Supplementary Appendix
Climate Change: Project Adaptation Action (PAA) Report

I. Basic Project Information

Project Title: BHU: SASEC Road Connectivity Project
Project Budget: $ 50.35 million
Location: Pemagatshel and Samdrupjongkar for the Nganglam-Deothang (ND) Road sub-project, Phuentsholing for the Mini Dry Port and Bypass road and Pasakha for the Access Road and Land Customs Station
Sector: Transport
Theme: Inclusive economic growth, Environmentally sustainable growth, Regional integration
Brief Description: This project includes the following subprojects: • 68km Nganglam-Dewathang (ND) road – construction of a highway with about 50 km being new road • Pasakha Access Road (1.2km) – improvement of the access road, • Phuentsholing Bypass road (about 2.7km) – improvement of an existing road and construction of a bridge, • Phuentsholing Mini Dry Port – upgrading of existing facilities • Alay Land Customs Station (LCS) – construction of a customs facility on Pasakha access road The ND Road subproject forms one of the missing links of the southern east-west highway. The subprojects in Phuentsholing and Pasakha will enhance the country's trade facilities and access routes in south western Bhutan.

II. Summary of Climate Risk Screening and Assessment

A. Sensitivity of project component(s) to climate/weather conditions and sea level	
1. 68km Nganglam-Dewathang road (ND Road) (Phuentsholing area in Chhukha district) 2. Phuentsholing Bypass road (about 2.7km) 3. Phuentsholing Mini Dry Port (Pasakha area in Chhukha district) 4. Pasakha Access Road (1.2km) 5. Alay Land Customs Station (LCS)	1. Annual mean temperature within the ND road project area is projected to rise by 2.4^{0}C. Monthly mean temperature is projected to be higher (>2.80C) in February, March, and April. August is projected to experience the lowest temperature rise (<2^{0}C). Spatially, the magnitude of temperature rise increases with increase in both latitude and altitude. For the project sites in Chhukha district (southwestern Bhutan), annual mean temperature is projected to rise by 2.5^{0}C. 2. Annual precipitation within the ND road project area is projected to increase by 110mm (or 3.8%). Dry season rainfall (November-December-January-February) is projected to decrease by 12.7% (~8mm), wet season rainfall (March-October) is projected to increase by 4.1% (~118mm). Spatially, increase in precipitation decreases with latitude. For the project sites in Chhukha district, an increase of 101mm (2.2%) in annual precipitation is projected. 3. The project components are not sensitive to the sea level rise.
B. Climate Risk Screening	
Risk topic 1. Landslides due to precipitation 2. Floods 3. Drought	Description of the risk **1. Landslide triggered by precipitation:** **ND Road: Medium/High, Phuentsholing & Pasakha: Medium/High.** Annual precipitation for the ND Road subproject road area is high (~2950mm). Slopes in the country are highly susceptible to landslides especially in the rainy season. Landslides mostly occur in the eastern

	and southern foothill belt where the terrain is steep and rocks underlying the soil are highly fractured thus allowing easy seepage of water. In addition to direct damages, landslides can also create temporary blockages across river courses and have resulted in huge floods when the blockages are breached. **2. Flood:** **ND Road: Medium, Phuentsholing and Pasakha: High**. All project sites are prone to the risk of flash floods. Project sites within Chhukha district (Phuentsholing Bypass road, Pasakha Access Road, and the Alay Customs Station) are under a higher risk. Three rivers (Kirungri, Tshokhiri, and Duiri) intercept the ND Road subproject. Past events indicate that flash floods are occurring at an accelerating rate due to climate change as a result of global warming. Under the A2 scenario, the summer monsoon precipitation is projected to increase by over 4%. ICIMOD projected an increase of 7% in rainfall during the monsoon over eastern Himalayas by the middle of the 21st century, an increased intensity of extreme rainfall events. Under the conditions of rising temperature, precipitation is more likely to arrive in the form of heavy rains accompanied by an increase in flood risk. Flood risks are very likely to aggravate in the future. **3. Drought:** **ND Road: Low/Medium, Phuentsholing & Pasakha: Low**. The southeastern part of the country is prone to drought hazard. The winters of 2005 and 2006 experienced unusually dry winter with no rain and snow. Frequent drought may alter the thermal regime of pavements. Increased precipitation intensity and variability are projected to increase the risk of flooding and drought in any areas.
Climate Risk Classification: High	

