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Mainstreaming Climate Change Risk Management in Development

1 Main Consultancy Package (44768-012)

ROADS AND BRIDGES SECTOR

DoR

MYAGDI VULNERABILITY ASSESSMENT REPORT

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Version	A

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1 DISTRICT ASSETS/SYSTEM PRIORITIES

1.1 Briefing on Myagdi District

Overall View of the District

Myagdi district is located in Dhaulagiri zone in Western Development Region of Nepal. The district has borders with Manang, Kaski and Parbat districts in the east, Baglung and Rukum districts in the West, Dolpa and Mustang districts in the north and Baglung district in the south. The geographical location of the district lies between 83^{0} 08' to 83^{0} 53' east longitude and 28^{0} 20' to 28^{0} 47' north latitude. The altitude of the district ranges from 792 m to 8167m (Dhaulagiri Himal).

The area of the district is 2,297.06 sq. km having different topography. The plain land (river basin) constitutes 8 %, hills 56 % and high altitude (including himal) 36 %. Various types of vegetations grow due to diversity of topography.

The headquarter of the district is Beni which is located at the river banks of Kali Gandaki and Myagdi rivers. The district has 42 VDCs

The total population of the district is 1,35,613 of which 65,686 are male and 69,928 are female (source: Nepal Population Report 2011, Ministry of Health and population, GoN).

Major rivers in the district are; Kaligandaki, Myagdi, Rahughat, Ghar Khola, Thulo Khola etc.

Strategic Road Network in the District

There are 2 strategic roads in Myagdi District; (i) Myagdi District Border- Beni and (ii) Beni-Pairothapla . Both roads are the sections of Pokhara-Beni-Jomsom Road. The total length of these roads is 31 km of which 10 km is blacktop, 21 km is graveled. The total number of bridges along these roads is 8.

All the strategic roads and bridges in the district are managed by Pokhara Division of DoR. The division is mainly responsible for maintaining the Strategic Road Network (SRN). But it also carries out rehabilitation, upgrading and new construction of all types of strategic roads and bridges.

There are 35 nos. of permanent staff in the Division with 1 Division Chief (SDE), 7 Engineers, 1 Account Officer, 1 Section Officer, 7 sub-engineers and the rest auxiliary staff.

Climatological Record

The climatological record and monthly rainfall of the district is presented in Table 1 and 2.

Table 1: Climatological Record of Myagdi District

Location: Gurja Khani Latitude: 28^{o} 36' N; Longitude: 83^{o} 13E; Elevation: 2530 amsl (2008)

Air Temperature					Relative Humidity		Precipitation (mm)		No. of Rainy Days
Mean			Absolute Extreme		Observed at				
Max.	Min.	Daily	Max. & Date	Min. & Date	08:45 NST	17:45 NST	Total	Max. in 24 hrs. & Date	1:100
8.2			25.2/Aug.		67	80	2090	47/Sept	148

