34.4 (2) | 66.9 (2) | 131.9 (2) |
| 2003 | 31-Jul | 446.2 (16) | 224 (85) | 303 (58) | 362 (25) |
| 2004 | 3-Sep | 152.3 (1) | 29.1 (1) | 56.5 (1) | 111.4 (1) |
| 2005 | 7-Aug | 100.3 (1) | 19.1 (1) | 37.2 (1) | 73.4 (1) |
| 2006 | 9-Sep | 376.4 (9) | 71.8 (4) | 139.7 (5) | 275.4 (9) |

Note: Values in parentheses indicate return periods

The early warning/ evacuation system should be developed for minimizing the loss of properties and lives from rainfall triggered disasters on the highway and villages. Therefore, two separate early warning criteria are proposed for traffic control on the highway and for evacuation of village residents.

**Table 2.2.14 Warning Levels by the Modified Rainfall Amounts**

| Warning Level | Threshold rainfall amount | Action | |
|---|---|---|---|
| | | for the Highway | for Residents Evacuation |
| Level IV | 24-hour half-value modified rainfall amount : 180mm<br>Return periods: 10-year | Warning:<br>Recommendation mentioning road is unsafe | Warning:<br>Recommendation for evacuation |
| Level III | 24-hour half-value modified rainfall amount : 140mm<br>Return periods: 5-year | Caution:<br>Recommendation mentioning careful road passage | |
| Level II | 24-hour half-value modified rainfall amount : 80mm<br>Return periods: 2-year | Preparation:<br>(DRO)Calling up staff/ workers/equipment for emergency action Upload to web-page of DRO and Kabilash VDC the amount of 1 hour rainfall | Caution:<br>Recommendation to prepare for evacuation |
| Level I | 24-hour half-value modified rainfall amount : 60mm<br>Return periods: 1-year | | Preparation:<br>Informing the committee, monitoring team, Ward representative in VDC. Upload to web-page of DRO and Kabilash VDC the amount 1 hour rainfall |

In this system using the modified rainfall amounts, the predicted hourly rainfall values are employed. The predicted value means a predicted amount as one hour later at a certain point in time. The result of the analysis for the rainfall of June 31, 2003 is indicated following equation and Figure 2.2.10.The correlation coefficient between the observed value and the predicted value is 0.909.

Rprd = Robs (mm)

Where,

Rprd: Predicted hourly value as one hour later at a certain point in time

Robs: Observed hourly value at a certain point in time

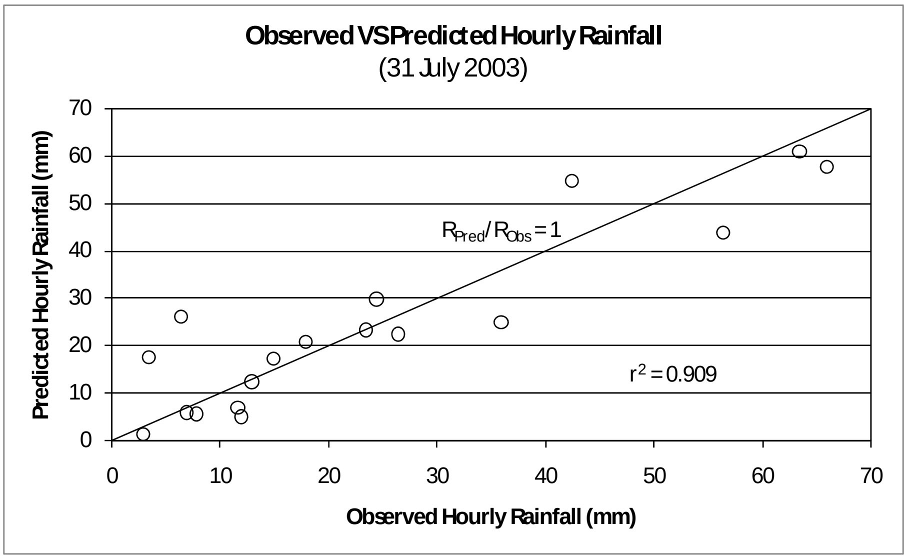



**Figure 2.2.10 Observed hourly rainfall and predicted hourly rainfall on the rainfall of June 31, 2003**

The threshold rainfall amounts and the predicted values in this study are preferable to be renewing by new data.

