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RURAL ROAD SECTOR (DOLIDAR): 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

Myagdi district is located in Dhaulagiri zone in Western Development Region of Nepal. The district is bordered 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 in the district due to diverse 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 135,613 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.

Rural Road Network

In total 17 rural roads (village and core network) with a total length of 413.5 kilometres are constructed or under construction in the district. Out of the total, only 256.5 km of roads are motorable (as per rural road data of DoLIDAR; FY 2009/10).

All the infrastructural works including rural roads of the district are being managed be District Technical Office (DTO). Myagdi DTO is headed by a senior divisional engineer (SDE). The other staffs in the DTO are: 1 Engineer, 2 Sub-engineers, 1 Nayab Subba and 4 support staffs.

For planning/implementation of rural road networks, DDCs/DTOs of all districts of the country are required to prepare District Transport Master Plan (DTMP). Myagdi District completed DTMP by engaging local consultants in 2006.

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

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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)

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 three assets were covered in baseline report. Among them Suspended Bridge across DoWA Khola (Planned) and Beni-Darbang-Dhorpatan Road are selected for vulnerability assessment and adaptation planning.

Suspended Bridge across Sunari Khola (Planned)

DDC had planned to construct a pedestrian (suspended) bridge across Sunari Khola. The selected bridge site was about 50m upstream from its confluence with Kali Gandaki River. The bridge was designed of 60 m length. While the DDC was about to start its construction, a big flood at the Sunari Khola transported large amount of debris and deposited at/around the bridge site in July 2013. Due to debris, the bed level was up by about 2.5-3m. As a consequence, the vertical clearance of the proposed bridge became less than required by the design guidelines. Hence DDC selected new bridge site at about 200m upstream from that location and designed a bridge of 108m length.

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Beni-Darbang-Dhorpatan Road at km 15

This road starts from Beni and runs along the left bank of Myagdi River. It passes through Darbang, Bhim, Lulang and terminates at Dhorpatan. The total length of this road is 51.5 km and its initial 19 km section starting from Beni is motorable.

Construction of this road was started by DDC about 10-12 years ago. In the beginning this road was only a motorable track. Later this road was upgraded/improved by DRILP.
For the past few years the road was frequently closed by landslide at km 15 (Lampata). Observing the site condition it seems that the main reason of landslide is the toe cutting of

the slope by the Myagdi River. At present DDC/DoLIDAR is constructing a stone masonry toe wall at the bottom of landslide area and is realigning about 80 meter long section of the road.

2 VULNERABILITY ASSESSMENT METHOD

2.1 Summary of method/process

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

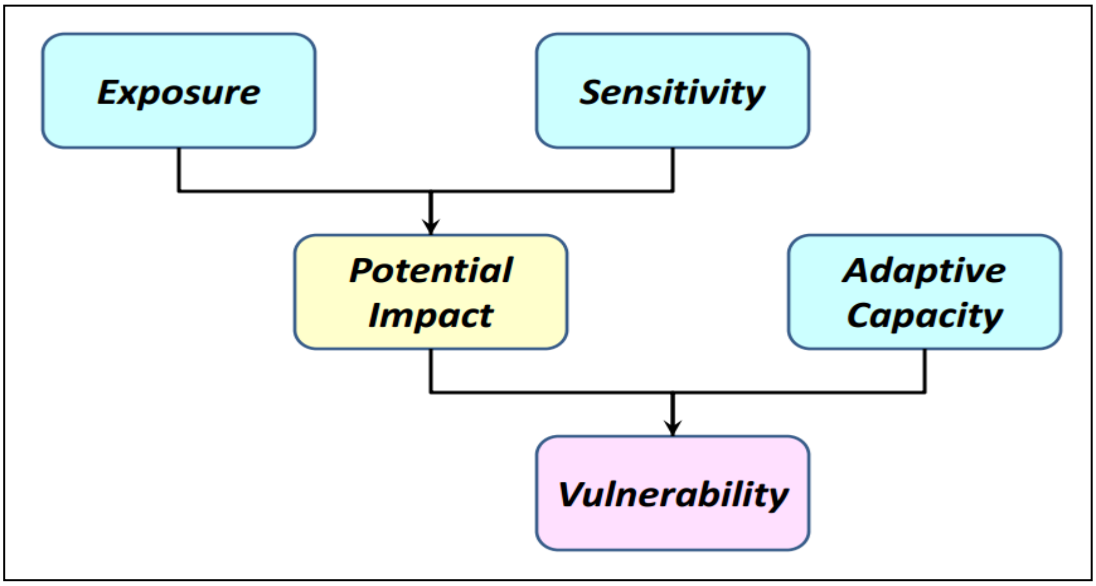

Fig 1: VA Process

There are two components in this phase

1. Assessing the impact of a climate threat on an asset and system; and
2. 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				
		Very Low	*Low*	*Medium*	*High*	*Very High*
Sensitivity of system to climate threat	*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.2: 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 3: Vulnerability Assessment Matrix

2.1 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) 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 Climate Change Threat Profile for Myagdi District show that the flood magnitude will increase in the range of between 16-41 % in 2040 and 40-57 % in 2060 for different return periods.