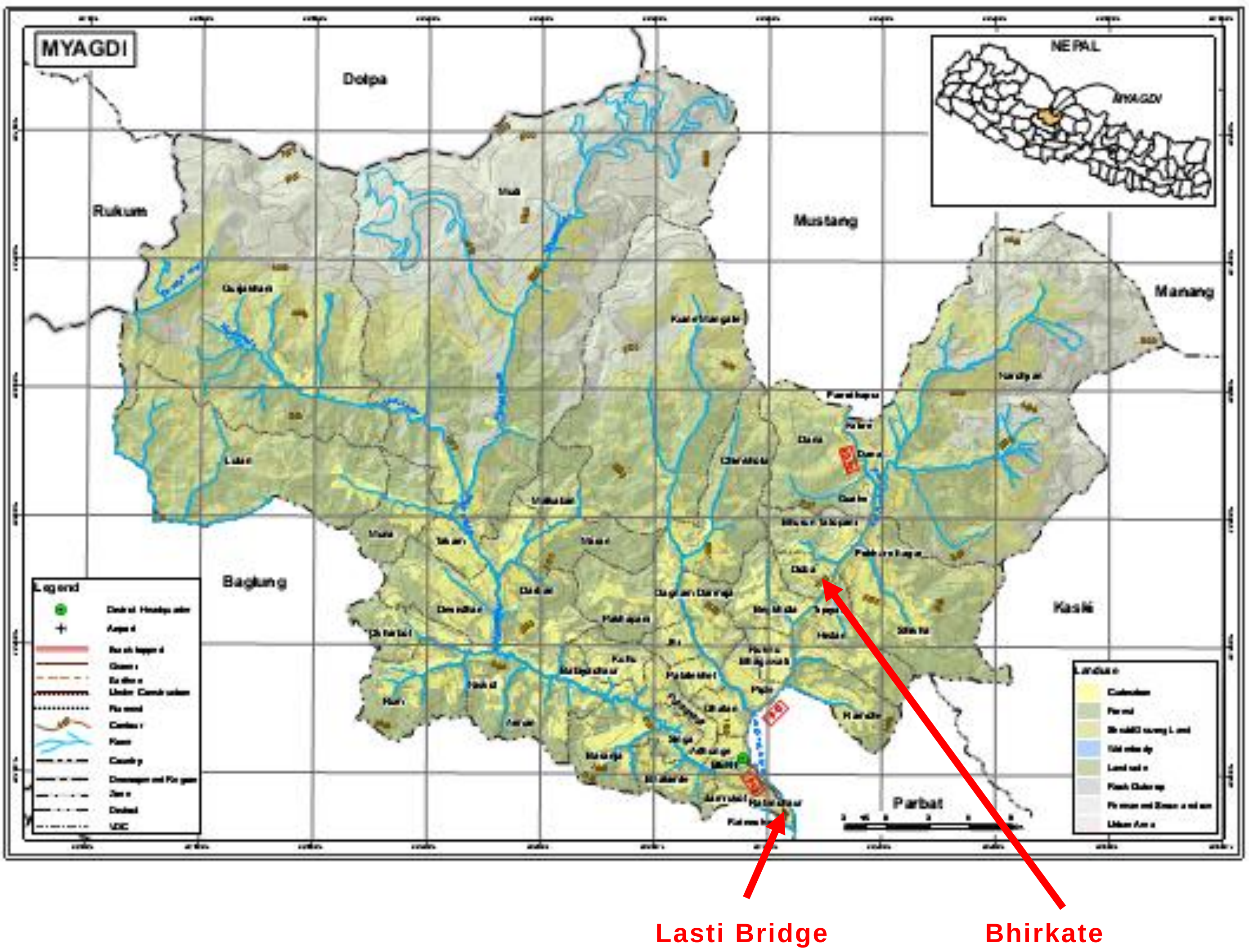
Source: Department of Hydrology and Meteorology

Table 2: Monthly Rainfall of Myagdi District (mm) Location: Beni

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0	3.6	27.6	14.3	104.3	119.8	375.4	420	176.1	101.8	2	3.3

Source: Department of Hydrology and Meteorology (2009)

Fig 1: Map of Myagdi District showing asset locations



1.2 Criteria for Identifying Priority Assets/Systems for the Vulnerability Assessment

In the road sectors (both DoR and DoLIDAR) it is considered that the primary assets or systems are the road links joining important centres of population or production for example a feeder road joining a national highway to a district centre is considered as a system. The priority assets in that system are the parts or sections of the link which, if affected by an extreme weather event, would cause serious disruption to the movement of traffic on the link.

The key criteria for prioritisation include:

- Infrastructure of national strategic importance
- Infrastructure of district strategic importance
- Infrastructure that has been impacted by past extreme events

- Infrastructure located in areas prone to past extreme events

In each district the consultant in consultation with the division chief prepared final lists of the priority structures of the district. The list was prepared following the criteria provided in District Office Report.

1.3 Description of Priority System

In total five assets were covered in baseline report. Among them road damage at Bhirkate (km 17) of Beni-Pairothapla Road Section and a medium bridge (which is under construction) across Lasti Khola are selected for vulnerability assessment and adaptation planning due to their importance and uniqueness.

Beni-Pairothapla Road Section at Bhirkate (km 17)

Beni-Pairothapla road stretch is one of the sections of Pokhara-Beni-Jomsom Road as well as main road in Myagdi District. It provides motorable link to several important areas of the district as well as to Jomsom, the headquarter of Mustang District.

Motorable track of this road was constructed by Nepal Army. The Army handed over this road to DoR few years ago. DoR, at present, is doing maintenance and landslide clearance works only. Until now it has not carried out any major improvement works and hence the condition of the road is poor.

In July 2012, Sunari Khola which joins the Kaligandaki River at km 17, transported large amount of debris. The debris obstructed the waterway of the Kaligandaki River at right bank. Due to obstruction at right bank, the river hit the left bank and severely damaged about 100 m long section of road. DoR, at present, is constructing retaining walls to protect the road and maintain the vehicular traffic (see photo).

Under construction bridge across Lasti Khola

DoR is constructing a single span RCC bridge across Lasti Khola, which is located at about 3 kilometer from Beni towards Pokhara side. The construction works were contracted to a local contractor. The works were progressing well and the contractor had already completed the following works and was planning to concrete the deck slab.

