Visakhapatnam–Chennai Industrial Corridor Development Program (RRP IND 48434)

Climate Risk Screening Report

Proposed Loan and Technical Assistance Grant
India: Visakhapatnam–Chennai
Industrial Corridor Development Program

Summary

Climate Projection

Temperature
Annual mean temperature in the project area is projected to increase by 2.24\(^\circ\) Celsius by 2050s under the IPCC RCP8.5 scenario. Temperature rise increases along with increasing distance from the coastline. The highest temperature rise is projected to occur in June (>2.6\(^\circ\)C) and the lowest in September (<1.93\(^\circ\)C).

Precipitation
Under the same scenario, annual total precipitation is projected to increase by 81mm or 8.8%. The increase is projected to occur overwhelmingly during the July-October season. Precipitation during dry season (January to April) is projected to decrease by 7mm or 8%. Spatially, precipitation increase is projected to be higher in the southwestern part of the project area and lower in the northeast.

Climate Impact

The main climate impact on the current project is the increasing risks of flooding, tropical cyclones (wind and surge), sea level rise, and rising temperatures.

Substations

1). Physical structures such as substations, roads, wastewater treatment plants, and stormwater drains are vulnerable to the increased risks of flooding and inundation.
2). Increased wind speed of tropical cyclones may cause more damages to the transmission lines.
3). Rising ambient temperatures reduce power transmission efficiency and cause more pronounced line sag.

Draft Report

C Y Ji
October 28, 2015
1. Project Information

<table>
<thead>
<tr>
<th>Project Title/No.</th>
<th>Country/Province(s)</th>
<th>Sector/Type</th>
<th>Modality/Amount</th>
<th>Stage</th>
</tr>
</thead>
</table>

Project Components

1. Ease of doing business improved

By 2025: 1). Andhra Pradesh’s rating improved to more than 75% and rank continues to remain in top 3 states in “Ease of doing business” surveys (Baseline:2015=rating of 70.12% and rank of 2 out of 32 states in the country as per the World Bank report); 2). E-portal and single-desk system operationalized in a gender-responsive manner for processing applications for starting and operating a business; 3). New industrial policy issued and implemented in a gender-responsive manner; 4). Sector policies notified and implemented for 10 sectors in a gender-responsive manner.

2. VCIC infrastructure strengthened

By 2025: 1). 11 power substations established and 250 km of transmission lines installed in accordance with the latest technologies to evacuate 2800 MW of power; 2). 93.6 km of roads widened to connect the nodes to gateways and urban areas; 3). 45 km of internal roads within industrial clusters improved; 4). 97 MLD of water made available to industrial nodes and 65 km of new water pipelines constructed; 5). 4 MLD CETP constructed and 47 km of storm water drains constructed.

3. Capacities of institutions strengthened and efficient program management implemented

1). On-the-job capacity-building program implemented for the EA/IA staff (30% women); 2). Corridor and cluster management institutions established and operational; 3). GESI Plan and CAPP are implemented on time; 4). Capacity development programs conducted for more than 200 EA/IAs staff (30% women).

2. Climate Projections

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline (1960-1990) and Projections (2050s, RCP8.5 Ensemble Mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Annual mean temperature in the project area is projected to increase by 2.24°Celsius from the baseline of 27.6°C. Temperature rise increases along with increasing distance from the coastline. The highest temperature rise is projected to occur in June (&gt;2.6°C) and the lowest in September (&lt;1.9°C).</td>
</tr>
</tbody>
</table>

Figure 1. Baseline and projected monthly mean temperature of the project area.

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2 Visakhapatnam–Chennai Industrial Corridor.
Climate Risk Screening Report

Precipitation

Annual total precipitation is projected to increase by 81mm or 8.8%. The increase is projected to occur overwhelmingly during the July-October season. Precipitation during dry season (January to April) is projected to decrease by 7mm or 8%. Spatially, precipitation increase is projected to be higher in the southwestern part of the project area and lower in the northeast.

Figure 2. Baseline and projected monthly precipitation of the project area.

