
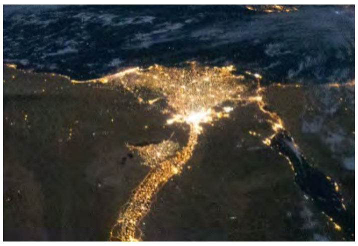








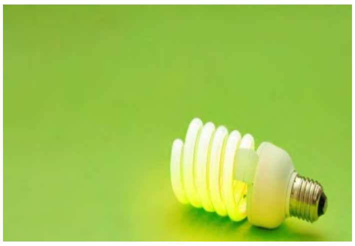
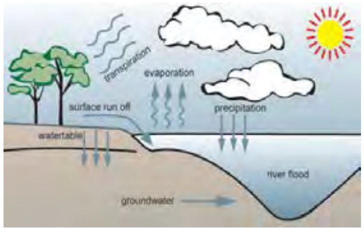




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RCREEE
Regional Center for Renewable Energy and Energy Efficiency
المركز الإقليمي للطاقة المتجددة وكفاءة الطاقة

Scatec 200MW Wind Farm in Egypt

Draft Climate Change Risk Assessment (CCRA)

March 2025

Presented By:

EcoConServ
ENVIRONMENTAL SOLUTIONS

EcoConServ Environmental Solutions
12 El-Saleh Ayoub St., Zamalek, Cairo11211, Egypt
Tel: +20227359078 /27364818
E-mail: genena@ecoconserv.com
URL: www.ecoconserv.com

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1. Climate Change Risk Assessment (CCRA)

1.1 Background

The project site is situated in the Red Sea Governorate. The site falls within Ras Gharib City, under the jurisdiction of the Ras Gharib City Council.

1.2 Methodology

Over the course of the Project's lifetime, a degree of climate change is anticipated due to historical greenhouse gas (GHG) emissions and the delayed response of the climate system, which could pose long-term risks to the Project.

To ensure the Project's continued operation, safety, security, and reliability, it is essential to identify and understand the risks and vulnerabilities it may face due to evolving climate conditions. Effective planning, management, and adaptation to identified climate-related impacts, uncertainties, and potential risks are crucial for long-term resilience.

The Climate Change Risk Assessment (CCRA) has been conducted to ensure compliance with the Equator Principles IV, specifically, according to the "Guidance Note on Climate Change Risk Assessment" (EP, 2020).

The CCRA investigates the relevant climate-related 'Physical Risks' defined as risks resulting from climate change which are event driven (acute) or longer-term shifts (chronic) in climate patterns. Acute physical climate risks can include increased severity and frequency of droughts, storms, floods, heat waves and wildfires. Chronic physical climate risks can include sea level rise and longer-term temperature increase.

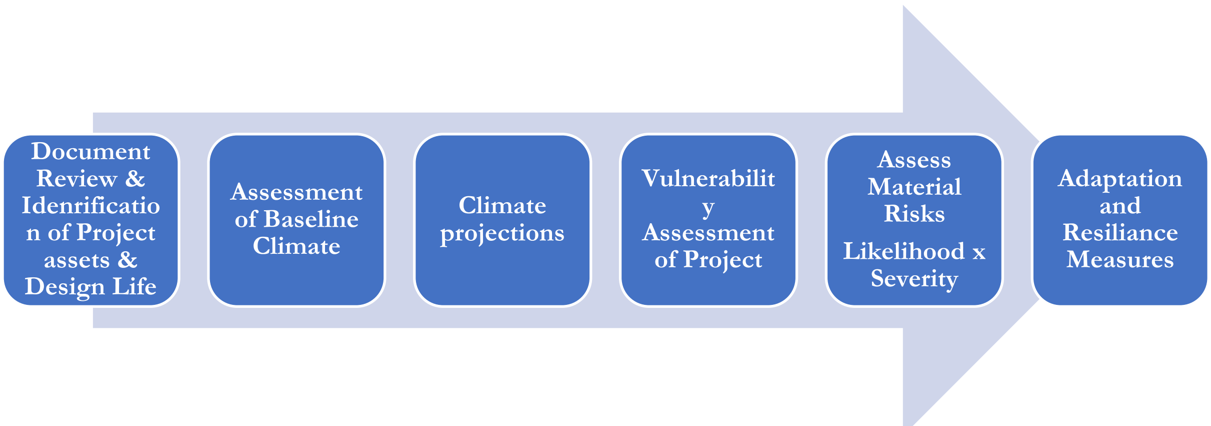
The CCRA will not include an assessment on 'Transition Risks' as indicated in the Guidance Note (which is only required for Projects with combined Scope 1 and Scope 2 emissions of more than 100,000 tons of CO2 equivalent annually – which is considered irrelevant for this Project). Those are risks related to policy, legal, technology, reputation and market changes.

The key physical risks will be investigated as part of the CCRA and which are relevant for the Project development include the following:

1. **Extreme Climate Conditions:**
   - Wind
   - Temperature Increase and Heat Waves
   - Drought
   - Sea Level Rise
   - Flash Floods

2. Associated health problems such as infectious diseases

It evaluates potential adverse impacts associated with global warming and climate change. The scope of the CCRA has been established based on the Equator Principles' guidance note on climate change risk assessment. Following this guidance, the assessment addresses climate-related "Physical Risks" as outlined by the Task Force on Climate-Related Financial Disclosures (TCFD). The CCRA identifies existing and anticipated climate-related risks—whether physical, transition-related, or both—that could impact the project during its contract period. It also reviews strategies, interventions, and processes designed to manage these risks effectively. The main steps involved in the CCRA include:



1.3 Scope of Assessment

The project components up to date are summarized in the table below.

Project Component	Description	Duration
Construction Phase		
Construction Machinery	These include excavators, cranes, bulldozers, etc..	**About 24 Months**
Temporary facilities	Workers facilities, storage areas etc..	
Batching Plant	A mobile / temporary concrete batching plant will be used for the concentrated mixing of concrete required for the construction of site infrastructure to include but not limited to foundations, buildings, and other	
Operation Phase		
Workers	Workers facilities, storage areas etc.. Occupational health and safety	**According to the PPA agreement, the Project is expected to be operational for 25 years**
Wind turbines	foundation, tower, nacelle, rotor blades, a rotor hub, gearbox, generator and a transformer	

Medium Voltage (MV) Cables	The wind turbines will be connected through medium voltage cables (22kV or 33kV) to an on-site substation (discussed below). The connection between the turbines and the substation will be made using underground transmission cables buried in ground by trenches.	
Communications Network	The Project will have a Supervisory Control and Data Acquisition (SCADA) system for the remote operation of the facilities. A communication network will be installed which will consist of fiber optic cables connecting the turbines together to the SCADA system at substation. The communication system will be installed in the same trenches as the MV cables discussed above.	
Substation	: The substation is a high voltage transformer unit that collects and converts the output from the turbines to a higher voltage (from 22kV or 33 kV to 220 kV) that is appropriate for connection with the High Voltage National Grid (220 kV). The substation also includes all the control and protection equipment, like circuit breakers, disconnectors, surge arrestors, etc	
Building Infrastructure	On-site building infrastructure will be required for the daily operation of the Project. Such buildings could include an administrative building (offices) used for normal daily operational related work, control room, workshop, and a warehouse for storage of equipment and machinery such as spare parts, oil cartridges, fuel, lubricants, etc.	
Road network	A road network will be required for installation of the turbines during the construction process and for ease of access to the turbines for maintenance purposes during operation.	
Overhead Transmission Line (OHTL)	the Overhead Transmission Line (OHTL) which will run from the Project site (from substation area) to the connection point with the National Grid.	

