



ESIA for Project Anma

Climate Change Risk Assessment

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ESIA for Project Anma

Climate Change Risk Assessment

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CONTENTS

1	INTRODUCTION	8
2	DOCUMENT PURPOSE/ OBJECTIVE	9
3	PROJECT DESCRIPTION	10
4	METHODOLOGY	11
4.1	Hazard Categorisation	12
4.2	Exposure and Vulnerability Categorization	14
4.3	Risk Categorization	14
5	PHYSICAL RISK ASSESSMENT	16
5.1	Water Availability Flood	16
5.1.1	Baseline Hazard	17
5.1.2	Climate Change Projection	23
5.1.3	Exposure and Vulnerability	30
5.1.4	Risk Assessment	30
5.2	Flood	31
5.2.1	Baseline Hazard	33
5.2.2	Climate Change Projections	40
5.2.3	Exposure and Vulnerability	45
5.2.4	Risk Assessment	45
5.3	Landslides	47
5.3.1	Baseline Hazard	47
5.3.2	Climate Change Projections	51
5.3.3	Exposure and Vulnerability	51
5.3.4	Risk Assessment	51
5.4	Extreme Heat	52
5.4.1	Baseline Hazard	52
5.4.2	Climate Change Projections	54
5.4.3	Exposure and Vulnerability	54
5.4.4	Risk Assessment	55
5.5	Cyclone and Hurricane	56
5.5.1	Baseline Hazard	56
5.5.2	Climate Change Projections	60
5.5.3	Exposure and Vulnerability	60
5.5.4	Risk Assessment	61
5.6	Wind Speed	62
5.6.1	Baseline Hazard	62
5.6.2	Climate Change Projections	66
5.6.3	Exposure and Vulnerability	66
5.6.4	Risk Assessment	66
5.7	Sea Level Rise	67
5.7.1	Baseline Hazard	67
5.7.2	Climate Change Projections	68
5.7.3	Exposure and Vulnerability	70
5.7.4	Risk Assessment	70
5.8	Lightning	71
5.8.1	Baseline Hazard	71
5.8.2	Climate Change Projections	73
5.8.3	Exposure and Vulnerability	76
5.8.4	Risk Assessment	76

6 CONCLUSIONS 78

APPENDIX A PROJECT DESCRIPTION

APPENDIX B GREENHOUSE GAS EMISSIONS DURING THE CONSTRUCTION PHASE

List of Tables

Table 4.1	Categorisation of Natural Hazards	12
Table 4.2	Climate Change Risk Level	15
Table 5.1	List of Parameters for Evaluation of Baseline Water Availability	16
Table 5.2	Qualitative Risk Level and Project Implications for Water Availability	31
Table 5.3	Parameters Used for Evaluation of Baseline Flood Hazard	32
Table 5.4	Qualitative Risk Level and Project Implications for Flood	45
Table 5.5	Qualitative Risk Level and Project Implications for Landslides	51
Table 5.6	Classification of Extreme Heat Hazard	54
Table 5.7	Qualitative Risk Level and Project Implications for Extreme Heat	55
Table 5.8	Saffir-Simpson Categorization of Cyclone/Hurricane	56
Table 5.9	Qualitative Risk Level and Project Implications for Cyclone and Hurricane	61
Table 5.10	Qualitative Risk Level and Project Implications for Wind Hazard	66
Table 5.11	Qualitative Risk Level and Project Implications for Sea Level Rise	70
Table 5.12	Qualitative Risk Level and Project Implications for Lightning	76
Table 6.1	Summary of Risk Level and Proposed Mitigation Measures	79

List of Figures

Figure 5.1	Baseline Water Stress	18
Figure 5.2	Baseline Seasonal Variability	20
Figure 5.3	Baseline Inter-Annual Variability	22
Figure 5.4	Projections of Water Supply during 2030 for RCP 8.5	24
Figure 5.5	Projections of Water Supply during 2040 for RCP 8.5	25
Figure 5.6	Projections of Water Stress during 2030 for RCP 8.5	26
Figure 5.7	Projections of Water Stress during 2040 for RCP 8.5	27
Figure 5.8	Projections of Seasonal Variability during 2030 for RCP 8.5	28
Figure 5.9	Projections of Seasonal Variability during 2040 for RCP 8.5	29
Figure 5.10	Baseline Riverine Flood Hazard (Inundation) Map	35
Figure 5.11	Baseline Coastal Flood Hazard (Inundation)	36
Figure 5.12	Baseline Flood Hazard Map	37
Figure 5.13	Baseline Riverine Flood Hazard	38
Figure 5.14	Baseline Coastal Flood Hazard	39
Figure 5.15	Projections of Coastal Flood Hazard 2030 8.5	41
Figure 5.16	Projections of Coastal Flood Hazard 2050 8.5	42
Figure 5.17	Projections of Riverine Flood Hazard 2030 8.5	43
Figure 5.18	Projections of Riverine Flood Hazard 2050 8.5	44
Figure 5.19	Baseline Landslide Hazard: Median Annual Rainfall-Triggered Landslide Hazard	48
Figure 5.20	Baseline Landslide Susceptibility	49
Figure 5.21	Baseline Landslide Hazard	50
Figure 5.22	Extreme Heat Hazard	53
Figure 5.23	Baseline Cyclone Intensity Map	57
Figure 5.24	Historical Hurricane Tracks Map	58
Figure 5.25	Highest Wind Speed due to Cyclone within 100km Radius of the Project Location	59
Figure 5.26	Baseline Average Wind Speed Map	64

Figure 5.27	Extreme Wind Speed 50 – Year	65
Figure 5.28	Map for Sea Level Rise Projections at Project location	69
Figure 5.29	Baseline Lightning Density Map.....	72
Figure 5.30	Projected Change in Convective Available Potential Energy (CAPE) by 2100 under RCP 8.5 Scenario	74
Figure 5.31	Projected Change for frequency of intense tropical and subtropical thunderstorms by 2100 under RCP 8.5 Scenario	75

Acronyms and Abbreviations

Name	Description
°C	Degree Celsius
AC	Alternating current
AOGCM	Atmosphere-Ocean General Circulation Model
AR4	Fourth Assessment Report
AWC	Anma Offshore Wind Energy
CAPE	Convective Available Potential Energy
CCRA	Climate Change Risk Assessment
cm	Centimetre
CMIP	Coupled Model Intercomparison Project
CO2	Carbon dioxide
CV	Coefficient of Variability
DC	Direct current
DTU	Technical University of Denmark
DTU	Technical University of Denmark
e.g.	Exempli Gratia
ECMWF	European Centre for Medium-Range Weather Forecasts
ECP	Energy and Climate Policy
EP4	Equator Principles 4
EPC	Engineering, Procurement and Construction
ESIA	Environmental and Social Impact Assessment
FAO	Food and Agriculture Organization
FES	Finite Element Solution
GASP	Global Atlas for Siting Parameters
GFDRR	Global Facility for Disaster Reduction and Recovery
GHG	Greenhouse Gas
GLD	Global Lightning Dataset
GLD360	Global Lightning Detection Network
GLOFRIS	Global Flood Risk with IMAGE Scenarios
GTSM	Global Tide and Surge Model
GTSR	Global Tide and Surge Reanalysis
h	Hour
HDD	Horizontal Directional Drilling
HV/LV	High voltage/Low voltage
HVAC	Heating, ventilation, and air conditioning
i.e.	id est
IAC	Inter Array Cable
IBTrACS	International Best Track Archive for Climate Stewardship
IPCC	Intergovernmental Panel on Climate Change

Name	Description
J/kg	Joule per kilogram
km	Kilometre
km ²	Squared kilometres
LIS	Lighting Imaging Sensor
m/s	Meters per second
mm	Millimetres
MW	Mega Watt
NOAA	National Oceanic and Atmospheric Administration
ONSS	Onshore Substation
OSHA	Occupational Safety and Health Administration
OSS	Offshore Substation
RCP	Representative Concentration Pathways
SCADA	Supervisory control and data acquisition
SEDAC	Socioeconomic Data and Applications Center
SLR	Sea level rise
TCFD	Task Force on Climate-Related Financial Disclosures
TRMM	Tropical Rainfall Measuring Mission
TWI	Temporary Worker Initiative
UNEP	The United Nations Environment Programme
USGS	United States Geological Survey
W m ²	Watt per square meter
WATCH Forcing Data	WATer and global Change Forcing Data
WBGT	WetBulb Globe Temperature
WCRP	World Climate Research Programme
WGCM	Working Group on Couple Modelling
WRI	World Resources Institute
WTG	Wind Turbine Generator

1 INTRODUCTION

Climate change is now widely and globally recognised as one of the most significant environmental challenges. In terms of response and adaptation to climate change, a range of international and national policies and legislations have been introduced and implemented to encourage the development of renewable energy, reduce greenhouse gas (GHG) emissions and combat the impacts of climate change.

According to the requirements of the Equator Principles 4 (EP4)¹ a Climate Change Risk Assessment (CCRA) is required for all Category A and, as appropriate, Category B Projects.

The depth and nature of the CCRA will depend on the type of project as well as the nature of risks, including their materiality and severity.

According to the Guidance Note on Climate Change Risk Assessment², for all projects, in all locations, when combined Scope 1 and Scope 2 emissions are expected to be more than 100,000 tonnes of CO₂ equivalent annually, the CCRA is to include consideration of climate-related 'Transition Risks' (as defined by the Task Force on Climate-Related Financial Disclosures (TCFD))³. The CCRA must also include a completed alternatives analysis which evaluates lower GHG intensive alternatives. TCFD Recommendations state that "Transitioning to a lower-carbon economy may entail extensive policy, legal, technology, reputation and market changes to address mitigation and adaptation requirements related to climate change".

The GHG emissions during the construction phase, based on an 8-hour workday, are estimated to total 10,088.84 tCO₂eq annually, as detailed in Appendix B. Emissions during the operational phase are negligible and therefore have not been evaluated.

As it is not expected that the Project will emit more than 100,000 tonnes of CO₂ equivalent annually and, therefore, the Project Proponent is not obliged to assess the Transition Risk analysis.

The Project aligns closely with South Korea's national and international climate commitments, including the Paris Agreement, which aims to limit global temperature rise to well below 2°C and pursue efforts to keep it to 1.5°C above pre-industrial levels. South Korea's Nationally Determined Contribution (NDC) commits to reducing GHG emissions by 40% from 2018 levels by 2030 and achieving carbon neutrality by 2050 through renewable energy deployment, industrial decarbonization, and energy efficiency improvements.

This offshore wind project directly supports these commitments by generating circa 1.5 GWh of renewable energy annually, displacing a significant amount of fossil fuel-based electricity production, and avoiding circa 274,084 tonnes of CO₂ emissions per year. These contributions align with the government's Renewable Energy 3020 Plan, which aims for renewable energy to constitute 20% of the national energy mix by 2030, as well as other policies targeting net-zero emissions.

In addition to reducing emissions, the Project addresses physical climate risks such as sea level rise and increased typhoon intensity. By adopting advanced turbine designs and resilient infrastructure, the Project ensures robust operations while supporting South Korea's Long-term Strategies (LTS) to enhance climate resilience and adaptive capacity.

The Project's annual emissions fall significantly below the threshold of 100,000 tonnes of CO₂ equivalent, demonstrating its alignment with efforts to reduce greenhouse gas emissions and support the transition to a low-carbon economy. While a detailed Transition Risk analysis is not required, the

¹ The Equator Principles, July 2020. A financial industry benchmark for determining, assessing and managing environmental and social risk in projects. Available at https://equator-principles.com/app/uploads/The-Equator-Principles_EP4_July2020.pdf [Last Accessed January 2023]

² The Equator Principles, September 2020. Guidance Note on Climate Change Risk Assessment. Available at https://equator-principles.com/app/uploads/CCRA_Guidance_Note_Sept2020.pdf [Last Accessed January 2023]

³ Task Force on Climate-Related Disclosures, Recommendations of the Task Force on Climate-related Financial Disclosures, June 2017, p 6.

Project fully aligns with South Korea's Nationally Determined Contribution to National Climate Commitments (NCCs) and renewable energy goals, playing a crucial role in advancing the nation's sustainable and low-carbon economic transition.

2 DOCUMENT PURPOSE/ OBJECTIVE

The primary objective of this report is to follow a methodical process to identify and analyse hazards directly linked to climate change within the specific context of the project.

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

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

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

3 PROJECT DESCRIPTION

The Project Description, including the project's background (location, milestones, facilities and components, summary of EPC construction activities) is provided in Appendix A.

It has been developed as a standalone document to be read in conjunction with the main ESIA report. This ensures optimal coherence of the information through the updates and revisions.

This assessment is focusing on five (5) major Project components:

- Wind Turbine Generators (WTGs);
- Offshore substation (OSS);
- Offshore Export Cable: within this report, when referring to Offshore Export Cable it is included the Inter Array Cable (IAC) as the implications related to physical risks are the same;
- Onshore Substation (ONS); and
- Onshore Export Cable.

4 METHODOLOGY

The key objective of this assessment is to understand the potential high-level physical risks to the Project from climate change. The methodology constituted of three (3) major steps as given below:

- Step 1: Desktop Review of the baseline natural hazards

For the first step, a desktop-based review of prominent natural hazards was undertaken at the Project locations offshore as well as onshore. The natural hazards are then evaluated and categorised based on potential to cause damage to the natural environment due to intensity / severity and frequency.

- Step 2: Evaluation of climate change projections

This second step involved evaluation projections for various climate variables such as temperature, sea level and precipitation. The climate change projections data involved multi-model mean climate change projections published under Coupled Model Intercomparison Project 5 (CMIP-5)⁴, which is a recognised standard by the Intergovernmental Panel on Climate Change (IPCC). The climate change scenarios for which the data was evaluated involved RCP 8.5 over timelines of 2030 and 2050. When public database provide only estimates for year 2040, ERM has used educated speculation and professional judgment to evaluate the potential risk at long term horizon, i.e. 2050.

- Step 3: Qualitative estimation of future hazards and physical risks

The third step involved use of the future projections on natural hazards to evaluate the potential risks in future. Qualitative estimation of future natural hazards was also conducted based on changes in indicator climate variables which are likely to affect a particular natural hazard, and baseline natural hazards in cases where future hazard level was not readily available. Hazard level in combination with exposure and vulnerability levels are used to estimate the physical risk to the project.

Further, the qualitative evaluation of the impacts of climate change on natural hazards is an exercise of educated speculation and professional judgement. The likely changes in natural hazards presented here are based on the possible relation between the natural hazards and climatic parameters.

What are the Representative Concentration Pathways (RCP)?

RCPs usually refer to the portion of the concentration pathway extending up to the year 2100, for which Integrated Assessment Models produced corresponding emission scenarios. Each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. The term pathway emphasises that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome.

Four (4) RCPs produced from Integrated Assessment Models were selected from the published literature and are used in the Fifth Intergovernmental Panel on Climate Change (IPCC) Assessment as a basis for the climate predictions and projections are as follows:

RCP2.6 One pathway where radiative forcing peaks at approximately 3 W m^{-2} before 2100 and then declines (the corresponding ECP assuming constant emissions after 2100);

RCP4.5 and RCP6.0 Two intermediate stabilisation pathways in which radiative forcing is stabilised at approximately 4.5 W m^{-2} and 6.0 W m^{-2} after 2100 (the corresponding ECPs assuming constant concentrations after 2150);

⁴ Under the World Climate Research Programme (WCRP) the Working Group on Coupled Modelling (WGCM) established the Coupled Model Intercomparison Project (CMIP) as a standard experimental protocol for studying the output of coupled atmosphere-ocean general circulation models (AOGCMs). CMIP provides a community-based infrastructure in support of climate model diagnosis, validation, intercomparison, documentation and data access. This framework enables a diverse community of scientists to analyse GCMs in a systematic fashion, a process which serves to facilitate model improvement.

RCP8.5 One high pathway for which radiative forcing reaches greater than 8.5 W m⁻² by 2100 and continues to rise for some amount of time (the corresponding ECP assuming constant emissions after 2100 and constant concentrations after 2250).

4.1 Hazard Categorisation

Hazard is defined by the IPCC AR6⁵ as:

The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.

Open access databases have been reviewed to assess the hazard level at the project site. As different sources present different classifications, ERM has reorganized those into three levels: low, medium and high.

The below table presents the classification of the hazard level used in this report.

Table 4.1 Categorisation of Natural Hazards

Hazard (Criteria for Categorisation)	Original Categorisation	Report Categorization
Water Availability		
Water Stress Source: WRI-Aqueduct Water Risk Atlas 3.0 <i>(Based on ratio of total water withdrawal to available renewable water resources (surface and groundwater))</i>	Low: < 10%	Low: <20%
	Low-Medium: 10-20%	
	Medium-High: 20-40%	Medium: 20-40%
	High: 40-80%	High: >40%
	Extremely High: >80%	
Inter Annual Variability Source: WRI-Aqueduct Water Risk Atlas <i>(Based on coefficient of variability (CV) as ratio of standard deviation of the available water and the mean available water during the period of 1960-2014 on monthly and annual basis)</i>	Low: <0.25	Low: <0.25
	Low-medium: 0.25-0.50	Medium: 0.25-0.5
	Medium-high: 0.50-0.75	High: >0.5
	High: 0.75-1.00	
	Extremely High: >1.00	
Seasonal Variability Source: WRI-Aqueduct Water Risk Atlas <i>(Based on coefficient of variability (CV) as ratio of standard deviation of the annual available water and the annual mean available water during the period of 1960-2014)</i>	Low: <0.33	Low: <0.33
	Low-medium: 0.33-0.66	Medium: 0.33-0.66
	Medium-high: 0.66-1.00	High: >0.66
	High: 1.00-1.33	
	Extremely High: >1.33	
Floods Inland and Coastal		
Riverine Flood Risk Source: WRI-Aqueduct Water Risk Atlas <i>(Based on population exposed to floods per 1,000 people)</i>	Low: 0-1/1,000 (people)	Low: 0-2/ 1,000
	Low-Medium: 1-2/1,000	Medium: 2-6/ 1,000
	Medium-High: 2-6/1,000	
	High: 6-10/1,000	High: > 6/ 1,000

⁵ IPCC, 2022: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

Hazard (Criteria for Categorisation)	Original Categorisation	Report Categorization
	Extremely High: >10/1,000	
Coastal Flood Risk Source: WRI-Aqueduct Water Risk Atlas (Based on population exposed to floods per 1,000,000 people)	Low: 0-9/ 1,000,000 (people)	Low: 0-9/ 1,000,000
	Low-Medium: 9-70/ 1,000,000	Medium: 9-300/ 1,000,000
	Medium-High: 70-300/ 1,000,000	
	High: 300-2000/ 1,000,000	High: >300/ 1,000,000
	Extremely High:>2000/ 1,000,000	
Flood Hazard Map Source: WRI-Aqueduct Flood Tool (Based on depth of inundation in meters)	No original categorisation	Low: ≤0.5m
		Medium: 0.5-1.5m
		High: > 1.5m
Flood Hazard Map Source: FM Global (Based on probability of flood occurring each year for a given flood return period)	Moderate: Locations in a 500-year flood zone with a chance of at least 0.2% of experiencing a flood each year	Medium
	High: Locations in a 100-year flood zone with a chance of at least 1% of experiencing a flood each year	High
Landslides		
Landslides Susceptibility Source: Think Hazard ⁶ (The classify hazards based on probabilistic data in Think Hazard)	Very Low	Low
	Low	
	Medium	Medium
	High	High
Landslides Hazard Source: Think Hazard ⁷ (The classify hazards based on probabilistic data in Think Hazard)	Low	Low
	Moderate	Medium
	High	High
	Very High	
Extreme Heat Source: Think Hazard (Based on widely accepted heat stress indicator, the Wet Bulb Globe Temperature (°C))	Very Low: <25°C	Low: under 28°C
	Low: >25°C	
	Medium: >28°C	Medium: between 28 and 32°C
	High: >32°C	High: above 32°C
Cyclone and Hurricane Intensity Source: UNEP global Risk Data Platform (Cyclone categories based on damage potential as classified by Saffir-Simpson Scale)	Category 1: 119-153 km/h	Low: 119-153 km/h
	Category 2: 154-177 km/h	Medium: 154-177 km/h
	Category 3: 178-208 km/h	High: above 178 km/h
	Category 4: 209-251 km/h	
	Category 5: ≥252 km/h	
Wind Speed Source: Global Wind Atlas (Based on damage potential of wind speed (m/s) with reference to the Beaufort's scale)	0: <1 m/s	Low: ≤ 11 m/s
	1: 1-2 m/s	
	2: 2-3 m/s	
	3: 4-5 m/s	
	4: 6-8 m/s	
	5: 9-11 m/s	
	6: 11-14 m/s	Medium: 11-21 m/s

⁶ GIS processing International Centre for Geohazards /NGI. Preprocessing for ThinkHazard! conducted by GFDRR

⁷ GIS processing International Centre for Geohazards /NGI. Preprocessing for ThinkHazard! conducted by GFDRR

Hazard (Criteria for Categorisation)	Original Categorisation	Report Categorization
	7: 14-17 m/s	
	8: 17-21 m/s	
	9: 21-24 m/s	
	10: 25-28 m/s	High: ≥ 21 m/s
	11: 29-32 m/s	
	12: >33 m/s	
Sea Level Rise Source: CLIMsystems, Sea Level Rise for Cities <i>(Combined processes of local (absolute) sea level rise and local vertical land movement expressed in centimetres)</i>	No original categorisation	Low: 1-50cm
		Medium: 51-150cm
		High: 151-200cm
Lightning Source: Lighting Imaging Sensor (LIS) on TRMM Science Data <i>(Lightning Density average between 1998 and 2013 expressed as Flashes per km²)</i>	No original categorisation	Low: 1-20
		Medium: 21-60
		High: >61

4.2 Exposure and Vulnerability Categorization

Exposure and vulnerability of the Project are necessary to determine the risk level.

Vulnerability is defined by the IPCC AR6⁸ as:

The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Exposure is defined as:

The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.

Details of the Project location, design of components, buildings and infrastructures, activities of operation and maintenance personnel are used to determine the exposure of the Project to the hazards. Vulnerability can then be assessed in more detail, drawing on Project design information and standards together with any other factors which may provide resilience, e.g., pre-existing flood prevention measures.

The combination of exposure and vulnerability is categorized in three levels: low, medium, high.

4.3 Risk Categorization

Risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards. Such interaction is complex and subject to uncertainty, therefore, ERM has performed a qualitative evaluation based on educated speculation and professional judgement.

The relation between hazard, vulnerability and exposure is presented in the below table.

⁸ IPCC, 2022: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

Table 4.2 Climate Change Risk Level

		Hazard		
Exposure x Vulnerability		Low	Medium	High
	Low	Low	Low	Low
	Medium	Low	Medium	Medium
	High	Medium	High	High

5 PHYSICAL RISK ASSESSMENT

5.1 Water Availability Flood

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

Table 5.1 List of Parameters for Evaluation of Baseline Water Availability

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

5.1.1 Baseline Hazard

5.1.1.1 Water Stress

The baseline water stress map is presented in **Figure 5.1**. The specific location is a few kilometres outside the area calculated by the model and therefore has no data. However, considering the distribution of water stress in the hydrological basin where the Project is located, i.e., South Korea Coast 2 basin⁹, the hazard level is categorized as “High” water stress indicating likely competition for common water resources or lower availability of water in the area. Hence, the baseline hazard due to water stress is categorised to be “**High**”.

⁹ Food and Agriculture Organization (FAO) Land and Water Division Major hydrological basins of the world, 2022. Available at: <https://data.apps.fao.org/catalog/iso/f2615a41-6383-4aa4-aa21-743330eb03ae>

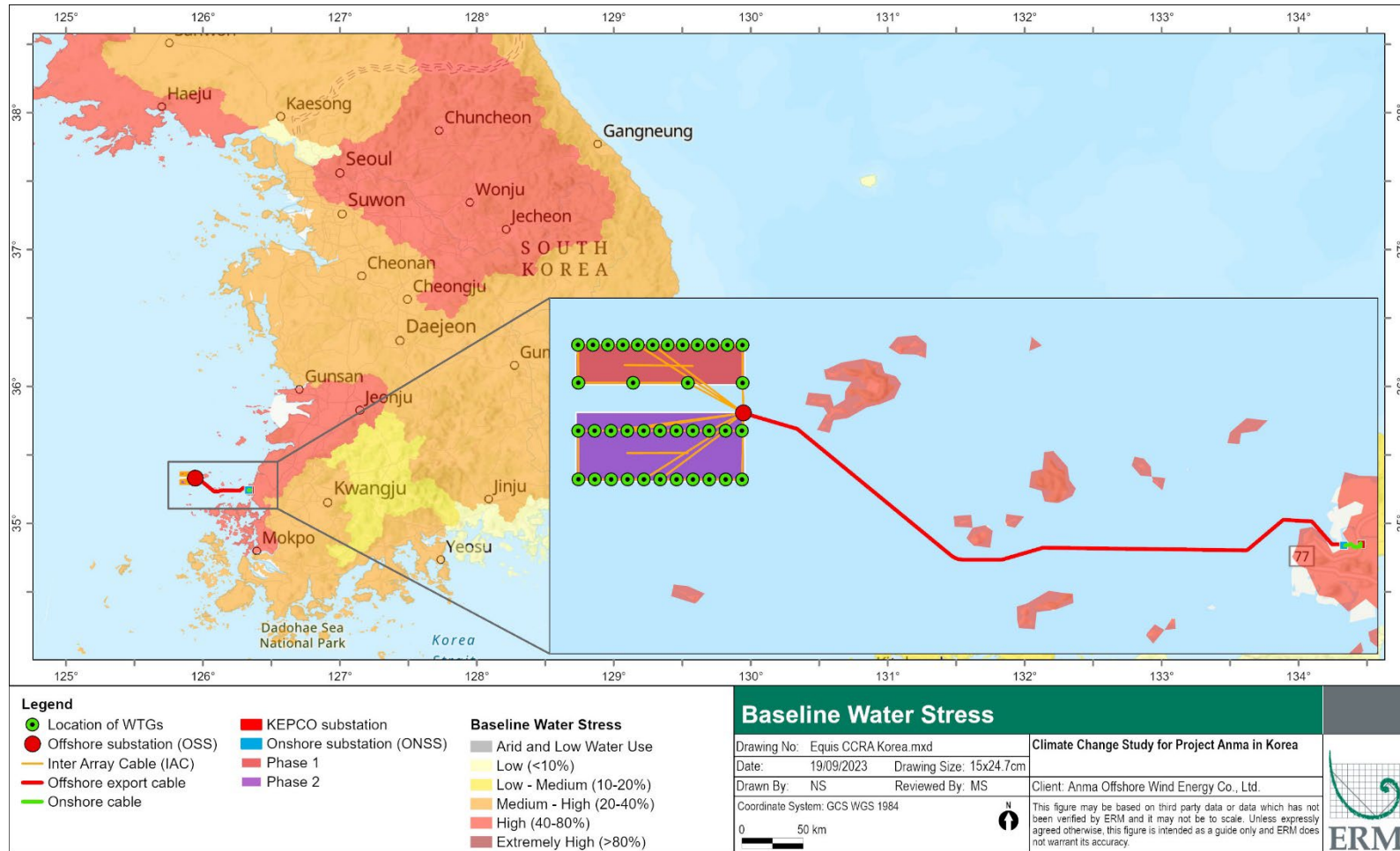


Figure 5.1 Baseline Water Stress

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

5.1.1.2 Seasonal Variability

Seasonal Variability map presented in **Figure 5.2** indicates the likelihood of variations in water availability over different months within a year as “Low-Medium”. This indicates that the supply of water over different month does not vary significantly. However, considering the baseline hazard due to seasonal variability as show in the **Table 4.1**, the hazard level is categorised to be “**Medium**”.