3. Natural Hazard

<table>
<thead>
<tr>
<th>Type</th>
<th>Overall Risk/Hazard</th>
<th>Climate Impact</th>
<th>Climate Variables/Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthquake</td>
<td>Low</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Evaluation</td>
<td>The project area is generally regarded as free of seismic hazard. The only area indicated as having a low risk is the area centered around the district of Prakasam. Peak Ground Acceleration (PGA) is less than 0.1.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landslide Triggered by Earthquake</td>
<td>None</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Landslide Triggered by precipitation</td>
<td>Low</td>
<td>High</td>
<td>Increased Monsoon Intensity/Medium</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Low risk within the districts of Vishakhapatnam, East Godavari, Cuddapah, and Chittoor.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate Change Assessment</td>
<td>Increased rainfall intensity and increased number of extreme rainfall events(^4) could trigger more frequent landslides. Due to the low slope gradients of the rugged terrains within the project area, the level of landslide risk will remain low.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest Fire</td>
<td>Low</td>
<td>Medium</td>
<td>Rising temperatures/Low</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Low risk is found within the districts of East Godavari, West Godavari, Cuddapah, and Chittoor. About 24% of the 18,000 forest compartments within Andhra Pradesh are prone to fire. There were over 15,000 forest fire incidents reported during the last 10 years. Fires in Andhra Pradesh are ‘ground fires’ in nature, which usually occur between November and May. March is the most susceptible month(^5). Most forest fires are manmade.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Climate Change Implications | Although most of the fire incidents in Andhra Pradesh are manmade, the highest frequency of occurrence is in the hottest month (May). The relationship between meteorological conditions and fire occurrence is well known\(^6\). Forest fires tend to be concentrated in summer months when temperature is high and air humidity and fuel moisture are low. Rising temperatures and decreasing precipitation during the pre-monsoon period will result in reduced moisture content of fuel (i.e. biomass) thus making forests more susceptible to wildfire. Trees that are deprived of water become drier, and once ignited, burn at...

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\(^3\) According to Earthquake Hazard Map of India from BMTPC, the entire state of Assam falls within Seismic hazard Zones IV and V i.e. high and very high damage risk zones. BMTPC: Vulnerability Atlas – 2\(^{nd}\) Edition; Peer Group, MoH&UPA; Map is based on digitized data of SOI, GOI.

\(^4\) Khaladkar et al., 2009, Indian Institute of Tropical Meteorology.


### Climate Risk Screening Report

<table>
<thead>
<tr>
<th>Flood</th>
<th>Evaluation</th>
<th>Climate Change Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Andhra Pradesh is among the 11 Indian states most susceptible to flooding. All areas in the vicinity of the coastline are prone to a medium to high risk of flooding. The highest risk is found within the districts of East Godavari, West Godavari, Krishna, and Guntur. The Godavari and the Krishna rivers have well-defined and stable courses. Their natural and manmade banks are capable of carrying flood discharges with the exception of their delta areas. Floods are often caused by unplanned urban growth, improper upkeep of drainage systems and mismanagement of discharges from dams though they are erroneously thought to be always of natural origin.</td>
<td>One of the most pronounced effects of climate change is the increase in heavy rainfall with higher intensity. Under the conditions of rising temperatures, precipitation is more likely to arrive in the form of heavy rains accompanied by an increase in flood risk. Research shows that the trends of heavy precipitation (&gt;100mm) events in the last 50 years in India is increasing as compared to precipitation events less than 100mm. Flood risk from Godavari, Krishna and other rivers is likely to aggravate due to projected increase in monsoon precipitation (&gt;5.6% increase from June to September) as well as the projected increase in the number of extreme rainy days. Analysis of one-day extreme rainfall series has shown that the intensity of extreme rainfall has increased over coastal Andhra Pradesh (and its adjoining areas). The effect of climate change is already occurring. The October 2009 heavy flooding of Krishna and Godavari rivers is believed to be the first occurrence in 1,000 years. Three days of unprecedented rainfall in the Krishna and Godavari river basins. Some 700 mm over a week, and about 400 mm of rain took place in three days.</td>
</tr>
<tr>
<td>Low</td>
<td>Andhra Pradesh is prone to drought like conditions and is ranked the third highest drought prone State after Rajasthan and Karnataka. Frequent drying (and wetting) may impact the stability of pylons. In general, the impact of drought is not significant factor in transmission and distribution networks. However, drought</td>
<td></td>
</tr>
<tr>
<td>Rising temperatures/High</td>
<td>Increasing Precipitation/Low to Medium</td>
<td></td>
</tr>
</tbody>
</table>

