APPENDIX C ENVIRONMENTAL BASELINE METHODOLOGY

C ENVIRONMENTAL BASELINE METHODOLOGY

C.1 PHYSICAL ENVIRONMENT

C.1.1 TOPOGRAPHY OF BHUTAN

Bhutan is a landlocked country situated in the eastern Himalayas and the border is defined by rugged terrain including high mountains, valleys and rivers. The country shares boundaries with China to the north and India to the south, east, and west.

Bhutan’s topography shaped by its location in the eastern Himalayas that ranges from deep valleys to towering mountains. The country's mountain systems are part of the greater Himalayan range, which extends across Nepal, India, and Bhutan, and are divided into several distinct ranges.

The Northern Bhutan is dominated by the Greater Himalayas, which lies along the Tibetan border, with several notable high peaks such as Gangkhar Peunsum and Jomolhari, ranged from 7,000 meters and above. The glaciers from the northern side of Bhutan feed Bhutan’s river systems.

The Black Mountains at central Bhutan divides the eastern and western Bhutan with peaks ranged from 1,500 to 5,000 meters with dense forest area with rich biodiversity.

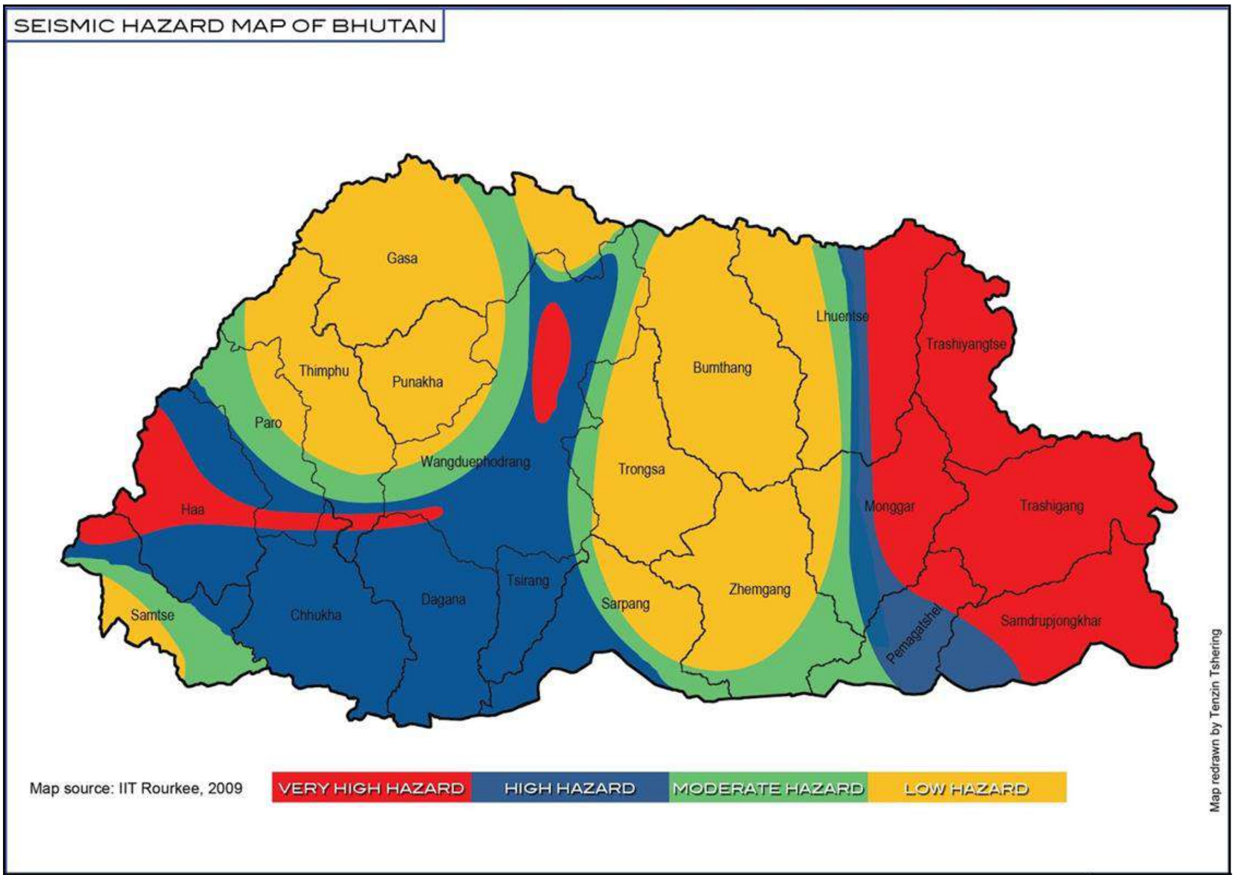
C.1.1 SEISMICITY OF BHUTAN

According to the Indian Regional Seismo-tectonic Zonation Map, Bhutan falls within Zone V, indicating a very high seismic risk. As shown in Figure C-1, the Rourkee Map classifies the west portion of Sarpang as having a high seismic hazard, including part of Gelephu.[2] The estimated seismic hazard levels for northeast India and Bhutan are fell into zone VI based on 1964 MSK Intensity Scale for earthquake ground shaking. The latest map shows Bhutan lies in Seismic Zone VI, which has a PGA of 0.50g and 0.75g for a return periods of 475 and 2,475 years respectively.[3]

[2] IIT Rourkee. (2009). State of Bhutan’s hydropower projects. https://yesheydorji.blogspot.com/2017/06/state-of-bhutans-hydropower-projects.html

[3] Draft Indian Standard Criteria for Earthquake Resistant Design of Structures Part 1 General Provisions [Seventh Revision of IS 1893 (Part 1)] (ICS No. 91.120.25). https://www.services.bis.gov.in/tmp/WCCED21022343_26042023_2.pdf

FIGURE C-1 SEISMIC HAZARD RISK MAP OF BHUTAN



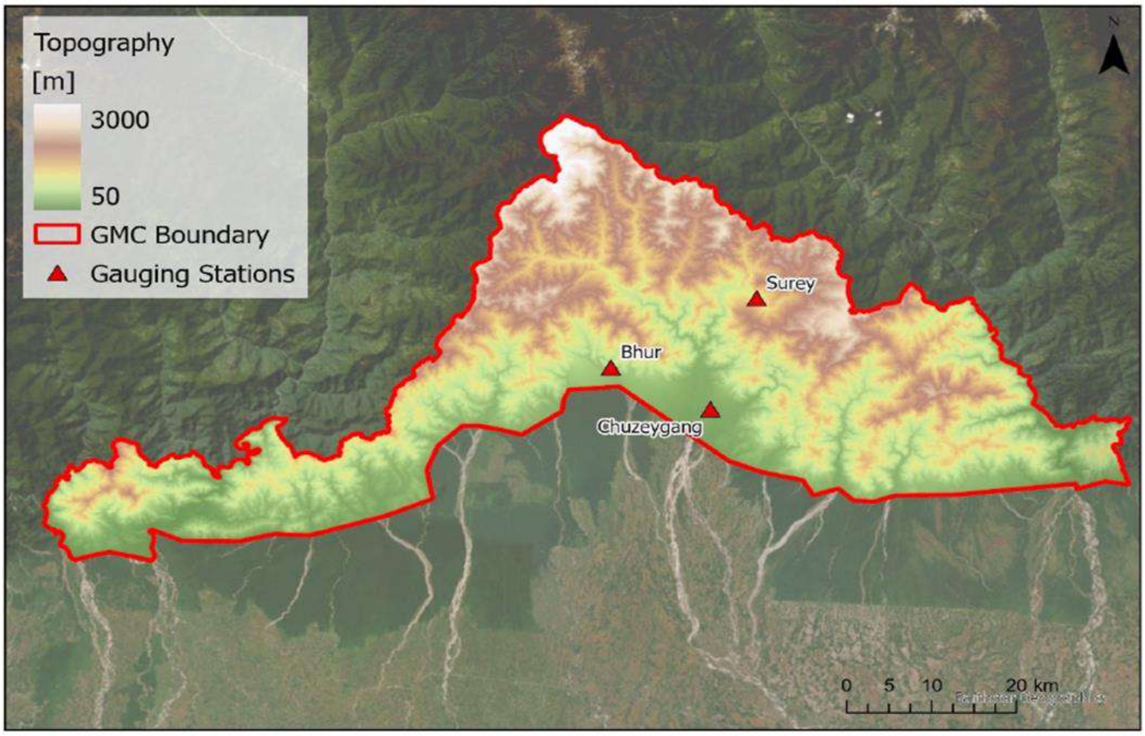
Seismic Hazard Risk Map of Bhutan		
0750493 Gelephu-Tareythang Road Project		ERM
Figure Source: IIT Rourkee (2009)	Date: September 2024	

C.1.2 CLIMATE

The climate of Bhutan varies significantly according to latitude and altitude. The country has three distinct climatic zones: subtropical, alpine and temperate, which encompass numerous micro-climates due to dramatic variations in elevation and topography.[4] Two main factors causing climatic variation of mean temperature and precipitation are the vast differences in altitude in the country and the influence of the North Indian monsoons. The rain gauging stations location is indicated in ***Figure C-2***.

[4] National Center for Hydrology and Meteorology. (2019). Analysis of Historical Climate and Climate Projection for Bhutan

FIGURE C-2 ELEVATION MAP INDICATING THE DIFFERENT RAIN GAUGING STATIONS



Elevation Map Indicating the Different Rain Gauging Stations		ERM
0750493 Gelephu-Tareythang Road Project		
Figure Source: CDR (2024)	Date: October 2024	

C.2 WATER RESOURCES AND HYDROLOGY

Most major rivers in Bhutan originate from glaciers and are replenished by watershed sources. The river system is characterized by main rivers flowing north to south from the Himalayas, with tributaries moving in an east-west direction. They typically feature steep gradients and narrow, steep-sided valleys that occasionally widen to create small, flat areas suitable for cultivation. Short rain-fed tributaries descend steeply from the east or west to join the major rivers.

The distinct rainy and dry seasons in Bhutan cause significant seasonal variations in river flows. During the monsoon season, rivers carry large volumes of water and often high sediment loads. Conversely, flow levels are relatively low during the dry season due to reduced rainfall and the limited presence of major groundwater reservoirs.

Bhutan has four major river systems: the Drangme Chhu (or Manas River System), the Punatsang Chhu (Sankosh River System), the Wang Chhu (Raidak River System), and the Amo Chhu (Torsa River System).

C.3 WATER QUALITY

C3.1 SURFACE WATER QUALITY

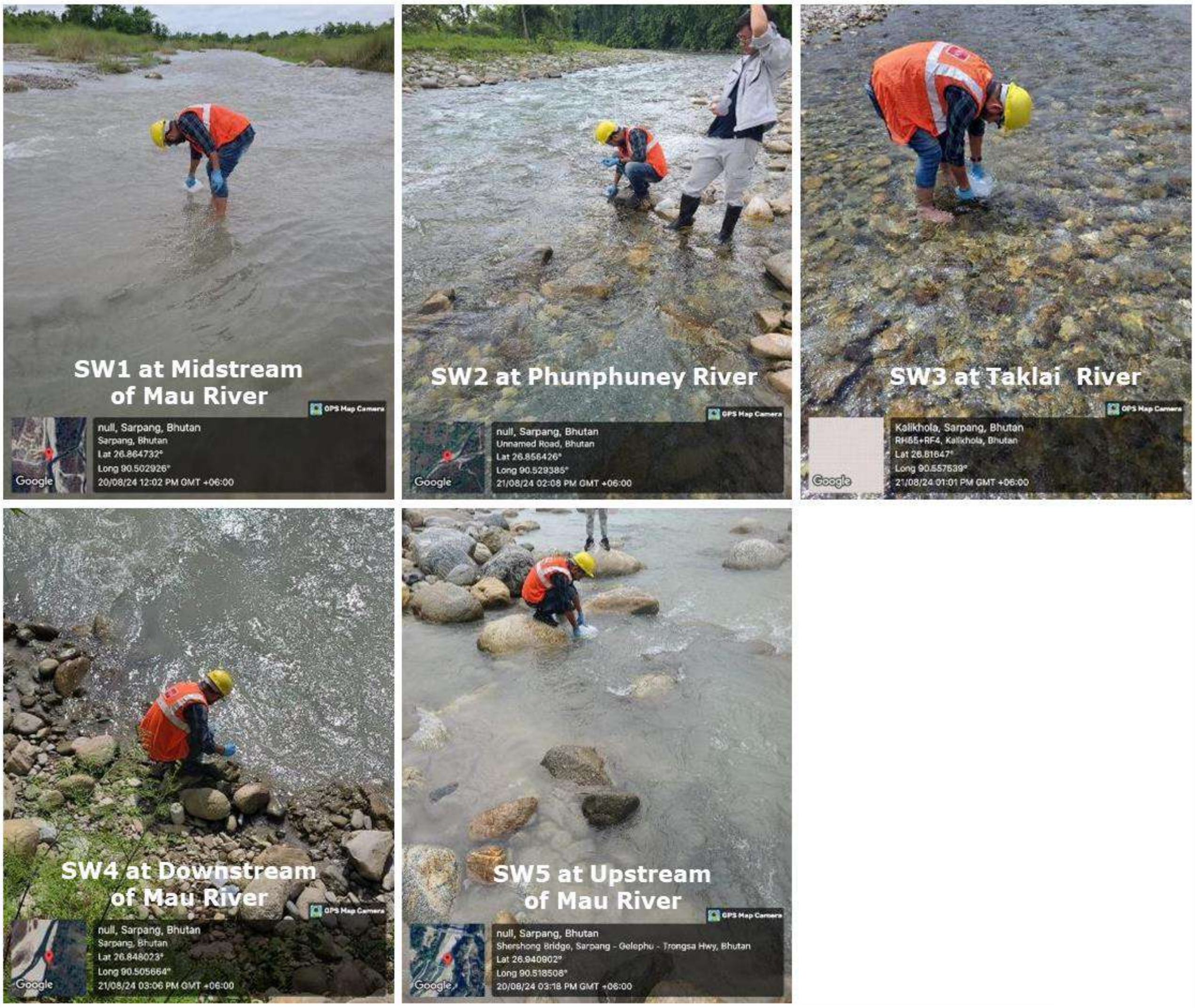
The baseline data for surface water quality assessment was done based on the parameters given in Baseline sampling plan. Five Surface water (n=10) sampling sites have been chosen for the investigation based on the physiographical condition. The selection of sites was done considering the location of different Project components, junction of streams course, spots of high-water velocity and some of the stagnated pools along with the areas having human interference. Both sites were targeted based on availability of human activities.

Surface water sampling was conducted on 20-21 August 2024 at five (05) sites, conducted by Mitra S K Laboratory (***Figure C-3***). A total of ten (10) grab water samples were collected and tested for various physical and chemical parameters, as well as microbiological, and radioactivity. The sampling water was analyzed by an accredited laboratory (Mitra S K Laboratory) and the results were compared to the Ambient Water Quality Criteria, Environmental Standards, 2020[5] and Guidelines for Drinking-Water Quality 4th edition[6].

For carrying out the Compliance Monitoring and assessing its conformance to the regulation the standard for the Environmental Commodity following specified national and international standard used in this study which are the Indian Standard Specifications for Surface Water Quality Standards (as per IS:2296) for Surface water.

[5] National Environment Commission Royal Government of Bhutan, June 2020.
[6] World Health Organization, 2022.

FIGURE C-3 DOCUMENTATION OF SURFACE WATER SAMPLING



Photos of Surface Water Quality Monitoring		
0750493 Gelephu-Tareythang Road Project		ERM
Photo Credit: Mitra S K Laboratory	Date: September 2024	

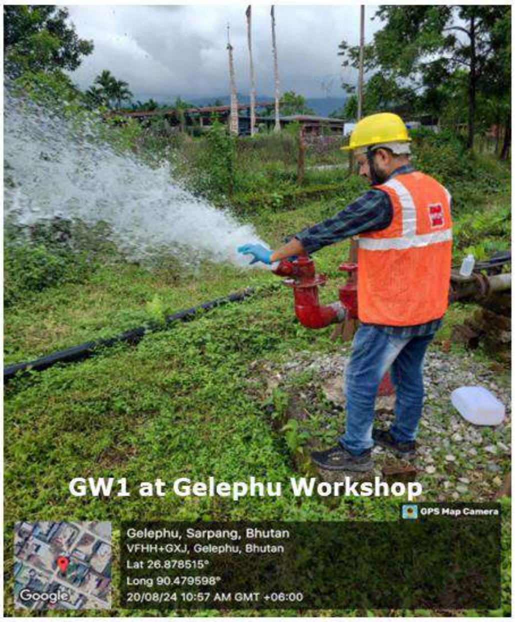
C3.2 GROUNDWATER QUALITY

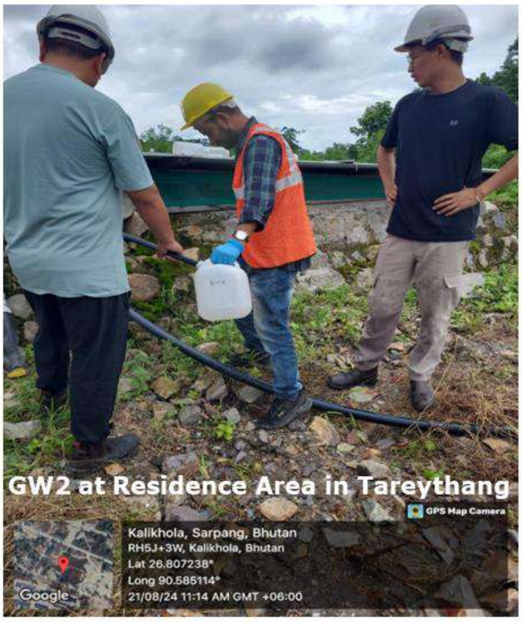
The baseline data for groundwater quality assessment was done based on the parameters given in Baseline sampling plan. Six (n=4) groundwater sampling sites have been chosen for the investigation based on the physiographical condition.

Groundwater sampling was conducted on 20-21 August 2024 at two (02) sites, conducted by Mitra S K Laboratory (***Figure C-4***). A total of four (04) grab water samples were collected and tested for various physical and chemical parameters, as well as microbiological, and radioactivity. The sampling water was analyzed by an accredited laboratory (Mitra S K Laboratory) and the results were compared to the Ambient Water Quality Criteria, National Environment Commission Royal Government of Bhutan, June 2020 and Guidelines for Drinking-Water Quality 4th edition.

For carrying out the Compliance Monitoring and assessing its conformance to the regulation the standard for the Environmental Commodity following specified national and international standard used in this study which are the Indian Standard Specifications for Drinking Water. IS: 10500, regulation 2012 for essential characteristics of drinking water.

FIGURE C-4 DOCUMENTATION OF GROUNDWATER SAMPLING





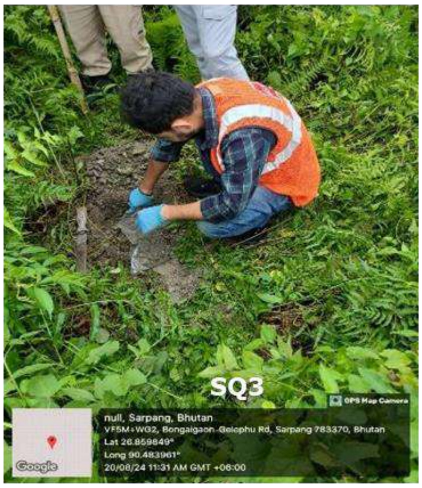
Photos of Groundwater Quality Monitoring		
0750493 Gelephu-Tareythang Road Project		ERM
Photo Credit: Mitra S K Laboratory	Date: September 2024	

C.4 SOIL QUALITY

The monitoring of the soil quality was carried out to understand the impacts on the soil, especially on the fertian soil sample was collected at 10-15 cm depth from surface (***Figure C-5***).

