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ROADS AND BRIDGES SECTOR

DoR

CHITWAN VULNERABILITY ASSESSMENT REPORT

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TABLE OF CONTENTS

1 DISTRICT ASSETS/SYSTEM PRIORITIES

1.1 Briefing on Chitwan District

Overall View of the District

Chitwan District is located in the western part of Narayani Zone in Central Development Region. The total area of the district is 2,218 km² of which major part lies in Siwalik Region. According to 2011 census the population of the district was 566,661. Chitwan is particularly rich with flora and fauna. Nepal's first national park "Bharatpur National Park" together with the adjacent Parsa Wildlife Reserve supports species diversity much higher than any other part in the Indian subcontinent.

Major Rivers in the districts are: Narayani, Trishuli , East Rapti, Lothar, Bhorle, Kali, Khahare etc

Bharatpur, the headquarter of Chitwan District is the seventh largest city of the country. It is also a commercial and service centre of central south Nepal and major destination for higher education, health care and transportation of the region.

Strategic Road Network in Chitwan

In total there are 12 strategic roads in Chitwan District including three main National Highways; Mahendra Raj Marga (MRM) (H01), Prithvi Raj Marga (PRM)(H04) and Narayanghat Mugling Raj Marga (H05). The total length of strategic roads in the district is 344.27 km of which 253.27 km is blacktop, 72 km is graveled, 19 km is earthen. The total number of bridges along these roads is 58.

All the strategic roads and bridges in the district are managed by Bharatpur Division of DoR. The division is mainly responsible for maintaining the Strategic Road Network (SRN). It also carries out maintenance, rehabilitation and upgrading of district and regional roads.

There are 34 nos. of permanent staff currently working under this Division with 1 Division Chief (SDE), 4 Engineers, 1 Account Officer, 12 sub-engineers and 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 Chitwan District

Location: Rampuri; Latitude: 27^{o} 37' N; Longitude: 84^{o} 25E; Elevation: 256 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
30.7	18.3	24.5	40.0 May	4.2 Jan	87	74	2743	155/Sept	112

Source: Department of Hydrology and Meteorology

Table 2: Monthly Rainfall of Chitwan District

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0	0.1	0	7.3	274.2	179.2	465.5	753.5	126.3	101.1	0	2

Source: Department of Hydrology and Meteorology

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 Lothar Bridge along MRM and Landslide Protection works at Mauri along Narayanghat-Mugling Highway are selected for vulnerability assessment and adaptation planning due to their importance and uniqueness.

Lothar Bridge

The bridge is located along MRM at the boarder of Chitwan and Makwanpur Districts. The bridge was designed by ND Lea and Associates and was completed in 1977. It has five spans and its total length is 150m.

The abutments and piers of the bridge are RCC whereas the superstructure is prestressed concrete. Although the bridge was constructed more than 35 years ago, the structural components of the bridge are still in very good condition and any major maintenance works are not required.

The bridge cost is estimated to be about 250 million rupees at current price.

When the bridge was completed the clear vertical clearance of the invert level of bridge was about 8m. However, due to substantial debris deposition in the last several years, the vertical clearance has reduced to 2.5m. Due to heavy siltation, the bed level of the river, at present, is higher than the ground level of the village located at downstream right bank. To protect the village, about 2 km long earthen dyke is constructed at this bank.

As per local people the river overtopped the bridge in 1993 and 2003. The floods did not damage the bridge structure but it eroded both banks and damaged land and properties of the village at the right bank. There is high risk of overtopping of the bridge and washing away it during heavy flood in future.

Landslide Protection works at Mauri

Narayanghat- Mugling Highway is one of the very important roads of the country. It is the main road linking Kathmandu with the Terai. Almost all the materials which are imported from foreign countries including India are transported through this road. This road was built by the Government of China and was completed in 1977. The total length of this road is 36.16 kilometer. The alignment of this road is located at the left bank of the Trishuli River.

This road faces two types of problem; toe cutting by Trishuli River at valley side and landslides at hill side. The problem of landslides starts mainly from km 16 from Narayanghat.

In 2060, there was a very heavy landslide above the Mauri Bridge (km 21+700). The landslides completely covered the bridge as well as severely damaged it. Due to this incident the road was blocked for about two days. After that incident GoN (DoR and DWIDP) constructed several gabion check dams at the upstream slope of the Mauri Khola to stabilize the landslides. The check dams are functioning satisfactorily until now.