- construction of both abutments
- placement of all the formworks/falseworks;
- placement of reinforcement for beams and slabs.

In the mean time a flash flood occurred on the night of June 10, 2013 and washed away all the formworks and reinforcements. When the consultant visited the site, the contractor was collecting and stockpiling the formworks and reinforcements. Due to this incident the schedule of concreting of superstructure was delayed by about 3 months (after monsoon).
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According to local persons, Lasti Khola was almost dry before the incident.

2. VULNERABILITY ASSESSMENT METHOD

2.1Summary of method/process

The VA of the assets is carried out following the procedure as outlined below:

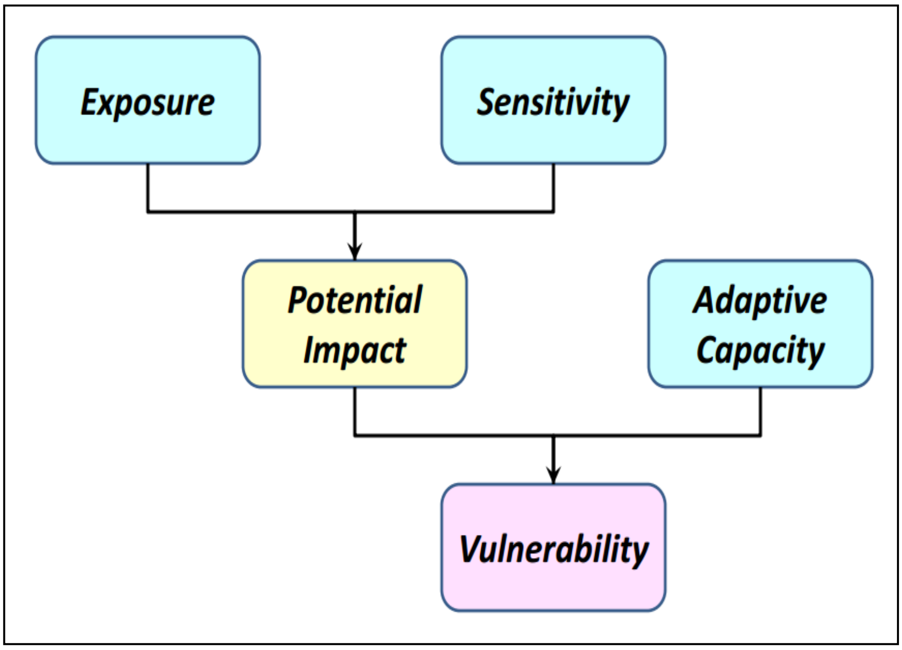

Fig 2: VA Process

There are two components in this phase

I. Assessing the impact of a climate threat on an asset and system; and
II. Defining the level of vulnerability of the asset and system to the projected threats.

Impact Assessment

The potential impact (or level of risk) is a function of the level of **exposure** to climate change induced threats and the **sensitivity** of the target asset or system to that exposure.

Exposure: exposure is the degree of climate stress on a particular asset. It is influenced by long-term changes in climate conditions and by changes in climate variability, including the magnitude and frequency of extreme events.

The following criteria influence exposure:

- Duration (e.g. hours or days of flooding)
- Location (e.g. distance from flood)
- Intensity (e.g. strength of rainfall, speed of flow)
- Magnitude (e.g. volume, flow or size of event)

Sensitivity: Sensitivity is the degree to which a system will be affected by, or be responsive to, climate change exposure.

The following variables affect infrastructure sensitivity:

i. Construction quality
ii. Levels of maintenance
iii. Protective system (e.g. river training wall to protect asset)
iv. Design (including safety margins)

A key tool in the process is the use of the **Climate Change Impacts Matrix** (Fig.2). The matrix is completed using descriptors for exposure and sensitivity, for example, 'very low' to 'very high'. If the exposure of a bridge to the threat of high flash floods is **High** (due to catchment area and topography) and its sensitivity to scour is **Very High** (due to soil type and foundation design) then the Matrix tells us that the **Impact** of the threat is **Very High**.

		Exposure of system to climate threat				
Sensitivity of system to climate threat		*Very Low*	*Low*	*Medium*	*High*	*Very High*
	Very High	*Medium*	*Medium*	*High*	*Very High*	*Very High*
	High	*Low*	*Medium*	*Medium*	*High*	*Very High*
	Medium	*Low*	*Medium*	*Medium*	*High*	*Very High*
	Low	*Low*	*Low*	*Medium*	*Medium*	*High*
	Very Low	*Very Low*	*Low*	*Low*	*Medium*	*High*

Fig.3: Impact Assessment Matrix

Vulnerability Assessment (VA)

A vulnerable system or asset is one that is sensitive to changes and extremes in climate and hydrology and one for which the ability to adapt is constrained. The vulnerability of an asset is therefore a function of the potential impact of changes in climate and the ability **(Adaptive Capacity)** of the responsible authority to respond to any possible impact.