As there are not national standard for soil quality, therefore the United States Environmental Protection Agency (USEPA) and *Dutch Standard: Dutch Target and Intervention Values (2000)* has been used for this study. USEPA has developed various soil standards and guidelines depending on the type of contamination, land use, and risk level. Ecological Soil Screening Levels (Eco-SSLs) for mammals are utilized as reference, which is designed to protect ecological receptors (plants, animals) from the effects of contaminants in soil.

FIGURE C-5 DOCUMENTATION OF SOIL SAMPLING



Photos of Soil Quality Monitoring		
0750493 Gelephu-Tareythang Road Project		ERM
Photo Credit: Mitra S K Laboratory	Date: September 2024	

C.5 AMBIENT AIR QUALITY

The distribution of pollutants in the atmosphere is influenced by several factors, such as the location of emission sources, both natural and anthropogenic, relief and meteorological phenomena that are felt, namely wind, atmospheric stability conditions, inversions thermal, humidity, temperature, among others. Baseline air quality typically varies across any particular area. In essence, the baseline can be considered in the following components:

- ***Natural Baseline*** *– this represents the pollution concentrations that are ubiquitous in the region due to sources other than human activity. This primarily influences* PM_{10} */* $PM_{2.5}$ *concentrations. Naturally occurring* NO_x *and* NO_2 *are typically minimal.*
- ***Regional Sources*** *– this represents the pollution concentrations that arise from large point or non-point sources that will affect substantial areas.*
- ***Local Sources*** *– this represents pollutant concentrations that vary on a small spatial scale but may be substantially elevated on a local level. An example of such sources includes road traffic and in the middle of towns where there are vehicles, industry and multiple small-scale sources. These sources can lead to elevated pollutant concentrations on a localised scale, for the pollutants of interest.*

The baseline environmental conditions in Gelephu are characterized by a combination of urban, rural, and semi-industrial elements. This creates a mix of natural and anthropogenic influences The air quality in Gelephu is generally influenced by local traffic, household emissions (including wood and biomass burning), and cross-border pollution from India. While Bhutan's air quality is typically better compared to heavily industrialized countries, rapid urbanization and increased vehicle traffic may lead to localized degradation of air quality. Emissions of PM_{10} and $PM_{2.5}$, NO_x, and CO are expected to be the primary pollutants in ambient air.

The key rationale for baseline study is to determine the current state of the airshed in the Project area. The approach to the baseline monitoring was informed by the WBG EHS Guidelines: Environmental: Air Emissions and Ambient Air Quality (2007) and ERM professional judgement and experience However, the framework does not contain any prescriptive methodologies and therefore reference has been made to other international guidelines.

The baseline study encompassed ambient monitoring of NO_2, NO_x, SO_2, PM_{10} and $PM_{2.5}$. The pollutants of interest are based on a review of the proposed activities against the relevant international guidance, namely increased traffic (exhausts from vehicle engines), and equipment such as trucks, and excavators and emissions from construction-related activities.

Monitoring air quality across different seasons helps identify trends and patterns in pollutant levels. This is essential for understanding the typical air quality conditions and detecting any deviations that might indicate emerging issues or changes in pollution sources. At the time of writing, only the wet season data has been collected and analysed. Monitoring of the dry season will be undertaken and will be incorporated into the ongoing assessment of air quality once available.

C5.1 PM_{10} AND $PM_{2.5}$

PM monitoring was undertaken for two months in the wet ad dry seasons (at the time of writin, only the wet season data is available). The monitor used was an Aeroqual AQS air monitor. The location was chosen based on the following factors: Accessibility, security, power supply, proximity to the Project area and sensitive receptors. Data from the Aeroqual was downloaded after 23 days; the periods of missing data are attributed to power cuts in the area.

The locations for air quality monitoring were selected based on the proximity to sensitive receptors, which include areas with populations likely to be impacted by the project's activities. Of note is that the baseline survey was undertaken prior to confirmation of the exact road route. These locations are prioritized for monitoring to ensure that any potential air quality impacts from the project are accurately assessed and mitigated, thereby protecting public health and safety.

C5.2 NO_X, NO_2 AND SO_2

Monitoring was undertaken for the following pollutants, NO_x, NO_2 and SO_2 using Palmes-type diffusion tubes (see ***Figure C-6***), provided and analysed by Gradko Laboratories and deployed for approximately 30 days per sampling round. The diffusion tubes were sent for laboratory analysis to determine the period mean concentration.

FIGURE C-6 DIFFUSION TUBE (AQ1)

C.6 AMBIENT NOISE CONDITION

To assess background noise levels at each sampling location, all acoustic instrumentation used throughout the monitoring program can meet the requirements of IEC 61672 "Class 1 or 2 Sound Level Meter" with an A-weighting response curve. Noise logger shall be programmed to continuously record the following noise level indices in 10-minute intervals: L_{Aeq}, L_{Amax} and L_{A90}, L_{A10} and L_{Amin}.

Baseline noise sampling was conducted at seven (07) locations across the Project impact area to measure ambient noise levels using sound level meters over a period of 48 hours. The noise sampling was conducted by Department of Energy and Climate Change (DECC).

C.7 TRAFFIC AND TRANSPORT

C7.1 RELEVANT Standards AND GUIDELINES

C7.1.1 BHUTAN STANDARDS

The **Road Act (2013)** establishes the roles of governmental bodies to build, maintain, fund, and administer the road network. The Road Act requires that the Bhutan Department of Roads prepare a national roads master plan and 5-year implementation plans; develop road and bridge design standards, manuals, and technical guides; implement road design and construction standards; pursue the planning, construction, and maintenance of national roads; and enforce safety standards in road design. The Road Act requires that local governments submit road plans for their jurisdictions to be incorporated into the national road master plan and pursue the planning, construction, and maintenance of local roads, pedestrian ways and bicycle tracks. The Department of Roads operates within the Ministry of Works and Human Settlement.

The **Road Rules and Regulations (2016)** establish administrative authority and procedures for the Department of Roads and local governments to administer the Roads Act. The document provides dispute resolution procedures; requires a Traffic Management Plan for road construction or maintenance activities that would affect road users, a Traffic Management Plan is required, to be prepared in consultation with the Traffic Division of the Royal Bhutan Police and the Road Safety and Transport Authority of the local jurisdiction. The Rules also provide that entities working on a road open to traffic must take all reasonable measures to prevent accidents or injury to construction workers and road users, or damage to assets.

The **Road Safety and Transport Act (1999)** and the **Road Safety and Transport Regulations (2021**) establish requirements for driver licensing, motor vehicle registration, driving under the influence of alcohol or drugs, speed limits, traffic regulations, motor vehicle insurance, and commercial passenger vehicles. The regulations are administered by regional offices of the Road Safety and Transport Authority, under the Bhutan Ministry of Information and Communications. The Traffic Division of the Royal Bhutan Police provides traffic enforcement.

The **Road Classification System in Bhutan (2017)** was published by the Ministry of Works and Human Settlement to provide a clear understanding of definition and technical standards of various road categories.[7] The standards address right-of-way width, standard cross sections, design speed, horizontal and vertical alignment, and other road design elements.

[7] Ministry of Works and Human Settlement, Department of Roads. 2017. *Road Classification System in Bhutan.* Available from: https://www.moit.gov.bt/wp-content/uploads/2014/03/Road-Classification-System-in-Bhutan-Final.pdf.

C7.1.2 INTERNATIONAL STANDARDS

C.7.1.1.1World Bank Group Environmental and Social Standards

The World Bank Group's Environmental and Social Standards for Community Health and Safety address traffic and road safety in paragraphs 10 through 13:[8]

> 10. The Borrower will identify, evaluate and monitor the potential traffic and road safety risks to workers, affected communities and road users throughout the Project life-cycle and, where appropriate, will develop measures and plans to address them. The Borrower will incorporate technically and financially feasible road safety measures into the Project design to prevent and mitigate potential road safety risks to road users and affected communities.
>
> 11. Where appropriate, the Borrower will undertake a road safety assessment for each phase of the Project, and will monitor incidents and accidents, and prepare regular reports of such monitoring. The Borrower will use the reports to identify negative safety issues, and establish and implement measures to resolve them.
>
> 12. For vehicles or fleets of vehicles for the purposes of the Project (owned or leased), the Borrower will put in place appropriate processes, including driver training, to improve driver and vehicle safety, as well as systems for monitoring and enforcement. The Borrower will consider the safety record or rating of vehicles in purchase or leasing decisions and require regular maintenance of all Project vehicles.
>
> 13. For Projects that operate construction and other equipment on public roads or where the use of Project equipment could have an impact on public roads or other public infrastructure, the Borrower will take appropriate safety measures to avoid the occurrence of incidents and injuries to members of the public associated with the operation of such equipment.

C.7.1.1.2IFC Environmental, Health and Safety Guidelines, 2007

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP). Performance measures in the Guidelines are normally acceptable to the World Bank Group and are generally considered to be achievable in new facilities at reasonable costs.[9] The following Guidelines have applicability to road construction, design, and operation.

IFC Environmental, Health, and Safety General Guidelines

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[8] World Bank Group (WBG) 2017. *Environmental and Social Framework.* Available at: https://pubdocs.worldbank.org/en/837721522762050108/Environmental-and-Social-Framework.pdf#page=59&zoom=80. Accessed October 2024.

[9] IFC (International Finance Corporation). 2007. *Environmental, Health, and Safety (EHS) Guidelines.* April 30, 2007. Available at: https://www.ifc.org/content/dam/ifc/doc/2000/2007-general-ehs-guidelines-en.pdf. Accessed October 2024.

Section 3.4 of the IFC EHS General Guidelines addresses traffic safety, emphasizing the "adoption of safety measures that are protective of Project workers and road users, including those who are most vulnerable to road traffic accidents." The guidelines for traffic safety, listed below, are applicable to Project construction practices:[10]

- Adoption of best transport safety practices across all aspects of Project operations with the goal of preventing traffic accidents and minimizing injuries suffered by Project personnel and the public. Measures should include:
  - Emphasizing safety aspects among drivers;
  - Improving driving skills and requiring licensing of drivers;
  - Adopting limits for trip duration and arranging driver rosters to avoid overtiredness;
  - Avoiding dangerous routes and times of day to reduce the risk of accidents;
  - Use of speed control devices (governors) on trucks, and remote monitoring of driver actions.
- Regular maintenance of vehicles and use of manufacturer approved parts to minimize potentially serious accidents caused by equipment malfunction or premature failure;
- Where the Project may contribute to a significant increase in traffic along existing roads, or where road transport is a significant component of a Project, additional measures include:
  - Minimizing pedestrian interaction with construction vehicles;
  - Collaboration with local communities and responsible authorities to improve signage, visibility and overall safety of roads, particularly along stretches located near schools or other locations where children may be present. Collaborating with local communities on education about traffic and pedestrian safety (e.g. school education campaigns);
  - Coordination with emergency responders to ensure that appropriate first aid is provided in the event of accidents;
  - Using locally sourced materials, whenever possible, to minimize transport distances. Locating associated facilities such as worker camps close to Project sites and arranging worker bus transport to minimizing external traffic;
  - Employing safe traffic control measures, including road signs and flag persons to warn of dangerous conditions.

IFC Environmental, Health, and Safety Guidelines for Toll Roads

The 2007 EHS Guidelines include Industry Sector Guidelines. The Industry Sector Guidelines for Toll Roads include measures relevant to construction, operation and maintenance of large road projects including associated bridges.[11] Transportation-related guidelines within this document address pedestrian and traffic safety, including the following strategies:

[10] IFC 2007a

[11] IFC (International Finance Corporation. 2007b. *Environmental, Health, and Safety Guidelines for Toll Roads. April 30, 2007.* Available at: https://www.ifc.org/content/dam/ifc/doc/2000/2007-toll-roads-ehs-guidelines-en.pdf. Accessed October 2024.

Pedestrian Safety:

- Provision of safe corridors along the road alignment and construction areas, including tunnels and bridges (e.g. paths separated from the roadway), and safe crossings (preferably over or under the roadway) for pedestrians and bicyclists during construction and operation;
  - Installation of barriers (e.g. fencing, plantings) to deter pedestrian access to the roadway except at designated crossing points;
  - Installation and maintenance of speed control and traffic calming devices at pedestrian crossing areas; and
  - Installation and maintenance of all signs, signals, markings, and other devices used to regulate traffic, specifically those related to pedestrian facilities or bikeways.

Traffic Safety:

- Installation and maintenance of all signs, signals, markings, and other devices used to regulate traffic, including posted speed limits, warnings of sharp turns, or other special road conditions;
- Setting of speed limits appropriate to the road and traffic conditions;
- Design of roadways to accommodate anticipated traffic volume and flow;
- Maintenance of the road to prevent mechanical failure of vehicles due to road conditions;
- Construction of roadside rest areas at strategic locations to minimize driver fatigue; and
- Installation of measures to reduce collisions between animals and vehicles.

C7.2 METHOD OF ASSESSMENT

The Project's effects on traffic and transportation are identified by anticipating the type and amount of Project-generated traffic during construction, and the change in traffic patterns resulting from the proposed new road. Direct and indirect impacts arising from the Project, both positive and negative, are considered and the likely significant effects described. Mitigation measures to reduce likely significant effects are described. The residual significant effects, both positive and negative, are then reported.

The magnitude of the road traffic impacts is defined as described in Appendix B of the ESIA. ***Table B-1*** defines the magnitude of impacts specific to transportation, while ***Table B-2*** defines the significance of those impacts specific to transportation. Road system users include drivers, passengers, public transit users, pedestrians, and bicyclists.

TABLE B-1 MAGNITUDE OF TRANSPORTATION IMPACTS

Magnitude	Description
Low	Project traffic impacts are limited to the area immediately surrounding the Project site. Minimal travel delays or increases in traffic safety risks are expected due to Project traffic and Project traffic has no discernible effect on road infrastructure conditions.
Medium	Project traffic impacts affect the road network close to the Project site. Project traffic would result in moderate delays, noticeable increases in transportation safety risk, and/or noticeable effects on road infrastructure condition that necessitates increased maintenance.
High	Project traffic impacts an extensive portion of the road network. Traffic volumes would result in extensive delays and/or substantial impacts on road infrastructure conditions that necessitates substantial maintenance, including emergency repairs.

TABLE B-2 TRANSPORTATION IMPACT SIGNIFICANCE

Impact Rating	Rating Definition
Low	Current and future road system users will not be affected by a particular activity, or the predicted effect is deemed to be ‘imperceptible’ or is indistinguishable from natural background variations.
Moderate	Current and future road system users will experience a noticeable effect, but the impact magnitude is small (with or without mitigation) and/or the receptor is of low sensitivity/ vulnerability. In either case, the magnitude should be well within applicable standards.
Substantial	Current and future road system users will experience a noticeable effect in travel patterns or road conditions that may alter user ability to achieve necessary travel or result in travel hazards.
High	An accepted road system limit or standard may be exceeded, or large magnitude impacts occur to sensitive road system users.

C.8 CLIMATE CHANGE RISK ASSESSMENT

C8.1 INTRODUCTION

The primary objective of this chapter is to follow a methodical process to identify and analyze hazards directly linked to climate change within the specific context of the Project.

Subsequently, an evaluation of Project-specific vulnerabilities and exposure related to the hazard will be conducted.

The risk assessment will be provided based on understanding of the potential impact considering vulnerability, hazard, and exposure. Climate hazard trends in combination with Project-specific exposure and vulnerability are assessed to identify climate risks and their materiality to the Project.

Finally, a series of mitigation measures are proposed to reduce the risk level to the Project.

C8.2 WATER AVAILABILITY

Availability of water in the airport boundary was assessed based on data from the online water risk assessment tool WRI-Aqueduct Water Risk Atlas for Water Stress, Seasonal Variability, and Inter-annual Variability. The description of the parameters assessed is provided in the table below.

TABLE C-3 LIST OF PARAMETERS FOR EVALUATION OF BASELINE WATER AVAILABILITY

No.	Parameter	Definition
1	Baseline Water Stress	Baseline water stress is defined as the ratio of the total annual water withdrawals to the total available annual water renewable supply, accounting for upstream consumptive use. Higher values indicate more competition among users.
2	Seasonal Variability	Seasonal variability measures the average within-year variability of available water supply, including both renewable surface and groundwater supplies. Higher values indicate wider variations of available supply within a year.
3	Inter Annual Variability	Inter-annual variability measures the average between year variability of available water supply, including both renewable surface and groundwater supplies. Higher values indicate wider variations in available supply from year to year.

C8.2.1 BASELINE HAZARD

C.8.1.1.1 Water Stress

The baseline water stress map is presented in ***Figure C-7***. According to the WRI information, the specific location of the Project is Ganges - Bramaputra basin. The water stress shows 'Low' indicating that the ratio of total water demand to the available renewable surface and groundwater supplies is relatively small. This indicates there is less competition among users (domestic, industrial, irrigation, and livestock) for the available water resources. Hence, considering the hazard categorization due to water stress is categorized to be "Low".