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 reducing clearance under bridge	Medium to Very 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 an 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 DoLIDAR and DDC/DTO is not a simple task. Baseline assessments including consultations and site visits have shown that the DTO Myagdi which is responsible for rural roads and bridges in the district has the following capacities:

- Sufficient experience in rural road and trail bridge construction;
- Do not have sufficient experience in design of roads and bridges
- Insufficient technical manpower in comparison to the number of projects;
- Inadequate financial resources;
- Inadequate management system; and
- Not very prompt in responding to disasters.

However, the efficiency and technical capability of DTO has increased in the last few years after the involvement of big donors such ADB, WB, DfID etc in the rural transport sector.. Considering the above factors, it is deemed that the adaptive capacity of DoLIDAR/DDC/DTO as **'Medium'.**

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 Assessment Matrix provided in Fig.3.

3 VULNERABILITY ASSESSMENT OF ASSETS

3.1 Asset Description

Suspended Bridge across Sunari Khola (Planned but abandoned)

The following table describes the important detail aspects of the asset

Table 6: Salient Features of the Asset

Location	50 m upstream of confluence between Sunari Khola and Kaligandaki River and at opposite bank where 100 m long section Beni-Jomsom road is badly damaged.
Total Length and no. of spans	Total length= 60 m of previously designed bridge (abandoned) Total length= 108 m of new (relocated) bridge 1 span
Service Provided by the Bridge	Provides links to several parts of Doba VDC
Responsible Agency	DDC/DTO, Myagdi
Major Aspects of the Asset	It is a typical suspended bridge with concrete towers at two sides. The walkway is supported by steel cables.

Existing Condition of different components	The bridge is still not constructed.

Fig. 4a: Photo of abandoned bridge site. The bed level is raised by about 2.5-3 m at this location. One of main reasons of debris deposition is due to the obstruction of the Khola by Kaligandaki River which is about 50 m downstream from this location. The span length of the bridge at this site was fixed 60m.

Fig. 4b: Axis of the proposed bridge at new location. This site is about 200m upstream from the previous axis. The bridge at this location is designed of 108m length**.**

Fig.4c:There are big landslides at the catchment areas of the Khola. These landslides functioned as a dam and obstructed the river for a long time. When the discharge of the Khola broke the dam it transported large amount of debris and deposited at the confluence. This is also one of the reasons of transportation of large amount of debris.

Fig. 4d: Confluence of Sunari Khola with Kaligandaki River. The debris transported by Khola can be seen at the left side. DoR is constructing a motorable bridge at about 100m downstream of the confluence.

Beni-Darbang-Dhorpatan Road at km 15

The following table describes the important detail aspects of the asset

Table 7: Salient Features of the Asset

Name of the Road	***Beni-Darbang-Dhorpatan Road***
Road Category	District Road Core Network (DRCN)
Service Provided by the Road	Provides motorable road service to south-western VDCs of the district.
Responsible Agency	DDC/DTO, Myagdi
Location of Asset (Culvert)	km 15
Major Aspects of the Asset	- Roads - Toe wall
Existing Condition of different components	Construction activities for realignment of road is going on (see photo). Toe walls are almost complete.

Fig. 5a: Photo showing landslide area. The road seen at the top is the existing alignment and the lower one is the new one. Small part of Myagdi River and protection wall can be seen on the right side.

Fig.5b: This is the location where the Myagdi River hits the banks and causes landslides. DDC has constructed stone masonry. At downstream of the stonemasonry wall, DDC is also constructing a gabion wall above the rock.

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Fig. 5c: Photo of Myagdi River from the road. At this location, the river constantly hits the left bank and erodes it.

Fig. 5d: Construction activities of new road is going on. The elevation of the new alignment is about 15m lower than the existing alignment.

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 Bangi River is provided below. The bridge is located in Arghakhanci District in Western Development Region and was completed about 8 years ago.