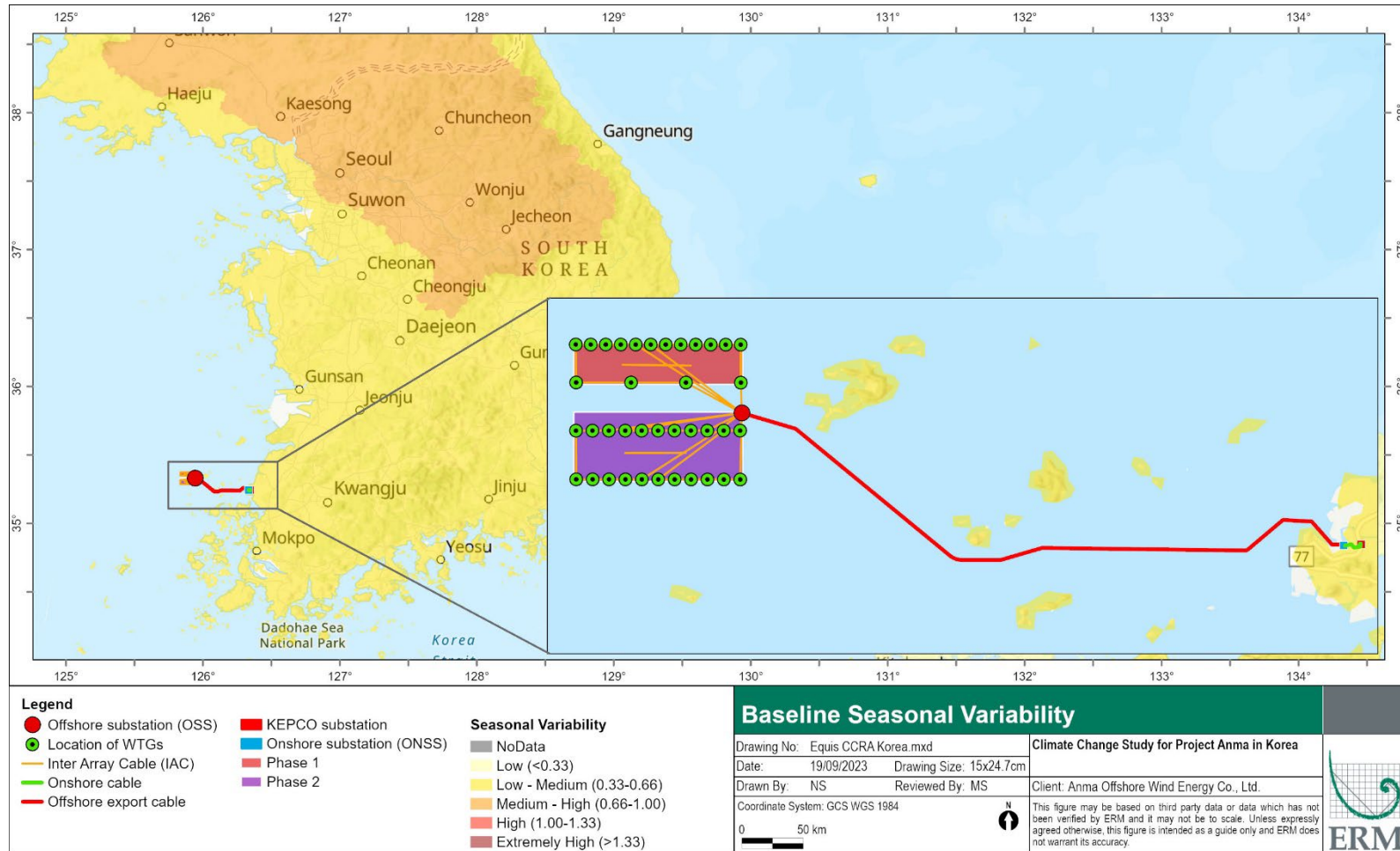


Figure 5.2 Baseline Seasonal Variability

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

5.1.1.3 Inter-Annual Variability

Inter-Annual Variability map presented in **Figure 5.3** indicates the variations in water availability over different years is 'Low-Medium'. This indicates that the supply of water over different years is likely to have higher variations similar to seasonal variation. However, the baseline hazard due to inter-annual variability as show in the **Table 4.1**, the hazard level is categorised to be "**Medium**".

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

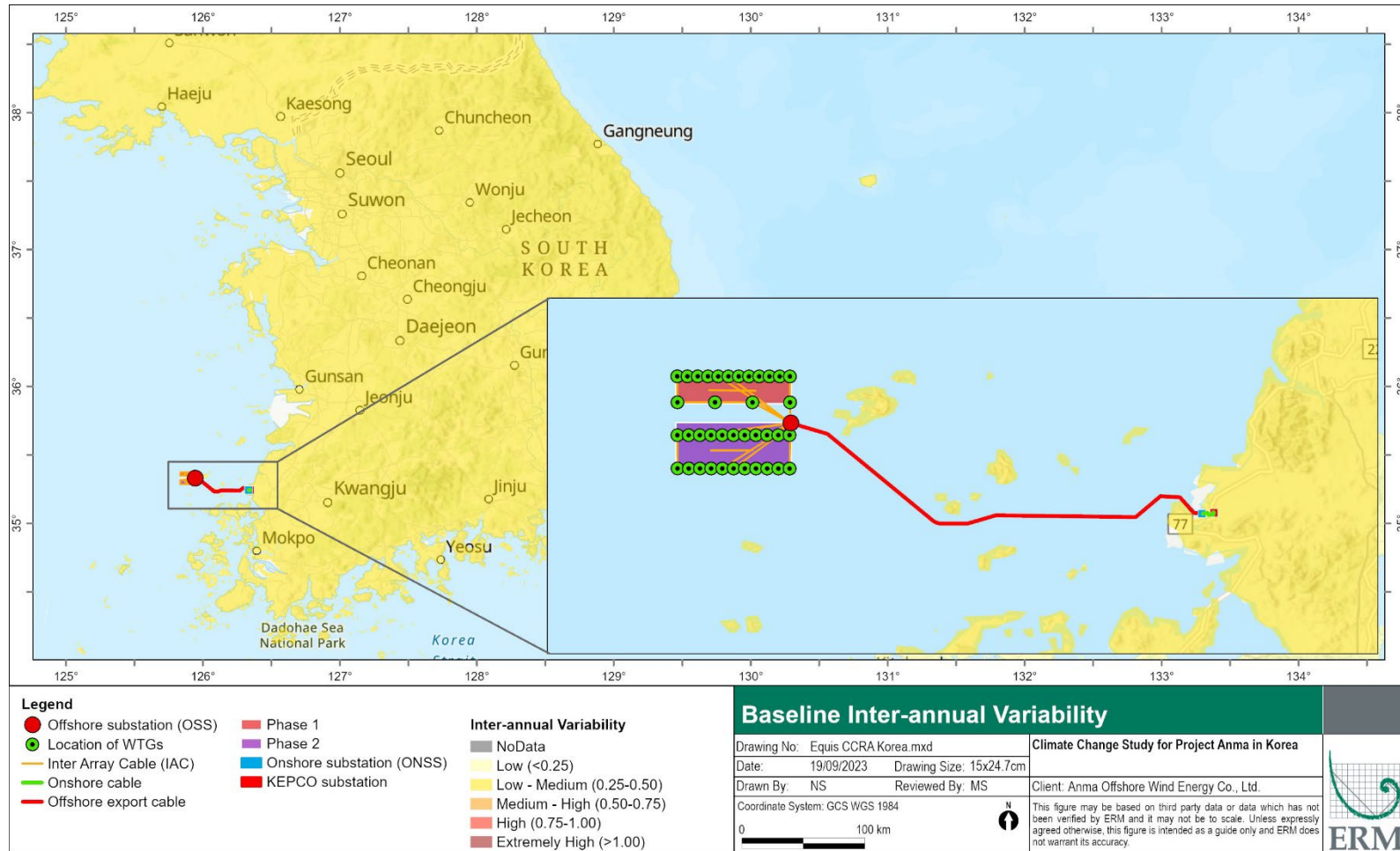


Figure 5.3 Baseline Inter-Annual Variability

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

5.1.2 Climate Change Projection

Water availability was assessed based on the evaluation of projections for water supply, water stress, and seasonal variability under climate change scenario.

The water availability will be obtained from the Water Risk Atlas Tool 3.0, provided by the World Resources Institute (WRI). However, the tool utilizes analysis models to project potential changes in future water demand and supply over the next three decades, centered around the years 2020, 2030, and 2040¹⁰. Therefore, the projection data for the year 2040 will be used to evaluate potential long-term risks, specifically for the year 2050.

Water supply, which is an indicator for availability of total renewable surface water, is projected to remain near normal over all climate change scenarios (i.e. 2030 and 2050) as presented in **Figure 5.4** and **Figure 5.5**.

This indicates that the changes (increase or decrease) in available surface water resources are likely to be insignificant in future and the total available surface water resource is likely to remain same as the baseline.

Further, water stress is projected to be “Extremely High” under all climate change scenarios as presented in **Figure 5.6** and **Figure 5.7**. Seasonal variability is also projected to be “Medium-High” over all climate change scenarios as presented in **Figure 5.8** and **Figure 5.9**. This indicates a higher hazard of the water stress and seasonal variability in future.

Based on the information for the three (3) indicators, the hazard of water availability in the future is considered to be “**High**”.

¹⁰ Aqueduct Water Stress Projections: Decadal Projections of Water Supply and Demand Using CMIP5 GCMs. Available at <https://www.wri.org/research/aqueduct-water-stress-projections-decadal-projections-water-supply-and-demand-using-cmip5>. Access on 19 Sep 2023

5.1.2.1 Projections of Water Supply

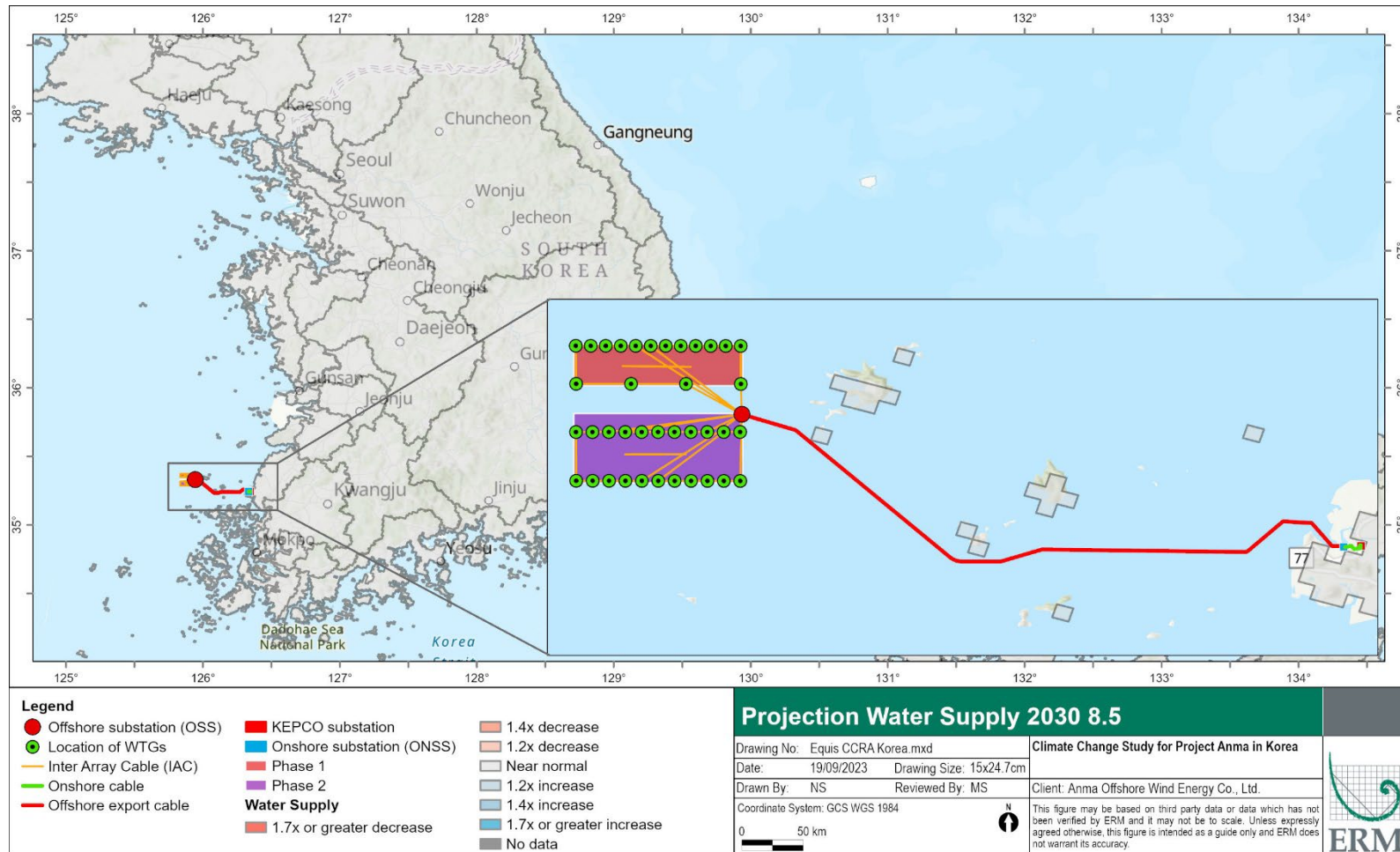


Figure 5.4 Projections of Water Supply during 2030 for RCP 8.5

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

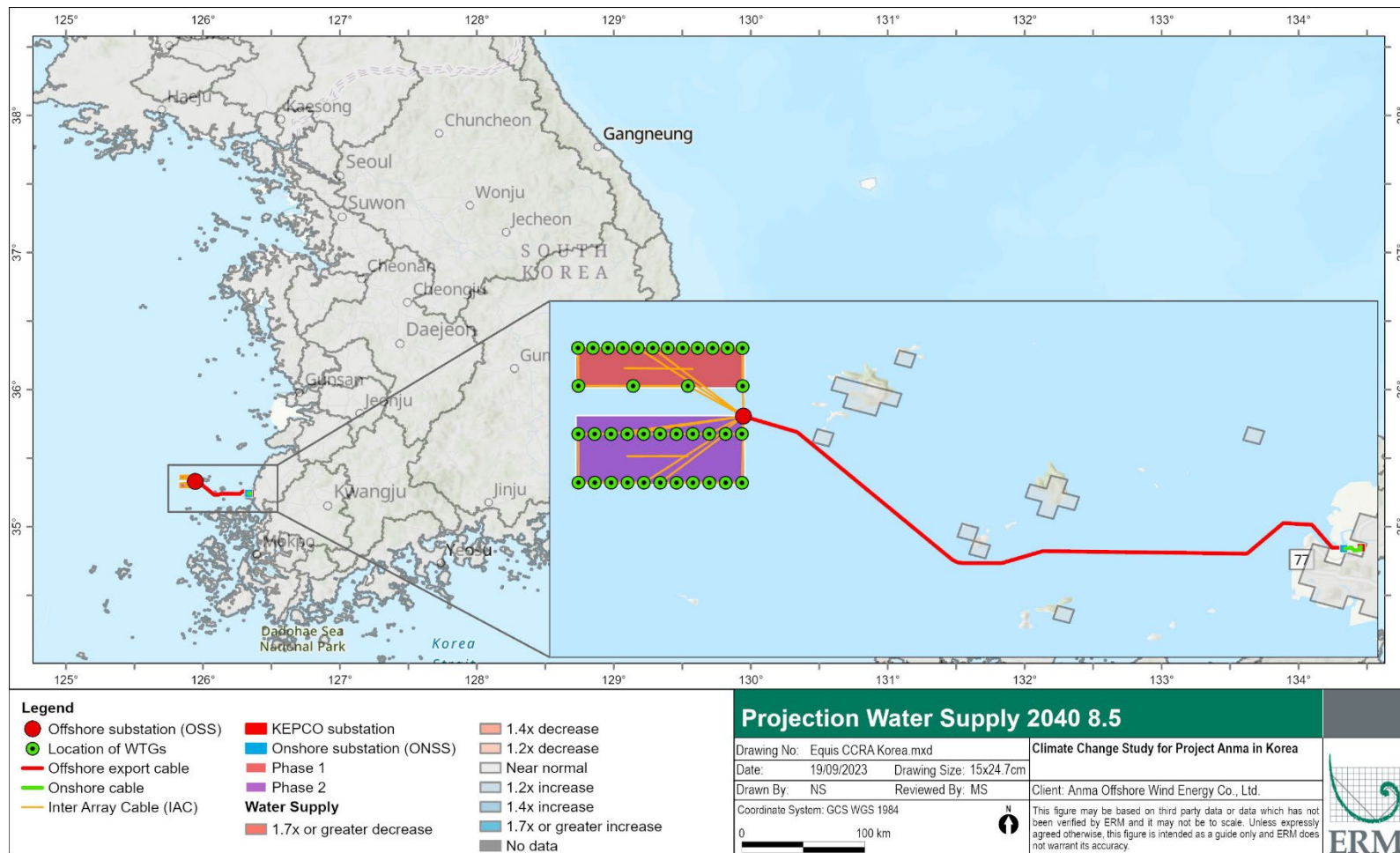


Figure 5.5 Projections of Water Supply during 2040 for RCP 8.5

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

5.1.2.2 Projections of Water Stress

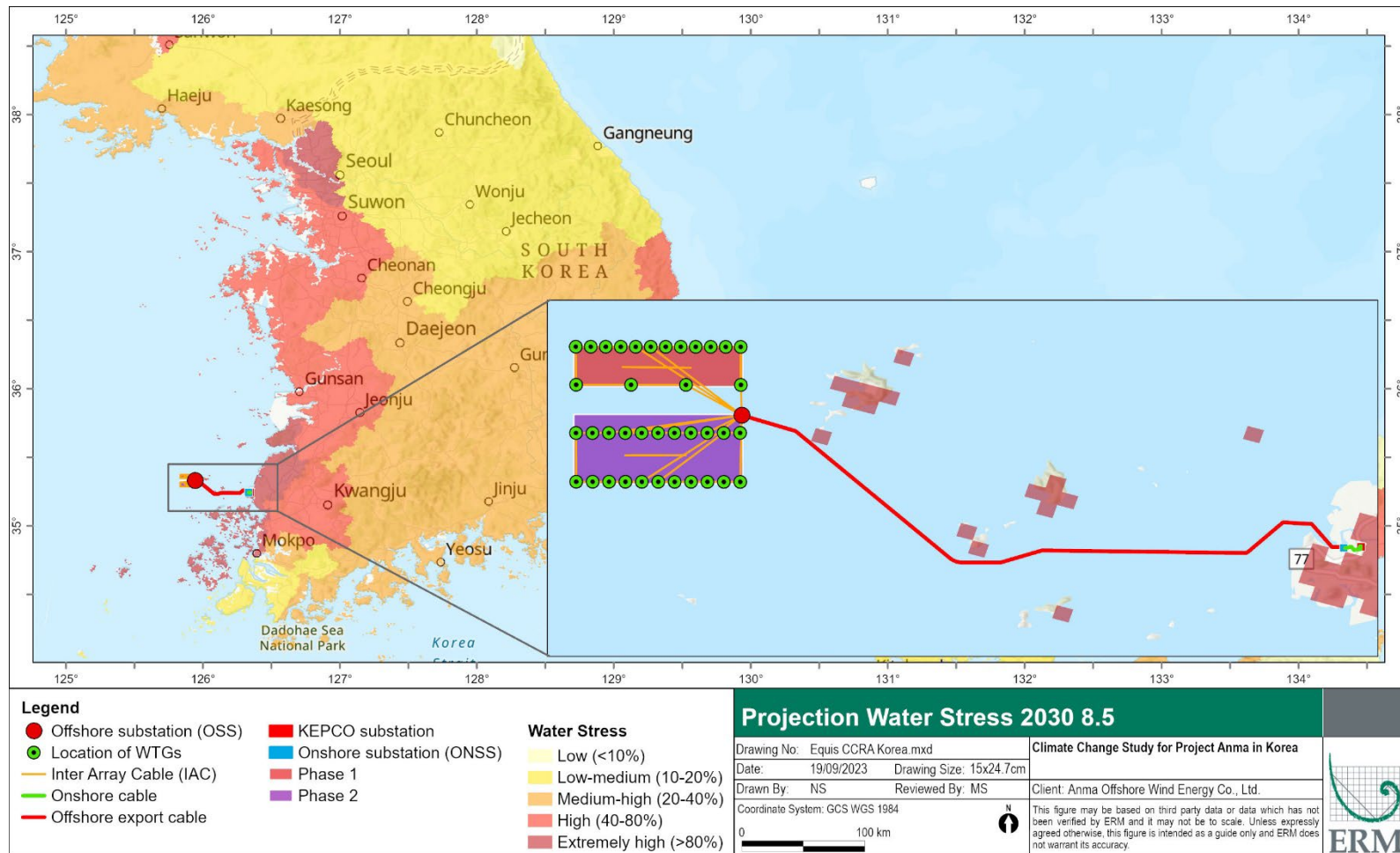


Figure 5.6 Projections of Water Stress during 2030 for RCP 8.5

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

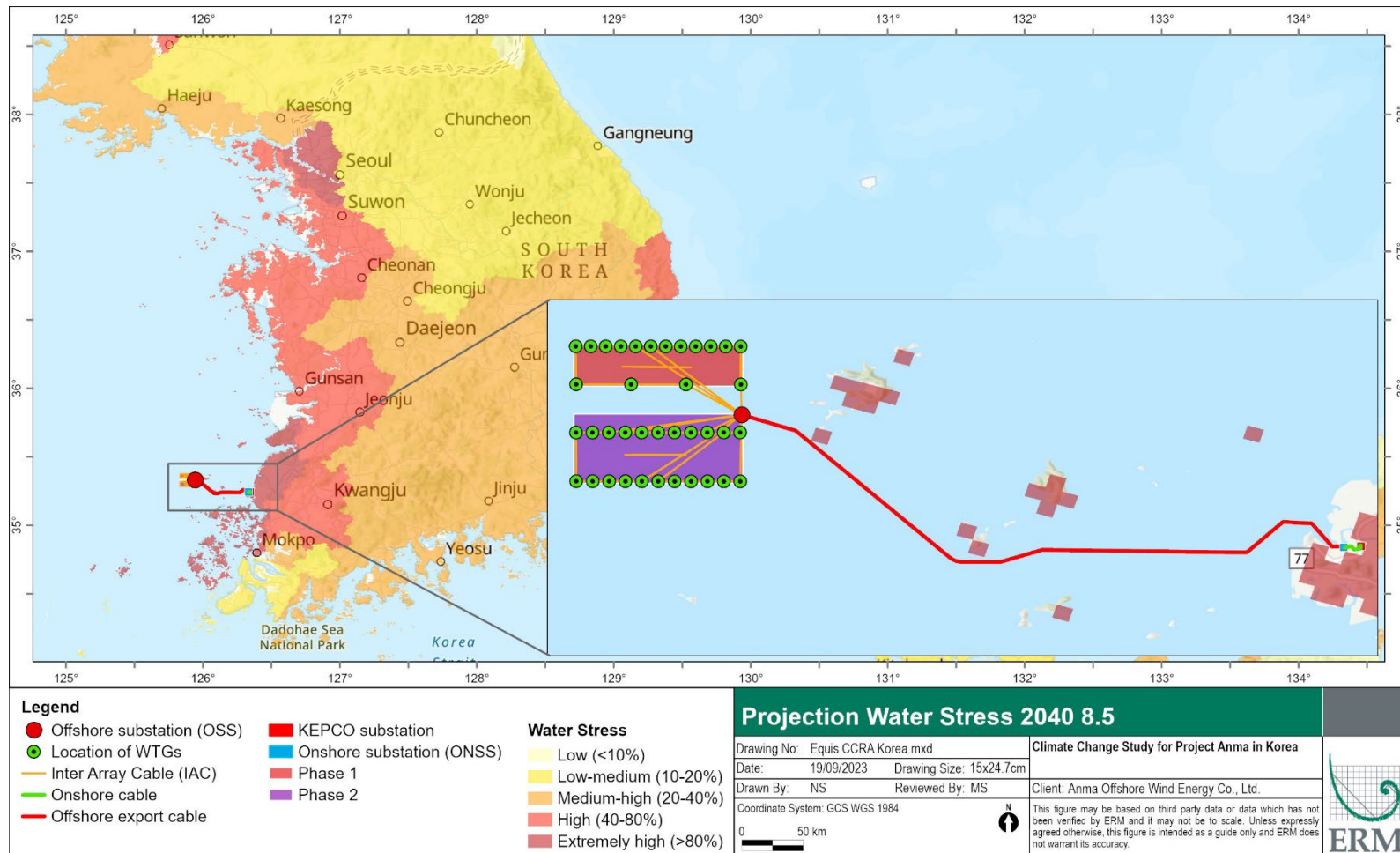


Figure 5.7 Projections of Water Stress during 2040 for RCP 8.5

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

5.1.2.3 Projections of Seasonal Variability

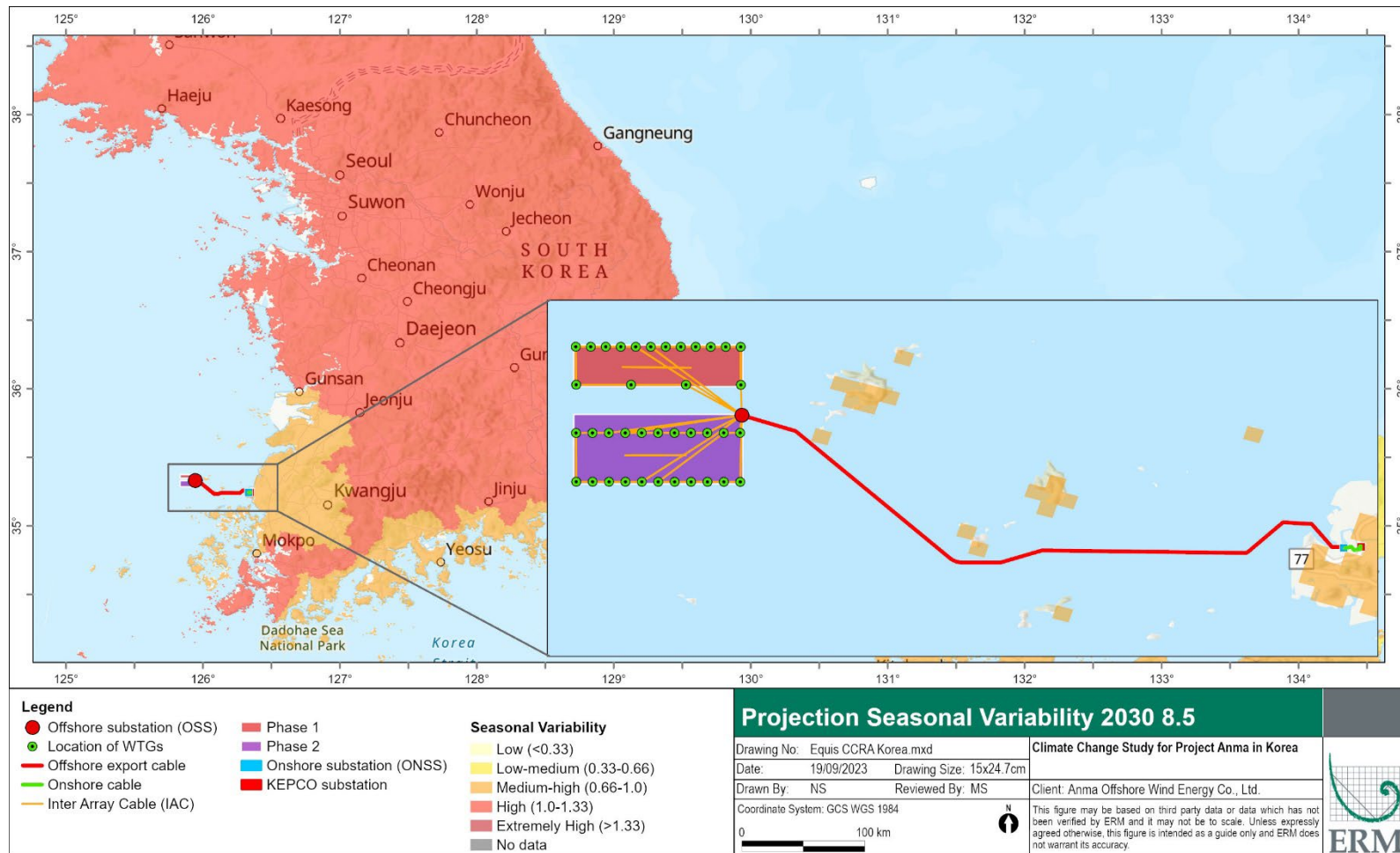


Figure 5.8 Projections of Seasonal Variability during 2030 for RCP 8.5

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

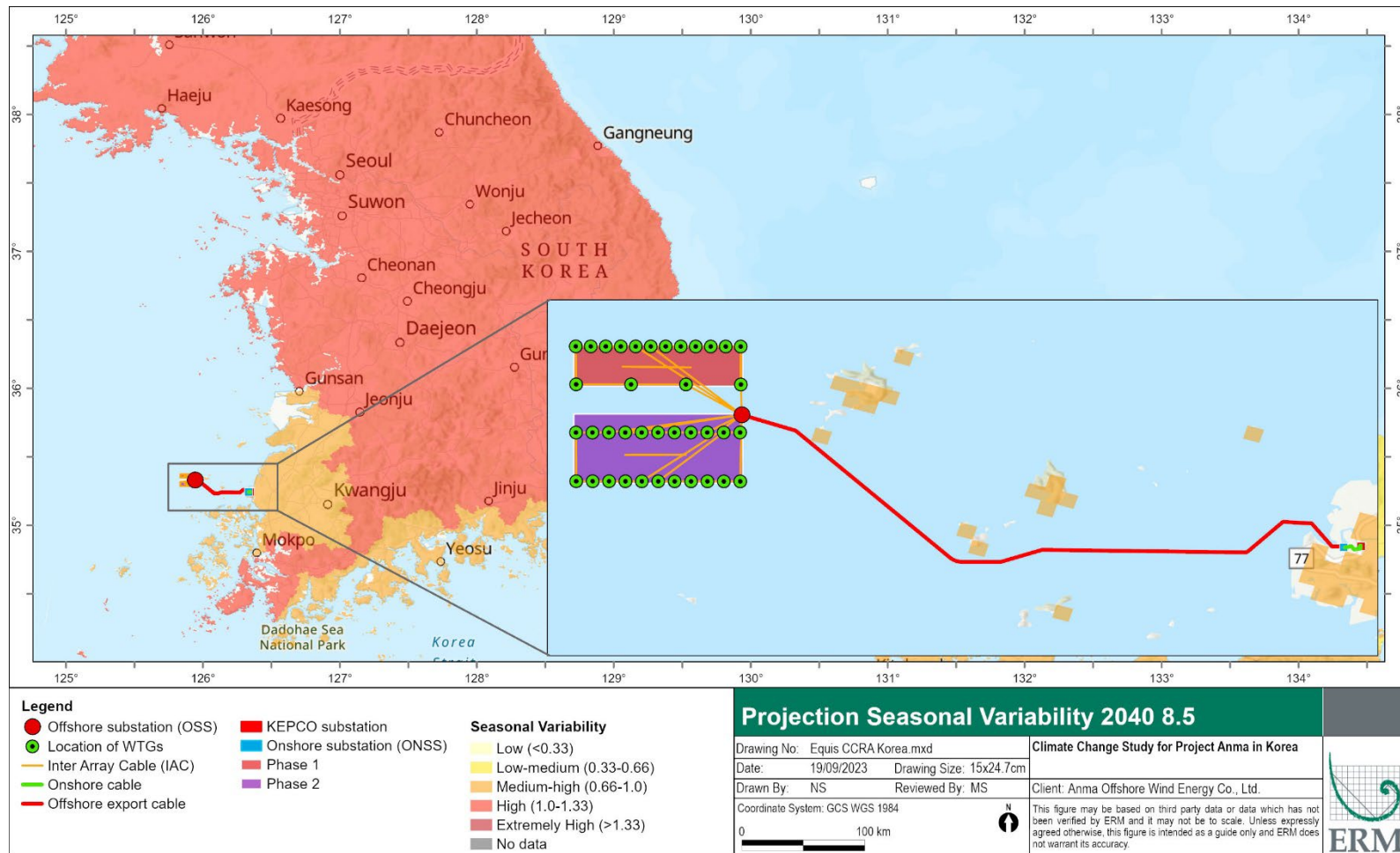


Figure 5.9 Projections of Seasonal Variability during 2040 for RCP 8.5

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

5.1.3 Exposure and Vulnerability

For to the offshore facilities, water consumption will be necessary during maintenance periods, but it will mostly be collected from rainfall, minimizing the required external supply. Consequently, the water requirement is expected to be minimal, which translate in a low exposure and vulnerability.