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14 Khaladkar et al., 2009, Indian Institute of Tropical Meteorology.
conditions may seriously impact road infrastructure. The most common type of impact on pavement is the longitudinal cracking with breaks in the asphalt parallel to the road’s center stripe. The cracks typically start near the road’s outer edge because the soil alongside the pavement is exposed to the heat and lost moisture to evaporation. As the soil began to compress, it would bend the outside of the road. A series of three or four cracks are often observed as the drying progressed toward the road’s center. The drought also caused problems with concrete box culverts running crossways underneath roads. The culverts tended to remain stationary, but the asphalt on either side sagged from soil displacement and cracks formed across the road.  

| Climate Change | Increased precipitation intensity and variability are projected to increase the risk of drought in any area. Soil moisture loss through evapotranspiration is projected to increase as a result of projected increase in annual mean temperature (2.5°Celsius by 2050s). The IPCC reports and other climate model predictions indicate that the global change is likely to increase the vulnerability of tropical countries to drought, more so in South Asia (IPCC, 2001, 1996). Increased precipitation intensity and variability are projected to increase the risk of both flooding and drought in any area. The risk of drought is very likely to escalate in the future.  

| Cyclone Wind Evaluation | All nine coastal districts of Andhra Pradesh are extremely vulnerable to cyclonic storms and damages resulting from cyclones. For the current project, transmission lines are potentially the most susceptible to cyclone wind damages. In many cases, wind loads can govern the design of transmission lines. Wind is also a significant hazard to road transport. Gusts, eddies, lulls, and changes in wind direction are often greatest near the ground in extreme wind episodes. During these episodes, the majority of fatalities are generally transport related. Strong winds of cyclones possess a great destructive force that may cause large scale damages to road infrastructure (e.g., bridges, buildings, etc.). Additionally, strong winds can also cause damages to roadside infrastructure (e.g., signs, lighting fixtures and supports, etc.). Generally speaking, winds are viewed as less of a hazard than rain and flooding.  

| Climate Change Assessment | Most studies for the North Indian Ocean agree that the frequency of tropical cyclones is declining, while the intensity of cyclones has been observed to have increased. It is extremely difficult to confirm whether the impact of climate change has exceeded the natural variability and has manifested a detectable signal. In terms of historical tropical cyclone activity, a 2010 WMO assessment of tropical cyclones and climate change concluded that “it remains uncertain whether past changes in tropical cyclone activity have exceeded the variability expected from natural causes.” This conclusion applied to all basins around the globe. According to IPCC (2007), “there is less certainty about the changes in frequency and intensity of tropical cyclones on a regional basis than for temperature and precipitation changes… however, extreme rainfall and winds associated with tropical cyclones are likely to increase in South Asia”. Simulations of tropical cyclones in the Bay of Bengal from the regional climate  

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21 The confidence level is low due to the fact that there exists a large degree of uncertainty regarding the future scenarios of cyclone activities within the North Indian Ocean.
model (PRECIS) show an increase in the frequency of cyclones in the Bay of Bengal under the A2 scenario compared to the baseline (1961-1990). The risks of wind could be expected to increase in the future.

Figure 3. Projected changes in tropical cyclone statistics. All values represent expected percent change in the average over period 2081–2100 relative to 2000–2019, under an A1B-like scenario, based on expert judgment after subjective normalization of the model projections.

