Water Sustainability Assessment Program: Osotspa Ayutthaya Plant Bang Pa-In District, Phra Nakhon Si Ayutthaya

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Acronyms and Abbreviations

Name	Description
AST	Above Ground Storage Tank
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
ERM	Environmental Resources Management
DIW	Department of Industrial Work
DGR	Department of Groundwater Resources
DMR	Department of Mineral Resources
LaSII	Land Subsidence International Initiative
PWA	Provincial Water Authority
OSP	Osotspa Public Company Limited
OSP-AY	Osotspa Ayutthaya Plant
RO	Reverse Osmosis
SGI-AY	Siam Glass Industry Co., Ltd.
SBM	Siam Bev Manufacturing Co., Ltd.
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UST	Under Ground Storage Tank
WSA	Water Sustainability Assessment
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant
MCM, Mm^3	Million Cubic Meter
MSL	Mean Sea Level
m	Meter
km	Kilometre
m bgl	Metre below ground level

EXECUTIVE SUMMARY

ERM-Siam Co., Ltd (hereinafter referred to as ERM) was commissioned by Osotspa Public Company Limited (referred to as "Osotspa"/Client"), for undertaking Water Sustainability Assessment Program (WSP) for their three (03) operational units involved in manufacturing of beverage and glass bottles (referred as "Site" / "Facility" / "Plant") as listed below;

- Osotspa Ayutthaya Plant (hereinafter referred to as the 'OSP-AY')
- Siam Glass Industry Co., Ltd. (hereinafter referred to as the 'SGI-AY')
- Siam Bev Manufacturing Co., Ltd. (hereinafter referred to as the 'SBM')

This report represents the Water Sustainability Assessment for the aforementioned Site. The Site is located at 48/9 Moo 7, Asian Highway Road, Khlong Suan Plu Sub-district, Phra Nakhon Si Ayutthaya Province of Thailand.

The objectives of the assessment consist of the following:

- Identify current and future risks associated with freshwater availability and develop appropriate mitigation actions; and
- Enable Osotspa to evaluate its freshwater management position for its high freshwater withdrawal assets.

The approach of this assessment included;

- Review of secondary data available in the public domain and that provided by the Site. This also included catchment delineation and characterization;
- Quantifying water availability using secondary information, future climate change assessment by using World Resources Institute (WRI) Water Risk Framework results, changes in land use and land cover and socioeconomic development in the region for 2030 and 2040;
- Water risk evaluation for both direct operations and source water-related supply that the Site relies on;
- Developing Site level water resource management plans to mitigate future water risks for business resilience;

The Site visit was performed on 25th August 2022 by ERM assessors Ms. Yaneenart Vinittumkul and Ms. Sutima Paaopanchon with the support of Osotspa personnel during the Site visit as well as Site perception survey was conducted between 5th to 6th September 2022 by Mr. Pongpoth Pinitpreecha, Mr.Krittaphas Denpaiboon, Ms. Nooch Soodcharoen and Ms. Rattiya Konsalad.

The primary source of water to the Site is groundwater which is withdrawn from five (5) on-site bore wells drilled up to a depth of approximately 100 - 190 meters deep below ground level (m bgl) and additional supply water from Provincial Water Authority (PWA).

Climate and Groundwater Assessment

As the primary water source of the Site is the Groundwater, so in order to understand its conditions in the baseline and future years for RCP4.5 (Representative Concentration Pathway with 4.5 W/m^2 radiative forcing) and RCP8.5 (Representative Concentration Pathway with 8.5 W/m^2 radiative forcing) climate scenario, ERM used Aqueduct tool. The tool was developed by the World Resources Institute (WRI) which has indicators of water quantity, water variability, water quality, public awareness of water issues, access to water, and ecosystem vulnerability. To understand the current status of water use ERM used the *Baseline Water Stress* indicator. To gain some perspective on future water stress, the *Projected Change in Water Stress* indicator was used. To understand current intra-annual variation in water availability, the *Seasonal Variability indicator* was used and to understand projected intra-annual variation in water availability *Projected Seasonal Variability indicator* was used;

Based on the results from Aqueduct tool, the baseline water stress is indicated to be “High” due to the competition among multiple stakeholders dependent on a common water resource. Projected water stress is also classified as “Medium-High” due to the increase in project rainfall. Seasonal variability is classified as “High” and the project seasonal variability is classified as “High” resulting in flooding in the wet season or acute water scarcity during the dry season.

Further, the status of groundwater is assessed in the entire country, Phra Nakorn Si Ayutthaya province, and the Site using secondary sources and available observed data from the local government agency. ERM also analyzed reports on Geology, Hydrogeology and Groundwater quality. Groundwater aquifers underlying water basins in Thailand are recharged by rainfall and seepage from rivers. Thailand receives abundant rainfall and therefore, groundwater availability in aquifers fluctuates with seasonal variability and the region’s annual precipitation. In 2019, Thailand’s reported annual groundwater recharge from rainfall is approximately 72,987 Mm^3/year in which the quantity available for use is up to ~45,385 Mm3/year. Thailand has a total of ~30,645 Mm^3/year of groundwater potential for use per year. It was reported that Thailand only extracts about 33% of the total volume of groundwater aquifer that is recharged in a year. To track the changes in groundwater level and quality, public owned observation bore wells are installed throughout Thailand. There are 121,851 private-owned bore wells in Thailand. Department of Groundwater Resource reported that the demand for groundwater has increased in the past years as Thailand faces more severe and prolonged droughts as well as the deterioration of surface water surface quality. As a result, groundwater levels tend to decrease in some areas during the year.

The groundwater level in Phra Nakorn Si Ayutthaya province is reported to be unchanged or slightly changed due to the amount of rainfall with no more than 1 meter per year. Phra Nakorn Si Ayutthaya Province is classified as a **Critical Zone** where groundwater is withdrawn in excess of the amount of groundwater replenishment resulting in a decrease in the groundwater level, land subsidence and diffusion of saltwater into the groundwater in coastal areas. The nearest monitoring station to the Site is located in Ban Krot Sub-district at which four (4) monitoring wells are installed. The depth of these bore well ranged from 198-270 m below ground level and water level of 19-39 m.

There are a total of five (5) bore wells installed within the Site premise which is up to a depth of ~ 100-190 m below ground level tapping the Phra Pradaeng and further beyond the Nakhorn Luang Aquifer of the Chao Phraya River Basin. Four of them were reported to be in operation and another was reported to be on standby. It was reported that the Site operates only one bore well at a time for an average of 10 hours per time, chosen based on the locational distance between each well and their groundwater yield. Nevertheless, it was reported that the Site has never conducted groundwater level monitoring as it is not required by local regulation. According to the Site activities, it is expected that the groundwater vulnerability due to unscientific application of agrochemicals via agricultural run-off is considered to be ‘low’ to ‘moderate’.

The quality of groundwater in Thailand is generally high in iron and manganese, and the western area shows an elevated concentration of fluoride values. The location where the Site is located is reported to have a high Manganese concentration in groundwater. Groundwater quality monitoring of each bore well are conducted by the Site personnel on daily basis using automatic probes for measuring the following parameter, conductivity, turbidity and pH. The physical and chemical parameters conducted by external laboratory under Department of Groundwater on monthly basis.

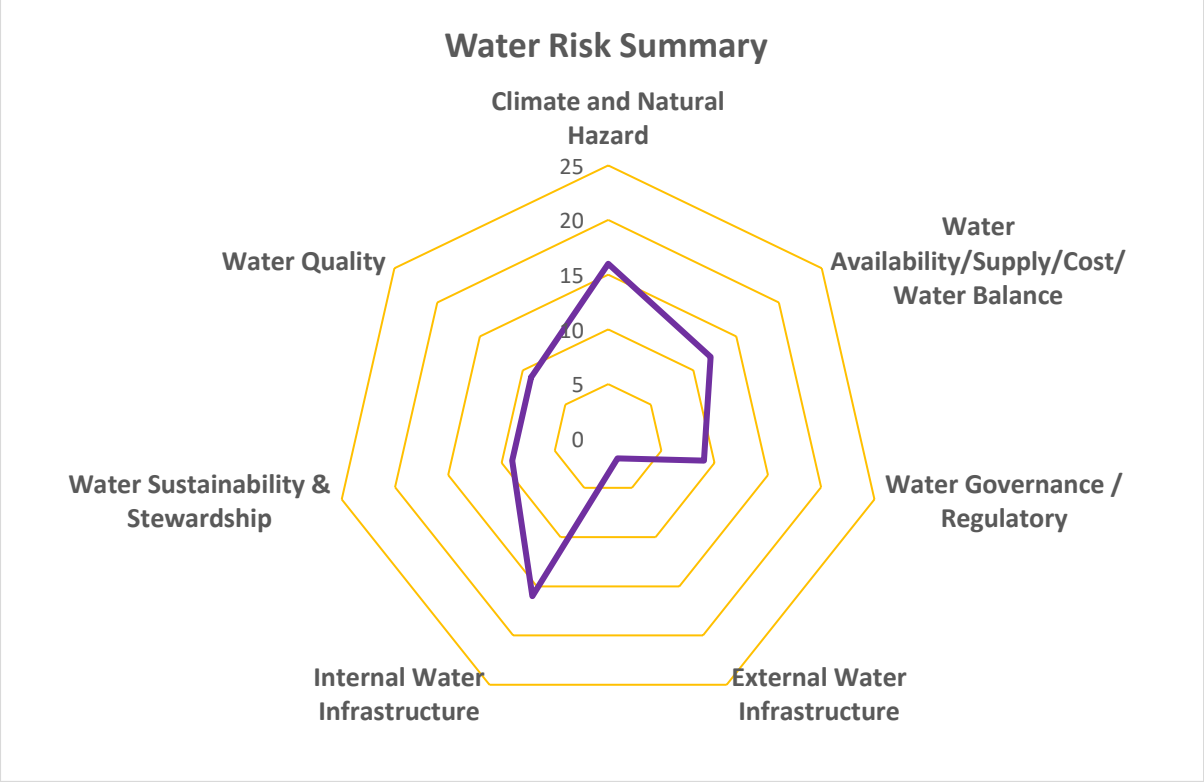
Water Risk Assessment

As part of the water risk assessment, ERM first gathered information about the primary (groundwater) and secondary water source (PWA water supply) to the Site from the institutional structure and stakeholders within the Phra Nakhon Si Ayutthaya province, who are involved in water governance, management, and supply. To evaluate the risk associated with the water supply, ERM reviewed potential hazards that may pose risk to the water supply based on hazard risk assessment. In addition, media reports and Site input were reviewed to understand historical water-related business interruptions and developing concerns that may pose a hazard in the future. A ‘Probability-

Consequence Matrix' approach was adopted with a pre-defined qualitative interpretation of risk severity specific to the current assessment for categorizing and prioritizing risks for mitigation action.

From the analysis, it was understood that the Phra Nakhon Si Ayutthaya Province is categorized under "**Critical**" groundwater zone due to the declining groundwater levels and land subsidence in the area. The Site is located in an area with "**High**" susceptibility to subsidence. It was reported by the Site that they have not faced any disruptions to their water infrastructure/supply because of land subsidence in the past. However, continuous abstraction of groundwater can exacerbate the rate of land subsidence and cause possible damage to the integrity of buildings and water infrastructure like water pipelines, sewer drains, etc.

Other hazards that may pose risk to the Site water infrastructure and water supply from PWA include damage from flooding. The Phra Nakhon Si Ayutthaya province is highly prone to floods caused by water run-off. The Site has carried out a flood impact assessment on-site, however, the mitigation plan is underway and not fully implemented. The summary of water-related risk attributes and their risk factor was qualitatively evaluated and categorized in a risk matrix and presented in the spider diagram as shown below;



The study showed that the Site only monitors three (03) parameters for raw water obtained from the bore wells and PWA water. Although all three parameters were found to be compliant with the "Thailand Drinking Water Standards", it is critical that the Site analyses the raw water for a comprehensive suite of analytes to avoid any risks associated with the introduction of contaminants into aquifer/surface water bodies from the discharge of domestic wastewater directly into water bodies by surrounding communities as observed during the environmental and perception survey. Further, the treated wastewater analyzed as per the "Effluent Standards for factories set by the Ministry of Natural Resource and Environment" does not account for all the parameters addressed in the standard like heavy metal, pesticides, and microbiological parameters. Currently, only nine (09) out of sixteen (16) parameters are analyzed by the Site.

The on-site WWTP at the OSP-AY Plant has reported several incidences (from August 2021 to December 2021) where the WWTP operated exceeding (~3,150 m^3/day) its maximum design capacity of 2,500 m^3. It was documented that the exceeding events were due to the maintenance of the WWTP

system including, cleaning or maintenance of the retention pond and re-treating of wastewater from MSBR tanks. It was informed that the existing infrastructure was capable of handling the surplus amount, however, this sudden influx in wastewater can reduce the efficiency of the treatment process and pose risk to the quality of the treated wastewater produced from the WWTP. Further, it was reported that the treated wastewater from the WWTP was reused for gardening, in cooling towers and toilets. However, the Site has not determined the acceptable hydraulic loading rate for the land within its boundaries to estimate the optimum land application/discharge rate. Excessive land application of recycled water is likely to result in run-off and infiltration of applied wastewater into the nearby soils and shallow groundwater, in turn resulting in potential soil and groundwater impacts.

In the case of the SGI-AY Plant, it is not allowed to discharge the treated wastewater from its on-site WWTP as per the regulations set by the authorized agency. As a result, the treated wastewater is stored in the retention pond and allowed to evaporate for its disposal. It was found that the retention pond was not provided with a concrete lining. Further, the Site has not determined the evaporation rate as well as quantified (no flow meters are installed) the volume of treated wastewater discharged into the retention pond. Thus, there is a possibility of infiltration of treated wastewater into the soil and groundwater table resulting in contamination of the water source.

