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RURAL ROAD SECTOR
(DOLIDAR)
ACHHAM VULNERABILITY ASSESSMENT REPORT

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Version	A

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1 DISTRICT ASSETS/SYSTEM PRIORITIES

1.1 Briefing on Achham District

Overall View

Achham District is located in Seti Zone of the Far-Western Development Region of Nepal. It borders with Kalikot and Dailekh districts to the East, Doti district to the West, Bajura and Bajhang districts to the North and Surkhet of Bheri Zone to the South. Topographically, Achham district is located on 28°46' - 29°23' latitude and 81° 32' - 81°35' longitudes. The district is divided into 2 Electoral constituencies, 13 Illakas and 75 VDCs. Its headquarter is Mangalsen.

The total area of the district is 1,692 sq km of which major area lies on Mid-hill and few on high hill. The lowest and highest elevation point of the district is 540 meter and 3,820 respectively.

The total population of the district is 276,483 of which 134,840 are male and 141,643 are female (source: Nepal Population Report 2011, Ministry of Health and population, GoN).

Major rivers in the district are: Budhi Ganga, Kailash Khola, Kamali, Jiadi Khola.etc.

Rural Road Network

All the infrastructural works including rural roads of the district are being managed by Achham District Technical Office (DTO). DTO is headed by an Engineer. The other staff in the DTO are: 4 sub-engineer, 3 Assistant Sub-engineers, 1 Nayab Subba and 9 auxilary staff. .

District Transport Master Plan (DTMP) is the key tool for implementation of rural roads. Hence DoLIDAR has instructed DDCs/DTOs of all 75 districts of the country for timely preparation/update of DTMP. Achham DDC/DTO prepared DTMP in March 2013 by engaging local consultants.

As per DTMP the total length of the rural roads in the district is 472 km of which 342 km are district road core network (DRCN), and the remaining 130 km are village roads. The rural road status in the district is given in table 1.

Table 1: Length of Rural Road in the District

Road Class	Total length	Black Top	Gravel	Earthen
District road core network	342.24			342.24
Village roads	129.73			129.73
Total	**471.97**		**-**	**471.97**

Source: DTMP of Achham, 2013

As seen in above table all of the rural roads are earthen. None of the roads are black topped or gravelled. Out of total 75 VDCs in the district the existing DRCN roads link 35 VDC headquarters.

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Climatological Record

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

Table 1: Climatological Record of Achham District

Location: Achham Latitude: 28^{o} 57' N; Longitude: 81^{o} 17E; Elevation: 650 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
23.4	14	18.7	36.5/Mar.	4.2/Jan	58	60	224	20/Jul	26

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 three assets were covered in baseline report. Among them Mangalsen-Oligaun-Jupu-Sila Road and Budhi Ganga Suspension Bridge road are selected for vulnerability assessment and adaptation planning. Their location is shown in Fig.1.

Budhiganga Suspension Bridge Mangalsen-Oligaun-Jupu-Sila Road

Fig. 1: District maps showing asset locations

Landslide at km 4 of Mangalsen-Oligaun-Jupu-Sila Road

It is one of the important roads of the district. It provides motorable link to several central VDCs with Mangalsen (district headquarter). The total length of the road is 28 km. DDC started to construct this road on 2008 and the earthen track is opened up to 16 km. DDC has spent about 6 million rupees for opening of the track. But vehicles do not ply on this road due to landslides at several locations. The road also lacks basic structures (retaining and drainage).

In 2012, there occurred big landslides near km 4 causing complete road closure. The total cost of for clearing and stabilizing all the landslides is estimated to be around 10 million rupees. This amount is very big for Achham DDC/DTO which has resource constraint and hence is not able to clear and stabilize until now.

Budhiganga Suspension Bridge

The bridge is located inside the core area of Sanfebagar, a major settlement in Achham District. It was constructed about 40 years ago with support from US Aid. The total length of the bridge is 80m. Until the construction of motorable bridge, it was the only crossing structure for the people residing at both sides of the river. Although the bridge was constructed a long time ago, its condition is good. Major problems, except damage to bank protection walls were not observed.