FIGURE C-7 BASELINE WATER STRESS

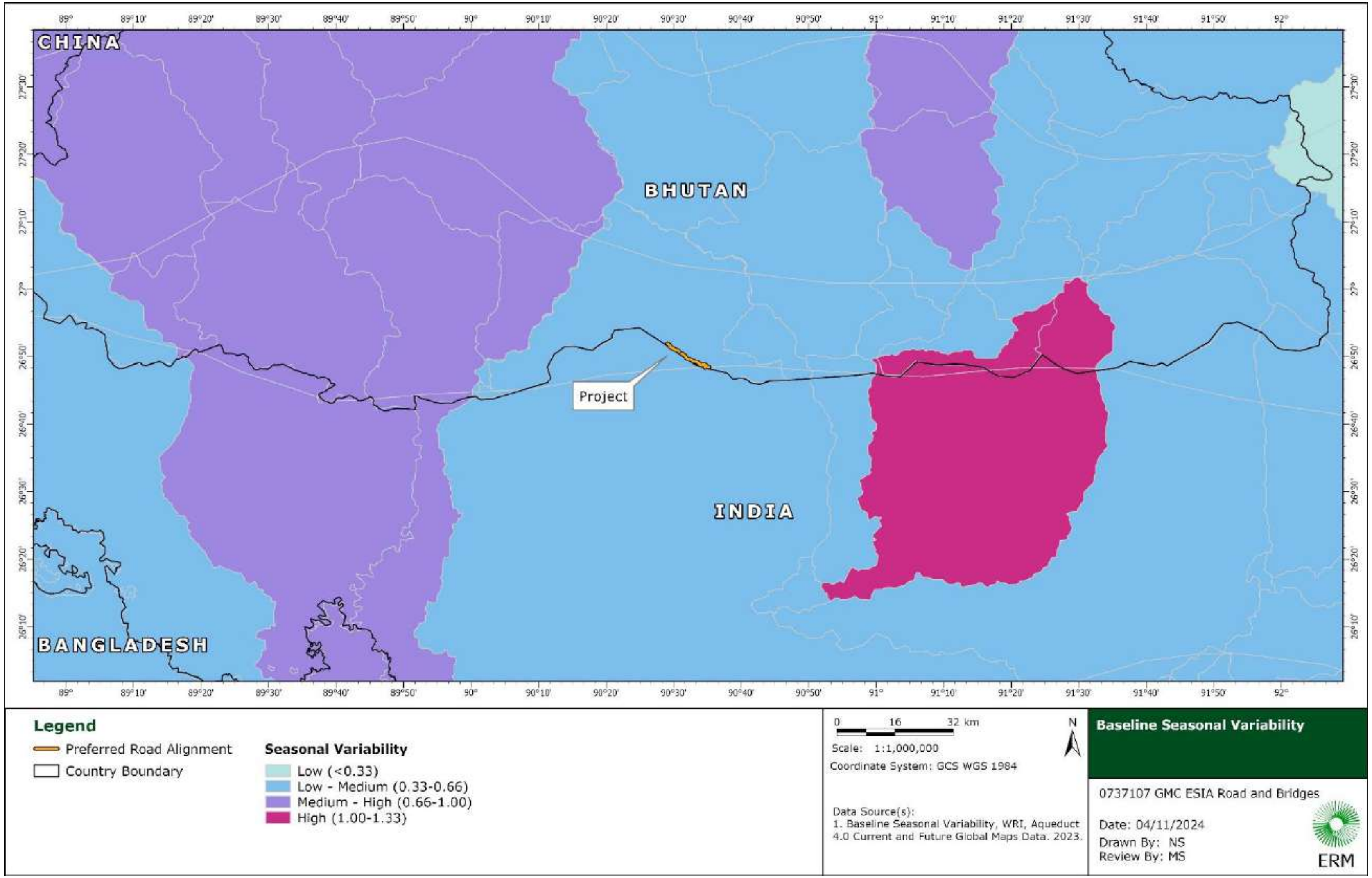
Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

C.8.1.1.2 Seasonal Variability

Seasonal Variability map presented in ***Figure C-8*** indicates the likelihood of variations in water availability over different months within a year as 'Low to Medium'. This indicates that the supply of water over different months does not vary significantly. Considering the baseline hazard due to seasonal variability the hazard level is categorized to be **"Medium".**

During stakeholder consultations conducted in 2024, it was noted that residents experience shortage of water during dry season. However, such scarcity is understood to be related to insufficient infrastructure rather than lack of water resources.

FIGURE C-8 BASELINE SEASONAL VARIABILITY



Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

C.8.1.1.3 Inter-Annual Variability

Inter-Annual Variability map presented in ***Figure C-9*** indicates the variations in water availability over different years is 'Low'. This indicates that the supply of water over different years is likely to be similar to seasonal variation. The baseline hazard due to inter-annual variability is categorized as "**Low**".

FIGURE C-9 BASELINE INTER-ANNUAL VARIABILITY

Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

C.8.1.1.4Hazard of Baseline Water Availability

Based on the baseline water stress, seasonal variability, and inter-annual variability, identify a region characterized by a consistently reliable water source. There is a sufficient amount of water that meets the majority of requirements, and the differences in water levels from season to season or year to year are not significant.

In conclusion, based on the evaluation of baseline water stress, seasonal variability, and inter-annual variability, the hazard due to availability of water is considered to be "**Medium**" on a conservative basis based on the medium hazard level associated to seasonal variability.

C8.2.2 CLIMATE CHANGE PROJECTION

Water availability was assessed based on the evaluation of projections for water depletion, water stress, and seasonal variability under climate change scenario. The water availability will be assessed by using the "pessimistic" scenario (SSP5 RCP8.5) for both near-term and long-term periods (i.e. 2030 and 2050). The data were obtained from the WRI-Aqueduct Water Risk Atlas.

Water depletion measures the level of how humans consume water from accessible sources of fresh water. A higher depletion number indicates an increased demand for water supplies. The projection shows 'Low' in both 2030 and 2050, meaning the current pace of water consumption is not significantly impact the overall supply of freshwater resources until 2050.

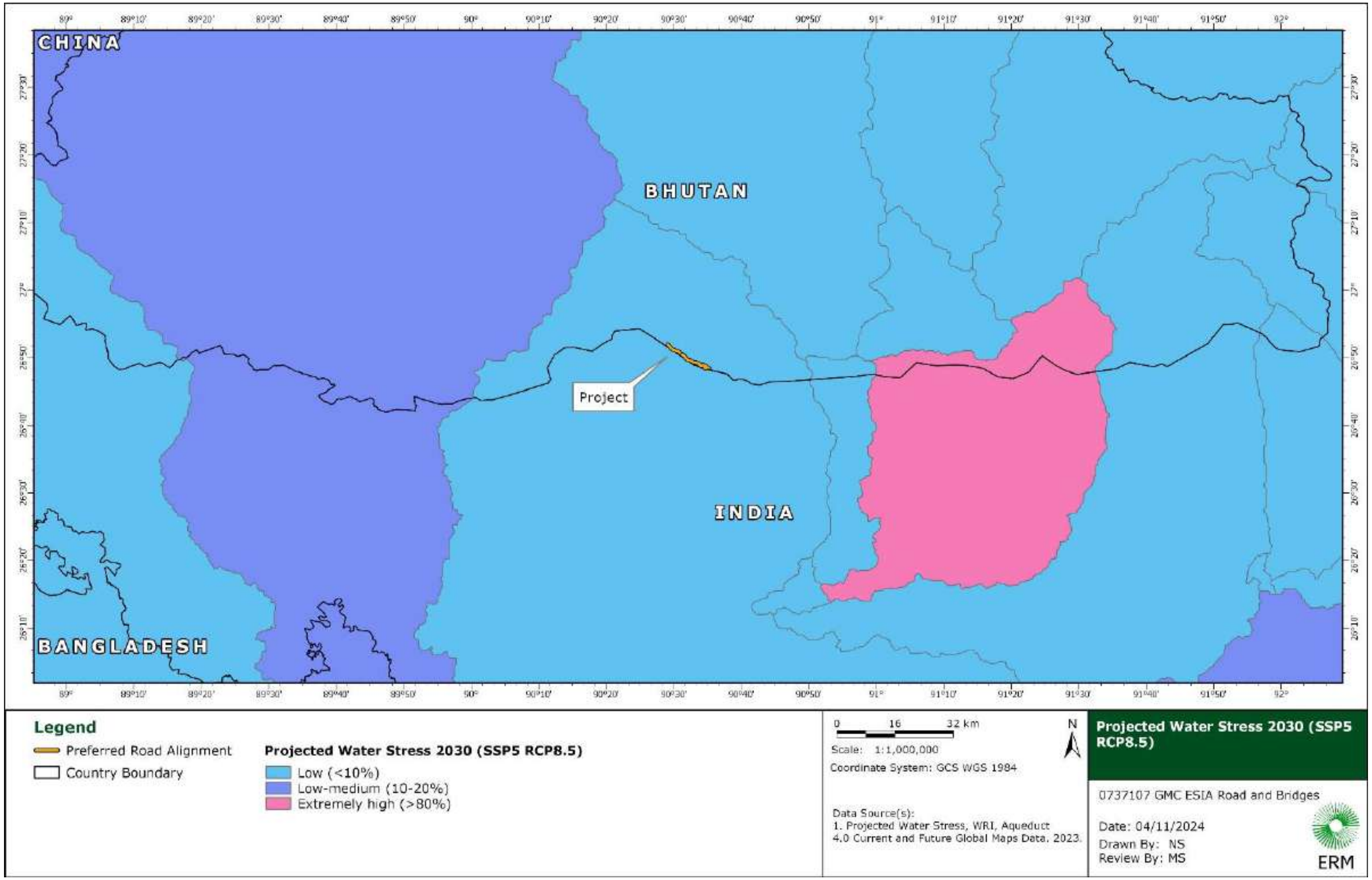
Further, water stress is projected to be 'Low' under all climate change scenarios as presented in ***Figure C-10*** and ***Figure C-11***. Seasonal variability is projected to be 'Low to Medium' for all climate change scenarios as presented in ***Figure C-12*** and ***Figure C-13*** indicates a similar seasonal variability in the future.

Consider the hazard categorization the water depletion and water stress will be classified as 'Low', and the water seasonal variability remain 'Medium'.

Based on the information for the three (3) indicators, an imbalance between supply and demand could occur leading to a water shortage. Hence, the hazard of water availability in the future remains **"Medium"**.

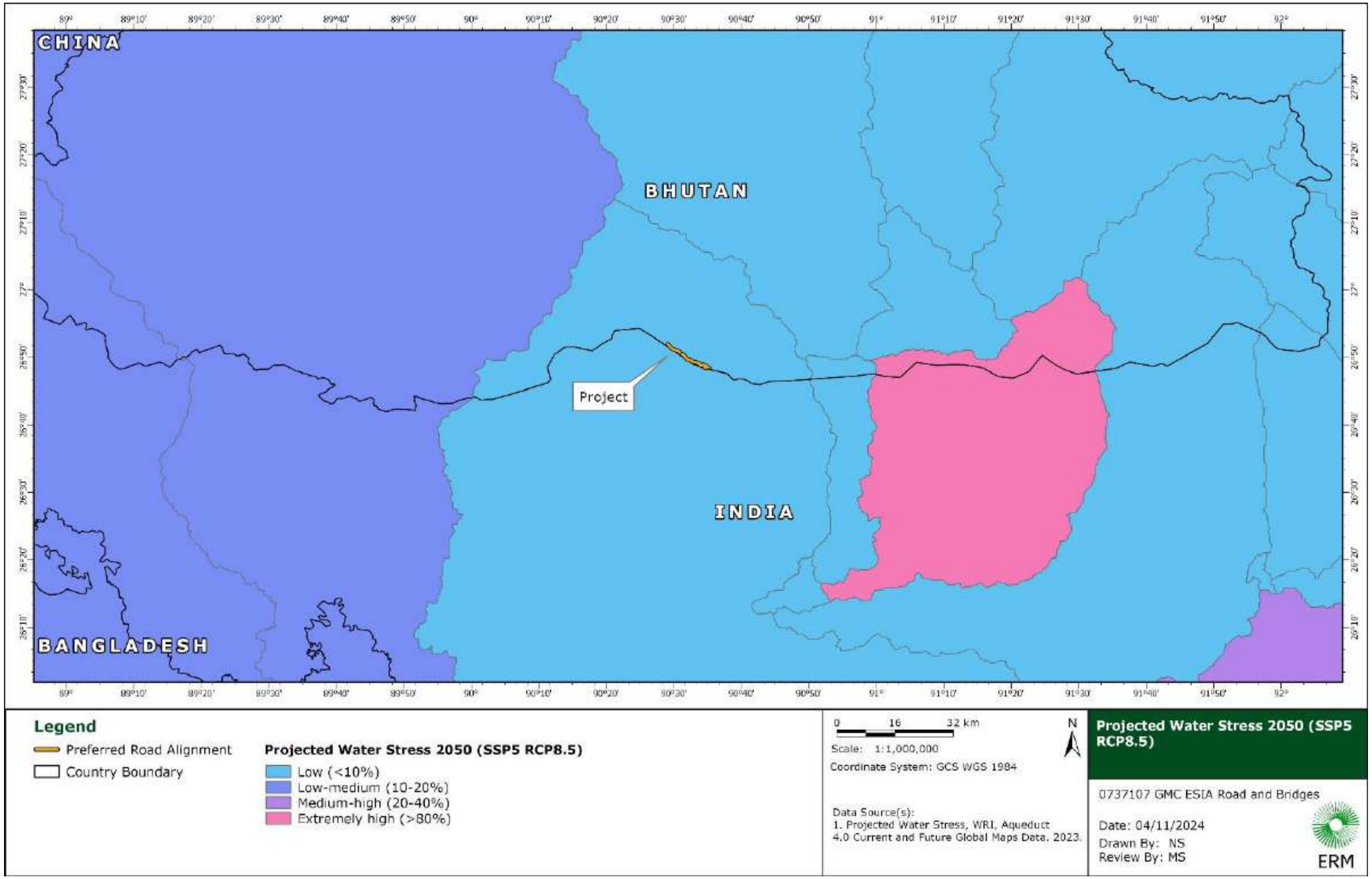
C.8.1.1.5 Projections of Water Stress

FIGURE C-10 PROJECTIONS OF WATER STRESS DURING 2030 FOR RCP 8.5



Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

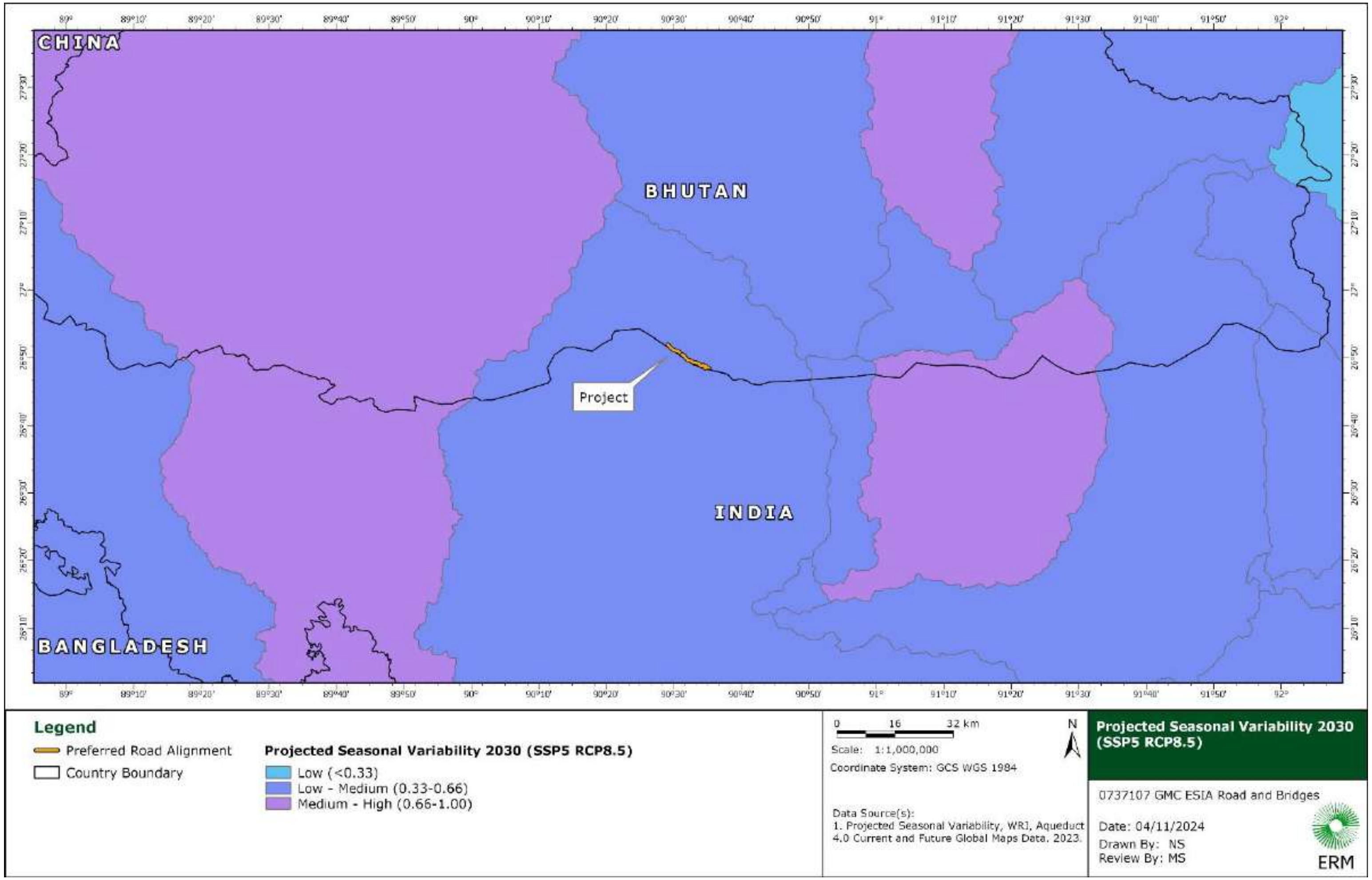
FIGURE C-11 PROJECTIONS OF WATER STRESS DURING 2050 FOR RCP 8.5



Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

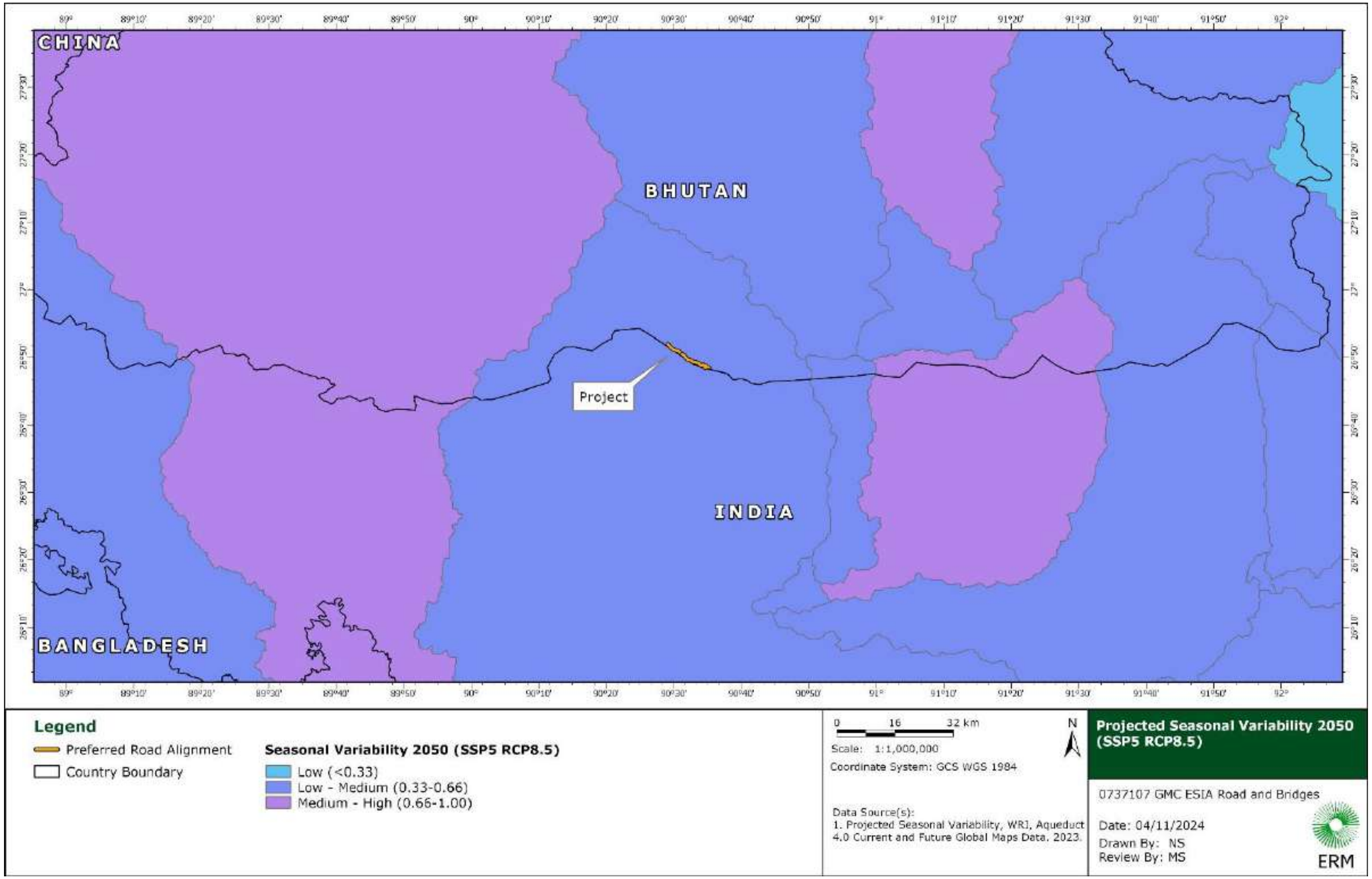
C.8.1.1.6 Projections of Seasonal Variability