For the onshore facilities, water will be required during both the construction and operation phases. During the construction phase, water will be needed for drilling activities, and this can be sourced from either brackish water or fresh water. Given the Project's proximity to the sea, water resources are easily accessible.

During the operation phase, the Onshore Substation will require water for sanitary purposes. However, the water consumption is expected to be low.

Considering the overall Project design, type of water source and location, the Project's exposure and vulnerability level is categorized as "Low".

5.1.4 Risk Assessment

The table below shows the summary of risk assessment.

Table 5.2 Qualitative Risk Level and Project Implications for Water Availability

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
Hazard Level	High	High	High
Exposure x Vulnerab. Level	Low	Low	Low
Risk Level	Low	Low	Low
Implications for the Project	WTG	Operation of the turbines do not require consumption of large quantities of fresh water. Cooling of WTG components is based on recirculation of coolant liquid and therefore not subject to variation in water availability.	
	Offshore Substation	The offshore substation is unmanned; therefore, it is not expected to have personnel on board on continuous basis. Personnel will be present during maintenance periods. Drinkable water is brought on the OSS by the maintenance personnel. Water for the cleaning system is collected from cooling system. Water for the fire and safety system is preinstalled (expected to be exchanged every year or so).	
	Offshore Export Cable	The offshore export cables will pass the existing embankment at landfall area. The Horizontal Directional Drills (HDD) method is being considered to use and water will be used for drilling only during construction stage, therefore, no water consumption is expected during operation stage.	
	Onshore Substation	The substation have a building including an office, and a warehouse. It is expected that the office will be equipped with toilets and require a minimum amount of freshwater for sanitary purposes. Limited consumption of water for cooling processes is expected.	
	Onshore Export Cable	It is not expected the export cable to require any water consumption to operate.	
Key Potential Impacts	Minor impacts for the operation of the onshore substation.		
Implemented Mitigations	Turn off water when not in use at the onshore substation to reduce water consumption for cooling and sanitary purposes.		

5.2 Flood

Floods can be defined as overflow of 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 or combined effect of tides, surges and increase in the sea surface elevation.

Floods have the capacity to cause widespread devastation at both local and regional levels. Submergence, washing away of structures, and damage to infrastructure, buildings, and sewage systems are all potential consequences of a flooding event. Floods may also impair electricity transmission and generation, destroy agricultural land and crops, contaminate fresh water supplies, spread waterborne infections, and cause fatalities. Flood hazard in the present assessment was assessed based on the review of the open-source data for different flooding parameters as presented in the below table.

Table 5.3 Parameters Used for Evaluation of Baseline Flood Hazard

No.	Parameter	Description
1	Riverine Flood Risk Map ¹¹	Riverine flood risk is a measure of the percentage of population expected to be affected by riverine flooding in an average year, accounting for existing flood protection standards. Higher values indicate greater proportion of the population is expected to be impacted by flooding.
2	Riverine Flood Hazard Map ¹²	To calculate the river hazard layers for the individual return periods, the GLOFRIS model ¹³ was used. GLOFRIS uses a global hydrological model, PCR-GLOBWB ^{14, 15} , with a river and floodplain routing scheme to make long-term simulations of discharges and flood levels for several climate conditions. The meteorological datasets of the European Union Water and Global Change Program ¹⁶ and the Inter-sectoral Impact Model Intercomparison Project ¹⁷ were used to force PCR-GLOBWB over various time periods, between 1950 and 2099.
3	Flood Hazard Map ¹⁸	The flood maps prepared by FM-Global are based on historical data, physical hydrology and hydraulic data accounting for external factors such as rainfall, evaporation, snowmelt, and terrain.
4	Coastal Flood Risk Map ¹⁹	Coastal flood risk is a measure of the percentage of population expected to be affected by Coastal flooding in an average year, accounting for existing flood

¹¹ WRI- Aqueduct Flood Hazard Maps. Available at <https://www.wri.org/data/aqueduct-floods-hazard-maps>

¹² WRI- Aqueduct Flood Hazard Maps. Available at <https://www.wri.org/data/aqueduct-floods-hazard-maps>

¹³ Ward, P.J., Hessel C. W, Kuzma, S., Bierkens M. F.P., Bouwman, A., De Moel, H., Díaz Loaiza, A., Eilander, D., Enghardt, J., Erkens, G., Gebremedhin, E.T., Iceland, C., Kooi, H., Ligtoet, W., Muis, S., Scussolini, P., Sutanudjaja, E.H., Van Beek, R., Van Bommel, B., Van Huijstee, J., Van Rijn, F., Van Wesenbeeck, B., Vatvani, D., Verlaan, M., Tiggeloven T., and Luo, T., 2020, Aqueduct Floods Methodology. Available at: <https://www.wri.org/publication/aqueduct-floods-methodology>

¹⁴ Sutanudjaja, E.H., van Beek, R., Wanders, N., Wada, Y., Bosmans, J.H.C., Drost, N., van der Ent, R.J., de Graaf, I.E.M., Hoch, J.M., de Jong, K., Karssenberg, D., Lopez Lopez, P., Peßenteiner, S., Schmitz, O., Straatsma, M.W., Vannamettee, E., Wisser, D., Bierkens, M.F.P., 2018. PCR-GLOBWB 2: a 5 arcmin global hydrological and water resources model. Geosci. Model Dev. (GMD) 11, 2429–2453. <https://doi.org/10.5194/gmd-11-2429-2018>.

¹⁵ (PDF) Random forests-based error-correction of streamflow from a large-scale hydrological model: Using model state variables to estimate error terms. Available from: https://www.researchgate.net/publication/356755509_Random_forests-based_error-correction_of_streamflow_from_a_large-scale_hydrological_model_Using_model_state_variables_to_estimate_error_terms [accessed Jan 26 2022].

¹⁶ Weedon, Graham & Gomes, S. & Viterbo, Pedro & Shuttleworth, W. & Blyth, Eleanor & Österle, H. & Adam, J. & Bellouin, N. & Boucher, Olivier & Best, M.. (2011). Creation of the WATCH Forcing Data and Its Use to Assess Global and Regional Reference Crop Evaporation over Land during the Twentieth Century. Journal of Hydrometeorology. 12. 823-848. 10.1175/2011JHM1369.1.

¹⁷ Hempel, Sabrina & Frieler, Katja & Warszawski, Lila & Schewe, Jacob & Piontek, Franziska. (2013). A trend-preserving bias correction – The ISI-MIP approach. Earth System Dynamics Discussions. 4. 49. 10.5194/esdd-4-49-2013.

¹⁸ FM Global. Available at <https://www.fmglobal.com/research-and-resources/nathaz-toolkit/flood-map>

¹⁹ WRI- Aqueduct Water Risk Atlas. Available at <https://www.wri.org/applications/aqueduct/water-risk-atlas/>

No.	Parameter	Description
		protection standards. Higher values indicate greater proportion of the population is expected to be impacted by flooding.
5	Coastal Flood Hazard Map ²⁰	To estimate coastal hazard, the Global Tide and Surge Reanalysis (GTSR) dataset ²¹ was used as a database of extreme water levels. GTSR is a global dataset of daily sea levels (due to tide and storm surge) for 1979–2014, based on the hydrodynamic Global Tide and Surge Model (GTSM). Surge is simulated using wind and pressure fields from the European Centre for Medium Range Weather Forecasts (ECMWF) Re-analysis-Interim (ERA-Interim) dataset ²² . Tide is simulated using a separate model, the Finite Element Solution 2012 (FES 2012) model ²³ .

5.2.1 Baseline Hazard

5.2.1.1 Riverine and Coastal Flood Hazard (Inundation)

Riverine and coastal flood hazard maps are presented in **Figure 5.10** and **Figure 5.11**. The riverine hazard map indicates a low flood hazard with estimated inundation depth less than 0.5 m. Coastal inundation map indicates a medium to high flood hazard in proximity to the Project Area with estimated inundation depth between 0.5-1.5 m. As the resolution of the model aimed at describing macro-areas, the results should be interpreted and not considered as precise to the meter. For this reason, it is inferred that the Jeollanam-do Area presents some relatively flat areas at low elevations and some of those are in proximity or overlapping the onshore substation and export cable. The hazard level is conservatively considered “**Medium**”.

Flood hazard map from FM Global, 2019 was also reviewed and presented in **Figure 5.12**. It indicates high probability of occurrence of flood hazard in the Jeollanam-do Area. High hazard areas are shown to be adjacent to the onshore export cable and the onshore substation which given the coarse resolution of the model output it cannot be excluded that some portion may overlap with high hazard areas. The onshore substation is at approximately 1 km from the coast and the high flood hazard area at approximately 5 m above sea level. As a conservative approach, the area can be considered as “**High**” hazard level: locations in a 100-year flood zone with a chance of at least 1% of experiencing a flood each year.

5.2.1.2 Riverine and Coastal Flood Hazard (Catchment Level)

Catchment level riverine flood hazard based on population and economic exposure to floods was reported to be “low-medium” as presented in **Figure 5.13**. However, the FM Global²⁴ model show a “**High**” hazard for flooding probably due to a combination of low elevation, relatively plain surface and presence of the Bulgapcheon stream. Coastal flood hazard was reported to be “medium-high” as

²⁰ Idem

²¹ Muis, S., M. Verlaan, H. C. Winsemius, J. C. J. H. Aerts, and P. J. Ward (2016), A global reanalysis of storm surge and extreme sea levels, Nat. Commun., 7(11969), 1– 11. doi:10.1038/ncomms11969

²² Dee, D.P., Uppala, S.M., Simmons, A.J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M.A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A.C.M., van de Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, A.J., Haimberger, L., Healy, S.B., Hersbach, H., Hólm, E.V., Isaksen, I., Kållberg, P., Köhler, M., Matricardi, M., McNally, A.P., Monge-Sanz, B.M., Morcrette, J.-J., Park, B.-K., Peubey, C., de Rosnay, P., Tavolato, C., Thépaut, J.-N. and Vitart, F. (2011), The ERA-Interim reanalysis: configuration and performance of the data assimilation system. Q.J.R. Meteorol. Soc., 137: 553–597. <https://doi.org/10.1002/qj.828>

²³ Carrere, Loren & Lyard, F. (2003). Modelling the barotropic response of the global ocean to atmospheric wind and pressure forcing Comparisons with observations. Geophysical Research Letters. 30. 10.1029/2002GL016473 .

²⁴ FM Global. Available at <https://www.fmglobal.com/research-and-resources/nathaz-toolkit/flood-map>

presented in **Figure 5.14**. The overall flood hazard from riverine and coastal flood was evaluated to be '**Medium**' in the baseline.

Based on evaluation multiple data sets, the flood hazard level will be considered as the worst case scenario. Hence, the flood hazard under baseline scenario is considered to be "**High**".

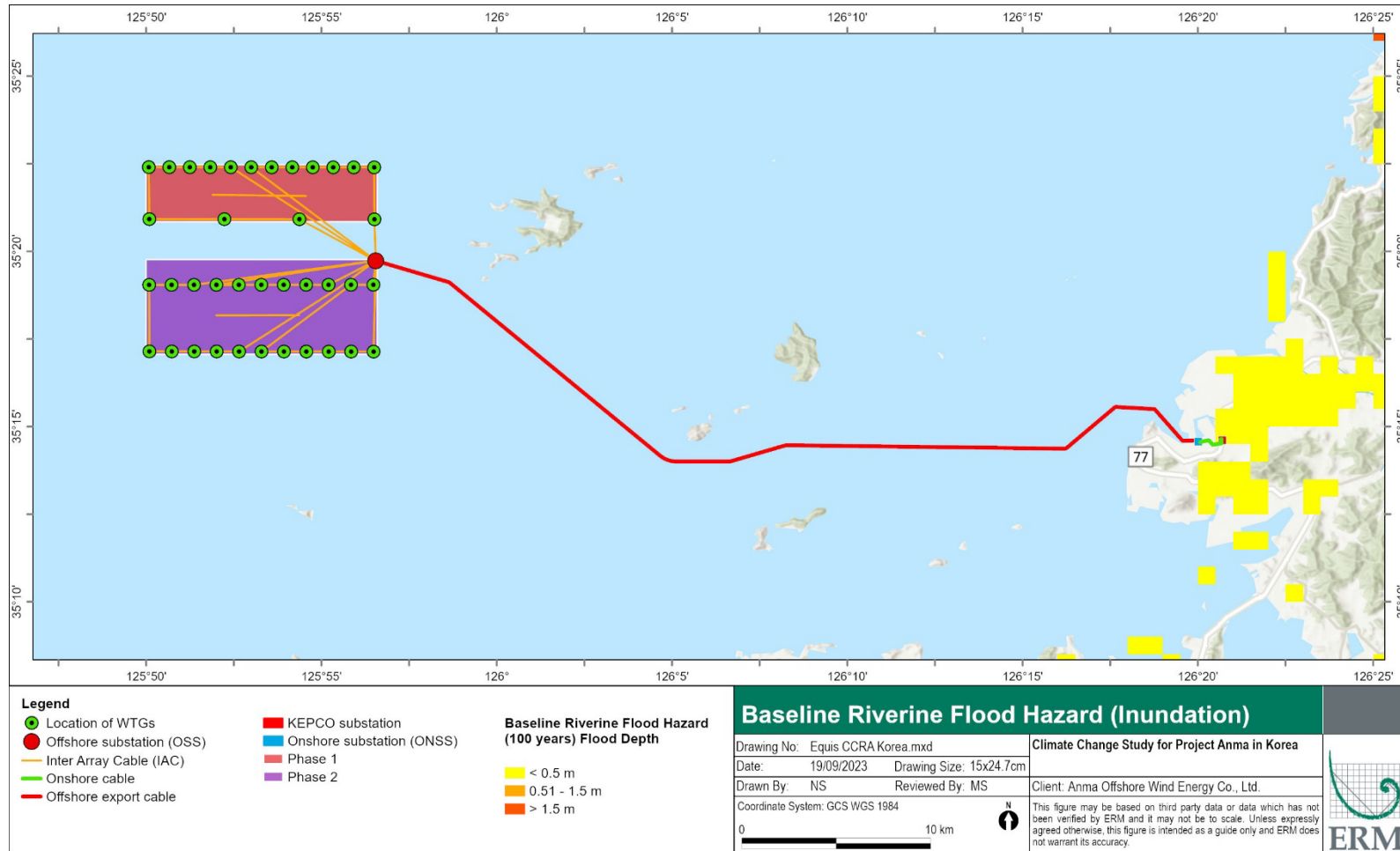


Figure 5.10 Baseline Riverine Flood Hazard (Inundation) Map

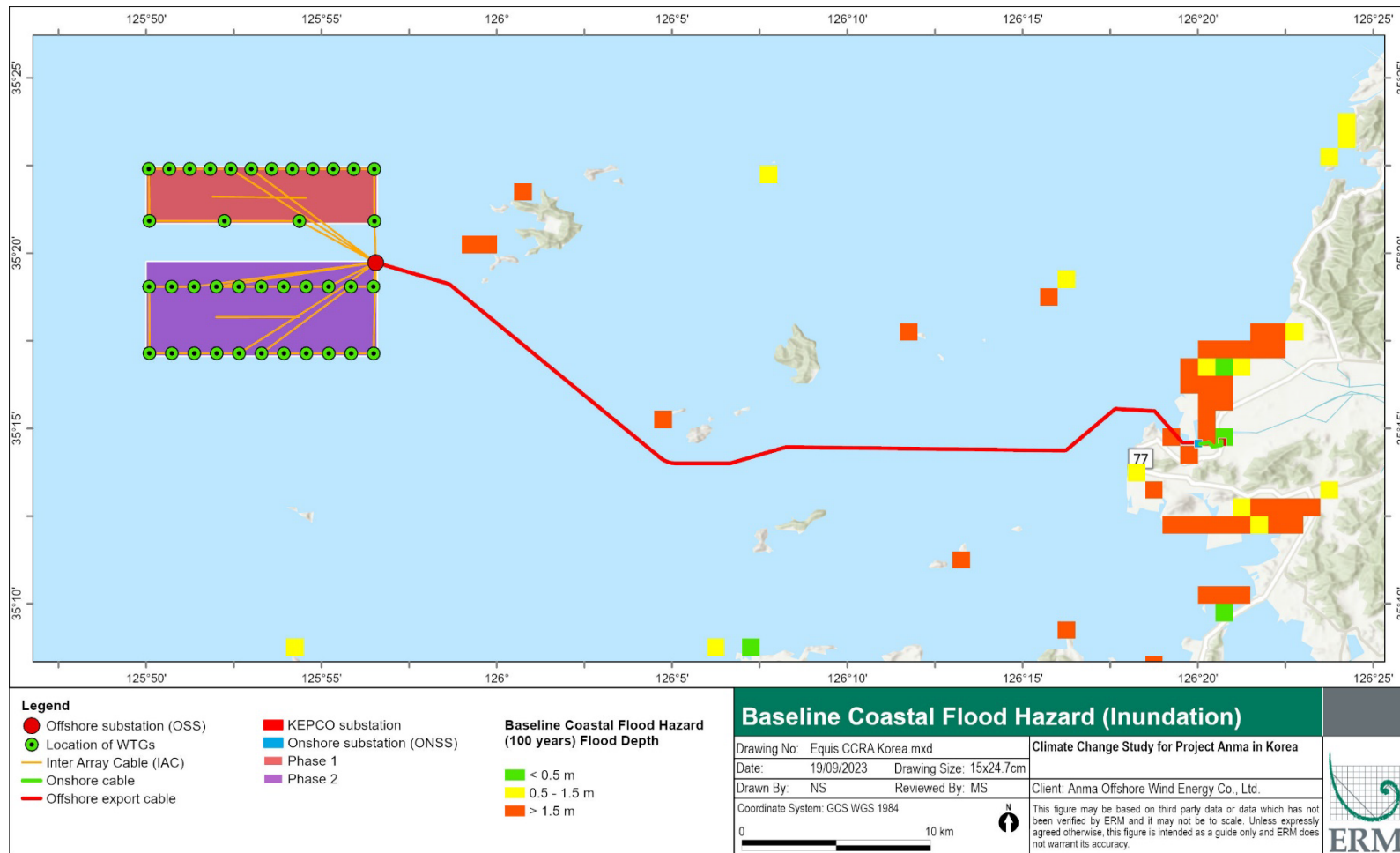


Figure 5.11 Baseline Coastal Flood Hazard (Inundation)

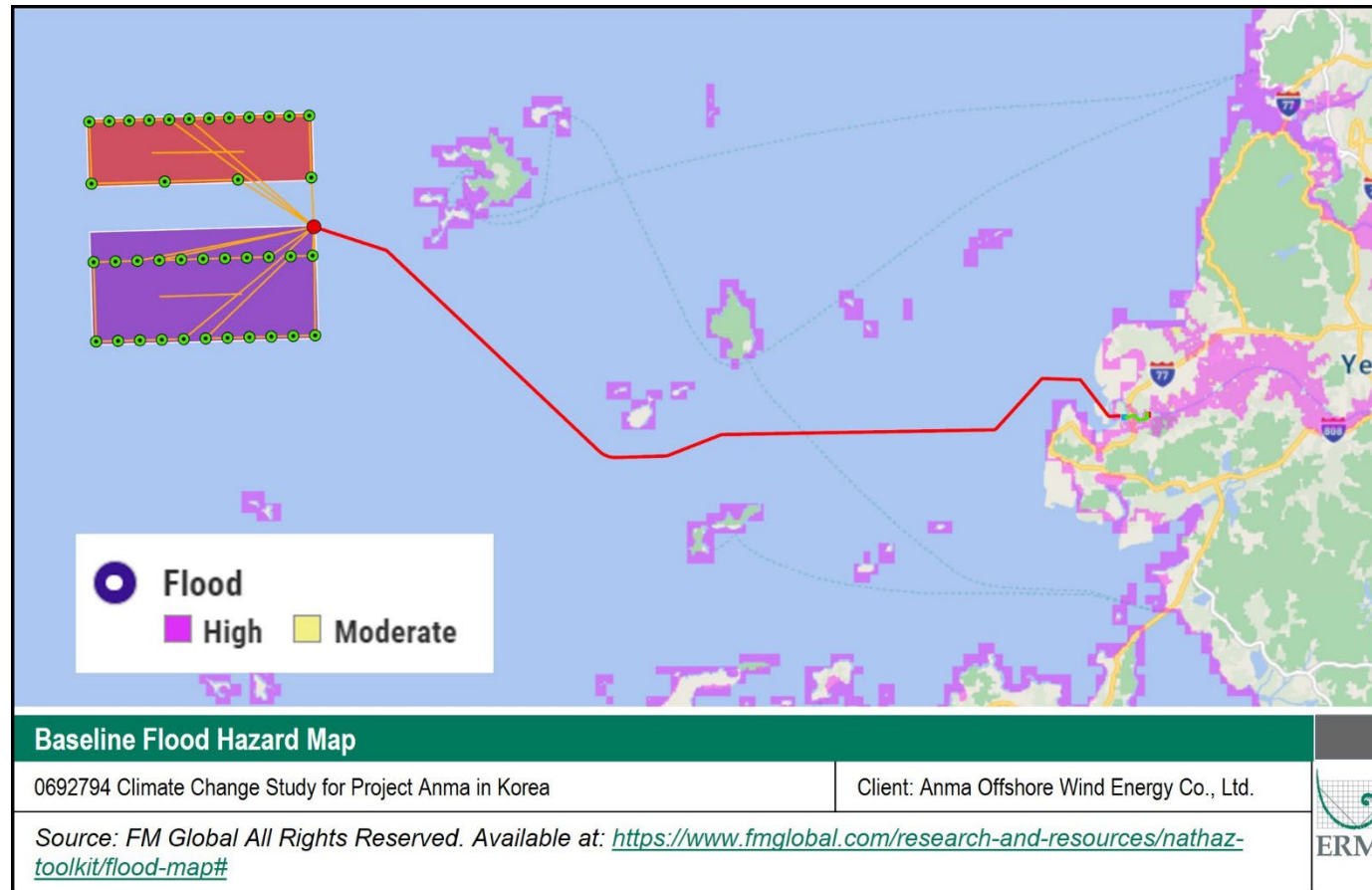


Figure 5.12 Baseline Flood Hazard Map

Source: FM Global All Rights Reserved. Available at: <https://www.fmglobal.com/research-and-resources/nathaz-toolkit/flood-map#>

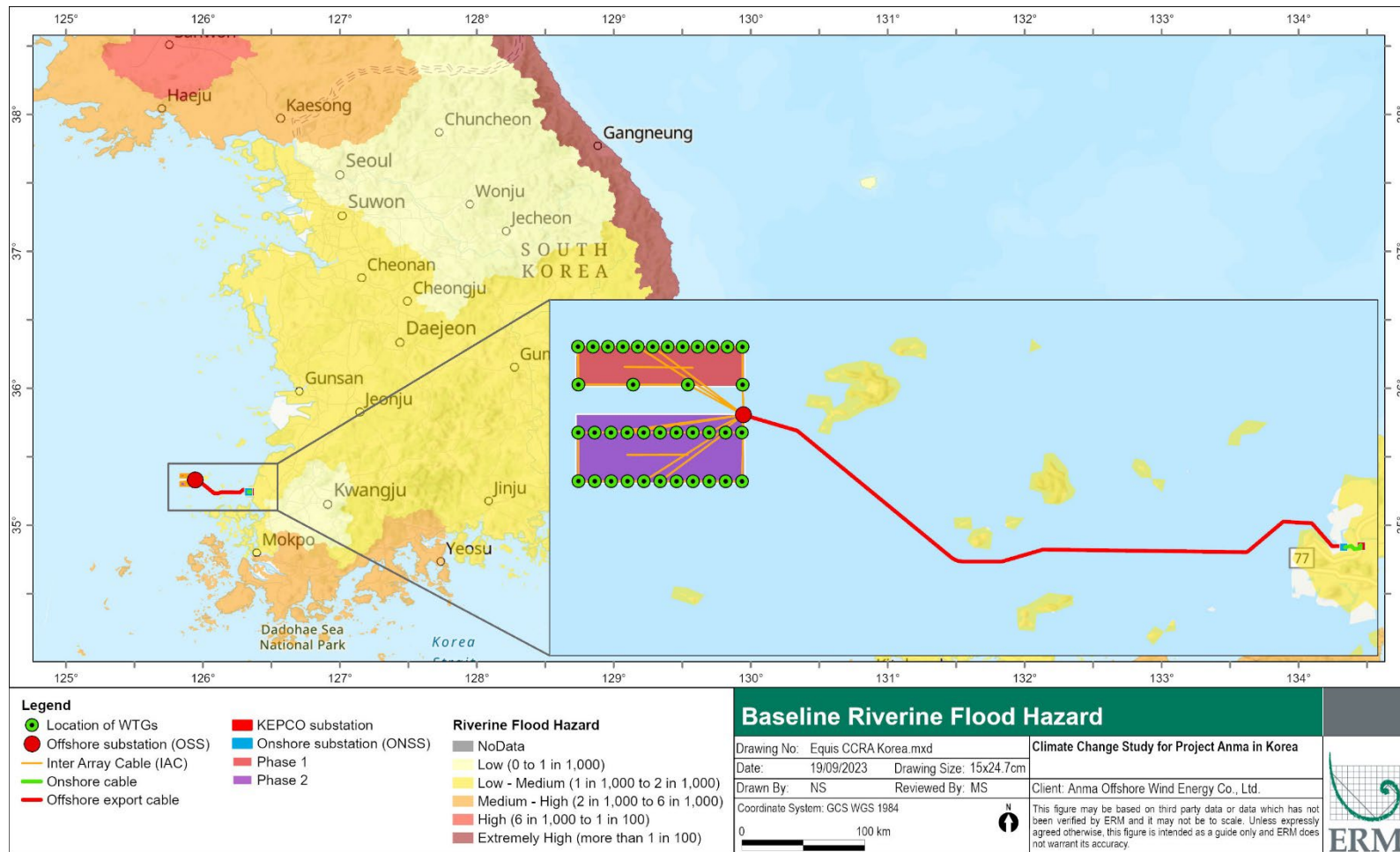


Figure 5.13 Baseline Riverine Flood Hazard

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

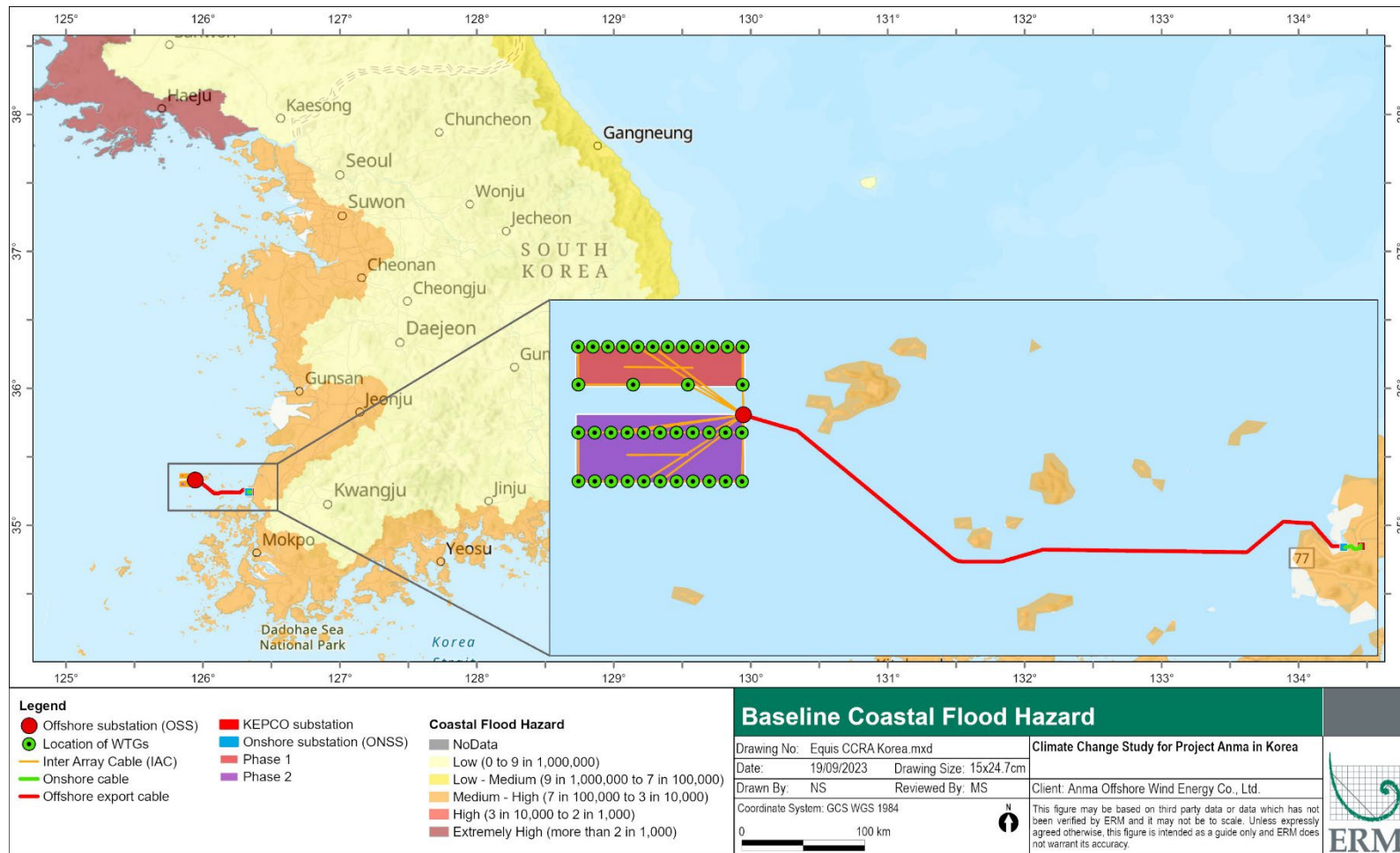


Figure 5.14 Baseline Coastal Flood Hazard

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

5.2.2 Climate Change Projections

Flood risk maps under climate change scenario from WRI-Aqueduct Flood Tool were evaluated to assess the future flood hazard under climate change scenario. **Figure 5.15** and **Figure 5.16** present the coastal flood maps for climate change scenarios of RCP 8.5 2030 and 2050 respectively. **Figure 5.17** and **Figure 5.18** present the riverine flooding for climate change scenarios of RCP 8.5 2030 and 2050 respectively. Accordingly, the flood hazard due to riverine flooding is projected to remain low with flood inundation depth of less than 0.5 m. However, the coastal flooding at locations surrounding the Onshore Substation remain “High”. Hence, the overall flood hazard is considered to remain same as the baseline i.e. “**High**”.

