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Mainstreaming Climate Change Risk Management in Development

1 Main Consultancy Package (44768-012)

Department of Local Development and Agricultural Roads, DoLIDAR

Dolakha District

VULNERABILITY ASSESSMENT REPORT

Prepared by	ICEM – International Centre for Environmental Management
	METCON Consultants
	APTEC Consulting
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Version	A

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1 DISTRICT ASSETS/SYSTEM PRIORITIES

1.1 Briefing on Sector in Dolakha District

1.1.1 Rural Transport Network in Dolakha District

Dolakha is a mountainous District of Janakpur Zone in the central Development Region. Its headquarter is Charikot which is located at a distance of 132 km from Kathmandu. The area and population of the district is 2,191 sq.km and 204,229 (2001 census) respectively. The district extends from north to east consisting of 51 VDCs and 1 municipality.

In total 81 rural roads (village and core network) with a total length of 1155 kilometersis identified in the district. At present DDC/DoLIDAR is implementing 711 km of rural roads of which 0.5 km is black topped, 108 km is gravel and 603 km is earthen. However, the length of the trafficable roads is only 477 km. DDC Dolakha has recently started constructing motorable bridges with the assistance of Rural Reconstruction and Rehabilitation Sector Development Program (RRRSDP) and Swiss Development Corporation(SDC).

1.1.2 District Technical Office

District Technical Office (DTO) of Dolakha is responsible for planning, implementation and maintenance of all types of rural roads in the district. There are 23 nos. of staff currently working in the DTO with 1 DTO Chief (SDE), 2 Engineers, 6 Sub-engineers), 9 Assistant Sub- engineers and other support staff.

Although all the districts are required to prepare District Transport Master Plan (DTMP) Dolakha has not prepared it until now. However, the District Transport Infrastructure Committee of all party meeting on 2070/1/3 prioritised 16 roads for construction and prepared their implementation 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

Naypul-Pohati-Dandakharka Road (DTMP Code22A008R)

This is an important road in the district. It starts from the Tamakoshi Bridge (located on Lamsangu-Jiri Road) and runs along the left bank of Tamakoshi River (Note: Tamakoshi-Manthali Road lies at the left bank of the river). The total length of the road is 26 km and the motorable track is opened at the first 19 kilometres. This road serves Phasku, Pawati, Ghyangsuthokar, Bhedpu, Melung and Dandakharka VDCs. The existing condition of the road is very poor. Major section of the road is earthen and very few drainage and retaining structures are constructed on it.

DDC started the construction of this road in 2008. Later DoLIDAR allocated budget for this road under local road program. Some time after of its construction, a big landslide occurred at km 13+500 and washed away 100 m section of the road. Although DDC allocates substantial amount for track opening of this section after each rainy season, it is damaged time and again in monsoon. The field observation showed that the landslides cannot be stabilized with DDC's regular budget which amounts in the range of 1 million rupees per year for the whole road. Realizing the importance of the road, DDC planned to include the whole road for upgrading in the next phase of RRRSDP (an ADB funded program).