## 2.3 Road Slope Disasters on Narayangharh-Mugling Highway in 2003

The N-M Highway was damaged badly due to landslides and debris flows because of heavy rainfall (446.2 mm at Devghat) on 31 July 2003. The damages caused by 2003 disasters in the villages along the highway and on the highway itself were studied.

In this section, the characteristics of the road slope disaster in 2003 is comprehensively described, that based on reference data and photo identification using satellite photos in 2005, aerial photos in 1992 and on-site photos after 2003 disaster. Next, the objective figures of the damages are reviewed.

### 2.3.1 The characteristics in 2003 disaster

The boundary of the debris movement characteristics in the slope is Station 15 as shown in Figure 2.3.1 below. Characteristics of the road slope disaster in each area are also shown in said figure.

**(1) Station 10 to 15**

The dip of stratum is opposite to the slope, and the upper portion of the slope is steep where as middle to the lower portion of the slope is relatively gentle and dominated by talus deposits, and the width of the stream is relatively broad. Some failures occur in the upper slope, which induce the collapse of the riverside and debris flow on the stream.

At the moment, there is no serious influence to the road because of substantial distance between the stream level and the road. However, it is possible that consecutive debris flow destroys the road due to rising stream level by the debris deposit in near future.

There is no deep failure (deep slide) in this area.

**(2) Station 15 to 36 (to Mugling)**

The dip of stratum is parallel to the slope, and there are many clear features indicating large scale slide. Many failures were occurred along the streams around the slide features that were not moved themselves in 2003 disaster, especially between Station 17 to 28. It is possible that the failures induce some slide. Few failures like these types were occurred in 2003 between Station 28 to Mugling.

These failures that occurred along the streams between Station 17 to 28 flew over the N-M Highway as debris flows, and did not destroy the highway.

There is no deep failure (deep slide) in this area.

Other types of the debris movement there were occurred all over the highway in 2003 disaster, which is only confirmed by reference reports. These disasters are described as follows.

**Road foundation failure**: the failures were occurred by 1) flowing surface water over the road and 2) erosion along the Trishuli River.

**Small slide movement**: the slide movements were not accompanied by slide feature, which were occurred in the mountainside slope.