The following variables affect the **adaptive capacity** of the responsible institution:

i. Institutional Strengths/Weaknesses
ii. Financial Resources
iii. Technical Capacity
iv. Ability to respond effectively to extreme events in the District

The Vulnerability of an asset is determined by applying the Impact value given by the Impacts matrix and the assessed value of adaptive capacity to the **Vulnerability Assessment Matrix** (Fig. 3).

This value of **Vulnerability** obtained (from Very High to Very Low) is then carried forward to the Adaptation Planning phase of the Climate Change Risk Management methodology

		Impact				
		Very Low *Inconvenience (days)*	*Low* *Short disruption to system function (weeks)*	*Medium* *Medium term disruption to system function (months)*	*High* *Long term damage to system property or function (years)*	*Very High* *Loss of life, livelihood or system integrity*
Adaptive Capacity	*Very Low* *Very limited institutional capacity and no access to technical or financial resources*	*Medium*	*Medium*	*High*	*Very High*	*Very High*
	Low *Limited institutional capacity and limited access to technical and financial resources*	*Low*	*Medium*	*Medium*	*High*	*Very High*
	Medium *Growing institutional capacity and access to technical or financial resources*	*Low*	*Medium*	*Medium*	*High*	*Very High*
	High *Sound institutional capacity and good access to technical and financial resources*	*Low*	*Low*	*Medium*	*Medium*	*High*
	Very High *Exceptional institutional capacity and abundant access to technical and financial resources*	*Very Low*	*Low*	*Low*	*Medium*	*High*

Fig 4: Vulnerability Assessment Matrix

2.2 Interpretation of the climate vulnerability assessment methodology criteria for the Roads Sector

In the highways sectors there are two major elements which make up a road link:

1) Road pavement & side drainage
2) Bridges and cross drainage structures

It is necessary to consider for both these elements their sensitivity and exposure to the various increased threats due to climate change.

Sensitivity

The following tables outline the sensitivity of the two road elements to various climate threats.

Table 3. Road pavement and side drains sensitivity to climate threats

CLIMATE THREAT	SENSITIVITY	IMPACT
Increased rainfall Increased intensity of rainfall	Depends on condition of existing pavement – a pavement in poor condition will have a High sensitivity	Damage to surface of pavement
Increased rainfall Increased intensity of rainfall	Side drains which are in good condition and well maintained will have a low sensitivity	Damage to side drains
Increased rainfall increases instability of hillside Increased intensity of rainfall increases instability of slope High flow in river scours base of hillside & causes landslide	A road across an hillside prone to landslides will have a Very High sensitivity A road above a river which is eroding the toe of the hillside will have a Very High Sensitivity	Landslide destroys road & side drains
Increased rainfall causes high monsoon flood Intense rainfall causes flash flood	A road constructed next to a river will have a Very High sensitivity	Road running along river valley damaged by adjacent river

Table 4. Cross road drainage sensitivity to climate threats

CLIMATE THREAT	SENSITIVITY	IMPACT
Increased rainfall causes riverine flooding	A road with adequate cross drainage structures for today's floods will have an increasing sensitivity as climate change takes effect	Road on embankment crossing flood plain washed out
Increased intensity of rainfall causes large flash flood	Design and condition of bridge foundations will cause sensitivity to vary from Medium to Very High	Bridge on river with small catchment area is damaged by flood
Increased intensity of rainfall increases size of flash flood	Design and condition of causeway slab and retaining walls will mean sensitivity will vary from Medium to Very High	Causeway for stream with small catchment area washed out by flood
Increased temperature variation from cold to hot season	The condition and design of the expansion joints & bearings will cause the sensitivity to vary from Low to High	Large Bridge over major river – damage to bearings & expansion joints
Increased rainfall causes high monsoon flood	The condition and design of the bridge piers and abutments will cause the sensitivity to vary from Low to Very High	Settlement or scour at pier or abutment

Exposure

The above tables illustrate examples of the sensitivity of various elements in the highway infrastructure to climate change. It shows that for both roads & bridges the major climate change threats are increased rainfall and intensity of rainfall which result in high monsoon floods, riverine floods and flash floods. For large bridges, very high temperature variations will be a threat to the viability of expansion joints and bearings.

The table below provides interpretation of exposure for different road and bridge assets to the climate threats identified for Myagdi district. This general interpretation can be used along with consideration of the relative magnitude of the climate change threat at the target system site to assess the exposure of the assets of the target system.