2 VULNERABILITY ASSESSMENT METHOD

2.1 Summary of method/process

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

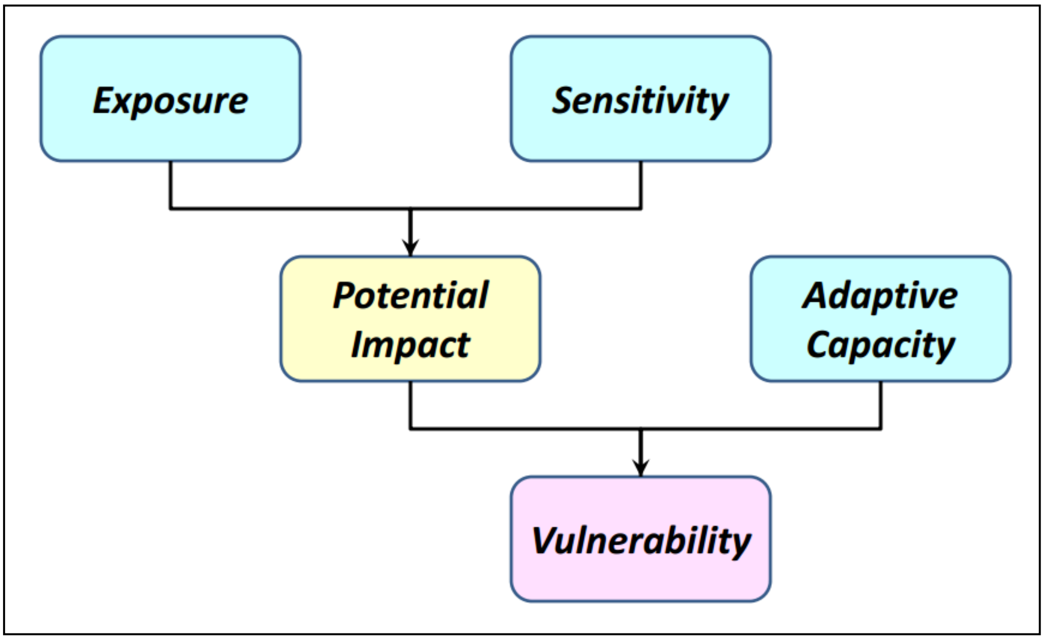

Fig 1: VA Process

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 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 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 Dolakha 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 Dolakha 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 Dolakha 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 Dolakha 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 the number of projects;
- Inadequate financial resources;
- Inadequate management system; and
- Not very prompt in responding to disasters.

However, the efficiency of DDC/DTO has increased in the last few years after the involvement of big donors such ADB, WB, DfIDetc in the rural transport. Considering the above factors, it is considered 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 THE ASSET

3.1 Asset Description

The following table describes the important detail aspects of the asset

Table 4: Salient Features of the Asset

Name of the Road	Naypul-Pohati-Dandakharka Road (DTMP Code22A008R)
Road Category	District Road Core Network (DRCN)
Service Provided by the Road	Provides motorable road service to serves Phasku, Pawati, Ghyangsuthokar, Bhedpu, Melung and Dandakharka VDCs in the southern part of Dolakha District..
Responsible Agency	DDC/DTO, Dolakha
Location of Asset	Km 13+500
Major Aspects of the Asset	- 100 m long road section is suffering from continuous landslides since its construction in 2008; - Small stream is eroding toe of the hill slope and triggering landslides - A small intake of water supply system is constructed at a distance of 20m at the hill side. The overflow from the intake is also causing more landslides. - The whole area is unstable due to poor geology; - DoR has constructed 20m long breast wall at the middle of the landslide; the site condition requires more breast walls
Existing Condition of different components	- The landslide is still active; - The leakage from intake is not stopped; - The condition of breast wall is good.

Fig. 4a: Photo covering the total area of the landslide and the damaged portion of the road. As seen on photo, the slope consists of loose loose gravels and materials mixed with boulders which is very susceptible to landslide. Gabion breast wall is provided at the middle of the landslide.

Fig. 4b: Small RCC intake of about 2m long, 1m wide and 1.5m high. This intake is meant for small water supply system which serves about 50-60 houses. During rainy season when the discharge in the source is high, excess water overflow from the tank and make the area very wet and unstable. This phenomenon is also one of the main causes of the landslide.

Fig. 4c: Photo showing the stream which flows along at the toe of the slide and causes toe cutting. This is one of the main reason for slope failure of the whole area.

3.2 Climate Change Threat to the Infrastructures in Dolakha District

The climate change threat profiles for Dolakha District were prepared by the hydrological modelling teams. The threat profile is provided in Annex 3. The effect of climate change to the road and bridge sector (both strategic and rural) as implied by the threat profiles is outlined below.

3.2.1 Threat due to Temperature Increase

As per the threat profiles, the temperature increase scenario in Dolakha District in 2060 will be as follows:

- The average increase in minimum temperature will be 2.2^0 C (with maximum increase of 3.5^0 C in February and minimum increase of 1.0^0 C in May).
- The average increase in maximum temperature will be 1.7^0 C (with maximum increase of 4.0^0 C in February and minimum increase of 0.7^0 C in March).

Adverse effect on the rural transport infrastructures due to above temperature rise will be nominal.

3.2.2 Threat due to Precipitation Increase

The threat profiles show that duration of extreme rainfall events with high intensity will occur more often than before. The following conclusions can be drawn from the threat profile.

- Duration of extreme rainfall events with high intensity will be more. For example for the 25 year ARI event the duration of 100 mm /h rainfall intensity is 15 minutes at present but will increase to 45 minutes in 2060 and;

- Floods with a return period of 2, 5, 10, 25, 50, 100 and 200 will increase in volume 57, 57, 56, 50, 47, 43 and 40 percentages respectively.

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 levels of bridges/culverts.
<u>Foundation depth of bridges/culverts</u>: The increased discharge will cause more scouring requiring more deeper foundation.
<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 floods. The wetting of subgrade for longer duration will decrease its strength (CBR) requiring thicker road pavement.
<u>Landslides</u>: The events and scale of landslide will be higher with the increase in precipitation.