1.4 Summary of method/process

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

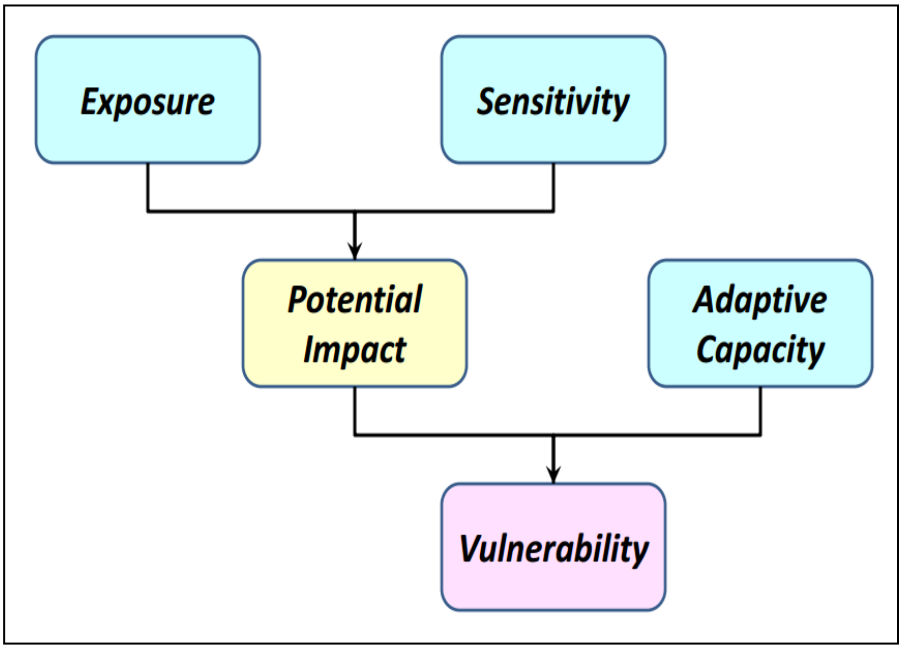

Fig 1: VA Process

There are two components in this phase

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.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

1.5 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 1. 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	A road across an hillside prone to landslides will have a Very High sensitivity A road above a river which is eroding	Landslide destroys road & side drains

High flow in river scours base of hillside & causes landslide	the toe of the hillside will have a Very High Sensitivity	
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 2. 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 Chitwan 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 Chitwan District will generally, depending also on upstream catchment area and topography, have a High or Very High Exposure to climate change.

Table 3. 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	High to Very High

		foundations	
		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 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 Chitwan 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 Chitwan 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.3.

2 VULNERABILITY ASSESSMENT OF THE ASSET

2.1 Asset Description

Lothar Bridge

The following table describes the important aspects of Lothar Bridge

Table 4: Salient Features of Lothar Bridge (Asset 1)

Name of the Bridge	Lothar
Total length	Total length = 150 m; No of spans = five
Location of Asset	At km 437.55 of Mahendra Rahjmarga (MRM)
Road Category	National Highway
Service Provided by the Road	Connects all terai districts of Nepal; one of the most important roads of the country.
Responsible Agency	Bharatpur Division of DoR
Major Components of the Asset	Bridge (superstructure, abutments, piers), bank protection works, approach roads etc.
Existing Condition of different components	Bridge: good; there is no damage even after 35 years of construction. Bank protection works: some are damaged and some are good. Approach Road: good.

	Major problem: extensive siltation

Fig. 4a: Extensive siltation near/at the bridge site. Difference between bed level and bridge is reduced to 2.5 m which was 8m in 1978. This shows bed level has risen by 6m within the span of 35 years. If the situation is not controlled the bridge will be washed away in future

4b: View of the bridge from the dyke at right bank, downstream. The elevation of the adjoining village at this side is less than that of river bed level (see the level of the temple). DoR has constructed a long dyke to protect the village

Fig. 4c: General view of the dyke. Its top width is about 4m and is protected by gabion mattress at river side.

Fig. 4d: Photo showing excavaton of river bed materials at downstream. DDC contracted to a private company to extract the river bed from the bridge site to lower the river bed level. However, the speed of extraction is very slow.

