Geothermal Power Plant Project Ijen Bondowoso

Climate Change Risk Assessment

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Geothermal Power Plant Project Ijen Bondowoso

Climate Change Risk Assessment

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1. INTRODUCTION

Climate change is now widely and globally recognised as one of the most significant environmental challenges. In terms of response and adaption 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.

A Climate Change Risk Assessment is performed for the 110 MW (2 x 55 MW) geothermal project ("the Project") located at Blawan Ijen, Bondowoso East Java (the "Site") by MEDCO CAHAYA GEOTHERMAL ("MCG") which is a subsidiary of Medco Power Indonesia.

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 Assessment[2], for all projects, in all locations, when combined Scope 1 and Scope 2 emissions are expected to be more than 100,000 tonnes of CO_2 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".

It is not expected that the Project will emit more than 100,000 tonnes of CO_2 equivalent annually and, therefore, the Project Proponent is not obliged to assess the Transition Risk analysis.

[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.

2. 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 location. The natural hazard is 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, and precipitation. The climate change projections data involved multi-model mean climate change projections published under Coupled Model Intercomparison Project 6 (CMIP-6)[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.

- Step 3: Qualitative Estimation of Future Hazards and Physical Risks

The third step involved use of the future projections on natural hazard 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 hazard in cases where future hazard risk was not readily available.

It should be noted that this is a high-level review of publicly available information, and no detailed site-specific analysis or modelling has been undertaken. Hence, further investigation may be warranted to quantify the risks in more detail for consideration of adaptation measures.

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.

[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 analyze GCMs in a systematic fashion, a process which serves to facilitate model improvement.

3. PHYSICAL RISK ASSESSMENT

3.1 Water Availability

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 Table 3.1.

Table 3.1 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 value indicates 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.

3.1.1 Baseline Risk

3.1.1.1 Water Stress

The baseline water stress map is presented in **Error! Reference source not found.** and it shows that the distribution of water stress in the Project area is "Low-Medium". Therefore, the baseline hazard due to water stress is categorised to be **"Low"**.

3.1.1.2 Seasonal Variability

Seasonal Variability map presented in

Figure **3-2** 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. Hence, the baseline hazard due to seasonal variability is categorised to be **“Medium”**.

3.1.1.3 Inter-Annual Variability

Inter-Annual Variability map presented in

Figure **3-3** indicates the variations in water availability over different years is “Low-Medium”. Hence, the baseline hazard due to inter-annual variability is categorised to be **“Medium”**.

Accordingly, based on the evaluation of baseline water stress, seasonal variability, and inter-annual variability the hazard due to availability of water is considered to be **“Medium”**.

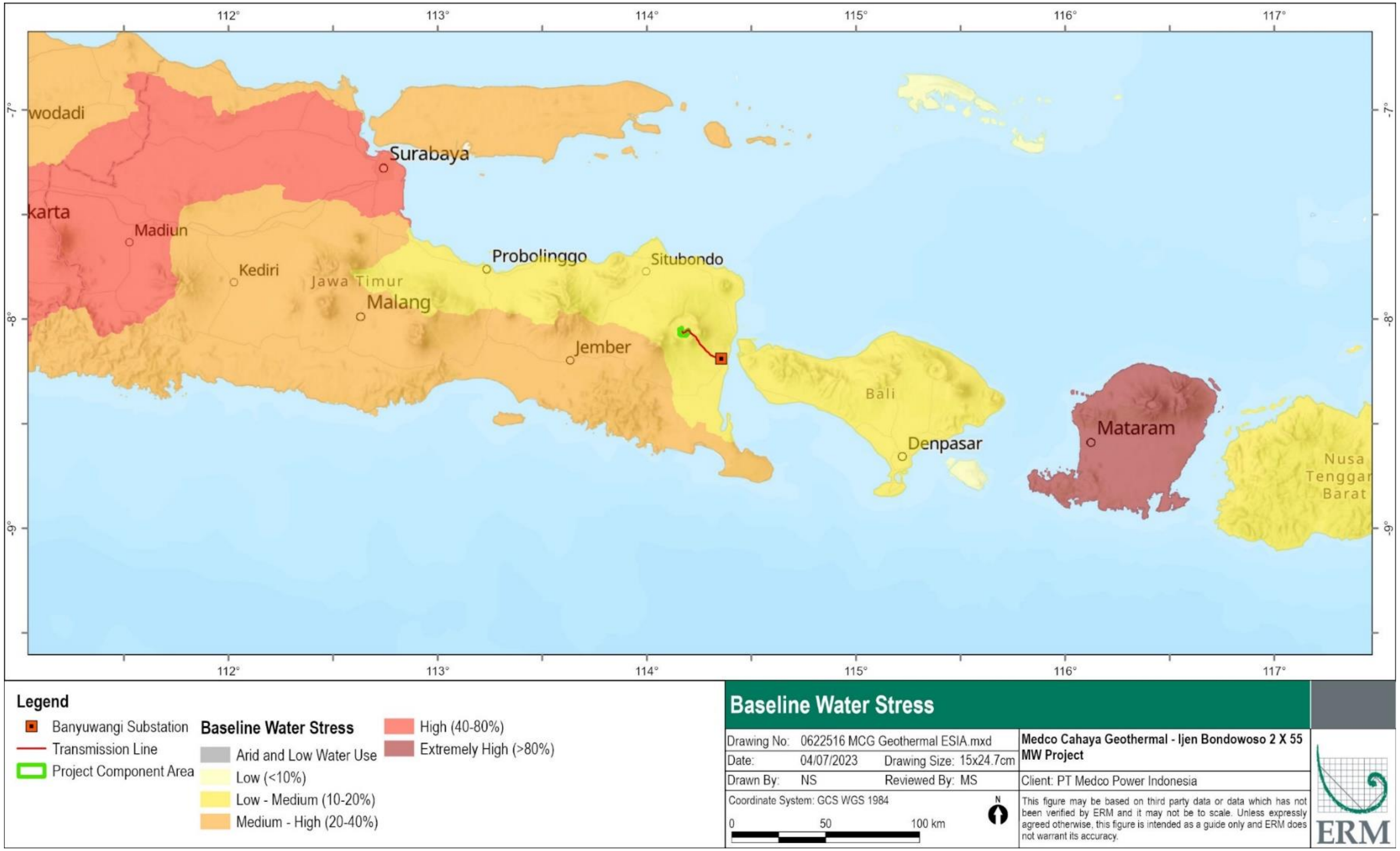

Figure 3-1 Baseline Water Stress

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

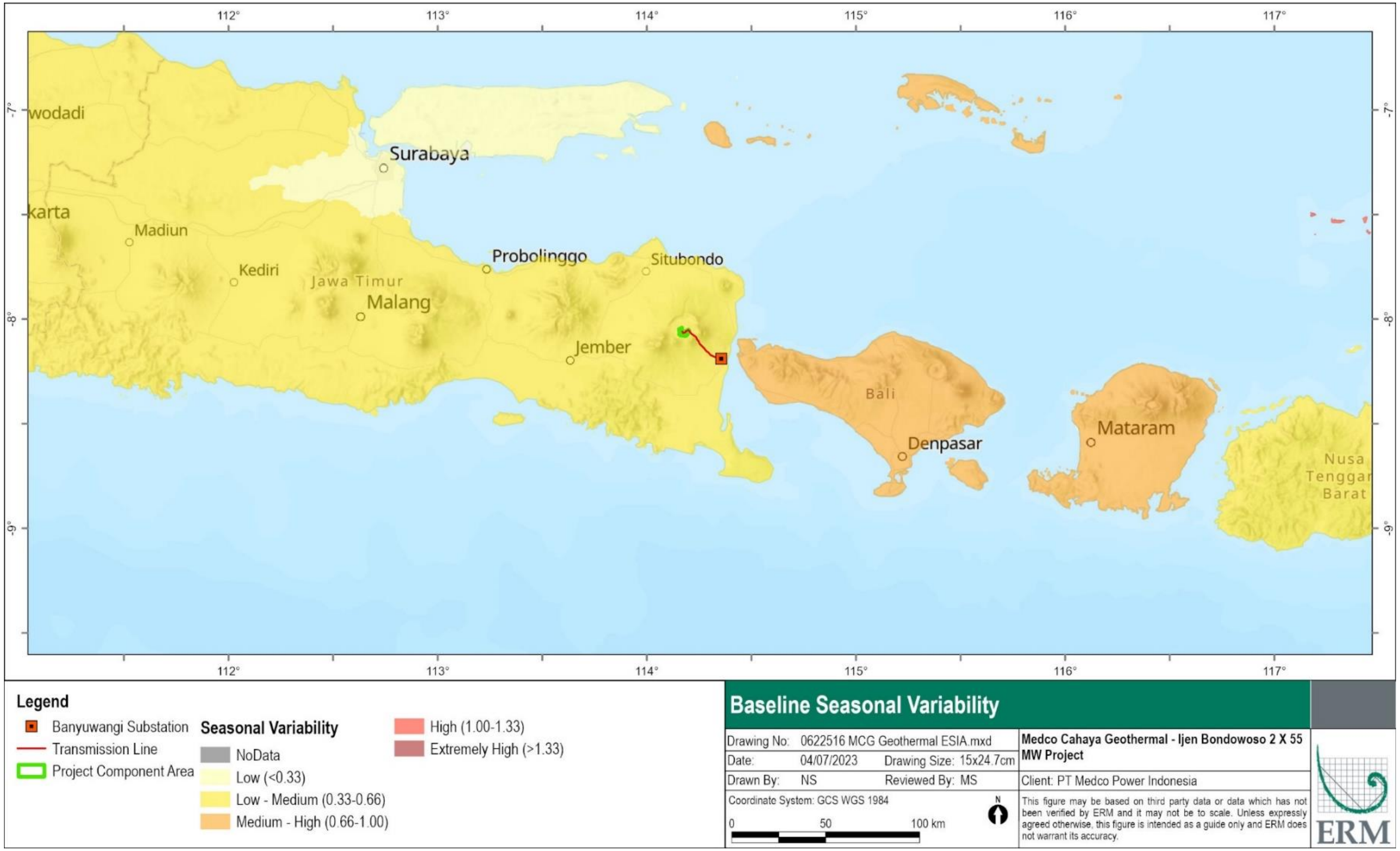

Figure 3-2 Baseline Seasonal Variability

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

Figure 3-3 Baseline Inter-Annual Variability

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

3.1.2 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.

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 2040) as presented in

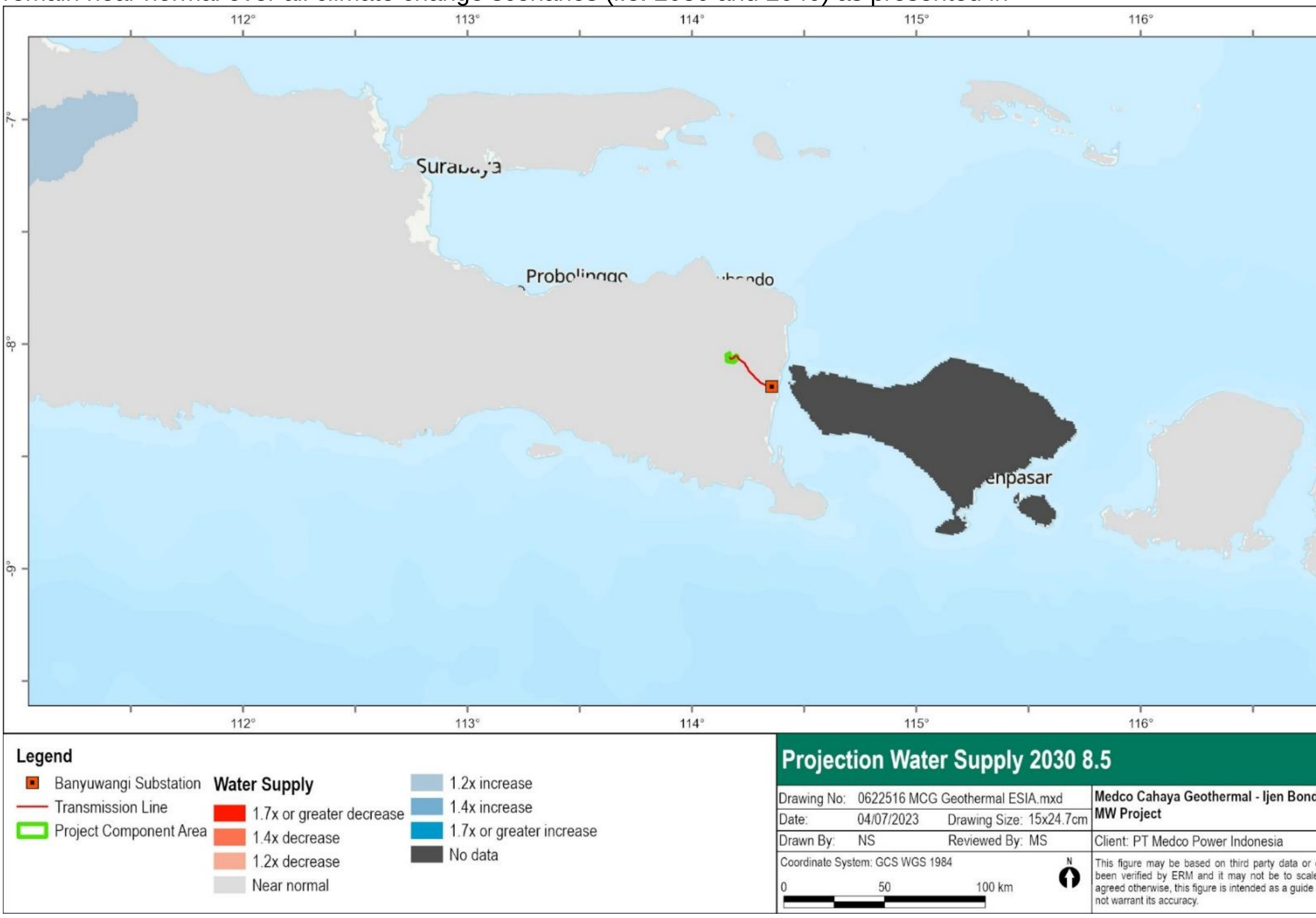

Figure **3-8** and

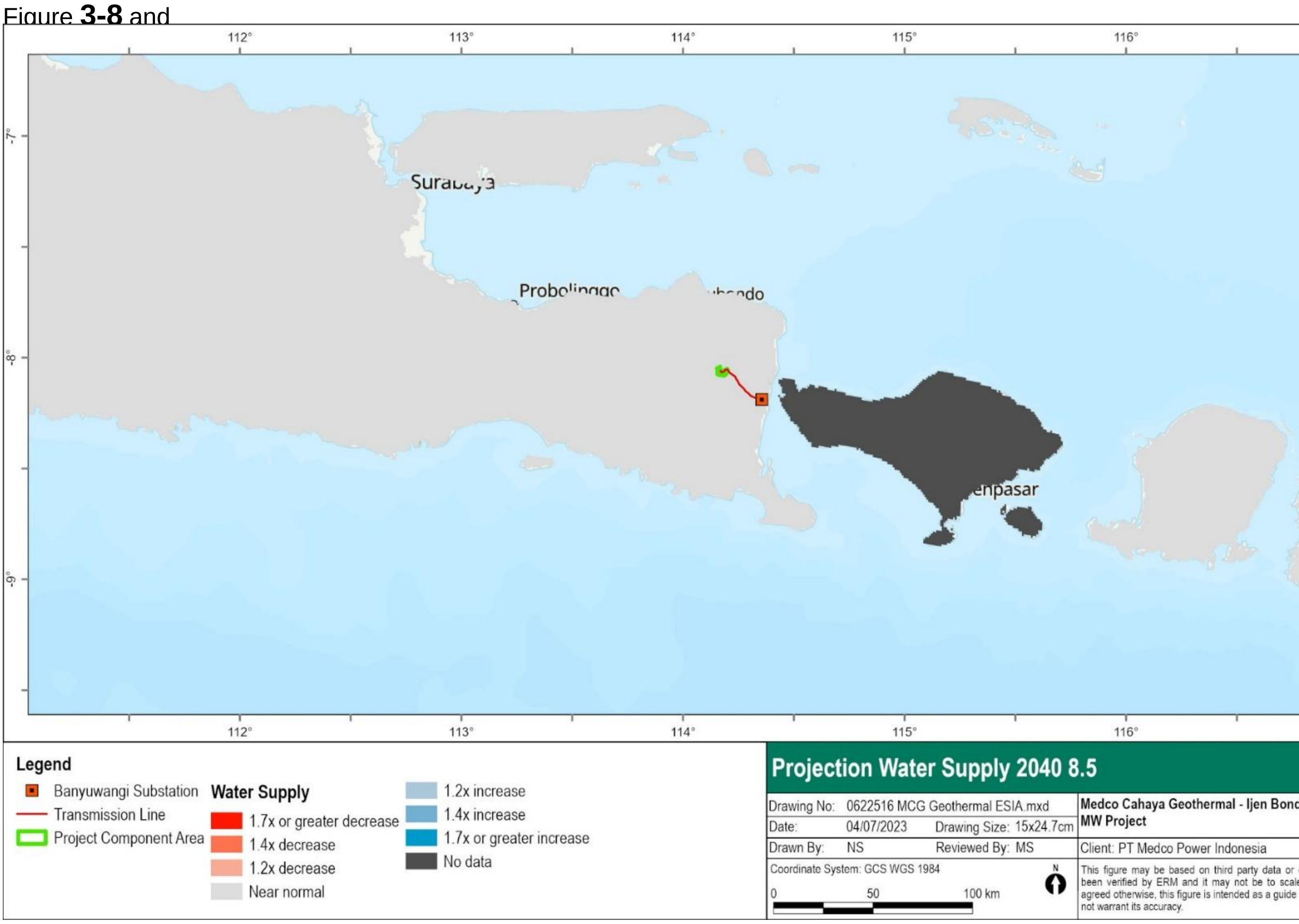

Figure **3-9**.

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, which is abundant.

Further, water stress is projected to be “Extremely High” under all climate change scenarios as presented in

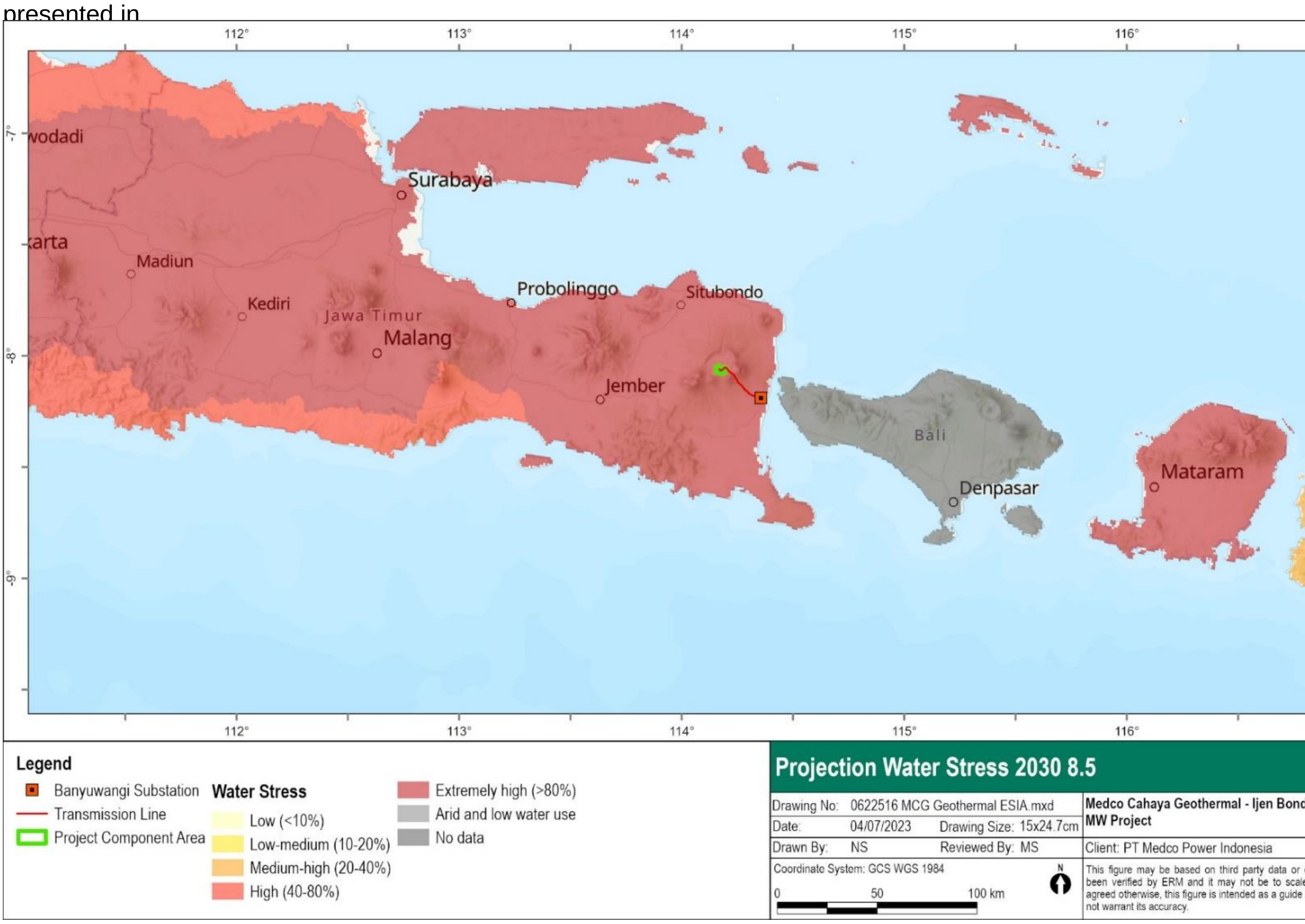

Figure **3-4** and

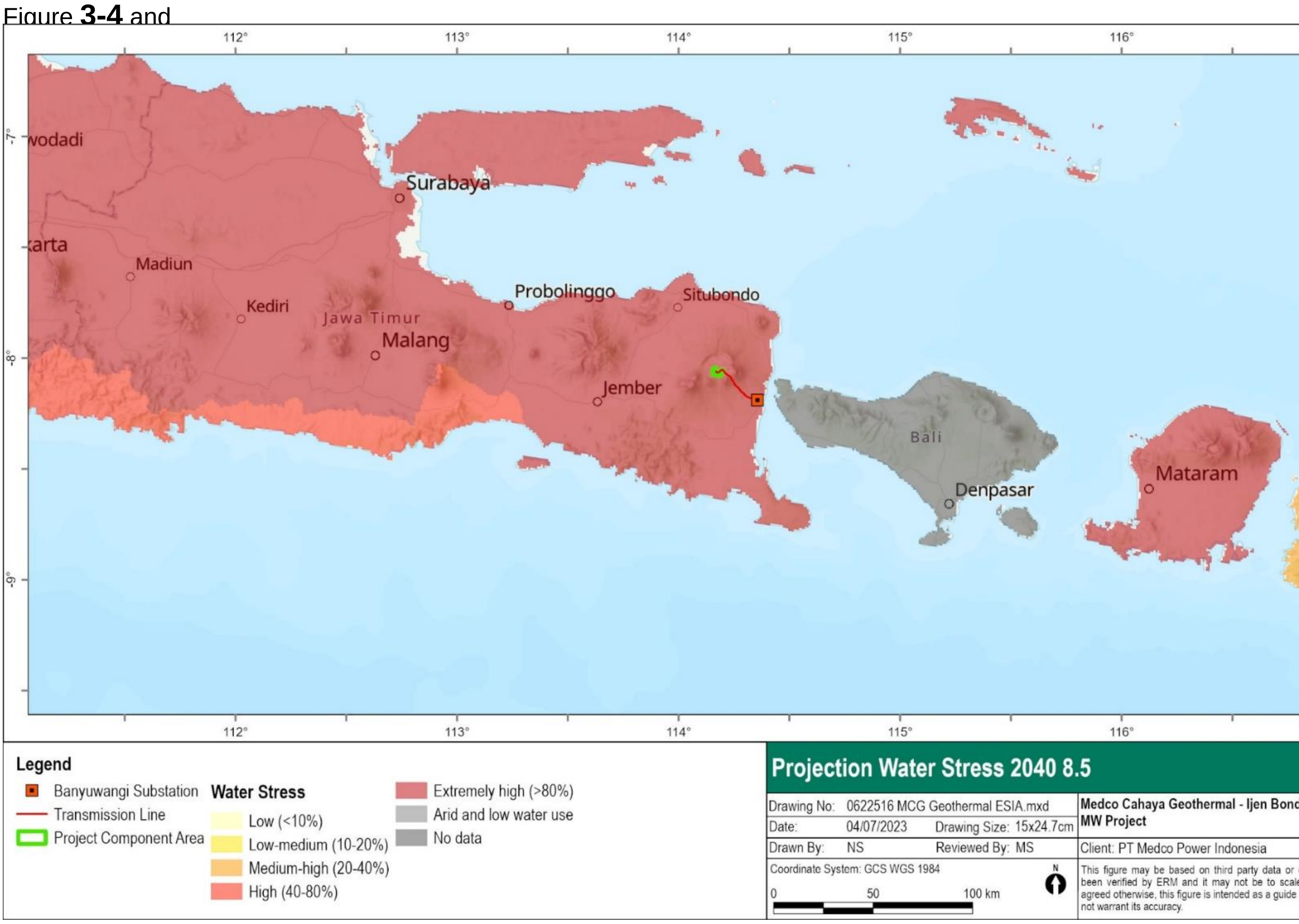

Figure **3-5** respectively. Seasonal variability is also projected to be "High" over both climate change scenarios as presented in