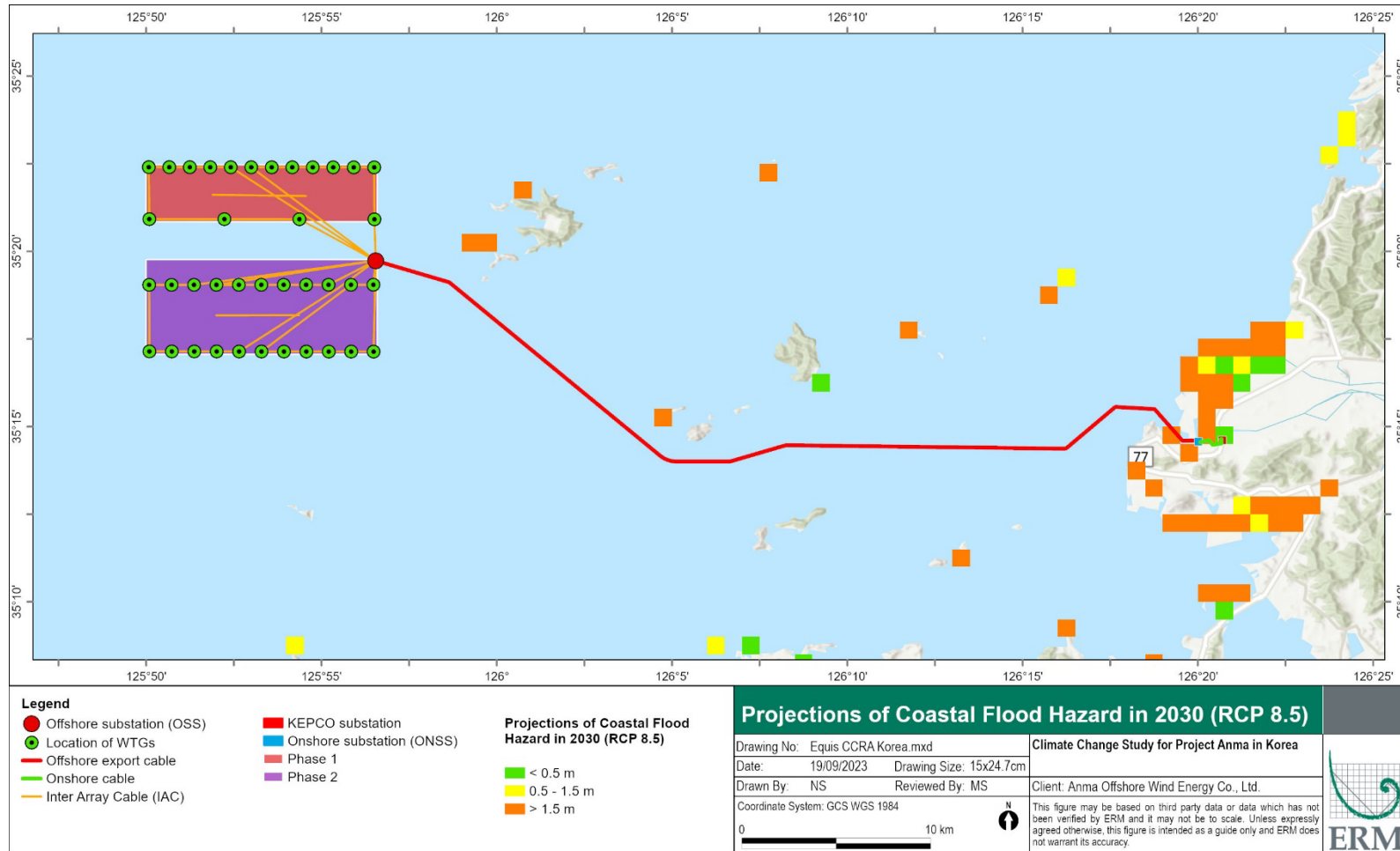


Figure 5.15 Projections of Coastal Flood Hazard 2030 8.5

Source: WRI- Aqueduct Flood Risk Atlas. Available at <https://www.wri.org/applications/aqueduct/floods/>

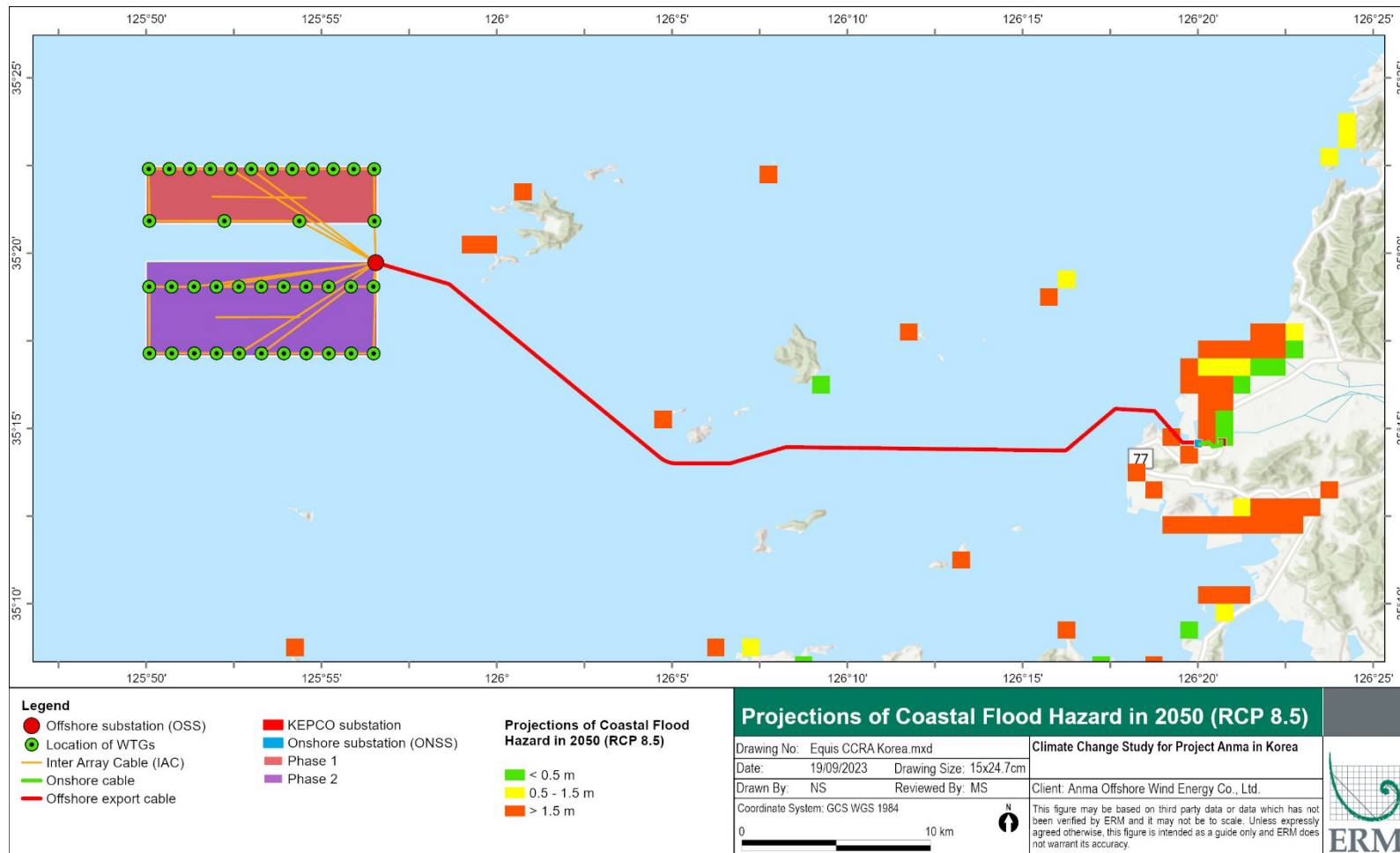


Figure 5.16 Projections of Coastal Flood Hazard 2050 8.5

Source: WRI- Aqueduct Flood Risk Atlas. Available at <https://www.wri.org/applications/aqueduct/floods/>

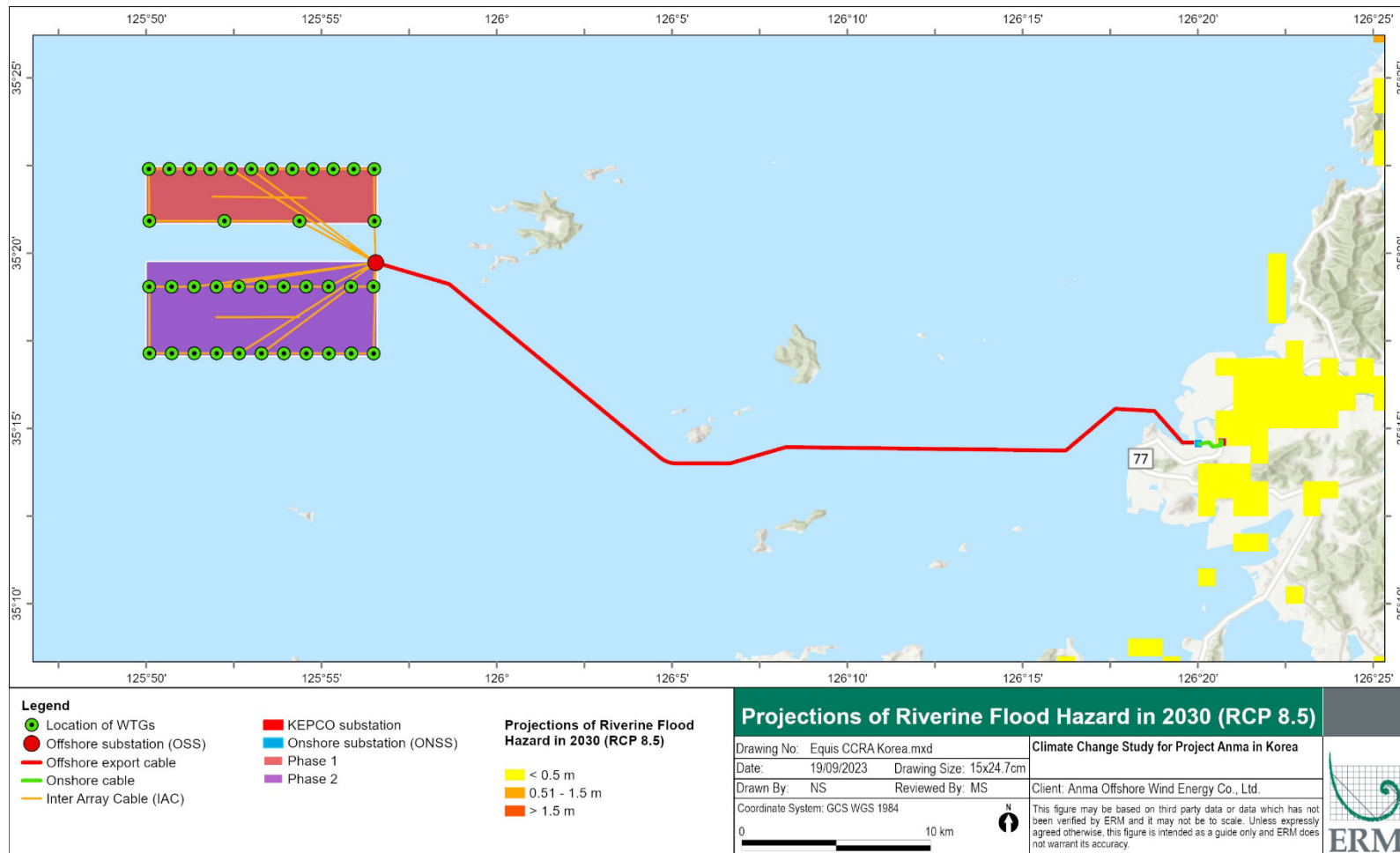


Figure 5.17 Projections of Riverine Flood Hazard 2030 8.5

Source: WRI- Aqueduct Flood Risk Atlas. Available at <https://www.wri.org/applications/aqueduct/floods/>

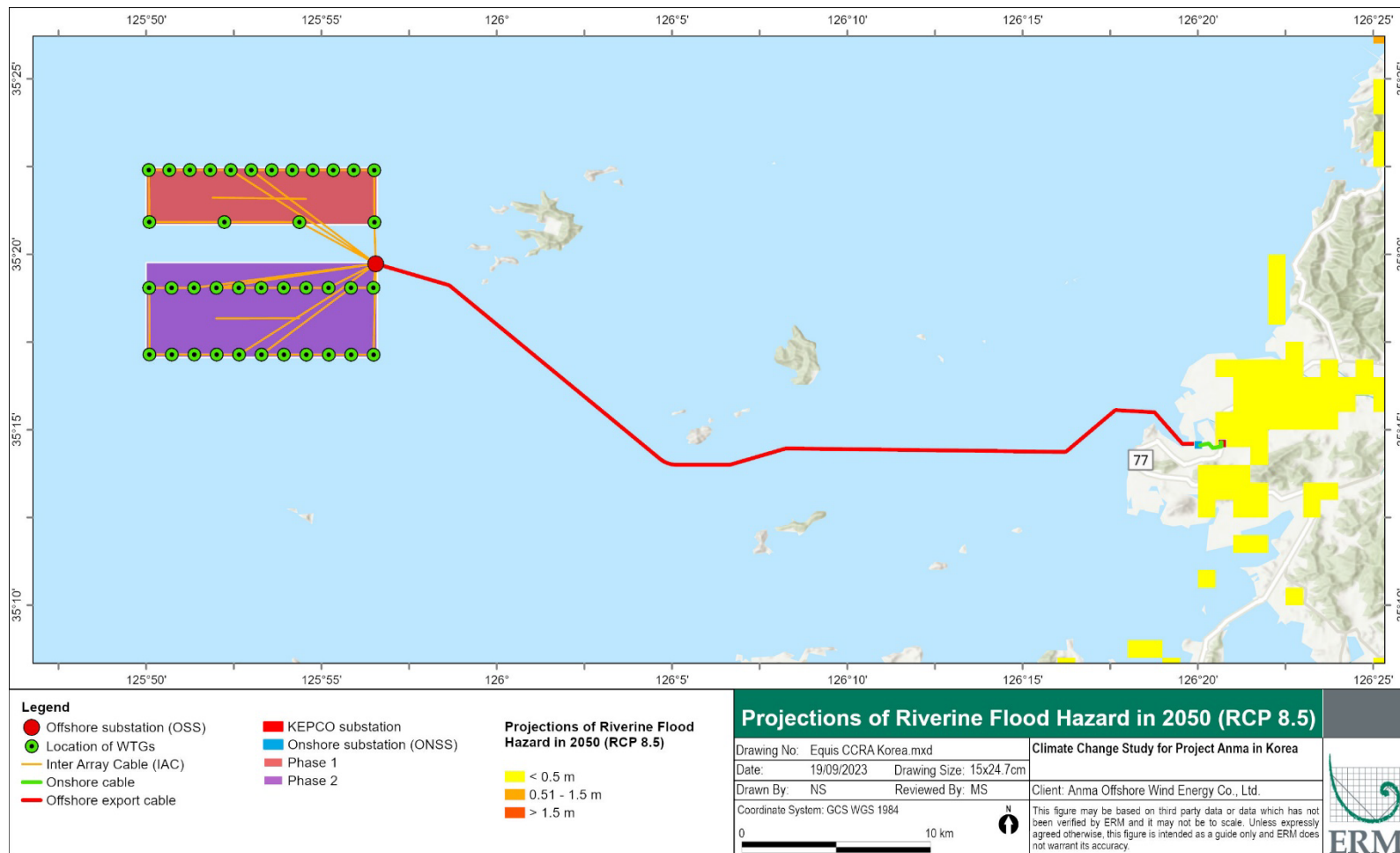


Figure 5.18 Projections of Riverine Flood Hazard 2050 8.5

Source: WRI- Aqueduct Flood Risk Atlas. Available at <https://www.wri.org/applications/aqueduct/floods/>

5.2.3 Exposure and Vulnerability

The offshore Project area will not have significant impact by flooding since the offshore facilities located in the sea area and the Offshore Export Cable is laying on the seabed.

Offshore Export Cable terminates near the Onshore Substation in an underground Transition Joint Bay, which is designed to continue operating in the event of flooding.

For the onshore Project area, the facilities (i.e., onshore substation) might be affected by flooding since the Project location is located near the estuary of Bulgapcheon river, relatively close to the sea (<1 km), on a relatively flat area which is likely to reclaimed land. The buildings will be at an elevation of 4 meters above sea level and the ground floor may be exposed to water penetration during flooding events.

Considering the information provided, the Onshore Substation exposure and vulnerability level is categorized as “High”.

5.2.4 Risk Assessment

The table below shows the summary of risk assessment.

Table 5.4 Qualitative Risk Level and Project Implications for Flood

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
Hazard Level	High	High	High
Exposure x Vulnerab. Level	High	High	High
Risk Level	High	High	High
Implications for the Project	WTG	Not applicable to WTG as they are located offshore.	
	Offshore Substation	Not applicable to Offshore Substation as it is located offshore.	
	Offshore Export Cable	Offshore Export Cable terminates near the Onshore Substation in an underground Transition Joint Bay, which is designed to continue operating in the event of flooding.	
	Onshore Substation	In the event of flooding, substations may lose HVAC systems, AC station service, communications, or DC battery systems. They may experience water damage to protection, automation, and control equipment; damage to high voltage equipment from flooding in switchyard; de-energization of the entire substation; or even fire or catastrophic loss. It is expected the onshore substation to be an indoor type and that most of the equipment will be placed indoor with limited portion of the equipment placed outdoor.	
	Onshore Export Cable	Buried cable are in general more resistant to flood events compared to overhead line design. ²⁵ Despite being rare, a risk	

²⁵ U.S. department of Energy, 2010. Hardening and Resiliency – U.S. Energy Industry Response to Recent Hurricane Seasons. Infrastructure Security and Energy Restoration Office of Electricity Delivery and Energy Reliability. Pp. 86 [Available at: <https://www.oe.netl.doe.gov/docs/HR-Report-final-081710.pdf>]

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
		of water infiltration is still present at connection points between different cable segments or to substations. Despite the potential for water infiltration, power transmission can continue, but the most severe outcome of damage could result in a power outage.	
Key Potential Impacts	• Potential interruption of the operation of the onshore substation • Damage of infrastructure requiring replacement of onshore export cable sections or substation components		
Implemented Mitigations	• Elevate foundation level of building and outdoor equipment. • Design the drainage system taking into consideration flood risk. • Use waterproof sealing type for onshore cable.		

5.3 Landslides

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

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

Landslides have been assessed using two features: susceptibility and hazard.

Susceptibility describes the structural properties of terrain and geomorphology that make an area prone to landslide, e.g. geology, slope angle, elevation etc. However, an area prone/susceptible to landslide needs a trigger to manifest the landslide event. Precipitation is the most common trigger, but it can be initiated by earthquake or human event as well. The combination of susceptibility and availability of triggers is used to estimate the landslide risk.

In this assessment, the landslide hazard at the Project area was evaluated based on the landslides due to precipitation as precipitation is anticipated to be influenced by climate change.

An area can be highly susceptible to landslide but low hazard when there are limited triggers, for example a slopy area with scarce vegetation but in an arid region. Similarly, an area can be of low landslide susceptibility but high landslide hazard if there is the potential for a sufficiently large trigger. The Global Facility for Disaster Reduction and Recovery²⁶ provides data landslides hazard due to precipitation. The data is in the form of raster images with land slide hazard classified in four classes: Very low, Low, Medium, and High.

In this report, the risk level of landslides is also compared to the Korean Safety Map by Ministry of Interior and Safety. The map classifies the risk in a scale from Grade 5, i.e. low risk, to Grade 1, i.e. high risk. The database also provides a historical database of landslides.

5.3.1 Baseline Hazard

Figure 5.19 presents the map for landslides due to precipitation which shows that the onshore export cable and onshore substation located in “Low” hazard area. Landslide susceptibility within study area is reported to vary between “Very Low” to “Low” as presented in **Figure 5.20**. This indicates that the rainfall patterns, terrain slope, geology, soil, land cover, and (possibly) earthquakes in this location make isolated landslides an unlikely hazard. Moreover, the hazard level of landslides is assessed based on the Korean Safety Map by Ministry of Interior and Safety as shows in **Figure 5.21**. The map shows that the onshore export cable and onshore substation do not cross any area subject to landslides hazard. Based on this information, the baseline landslides hazard is categorised to be “Low”.

²⁶ GIS processing International Centre for Geohazards /NGI. Preprocessing for ThinkHazard! conducted by GFDRR

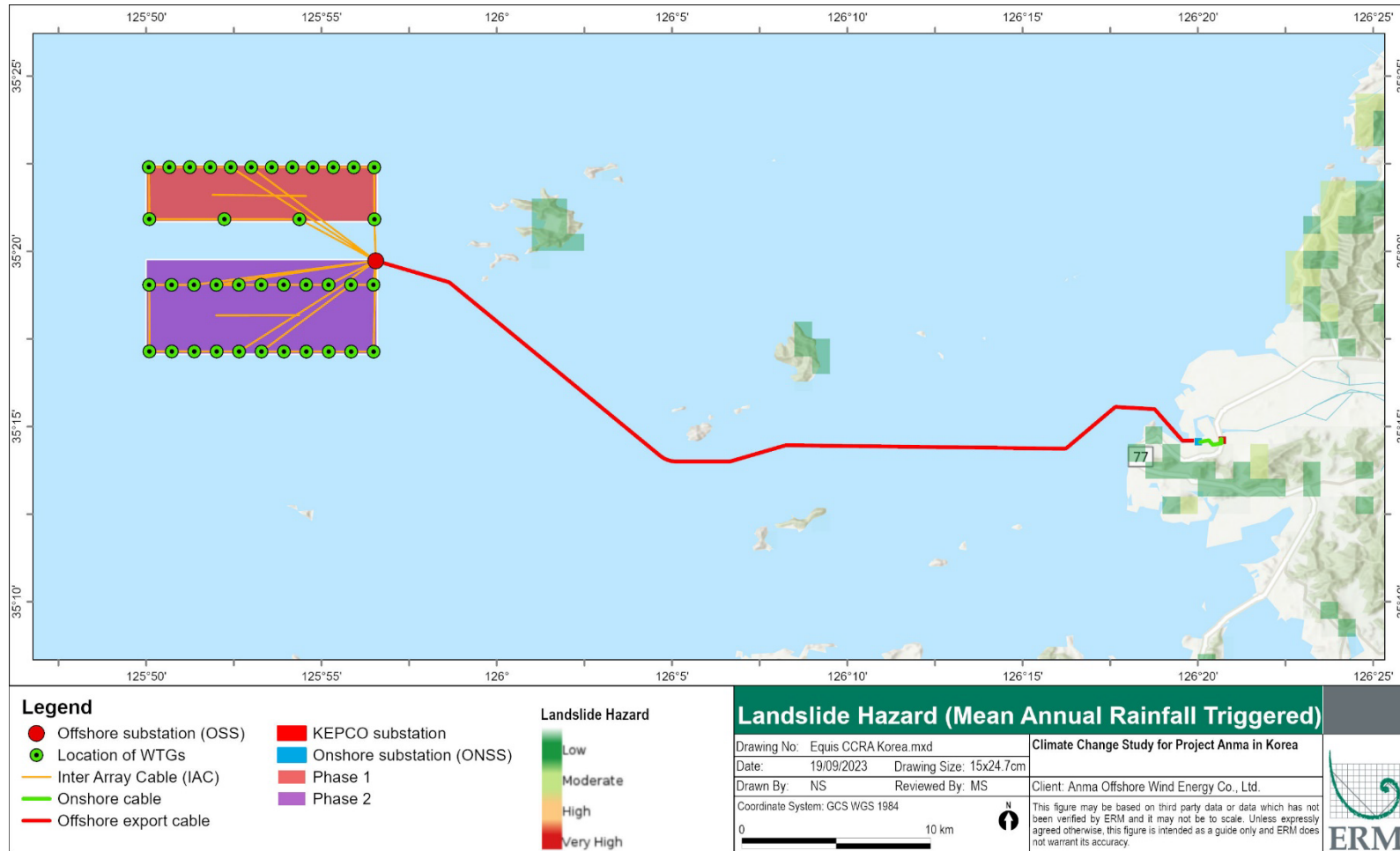


Figure 5.19 Baseline Landslide Hazard: Median Annual Rainfall-Triggered Landslide Hazard

Source: Global Facility for Disaster Reduction and Recovery (GFDRR). Available at <https://www.geonode-gfdrilab.org/>

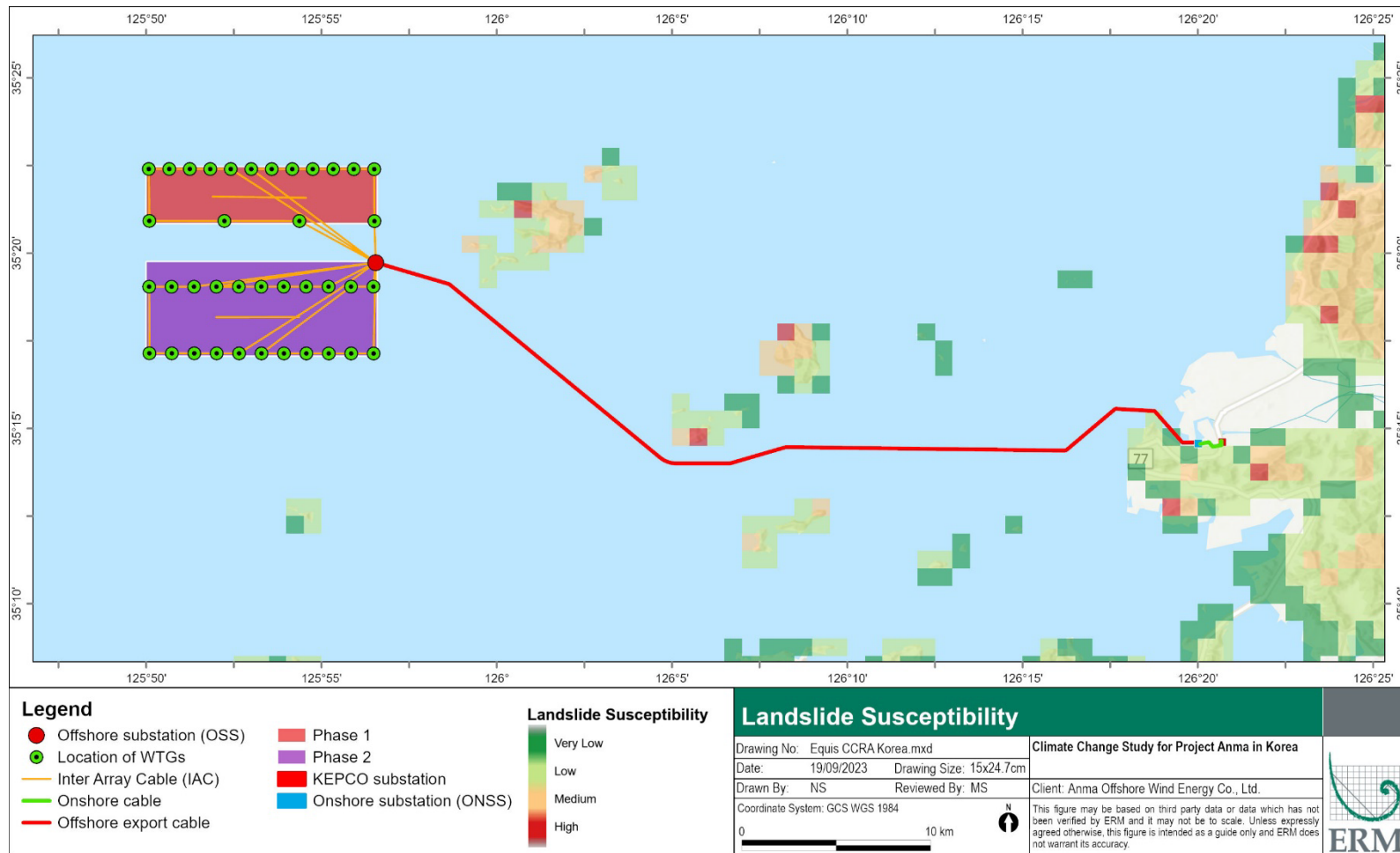


Figure 5.20 Baseline Landslide Susceptibility

Source: Global Facility for Disaster Reduction and Recovery (GFDRR). Available at <https://www.geonode-gfdrilab.org/>



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17 January 2025 Page 50

5.3.2 Climate Change Projections

According to the Korean Climate Change Assessment Report 2020 state that future precipitation events will intensify in the Korean peninsula²⁷, which can lead to a higher hazard of landslide. However, no substantial changes in the geomorphology of the area are projected by 2050, and the project location is in a flat area. As a result, there is no potential for landslides. Therefore, it is assumed that the footprint of the Onshore Export Cable and Onshore Substation will remain at “**Low**” hazard level.