1.4 Baseline

1.4.1 Temperature [1]

The climate in the Red Sea undergoes significant seasonal variations in temperature. The mean daily maximum temperature peaks at 34°C during July and August, making these the hottest months, while it drops to 19°C in January, the coolest month. Hottest days peak at around 40°C during the summer months before gradually decreasing after September.

Similarly, the mean daily minimum temperature reaches its highest point of 26°C in July and August and its lowest at 10°C in January. In contrast, cold nights, marked by below-average temperatures, are most common in winter, with values dropping close to 10°C, and they diminish through spring and summer. The figure below illustrates the monthly average surface air temperature from 1991-2020 in the different months of the year.

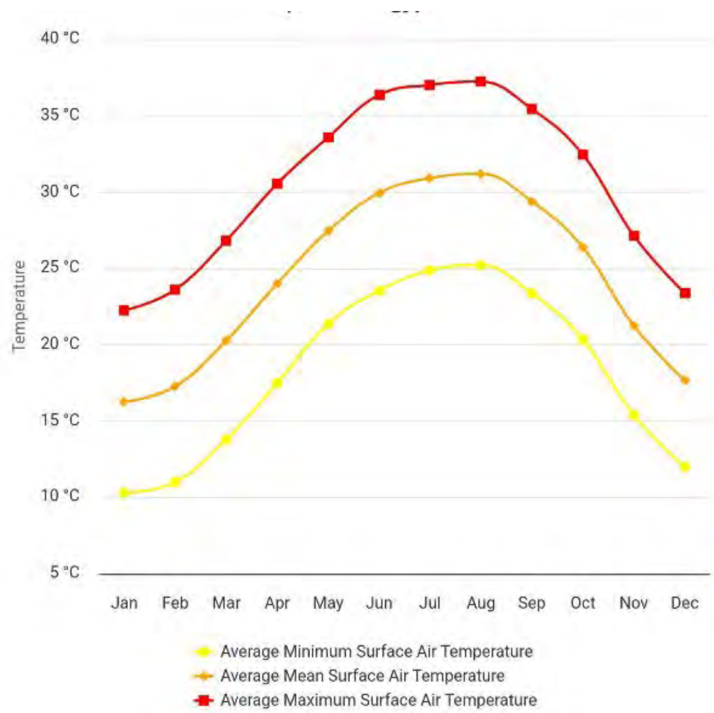


Figure 1-1: Monthly Average Surface Air Temperature

As illustrated in the Figures below, the observed average trends in surface air temperature over the Red Sea region of Egypt from 1901 to 2023 indicate a consistent increase across mean, maximum, and minimum temperatures. The annual average mean temperature has risen from approximately 23°C in the early 20th century to around 25°C in recent years. The maximum temperature follows a similar upward trend, increasing from about 29°C to over 31°C, while the minimum temperature has risen from nearly 17°C to above 19°C.

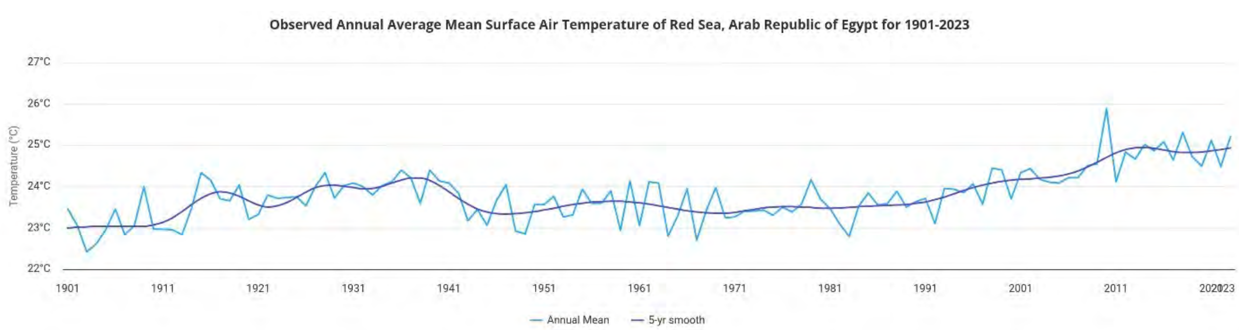


Figure 1-2: Average mean surface air temperature

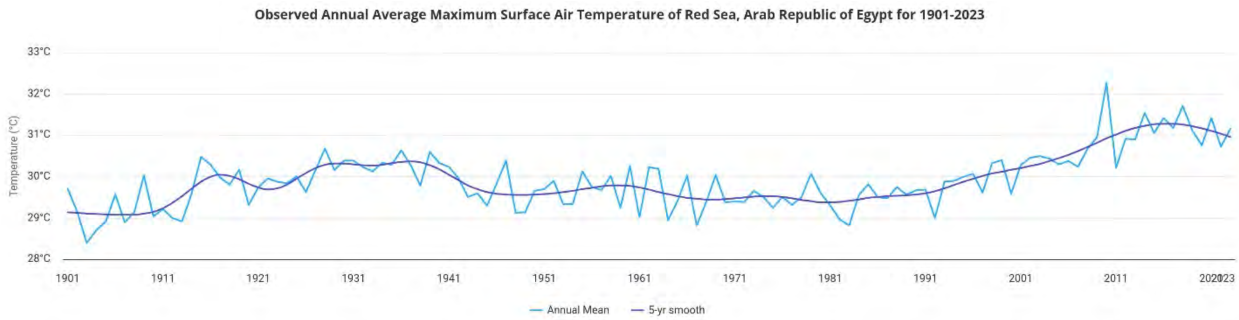


Figure 1-3: Average maximum surface air temperature

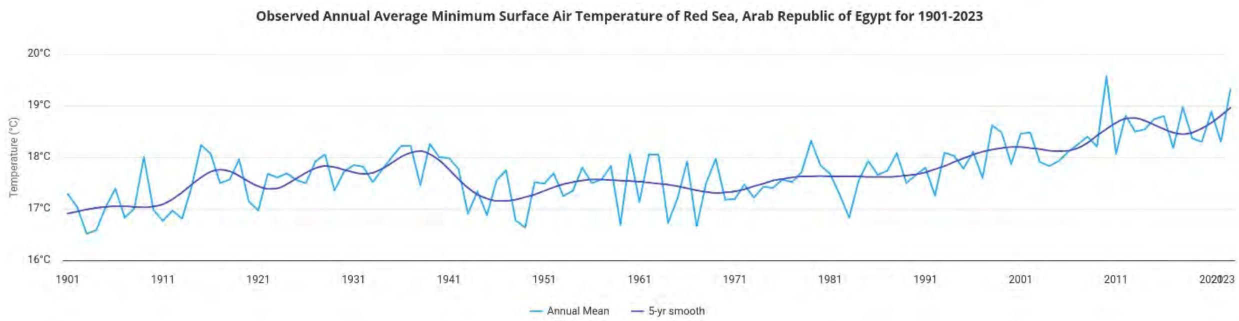


Figure 1-4: Average minimum surface air temperature

The observed seasonal mean, minimum, and maximum temperatures for the Red Sea region recorded over four time periods: 1901–1930, 1931–1960, 1961–1990, and 1991–2020 also recorded an increasing trend over time.

The mean seasonal temperature has risen, with the most recent period (1991–2020) showing the highest values. For instance, the mean temperature in DJF increased from 16.45°C (1901–1930) to 17.07°C (1991–2020), while in JJA, it rose from 29.38°C to 30.7°C over the same period.

The minimum temperature has also increased, particularly in DJF, where it rose from 10.6°C (1901–1930) to 11.12°C (1991–2020), and in JJA, where it increased from 23.15°C to 24.56°C.

The maximum temperature exhibits a similar trend, with JJA reaching the highest recorded values, increasing from 35.66°C (1901–1930) to 36.88°C (1991–2020).