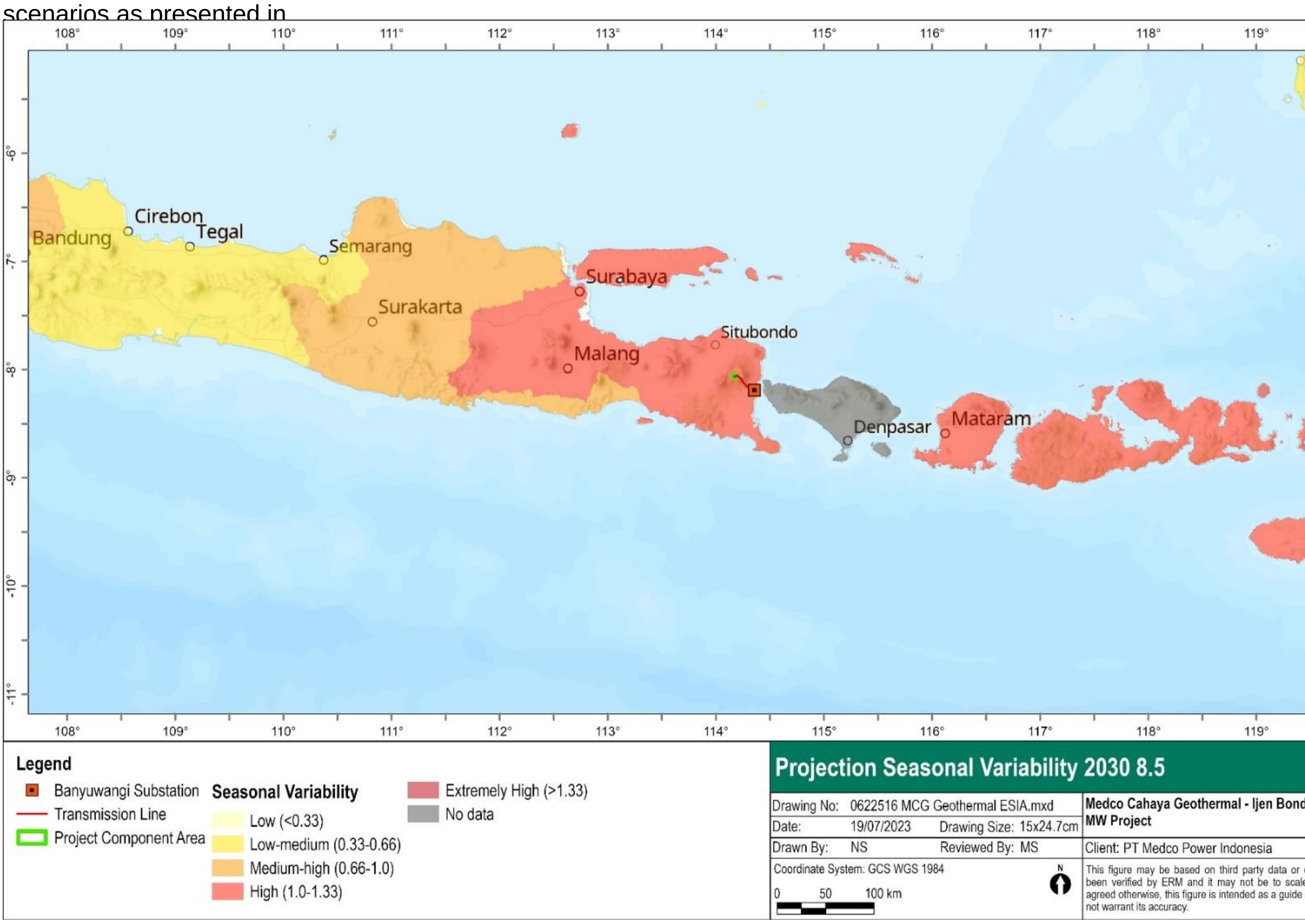

Figure 3-6 and

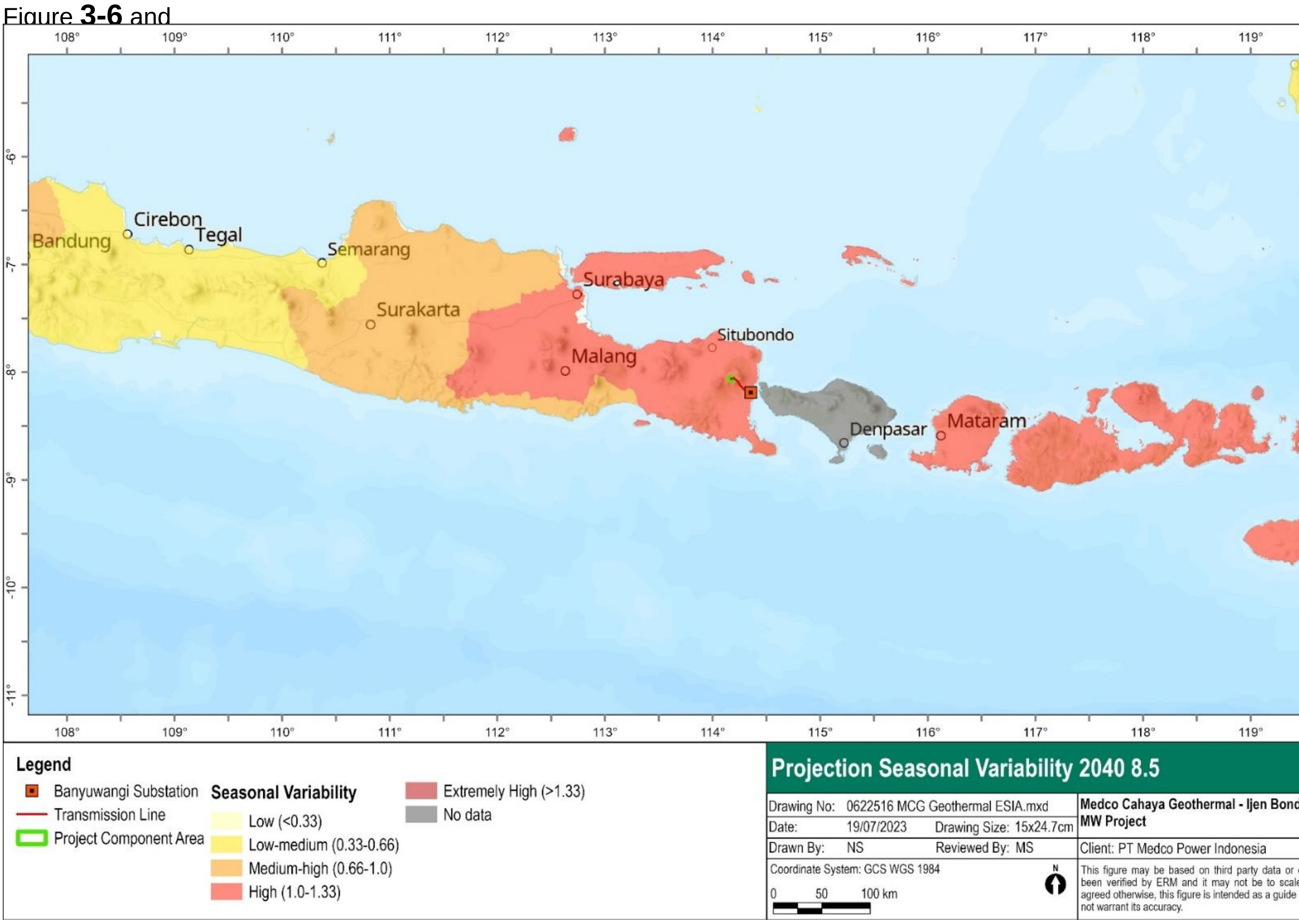

Figure 3-7. This indicates a similar seasonal variability in future.

However, upon studying and gathering information about water in the project area, it was discovered that the demand for water is rising in accordance with the increasing population. However, water does not increase at the same rate as the demand[5]. Coupled with the report regarding the high-risk potential of drought in the Bondowoso Regency area[6], based on all the aforementioned information, it becomes evident that the risk of future water availability is conservatively deemed to be **"High".**

[5] INDONESIA Country Water Assessment, Mark de Bel, April 2016. Available at https://www.researchgate.net/publication/301695613_INDONESIA_Country_Water_Assessment

[6] Assessment of Drought Disasters (EDI) Based on ENSO and NOAA Climate Data Using ANN in Bondowoso Regency, Evid Zulhaqi, 2023. Available at https://jurnalpengairan.ub.ac.id/index.php/jtp/article/view/670/416