FIGURE C-12 PROJECTIONS OF SEASONAL VARIABILITY DURING 2030 FOR RCP 8.5



Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

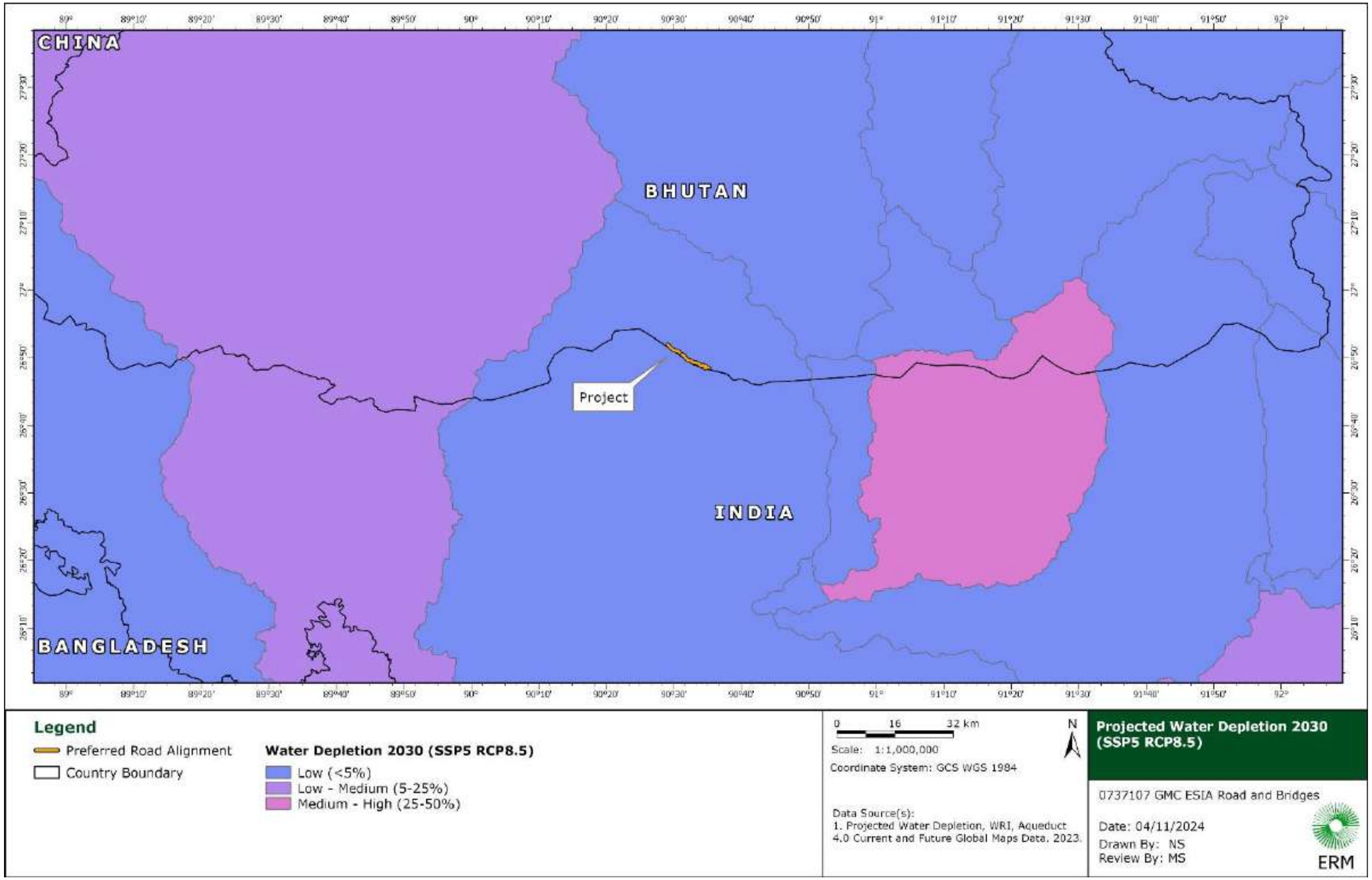
FIGURE C-13 PROJECTIONS OF SEASONAL VARIABILITY DURING 2050 FOR RCP 8.5



Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

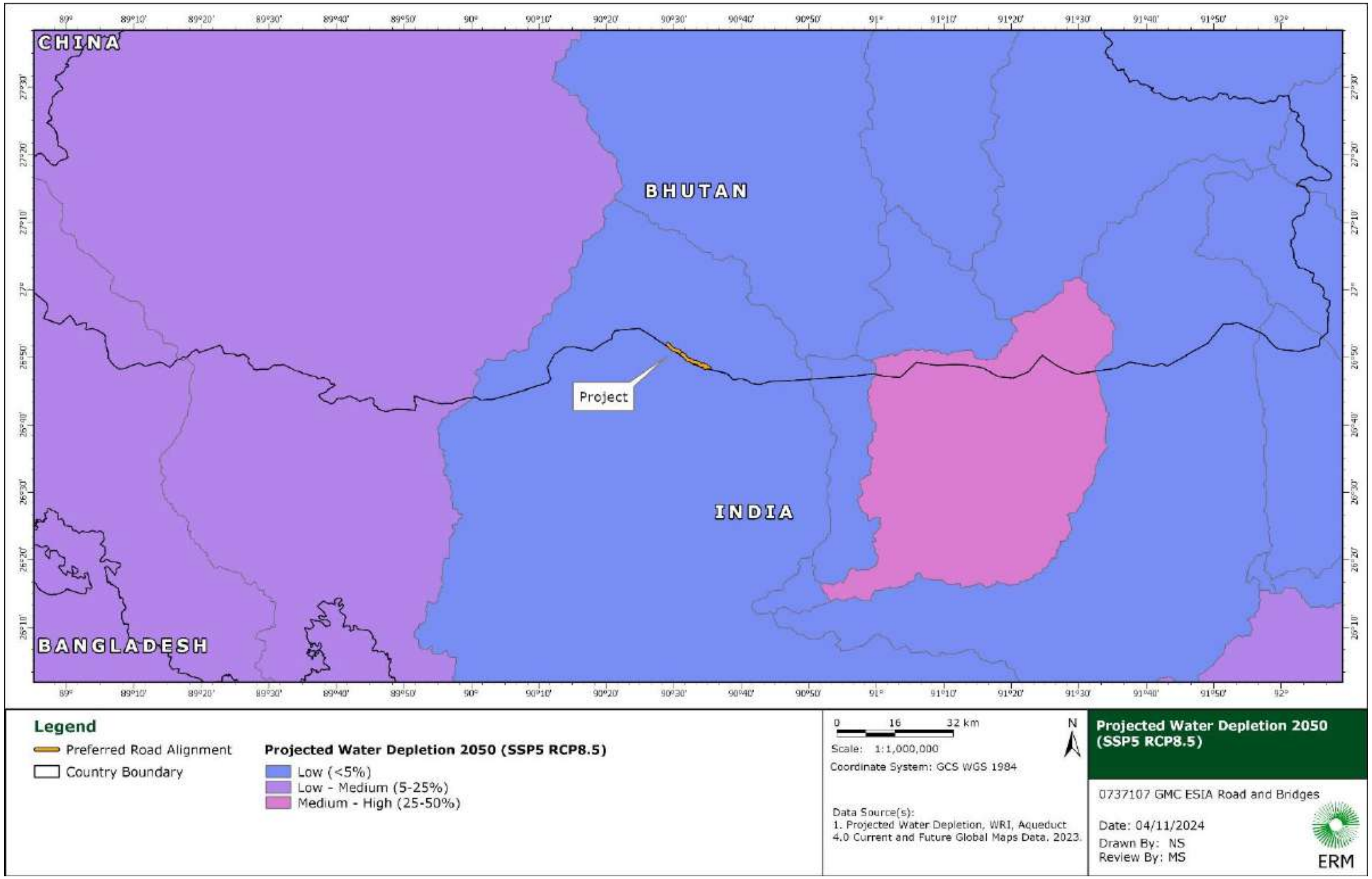
C.8.1.1.7 Projections of Water Depletion

FIGURE C-14 PROJECTIONS OF WATER DEPLETION DURING 2030 FOR RCP 8.5



Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

FIGURE C-15 PROJECTIONS OF WATER DEPLETION DURING 2050 FOR RCP 8.5



Source: WRI- Aqueduct Water Risk Atlas. Available at https://www.wri.org/applications/aqueduct/water-risk-atlas/

C8.2.3 EXPOSURE AND VULNERABILITY

The project’s exposure to water availability issues will primarily occur during the construction phase, as water is essential for activities like dust control and material mixing. Therefore, as the construction phase will last only for 3.5 years, the climate change related risks are unlikely to occur. During operation the water use is limited to potential cleaning during the dry season and watering of the roadside greenery (likely to be limited to the Mau River Bridge) both likely to require a negligible amount of water.

Based on the information provided above, the Project's exposure and vulnerability will be considered as **“Low”**.

C8.2.4 WATER AVAILABILITY RISK ASSESSMENT

The table below shows the summary of risk assessment.

TABLE C-4 QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR WATER AVAILABILITY

	Baseline	**RCP 8.5 - 2030**	**RCP 8.5 - 2050**
Hazard Level	**Low**	**Low**	**Low**
Exposure x Vulnerability Level	**Low**	**Low**	**Low**
Risk Level	**Low**	**Low**	**Low**
Implications for the Project	• Potential competition on water-use during the operation phase		
Key Potential Impacts	• No significant impacts identified		
Implemented Mitigations	• If possible, recycle water used for road cleaning to water the roadside greenery.		

C8.3 FLOOD

Floods can be defined as the overflow of water resulting in the submergence of dry lands. Floods can be categorized as inland and coastal in nature. Inland flooding may be caused due to heavy rainfall, resulting in high run-off leading to water accumulation in low lying areas, or overtopping of water bodies such as rivers, streams, lakes, ponds, and tanks. Coastal flooding is a result of the ingress of the ocean or sea water via the coastal and/or estuarine systems onto open land. This could be a standalone of the combined effect of tides, surges, and increases in the sea surface elevation.

Floods are likely to result in widespread local as well as regional level destruction. This can be caused due to submergence, washing away, and damage to infrastructure, buildings, structures, sewerage systems, damage to power transmission and power generation, loss of agricultural land and crops, contamination of freshwater sources, propagation of waterborne diseases, and loss of life.

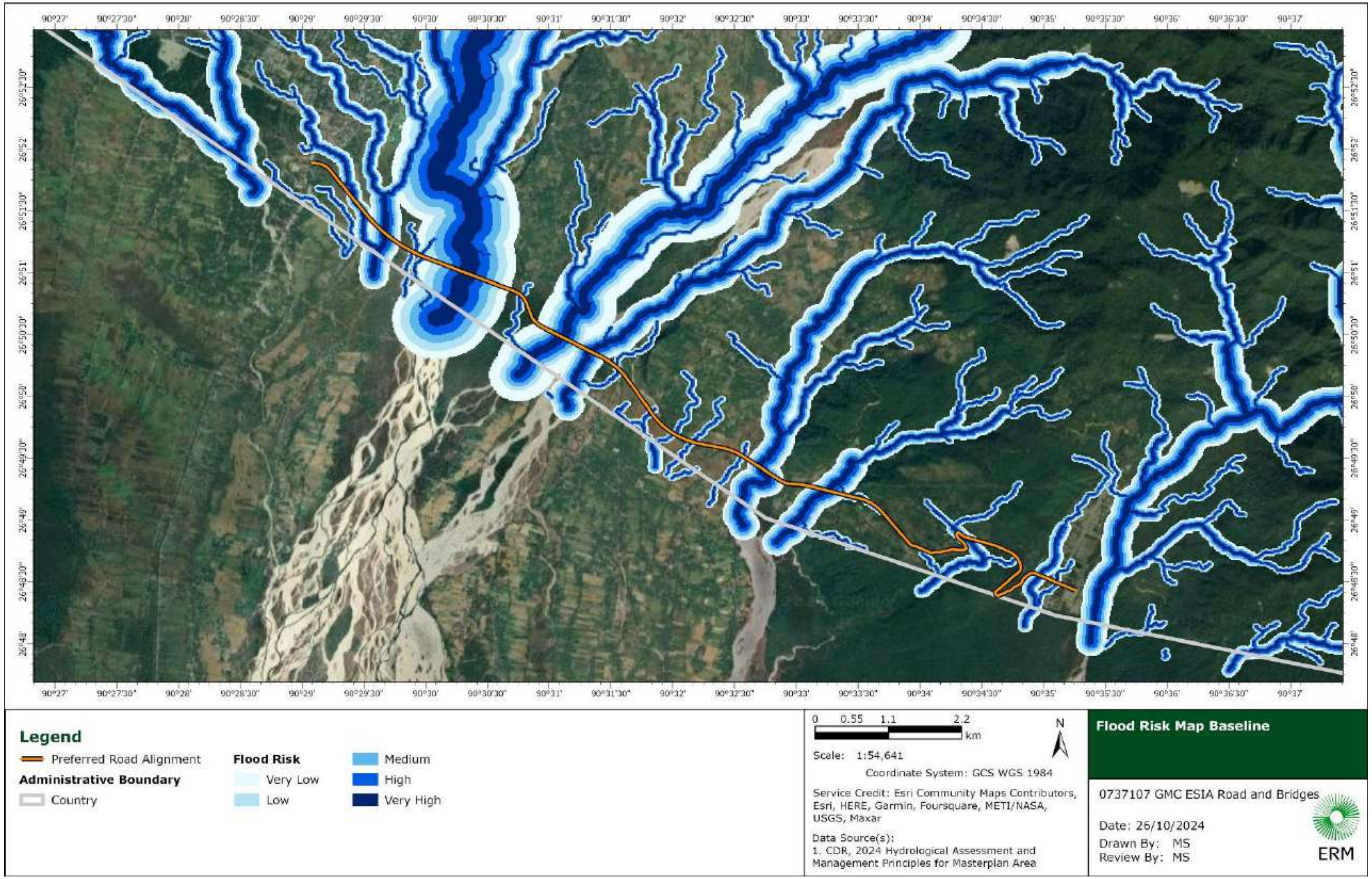
C8.3.1 BASELINE HAZARD

CDR International conducted a comprehensive study on the hydrologic and river systems for the Gelephu Mindfulness City Project.[12] A detailed hydraulic assessment was performed using various models and historical rainfall data, which were extrapolated into Intensity-Duration-Frequency (IDF) curves that included a climate change factor. Rainfall time series derived from these curves were used as inputs for hydrological and flood models. The hydrological model simulated watershed processes, generating discharge time series for perennial rivers, while the flood model evaluated compound scenarios involving riverine and pluvial floods, estimating flood depths, extents, and velocities.

The model shows that the Project is crossing areas with high risk of flooding. Therefore, it is conservatively considered a "**high**" hazard for the Project.

[12] CDR, 2024. Hydrological Development of the Gelephu Mindfulness City Project, Bhutan. Hydrological Assessment and Management Principles for Masterplan Area. Pp. 62

FIGURE C-16 FLOOD RISK MAP BASELINE

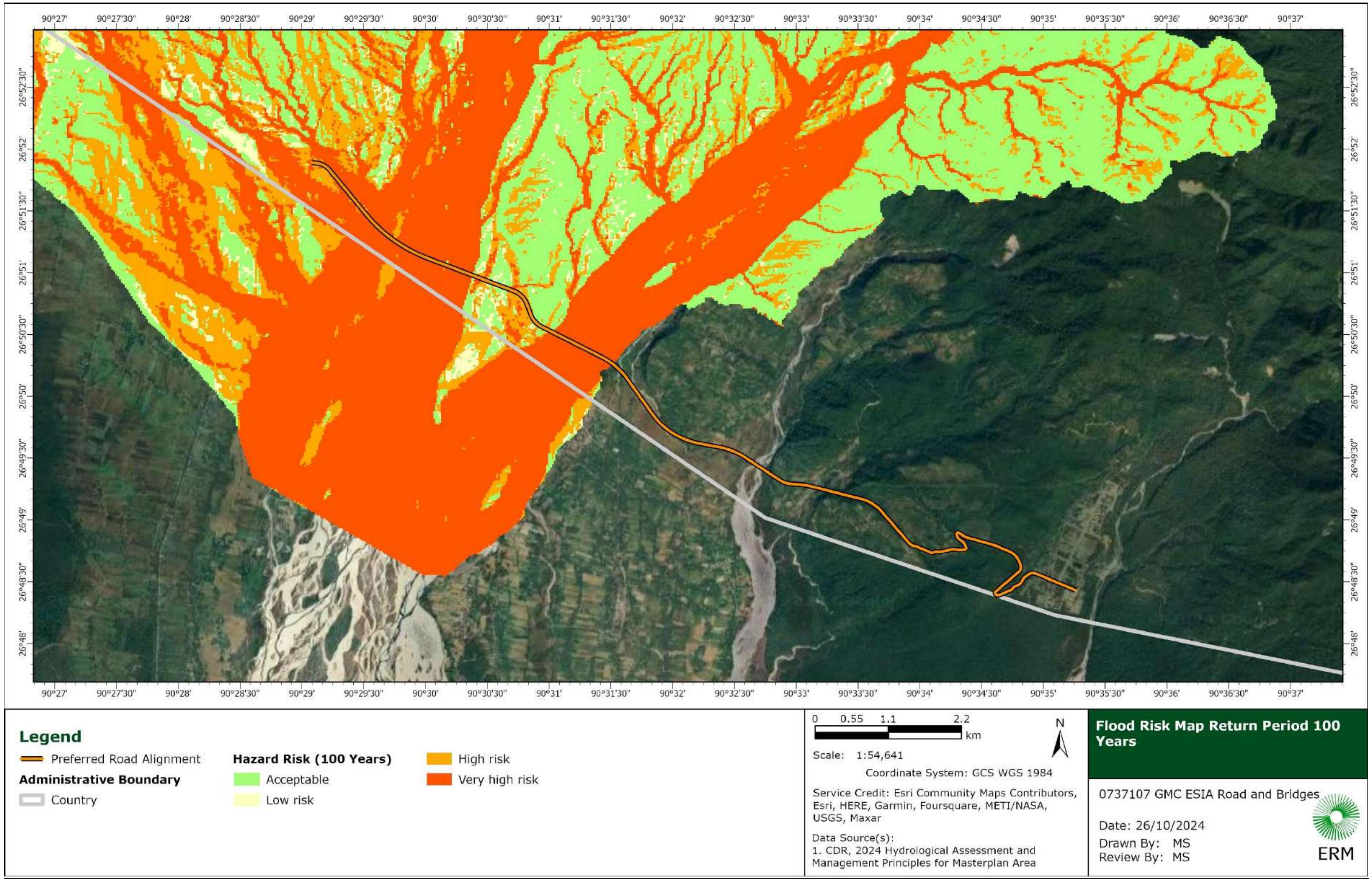


C8.3.2 CLIMATE CHANGE PROJECTIONS

CDR International modeled the risk of flooding with a return period of 100 years. The model took into account future climate change scenario to provide comprehensive results. However, at the time of writing this CCRA, the modelling only included the Mau River and Taklai River. The modeling is currently being expanded to cover the entire length of the Gelephu Tareythang road, but the results are not included in this assessment.

