# Climate Risk and Adaption Assessment (CRA) for 300MW Solar Power Plant

## Project Location: Anantapur and YSR Districts, Andhra Pradesh

## Final Draft Report

**October 2024**

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## Acronyms

| Acronyms | Description |
|---|---|
| SAEL | SAEL Industries Limited |
| E&S Advisors | Environment & Social Advisors |
| TCFD | Task Force on Climate-Related Financial Disclosure |
| CRA | Climate Risk and Adaption Assessment |
| CMIP | Coupled Model Intercomparison Project |
| RCP | Representative Concentration Pathway |
| BMTPC | Building Materials and Technology Promotion Council |
| IPCC | Intergovernmental Panel on Climate Change |
| AR | Assessment Report |
| NAPCC | National Action Plan on Climate Change |
| BEE | Bureau of Energy Efficiency |
| UNFCCC | United Nations Framework Convention on Climate Change |
| GRIHA | Green Rating for Integrated Habitat Assessment |
| ISA | International Solar Alliance |
| REDD | Reducing Emissions from Deforestation and forest Degradation |
| CCAP | Climate Change Action Programme |
| NAFCC | National Adaptation Fund on Climate Change |
| MoEFCC | Ministry of Environment, Forest and Climate Change |



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| | |
|---|---|
| IWMP | Integrated Watershed Management Program |
| NVBDCP | National Vector Borne Disease Control Programme |
| CDRI | Coalition for Disaster Resilient Infrastructure |
| SDRF | State Disaster Response Fund |
| NDMA | National Disaster Management Authority |
| SDMA | State Disaster Management Authorities |
| DDMA | District Disaster Management Authorities |
| NPDM | National Policy on Disaster Management |
| CBRN | Chemical, Biological, Radiological and Nuclear |
| DRR | Disaster Risk Reduction |
| SDG | Sustainable Development Goals |
| APSAPCC | Andhra Pradesh State Action Plan on Climate Change |
| EMPRI | Environmental Management and Policy Research Institute (EMPRI)7, Bengaluru, an autonomous body of the Department of Forest, Ecology and Environment, Government |
| APSDMP | Andhra Pradesh State Disaster Management Plan |
| R95PTOT | Annual total precipitation when Rainfall Run-off (RR) > 95p |
| RX5day | Maximum Cumulative 5Days Rainfall |
| RX1day | Maximum 1 Day Rainfall |
| CORDEX | Coordinated Regional Climate Downscaling Experiment |
| SDII | Simple Daily Intensity Index |
| NOAA | National Oceanic and Atmospheric Administration |
| NSSL | National Severe Storm Laboratory |
| NASA | National Aeronautics and Space Administration |
| CAPE | Convective Available Potential Energy |



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# 1 Introduction

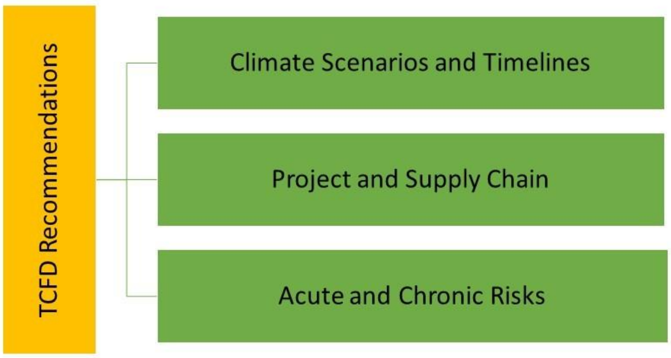
SAEL Industries Limited (hereinafter referred to as 'SAEL' or 'Client') commissioned Environment & Social Advisors (hereinafter referred to as 'E&S Advisors') to conduct Climate Risk and Adaption Assessment (CRA) for 300MW Solar Power Plant located in Anantapur and YSR Districts, Andhra Pradesh (referred to as "Project").

The assessment was required to be undertaken against international standards to meet the requirement in terms of Task Force on Climate-Related Financial Disclosure (TCFD). The assessment involved review of national level plans and commitments towards climate change followed by evaluation of natural hazard under baseline and climate change conditions.

Climate change risk assessment is required to understand the physical threats in terms of climate driven natural hazards likely to affect the said project. Accordingly, present assessment was performed with an aim of qualitative evaluation of the natural hazards likely to affect the said project under present (baseline) and future scenarios (climate change scenarios) of projected greenhouse gas emissions.

The assessment was conducted in accordance with the requirements of the Task Force on Climate Related Financial Disclosers (TCFD). TCFD[1] recommends assessment of financially material climate related physical risks including acute and chronic risks over different relevant time horizons and scenarios including 2°C or lower scenario. The assessment may include impacts on products and services, supply chain and /or value chain, adaption and mitigation activities, investment in research and development, and operations. ***Table 1-1*** provide an overview of TCFD related to Climate Change Risk Assessment

Figure 1-1: Key Components of TCFD related to Climate Risk Assessment




## 1.1 Objective

The assessment was conducted with following objective:

- Evaluate and identify the potential hazards to the Project arising from current and future climate variables.
- To understand the likely implications of theses hazards on the proposed project, communities and ecology in the surrounding area.
- To assess any implication of the project which may exacerbate climate change impacts on climate change of communities and ecology; and

[1] TCFD, 2017. Implementing the Recommendations of the Task Force on Climate-related Financial Disclosures. Available at: https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-TCFD-Annex-062817.pdft

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- To evaluate how the present project considerations can accommodate potential impacts of climate change in terms of risk assessment.

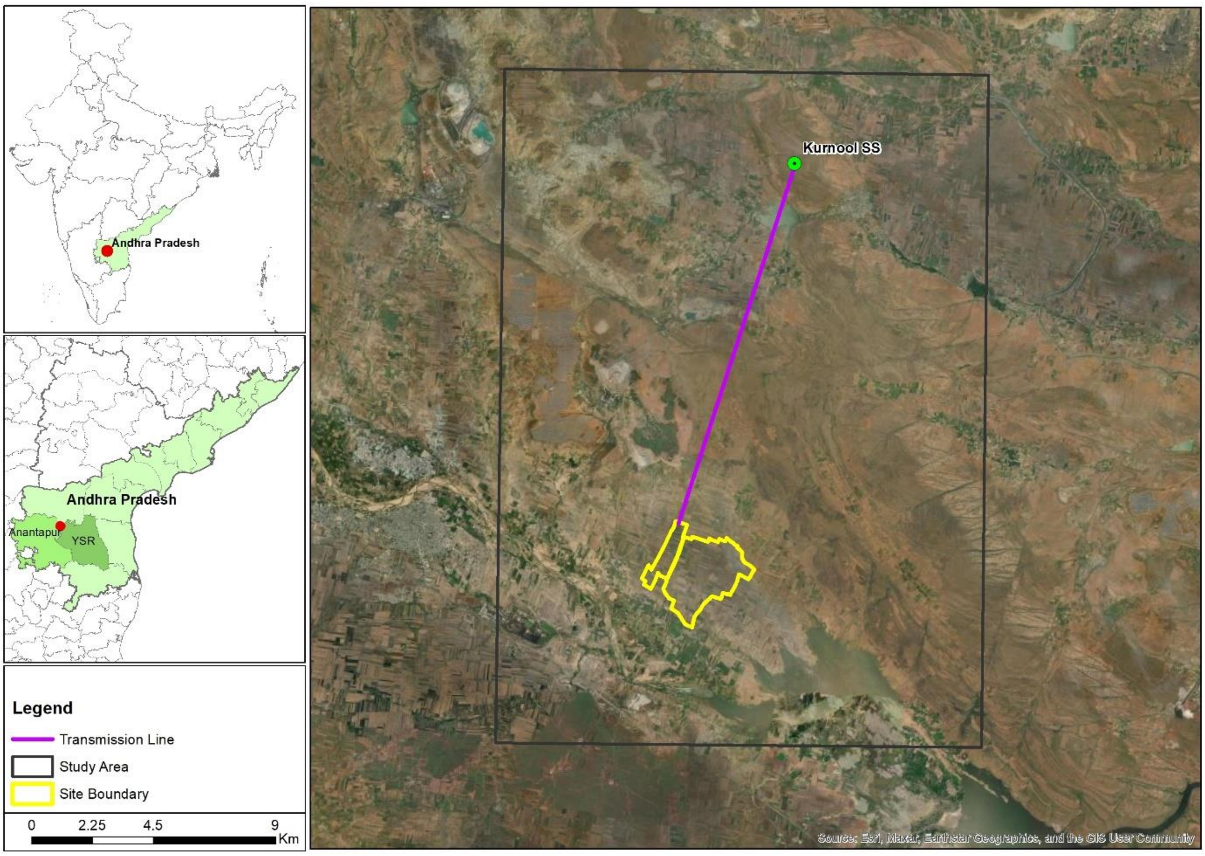
## 1.2 Site Setting and Study Area

The site setting of the proposed 300MW Solar power project located in Anantapur and YSR districts in Andhra Pradesh is summarised below, and ***Figure 1-1*** presents location of the Solar Power Plant

- 300MW Solar Power Plant: The proposed 300 MW Solar Power Project spans across diverse terrains, encompassing flat to undulating private shrub/waste land and agricultural land spread across Koduru village, Kondapuram mandal, YSR District and Bodaipalle, Tadipatri mandal, Anantapur District, Andhra Pradesh. The project's site elevation varies from 242 m to 255 m above mean sea level.
- Transmission Line: The transmission line spans eight villages, identified using Survey of India toposheets: K Sirige Palle, Uruchinthala, Ummaipalle, Thollamadugu, Shotrium Chennampalle, Nandipadu, and Thimmanayunipeta. The elevation in this area varies from 246 m to 404 m above mean sea level.

  The Project lies between the following coordinates:
  - North-west corner point: 15.06°N, 78.04° E
  - Nort-east corner point: 15.06°N, 78.21° E
  - South-east corner point: 14.84°N, 78.21° E
  - South-west corner point: 14.84°N, 78.04° E

Figure 1-2: Site location map of proposed 300MW Solar Power Plant



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The Area of Assessment for the Climate Risk and Adaption Assessment (CRA) was selected based on the TCFD's recognition and guidelines. Accordingly, the study area was selected to include the major project components from proposed hybrid project (hereinafter referred to as 'Key Assets') as presented in ***Table 1-1*** .

Table 1-1: Key Project Assets

| Study Area | Major Components |
|---|---|
| 300MW Solar power project | 1. PV Modules |
| | 2. Transmission Line |
| | 3. Inverter |
| | 4. Storage Room |
| | 5. Site Office |
| | 6. Access Road |

## 1.3 National Climate Policies and Framework

The review of national level action plans for climate change indicated promotion and implementation of renewable energy in general and solar energy projects in particular to reduce greenhouse gas emission and providing power in the remote area as one of the aims to address climate change related issues.

India has set a target to reduce the carbon intensity of the nation's economy by less than 45% by the end of the decade, achieve 50 percent cumulative electric power installed by 2030 from renewables, and achieve net-zero carbon emissions by 2070.

According to data from the Ministry of New and Renewable Energy (MNRE), India achieved a solar power generation capacity of 81.81GW and a wind power generation capacity of 45.88GW by March 2024. India aims for 500 GW of renewable energy installed capacity by 2030. Accordingly, the proposed project can be considered to be in alignment with the national commitment for production of renewable energy.

Further, the National Policy on Disaster Management recognises the natural disaster such as earthquake, flood, river erosion cyclones, and tsunamis etc. have detrimental effect on economy of the nation. The policy also recognises the need for systematic plan to manage these hazards involving six elements as: preparedness, response, prevention, mitigation, rehabilitation and recovery.

## 1.4 Climate Change Risks to Solar Farms

The escalating impacts of climate change are leading to a rise in both the frequency and severity of extreme weather events, heightening the risk of surpassing critical coping thresholds. Solar Energy projects could face various challenges including infrastructure damage, delays, water supply constraints, production losses, disruptions in power supply transmission, and fluctuations in energy demand. Additionally, there's a growing concern for employee health and safety, potential damage to business reputation, regulatory non-compliance, threats to social acceptance, and financial instability.



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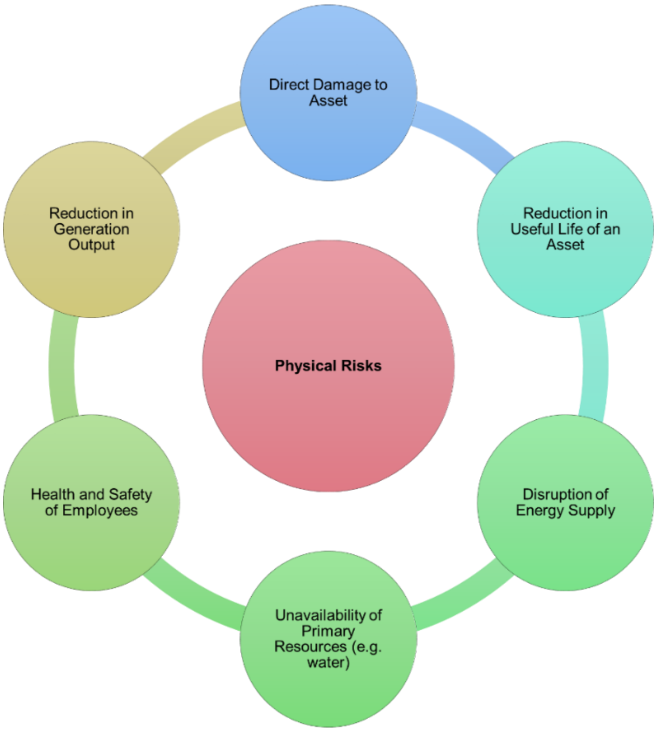
***Figure 1-3*** presents the general risks on solar energy projects as a result of climate change. Anticipated impacts of these climate changes were reported to be flooding, damage to building construction, disruption of energy transmission, increased insurance premiums, higher operating costs, early retirement of assets, decreased production capacity, and high variability in availability of water.

As, some these hazards are climate driven, these are likely undergoing changes as a result of climate change in future, in terms of intensification of likelihood or severity, affecting the project as presented in ***Figure 1-3***.

Therefore, it becomes important to identify such hazards which might affect the project location under baseline and climate change condition. Accordingly, present assessment aims at Screening Level Climate Risk and Adaption Assessment for proposed project sites identified above.

Figure 1-3: General Implications of Climate Change on Solar Farms




Therefore, it becomes important to identify such hazards which are likely to affect the project locations under baseline and climate change condition. Accordingly, present assessment aims at Screening Level Natural Hazard Climate Risk Assessment for proposed project sites identified above.

The present assessment is a high-level qualitative screening exercise, involving application of scientific principles, and professional judgement based on the best available data sources and information in the open source.

As a part of this assessment following natural hazards were evaluated under baseline and climate change conditions using a stepped approach as presented in ***Figure 1-4*** below.

- Water Availability
- Riverine Flood
- Extreme Heat
- Cyclone



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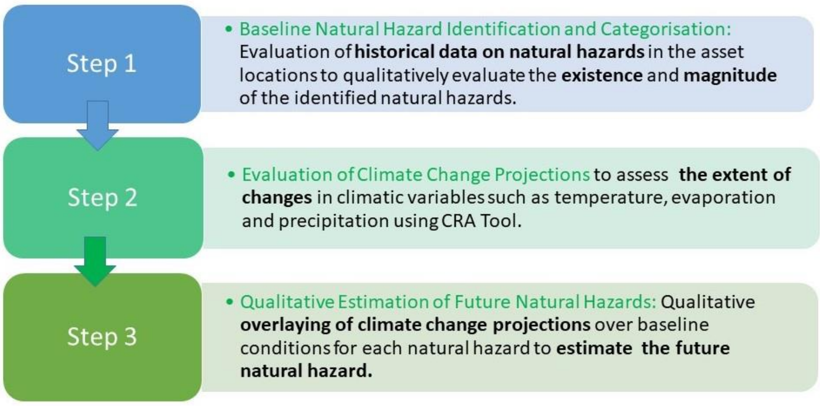
- Wind Speed
- Thunderstorm and Lightning

Figure 1-4: Approach for the Present Assessment




The baseline hazard was evaluated based on the review of recognised global and national level open-source databases/literature as presented in ***Table 2-1*** of the report. The hazards were categorised in four categories as No Hazard, Low, Medium, High and Not Classification. The hazards were categorised based on the potential of the hazard to inflict damage on built and natural environment, and health and safety as presented in ***Table 2-2*** of the report.

Representative Concentration Pathways (RCPs) are climate change scenarios that show future greenhouse gas concentrations and have been formally adopted by Intergovernmental Panel on Climate Change (IPCC). The four RCPs (RCP2.6, RCP4.5, RCP6, and RCP8.5) are named according to the range of radiative forcing values (2.6, 4.5, 6, and 8.5 W/m2, respectively) projected for the year 2100. Higher RCP values mean more emissions, leading to higher temperatures and greater climate change effects. Lower RCP values are preferable but demand stronger mitigation efforts The likely changes in above hazards due to climate changes were evaluated qualitatively for climate change scenarios of RCP 4.5 and RCP 8.5 during timeframes for 2030 and 2050, using CMIP-5 Climate Change Projections following the TCFD guidelines as recommended. The likely changes in hazards are based on application of specific principles, professional judgments and likely relation between natural hazards and the climate parameter.

This report does not include the climate change scenario of RCP 2.6 due to a lack of adequate data from secondary sources references listed in Table 2-1 and its temporal relevance. RCP 2.6 is a "very stringent" pathway. According to the IPCC, RCP 2.6 requires that carbon dioxide ($CO_2$) emissions start declining by 2020 and go to zero by 2100. It also requires that methane emissions ($CH_4$) go to approximately half the $CH_4$ levels of 2020, and that sulphur dioxide ($SO_2$) emissions decline to approximately 10% of those of 1980–1990.

The assessment indicated that extreme heat is likely to ‘High’ hazard under baseline and climate change conditions. Cyclone and Wind speed Indicated ‘Low’ hazard under baseline and ‘Medium’ hazard in climate change conditions. Water availability is likely to ‘Medium’ hazard under baseline and ‘High’ hazard under climate change conditions. Following the evaluation of natural hazard under baseline and climate change condition, general recommendations were provided on implications, available control measures and additional recommendations for each of the natural hazard were provided as presented in Section 4 of the report.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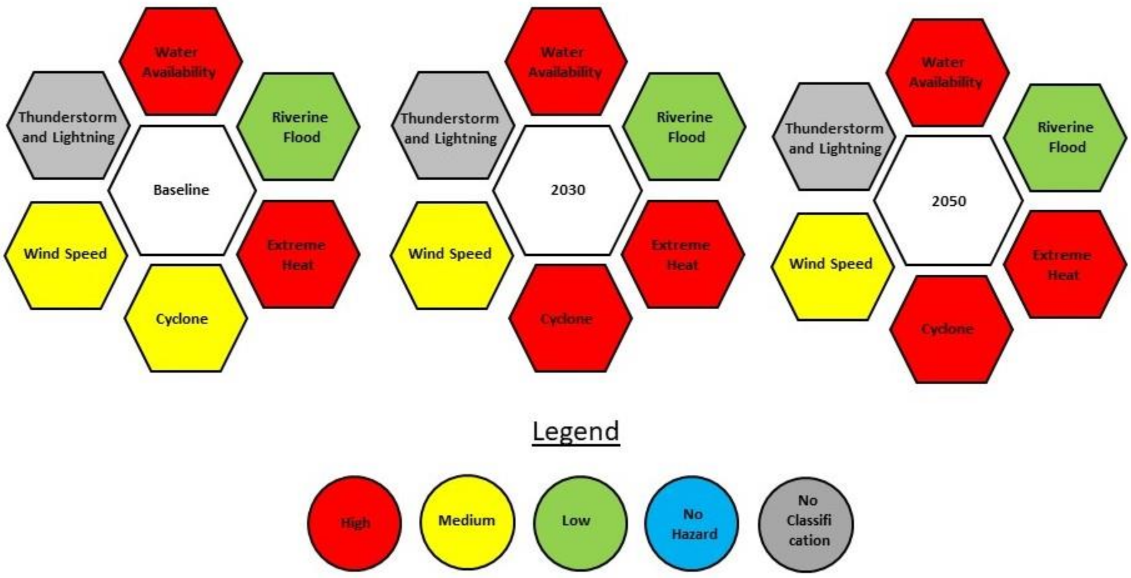
## 1.5 Climate Hazard Assessment – Key Findings

*Figure 1-5* presents the summery of natural hazards under baseline and climate change scenarios of RCP 4.5 and RCP 8.5.

Figure 1-5: Summary of Natural Hazards under Baseline and Climate Change Scenarios of RCP 4.5 and RCP 8.5




It should be noted that although the riverine flood presented 'No Hazard' within Study Area, localised flooding can happen due to changes in land-use due to project development and extreme rainfall. Data on such localised flooding is not available and evaluation of such localised flooding need Site level assessment involving modelling studies. Therefore, although there is no riverine flood hazard indicated at project site, the general implications of flood were identified, with recommendation for site level flood risk assessment.

## 1.6 Implications Analysis

Based on the future natural hazard, project sites implications were evaluated for the solar power plant, infrastructure and components. Along with this, further preventive actions, management plans and adaptation measures were recommended. These are presented in ***Table 5-1*** of the report.



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# 2 Methodology

The assessment commences by gathering geospatial data pertaining to the Study Area under evaluation. This data serves as the foundation for collecting and organizing baseline information on natural hazards and climate change projections. Importantly, it is emphasized that the assessment utilizes openly accessible data sources. A concise overview of the sequential steps conducted in this study is outlined below.

- In the initial phase, attention is directed towards assessing historical data concerning natural hazards within the area of interest, aiming to ascertain the presence and intensity / magnitude of identified natural hazards. This assessment was performed qualitatively based on the availability of historical data. The potential impact of each natural hazard was evaluated on a scale of three levels categorized as **Low, Medium, and High.** The hazard categorisation was based on the potential impact on built and natural environment considering intensity/ magnitude, and/or frequency of the hazard in the region.
- The second step constitutes evaluation of climate change projections to assess the extent of changes in climatic variables such as precipitation, and temperature. This provided information on any significant changes in temperature and precipitation in the upstream of the Site which may have impact on the Site operations in future.
- The third step involves the evaluation of baseline risk from each natural hazard; the outputs from climate change projections are overlaid qualitatively on the baseline conditions for each hazard to categorize the climate change risk using only the hazard intensity.