The highway infrastructure in Myagdi District will generally, depending also on upstream catchment area and topography, have a High or Very High Exposure to climate change.

Table 5. Interpretation of climate change threats and exposure for road and bridge assets

TYPE OF ASSET	CC THREAT	EFFECT OF THREAT	EXPOSURE
Large bridge on large river	Increase in max. temperature	Increase in expansion of deck – more stress on joints and bearings	Low to Medium
	Increase in wet season flow	Increased velocity of flow increases likelihood of scour to foundations	High to Very High
		Increased height of flood threatens stability of bridge deck and causes erosion of approach roads	Medium to Very High
		Increased sedimentation	Medium to Very

		reducing clearance under bridge	High
Smaller bridge on smaller river	Increasing risk & severity of flash floods during wet season	Increased velocity of flow increases likelihood of scour to foundations	Medium to Very High
		Increased height of flood threatens stability of bridge deck and causes erosion of approach roads	Medium to Very High
Pipe culverts & causeways on roads crossing watershed	On hill roads - increasing risk & severity of flash floods during wet season	Increased velocity of flow threatens to wash out pipe/ causeway & headwalls	High to Very High
	On flood plain roads - increase in wet season flow	Increase volume of flow threatens to wash out pipe/ causeway & headwalls	High to Very High
Hill road crossing watershed on sloping ground	Increasing risk of landslides	Road blocked or totally destroyed	Medium to Very High
Hill road running along valley bottom adjacent to river	Increasing wet season flow	Road eroded by height & high velocity of flow	High to Very High
	Increasing risk & severity of flash floods		
	Increasing risk of landslides	Road destroyed as erosion to toe of hillside causes landslide	
Road crossing flood plain	Increasing wet season flow and water levels	Road overtopped by flood water and pavement/ embankment destroyed	Medium to Very High

Impact

The impact of extreme weather event on an asset is a function of the Sensitivity and the Exposure and can be found by considering the Climate Change Impacts Matrix given in Fig. 2 and interpolating between the value of Sensitivity and the value of Exposure to give a value for Impact.

The value for Impact obtained by using the Impacts Matrix should be judged from a practical engineering point of view and if considered incorrect then the values used for Exposure and Sensitivity should be revisited. In particular, for road infrastructure, the value for sensitivity is very difficult to determine without carrying out detailed condition surveys for the particular asset under review. If sufficient design detail is unavailable, or the ground conditions difficult to judge, then an expert judgment of Sensitivity needs to be made and clear notes made justifying the decision.

Adaptive Capacity

Evaluating the Adaptive Capacity of the Department of Roads in a District is not a simple task. Baseline assessments including consultations and site visits have shown that the DRO which is responsible for strategic roads and bridges in the Myagdi District has:

- Extensive experience in design and construction of roads and bridges;
- Sound financial resources;
- Sufficient trained and skilled man power available for design and construction of bridges;

- Adequate management system; and
- Good ability to respond promptly to disasters.

However in the baseline assessments (see Baseline Assessment Report for the Myagdi District) for the district it was also observed:

a) Approved Budget funds are not released on time;
b) Programmes are not approved on time;
c) Very low bids are submitted by the contractors; and
d) Contractors receive mobilization advance but do not execute the work on time.

DoR has shown it is able to respond rapidly to emergencies where road links are disrupted. However the ability or preparedness of DoR to respond to possible future threats to the road infrastructure has yet to be demonstrated.

The above findings indicate that the Adaptive Capacity of the DoR Division offices is "High"

Vulnerability Scoring: Based on the impact and adaptive capacity assessments, the vulnerability of the asset against the climate change threats is estimated using the guiding Vulnerability Matrix as provided in Fig.4.

3. VULNERABILITY ASSESSMENT OF THE ASSET

3.1 Asset Description

Beni-Pairothapla Road Section at Bhirkate (km 17)

The following table describes the important aspects of the asset.

Table 6: Salient features of *Road damage at Bhirkate (km 17)* (Asset 1)

Name of the Road	Beni-Pairothapla (section of Pokhara-Beni -Jomsom Road)
Road Category	National Highway
Location of Asset	At km 17 from Beni
Length of the damaged	About 100m
Service Provided by the Road	Connects northern part of Myagdi District, Mustang District and China.
Responsible Agency	Pokhara Division of DoR
Major Components of the Asset	Road and bank protection works
Existing Condition of different components	Road: very poor, recently damaged by flood. Road protection works: recently completed (fair to good) **Major problem: Extensive erosion/damage to road by Kaligandaki River**

Fig.4a Damaged section of the road at km 17. The damage occurred due to extensive bank erosion by Kaligandaki River. At present, DoR is constructing gabion wall to protect the road from river damage.