The model identifies areas of high risk in the lowland on the western portion of the road and on the riverbanks of the Mau and Taklai Rivers. Therefore, the hazard of climate change associated with flooding is considered “**high**”.

FIGURE C-17 FLOOD RISK MAP RETURN PERIOD 100 YEARS



C8.3.3 EXPOSURE AND VULNERABILITY

The road and bridges will be located in areas prone to flooding. The bridges will be particularly exposed to the high flow of the rivers during the wet season.

Floodwaters can erode bridge supports by washing away protective soil and destabilizing pylons, leading to weakened structural integrity and potential collapse.

For roadways, intense flooding can penetrate and undermine foundations, causing asphalt and concrete layers to crack, buckle, or wash away entirely, rendering the surfaces impassable and dangerous. Additionally, fast-moving floodwaters can strip away protective embankments and side slopes, creating further erosion along the road's edges and destabilizing adjacent land.

Considering the information provided, the Project exposure and vulnerability level is categorized as **"High".**

C8.3.4 RISK ASSESSMENT

The table below shows the summary of risk assessment.

TABLE C-5 QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR FLOOD

	Baseline	**RCP 8.5 - 2030**	**RCP 8.5 - 2050**
Hazard Level	**High**	**High**	**High**
Exposure x Vulnerability Level	**High**	**High**	**High**
Risk Level	**High**	**High**	**High**
Implications for the Project	• Floodwaters can erode bridge supports, weaken road foundations, and wash away pavement, creating hazardous conditions for the users and requiring additional budget for maintenance operations		
Key Potential Impacts	• Structural damage for both road and bridges weakening structural integrity and, in the worst case, resulting in the collapse of the bridge structure • Surface erosion generating cracks in the pavement of the road • Floods can erode embankments, slopes, and shoulders, making roads vulnerable to further collapse and reducing road stability • Isolation of communities • Economic losses associated to reparation cost and disruption on local supply chain		

<table>
<tr><th></th><th>Baseline</th><th>RCP 8.5 - 2030</th><th>RCP 8.5 - 2050</th></tr>
<tr><td>Implemented Mitigations</td><td colspan="3">• Complete the flood modelling for the entire length of the Gelephu Tareythang road
• Coordinate with the design of upstream infrastructure associated to the Gelephu Mindfulness City to integrate water retention structures that would reduce the flow and risk of flooding along the road
• Integrate the results on the full model to the detailed engineering design of the road and bridges and include at least the risk associated with a 100 year return period, taking into consideration the effects of climate change
• Design facilities and infrastructure (e.g., bridges, accommodation) to withstand flooding, including but not limited to the following measures:
o Avoid placement of any vulnerable infrastructure (e.g. electrical installations) within natural drainage channels and floodplains and ensure that the finished floor levels of buildings are above modelled flood zones;
o Debris protection will be provided at the base of the piers in the river crossings to protect the piers from impacts. Scour protection will also be provided in the form of boulders surrounding the base of the foundation;
o To control erosion on the riverbanks and limit the extent of flooding, gabion basket walls are proposed upstream and downstream of the highway at the bridges crossing the Mau River, Jengkhurung and Taklai Rivers, and the Langer River; and
o Box culverts will be introduced perpendicular to the highway at regular intervals along the embankment section to allow potential flood water to flow underneath the highway preventing flooding of the highway.
• Prepare an Emergency Preparedness and Response Plan describing in detail the procedures the Contractor will put in place in the event of a flood. This plan, which will be prepared by the Contractor, will describe emergency procedures and communication protocols for alerting local villages and construction workers of any emergency conditions.</td></tr>
</table>

C8.4 LANDSLIDES

As per the United States Geological Survey (USGS), a landslide is defined as the movement of a mass of rock, debris, or earth down a slope. Several factors are responsible for occurrence of landslides. Some of these are poor mechanical stability, heavy rainfall events, geological formation, earthquake, vibration (mechanical) and slope, and could be influenced largely by human activities at a local level. Some of the human activities which are likely to cause or aggravate landslides are deforestation, cultivation, construction, vibration from heavy machinery and traffic, blasting and mining activities, and large and unstable earthwork/ excavation.

Landslides can cause wide stream damage such as disruption of infrastructure in form of roads and highways, damage to structures/buildings, power transmission lines and burial or damage of settlements resulting in loss of life.

C8.4.1 BASELINE HAZARD

CDR International conducted a comprehensive study on the hydrologic and river systems for the Gelephu Mindfulness City Project.[13] Such study included a preliminary estimate of the landslide hazard in Sarpang region.

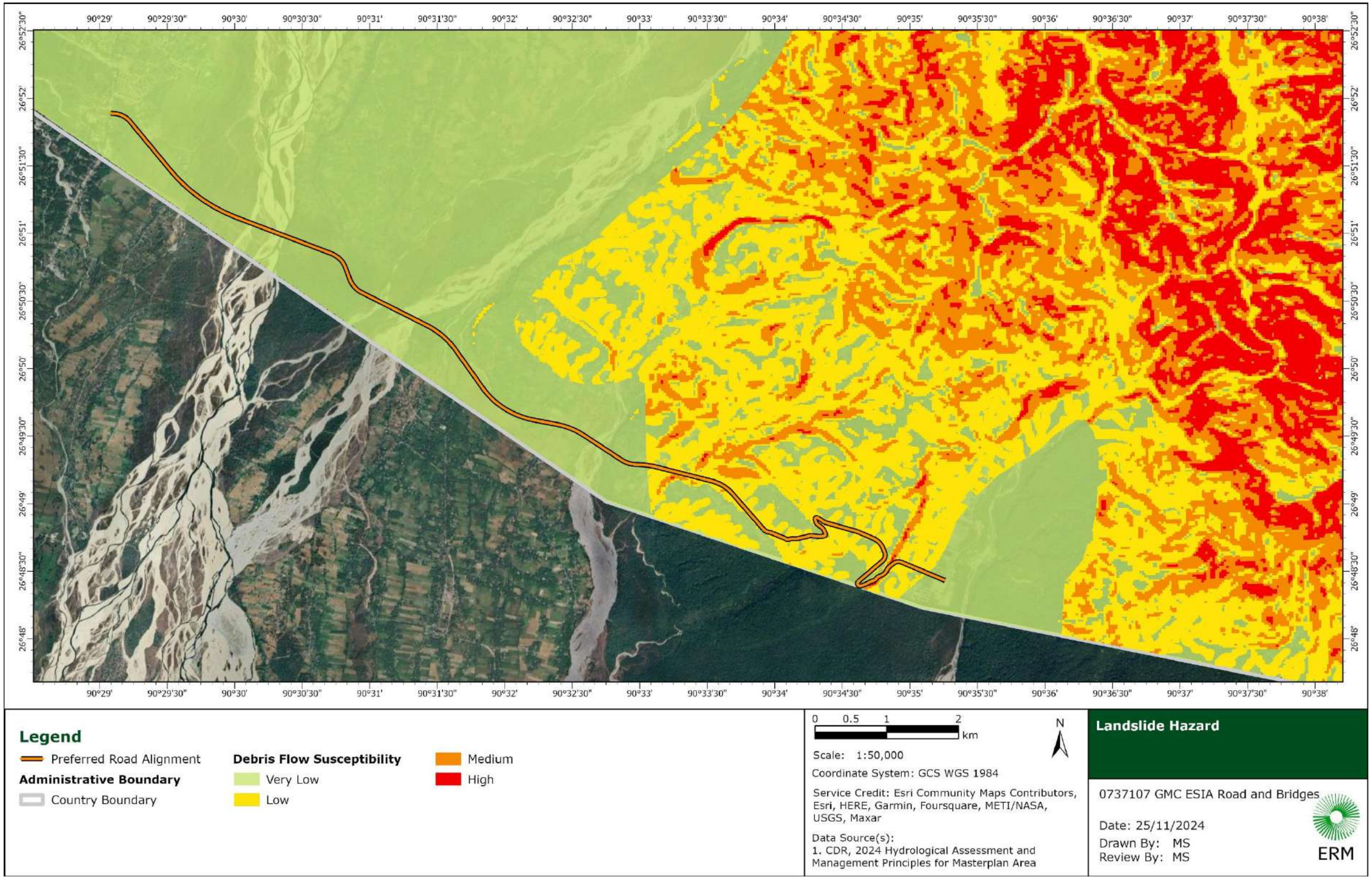
Although Gelephu town is situated on a relatively flat alluvial plain, the section of the road extending toward Tareythang traverses a more undulating and sloped terrain. This variation in topography introduces differing environmental conditions along the route, potentially increasing susceptibility to erosion, landslides, and drainage challenges in the sloped areas.

Almost the entire area overlapping with the proposed road alignment is classified as very low to low risk, with the exception of the last 500 m of the road that is descending to Tareythang, which is classified as medium to high.

The overall risk is conservatively assumed as "Medium" with particular reference to the 500 m of road close to Tareythang.

[13] CDR, 2024. Hydrological Development of the Gelephu Mindfulness City Project, Bhutan. Hydrological Assessment and Management Principles for Masterplan Area. Pp. 62

FIGURE C-18 BASELINE LANDSLIDE HAZARD



C8.4.2 CLIMATE CHANGE PROJECTIONS

The likelihood of landslides can be monitored by tracking rainfall patterns. Heavier rainfall events can increase the risk of landslides.

Considering the results of the CDR International study[14], the future climate scenario show potential increase of high rainfall intensity events, leading to higher risk of precipitation-induced landslides.

However, the morphology of the majority of the area crossed by the road is a relatively flat alluvial plain.

Similarly for the baseline risk evaluation, the overall risk is conservatively assumed as "**Medium**" with particular reference to the 500 m of road close to Tareythang.

C8.4.3 EXPOSURE AND VULNERABILITY

The Project is potentially susceptible to landslides, which could lead to impacts, including interruptions to traffic flow and accessibility along the route. In more extreme instances, landslides could inflict structural damage on the road infrastructure, requiring repairs and potentially compromising the safety and functionality of the corridor.

However, due to the area's topography, only the 500-meter segment of road near Tareythang is at risk.

Considering the factors mentioned above, the level of exposure and vulnerability is assigned as **"Low"**.

C8.4.4 RISK ASSESSMENT

The table below shows the summary of risk assessment.

TABLE C-6 QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR LANDSLIDES

	Baseline	**RCP 8.5 - 2030**	**RCP 8.5 - 2050**
Hazard Level	**Medium**	**Medium**	**Medium**
Exposure x Vulnerab. Level	**Low**	**Low**	**Low**
Risk Level	**Low**	**Low**	**Low**
Implications for the Project	• Potential interruptions to traffic flow and accessibility along the route. In more extreme instances, landslides could inflict structural damage on the road infrastructure, requiring repairs and potentially compromising the safety and functionality of the corridor.		
Key Potential Impacts	• Pavement damage or, in extreme cases, structural damage for road • Isolation of communities • Economic losses associated to reparation cost and disruption on local supply chain		

[14] CDR, 2024. Hydrological Development of the Gelephu Mindfulness City Project, Bhutan. Hydrological Assessment and Management Principles for Masterplan Area. Pp. 62

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
Implemented Mitigations	• Integrate slope stabilization structures (e.g. retaining walls, gravity walls, etc.) in the detailed design of the road • Reduce soil erosion by maintaining existing vegetation or revegetating ground movement areas through geotextiles or similar techniques along the 500 m road segment near Tareythang • Ensure correct drainage of rain and groundwater to avoid building up pressure on soil structure • Stabilize the slope by including supporting structures (e.g. retaining walls, gravity walls, etc.) or by stabilizing the soil structure • Regular inspection to identify potential structure failure (e.g. cracking, soil movements, water breaks from ground surface, etc.)The Project Contractor and Operator will develop and implement an Emergency Preparedness and Response Plan, which will include measures specifically for landslides. This plan will include at a minimum the following key mitigation measures: o Closely monitor slope stability, especially those slopes most susceptible to landslides and where construction activity is occurring directly above a settlement or populated area. The construction contractor will include a slope stability monitoring strategy as part of the Response Plan to detect movement of overburden material, which could serve as an early warning of a potential landslide; o Avoidance of landslide prone areas in siting and design; and o Minimize disturbance of steep slopes by careful selection and siting of the Project.		

C8.5 EXTREME HEAT

Extreme heat is defined based on the maximum extreme heat hazard level for the selected area. Hazard level reflects expected frequency of extreme heat conditions, using simulations of long-term variations in temperature and expert guidance. Extreme heat is assessed using a widely accepted heat stress indicator, the Wet Bulb Globe Temperature (°C)[15]. The WetBulb Globe Temperature (WBGT) is a measure of the heat stress in direct sunlight, which takes into account: temperature, humidity, wind speed, sun angle and cloud cover (solar radiation). It differs from the heat index, which takes into consideration temperature and humidity and is calculated for shaded areas. The WBGT has an obvious relevance for human health, but it is relevant in all kinds of Projects and sectors, including infrastructure related, as heat stress affects personnel and stakeholders, and therefore the design of buildings and infrastructure. In general, the WBGT is a relevant enough proxy to quantify the strain on physical infrastructure (energy, water, transport), such as increased demands for water and electricity, which may also affect decisions related to infrastructure.

C8.5.1 BASELINE HAZARD

The hazard of extreme heat was assessed regionally using the Global extreme heat hazard 20 Year Return Period from Global Facility for Disaster Reduction and Recovery (GFDRR). Extreme Heat hazard is classified based on the daily maximum Wet Bulb Globe Temperature (WBGT, °C). The ***Figure C-19*** is showing daily maximum WGBT ranging between 32°C to 34°C at the Project.

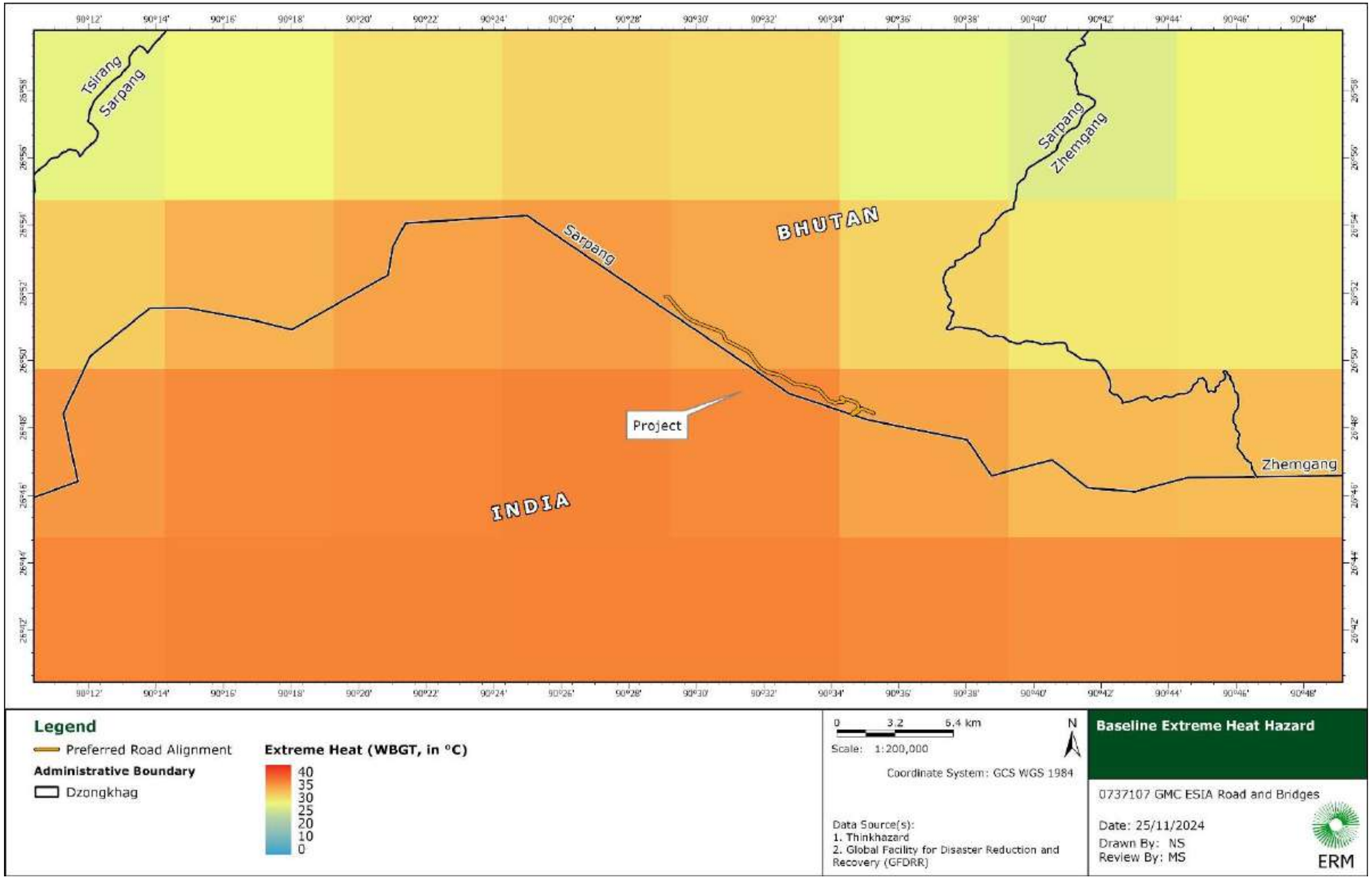
[15] ThinkHazard. 2020. Sumba Timur: https://thinkhazard.org/en/report/18158-indonesia-nusatenggara-timur-sumba-timur/EH

Furthermore, data collected from the Gelephu airport, Sarpang, and Chhuzanggang meteorological stations between 1996 and 2024 indicate that the highest temperatures occur in summer. The average maximum temperature for both Sarpang and Chhuzanggang stations is reported to be 32°C during this period[16].

The classification is based on hazard categorization, the extreme heat hazard is categorized as **"High"**.

[16] Basis of Design of Bhutan Gelephu Airport, NACO. 2024.

FIGURE C-19 AVERAGE MAXIMUM SURFACE AIR TEMPERATURE 1991-2020



Source: Climate Change Knowledge Portal. Available at https://climateknowledgeportal.worldbank.org/country/bhutan/climate-data-historical. Accessed on 09 October 2024

C8.5.2 CLIMATE CHANGE PROJECTIONS

Climate change projections indicate an increase in maximum temperature and warm spell duration. The temperature projection was obtained from the IPCC WGI Interactive Atlas that provide the climate change data from the IPCC's Sixth Assessment Report (AR6). These reports detail anticipated alterations in climate impact drivers (CIDs), including temperature, snow melt, and wind patterns, which are attributable to future GHG emissions.

Based on the CMIP6 model, using baseline data during 1995 – 2014, the maximum of maximum temperatures changes in degree Celsius was evaluated for Ganges-Brahmaputra River basin.