3.1.2.1 Projections of Water Stress

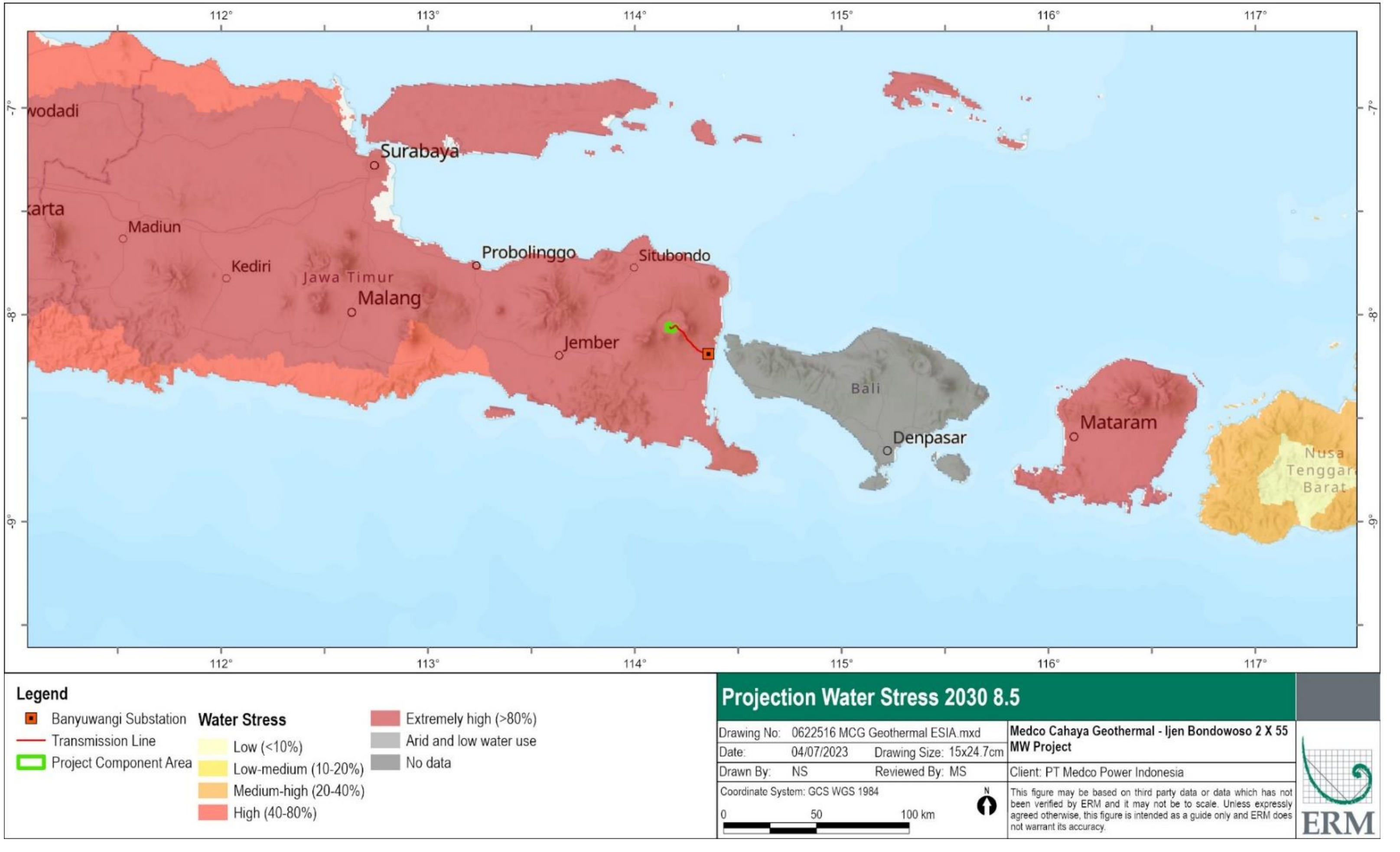

Figure 3-4 Projections of Water Stress during 2030 for RCP 8.5

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

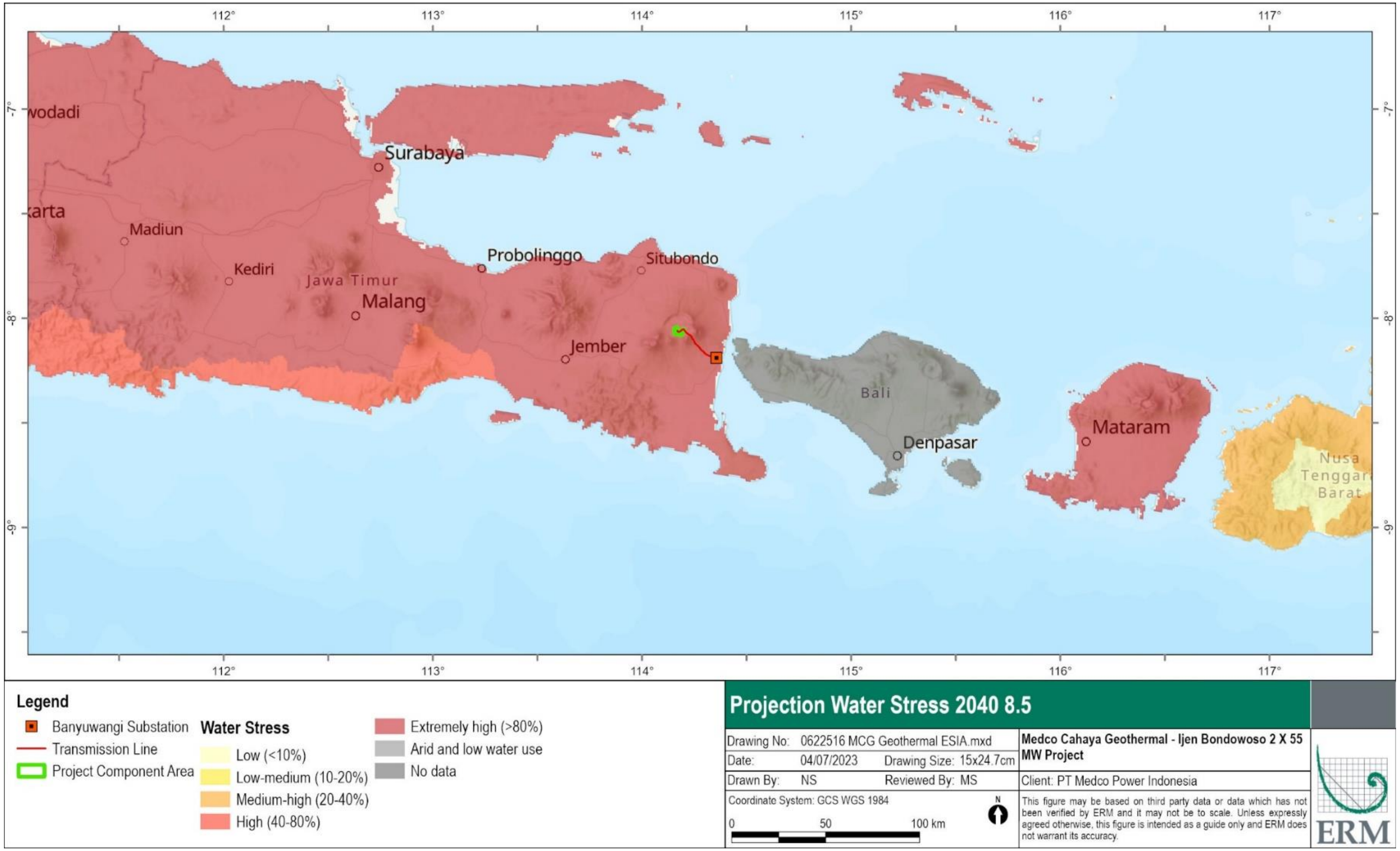

Figure 3-5 Projections of Water Stress during 2040 for RCP 8.5

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

3.1.2.2 Projections of Seasonal Variability

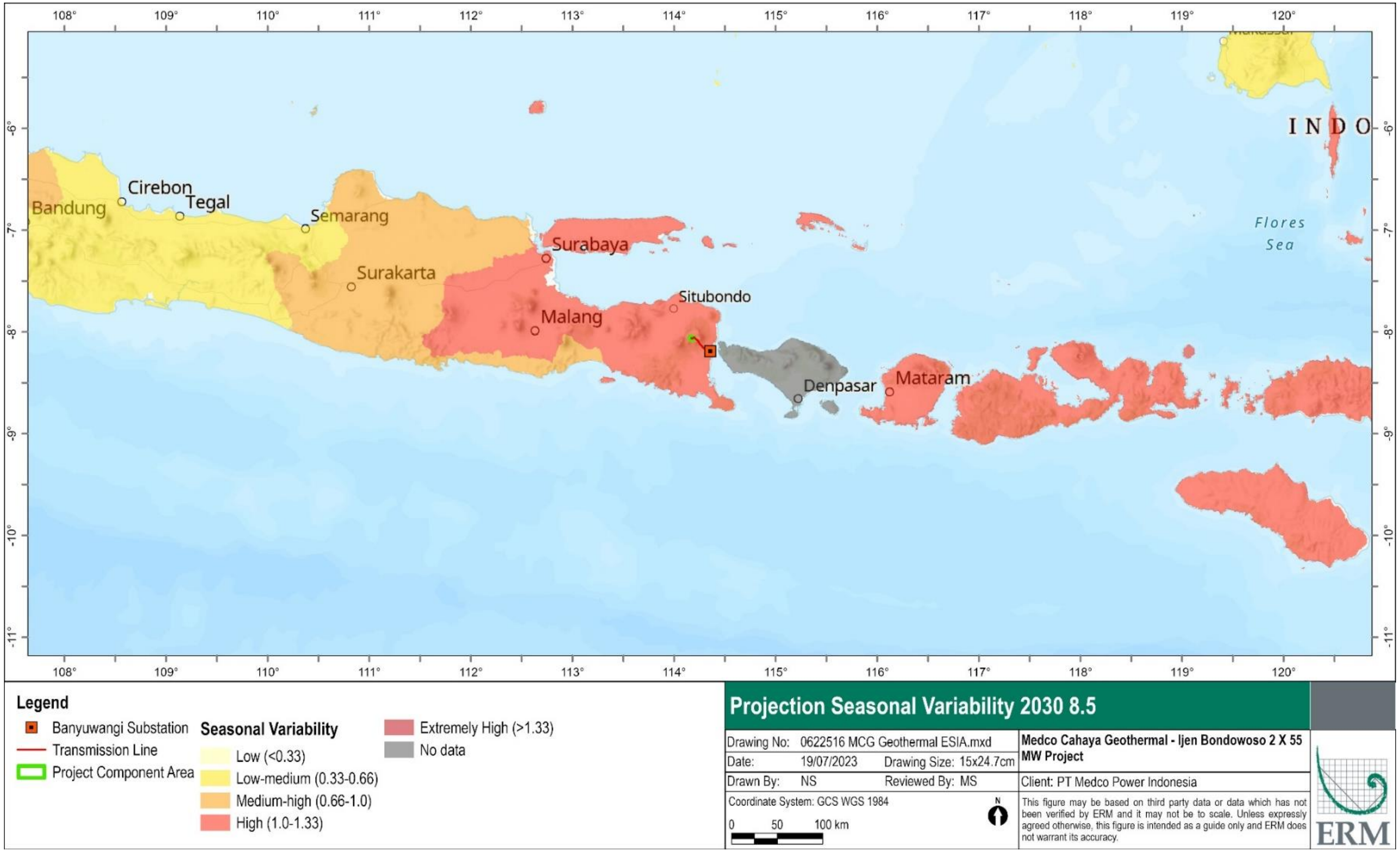

Figure 3-6 Projections of Seasonal Variability during 2030 for RCP 8.5

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

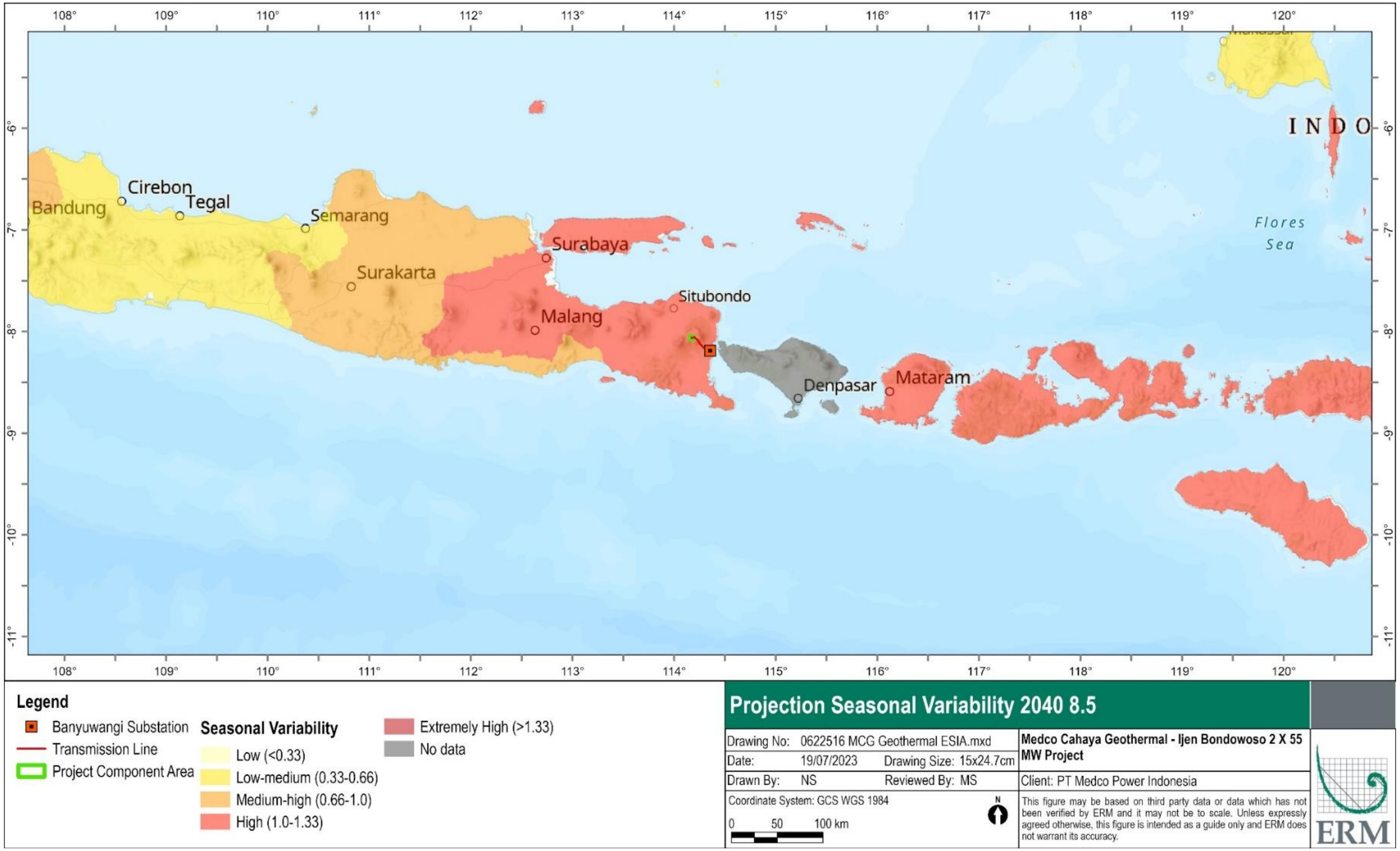

Figure 3-7 Projections of Seasonal Variability during 2040 for RCP 8.5

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

3.1.2.3 Projections of Water Supply

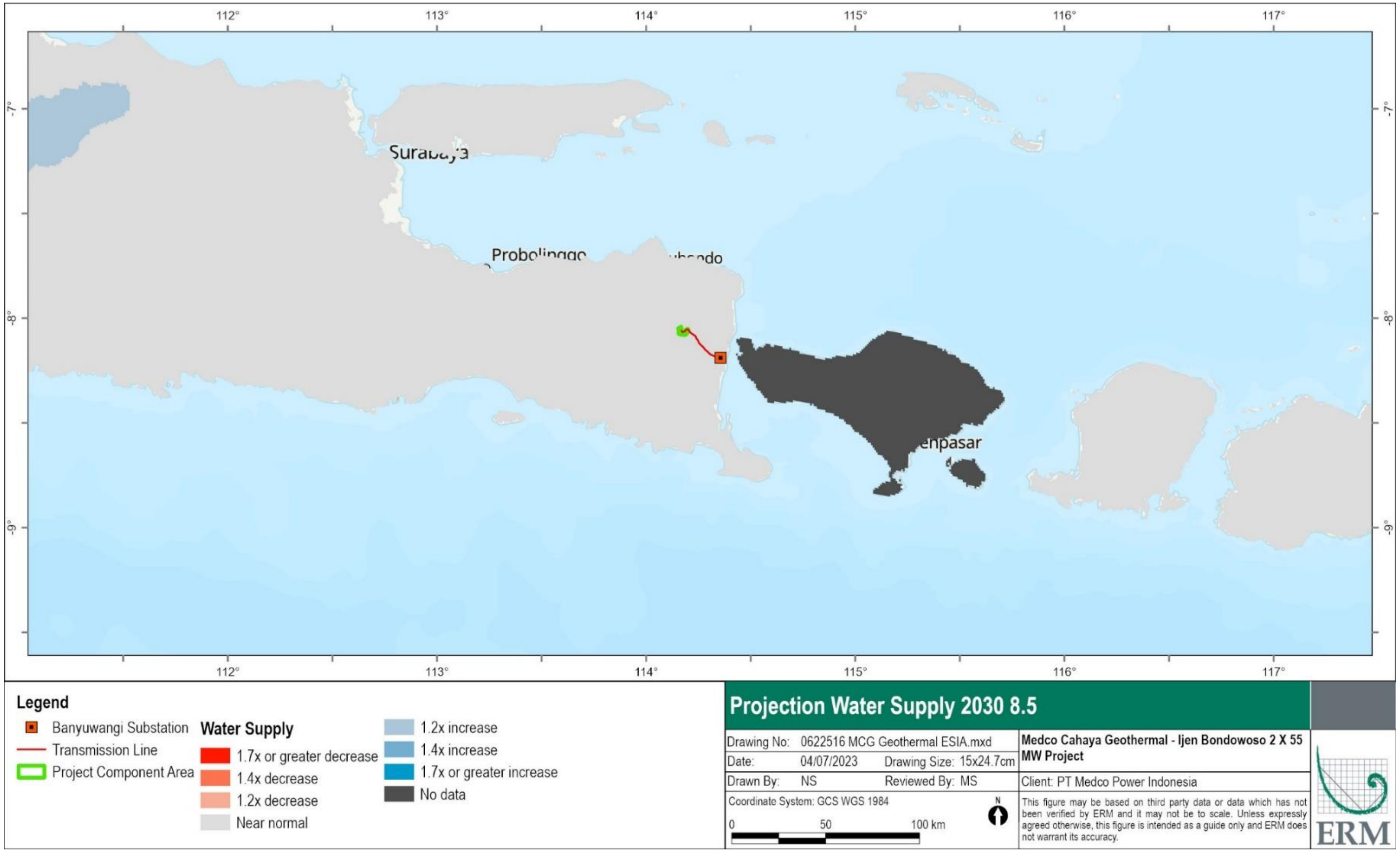

Figure 3-8 Projections of Water Supply during 2030 for RCP 8.5

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

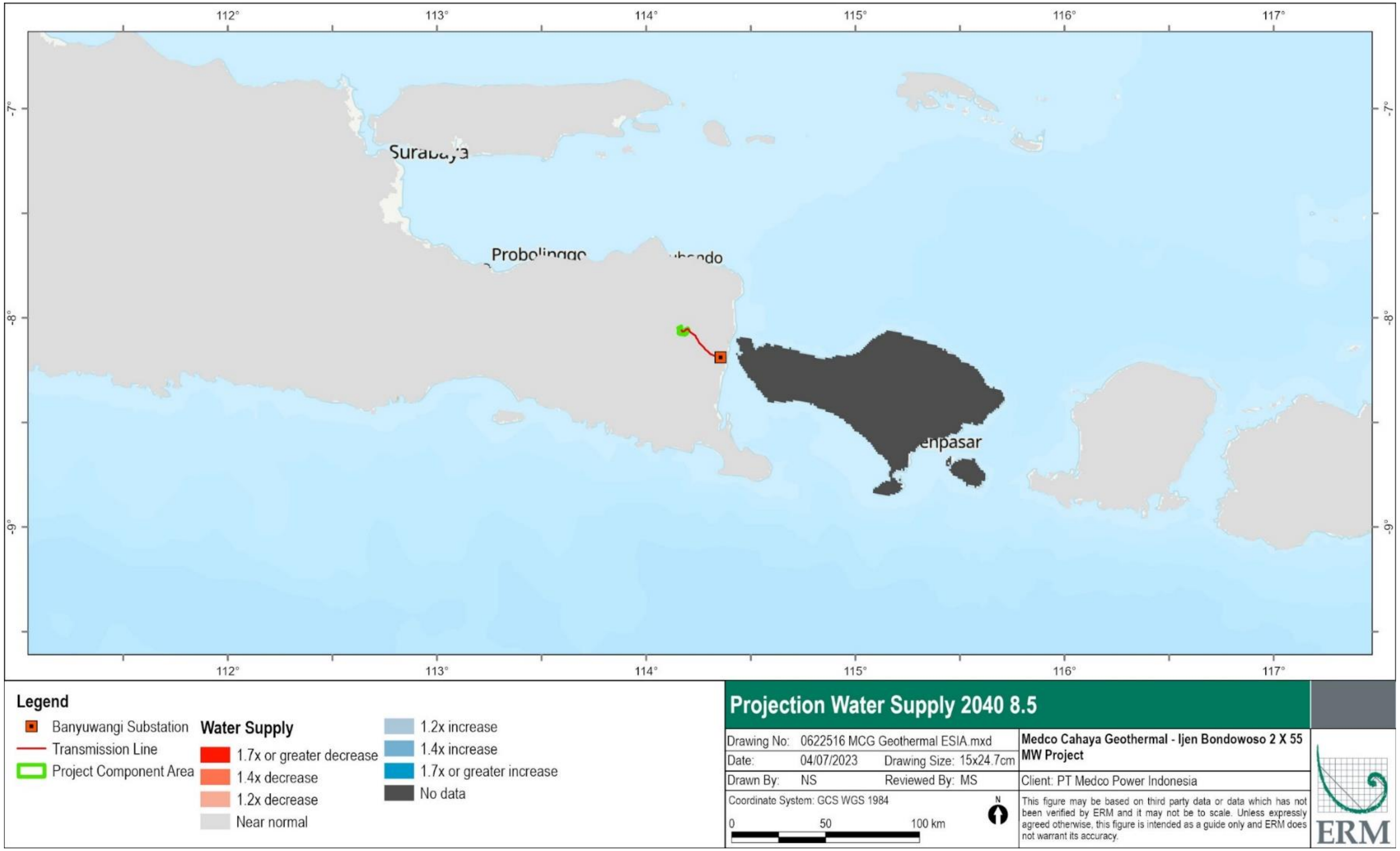

Figure 3-9 Projections of Water Supply during 2040 for RCP 8.5

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

3.1.3 Risk Assessment

The below table provides a qualitative physical risk level for and propose mitigation measures to reduce the impacts for the project.

Table 3.2 Qualitative Risk Level and Project Implications for Water Availability

	Baseline		RCP 8.5 - 2030	RCP 8.5 - 2050
Risk Level	**Medium**		**High**	**High**
Implications for the Project	Power Plant	High water availability risk may affect the power plant operations. Water is essential for various aspects of geothermal power plants, including heat transfer, steam generation, cooling, and working fluid circulation.[7] Other operations or activities, such as washing, cleaning, and worker use may also be compromised during times of water scarcity.		
	Transmission Line	It is not expected the transmission line to require any water consumption to operate		
Key Potential Impacts	▪ High water stress implies limited water availability in the region where the geothermal plant is located. This scarcity can pose a significant challenge to the project's water requirements for cooling, condensing, and geothermal fluid treatment. ▪ It could lead to operational disruptions if the plant's cooling and condensing systems cannot function optimally, potentially leading to downtime and revenue loss			
Recommended Mitigations	▪ Include a water risk assessment in the feasibility / engineering studies ▪ Implement water conservation measures. ▪ Adopt water efficient processes to reduce the water consumption cooling ▪ Explore opportunities for recycle and reuse of wastewater. ▪ Identify water storage infrastructure to ensure uninterrupted water supply during dry period.			

[7] GEOTHERMAL ENERGY: THE ENERGY-WATER NEXUS. Christopher Harto, Jenna Schroeder, Lou Martino, Robert Horner, and Corrie Clark, 2013. Available at https://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2013/Harto.pdf

3.2 Extreme Heat

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). [8]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 a 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.

3.2.1 Baseline Risk

The risk of extreme heat was evaluated on a regional level using the Think Hazard report in East Java (Jawa Timur)[9]. The extreme heat hazard in East Java is reported to be "Medium" as illustrated in

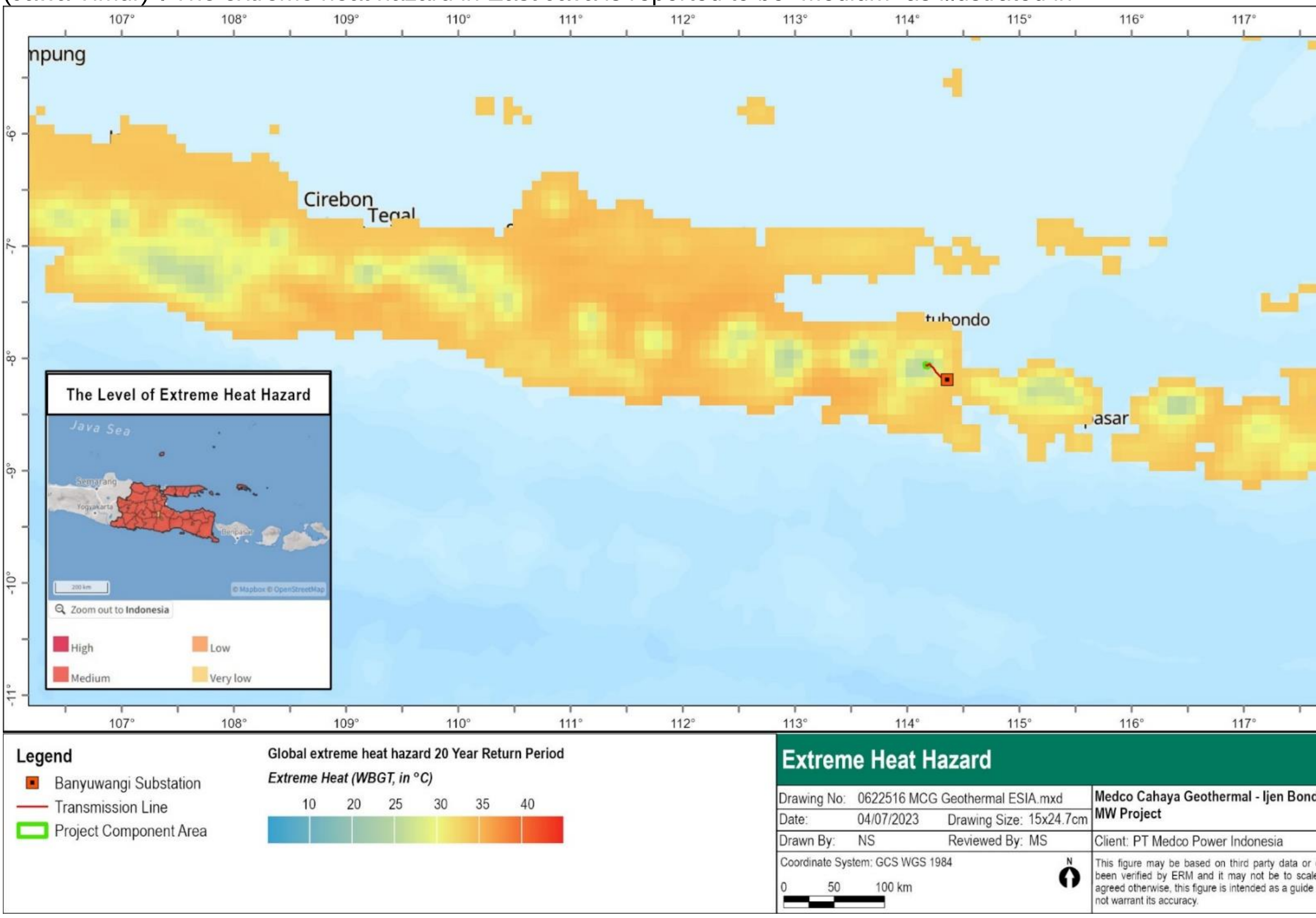

Figure **3-10** The classification is based on damaging intensity thresholds as presented in the below table.

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[8] ThinkHazard. 2020. Indonesia: https://thinkhazard.org/en/report/116-indonesia/EH

[9] Think Hazard. [Available at: https://thinkhazard.org/]

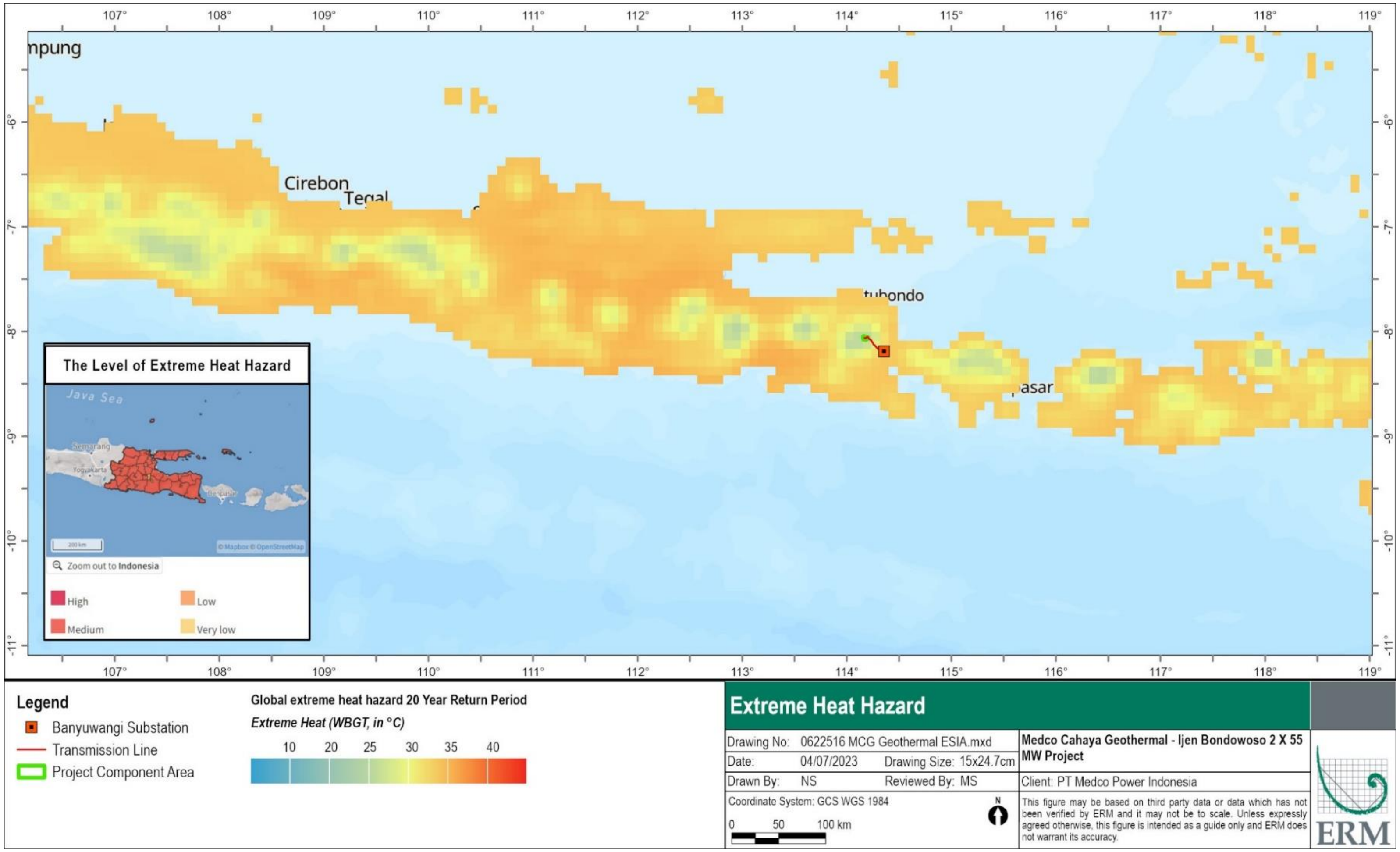

Figure 3-10 Extreme Heat Hazard

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

3.2.2 Climate Change Projection

Projections of Maximum of Daily Max Temperatures, by season based on the CMIP6 and accessible through the Climate Change Knowledge Portal, show that temperature in Jawa Timur, Indonesia may continually increase. However, when considering 2030 time horizon for the SSP5 scenario, the daily maximum temperature will range between 32.68 °C to 36.72 °C. A similar trend is observed for 2050 time horizon: the daily maximum temperature will range between 33.37 °C to 37.56 °C (Appendix B).

Based on the information for daily maximum temperature projections, the risk of extreme heat in the future is conservatively considered to be **"High"** for 2030 and **"High"** for 2050.

3.2.3 Risk Assessment

The below table provides a qualitative physical risk level for and propose mitigation measures to reduce the impacts for the project.

Table 3.3 Qualitative Risk Level and Project Implications for Extreme Heat

<table>
<tr><th></th><th colspan="2">Baseline</th><th>RCP 8.5 - 2030</th><th>RCP 8.5 - 2050</th></tr>
<tr><td>Risk Level</td><td colspan="2">Medium</td><td>High</td><td>High</td></tr>
<tr><td rowspan="2">Implications for the Project</td><td>Power Plant</td><td colspan="3">Extreme heat can subject plant components to thermal stress. It can also impact the reliability of electrical and mechanical systems, potentially affecting the safety and stability of the plant's operations. Extremely high ambient temperatures may compromise the performance of cooling systems, and workers (hydration).</td></tr>
<tr><td>Transmission Line</td><td colspan="3">Overhead transmission line could be affected by the extreme heat since the structures and transmission lines are exposed to the air. However, since workers are not expected to work close to the transmission line, the risk of harmful effects on personnel is low.</td></tr>
<tr><td>Key Potential Impacts</td><td colspan="4">Equipment overheating or failures due to extreme heat can cause operational disruptions, leading to downtime and reduced power availability.
Workers involved in outdoor operational and maintenance activities may be exposed to extreme heat events and suffer heat stress or heat exhaustion.</td></tr>
<tr><td>Recommended Mitigations</td><td colspan="4">Provide adequate Personal Protective Equipment to work outdoor.
Limit outdoor activities during extreme heat events.
Implement water-efficient technologies and practices, such as optimizing cooling systems, reducing leaks, and recycling water, to minimize water usage and increase the plant's water efficiency during extreme heat events.
Train workers to identify the symptoms of heat stress and first aid. Take necessary measures to counter heat stress impacts to personnel, especially workers.
Develop cool and shaded resting spaces (indoor or outdoor) for workers and other external personnel.</td></tr>
</table>

3.3 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[10], was utilized.