2 VULNERABILITY ASSESSMENT METHOD

2.1 Summary of method/process

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

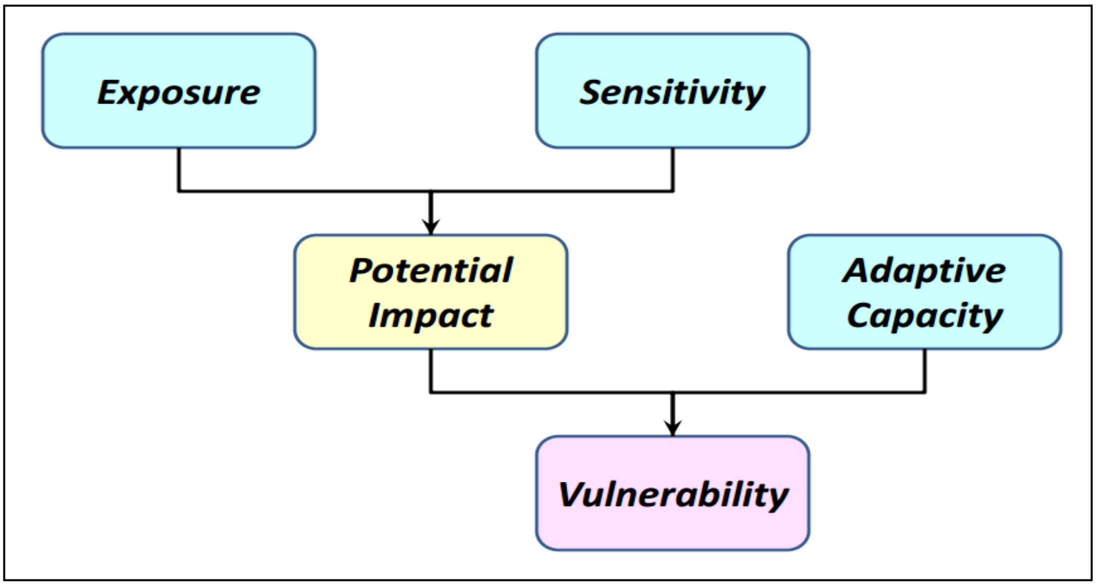

Fig 2: VA Process

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.3). 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.3: Impact Assessment Matrix

Vulnerability Assessment (VA)

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

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

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

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

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

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

Fig 4: Vulnerability Assessment Matrix

2.1 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 Achham 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 Achham 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 Achham 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 Achham 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

Landslide at km 4 of Mangalsen-Oligaun-Jupu-Sila Road

Table 6: Salient Features of the Asset

Type of Road	**District road core network (DRCN)**
Name of VDCs influenced by road	Oligaun, Jupa, Sutar, Bhatkatiya, Ramaroshan.
Financed by	DDC Achham
Implementing agency	DDC/DTO, Achham
Location of the road	In the central area of the district.
Major components of the Asset	- Road - Few structures (retaining and drainage structures)
Existing Condition of different components	- Poor; lacks protection and drainage structures - Vehicles cannot ply due to landslides

Fig. 5a: Photo of landslide from Mangalsen side. There are several landslides along 200m long section near km 4. These landslides have completely blocked the road.

Fig. 5b: Overall view of the main landslide. It is a huge landslide it extends up to 40m at the hill slope.

Fig. 5c: There is another big landslide at about 100m from the main landslide towards Jupu side.

Fig. 5d: There is one gully between the above landslides. Main landslide is at the right side of the gully and the second landslide is at the left side. Several slips (minor landslides) have also started to develop at this gully.

Budhiganga Suspension Bridge

The following table describes the important detail aspects of the asset

Table 7: Salient Features of the Asset

Name of the bridge	**Budhiganga suspension bridge**
Bridge length	80 m
Location	Inside the core area of Sanfebagar settlement;
Financed by	US Aid
Implementing agency	Technical Office of Achham DDC.
Existing Condition of different components	-Superstructure (cables, steel deck, wind guys etc.): good -Bank protection works: damaged at some locations

Fig. 5a: Carriageway views of the bridge. Major components of the bridge are in good condition.

Fig.6 b: Right bank of the river at upstream. The bank is rocky and does not require major bank protection works.

Fig. 6c: Long gabion walls are provided at the left bank. The major settlement Sanfebagar area is located at left bank. If the walls collapse there will be heavy loss of lives and properties.

