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Department of Local Development and Agricultural Roads (DoLIDAR):

BANKE VULNERABILITY ASSESSMENT REPORT

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1 DISTRICT ASSETS/SYSTEM PRIORITIES

1.1 Briefing on Sector in Banke District

1.1.1 Overall View of the District

Banke District is located in the Mid-Western Region with Nepalgunj as its district headquarters. It covers an area of 2,337 km² and has a population of 493,017 as per 2011 census. The major part of the district lies in the terai. There are 46 VDCs and one municipality.

The major rivers in the district are Rapti, Man, Jhuri, Ooj, Sukhar, Khairi etc. Among them the Rapti is the largest and a very important river in the district.

The district is considered as one of the hottest districts in the country. According to the hydrological and meteorological data of 2008, the maximum temperature and annual rainfall in Nepalgunj was 42.5^{0} C and 2104 mm respectively.

1.1.2 Rural Road Network in the District

In total 101 rural roads (village and core network) with a total length of 497 kilometres are completed or being upgraded in the district. Out of the total, 47.64 km is black topped, 313.33 km is gravel and 136.43 km is earthen.

All the infrastructural works including the rural roads of the district are being managed be the District Technical Office (DTO). Banke DTO is headed by a senior divisional engineer (SDE). The other staff in the DTO are: 3 Engineers, 3 Sub-engineers, 6 assistant sub-engineers, 1 accountant and 5 support staff.

For planning/implementation of rural road networks, the District Development Committee (DDC)/DTO of all districts of the country are required to prepare District Transport Master Plan (DTMP). Banke has just started this process and made a contract with Everest Engineering Consult for preparation of the plan. Everest Consult is preparing the plan.

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

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In total three assets were covered in baseline report. Among them, RRM-Tirtiriya-Udhrapur-Sitapur Road and the Culvert across Kiron Nala along Nepalganuj-Paraspur-Gaughat Road are selected for vulnerability assessment and adaptation planning due to their importance.

1.3.1 RRM-Tirtiriya-Udhrapur-Sitapur Road

This road is located in the western part of the district. It starts from MRM and proceeds towards south and terminates at Sitapur. The road has a total length of 11.31 kilometre with gravel surface at major sections. Cross drainage structures (CDs) are constructed at several locations but they are not sufficient. Although it is a District Class A Road and should have formation width of 6m in fact the width is less than specified.

There is one water channel at km 9+200 which is draining the water from the surrounding area. The channel is not functioning properly as local people annexed a substantial area for cultivation.

In 2012, DDC/DTO with the support of local people constructed a three cell, 90 cm dia pipe culvert at this location. The culvert is not sufficient to drain the water and hence the excess water overflows the road and damages it and adjoining areas.

1.3.2 Culvert across KironNala along Nepalganuj-Paraspur-Gaughat Road

The culvert is located at Km 8+500 along Nepalgunj-Paraspur-Gaughat Road and was constructed about 12 years ago. The culvert has two spans of 6m each and has a carriageway width of 4.25m. The road is one of the important roads in the district and hence is already black topped.

The left approach road of the culvert was washed away during the flood of 2011 due to overflow of water from the culvert. DDC constructed 20 m long causeway at washed away section. The condition of the causeway is good.

2 VULNERABILITY ASSESSMENT METHOD

2.1 Summary of method/process

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

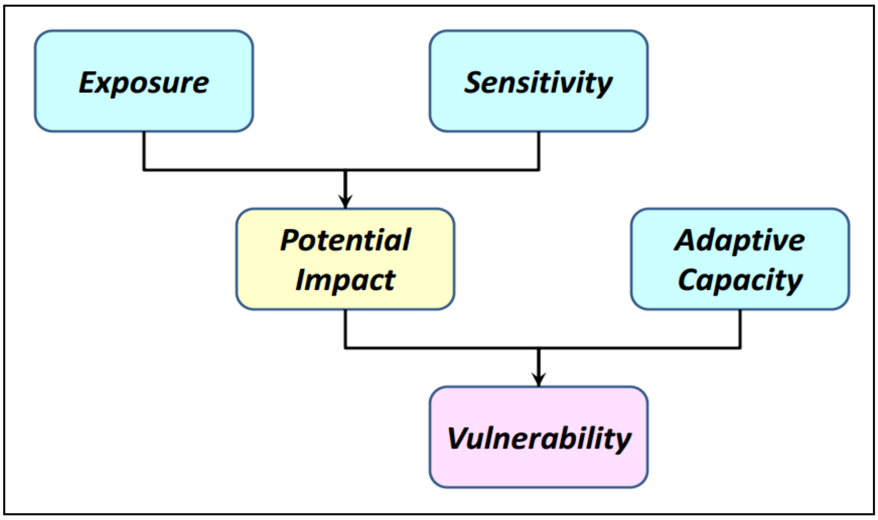

Fig 1: VA Process

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.