Salient Features of the Bridge

1. Name of the river: Bangi
2. Location: At km 0+100 of Chutrabesi-Sandhikharka Road in Western Development Region
3. Type of Bridge:
   a) Superstructure: RCC T beam bridge
   b) Sub-structure: RCC abutments and piers
   c) Foundation of pier: Open
   d) Foundation of abutment: Open
   e) Total length of the bridge: 40m (2x20m)
   f) No of spans: 2

4. Hydrological Parameters
   a) Max discharge for 100 yrs return period: 408.45 m3/sec
   b) Lacey's Regime Width: 97 m
   c) Maximum scour depth : 5.12 m below HFL or 2m below minimum bed level
   d) HFL corresponding to 100yrs: 100.9m or 3m 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 Bangi River (same as for 50 year for Mangla Ghat in Myagdi), the new hydrological parameters will be as follows:

a) Max discharge for 100 yrs return period: 727 m3/sec
b) Lacey's Regime Width: 129 m
c) Maximum scour depth : 6.86 m below HFL or 3 m below minimum bed level
d) HFL corresponding to 100yrs: 101.75 m or 3.75m above bed level (see fig. 6)

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

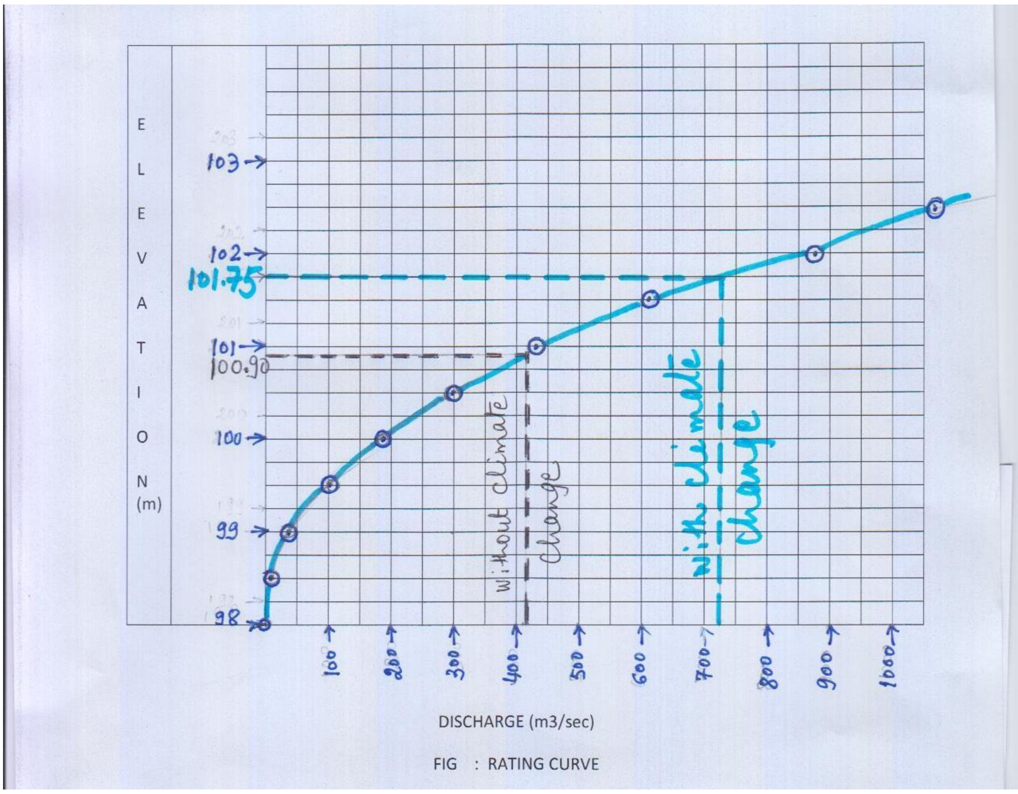

Fig. 6: Relation between maximum discharge and HFL (with and without climate change) of Bangi Bridge in Arghakhanchi District.

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)	408.45	727	319	It is assumed that flood will increase by 78% ; same as of Mangla Ghat in Myagdi
2	Lacey's Regime Width (m)	97	129	32	Due to hilly topography, 10 m longer bridge could suffice.

3	Maximum scour depth below bed level (m)	2	3	1	
4	HFL corresponding to 100yrs return period (m)	100.90	101.75	1.15	

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 10 m;
b) The height of the bridge should be increased by 1.15 m
c) The foundation depth should be increased by 1m.
d) Section of abutments and piers should be increased to withstand the additional impact due to higher flood.