***Figure 2-1*** provides the framework for the current assessment for the extraction of historical and projected data, evaluation of baseline natural hazards and superimposition of climate change projections. The final output is in terms of a semi-quantitative hazard matrix which presents cumulative hazard levels for each study area under baseline and climate change scenario. Based on this outcome, Environment & Social Advisors evaluated the high-level implications and the corresponding recommendations for the project components.


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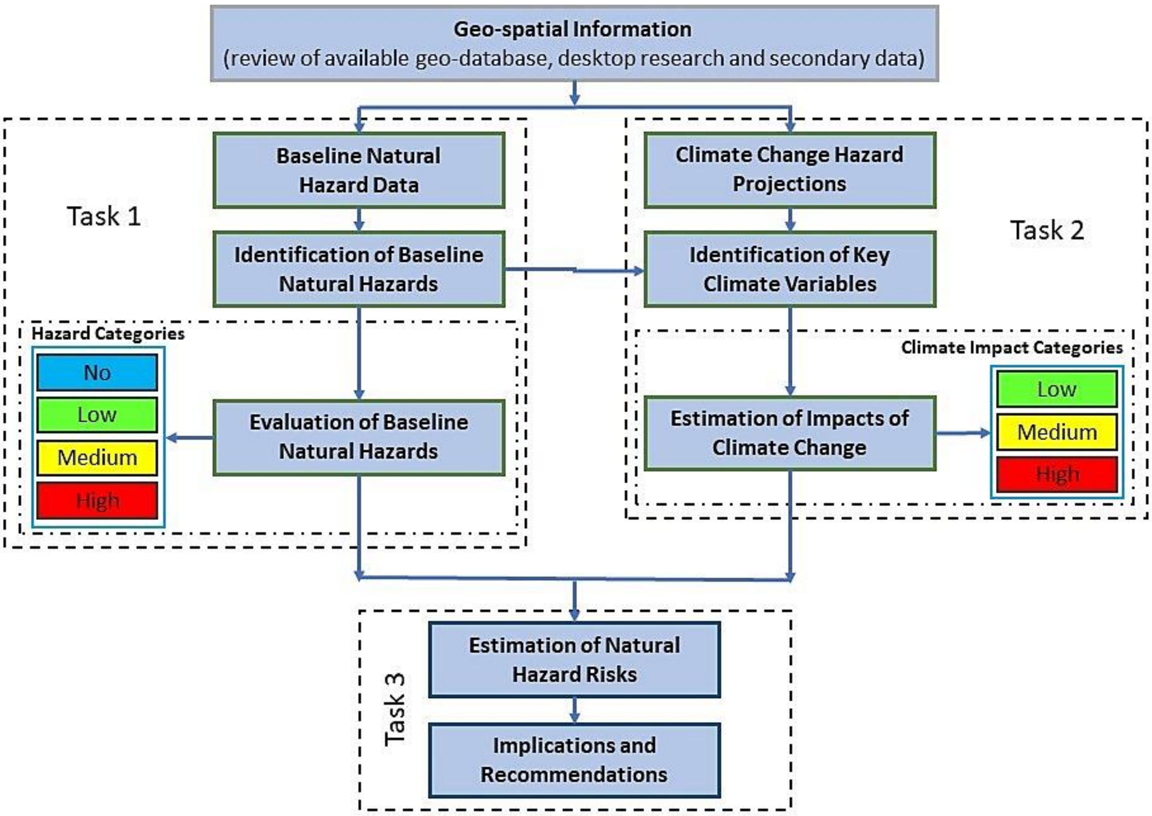
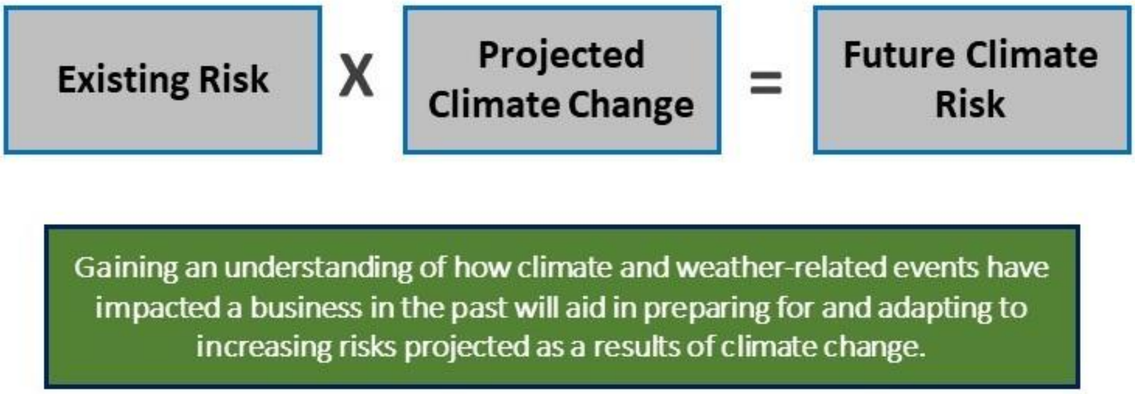
Figure 2-1: General Framework for a Natural Hazard and Climate Change Impact Assessment




In short, the process of assessment of climate risks involves the evaluation of likely impacts from climate change projections on the existing baseline risks to inform the business units on potential future risks (*Figure 2-2*).

Figure 2-2: Process to Evaluate Threats Due to Natural Hazards under Climate Change Scenarios




## 2.1 Baseline Natural Hazard Evaluation

The assessment involved evaluating various natural hazards, as depicted in *Figure 2-3*, through a comprehensive review of established global and national-level databases and literature. The Study Area's elevation spans from 238 meters to 256 meters above mean sea level, with a distance of approximately 215 kilometres from the Bay of Bengal Sea in the eastward direction. A waterbody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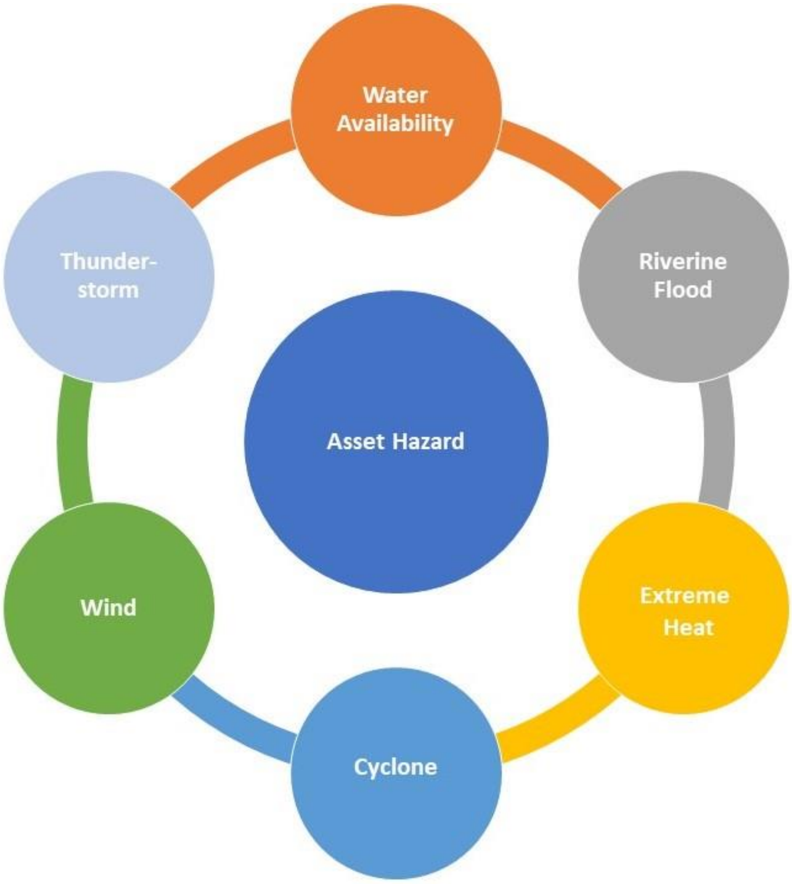
located east of the solar plant boundary, along with two streams—one flowing diagonally from the northwest to the southeast corners of the study area, and the other running east to west in the southern section—are connected to tributaries of the Penna River.

The topography of Anantapur and YSR districts showcases a blend of terrains with flat to gentle slopes, including flat plains, undulating landscapes, and occasional hills. Both districts are predominantly characterized by fertile agricultural land, intersected by rivers, streams, and reservoirs. In some areas, particularly near the borders, there may be elevated regions with rugged terrain. Additionally, pockets of forested areas and shrublands can be found throughout both districts.

Based on the location of the study areas and general topography, hazards due to coastal flooding, sea level rise and landslides were not evaluated in the present assessment.

Figure 2-3: Hazards Evaluated in this Assessment.




Various data sources used in the present assessment for evaluation of baseline natural hazard are presented in ***Figure 2-1***. ***Figure 2-2*** presents the criteria for categorisation and normalisation of hazard categories adopted in the present assessment.

Table 2-1: Data Sources used for Baseline Natural Hazard Evaluation

| Natural Hazard | Factors Assessed | Data Sources |
|---|---|---|
| Water Availability | WaterStress | Hofste, R., S. Kuzma, S. Walker, E.H. Sutanudjaja, M.F.P. Bierkens, M.J.M. Kuijper, M. Faneca Sanchez, R. Van Beek, Y. Wada, S.G. Rodrguez and P. Rei. 2019. “Aqueduct 3.0: Updated Decision Relevant Global Water Risk Indicators.” Technical Note. Accessed9 June 2020. |



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| | | |
|---|---|---|
| | Seasonal Variability | Available at: https://www.wri.org/publication/aqueduct-30 |
| Flood | WRI-Aqueduct Flood Tool | Available at: https://www.wri.org/resources/data-sets/aqueduct-floods-hazard-maps |
| | Flood Hazard Mapof India | Building Material and Technology Promotion Council (BMTPC)Available at: https://bmtpc.org/DataFiles/CMS/file/VAI2019/flood.html |
| Extreme Heat | Extreme heat hazard level | ThinkHazard. 2020. Available at: https://thinkhazard.org/en/report/17548-india-andhra-pradesh-anantapur/EH |
| Cyclone | Cyclone Tracks | NOAA Historical Hurricane TracksAvailable at: https://coast.noaa.gov/hurricanes/#map=6.61/15.42/75.658&search=ey |
| | CycloneIntensity Maps | UNEP, 2013. Global Risk Data Platform: Tropical cyclones wind speed buffers footprint 1970-2009. Accessed 9 June 2020. Available at: https://preview.grid.unep.ch/index.php?preview=data&events=cyclones&evcat=4&lang=eng |
| Wind Speed | Average Wind SpeedMap of the World | DTU (Technical University of Denmark). 2019. Global Wind Atlas 2.0. Accessed 9 June2020. Available at: https://globalwindatlas.info |
| | Wind Hazard Map | Building Material and Technology Promotion Council (BMTPC)Available at: https://bmtpc.org/DataFiles/CMS/file/VAI2019/WIND-kr.html |
| Thunderstorm | Thunder storm Incidence map | Building Material and Technology Promotion Council (BMTPC)Available at: https://bmtpc.org/DataFiles/CMS/file/VAI2019/th.html |

## Table 2-2: Categorisation of Natural Hazards

| No. | Hazard | Original Categorization | Modified Categorization |
|---|---|---|---|
| 1 | **Water Availability** | | |
| 1.1 | Water Stress<br>Based on ratio of total water withdrawal to available renewable water resources (surface and groundwater) | Low: <10% | Low: <10% |
| | | Low-Medium: 10-20% | Medium: 10-20% |
| | | Medium-High: 20-40% | High: >20% |
| | | High: 40-80% | |
| | | Extremely High: >80% | |



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| No. | Hazard | Original Categorization | Modified Categorization |
|---|---|---|---|
| 1.2 | Seasonal Variability<br>*Based on coefficient of variability as ratio of standard deviation of the annual available water and the annualmean available water during the period of 1960-2014* | Low: <0.33 | Low: <0.33 |
| | | Low-Medium: 0.33-0.66 | Medium: 0.33-0.66 |
| | | Medium-High: 0.66-1 | High: >0.66 |
| | | High: 1-1.33 | |
| | | Extremely High: >1.33 | |
| 2 | Flood | | |
| 2.1 | WRI-Aqueduct Flood tool<br>*Based on depth of inundation with reference to the impact onperson walking through the flood water and standing vehicle as suggested by FEMA* | No classification | Low: <0.5 m |
| | | | Medium: 0.5-1.5 m |
| | | | High: >1.5 m |
| 3 | Extreme Heat | | |
| 3.1 | Extreme Heat<br>Hazard level reflects expected frequency of extreme heat conditions, using simulations oflong-term variations in temperature and expert guidance. Extreme heat is assessed using a widely accepted heat stress indicator, the Wet Bulb Globe Temperature (°C). | Very Low | Low |
| | | Low | |
| | | Medium | Medium |
| | | High | High |
| 4 | Cyclone | | |
| 4.1 | Cyclone and Hurricane<br>Cyclone categories based on damage potential as classified by Saffir-Simpson Scale | Category 1: 119-153 km/h | Low: Category 1 (119-153 km/h) |
| | | Category 2: 154-177 km/h | Medium: Category 2 (154-177 km/h) |
| | | Category 3: 178-208 km/h | High: ≥ Category 3 (>177 km/h) |
| | | Category 4: 209-251 km/h | |
| | | Category 5: ≥252 km/h | |
| 5 | Wind speed | | |



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| No. | Hazard | Original Categorization | Modified Categorization |
|---|---|---|---|
| 5.1 | Beaufort's Scale | Calm (0): < 1m/s | Low: ≤ 11m/s |
| | | Light Air (1): 1-2 m/s | |
| | | Light Breeze: (2) 2-3 m/s | |
| | | Gentle Breeze (3): 4-5m/s | |
| | | Moderate Breeze (4): 6-8m/s | |
| | | Fresh Breeze (5): 9-11m/s | |
| | | Strong Breeze (6): 11-14m/s | Medium: 11-21 m/s |
| | | Near Gale (7): 14-17 m/s | |
| | | Gale (8): 17-21 m/s | |
| | | Strong Gale (9): 19-24m/s | High: > 21 m/s |
| | | Storm (10): 25-28 m/s | |
| | | Violent Storm (11): 29-32m/s | |
| | | Hurricane (12): >32 m/s | |
| 5.2 | BMTPC Wind HazardCategorization<br>Based on basic wind speed (peak wind speed averaged over 3 sec for a 50-year returnperiod) | Low damage: 33 m/s | Low: ≤ 33m/s |
| | | Moderate Damage (ZoneB): 39 m/s | Medium: 33-44 m/s |
| | | Moderate Damage (ZoneA): 44 m/s | High: > 44 m/s |
| | | High Damage: 47 m/s | |
| | | Very High Damage (ZoneA): 50 m/s | |
| | | Very High Damage (ZoneB): 55 m/s | |
| **6.** | **Thunderstorm** | | |
| 6.1 | BMTPC Thunderstorm Incidence Categorization<br>(Based on Thunderstorm incidence at a particular station during period 1981-2010) | Very Low Occurrence | Low: ≤ 30 |
| | | Low Occurrence | |
| | | Medium Low Occurrence | Medium: 31-60 |
| | | Medium High Occurrence | |
| | | High Occurrence | High: > 60 |
| | | Very High Occurrence | |



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## 2.2 Climate Change Evaluation

The analysis of future climate change involves assessment of a range of different indicators modelled as part of the IPCC 5th Assessment Report published in 2013 (IPCC, 2013). Emissions scenarios describe future releases of greenhouse gases, aerosols, and other pollutants into the atmosphere and provide inputs to climate models. Representative Concentration Pathways (RCPs) are consistent sets of projections of components of radiative forcing (i.e., the change in the balance between incoming and outgoing radiation to the atmosphere caused primarily by changes in atmospheric composition) that are meant to serve as input for climate modelling.

Climate change projection values are available for a number of climate variables at various time horizons in the future under different future greenhouse gas emissions scenarios. The assessment looks at projected change for the years 2030 (quarter-century), and 2050 (mid-century) where two (2) future emission scenarios, RCP 4.5 and RCP 8.5 were analysed.

The raw data was processed in order to obtain information for the relevant years and emission scenarios and to format it in a manner which could be uploaded into ArcGIS. The basic approach involved the following steps:

- First, the output from each climate model was averaged over time, giving a single value for the time period (i.e., an average value was obtained for 2030 for the period 2025-2035, and for 2050over the period 2045-2055.
- This mean value was then averaged together with the corresponding values from all other models. This provided the 'Multi-Model-Mean' value to be used for this analysis. It should be noted that some models do not include projections for both RCP scenarios and therefore, the multi-Model-mean approach used in this assessment includes only those models that provided projections for both scenarios to ensure internal consistency.
- A baseline value, which is the time-averaged, model-averaged value of the variable from 1981-2000, was calculated. The baseline is the modelled baseline and does not incorporate any observed values.

Differences from the baseline for 2030, and 2050 for the RCP 4.5 and the RCP 8.5 emissions scenarios were also calculated in this manner. Positive values indicate that the variable is projected to increase, while negative values indicate that the variable is projected to decrease.

## 2.3 Qualitative Estimation of Impact of Climate Change

Based on the review of the climate projection data, percentage changes in climate indicators were evaluated. The impact of these changes on occurrence of natural hazards (intensity and/or frequency) was qualitatively evaluated based on the percentage changes in temperature and precipitation indicators to determine the extent of vulnerability under climate change conditions. ***Table 2-3*** presents the impact criteria considered in the present assessment. Changes to future natural hazards were evaluated in comparison to the baseline natural hazards based on the changes in temperature (WarmSpell Duration Index, Average Temperature and Average Maximum Temperature) and precipitation (One Day Maximum Rainfall, Consecutive 5 days Maximum Rainfall, Number of Days with Heavy rainfall) parameters.



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## Table 2-3: Criteria for Evaluation of Climate Change Impacts

| Type of Vulnerability | Temperature Parameters (Warm Spell Duration Index, Average Temperature, Average Maximum Temperature) | Precipitation (One Day Maximum Rainfall, Consecutive 5 days Maximum Rainfall, Number of Days with Heavy rainfall) |
|---|---|---|
| Low | <=5% | <=5% |
| Medium | 5-10% | 5-10% |
| High | >10% | >10% |



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# 3 Review of Climate Change and Disaster Management Policy in India

## 3.1 National Level Policies and Plans

### 3.1.1 National Action Plan on Climate Change (2008)

The Government of India launched National Action Plan on Climate Change (NAPCC) in 2008 outlining eight (8) National Missions on climate change[2]. These include:

- National Solar Mission
- National Mission for Enhanced Energy Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for Sustaining the Himalayan Eco-system
- National Mission for a Green India
- National Mission for Sustainable Agriculture
- National Mission on Strategic Knowledge for Climate Change

Under this purview the National Action Plan for Climate Change recognized following dimension to address the threats from climate change and sustain required economic growth of the country-

- Protection of Poor
- Sustainability
- Implementation
- International cooperation

The key National Missions and their objectives are listed under ***Table 3-1.***

Table 3-1: Summary of National Missions Identified under NAPCC

| Sr. No. | Mission Name | Mission Objectives |
|---|---|---|
| 1 | National Solar Mission | • To expand on renewable energy and reduce greenhouse gas emissions.<br>• Enable decentralized distribution of power in remote areas, empowering people at grass root level.<br>• R&D with international cooperation |
| 2 | National Mission for Enhanced Energy Efficiency | • Establishment of institutional mechanism such as Bureau of Energy Efficiency (BEE)<br>• It was aimed to save 10,000MW of energy by end of 2012.<br>• Promotion of energy efficient industries through certification and<br>• Promoting energy efficient appliances |
| 3 | National Mission on SustainableHabitat | • Energy efficient buildings (better building materials and design)<br>• Management of solid waste (recycling and reuse)<br>• National program for R&D in bio-chemical conversion, wastewater reuse, sewage utilization and recycling etc. |

[2] http://cckpindia.nic.in/assets/NAPCC/NAPCC_Document.pdf



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| Sr. No. | Mission Name | Mission Objectives |
|---|---|---|
| 4 | National Water Mission | • Aims to ensure integrated water resource management to conserve and minimize wastage of water and ensure equitable distribution.<br>• It seeks to ensure considerable water supply in urban areas is met by recycled water and in coastal areas adoptionof low temperature desalination technologies.<br>• Rainwater harvesting |
| 5 | National Mission for SustainingHimalayan Ecosystem | • Evolve management measures for sustaining and safeguarding the Himalayan Ecosystem<br>• Establishing observation and monitoring network |
| 6 | National Mission for Green India | • Enhancing ecosystem services including carbon sink |

The key takeaway is that the government of India is focused on enhancing activities under the National Missions with respect to adaptation, mitigation and capacity building and undertake additional interventions like launch of new missions such as on Health and Coastal areas.

### 3.1.2 Nationally Determined Contributions (NDC's)

India has committed to the objectives of Paris Agreement through the following goals[3]-

- To put forward and further propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation.
- To adopt a climate friendly and a cleaner path than the one followed hitherto by others at corresponding level of economic development.
- To reduce the emissions intensity of its GDP by 33 to 35 percent by 2030 from 2005 level.
- To achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030 with the help of transfer of technology and low-cost international finance including from Green Climate Fund (GCF).
- To create an additional carbon sink of 2.5 to 3 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030.
- To better adapt to climate change by enhancing investments in development programmes in sectors vulnerable to climate change, particularly agriculture, water resources, Himalayan region, coastal regions, health and disaster management.
- To mobilize domestic and new & additional funds from developed countries to implement the above mitigation and adaptation actions in view of the resource required and the resource gap.
- To build capacities, create domestic framework and international architecture for quick diffusion of cutting-edge climate technology in India and for joint collaborative R&D for such future technologies.

*The key takeaway for the project is an increased emphasis from the government to rely on clean sources of energy including solar and wind energy to satisfy the energy demands of the country and reduce greenhouse gas emissions through the use of non-renewable forms of energy*.

[3] https://cckpindia.nic.in/indias-ndc/


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### 3.1.3 Climate Change Mitigation Actions

India's mitigation policies and actions must be understood in the context of its longstanding position that climate change is a global challenge, a position in accordance with the spirit of the UNFCCC. The following mitigation programmes were identified by various Ministries and Authorities[4].