<table>
<thead>
<tr>
<th>Cyclone Surge</th>
<th>High</th>
<th>High</th>
<th>Increased Cyclone Intensity/ Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation</td>
<td>Storm surge caused by tropical cyclones is a devastating hazard along the east coast of India. Along Andhra Pradesh coast, the section between Ongole and Machilipatnam (particularly between Nizampatnam and Machilipatnam) is most prone to storm surges. It is recognized as vulnerable to high surges among the segments of the east coast of India. Out of 31.57 million people living in the coastal districts of AP, approximately 2.9 million are vulnerable to cyclones. Figure 4 shows that the cyclone surge within the coastal regions of Andhra Pradesh is among the highest along the Bay of Bengal.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4. Coastal Districts of India Prone to Cyclone Hazard. Source: Mandalan and Mohapatra (NDMA), 2010.

| Climate Change Evaluation | Cyclones originating from the Bay of Bengal have been noted to decrease since 1970 but the intensity has increased, and the frequency of monsoon depressions and cyclones formation in Bay of Bengal has increased. An analysis of the frequencies of cyclones on the East of |

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28 IPCC AR5 - The Physical Science Basis, Page 108.
29 The confidence level is low due to the fact that there exists a large degree of uncertainty regarding the future scenarios of cyclone activities within the North Indian Ocean.
30 Revenue (Disaster Management II) Department, GoAP.
India during 1891-1990 shows that nearly 262 cyclones occurred (92 severe) in a 50km wide strip on the East Coast of India. Future projections suggest increases in both the intensity and the number of cyclones in the Bay of Bengal. “In the northern Bay of Bengal, simulated changes in storminess cause changes in extreme water levels. When added to consistent relative sea-level rise scenarios, these result in increases in extreme water levels across the Bay…” (IPCC AR4, 2007). It is extremely difficult to confirm whether the impact of climate change has exceeded the natural variability and has manifested a detectable signal. A 2010 WMO assessment of tropical cyclones and climate change concluded that “it remains uncertain whether past changes in tropical cyclone activity have exceeded the variability expected from natural causes.” This conclusion applied to all basins around the globe. According to IPCC (2007), “there is less certainty about the changes in frequency and intensity of tropical cyclones on a regional basis than for temperature and precipitation changes… however, extreme rainfall and winds associated with tropical cyclones are likely to increase in South Asia”. Simulations of tropical cyclones in the Bay of Bengal from the regional climate model (PRECIS) show an increase in the frequency of cyclones in the Bay of Bengal under the A2 scenario compared to the baseline (1961-1990). The risks of both wind and surge are expected to escalate.

Increasing risks of storm surge from tropical cyclones due to global warming along the coastal regions of Bay of Bengal is particularly worrisome.

Unnikrishnan et al. (2011) projected that, by the 21st century, the average increase in 1-in-100 year return period storm tide is about 10%. The 1-in-100 year return period of sea-level heights is commonly used for planning purposes. The research conducted by Unnikrishnan et al. (2011) showed an increase in surge height (1-in-100 year return period) for all tidal gauge stations along the northern coast of Bay of Bengal (Table 1). For example, at Visakhapatnam, the surge height at 2071-2100 is 2.94±0.08m.

<table>
<thead>
<tr>
<th>Station</th>
<th>100-year return level (1961–1990) (m) relative to the chart datum</th>
<th>100-year return level (2071–2100) (m) relative to the chart datum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visakhapatnam</td>
<td>2.53 ± 0.08</td>
<td>2.94 ± 0.08</td>
</tr>
<tr>
<td>Kalingapatnam</td>
<td>2.47 ± 0.06</td>
<td>2.99 ± 0.07</td>
</tr>
<tr>
<td>Gopalapur</td>
<td>3.17 ± 0.10</td>
<td>3.70 ± 0.11</td>
</tr>
<tr>
<td>Paradip</td>
<td>3.63 ± 0.09</td>
<td>4.36 ± 0.11</td>
</tr>
<tr>
<td>False Point</td>
<td>3.77 ± 0.11</td>
<td>4.19 ± 0.11</td>
</tr>
<tr>
<td>Short Island</td>
<td>4.32 ± 0.11</td>
<td>4.99 ± 0.13</td>
</tr>
<tr>
<td>Sagar</td>
<td>7.98 ± 0.26</td>
<td>7.96 ± 0.20</td>
</tr>
<tr>
<td>Kolkata</td>
<td>7.14 ± 0.18</td>
<td>7.34 ± 0.17</td>
</tr>
</tbody>
</table>