5.3.3 Exposure and Vulnerability

The offshore Project area is not exposed to landslides due to its distance from areas with subject to landslides hazard.

In the context of the onshore Project area, given the flat terrain and distance to areas subject to landslides, it is considered not exposed.

Based on the above consideration, the exposure and vulnerability level are considered low.

5.3.4 Risk Assessment

The table below shows the summary of risk assessment.

Table 5.5 Qualitative Risk Level and Project Implications for Landslides

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
Hazard Level	Low	Low	Low
Exposure x Vulnerab. Level	Low	Low	Low
Risk Level	Low	Low	Low
Implications for the Project	WTG	Not applicable to WTG as they are located offshore.	
	Offshore Substation	Not applicable to Offshore Substation as it is located offshore.	
	Offshore Export Cable	Not applicable to Offshore Export Cable as it is located offshore.	
	Onshore Substation	Landslides around the substation may prevent access to the facility delaying management and maintenance operations. However, the local road network provides multiple routes to access the Project area.	
	Onshore Export Cable	Landslides are not anticipated at the ONS site, as the nearest mountain is over 1 kilometre away and has an elevation of less than 150 meters. In the event of landslides affecting the onshore export cable, movement of soil over the line corridor may hinder maintenance operations. However, the section of the onshore export cable is relatively short that even in the unlikely situation	

²⁷ Korea Meteorological Administration, 2020. Korean Climate Change Assessment Report 2020 – The physical Science Basis. ISBN 978-89-954715-9-3. [Available at: http://www.climate.go.kr/home/cc_data/2020/Korean_Climate_Change_Assessment_Report_2020_1_eng_summary.pdf]

		where export cable is covered in soil, the removal operations would be relatively easy and fast.
Key Potential Impacts	• Delay of logistic and maintenance operations.	
Implemented Mitigations	• None required.	

5.4 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)²⁸. The WetBulb Globe Temperature (WBGT) is a measure of the heat stress in direct sunlight, which takes into account: temperature, humidity, wind speed, sun angle and cloud cover (solar radiation). It differs from the heat index, which takes into consideration temperature and humidity and is calculated for shaded areas. The WBGT has an obvious relevance for human health, but it is relevant in all kinds of projects and sectors, including infrastructure related, as heat stress affects personnel and stakeholders, and therefore the design of buildings and infrastructure. In general, the WBGT is a relevant enough proxy to quantify the strain on physical infrastructure (energy, water, transport), such as increased demands for water and electricity, which may also affect decisions related to infrastructure.

5.4.1 Baseline Hazard

The hazard of extreme heat was evaluated on a regional level using the Think Hazard report in South Korea²⁹. The extreme heat hazard in Jeollanam-do is reported to be “**Medium**” as illustrated in **Figure 5.22** The classification is based on damaging intensity thresholds as presented in the below table.

²⁸ ThinkHazard. 2020. Republic of Korea: <https://thinkhazard.org/en/report/24980-republic-of-korea-kyonggi-do-administrativeunit-not-available/EH>

²⁹ Think Hazard. [Available at: <https://thinkhazard.org/>]

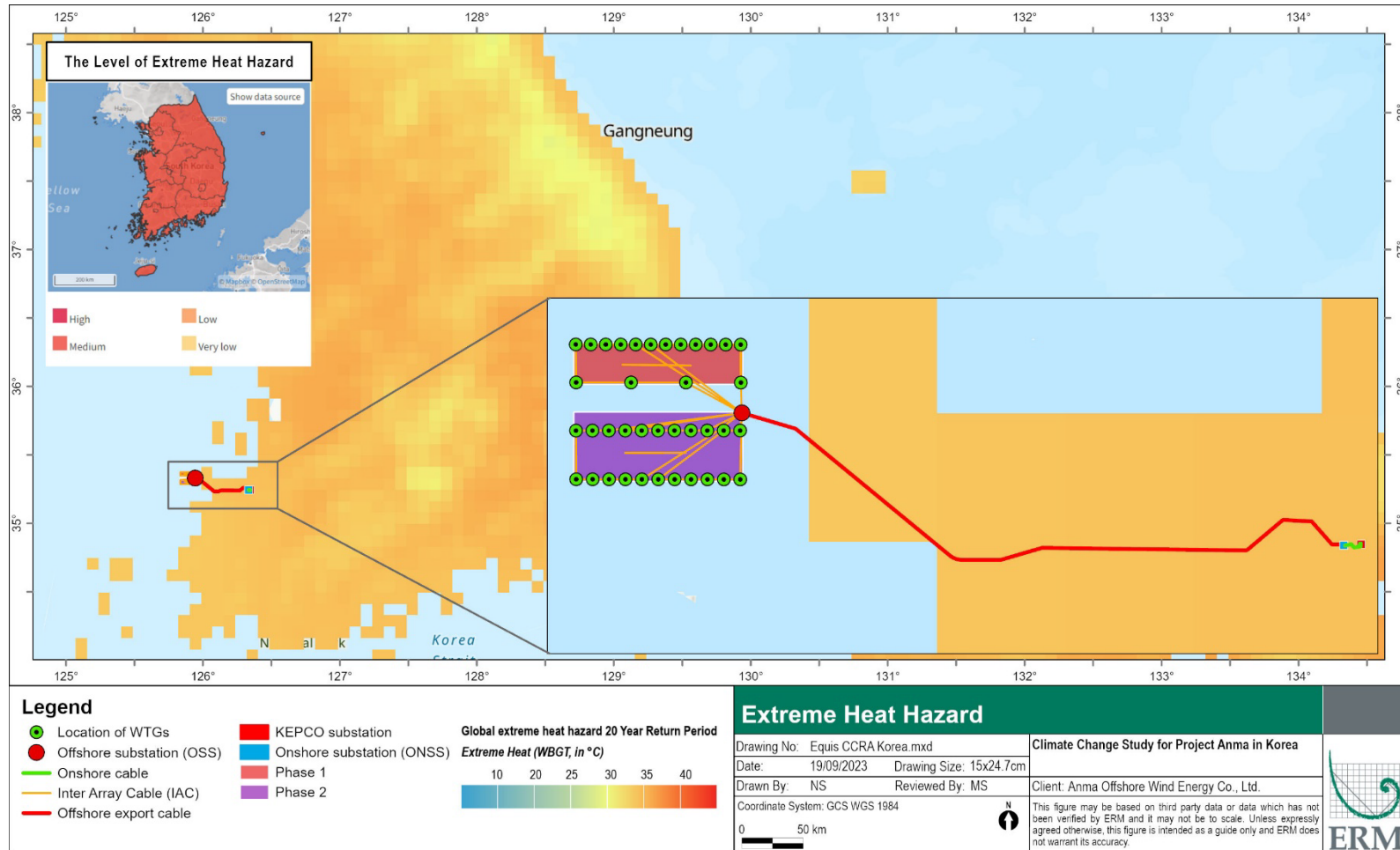


Figure 5.22 Extreme Heat Hazard

Source: ThinkHazard. Available at <https://thinkhazard.org/en/> and Global Facility for Disaster Reduction and Recovery (GFDRR). Available at <https://www.geonode-gfdrmlab.org/>

Table 5.6 Classification of Extreme Heat Hazard

Wet Bulb Temperature	Hazard Classification
>32°C	High
28°C - 32°C	Medium
25°C - 27°C	Low
<25°C	Very Low

5.4.2 Climate Change Projections

Climate change projections indicate increase in maximum temperature and warm spell duration.

In the short-term outlook (2024~2050) for temperature and extreme climate events, it is predicted that the average temperature will increase by +1.33°C to +1.93°C in all RCP scenarios.³⁰ The prediction based on the RCP 8.5 is +1.75°C compared to the 1981~2005 average.

Indices of extreme high temperatures such as the number of heatwave days, tropical nights, and summer days are expected to increase, while low temperature-related indices such as the number of cold wave days, ice days, and frost days are predicted to decrease.³¹

These changes are likely to significantly impact occurrence heat waves and extreme heat in future.

Accordingly, the hazard due to extreme heat is considered to be **“High”** under future climate change scenarios.

5.4.3 Exposure and Vulnerability

WTG have ambient temperature tolerance range associated with turbine design. Typical turbines can operate normally between -20°C to 35°C (ambient temperature). High ambient temperatures may affect the performance of the generator and overall electrical components and will result in a sub-optimal power generation performance. Ambient temperature can also affect air density and affect the power generation of the turbine. Structural damage to the turbine due to high ambient temperature is rare and the design took into consideration the project specific weather conditions.

Extreme heat could affect the well-being of personnel working on the Offshore Substation during maintenance period.

Offshore export cables are designed and sized according to the operating ambient temperature, where sea water temperature plays a significant factor. An increase in sea water temperature may reduce the transmission capacity of the submarine cable, or in the worst case, damage the submarine cable. Distributed Temperature Sensing will mitigate this impact by informing the operator of the conductor temperature.

Extreme heat could affect the well-being of personnel working outdoors at the Onshore Substation. Moreover, extreme heat can cause the overheat of the substation facilities such as cooling system.

Underground cables are designed and sized according to the operating ambient temperature, where air temperature plays a significant factor. An increase in air temperature may reduce the transmission capacity of the underground cable, or in the worst case, damage the underground cable.

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

³⁰ Korea Meteorological Administration, 2020. Korean Climate Change Assessment Report 2020 – The physical Science Basis. ISBN 978-89-954715-9-3. [Available at: http://www.climate.go.kr/home/cc_data/2020/Korean_Climate_Change_Assessment_Report_2020_1_eng_summary.pdf]

³¹ Idem

5.4.4 Risk Assessment

The table below shows the summary of risk assessment.

Table 5.7 Qualitative Risk Level and Project Implications for Extreme Heat

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
Hazard Level	Medium	High	High
Exposure x Vulnerab. Level	Medium	Medium	Medium
Risk Level	Medium	Medium	Medium
Implications for the Project	WTG	WTG have ambient temperature tolerance range associated with turbine design. Typical turbines can operate normally between - 20°C to 35°C (ambient temperature). High ambient temperatures may affect the performance of the generator and overall electrical components and will result in a sub-optimal power generation performance. Ambient temperature can also affect air density and affect the power generation of the turbine. Structural damage to the turbine due to high ambient temperature is rare and the design took into consideration the project specific weather conditions.	
	Offshore substation	Extreme heat could affect the well-being of personnel working on the maintenance period. The worker should consider having heat protection equipment during the maintenance time. High temperature may however compromise the regular functionality of the main equipment	
	Offshore Export Cable	Submarine cables are designed and sized according to the operating ambient temperature, where sea water temperature plays a significant factor. An increase in sea water temperature may reduce the transmission capacity of the submarine cable, or in the worst case, damage the submarine cable. Distributed Temperature Sensing will mitigate this impact by informing the operator of the conductor temperature.	
	Onshore Substation	Extreme heat could affect the well-being of personnel working outdoors at the substation. Moreover, extreme heat can cause the overheat of the substation facilities such as cooling system.	
	Onshore Export Cable	Underground cables are designed and sized according to the operating ambient temperature, where air temperature plays a significant factor. An increase in air temperature may reduce the transmission capacity of the underground cable, or in the worst case, damage the underground cable.	
Key Potential Impacts	Heat stress or heat exhaustion for personnel operating in the onshore substation or performing maintenance work within the WTG hub.		

Implemented Mitigations	• Make appropriate considerations while designing the cooling and ventilation systems of the onshore substation and WTG hubs. • Assess risk and put in place mitigation measure if workers are to operate at temperatures higher than 32 °C³² during maintenance of WTG or operation of the onshore substation
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5.5 Cyclone and Hurricane

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

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

5.5.1 Baseline Hazard

The cyclonic storms are generally classified into five (5) categories based on Saffir-Simpson categorisation of hurricane as summarised in **Table 5.8**. **Figure 5.23** and **Figure 5.24** present the cyclone intensity, and historical hurricane tracks maps within the Project area. The historical data is generally available since 1842 as per NOAA³³. The Project Area was reported in an area prone to Category 1 cyclones as defined by Saffir- Simpson scale. Furthermore, review of historical tracks captured by NOAA since 1842 indicates seven (7) hurricanes (including two (2) Category 2 hurricanes) and approximately 20 tropical storms have passed within 100 km radial distance from the Project Area.

The maximum wind speed recorded within 100 km radius of the Project location was reported to be 49 m/s (95 knots) during the cyclone Kompasu in 2010 (as per NOAA) as presented in **Figure 5.25**.

Based on these maps, cyclone hazard was evaluated as “**Medium**” at the Project and its surrounding area have experienced up to Category 2 cyclones.

Table 5.8 Saffir-Simpson Categorization of Cyclone/Hurricane

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

³² Occupational Safety and Health Administration's (OSHA's) Temporary Worker Initiative (TWI), 2022. Exposure to Outdoor and Indoor Heat-Related Hazards. Available at: <https://www.osha.gov/sites/default/files/publications/OSHA4185.pdf>

³³ National Oceanic and Atmospheric Administration (NOAA). Available at <https://coast.noaa.gov/hurricanes>

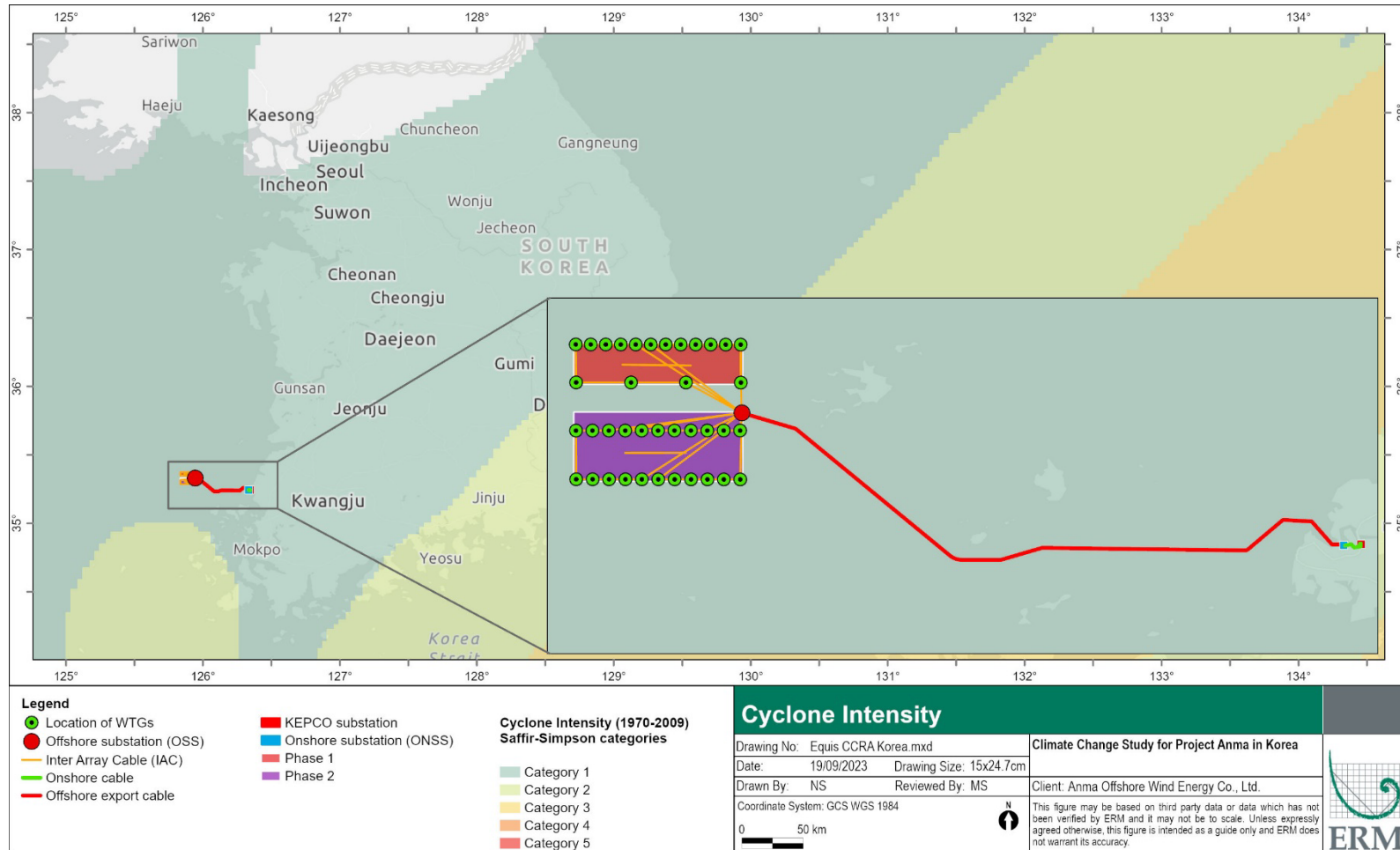


Figure 5.23 Baseline Cyclone Intensity Map

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

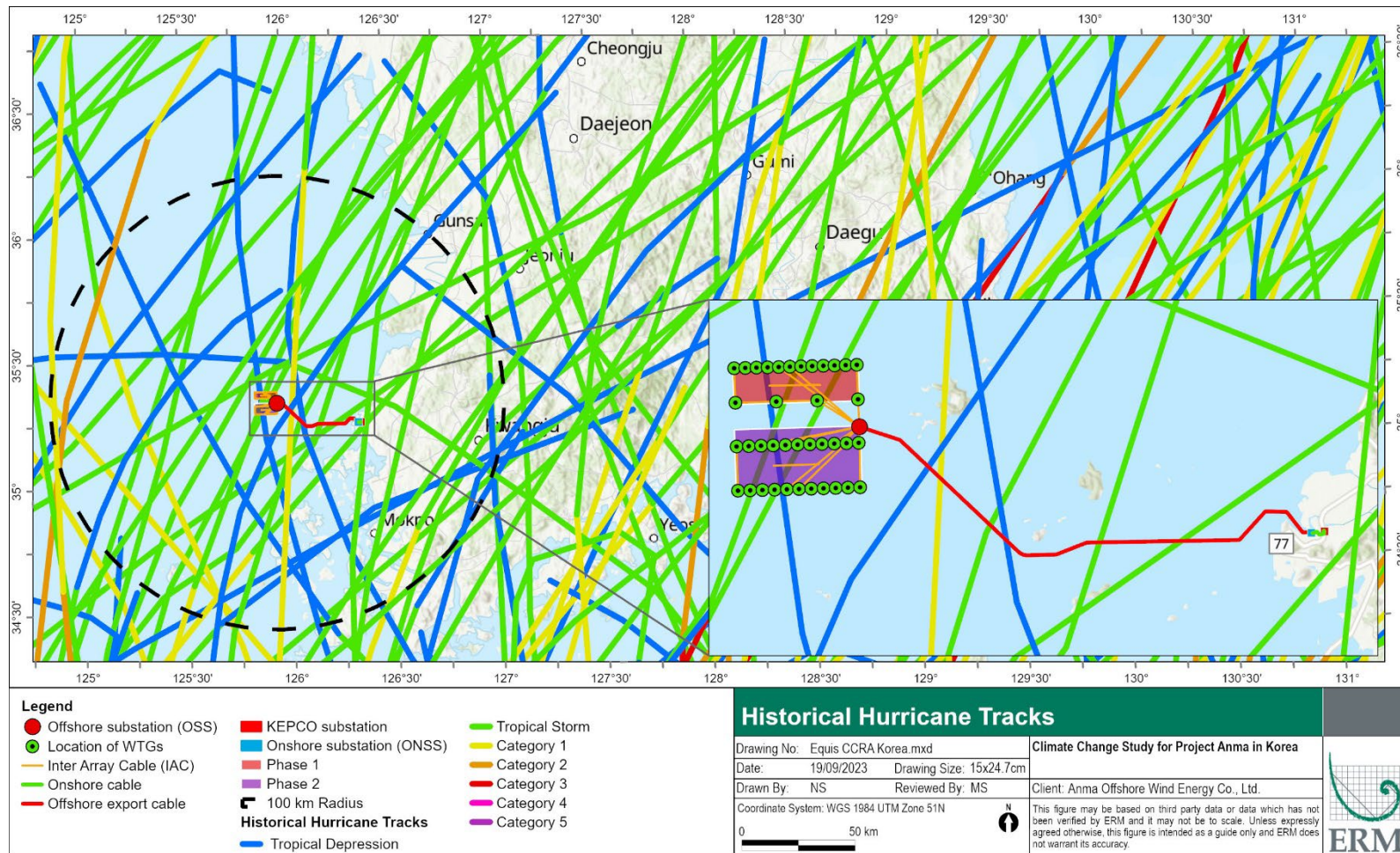


Figure 5.24 Historical Hurricane Tracks Map

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

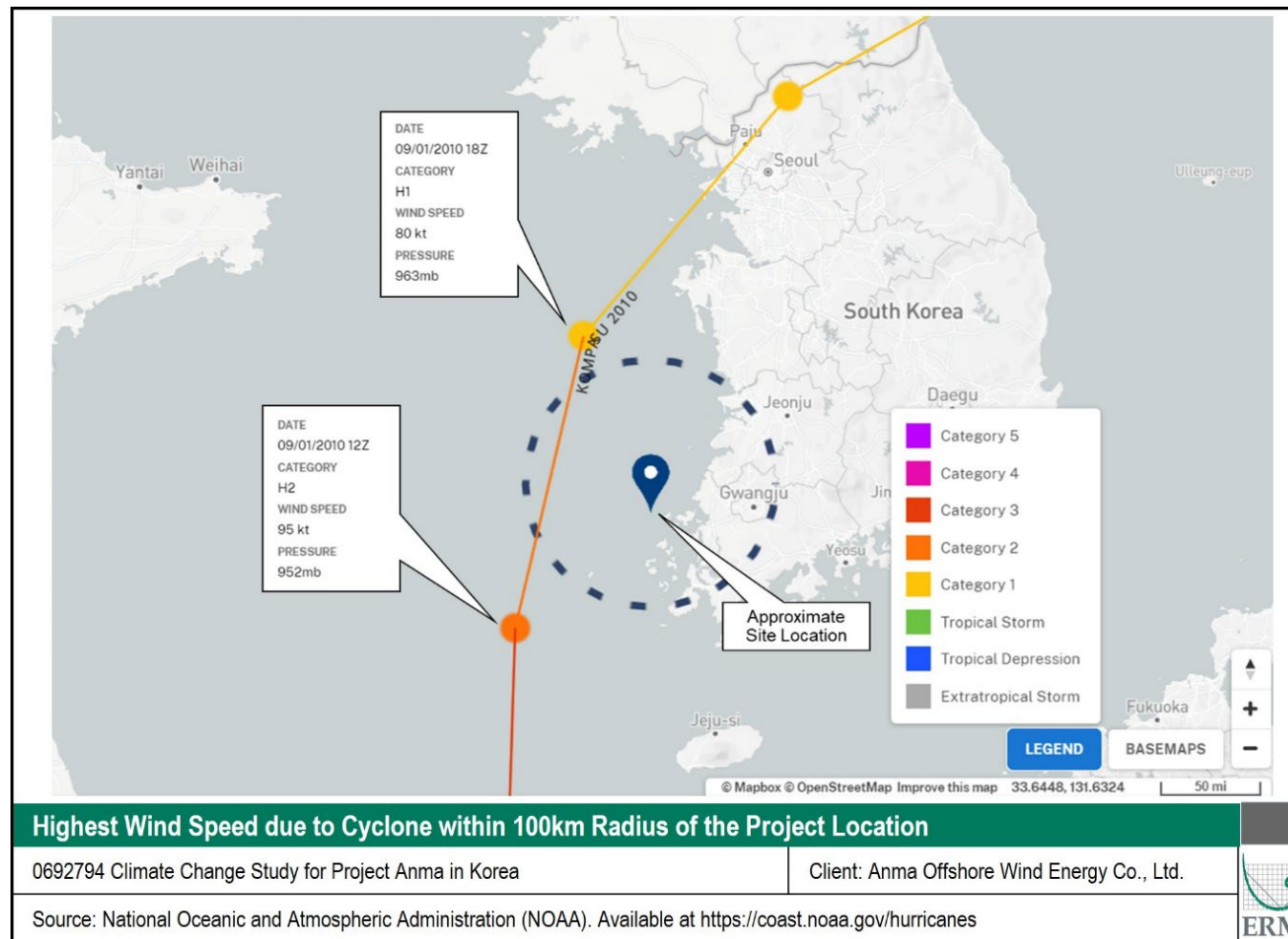


Figure 5.25 Highest Wind Speed due to Cyclone within 100km Radius of the Project Location

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

5.5.2 Climate Change Projections

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

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

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

Climate change studies suggested likely increase in peak wind intensity and near storm precipitation in future tropical cyclones and decrease in overall frequency of cyclones. Spatial resolution of some of the earlier models used in AR4 is generally reported to be too coarse to simulate tropical cyclones. The recent advances in downscaling techniques are reported to indicate some level of success in simulating/ reproducing observed tropical cyclone characteristics. However, it should be noted that limitations and high uncertainty exist in simulation of tropical storms.

The report noted similar remarks stating that the limited period of 30-40 years of observations is not sufficient to conclusively distinguish anthropogenic induced changes with decadal changes in overall cyclone frequencies. Further studies conducted for detection of Category 4 and 5 cyclones over recent decades indicated increasing trend. However, these changes in frequency are reported to vary from one ocean basin to another. Studies conducted with higher degree of warming indicated decreasing trend in total number of tropical cyclones while increase in Category 4-5 cyclones.

The recent study by Knutson et. al.³⁴ (2020) indicated likely changes for occurrences of tropical cyclone over north-west Pacific Ocean as following:

- Overall frequency of tropical cyclone may change by -30 to +20% with median change of -12%;
- Changes in frequency of category 4-5 cyclone between -25 to +40% with median change of -5%;
- Intensity of cyclone indicated likely increase by 1 to +9% with median of +5% increase under +2°C scenario by end of century.

Accordingly, considering the likely changes in frequency and intensity of cyclones, the cyclone hazard is evaluated to remain “**Medium**” in future.

5.5.3 Exposure and Vulnerability

WTG can be exposed to extreme wind speed combined with pressure from waves on the turbine foundation that can lead to structural damage. However, the vulnerability is reduced by choice in their design that allows them to withstand Category 2 hurricanes and wind speed above 25 m/s.

³⁴ Knutson, T., Camargo, S.J., Chan, J.C.L., Emanuel, K., Ho, C.H., Kossin, J., Mohapatra, M., Satoh, M., Sugi, M., Walsh, K., and Wu, L., 2020. Tropical Cyclones and Climate Change Assessment: Part II: Projected Response to Anthropogenic Warming. Bulletin of the American Meteorological Society 101-3, pp. e303-e322 <https://doi.org/10.1175/BAMS-D-18-0194.1>

The Offshore Substation is exposed to hurricanes, but design choices have decreased its vulnerability. High wind speed may lead to small damage not influencing the functionality of the substation.

With regards to the Offshore Export Cable, it is not expected to be exposed or vulnerable to hurricanes as it is buried.

Increased wind speed and intense precipitation may lead to damage to the roof of the Onshore Substation or flooding of the lower floors which in turn can damage the electrical equipment. Personnel operating-maintaining the Onshore Substation during hurricanes may be exposed to the intensified winds and vulnerable to falling objects.

As the onshore export cable will be buried depth of minimum 1.9 m, it is not considered exposed to hurricane.

Considering the information provided, the Project's exposure level is categorized as “**High**” based on the exposure and vulnerability of the Onshore Substation.

5.5.4 Risk Assessment

The table below shows the summary of risk assessment.

Table 5.9 Qualitative Risk Level and Project Implications for Cyclone and Hurricane

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
Hazard Level	Medium	Medium	Medium
Exposure x Vulnerab. Level	High	High	High
Risk Level	High	High	High
Implications for the Project	WTG	Extreme wind speed combined with pressure from waves on the turbine foundation can lead to structural damage. Modern wind turbines are designed to withstand Category 2 hurricanes and wind speed above 25 m/s. International standards acknowledge that a large part of the installation of new offshore wind farms are occurring in areas subject to tropical cyclones and are adapting design guidelines to guarantee withstanding of extreme wind speed. ³⁵ Inappropriate design may lead to structural or superficial damage to WTG with consequent reduction of power generation and increase of maintenance cost.	
	Offshore substation	Offshore substation will be designed to withstand the weather condition foreseen in the area, so no vulnerability is foreseen. High wind speed may lead to small damages not influencing the functionality of the substation	
	Offshore Export Cable	No implications as it will be buried.	