Site is also considering increasing the ratio of PWA water (currently 25%) to reduce groundwater abstraction in the future. However, the source of water to the PWA is currently not known. Other water supply infrastructure information like the water treatment plant catering to PWA water, the raw water quality status, the intermediate reservoirs, transmission pipelines, etc is not known. This information is extremely critical to assess the risks associated with them in case the Site diverts to PWA supply as its primary source of water. Due to the lack of information at this point, the risks associated with them could not be identified.

Further, future regulatory changes associated with groundwater abstraction and water supply from PWA in the form of revisions to water tariffs were identified as a potential risk in the future.

Considering the magnitude of the Site's overall water requirement (~1656 MLD), the Site is recommended to pursue ambitious goals towards water use optimization as an integral part of water risk mitigation action. ERM has identified opportunities to enhance conservation efforts which include the development of a scientific water balance for all three operational units, cooling tower management, installation of piezometers, reusing treated wastewater, and installation of flowmeters (at the SGI-AY Plant), etc. This would reduce the dependency on freshwater resources to a smaller extent as well as contribute to the Site's sustainability commitments. However, in a worst-case scenario of complete disruption of the existing water supply arrangement (an emergency), the Site would have to procure ~1656 MLD of freshwater from an alternate source. To be prepared for such emergencies, the Site needs to identify alternate water sources to serve as an aid in evaluating the feasibility of maintaining an uninterrupted water supply to the Site in case the existing arrangement is unable to cater to the minimum volume of water required for normal operations during extreme water stress periods and emergencies. The Site could also harvest rainwater and use it as an alternate source.

Based on a broad level understanding of the Site's water usage pattern, concerns associated with water security, and the current level of water-related action beyond the Site boundary, ERM has developed a holistic approach towards water resources management, which includes a combination of water use optimization, emergency preparedness, and long-term sustainability. A water risk mitigation and resource management plan is developed based on risks and is summarized in the table below.

Risk Factor	Mitigation Measure
'Extreme Emergency' resulting from disruption of existing established water supply from	**Internal Measure:** Prioritization of critical operations and quantity of water required
	Internal Measure: Create Additional On-Site Buffer Storage Capacity for 2-3 days

Risk Factor	Mitigation Measure
on-site bore wells and PWA	**Internal Measure:** Identify and establish alternate water supply arrangements –
Possible increase in water tariffs	**Internal Measure:** Sensitivity Analysis of the cost of water
Water Quality	**Internal Measure:** Monitoring of raw water quality for a comprehensive suite of analytes Monitoring of treated wastewater quality for a comprehensive suite of analytes
Water Sustainability & Stewardship	**Internal Measure:** Water Use Optimization (water conservation + harvesting rainwater)
	External Measure: Collective Water Conservation (lead the way for other industries to join the movement) Catchment Level Stewardship Action (to be evaluated) Stakeholder engagement plan Positive contribution to good water governance in the catchment. Identification of private water trucking vendors.

1. INTRODUCTION

1.1 Scope of work

ERM-Siam Co., Ltd (hereinafter referred to as ERM) was commissioned by Osotspa Public Company Limited (referred to as "Osotspa"/Client"), for undertaking Water Sustainability Assessment Program (WSP) for their three (3) operational beverage and glass bottle manufacturing plants named as follow;

1.) Osotspa Ayutthaya Plant (hereinafter referred to as the 'OSP-AY')

2.) Siam Glass Industry Co., Ltd. (hereinafter referred to as the 'SGI-AY')

3.) Siam Bev Manufacturing Co., Ltd. (hereinafter referred to as the 'SBM')

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The Site visit was performed on 25 August 2022 by ERM assessors Ms. Yaneenart Vinittumkul Ms. Sutima Paaopanchon under Osotspa personnel support to ERM during the Site visit as well as Site perception survey conducted between 5th to 6th September 2022 by Mr. Pongpoth Pinitpreecha, Mr.Krittaphas Denpaiboon, Ms. Nooch Soodcharoen, and Ms. Rattiya Konsalad.

WSA has been conducted to evaluate current (and forward-looking to the extent possible) water-related issues and/or risks associated with the subject facility. Major tasks undertaken as part of this assessment are presented in the following **Figure 1-1**.

 # WSA is recommended to be updated every 3 to 5 years.

Figure 1-1 Approach for WSA

1.2 Reliance

The Final Report can then be circulated to interested third parties on condition that the report is disclosed in its entirety for information purposes only. Third parties could rely on ERM report based on the facts. ERM's contractual liability is only limited to the purchaser of the service (Osotspa) and ERM's liability would not extend to third parties, except in the case of professional negligence. Third parties can obtain reliance on ERM's report, subject to agreement to the Terms and Conditions used between the Client and ERM, and each party signing an appropriate reliance letter.

1.3 Limitations

This Report is based upon the application of scientific principles and professional judgment to certain facts with subjective interpretations. Professional judgments expressed herein are based on the facts currently available within the limits of the existing data, scope of work, budget, and schedule. It is specifically ERM's intent that the conclusions and recommendations stated herein will be intended as guidance and not necessarily a firm course of action except where explicitly stated as such. We make no warranties, including, without limitation, warranties as to merchantability or fitness for a particular purpose. In addition, the information provided to Osotspa in this Report is not to be construed as legal advice.

ERM has made, pursuant to the project scope, budget, and schedule, reasonable efforts to obtain relevant information from relevant federal or state-level statutory bodies, NGOs, and other government sources. However, based on ERM's past experience with government officials and statutory bodies, we cannot guarantee that these efforts will necessarily yield complete information.

In that information requested by Osotspa under this assignment may in certain circumstances be derived from or based on verbal communications with government officials/ statutory bodies (rather than official written sources), there can be no assurance that the said information is complete, representative, or will not change over time. Any forward-looking risk assessment is based on certain assumptions that are informed and limited by the availability, quality, reliability, or accuracy of the information/ secondary data and to that extent, is inherently subject to uncertainties.

Notwithstanding anything to the contrary, there can be no assurance that fully definitive or desired results will be obtained, or if any results are obtained, that they will be supportive of any given course of action. The services may include the application of judgment and certain results of this work may be based on subjective interpretation. Notwithstanding anything to the contrary, we make no warranties, express or implied, including without limitation, warranties as to merchantability or fitness for a particular purpose.

ERM is not engaged in environmental consulting and reporting for the purposes of advertising, sales promotion, or endorsement of any client's interests, including raising investment capital or recommending investment decisions, or other publicity purposes. The client acknowledges that any reports prepared by ERM are for the exclusive use of the client and agrees that ERM's reports or correspondence will not be used or reproduced in full or in part for such promotional purposes, and may not be used or relied upon in any prospectus or offering circular. Osotspa also agrees that none of its advertising, sales promotion, or other publicity matter containing information obtained from these audits and reports refer to ERM's trade name. Nothing contained in the report of ERM shall be construed as a warranty or affirmation by ERM that the Site and property described in the report are suitable collateral for any loan or that acquisition of such property by any lender through foreclosure proceedings or otherwise will pose no risk of potential environmental liability on the part of such lender. The methodology mentioned in this document, however, may contain ERM trade secrets and is an intellectual property of ERM. The information provided by ERM under this document is not construed as legal advice.

2. PRELIMINARY DATA COLLECTION

The Site is located in Khlong Suan Plu Sub-district, Phra Nakhon Si Ayutthaya Province, Thailand. Phra Nakhon Si Ayutthaya is a province in the central region of Thailand, situated in the north of Bangkok, approximately 80 km as shown in **Figure 2-1**.

OSP-AY and SBM plants are involved in the production of energy drinks and other non-alcohol beverages while SGI-AY produces glass bottle containers to serve the aforementioned beverage production plants. It is reported that the OSP-AY plant, SGI-AY plant and SBM plant are operational since the years 1998, 2005 and 2014, respectively. In 2021, approximately 259,500 and 11,300 m^3 of drinking products were produced by OSP-AY and SBM, respectively while 730 million bottles were manufactured in SGI-AY during the year. The primary source of water to the Site is groundwater which is withdrawn from five (5) on-site bore wells drilled up to a depth of approximately 100 - 190 meters deep below ground level (m bgl) and additional supply water from Provincial Water Authority (PWA).

The Site's average and peak groundwater withdrawal in 2021 was reported to be ~3,770 m^3/day (3.77 MLD) and ~5,030 m^3/day (5.03 MLD) respectively. Alongside, the Site's average and peak water consumption from PWA was reported to be ~765 m^3/day and ~1,895 m^3/day (1.895 MLD) respectively. The proportion of the Site's groundwater and supply water was currently reported to be in the ratio 75:25 respectively. The Site's average and peak withdrawal from both groundwater and PWA is reported to be ~4,535 m^3/day (4.535 MLD) and 6,925 m^3/day (6.925 MLD) respectively.

An on-site Water Treatment Plant (WTP) of 3,800 m^3/day (3.8 MLD) design capacity is located within OSP-AY Plant. The WTP is used for the treatment of raw water from bore wells as well as municipal water. The treated water from the on-site WTP is also supplied to the SBM and SGI-AY Plants. However, the break-up of the treated water supplied to the Plants was not available for review.

Site operates two (02) on-site Wastewater Treatment Plants (WWTP) for the treatment of effluent and domestic sewage generated at the Site. A WWTP with a design capacity of 2,500 m^3/day (2.50 MLD) is used for the treatment of combined wastewater from OSP-AY and SBM while SGI-AY has a WWTP with a design capacity of 50 m^3/day.

- The WWTP catering to OSP-AY and SBM facilities is operational since 2013. The average and peak quantity of wastewater generated in 2021 was reported to be ~1,810 m3/day (1.81 MLD) and ~3,150 m^3/day (3.15 MLD), respectively. As reported by the Site, the peak quantity of ~3,150 m^3/day which is greater than the design capacity of the WWTP was generated as a result of maintenance activity in the on-site WWTP. The wastewater infrastructure on-Site was capable of accommodating the above-mentioned surplus volume.
- Reportedly, a portion of the treated effluent is reused for gardening, cooling tower, and toilet, while the remainder is directed to the OSP-AY retention pond and eventually discharged into the local canal Khlong Thap Taeng on daily basis. Around 485 m^3/day of treated wastewater is discharged into the irrigation canal, while the volume of treated wastewater reused on the Site is not known. There are flowmeters installed in the WWTP.

As for SGI-AY, the treated wastewater from the on-site WWTP is directed to the retention pond for disposal. It was reported that SGI-AY is restricted from discharging its treated wastewater off-Site as per government regulation. As a result, the treated wastewater in the retention pond is left to evaporate. The amount of treated wastewater discharged into the retention pond and its evaporation rate was not known. It was reported that no flowmeters are installed at the inlet and outlet of WWTP at SGI-AY.

Wastewater quality from both facilities was reported to be monitored regularly and available records indicated no exceedances above regulatory limits.