Table 1. Hundred-year return levels and standard errors associated with the Gumbel fit at ground observation stations, estimated from the storm surge model simulations. Source: Unnikrishnan et al., 2011.

The risk of Tsunami along the coast of Andhra Pradesh is between medium and high. The coast of East Godavari, West Godavari, and southern Nellore appear to have the highest risk.

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The Indo-Burma-Sumatra subduction zone is known to trigger large undersea earthquakes capable of generating tsunamis in the Indian Ocean. Indicators suggest a high potential for giant earthquakes along the coast of Myanmar which could be especially dangerous for the east coast of India. A study found that tsunami run-up could reach >2.0m along the eastern coasts.

<table>
<thead>
<tr>
<th>Sea Level Rise</th>
<th>High</th>
<th>Rising Ocean Temperatures/Thermal Expansion of Ocean Water, Melting of Glaciers/Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation</td>
<td>The coastal areas of East Godavari, West Godavari, Krishna, Guntur, Prakasam, Nellore, and Thiruvallur are below 5m in elevation and are extremely vulnerable to the effect of sea level rise. A study using a coastal vulnerability index combining coastal geomorphology, coastal slope, shoreline change, mean spring tide range, and significant wave height showed that about 43% of the 1,030km-long AP coast is under very high risk, followed by another 35% under high risk if the sea level rises by ~0.6m displacement than 1.29 million people living within 2.0 m elevation in 282 villages in the region.</td>
<td></td>
</tr>
</tbody>
</table>

The physical effects of sea level rise include inundation of low lying areas, erosion of beaches and bluffs, saltwater intrusion into aquifers and surface waters, higher water tables and increased flooding and storm damage.

Figure 5. Coastal Vulnerability Index. Source: Rao et al., 2008.

Climate Change Evaluation

The IPCC AR5 projected that, under the worst-case scenario (RCP8.5), global sea level by the end of the century will rise by between 45 and 82mm. Sea level rise will result in increased coastal flooding, increased storm surge height. The effect of a higher sea level is the retreat of the current shoreline closer to existing structures and settlements. Holding all other factors constant, a storm surge occurring at a higher sea level would cause more areas inundated than a cyclone of an equal intensity at present sea level, simply because the shoreline would be further inland than today and storm surge would build from a higher base.

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“In the northern Bay of Bengal, simulated changes in storminess cause changes in extreme water levels. When added to consistent relative sea-level rise scenarios, these result in increases in extreme water levels across the Bay, especially near Kolkata” (IPCC AR4, 200745). Extreme sea-level projections46 under the A2 scenario along the east coast of India (using a storm surge model developed for the Bay of Bengal, driven by winds and surface atmospheric pressure) show that a uniform sea-level rise of 4 mm/year from 1990 was included from the present levels. The 100-year return levels of extreme sea-level events are found to be higher by about 15–20% for A2 than those in the baseline for locations north of Visakhapatnam.

Figure 6. Projections of global mean sea level rise over the 21st century relative to 1986–2005, IPCC AR547.