³⁵ International Renewable Energy Agency, 2018. Nurturing Offshore Wind Markets: Good Practices for International Standardization. International Renewable Energy Agency, Abu Dhabi

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
	Onshore Substation	Increased wind speed and intense precipitation may lead to damage to roof or flooding of the lower floors which in turn can damage the electrical equipment. Potential risk of damage to personnel operating-maintaining the substation	
	Onshore Export Cable	Not applicable to onshore transmission as it will be buried at a depth of minimum 1.9 m	
Key Potential Impacts	• Reduction of power generated • Potential accidents to operation and maintenance personnel		
Implemented Mitigations	• Appropriate SCADA system and controller • Inspection of WTG and Onshore Substation after any extreme weather event • Accurate weather forecast during operation • Design of the onshore substation roof taking into consideration extreme winds speed • Elevate the foundation level of the onshore substation and outdoor equipment to prevent flood damage to electrical components • Design appropriate drainage system to protect the onshore substation from intense precipitations during hurricanes and cyclones		

5.6 Wind Speed

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

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

For the purpose of this assessment, average wind speed data from Global Wind Atlas 2.0, a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU) in partnership with the World Bank Group, was utilized. Additionally, wind hazard was also evaluated based on maximum wind speed represented by basic wind speed considered for structural design in South Korea. The basic wind speed corresponds to maximum wind speed on a 100-year return period³⁶.

5.6.1 Baseline Hazard

The average wind speed at the Project Area was reported approximately 7 m/s as presented in **Figure 5.26**. Based on average and hourly wind speed data, the baseline hazard due to average wind

³⁶ Hahm, J.H., Jeong, H.Y, Kwak, K.H., 2019. Estimation of Strong Wind Distribution on the Korean Peninsula for Various Recurrence Periods: Significance of Nontyphoon Conditions. *Advances in Meteorology*, Article ID 8063169 <https://doi.org/10.1155/2019/8063169>

speed for the area is considered to be “Low”. This implies that the project area is not prone to wind hazard on a general basis. With regards to maximum wind speed, data were obtained from the windPROSPECTING. This tool allows users to visualize global wind resources and is based on the GASP (Global Atlas of Siting Parameters) project. The dataset used by the model includes extreme 50-year wind speeds values. According to this source, the extreme wind speed at the Project location was reported to be 36.4 to 27.1 m/s as presented in **Figure 5.27**. Therefore, the hazard associated with the maximum wind speed is considered “**High**” which means that the Project may experience hazardous wind speeds during certain storm events with larger return periods in the order of 100 years. Therefore, considering the worst-case scenario, the wind hazard is considered to be “**High**”.

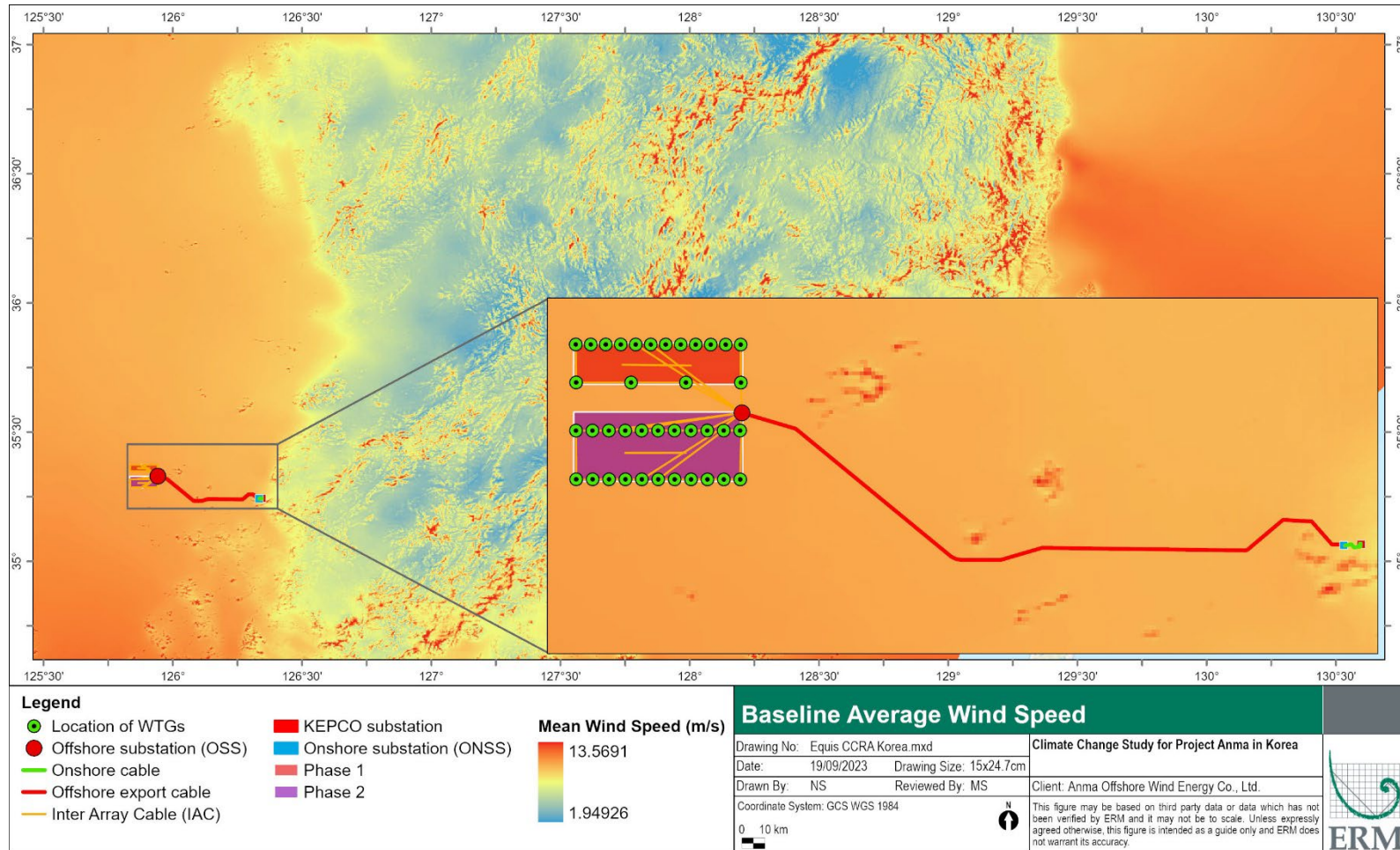


Figure 5.26 Baseline Average Wind Speed Map

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

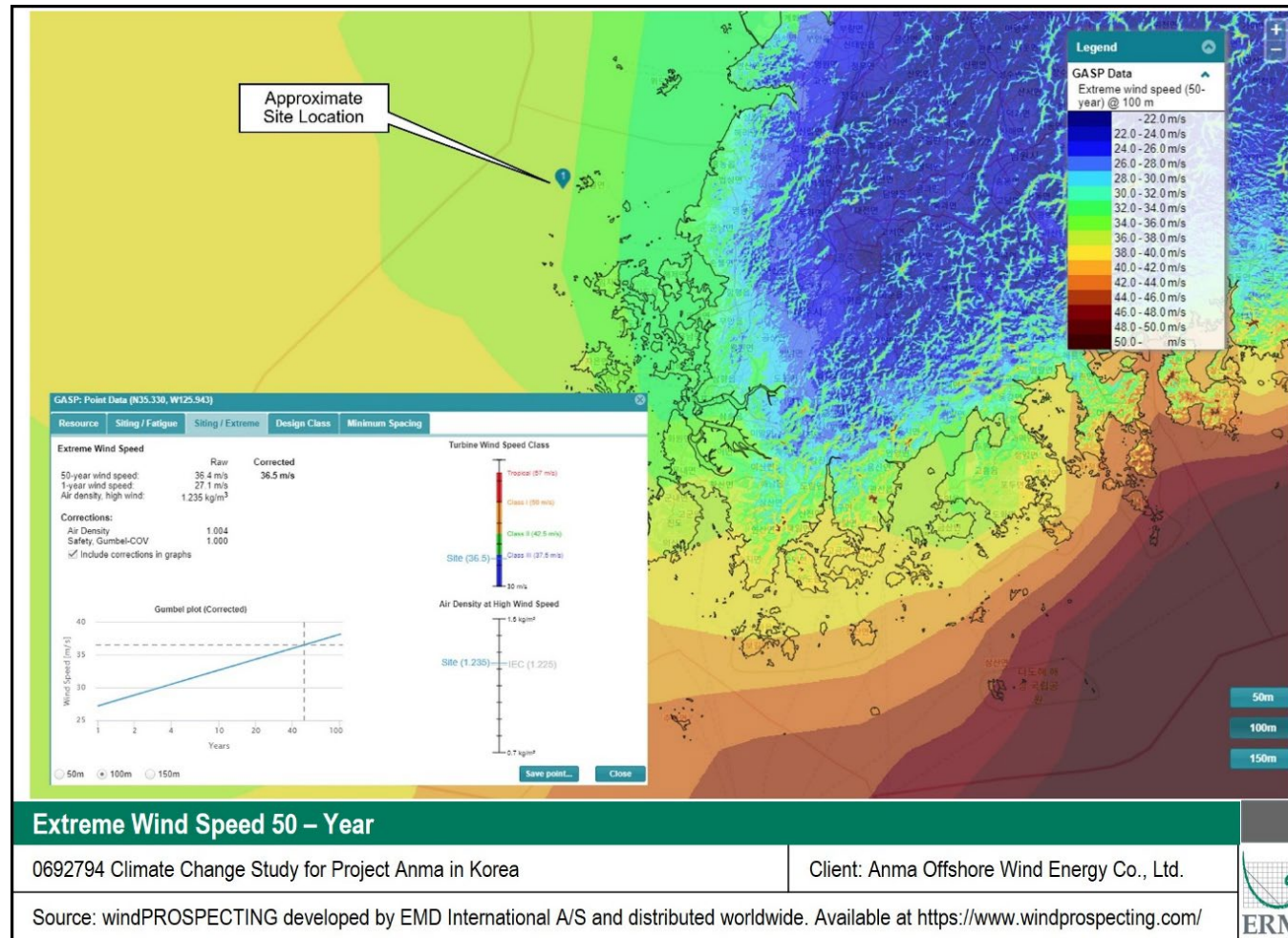


Figure 5.27 Extreme Wind Speed 50 – Year

Source: windPROSPECTING. Available at <https://www.windprospecting.com/>

5.6.2 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 2010³⁷. Considering the limited information available on wind speed projections and high uncertainty, the wind hazard under a climate change scenario is considered to be “**Low**” for average speed and “**High**” for maximum speed.

5.6.3 Exposure and Vulnerability

WTG are exposed to extreme wind speed conditions which could damage the structure of the turbine. Inappropriate design makes them vulnerable to damage or sub-optimal energy performance.

The design of the Offshore Substation makes it less vulnerable to high wind speed compared to WTG.

Offshore Export Cable and Onshore Export Cable are not exposed to extreme wind events as they are buried.

Increased wind speed may lead to damage to the roof of the Onshore Substation. Personnel operating-maintaining the Onshore Substation during extreme wind events may be exposed to falling objects and increase likelihood of accidents.

Considering the information provided, the Project's exposure level is categorized as “**High**” based on the Onshore Substation and WTG.

5.6.4 Risk Assessment

The table below shows the summary of risk assessment.

Table 5.10 Qualitative Risk Level and Project Implications for Wind Hazard

		Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
Hazard Level Average Wind Speed		Low	Low	Low
Hazard Level Maximum Wind Speed		High	High	High
Exposure x Vulnerability Level		High	High	High
Risk Level		High	High	High
Implications for the Project	WTG	Extreme wind speed and inappropriate design of WTG may lead to structural or superficial damage with consequent reduction of power generation and increase of maintenance cost.		
	Offshore substation	High wind speed may lead to small damages of the offshore substation not compromising its functionality		
	Offshore Export Cable	No exposure as it will be buried		

³⁷ 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>

	Onshore Substation	High wind speeds may damage the onshore substation by dislodging roofs panels. This may also cause safety issues to maintenance personnel working to operate the facilities.
	Onshore Export Cable	Not applicable to onshore export cable as it will be buried at a depth of minimum 1.9 m
Key Potential Impacts	• Structural damage of WTG, and onshore substation • Reduction of power generated • Potential accidents to operation and maintenance personnel	
Implemented Mitigations	• Turbine models designed in accordance with international and local standards • Appropriate SCADA system and controller • Inspection after any extreme weather event • Accurate weather forecast during operation and implement restrictions for work during high-speed wind conditions (e.g. no craning during wind speed greater than 15 m/s) • Prevent falling objects during high wind speeds by ensuring offshore workers use tethering and secure all open objects before leaving WTG (e.g. hatches) • Design the onshore substation layout to mitigate risk of falling objects in areas to be occupied by infrastructure or personnel • Design of the onshore substation roof taking into consideration extreme winds speed	

5.7 Sea Level Rise

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

5.7.1 Baseline Hazard

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

5.7.2 Climate Change Projections

Based on projections for regional sea level rise reported by IPCC the sea level rise near Korean Peninsula and Yellow Sea is likely to be in the range of +0.2 to +0.4 m by 2050 under RCP 8.5 scenario.

Further, vertical land movement/ motion is also reported to be an important factor which can affect the net impact of regional sea level rise. Vertical land movement is a term used to describe movement of land (upward or downward) due to the effect of tectonic movements, subsidence, or ground water extraction. Areas where the vertical land movement is upwards experience comparatively lower sea level rise. Whereas areas with downward land movement are anticipated to experience stronger sea level rise.

For present assessment, the hazard due to sea level rise is evaluated based on the sea level rise projections from Sea Level Rise for Cities Tool from Climsystems. Accordingly, the sea level rise compared to 1995 level at the Project Area is projected to be +32 cm by 2040, +56 cm by 2060, +88 cm by 2080 and +128 cm by 2100. **Figure 5.28** presents the map of sea level rise near the Project Area.

Considering projected sea level rise of approximately +32 cm, and ground elevation at the onshore substation minimum 4 m above sea level (based on Google Earth topography), the hazard due to sea level rise is considered to be “**Low**” for the onshore substation. However, it should be noted that the combined effect of coastal erosion and loss of the dune system may exacerbate the effects of the sea level rise. Therefore, it is important to maintain the coastal dune system and native vegetation.

The onshore export cable is located at elevation below 1 m above sea level along flat agricultural areas obtained through land reclamation process and as such, the sea level rise may adversely affect the plains and require maintenance of the dikes to avoid land submersion. The hazard due to the level rise is conservatively assumed “**Medium**”.

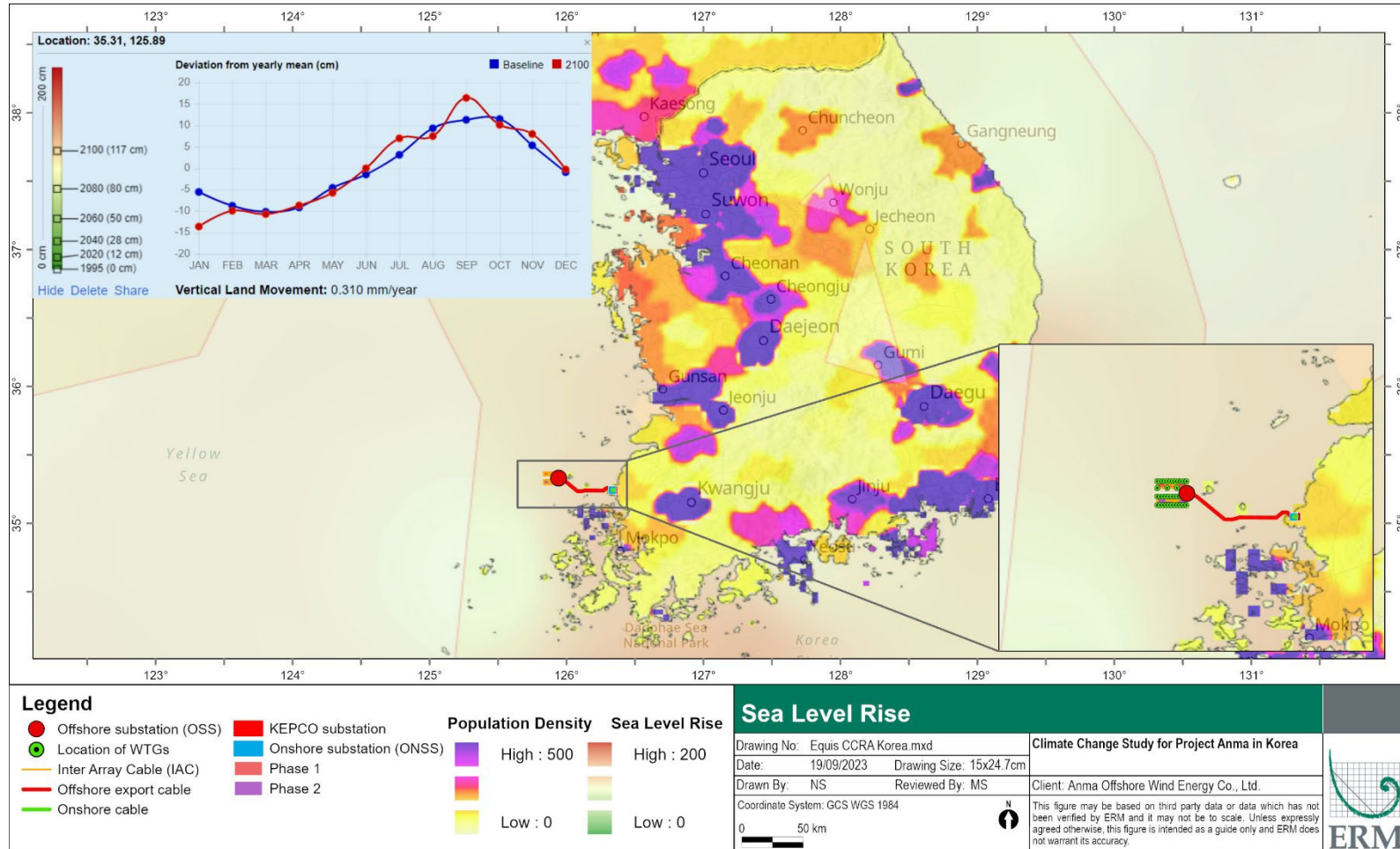


Figure 5.28 Map for Sea Level Rise Projections at Project location

Source: SLR and Vertical Land Movement for Cities Version: 1.0. Available at <https://slr-cities.climsystems.com/>

5.7.3 Exposure and Vulnerability

An increase of sea level between 32 cm to 56 cm is considered within the range of sea levels considered in the designs of foundations of WTGs and Offshore Substation against waves and tides highest expected levels. Therefore, the vulnerability of these facilities is considered to be “Low”.

Sea level rise is not affecting the export cable as it is buried in the seabed and, therefore, not exposed to this hazard.

Onshore Substation is situated at an elevation of minimum 4 meters above sea level. However, it should be noted that the combined effect of coastal erosion and loss of the dune system may exacerbate the effects of the sea level rise. Assuming that the authorities will perform maintenance of the dikes, it is possible to consider a “Low” level of exposure for this facility.

Since the onshore cables will be buried at a minimum depth of 1.9 meters from ground level and surrounded by agricultural areas, the likelihood of submersion is minimal. therefore, the potential for increased material wear and frequent maintenance due to submersion is unlikely.

Considering the information provided, the Project's exposure level is categorized as “Low”.

5.7.4 Risk Assessment

The table below shows the summary of risk assessment.

Table 5.11 Qualitative Risk Level and Project Implications for Sea Level Rise

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
Hazard Level	Not Applicable	Medium	Medium
Exposure x Vulnerab. Level	Low	Low	Low
Risk Level	Low	Low	Low
Implications for the Project	WTG	Sea level rise range projected for the operation period is within the range of sea levels considered in the designs of foundations against waves and tides highest expected levels.	
	Offshore substation	Sea level rise range projected for the operation period is within the range of sea levels considered in the designs of foundations against waves and tides highest expected levels.	
	Offshore Export Cable	No implications as it will be buried.	
	Onshore Substation	As the onshore substation is located minimum 4 m above sea level, it is not expected the sea level to reach the building. However, coastal erosion may change the topographic profile and as the substation is 300 m from the coastal line this may affect potential flooding events.	
	Onshore Export Cable	Since the onshore cables will be buried at a minimum depth of 1.9 meters from ground level and surrounded by agricultural areas, the likelihood of submersion is minimal.	

Key Potential Impacts	Increased wearing of onshore export cable
Implemented Mitigations	Type of the cable will be XLPE which has high resistant to moisture and designed for long term durability. Further, pulling method will be underground concept with electrical duct which provide robust protection against sea level rise and potential exposure to seawater.

5.8 Lightning

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

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

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

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

Lightning can cause both destruction of infrastructure and lives. About 2,000 people are killed worldwide by lightning each year. Hundreds more survive strikes but suffer from a variety of lasting symptoms, including memory loss, dizziness, weakness, numbness, and other life-altering ailments³⁸.

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

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

5.8.1 Baseline Hazard

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

Lightning flash density map presented in **Figure 5.29** indicates the density of lightning flashes to be 4 events km⁻² year⁻¹ during the period 2016 - 2022 at the Project Area. Very limited information is available in the public domain regarding the hazard classification of lightning. However, when compared to other regions, the hazard in the Project area can be assumed as "**Low**".

³⁸ National Geographic, N.D. <https://www.nationalgeographic.com/environment/natural-disasters/lightning/>

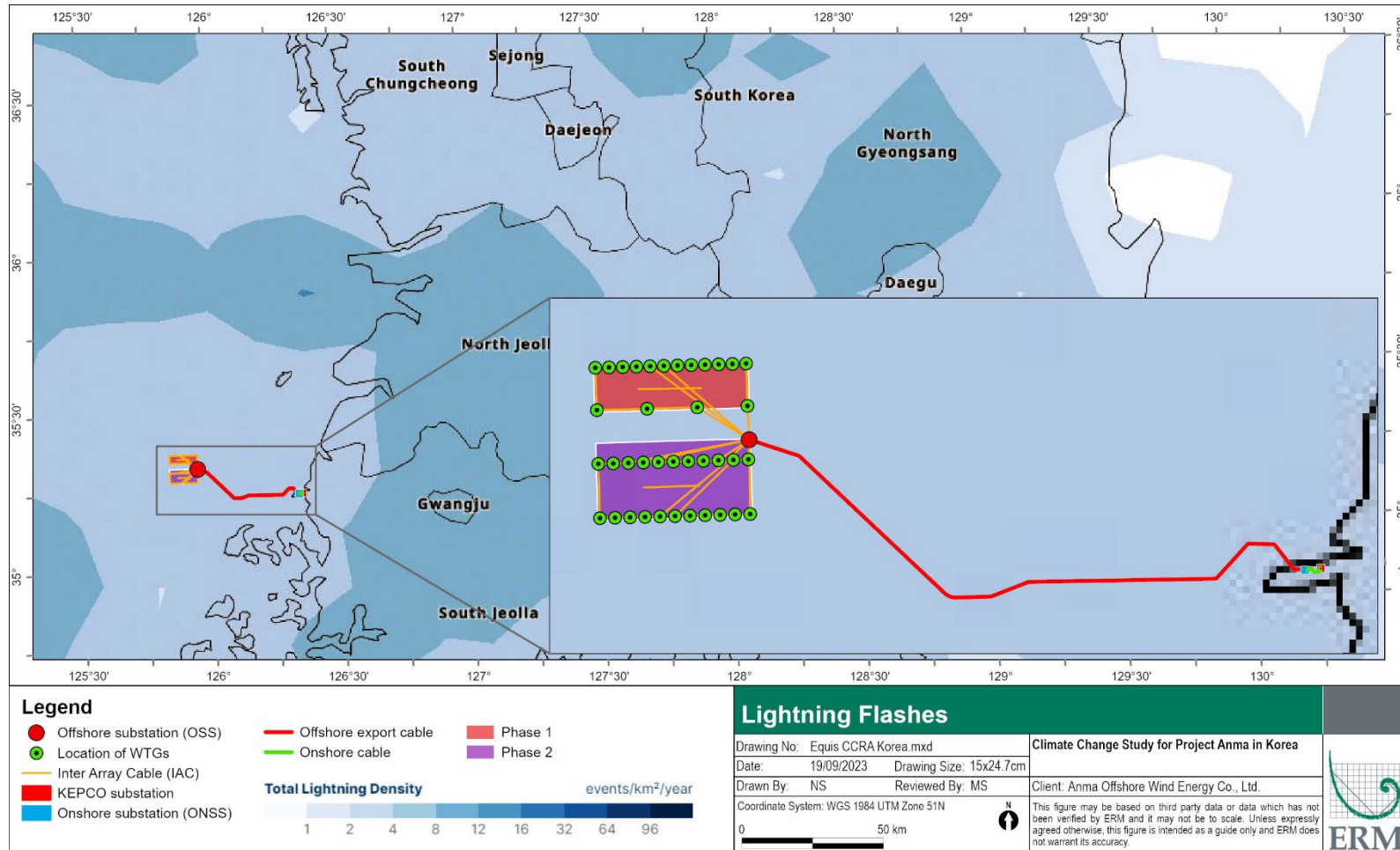


Figure 5.29 Baseline Lightning Density Map

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

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

5.8.2 Climate Change Projections

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

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

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.

CAPE at the Project area is likely to increase between +500 J/kg and +1000 J/kg by 2100 for RCP 8.5 scenario as presented in **Figure 5.30**. In general, the studies indicate an increase in potential for intense thunderstorms in warming atmosphere. Accordingly, the projected increase in number of days with conditions favourable for formations of thunderstorms is reported to be between 0 days/years and +10 days/year by 2100 under RCP 8.5 scenario. **Figure 5.31** presents the likely increase in number of days per year with conditions favourable for severe thunderstorm by end of the century. Hence, an increase in lightning activity/frequency may be experienced in future. The presence of wind turbines may trigger additional lightning events due to the movement of rotor blades initiating a discharge or a so-called “Upward lightning”. However, given the geographical location of South Korea and global distribution of lightning events, it is assumed a “**Low**” hazard level at the Project Area.