3.3.1 Baseline Risk

Based on basic wind speed map, the average wind speed near the Project is approximately 2.7 m/s as presented in

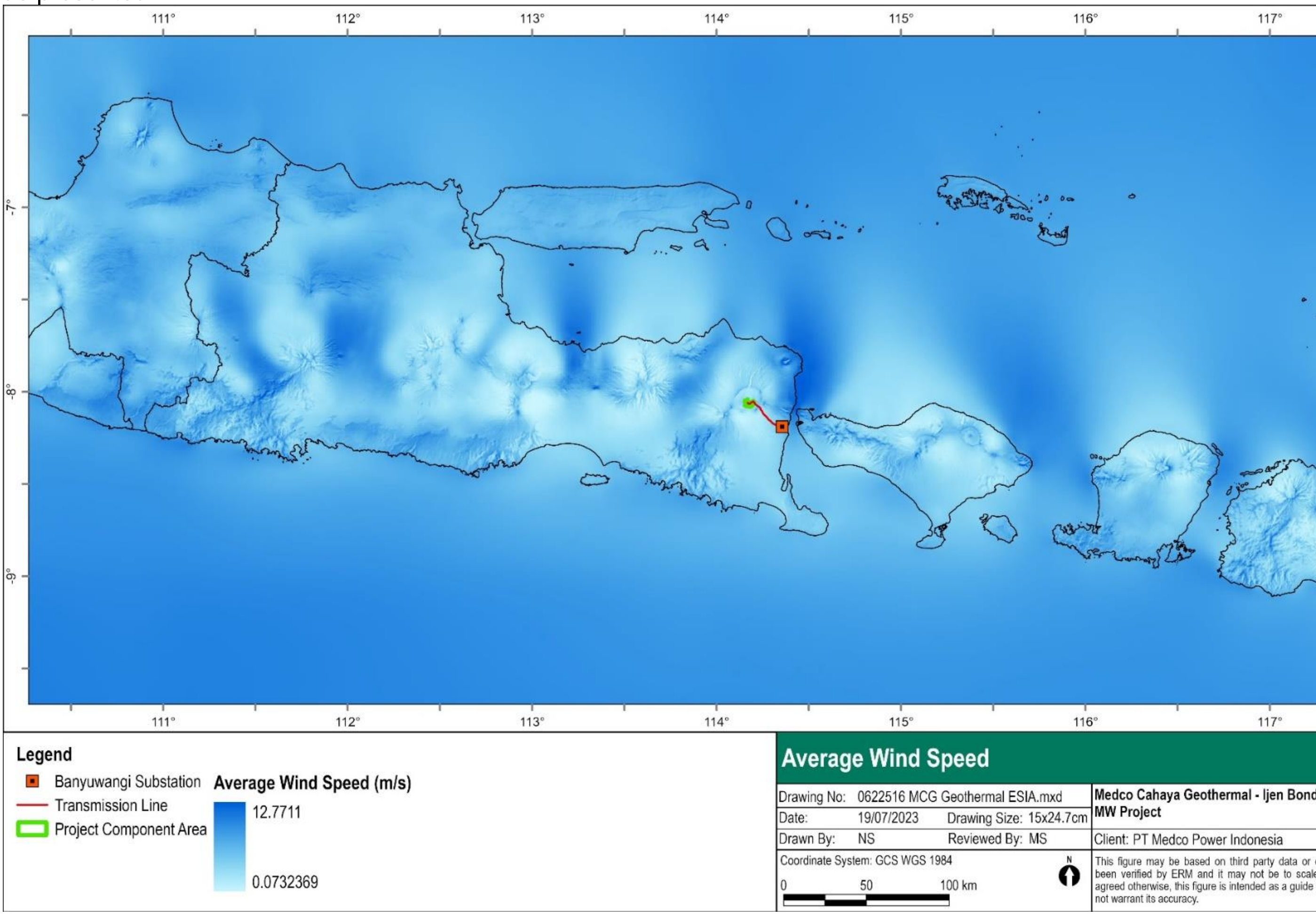

Figure **3-11**. Based on average and hourly wind speed data, the baseline hazard due to average wind speed for the area is considered to be "**Low**". This implies that the project area is not prone to wind hazard on a general basis.

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10 Global Wind Atlas 3.0, a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU). The Global Wind Atlas 3.0 is released in partnership with the World Bank Group, utilizing data provided by Vortex, using funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalwindatlas.info

With regards to maximum wind speed, data were obtained from the windPROSPECTING[11]. 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 9.9 m/s as presented in Figure 3-12. Therefore, the risk associated with the maximum wind speed is considered "**Low".**

[11] windPROSPECTING. [Available at: https://www.windprospecting.com/]

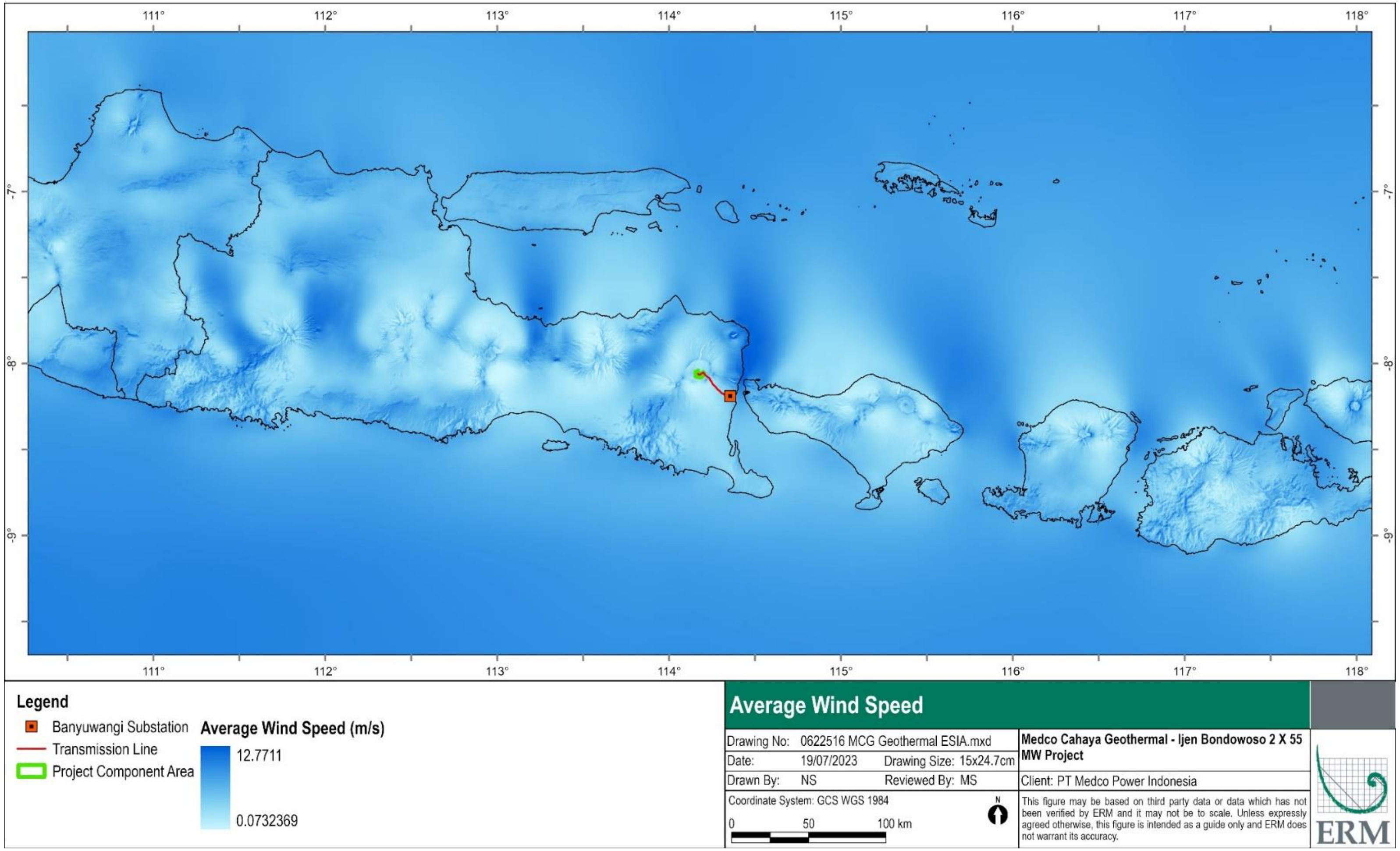


Figure 3-11 Baseline Average Wind Speed Map

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

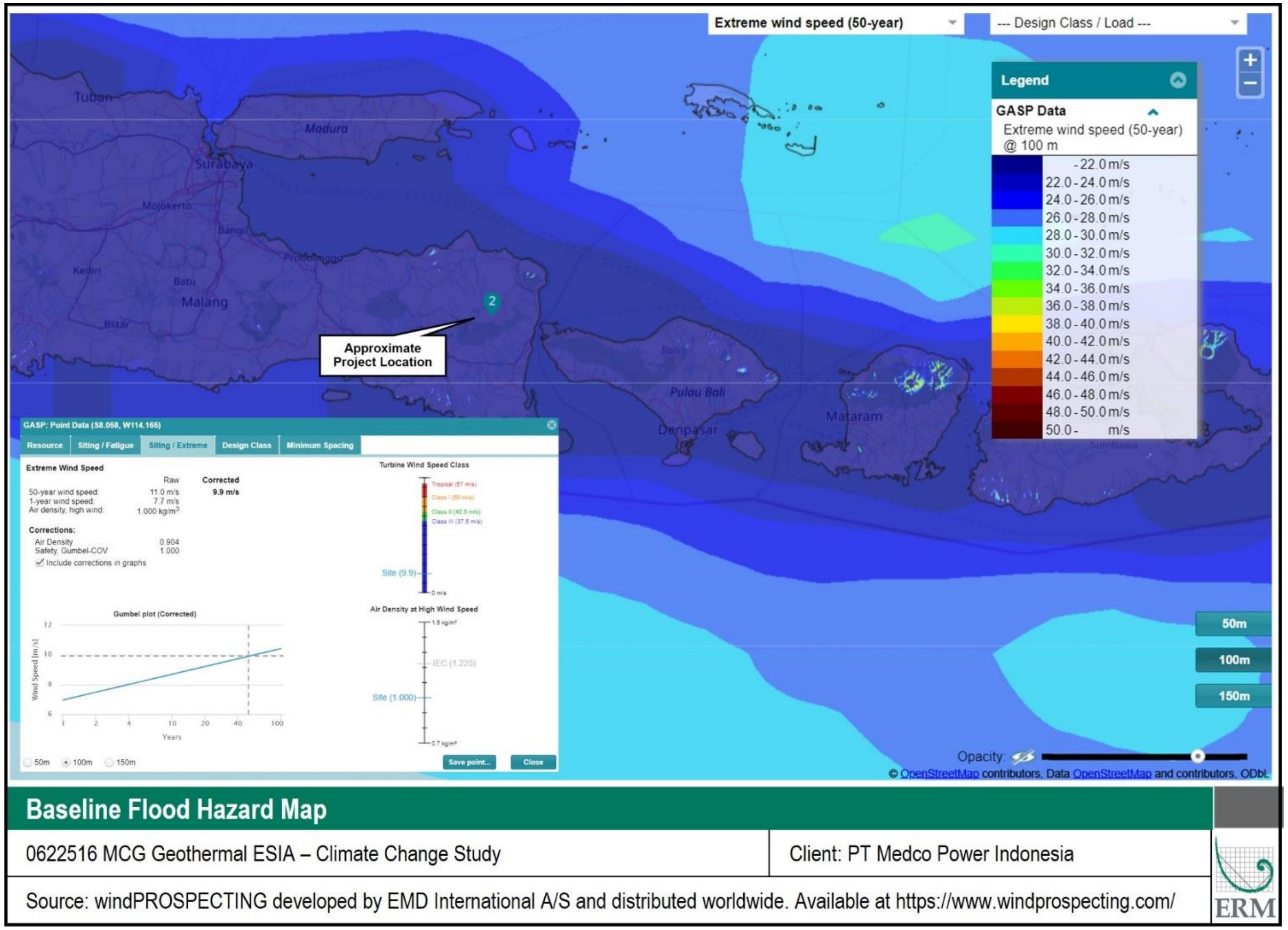


Figure 3-12 Extreme Wind Speed 50 - Year

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

3.3.2 Climate Change Projection

The climate models for wind speed indicate a high degree of uncertainty with models projecting increase, decrease, or no change in the future. However, a recent study from the IPCC has modelled the future projection of surface wind across the globe[12]. According to the IPCC interactive atlas, the surface wind changes 0.03% in near term scenario and -1.76% in medium term scenario as present in Figure 3-13 and Figure 3-14. The change in significance indicates a considerable shift toward decrease of surface wind speed both on near term (2040) and medium term (2060). Considering the limited information available, the wind hazard under a climate change scenario is considered to be **"Low"** for average speed and "**Low**" for maximum speed.

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

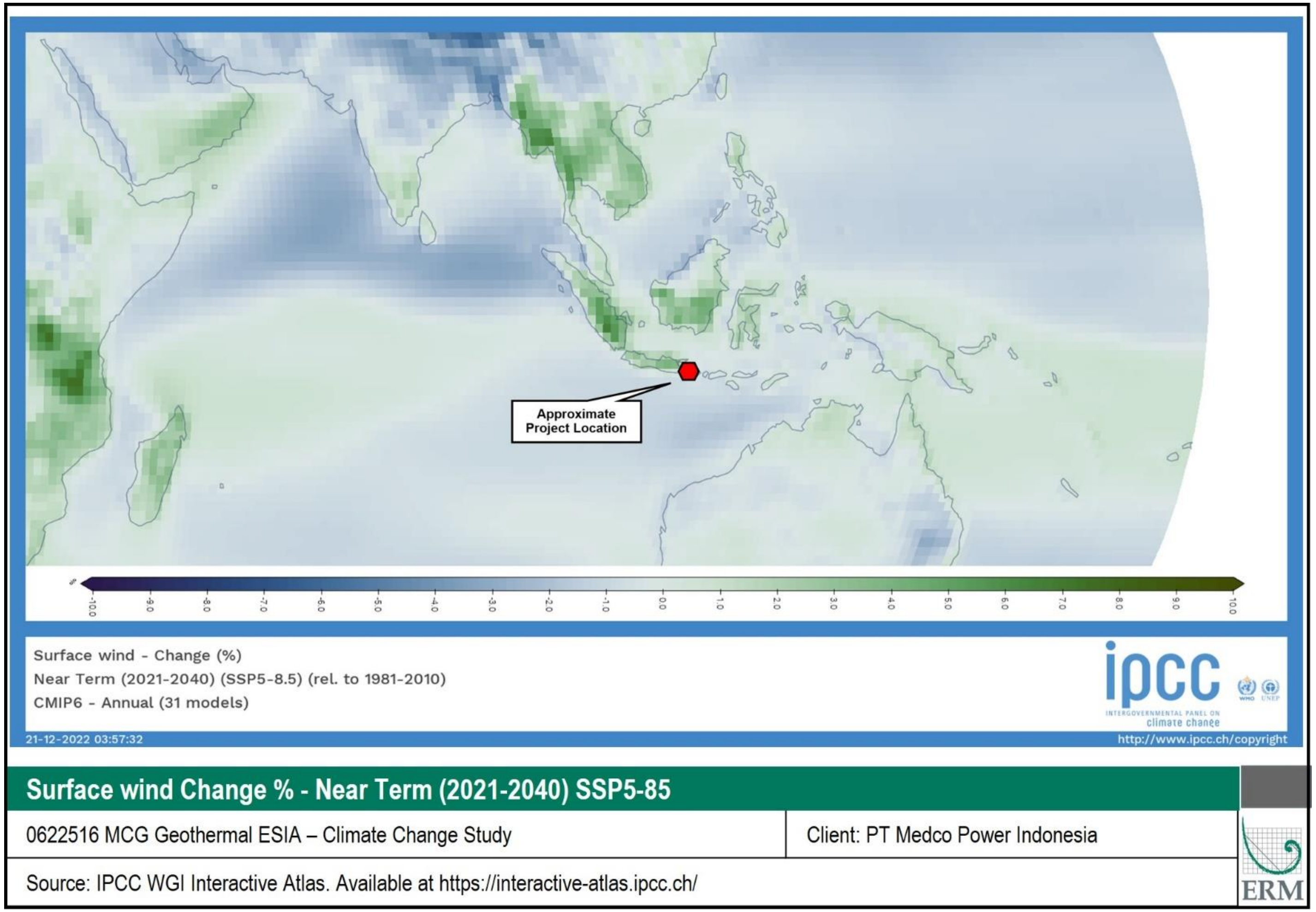


Figure 3-13 Surface wind Change % - Near Term (2021-2040)

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

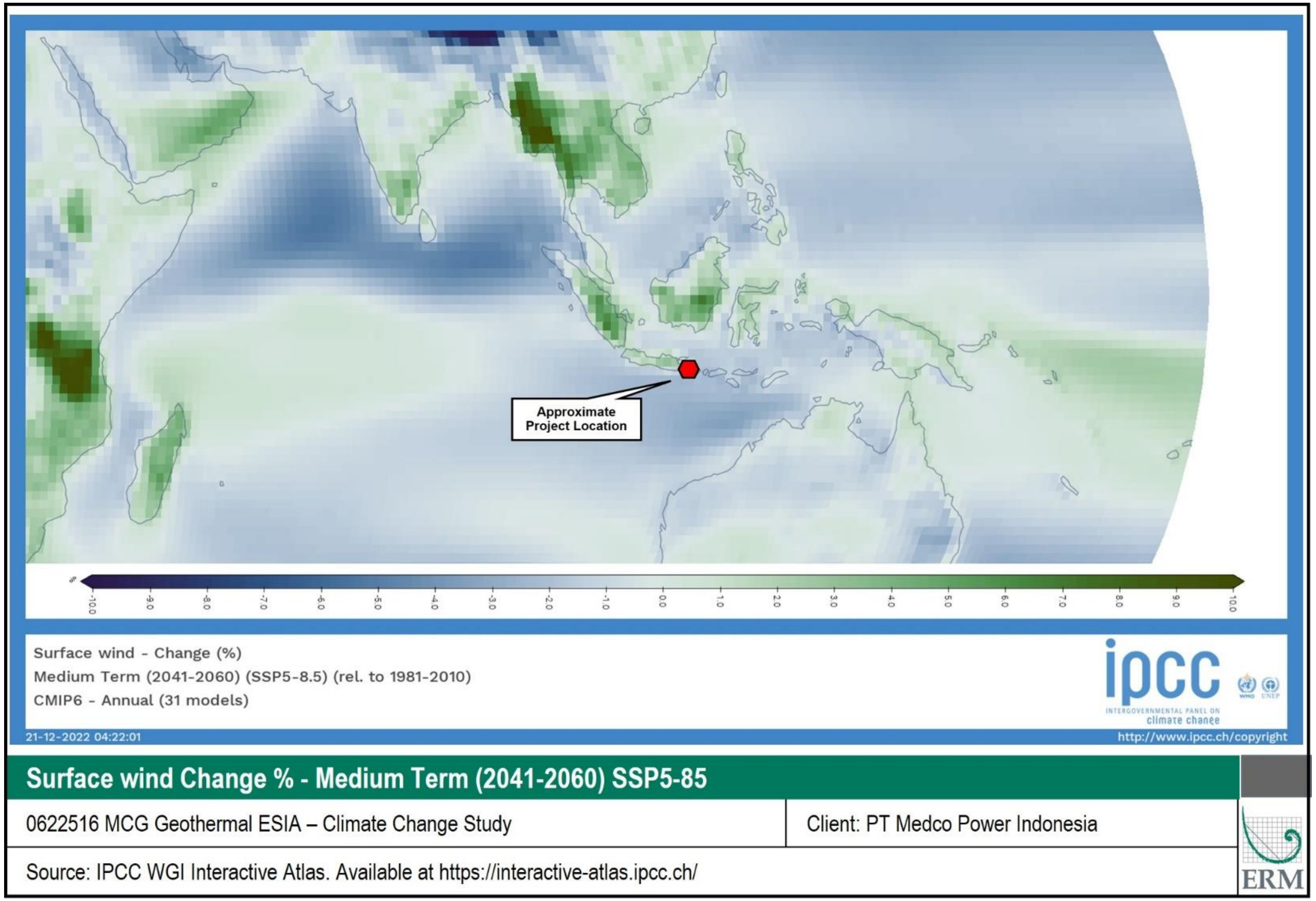


Figure 3-14 Projection of Surface wind Change % - Medium Term (2041-2060)

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

3.3.3 Risk Assessment

The below table provides a qualitative physical risk level for and propose mitigation measures to reduce the impacts for the project.

Table 3.4 Qualitative Risk Level and Project Implications for Wind Speed

		Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
Risk Level Average Wind Speed		**Low**	**Low**	**Low**
Risk Level Maximum Wind Speed		**Low**	**Low**	**Low**
Implications for the Project	Power Plant	The wind speed indicates as low risk for both the average wind speed and maximum wind speed. Low wind speeds have no direct impact on geothermal power plants since they generate energy using heat from the Earth's interior.		
	Transmission Line	Extreme wind speed may transfer energy and inflict damage to the structure of Transmission Line. High wind speed can break down the transmission line and may cause power delivery failure.		
Key Potential Impacts	• Extreme wind speeds may have an impact on transmission lines, which are critical for delivering power generated at the plant to the electric grid.			
Recommended Mitigations	• Regular maintenance of the Transmission Line right of way to ensure is free from obstacles and vegetation that may fall on the line during extreme wind events.			

3.4 Lightning

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

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

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

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

Lightning can cause both destruction of infrastructure and lives. About 2,000 people are killed worldwide by lightning each year. Hundreds more survive strikes but suffer from a variety of lasting symptoms, including memory loss, dizziness, weakness, numbness, and other life-altering ailments[13].

For this assessment, data from Vaisala's Interactive Global Lightning Density Map[14] was used. This interactive map displays the average lightning density observed for every country and ocean in the world for 2016 through 2022.

3.4.1 Baseline Risk

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

Lightning flash density map presented in Figure 3-15 **Error! Reference source not found.**indicates the density of lightning flashes to be 32 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 risk in the Project area can be assumed as “**Medium**”.