Landslide Protection works at Mauri (Asset 2)

The following table describes the important aspects of the asset

Table 5: Salient Features of Landslide Protection works at Mauri

Name of the Road	Narayanghat-Mugling
Road Category	National Highway
Service Provided by the Road	- Main Road connecting Kathmandu with terai districts and India - Almost all the goods and passengers to Kathmandu are transported through this road.
Responsible Agency	Bharatpur Division of DoR
Location of Asset	At km of Narayanghat-Mugling Road
Major Components of the Asset	Gabion check dams, road, bridge, breast wall etc.
Existing Condition of different components	Gabion check dam: good but overtopped by debris Road and bridge: good; Breast wall: good

5a: Photo showing series of check dams at hill side of the road. As seen on photo, the check dam starts from the immediate hill slope of the road and extends to about 150m upstream.

5 b: Large quantities of landslide materials are deposited at the middle of the slope. These materials started overtopping the check dams. These deposited materials should be cleared timely otherwise it may damage the check dams, road and bridge.

5c: Top of the hill slope. There is cultivated land at hill top. Due to cultivation, the water penetrates the land and loosens the hill slope. This is also one of the main reasons of landslides at this area. A scar of old landslide can also be seen on photo.

5d: Stone masonry breast wall near the bridge. As seen, substantial amount of water is coming out of the weep holes. Such water sprouts indicate that the slope is very wet. Landslides are very common on such wet slopes.

2.2 Climate Change Threat to Infrastructures in Chitwan District

In order to find out the climate change effect on roads and bridges, climate change threat profiles for Chitwan District is prepared. Findings of the threat profiles are briefly described in the following sections.

Threat due to Temperature Increase

As per the threat profiles, the average temperature increase in Chitwan District will be 1.6^0 by 2060

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

Threat due to Precipitation and Flood Increase

A study was made on Rapti River at Meghauli to find out the increase in flow due to climate change. (See Annex 1; 2.10 Change in annual recurrence interval). The findings showed that:

- Annual recurrence interval of 100 years interval flood (which is usually used for design of major bridges) will occur at an interval of 30 yrs;
- Annual recurrence interval of 25 years interval flood (which is usually used for drainage and retaining structures) will occur at an interval of 10 yrs;

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.

2.3 Vulnerability Assessment Results

The following tables show the VA results of the assets.

Table 6: Vulnerability Analysis of Lothar Bridge (Asset 1)

Climate Change Threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Component 1: Bridge Superstructure							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing wet season flow.	Overtopping of bridge by flash flood.	VH[1]	VH[2]	VH	The bridge will collapse. The road will be closed for several months.	H[3]	H
Component 2: Bank protection works							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing wet season flow	Damage to bank protection works due to increase in flood.	VH[4]	H[5]	VH	Bank protection works will be damaged at several locations. There will be loss of lives and properties.	H[3]	H
Component 3: Approach Roads							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing wet season flow	Damage to approach roads due to increase in flood.	M[6]	H[7]	M	Both the approach roads near the river will be damaged. Some sections especially located near the river bank will be washed away.	H[3]	M

Notes:

1. *The vertical clearance of the bridge has reduced to 2.5m from 8m in the last 35 years due to heavy siltation. The flood of 1993 and 2003 overtopped the bridge. With increase in flood, the damaging capacity of the river will substantially increase which may wash away the bridge. Several bridges in Nepal are washed away by flood.*
2. *Although the construction quality is very good, the sensitivity of bridge has become very high due to heavy siltation. As the bridge is located along the most important section of the national highway its sensitivity is further increased.*
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. *Some bank protection works are properly designed (especially the dyke at right bank of downstream side) and some are constructed without considering the hydrological parameters such as scour depth (launching aprons are not provided at many locations), width of waterway during high flood, HFL etc. The quality of bank protection works at some locations is good whereas it is poor at several instances. Hence the sensitivity is considered as medium.*
6. *Bank protection works are constructed at both sides of the river. The river will damage/wash away approach roads in extreme flood condition only. .*
7. *The quality of approach road is good. But its sensitivity is considered high due to its importance.*

Note: The Vulnerability Assessment Matrix shows that the vulnerability of bridge superstructure is "high". In actual the vulnerability is "Catastrophic" because of its location and the possible consequences after its collapse.