Fig.4b At right side of the photo, the heap of gravels and boulders is the debris deposited by Sunari Khola in July 2013. The debris pushed the River towards left bank and severely damaged the road.

Fig. 4c View of debris deposited by Sunari Khola from the road. According to the district technicians, the bed level of the Sunari Khola was raised by 2-3 meter after debris deposition.

Fig. 4d: Photo of newly constructed wall to protect the road which is located at left bank. The photo is taken from right bank. DoR has already constructed about 100 long stone masonry/concrete protection walls and reconstructed damaged road section. DoR is constructing a motorable bridge near the damaged road. Right abutment of the bridge is also seen on photo.

Under construction bridge across Lasti Khola (Asset 2)

The following table describes the important aspects of the asset

Table 7: Salient Features of the Bridge

Name of the Bridge	Lasti
Name of the Road	Maldhunga-Beni; Section of Pokhara-Beni-Jomsom Road
Road Category	National Highway
Total length	25m
No. Of spans	1
Responsible Agency	Pokhara Division of DoR
Location of Asset	3 km from Beni towards Pokhara side.
Major Components of the Asset	Concrete abutments at both sides. 25 m long RCC superstructure under construction
Existing Condition of different components	Abutments: good Formwork/struts and reinforcement of deck slab and beams washed away by flash flood.

Fig. 5a: View of the bridge after the flood washed away formworks, struts, and reinforcements. Upstream view of the khola is also seen on photo. The photo was taken after 3 days of the event. As seen on photo, the khola has already dried up.

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Fig. 5 b: The labours are stock piling the formworks and reinforcements which were washed away by the flood. The concrete abutment at right side which was recently completed can be seen on photo. The condition of both abutments is good.

Fig.5c: Existing temporary wooden (motorable) bridge. This bridge is located at about 15 m upstream from the damaged bridge. At present all the vehicles and pedestrians use this bridge for crossing.

3.2 Climate Change Threat to Infrastructures in Myagdi District

The experts of this study team prepared threat profiles for Myagdi District. Findings of the threat profiles and the climate change effects on roads and bridges are described below in brief.

Threat due to Temperature Increase

As per the threat profiles, the average temperature increase in Myagdi District will be 1.7^0 by 2050.

Adverse effect on the road and bridge assets due to above temperature rise will be nominal.

Threat due to Precipitation and Flood Increase

The threat profile indicated the following change on rainfall and flood patterns:

(i) Increasing number of extreme rainfall events – events that now occur every 10 years are projected to occur every 2 years
(ii) Increasing wet season flow on the Kali Gandaki River – peak monthly average flow in wet season will increase by up to 89%
(iii) Increasing flooding frequency of the Myagdi River– the one in fifty year return period flow will increase by 78% (from 1006 m3/s to 1790 m3/s) at Mangla Ghat

The above findings show that there will substantial increase in frequency and magnitude of extreme discharge. Hence following aspects need serious consideration while designing road and bridge structures:

Design life: At present the important bridges are designed for 100 years return period and rural road bridges for 50 years return period. The drainage structures, in general are designed for 10, 20 or 25 years depending upon the importance of the roads. In order to accommodate the increased flood volumes, bridges as well as drainage structures should be designed for higher return periods. For example there will be a need to design important bridges for more than 200 years return period (instead of 100), rural road bridges for 100 years return period (instead of 50) and drainage structures for 50 years return period (instead of 25) to accommodate the increasing flood volumes.

Invert level of bridges/culverts: Due to increase in discharge, the high flood level (HFL) will increase. This will require increasing the invert level of bridges/culverts.

Foundation depth of bridges/culverts: The increased discharge will cause more scouring requiring more foundation depth.

Size of drainage structures: Sizes of both side drainage and cross drainage structures should be increased to accommodate increased flood volumes.

Road pavement: Roads lying in low land and adjacent to rivers will be highly affected by increased flood. The wetting of subgrade for longer duration will decrease its strength (CBR) requiring thicker road pavement.

3.3 Effect on Bridge Design Parameters due to increase in rainfall/flood (Climate Change Effect) - an example

In order to assess climate change effect on bridge design, a brief study of previously designed bridge across Bheri River is provided below. The bridge, which is located in Surkhet District in Mid Western Development Region was designed about 10 years ago and is on completion stage.