Table 1-1: Observed Seasonal Mean, Minimum, and Maximum Temperatures (°C) for the Red Sea Region Across Different Time Periods (1901–2020)

	1991-2020				1961-1990				1931-1960				1901-1930			
Units:°C	**DJF**	**MAM**	**JJA**	**SON**	**DJF**	**MAM**	**JJA**	**SON**	**DJF**	**MAM**	**JJA**	**SON**	**DJF**	**MAM**	**JJA**	**SON**
Observed Average Seasonal Mean Temperature	17.07	23.91	30.7	25.68	16.42	23.2	29.55	24.65	16.78	23.3	29.54	25.09	16.45	23.04	29.38	24.87
Observed Average Seasonal Minimum Temperature	11.12	17.55	24.56	19.72	10.6	16.97	23.52	18.9	10.84	16.85	23.29	19.19	10.6	16.63	23.15	18.96
Observed Average Seasonal Maximum Temperature	23.06	30.33	36.88	31.7	22.3	29.48	35.63	30.46	22.77	29.8	35.85	31.04	22.35	29.5	35.66	30.83

1.4.2 Wind

The wind speed analysis for Ras Gharib reveals distinct seasonal trends and variations in wind speed distribution throughout the year. During the winter months (December to February), wind speeds predominantly fall in the lower ranges of 5–20 km/h.

As the year progresses into spring and summer (March to August), there is a notable increase in mid-range wind speeds of 20–40 km/h, with June and July experiencing the highest frequency of these stronger winds. Occasionally, higher wind speeds exceeding 40 km/h are observed during the summer months, but they remain infrequent.

During Autumn (September to November), wind speeds gradually decrease from the mid-year peaks. October and November, in particular, show a higher concentration of lower wind speeds (5–20 km/h), reflecting a return to calmer conditions similar to those of winter.

1.4.3 Precipitation

The project area experiences precipitation patterns similar to those observed in northern Red Sea cities like Hurghada, with annual precipitation remaining well below 100 mm. Long-term data indicate that precipitation is minimal throughout the year, with most days classified as "dry days." The highest rainfall amounts are recorded during the winter (DJF) and spring (MAM) seasons, averaging around 4–6 mm per season in recent decades, while summer (JJA) experiences the least precipitation, typically around 3 mm or less.

In Ras Gharib, rainfall events are sporadic and generally light, with amounts rarely exceeding 2 mm. These events are slightly more frequent in winter, particularly in January and February, but their overall contribution remains negligible. The period from March to November shows an almost complete absence of significant rainfall, aligning with the overall arid climate of the region.

Despite the low annual precipitation, the Red Sea region is occasionally subject to flash floods, which tend to occur once every 5 to 10 years. These extreme events result from atmospheric pressure differences between cooler European air masses and warmer conditions over Asia, leading to intense but short-lived rainfall episodes.

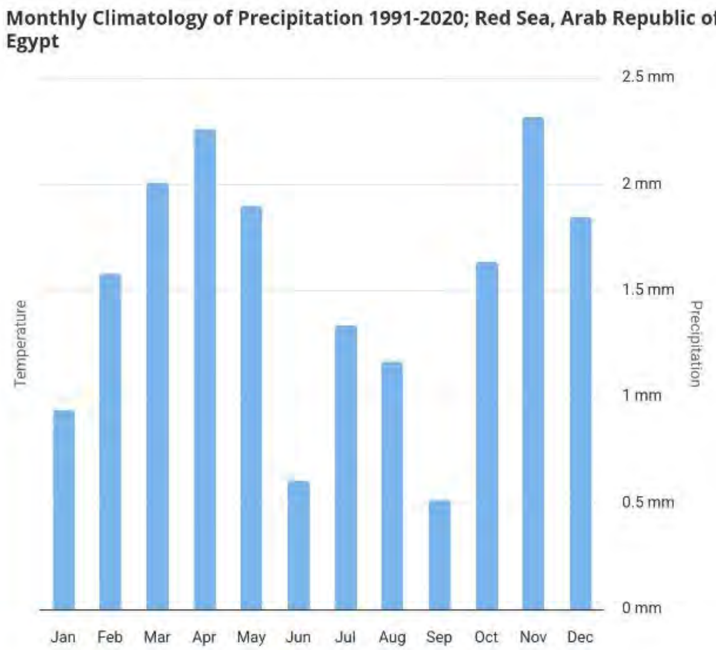


Figure 1-5: Monthly Climatology of Precipitation 1991-2020, Red Sea

Table 1-2: Observed Average Seasonal Precipitation (mm) for the Red Sea Region Across Different Time Periods (1901–2020)

	1991-2020				1961-1990				1931-1960				1901-1930			
Units: mm	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
	4.32	6.17	3.12	4.49	4.02	7.21	3.13	6.02	3.48	4.85	3.09	5.68	5.42	8.32	3.08	6.01

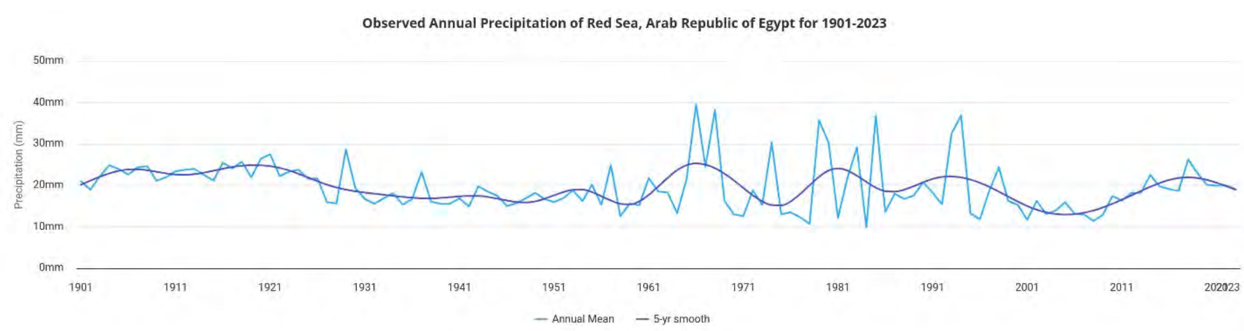


Figure 1-6: Observed Annual Precipitation Trends in the Red Sea Region (1901–2023)

1.4.4 Cyclones

Ras Ghareb, situated along the Egyptian Red Sea coast, falls within the broader climatic and oceanic influence of the Indian Ocean and the Egyptian Exclusive Economic Zone (EEZ). While the Indian Ocean basin has a well-documented history of cyclonic activity, historical analyses indicate no recorded occurrences of major cyclones within the Egyptian EEZ. However, given the regional atmospheric and oceanic patterns, any residual effects of cyclones from the Indian Ocean, such as changes in wind patterns, storm surges, or indirect weather disturbances, does however, have some minor implications for Ras Ghareb's coastal conditions.

This trend is further reflected in the simulated data on cyclone frequency and intensity across different regions. The chart below illustrates the relative frequency of various cyclone categories globally, within the Indian Ocean, the Egyptian EEZ, and Egypt's landfall regions from 1951 to 2014. Within Egypt's EEZ, all recorded storms fall under the Tropical Storm category (100%), indicating that higher-intensity cyclones (Categories 1–5) do not occur in this zone. For Egypt's landfall regions, 96.53% of recorded storms remain as Tropical Storms, with only a small fraction (3.47%) classified as Category 1 cyclones. No cyclones of Categories 2–5 make landfall in Egypt.