3.4 Vulnerability Assessment Results

The table below presents the vulnerability assessment for the differe*nt components of the asset are presented below.*

Table 8. Vulnerability assessment *of suspension bridge across Sunari Khola Bridge (abandoned due to debris deposition)*

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 • Increase in flood in wet season. • Increase in landslides	Increased flood will transport more debris. This will make the site more vulnerable.	VH[1]	H[2]	VH[1]	The flood has deposited large amount of debris. Because of such deposition, the vertical clearance of the bridge became less than minimum. As a consequence, the bridge site was shifted by about 200m upstream.	M[3]	VH

Notes:

1. *The exposure is very high because such incidence happened at regular interval in the past. With increase in rainfall frequency and intensity, such incidents will be much higher.*
2. *The sensitivity is high because the cost of the new bridge has increased by three times.*
3. *Refer to section 2.2.4.*

Table 9: Vulnerability assessment of Beni-Darbang-Dhorpatan Road at km 15

Climate change threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Component 1: Roads							
• Increasing intensity and duration of rainfall; • Increasing number of extreme rainfall events; • Increase in flood in wet season. • Increase in landslides	Increase in rainfall intensity will speed up the frequency and intensity of road failure.	VH[1]	H[2]	VH	Damage to road will be more. Vehicle and pedestrian traffic will be obstructed for longer period.	M[3]	VH
Component 2: Slope failure							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increase in flood in wet season. • Increase in landslides	Probability of slope failure will significantly increase due to: (i) more surface water at the hill slope above the road and (ii) more toe erosion due to higher flood at the Myagdi River	VH[4]	M[5]	VH	The slope failure at/near the top will cause traffic closure. In case of big slope failure, the whole road section will crumble.	M[3]	VH
Component 3: Toe wall							

• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increase in flood in wet season. • Increase in landslides	The threat to walls will increase due to: - Increase in pore pressure due to higher rainfall; - More scouring - Higher impact by the river at/near the wall	VH[6]	H[7]	VH	The toe wall will collapse and the whole slope including road section above it will slip.	M[3]	VH

Notes:

1. *The asset has high exposure and is already suffering from frequent landslide problem. With climate change effect, the exposure will increase.*
2. *The asset is located along district road and has less traffic. The loss of lives and properties will not significant. However, the reconstruction cost of the road will be high.*
3. *Refer to section 2.2.4.*
4. *Slope failure is occurring at frequent interval. Frequency and intensity of such incidence will significantly increase.*
5. *Small slope failure will close the road for hours/days. However, big slope failures may wash away whole road section. Cost of road reconstruction could be high.*
6. *The wall has high exposure to climate change effect because pore pressure at the wall will increase. Bed scouring at /near the wall and river impact to the wall will significantly increase.*
7. *If the wall fails the whole slope including road will slip.. Significant DDC budget will be required to reconstruct the road. Loss of lives will not be high.*

3.5 Asset Vulnerability Summary

Vulnerability summary of both the assets is provided in table 8 and 9.

Table 8. Summary of Vulnerability assessment of Sunari (planned) Bridge

THREAT	IMPACT	EXPOSURE	SENSITIVITY	IMPACT	ADAPTIVE CAPACITY	VULN.	COMMENTS
Increasing intensity and frequency of extreme rainfall events will accelerate scouring /silting process.	The khola deposited large amount of debris at the confluence. Because of deposition the bridge site is shifted at upstream .	VH	H	VH	M	VH	Increase in frequency and intensity of rains such incidents will increase significantly. The sensitivity is considered high because the loss of such incidence may cause huge damage to the whole area although the loss of lives may be low.

Table 9. Summary of Vulnerability of Beni-Darbang-Dhorpatan Road at km 15

THREAT	IMPACT	EXPOSURE	SENSITIVITY	IMPACT	ADAPTIVE CAPACITY	VULN.	COMMENTS
Increasing intensity and frequency of extreme rainfall events	Damage to road will be more. Vehicle and pedestrian traffic will be obstructed for longer period.	VH	H	VH	M	VH	The sensitivity is high because there is high probability of road slip. If the road slips the traffic will be closed for long period and reconstruction cost may be very high.
Increasing intensity and frequency of extreme rainfall events	The slope failure at the top will cause the traffic closure. In case of big slope failure, the whole road section will crumble	VH	H	VH	M	VH	The slope failure, in general, will be manageable. It may close traffic for few hours/days but it will not create heavy loss of lives and properties. Hence the sensitivity is considered medium.

Increasing intensity and frequency of extreme rainfall events	The toe wall will collapse and the whole slope including road section above it will slip.	VH	H	VH	M	VH	Myagdi River is hitting the bottom of the slope. This is the main cause of high vulnerability of toe wall.