C. Climate risk assessment

1. Due diligence was conducted as below.
   a. Conducted a stand-alone climate change vulnerability assessment for the ND Road.
   b. Reviewed climate change projections for Bhutan in general, and project area in detail based on International Centre for Integrated Mountain Development, Indian Meteorological Department (IMD), Indian Institute of Tropical Meteorology (IITM), and National Environment Commission, Bhutan. –"Vulnerability and Adaptation Assessment Volume I, Technical Paper, 2011" which used Precis-downscaled HadCM3 and ECHAM5 simulated data.
   c. Conducted hydrological assessment including modeling of the major watersheds crossed by ND Road. Description of local climate surrounding the ND Road. The climate baseline was established using and processing precipitation, and temperature data from the Rainfall, Meteorology Section, Hydro Met Services Division, Department of Energy, Ministry of Economic Affairs, Thimphu.
   d. Prepared vulnerability maps identifying specific areas needing appropriate adaptation measures with like drainage structures and slope protective structures/measures.
   e. Used Clausius-Clapeyron Model to predict increase in rainfall and surface runoff from the projected increase in temperature.
   f. Reviewed current road design, construction, and maintenance practices in in Bhutan and identified areas of improvements. The climate risk assessment looked into the proposed pavement, slope protection, drainage, and bridge design construction practices and recommended adaptation measures.

2. Recommendations were drawn as below.
    a. Measures of slope stabilization should be implemented.
    b. For flood-prone areas/road sections, incorporation of adequate land drainage, increased clearance of bridges, adequate base height, etc. The design storm for all hydrological features should be calculated based on a large scale, detailed assessment of future climate scenarios within the project areas.
    c. Dynamics of soil moisture due to frequent drought/flooding needs to be incorporated into project design.

III. Climate Risk Management Response within the Project

The main climate-sensitive components of the project are protection walls, bridges and drainage structures. Specific adjustments made in the design to withstand future climate extremes for the ND Road and the Pasakha Access Road subprojects are:

1. **Plain Cement Concrete (PCC) for all concrete works including drainage structures**: Use of the M15 mix requiring a higher proportion of cement as opposed to the norm where the M10 mix with a lower cement proportion is used. This improves the strength of the concrete and hence its ability to withstand extreme weather.
2. **Cement Mortar for all concrete works including drainage structures**: Normally a ratio of 1:6 (cement:sand) is used. This ratio has now been revised to 1:4 inorder to increase the strength of the mortar.
3. **Random Rubble Masonry (RRM) wall**: Normally only the top and bottom section of the wall is made of cement, the middle section is made of stones stacked on top of each other. Now the entire wall is made of cement in order to improve the strength of the wall to hold debris and material falling on the hillside and support the road embankment on the valley side of the road. (Extensive bioengineering for slope protection is already a normal practice in Bhutan, hence thought it is an adaptation activity it is not mentioned separately here)
4. **Number of cross drainage structures**: Normally 4 cross drains are constructed per kilometer of road. This has been increased to 5 cross drains per kilometer in order to facilitate increased discharge levels.
5. **Hume pipes**: Hume pipes are one of two types of common cross drain types in Bhutan. Normally the diameter of the hume pipes used are 450mm, 600mm or 900mm. Now a 1200mm hume pipe has been introduced and only 900mm and 1200mm are included in the design in order to facilitate proper flow of water and avoid frequent blockages due to debris being washed down.
6. **L drain**: Normally the floor of the L drains has a 15% slope. It has been increased to 20% to improve the capacity for discharging increased quantities of water.
7. **Trapezoidal drain**: Normally only L drains are the longitudinal drains constructed along highways in Bhutan. Now a trapezoidal drain has been introduced to improve the capacity of the drains to discharge increased quantities of water.
8. **Bridge protection**: Normally provision for wing walls to protect the bridge foundation and abutment from scouring is done on ad hoc and on a reactive basis. Now a provision has been made to have wing walls for all bridges on a proactive basis. (The normal bridge height design already provides adequate clearance for discharging increased quantities of rainfall/water).

After incorporation of all the above design adjustments based on the recommendations of the climate vulnerability study it was found that the civil works costs for the ND Road subproject increased by approximately 5.1% ($1.6 mil out of $31.6 mil). Since the Pasakha Access Road is only 1.2 km of an existing road and includes construction of two bridges, the adaptation costs are much lower and amount only about 0.2% ($0.01 mil out of $5.9 mil) of the civil works costs.

The detailed design for the Phuentsholing Bypass Road is yet to be prepared. Hence recommendations for incorporation of relevant adaptation measures similar to those taken for ND Road subproject will be provided to the design consultant. A design and build contract package is being adopted for the procurement of Phuentsholing mini-dry port works. The contract agreement will require the contractor to design drainage systems that are adequate to drain future increases in rainfall. For the Alay Land Customs Station appropriate embankment protection measures and drainage systems that can withstand debris flows and future increases in rainfall respectively will be recommended in the detailed design.