In contrast, the Indian Ocean and global data reveal a significantly higher occurrence of intense storms, particularly in the Indian Ocean, where stronger cyclones are more frequent. This indicates that as storms approach Egypt, they tend to weaken significantly, with only tropical storms and occasional Category 1 cyclones reaching landfall. This aligns with the broader pattern of cyclone intensity diminishing as storms move from the open ocean towards land, reinforcing the relative protection of Ras Ghareb from severe cyclonic impacts.

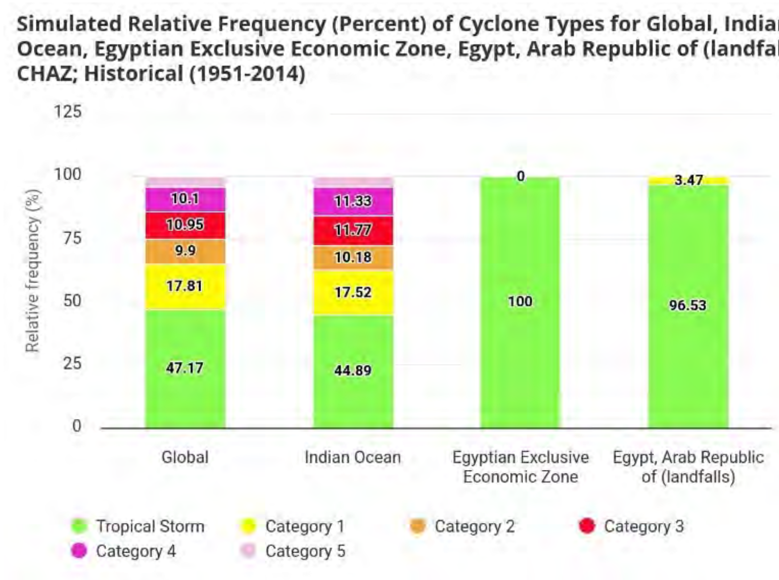


Figure 1-7: Simulated annual time series of cyclone counts in the Indian Ocean for the period 1951–2014

1.4.5 Extreme precipitation

Due to the arid nature of the project area, significant rainfall events are uncommon and typically spread over long intervals. While short-duration, lower-intensity rainfall can be expected and the probability of experiencing extreme precipitation remains minimal.

The historical analysis of the largest 1-day precipitation events in the Red Sea region of Egypt reveals that extreme rainfall events are rare. The return levels indicate that the median precipitation amount increases with longer return periods, from 10.51 mm for a 5-year event to 46.23 mm for a 100-year event, indicating the low frequency of high-intensity storms. The 90th percentile values further emphasize the potential for extreme outliers, with precipitation levels reaching 80.43 mm for a 100-year return period.

Meanwhile, the return period analysis suggests that lower-intensity precipitation events, such as 25 mm, occur approximately every 26 years whereas heavier rainfall events, such as 100 mm, have a median recurrence of 547 years, making them extremely rare. The likelihood of experiencing 200 mm of rainfall in a single day is therefore exceptionally low, with an estimated return period exceeding 2,600 years.

Table 1-3: Largest 1-Day Precipitation for Red Sea, Arab Republic of Egypt Return Levels, Historical: 1985-2014 (mm)

	Return Levels, Historical: 1985-2014 (center 2000) (mm)																	
Event	5-yr			10-yr			20-yr			25-yr			50-yr			100-yr		
	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th
Historical	5.08	10.51	17.43	6.86	15.27	23.99	8.96	21.53	34.18	9.73	24.02	38.42	12.06	33.17	55.40	14.33	46.23	80.43

Table 1-4: Largest 1-Day Precipitation for Red Sea, Arab Republic of Egypt Return Period, Historical: 1985-2014 (years)

Return Period, Historical: 1985-2014 (center 2000) (years)															
Event	25mm			50mm			100mm			150mm			200mm		
	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th	10th	median	90th
Historical	9.87	26.23	315.13	40.09	120.82	3958.61	145.98	547.26	6145.57	299.35	1402.34	8835.01	491.03	2613.45	10914.79

Similarly, the analysis of the largest 5-day cumulative precipitation for Egypt, based on historical data from 1985 to 2014, reveals an increasing trend in precipitation levels with longer return periods. The median precipitation for a 5-year event is 16.40 mm, rising to 24.19 mm for a 10-year event, 33.80 mm for a 20-year event, and 37.85 mm for a 25-year event. For more extreme events, the median precipitation reaches 53.88 mm at a 50-year return period and 74.88 mm for a 100-year event. The 90th percentile values are significantly higher, peaking at 131.89 mm for a 100-year event, highlighting the potential for extreme rainfall occurrences.

The return period data further illustrates the rarity of high precipitation amounts. A 25 mm event occurs with a median return period of 10.81 years, whereas a 50 mm event has a median return period of 42.42 years. Larger rainfall amounts, such as 100 mm, have an expected return period of 187.51 years, and extreme events reaching 200 mm are exceptionally rare, with a median recurrence of 836.06 years. The wide range between the 10th and 90th percentile values for return periods, particularly for higher precipitation amounts, suggests substantial variability and uncertainty in extreme rainfall events.

Table 1-5: Largest 5-Day Cumulative Precipitation for Red Sea, Arab Republic of Egypt- Return Levels, Historical: 1985-2014 (mm)

Return Levels, Historical: 1985-2014 (center 2000) (mm)																		
Event	**5-yr**			**10-yr**			**20-yr**			**25-yr**			**50-yr**			**100-yr**		
	10th	**median**	**90th**	**10th**	**median**	**90th**	**10th**	**median**	**90th**	**10th**	**median**	**90th**	**10th**	**median**	**90th**	**10th**	**median**	**90th**
Historical	8.82	16.40	30.30	12.51	24.19	42.02	16.45	33.80	57.16	17.73	37.85	63.57	22.21	53.88	91.39	27.15	74.88	131.89

Table 1-6: Largest 5-Day Cumulative Precipitation for Red Sea, Arab Republic of Egypt - Return Period, Historical: 1985-2014 (years)

Return Period, Historical: 1985-2014 (center 2000) (years)															
Event	**25mm**			**50mm**			**100mm**			**150mm**			**200mm**		
	10th	**median**	**90th**	**10th**	**median**	**90th**	**10th**	**median**	**90th**	**10th**	**median**	**90th**	**10th**	**median**	**90th**
Historical	3.04	10.81	80.00	15.75	42.42	725.46	60.68	187.51	6849.59	127.95	448.40	4979.82	212.20	836.06	6818.93

1.5 Projected climate change from baseline conditions[1]

Projections and models indicate that some areas close to the project area, namely Hurghada and Ras Ghareb may exhibit various climate change impacts, including rising sea levels. Additionally, the frequency and severity of extreme weather events—such as heatwaves, flash floods, heavy rainfall, and sand and dust storms—are expected, posing significant challenges to infrastructure.

The sections below assesses climate change risks specific to the project area according to projections of various parameters based on the models conducted.

These models consider four scenarios driven by greenhouse gas emissions, analyzing their impacts over the short, medium, and long term.

These projections are relative to the historical reference period (1995–2014) for each climate change Shared Socioeconomic Pathways (SSPs) of projected socioeconomic global changes up to 2100 as defined in the IPCC Sixth Assessment Report on climate change in 2021. The SSP scenarios represent different socioeconomic pathways, ranging from low-emission (SSP1-2.6) to high-emission (SSP5-8.5), each affecting global temperature increases differently. The projections span four key periods: near term (2020–2039), mid-term (2040–2059 and 2060–2079), and long-term (2080–2099).

1.5.1 Temperature

In the **near term (2020–2039)**, the projected temperature increases range from +1.02°C to +2.09°C across all scenarios. SSP1-2.6, shows the lowest differences, while SSP5-8.5, characterized by high fossil fuel reliance, exhibits the largest increase.