Salient Features of the Bridge

1. Name of the river: Bheri
2. Location: At km 45 of Chhinchu-Jajarkot Road in Mid Western Development Region
3. Type of Bridge:
   a) Superstructure: Steel truss with RCC deck slab
   b) Sub-structure: RCC abutments and piers
   c) Foundation of pier: 6m dia and 15 m long well
   d) Foundation of abutment: Open
   e) Total length of the bridge: 180m
   f) No of spans: 4

4. Hydrological Parameters
   a) Max discharge for 100 yrs return period: 8205 m3/sec
   b) Lacey's Regime Width: 434.80m
   c) Maximum scour depth : 13.22m below HFL or 4.74m below minimum bed level
   d) HFL corresponding to 100yrs: 96.7m above bed level (see fig. 6)

Climate Change Effect on Hydrological and Bridge Design parameters

If it is assumed that one in 100 year return period flow will increase by 78% due to climate change in Bheri River (same as for 50 year for Mangla Ghat in Myagdi), the new hydrological parameters at the bridge site will be as follows:

a) Max discharge for 100 yrs return period: 14605m3/sec
b) Lacey's Regime Width: 774.3 m
c) Maximum scour depth : 17.92 m below HFL or 6.92 m below minimum bed level
d) HFL corresponding to 100yrs: 99.5 m (see fig. 6)

Note: The above data are derived using the same formula, which were applied for design of Bheri Bridge.

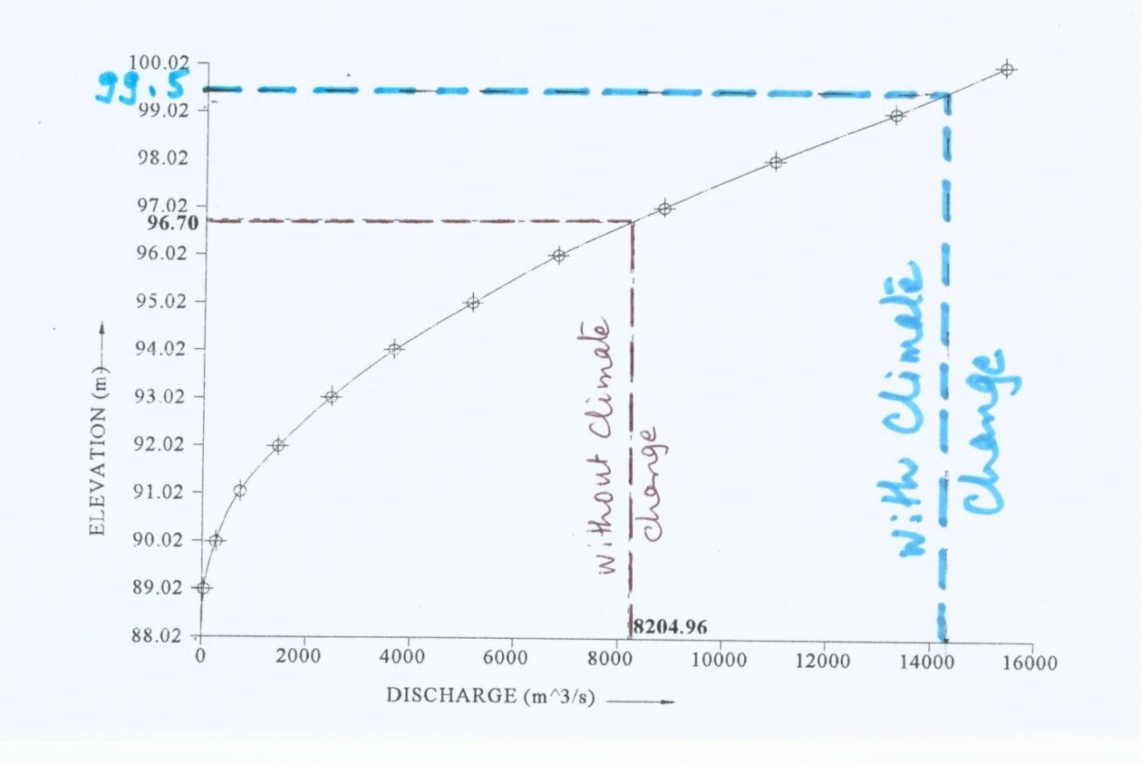

Fig. 6: Relation between maximum discharge and HFL (with and without climate change).