TABLE C-7 CMIP6 - MAXIMUM OF MAXIMUM TEMPERATURES (TXX) CHANGE DEG C - NEAR TERM (2021-2040) SSP5-8.5 (REL. TO 1850-1900) - GANGES-BRAHMAPUTRA

Period	Scenario	Median	P25	P75	P10	P90	P5	P95
Near Term (2021-2040)	SSP5-8.5	1.2	0.7	1.7	0.1	2.2	0	2.4
Medium Term (2041-2060)	SSP5-8.5	2.2	1.6	2.9	1.3	3.4	1.1	3.8
Long Term (2081-2100)	SSP5-8.5	5.1	4.2	6.3	3.4	7.1	3.3	7.5

Source: IPCC WGI Interactive Atlas

Table C-7 shows the projected global average temperature increase under a high greenhouse gas emissions scenario (SSP5-8.5) for different time periods. In the near-term outlook (2021~2040), the median temperature increase is projected to be 1.2°C, with a 50% chance that it will be between 0.7°C and 1.7°C. There is a 95% chance that the increase will be between 0°C and 2.4°C.

For the medium-term outlook (2041~2060), the median temperature increase is projected to be 2.2°C, with a 50% chance that it will be between 1.6°C and 2.9°C. There is a 95% chance that the increase will be between 1.1°C and 3.8°C.

Based on the information above and considering the baseline extreme heat temperature and the projected temperature increase the extreme heat is considered to be **"High"** under future climate change scenarios.

C8.5.3 EXPOSURE AND VULNERABILITY

Roads take in a large amount of solar heat throughout the day, causing their surface temperatures to rise significantly. Based on the information found, asphalt may begin to soften when the temperature surpasses 48 degrees Celsius[17].

[17] Texas Roads Could Melt as Potentially Record-Breaking Heat Wave Hits. May 03, 2024. Access via https://www.newsweek.com/texas-roads-could-melt-potentially-record-breaking-heat-wave-1897050

Hence, roads are vulnerable to heat because thermal expansion can lead to cracks, potholes, or uneven surfaces, which reduces their lifespan and increases maintenance costs.

Considering the information provided, the Project's exposure and vulnerability level is categorized as **"Medium".**

C8.5.4 RISK ASSESSMENT

The table below shows the summary of risk assessment.

TABLE C-8 QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR EXTREME HEAT

	Baseline	**RCP 8.5 - 2030**	**RCP 8.5 - 2050**
Hazard Level	**High**	**High**	**High**
Exposure x Vulnerability Level	**Medium**	**Medium**	**Medium**
Risk Level	**Medium**	**Medium**	**Medium**
Implications for the Project	Thermal expansion leads to the formation of cracks and potholes, while the deterioration of materials shortens the lifespan of the road and raises maintenance expenses. Heat-resistant materials or asphalt mixes can help roads withstand higher temperatures and prevent premature damage.		
Key Potential Impacts	• Reduces the overall lifespan of roads • High temperatures cause cracks and potholes or uneven surfaces • Workers are at risk of heat exhaustion during maintenance.		
Implemented Mitigations	• Schedule heavy labor work during cooler parts of the day • Set up cooling areas and provide heat protection for worker.		

C8.6 CYCLONE AND HURRICANE

As per the American Meteorological Society, a cyclone or hurricane is a large-scale air mass that rotates around a strong centre of low atmospheric pressure. Tropical cyclones are formed over oceans due to conducive and coinciding conditions such as warm sea surface temperatures, atmospheric instability, high humidity in the lower and middle levels of troposphere, Coriolis force to develop low pressure centre and low vertical wind shear. Cyclones bring high wind speeds and heavy downpour with them, which are likely to cause disruption to infrastructure, structures, flooding and other damage to buildings and natural environment.

For this assessment, cyclone hazard at the airport boundary was evaluated based on cyclone intensity United Nations Environment Programme (UNEP) Global Data Platform, cyclone frequency data from Socioeconomic Data and Applications Center (SEDAC), and historical hurricane tracks data from National Oceanic and Atmospheric Administration (NOAA).

C8.6.1 BASELINE HAZARD

The cyclonic storms are generally classified into five (5) categories based on Saffir-Simpson categorization of hurricanes as summarized in ***Table C-9***.

Figure C-20 presents the historical hurricane track maps within 100 km radius from the project. A review of historical tracks captured by NOAA since 1842 indicates 1 tropical depression have passed within 100 km radial distance with the maximum wind speed of 55.56 km/h (30 knots) as presented in ***Figure C-21***.

Moreover, historical cyclone data from National Center for Hydrology and Meteorology of Royal Government of Bhutan reports that Bhutan was affected from cyclone Remal in 2024[18]. However, by the time the storm approached Bhutan, it had weakened to a tropical depression which caused only heavy rainfall.

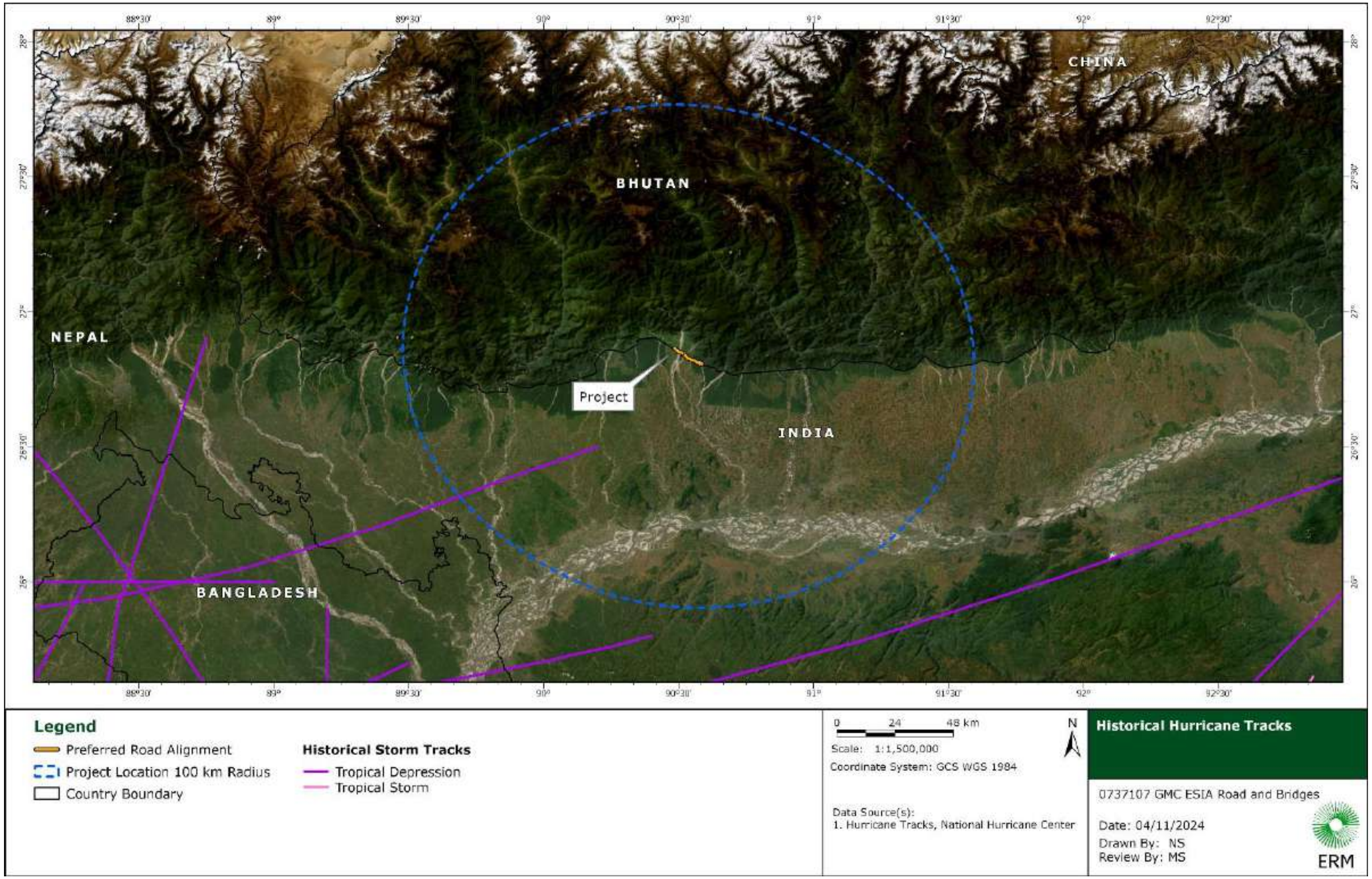
Based on these maps, cyclone hazard was evaluated as **"Low"**.

TABLE C-9 SAFFIR-SIMPSON CATEGORIZATION OF CYCLONE/HURRICANE

Hurricane Category	**Wind Speed Criteria (km/h)**
Tropical Storm	<119
Category 1	119-153
Category 2	154-177
Category 3	178-208
Category 4	209-251
Category 5	>251

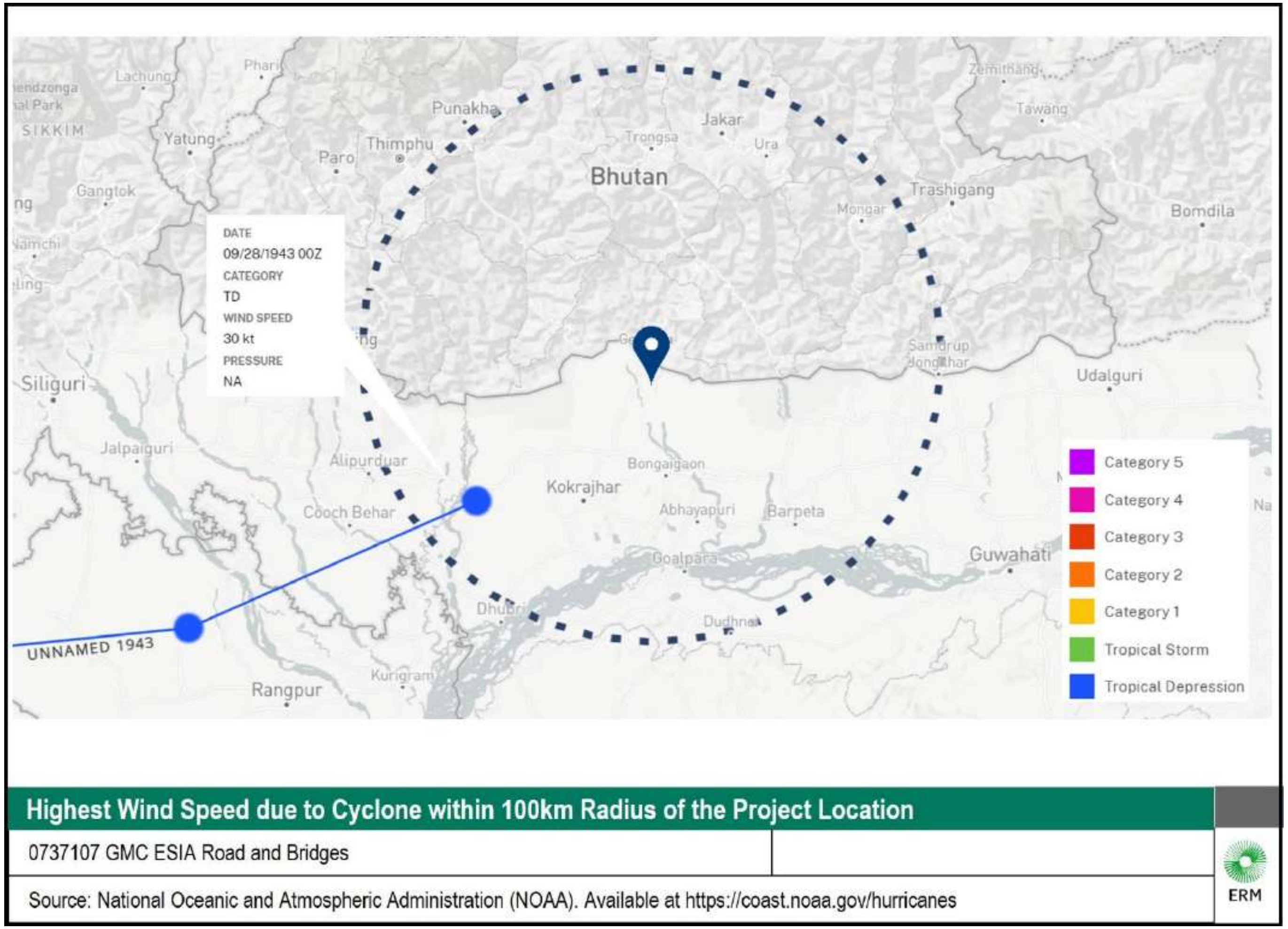
[18] Weather Advisory on Heavy Rainfall from Hydrology and Meteorology of Royal Government of Bhutan 7 July 2024. Via https://www.nchm.gov.bt/home/homeview/1

FIGURE C-20 HISTORICAL HURRICANE TRACKS MAP



Source: International Best Track Archive for Climate Stewardship (IBTrACS) from NOAA. Available at: Index of /data/international-best-track-archive-for-climate-stewardship-ibtracs/v04r00/access/shapefile (noaa.gov)

FIGURE C-21 HIGHEST WIND SPEED DUE TO CYCLONE WITHIN 100KM RADIUS OF THE PROJECT LOCATION



Source: Source: National Oceanic and Atmospheric Administration (NOAA). Available at https://coast.noaa.gov/hurricanes

C8.6.2 CLIMATE CHANGE PROJECTIONS

Tropical cyclones or Typhoons occur in most of the tropical oceans and present significant threat to coastal communities and infrastructure. Every year about 90 cyclones or Typhoons are reported to occur globally. Further, this number is reported to remained pretty constant since the period of geostationary satellites (1970s). However, changes in inter-annual and multi-decadal frequency within individual ocean basin are reported to be substantial.

Literature review indicated the detection of trends in cyclone or typhoons occurrences (frequency and intensity) is a challenge due to: i) Changes in observation technology, ii) variations in protocol for identification of cyclones or Typhoons in different ocean basins, iii) limited availability of homogeneous data (30-40 years).

Global reanalysis of tropical cyclone or typhoons intensity using homogenous satellite data indicated increasing trend in intensity of cyclones, with a suggestive link between cyclone or typhoons intensity and climate change. However, these observations based on 30 years' period are reported to be insufficient to conclusively provide the evidence for long term trend.

Climate change studies suggested likely increase in peak wind intensity and near storm precipitation in future tropical cyclones and decrease in overall frequency of cyclones.

Furthermore, a review of literature on the Bay of Bengal's tropical cyclones found that while the overall number and intensity of Bay of Bengal cyclones may decrease in the coming decades (2020–49), post-monsoon cyclones in the northern part of the bay could potentially become more intense[19].

Based on the fact that due to the Bhutan's location, the country is not directly in the path of cyclones, it is assessed that the future hazard level is **"Low"** for all future climate scenarios.

C8.6.3 EXPOSURE AND VULNERABILITY

The project is located in Sarpang, Bhutan, a landlocked region in the Himalayas that is generally not directly affected by cyclones or hurricanes.

Considering the information provided, the Project's exposure level is categorized as **"Low".**

C8.6.4 RISK ASSESSMENT

The table below shows the summary of risk assessment.

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[19] Fahad, Abdullah A., Oreste Reale, Andrea Molod, Tahmidul Azom Sany, Md Tashin Ahammad, and Dimitris Menemenlis. "The Role of Tropical Easterly Jet on the Bay of Bengal's Tropical Cyclones: Observed Climatology and Future Projection." Journal of Climate 36, no. 17 (2023): 5825-5840. https://doi.org/10.1175/JCLI-D-22-0804.1. Via https://journals.ametsoc.org/view/journals/clim/36/17/JCLI-D-22-0804.1.xml

TABLE C-10 QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR CYCLONE AND HURRICANE

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
Hazard Level	**Low**	**Low**	**Low**
Exposure x Vulnerab. Level	**Low**	**Low**	**Low**
Risk Level	**Low**	**Low**	**Low**
Implications for the Project	The implication for the project is minimal in terms of storm-related risks since the project is not locate in the prone area of cyclone and hurricane.		
Key Potential Impacts	• Safety of the worker during maintenance operations.		
Implemented Mitigations	• Implement safety procedures during severe weather. • Monitor real-time weather conditions to be prepared for potential severe weather events.		

C8.7 WIND SPEED

Winds are defined as large scale movement of gases in the earth's atmosphere. These are typically caused by differences in atmospheric pressure on earth surface and atmosphere. Depending upon the pressure gradient, winds of various speeds are propagated. Although winds are felt at a local scale, these are largely influenced by complex process at a regional and global scale.

Winds of high speed are likely to cause damage to natural and built environment, the extent of which depends upon magnitude of their velocity and pressure differential. High winds can cause damage to high rise structures, swaying of bridges or other structures, also leading to collapse, uprooting of trees, propagation of dust, migration of air borne contamination, spreading of wildfires, etc.

For the purpose of this assessment, average wind speed data from Global Wind Atlas 2.0, a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU) in partnership with the World Bank Group, was utilized. Additionally, wind speed study in the EIA conducted by E&A (November 2020) will be reviewed. The basic wind speed corresponds to maximum wind speed on a 100-year return period[20].

C8.7.1 BASELINE HAZARD

However, the average wind speed at the project was reported less than 2.8 m/s at 10 m height as presented in ***Figure C-22.*** Based on average and hourly wind speed data, the baseline hazard due to average wind speed for the area is considered to be 'Low'.