In the **mid-term (2040–2059)**, temperature differences increase, ranging from +1.43°C to +2.95°C, with SSP5-8.5 showing the highest increases. This trend continues in the **mid-term (2060–2079)**, where differences range from +1.43°C to +4.51°C, with SSP5-8.5 showing rapid warming compared to SSP1-2.6, which remains the most controlled scenario.

By the **long-term (2080–2099)**, the temperature differences reach between +1.22°C and +4.51°C. SSP5-8.5 consistently records the largest increases across all periods representing high-emission trajectory and underscoring the critical need for mitigation strategies. In contrast, SSP1-2.6 demonstrates the smallest temperature increases.

Table 1-7: Differences between Projected Average Mean Surface Air Temperature and historical reference by SSP Scenario

Scenario	Near term, 2020–2039 (°C)	Mid-term, 2040–2059 (°C)	Mid-term, 2060–2079 (°C)	Long-term 2080 -2099 (°C)
SSP1-2.6	1.02–1.35	1.43–1.81	1.43–1.92	1.22–1.92
SSP2-4.5	1.07–1.64	1.66–2.07	1.66–2.90	1.82–2.90
SSP3-7.0	1.04–1.67	1.84–2.32	1.84–3.71	2.22–3.71

[1] https://climateknowledgeportal.worldbank.org/country/egypt/climate-data-projections

SSP5-8.5	1.14–2.09	2.18–2.95	2.18–4.51	2.92–4.51

The most extreme scenario predicts a temperature rise of 2.18–2.95 to degrees Celsius above pre-industrial levels between 2040 and 2059 and it could reach 4.51 between 2080-2099. Such a scenario could result in irreversible impacts, accompanied by a significant increase in critical extreme events such as floods, droughts, heatwaves, and hurricanes on both global and regional scales.

1.5.2 Precipitation

The precipitation data from the closest weather station from 2015 to 2024 highlights significant variability in rainfall across the years and months. Notably, October 2016 recorded the highest precipitation in the dataset at 51.3, making it a flash flood. Another notable year is 2015, where October recorded 5.2, which is relatively high compared to other months and years.

In recent years, 2022 showed moderate precipitation, with January and February recording 16 and 2.1, respectively. In contrast, the earlier years, such as 2017 and 2019, experienced sparse precipitation limited to specific months like February and May, both with small values of 2 or less.

In addition, examining the projected differences in precipitation relative to the historical reference period (1995–2014) for various SSP scenarios across four periods: near term (2020–2039), mid-term (2040–2059 and 2060–2079), and long term (2080–2099). In the near term, all SSP scenarios exhibit small increases in precipitation, with SSP1-2.6 showing a modest rise of +0.07 mm/month and SSP5-8.5 reflecting the highest increase of +0.12 mm/month. These minor changes suggest limited divergence in global precipitation patterns in the near future. As we move into the mid-term (2040–2059), the differences become slightly more pronounced, with SSP1-2.6 continuing to show steady increases (+0.11 mm/month), while SSP5-8.5 sees a slightly lower rise of +0.08 mm/month. Interestingly, SSP2-4.5 and SSP3-7.0 display smaller increases, highlighting variability as emissions and socioeconomic conditions evolve.

In the mid-term period (2060–2079), greater variability emerges. SSP1-2.6 maintains a consistent increase (+0.11 mm/month), while SSP5-8.5 records the highest rise across all scenarios (+0.23 mm/month). However, SSP2-4.5 and SSP3-7.0 experience decreases of −0.07 mm/month and −0.16 mm/month, respectively, suggesting disruptions to regional precipitation patterns. By the long term (2080–2099), differences remain diverse, with SSP1-2.6 showing a moderate increase of +0.18 mm/month and SSP5-8.5 reflecting a small rise of +0.04 mm/month. Notably, SSP3-7.0 records the largest increase (+0.39 mm/month), highlighting the unpredictability of precipitation patterns under fragmented development scenarios.

Overall, SSP1-2.6 demonstrates consistent, moderate increases, reflecting the stabilizing effects of a sustainable pathway, while SSP5-8.5 and SSP3-7.0 show higher variability, with significant increases or decreases depending on the period.

Scenario	**Near term, 2020–2039 (mm/month)**	**Mid-term, 2040–2059 (mm/month)**	**Mid-term, 2060–2079 (mm/month)**	**Long-term, 2080–2099 (mm/month)**
SSP1-2.6	+0.07	+0.11	+0.11	+0.18
SSP2-4.5	+0.10	+0.03	−0.07	−0.03

SSP3-7.0	+0.02	+0.04	−0.16	+0.39
SSP5-8.5	+0.12	+0.08	+0.23	+0.04

1.5.3 Wind[2]

Under the RCP 8.5 scenario, wind speed projections for Egypt show varied trends. While some areas, like the northern coastal zone, are expected to experience a decline in wind speed, the Gulf of Suez is projected to have a slight increase in wind speed. Despite this increase, the overall change in wind speed across Egypt is expected to remain marginal, with relative variations within ±5% by 2065 compared to the baseline period of 1970–2005.

In terms of wind energy potential, the Gulf of Suez is one of the regions with relatively high current potential, with wind speeds exceeding 4 m/s. However, according to some study projections, areas in the Gulf of Suez with wind energy potential above 50 W/m² may experience a decrease of approximately 2.5% by 2065 under the same scenario.

For the project duration until 2050, the following key points apply:

- **Wind Speed Stability**: Changes in wind speed are projected to remain within ±5% relative to the baseline (1970–2005). For the Gulf of Suez, wind conditions conducive to energy generation are likely to persist.
- **Wind Energy Potential**: The wind energy potential in areas with high current capacity (e.g., the Gulf of Suez) shows minimal decline, with decreases less significant than those projected for 2065. Specifically, the Gulf of Suez is less likely to see major disruptions in wind energy output during the project duration.

1.6 Climate Hazards

1.6.1 Previous Climate Hazard

The project is situated between Ras Ghareb and Hurghada, both of which have experienced various climate change hazards. Previous climate damages as a result of extreme climate conditions were researched to draw on lessons learned. Reflecting on the previous damages can suggest the scale of damage that can be expected as a result of climatic factors. These are summarized in the table below.

Date	Climatic Event	Location	Impact
October 2016[3]	In October 2016, the city of Ras Gharib in the Red Sea Governorate	**Ras Ghareb**	The incident led to widespread inundation and caused significant human and material losses. Water spread throughout the streets of Ras Gharib, submerging houses and buildings,

[2] Hassaan, M. A., Abdrabo, M. A. K. A., Hussein, H. H. A., Ghanem, A. A. A., & Abdel-Latif, H. (2023). *Potential impacts of climate change on renewable energy in Egypt*. Alexandria University. https://doi.org/10.21203/rs.3.rs-3558017/v1

[3] https://www.elbalad.news/2470253

	experienced devastating floods that lasted for six hours		sweeping away vehicles, and destroying infrastructure. This catastrophe resulted in the death of 13 people, injuries to dozens, and material losses amounting to millions.
November 2016[4]	Flash flood / heavy rains	Hurghada	Heavy rainfall led to significant flooding in Hurghada, causing mudslides that disrupted transportation between Hurghada and Cairo. This event resulted in the loss of three lives.
January 2022[5]	Hailstorm	Hurghada	Hurghada witnessed heavy rain with hail, accompanied by lightning and thunder. It cause **breaking of roofs and windows.**