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

[14] Vaisala's Interactive Global Lightning Density Map. Available at: https://interactive-lightning-map.vaisala.com/?_ga=2.13283636.2075757537.1656405986-847756934.1656405986

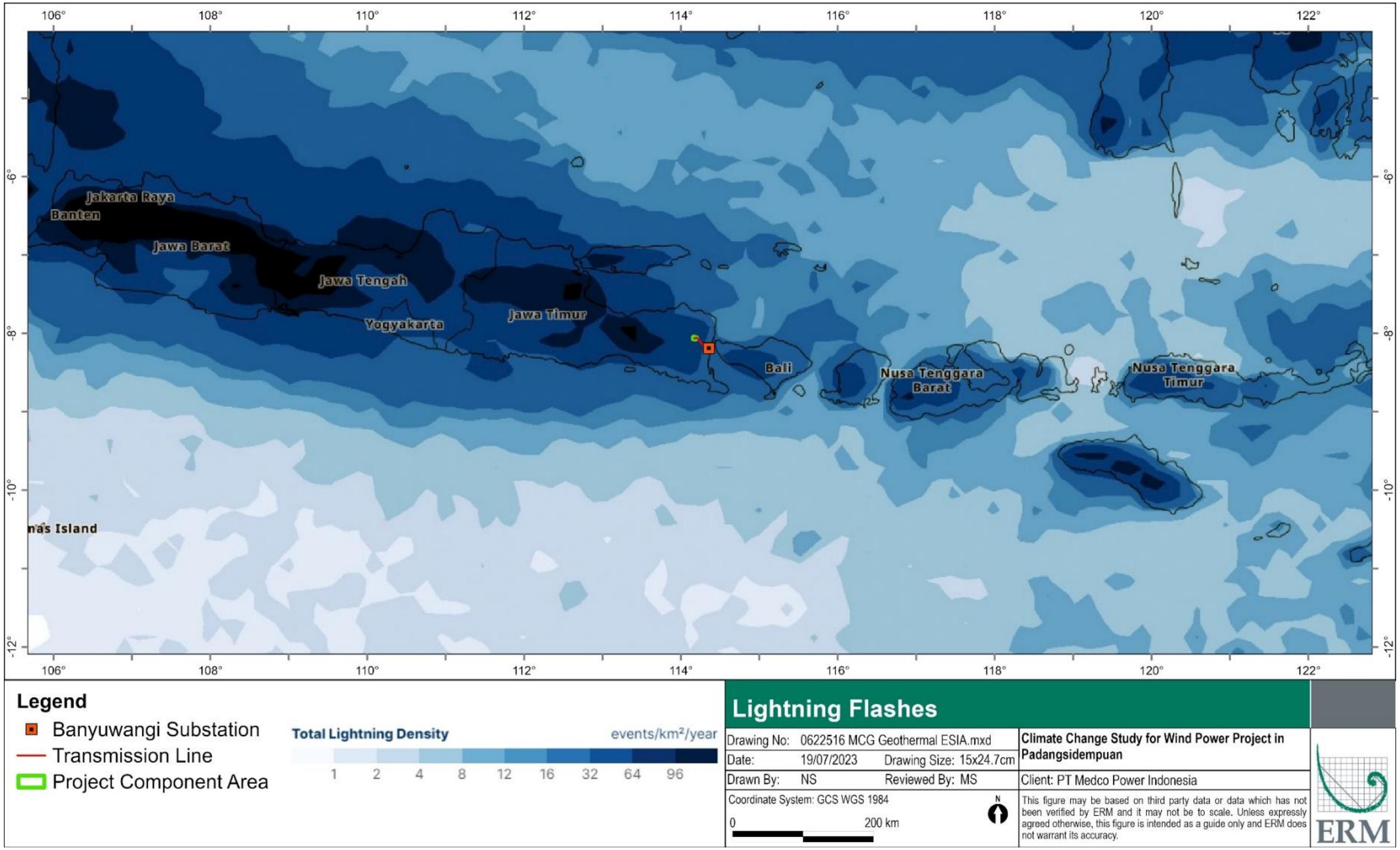


Figure 3-15 Baseline Lightning Density Map

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

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

3.4.2 Climate Change Projection

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

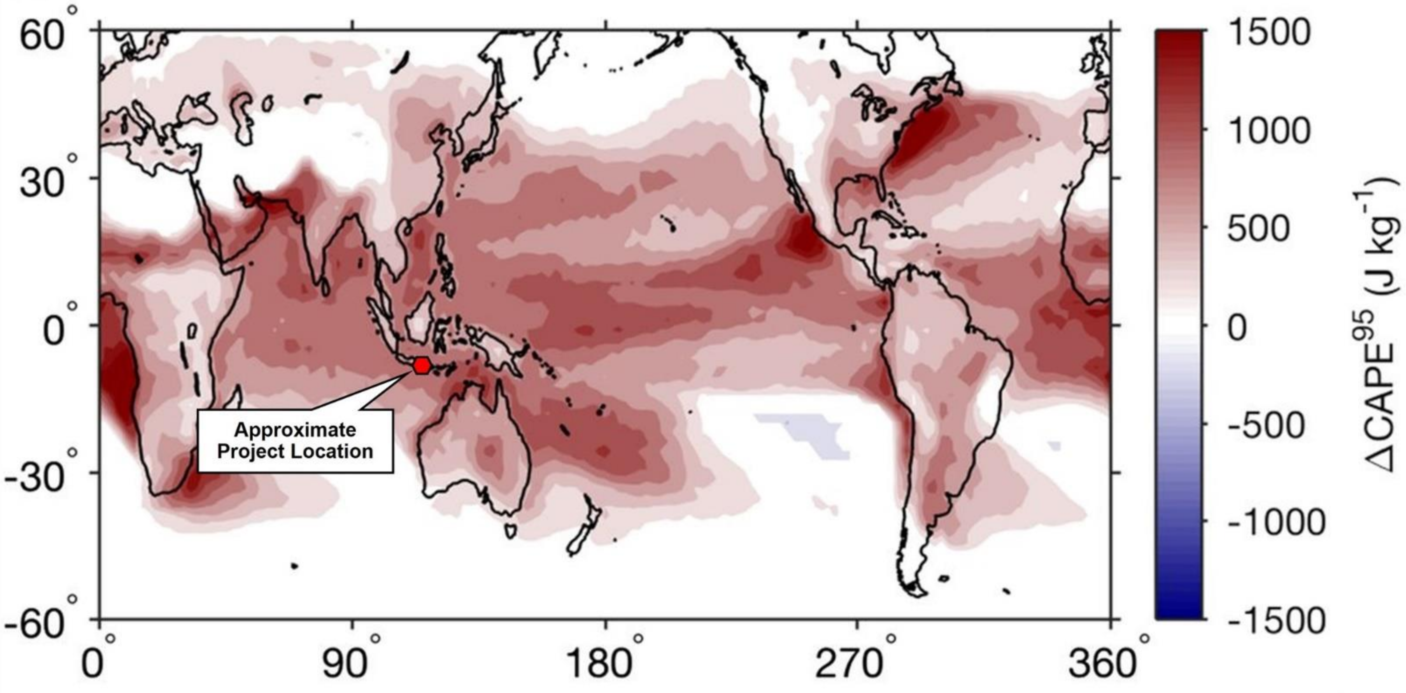
Literature review indicates that predicting changes in thunderstorm directly is difficult task, and hence generally changes in large scale environmental conditions conducive to thunderstorms are used as an indirect measure. One such factor is convective available potential energy (CAPE), which is a measure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

Literature review indicates tropical and subtropical CAPE extremes increasing sharply with warming across ensembles of GCMs participating in CMIP6. In general, the studies indicate an increase in potential for intense thunderstorms in warming atmosphere.[15]

CAPE at Project site is likely to increase by 500 - 1000 J/kg by 2100 for RCP 8.5 scenario as presented in Figure 3-16. In general, the studies indicate an increase in potential for intense thunderstorms in warming atmosphere. Figure 3-17 presents the likely increase in number of days per year with conditions favourable for severe thunderstorm by end of the century. Accordingly, the projected increase in number of days with conditions favourable for formations of thunderstorms is reported to be between 0-25/year by 2100 under RCP 8.5 scenario Hence, an increase in lightning activity/frequency may be experienced in future.

Although it is likely to occur an increased probability of lightning events, based on a baseline value of 32 events km^{-2} $year^{-1}$, it is assessed a future risk of lightning within the **“Medium”** hazard level at the Project location.

[15] Singh 2017. Tropical thunderstorms are set to grow stronger as the world warms. DownToEarth. Available at: https://www.downtoearth.org.in/news/climate-change/tropical-thunderstorms-are-set-to-grow-stronger-as-the-world-warms-58902



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

0622516 MCG Geothermal ESIA – Climate Change Study	Client: PT Medco Power Indonesia

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 3-16 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

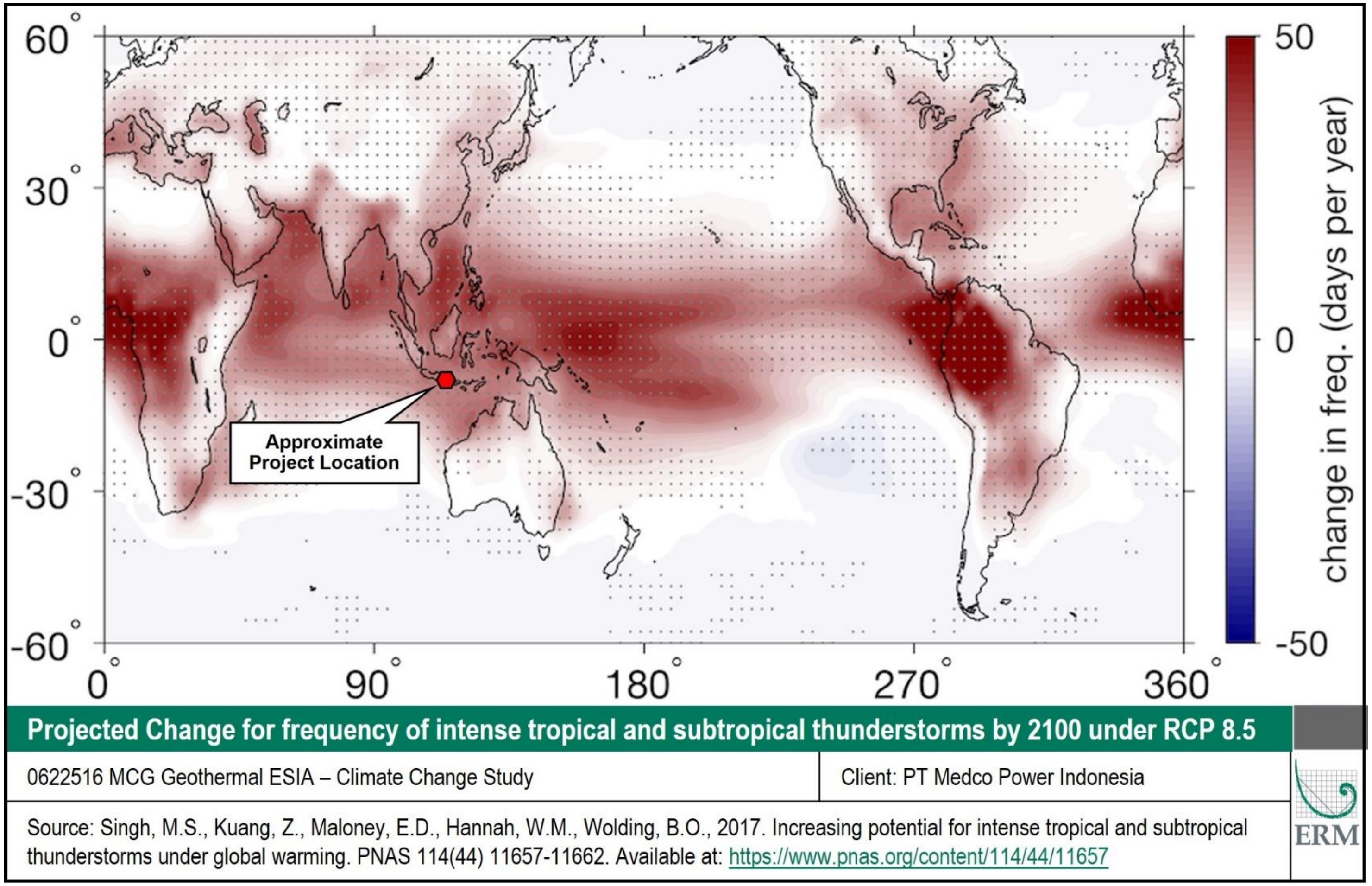


Figure 3-17 Projected Change for frequency of intense tropical and subtropical thunderstorms by 2100 under RCP 8.5 Scenario

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

3.4.3 Risk Assessment

The below table provides a qualitative physical risk level for and propose mitigation measures to reduce the impacts for the project.

Table 3.5 Qualitative Risk Level and Project Implications for Lightning

	Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
Risk Level	**Medium**	**Medium**	**Medium**
Implications for the Project	Power Plant	In general, geothermal power facilities are less susceptible to lightning-related issues. However, the operation of geothermal power plants may be affected by lightning since Indonesia is located in a region with a relatively high keraunic level compared to the rest of the world. Ground flash density in the geothermal plant of interest might reach 5.8 strikes/km^2/year[16]. Accordingly, lightning strike may have implications on structural safety, safety of electrical/ electronic equipment, stored material and workers working at the Site.	
	Transmission Line	Potential corrosion of materials at the connection point between the transmission line and power plant may offer an opportunity for the current discharge to damage the cable.	
Key Potential Impacts	• Operational disruptions caused by lightning-related damage may lead to downtime, reducing the geothermal plant's electricity generation and data transmission and control systems, which are crucial for the plant's efficient operation and safety. • It may trigger fires, which can pose a risk to the geothermal plant's infrastructure and surrounding areas that poses a risk to personnel, equipment, and the environment.		
Recommended Mitigations	• Follow national standards in order to prevent damage from lightning. • Install lightning arresters and earthing rods. • Creating and updating emergency response plans that address lightning-related hazards, such as fire prevention and worker safety, on a regular basis.		

3.5 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 of combined effect of tides, surges and increase in the sea surface elevation.

Floods are likely to result in widespread local as well as regional level destruction. This can be caused due to submergence, washing away and damage to infrastructure, buildings, structures, sewerage

[16] EMC-based Lightning Protection Systems for Instrumentation Systems of Geothermal Power Plant. 2012. Djoko Darwanto, Twi Sevon Rumdy, Deny Hamdam. Available at https://ieeexplore.ieee.org/document/6237870

systems, damage to power transmission and power generation, loss of agricultural land and crops, contamination of fresh water sources, propagation of water borne diseases and loss of life. Flood hazard in the present assessment was assessed based on the review of open-source data for different flooding parameters as presented in the below table.

Table 3.6 Parameters Used for Evaluation of Baseline Flood Hazard

No.	Parameter	Description
1	Riverine Flood Risk Map[17]	Riverine flood risk is the percentage of the population that is expected to be impacted by Riverine flooding in an average year, taking into account existing flood-protection standards.
2	Riverine Flood Hazard Map[18]	To calculate the river hazard layers for the individual return periods, the GLOFRIS model[19] was used. GLOFRIS uses a global hydrological model, PCR-GLOBWB [20], 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[21] and the Inter-sectoral Impact Model Intercomparison Project[22] were used to force PCRGLOBWB over various time periods, between 1950 and 2099.
3	Flood Hazard Map[23]	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[24]	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 protection standards. Higher values indicate greater proportion of the population is expected to be impacted by flooding.

[17] WRI- Aqueduct Flood Hazard Maps. Available at https://www.wri.org/research/aqueduct-30-updated-decision-relevant-global-water-risk-indicators

[18] Idem

[19] Ward, P.J,. Hessel C. W, Kuzma, S., Bierkens M. F.P., Bouwman, A., De Moel, H., Díaz Loaiza, A., Eilander, D., Englhardt, J., Erkens, G., Gebremedhin, E.T., Iceland, C., Kooi, H., Ligtvoet, W., Muis, S., Scussolini, P., Sutanudjaja, E.H., Van Beek, R., Van Bemmel, 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/aqueductfloods-Methodology

[20] 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., Vannametee, 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].

[21] 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.

[22] 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.

[23] FM Global. Available at https://www.fmglobal.com/research-and-resources/nathaz-toolkit/flood-map

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

No.	Parameter	Description
5	Coastal Flood Hazard Map[25]	To estimate coastal hazard, the Global Tide and Surge Reanalysis (GTSR) dataset[26] 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[27]. Tide is simulated using a separate model, the Finite Element Solution 2012 (FES 2012) model[28].

3.5.1 Baseline Risk

3.5.1.1 Riverine and Coastal Flood Hazard

The riverine hazard map and the coastal inundation map representing the depth of inundation under a flood with 100 year return period indicated low risk of inundation in project area. Moreover, the flood hazard zone was compiled using the Natural Hazard toolkit created by FM Global. The Worldwide Flood Map currently displays flood zones with high (100-year) and moderate (500-year) hazard. After analysing the Project, it was discovered that the project area was not in a flood hazard zone as display in Figure 3-18. Nonetheless, the Transmission Line and Substation of the project is located 3 kilometers away from the coastal area and stands at an elevation of 90 meters above sea level. In contrast, the coastal area's height is less than 4 meters. Consequently, the Transmission Line and Substation of the project is not susceptible to Coastal Flood Risks.

3.5.1.2 Riverine and Coastal Flood Risk

Catchment level riverine flood risk based on population and economic exposure to floods was reported to be “Low-Medium” as presented in Figure 3-19. Coastal flood risk was reported to be “Medium-High” as presented in Figure 3-20**Error! Reference source not found.**. However, the estimations from WRI-Aqueduct Flood Tool are based on regional characteristics, while the local conditions related to elevation, slope and distance to high-risk areas, are showing a low risk of flooding for the Project facilities. Hence, the overall flood risk for the Project from riverine and coastal flood was evaluated to be **“Low”** in the baseline.

[25] Idem

[26] 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

[27] 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, L., 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