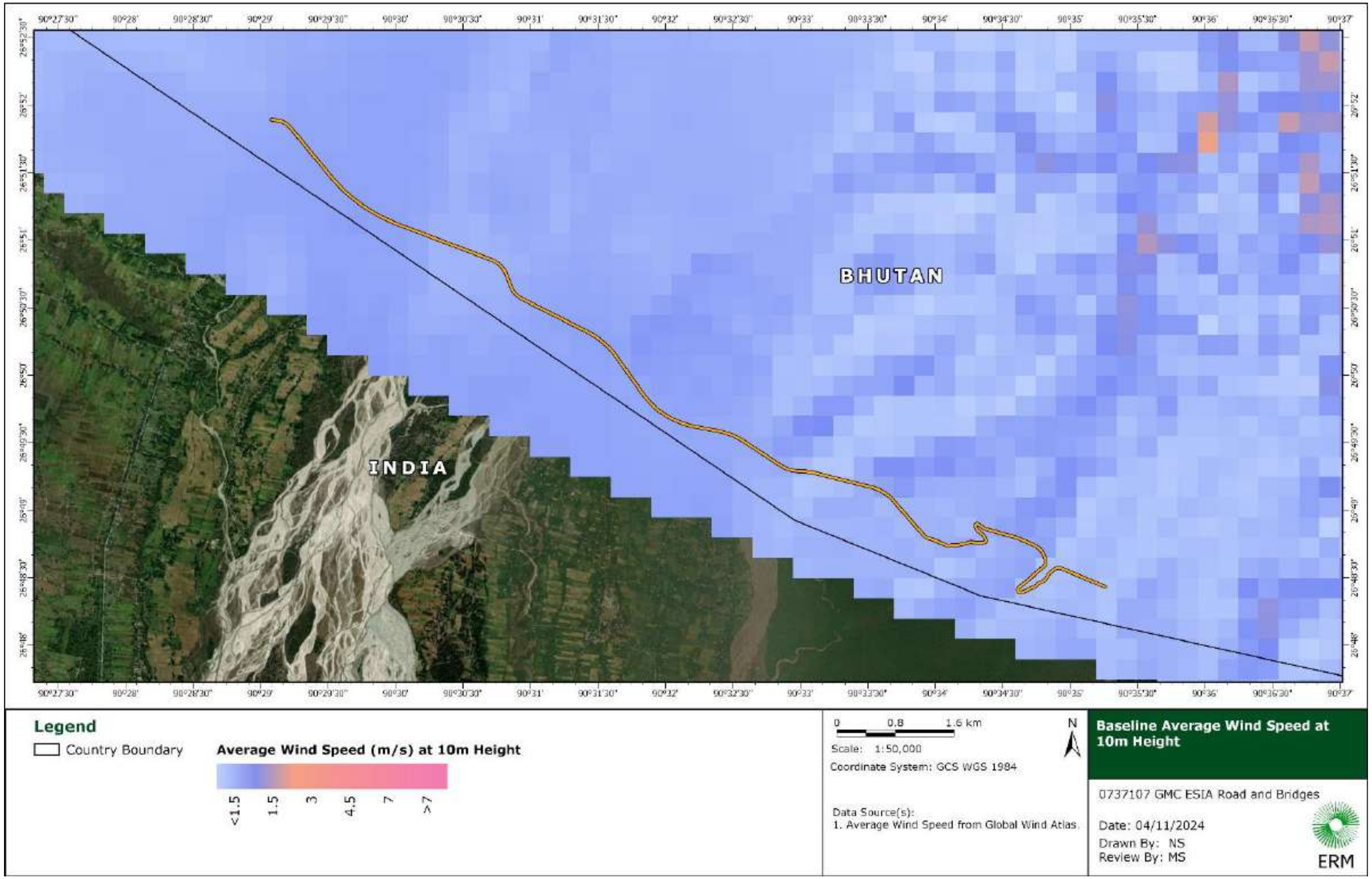
Based on the report of Basis of Design of Bhutan Gelephu Airport by NACO, wind speed data was collected from the meteorological station including Chhuzanggang station which

[20] Hahm, J.H., Jeong, H.Y, Kwak, K.H., 2019. Estimation of Strong Wind Distribution on the Korean Peninsula for Various Recurrence Periods: Significance of Nontyphoon Conditions. Advances in Meteorology, Article ID 8063169 https://doi.org/10.1155/2019/8063169

away from the project approximately 2 kilometers. The study report that the wind speed does not exceed 10 knots for all the measurements.

Therefore, the risk associated with the maximum wind speed is considered **"Low"**.

FIGURE C-22 BASELINE AVERAGE WIND SPEED MAP



Source: Global Wind Atlas. Available at https://globalwindatlas.info/en

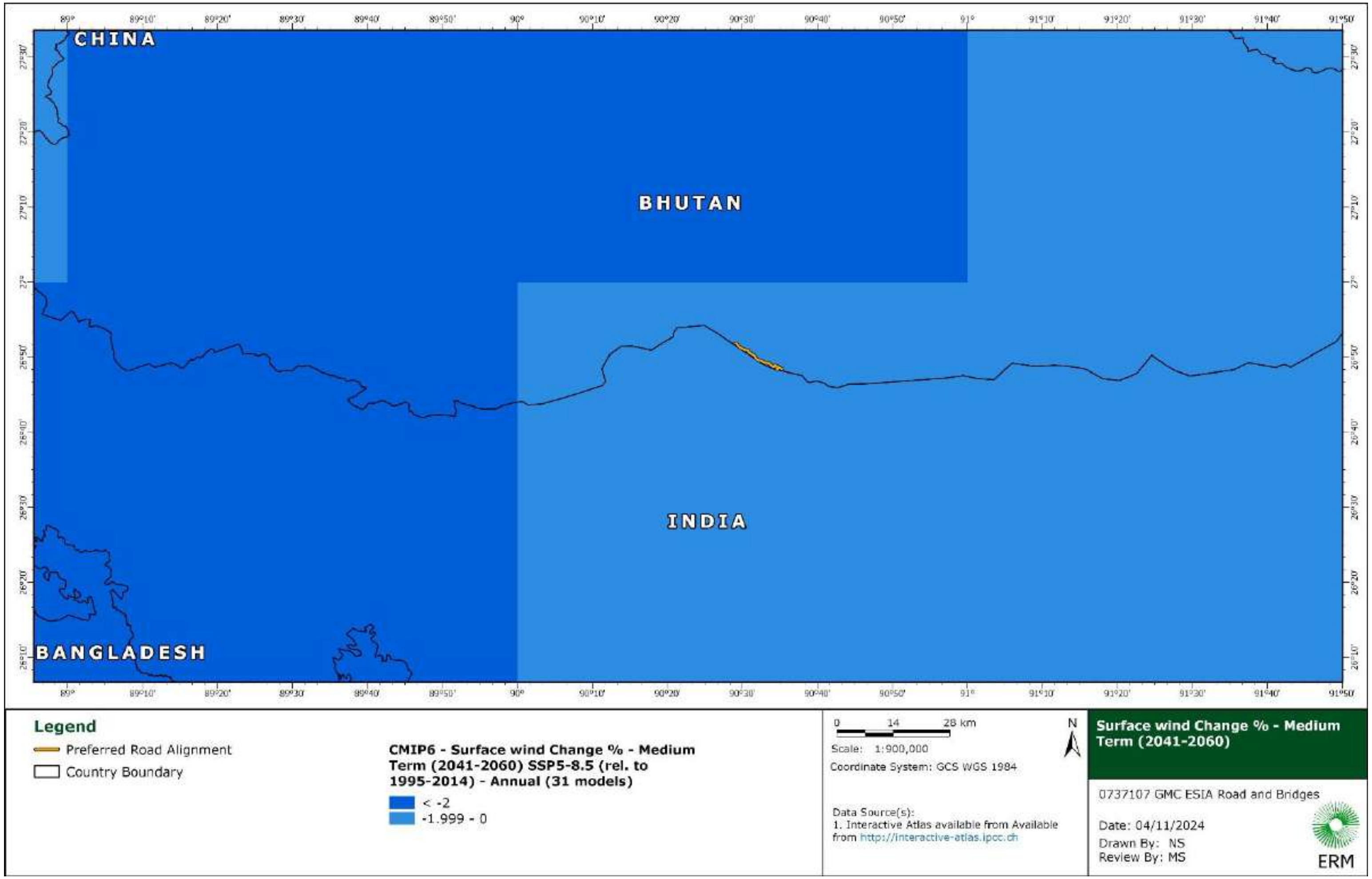
C8.7.2 CLIMATE CHANGE PROJECTIONS

The climate models for wind speed indicate a high degree of uncertainty with models projecting increase, decrease, or no change in the future. However, a recent study from the IPCC has modeled the future projection of surface wind across the globe[21]. According to the IPCC interactive atlas, the Ganges-Brahmaputra basin may be subject to a decrease of surface wind speed approximately -1.75% as shown in ***Figure C-23***. This dedicates that the surface wind speed remains almost the same in the future.

Considering the limited information available, the wind hazard under a climate change scenario is considered to be **"Low"**.

[21] Gutiérrez, J.M., R.G. Jones, G.T. Narisma, L.M. Alves, M. Amjad, I.V. Gorodetskaya, M. Grose, N.A.B. Klutse, S. Krakovska, J. Li, D. Martínez-Castro, L.O. Mearns, S.H. Mernild, T. Ngo-Duc, B. van den Hurk, and J.-H. Yoon, 2021: Atlas. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L.Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K.Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press. Interactive Atlas available from Available from http://interactive-atlas.ipcc.ch/

FIGURE C-23 SURFACE WIND CHANGE % - MEDIUM TERM (2041-2060)



Source: IPCC WGI Interactive Atlas. Available at: https://interactive-atlas.ipcc.ch/

C8.7.3 EXPOSURE AND VULNERABILITY

Generally, road projects are not highly exposed or vulnerable to wind speed. However, extreme wind events can impact construction activities, increasing risks for workers and equipment, and potentially delaying progress.

However, considering that the Project is located in a low risk of extreme wind hazard, the Project's exposure level is categorized as **"Low"** based on the given information above.

C87.4 RISK ASSESSMENT

The table below shows the summary of risk assessment.

TABLE C-11 QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR WIND HAZARD

	Baseline	**RCP 8.5 - 2030**	**RCP 8.5 - 2050**
Hazard Level Average Wind Speed	**Low**	**Low**	**Low**
Hazard Level Maximum Wind Speed	**Low**	**Low**	**Low**
Exposure x Vulnerability Level	**Low**	**Low**	**Low**
Risk Level	**Low**	**Low**	**Low**
Implications for the Project	The construction of roads typically takes place in open or elevated areas. The risks to workers and equipment can be caused by high wind speeds, which can affect construction activities. Due to low extreme wind speed risk, the project is not expected to be at risk.		
Key Potential Impacts	• Not applicable.		
Implemented Mitigations	• Not required		

C8.8 SEA LEVEL RISE

Sea level rise is the phenomenon of increasing or rise in the sea surface elevation. The two (2) main reasons attributed to this phenomenon are 1) the added water from melting ice sheets and glaciers and 2) the thermal expansion of seawater as it warms-up. This is primarily due to global warming, resulting in accelerated melting of glaciers and snow. Impacts of sea level rise may further intensify or reduce due to vertical land movement. Current and future sea level rise is set to have a number of impacts, particularly on coastal systems. Such impacts include increased coastal erosion, higher storm-surge flooding, inhibition of primary production processes, more extensive coastal inundation, changes in surface water quality and groundwater characteristics, increased loss of land/property and coastal habitats, increased flood risk and potential loss of life/ property, loss of nonmonetary cultural resources and values, impacts on agriculture and aquaculture through decline in soil and water quality, and loss of tourism, recreation, and transportation functions. Some of the most vulnerable entities to sea level rise are habitations along the coastal regions, island nations/states and coastal ecosystems.

C8.8.1 BASELINE HAZARD

No baseline hazard due to sea level (rise) was considered as it is a phenomenon driven by climate change. Therefore, hazard due to sea level rise was only evaluated under climate change scenario.

C8.8.2 CLIMATE CHANGE PROJECTIONS

No implications as located far from areas susceptible to sea level rise. Hence, no change is considered for the sea level rise.

C8.8.3 EXPOSURE AND VULNERABILITY

The project is located in the Sarpang, Bhutan which it is a landlocked area situated high in the Himalayan mountains. With no coastal areas, it is geographically isolated from the direct impacts of rising sea levels, meaning it has **No** vulnerability and exposure from sea level rise.

C8.8.4 RISK ASSESSMENT

The table below shows the summary of risk assessment.

TABLE C-12 QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR SEA LEVEL RISE

	Baseline	**RCP 8.5 - 2030**	**RCP 8.5 - 2050**
Hazard Level	**Not Applicable**	**Not Applicable**	**Not Applicable**
Exposure x Vulnerability Level	**Not Applicable**	**Not Applicable**	**Not Applicable**
Risk Level	**Not Applicable**	**Not Applicable**	**Not Applicable**

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
Implications for the Project	No implications as located far from areas susceptible to sea level rise.		
Key Potential Impacts	• None identified		
Implemented Mitigations	• Not required		

C8.9 LIGHTNING

Lightning is an electrical discharge caused by imbalances between storm clouds and the ground, or within the clouds themselves. Most lightning occurs within the clouds.

During a storm, colliding particles of rain, ice, or snow inside storm clouds increase the imbalance between storm clouds and the ground, and often negatively charge the lower reaches of storm clouds.

Objects on the ground, like steeples, trees, and the Earth itself, become positively charged creating an imbalance that nature seeks to remedy by passing current between the two charges.

Lightning is extremely hot. A flash can heat the air around it to temperatures five times hotter than the sun's surface. This heat causes surrounding air to rapidly expand and vibrate, which creates the pealing thunder that is heard a short time after seeing a lightning flash.

Lightning can cause both destruction of infrastructure and lives. About 2,000 people are killed worldwide by lightning each year. Hundreds more survive strikes but suffer from a variety of lasting symptoms, including memory loss, dizziness, weakness, numbness, and other life-altering ailments[22].

For this assessment, data from the Tropical Rainfall Measuring Mission (TRMM) lightning Imaging Sensor (LIS) was used. TRMM LIS was a space-based lightning sensor aboard the Tropical Rainfall Measuring Mission satellite.

The TRMM LIS instrument recorded the time of occurrence of a lightning event, measured the radiant energy and estimated the location during both day and night conditions with high detection efficiency.

C8.9.1 BASELINE HAZARD

Vaisala's Interactive Global Lightning Density Map is a space-based lightning detection system using Global Lighting Dataset GLD360 which is real-time data from the industry's most accurate global detection network.

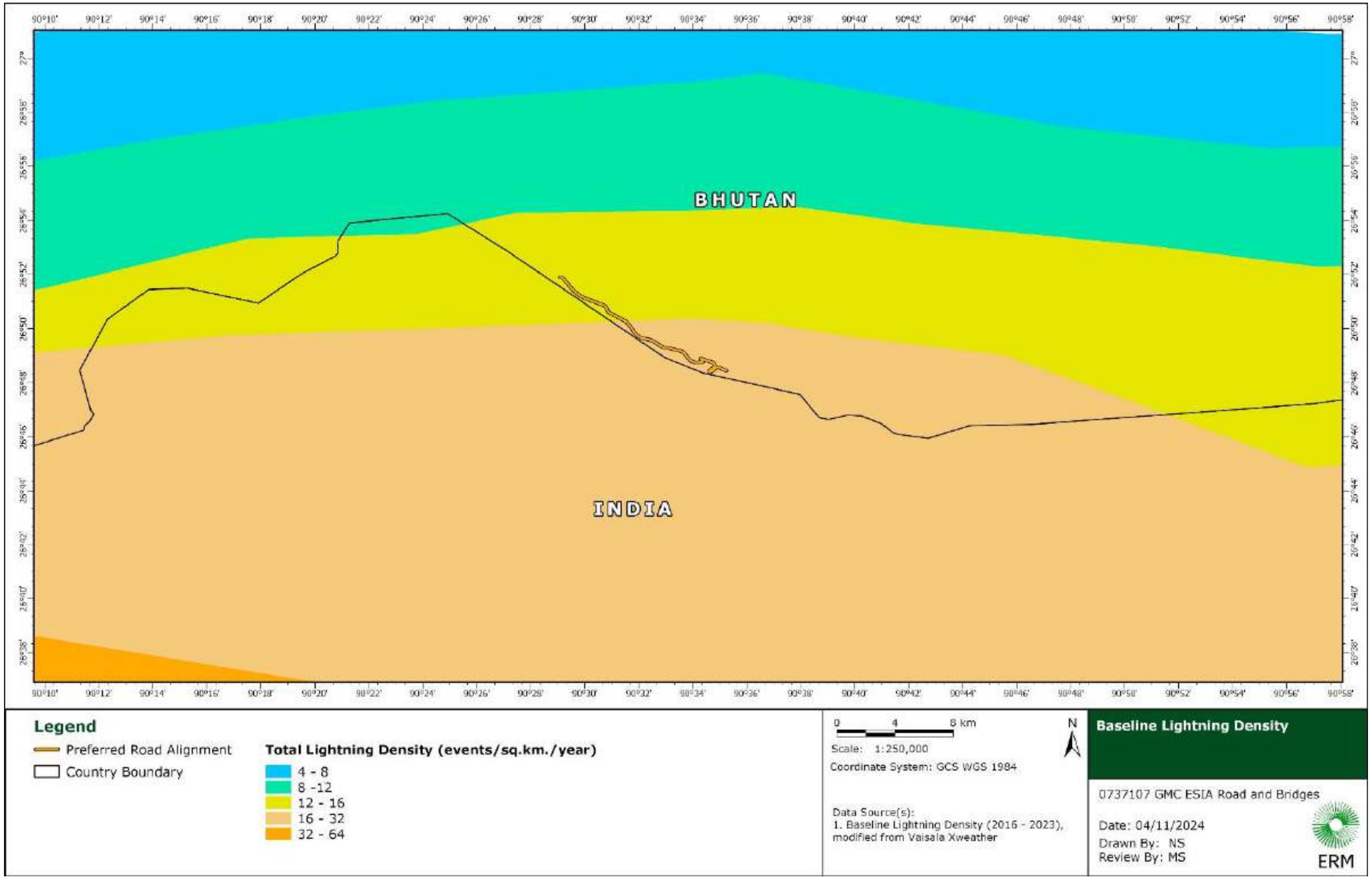
The lightning flash density map presented in ***Figure C-24*** indicates the density of lightning flashes to be 12 - 16 events km-2 year-1 during the period 2016 - 2023 along the road

[22] National Geographic, N.D. https://www.nationalgeographic.com/environment/natural-disasters/lightning/

alignment. Very limited information is available in the public domain regarding the hazard classification of lightning.

However, considering the hazard categorization the hazard in the airport boundary can be assumed as **“Low”**.

FIGURE C-24 BASELINE LIGHTNING DENSITY MAP



Source: Vaisala's Interactive Global Lightning Density Map. Available at:

https://interactive-lightning-map.vaisala.com/?_ga=2.13283636.2075757537.1656405986-847756934.1656405986

C8.9.2 CLIMATE CHANGE PROJECTIONS

There are no direct projections available for lightning. However, as lightning usually occurs during thunderstorms, any changes in occurrences of thunderstorm are considered as measure for changes in lightning in future.

Literature review indicates that predicting changes in thunderstorm directly is difficult task, and hence generally changes in large scale environmental conditions conducive to thunderstorms are used as an indirect measure. One such factor is convective available potential energy (CAPE), which is a measure of maximum kinetic energy obtainable by an air parcel lifted adiabatically from near surface. CAPE is also reported to be important large-scale indicator for the potential lightning.