Table 1-8: Recent Climate Hazards to Railways as a result of Climate Change

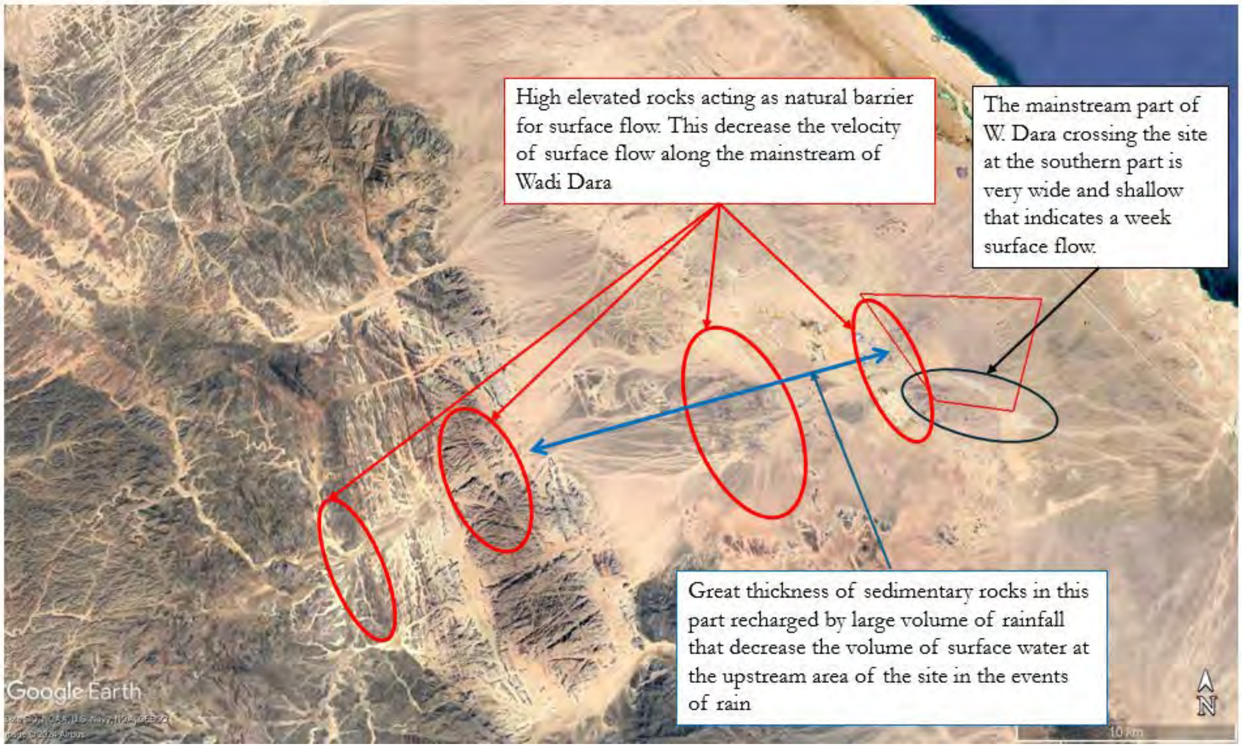
1.6.2 Project Areas Climate Hazards

According to the available information, the main climate risks identified in the project area are the following:

Prolonged exposure to extreme heat: According to Think Hazard, the weather in Ras Gharib is at risk of prolonged exposure to extreme heat, that could possibly result in heat stress. Such events are expected to occur at least once in the next five years.[6] In addition, this was confirmed by the projections on the world bank climate change knowledge portal as demonstrated in previous section 1.5.1.

Flash floods and flooding – The project is strategically situated in an area in Wadi Dara where the main drainage line South of the site is intersected by elevated rocks which acts as a natural barrier for surface flow, reducing the velocity of floodwaters and creating a weak surface flow (sheet flow). Additionally, the other drainage line to the north of the project site features a small watershed and a wadi with a broad, shallow main stream, contributing to weak surface flow.

[4] https://central2r.com/en/natural-disasters-in-egypt-catastrophes-of-the-past-and-risks-of-the-future.html
[5] https://watchers.news/2022/01/03/hurghada-egypt-haistorm-january-1-2022/
[6] https://thinkhazard.org/en/



Coastal floods- The site's topography is advantageous, with elevations ranging from 96 to 140 meters above sea level, reducing the risk of coastal flooding.

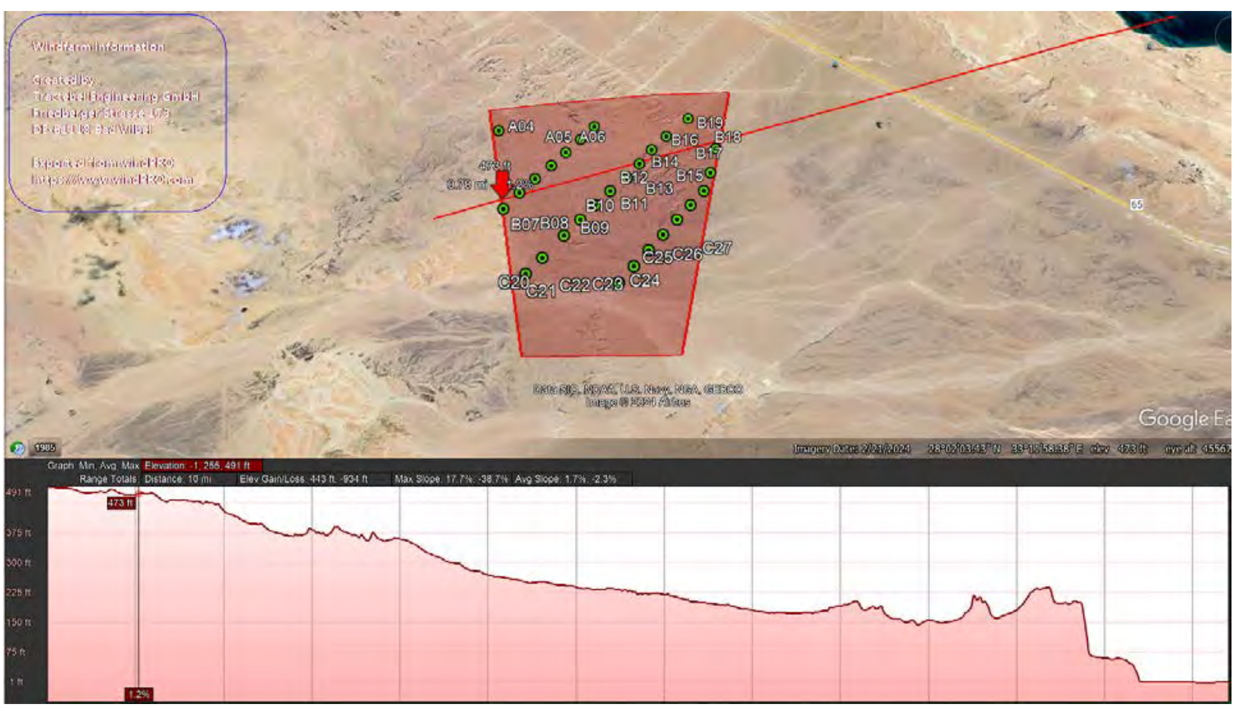


Figure 1-8: Site profile with respect to sea level

1.7 Climate Change Resilience Assessment

Using the baseline study carried out, the Consultant assessed the climate related risks such as heat, precipitation, and floods on the project components, namely those related to the assets and operations.

1.7.1 Project Vulnerabilities

As an initial step in the assessment, the Consultant conducted a vulnerability analysis to identify the climate hazards to which the project is exposed and to determine which hazards should be included in a more detailed risk assessment. Given that the project's location is already established, only site-specific climate hazards identified in the earlier baseline chapters as relevant to the project's components were considered. This approach ensures that the sensitivity analysis focuses on climate hazards deemed significant to the project.

The vulnerability assessment mainly considers the climatic conditions specific to the project area and is used to scope in/scope out impacts.