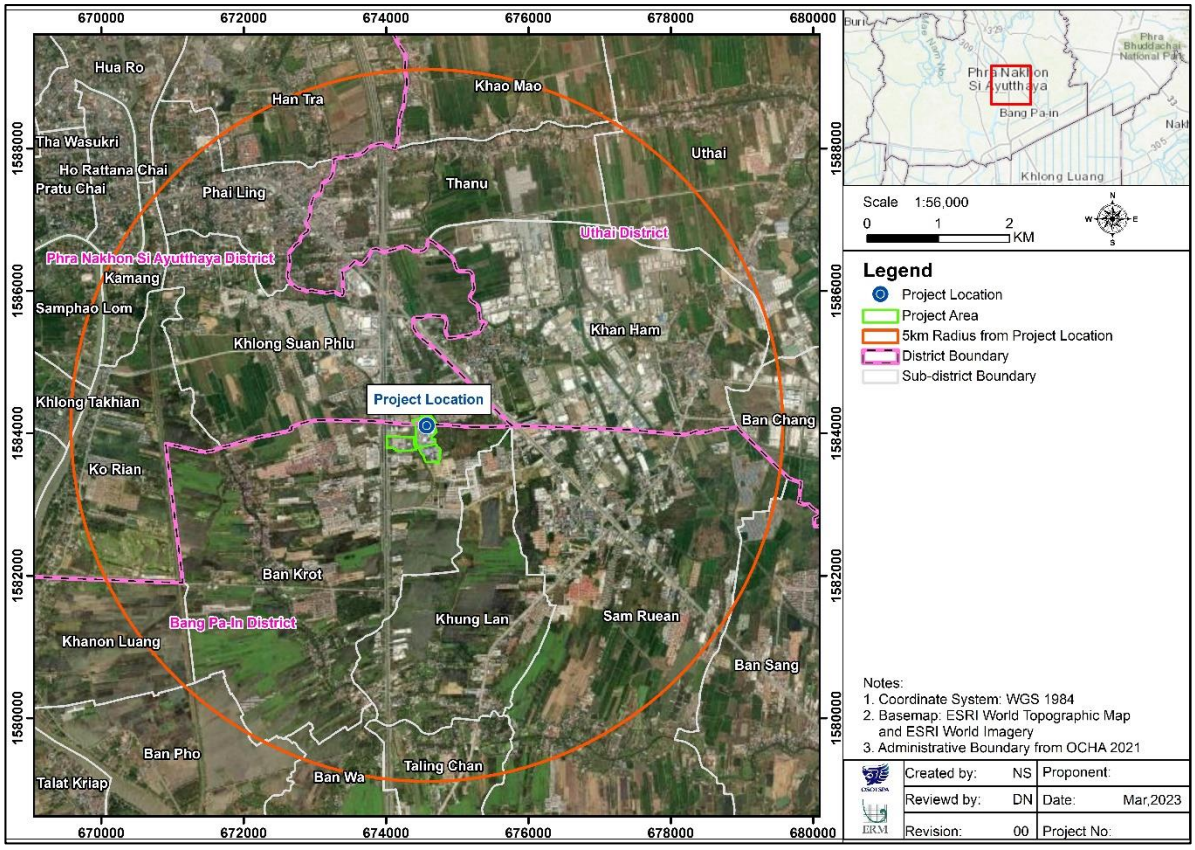
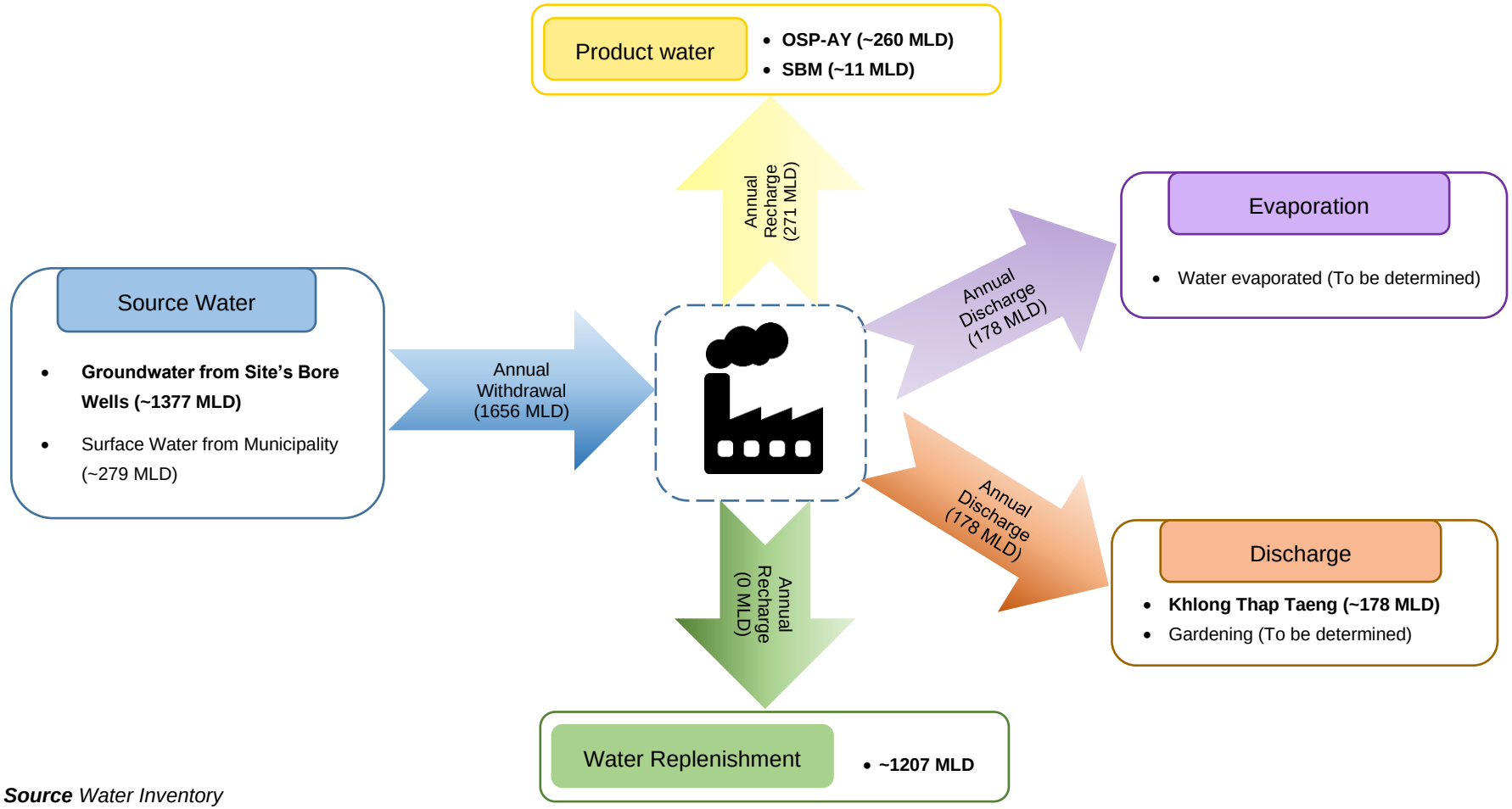


Figure 2-1 Plant Location Map

This assessment is based on the watershed approach. The watershed approach reflects a common understanding of the roles, priorities and responsibilities of all stakeholders within a watershed. It considers upstream and downstream interactions, direct and indirect impacts on the business, and sustainability in general.

The water balance for the Site for the year 2021 is provided in **Figure 2-2**.



Source *Water Inventory*

Note*:. Water offset estimation as shown in the above figure is presented for understanding the unit's status towards hydrological independence on a fundamental level only. This does NOT reflect the technicality of water quality, water source, efficiency, among other aspects. Hence, this should NOT be considered as a basis for any association with water neutrality.*

Figure 2-2 ***Water Inventory***

As may be observed from the water inventory in **Figure 2-2**, the total water withdrawal by the Site in the year 2021 was ~1656 MLD while only 271 MLD has been converted to products. As per the information provided, only 178 MLD of treated wastewater was discharged to the local receiving body, regardless of water re-used for gardening and water evaporated in the retention pond. Therefore, approximately 1207 MLD per year or more volume of water is required to be returned to within the watershed to achieve watershed-level water neutrality (associated with water consumption at the Site). However, it is recommended for the Site to keep a record of water discharged by gardening and water evaporated in the ponds to identify the amount of water to be replenished to water sources. The Plant does not undertake any on-Site or watershed-level water replenishment activities and is on the debit side of the water balance.

3. SITE DESCRIPTION AND SETTING

3.1 Site Location

Osotspa was established in 1891. The Site is located (14° 19.409'N 100° 37.119'E) in Khlong Suan Plu Sub-district, Phra Nakhon Si Ayutthaya Province central region of Thailand. Phra Nakhon Si Ayutthaya is in the lower central plains of the country with an area of approximately 2,556.64 square kilometers.

Most area of Phra Nakhon Si Ayutthaya is rice fields, with no mountains or forests. The Chao Phraya River, the Pa Sak River, the Lop Buri River, and the Noi River are the four major rivers that run through the area.

3.2 Site Layout

The Site is involved in the manufacturing of glass bottles and is a beverage distribution centre. Google Imagery Site Map and Site layout are illustrated in **Figure 3-1** and **Figure 3-2**, respectively. The total production capacity of the plant was reported to be around 270,000 m^3 per year and there are plans to increase such production volume by 15 percent in the next five years. The Site occupies approximately 57,061 m^2 built-up area, a warehouse spread over 38,500 m^2, including, an 18,815 m^2 greenbelt area and an additional 94,080 m^2 for other purposes and vacant land. The factory area of the Site can be divided into four (4) main areas including:

- OSP-AY (Beverage production plant) covers an area of 93,456 m^2
  - Nine (9) Production lines;
  - Utility area includes boilers, generators, chillers and pumps;
  - Three (3) Raw water treatment systems;
  - General waste and hazardous waste storage area;
  - Wastewater treatment plant;
  - Treated wastewater pond; and
  - Canteen
- SBM (Beverage production plant) covers an area of 56,548 m^2
  - Production lines;
  - General waste and hazardous waste storage area;
  - Underground wastewater tank; and
  - Plant warehouse
- SGI-AY (Glass bottle production plant) covers an area of 19,952 m^2
  - Production lines;
  - Raw water treatment system and raw water storage;
  - General waste and hazardous waste storage area;
  - Wastewater pond; and
  - Plant warehouse
- Warehouse covering an area of 38,500 m^2

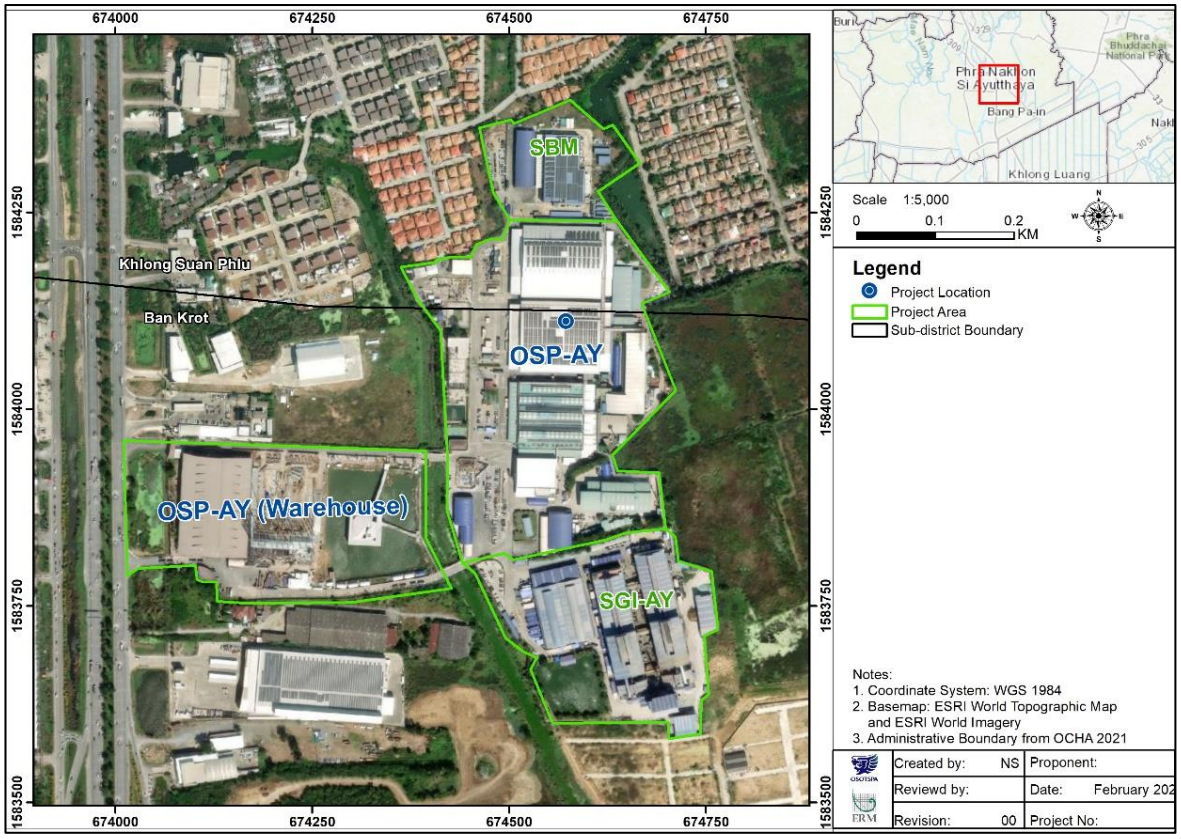


Figure 3-1 Google Imagery Site Layout Map

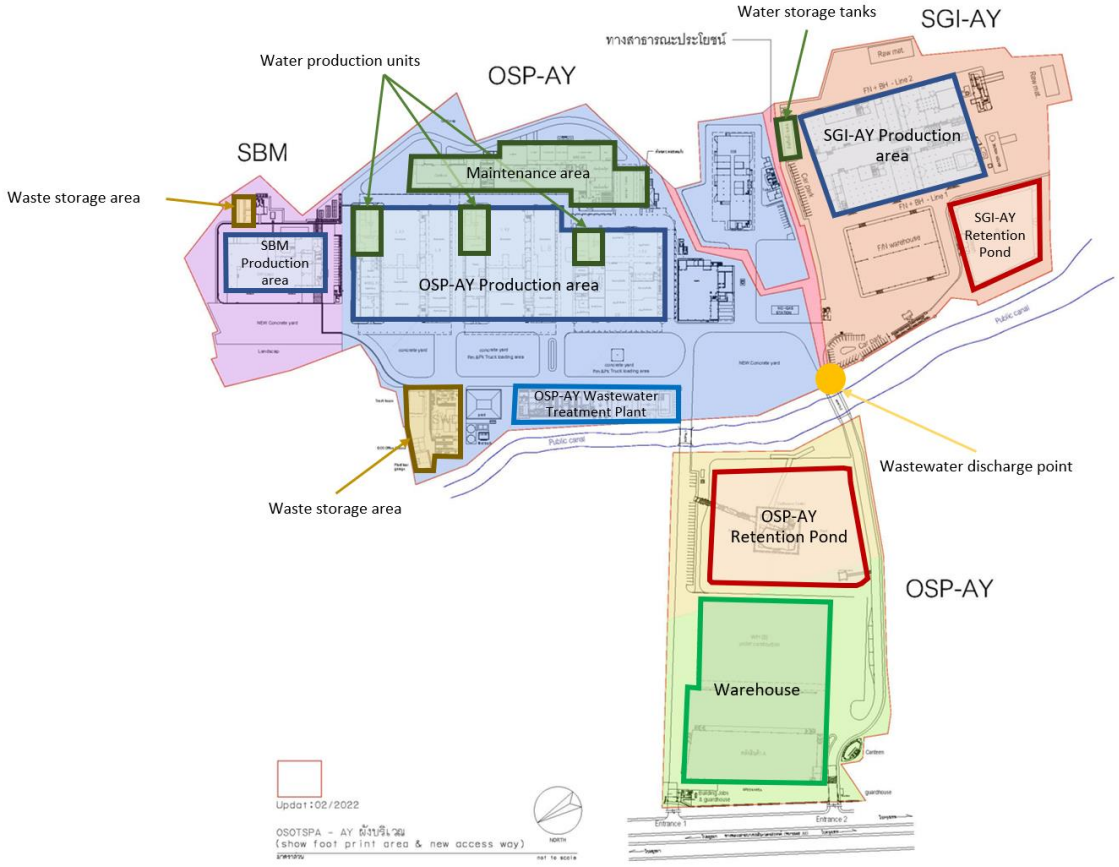


Figure 3-2 Site Layout

3.3 Site Surrounding

The Site is in Khlong Suan Plu Sub-district, Phra Nakhon Si Ayutthaya Province, and is surrounded by built-up and agricultural, specifically the study area (~5 km radius). The adjacent properties and nearby land use of the Site observed from Google Earth and Land use from the Land Development Department are summarized in **Table 3-1** and **Figure 3-3**.