- Solar Energy - To deploy 100 GW solar power by 2022.
- Wind Energy - Deployment of 60 GW Wind Energy by 2022 and stable at the same level until 2030.
- Green Rating for Integrated Habitat Assessment (GRIHA) - To recognize energy-efficient buildings, as well as to stimulate their large-scale replication.
- Green Energy Corridor Project - Aims at synchronizing electricity produced from renewable sources, such as solar and wind, with conventional power stations in the grid.
- International Solar Alliance (ISA) - To provide a dedicated platform for cooperation among solar-resource-rich countries, through which the global community, including governments, bilateral and multilateral organizations, corporates, industry, and other stakeholders, can contribute to help achieve the common goal of increasing the use and quality of solar energy in meeting energy needs of prospective ISA member countries in a safe, convenient, affordable, equitable and sustainable manner.
- National Smart Grid Mission - Established to accelerate Smart Grid deployment in India.
- REDD+ Reducing emissions - To achieve additional carbon sequestration, emission reduction, improve forest-based livelihoods, conservation of rare, endemic, and endangered species found in the area and improvement of watershed hydrology.
- Climate Change Action Programme (CCAP) - to create and strengthen the scientific and analytical capacity for assessment of climate change in the country, putting in place appropriate institutional framework for scientific and policy initiatives and implementation of climate change related actions in the context of sustainable development.

*The key takeaway for the project is an increased emphasis from the government to rely on clean sources of energy including solar and wind energy to satisfy the energy demands of the country and reduce greenhouse gas emissions through the use of non-renewable forms of energy.*

### 3.1.4 Climate Change Adaptation Actions

The adverse impacts of climate change on the developmental prospects of the country are amplified enormously by the existence of widespread poverty and dependence of a large proportion of the population on climate sensitive sectors for livelihood. A range of actions have been introduced to address it[5] which are given below:

National Adaptation Fund on Climate Change (NAFCC) - NAFCC was launched in 2015-16 by Ministry of Environment, Forest and Climate Change (MoEFCC) to cover vulnerable sectors such as Water, Agriculture and Animal Husbandry, Forestry, Ecosystems and Biodiversity across the country. The overall aim of the fund is to support concrete adaptation activities which are not covered under on-going activities through the schemes of State and National Government that reduce the adverse effects of climate change facing community, sector and states. The Fund is meant to assist National and State level activities to meet the cost of adaptation measures in areas that are particularly vulnerable to the adverse impacts of climate Change.

- Programmes/Schemes with Adaptation Co-benefits - Programmes were identified by the government of India which provide additional benefits of climate change in the arenas of

[4] https://cckpindia.nic.in/mitigation-actions/

[5] https://cckpindia.nic.in/adaptation-actions



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agriculture, agroforestry, water supply and sanitation, water conservation, food security, soil quality, heatwave management, Integrated Watershed Management Program (IWMP), National Vector Borne Disease Control Programme (NVBDCP), State Disaster Response Fund, and Coalition for Disaster Resilient Infrastructure (CDRI).

Among all the above actions, the most relevant actions in the context of this project include:

- Guidelines for preparation of Action Plan – Prevention and Management of Heatwave 2019- It aims for improving the capacity of the States to deal with heat wave management in a planned manner.
- State Disaster Response Fund - Primary fund available with State Governments for responses to notified disasters. Disasters covered under SDRF: Cyclone, drought, earthquake, fire, flood, tsunami, hailstorm, landslide, avalanche, cloudburst, pest attack, frost and cold waves.
- Coalition for Disaster Resilient Infrastructure (CDRI) - Aims to promote resilience of new and existing infrastructure systems to climate and disaster risks.

### 3.1.5 Disaster Management (DM) Act, 2005

The Disaster Management Act, 2005 (DM Act 2005) lays down institutional and coordination mechanism for effective Disaster Management (DM) at the national, state, district and local levels. As mandated by this Act, the Government of India created a multi-layered institutional system consisting of the National Disaster Management Authority (NDMA) headed by the Prime Minister, the State Disaster Management Authorities (SDMA) headed by the respective Chief Ministers and the District Disaster Management Authorities (DDMA) headed by the District Collectors/ District Magistrate and co-chaired by Chairpersons of the local bodies.

### 3.1.6 National Policy on Disaster Management (NPDM), 2009

The National Policy on Disaster Management (2009) recognized that disasters have detrimental effects on economic development of the nation. Moreover, the policy affirmed that the socially and economically weaker sections of the society are the most vulnerable to the natural disaster. Below are the key components of the policy:

- This policy considers the natural disasters such as earthquake, floods and river erosion, cyclones and tsunamis, and landslides and avalanches and emergencies of modern times such as Chemical, Biological, Radiological and Nuclear (commonly known as CBRN) emergencies. The key natural hazards identified under this policy are illustrated in ***Figure 3-1.***
- The policy considers disaster management as a cyclic process consisting of six elements: prevention, mitigation, preparedness, response, rehabilitation, and recovery.
- It emphasises the need of an institutional structure for natural disaster management comprising central body of National Disaster Management Authority (NDMA) headed by Prime Minister of India, State Disaster Management Authorities (SDMAs) headed by respective Chief Ministers of the State, and District Disaster Management Authorities (DDMAs).

Figure 3-1: Natural Disasters considered under National Policy for Disaster Management



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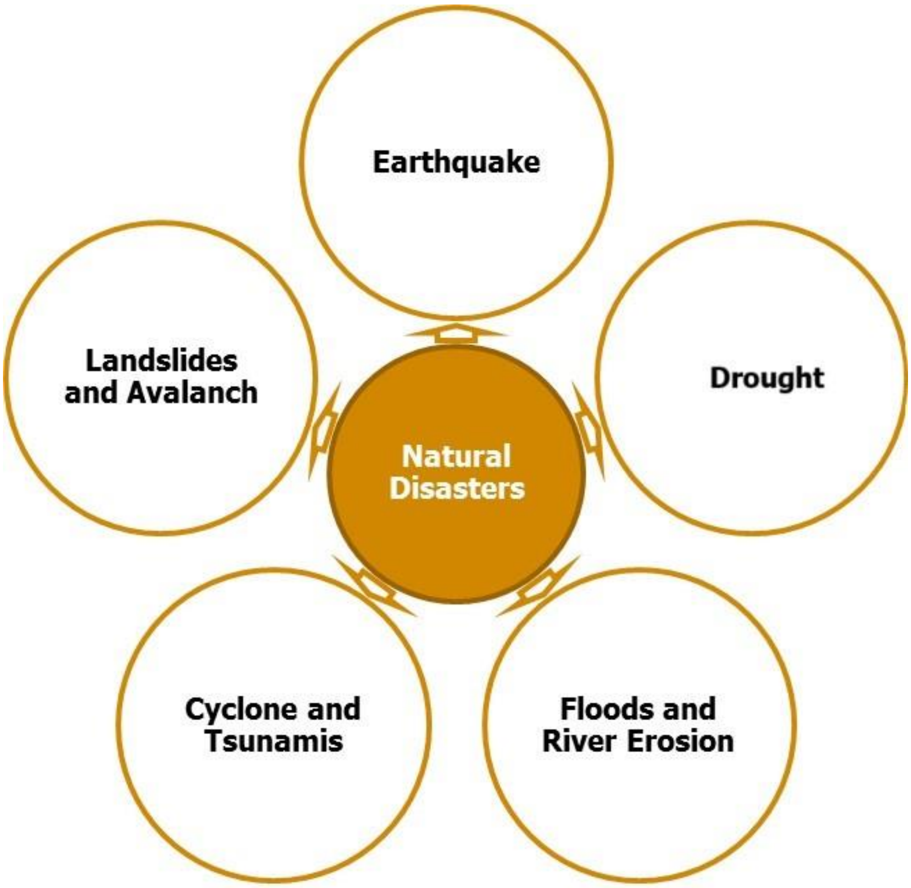


### 3.1.7 National Disaster Management Plan, 2019

The National Disaster Management Plan (NDMP)[6] provides a framework and direction to the Government agencies for all phases of disaster management cycle. The NDMP is a "dynamic document" in the sense that it will be periodically improved keeping up with the emerging global best practices and knowledge base in disaster management. It is in accordance with the provisions of the Disaster Management (DM) Act 2005, the guidance given in the National Policy on Disaster Management (NPDM) 2009, and the established National practices.

The NDMP recognizes the need to minimize, if not eliminate, any ambiguity in the responsibility framework. It, therefore, specifies who is responsible for what at different stages of managing disasters. It is meant to be implemented in a flexible and scalable manner in all phases of disaster management: a) Mitigation (prevention and risk reduction), b) Preparedness, c) Response and d) Recovery (immediate restoration and build-back beer). While the names of ministries/ departments of the Centre and State/UT having specific roles and responsibilities are mentioned in the Plan, in the spirit of the DM Act 2005 and the exigencies of humanitarian response, every ministry/ department and agency is expected to contribute to DM going beyond their normal rules of business. The key features of the NDMP are summarised below:

- Conforming to the national legal mandates - the DM Act 2005 and the NPDM 2009
- Participating proactively to realising the global goals as per agreements to which India is signatory - Sendai Framework for Disaster Risk Reduction (DRR), Sustainable Development Goals (SDGs) and Conference of Pares (COP21) Paris Agreement on Climate Change
- Prime Minister's Ten Point Agenda for DRR articulating contemporary national priorities.

[6] https://reliefweb.int/sites/reliefweb.int/files/resources/ndmp-2019.pd



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- Social inclusion as a ubiquitous and cross-cutting principle
- Mainstreaming DRR as an integral feature
- The NDMP covers disaster management cycle for all types of hazards - natural and human-induced.
- The role of the central agencies is to support the disaster-affected State or the UT in response to requests for assistance in disaster management planning, preparedness, and capacity building, the central agencies will constantly work to upgrade Indian DM systems and practices as per global trends.
- The priories of the Sendai Framework and those related to DRR in SDGs and Paris Agreement have been integrated into the planning framework for Disaster Risk Reduction under the following Thematic Areas for Disaster Risk Reduction:
    - Understanding Risk
    - Inter-Agency Coordination
    - Investing in DRR – Structural Measures
    - Investing in DRR – Non-Structural Measures
    - Capacity Development and
    - Climate Change Risk Management
- Climate change induced events such as cyclone, flood, landslide, drought, thunderstorm, lightening, etc., should be accounted for in disaster management.
- Integration of disaster risk reduction and climate change adaptation should be targeted.
- Involvement of private sector in disaster management and for businesses to integrate disaster risk into their management processes and involve the private sector in the areas of:
    - Technical support
    - Reconstruction effort
    - Risk management including covering risks to their own assets.
    - Risk-informed investments in recovery efforts

## 3.2 State Level Policies and Plans

### 3.2.1 State Action Plan on Climate Change (SAPCC) for Andhra Pradesh

The Ministry of Environment and Forests called upon the States to expeditiously prepare the State Action Plans on Climate Change consistent with the strategy outlined in National Action Plan on Climate Change (SAPCC) for Andhra Pradesh. The SAPCC is a dynamic and flexible policy framework which will follow a continuous interactive process to reflect the changes and developments happening at the national, State and local levels. The stakeholders' consultation process is an important aspect of SAPCC. Stakeholder engagement and consultation aligns them into the planning framework, and broadens and deepens perspectives and involvement in implementation of the State Action Plans for building a climate resilient economy. This SAPCC has been designed following stakeholders' concerns and issues.

A detailed diagnostic study, following the UNDP (United Nations Development Programme) methodologies (UNDP Adaptation Policy Framework and Human Development Index) has been performed to assess the climate change vulnerability profile of Andhra Pradesh. It is based on the basic hypothesis that climate change vulnerability of a region is a function of two key variables:

- Adaptive capacity of the region
- Physical exposure of the region to climatic events.

An index has been developed to estimate these two parameters.16 major sectors which are seriously impacted by CC (agriculture, coastal zone, disaster management, rural development, transport, energy, industry, tourism, mining, forestry and biodiversity, urban development and waste



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management, health and family welfare, animal husbandry, fisheries, irrigation and water) have been identified for the State.

### 3.2.2 Andhra Pradesh State Disaster Management Plan (APSDMP)

The Andhra Pradesh State Disaster Management Plan (APSDMP)[7] provides a framework and guidance to the State Government agencies and other stakeholders for managing the disasters, in accordance with the provisions of the DM Act 2005. The APSDMP is being revised and upgraded annually, by incorporating the lessons learnt from the recent disasters that occurred in the State and also the best practices adopted elsewhere towards disaster management. The plan has been prepared by carefully incorporating the guidance given in the National Policy on Disaster Management (NPDM-2016), Prime Minister's 10 Point Agenda for Disaster Risk Reduction and SENDAI Framework for DRR (2015-30). This Plan has been developed aligning to the National Disaster Management Plan (NDMP-2019).

The key objectives of the APSDMP[1] are enlisted below.

- Assess various hazards, vulnerability, capacity and risk associated with state;
- Lay down various measures and guidelines for prevention and mitigation;
- Lay down preparedness measures for all stakeholders;
- Build the capacity of all stakeholders in the state to cope with the disaster and promote community based disaster management;
- Mainstream disaster management concerns into the developmental planning process;
- Develop efficient, streamlined and rapid disaster response and relief mechanisms in the state;
- Provide clarity on roles and responsibilities for stakeholders involved in various phases of disaster management.
- Ensure co-ordination and promote productive partnership with all other agencies related to the disaster management; and
- Commence recovery program as an opportunity to build back better in case of a future disaster by incorporating community participation in the program.

### 3.2.3 Review of National or State Level Climate Change Data

The following book was reviewed to evaluate national and regional climate data under baseline and climate scenarios.

- Krishnan, R., Sanjay, J., Gnanaseelan, C., Mujumdar, M., Kulkarni, A., Chakraborty, S. (2020) Assessment of climate change over the Indian region: a report of the Ministry of Earth Sciences (MoES), Government of India. https://doi.org/10.1007/978-981-15-4327-2

***Table 3-2*** summarises the climate change data for India and the region surrounding the study area for precipitation, temperature, heatwave, droughts, dust storms and cyclones. Following is the summary of key climate indicator projections in the region surrounding the study area-

- Average temperature is projected to rise by approximately 4.4°C relative to the recent past(1976–2005 average), under the RCP8.5 scenario.
- The projected mean change in the frequency of heatwaves for the mid- and end-twenty-first century under RCP8.5 scenario relative to the historical reference period (1976–2005) are medium over the study region (more than 3 days per summer season) compared to other parts of India.
- The precipitation changes in the long-term are projected with an increment of over 10% over study area and the adjoining territory of the nation.
- In RCP 8.5, very wet days to total wet day precipitation (R95PTOT), and the daily intensity index(SDII) are projected to rise by 15 and 40 %, by the end of the twenty-first century, whereas and maximum 5-

[7] https://apsdma.ap.gov.in/files/4afe4671523e4dae338d84cc9560ccde.pdf



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day precipitation (RX5day) is projected to rise by more than 40 %.

- Climate models project high likelihood of increase in the frequency (>3 events per decade),intensity and area under drought conditions by the end of the twenty-first century under theRCP8.5 scenario.

### Table 3-2: Summary of Observed and Projected Climatic Changes in India and Study Region

| Climate Driver or Hazard | Observed Changes in India | Projected Changes in India | Projected Changes in Andhra Pradesh Regional Level |
|---|---|---|---|
| Average Temperature | • India's average temperature has risen by around 0.7°C during1901–2018. | • By the end of the twenty-first century, average temperature over India is projected to rise by approximately 4.4°C relative to the recent past (1976–2005 average), under the RCP8.5 scenario | • Similar to the India level data |
| Warm Day and Warm Night | • In the recent 30-year period (1986–2015), temperatures of thewarmest day of the year have risen by about 0.63°C | • By the end of the twenty-first century, warmest day temperature is projected to rise by approximately 4.7°C relative to the corresponding temperatures in the recent past (1976–2005 average), under the RCP8.5 scenario.<br>• By the end of the twenty-first century, the frequencies of occurrence of warm days and warmnights are projected to increase by 55% and 70%, respectively, relative to the reference period 1976-2005, under the RCP8.5 scenario. | • No data was reported |
| Cold Night | • In the recent 30-year period (1986–2015), temperatures of thecoldest night of the year have risen by about 0.4°C | • By the end of the twenty-first century, this temperatureis projected to rise by approximately 5.5°C, relative to the corresponding temperatures in the recent past (1976–2005 average), under the RCP8.5 scenario. | • No data was reported |
| Average and Seasonal Precipitation | • In the recent period 1951–2015 as well as 1986–2015 theannual rainfall series shows decreasing trend which is not statistically significant.<br>• The summer monsoon precipitation (June to September) over India has declined by around 6% from 1951 to 2015.<br>• The variability of south Indian monsoon rainfall has increased inthe period 1959–2016. | • Indian summer monsoon precipitation is projectedto increase by 5–10% by end of twenty-first century.<br>• Indian winter monsoon precipitation is projected to increase between 10-35 % by the end of the twenty-first century. | • The CORDEX multi-RCM ensemble mean annual precipitation mid-term increase exceeds 10% over the west coast and the adjoining southern parts of the Indian peninsula for RCP4.5 scenario, |



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| Climate Driver or Hazard | Observed Changes in India | Projected Changes in India | Projected Changes in Andhra Pradesh Regional Level |
|---|---|---|---|
| | | | while in the long-term the change for this mid-scenario exceeds 20% over the south-central and the adjoining states |
| Precipitation Indices | There has been a shift in the recent period toward more frequent dry spells (27% higher during 1981–2011 relative to1951–1980) and more intense wet spells during the summermonsoon season. | • Relative changes in the contribution of very wet days to total wet day precipitation (R95PTOT), thedaily intensity index (SDII) and maximum 5-day precipitation (RX5day) with respect to 1976–2005 are projected to increase throughout the twenty- first century.<br>• In RCP8.5, R95PTOT and SDII are projected to rise by 15 and 21%, by the end of the twenty-first century, whereas RX5day is projected to rise by 38%. | • In RCP8.5, R95PTOT and SDII are projected to rise by 15 and 40 %,by the end of the twenty-first century, whereas RX5day is projected to rise by more than 40 %. |
| Drought | • The challenges faced are of a significantly different scale. The monsoon has become increasingly erratic and unpredictable, resulting in extreme rainfall on one hand and sudden drought on the other. Concerningly, the drought-prone area in India has expanded by 57 percent since 1997, while occurrences of heavy rainfall have surged by almost 85 percent since 2012. | • Climate models project high likelihood of increase in the frequency (>2 events per decade), intensity and area under drought conditions in India by the end of thetwenty-first century under the RCP8.5 scenario | • Climate models project high likelihood of increase in the frequency (>3 events per decade), intensity and area under drought conditions by the end of the twenty-first century under the RCP8.5 scenario. |
| Dust storms and Thunderstorms | • The annual mean frequencies of dust storms are Lower in southern states compare to northern states<br>• There is a decline in the dust loading of the atmosphere, or a decrease in intensity of dust storms, during the period 2000–2017 due to increasing pre-monsoon rains over the southern states and the Indo-Gangetic Plains.<br>• Analyses from the observations show a decline in number of thunderstorm days (1981–2010 relative to 1950– | • It is generally correlated that the temperature increase associated with global climate change will lead to increased thunderstorm intensity and associated heavy precipitation events. | • No data was reported |



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| Climate Driver or Hazard | Observed Changes in India | Projected Changes in India | Projected Changes in Andhra Pradesh Regional Level |
|---|---|---|---|
| | 1980) by 34% over the Indian region, while there is a rise in short- span high-intensity rain occurrences (mini-cloudbursts) alongthe west coast of India (5 per decade) | | |
| Cyclone | • There has been a significant increase in the annual frequency of tropical cyclones over the South Indian Ocean (SIO) basin from 1980-81 to 2010-11, the basin has an average of 9.3 tropical storms per year. In contrast, the frequency of very severe cyclonic storms (VSCSs) during the post-monsoon season has increased significantly (+1 event per decade) during the last<br>• From 1980–2007, 12.5 cyclones per year are formed, with 85% of them forming in November–April. | • Climate models project a rise in the intensity of tropicalcyclones in the SIO basin during the twenty-first century. | • No data was reported |



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# 4 Natural Hazard and Climate Change Assessment

This section documents the baseline for natural hazards based on historical data from global, regional, and national databases followed by qualitative evaluation of impacts of climate change on natural hazards.

It should be noted that this is a very high-level review of publicly available information, and no detailed site-specific analysis or modelling has been undertaken. Hence, further investigation may be required to quantify the risks in more detail for consideration of adaptation measures. The likely changes in natural hazards presented here are based on the possible relation between the natural hazards and climatic parameters.

The Study Area's elevation spans from 238 meters to 256 meters above mean sea level, with a distance of approximately 215 kilometres from the Bay of Bengal Sea in the eastward direction. A waterbody located east of the solar plant boundary, along with two streams—one flowing diagonally from the northwest to the southeast corners of the study area, and the other running east to west in the southern section—are connected to tributaries of the Penna River. The topography of Anantapur and YSR districts showcases a blend of terrains with flat to gentle slopes, including flat plains, undulating landscapes, and occasional hills. Both districts are predominantly characterized by fertile agricultural land, intersected by rivers, streams, and reservoirs. In some areas, particularly near the borders, there may be elevated regions with rugged terrain. Additionally, pockets of forested areas and shrublands can be found throughout both districts.

Based on the location of the study areas and general topography, hazards due to coastal flooding, sea level rise and landslides were not evaluated in the present assessment.

## 4.1 Water Availability

Anantapur and YSR districts are classified as extremely high according to the information available to WRI-Aqueduct tool. Availability of water at the study area location was assessed based on data from online water risk assessment tool WRI-Aqueduct Water Risk Atlas for Water Stress, and Seasonal Variability. The description of parameters assessed is provided in ***Table 4-1***.

Table 4-1: Indicators Assessed for Baseline Water Availability

| S.No. | Parameter | Definition |
|---|---|---|
| 1 | Baseline WaterStress (BWS) | 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 value indicates more competition amongusers. |
| 2 | Seasonal Variability(SV) | Seasonal variability indicates variation in water supply between months of theyear. |

### 4.1.1 Baseline

The baseline water stress map presented in ***Figure 4-1*** indicates 'Extremely High' water stress at Study Area. Higher water stress may be considered to indicate high competition for common water resource or lower availability of water in the area. Hence, the baseline hazard due to water stress is categorised to be **'Extremely High'**.

Seasonal Variability as presented in ***Figure 4-2*** indicated variation between 'Medium- High to High' for all study. Hence, baseline hazard towards water availability due to seasonal variability is considered to be **'High'**.


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Accordingly, considering 'Extremely High' water stress and 'High' seasonal variability, overall hazard towards water availability under baseline conditions is considered to be **'High'**.