Vulnerability = Sensitivity x Exposure

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Table 1-9: Vulnerability Assessment

Common Climate Drivers in Project Area	Exposure	Scoped in/Out	Sensitivity of project components							
			Construction Phase	Operational Phase						
				Wind turbines	Medium Voltage (MV) Cables	Communications Network	Substation	Building Infrastructure	Road network	Overhead Transmission Line (OHTL)
High temperatures[7]	High	Scoped in	Risk of heat stress to workers & damage /interruption to machinery	Material Damage	Minimal impacts since the cables are buried		Excessive heat and thermal stress leading to equipment shutdown and interruptions in supply.	Deformation to infrastructure		
Precipitation- Change in annual average (Heavy rain, high average seasonal rainfall and flooding)	Low	Scoped Out	Low risk of delays	Material Damage	impacts are minimal since they are buried underground cables.	Material Damage	Material Damage	Material Damage	Material Damage	Material Damage
Precipitation- extreme rainfall events (Flash Flood)	High	Scoped Out	Could cause damage to machinery and affect the construction	Structural materials and concrete foundations may deteriorate due to flash flooding and rain infiltration, potentially causing ground saturation and instability. Additionally, damage to the structures protecting electrical equipment could lead to supply interruptions or disruptions.	Flooding of electrical cables can cause supply interruptions or outages, accompanied by the risk of ground saturation and possible ground instability.		Flooding of structure.	Structural Integrity risk due to Material Damage	High- Accessibility difficulties	power loss and degradation of overhead lines. Flash flooding may damage the infrastructure supporting overhead lines by destabilizing their foundations.
Flooding (coastal)	Insignificant	Scoped Out	High-damage to equipment	Material damage	Impacts are minimal since they are buried underground cables.		Material Damage			
Windstorms	Medium	Scoped in	Worker safety risks Risks to structures stability	Potential instability and turbine shutdown during high wind conditions.	Buried underground		Risk of damage	Damage to building	Damage of road surface	Risk of damage and possible dewiring

Table 1-10: Sensitivity and exposure Assessment Matrix
Source: Consultant Analysis

[7] https://www.swissre.com/institute/research/topics-and-risk-dialogues/climate-and-natural-catastrophe-risk/climate-change-wind-power.html

1.8 Risk Assessment

1.8.1 Methodology

The key hazards identified in the vulnerability assessment were further assessed against the baseline climate situation in more detail to understand their level of risk on the project components. Risk was assessed to examine the following:

- Against the baseline risk for both the construction and operation stage.
- Against future climate risk during operation

Each potential climate hazard resulting directly or indirectly on impacts on the project is categorized based on the magnitude and probability of occurrence according to the Jasper's Methodology. Based on these two parameters, the risk significance is evaluated.

The criteria for defining the risk severity includes assessing the following parameters:

- **Direct/Indirect**: describes the relationship between the climatic condition and the risk.
- **Duration**: the length of time over which the risk will be experienced. A risk may be present only while the climate event is active, or it could persist long after the climatic event is over, in which case the duration may be regarded as the time the project component receptor needs to recover from the effect.
- **Spatial extent**: the geographical area over which the risk is experienced.
- **Scale**: describes the degree to which the project component is potentially affected by the climate risks.

Severity Parameter	Description	Assignments
Direct/Indirect	Relationship of the effect on the project	**Direct** – Effects that result from a direct interaction between a climate event and the project (e.g. heavy rainfall flooding the facility) **Indirect** – Effects on the project which is not the result of a climate event affecting the project (e.g. community health affecting workforce)
Duration	Time during which the project is impacted	**Short Term** – One day to one week **Medium term**- One week to one month **Long term**- impact to sustain a number of years and up to the entire life of the facility
Spatial Extent	The area impacted in relation with the project's boundaries	**Low** – Risk is limited to the project site **Medium** – Risk on the project site and adjacent properties **High** – Risk affects communities/properties at a regional scale (with implications for the project)
Scale	The severity of the effect on the project.	**Low** – Project functions and/or processes remain unaltered, e.g. heat stress affects part of workforce **Medium** – Project functions and/or processes are notably altered, e.g. flooding results in a one-day shutdown **High** – Project functions and/or processes are significantly altered, e.g. flooding results in a two-week shutdown

Risk Significance= Probability x Severity

Table 1-11: Severity Parameters

Severity Parameter	**Description**	**Assignments**
Probability	Measure of the periodicity of the extreme weather event.	**(>10) – Occurs once in ten years or more- Low** **(5-10) – Occurs once in five to ten years- Medium** **(<1) – Occurs once a year or more-High**

Table 1-12: Probability of Occurrence

1.8.2 Climate Change Risk Assessment

The section below summarizes the climate change risk assessment during the construction and operational phase.

Table 1-13: Climate change risks to the project during construction

Climate Driver in Project Area	Risk	Direct/Indirect	Duration	Extent	Scale	Severity	Probability	Risk Significance
High temperature	Risk of heat stress to workers	Direct	Short-term	Local	High	**High**	**Medium**	**High**
	Damage /interruption to machinery	Direct	Short-term	Local	High	**High**	**Medium**	**High**
Precipitation- extreme rainfall events (Flash Flood)	**could cause** damage to machinery and affect the construction	Direct	Short-term	Local	Medium	**Medium**	**Medium**	**Medium**
	Risks to workers-slips, electric shocks, etc..	Direct	Short-term	Local	High	**High**	**Medium**	**Medium**
	Delay to construction schedule	Direct	Short-term	Local	Low	**Low**	**Low**	**Low**
Windstorms	High-Worker safety risks	Direct	Short-term	Local	High	**High**	**Medium**	**Medium**
	Delays to construction schedules	Direct	Short-term	Local	Low	**Low**	**Low**	**Low**

Source: Consultant Analysis

Table 1-14: Climate Change Risk Assessment during Operation

Climate Driver in Project Area	Risk	Direct/Indirect	Duration	Extent	Scale	Severity	Probability	Risk Significance
	Damage to Wind turbines material	Direct	Long-term	Local	High	**High**	**High**	**High**
	Damage to Medium Voltage (MV) material	Direct	Long-term	Local	High	**High**	**Insignificant**	**Low**
High temperatures	Excessive heat and thermal stress leading to Substation equipment shutdown and interruptions in supply.	Direct	Long-term	Local	High	**High**	**Medium**	**Medium**
	Deformation to Building Infrastructure	Direct	Long-term	Local	Medium	**Medium**	**Low**	**Low**
	Deformation to Road network-	Direct	Long-term	Local	Medium	**Medium**	**Low**	**Low**
	Deformation to Overhead Transmission Line (OHTL)-infrastructure	Direct	Long-term	Local	High	**High**	**High**	**High**
Change in annual average precipitation	Material Damage to Wind turbines	Long-term	Local	Medium	Low	**Low**	**Medium**	**Low**
	Increase in annual average precipitation has very limited impacts on Medium Voltage (MV) Cables since the cables are buried	Long-term	Local	Medium	Low	**Low**	**Insignificant**	**Insignificant**
	Increase in annual average precipitation can cause material damage to Substation	Long-term	Local	Medium	Low	**Low**	**Low**	**Low**
	Increase in annual average precipitation can cause deformation to Building Infrastructure	Long-term	Local	Medium	**Low**	**Low**	**Low**	**Low**
	Increase in annual average precipitation can cause deformation to road infrastructure	Long-term	Local	Medium	**Low**	**Low**	**Low**	**Low**
	Increase in annual average precipitation can cause -deformation to Overhead Transmission Line (OHTL) infrastructure	Long-term	Local	Medium	Low	**Low**	**Low**	**Low**
Extreme rainfall events (Flash Flood)	Extreme rainfall events (Flash Flood) can result in : degradation of structural materials and concrete foundations due to flash flooding and rain infiltration, with a risk of ground saturation and subsequent ground movements in Wind turbines and substation	Direct	Short-term	Local	High	**High**	**Low**	**Medium**
	Damage to substation structure housing electrical equipment resulting in loss or disruption of supply	Direct	Short-term	Local	High	**High**	**Low**	**Medium**
	extreme rainfall events (Flash Flood) on Medium Voltage (MV) Cables High: Flooding of electrical cables leading to supply disruptions or outages, along with the risk of ground saturation and potential ground movements.	Direct	Short-term	Local	High	**High**	**Insignificant**	**Low**