Table 7: Landslide Protection works at Mauri (Asset 2)

Climate Change Threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Component 1: Hill slope							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing in landslides	Increasing intensity and duration of rainfall will cause more landslides and will also enhance their scale.	VH[1]	VH[2]	VH	The landslide will severely damage the road and bridge The road traffic will be closed for several days.	H[3]	H
Component 2: Gabion check dams							
• Increasing intensity and duration of rainfall; • Increasing number of extreme rainfall events; • Increasing in landslides	The rise in intensity and duration of rainfall will cause more pore pressure to check dams. Similarly, the increase in landslide events will also cause more impact damage to check dams.	VH[4]	H[5]	VH	The check dams will be damaged. The slide materials will slip to the road and bridge sites and damage them and will also cause traffic closure.	H[3]	M
Component 3: Mauri Bridge and Road							

• Increasing intensity and duration of rainfall; • Increasing number of extreme rainfall events; • Increasing in landslides	Due to higher probability landslides (higher intensity and longer duration of rainfall) the threat to road and bridge will be more.	VH[6]	VH[7]	VH	The road and bridge will be damaged and the traffic will be closed for several hours/days if large landslides occur.	H[3]	H

1. *The area lies in very high rainfall intensity area. The rainfall intensity recorded at this location in 1993 is one of the highest ever recorded in Nepal. The slope is steep and unstable. The road was closed at several instances in the past due to landslides.*
2. *The slope is protected by constructing series of gabion check dams. But it is still very prone to landslide due to steep slope. The slope failure will cause traffic closure which is not permitted due to its extreme importance.*
3. *The adaptive capacity of DoR Division Road Office is High; see section 2.2.4.*
4. *The check dams are located on high landslide prone area.*
5. *The quality of wall is good but it is already overtopped by debris causing substantial increase in back pressure. Damage to check dams will cause movement of debris and road closure.*
6. *The road and bridge is located along very high landslide area.*
7. *The quality of road and bridge is good. But it will be heavily damaged by the probable landslide. The damage will cause road closure which is least desired on such highway. The reconstruction cost of the road and bridge will be high.*

2.4 Vulnerability Assessment Summary

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

Table 3: Vulnerability Assessment Summary of Lothar Bridge (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	Washing away of bridge	**VH**	**VH**	**VH**	**H**	**H**	The vertical clearance of the bridge has reduced to 2.5 m from 8m in 35 years due to heavy siltation. With increase in rainfall intensity and duration, the siltation process will further increase. If the vertical clearance is further reduced due to siltation, there will be high probability of washing away of bridge. If the bridge collapses, the MRM, which is one of the most important highways of the country will be closed for several days/months and will create havoc. Although the "Vulnerability Assessment Matrix" shows that the vulnerability is only "high" but in actual the vulnerability is "catastrophic".
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing wet season flow	Damage to dyke/ bank protection works	**VH**	**H**	**VH**	**H**	**H**	The exposure of the bank protection works is very high as they are located very near to the water current. Damage to dyke at downstream right bank will cause heavy loss of lives and properties as the ground elevation of the settlement is lower than the river bed level.

• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Increasing wet season flow	Damage to approach roads due to increase in flood.	**M**	**H**	**M**	**H**	**M**	Both the approach roads near the river will be damaged. Some sections especially located near the river bank will be washed away. The road can be rebuilt within short time.

Vulnerability Assessment Summary of Mauri (Asset 2)

THREAT	IMPACT	EXPOS.	SENSIT.	IMPACT	ADAPT. CAP.	VULN.	COMMENTS
• Increasing intensity and frequency of extreme rainfall events. • Increasing wet season flow	Will cause more landslides and will also enhance their scale. .	**VH**	**VH**	**VH**	**H**	**H**	The frequency and intensity of landslide will increase and may cause road closure at frequent interval. Similarly the intensity of landslides will be higher causing road closer for longer duration.
• Increasing intensity and frequency of extreme rainfall events. • Increasing wet season flow	Probability of damage to gabion check dams will be higher.	**VH**	**H**	**VH**	**H**	**H**	The gabion check dams are retaining huge amount of debris. If they collapse all the retained debris will move to the road causing damage and closure of road.
• Increasing intensity and frequency of extreme rainfall events. • Increasing wet season flow	Higher probability of damage to road and bridge due to increase in intensity and frequency of landslides..	**VH**	**VH**	**VH**	**H**	**H**	Probability of damage and closure of road and bridge will increase due increase in frequency and intensity of landslides.