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

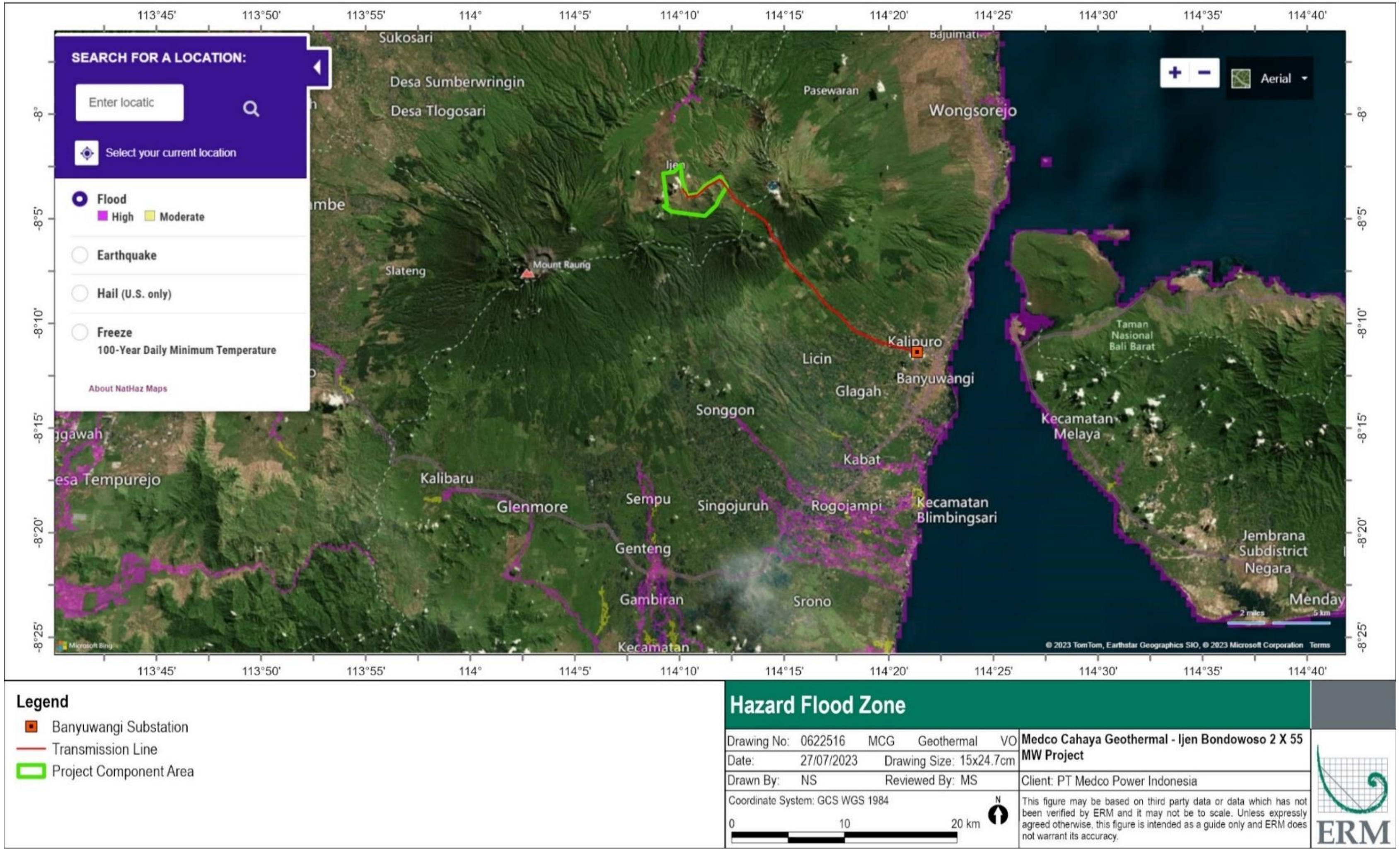


Figure 3-18 Hazard Flood Zones

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

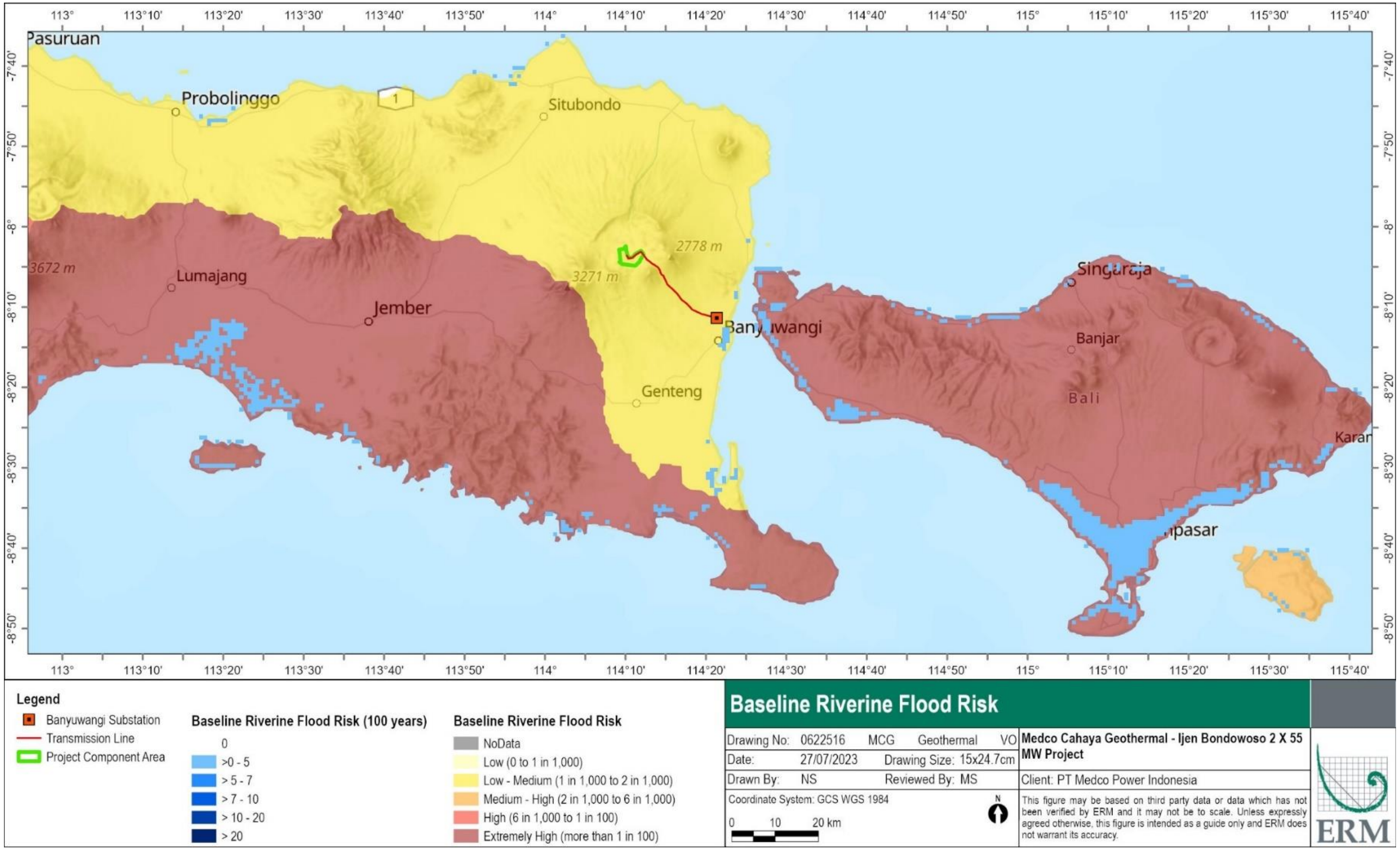


Figure 3-19 Baseline Riverine Flood Risk

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

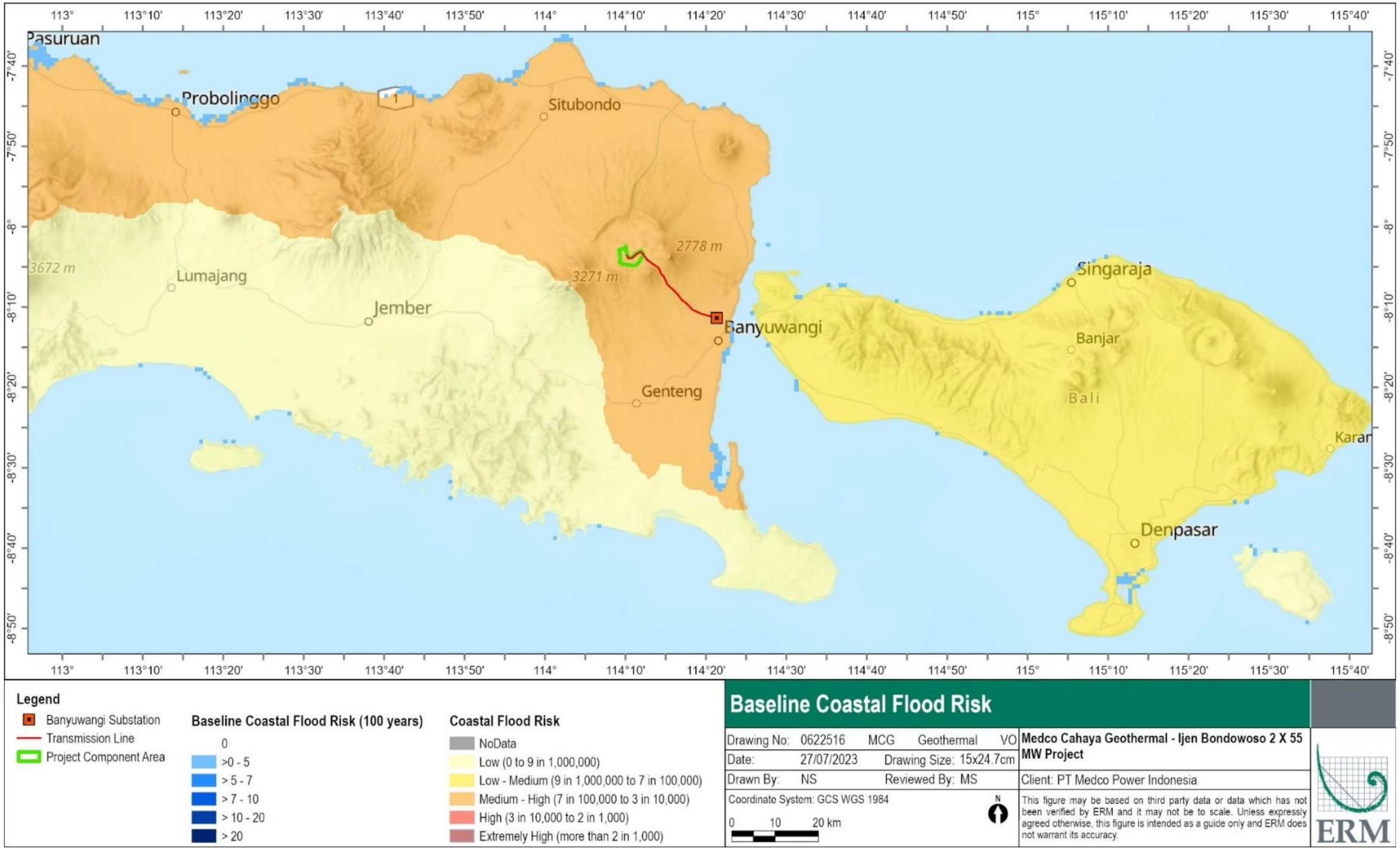


Figure 3-20 Baseline Coastal Flood Risk

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

3.5.2 Climate Change Projection

Flood hazard maps under climate change scenario from WRI-Aqueduct Flood Tool were evaluated to assess the future flood hazard under climate change scenario. Figure 3-21 and Figure 3-22 present the riverine for climate change scenarios of RCP 8.5 2030 and 2040 respectively. Figure 3-23 and Figure 3-24 present the coastal flood maps for climate change scenarios of RCP 8.5 2030 and 2040 respectively, for climate change scenarios of RCP 8.5 (2030), and RCP 8.5 (2040) for 100-year return period flood. Accordingly, the flood hazard due to riverine flooding is projected to remain low with no flood inundation. Similarly, the depth of inundation projected under climate change scenario show no risk of coastal flooding at the Project location. Hence, the overall flood hazard is considered to remain same as the baseline i.e. “**Low**”.

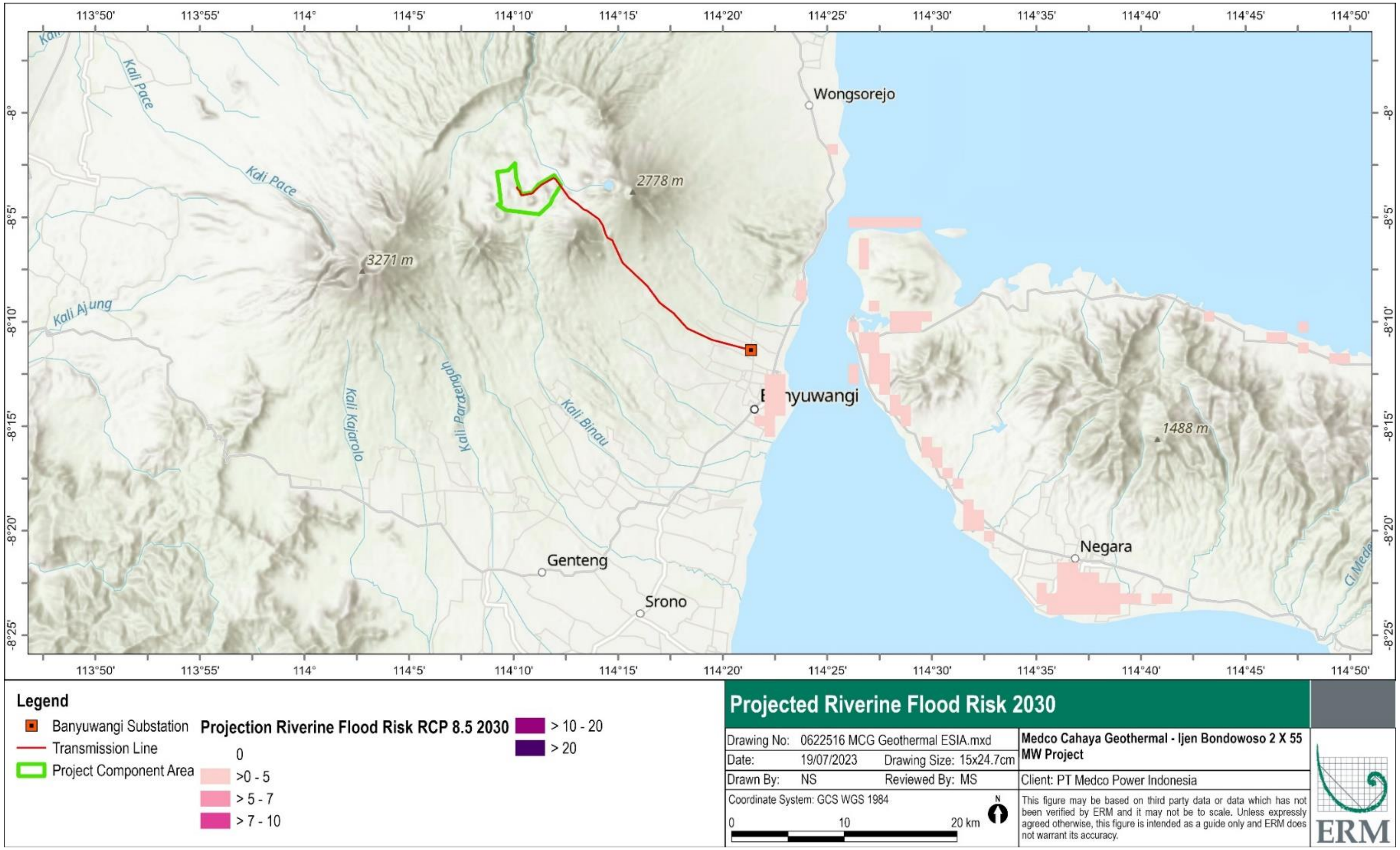


Figure 3-21 Projections of Riverine Flood for RCP 8.5 2030

Source: WRI- Aqueduct Flood. Available at https://www.wri.org/data/aqueduct-floods-hazard-maps

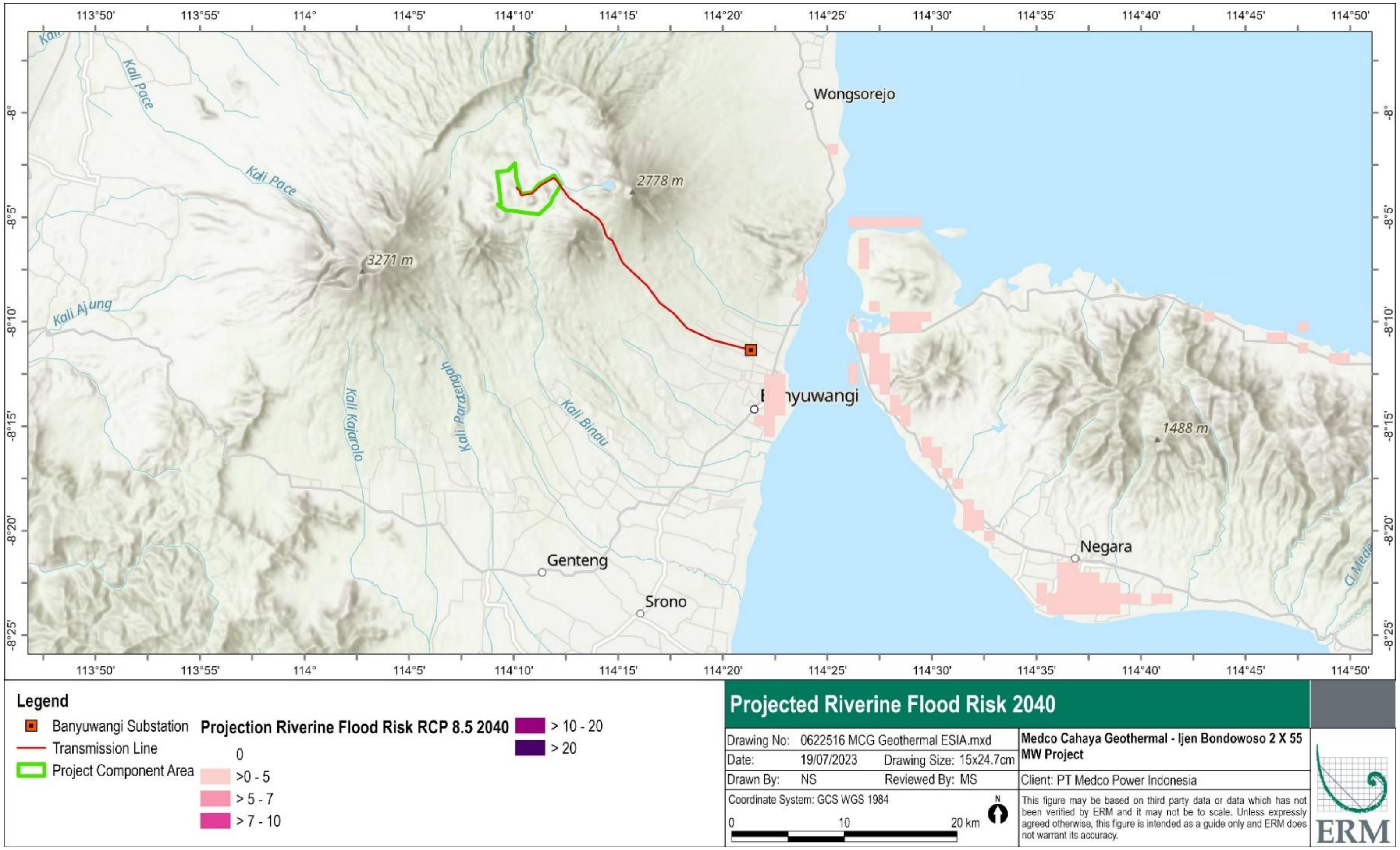


Figure 3-22 Projections of Riverine Flood for RCP 8.5 2040

Source: WRI- Aqueduct Flood. Available at https://www.wri.org/data/aqueduct-floods-hazard-maps

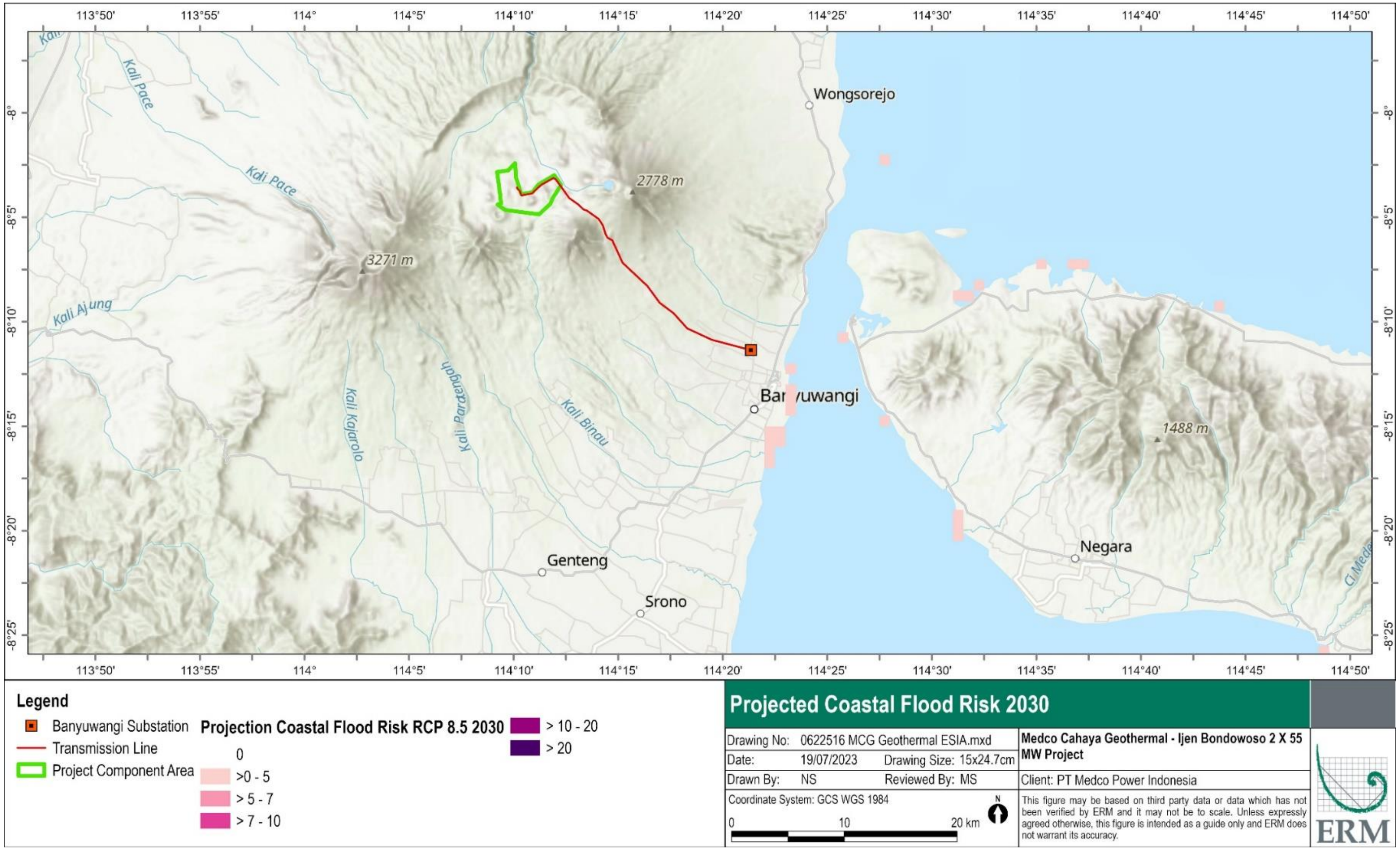


Figure 3-23 Projections of Coastal Flood for RCP 8.5 2030

Source: WRI- Aqueduct Flood. Available at https://www.wri.org/data/aqueduct-floods-hazard-maps

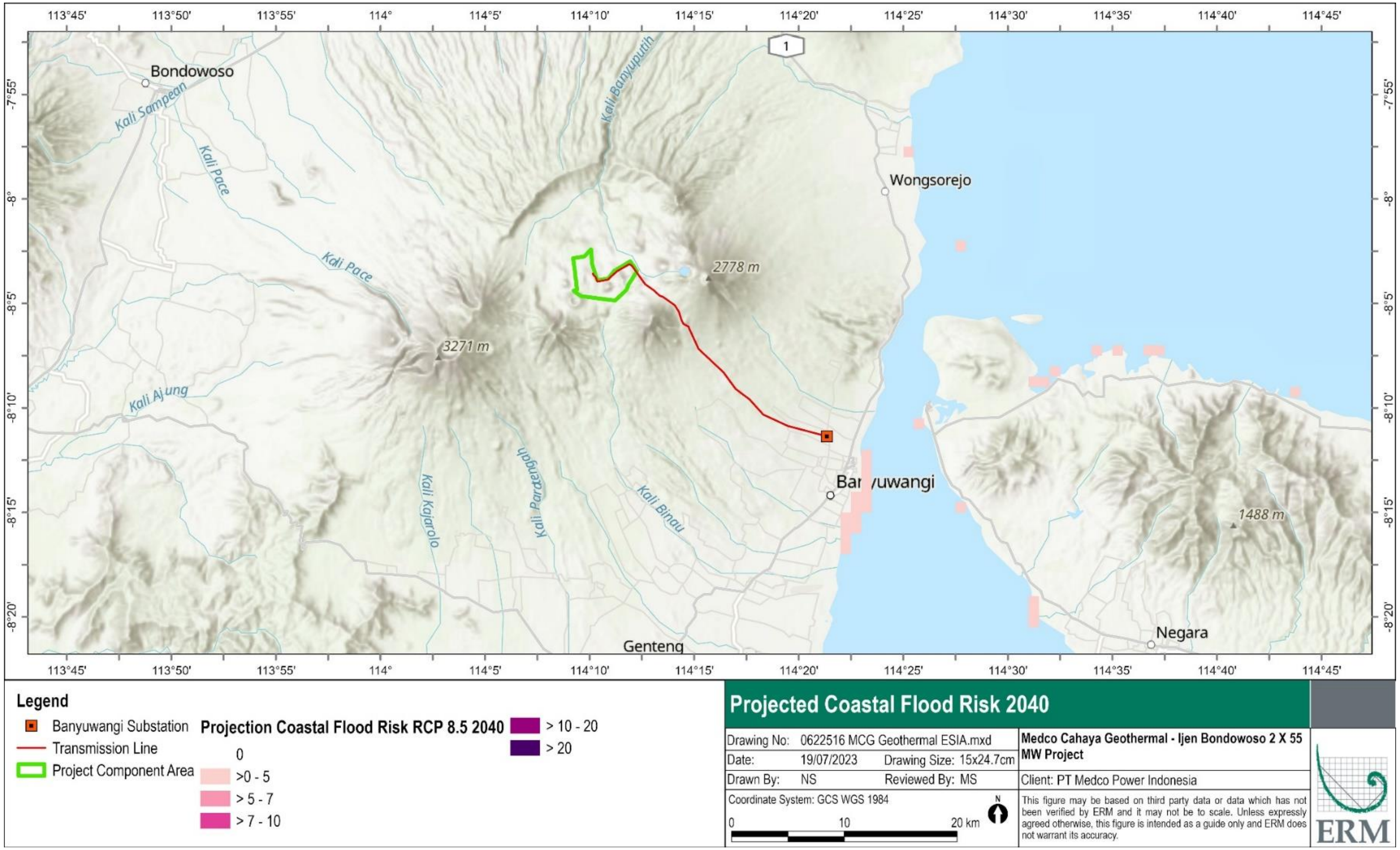


Figure 3-24 Projections of Coastal Flood for RCP 8.5 2040

Source: WRI- Aqueduct Flood. Available at https://www.wri.org/data/aqueduct-floods-hazard-maps

3.5.3 Risk Assessment

The below table provides a qualitative physical risk level for and propose mitigation measures to reduce the impacts for the project.

Table 3.7 Qualitative Risk Level and Project Implications for Flood

	Baseline		RCP 8.5 - 2030	RCP 8.5 - 2050
Risk Level	**Low**		**Low**	**Low**
Implications for the Project	Power Plant	As the power plant is located on a mountain ridge, it is unlikely that a flood could reach the power plant.		
	Transmission Line	Flood and water flow over the Transmission Line poles and towers foundations can generate soil erosion. Recurring events of floods may destabilize the foundation of the Transmission Line and affect its stability. In extreme cases this can affect the line tension between poles and towers.		
Key Potential Impacts	• Damage of infrastructure requiring replacement of components or extra maintenance activities			
Recommended Mitigations	• Design the drainage system taking into consideration flood risk at the Transmission Line pylons located at the lowland areas.			