Table 3-1 Site Surrounding

Direction	Land Use
North	Adjacent to the Site is land used for Urban/Built up. An existing residential property and factory make up the north boundary of the Site.
East	Adjacent to the Site is land used for agriculture (Paddy field). Further is a local canal (Khlong Nong Mai Sung) approximately 1.33 km from the project location.
West	Adjacent to the Site is land used for Urban/Built up and industrial land, further is a local canal (Khlong Thap Taeng) flow through the project location at the west of the Site.
South	Adjacent to the Site is land used for agriculture (Paddy field). The residential settlement area is located at approximately 360 m from the south of the Site

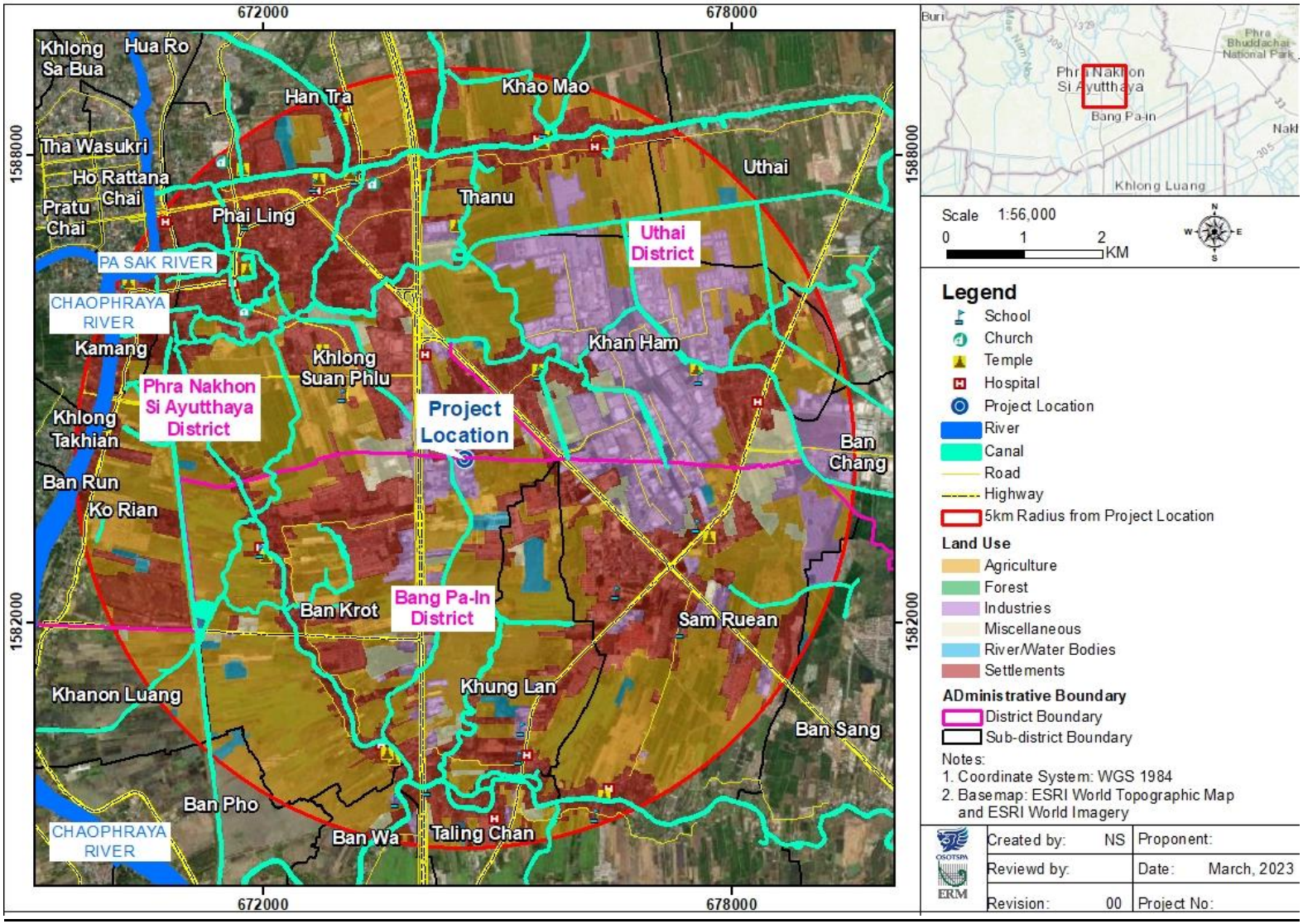


Figure 3-3 Surrounding Area of the Project Location

3.4 Study Area

For this assessment, the study area was considered as 5 km radius buffer from the project location, which is located in Khlong Suan Plu Sub-district, Phra Nakhon Si Ayutthaya Province (14° 19.409'N, 100° 37.119'E). The project location was divided into two (2) zones that are the production area (zone 1) including 3 plants, namely OSP-AY, SBM and SGI-AY, and the warehouse (zone 2).

3.5 Sites Source Water Supply

The source of water to the Site is groundwater abstracted from the five on-site bore wells and municipal water from PWA. Based on the documents provided for review and interview with the Site representatives, it was identified that approximately 75% of the total water consumption is sourced from on-site bore wells whilst the remaining 25% is sourced from PWA.

- The facility currently has four (4) operational bore wells and one (1) stand-by bore well within its premises to support its water requirements.
- The bore wells are reportedly installed up to a depth of ~ 100-190 m below ground level. It was reported that the Site operates only one bore well at a time for an average of 10 hours per day.
- Based on reports by the bore well maintenance personnel at the facility, water supply from the bore wells has been generally reliable. The details of the five on-site groundwater abstraction bore wells are as presented in **Table 3-2**.

Table 3-2 Onsite Groundwater abstraction wells information

Bore well ID	Year of construction	Yield (KL/h)	Depth (m bgl)
3804-0289	2001	1,280	190
4101-0031	2003	1,280	150
4403-0013	2011	800	102
731059-0002	2001	3,200	102
730463-0015	2020	3,200	106

- It was informed during the Site visit, that the Site acquired the permits for each bore well to abstract groundwater without exceeding the permitted volume which varies depending on drilling characteristics and hydrogeological data. However, the evidence of groundwater withdrawal permits and the consented volume of groundwater withdrawal was not available for review.
- The bore wells are installed within the fenced area with restricted access and are provided with proper enclosures to protect the wellhead from physical damage or sabotage.
- The Plant has installed mechanical flow meters for the measurement of daily withdrawal on all bore wells. Daily logs of groundwater abstraction were available for review.
- There are no piezometers installed on-site. It was reported that the Site has never conducted groundwater level monitoring as it is not required by local regulation.
- Groundwater quality monitoring of each bore well are conducted by the Site personnel on daily basis using automatic probes for measuring the following parameter, conductivity, turbidity and pH. The physical and chemical parameters are conducted by an external laboratory under the Department of Groundwater on monthly basis.
- The operating abstraction bore wells are scattered around the Site as shown in **Figure 3-4**.

- In the case of water supplied from PWA, the ultimate source of water supplied by PWA is not known. The information on the water treatment plant, source water quality, intermediate reservoirs, and transmission lines was not available.

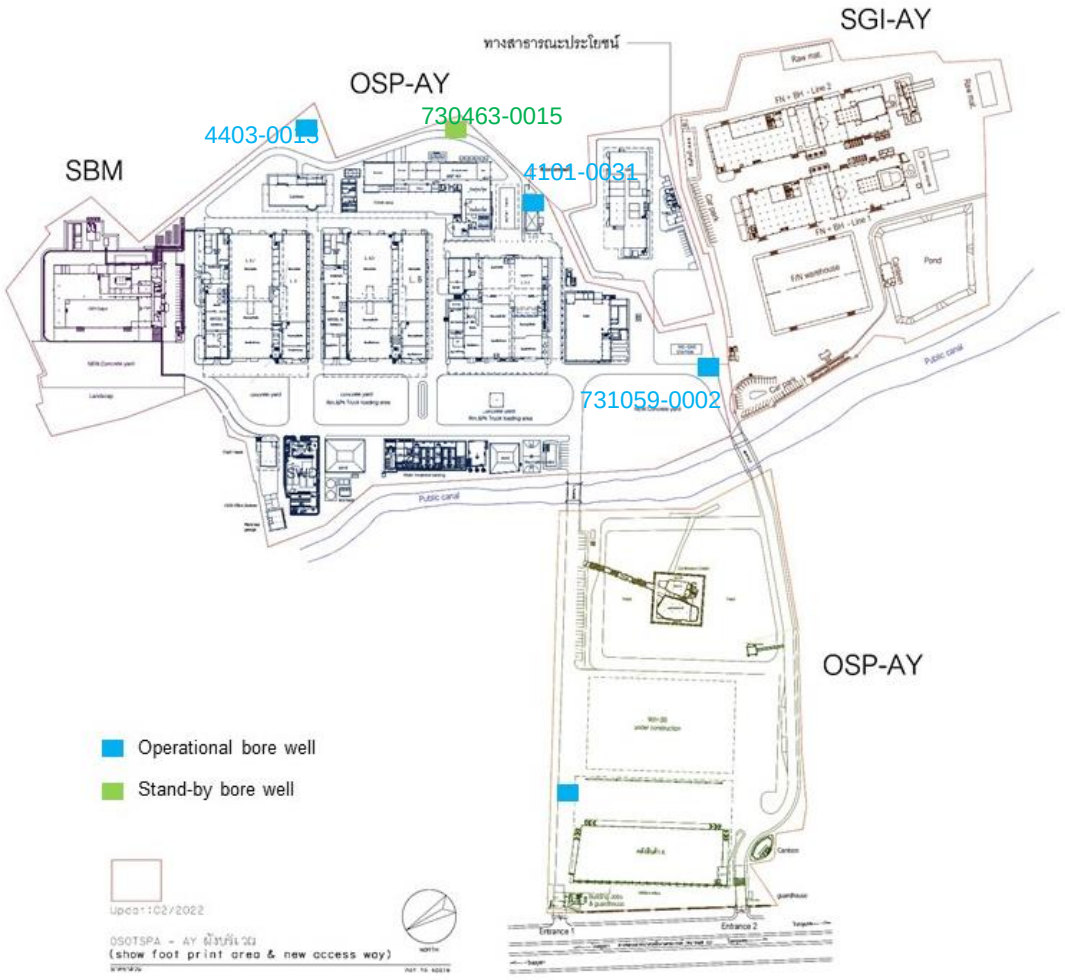


Figure 3-4 On-Site bore well locations

3.6 Water Withdrawal at the Site

Monthly water withdrawal data from the five (05) on-site bore wells and PWA was provided by the Site for the year 2021. The average daily withdrawal from the bore wells and municipal water was 3,770 m^3/day and 765 m^3/day respectively. The average daily water withdrawal from the bore wells for the year 2021 is presented in **Figure 3-5.**

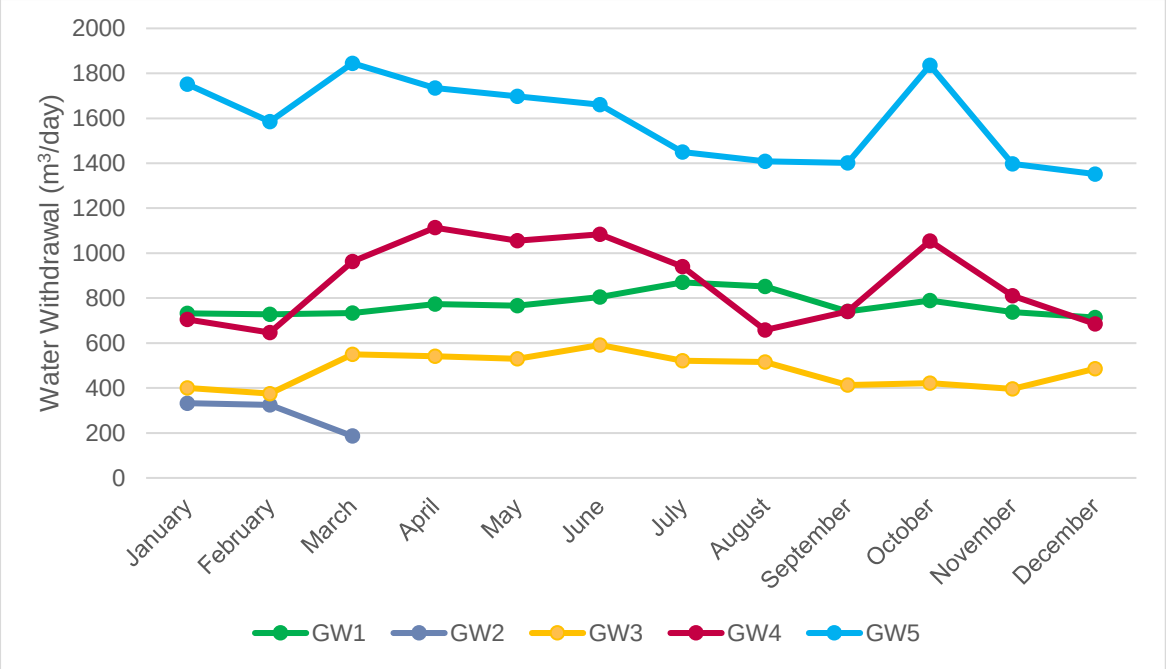


Figure 3-5 Average Daily Water Withdrawal from the on-site bore wells for 2021

As reported by the Site, four bore wells are used on a daily basis and one bore well is used as a standby. It can be observed from **Figure 3-5** that GW-2 was used as a standby bore well in 2021 as groundwater was not abstracted between March 2021 to December 2021. Groundwater is abstracted majorly from GW5 (42%), followed by GW4 (23%), GW1 (20%), GW3 (13%) and lastly GW2 (2%).