## Table 4-2: Hazard due to Baseline Water Availability

| Study Area | Baseline Hazard | | Overall Baseline Hazard |
|---|---|---|---|
| | Water Stress | Seasonal variability | |
| 300MW Solar Plan | High | High | High |
| Transmission Line | High | High | High |

## Figure 4-1: Baseline Water Stress

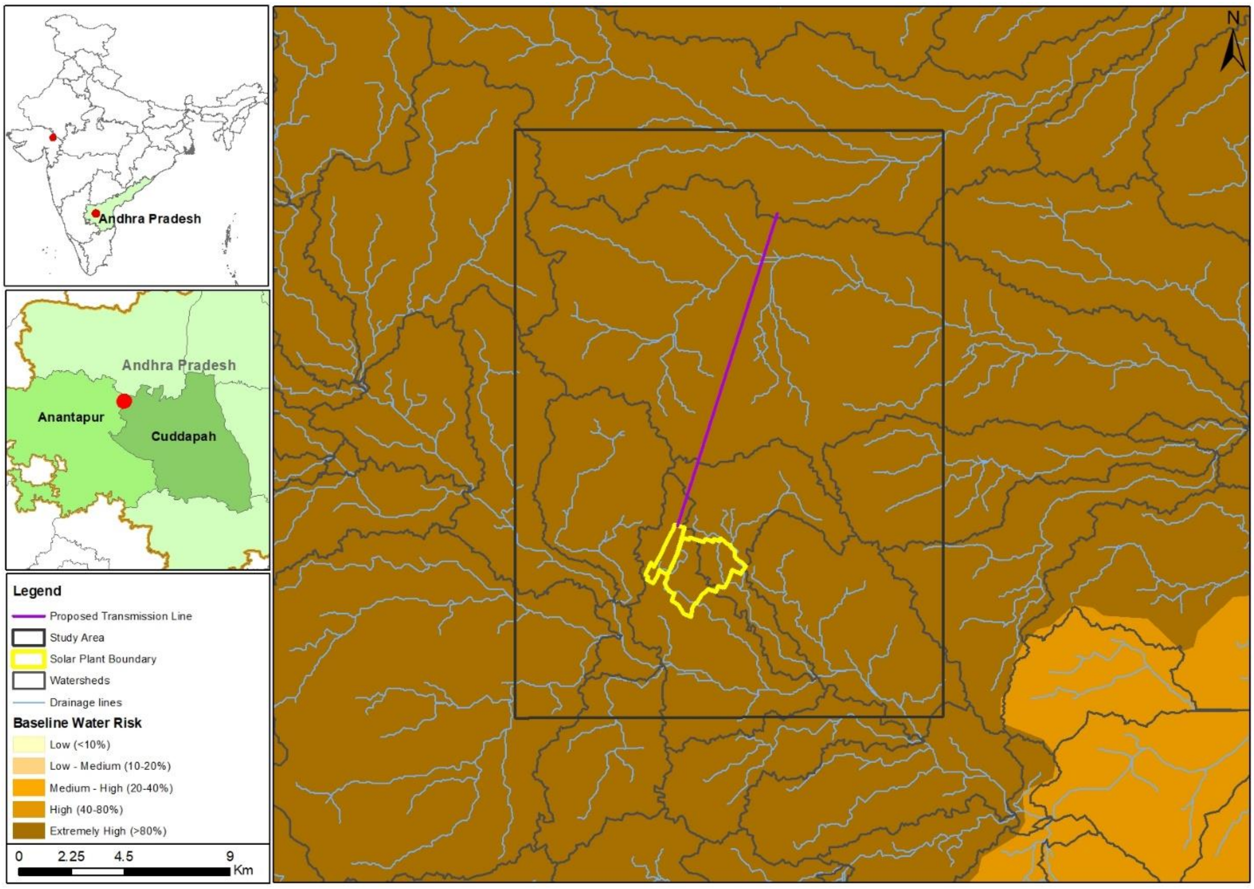




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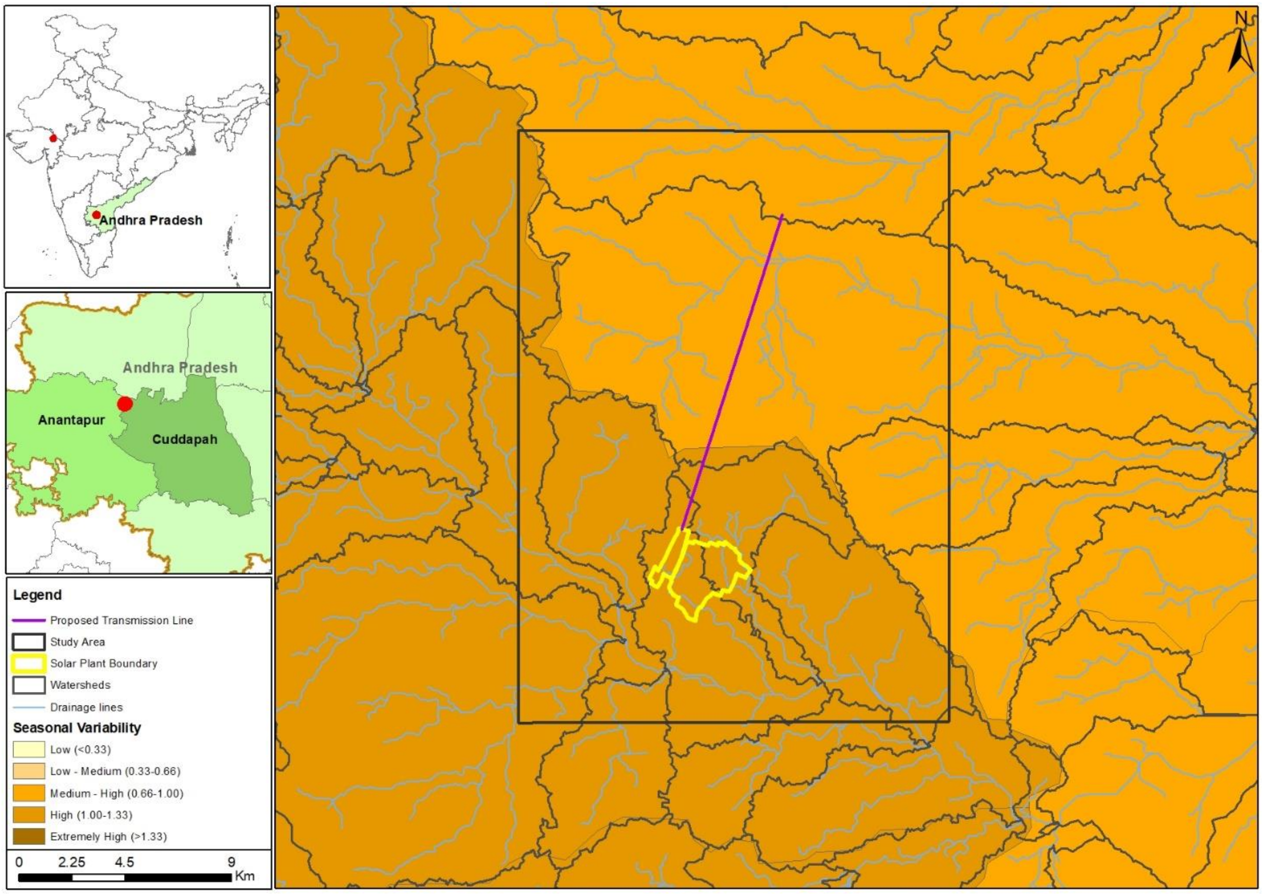
Figure 4-2: Seasonal Variability




### 4.1.2 Climate Change Projections

Further, projections for water stress and seasonal variability from WRI-Aqueduct were evaluated for RCP 4.5 and RCP 8.5 scenario for timeframes of 2030 and 2050. The projections for water stress under in 2030 under RCP 4.5 and RCP 8.5 and in 2050 under RCP 4.5 and RCP 8.5 are presented in ***Figure 4-3, Figure 4-4, Figure 4-5***, and ***Figure 4-6*** respectively. The projections for seasonal variability in 2030 under RCP 4.5 and RCP 8.5 and in 2050 under RCP 4.5 and RCP 8.5 are presented in ***Figure 4-7, Figure 4-8, Figure 4-9,*** and ***Figure 4-10*** respectively.

Climate change projections for water stress indicated the water stress to remain 'Extremely High' for all study areas under all climate scenario and timeframes. Whereas seasonal variability under all climate change scenarios and timeframes indicated as 'Extremely High' in all study areas.

Accordingly, overall hazard towards water availability under all climate change scenarios and timeframes is considered to be 'Extremely High'.

***Table 4-3*** summarises the future hazard for water availability for assets in the study area.



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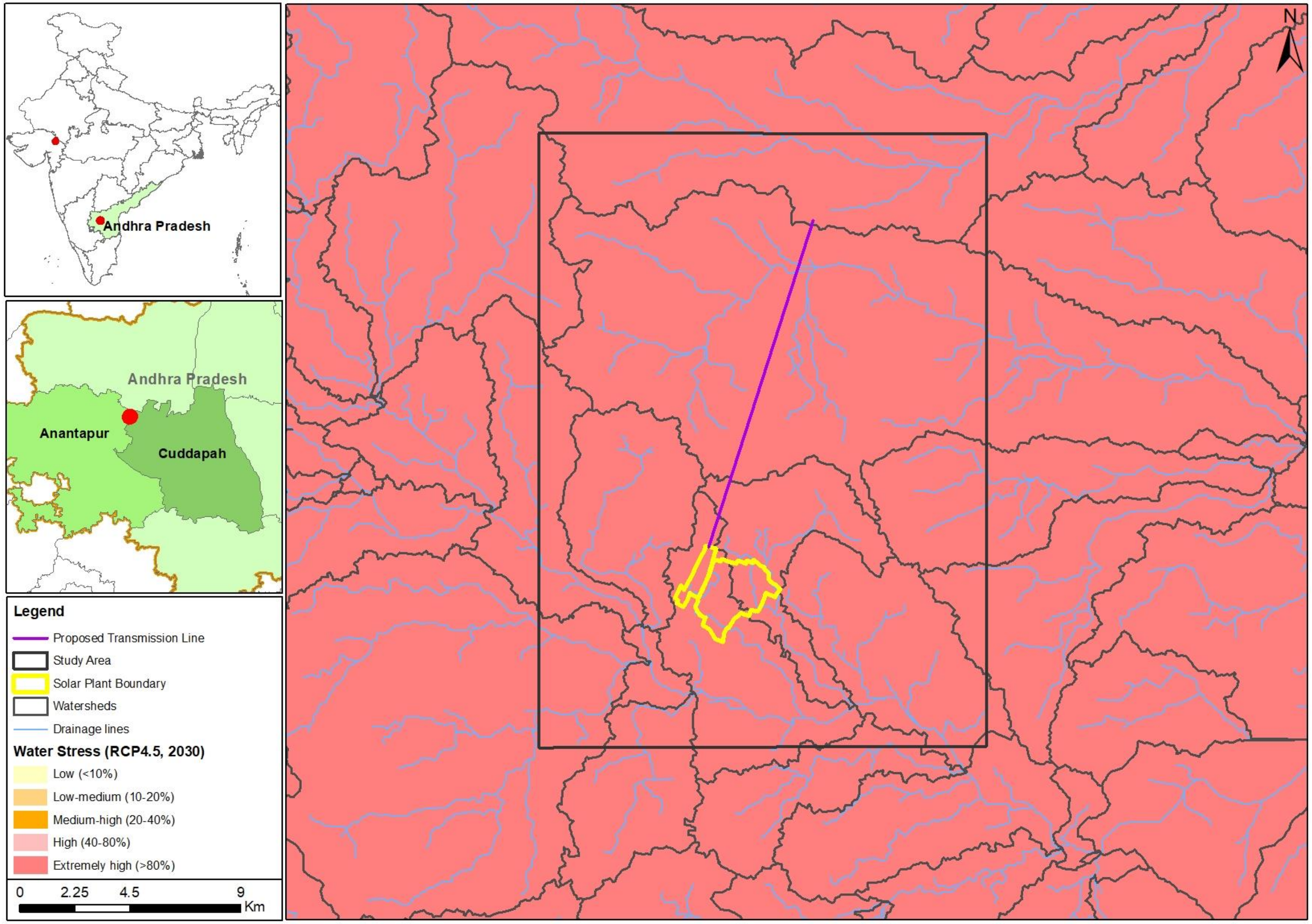
## Figure 4-3: Projected Water Stress in 2030 under RCP 4.5

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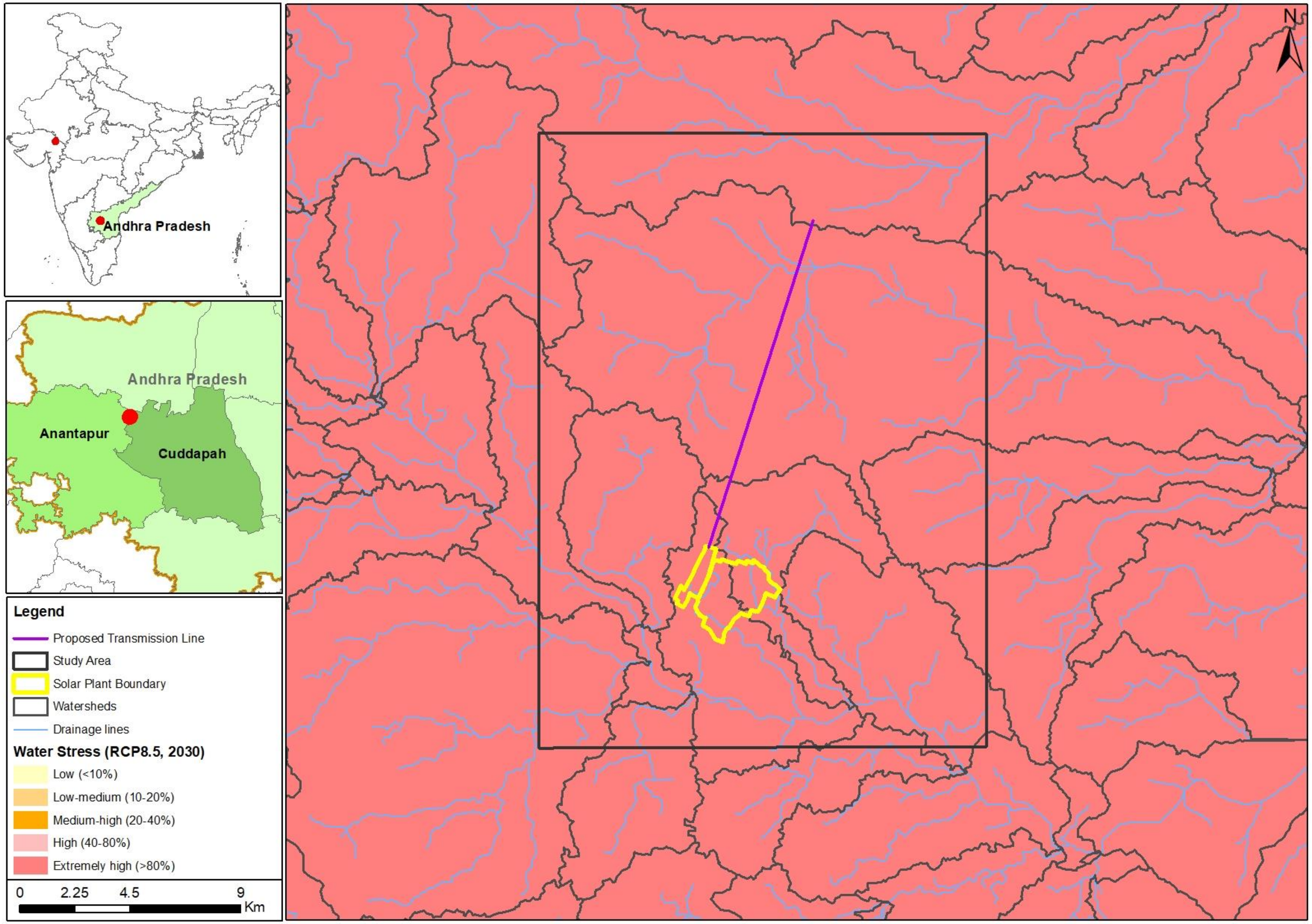
## Figure 4-4: Projected Water Stress in 2030 under RCP 8.5



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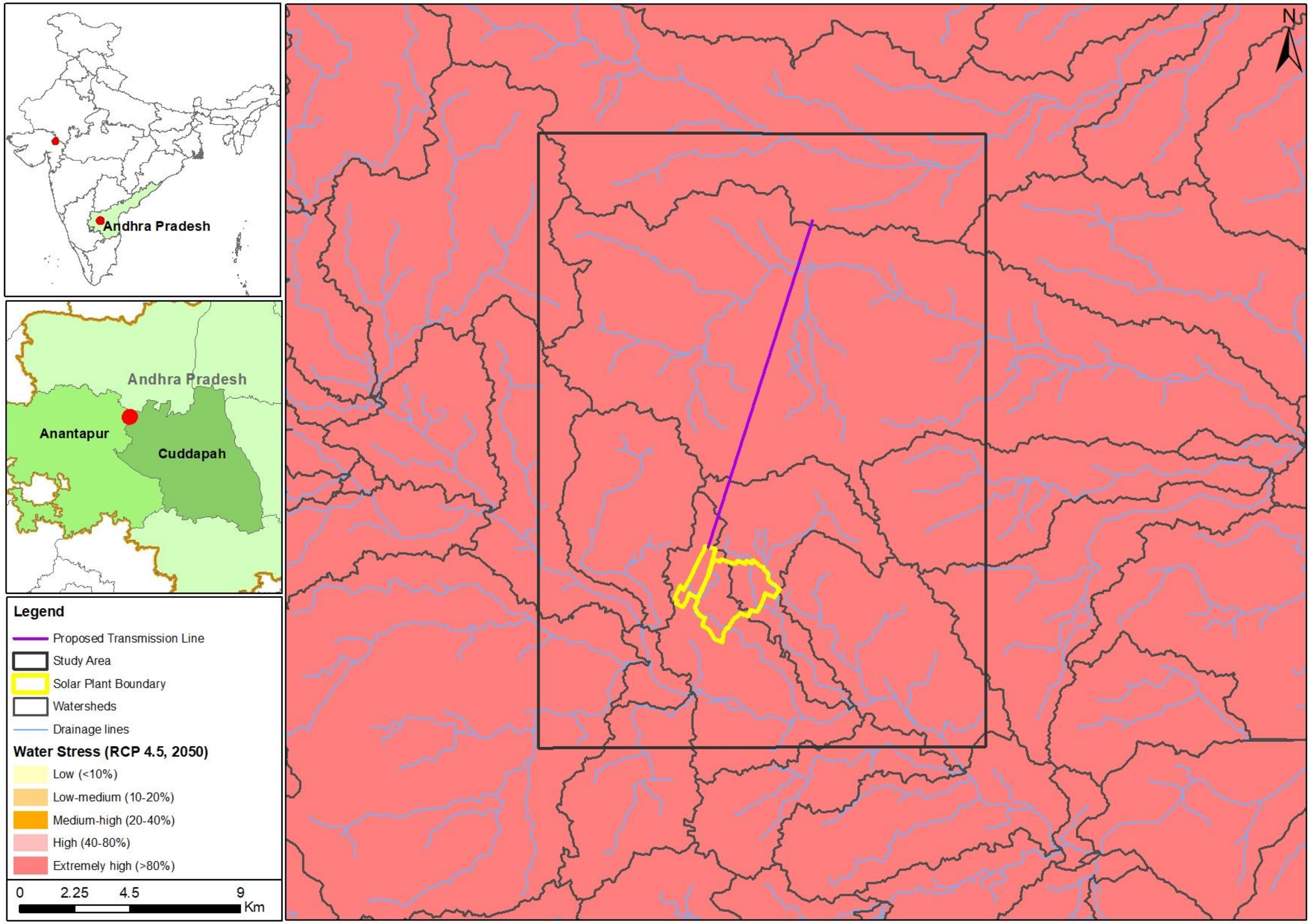
## Figure 4-5: Projected Water Stress in 2050 under RCP 4.5



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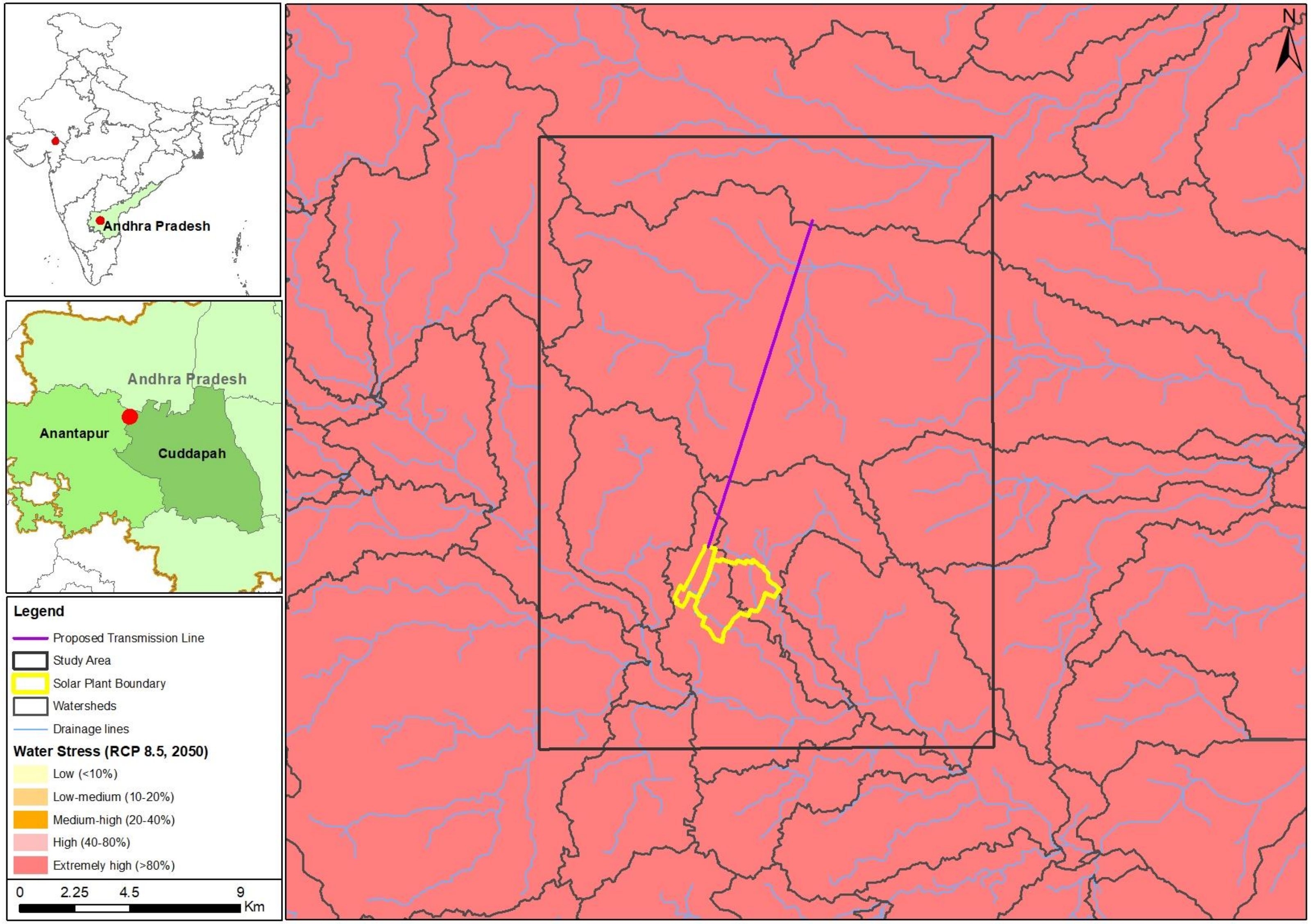
## Figure 4-6: Projected Water Stress in 2050 under RCP 8.5