Climate Driver in Project Area	Risk	Direct/Indirect	Duration	Extent	Scale	Severity	Probability	Risk Significance
Windstorms	extreme rainfall events (Flash Flood) on Building Infrastructure - Structural Integrity risk due to Material Damage	Direct	Short-term	Local	Low	**Low**	**Low**	**Low**
	extreme rainfall events (Flash Flood) on Road network-High- Accessibility difficulties	Direct	Short-term	Local	High	**High**	**Low**	**Medium**
	extreme rainfall events (Flash Flood) on Overhead Transmission Line (OHTL)-High-power loss and degradation of overhead lines. Flash flooding may damage the infrastructure supporting overhead lines by destabilizing their foundations.	Direct	Short-term	Local	High	**High**	**Low**	**Medium**
	Potential instability and turbine shutdown during high wind conditions.	Direct	Long-term	Local	Medium	**Medium**	**Medium**	**Medium**
	Windstorms on Medium Voltage (MV) Cables -Buried underground	Direct	Long-term	Local	Medium	**Medium**	**Low**	**Low**
	Windstorms on Substation - Risk of damage	Direct	Long-term	Local	High	**High**	**Medium**	**Medium**
	Windstorms on Building Infrastructure	Direct	Long-term	Local	Low	**Low**	**Medium**	**Low**
	Windstorms on Road network-Damage of road surface and accessibility restrictions	Direct	Long-term	Local	Medium	**Medium**	**Medium**	**Medium**

1.8.3 Potential Adaptation Measures

The following tables summarizes some of the climate driver, the assets, the impacts and mitigations.

Climate Driver	Asset	Impact	Mitigation measure
Precipitation	**Construction Phase**	• Damage to equipment and construction materials. • Flash floods flooding concrete foundations.	Drainage systems should be integrated into the design, guided by flood modeling that accounts for projected climate change impacts.
	Construction and Operational Phase	Safety hazards posed to workers on-site in cases of extreme rainfall events. These include: • Slips and trips • Electric hazards • Fire risks	• Measures should be taken to raise awareness of safety hazards during extreme rainfall, including regular OHS orientation and induction training for new employees. Toolbox talks should consistently cover site rules, personal protective measures, and injury prevention. • Training programs should address basic hazard awareness, site-specific risks, safe work practices, and emergency protocols for fire and natural disasters, including extreme rainfall. • Ensure all energized electrical devices and lines are clearly marked with appropriate warning signs. • Apply lockout/tagout procedures when performing service or maintenance tasks. • Regularly inspect electrical cords, cables, and tools for any signs of damage. • Use electrical equipment that is either double-insulated or properly grounded. • Locate and clearly mark all buried electrical wiring to prevent accidental contact.
	Wind Turbines & Transformers	• Material structure damage • Flooding of concrete foundations. • Potential for ground movements.	Turbine materials must be designed to withstand corrosion caused by precipitation infiltration.
	Substation	Flooding of electrical components can lead to supply loss or interruptions.	Drainage systems should be integrated into the design, guided by flood modeling that accounts for projected climate change impacts.

	Underground cables	Flooding of electrical components can lead to supply loss or interruptions	All cables will be securely enclosed in protective casings that meet international standards, ensuring they are sealed, water-resistant, and tested for water intrusion. These designs will comply with both legal and technical requirements.
	Overhead transmission lines	Rain infiltration can cause power outages and damage to overhead lines.	Overhead lines will be equipped with electrical insulation, making them water resistant
	Roads	Flash flooding poses a risk of eroding road surfaces, hindering site access and increasing the need for maintenance.	A monitoring system should be established to assess ground conditions after precipitation events, such as heavy rainfall or flash flooding. It is expected that drainage systems are already in place or will be installed across the site.
	Buildings	Flooding of foundations. And risk of soil movement	Drainage systems should be integrated into the design, guided by flood modeling that accounts for projected climate change impacts.

Climate Driver	Asset	Impact	Mitigation measure
Heat waves	**Construction Phase**	• Machinery overheating poses a fire hazard. • Equipment and materials, including turbine structures, may degrade under extreme heat.	A monitoring system should be implemented to assess temperature levels and the condition of equipment, machinery, and materials. This system should be incorporated into the Construction Management Plan, detailing measures to minimize risks on machinery.
	Workers (Construction and Operational Phase)	Site workers face potential health risks from heat-related illnesses (risk of heat stress to workers)	Incorporate measures into the Construction Management Plan, detailing mitigations to minimize heat stress risks for site workers. These include the following: • Training (inductions/refresher and toolbox talks) to raise awareness including the following precautions during hot days: o Work under the shade where possible. o Rehydrating requirements by drinking water every hour. o Take regular breaks in cool and shaded areas. o Sponge yourself with water during breaks or meals. • Temperature-related stress management procedures should be implemented which include: o Monitoring weather forecasts for outdoor work to provide o advance warning of extreme weather and scheduling work accordingly o Adjustment of work and rest periods according to temperature stress management procedures provided by ACGIH67, depending on the temperature and workloads o Providing temporary shelters to protect against the elements during working activities or for use as rest areas

	Wind Turbines & Transformers	o Materials degrade more rapidly under higher UV exposure, resulting in issues such as fading, brittleness, weathering of coatings, and discoloration. o High temperatures may cause turbines to operate at reduced capacity or temporarily cease functioning.	Turbine materials will be designed to resist elevated temperatures.
	Substation	o Excessive heat in electrical components can lead to supply interruptions or outages. o There is a heightened risk of fire under these conditions.	The substation will be equipped with an air-insulated cooling system and temperature sensors to prevent electrical components from overheating. All electronic equipment will be installed indoors, shielding it from direct exposure to solar radiation. It is advised to establish a monitoring system to regularly assess temperature levels and the condition of equipment within the substation, particularly after extreme heat events and during extended heatwaves.
	Overhead transmission lines	High temperatures can cause the overhead line to expand and sag, increasing the risk of de-wiring.	The overhead lines will be designed and constructed using materials capable of withstanding temperature fluctuations, including both heat and cold.
	Roads	Potential melting and deformation of road surfaces.	Materials will be specifically selected to accommodate variations in temperature, ensuring durability and performance under different conditions. Additionally, a monitoring system should be implemented to regularly assess ground conditions after extreme weather events, such as heavy rainfall or significant temperature changes, to mitigate potential impacts effectively.
	Buildings	Accelerated material degradation, leading to brittleness and discoloration. Excessive heat may also cause electrical components to overheat, resulting in supply interruptions or failures and an increased risk of fire.	
Changes in Wind Patterns	**Marginal Decline in Energy Output**	High-potential areas in the Gulf of Suez might experience a slight decrease in wind energy potential (less than 5%) due to projected changes in wind speed.	Technological Adaptations: Although changes are minor, adopting turbine technology with improved sensitivity to slight wind variations may help optimize energy output.

	Reduced Efficiency in High-Potential Zones	The efficiency of turbines in areas with wind energy potential above 50 W/m² could decline slightly, impacting overall output.	Regular Monitoring and Maintenance: Implement advanced monitoring systems to track wind patterns and turbine performance, ensuring prompt responses to any operational inefficiencies.