Bore wells are used as the primary source of water in the Site whereas PWA supply water is used as the secondary source. As seen in **Figure 3-6**, the Site withdraws water from the bore wells and PWA supply in the ratio of 75:25. The total water withdrawal in 2021 was 13,77,299 m^3/day from bore wells and 2,79,080 m^3/day from PWA water.

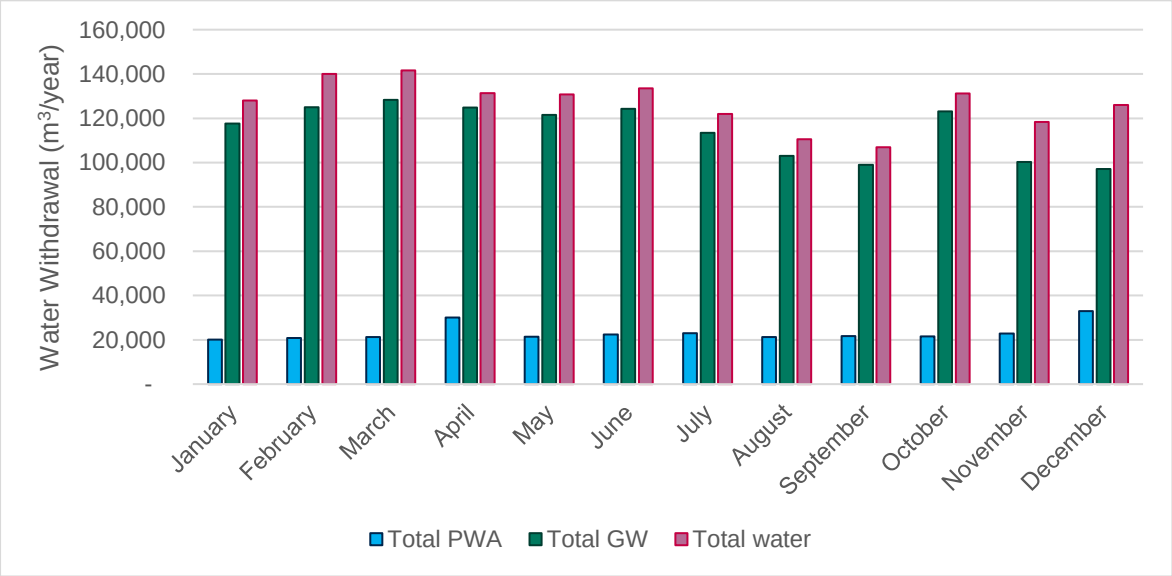


Figure 3-6 Total water withdrawal for 2021

It was reported by the Site, that there are plans to increase the percentage of water supplied by PWA in order to reduce groundwater consumption. The water consumed in the various processes (WTP,

coolers, boilers, domestic use, etc.) was not shared by the Site. The Site is anticipating an increase in water withdrawal/usage in the next 5 years. However, information about the increase in production or percentage increase in water usage on-site in the future was not available.

3.7 Water Cost

The water source for the Site is both groundwater and municipal water. The water tariff per m^3 for both groundwater and municipal water is provided below:

- Groundwater usage was charged 1.00 Baht for every cubic meter of groundwater since 1985. Groundwater tariffs have been updated periodically until 2014 except for provinces in the "***Critical***" zone which are obliged to pay a groundwater tariff of 13 THB/m^3, and other provinces in the Kingdom are required to pay the 3.5 THB/m^3 fee. Since Phra Nakon Si Ayutthaya Province is classified as a "**Critical**" Zone where groundwater withdrawal is in excess compared to the amount of groundwater replenishment resulting in a decrease in the groundwater level, the Site is charged 13 THB/m^3.
- As per the information shared on PWA official website[1], the water tariff rate for state enterprises and large businesses with water usage of >3000 m^3/month is 29 THB/m^3.

3.8 Nearby Sensitive Receptors

Based on the ESRI World Imagery Map, no ecologically sensitive receptors, i.e., National parks, Sanctuaries and/ or Ramsar Sites were identified within the study area. However, the Ping River which is the major canal draining the area is located in close proximity (4 km east) of the Site. The Ping River originated from the Chiang Dao Mountain in Chiangmai province, flows down throughout Lampoon, Tak, and Kamphaeng Phet provinces, and then joins the Nan River, forming the Chao Phraya River, in Nakhon Sawan province. The sensitive Receptors were identified and illustrated in **Figure 3-7**.

[1] https://en.pwa.co.th/contents/service/table-price

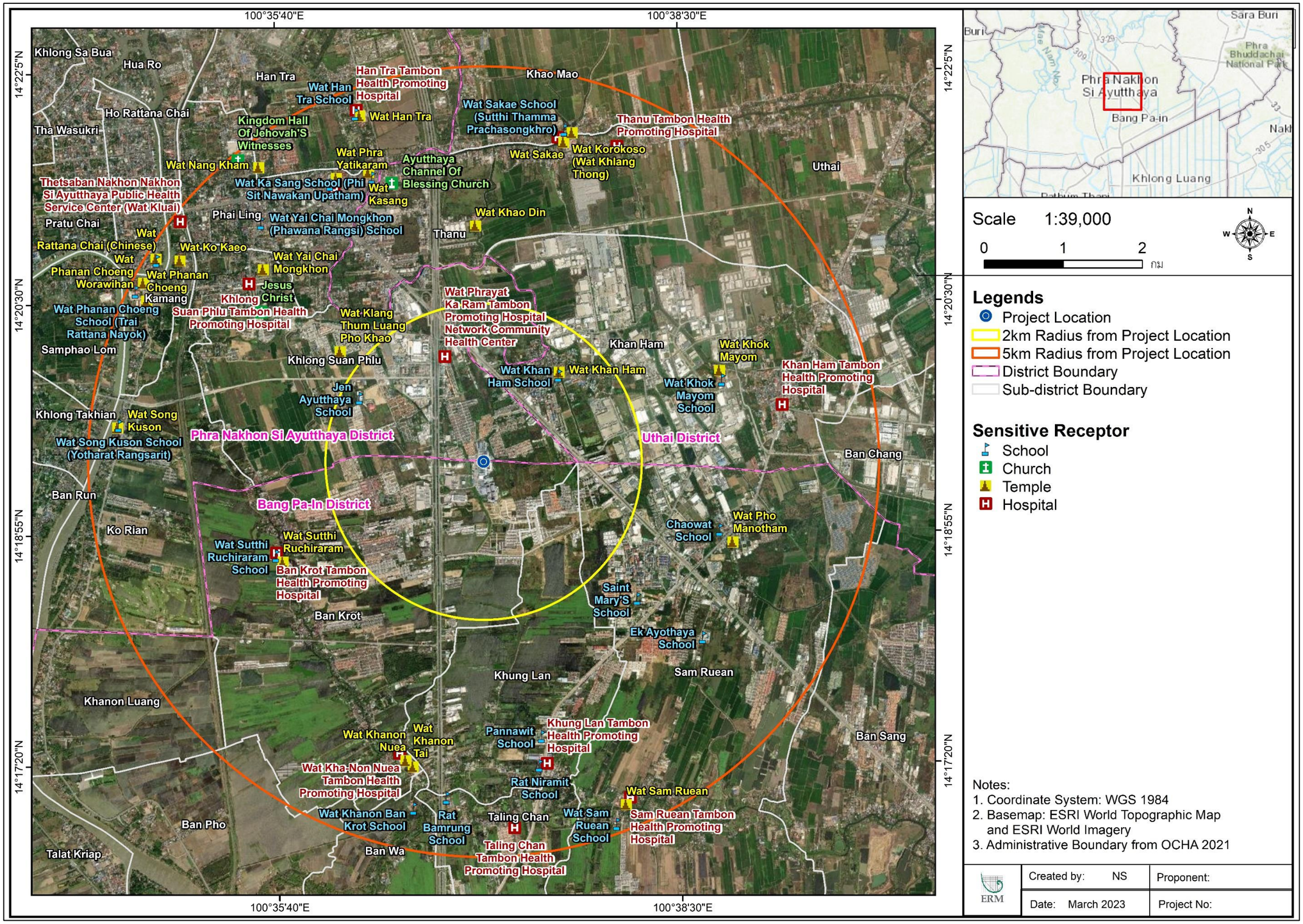


Figure 3-7 Social Sensitive Receptors within 5 km Radius from The Project Location

3.9 Nearby Settlements

A total of sixty-eight (68) villages were identified within a radial zone of 5 km around the project location. These villages are presented in the map as shown **Figure 3-8** below.

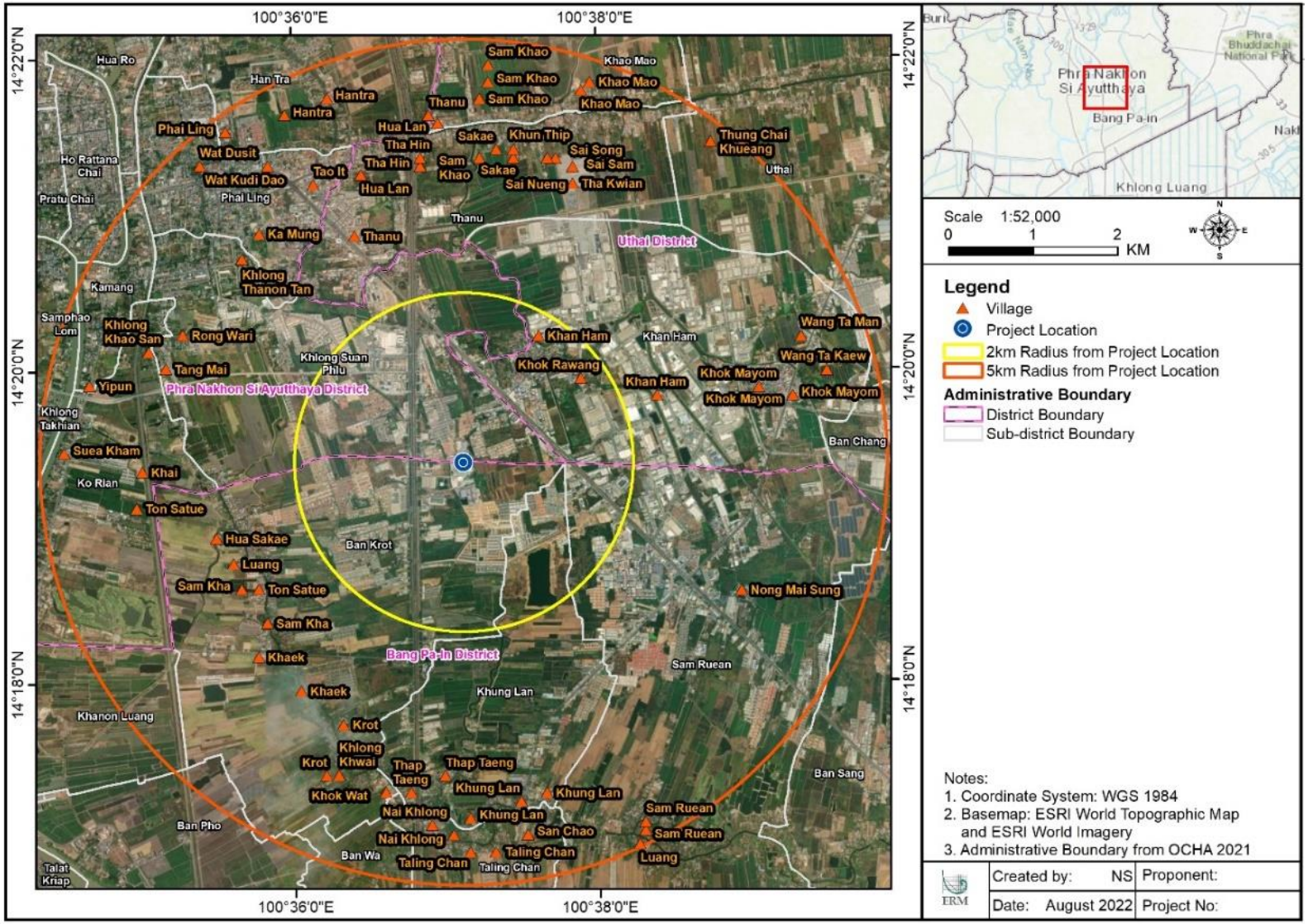


Figure 3-8 Settlements Overview

3.10 Important Water Related Areas

The Pa Sak River begins in the Phetchabun Mountains, Dan Sai District, Loei Province, and flows through Phetchabun Province as the province's backbone. It then flows through the eastern parts of Lopburi Province and Saraburi Province and joins the Lopburi River northeast of Ayutthaya Island, where it flows into the Chao Phraya River southeast of Ayutthaya.

As shown in **Figure 3-9,** the Pa Sak River flows down to connect the Chao Phraya River northwest of the project location. Within a 5-kilometer radius of the project site, there are 41 local canal flow through project studies.