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## Figure 4-7: Projected Seasonal Variability in 2030 under RCP 4.5

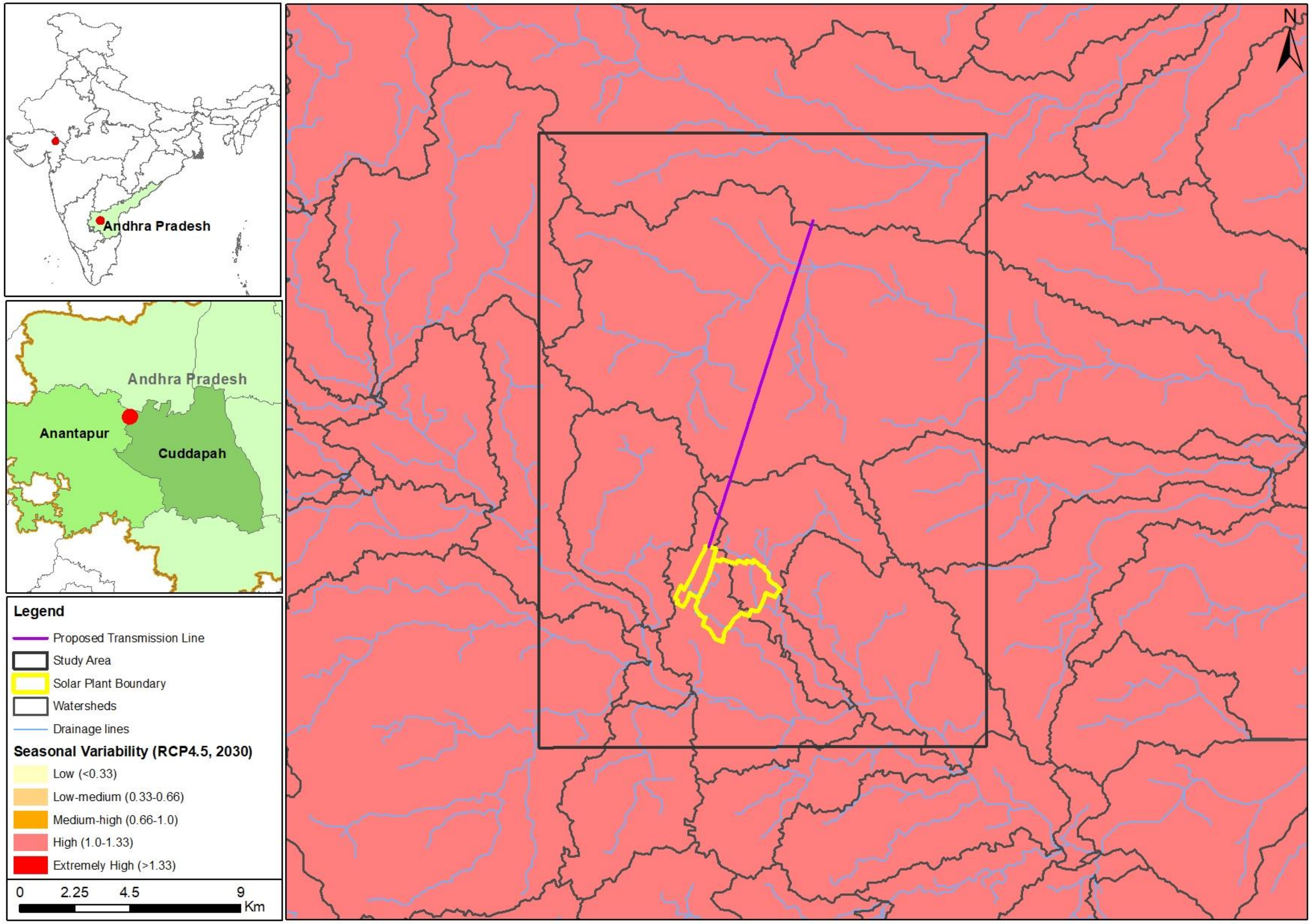




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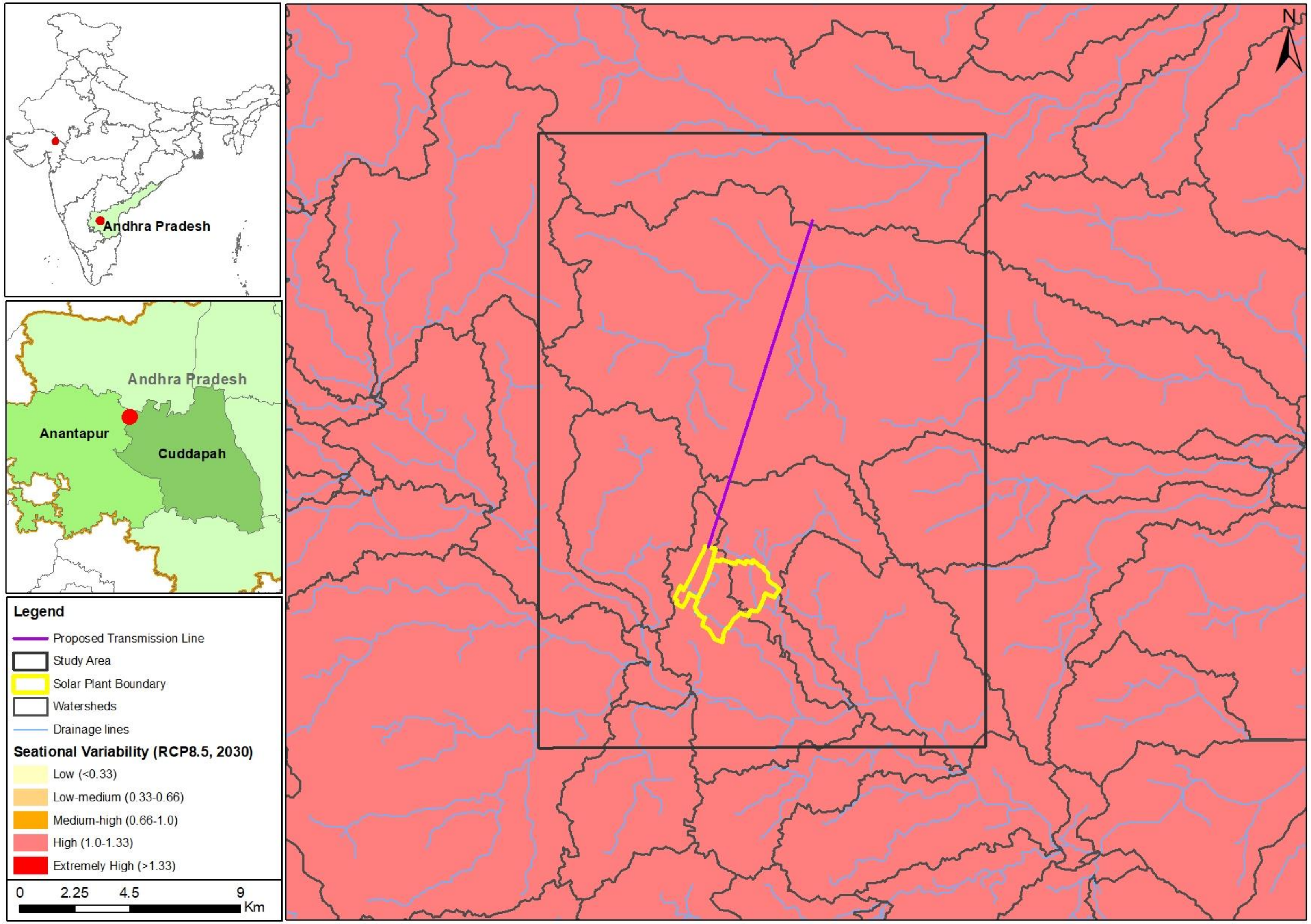
Figure 4-8: Projected Seasonal Variability in 2030 under RCP 8.5



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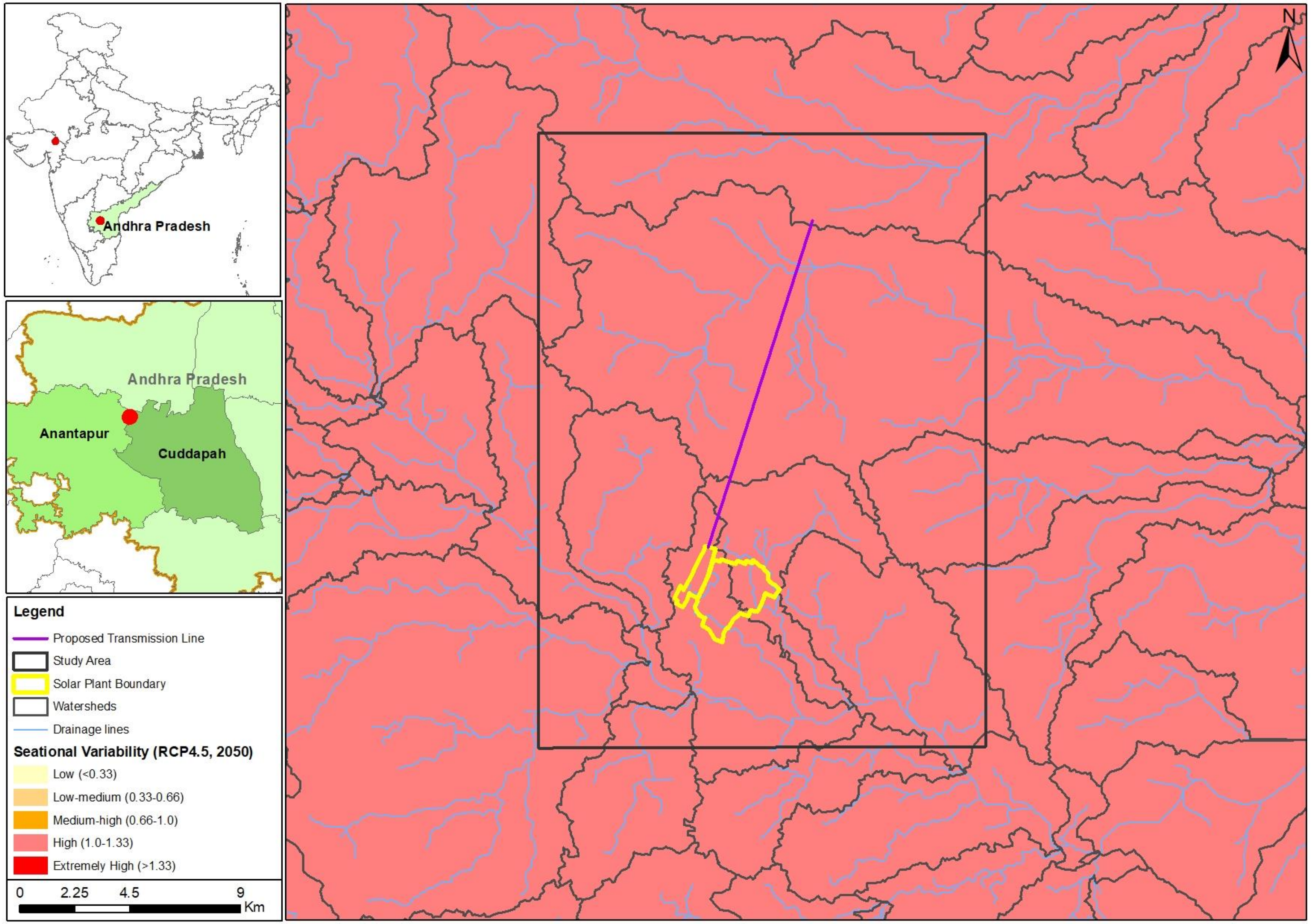
## Figure 4-9: Projected Seasonal Variability in 2050 under RCP 4.5



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## Figure 4-10: Projected Seasonal Variability in 2050 under RCP 8.5

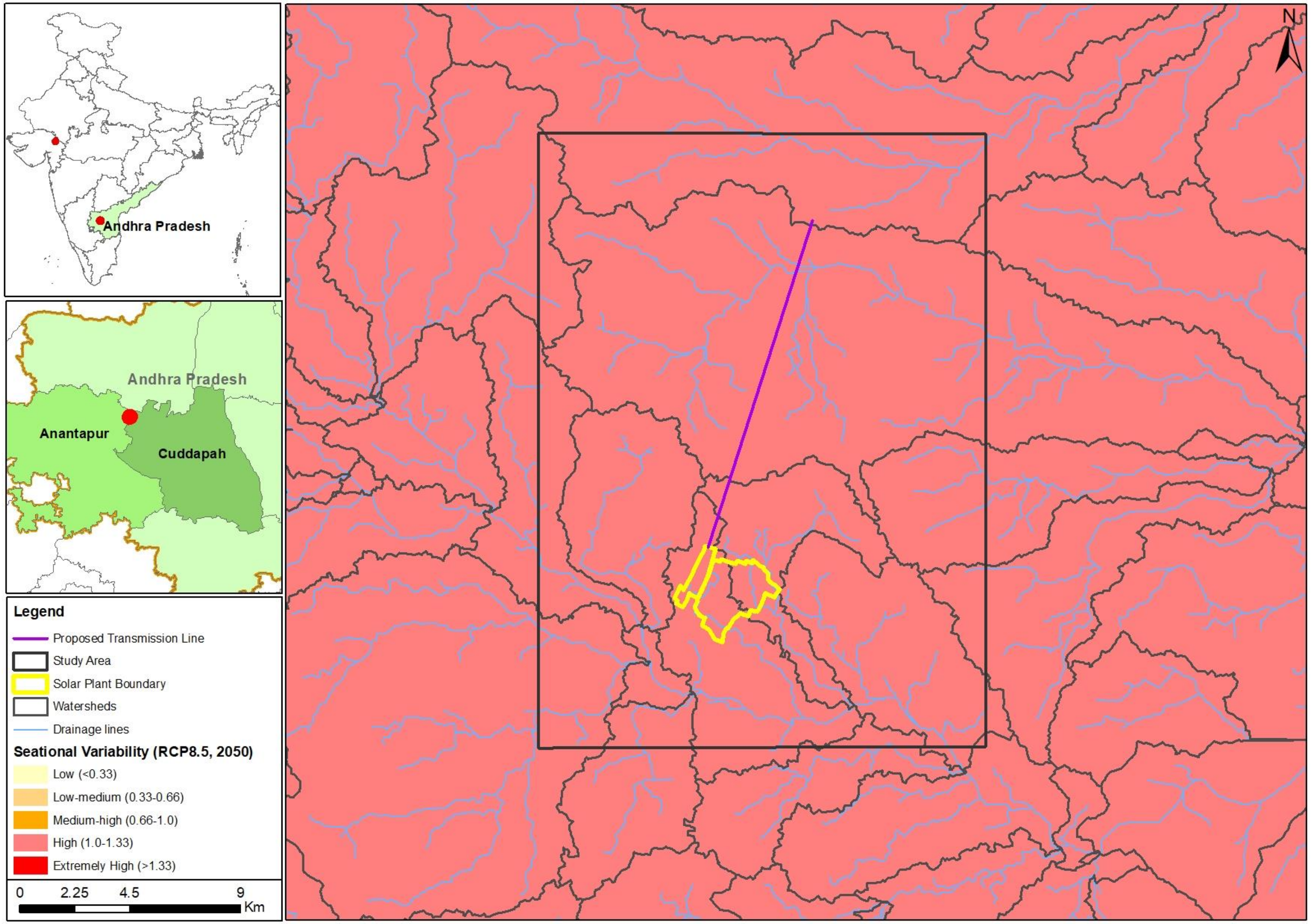




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Table 4-3: Future Hazard due to Water Availability

| Study Area | Future Hazard | | | | | | | | Overall Future Hazard | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Water Stress | | | | Seasonal Variability | | | | | | | |
| | RCP 4.5 | | RCP 8.5 | | RCP 4.5 | | RCP 8.5 | | RCP 4.5 | | RCP 8.5 | |
| | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 |
| 300MW Solar | High | High | High | High | High | High | High | High | High | High | High | High |
| Transmission Line | High | High | High | High | High | High | High | High | High | High | High | High |

### 4.1.3 Project Implications

- Limited water availability can delay construction timelines and increase costs.
- Projects located in ‘High’ water-scarce areas and need to prioritize water-efficient technologies or consider alternative locations with better water access.
- Water scarcity can have environmental implications for renewable energy projects. Drawing water from local sources may impact ecosystems and wildlife habitats.
- Regular washing or cleaning of solar panels are crucial for optimal energy output, but limited water availability makes this more difficult.
- Regulatory requirements related to water usage and environmental impact may affect project development and operation. Projects must comply with local regulations governing water usage, discharge, and environmental conservation.

## 4.2 Riverine Floods

Floods can be defined as logging of excess water resulting in submergence of dry lands. Floods can be categorised 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 ingress of the ocean or sea water via the coastal and/or estuarine systems onto open land. This could be a standalone of combined effect of tides, surges and sea level rise. Coastal flooding was not evaluated in the study area due to its inland location and significant distance from the coast in the order of ~215 km.

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 fresh water sources, propagation of water borne diseases and loss of life.

For evaluation of baseline flood hazard, flood hazard map prepared by building Material and Technology Promotion Council (BMTPC) of India were reviewed. The flood hazard map provides a thematic representation of areas in India likely get flooded.

Further the riverine flood hazard was also evaluated based on review of riverine flood inundation data from WRI-Aqueduct Flood Tool. The tool gives the riverine flood hazard for different return periods using GLOFRIS model. Where, GLOFRIS uses a global hydrological model, PCR-GLOBWB (Sutanudjaja


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et al. 2018), with a river and floodplain routing scheme to make long-term simulations of discharges and flood levels for several climate conditions.

### 4.2.1 Baseline

As per ThinkHazard Tool[8] and secondary information, Anantapur and YSR riverine flood hazard is classified as low. According to the BMTPC's State of Andhra Pradesh flood hazard map presented in ***Figure 4-11***, the study area is situated in close proximity to a flood-prone area. Therefore, low riverine flood hazard in considered for all the study areas.

Similarly, WRI-Aqueduct projections for flood at 100-year return period (***Figure 4-12***) indicated 'low' riverine flooding in any of the study areas. Accordingly, 'low' riverine flood hazard is considered for the entire study area under baseline conditions.