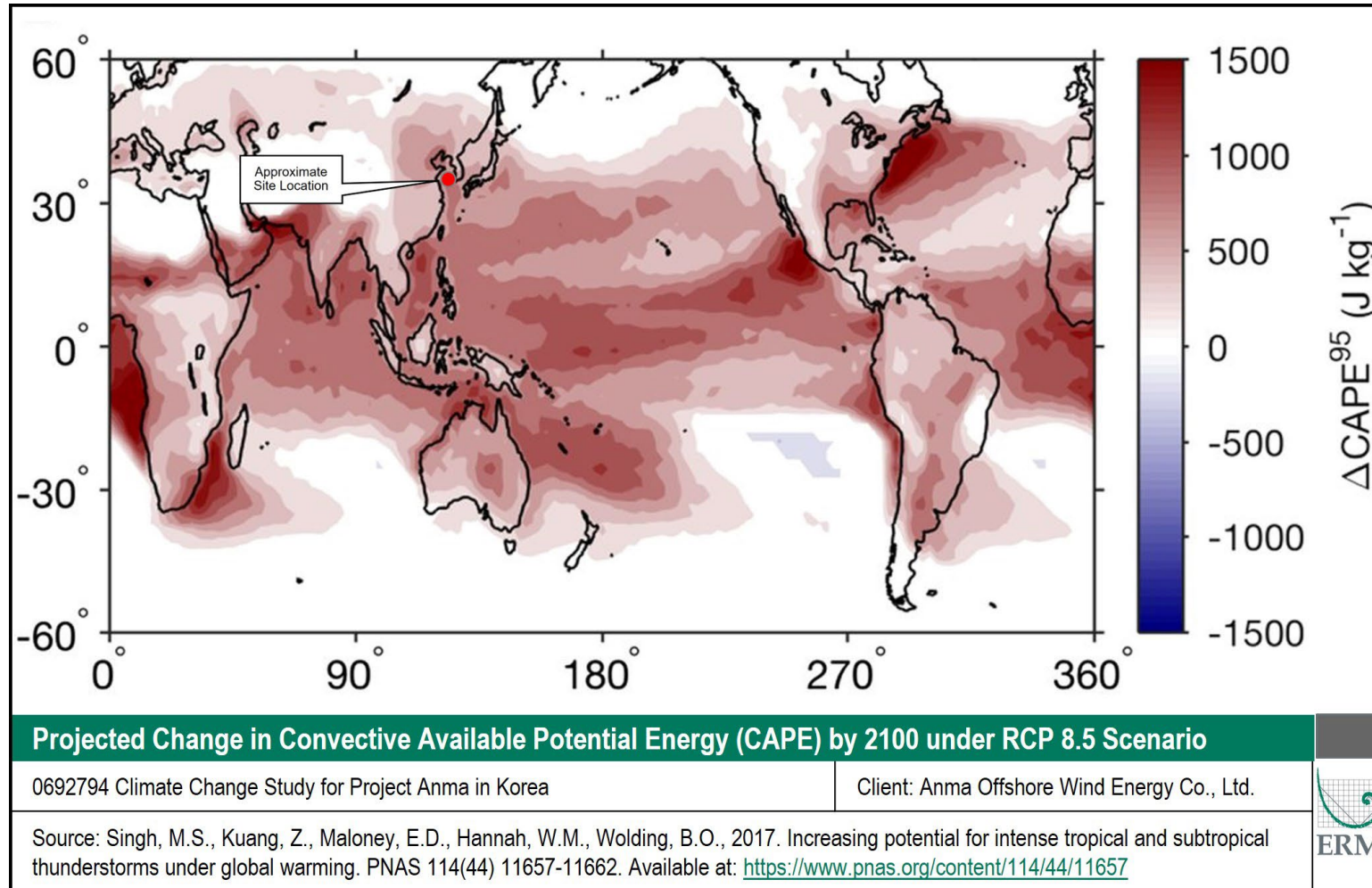


Figure 5.30 Projected Change in Convective Available Potential Energy (CAPE) by 2100 under RCP 8.5 Scenario

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

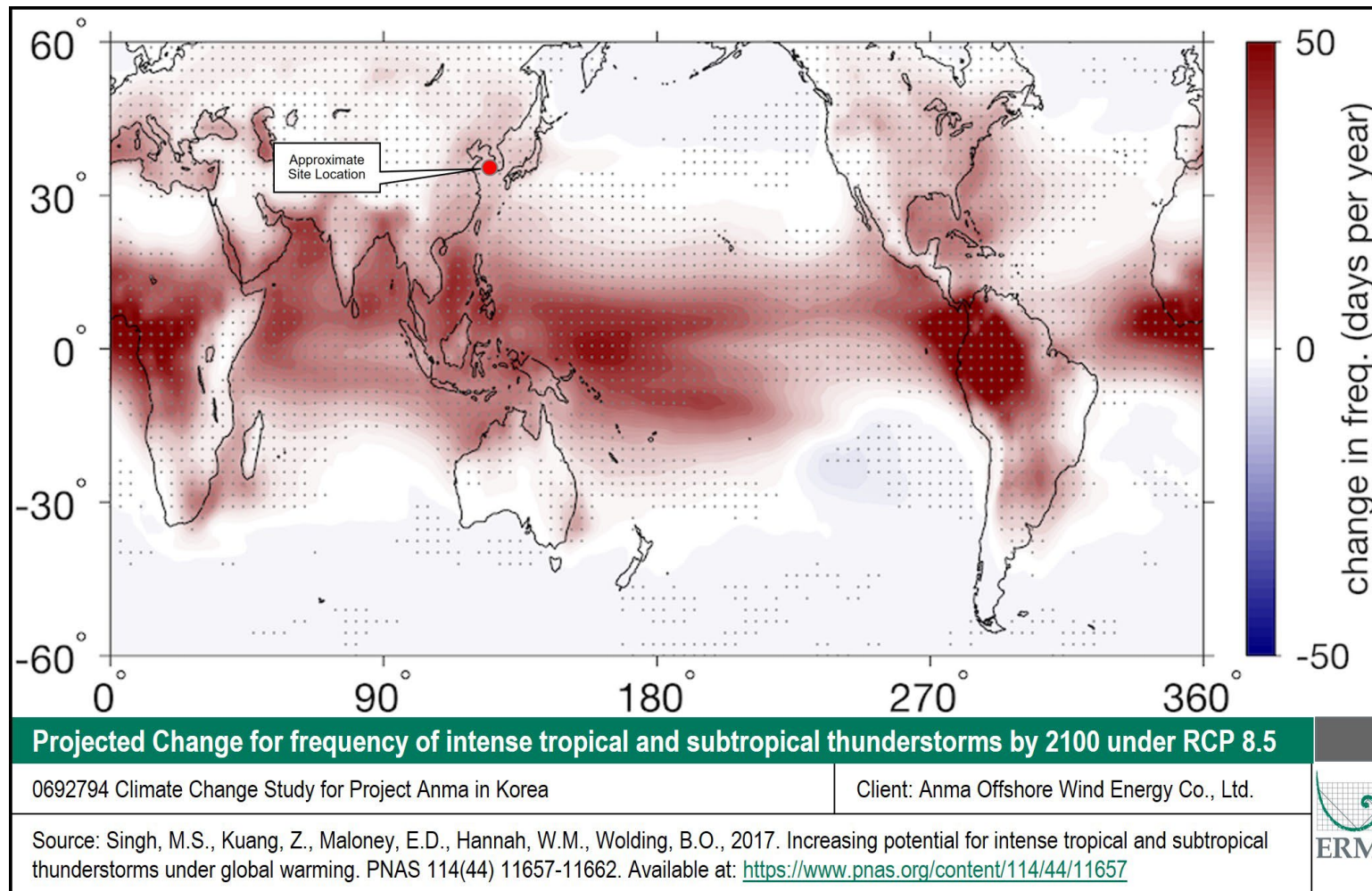


Figure 5.31 Projected Change for frequency of intense tropical and subtropical thunderstorms by 2100 under RCP 8.5 Scenario

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

5.8.3 Exposure and Vulnerability

Typically, wind turbines are exposed to lightning strikes. A WTG stroke by a lightning could sustain structural damage to its control system, wind turbine blades, electrical generators, etc.³⁹

It is assumed that both Offshore and Onshore Substations are following national and international standards for prevention of lightning damage and equipped with lightning arresters, grounding system and surge protection devices, which make these facilities not vulnerable to lightning hazard.

Given that the onshore export cable is buried at a depth of minimum 1.9 m and insulated, no exposure is expected.

The Export Cable is equipped with surge arrestors, which makes it less vulnerable to lightning.

Considering the information provided, the Project's exposure level is categorized as “High”.

5.8.4 Risk Assessment

The table below shows the summary of risk assessment.

Table 5.12 Qualitative Risk Level and Project Implications for Lightning

	Baseline	RCP 8.5 – 2030	RCP 8.5 – 2050
Hazard Level	Low	Low	Low
Exposure x Vulnerab Level	High	High	High
Risk Level	Medium	Medium	Medium
Implications for the Project	WTG	Lightning hitting a WTG may lead to structural damage. Statistically, damages to the control system are the most common (51 % of the cases), while damages to the power system (to some degree including simple interruptions), generator and blades each account for about 10 % ⁴⁰ .	
	Offshore substation	Assuming that the design of the offshore substation follows national standards for prevention of lightning damage, no relevant implications are expected.	
	Offshore Export Cable	The Export Cable is equipped with surge arrestors which mitigates the impacts of lightning strikes.	
	Onshore Substation	Assuming that the design of the onshore substation follows national standards for prevention of lightning damage, no relevant implications are expected.	
	Onshore Export Cable	Given that the export cable is buried at a depth of minimum 1.9 m and insulated, no relevant implications are expected.	

³⁹ Wind Turbines and Lightning. Available at <https://www.nachi.org/wind-turbines-lightning.htm#:~:text=A%20lightning%20strike%20to%20an,the%20leading%20and%20trailing%20edges.>

⁴⁰ Sorensen, T., Jensen, F. V., Raben, N., Lykkegaard, J. and Saxov J, 2001. Lightning Protection for Offshore Wind Turbines. Available at: http://www.cired.net/publications/cired2001/4_14.pdf

	Baseline	RCP 8.5 – 2030	RCP 8.5 – 2050
Key Potential Impacts	Possibility of structural damage of WTG and consequent loss of power generation		
Implemented Mitigations	- Follow international standards when designing the WTG to withstand the effect of lightning - Follow national standards in order to prevent damage from lightning - Yearly inspections of lightning protection system to ensure system is operational. Repairs to be made as soon as possible when this is not functioning		

6 CONCLUSIONS

The Climate Change Risk Assessment consisted of a review of current and future physical hazards in the Project Area. The future projections were evaluated based on the RCP 8.5 over timelines of 2030 and 2050. The assessment identified potential high risk levels for flood, cyclone and hurricane, and extreme wind speed in baseline and both 2030 and 2050 scenarios.

A summary of the key potential impacts and proposed mitigations is provided in the below **Table 6.1**.

To reduce the risk from flooding, raising the level of the base of the structure as well as any outside equipment is recommended. Also, ensure that drainage system is designed with the possibility of flooding in consideration. For Onshore Cables, the watertight sealing type should be used.

To reduce the risk of cyclones and hurricane's impacts, the design of the Onshore Substation roof should take into consideration extreme winds speed and an appropriate drainage system to protect the Onshore Substation from intense precipitations during such events. In addition, appropriate SCADA system and controller should be installed, WTG and Onshore Substation should be inspected after any extreme weather event, weather forecast should be monitored during operation, and the foundation level of the Onshore Substation and outdoor equipment should be elevated to prevent flood damage to electrical components.

The maximum wind speed was classified as high, which might cause structural damage to WTGs and accidents to maintenance personnel. To minimize the risk of damage during extreme wind speed events, it is advised that the Turbine type be designed in accordance with international and local standard. Additionally, the Project developer should include restrictions for operating outdoors under high-speed wind conditions, including the requirement for offshore employees to utilize tethering and secure any exposed objects before leaving WTG.

Table 6.1 Summary of Risk Level and Proposed Mitigation Measures

Hazard		Baseline	RCP 8.5		Key Potential Impacts	Mitigation Measures	Residual Risk Level
			2030	2050			
Water Availability	Hazard Level	High	High	High	Minor impacts for the operation of the onshore substation.	Turn off water when not in use at the onshore substation to reduce water consumption for cooling and sanitary purposes.	Low
	Exposure x Vulnerab. Level	Low	Low	Low			
	Risk Level	Low	Low	Low			
Flood	Hazard Level	High	High	High	- Potential interruption of the operation of the onshore substation - Damage of infrastructure requiring replacement of onshore export cable sections or substation components	- Elevate foundation level of building and outdoor equipment. - Design the drainage system taking into consideration flood risk. - Use waterproof sealing type for onshore cable.	Low
	Exposure x Vulnerab. Level	High	High	High			
	Risk Level	High	High	High			
Landslides	Hazard Level	Low	Low	Low	Delay of logistic and maintenance operations	None required	Low
	Exposure x Vulnerab. Level	Low	Low	Low			

Hazard		Baseline	RCP 8.5		Key Potential Impacts	Mitigation Measures	Residual Risk Level
			2030	2050			
	Risk Level	Low	Low	Low			
Extreme Heat	Hazard Level	Medium	High	High	Heat stress or heat exhaustion for personnel operating in the onshore substation or performing maintenance work within the WTG hub	- Make appropriate considerations while designing the cooling and ventilation systems of the onshore substation and WTG hubs. - Assess risk and put in place mitigation measure if workers are to operate at temperatures higher than 32 °C during maintenance of WTG or operation of the onshore substation	Low
	Exposure x Vulnerab. Level	Medium	Medium	Medium			
	Risk Level	Medium	Medium	Medium			
Cyclone and Hurricane	Hazard Level	Medium	Medium	Medium	- Reduction of power generated. - Potential accidents to operation and maintenance personnel	- Appropriate SCADA system and controller - Inspection of WTG and Onshore Substation after any extreme weather event - Accurate weather forecast during operation.	Low
	Exposure x Vulnerab. Level	High	High	High			

Hazard		Baseline	RCP 8.5		Key Potential Impacts	Mitigation Measures	Residual Risk Level
			2030	2050			
	Risk Level	High	High	High		- Design of the onshore substation roof taking into consideration extreme winds speed - Elevate the foundation level of the onshore substation and outdoor equipment to prevent flood damage to electrical components. - Design appropriate drainage system to protect the onshore substation from intense precipitations during hurricanes and cyclones.	
Wind Speed	Hazard Level Average Wind Speed	Low	Low	Low	- Structural damage of WTG, and onshore substation - Reduction of power generated - Potential accidents to operation and maintenance personnel	- Turbine models designed in accordance with international and local standards - Appropriate SCADA system and controller - Inspection after any extreme weather event - Accurate weather forecast during operation and implement restrictions for work during high-	Low
	Hazard Level Maximum Wind Speed	High	High	High			
	Exposure x Vulnerability Level	High	High	High			

Hazard		Baseline	RCP 8.5		Key Potential Impacts	Mitigation Measures	Residual Risk Level
			2030	2050			
	Risk Level	High	High	High		speed wind conditions (e.g. no craning during wind speed greater than 15 m/s) - Prevent falling objects during high wind speeds by ensuring offshore workers use tethering and secure all open objects before leaving WTG (e.g. hatches) - Design the onshore substation layout to mitigate risk of falling objects in areas to be occupied by infrastructure or personnel - Design of the onshore substation roof taking into consideration extreme winds speed	
Sea Level Rise	Hazard Level	Not Applicable	Medium	Medium	Increased wearing of Onshore export cable	- Consider elevation of onshore export cable during detailed design of routing - Liaise with local authorities to guarantee appropriate maintenance of dikes	Low
	Exposure x Vulnerab. Level	Low	Low	Low			
	Risk Level	Low	Low	Low			

Hazard		Baseline	RCP 8.5		Key Potential Impacts	Mitigation Measures	Residual Risk Level
			2030	2050			
Lightning	Hazard Level	Low	Low	Low	Possibility of structural damage of WTG and consequent loss of power generation	- Follow international standards when designing the WTG to withstand the effect of lightning - Follow national standards in order to prevent damage from lightning - Yearly inspections of lightning protection system to ensure system is operational. Repairs to be made as soon as possible when this is not functioning	Low
	Exposure x Vulnerab Level	High	High	High			
	Risk Level	Medium	Medium	Medium			

APPENDIX A PROJECT DESCRIPTION



ESIA for Project Anma

Project Description

7 October 2024

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Signature Page

7 October 2024

ESIA for Project Anma

Project Description

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CONTENTS

1.	OVERVIEW.....	1
2.	PROJECT LOCATION	2
3.	PROJECT HISTORY	3
3.1	Key Milestones	3
3.2	Versions and Alterations	3
4.	PROJECT FACILITIES AND COMPONENTS	6
4.1	Wind Turbine Generator	6
4.2	Inter-array Cables (IAC) and Offshore Export Cables (EXC).....	8
4.3	Offshore Substation (OSS)	8
4.4	Onshore Export Cable	8
4.5	Onshore Substation (ONS)	9
4.6	Military Radar.....	9
4.7	Bird Monitoring Radar.....	9
4.8	Operation and Maintenance (O&M)	9
5.	SUMMARY ON CONSTRUCTION ACTIVITIES	10
5.1	Foundations (FOU)	10
5.1.1	Pin-pile	10
5.1.2	Jacket	10
5.2	Inter Array Cable.....	11
5.3	Offshore Export Cable	11
5.4	Offshore Substation	13
5.5	Onshore Substation (ONS) & Onshore Cable.....	13
5.6	WTG	14
5.7	Transition Joint Bay (TJB).....	14
5.8	Operation and Maintenance (O&M)	14
5.9	Military Radar.....	15
5.10	Bird Monitoring Radar.....	15
6.	EPC SCHEDULE.....	16

List of Tables

Table 2.1	Coordinate for the WTGs	2
Table 3.1	History of Project Components	4
Table 4.1	WTG details	7
Table 4.2	Offshore Substation Details	8

List of Figures

Figure 3.1	Location of Project Site	5
Figure 4.1	Conceptual Figure of the WTG	7
Figure 6.1	Anma Offshore Wind Power Project Master Plan	16

Acronyms and Abbreviations

AWC	Anma Offshore Wind Energy
AZE	Alliance for Zero Extinction
BAP	Biodiversity Action Plan
bgs	below ground surface
CCRA	Climate Change Risk Assessment
CHA	Critical Habitat Assessment
CPS	Cable Protection System
CRM	Collision Risk Modelling
EBL	Electric Business License
E&S	Environmental and Social
EAAF	East Asian–Australasian Flyway
EHS	Environmental, Health and Safety
EIA	Environmental Impact Assessment
EMS	Environmental Management System
EP	Equator Principles
EPAP	Equator Principles Action Plan
EPC	Engineering, Procurement and Construction
EPFI	Equator Principles Financial Institutions
ERM	ERM Korea Ltd.
EN	Endangered
ESAP	Environmental and Social Action Plan
ESDD	Environmental and Social Due Diligence
ESG	Environmental Social Governance
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental and Social Management Plan
ESMS	Environmental and Social Management System
ESS	Environmental and Social Standards
EXC	Export Cable
FA	Fisheries Act
FDA	Fishery Damage Assessment
FDIA	Fishery Damage Impact Assessment
FOU	Foundation
FTEs	Full Time Employees

GHG	Greenhouse Gas
GIPS	Geotechnical Information Portal System
GIS	Gas Insulated Switchgear
HDD	Horizontal Directional Drilling
H&S	Health and Safety
HR	Human Resources
IAC	Inter Array Cable
IBA	Important Bird Areas
IBAT	Integrated Biodiversity Assessment Tool
ID	Identity
IESC	Independent E&S Consultant
IFC	International Finance Corporation
IPA	Important Plant Areas
ISO	International Organisation for Standardisation
IUCN	International Union for Conservation of Nature
KBA	Key Biodiversity Area
KEPCO	Korea Electric Power Corporation
kV	kilovolt
LC	Least Concern
LIDAR	Laser Imaging, Detection And Ranging
LRP	Livelihood Restoration Plan
LURIS	Land Use Regulation Information Service
MEMA	Marine Environment Management Act
MoE	Ministry of Environment
NGIC	National Groundwater Information Center
NGO	Non-Governmental Organisation
OHS	Occupational, Health and Safety
ONS	Onshore Substation
OSS	Offshore Substation
OPPW	Occupancy Permit of Public Waters
PDCA	Plan-Do-Check-Act
PFDIA	Preliminary Fishery Damage Impact Assessment
PS	Performance Standard
PWMRA	Public Waters Management and Reclamation Act

Q	Quarter
RAP	Resettlement Action Plan
SEP	Stakeholder Engagement Plan
SGRE	Siemens Gamesa Renewable Energy
SOP	Standard Operating Procedure
TJB	Transition Joint Bay
TMS	Tele-Monitoring System
VU	Vulnerable
WBG	World Bank Group
WGS	World Geodetic System
WTG	Wind Turbine Generator
XLPE	Cross-linked polyethylene

1. OVERVIEW

The Project consists of two (2) phases - Phase 1 and Phase 2 - corresponding to Electricity Business Licences (EBL 1 and EBL 2). The Project will utilise Siemens Gamesa Renewable Energy's (SGRE) SG DD-236 14.0 MW wind turbine generators (hereinafter as "WTGs"). Phase 1 consists of 16 WTG units with a permitted total capacity of 224 MW and Phase 2 consists of 22 WTG units with a permitted total capacity of 308 MW. The Project's wind turbines area will take up a total area of 80 km² of public waters.

The WTGs will be connected via 66kV Inter-Array submarine cables (hereinafter as "IACs" - Phase 1: circa 51 km and Phase 2: circa 69 km) to the Offshore Substation (hereinafter as "OSS") (125°56'32.86"E, 35°19'44.00" N¹).

230kV export submarine cables (hereinafter as "EXCs") will then be routed to the Onshore Substation (hereinafter as "ONS"). And then, using 154kV onshore cables, electricity will be connected to the West Yeonggwang (or Seoyeonggwang) KEPCO onshore substation operated by KEPCO.

¹ WGS 84

2. PROJECT LOCATION

The area proposed for installation of the Project WTGs (the Site) is situated in the Yellow Sea (or West Sea) West of Anma Island, Yeonggwang-gun, Jeollanam-do, South Korea. The coordinates of the WTGs, as well as the Project location and its surrounding areas are presented in Table 2.1 and Figure 3.1 respectively.

Table 2.1 Coordinate for the WTGs

WTG ID for Phase 1	Coordinate (WGS 84)		WTG ID for Phase 2	Coordinate (WGS 84)	
	Longitude ±ddmmss.ss	Latitude ±ddmmss.ss		Longitude ±ddmmss.ss	Latitude ±ddmmss.ss
A01	125°50'4.5"	35°22'24.1"	C01	125°50'5.1"	35°19'2.58"
A02	125°50'39.6"	35°22'24.1"	C02	125°50'43.46"	35°19'2.59"
A03	125°51'14.7"	35°22'24.1"	C03	125°51'21.86"	35°19'2.63"
A04	125°51'49.7"	35°22'24.0"	C04	125°52'0.23"	35°19'2.63"
A05	125°52'24.8"	35°22'24.0"	C05	125°52'38.63"	35°19'2.65"
A06	125°52'59.9"	35°22'24.0"	C06	125°53'17.03"	35°19'2.68"
A07	125°53'34.9"	35°22'24.0"	C07	125°53'55.39"	35°19'2.7"
A08	125°54'10.0"	35°22'23.9"	C08	125°54'33.79"	35°19'2.72"
A09	125°54'45.1"	35°22'23.9"	C09	125°55'12.15"	35°19'2.73"
A10	125°55'20.1"	35°22'23.8"	C10	125°55'50.55"	35°19'2.75"
A11	125°55'55.2"	35°22'23.8"	C11	125°56'28.91"	35°19'2.79"
A12	125°56'30.3"	35°22'23.8"	D01	125°50'5.56"	35°17'8.65"
B01	125°50'5.4"	35°20'55.2"	D02	125°50'43.94"	35°17'8.59"
B02	125°52'13.8"	35°20'55.2"	D03	125°51'22.33"	35°17'8.56"
B03	125°54'22.3"	35°20'55.0"	D04	125°52'0.67"	35°17'8.53"
B04	125°56'30.7"	35°20'54.9"	D05	125°52'39.05"	35°17'8.49"
			D06	125°53'17.4"	35°17'8.46"
			D07	125°53'55.78"	35°17'8.41"
			D08	125°54'34.17"	35°17'8.4"
			D09	125°55'12.51"	35°17'8.35"
			D10	125°55'50.9"	35°17'8.33"
			D11	125°56'29.24"	35°17'8.27"
Offshore Substation	125°56'32.86"	35°19'44.00"			

Source: AWC dated 18 July 2023

3. PROJECT HISTORY

3.1 Key Milestones

The achieved milestones of the Project have been summarized below:

- October 2017: Installation of a wind condition measuring instrument (Hoeng-do onshore LiDAR) for preparation of electric business license (EBL) for Phase 1;
- April 2019: Acquired EBL for Phase 1;
- May 2019: Installation of wind condition gauge (offshore LiDAR) for preparation of EBL for Phase 2;
- July 2020: Acquired EBL Alteration for Phase 1, and acquired EBL for Phase 2;
- April 2022: Submission of draft Environmental Impact Assessment for Anma Project (hereinafter Draft Regulatory EIA);
- December 2022: Submission of Final Regulatory EIA (updated January 2023);
- June 2023: Submission of Supplementary Regulatory EIA;
- July 2023: Obtained EIA agreement;
- August 2023: Marine Traffic Safety Assessment approved.

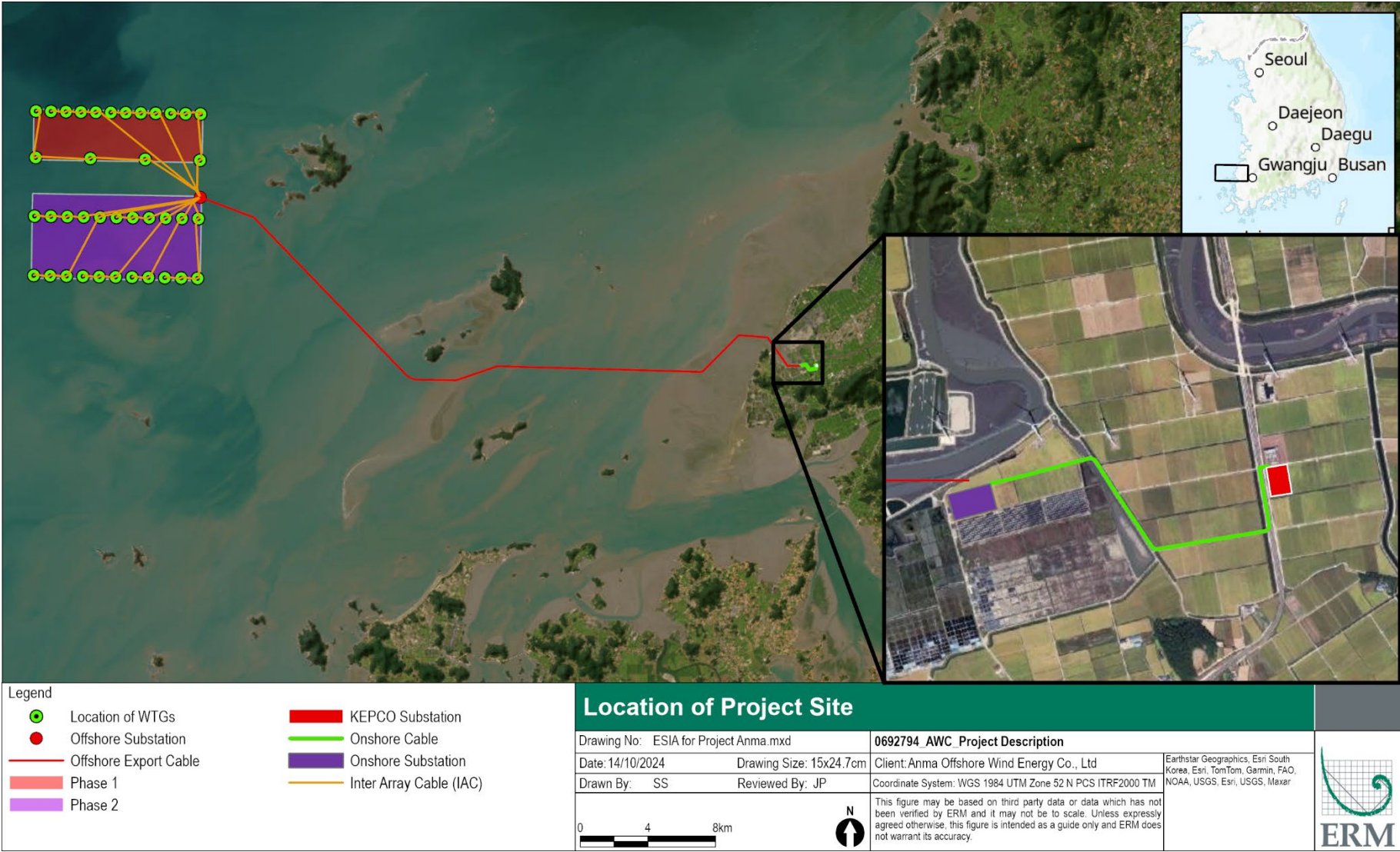
3.2 Versions and Alterations

- Version 1: Draft Regulatory EIA, dated April 2022;
- Version 2: Final Regulatory EIA, dated December 2022 and Supplementary Regulatory EIA, dated June 2023; and
- Version 3: As of August 2023, it is anticipated that the preferred components, layouts and selected construction methods that are incorporated into this ESIA will result in an update process in the EIA and all necessary permits (hereinafter Version 3 AWF).

Table 3.1 History of Project Components

	WTGs numbers & capacity	WTGs type	OSS location & type	IAC location & type	EXC location & type	ONS location & type	Onshore cable location & type	Other
Version 1	528 MW 66 WTGs- 8 MW	WinDS8000 Doosan	Juk-do onshore substation	66 kV Phase 1: 43.3 km (3 strands) Phase2: 57.8km (4 strands)	154kV XLPE 800 mm ² 3-core, (approx. 40.4km)	1508-1 Jisan-ri, Baeksu-eup, Yeonggwang-gun, Jeollanam-do	154kV XLPE 800 mm ² single core, 12 wires (about 7.6km)	Songji-do overhead line: approx. 1.5 km
Version 2	546 MW 39 WTGs- 14 MW	SG DD-236 SIEMENS Gamesa	Offshore substation 125°53'55.2"E 35°19'45.45"N	66 kV Phase 1: approx. 32.0 km Phase2: approx. 36.2 km	154kV XLPE 800 mm ² 3-cores, (approx. 44.9km)	286-3 Songam-ri, Yeomsan-myeon, Yeonggwang-gun, Jeollanam-do	154kV XLPE 2000 mm ² single core, (approx. 1.1km × 6 strands)	No overhead line
Version 3	532 MW 38 WTGs- 14 MW	No change	Offshore substation 125°56'32.86"E 35°19'44.00"N	66 kV Phase 1: approx. 51 km Phase 2: approx. 69 km	230kV XLPE 3-core Approx.41.6 km route length	No change	154kV XLPE single core Approx. 1.5 km route length	No change

Source: Draft Regulatory EIA /Final and Supplementary Regulatory EIA / Version 3 AWF



Note: Some final designs are still under validation process and thus will be updated in relevant documents later.

Source: Version 3 AWF

Figure 3.1 Location of Project Site

4. PROJECT FACILITIES AND COMPONENTS

The main Project components as per the Final Regulatory EIA is summarized below:

- A wind turbines area divided in 2 areas (i.e. Phase 1 and Phase 2), comprised of 38 WTGs with a permitted total capacity of 532 MW;
- 38 SGRE's SG DD-236 14.0 MW WTGs comprised of the tower, foundation, nacelle, hub, rotor, and rotor blades;
- circa 120 km of 66 kV Inter-Array Cables (total for both Phase 1 and Phase 2);
- One (1) Offshore Substation (converting 66 kV to 230 kV);
- Two circuits, each circa 42 km of 230kV offshore export cable (connecting from Offshore Substation to the mainland);
- A Transition Joint Bay at the landing point, receiving the 230kV offshore export cable;
- Two circuits, circa 150m each of 230kV onshore cable (connecting the Transition Joint Bay to the Onshore Substation);
- One (1) Onshore Substation (converting 230 kV to 154kV);
- Two circuits, each circa 1.5 km of 154 kV onshore cable (connecting from the Onshore Substation to the KEPCO substation being the grid connection point); and
- One (1) Korea Electric Power Corporation (KEPCO) substation (owned and operated by KEPCO).

For clarity:

One circuit of offshore export cable refers to one (1) cable, each with three (3) power conductors within the cable.

One circuit of onshore cable refers to three (3) cables, each with one (1) power conductor within the cable.