<table>
<thead>
<tr>
<th>Heat Waves</th>
<th>High</th>
<th>Low</th>
<th>Rising Temperatures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation</td>
<td>Heat waves are climatologically extreme events when abnormally higher temperatures relative to normal occur. Heat waves occur in Andhra Pradesh during the months of April, May, and June. Between May and June in 2003, heat wave conditions in Andhra Pradesh claimed more than 3,000 lives48. In addition to health concerns, excessive heat can also lead to power outages as heavy demands for air conditioning strain the power grid.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate Change Implications</td>
<td>With an overall warming of the Earth’s climate, heat waves are expected to become more frequent, longer, and more intense in places where they already occur49. For the project area, the monthly maximum temperature for April, May, and June is projected to exceed 40°C by 2050s under the worst case scenario (RCP8.5) and the month of May is projected to experience a maximum temperature of 43.7°C. The probability of occurrence of heat waves is projected to increase in the future.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

47 IPCC, 2013. Figure TS22. Page 100. CLIMATE CHANGE 2013 - The Physical Science Basis, WGI, IPCC AR5.  
49 Website of US EPA on climate change.
Climate Risk Screening Report

**Figure 7.** Baseline and projected Monthly Maximum Temperature of the Project Area.

<table>
<thead>
<tr>
<th>GLOF</th>
<th>None</th>
<th>High</th>
<th>Rising Temperatures/Accelerated Melting of Glaciers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lightning</strong></td>
<td>Medium/High</td>
<td>Medium</td>
<td>Temperature Rise/Low</td>
</tr>
<tr>
<td><strong>Evaluation</strong></td>
<td>Low to medium risk over the southwestern part of the project area, high risk over the northeastern part, based on 9-year satellite measurements (combined 1995–2003 data from the Optical Transient Detector and 1998–2003 data from the Lightning Imaging Sensor)(^{50}). Sea-level rise and coastal vulnerability: an assessment of Andhra Pradesh coast. Lightning is one of the most serious causes of over-voltage. Lightning surges may also cause serious damages to the expensive equipment in the power system (e.g., generators, transformers, etc.) either by direct strokes on the equipment or by strokes on the transmission lines that reach the equipment as traveling waves.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Climate Change Implications</strong></td>
<td>The spatial distribution of lightning around the world is directly linked to climate, which is primarily driven by solar insolation. Lightning is positively correlated with surface temperature on short time scales, as well as variations in the upper tropospheric water vapor and ozone both of which are GHGs. It is generally expected that lightning activity will increase in a warmer climate (IPCC, 2007(^{51})) as numerous climate model simulations(^{52,53,54}) have shown. Although the parameterizations of lightning in the models are quite crude, the models nevertheless manage to duplicate the present global lightning climatology(^{55}), and all of the model studies indicate that there could be less thunderstorms overall, but they could become more intense, which in turn may increase the amount of lightning by 10% for every 1k degree of global warming(^{56}).</td>
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<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>4. Sector-Specific Climate Risks</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Sensitive Components</th>
<th>Climate Variables</th>
<th>Climate Change Impact Analyses(^{57})</th>
</tr>
</thead>
</table>

\(^{50}\) [http://thunder.nsstc.nasa.gov/data/](http://thunder.nsstc.nasa.gov/data/).

\(^{51}\) [http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch7s7-4-4-2.html](http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch7s7-4-4-2.html).


\(^{56}\) [http://thunder.nsstc.nasa.gov/data/](http://thunder.nsstc.nasa.gov/data/).

\(^{57}\) The sector-specific climate risks are written largely based on a previous screening report dated in July 2013 when the project sites were not decided.
### Physical Structures (Substation, roads, wastewater treatment plants, storm water drains)

- **Increased Intensity of Precipitation / Increased River Discharge and Peak Flow / Sea Level Rise / Increased Storm Surge**

The project areas particularly the areas in close vicinity of the coastline are extremely vulnerable to the risks of coastal flooding due to projected increase in monsoon precipitation, increased peak discharge of river flows, increased storm surge, and sea level rise. Physical structures such as substations, roads, and wastewater treatment plants must therefore be designed to adapt to the future scenarios of climate change to avoid damages caused by inundation.

Heavy monsoon rains can easily overwhelm drainage systems. The capacity of storm water drains must be therefore adequate enough to cope with increased storm water accumulation.