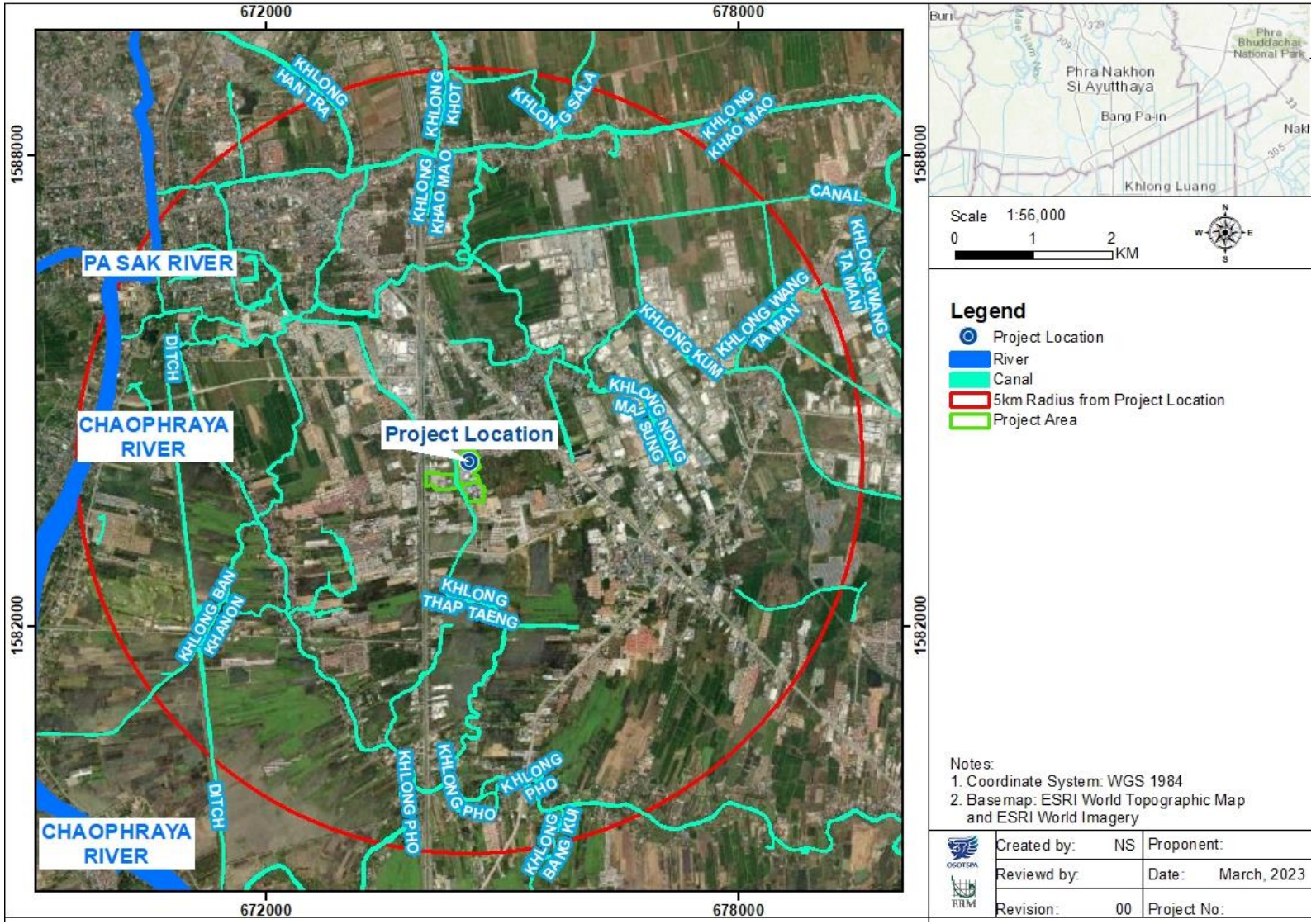


Figure 3-9 Important Water Related Areas

Key Findings:

- The Site is not located within a designated industrial area/zone.
- The primary source of water to support Plant operations is withdrawn from on-site abstraction wells and supply water from PWA with the proportional rate of 75% groundwater and 25% supply water.
- The Site has five (5) on-site abstraction wells, four (4) in operation and one (1) in stand-by mode which are used for groundwater abstraction. The bore wells were installed since 2001-2020.
- Based on interview with Site representatives, the on-Site bore wells are registered with the Provincial Office of Natural Resources and Environment Phra Nakhon Si Ayutthaya, however, no evidence of such document provide for review.
- The study area has two major rivers within a radius of 5 km which are the Pa Sak River and the Chao Phraya River. The Pa Sak River flows through the study area at the northwest side of the project, an approximate distance of 4.6 kilometers and the Chao Phraya River is 4.7 kilometers at the west of the project location.
- There were no ecologically sensitive receptors found within a 5 km radius of the Site.
- The Site is surrounded by 44.7% of agricultural lands, 48.5% of urban/built-up area, 78.43% of river/water bodies and 3.98 % of others area.
- A total of sixty-eight (68) settlements are located within a 5 km radius around the Site. Most households in the study area have access to water via village water (groundwater and surface water) supplied by Sub-district Administration Organization or Municipality.
- The Site treats the industrial wastewater and sewage (wastewater) via Wastewater Treatment Plant, before finally discharging into Khlong Thap Taeng lies between OSP-AY and SGI-AY.

4. HYDROMETEOROLOGICAL DATA INTERPRETATION

4.1 Hydrometeorological Setting

Based on the information from the Thai Meteorological Department, Phra Nakhon Si Ayutthaya Province is influenced by two types of monsoons: the northeast monsoon and the southwest monsoon. The northeast monsoon comes from the northeast and covers the area of Phra Nakhon Si Ayutthaya Province during the winter season. This causes cold and dry weather in the area. The southwest monsoon is another type of monsoon which comes from the southwest during the rainy season, causing it humid and rainy. The temperature in Phra Nakhon Si Ayutthaya is quite high and humid in the summer, but not particularly cold in the winter. Throughout the year, the average temperature is 28 °C, the minimum temperature is 23 °C, and the maximum temperature is 33.8 °C.

Phra Nakhon Si Ayutthaya Province is divided into three (3) seasons:

- **Winter:** The northeast monsoon season begins in mid-October and ends in mid-February. During this time, high air pressure from China will cover parts of Thailand. However, Phra Nakhon Si Ayutthaya Province is in the central of Thailand, winter arrives later than the north and northeast. As a result, the Phra Nakhon Si Ayutthaya Province's winter begins around the middle of November.
- **Summer:** Summer begins in mid-February, when the northeast monsoon ends, and ends in mid-May. The weather is hot and humid in the summer. Temperatures range between 34.5 and 36.3 °C. April was reported to be the hottest month of the year, with a temperature of 36.3 °C.
- **Rainy:** The rainy season lasts from mid-May to mid-October. During this time, the southwest monsoon prevails over Thailand, and the low air pressure trough that covers the southern region of Thailand will move up to cover the central and northern regions. This causes more rain during this period. However, it has been reported that September is the wettest month of the year.

4.1.1 Rainfall

The study area is in Phra Nakhon Si Ayutthaya Province, which receives rainfall from May to October. Annual rainfall data from the assessment period of 2011 - 2021 was collected by the TMD at the rain gauge Ayutthaya station which indicated in **Figure 4-1**. The collected data was further analyzed as shown in **Figure 4-1**.

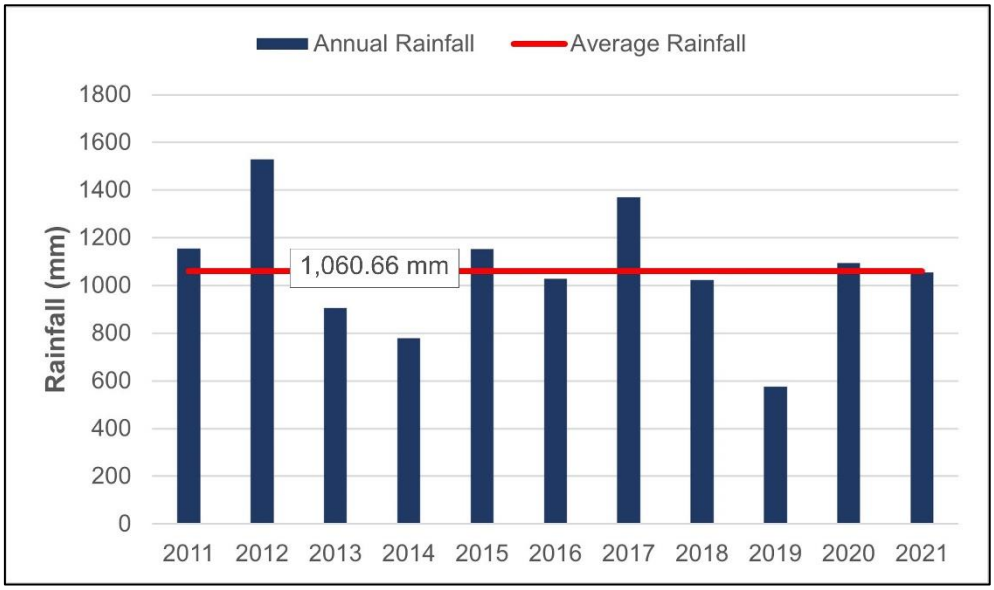


Figure 4-1 Annual Rainfall Trend of Phra Nakhon Si Ayutthaya Province (2011 – 2021)

The following observations were noted based on the above data:

- The minimum and maximum annual rainfall recorded between 2011 - 2021 at the rain gauge Ayutthaya station in Phra Nakhon Si Ayutthaya Province was reported to be 575.8 mm and 1,529.62 mm occurred in 2019 and 2012, respectively.
- The average annual rainfall during the assessment period 2011 - 2021 is 1,060.66 mm.
- Six (6) years received annual rainfall below the total average rainfall received during the assessment period of which 2 years were observed to be deficient which received rainfall of -19% to -59% compared to average rainfall of the period mentioned. One (1) scanty rainfall years were observed in 2019 with amount of rainfall below -59% of 10-year average.

4.1.2 Droughts

Drought is characterized by a scarcity of drinking water and water. Various plants, lack of water, and inability to grow normally in any one area for an extended period until causing damage Climate change conditions, which cause shorter rainy seasons, have a wide impact on communities, society, and the economy. As a result, the dry season will be extended. According to the Water Crisis Prevention Center in Thailand, Phra Nakhon Si Ayutthaya Province is not at risk of drought.

However, as per the WRI aqueduct the baseline drought risk for the area in which Site is located is identified to be medium to high (0.6-0.8) as shown in **Figure 4-2**.

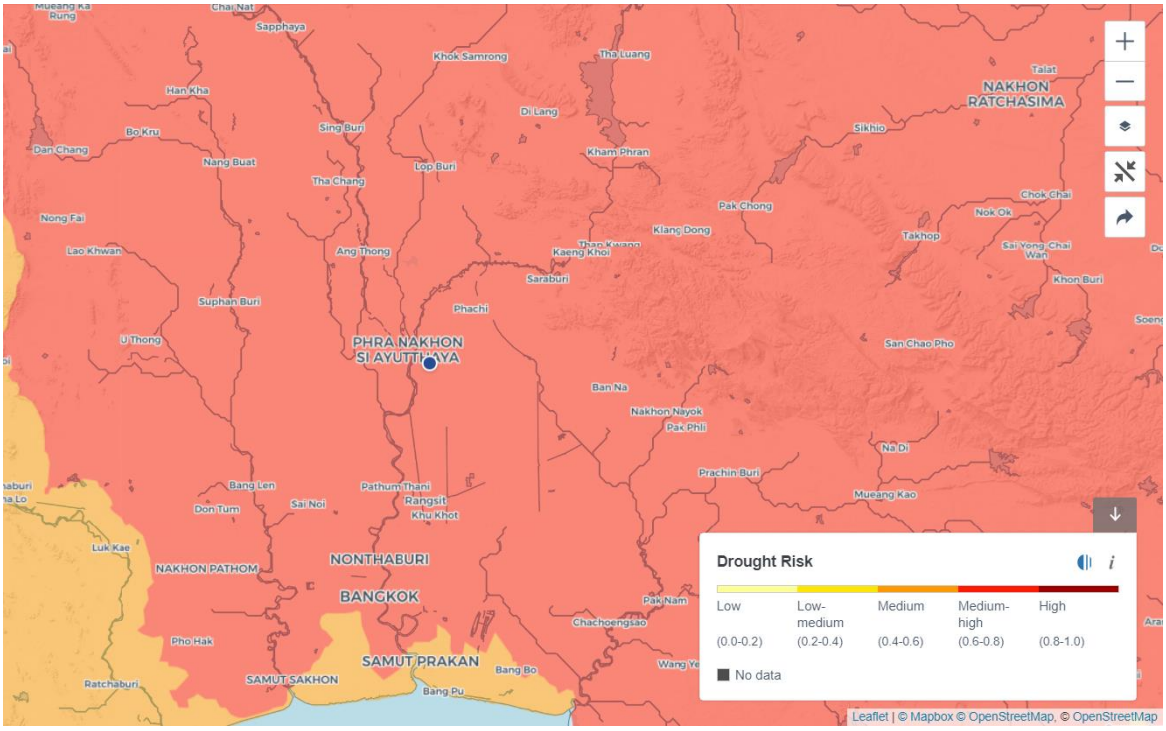


Figure 4-2 Drought Risk Assessment for the Site property region using Aqueduct.

4.1.3 Flood Risk

Flooding is a common disaster in the Phra Nakhon Si Ayutthaya province caused by water run-off. The main cause of water overflow in Phra Nakhon Si Ayutthaya Province is the amount of water in the north and upper central region, as well as water management through the Royal Irrigation Department's Chao Phraya, Chai Nat, and Rama Six dams.