2.1 Climate Change Threat to Infrastructures in Achham District

The experts of the study team prepared a climate threat profile of Achham District. The profile is submitted in Annex 1 and its summary is given below.

Threat due to Temperature Increase

Increase in average maximum temperature up to1.5°C in the wet season

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

Threat due to Precipitation and Flood Increase

The rainfall pattern will change in the following manner:

- Increasing number of extreme rainfall events – at Benighat events that now occur every 50 years are projected to occur every 30 years
- Increasing wet season flow on the Karnali River – peak monthly average flow at Benighat will increase by up to 13%
- The peak flow will shift from July to August

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 Vulnerability Assessment Results

The tables below present the vulnerability assessment for the different components of the assets.

Table 8. Landslide at km 4 of Mangalsen-Oligaun-Jupu-Sila Road

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 landslide events	Increase in intensity and duration of rainfall will weaken the slope stability.	VH[1]	L[2]	H	Frequency and intensity of landslide events will substantially increase	M[3]	M
Component 2: Road							
• Increasing intensity and duration of rainfall • Increasing number of extreme rainfall events	Increase in intensity and duration of rainfall will weaken the sub-grade.	H[4]	L[5]	M	The road will be severely damaged. The road surface will be covered with mud. Vehicles will not be able to ply on such road.	M[3]	M

Notes:

1. *The hill slope is very unstable and landslide occurrence is common. With increase in rainfall the scale and frequency of landslides will be substantially higher.*
2. *The road has very low traffic. There are not any houses near the landslide area. Loss of lives and properties will be nominal.*

3. *Refer to section 2.2.4.*
4. *The road is earthen and hence is highly exposed to increase in rainfall intensity and duration.*
5. *The road will be muddy making very difficult for movement of vehicles. Traffic may be closed for few hours/days. As the road has very low traffic, the sensititivity is considered low.*

Table 9: Budhiganga Suspension Bridge

Climate change threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Component 1: Bank protection wall							
• Increasing intensity and duration of rainfall; • Increasing number of extreme rainfall events; • Increasing in wet season flow.	Increase in wet season flow will cause more scour and flood impact to the bank protection walls.	VH[1]	M[2]	VH	Damage to walls will be more. Some sections of the wall may collapse.	M[3]	VH

Notes:

1. *The bank protection wall is located very near to the main river course.*
2. *The wall is regulating the river course and it is also protecting the airport and main settlement area of Sanfebagar. There will be huge loss of lives and properties if the wall collapses. However, major incident has not happened in the past. As the condition of wall is good. the sensitivity is considered medium.*
3. *Refer to section 2.2.4.*

Remarks: Vulnerability analysis of Bridge deck, cables and towers of the suspension bridge is not carried out because they are safe from increase in wet season flow.

3.4 Asset Vulnerability Summary

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

Table 8. Landslide at km 4 of Mangalsen-Oligaun-Jupu-Sila Road

THREAT	IMPACT	EXPOSURE	SENSITIVITY	IMPACT	ADAPTIVE CAPACITY	VULN.	COMMENTS
Increase in intensity and duration of rainfall will weaken the slope stability.	Frequency and intensity of landslide will substantially increase.	VH	L	H	M	M	The slope of the whole landslide area is very fragile. The landslides can be stabilized by providing large number retaining walls, proper drainage management and bio-engineering works. At few locations, realignment of road may be required.
Increase in intensity and duration of rainfall will weaken the subgrade strength.	The road will be severely damaged. The road surface will be covered with mud. Vehicles will not be able to ply on such road. .	H	L	M	M	M	The surface water should be adequately managed and the road section at the landslide area should be gravelled. The above measures should be done only after stabilizing the landslide.

Table 9. Budhiganga Suspension Bridge

THREAT	IMPACT	EXPOSURE	SENSITIVITY	IMPACT	ADAPTIVE CAPACITY	VULN.	COMMENTS
Increase in wet season flow will cause more scour and flood impact to the bank protection walls.	Damage to walls will be more. Some sections of the wall may collapse.	VH	M	VH	M	M	The bank protection wall is functioning properly. There were not any extreme events due to wall failure. With increase in wet season flow, the wall may collapse and may cause heavy loss of lives and properties. Hence DDC/DTO should be very careful on this aspect.

ANNEX 1: KEY CLIMATE CHANGE THREATS OF ACHHAM DISTRICT

(presented separately)