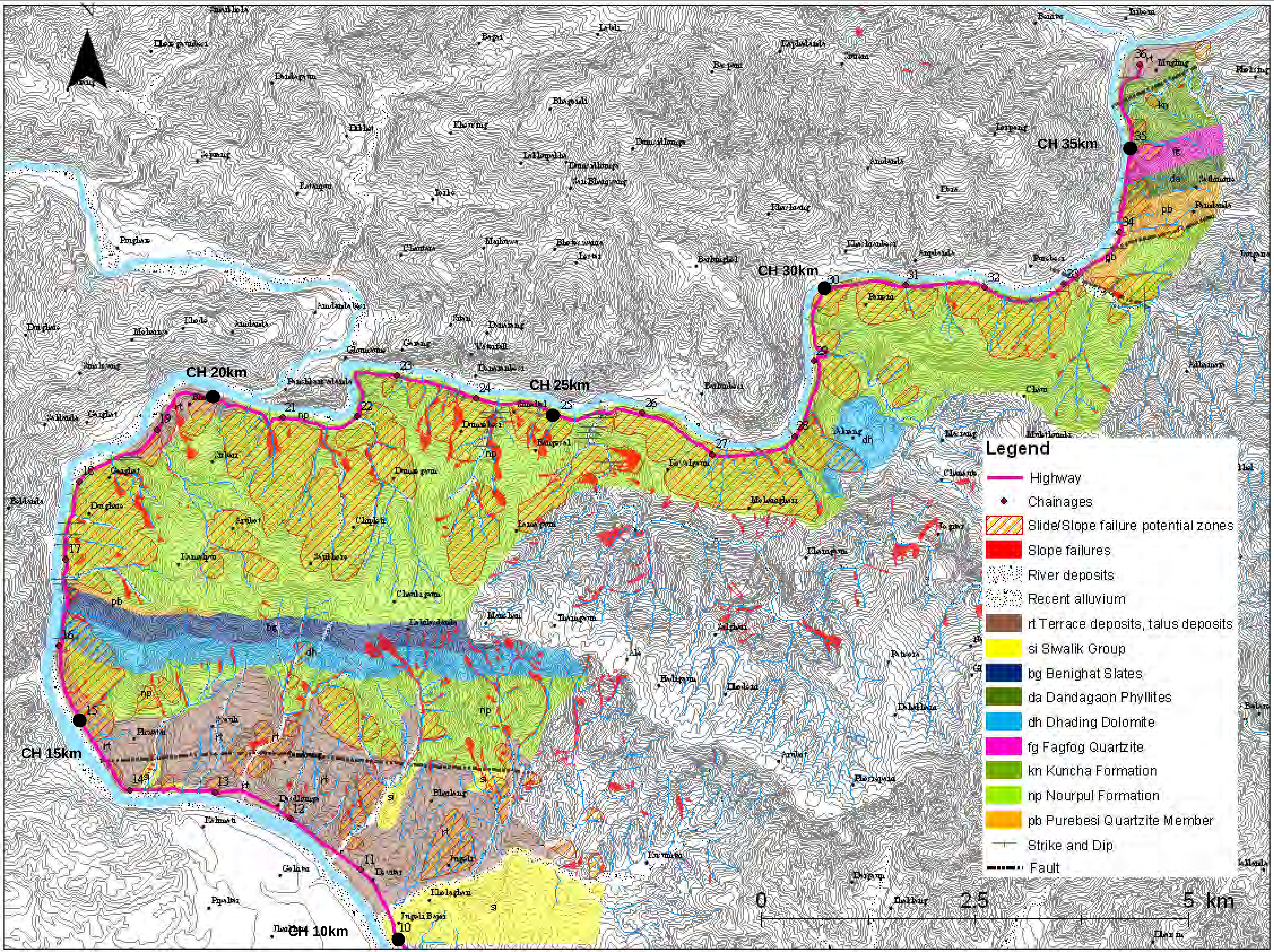



**Figure 2.3.1 Hazard map for CH 10 – 36 of N-M Highway**

### 2.3.2 Damages in 2003 disaster

**(1) Damages Caused in the Villages along the Highway**

The damages caused by 2003 and 2006 disasters in the villages lying along the highway were studied. In 2003 disaster, 18 people died and 69 houses were destroyed in Kabilash Village development committee (VDC). Similarly, in Chandi Bhanjyang VDC 9 people died, 5 injured and 5 houses were damaged (Table 2.3.1). In Darechok VDC, 1 person died and 2 houses were destroyed in 2003 disaster (Figure 2.3.2). However, in 2006 disaster, 3 people died and 15 houses destroyed in Kabilash VDC because of landslides and debris flows.

**Table 2.3.1 Lives and Properties Lost in Villages during 2003 & 2006 Disasters**

| Year | VDC/District | People | | Affected Family (Nos) | Livestock Loss (Nos) | House Destroyed (Nos) | Public Properties Losses | Estimated Loss (NRs) |
|---|---|---|---|---|---|---|---|---|
| | | Death (Nos) | Injured (Nos) | | | | | |
| 2003 | Darechok | 1 | | 2 | 13 | 2 | | 440,000.00 |
| | Chandi Bhanjyang | 9 | 5 | 4 | 44 | 5 | Culvert, School-1 | 530,000.00 |
| | Kabilas | 18 | | 69 | 164 | 69 | Road | 2,022,000.00 |
| 2006 | Kabilas | 3 | | | | 15 | | NA |