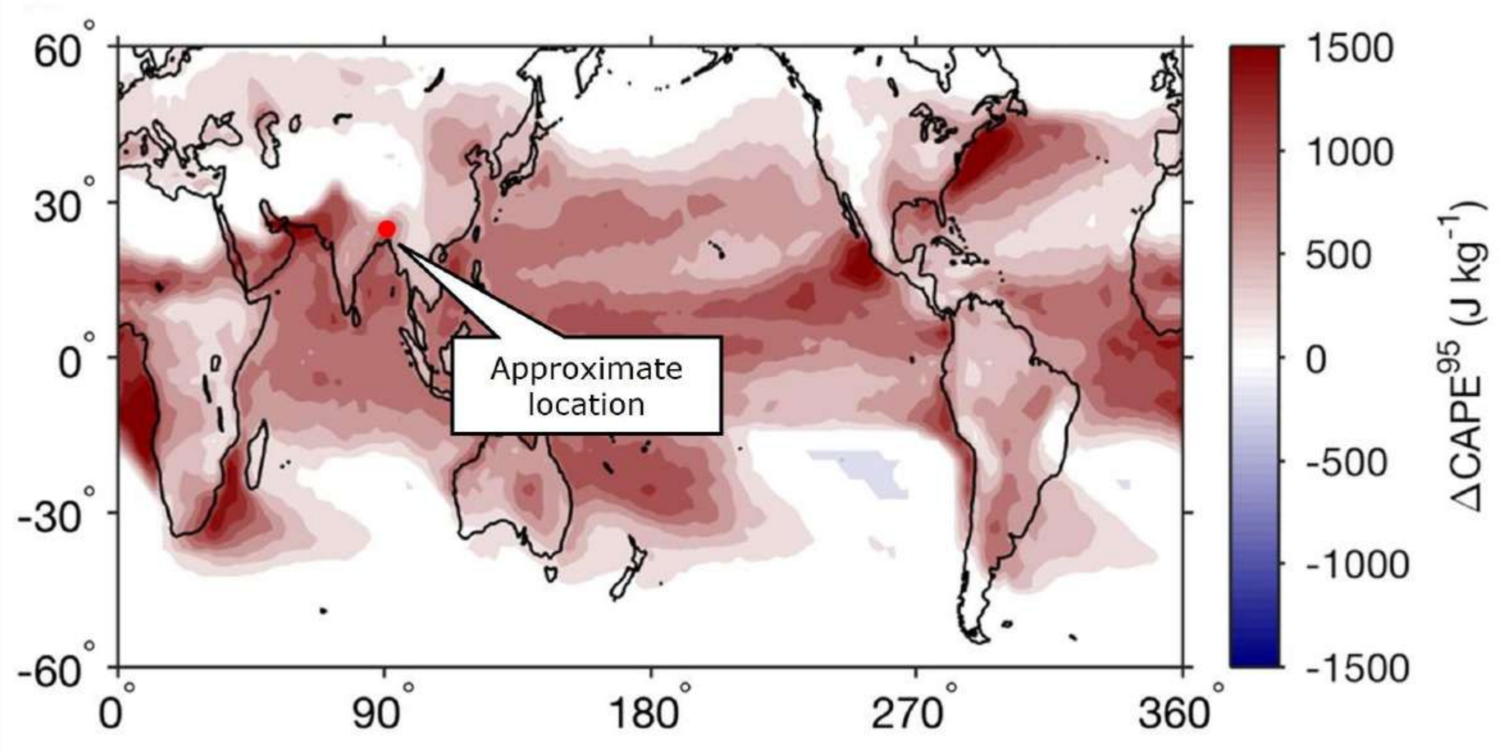
Literature review indicates tropical and subtropical CAPE extremes increasing sharply with warming across ensembles of GCMs participating in CMIP6. In general, the studies indicate an increase in potential for intense thunderstorms in warming atmosphere.

CAPE at Project site is likely to increase by 500 - 1000 J/kg by 2100 for RCP 8.5 scenario as presented in ***Figure C-25***. In general, the studies indicate an increase in potential for intense thunderstorms in a warming atmosphere. ***Figure C-26*** presents the likely increase in a number of days per year with conditions favorable for severe thunderstorm by end of the century. Accordingly, the projected increase in number of days with conditions favorable for formations of thunderstorms is reported to be between 30-40/year by 2100 under RCP 8.5 scenario. Hence, an increase in lightning activity/frequency may be experienced in the future.

It is possible that the probability of lightning events may increase to 42 - 56 events/year, based on the projected increase of thunderstorm day in ***Figure C-26.*** This indicates that the projection risk of lightning hazards is 'Low'.

Considered the worst-case scenario, it is assessed a future risk of lightning to be a **"Low"** hazard level at the Project location.

FIGURE C-25 PROJECTED CHANGE IN CONVECTIVE AVAILABLE POTENTIAL ENERGY (CAPE) BY 2100 UNDER RCP 8.5 SCENARIO



Projected Change in Convective Available Potential Energy (CAPE) by 2100 under RCP 8.5 Scenario

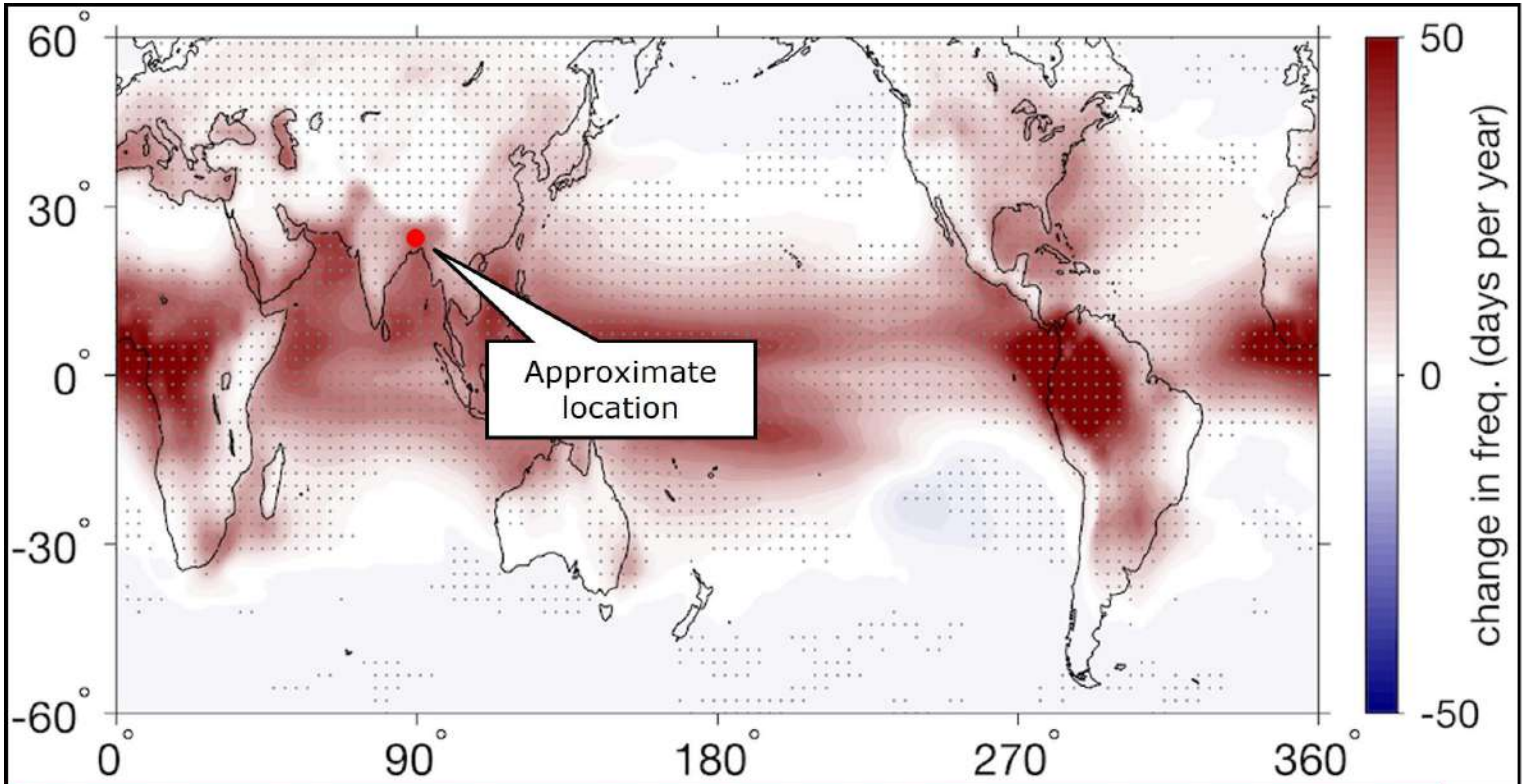
0743906 MQDC Bhutan Ph1 Road Bridge

Source: Singh, M.S., Kuang, Z., Maloney, E.D., Hannah, W.M., Wolding, B.O., 2017. Increasing potential for intense tropical and subtropical thunderstorms under global warming. PNAS 114(44) 11657-11662. Available at: https://www.pnas.org/content/114/44/11657

ERM

Source: Singh, M.S., Kuang, Z., Maloney, E.D., Hannah, W.M., Wolding, B.O., 2017. Increasing potential for intense tropical and subtropical thunderstorms under global warming. PNAS 114(44) 11657-11662. Available at: https://www.pnas.org/content/114/44/11657

FIGURE C-26 PROJECTED CHANGE FOR FREQUENCY OF INTENSE TROPICAL AND SUBTROPICAL THUNDERSTORMS BY 2100 UNDER RCP 8.5 SCENARIO



Projected Change for frequency of intense tropical and subtropical thunderstorms by 2100 under RCP 8.5

0743906 MQDC Bhutan Ph1 Road Bridge

Source: Singh, M.S., Kuang, Z., Maloney, E.D., Hannah, W.M., Wolding, B.O., 2017. Increasing potential for intense tropical and subtropical thunderstorms under global warming. PNAS 114(44) 11657-11662. Available at: https://www.pnas.org/content/114/44/11657

ERM

Source: Singh, M.S., Kuang, Z., Maloney, E.D., Hannah, W.M., Wolding, B.O., 2017. Increasing potential for intense tropical and subtropical thunderstorms under global warming. PNAS 114(44) 11657-11662. Available at: https://www.pnas.org/content/114/44/11657

C8.9.3 EXPOSURE AND VULNERABILITY

The road and bridge structures have limited exposure to lightning, as strikes are more likely to discharge onto taller structures, such as trees and utility poles.

In the unlikely event of a lightning strike directly on the road surface, only minor surface damage is expected. Thunderstorms, however, could pose safety risks to personnel conducting maintenance activities. Fortunately, maintenance operations for this project are infrequent and generally scheduled during dry weather conditions, further minimizing risk exposure to lightning-related hazards.

Hence, the exposure and vulnerability of the Project are considered to be **"Low"**.

C8.9.4 RISK ASSESSMENT

The table below shows the summary of risk assessment.

TABLE C-13 QUALITATIVE RISK LEVEL AND PROJECT IMPLICATIONS FOR LIGHTNING

	Baseline	**RCP 8.5 – 2030**	**RCP 8.5 – 2050**
Hazard Level	**Low**	**Low**	**Low**
Exposure x Vulnerability Level	**Low**	**Low**	**Low**
Risk Level	**Low**	**Low**	**Low**
Implications for the Project	In the unlikely event of a lightning strike directly on the road surface, only minor surface damage is expected.		
Key Potential Impacts	• None identified		
Implemented Mitigations	• Not required		

C8.10 CONCLUSION

The below table summarizes the risk level and mitigation measures identified for the Project.

TABLE C-14 SUMMARY OF RISK LEVEL FOR THE PROJECT

Hazard	Risk Level			Mitigation Measures	Residual Risk Level
		RCP 8.5			
	Baseline	2030	2050		
Water Availability	Low	Low	Low	• If possible, recycle water used for road cleaning to water the roadside greenery.	Low
Flood	High	High	High	• DoST to complete the flood modelling for the entire length of the Gelephu Tareythang road through collaboration with the engineering team • DoST to maintain coordination with the parties responsible for the design of upstream infrastructure associated to the Gelephu Mindfulness City. The coordination will ensure that the water retention structures that are installed within the Gelephy Mindfulness City will reduce the water/debris flow and risk of flooding along the road • Integrate the results on the full model to the detailed engineering design of the road and bridges and include at least the risk associated with a 100 year return period	Low
Landslides	Low	Low	Low	• Integrate slope stabilization structures (e.g. retaining walls, gravity walls, etc.) in the detailed design of the road • Reduce soil erosion by maintaining existing vegetation or revegetating ground movement areas through geotextiles or similar techniques along the 500 m road segment near Tareythang • Ensure correct drainage of rain and groundwater to avoid building up pressure on soil structure • Stabilize the slope by including supporting structures (e.g. retaining walls, gravity walls, etc.) or by stabilizing the soil structure • Regular inspection to identify potential structure failure (e.g. cracking, soil movements, water breaks from ground surface, etc.)	Low
Extreme Heat	Medium	Medium	Medium	• Schedule heavy labor work during cooler parts of the day • Set up cooling areas and provide heat protection for worker.	Low
Cyclone and Hurricane	Low	Low	Low	• Implement safety procedures during severe weather. • Monitor real-time weather conditions to be prepared for potential severe weather events.	Low

Hazard	Risk Level			Mitigation Measures	Residual Risk Level
	Baseline	RCP 8.5			
		2030	2050		
Wind Speed	Low	Low	Low	• Not required	Low
Sea Level Rise	Not Applicable	Not Applicable	Not Applicable	• Not required	Low
Lightning	Low	Low	Low	• Not required	Low

C.9 GHG EMISSION ASSESSMENT METHOD

This section will summarize the greenhouse gas emissions during the construction and operation phases of the project. It includes direct emissions, also known as Scope 1, from sources under operational control, as well as indirect emissions from Scope 2 and Scope 3. Scope 2 refers to emissions resulting from the generation of purchased electricity by the project developer, while Scope 3 covers emissions from other sources.

The greenhouse gas emission assessment results will help project owners better understand the project's impacts and sources of emissions. This provides an opportunity to set a clear direction and reduce emissions early in the design phase, while also considering emissions from alternative options.

The general approach used to evaluate the potential GHG emission effects of the Project was to estimate the GHG emissions from the Project for the phase of activity (i.e., construction and operation) determined to have the highest (i.e. bounding) quantity of GHG emissions. The calculated GHG emissions reported herein are based on **conservative estimates** and may overestimate the actual emissions. GHG reporting requirements should be assessed based on actual annual emission totals and not those reported in this document.

C9.1 SCOPE OF ASSESSMENT

The GHG Protocol establishes an international standard for accounting and reporting GHG emissions. According to the GHG Protocol, GHG emissions are divided into three categories, or scopes:

- Scope 1 emissions: Direct GHG emissions occur from sources that are owned or controlled by the reporting entity.

- Scope 2 emissions: Indirect emissions that accounts for GHG emissions from the generation of purchased energy products (principally electricity, steam/heat) by the reporting entity. For the Project, this includes energy purchased for day-to-day operations at the facility including machinery and equipment.
- Scope 3 emissions: Indirect emissions that are a consequence of the activities of the reporting entity but occurs from sources not owned or controlled by the reporting entity. Examples of Scope 3 activities include extraction and production of purchased materials, transportation of purchased fuels, and use of sold products and services.

In this Project, the calculation of greenhouse gas emissions will focus specifically on the construction and operation phases. During the construction phase, only Scope 1 and Scope 2 emissions will be considered, covering emissions from fuel consumption and electricity use during construction. The Scope 3 emissions during the construction phase are not included in this GHG assessment. However, calculating Scope 3 emissions for the construction phase is something we will consider studying in the future, as it would provide a more accurate and comprehensive picture of the overall greenhouse gas emissions. For the operation phase, only Scope 3 emissions will be calculated, which include other types of greenhouse gas emissions, such as those from vehicle use on roads during the operational phase.

C9.2 ASSESSMENT BOUNDARY

The assessment will cover greenhouse gas emissions during the construction and operation phases of the Gelephu-Tareythang Road project on the Southern East-West Highway in Sarpang, Bhutan. This includes the construction of the road and bridges between Gelephu and Tareythang. Emissions will result from fuel combustion used to power construction activities, and indirect emissions from electricity consumption during the construction phase. Additionally, the greenhouse gas assessment will account for other emissions during the project’s operational phase, such as those from vehicles using the newly constructed road.

The greenhouse gas emissions resulting from deforestation for road construction will not be included in the emission assessment. This is because emissions from tree removal fall under Scope 3, and for this project, only Scope 1 and Scope 2 emissions will be assessed during the construction phase. Therefore, emissions from deforestation will not be considered in the evaluation.

C9.3 RELEVANT STANDARD AND GUIDELINES

This section provides a detailed overview of the comprehensive legislative framework governing greenhouse gas (GHG) emissions at the national level. It covers essential national laws, policies, and regulations, as well as relevant international agreements and guidelines that play a significant role in GHG emissions management. These legislative measures are designed to ensure compliance with environmental standards and promote sustainable practices across various sectors. For more information about the relevant standards and guidelines, please refer to ***Chapter 3***.

C9.4 LIMITATIONS OF THE ASSESSMENT

The following limitations have been identified for this assessment.

Scope Limitations:

- The greenhouse gas assessment will only evaluate the construction phase and operation phase.
- The greenhouse gas emissions assessment during the construction phase does not include Scope 3, which means it will not cover raw material production and emissions from deforestation for road construction.
- During the Operation phase, the greenhouse gas emissions assessment will only cover Scope 3.
- This greenhouse gas emissions assessment is high-level, and therefore, minor emissions may not be included in the evaluation.

Data Availability and Accuracy:

- The IPCC guidelines use “tiers” (from 1 to 3) to rate the reliability and methodological complexity of emission factors and activity data. It is good practice to report tiers for all emission sources included in the inventory. Tier 1 is the basic method, frequently utilizing IPCC-recommended country-level defaults, whereas Tier 2 involves country-specific data while Tier 3 involves Project-specific data. The higher the tier rank, the higher the quality of data is needed for assessment. This report primarily targets Tier 3 data use, but data constraints may necessitate the use of the Tier 1 and Tier 2 methodology.
- The accuracy of the GHG assessment depends on the availability and reliability of data sources used for emission calculations, which are mainly based on the data available in the Initial Options Study.
- Limitations may arise due to incomplete or insufficient data on energy consumption, emission factors, or other relevant parameters.
- Missing or incomplete information regarding the source population and activity data.
- Poor understanding of temporal and seasonal variations in the sources.
- The results from the GHG assessment in this report may not reflect the true quantity of emissions of the Project, as some GHG sources that might be significant are screened out due to the lack of information at the time writing this report.

Assumptions and Simplifications:

- The assessment may involve certain assumptions or simplifications due to limited data availability or complexity of certain processes.
- Simplifications may include using average emission factors or default values for certain emission sources or activities.
- Assuming similar vehicle growth rates and vehicle types reflects a realistic scenario, as these factors are likely to be influenced by broader economic and policy trends that affect both routes similarly.
- Having control variables—i.e., vehicle types, fuel usage, and growth rates, in both scenarios—helps in focusing on the differences in emissions due to the route characteristics alone.

Boundary Definitions:

- The geographical boundary of the assessment is defined based on the project site and its immediate surroundings. For this project, the boundary encompasses the area of road construction between Gelephu and Tareythang.
- Greenhouse gas emissions beyond the defined boundary, such as emissions from the production of construction materials and deforestation, are not considered.

Future Uncertainties:

- Should there be significant changes in factors such as assumptions made in Project description, engineering design, or agreed assessment criteria, the elements of this assessment and associated management, mitigation, and monitoring measures may need to be updated to reflect those changes.
- The assessment is based on current data and assumptions and does not account for potential future changes in technology, regulations, or operational practices.
- Future uncertainties, such as changes in energy sources, emission standards, or project expansion plans, are not considered in the assessment.

C9.5 REFERENCE GUIDELINES AND STANDARD

The basic methodologies used to estimate the GHG emissions in this report will apply the following guidelines:

- **Scope 1**: This assessment will use GHG Protocol guidelines for mobile combustion, which GHG Protocol calculation tool was develop by IPCC Guidelines. Therefore, GHG Scope 1 assessment will deploy the IPCC approach.
- **Scope 2**: The assessment of Scope 2 emissions will be based on the GHG Protocol Scope 2 guidance. However, the Scope 2 emissions considered will only cover the electricity used by construction equipment during the construction phase. Additionally, since Bhutan generates its own electricity, primarily from hydro sources, we will use the Emission Factor calculated by the International Renewable Energy Agency (IRENA) for our calculations.
- **Scope 3**: The assessment of Scope 3 emissions will follow the GHG Protocol Scope 3 guidance[23]. Scope 3 will cover the operation phase, including the greenhouse gas emissions from burning fuel in vehicles using the road. These emissions fall under Scope 3 category 11, "Use of Sold Products", and are considered indirect emissions.

[23] Technical guidance for Calculation Scope 3 Emission, available in;
https://ghgprotocol.org/sites/default/files/2023-03/Scope3_Calculation_Guidance_0%5B1%5D.pdf