3.6 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 transmission lines and burial or damage of settlements resulting in loss of life.

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

Landslide 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 hazard.

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 Recovery[29] 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.

3.6.1 Baseline Risk

Landslide susceptibility within study area is reported to vary between “No Hazard” to “Medium” as presented in Figure 3-25. This indicates that the project area is susceptible to landslides owing to factors such as land cover, soil type, and slope. Moreover, the landslide hazard triggered by rainfall map as presented in Figure 3-26 indicate “No Hazard” due to landslides triggered by precipitation within Study area. Moreover, it was reported that the total landslides hazard is between “very low” to “Low” as Figure 3-27. Accordingly, overall hazard due to landslides triggered by precipitation is considered to be **“Low”.**

Based on the information from public databases, the hazard level for landslides is conservatively categorized as **“Low”.**

[29] GIS processing International Centre for Geohazards /NGI. Preprocessing for ThinkHazard! conducted by GFDRR

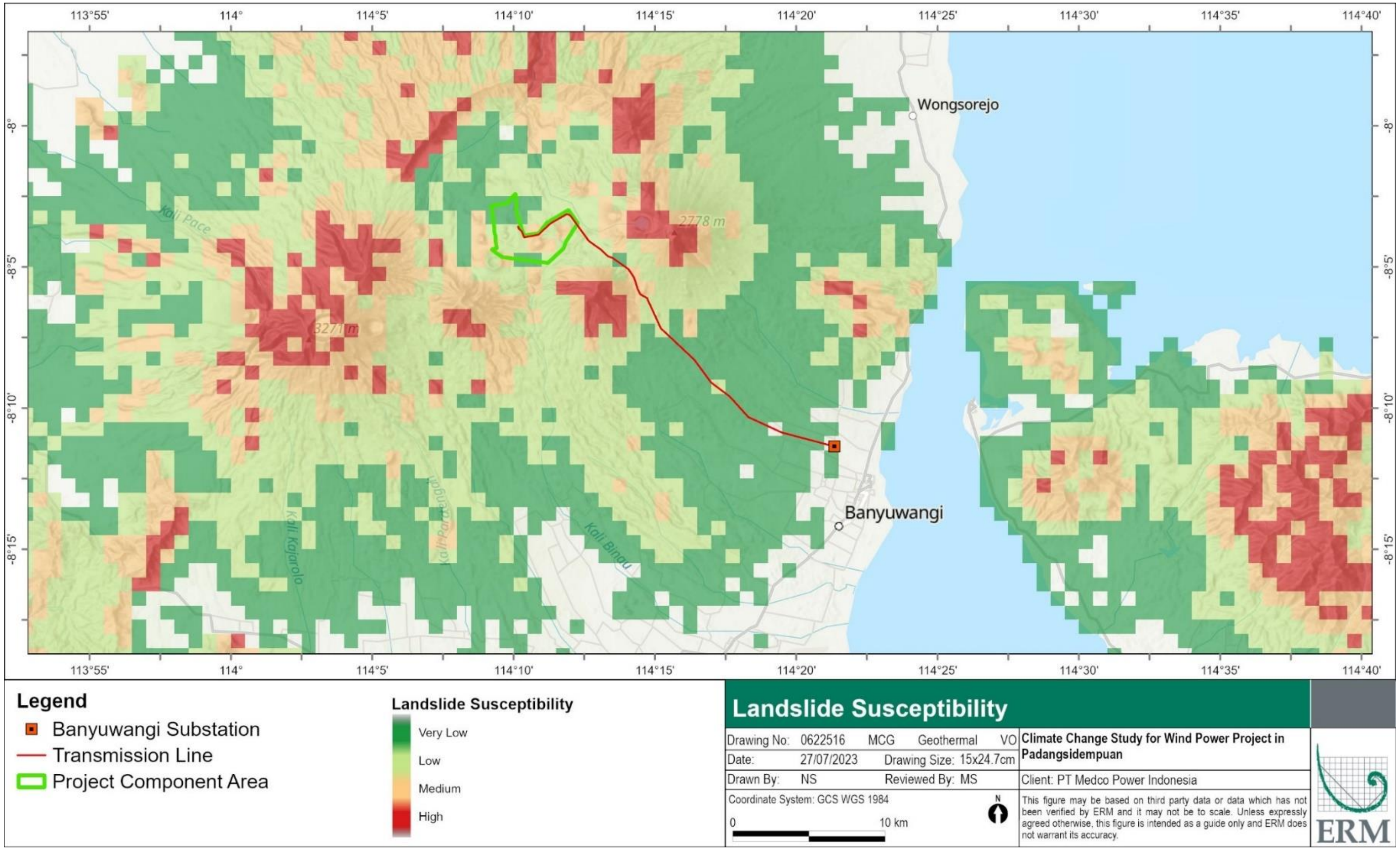


Figure 3-25 Baseline Landslide Susceptibility

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

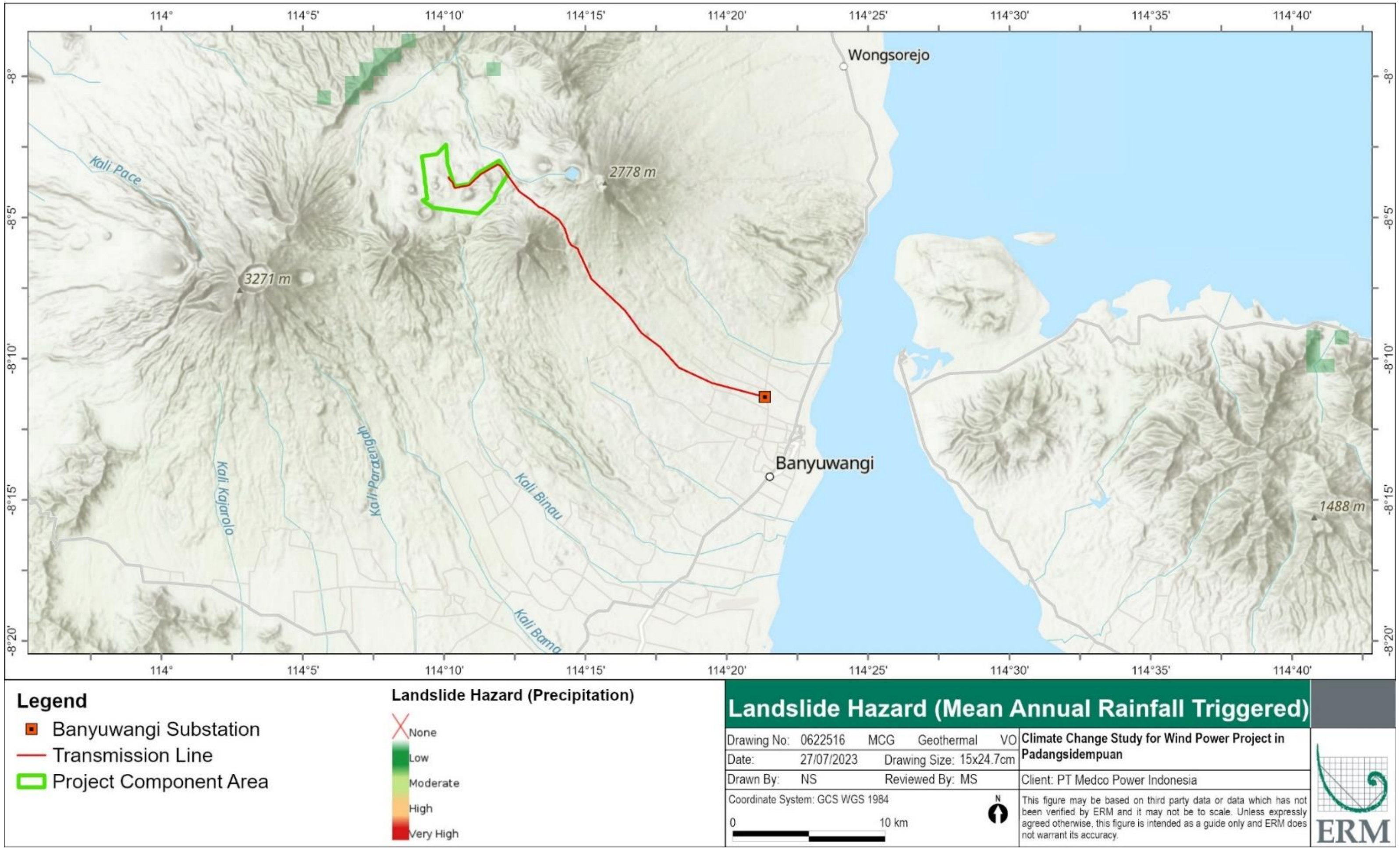


Figure 3-26 Baseline Landslide Hazard: Median Annual Rainfall-Triggered Landslide Hazard

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

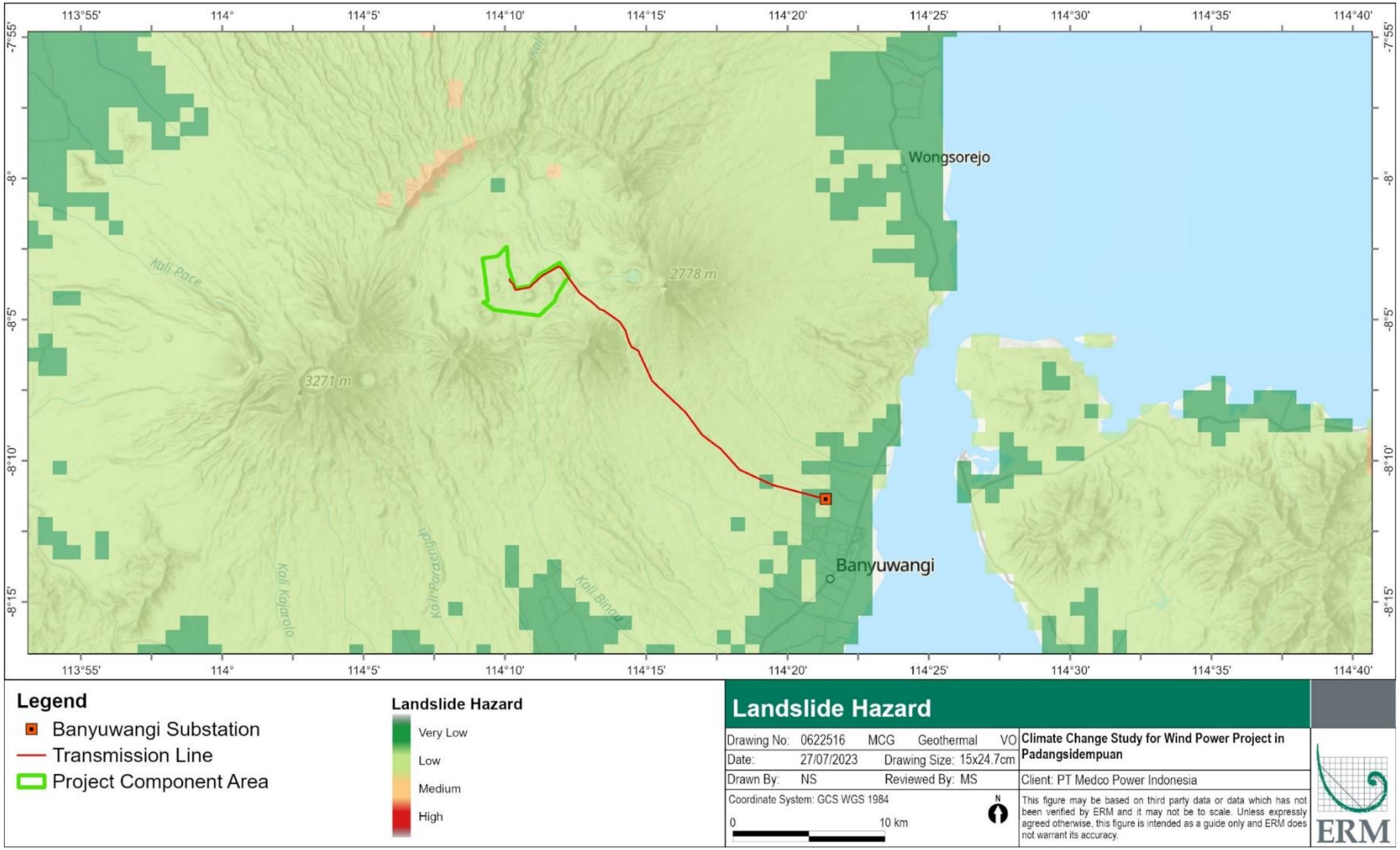


Figure 3-27 Baseline Landslide Hazard

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

3.6.2 Climate Change Projection

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

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

Landslides can be triggered due to two major reasons: earthquakes and precipitation. In this assessment, the landslide hazard at the Site property was evaluated based on the landslides due to precipitation as precipitation is anticipated to be influenced by climate change.

Projected days with precipitation >50mm of Jawa Timur, Indonesia based on the CMIP6 and accessible through the Climate Change Knowledge Portal[30], show that Jawa Timur may experience an increase over the 2040 and 2060 time horizons as Figure 3-28. Additionally, the low risk of landslide in the baseline, the hazard due to landslides triggered by precipitation is considered to remain **"Low"** under all climate change scenarios.

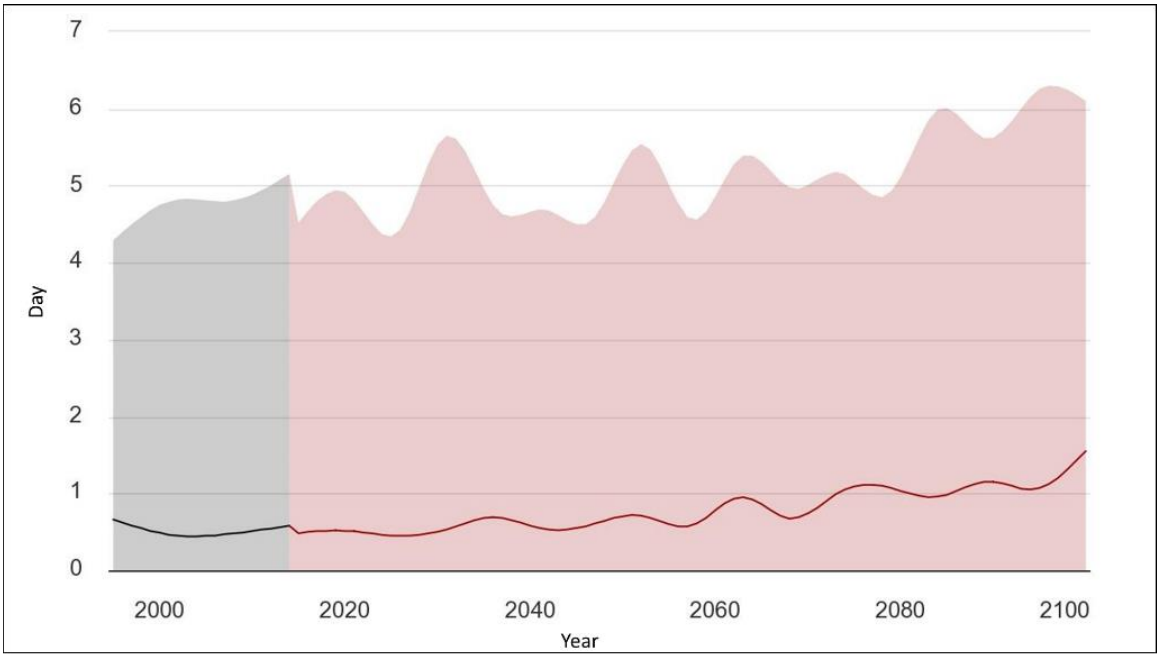


Figure 3-28 Projected days with precipitation >50mm of Jawa Timur, Indonesia; (Ref. Period: 1995 – 2014), Multi-Model Ensemble

Source: World Bank Group, Climate Change Knowledge Portal. Available at: https://climateknowledgeportal.worldbank.org/country/indonesia/climate-data-projections

[30] World Bank Group, Climate Change Knowledge Portal. Available at: https://climateknowledgeportal.worldbank.org/country/indonesia/climate-data-projections

3.6.3 Risk Assessment

The below table provides a qualitative physical risk level for and propose mitigation measures to reduce the impacts for the project.

Table 3.8 Qualitative Risk Level and Project Implications for Landslides

	Baseline		RCP 8.5 - 2030	RCP 8.5 - 2050
Risk Level	**Low**		**Low**	**Low**
Implications for the Project	Power Plant	Landslides might have a severe and perhaps harmful influence on geothermal power facilities, compromising their infrastructure, operations, and safety. However, the project's geothermal power plant is located in a low-risk landslide danger location.		
	Transmission Line	In the event of landslides affecting the Transmission Line, movement of soil at the base of suspension towers may destabilize their foundation and affect their stability. In extreme cases this can affect the line tension between poles and towers. Landslides along the Transmission Line routing may also prevent access to towers and delay operation of management and maintenance.		
Key Potential Impacts	• Extreme short duration but intense rainfall may cause landslides in mountainous/hilly areas where the geothermal construction activities and area of operations are located. These may impact the geothermal activities during construction and commercial operation and maintenance[31] • Landslides may damage transmission lines, decreasing a power plant's capacity to export electricity to the grid and leading to widespread power outages.			
Recommended Mitigations	• Ensure correct drainage of ground water to avoid building up pressure or the building and soil structure. • Reduce the slope of the Project site through ground movement			

[31] INO: PT Geo Dipa Energi (GDP) Geothermal Power Generation Project. Available at Geothermal Power Generation Project: Climate Change Assessment (adb.org)

3.7 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 the purpose of 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).

3.7.1 Baseline Risk

The cyclonic storms are generally classified into five (5) categories based on Saffir-Simpson categorisation of hurricane as summarised in Table 3.9. Figure 3-29 and Figure 3-30 present the cyclone intensity, and historical hurricane tracks maps within the Project area. The historical data is generally available since 1842 as per NOAA. The Project Area was reported in an area not prone to cyclones. Furthermore, review of historical tracks captured by NOAA since 1842 indicates only 1 tropical depression storm that has passed within 100 km radial distance from the Project Area.

The maximum wind speed recorded within 100 km radius of the Site location was reported to be 37.04 km/h (20 knots) during the hurricane GILLIAN in 2014 (as per NOAA) as presented in Figure 3-31.

Based on these maps, cyclone risk was evaluated as “**Low**” at the Site and its surrounding.

Table 3.9 Saffir-Simpson Categorization of Cyclone/Hurricane

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

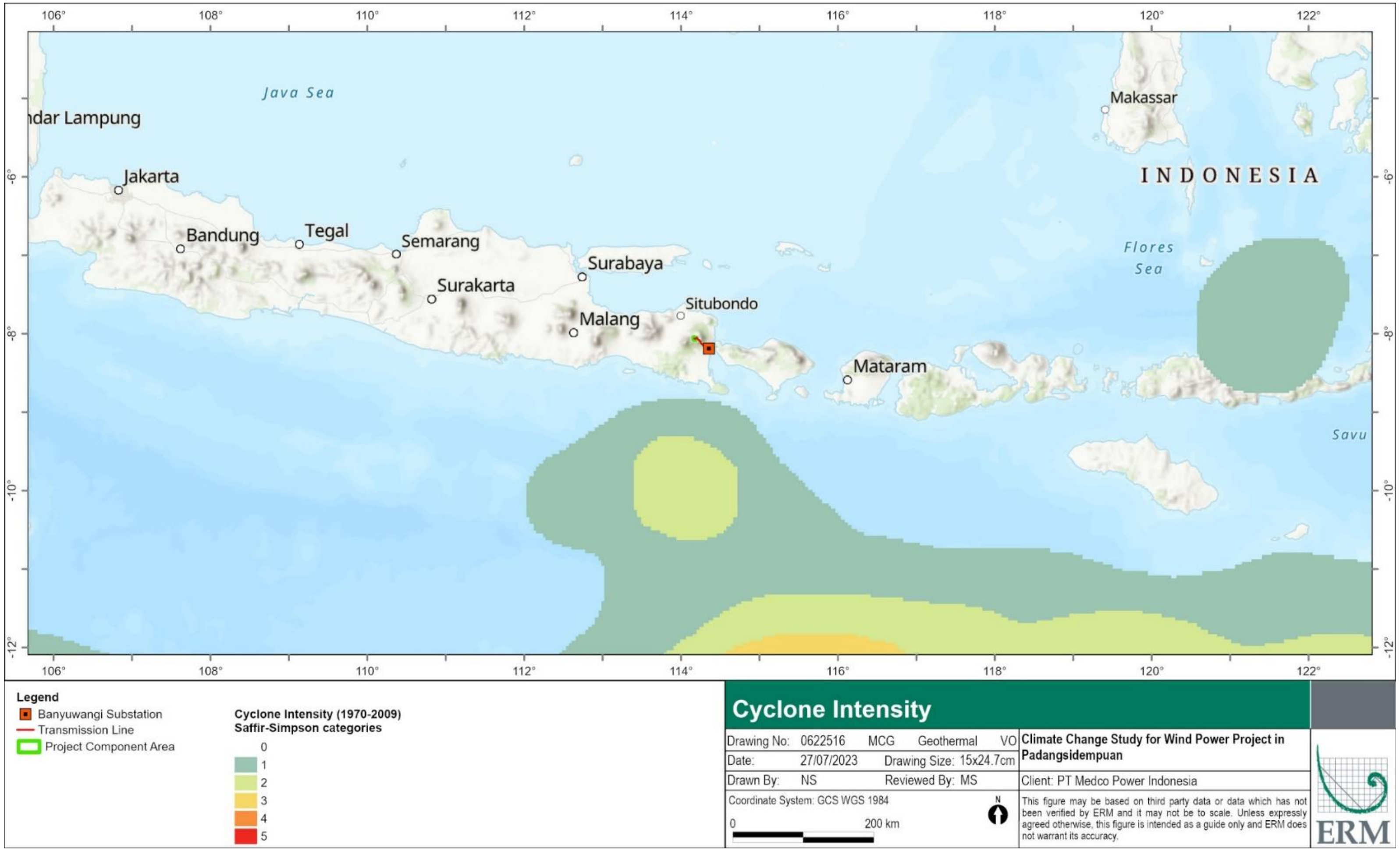


Figure 3-29 Baseline Cyclone Intensity Map

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 (noaa.gov)]