Source: Disaster Review 2003 & 2006, DWIDP & VDC Records

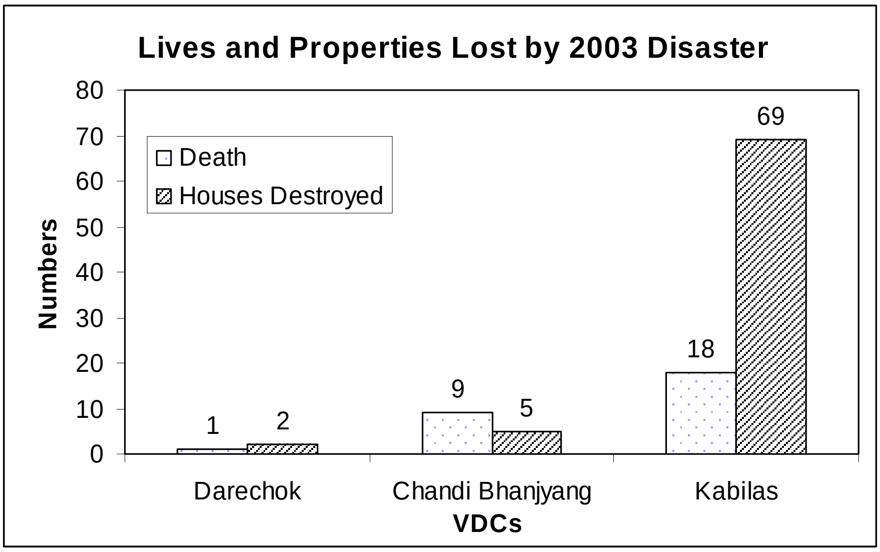



**Figure 2.3.2 Lives and Properties Lost in 2003 Disaster in Villages**

**(2) Damages Caused on the Narayangharh-Mugling Highway**

Damages recorded caused on the N-M Highway are presented in Table 2.3.2. During 2003 disaster on the N-M Highway, 2 bridges, 9 culverts, 8675 m road pavement, 494 m retaining wall and 1480 m embankment were damaged. The bigger volumes of debris flow occurred in Mohore Khola (21+560), gullies of Ch. 23+760, Khahare Khola (11+300) and Gaighat Khola (18+460 ); and total estimated volume of debris at those locations were 60,268, 28,955, 22,837 and 15,089 m$^3$ respectively as shown in Table 2.3.3.

**Table 2.3.2 Properties Lost on N-M Highway by 2003 Disaster**

| S. N. | Property | Destroyed Units |
|---|---|---|
| 1 | Bridges Destroyed (Nos) | 2 |
| 2 | Culverts Destroyed (Nos) | 9 |
| 3 | Road Pavement Destroyed (m) | 8675 |
| 4 | Retaining Wall Damaged (m) | 494 |
| 5 | Embankment Damaged (m) | 1480 |

Source: DWIDP Bulletin 2005-6

The Central Divisional Road Office (CDRO), Bharatpur played major role for rehabilitation of N-M Highway after 2003 disaster. The CDRO has cleared about 199,529 $m^3$ of debris coming from up hill sides and cross streams. At some location vehicles movement was disturbed up to 28 days because of debris clearance works.

**Table 2.3.3 Debris Deposited on N-M Highway in 2003 Disaster and CDRO's Actions**

| S. N. | Chainage | Contractors E/W Work Volume ($m^3$) | Machinery Work (hr) | | Disturbed Days | Volume ($m^3$) | Total Volume ($m^3$) |
|---|---|---|---|---|---|---|---|
| | | | Loader | Excavator | | | |
| 1 | 8+000 | | 24 | | 1 | 1560 | 1560 |
| 2 | 11+300 | 21075 | 10.5 | 9 | 3 | 1762 | 22837 |
| 3 | 16+800 | | 5 | | | 325 | 325 |
| 4 | 17+560 | 1003 | 15 | | 3 | 975 | 1978 |
| 5 | 18+460 | 10093 | 38 | 21 | 10 | 4990 | 15089 |
| 6 | 20+800 | 148 | 20 | | 2 | 1300 | 1448 |
| 7 | 21+560 | 43938 | 134 | 63.5 | 28 | 16330 | 60268 |
| 8 | 23+550 | 707 | 4 | | | 260 | 967 |
| 9 | 23+760 | 2932 | 251.7 | 80.5 | 25 | 26023 | 28955 |
| 10 | 23+770 | | 23 | 3.5 | 5 | 1915 | 1915 |
| 11 | 23+800 | 1715 | 35 | | 12 | 2275 | 3990 |
| 12 | 24+400 | 1194 | 16.5 | 3 | 11 | 1432 | 2626 |
| 13 | 24+740 | 3671 | 16.75 | | 8 | 1089 | 4760 |
| 14 | 27+060 | 3663 | | | | | 3663 |
| 15 | 27+850 | 3522 | | | | | 3522 |
| 16 | 29+500 | 1596 | | | | | 1596 |
| 17 | 30+890 | 654 | 29 | | 15 | 1885 | 2539 |
| 18 | 31+400 | 2232 | 1.5 | | 1 | 97.5 | 2329 |
| 19 | 31+890 | 3231 | | | | | 3231 |
| 20 | 32+400 | | 6.5 | | | 422 | 422 |
| 21 | 34+090 | 139 | | | | | 139 |

Source: DWIDP Bulletin 2005-6

**(3) N-M Highway Rehabilitation Works by CDRO after 2003 Disaster**

Besides debris clearance works to allow for vehicular movement on the N-M Highway after the 2003 disaster, CDRO has also constructed slope stabilization structures along the highway as preventive measures against slope disasters. As presented in Table 2.3.4, the CDOR has constructed breast walls (809 m), retaining walls (538 m), check dams (42), guide walls (104 m), spur (1), anchor walls (4), catch pits (7) and toe walls (269 m).