3.3 Vulnerability Assessment Results

The table below presents the vulnerability assessment for the components of the road section and other structures on Nayapul-Pohati-Dandakharka Road. The analysis found that the most vulnerable components are he road section and breast wall.

Table 5. Vulnerability assessment for landslide protection works at km 13+500 of Naypul-Pohati-Dandakharka Road

Climate change threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerabilit y
Component 1: Hill side and valley side slopes of the road							
Increase in precipitation Increasing risk of Landslides	Increased threat to slope stability due high increase in moisture content at the slopes There may be increase in flow at the stream at the bottom of slope. This will accelerate toe erosion and consequently invite slope failure of whole area.	VH[1] H[3]	L[2] L[4]	H M	The road would be closed for a considerable time. But the road has very little traffic.Hence the impact of the slope failure will be medium to high for both cases.	M[5] M[5]	H M
Component 2: Gabion Breast Wall							
Increase in precipitation Increasing risk of Landslides	Threat of damage to previously built breast wall from increased pore water pressure	VH[1]	L[6]	H	The road will be closed for short duration. But the road has very little traffic. Hence the impact of the slope failure will be highas per matrix but in actual the impact will medium.	M[5]	M

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1. *The exposure is very high because the whole slope is unstable due to weak geology of the slope. Several events occurred in the past and climate change effect will increase the probability of a more extreme event occurring;*
2. *The sensitivity is low because the slope failure will affect only nominal traffic;*
3. *The exposure is high rather than very high because the threat of such an event can be minimized if protection measures are adopted timely*
4. *The sensitivity is low because the slope failure will affect only nominal traffic;*
5. *Refer to section 2.2.4.*
6. *The quality of the breast wall is good.*

3.4 Asset Vulnerability Summary

The table below provides a summary of the vulnerability assessment for the components of the bridge and approach roads for km 13+500 of Naypul-Pohati-Dandakharka Road. The analysis found that the vulnerability of the asset to the CC threat is medium.

Table 6. Summary of vulnerability assessment for landslide protection works at km 13+500 of Naypul-Pohati-Dandakharka Road

THREAT	IMPACT	EXPOSURE	SENSITIVITY	IMPACT	ADAPTIVE CAPACITY	VULN.	COMMENTS
Increasing intensity and frequency of extreme rainfall events	Road washed away due to landslides.	VH	L	H	M	H	The sensitivity of road stretch which makes up this asset is very difficult to ascertain as slope stability analysis of the area is not carried out. But considering very low traffic the sensitivity is assumed low.
Increasing intensity and frequency of extreme rainfall events	Damage to gabion breast wall.	H	L	M	M	M	There have been several landslide instances in the past. But considering the quality of walls which is good and low traffic on the road the sensitivity is assumed low.
Increasing wet season flow and flash floods	Toe erosion due to increase in flood at the stream at the bottom of the slope	VH	L	H	M	H	The slope is suffering from the toe erosion but due to low traffic its sensitivity is assumed low. DDC/DTO has not taken any preventive measures showing that their adaptive capacity is medium.

ANNEX 1 SITE VULNERABILITY ASSESSMENT SHEET

CC THREATS	DESCRIPTION OF THREATS
Change and shift in regular climate	
Increase/decrease in temperature	
Increase/decrease in precipitation	
Increase/decrease in flow	
Change and shift in events	
Riverine flooding	
Extreme localised pooling/flooding	
Flash floods	
River bed scouring +Bank erosion	
Landslides	

EXPOSURE	**SCORE VL TO VH**
SENSITIVITY	**SCORE VL TO VH**
IMPACT	**SCORE VL TO VH**
ADAPTIVE CAPACITY	**SCORE VL TO VH**
VULNERABILITY SCORE: VL TO VH	

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ANNEX 2 VULNERABILITY ASSESSMENT COMPARISON TABLE

Asset:

CC Threats	Interpretation of threat	Exposure	Sensitivity	Impact Level	Impact Summary	Adaptive capacity	Vulnerability
Component 1							
Component 2							
Component 3							

NOTES:

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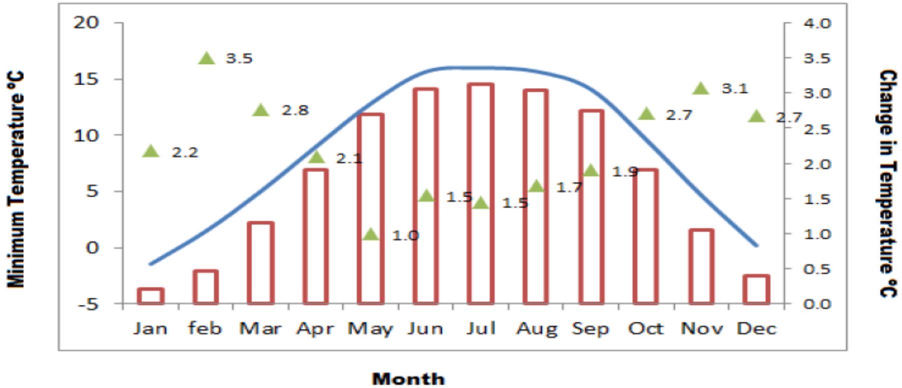
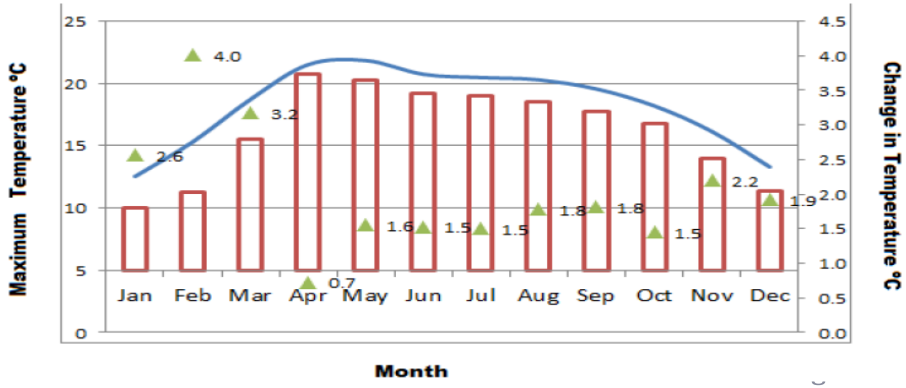
ANNEX 3: KEY CLIMATE CHANGE THREATS

Max/Min temperature
(Charikot, Dolakha)

Month	Change in Minimum Monthly Temperature °C (2060)	Change in Maximum Monthly Temperature °C (2060)
Jan	+2.1	+2.6
Feb	+3.5	+4.0
Mar	+2.8	+3.2
Apr	+2.1	+0.7
May	+1.0	+1.6
Jun	+1.5	+1.5
Jul	+1.5	+1.5
Aug	+1.7	+1.8
Sep	+1.9	+1.8
Oct	+2.7	+1.5
Nov	+3.1	+1.2
Dec	+2.7	+1.9





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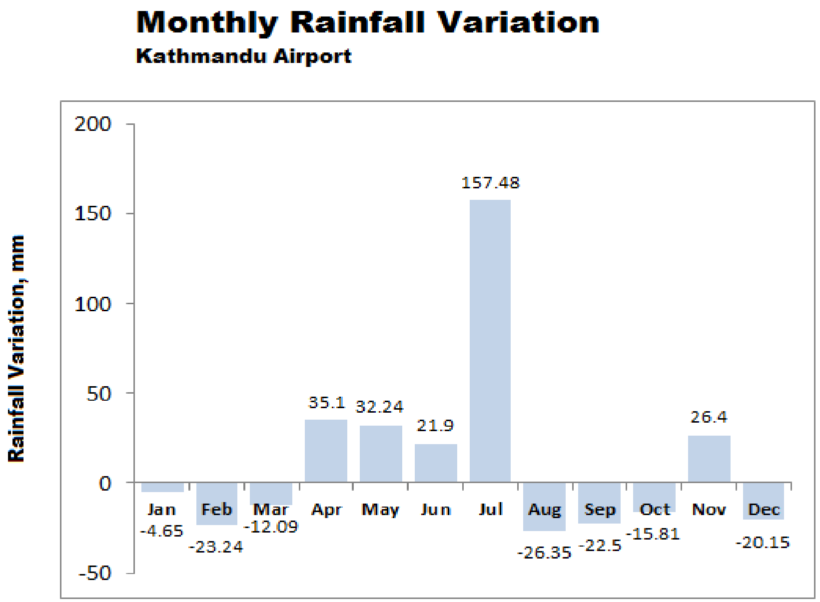
Seasonal changes in rainfall