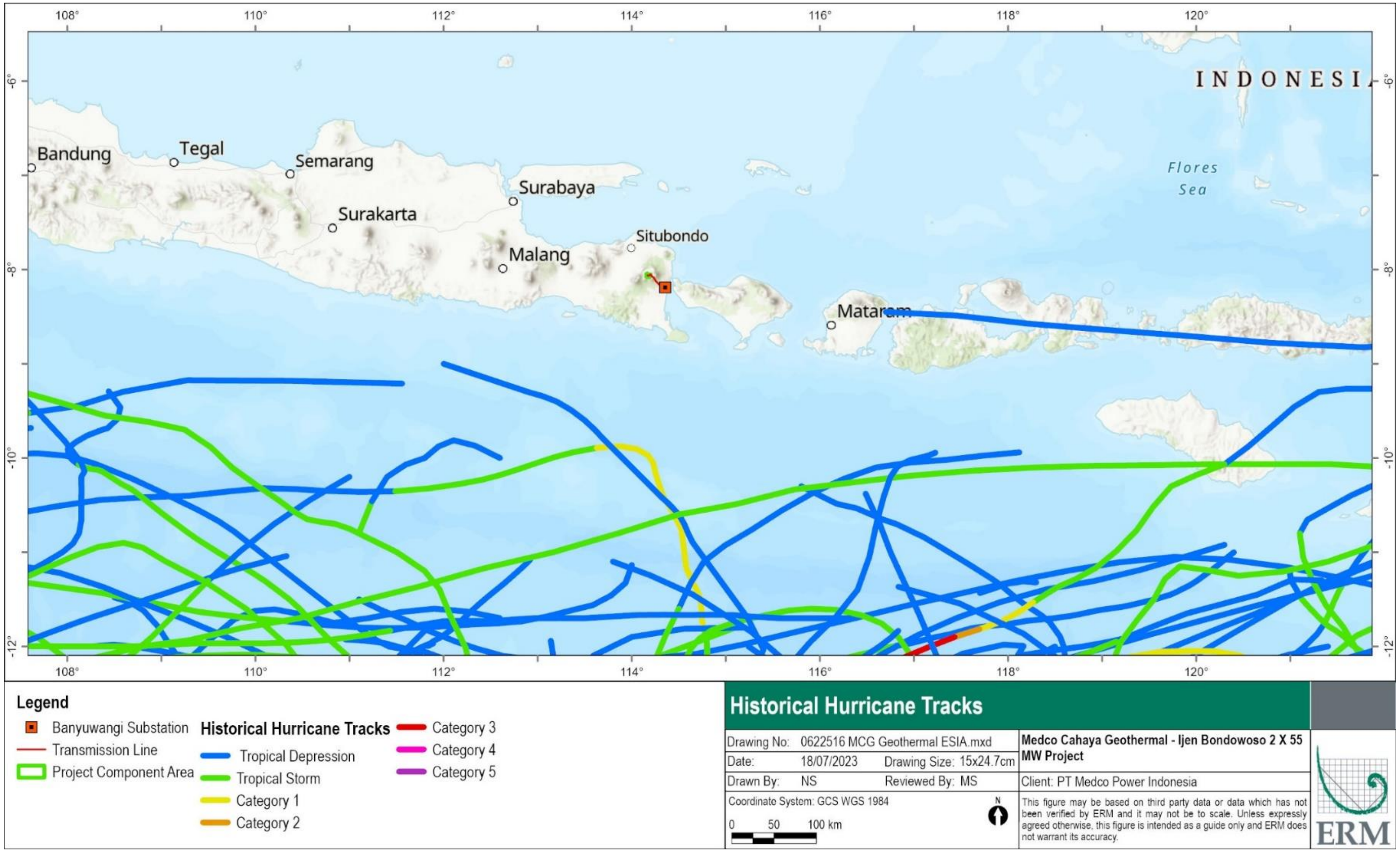


Figure 3-30 Historical Hurricane Tracks Map

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

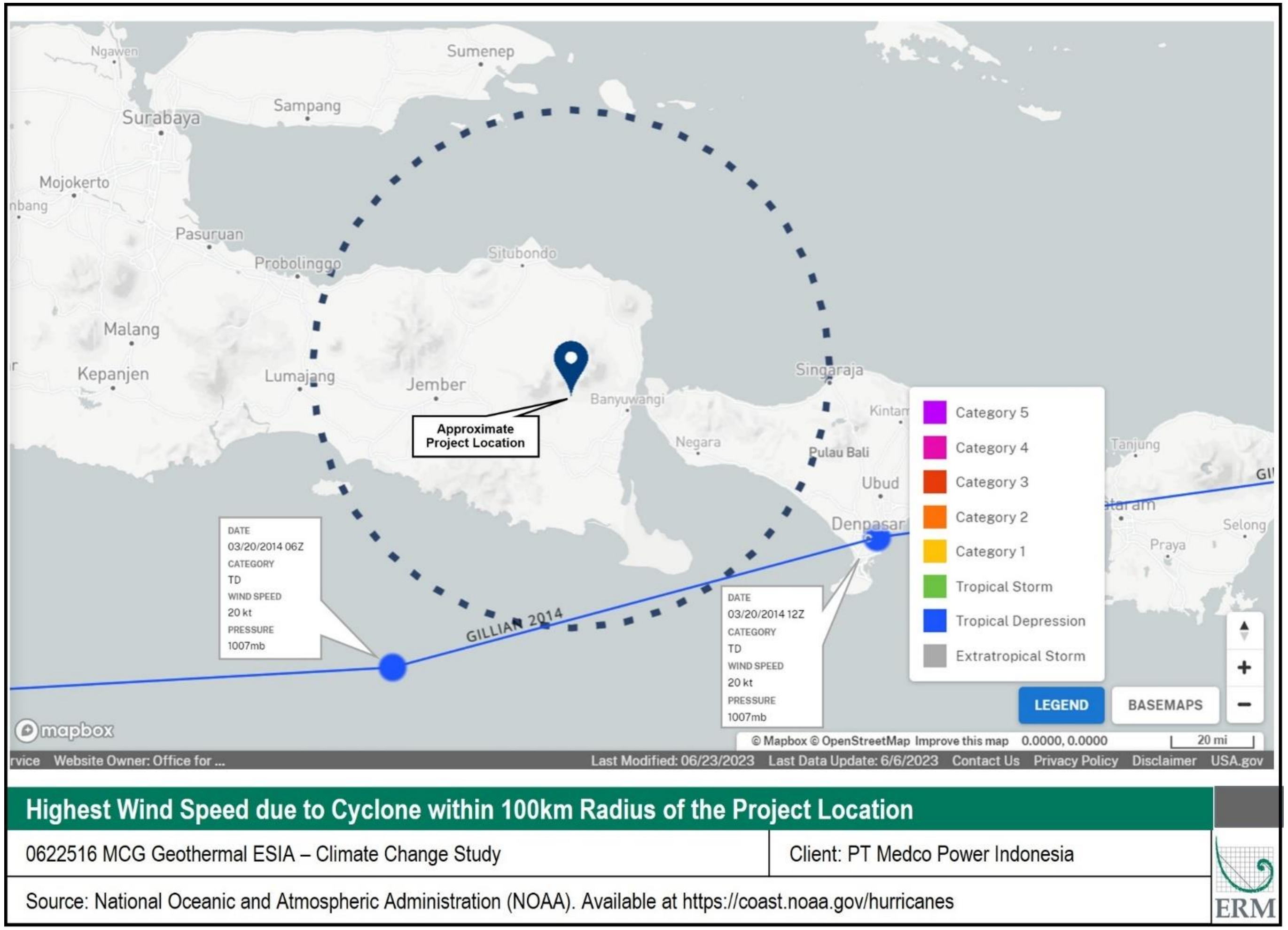


Figure 3-31 Highest Wind Speed due to Cyclone within 100km Radius of the Site Location

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

3.7.2 Climate Change Projection

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

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

Climate change studies suggested likely increase in peak wind intensity and near storm precipitation in future tropical cyclones, and decrease in overall frequency of cyclones. 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 there exists limitations and high uncertainty in simulation of tropical storms.

The report noted similar remarks stating that the limited period of 30-40 years of observations is not enough 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.

According to the World Bank, Indonesia is impacted from the movement of tropical cyclones in the south eastern Indian Ocean between January and April, which bring strong winds and heavy rainfall Increased sea-surface temperatures associated with climate change are projected to increase tropical cyclone intensity[32].

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

3.7.3 Risk Assessment

The below table provides a qualitative physical risk level for and propose mitigation measures to reduce the impacts for the project.

Table 3.10 Qualitative Risk Level and Project Implications for Cyclone and Hurricane

	Baseline		RCP 8.5 - 2030	RCP 8.5 - 2050
Risk Level	**Low**		**Low**	**Low**
	Power Plant	While the intensity of cyclones and hurricanes varies, even those classified as "low risk level" can have a significant influence on		

[32] Climate Risk Profile: Indonesia (2021): The World Bank Group and Asian Development Bank [Available at: https://climateknowledgeportal.worldbank.org/sites/default/files/2021-05/15504-Indonesia%20Country%20Profile-WEB_0.pdf]

Implications for the Project		geothermal power facilities. Cyclones and hurricanes may inflict substantial damage to geothermal power plant infrastructure. Cyclones and hurricanes often bring heavy rain, which can cause extensive flooding and power outages, which may disrupt power plant operations.
	Transmission Line	Extreme wind speed may transfer energy and inflict damage to the structure of Transmission Line. High wind speed can break down the transmission line and may cause power delivery failure.
Key Potential Impacts	• Unlikely to have significant impacts due to the location of the Project site	
Recommended Mitigations	• Accurate weather forecast during operation. • Inspection after any extreme weather event • Ensure that critical equipment is properly maintained, and that backup power systems are in place and functional.	

3.8 Sea Level Rise

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

3.8.1 Baseline Risk

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.

3.8.2 Climate Change Projection

For the purpose of 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[33]. The analysis results show that the project area reported a 23 cm, 43 cm, 70 cm and 104 cm sea level rise in 2040, 2060, 2080, and 2100 respectively as shown in Figure 3-32.

In addition, the elevation of the Project location, power plant, Transmission Line location is approximately 50 - 2,462 m above sea level (Google Earth topography data). Therefore, there is no risk due to sea level rise.

[33] https://www.climsystems.com/slr-cities-app/

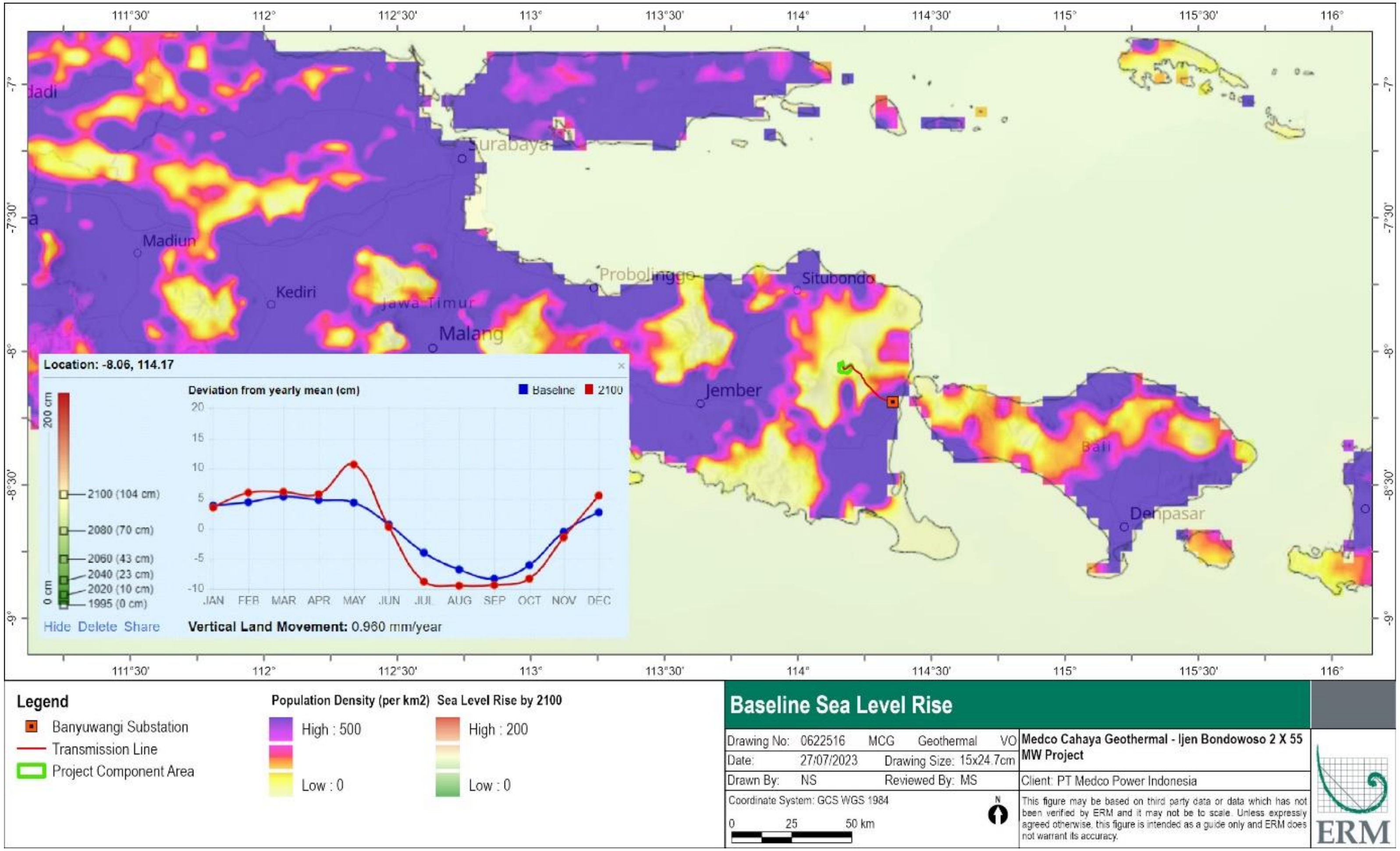


Figure 3-32 Map for Sea Level Rise Projections at Site location

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

3.8.3 Risk Assessment

The below table provides a qualitative physical risk level for and propose mitigation measures to reduce the impacts for the project.

Table 3.11 Qualitative Risk Level and Project Implications for Sea Level Rise

		Baseline	RCP 8.5 - 2030	RCP 8.5 - 2050
Risk Level		**No Hazard**	**No Hazard**	**No Hazard**
Implications for the Project	Power Plant	No implications as located far from areas susceptible to sea level rise.		
	Transmission Line	No implications as located far from areas susceptible to sea level rise.		
Key Potential Impacts	• None identified			
Recommended Mitigations	• None identified			

3.9 Hazard Categorisation

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

Table 3.12 Categorisation of Natural Hazards

Hazard (Criteria for Categorisation)	Original Categorisation	Report Categorization
Water Availability		
Water Stress Source: WRI-Aqueduct Water Risk Atlas 3.0 *(Based on ratio of total water withdrawal to available renewable water resources (surface and groundwater))*	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 *(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)*	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 *(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)*	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 *(Based on population exposed to floods per 1000 people)*	Low: 0-1/1000 (people)	Low: 0-2/ 1000
	Low-Medium: 1-2/1000	Medium: 2-6/ 1000
	Medium-High: 2-6/1000	
	High: 6-10/1000	High: > 6/ 1000
	Extremely High: >10/1000	
Coastal Flood Risk Source: WRI-Aqueduct Water Risk Atlas *(Based on population exposed to floods per 1000000 people)*	Low: 0-9/ 1000000 (people)	Low: 0-9/ 1000000
	Low-Medium: 9-70/ 1000000	Medium: 9-300/ 1000000
	Medium-High: 70-300/ 1000000	
	High: 300-2000/ 1000000	High: >300/ 1000000
	Extremely High:>2000/ 1000000	
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: Moderate
	High: Locations in a 100-year flood zone with a chance of at least 1% of experiencing a flood each year	High: High
Landslides Susceptibility Source: Think Hazard[34]	Very Low	Low
	Low	

[34] GIS processing International Centre for Geohazards /NGI. Preprocessing for ThinkHazard! conducted by GFDRR

Hazard (Criteria for Categorisation)	Original Categorisation	Report Categorization
(The classify hazards based on probabilistic data in Think Hazard)	Medium	Medium
	High	High
Landslides Hazard Source: Think Hazard[35] *(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: Very Low + Low
	Low: >25°C	
	Medium: >28°C	Medium: Medium
	High: >32°C	High: High
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: Category 1
	Category 2: 154-177 km/h	Medium: Category 2
	Category 3: 178-208 km/h	High: ⩾ Category 3
	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
	7: 14-17 m/s	
	8: 17-21 m/s	
	9: 21-24 m/s	High: ≥ 21 m/s
	10: 25-28 m/s	
	11: 29-32 m/s	
	12: >33 m/s	
Sea Level Rise Source: CLIMsystems, Sea Level Rise for Cities *(Combined processes of local (absolute) sea level rise and local vertical land movement expressed in centimetres)*	No original categorisation	Low: 1-50cm
		Medium: 51-150cm
		High: 151-200cm
Lightning Source: Lighting Imaging Sensor (LIS) on TRMM Science Data *(Lightning Density average between 1998 and 2013 expressed as Flashes per km^2)*	No original categorisation	Low:1-20
		Medium: 21-60
		High: >61

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

4. CONCLUSIONS

A Climate Change Risk Assessment was performed for the Project located at Blawan Ijen, Bondowoso East Java by MEDCO Cahaya Geothermal (“MCG”) which is a subsidiary of Medco Power Indonesia.

The Climate Change Risk Assessment consisted of a review of current and future physical hazards in the Project. The future projections were evaluated based on the Representative Concentration Pathways (RCP) 8.5 over timelines of 2030 and 2050. The assessment identified potential high-risk levels for water availability and extreme heat in 2030 and 2050 scenarios.

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

High water stress signifies constrained access to water resources. This scarcity of water supply introduces an obstacle concerning the project's water needs, which includes cooling, condensing, and treatment of geothermal fluids. Consequently, there is a possibility of encountering disruptions in operational processes if the cooling and condensing systems of the plant experience compromised functionality. Such suboptimal performance has the potential to induce periods of operational downtime, thereby giving rise to potential financial setbacks.

To address this risk, it is recommended to include a water risk assessment in the feasibility / engineering studies. This can lead to identification of which project components may implement water conservation measures.

The potential high risk of extreme heat can lead to several consequences. Personnel operating outdoor or in confined spaces may experience heat stress or heat exhaustion. Additionally, extreme heat can cause equipment to overheat or fail, resulting in operational disruptions. This can lead to downtime and reduced power availability.

Therefore, it is recommended to implement water-efficient technologies and practices, such as optimizing cooling systems, reducing leaks, and recycling water, to minimize water usage and increase the plant's water efficiency during extreme heat events. To reduce the risk of adverse effects of extreme heat to Project personnel, it is first recommended providing adequate Personal Protective Equipment for outdoor workers. Second, it's advisable to limit outdoor activities during extreme heat events to reduce exposure. Third, ensure workers are trained to identify symptoms of heat stress and administer first aid as needed. Countermeasures should be taken to address the impacts of heat stress on personnel, particularly workers. Finally, consider developing cool and shaded resting spaces for workers and other external personnel to provide relief from the heat.

The level of risk identified for the different hazards is related to the Project Location and its surroundings. It should be considered as the level of risk of a particular hazard to occur in the investigated location. However, each risk rating has different potential implications to the Project. A series of mitigation measures were proposed to mitigate adverse effects of Climate Change on the Project components, i.e. Power plant and Transmission Line, including considerations on Project personnel. Upon implementation of the recommended mitigation measures, the residual level of risk for the Project was estimated to be low for each hazard category considered.

The information provided in the assessment are intended to advise the Client on possible mitigation strategies. It should not be intended as actual prediction of future extreme events.

Table 4.1 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	Medium	High	High	▪ High water stress implies limited water availability in the region where the geothermal plant is located. This scarcity can pose a significant challenge to the project's water requirements for cooling, condensing, and geothermal fluid treatment. ▪ It could lead to operational disruptions if the plant's cooling and condensing systems cannot function optimally, potentially leading to downtime and revenue loss	▪ Include a water risk assessment in the feasibility / engineering studies ▪ Implement water conservation measures. ▪ Adopt water efficient processes to reduce the water consumption cooling ▪ Explore opportunities for recycle and reuse of wastewater. ▪ Identify water storage infrastructure to ensure uninterrupted water supply during dry period.	Low
Extreme Heat	Medium	High	High	▪ Equipment overheating or failures due to extreme heat can cause operational disruptions, leading to downtime and reduced power availability. ▪ Workers involved in outdoor operational and maintenance activities may be exposed to extreme heat events and suffer heat stress or heat exhaustion.	▪ Provide adequate Personal Protective Equipment to work outdoor. ▪ Limit outdoor activities during extreme heat events. ▪ Implement water-efficient technologies and practices, such as optimizing cooling systems, reducing leaks, and recycling water, to minimize water usage and increase the plant's water efficiency during extreme heat events. ▪ Train workers to identify the symptoms of heat stress and first aid. Take necessary measures to counter heat stress impacts to personnel, especially workers. ▪ Develop cool and shaded resting spaces (indoor or outdoor) for workers and other external personnel.	Low

Hazard	Baseline	RCP 8.5 2030	RCP 8.5 2050	Key Potential Impacts	Mitigation Measures	Residual Risk Level
Wind Speed (Average)	Low	Low	Low	▪ Extreme wind speeds may have an impact on transmission lines, which are critical for delivering power generated at the plant to the electric grid.	▪ Regular maintenance of the Transmission Line right of way to ensure is free from obstacles and vegetation that may fall on the line during extreme wind events.	Low
Wind Speed (Maximum)	Low	Low	Low			Low
Lightning	Medium	Medium	Medium	▪ Operational disruptions caused by lightning-related damage may lead to downtime, reducing the geothermal plant's electricity generation and data transmission and control systems, which are crucial for the plant's efficient operation and safety. ▪ It may trigger fires, which can pose a risk to the geothermal plant's infrastructure and surrounding areas that poses a risk to personnel, equipment, and the environment.	▪ Follow national standards in order to prevent damage from lightning. ▪ Install lightning arresters and earthing rods. ▪ Creating and updating emergency response plans that address lightning-related hazards, such as fire prevention and worker safety, on a regular basis.	Low
Flood	Low	Low	Low	▪ Damage of infrastructure requiring replacement of components or extra maintenance activities	▪ Design the drainage system taking into consideration flood risk at the Transmission Line pylons located at the lowland areas.	Low

Hazard	Baseline	RCP 8.5		Key Potential Impacts	Mitigation Measures	Residual Risk Level
		2030	2050			
Landslides	Low	Low	Low	▪ Extreme short duration but intense rainfall may cause landslides in mountainous/hilly areas where the geothermal construction activities and area of operations are located. These may impact the geothermal activities during construction and commercial operation and maintenance ▪ Landslides may damage transmission lines, decreasing a power plant's capacity to export electricity to the grid and leading to widespread power outages.	▪ Ensure correct drainage of ground water to avoid building up pressure or the building and soil structure. ▪ Reduce the slope of the Project site through ground movement	Low
Cyclone and Hurricane	Low	Low	Low	▪ Unlikely to have significant impacts due to the location of the Project site	▪ Accurate weather forecast during operation. ▪ Inspection after any extreme weather event ▪ Ensure that critical equipment is properly maintained, and that backup power systems are in place and functional.	Low
Sea Level Rise	No Hazard	No Hazard	No Hazard	▪ None identified	▪ None identified	Low

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