**Table 2.3.4 CDRO's Rehabilitation Works after 2003 Disaster**

| S. N. | Structure | Constructed Unit |
|---|---|---|
| 1 | Breast walls (m) | 809 |
| 2 | Retaining walls (m) | 538 |
| 3 | Check dams (Nos) | 42 |
| 4 | Guide walls (m) | 104 |
| 5 | Anchor walls (Nos) | 4 |
| 6 | Catch pits (Nos) | 7 |
| 7 | Toe walls (m) | 269 |
| 8 | Spur (Nos) | 1 |

Source: DWIDP Bulletin 2005-6

The details on the slope stabilization structures constructed by the Central Divisional Road Office (CDRO) Bharatpur after 2003 disasters are presented with their locations (Table 2.3.5).

**Table 2.3.5 CDRO's Slope Stabilization Works after 2003 Disaster and their Locations**

| S. N. | Structure | Constructed Location |
|---|---|---|
| 1 | Breast wall | |
| | a. Gabion | 8+930, 12+040, 15+360, 16+990, 17+115, 18+850, 20+350, 26+710, 30+550, 31+475, 31+810 |
| | b. Masonry | 8+660, 13+035, 18+750, 18+790, 19+580, 20+350, 20+800, 21+130, 21+925, 24+000, 24+600, 26+710, 30+550 |
| 2 | Retaining wall | |
| | a. Gabion | 9+500, 14+300, 18+696, 20+350, 20+850, 21+080, 21+642, 21+850, 20+800, 27+280 |
| | b. Masonry | 11+620, 15+060, 17+850, 18+355, 18+415, 21+175, 21+850, 23+423, 23+570, 11+650, 17+050, 24+850, 27+160, 27+280, 28+080, 31+630, 31+810, 32+550, |
| | c. R.C.C. | 21+040, 29+325 |
| 3 | Toe Wall | |
| | a. Concrete toe wall | 16+850, 17+850, 19+450, 24+000 |
| | b. Masonry toe wall | 23+785, 32+475 |
| | c. Gabion toe wall | 26+250, 32+475 |
| 4 | Catch pit wall | 15+060, 24+750, 25+070, 27+070, 29+825, 30+456, 31+400 |
| 5 | Check dam | |
| | a. Gabion | 11+100, 15+060, 16+950, 17+295, 17+560, 18+460, 20+200, 20+800, 21+130, 21+560, 22+150, 23+080, 23+550, 23+780, 24+400, 24+750, 25+070, 26+960, 27+070, 27+160, 27+200, 27+545, 27+600, 27+860, 29+825, 30+456, 30+890, 31+400, 32+890, 34+090, |
| | b. Masonry | 15+930, 30+890 |
| 6 | Gabion guide wall | 11+300, 19+450, 18+460 |
| 7 | Gabion spur | 11+300 |
| 8 | R. C. C. Anchor wall | 17+115, 24+600, 31+875, 31+890 |

Source: DWIDP Bulletin 2005-6

## 2.4 Debris Flow Disaster at Ruwa Khola in 2003

The 2003 heavy rainfall caused a lot of slope failures and associated debris flow in the Ruwa Khola, a branch of the Marsyangdi River, and other river valleys.

The Marsyangdi power house is located on the left side just at the confluence of the Marsyangdi River and its tributary, the Ruwa Khola about 4 km north from Mugling along the way to Pokhara. The Marsyangdi power house started operation and has an installed capacity of 69 MW.

The 2003 rainfall and its triggering debris flow in the Ruwa Khola on July 30 caused a large damage to the power house, stopping operation for nine days with a direct loss of about 1.0 billion Rs.

The following describes the 2003 sediment-related disaster and associated damage. In addition, the previous information is based on JICA Expert Report (Hiruma, Dec., 2003) titled "Debris Flow Disaster in Ruwa Khola in July 2003 and Its Affection to Marsyangdi Power House".

### 2.4.1 Outline of Debris Flow Disaster

#### (1) Occurrence Time and Triggers

Date and time of Occurrence: AM 2:00, July 30, 2003.