***Table 4-4*** summarises the baseline hazard for riverine flood for assets in the study area.

Table 4-4: Baseline Riverine Flood Hazard

| Study Area | Baseline Hazard | | Overall Baseline Hazard |
|---|---|---|---|
| | BMTPC | WRI-Aqueduct | |
| 300 MW Solar Plant | Low | Low | Low |
| Transmission Line | None | None | None |

[8] https://thinkhazard.org/en/report/17548-india-andhra-pradesh-anantapur/EH



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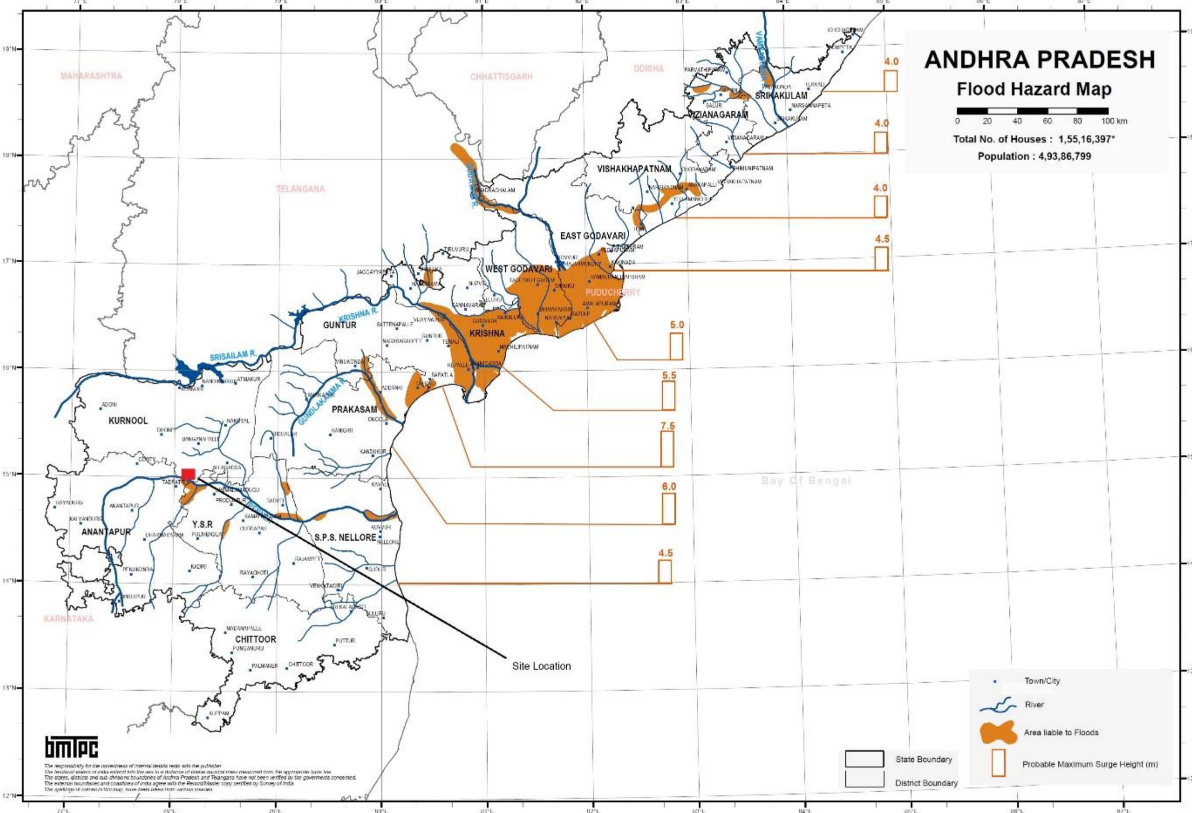
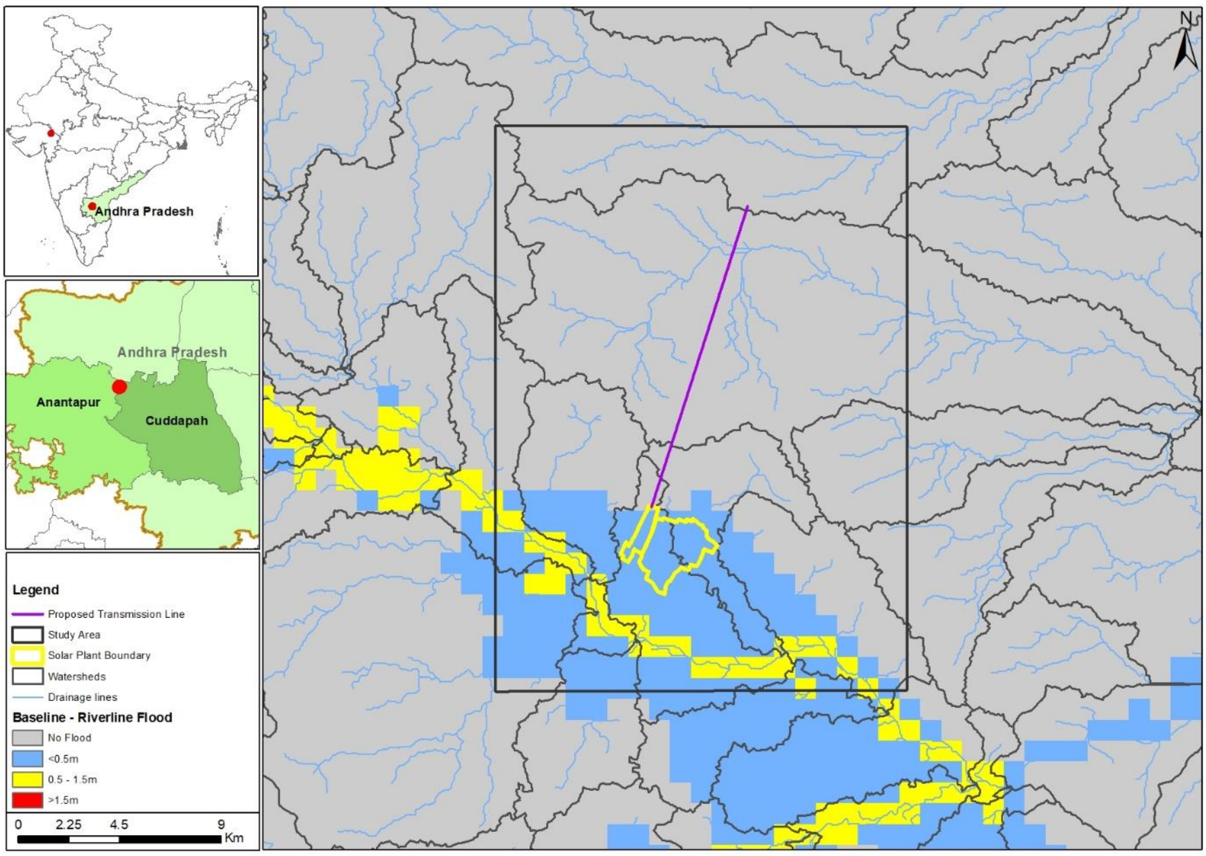
## Figure 4-11: Flood Hazard Map of India




## Figure 4-12: Baseline Riverine Flood Hazard



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### 4.2.2 Climate Change Projections

Riverine flood hazard under climate change conditions was evaluated based on the projections from WRI-Aqueduct Flood Tool for a 100-year return period flood as presented in ***Figure 4-13,*** and ***Figure 4-14*** for RCP4.5 and RCP8.5 for 2030 and ***Figure 4-15***, and ***Figure 4-16*** for RCP4.5 and RCP8.5 for 2050, respectively. Accordingly, low flooding was projected for the Solar plant and no flooding was projected for Transmission Line under all climate change scenarios and timeframes. Hence, low hazard due to riverine flood is considered for all study areas.

Climate change is likely to intensify the extreme rainfall events such as one day and five-day consecutive rainfall. The study area is likely to anticipate an increase in one day maximum rainfall by up to 8.4% by 2050 under RCP 8.5 scenario, and maximum consecutive five-day rainfall by up to 7.2% by 2050 under RCP 8.5 scenario. This may result in increased intensity/ frequency of flash floods in future.

***Table 4-5*** summarises the future hazard for riverine flood for assets in the study area.



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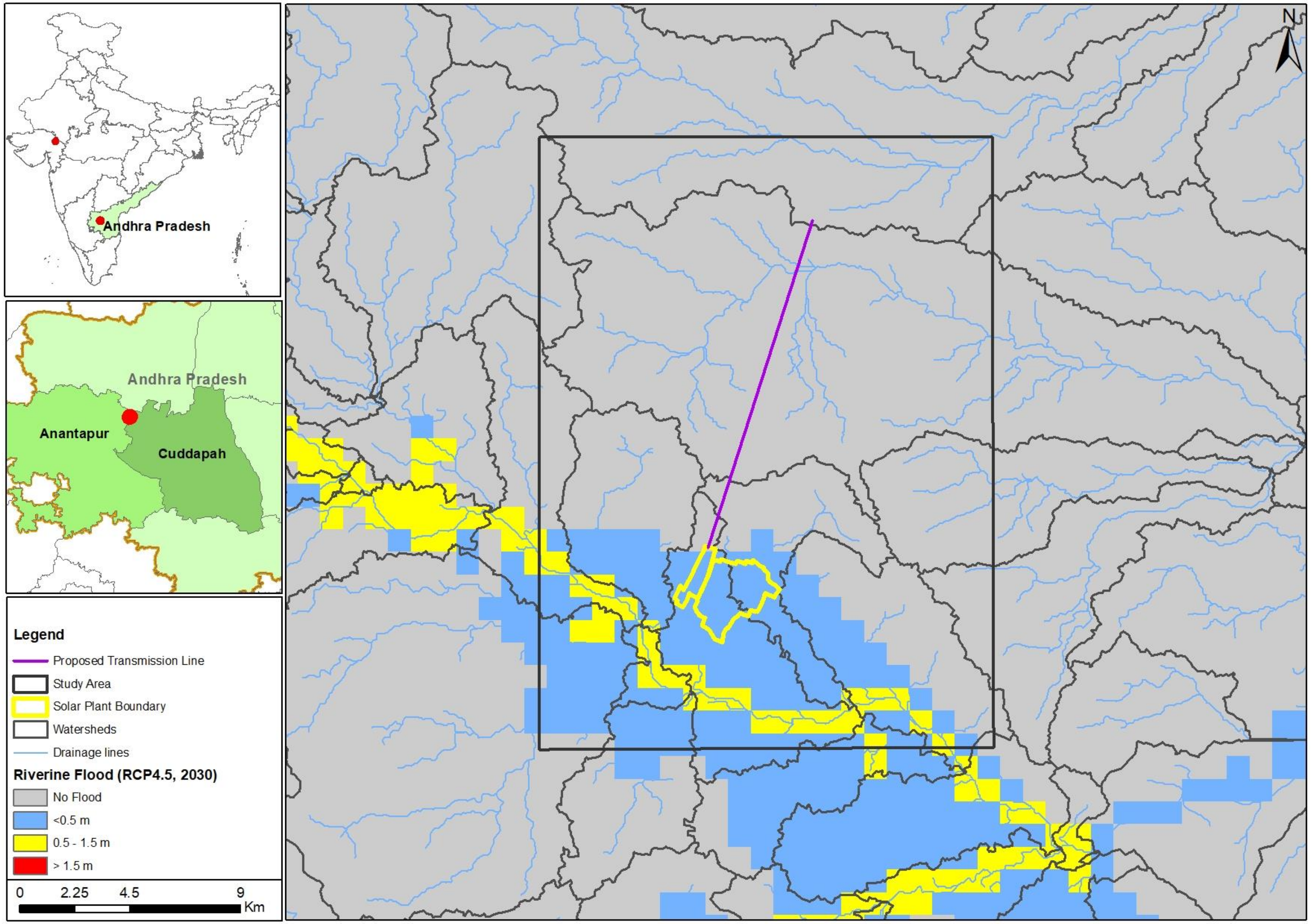
Figure 4-13: Projected Riverine Flood in 2030 under RCP 4.5

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## Figure 4-14: Projected Riverine Flood in 2030 under RCP 8.5

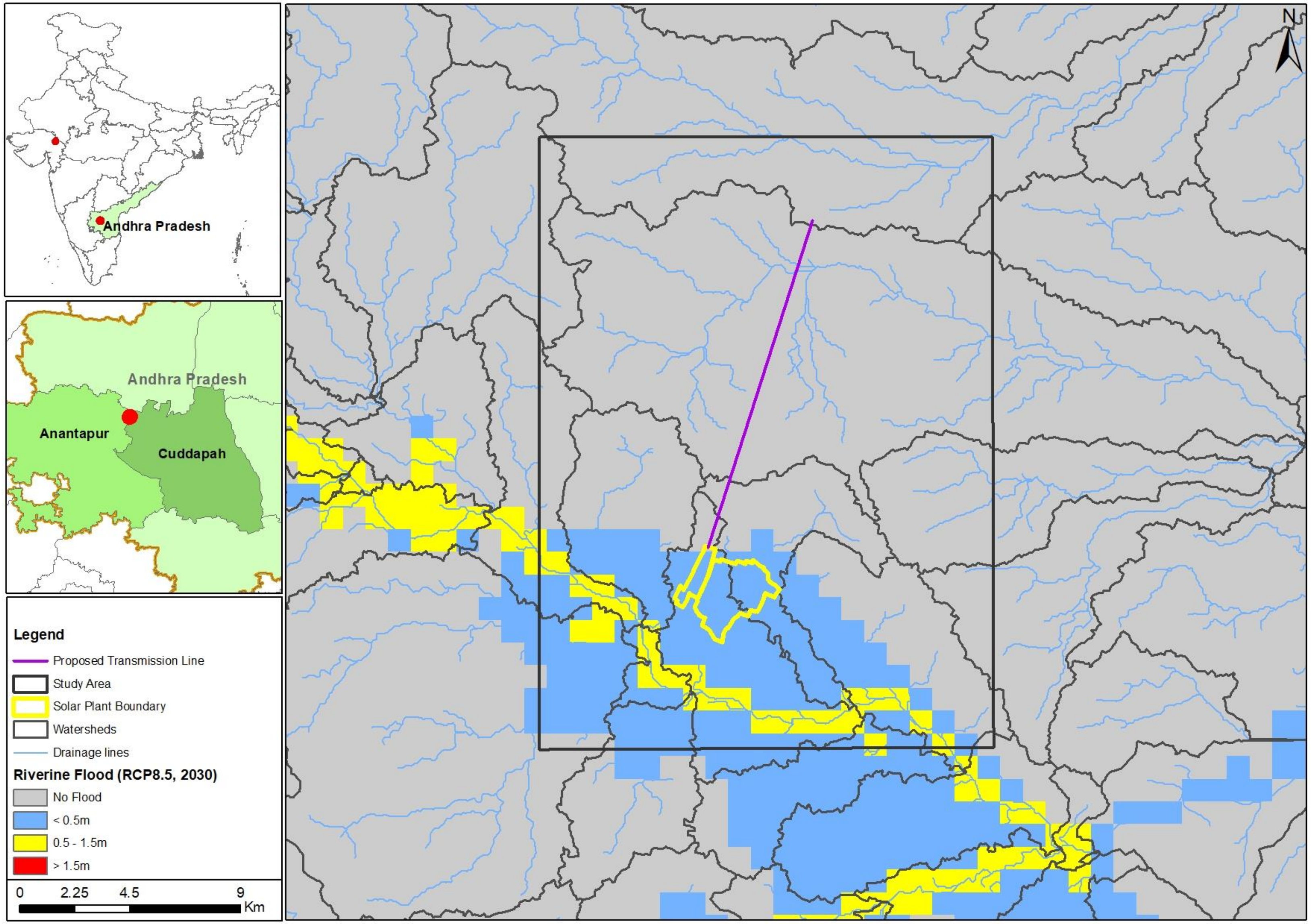




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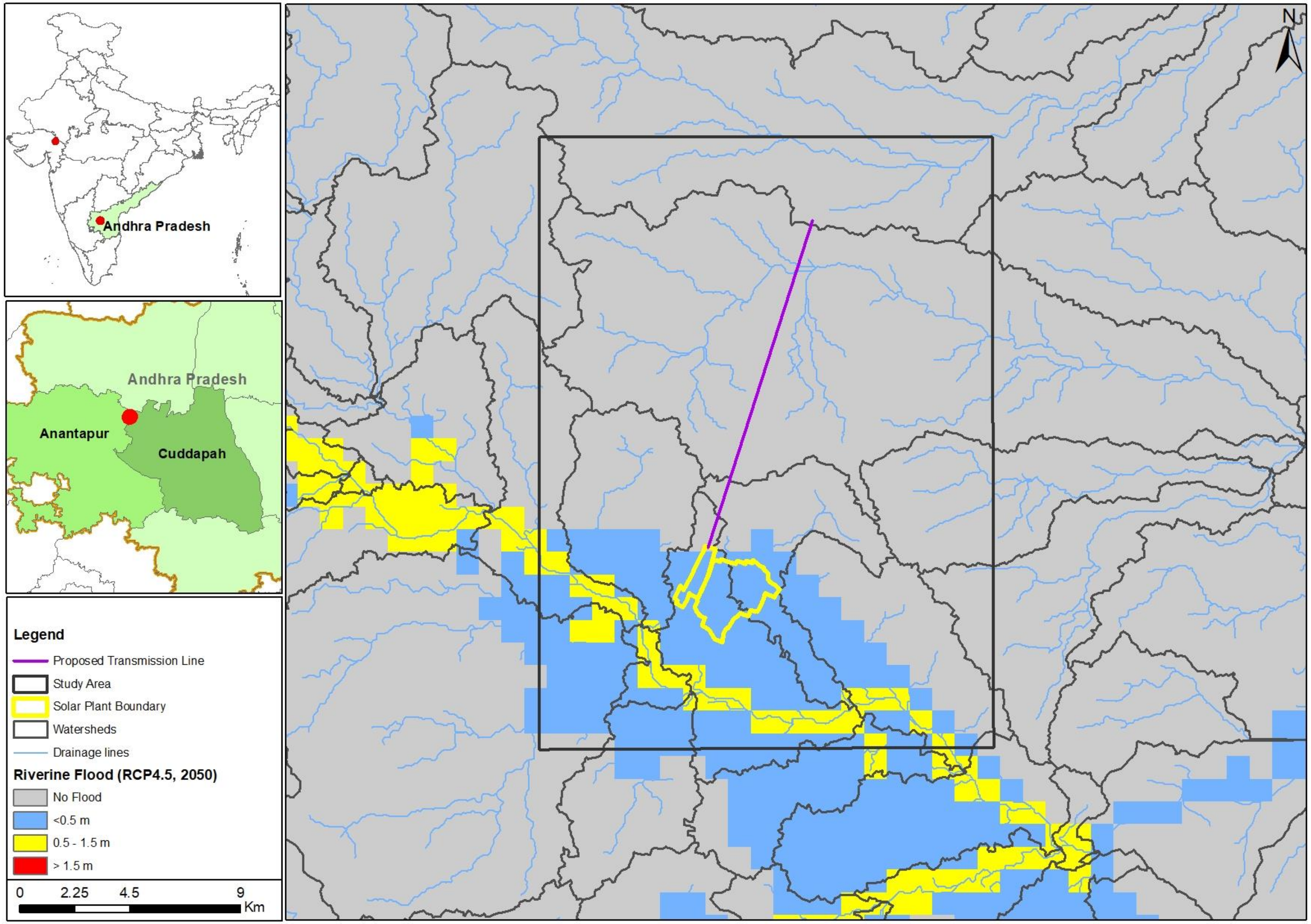
Figure 4-15: Projected Riverine Flood in 2050 under RCP 4.5



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## Figure 4-16: Projected Riverine Flood in 2050 under RCP 8.5

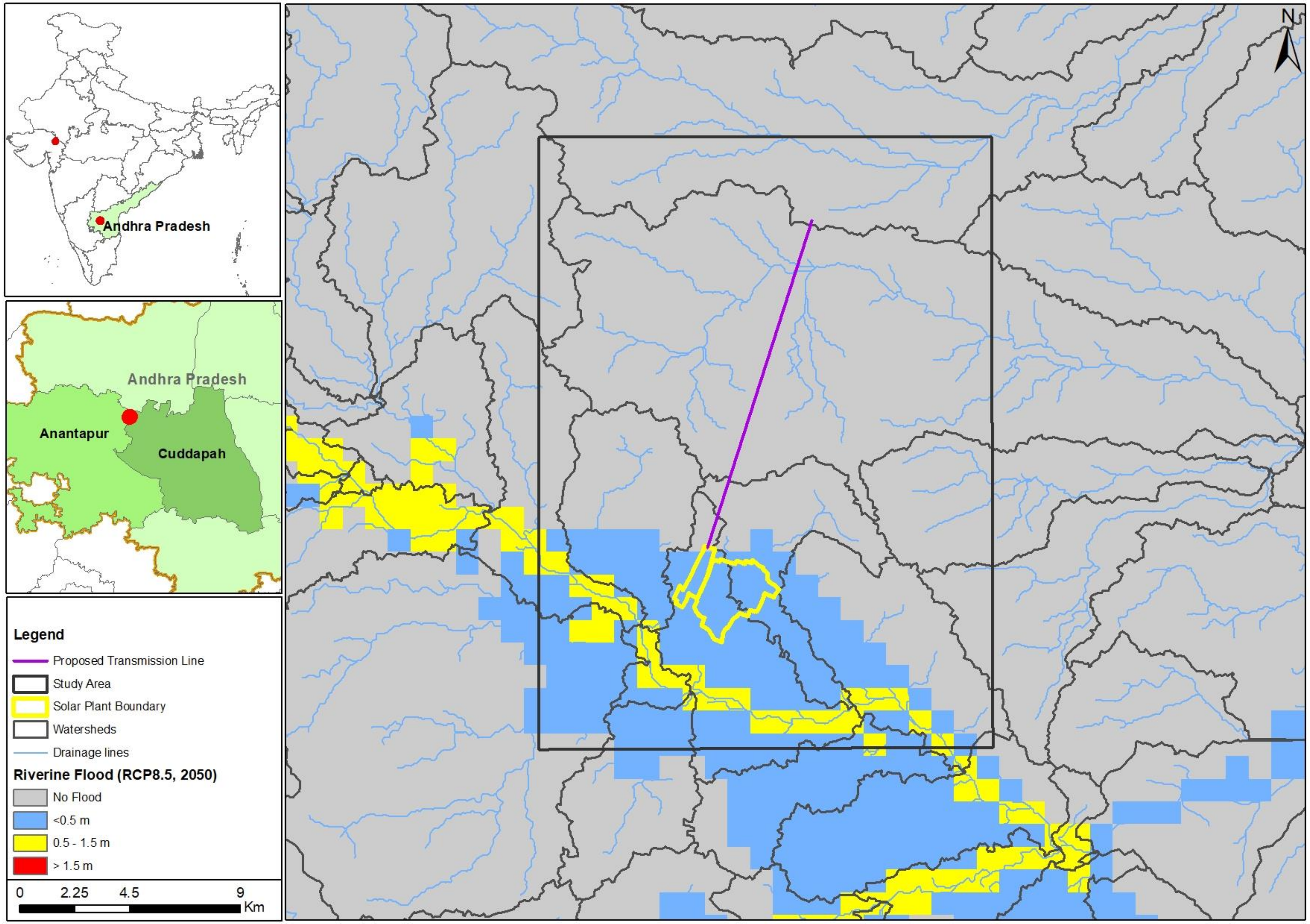




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Table 4-5: Future Hazard due to Riverine Floods

| Study Area | RCP 4.5 | | RCP 8.5 | |
|---|---|---|---|---|
| | 2030 | 2050 | 2030 | 2050 |
| 300 MW Solar Plant | Low | Low | Low | Low |
| Transmission Line | Low | Low | Low | Low |

### 4.2.3 Project Implications

Considering low riverine flood hazard at the Study area, no implications of the riverine floods on project are considered. However, localised flooding can take place due to future changes in land use/ topography and extreme precipitation (short duration high intensity rainfall events). Such flooding in general can occur as a flash flood and have range of implications including damage to assets, environmental liabilities, and safety of workers/ employees. General implications of flooding for a solar power project are given below.

- Flash floods can severely damage the project infrastructure in form of physical damage to components stationed close to ground level, water damage, washing out of loosely anchored component or temporary structure.
- Inundation due to floods may render some of the project areas inaccessible temporarily.
- Moreover, mud and silt brought by the flood water may get deposited within project area damaging the key assets or impeding the accessibility even after the flood water recedes.
- Also, flash floods can erode the topsoil and expose the foundation of the PV modules and endanger the stability of structure.
- Flash flood also pose a significant risk to the safety of people/ employees working in the open as they may get stuck or inundated during flash floods.

## 4.3 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)[9]. Extreme heat hazard is further categorised in four categories as presented in ***Table 4-6***.

Table 4-6: Classification Extreme Heat Risk

| Wet Bulb Temperature | Risk Classification |
|---|---|
| >32°C | High |
| >28°C | Medium |
| >25°C | Low |
| <25°C | Very Low |

[9] https://thinkhazard.org/en/report/17548-india-andhra-pradesh-anantapur/EH

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The Wet Bulb 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 shady 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[10]. Extreme heat was evaluated based on baseline and projected temperature.