The worst flood witnessed in the past years was reported to have occurred in 2011. During June to October 2011, Thailand received 2,205 mm more rainfall then average, approximately 42% higher. This is influenced by a variety of factors including: the five key tropical storms, monsoon trough, and the presence of the La Niña, a phenomenon that occurs from reduced surface ocean temperature which results in an increased and earlier than expected precipitation. In addition, the water released from Bhumibol and Sirikit dams have escalated the amount of water run-off from Chao Phraya River. The water level of the flood was reported to be over 50 cm from ground level.

According to the disaster Risk Management Plan, 2015 (Revision, 2020) report, it was stated that Phra Nakhon Si Ayutthaya province has been affected by water run-off in 2011 and 2021 due to the water overflow. Moreover, the areas that were considered as high flood risk is present as the following **Table 4-1**.

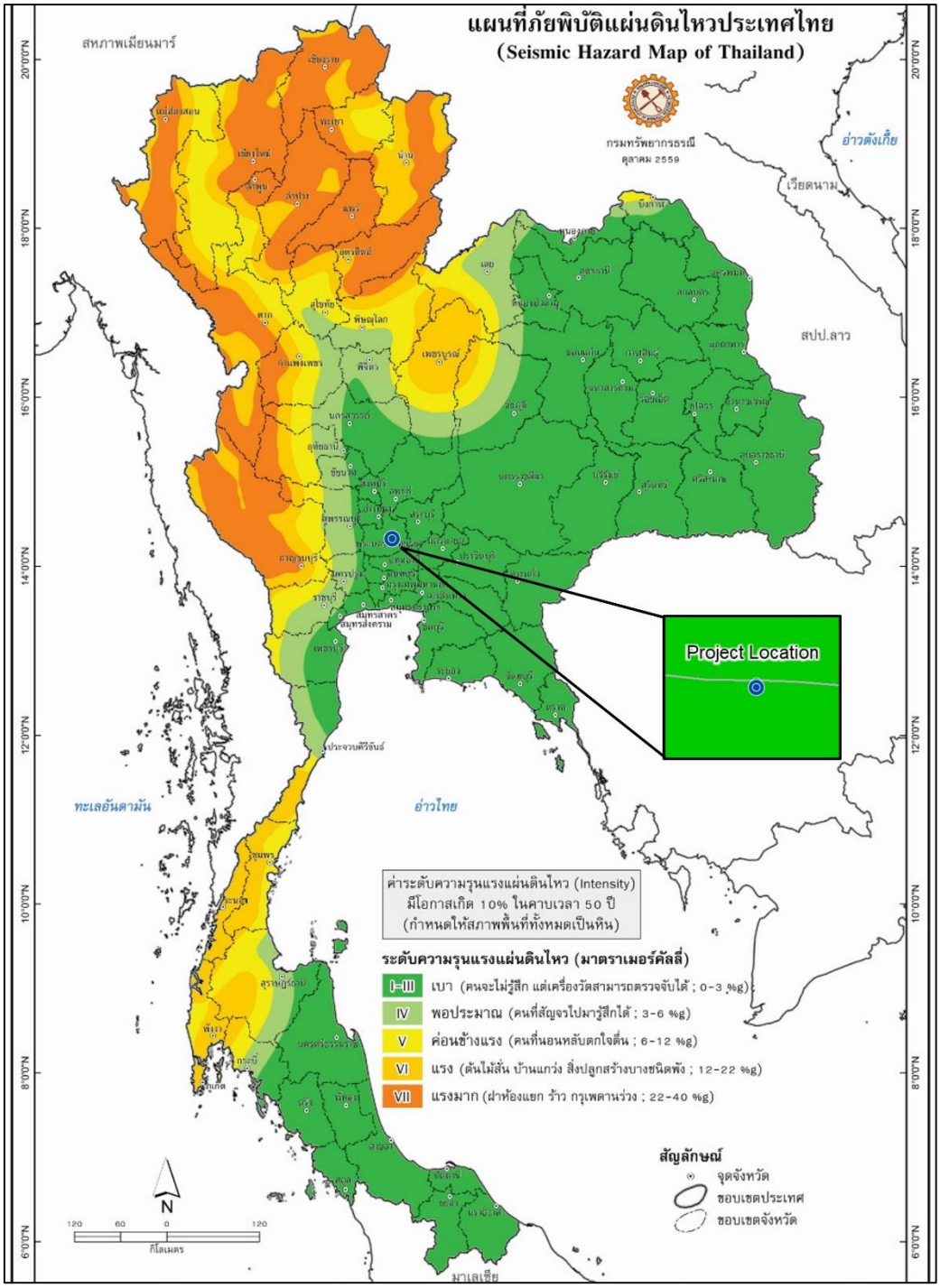
Table 4-1 Flood Risk Level in District of Phra Nakhon Si Ayutthaya Province

High Risk	Medium Risk	Low Risk
1. Sena 2. Bang Ban 3. Bang Sai (1404) **4. Phra Nakhon Si Ayutthaya** 5. Bang Pa-in 6. Phak Hai	1. Tha Ruea 2. Nakhon Luang 3. Maha Rat 4. Bang Pahan 5. Ban Phraek	1. Phachi 2. Lat Bua Luang 3. Uthai 4. Wang Noi 5. Bang Sai (1413)

The average annual rainfall for the period 2011-2021 was reported as 1,060.66 mm. There has been no reports of meteorological droughts during the assessment period. The flood occurs on a regular basis to surrounded districts, but the worst one was reported to have occurred in 2011.

4.1.4 Seismic Risk

The Thailand Seismic Hazard Map, shown in **Figure 4-3**, is used to assess the severity and intensity of earthquakes with a 10% chance of occurring within the next 50 years, according to the Mercalli Scale. According to this scale, Phra Nakon Si Ayutthaya Province is categorized as having a Seismic Zone between I and III, indicating that it will experience a low level of earthquake. According to Thailand's Department of Disaster Prevention and Mitigation, there is no record of an earthquake in Phra Nakon Si Ayutthaya Province. As a result of this conclusion, it can be hypothesized that Phra Nakon Si Ayutthaya Province has a low risk of seismic activity.



Source: Thailand Country Report 2017, Asian Disaster Reduction Center. Accessed by: https://www.adrc.asia/countryreport/THA/2017/Thailand_CR2017B.pdf

Figure 4-3 Seismic Hazard Map for Thailand

4.1.5 Land Subsidence Risk

Subsidence lowering of Earth's land surface is a phenomenon that can be caused by a range of natural or anthropogenic triggers related to mobilization of underground solids or fluids. Groundwater depletion can generate a slow process of subsidence that can develop over a period of months to years and extends over large areas. Subsidence permanently reduces aquifer-system storage capacity, causes earth fissures, damages buildings and civil infrastructure, and increases flood susceptibility and risk.

Land subsidence can have a significant impact on water infrastructure such as water treatment plants, pipelines, and tanks. Following are some of the effects that land subsidence can have on water infrastructure:

- Water pipelines: Land subsidence can cause damage to water pipelines by altering their alignment, causing them to crack or even break. When the ground sinks beneath a pipeline, it can cause the pipeline to sag or buckle, potentially leading to leaks or even a complete failure of the pipeline.
- Water treatment plants: Land subsidence can also cause damage to water treatment plants. As the ground sinks, it can cause the foundation of the treatment plant to shift, which can lead to structural damage. In addition, subsidence can cause the settling of the treatment plant's settling basins and clarifiers, which can reduce their effectiveness in removing solids from the water.
- Water storage tanks: Land subsidence can cause water storage tanks to tilt or even collapse. As the ground sinks, the tank's foundation can become unstable, causing the tank to shift and potentially rupture. This can result in a loss of water and damage to the surrounding area.
- Groundwater wells: Land subsidence can cause the water level in groundwater wells to drop, making it more difficult and expensive to extract water. Additionally, subsidence can cause the wells to become misaligned, potentially leading to damage or the need for costly repairs.

Overall, land subsidence can have serious consequences for water infrastructure potentially leading to water loss, contamination, and other issues. It is important to monitor subsidence and take measures to mitigate its effects on water infrastructure.

The UNESCO Land Subsidence International Initiative (LaSII) Global Subsidence Map[2], has modelled the world distribution of the subsidence phenomenon. The model takes into consideration a series of factors including lithology, land cover, climate, slope, population density, irrigation areas, groundwater storage variation between 1960 and 2010, baseline water stress, floodable areas and (low) elevation areas. The probability of subsidence is classified using a six-levels equal interval scale that goes from Low to High.

According to the UNESCO LaSII as shown in **Figure 4-4**, the Site is located in an area with “High” susceptibility of subsidence. Overall, the entire basin of the Chao Phraya is categorized between “Medium-High” to “High” susceptibility. It is not possible to quantify the actual subsidence rate as the purpose of the model is to provide a distribution of the susceptibility at global scale. However, when considering smaller scale studies[3] focused on the Bangkok metropolitan area, it is possible to observe that the northern portion of the Chao Phraya River has lower rates of subsidence than the southern stretch of the river. According to Aobpaet et al. (2012), the subsidence rate in the north Chao Phraya can vary between -7 mm/year to -18 mm/year.

[2] Herrera-García et al., Mapping the global threat of land subsidence. 2020, Science, Vol. 371, Issue 6524, pp. 34-36. DOI: 10.1126/science.abb8549

[3] Aobpaet, A., Caro Cuenca, M., Hooper, A., Trisirisatayawong, I., 2012. InSAR time-series analysis of land subsidence in Bangkok, Thailand. International Journal of Remote Sensing. Vol. 34, No. 8, pp. 2969-2982

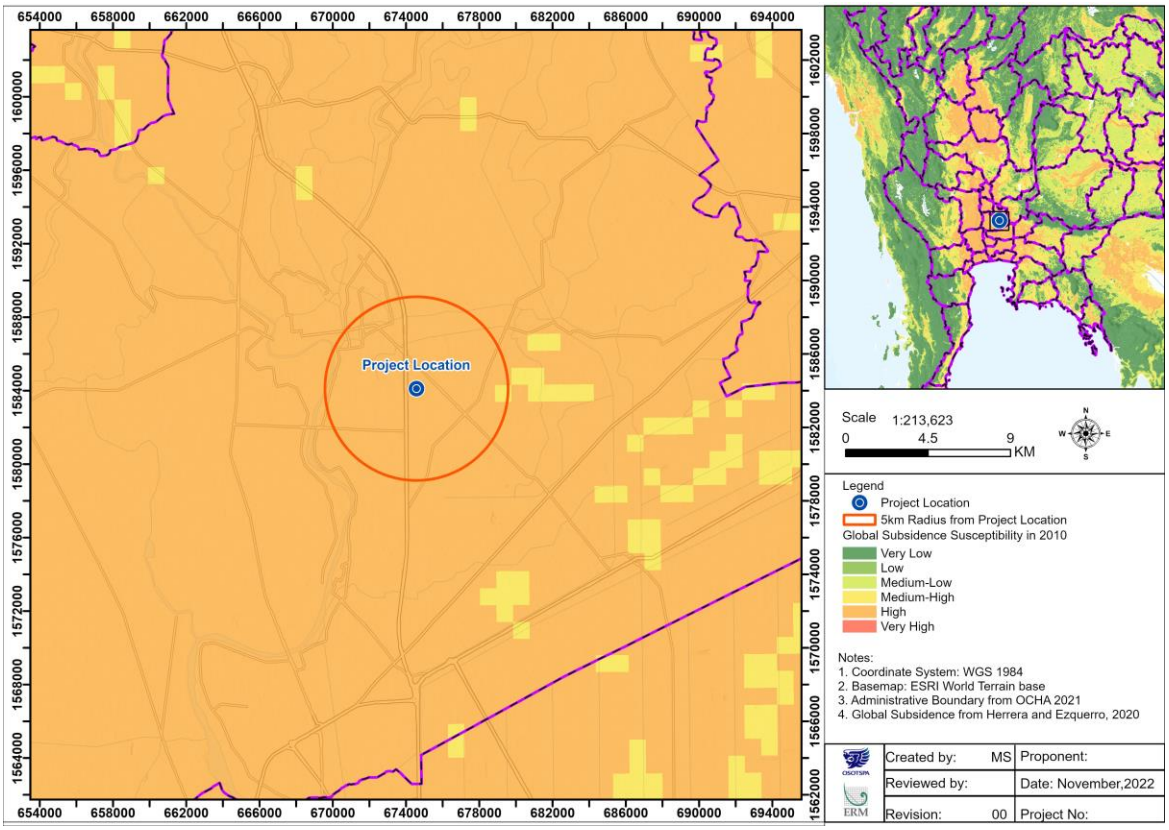


Figure 4-4 Land subsidence Map

Key Findings:

- Phra Nakhon Si Ayutthaya Province is influenced by two types of monsoons: the northeast monsoon and the southwest monsoon which causing hot and humid weather during summer and cold and dry during winter.
- The study area is further divided into three (3) seasons: summer, raining and winter.
- The rainy season lasts from the middle of May to the middle of October. During the assessment period 2011-2021, the average annual rainfall was 1,060.66 mm.
- Based on annual rainfall data from 2011 to 2021 (10 years), six years received annual rainfall that was below the total average rainfall received during the assessment period.
- According to the Water Crisis Prevention Center in Thailand, Phra Nakhon Si Ayutthaya Province is not at risk of drought. However, as per the WRI aqueduct the baseline drought risk for the area in which Site is located is identified to be **medium** to **high**.
- Flooding in Phra Nakhon Si Ayutthaya Province ranges from low to high risk. Bang Pa-in District and Phra Nakhon Si Ayutthaya District, which surround the project location were identified as **high**-risk flooding area.
- According to additional research, Phra Nakhon Si Ayutthaya Province experienced flooding in 2011 and 2021. As reported by the Site personnel, the Site has never experienced operation interruption due to flood that occurred in 2011 since high flood level was occurred in surrounding area only.
- Climate change impacts in form of changing rainfall patterns & intensities can be potential vulnerabilities for the subject area and need to be evaluated.