Trigger: Continuous rainfall from 17:00, July 29 (446.2 mm from 8:45 a,m., July 30 to 5:00 a.m., July 31, at Devghat Station)

#### (2) Debris Flow Disaster

The debris flow occurrence is summarized, on the basis of the field reconnaissance after debris flow disaster, which are as follows:

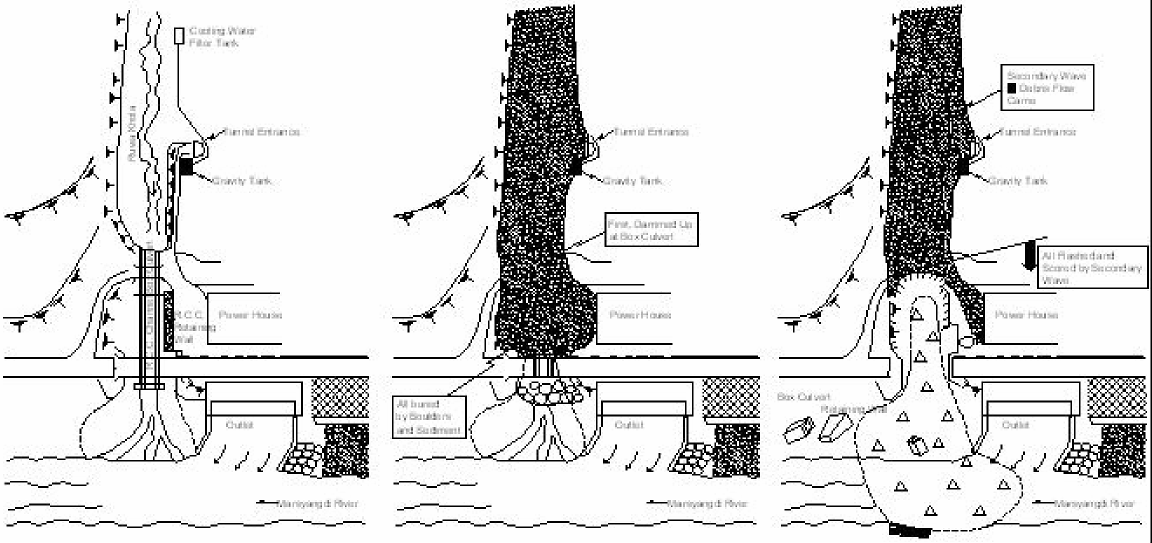
a) Slope failures on the valley slopes upstream of the power house and associated debris flows produced a large amount of debris materials, which began to be deposited from about 300 m upstream of the power house. That raised riverbed of about 3 to 4 m.

b) Before debris flow disaster, there was a foot trail, which crosses the river just upstream of the mouth of the Ruwa Khola. The path road blocked the river, in turn leading to deposition of debris flow sediment behind the path road, consequently damming up the river and raising the riverbed.

c) With the rising of the riverbed, the debris flow sediment gradually spread out laterally and partially the inlet of cooling water tunnel and the power house.

d) When the second debris flow occurred, the natural dam by the debris flow sediments was eroded by debris flow and failed, causing a larger debris flow. The bridge foundation and the box culvert were washed out by the associated debris flow

e) The failed sediments associated the debris flow materials flowed down into the Marsyangdi River, plugged the Marsyangdi River and dammed up river water again. This caused the river water and associated debris materials flowed into the tailrace tunnel.




a) Before debris flow

b) When the first wave of debris flow occurrence

c) After the second wave of debris flow occurrence

**Figure 2.4.1 Conceptual Illustration of the 2003 Debris Flow Occurrence**

### 2.4.2 Associated Damages

#### (1) Power plant

a) The power plant building was buried under debris flow sediments. The building itself was not damaged, the debris flow and subsequent inundation stood at 30 cm in the first floor and at 1.2 m in the basement. Draining and cleaning took three days.

b) The building foundation was exposed due to debris flow. Emergency measures, using gabion walls were executed.

c) Debris flow from the Ruwa Khola blocked the Marsyangdi River. The river water and associated debris materials flowed into the tailrace tunnel which faces the Marsyangdi River. One of the three gates was deformed by hit of shoulders. Drainage and cleaning took about one month.

**(2) Other facilities**

a) Outlet of cooling water tunnel facing the Ruwa Khola was buried under debris flow deposits.

b) Water supply pipe was washed out by debris flow.

c) Te box culvert just upstream of the confluence of the Marsyangdi River and the Ruwa Khola was completely washed out by the associated debris flow

d) The bridge foundation was partially washed out by the associated debris flow.