### 4.3.1 Baseline

The extreme heat hazard was evaluated on a regional level using the Think Hazard report for study area (ThinkHazard, 2020) and is shown in ***Figure 4-17***. The extreme heat hazard at all assets in study area is reported to be 'High'. Media reports indicated that the maximum day time temperature to often exceed 44.5°C in the region. ***Table 4-7*** presents the maximum temperatures recorded in summer season in study area during last eight years.

Table 4-7: Daily Maximum Temperatures Recorded in Summer Season in Jaisalmer from 2015-2020

| Year | Anantapur Daily Maximum Temperature (°C) | YSR Daily Maximum Temperature (°C) |
|---|---|---|
| 2024 | 44.4[11] | 43.2[12] |
| 2021 | 40.0[13] | 39 [14] |
| 2016 | 44.5[15] | 44[16] |

Accordingly, the extreme heat hazard for all the study is considered to be '**High**' under baseline conditions. ***Table 4-8*** summarises the baseline heat hazard at all assets in the study area.

Table 4-8: Baseline Extreme Heat hazard

| Study area | Overall Baseline Hazard |
|---|---|
| 300 MW Solar Plant | High |
| Transmission Line | High |

[10] https://thinkhazard.org/en/report/17548-india-andhra-pradesh-anantapur/EH
[11] https://www.newstap.in/andhra-pradesh/anantapur-sizzles-at-444-degrees-all-time-heat-record-for-april-1529460#:~:text=Even%20on%20April%207%2C%202024,degrees%20in%20the%20Rayalaseema%20region.
[12] https://www.newstap.in/andhra-pradesh/anantapur-sizzles-at-444-degrees-all-time-heat-record-for-april-1529460#:~:text=Even%20on%20April%207%2C%202024,degrees%20in%20the%20Rayalaseema%20region.
[13] https://www.timeanddate.com/weather/@10775064/historic?month=9&year=2021
[14] https://www.timeanddate.com/weather/@10775064/historic?month=9&year=2021
[15] https://www.thehansindia.com/posts/index/Andhra-Pradesh/2016-04-14/AP-records-489-degree-temperature/221477
[16] https://www.thehansindia.com/posts/index/Andhra-Pradesh/2016-04-14/AP-records-489-degree-temperature/221477



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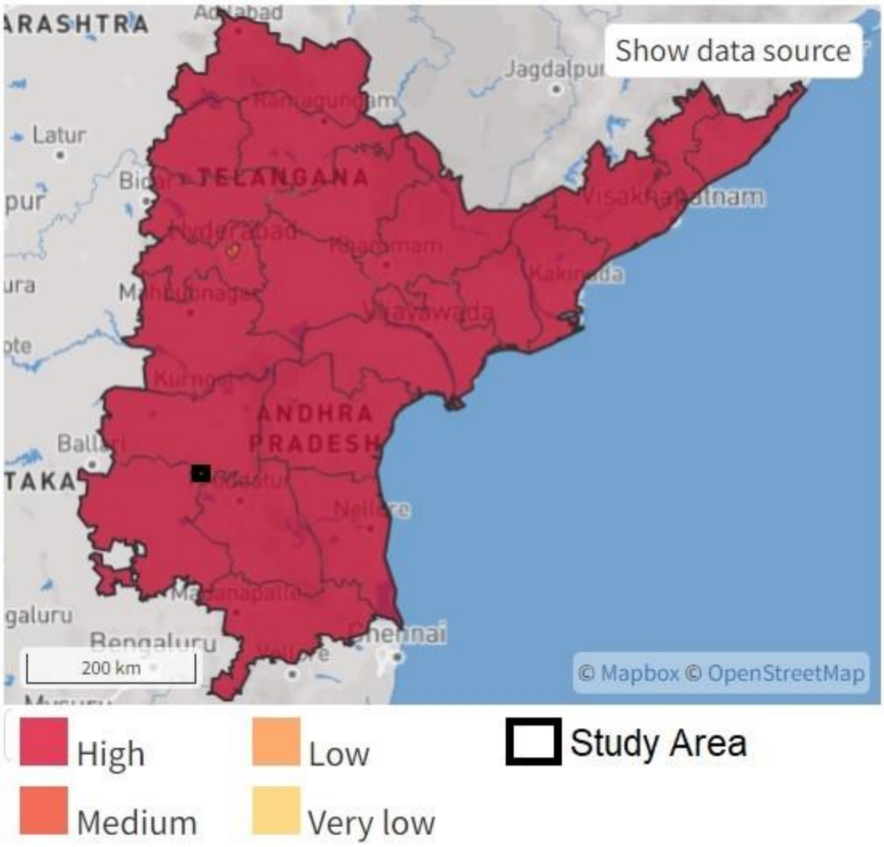
Figure 4-17: Baseline Extreme Heat Hazard




### 4.3.2 Climate Change Projections

In the absence of projections for wet bulb globe temperature the hazard due to extreme heat in future was evaluated based on projections for maximum temperature, extreme temperature, and warm spell duration index (WSDI). Climate change projection indicate increase in maximum daily temperature, and warm spell duration. Climate change projections indicate an increase in average maximum daily temperature by 1.46°C by 2050 and increase of 25 to more than 114 days in warm spell duration.

This indicates an increase in extreme temperatures and its duration which are likely to remain high. Hence, the hazard due to extreme heat for all study areas is considered to remain 'High' in future, under all climate change scenarios.

*Table 4-9* summarises the future hazard for extreme heat for assets in the study area.

Table 4-9: Future Hazard due to Extreme Heat at Study Area

| Study Area | RCP 4.5 | | RCP 8.5 | |
|---|---|---|---|---|
| | 2030 | 2050 | 2030 | 2050 |
| 300 MW Solar Plant | High | High | High | High |
| Transmission Line | High | High | High | High |



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### 4.3.3 Project Implications

Extreme heat conditions can have range of impacts including reduced efficiency of machines/tools and health impacts on human. Extreme heat may have following implications on the project components.

- High temperatures can decrease the efficiency of solar panels, leading to a reduction in electricity generation. Solar panels operate less efficiently as temperatures rise above their optimal operating range. For every 1°C increase in temperature above this range, solar panel efficiency can decrease by around 0.5%[17].
- Prolonged exposure to extreme heat can accelerate the degradation of solar panel materials, such as the photovoltaic cells and encapsulants. This degradation can lead to a decrease in the overall lifespan of the solar panels and a reduction in their long-term performance. However, the reduced efficiency due to higher temperature is likely to be compensated by the increased solar irradiance[18].
- Increased heat may also result in more energy demand. Literature review indicated that the high temperature also results in increased transmission losses. This may pose a challenge for supplying power in peak summer season when the demand is at peak[19].
- The likelihood of malfunctioning of step up/down transformers, electronic monitoring/ controlling units at high temperature cannot be ruled out.
- Extreme heat can also increase the risk of equipment failures and necessitate more frequent maintenance of solar plant components, including inverters, tracking systems, and electrical wiring. Components may be more prone to overheating and require additional cooling measures to maintain optimal performance.
- Any damage or reduced efficiency of the assets will result in loss of production. Also, it will incur additional costs for replacement of damaged asset or asset components.
- Extreme heat could affect the health & well-being of personnel working outdoors due to heat stress or heat exhaustion. It could also decrease the productivity of workers and reduce the working hours in the outdoor environment.
- During periods of extreme heat, water availability may be limited due to drought conditions or increased evaporation rates, posing challenges for maintaining adequate cooling of solar plant equipment.

## 4.4 Cyclone

A cyclone is a weather phenomenon characterized by strong winds rotating around a low-pressure centre. Cyclones form over warm ocean waters and can cause severe weather conditions including heavy rainfall, strong winds, storm surges, and sometimes tornadoes. Depending on their location and intensity, cyclones may be referred to as hurricanes, typhoons, or tropical cyclones. These storms can have significant impacts on coastal areas, leading to flooding, infrastructure damage, and loss of life.

In this assessment, the evaluation of cyclone hazards was conducted utilizing data from the Cyclone Occurrence Map of India provided by BMTPC (Building Materials and Technology Promotion Council), in conjunction with historical hurricane tracks data sourced from NOAA (National Oceanic and Atmospheric Administration).

The Cyclone Occurrence Map of India provided by BMTPC delineates regions susceptible to cyclone impacts and associated wind speeds (≥ 34kt or 17.5 m/s). This map is crafted utilizing sustained wind

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[17] https://blog.ecoflow.com/us/effects-of-temperature-on-solar-panel-efficiency/#:~:text=The%20optimal%20temperature%20for%20solar%20panels%20is%20around%2025%C2%B0,%25%2C%20affecting%20overall%20energy%20production.

[18] https://www.hindawi.com/journals/amete/2014/264506/

[19] https://iopscience.iop.org/article/10.1088/1748-9326/11/11/114008



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speed data recorded over a significant period from 1891 to 2008, offering insights into historical cyclone occurrences and their potential intensity across the Indian subcontinent.

The NOAA hurricane tracks tool offers a comprehensive database comprising tracks of more than 13,000 historical cyclones that have occurred since 1842. This extensive dataset provides valuable information on the paths and trajectories of past cyclonic events, facilitating detailed analysis and assessment of cyclone behaviour, patterns, and trends over the years.

### 4.4.1 Baseline

As per Cyclone occurrence map of India presented in ***Figure 4-18*** no historical cyclones are reported in the study area. Hence, no cyclone hazard at all assets within the study area was considered.

Based on the ThinkHazard data in ***Figure 4-19***, the cyclone hazard classification indicates a high risk based on current information. NOAA cyclone tracks data reveal that twelve cyclones have passed within approximately 100 km of the study area. The baseline assessment categorizes the hazard posed by cyclones as 'Medium' across all assets within the study area.

***Table 4-10*** summarises the baseline hazard from cyclone for assets in the study area.

Table 4-10: Baseline Cyclone Hazard for Assets in Study Area

| Study area | Overall Baseline Hazard |
|---|---|
| 300 MW Solar Plant | Medium |
| Transmission Line | Medium |



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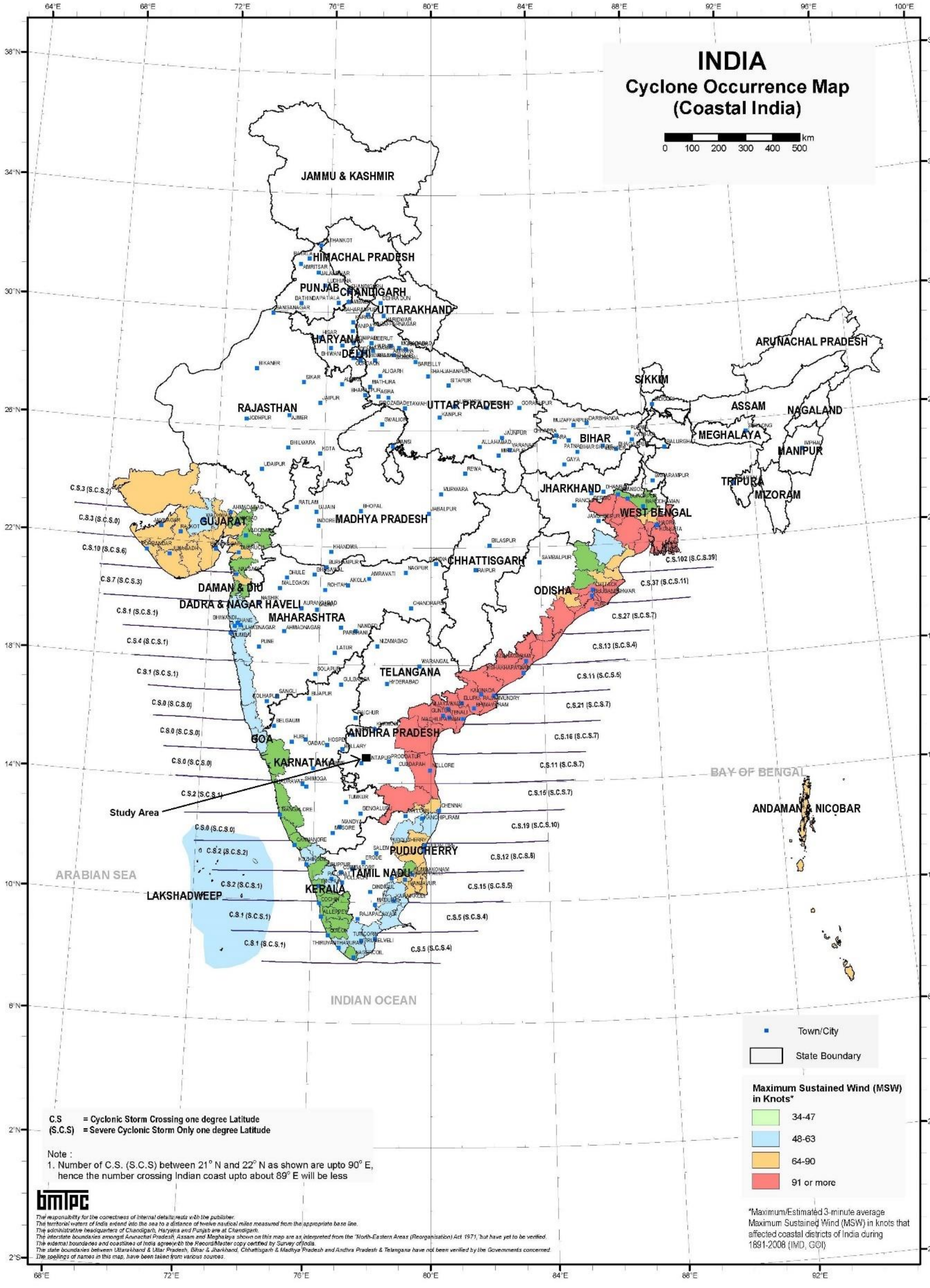
## Figure 4-18: Baseline Cyclone Hazard




BMTPC : Vulnerability Atlas- 3rd Edition; Peer Group, MoHUA; Map is Based on digitised data of SOI, GOI; Maximum Sustained Wind (MSW) Data from IMD, GOI. Disclaimer: The maps are solely for thematic presentation.



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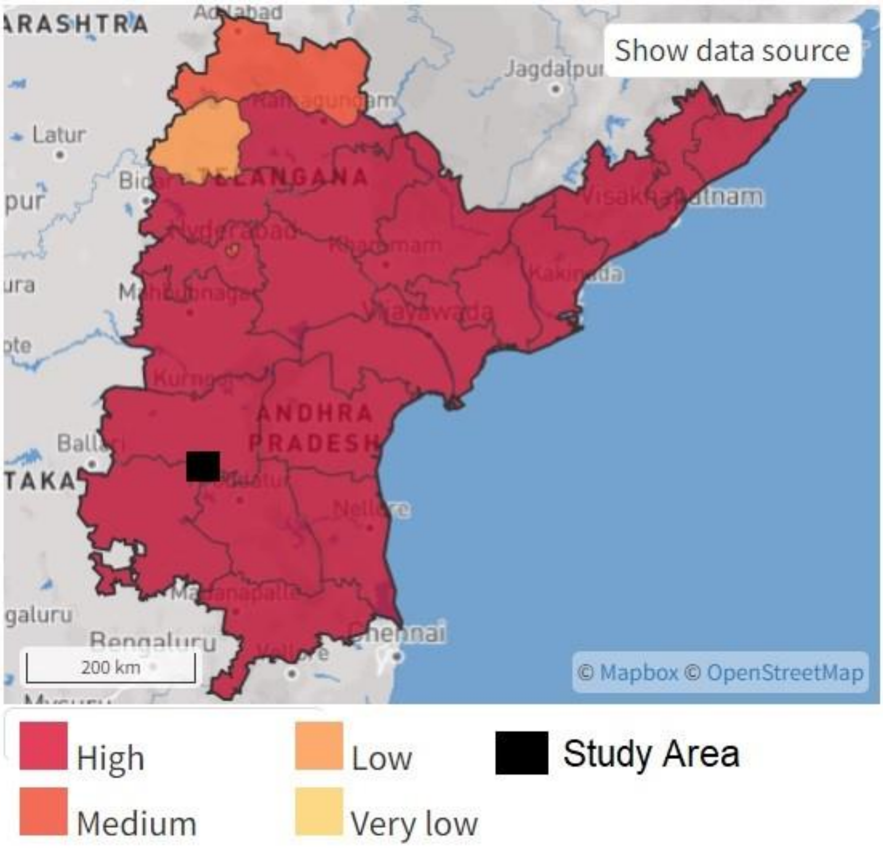
Figure 4-19: Baseline Cyclone Map




### 4.4.2 Climate Change Projections

Tropical cyclones, or typhoons, pose significant threats to coastal communities and infrastructure across various tropical oceans, with approximately 90 reported occurrences globally each year. Despite the advent of geo stationary satellites since the 1970s, the reported number of cyclones has remained relatively constant. However, substantial inter-annual and multi-decadal variations in frequency within individual ocean basins have been observed. Detecting trends in cyclone occurrences, including frequency and intensity, is challenging due to changes in observation technology, variations in identification protocols among different ocean basins, and limited availability of homogeneous data spanning 30-40 years.

Global reanalysis using homogeneous satellite data suggests an increasing trend in cyclone intensity, with a tentative link to climate change, but the observations spanning 30 years are insufficient to conclusively establish long-term trends. Climate change studies predict a likely increase in peak wind intensity and near-storm precipitation in future tropical cyclones, accompanied by a decrease in overall cyclone frequency. However, the spatial resolution of earlier models, such as those in the Fourth Assessment Report (AR4), is generally considered too coarse to accurately simulate tropical cyclones.

Recent advancements in downscaling techniques show some success in reproducing observed tropical cyclone characteristics, but limitations and high uncertainty persist in storm simulation. The IPCC's special report[20] on the 1.5°C scenario acknowledges that the limited observational period of

[20] https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap3_FINAL-1.pdf



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30-40 years is insufficient to definitively distinguish anthropogenic-induced changes from decadal variations in overall cyclone frequencies.

As per ThinkHazard[21], Global average tropical cyclone wind speed and rainfall is likely to increase in the future, and the global average frequency of tropical cyclones is likely to decrease or remain unchanged. It is possible that the frequency of the most intense tropical cyclones will increase substantially in some ocean regions (IPCC, 2013). The present hazard level in areas currently affected by tropical cyclones may increase in the long-term. Projects located in such areas should be robust to future increases in cyclone hazard.

However, considering historical cyclone occurrences and inland location of the study areas, the hazard due to cyclone under climate change scenario is considered to 'High'.

*Table 4-11* summarises the future hazard from cyclone for assets in the study area.

Table 4-11: Future Hazard due to Cyclone at Study Area

| Study Area | RCP 4.5 | | RCP 8.5 | |
|---|---|---|---|---|
| | 2030 | 2050 | 2030 | 2050 |
| 300 MW Solar Plant | High | High | High | High |
| Transmission Line | High | High | High | High |

### 4.4.3 Project Implications

- Cyclones can cause significant damage to solar panels due to high winds, heavy rain, and flying debris. Solar panels can be broken or dislodged by strong winds or flying objects.
- In general, as per NOAA, Category 1 Cyclones can damage the roofs of buildings, topple the shallow rooted tress, or snap the branches. It can inflict extensive damage to Transmission line resulting power outages over several days.
- Cyclones can disrupt the operation of solar projects by causing power outages, damage to electrical equipment, and interruptions in transmission lines. This can lead to reduced energy generation and financial losses for project operators.
- Cyclones pose safety risks to workers and personnel involved in the construction, operation, and maintenance of solar projects. Strong winds, heavy rain, and flying debris can endanger workers on-site, leading to injuries or fatalities.
- Damage caused by cyclones may result in project delays and increased construction and repair costs. Repairing or replacing damaged infrastructure, such as solar panels, can be time-consuming and expensive, potentially impacting project timelines and budgets.
- Enhancing the resilience of solar projects to cyclones is critical for minimizing the impacts of extreme weather events. This may involve implementing design modifications, such as stronger foundations or anchoring systems, and adopting advanced monitoring and forecasting technologies to better predict and prepare for cyclone events.

## 4.5 Wind Speed

Winds, characterized by the extensive movement of gases in Earth's atmosphere, primarily arise from variations in atmospheric pressure across the planet's surface and atmosphere. The gradient in

[21] https://thinkhazard.org/en/report/1485-india-andhra-pradesh/CY



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pressure prompts the propagation of winds at different speeds. While wind effects are noticeable locally, their behaviour is predominantly shaped by intricate processes operating at regional and global levels.

High-speed winds pose a significant threat to both natural and built environments, with the extent of damage determined by the velocity of the wind and the pressure differentials involved. These strong winds have the potential to inflict harm on tall structures and even lead to structural collapse. Additionally, they can uproot trees, trigger the propagation of dust and airborne contaminants, facilitate the spread of wildfires, and contribute to similar hazardous occurrences.

For the purpose of this assessment, average wind speed data 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, average wind speed data was complemented with hourly wind speed data for study area for the period 1985-2014 (Meteoblue, 2020[22]).

Moreover, in terms of assessing hazards, the maximum or extreme wind speeds were also analyzed utilizing the Wind Hazard Map of Andhra Pradesh, which was crafted by the Building Materials and Technology Promotion Council (BMTPC).

### 4.5.1 Baseline

According to the BMTPC, Andhra Pradesh State Disaster Management Plan and secondary information, Anantapur and YSR districts are categorized as Moderate Damage Risk Zone, indicating medium wind hazard levels.

Further, based on the average wind speed map as presented in ***Figure 4-20*** the hazard due to average wind speed at all study areas is evaluated to be 'Low'.

As per the wind hazard map of Andhra Pradesh presented in ***Figure 4-21*** the wind hazard at all the study areas is reported to under 'Moderate Damage Risk Zone-B' category (wind speed of 39 m/s). Accordingly, wind hazard at all the study areas is considered to be 'medium'. Therefore, from a hazard standpoint, the overall wind hazard in all study areas is deemed to be 'medium'.

***Table 4-12***: Baseline Wind Hazard in Study Area summarises the baseline hazard from average and maximum wind speed for assets in the study area.