Table 6: Comparative Chart

SN	Parameters	Base Year (without climate change)	2050 (With Climate Change)	Diff	Comments
1	Max discharge for 100 yrs return period (m3/sec)	8205	14605	6400	Flood increase by 78% same as of Mangla Ghat in Myagdi
2	Lacey's Regime Width (m)	434.80	774.3	339.5	Due to hilly topography, 50m longer bridge could suffice.
3	Maximum scour depth below bed level (m)	4.74	6.92	2.18	
4	HFL corresponding to 100yrs return period (m)	96.7	99.5	2.8	

Design Modification

The above comparative chart shows that following modification in design parameters should be made for new bridge to make it resilient to climate change.

a) The bridge length should be increased by about 50 m;
b) The height of the bridge should be increased by 2.8m

c) The foundation depth should be increased by 2.18 m or the length of the well should be increased to 17.2m from 15m.
d) Section of abutments and piers should be increased to withstand the additional impact due to higher flood.

3.4Vulnerability Assessment Results

The following tables show the VA results of the assets.

Table 7: Vulnerability Analysis of Beni-Pairothapla Road Section at Bhirkate (km 17 (Asset 1)

Climate Change Threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Component 1: Road							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing wet season flow.	Increase volume and frequency of flood will accelerate the erosion/damage process.	VH[1]	VH[2]	VH	The road is already in very critical situation. With increase in flood volume the road will be damaged beyond repair.	H[3]	H
Component 2: Road Protection Walls							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing wet season flow	Increase volume and frequency of flood may cause wall collapse.	VH[4]	VH[5]	VH	The protection walls which are being constructed at present are typical. They may protect the road from ordinary flood but cannot endure the impact of increased flood (due to climate change)	H[3]	H

Notes:

1. *The road is located adjacent to river. It is being damaged in the past on regular basis.*
2. *The design aspect of the road is poor. It is almost at the same level of Kaligandaki River (The road should be higher than the HFL of the river). The road has very few structures and hence is highly vulnerable to damage. It is the only road linking northern part of Myagdi and Mustang Districts.*
3. *The adaptive capacity of DoR Division Road Office is* ***High****; see section 2.2.4.*

4. *Bank protection works are very near to the main river course. They were damaged several times in the past;*
5. *The section of the bank protection works is adopted from typical design and cannot withstand impact due to higher flood. Damage/collapse of bank protection works will wash away the road causing traffic closure for several days.*

Note: The Vulnerability Assessment Matrix shows that the vulnerability of road and protection walls is "high". In actual the vulnerability is "Catastrophic" because the road will be closed for several days if the damage occurs.

Table 8: Under construction Bridge across Lasti Khola (Asset 2)

Climate Change Threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Component 1: Bridge							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing in flash floods	Probability and frequency of flash floods will increase with climate change effect.	H[1]	L[2]	M	Such incidents will be more frequent and will cause more damage to infrastructure works.	H[3]	M

Notes:

1. *The bridge site lies at the immediate foothill. Flash floods are common on such area.*
2. *Loss of lives and properties will be nominal as there very few houses at/near the bridge site. The damage did not obstruct the traffic because of a temporary bridge at its upstream.*
3. *The adaptive capacity of DoR Division Road Office is* ***High****; see section 2.2.4.*

3.5 Vulnerability Assessment Summary

The vulnerability assessment summary of both the above assets was carried out. The summary of the assessments is provided below.

Table 9: Vulnerability Assessment Summary of Beni-Pairothapla Road Section at Bhirkate (Bhirkate) (km 17 (Asset 1)

THREAT	IMPACT	EXPOS.	SENSIT.	IMPACT	ADAPT. CAP.	VULN.	COMMENTS
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing wet season flow	The road is already in very critical situation. With increase in flood volume the road will be damaged beyond repair.	**VH**	**VH**	**VH**	**H**	**H**	Kaligandaki is a big river having high damaging capacity. Hence it is eroding the road at several sections of the highway. With increase in flood volume (by more than 50% as threat profile suggests), its damaging capacity will be much higher. In such cases the road cannot be protected by providing typical walls (DoR is adopting this measure at present). The only option to construct robust roads which can be resilient to climate change is to shift the road away from the river at critical areas).
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing wet season flow	The protection walls which are being constructed at present are typical. They may protect the road from ordinary flood but cannot endure the impact of increased flood (due to climate change)	**VH**	**VH**	**VH**	**H**	**H**	The exposure of the bank protection works is very high as they are located very near to the water current. These walls, as mentioned earlier cannot endure impact of higher floods (due to climate change)

Table 10: Vulnerability Assessment Summary of Under construction Bridge across Lasti Khola (Asset 2)

THREAT	IMPACT	EXPOS.	SENSIT.	IMPACT	ADAPT. CAP.	VULN.	COMMENTS
• Increasing intensity and frequency of extreme rainfall events. • Increasing wet season flow	Such incidents will be more frequent and will cause more damage to infrastructure works.	**H**	**L**	**M**	**H**	**M**	With climate change effect the rainall pattern will be erratic. Its intensity and frequency will be higher than at present.