Kathmandu Airport

Month	Monthly rainfall,mm BL	Projected Rainfall 2060, mm	Change in Rainfall, mm	% change
Jan	34	29	-5	-14
Feb	47	24	-23	-49
Mar	57	45	-12	-21
Apr	72	107	35	49
May	211	243	32	15
Jun	344	366	22	6
Jul	326	484	157	48
Aug	337	311	-26	-8
Sep	305	282	-23	-7
Oct	148	132	-16	-11
Nov	56	83	26	47
Dec	65	45	-20	-31

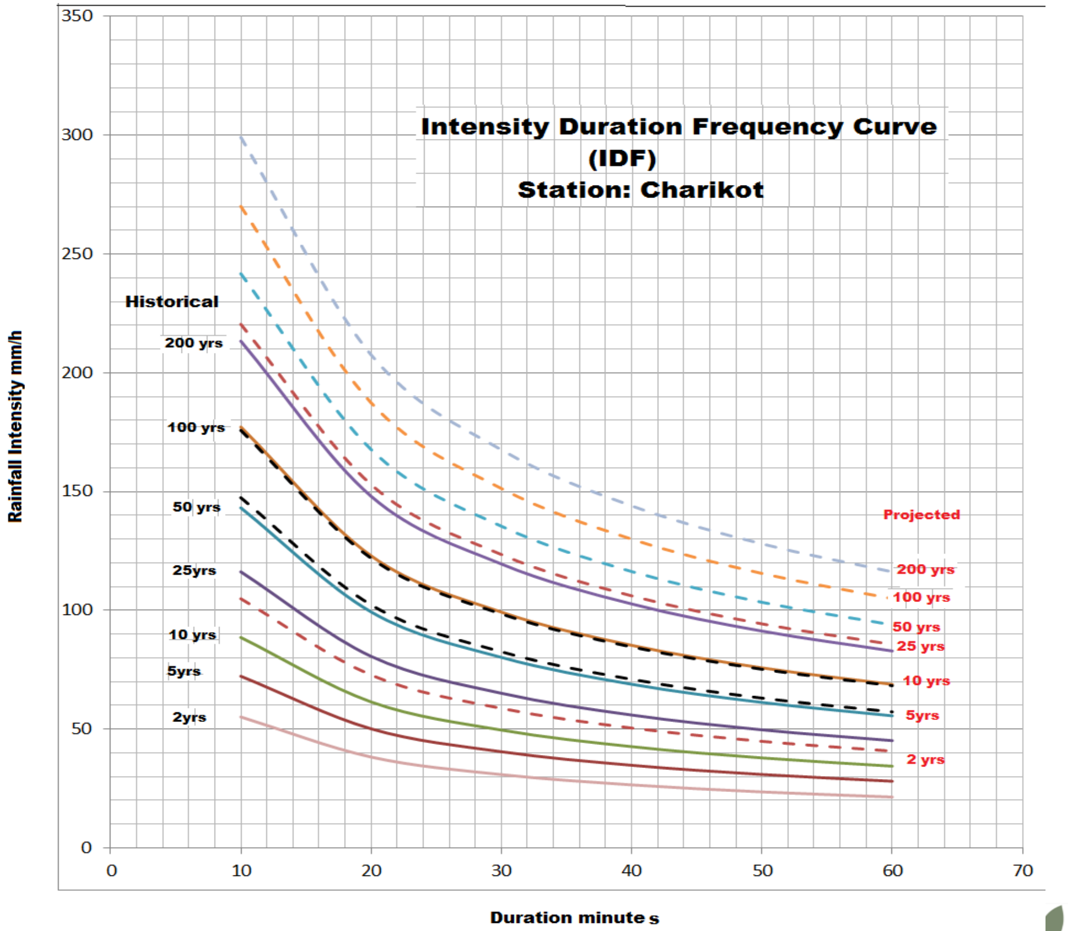
- Greatest increase end of dry/start of wet season
- Decrease end of wet season/start of dry

icem

Change in IDF curves
Charikot

- Intensity of rainfall events are increasing
- Increases are more pronounced for extreme rainfall

Charikot Return Period Years	% change
2	90
5	104
10	98
25	84
50	69
100	52
200	36



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Flood return periods

Return Period	Design Flood BL M3/s	Design Flood 2040 M3/s	Design Flood 2060 M3/s	%Δ 2040	%Δ 2060
2	799	1125	1254	+41	+57
5	1080	1474	1697	+36	+57
10	1280	1711	1998	+34	+56
25	1589	2019	2388	+27	+50
50	1825	2254	2683	+24	+47
100	2090	2492	2983	+19	+43
200	2350	2735	3289	+16	+40