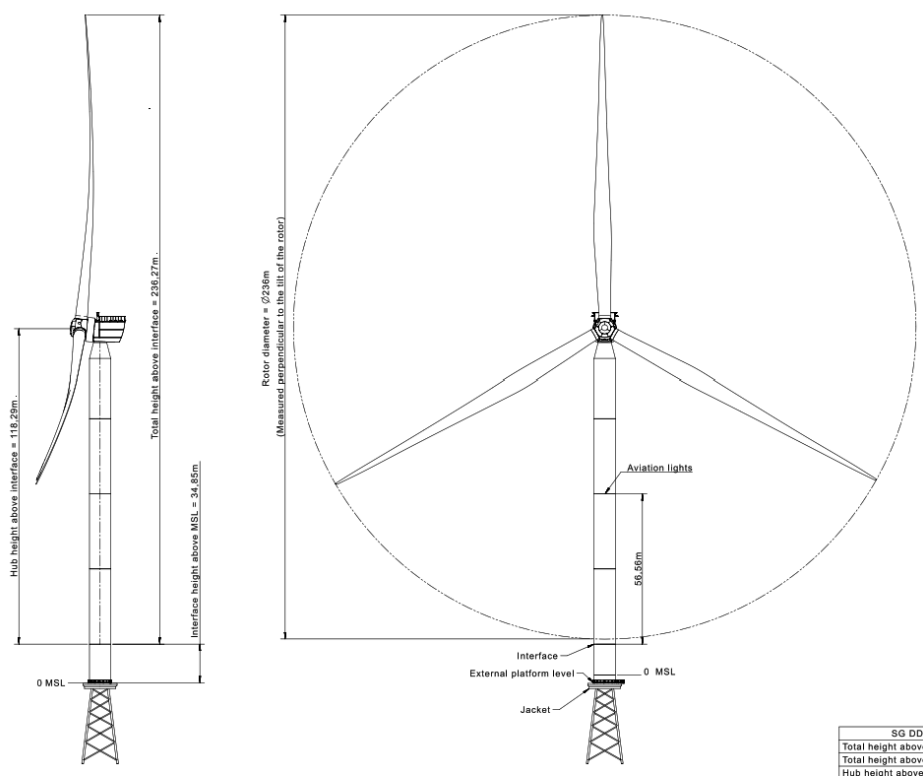
4.1 Wind Turbine Generator

The Version 3 configuration of wind turbines layout has been developed with 38 WTGs of 14 MW nominal capacity. Given the geographical context of the project site within the 'Northeast Asia-Oceania' Migratory Bird Flyway (EAAF) and its proximity to the breeding habitats of various marine bird species (such as Chilsan Island), a decision was made to curtail the number of WTGs and accordingly modify their arrangement. Elaborated information pertaining to the individual WTGs can be found in Table 4.1.

Table 4.1 WTG details

WTG Components	Parameter	Specifications
WTG	Type Class	SG DD-236
ROTOR	Type	3-bladed, horizontal axis
	Position	Upwind
	Diameter (m)	236
	Length of blade (m)	115
	Swept area (m ²)	43,500
TOWER	Type	Cylindrical and tapered tubular
	Hub height (m)	153
	Total height from Mean Sea Level (MSL) (m)	270
OPERATION DATA	Cut in Wind speed (m/s)	3
	Nominal Power (m/s)	at 12
	Cut out wind speed (m/s)	28

Source: Final and Supplementary Regulatory EIA / Version 3



Source: AWC dated 4 August 2023

Figure 4.1 Conceptual Figure of the WTG

4.2 Inter-array Cables (IAC) and Offshore Export Cables (EXC)

The Version 3 design entails all the IAC being concentrated to an Offshore Substation, and then, offshore export cables that directly connects with the mainland. The Version 3 plan is for all the inter array submarine cables to be 66 kV cross linked polyethylene cable (XLPE) submarine cable, the length of which is circa 51 km and 69 km for Phase 1 and Phase 2 respectively, and two (2) circuits of 230kV offshore export cables, each with a length of circa 42 km.

Detailed location of IAC and Offshore EXC are presented above in Figure 3.1.

The IACs will be installed to a target burial depth of between 3.0m to 3.5m, utilising a Jet Trencher for post lay burial operations.

The EXCs will be installed to a target burial depth of between 2.0m to 3.5m, depending on the water depth along the export cable route, where deeper water sections would have a deeper target burial depth. Burial operations for the EXCs will be performed by a Jetting Sled, through simultaneous lay and bury operations.

The EXC will be installed at landfall within a Horizontal Directional Drill (HDD) duct, approximately 120m in length under the sea. Upon exiting the HDD, the EXC will be held in situ via permanent beach clamps which horizontally hang off the cable and permanently secure them in position. The EXC will be terminated externally into a GIS arrangement as fitted to the ONS within a joint bay with land cable connections into the ONS GIS Building alternatively they will be pulled and terminated directly into the ONS GIS.

4.3 Offshore Substation (OSS)

An offshore substation is selected instead of installing it in Juk-do as the final design to avoid civil complaints and to reduce the overall impact to the environmental damage and the fisheries. Compared to the onshore substation, the offshore option will involve fewer external cables, resulting in relatively less environmental and fishing impacts. The opinions on the review of the offshore substation design were collected during the information session for residents as part of Draft Regulatory EIA and are documented therein. Insights and viewpoints concerning the assessment of the offshore substation design were obtained during a resident information session, a pivotal aspect of the Draft Regulatory EIA.

Currently the Offshore Substation is planned to transform the 66kV transmission voltage from the wind turbines into 230kV export transmission voltage. Table 4.2 shows the detail specification and location of OSS.

Detailed location of OSS is presented above in Figure 3.1.

Table 4.2 Offshore Substation Details

Parameter	Specification
Size	Topside: 32 m (Width) x 37 m (Depth) x 30 m (Height) Jacket: 23 m (Bottom Width) x 19 m (Top Width) x 55 m (Height) Pile: 73 m (Depth) x 12 EA
Location	125°56'32.86" E, 35°19'44.00" N

Source: Final Regulatory EIA / Version 3

4.4 Onshore Export Cable

The current landfall is in Yeomsan-myeon, Yeongwang-gun, Jeollanam-do. AWC plans to construct a 154 kV buried onshore cable route from their Onshore Substation to KEPCO onshore substation (West Yeonggwang KEPCO onshore substation). Most of the onshore underground cable route is expected

to be routed along existing roads, or then through rice paddies having been acquired and close other renewable power plants.

4.5 Onshore Substation (ONS)

The power that is generated (690 V) by the WTG will be boosted by the primary boosting transformer (690 V/66 kV) and then transmitted by the IAC (66 kV) to the Offshore Substation. The power will then be directed to the secondary step-up transformer (66 kV/154 kV) at the Offshore Substation, which will be connected to the grid connection point; Seoyeonggwang substation operated by KEPCO.

The AWC Onshore Substation will be in 286-3 Songam-ri, Yeomsan-myeon, Yeonggwang-gun, Jeollanam-do. The area is planned to be 1,550.41 m². The station will consist of three (3) buildings which include a substation, an office, and a warehouse. The office will consist of a three-story building, while the substation and warehouse will consist of one-story building each.

Figure 3.1 above shows the detail location of project site for onshore area.

4.6 Military Radar

The Project will install two radars structures upon request of Ministry of Army to compensate the obstruction generated by the WTGs once installed. The details and the localizations of the two structures shall be kept confidential due to the nature of the facilities. One radar shall be operating offshore and one radar shall be operating onshore.

The offshore radar will comprise a foundation and a top-side structure. The foundation type is yet to be determined and the dimensions of the top-side structure is expected to be no greater than 10mx10mx7.5. The construction is expected to start no earlier than Q1 2026. A maximum of 20 staff is estimated at peak time of installation phase and operation shall be unmanned.

The onshore radar will be installed on Imja island in Sinan province. The structure is estimated to comprise a steel tower measuring 5x5x10 meters. The construction is expected to earlier than May 2025 and the duration of the construction shall not exceed 6 months. A maximum of 7 persons shall be estimated during civil works and a maximum of 4 persons during steel tower installation. Operation phase planned to be unmanned.

4.7 Bird Monitoring Radar

As stipulated in the Final Regulatory EIA, a bird monitoring radar is scheduled to be established on Hoeng-do for a duration of one (1) year. The installation of the 2D Terma Scanner-5000 Radar is anticipated. The cabinet housing the monitoring system is approximately 3 meters in height, 3 meters in depth, and 3 meters in width. The antenna's height is estimated to be around 5.5 meters.

The exact placement and specifications of the monitoring equipment are currently pending finalization. Comprehensive details concerning this aspect will be provided at a later stage once they are confirmed.

4.8 Operation and Maintenance (O&M)

The project encompasses two distinct O&M harbour alternatives. One existing facility and one other location are matching the requirements for O&M harbour, however, the location of the O&M harbour is not available before lease contract execution due to high competition risk.

5. SUMMARY ON CONSTRUCTION ACTIVITIES

The purpose of this section is to provide a comprehensive overview of the high-level description of the EPC Package components and the EPC Schedule for the Project.

The EPC Package consists of various components essential for the successful execution of the Project. These components are designed to ensure optimal efficiency and adherence to project requirements. The detailed breakdown of each component, along with its specific role in the Project, is outlined below.

5.1 Foundations (FOU)

5.1.1 Pin-pile

The supplier responsible for the pin-pile has not been determined. The piling process involves several essential steps, including fabrication, transportation, and pile driving. The detailed description of each process involved in the piling work is outlined below:

1. Fabrication of piles;
2. Load out of piles onto vessel or barge;
3. Transport to offshore site; (In parallel prepare noise mitigation measures if required)
4. Upending of piles by installation vessel;
5. Lower piles to ground and wait until self-penetration is reached;
6. Lower hammer on top of pile;
7. Start pile driving activities until target depth is reached; and
8. Once done, lift hammer back to installation vessel, move to next location

Their primary activities are scheduled to commence in the third quarter of 2024, with the peak of their operations anticipated in the second quarter of 2025. At its peak, the estimated number of staff required will be approximately 200, and this period is expected to last for approximately 10 weeks. It is projected that around 10% of the workforce will consist of foreign workers, and the planned worker's accommodation is estimated to accommodate around 100 individuals.

5.1.2 Jacket

Jacket will be installed on the pin-pile after completion of pin-pile installation. The supplier responsible for the fabrication and installation of the windfarm jacket has not been finalized. The installation process of the windfarm jacket can be described as follows:

1. Fabrication of jacket;
2. Load out of Jacket onto vessel or barge;
3. Transport to offshore site lift jacket from barge and insert into pre-installed pin piles;
4. Start grouting to finalize connection between jacket and grout; and
5. Move to next location

The main activities of the Project are scheduled to commence in the fourth quarter of 2024, with the peak of their activities anticipated in the first quarter of 2026. During this peak period, it is estimated that approximately 200 staff members will be involved, and the activity is expected to last for approximately 10 weeks. It is anticipated that around 10% of the workers will be foreign workers.

5.2 Inter Array Cable

Installation of Inter Array Cable (IAC) will commence after completion of jacket installation. The contractor responsible for the installation of IAC has not been finalized. The main activity for the IAC installation is scheduled to begin by mid 2026. The IAC installation will involve the following key activities.

■ Site Preparation

1. Preparation of equipment for pull-in at the WTG foundation / OSS Jacket;
2. Pre-lay grapnel run on the seabed following the cable route; and
3. Pre-lay survey.

■ Installation

1. Mobilization of installation vessels and crew accommodations;
2. Cable loading from factory onto the installation vessel;
3. Removal of J-tube covers;
4. Cable pull-in (1st Cable End) including Cable Protection System (CPS) installation;
5. Cable surface laying;
6. Cable pull-in (2nd Cable end) including CPS installation;
7. Post lay survey;
8. Post lay burial, with jet trencher;
9. Post lay burial survey;
10. Remedial burial (if necessary only) with a jet trencher;
11. Remedial burial survey; and
12. Installation of rock bags on CPS at the WTG/ OSS (if necessary only).

During the peak period of their activities, which is expected to span from March 2026 to January 2027, the IAC installation team will consist of an estimated total of 100 - 160 staff members. These staff members will be further divided into two main groups. The first group, known as the Office Support / Management Teams, will comprise approximately 20 - 60 staff members. They will be responsible for providing support and managing various aspects of the IAC installation project. For their convenience, these team members will be accommodated in either major cities or locations near / around the port area depending on their function and role.

The second group is the Transport and Installation Vessel Crew, which will consist of approximately 80 - 100 staff members. This group will play a direct and hands-on role in the actual installation of the IAC. During their construction activities at sea, they will be accommodated either on the cable laying vessel (CLV) and a Service Operations Vessel (SOV).

Throughout the peak period, AWC expects that 10 - 30% of the workers in both groups may be foreigners. As the Project progresses and specific roles and requirements become clearer, further details regarding staffing and accommodation arrangements will be finalized and communicated accordingly.

5.3 Offshore Export Cable

Export Cable installation will occur almost in parallel to IAC installation. The contractor responsible for the installation of the offshore export cable has not been determined yet. The preparation of the offshore export cable route (such as HDD and TJB construction) is scheduled to begin in October

2024, with the actual cable installation set to commence in February 2026. The process of offshore export cable installation is described below:

■ Site Preparation

1. Construction of HDD;
2. Set up of silt curtains at excavation sites;
3. Excavation of Shore end landing approach;
4. Set up of pre-excavated trench wall stabilisation measures;
5. Set up of cable rollers in the pre-excavated trench;
6. Preparation of equipment for pull-in at the OSS Jacket and at the TJB area at the ONS;
7. Pre-lay grapnel run on the seabed following the cable route; and
8. Pre-lay survey.

■ Installation

1. Mobilization of installation vessels with cable storage and cable handling equipment;
2. Laying of cable section 1 of 2, on Circuit 1
 - a. Cable loading from factory onto the installation vessel;
 - b. Transit of the installation vessel from the factory to the near shore section near the mainland;
 - c. Cable shore end landing / beach pull-in (1st Cable End);
 - d. Backfilling of pre-excavated trenches of Circuit 1
 - e. Simultaneous lay and bury of the cable with a jetting sled towards the OSS;
 - f. Lay down of cable end at the middle of the route (near Gagi Island);
 - g. Return to the submarine cable factory;
3. Laying of cable section 1 of 2, on Circuit 2
 - a. Cable loading from factory onto the installation vessel;
 - b. Transit of the installation vessel from the factory to the near shore section near the mainland;
 - c. Cable shore end landing / beach pull-in (1st Cable End);
 - d. Backfilling of pre-excavated trenches of Circuit 2;
 - e. Simultaneous lay and bury of the cable with a jetting sled towards the OSS;
 - f. Lay down of cable end at the middle of the route (near Gagi Island);
 - g. Return to the submarine cable factory;
4. Laying of cable section 2 of 2, on Circuit 1
 - a. Cable loading from factory onto the installation vessel;
 - b. Transit of the installation vessel from the factory to the OSS;
 - c. Cable pull-in (1st Cable End) at the OSS;
 - d. Simultaneous lay and bury of the cable with a jetting sled towards the middle of the route;
 - e. Lay down of cable end at the middle of the route (near Gagi Island);
5. Laying of cable section 2 of 2, on Circuit 2
 - a. Cable loading from factory onto the installation vessel;

- b. Transit of the installation vessel from the factory to the OSS;
- c. Cable pull-in (1st Cable End) at the OSS;
- d. Simultaneous lay and bury of the cable with a jetting sled towards the middle of the route;
- e. Lay down of cable end at the middle of the route (near Gagi Island);
6. Cable joint assembly, deployment and protection of both Circuits 1 and 2 offshore joints;
7. Post installation survey;
8. Remedial burial (if necessary only) with a jet trencher; and
9. Installation of rock bags on CPS at the OSS (if necessary only).

During the peak of construction activities, expected to span from March to November 2026, approximately 170 to 260 staff will be involved in the installation process. These personnel will be divided into two main groups: the Office Support / Management Teams and the Transport and Installation Vessel Crew.

The Office Support / Management Teams, comprising about 20 to 60 staff, will be accommodated either in major cities or near / around the port depending on their function and role. Their primary responsibilities will be overseeing and managing various aspects of the installation, ensuring efficient coordination, and addressing any operational challenges.

On the other hand, the larger portion of the workforce, consisting of approximately 150 to 200 staff, will be the Transport and Installation Vessel Crew. These workers will be accommodated onboard the vessels (Cable Laying Barge, Support Barges, Jointing Jack Up Barge, etc.) during their activities.

5.4 Offshore Substation

The supplier responsible for the installation of offshore substation has not yet been determined. Installation of pin-pile and jacket will commence by end of 2026, and topside installation will follow. The process of offshore substation installation is described below:

1. Fabrication of substation components from outside of Korea (Singapore, Indonesia, or India);
2. Transportation of the assets (jacket, pin piles and topside) to site; and
3. Jacket installation, piling, topside installation and commissioning.

Estimated number of staff during installation and commissioning of Offshore Substation is approximately 12 – 24, 20% of whom are expected to be South Korean nationals, with the remainder foreign passport holders. Peak of their activities is expected to be December 2025 and January 2026 then September and October 2026. And all staff will be accommodating in vessel during their activities.

5.5 Onshore Substation (ONS) & Onshore Cable

The supplier responsible for the installation of onshore substation and Onshore Cable has not yet been determined. Their main construction activities will commence November 2024. The process of Onshore Substation and Export Cable installation are described below:

1. Installation of Onshore Cable between TJB and Onshore Substation;
2. Transmission cable installation between ONS - KEPCO substation;
3. Civil work: piling, foundation etc;
4. Electrical work: mesh grounding;
5. ONS building construction;
6. Electrical system installation;

7. Commissioning; and
8. KEPCO inspection.

The peak of construction activities is expected to be Q1 (construction) and Q3 (installation of electrical system) 2026 with each peak period expected to be 10 weeks respectively. Estimated number of staff during the peak will be approximately 70 - 100 (including vessel crew) who will be accommodated in Yeonggwang or Gwangju during their activities.

5.6 WTG

Siemens Gamesa Renewable Energy has been appointed as the WTG supplier for the Project. Their main construction activities are scheduled to commence around January 2027. The assembly and installation process of WTG are described below:

1. Transport of WTG components to the pre-assembly harbour;
2. Pre-assembly works (e.g. assembly of tower sections final preparation of blades and nacelles);
3. Transport of pre-assembled main components to the offshore windfarm;
4. WTG installation;
5. WTG commissioning and testing; and
6. Hand over to the Operations and Maintenance.

During the peak period of their activities, which is expected to span from Q2 to Q3 2027 (approximately 16 - 25 weeks), Siemens Gamesa Renewable Energy will conduct commissioning and installation processes concurrently. The estimated number of staff during this phase will be around 150 - 170 personnel, which includes the vessel crew. These staff members, predominantly foreigners, will be lodged in general accommodation such as hotels and motels in Mokpo, Gwangju, and the vessels while carrying out their tasks.

5.7 Transition Joint Bay (TJB)

However, it is planned that the transition joint bay installation will be incorporated as part of the Offshore Export Cable installation. The process of transition joint bay installation is described below:

1. Set up access roads, site fencing, site offices, etc;
2. HDD;
3. Excavate TJB Location;
4. Construction of TJB;
5. Install accessories and appliances inside the TJB;
6. Backfill of surrounding location; and
7. Reinstatement of condition (i.e. removal of fencing, site offices, access roads etc.).

During the peak of construction activities, which is expected to last approximately eight (8) weeks, the estimated number of staff will be around 15 to 30 individuals. Most of these staff members are expected to be South Korean nationals. To support their activities, suitable accommodations will be provided in either Yeonggwang or Gwangju.

5.8 Operation and Maintenance (O&M)

For the O&M, there might be modification work to the expected site. The following modification would be anticipated:

Onshore

1. Ground clearing and excavation works;
2. Laying of reinforced concrete (specifically for the warehouse and parking area);
3. Office building and warehouse construction (as per above dimensions);
4. Installation of water, electrical and sewage connectivity, depending on existing infrastructure; and
5. Car parking gravel and road gravel (depending on existing infrastructure).

Offshore

1. Development and re-paving of the existing quayside, including potential excavation and laying of reinforced concrete;
2. Marine dredging and construction of pontoons;
3. Installation of quayside crane;
4. Installation of water, electrical and sewage connectivity, depending on existing infrastructure; and
5. Car parking gravel and road gravel (depending on existing infrastructure).

5.9 Military Radar

The onshore radar tower is expected to have a height of approximately 14 meters and an area of 47.0 m². However, due to the confidentiality of military radar operations, specific details regarding the location and specifications will be updated at a later stage once they are finalized.

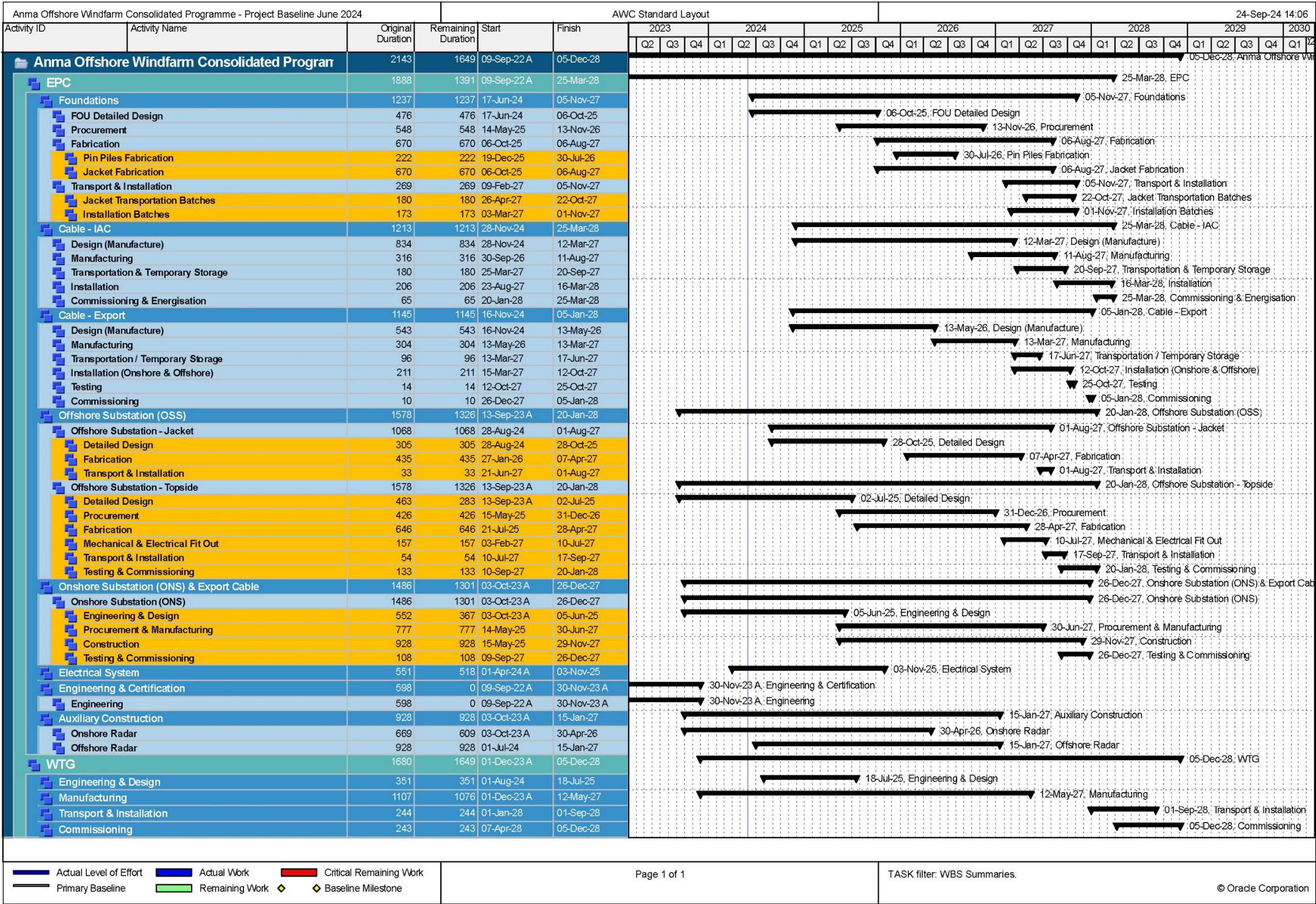
5.10 Bird Monitoring Radar

The installation of the 2D Terma Scanner-5000 Radar is anticipated. The cabinet housing the monitoring system is approximately and maximum 3 meters in height, 3 meters in depth, and 3 meters in width. The antenna's height is estimated to be around 5.5 meters.

The exact placement and specifications of the monitoring equipment are currently pending finalization. Comprehensive details concerning this aspect will be provided at a later stage once they are confirmed.

6. EPC SCHEDULE

Figure 6.1 shows the general EPC schedule planned. The EPC Schedule is a vital component of the Project plan, serving as a comprehensive roadmap that outlines the timeline and sequence of activities for the successful execution of the Project.



Reference: AWC - High Level Execution Schedule (August 2024)

Figure 6.1 Anma Offshore Wind Power Project Master Plan

APPENDIX B GREENHOUSE GAS EMISSIONS DURING THE CONSTRUCTION PHASE

Predicted Items

During construction, the main focus is on the greenhouse gas emissions expressed in terms of carbon dioxide equivalents (tCO₂ eq). These emissions arise from the use of fossil fuels and materials for the operation of construction equipment. For materials, greenhouse gas emissions are estimated based on the unit emission factor per quantity used.

Scope of Prediction

The greenhouse gas emission activities during the construction phase include the use of equipment and materials. Therefore, the spatial scope is limited to the construction site where the equipment and materials are used. Transportation from suppliers to the site is not included in the calculations.

Predicted Results

The fuel consumption for the equipment during construction is estimated based on the hourly fuel consumption. The estimated daily fuel consumption is as follows:

- Offshore equipment: 12,097.6 liters/day
- Onshore equipment: 614.6 liters/day

The following table presents the fuel usage for each piece of equipment during construction.

A 1 Equipment and Fuel Usage During Construction

Category	Name of Equipment		Capacity	Fuel Usage (l/hr)	Number of Units	Fuel Usage (l/day)
Offshore	Wind Turbine Area / OSS	Crane Ship	150ton	108.3	1	866.4
		Vessels	1,790kW	349.2	2	5,587.20
		Subtotal			3	6,453.60
	Export Cable	Mooring Ship	37.3kW	7.1	1	56.8
		Tugboat	1,790kW	349.2	2	5,587.20
		Subtotal			3	5,644.0
	Total				6	12,097.60
Onshore	Export Cable	Excavator	0.7m3	11.6	1	92.8
		Roller	1.0ton	2.5	1	20
		Subtotal			2	112.8
	Onshore Substation, Monitoring House	Excavator	0.7m3	11.6	1	92.8
		Loader	1.0ton	2.5	1	20
		Dump Truck	15.0ton	15.9	1	127.2
		Loader	3.5m3	19.9	1	159.2
		Grader	3.6m	16.2	1	129.6
		Subtotal			5	528.8
	Total				7	614.6

Note: An 8-hour workday is assumed for all equipment.

The GHG emissions from construction equipment are calculated based on the fuel usage and the application of global warming potentials (GWP) for each gas. The total emissions are estimated to be 10,088.84 tCO₂ eq.

Calculation Formulas for Fuel Usage and GHG Emissions

The following formulas are used to calculate the GHG emissions:

1. Calculation of Emissions (kg/day):

The emissions are calculated using the fuel consumption (ℓ/day), the emission factor (kg/TJ), and the net calorific value of the fuel (MJ/ℓ).

$$\text{Emissions (kg/day)} = \frac{\text{Fuel Usage (ℓ/day)} \times \text{Emission Factor (kg/TJ)} \times \text{Net Calorific Value (MJ/ℓ)}}{1,000,000}$$

Where:

- **Fuel Usage (ℓ/day):** The amount of fuel consumed by the equipment per day.
- **Emission Factor (kg/TJ):** The emission factor for each GHG (CO₂, CH₄, N₂O) in kg per terajoule (TJ) of energy.
- **Operational Hours per Day:** The number of hours the equipment operates per day (assumed to be 8 hours).
- **1,000,000:** Conversion factor from kg to metric tons.

2. Calculation of Total Emissions (tCO₂ eq):

The total emissions are calculated by converting CO₂ emissions into CO₂ equivalent using the global warming potential (GWP) of each gas.

$$\text{Total Emissions (tCO}_2 \text{ eq)} = \frac{\text{Emissions (kg/day)} \times \text{Global Warming Potential (GWP)}}{1,000}$$

Where:

- **Operational Hours per Day:** The number of hours the equipment operates per day (assumed to be 8 hours).
- **Global Warming Potential (GWP):** The global warming potential for each gas (CO₂ = 1, CH₄ = 21, N₂O = 310).

A 2 Greenhouse Gas Emissions from Fuel Usage During Construction

Category		Fuel Usage (ℓ/day)	Net Calorific Value (MJ/ℓ)	Emission Factor (kg/TJ)	Global Warming Potential	Emissions (kg/day)	Total Emissions (tCO ₂ eq)
Wind Turbine Area	CO ₂	6,453.60	35.3	74,100	1	16,880.88	5,064.26
	CH ₄			3	21	14.35	4.31
	N ₂ O			2	310	141.24	42.37
	Total					17,036.47	5,110.94

Offshore Export Cable	CO ₂	5,644.00	35.3	74,100	1	14,763.18	4,428.95
	CH ₄			3	21	12.55	3.77
	N ₂ O			2	310	123.52	37.06
	Total					14,899.25	4,469.78
Onshore Export Cable	CO ₂	112.8	35.3	74,100	1	295.05	88.52
	CH ₄			3	21	0.25	0.08
	N ₂ O			2	310	2.47	0.74
	Total					297.77	89.34
Onshore Substation, Monitoring House	CO ₂	528.8	35.3	74,100	1	1,383.20	414.96
	CH ₄			3	21	1.18	0.35
	N ₂ O			2	310	11.57	3.47
	Total					1,395.95	418.78
Total						33,629.44	10,088.84

Note: An 8-hour workday is assumed for all equipment.

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