2.1.1 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

2.1.2 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

2.2 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) 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.

2.2.1 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 High flow in river scours base of hillside & causes landslide	A road across a 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 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

2.2.2 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 Banke 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 Banke 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 Banke 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 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

2.2.3 *Impact*

The impact of an extreme weather event on an asset 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.

2.2.4 *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 Banke 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 rural transport. 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.

This road is of high priority in the district and hence it was included in RRRSDP for upgradation. There is a big landslide at km 5+500.

3 VULNERABILITY ASSESSMENT OF ASSETS

3.1 Asset Description

3.1.1 *RRM-Titiriaya-Sonpur-Udharpur-Sitapur Road*

The following table describes the important detail aspects of the asset

Table 4: Salient Features of the Asset

Name of the Road	**RRM-Titiriaya-Sonpur-Udharpur-Sitapur Road**
Length & Surface Type	Total length= 11.31 km; Gravel = 6.85 km; Earthen = 4.46 km
Road Category	District Road Core Network (DRCN)
Service Provided by the Road	Provides motorable road service to RRM-Titiriaya, Sonpur, Udharpur and SitapurVDCs in the western part of Banke District.
Responsible Agency	DDC/DTO, Banke
Location of Asset	Km 9+200
Major Aspects of the Asset	- The road section is gravelled - 3 cell pipe culvert is provided (design capacity is less due to design and construction defect) - Deep side drains are constructed at both sides
Existing Condition of different components	- Road embankment: Insufficient width, surface is undulated, washed away by flood at one location. - Pipe culvert: good

Fig. 4a: View of road towards Nepalgunj side. The road is gravelled and its condition is fair to good. The formation width is less than 6m although it is a Class A district.

4 b: Triple cell PC of 90 cm dia. The overall construction quality of the culvert is good. ThisStructure is not sufficient to drain the water. Moreover, the invert level of the culvert is about 40 cm higher than the ground level. This defect has also decreased the draining capacity.

Fig. 4c: Washed away section of the road towards Sitpur side from the culvert. The damage was before the construction of culvert. The main reason for washing away was the filling of the natural drainage channel. The problem is not solved even after the construction of culvert.

3.1.2 Culvert across KironNala along Nepalganuj-Paraspur-Gaughat Road

The following table describes the important detail aspects of the asset

Table 5: Salient Features of the Asset

Name of the Road	**Culvert across Kiron Nala**
Road Category	District Road Core Network (DRCN)
Service Provided by the Road	Provides motorable road service to Paraspur, Saigaun, and BelbharVDCs in the south-western part of Banke District.
Responsible Agency	DDC/DTO, Banke
Location of Asset (Culvert)	Km 8+500
Design Details	Length of the culvert = 12 m (2x6 m); carriageway width = 4.25 m
Major Aspects of the Asset	- Stone masonry abutments and piers, RCC slab - 20m long RCC causeway at left bank - Minor bank protection works
Existing Condition of different components	- Bridge: good; minor damage to abutments, pier and wing walls - RCC causeway: good

Fig. 4a: View of the culvert from US. The structure has already started to show sign of distress due to lack of adequate maintenance. The newly constructed concrete causeway is located at the left side of the culvert.

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4b: Upstream view of the stream from the culvert. The width of culvert is less than natural channel width. Hence it cannot pass full discharge and as a consequence the excess water passes through the left approach road and damages it.

Fig. 4c: Recently built causeway at the damaged portion of the road. The total length of the causeway is 20m and its condition is good. There is no damage to the causeway after it was constructed two years ago. Such structure may be replicated at other locations also.

3.2 Climate Change Threat to Infrastructures in Banke District

3.2.1 Threat due to Temperature Increase

As per the threat profiles, the average temperature increase in Banke District by 2060 will be up to 1.85^0.

Adverse effect on the asset due to above temperature rise will be nominal.

3.2.2 Threat due to Precipitation and Flood Increase

The threat profile findings are as follows:

- Increasing number of extreme rainfall events – events that now occur every 5 years are projected to occur every 2 years;
- Increasing wet season flow on the Raptif River at Kusum – peak monthly average flow in wet season will increase by up to 5%

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:

<u>Design life</u>: 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 may be a need to design important bridges for 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.