Table 4-12: Baseline Wind Hazard in Study Area

| Study Area | Baseline Hazard | | Overall Baseline Hazard |
|---|---|---|---|
| | Average Wind Speed | Maximum Wind Speed | |
| 300 MW Solar Plant | Medium | Medium | Medium |
| Transmission Line | Medium | Medium | Medium |

[22] Meteoblue, 2020. https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/balikpapan_indonesia_1650527\



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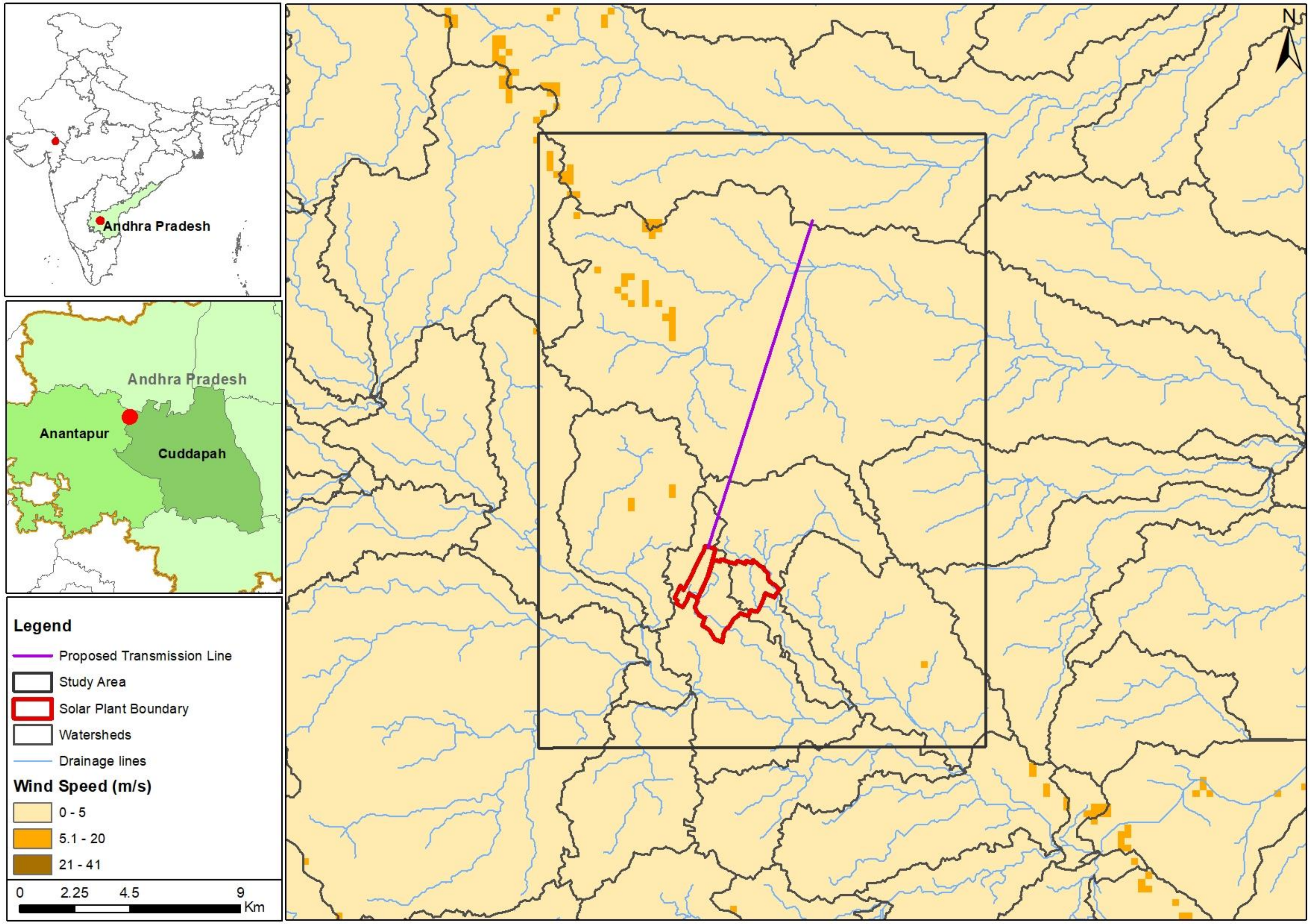
Figure 4-20: Baseline Average Wind Speed (at10m above the ground level)



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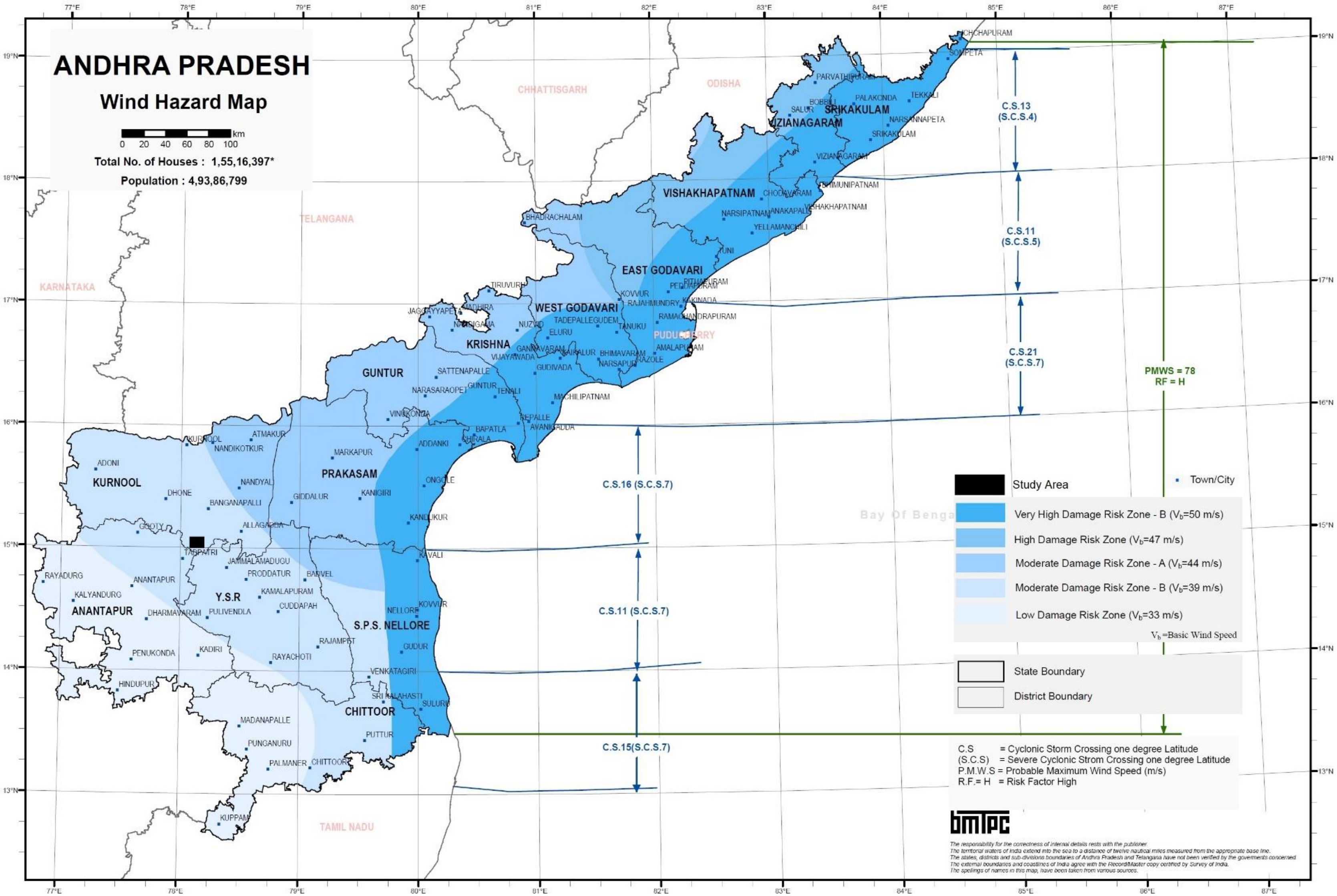
## Figure 4-21: Baseline Extreme Wind Speed



### 4.5.2 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 indicated rapid increases in wind speed across the globe since 2010 (Zeng et al., 2019)[23]. Considering the limited information available on wind speed projections and high uncertainty, the wind hazard under a climate change scenario and as per recent study is considered too 'Medium'. ***Table 4-13*** presents hazard due to average and extreme wind conditions in future.

Table 4-13: Future Hazard due to Wind

| Study Area | Future Hazard | | | | | | | | Overall Future Hazard | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average Wind Speed | | | | Maximum Wind Speed | | | | | | | |
| | RCP 4.5 | | RCP 8.5 | | RCP 4.5 | | RCP 8.5 | | RCP 4.5 | | RCP 8.5 | |
| | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 |
| 300 MW Solar Plant | Medium | Medium | Medium | Medium | Medium | Medium | Medium | Medium | Medium | Medium | Medium | Medium |
| Transmission Line | Medium | Medium | Medium | Medium | Medium | Medium | Medium | Medium | Medium | Medium | Medium | Medium |

### 4.5.3 Project Implication

- Solar panels are less affected by medium wind speeds; however, moderate winds can lead to mechanical stress on solar panel mounts and supporting structures. While solar panels are designed to withstand typical wind loads, sustained medium wind speeds may increase the risk of damage or dislodgement, particularly if the panels are not securely installed.
- Medium wind speeds may require adjustments to operational strategies for solar projects. Solar project operators may need to monitor panel stability and take preventive measures to mitigate the risk of damage.
- Solar projects may experience fluctuations in energy output due to changes in sunlight intensity and cloud cover associated with moderate wind conditions.
- Medium wind speeds may increase maintenance requirements for solar projects. Solar panels may need to be checked for signs of wear or damage caused by wind-induced vibrations.

## 4.6 Thunderstorms and Lightning

As per NOAA thunderstorm or convective storm is a storm when a rain shower is associated with lightning and thunder. Such storms are usually created by heating of ground surface resulting upward atmospheric motion that transport moisture along with air. Thunderstorms may lead to high wind conditions with gust speed exceeding 25 m/s, lightning strikes, extreme rainfall and flash floods, and hail showers[24].

As per National Severe Storm Laboratory (NSSL), lightning is a giant spark of electricity in the atmosphere between clouds, the air, or the ground. The process triggers instant release of energy of

[23] Zeng, Z., Ziegler, A. D., Searchinger, T., Yang, L., Chen, A., Ju, K., and. Wood, E. F. (2019). A reversal in global terrestrial stilling and its implications for wind energy production. Nature Climate Change, 9, 979-985. doi: https://doi.org/10.1038/s41558- 019-0622-6



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the order of 1 Gigajoule. Lightning can be caused in three (3) mechanisms; viz within the same thunder cloud, between two (2) thunderclouds or between a thundercloud and ground.

Lighting can cause damage to natural and built environment. Objects struck by lightning experience heat and magnetic forces of great magnitude. It can affect trees, by vaporizing the sap resulting in bursting of bark, damage to tall buildings and structures and several injuries or loss of life.

For the purpose of present assessment, thunderstorms and lightning were evaluated based on the thunderstorm incidence map of India from BMTPC and lightning flash data from NASA.

### 4.6.1 Baseline

Thunderstorm incidence map of India as presented in ***Figure 4-2*** indicated historical occurrences of thunderstorm in and around the Study area. Accordingly, the locations around the study were reported historical occurrences of thunderstorm in the range of 16-30 during the period of 1981-2010. Accordingly, BMTPC thunderstorm risk across all study areas is categorized at study area as 'Low'.

### 4.6.2 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 indicate that predicting changes in thunderstorm directly is difficult task, and hence generally changes in frequency of 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 CMIP5. In general, the studies indicate an increase in potential for intense thunderstorms in warming atmosphere.

***Figure 4-23*** indicates the likely increase in number of days per year with conditions favourable for severe thunderstorm due to increased CAPE by end of the century. Hence, increase in thunderstorm and lightning activity can be expected in future under climate change scenario.



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## Figure 4-22: Baseline Occurrence of Thunderstorms


BMTPC: Vulnerability Atlas - 3rd Edition: Peer Group, MoHUA, GOI; Map is Based on digitised data of SOI;Thunderstorm data from IMD. Disclaimer: The maps are solely for thematic presentation.



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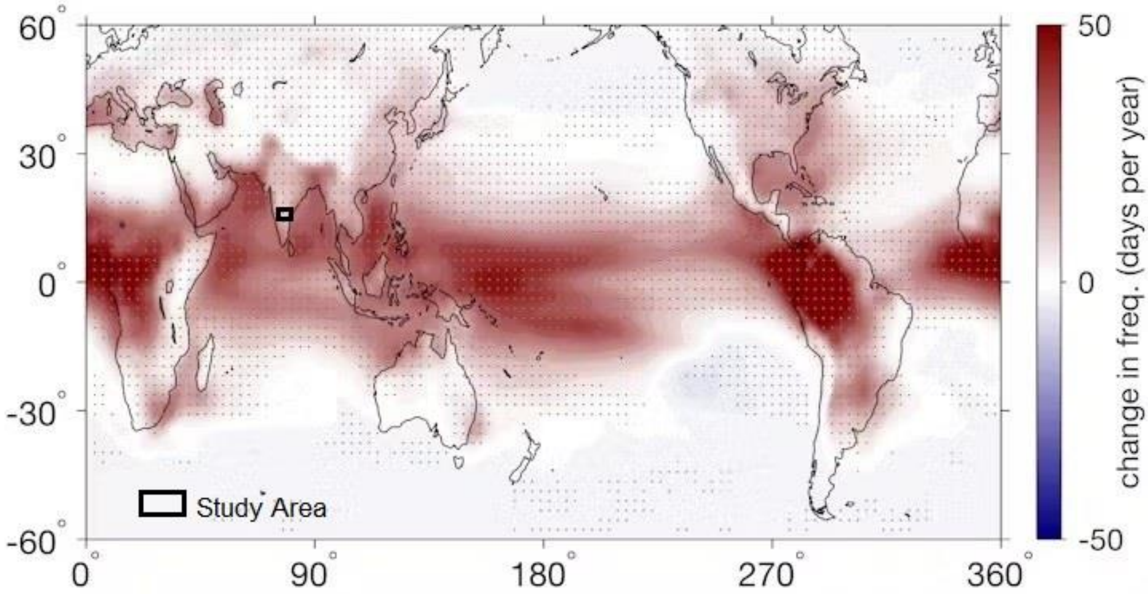
Figure 4-23: Projected Increase in Number of Days with Conditions Conducive to Formation of Thunderstorm




### 4.6.3 Project Implications

- Severe thunderstorms can damage power lines and other transmission infrastructure, leading to disruptions in the delivery of electricity generated by solar projects. This can affect the reliability of energy supply and potentially result in financial losses for project operators.
- After a thunderstorm, solar projects may require thorough inspections to assess any damage and ensure that equipment is functioning properly. This may involve checking for structural damage, inspecting electrical components, and performing preventive maintenance to prevent future issues.



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# 5 Hazard Summary and Implications

In this assessment, hazards are classified into five categories: Low, Medium, High, Not Applicable, and No Hazard, as indicated below. The hazards were categorised based on the potential of the hazard to inflict damage on built and natural environment, and health and safety. ***Table 5-1*** presents the summary of hazards and implications on the project components.

| Key | | Low | | Medium | | High/Very High | | Not Applicable /Not Required | | No Hazard |
|---|---|---|---|---|---|---|---|---|---|---|

Table 5-1: Hazard-Receptor Matrix

| Hazard | Hazard Category (Acute or Chronic) | Hazard Level | | | | Major Receptors | | | | | | Project design consideration | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RCP 4.5 (< 2°C scenario) | | RCP 8.5 (> 2°C scenario) | | | | | | | | | |
| | | 2030 | 2050 | 2030 | 2050 | PV Modules | Transmission line and Towers | Sub stations | Other Buildings | Employees | Communities | | |
| Water Availability | Chronic | | | | | ▪ Reduced water availability for panel cleaning.<br>▪ Reduced efficiency | No significant implications during operational Phase. | No significant implications during operational Phase. | No significant implications during operationalPhase. | Reduced availability for domestic usage including sanitation and drinking | Reduced availability for domestic and agricultural use | • During the operation phase, dry cleaning technology will be utilized for cleaning the photovoltaic (PV) modules.<br>• Additionally, for backup or in cases where more intensive cleaning is required, water-based cleaning will also be available as an option to maintain the optimal performance of the solar panels. | ▪ The issues related to availability of water should be assessed in greater detail and not just from an operational point of view.<br>▪ In case there is significant dependence on local source of water, detailed assessment for water scarcity and identification of alternate water sources may be conducted.<br>▪ Prepare and implement water conservation scheme e.g., rainwater harvesting at the project site. |
| RiverineFloods | Acute | | | | | • Flash floods can erode the top soil and expose the foundation of the PV modules and compromise the structural stability. | ▪ Flash floods can damage loosely anchored structures due to sudden runoff from precipitation.<br>▪ Prolonged inundation could result in electrical hazard or damage the electrical installation due to short circuiting etc. | ▪ Flash floods can damage loosely anchored structures due to sudden runoff from precipitation.<br>▪ Prolonged inundation could result in electrical hazard or damage the electrical installation due to short circuiting etc. | ▪ Flash floods can severely damage the project infrastructure in form of physical damage to components stationed | ▪ Inundation due to floods may render some of the project areas inaccessible temporarily or even after the flood | • Flash flood may cause damage in the nearby settlements, destroy crops and make inundated areas | • Based on the hydrology study, a drainage system will be designed and implemented on the site. | • Conduct a comprehensive evaluation at the asset level to ascertain and measure the potential risks posed by flash flood aiming to identify and quantify the likelihood and impact of flood risk.<br>• Incorporate flood risk considerations into the overall emergency preparedness and response strategy. |
| Extreme Heat | Acute | | | | | • Reduce Efficiency<br>• Damage to electronic monitoring/ | • Reduced transmission efficiency | • Overheating of components resulting in damage or | • Increase in cooling demand | • Reduced comfort levels<br>• Threat of heat stress/ heat stroke | • Reduced comfort levels<br>• Threat of heat stress/ heat stroke | • The N-type solar module with HOT 2.0 technology will be deployed to boost performance and reduce degradation in high-temperature conditions, with a | • Worker's resting areas, on-site offices, worker's quarters should be constructed with heat resisting material to keep the indoor temperature lower. |

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| Hazard | Hazard Category (Acute or Chronic) | Hazard Level | | | | Major Receptors | | | | | | Project design consideration | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RCP 4.5 (< 2ºC scenario) | | RCP 8.5 (> 2ºC scenario) | | | | | | | | | |
| | | 2030 | 2050 | 2030 | 2050 | PV Modules | Transmission line and Towers | Sub stations | Other Buildings | Employees | Communities | | |
| | | | | | | controlling component.<br>• Loss of production<br>• Costs for replacement of damaged assets | | reduced efficiency | | • Increased water demand | • Increased water demand | maximum temperature resistance ranging from -40°C to 85°C. | • A heat stress management plan should be prepared as part of standard operations and safety procedures.<br>• Consider extreme heat as one of the hazards in emergency preparedness and response plan.<br>• Train workers to identify the symptoms of heat stress and first aid. Take necessary measures to counter heat stress impacts to personnel, especially workers. |
| Cyclone | Acute | | | | | • Damage due to high wind speeds<br>• Uprooting of solar modules<br>• Lost production<br>• Cost for replacement of assets | • Damage, uprooting of transmission towers.<br>• Short- circuiting in transmission lines<br>• Cost for replacement of assets | • Structural damage due to heavy rainfall<br>• Cost for replacement of assets | • Damage/ collapse of non-permanent structures<br>• Cost for replacement of assets | • Medium wind speed can lead to threat towards safety of workers working at heights for installation or maintenance of transmission line during high wind conditions. The threat can be in the form of fall or injury to the eyes from the debris (sand/ dust) carried by the winds. | • Health and Safety | • The Horizontal Axis Tracker structure will be utilized to withstand high wind speeds of up to 129.17 km/h, in accordance with recommendations from the OEM of the tracker and in compliance with IS 875 (Part 3) - 2015, which outlines the design criteria for Cyclone resistance. | • Early warning system from national government or international organizations should be monitored.<br>• Directions issued by government during the cyclonic storm events should be followed.<br>• Recommendations for high wind speed and flooding shall apply in general.<br>• Include risk of high wind speed in the general emergency preparedness and response plan. |
| Wind Speed | Acute and chronic | | | | | • Damage due to medium wind speeds<br>• Uprooting of solar modules<br>• Settlement of dust carried by winds on solar panels resulting in reduced efficiency | • Damage, uprooting of transmission towers.<br>• Short- circuiting in transmission lines<br>• Cost for replacementof assets | • Structural damage<br>• Cost for replacementof assets | Damage/ collapseof non-permanent structures | • High or medium windspeed can lead to threat towards safety of workers working at heights for installation or maintenance of transmission line during high wind conditions. The threat can be in the form of fall or injury to the eyes from the | • Health and Safety<br>• Sand/ dust carried by the winds may get inhaled | • The Horizontal Axis Tracker structure will be utilized to withstand high wind speeds of up to 129.17 km/h, in accordance with recommendations from the OEM of the tracker and in compliance with IS 875 (Part 3) - 2015, which outlines the design criteria for wind load resistance. | • Include risk of high wind speed in the general emergency preparedness and response plan.<br>• Evaluate the design life of the cables, connectors and panels.<br>• Use of control sensors can optimize stow angles in relation to wind strength to safely position tracking arrays during storms.<br>• Incorporate the impact of flying debris due to high wind speed in the design of panels.<br>• All structures should be built in accordance with the national and international best practices to withstand wind pressure.<br>• |



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| Hazard | Hazard Category (Acute or Chronic) | Hazard Level | | | | Major Receptors | | | | | | Project design consideration | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RCP 4.5 (< 2°C scenario) | | RCP 8.5 (> 2°C scenario) | | | | | | | | | |
| | | 2030 | 2050 | 2030 | 2050 | PV Modules | Transmission line and Towers | Sub stations | Other Buildings | Employees | Communities | | |
| | | | | | | | | | | debris (sand/ dust) carried by the winds.<br>• Sand/ dust carried by the winds may get inhaled | | | |
| Thunderstorm | Acute | | | | | • Damage to electrical components due to lightning strike<br>• Lost in energy production.<br>• Cost for replacementof assets | • Grid failure<br>• Cost for replacementof assets | • Damage to electrical components due to lightningstrike<br>• Cost for replacementof assets | • Damage to electrical componentsdue to<br>• lightningstrike<br>• Cost for replacementof damagedgood | • People working inthe open during thunderstorm maybe consideredas most vulnerable<br>• Lightning strikes on human being mayresult in death or serious injuries | • People working in the open during thunderstorm may be considered as most vulnerable<br>• Lightning strikes on human being may result in death or serious injuries | • Hail test was done by design team and there was no evidence of a major visual defect of Solar Panels in Hail test. | • Include lightning protection in form of lightning rods in the design of solar power system according to national/ international standards.<br>• Perform regular inspections rightafter heavy rain |



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