### Overhead Transmission and Distribution Cables

- **High Temperatures / Highly sensitive to ambient temperature / Increased Electrical Resistance**
- **Thermal Expansion of Overhead Transmission Lines**

Higher temperatures cause increased power demand and lower transmission efficiency. The effect of increased ambient temperature on power transmission lines is increased resistance. Additionally, high ambient temperature will cause transmission lines to sag. This effect will become more pronounced during the April-June period in the future due to the projected rise in the monthly maximum temperature (the maximum temperature for May is projected to reach 43.7°C).

### Overhead Transmission and Distribution Cables

- **Increased Cyclone Wind Speed**

The overhead transmission and distribution cables are extremely vulnerable to strong winds brought by tropical cyclones. Projected increase in cyclone intensity will impose a serious threat to the overhead lines. For the current project, transmission lines are potentially the most susceptible to cyclone wind damages. In many cases, wind loads can govern the design of transmission lines.

### Road Pavement

- **Rising temperature, maximum temperature and number of consecutive hot days (heat waves) / Pavement Buckling, rutting, softening, etc.**

Heat stress is particularly relevant for asphalt road pavement for which binder may need to be adapted accordingly.

Longer periods of extreme heat, combined with traffic loading, speed and density can soften asphalt roads, leading to increased wear and tear and undermining pavement integrity. It is likely that there would be concerns regarding pavement integrity such as softening, traffic-related rutting, embrittlement, migration of liquid asphalt. As a result, road surfaces are likely to require greater maintenance in higher temperatures. These effects may be experienced particularly during the months of April, May, and June during which the maximum monthly temperature is projected to reach over 40.5°C (Figure 8). Additionally, thermal expansion in bridge expansion joints and paved surfaces may be experienced. Furthermore, increased drought may lead to increased susceptibility to consolidation of the substructure with (unequal) settlement, more generation of smog, and unavailability of water for compaction work.

![Monthly Max. Temp.](image)
5. GHG Emission and Indirect Impact

| Wastewater Treatment | Many gases (CO₂, CH₄, & N₂O) evolve from wastewater treatment that contribute to the green house affect. CH₄ and CO₂ are formed from the anaerobic decomposition of organic matter. N₂O is formed in nitrification and denitrification processes that are becoming more prevalent as the industry moves toward more complete nutrient removal. |

6. Summary of Screening Results

<table>
<thead>
<tr>
<th>Natural/Climatic Hazard</th>
<th>Flooding, Drought, Cyclone Wind and Surge, Heat Waves, Sea Level Rise, Tsunami, Lightning.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Components</td>
<td>1). Physical structures such as substations, roads, and wastewater treatment plants are vulnerable to increased risks of flooding and inundation. Heavy monsoon rains can easily overwhelm drainage systems. 2). Increased wind speed of tropical cyclones may cause more damages to the transmission lines. 3). Rising ambient temperatures reduce power transmission efficiency and cause more pronounced line sag.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall Scoring</th>
<th>Multi-Hazard Index</th>
<th>Climate Impact⁵⁹</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>High</td>
<td>A</td>
</tr>
</tbody>
</table>

7. Required Action

| Recommendations         | 1). Flood risks must be taken into account for the construction of the substations, roads, wastewater treatment plants, as well as the storm-water drainage systems. At least the 1-in-100 year return period should be used as the design flood. A detailed flood risk assessment needs to be conducted and the results shall be used to aid project design. 2). The overhead transmission lines must be able to withstand strong winds. A minimum overhead clearance of transmission lines must be maintained for safety. Material to reduce thermal sag (e.g., aluminum conductor composite core – ACCC) may need to be specified at project design stage. 3). Road design should also incorporate adaptation measures to curb the effect of rising temperatures and extreme heat. Examples of adaptation in design strategies include the use of heat-resistant paving materials; greater use of heat-tolerant street and highway landscaping; proper design/construction of milling out ruts; and overlay with more rut-resistant asphalt. For areas prone to flooding, improved asphalt/concrete mixtures may be applied. 4). Lightning protection must be installed for the power supply component of the project. |

⁵⁹ The severity of climate change impact is based on the evaluation of the consequences of changes in climatic variables upon the sector-specific activities of the project under scrutiny. Primarily, it is based on expert judgment.