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

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

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

<u>Road pavement</u>: 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 Vulnerability Assessment Results

The table below presents the vulnerability assessment for the different components of the asset. The analysis found that the most vulnerable components are the road embankment and pipe culvert.

Table 6. Vulnerability assessment for a road section at km 9+200 of RRM-Titiriaya-Sonpur-Udharpur-Sitapur Road

Climate change threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Component 1: Road embankment							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Flooding at the (natural) drainage system	Increase in intensity and duration of rainfall causes the flooding at the natural drainage system and damages the road embankment.	H[1]	L[2]	M	The road embankment will be damaged. But the impact level will be medium because the reconstruction cost will not be high and the road has little traffic.	M[3]	M
Component 2: Pipe culvert							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Flooding due to accumulation of water on the cultivated land	Increase in intensity and duration of rainfall causes the flooding and damages the pipe culvert.	H[4]	VL[5]	M	The PC will not undergo major damage as the construction quality of PC is good. The road has little traffic. .	M[3]	M

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Notes:

1. *The exposure is high because the road section is located at low land area (previously a natural drainage channel). All the accumulated water in the field passes through it. The road embankment was damaged several times in the past due to this phenomenon.*
2. *The road embankment is not protected and may suffer damage. The road will be closed for few days due to damage but it will not create big impact as the road has nominal traffic.*
3. *Refer to section 2.2.4.*
4. *The exposure is high because the road section is located at low land area (previously a natural drainage channel). All the accumulated water in the field passes through it.*
5. *The pipe culvert cannot pass the flood and hence the accumulated water may damage the pipe culvert. But the damage will not be high because the construction quality of pipe culvert is good. The road has little traffic.*

Table 7: Vulnerability assessment for Culvert across Kiron Nala

Climate change threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Component 1: Abutments, pier and wing walls of the bridge							
• Increasing intensity and duration of rainfall; • Increasing number of extreme rainfall events; • Increasing risk and severity of flash floods	Increase in flooding at the stream will damage the abutments, pier and wing walls	H[1]	VL[2]	M	Section abutments, pier, and protection works is heavy and hence theywill not collapse. However there will be minor break down and surface erosion	M[3]	M
Component 2: Concrete causeway							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events • Flooding due to accumulation of water on the cultivated land	Increase in intensity and duration of rainfall causes the flooding at the stream. The overflow from the stream passes through the causeway and damages it.	H[4]	VL[5]	M	The construction quality of causeway is good. Hence the structural damage to the causeway will not be significant. The road may be closed for few hours.	M[3]	M

Notes:

1. *The asset lies in the high rainfall area. The bridge site suffered high flooding in the past.*
2. *The section of abutments and pier is heavy. Flood at stream cannot damage them. .*
3. *Refer to section 2.2.4.*
4. *The asset is located in the high rainfall intensity area. The overflow of the river washed away the road embankment at this location.*
5. *The quality of concrete causeway is good. The overflow water cannot damage the structure.*

3.4 Asset Vulnerability Summary

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

Table 8. Summary ofVulnerability assessment for a road section at km 8+500 of RRM-Titiriaya-Sonpur-Udharpur-Sitapur Road

THREAT	IMPACT	EXPOSURE	SENSITIVITY	IMPACT	ADAPTIVE CAPACITY	VULN.	COMMENTS
Increasing intensity and frequency of extreme rainfall events	Damage to road embankment.	H	L	M	M	M	The road embankment may be damaged by flood. But the vulnerability will not be high because the reconstruction cost will not be high and traffic on road is very low.
Increasing intensity and frequency of extreme rainfall events	Damage to pipe culvert	H	VL	M	M	M	The sensitivity is very low because the construction quality is good and road has very little traffic. As result the vulnerability was found medium.

Table 9. Summary ofVulnerability assessment for Culvert across Kiron Nala

THREAT	IMPACT	EXPOSURE	SENSITIVITY	IMPACT	ADAPTIVE CAPACITY	VULN.	COMMENTS
Increasing intensity and frequency of extreme rainfall events	Flooding at the stream will damage the abutments, pier and wing walls.	H	VL	M	M	M	The sensitivity is very low because: • the bridge elements are structurally sound; • the road section has very little traffic. As result the vulnerability was found medium.
Increasing intensity and frequency of extreme rainfall events	The overflow from the stream passes through the causeway and damages it.	H	VL	M	M	M	The sensitivity is very low because the construction quality is good and road has very little traffic. As result the vulnerability was found medium.