- Phra Nakhon Si Ayutthaya Province is classified as low level of earthquake. There has been no record of an earthquake in Phra Nakon Si Ayutthaya Province, according to Thailand's Department of Disaster Prevention and Mitigation.
- Phra Nakhon Si Ayutthaya Province is classified as **high** risk of land subsidence as identified by UNESCO LaSII. According to the previous study, the subsidence rate in the north Chao Phraya can vary between -7 mm/year to -18 mm/year.

5. ASSESSMENT OF MICRO WATERSHED

5.1 Approach

Based on the Digital Elevation Model developed for the Site from USGS ASTER GDEM data, LANDSAT, and Google Earth Imagery, ERM identified key topographic features in the study area such as topographic highs and lows, natural drainage network and delineated the catchment area of the micro-watershed in which the Site is located. An ASTER GDEM having a 30 m resolution was used for detailed mapping of the micro watershed in which the Site lies.

5.1.1 Land Use/ Land Cover Map

Land use and land cover features are classified into the following categories:

- **Built-up Lands:** This category compromises of areas of human habitation including manmade structures like houses, commercial complex, transport network(s), communication lines, utilities, services, places of worships, recreational areas, etc. in both urban and rural areas.
- **Industries:** This category includes land under industrial activities.
- **Agriculture Lands:** This category includes land utilized for cultivation of crops, land currently under cultivation and fallow land.
- **Barren/ Scrub lands:** This category includes land currently under non cultivation, vacant land and land with small bushes / scrubs; and
- **River/Waterbodies/Streams:** This category constitutes of the area which is covering water, River and streams.

The land use map was prepared based on Land Use data that was provided by Land Development Department, Thailand.

5.2 Watershed Map

As the Site is located within the Chao Praya River's flood plain, the area is considered flat with a large expanse. As a result, for the purposes of this assessment, a micro watershed was manually delineated using the drainage network in the area. This delineated micro-watershed, which includes the Site, covers an area of approximately 3,963.55 km^2 and is located between the geographical coordinates 100°59'52.50" & 100°20'36.50"E longitude and 14°56'30.50" & 14° 8'9.50"N latitude. The base map for the watershed of interest is presented in the **Figure 5-1** below.

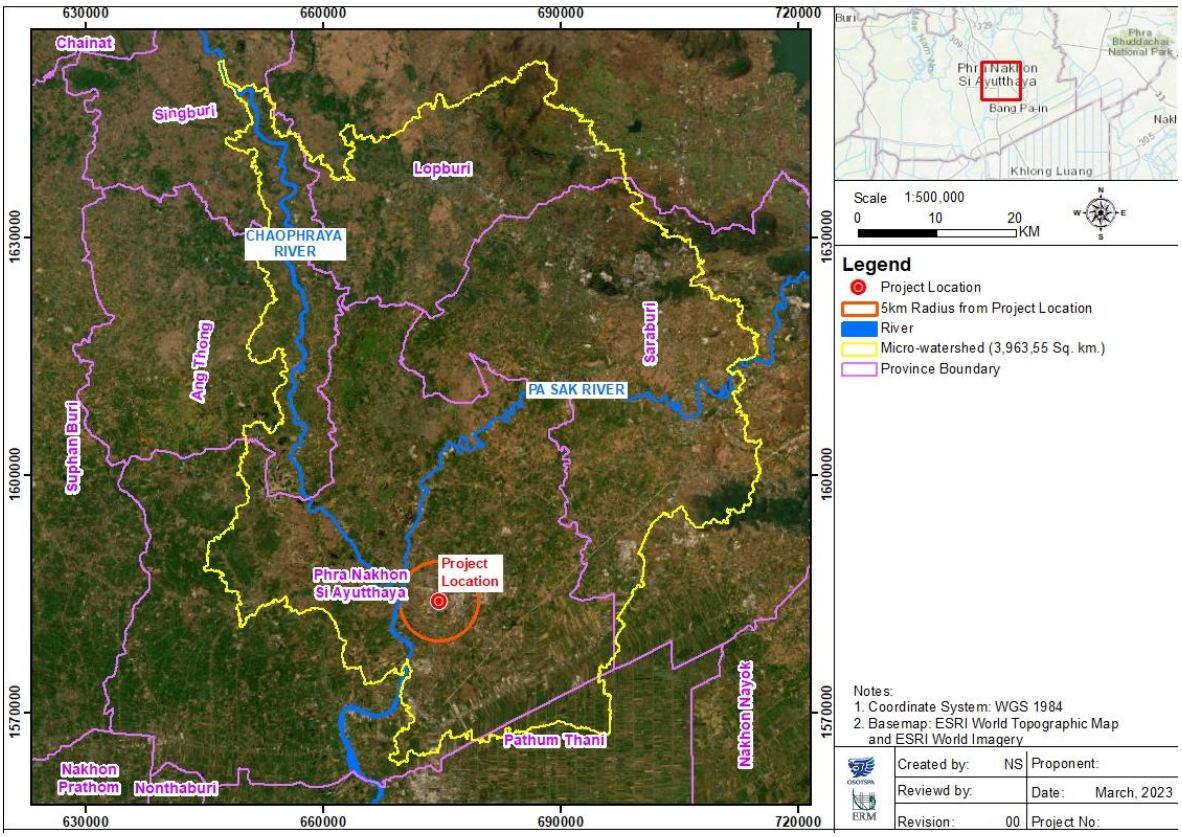
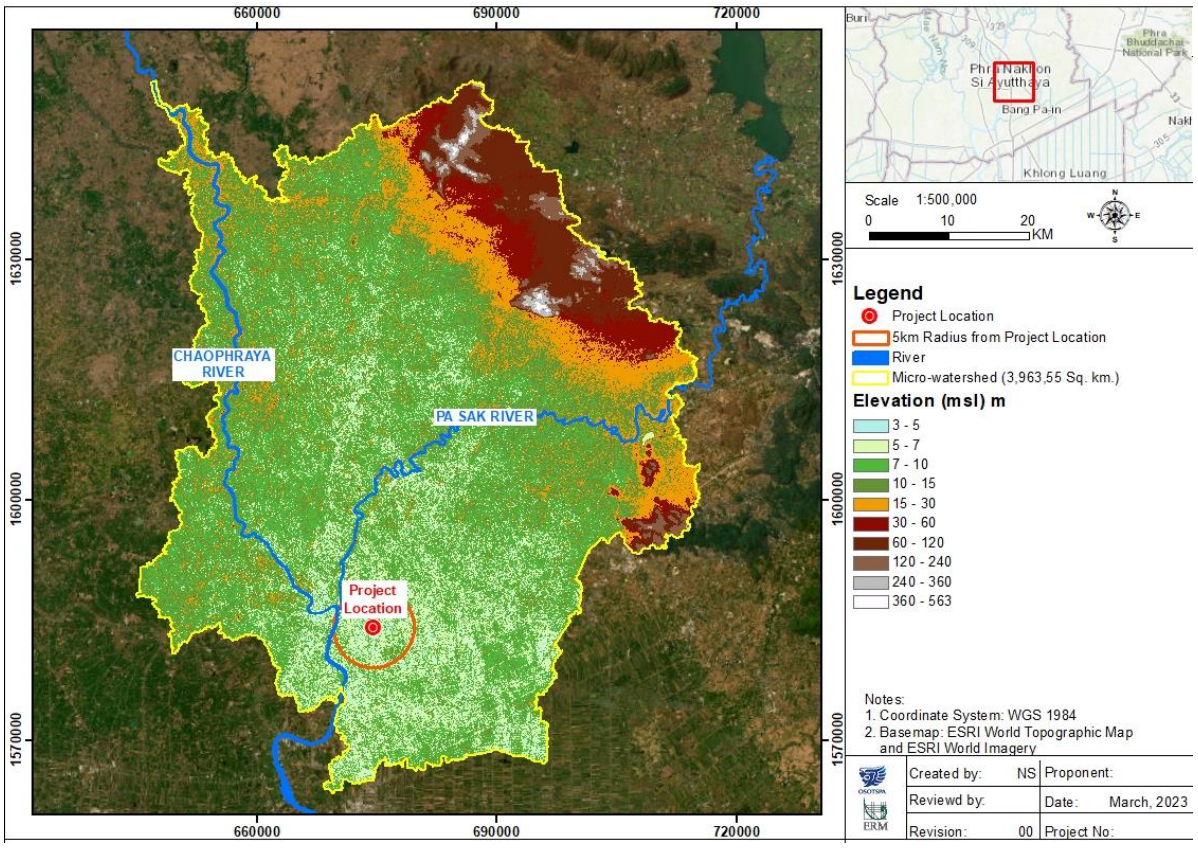


Figure 5-1 Project Location and Watershed Delineation

5.3 Topography and Drainage Map

The boundaries of the subject watershed, admeasuring ~ 3,963.55 Sq.km., were delineated using a Digital Elevation Model (DEM). The Site is located in the Southern of the watershed. The topography elevation varies from 3 to 563 m amsl and 1 to 25 m amsl within the watershed and 5 km radius buffer respectively as shown in **Figure 5-2**. The natural gradient of the watershed is observed to be in the southwestern direction with the natural drainage (streams and canal) and falls in the Chao Phraya River located southwest of the watershed.



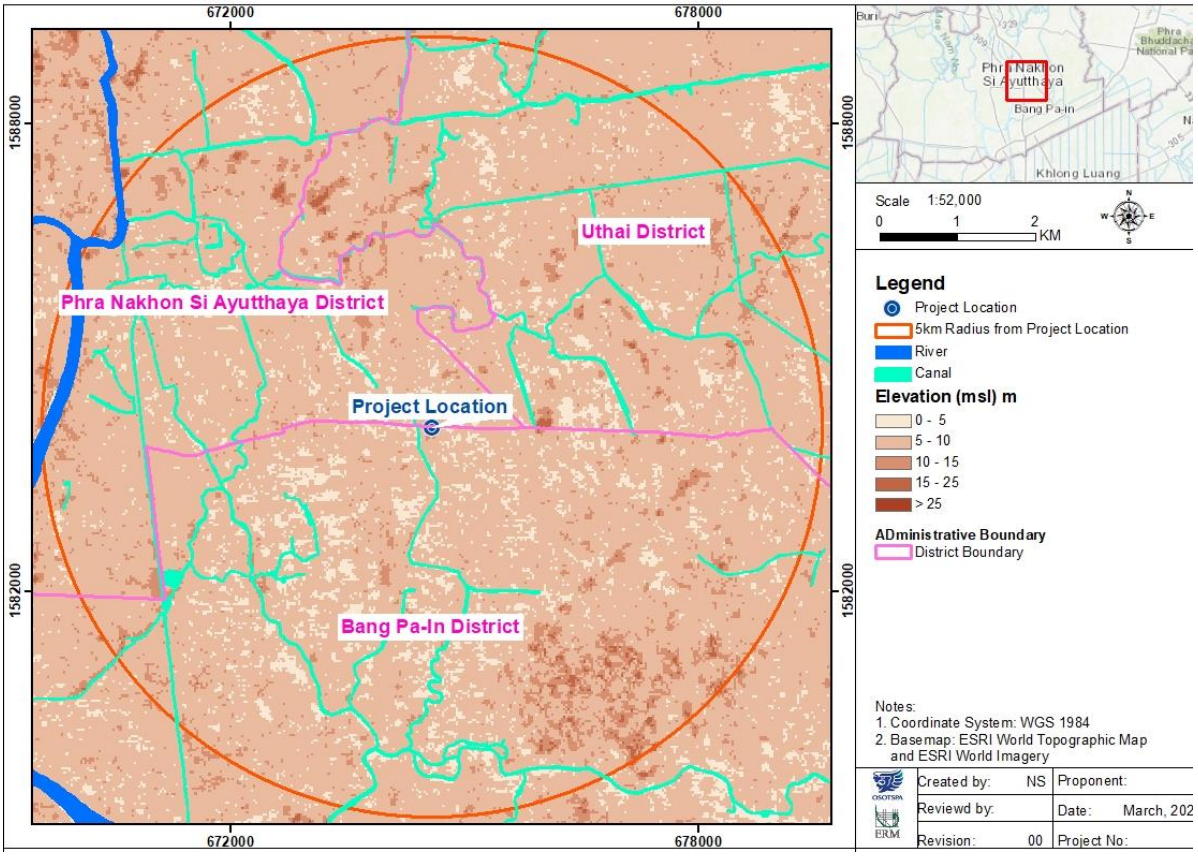


Figure 5-2 Topography Map of the Watershed and Study Area (5.0 km Radius from the Site)

5.4 Slope Map

Slope information plays an important role in land use and infiltration/ recharge characteristics of the terrain. The study area was divided in ten slope categories as follows;

Table 5-1 Slope categories

Approximate degrees	Terminology
0	Level
0.3 - 1.1	Nearly level
1.1 - 3	Very gentle slope
3 - 5	Gentle slope
5 - 8.5	Moderate slope
8.5 - 16.5	Strong slope
16.5 - 24	Very strong slope
24 - 35	Extreme slope
35 - 45	Steep slope
> 45	Very steep slope

Based on the findings of the data analysis in the area Micro-watershed of the area studied in **Figure 5-3**. The slope value is 0 - 63 Degree, while the area of Phra Nakhon Si Ayutthaya Province has a slope value of 0 - 23 Degree, ranging from Level to Very Strong slope, and the project's surrounding area has river network and canal. The closest main river is Chaophraya River ~4.7 km. This could lead to flooding concerns in the study area. If the amount of water in river/canal run-off.

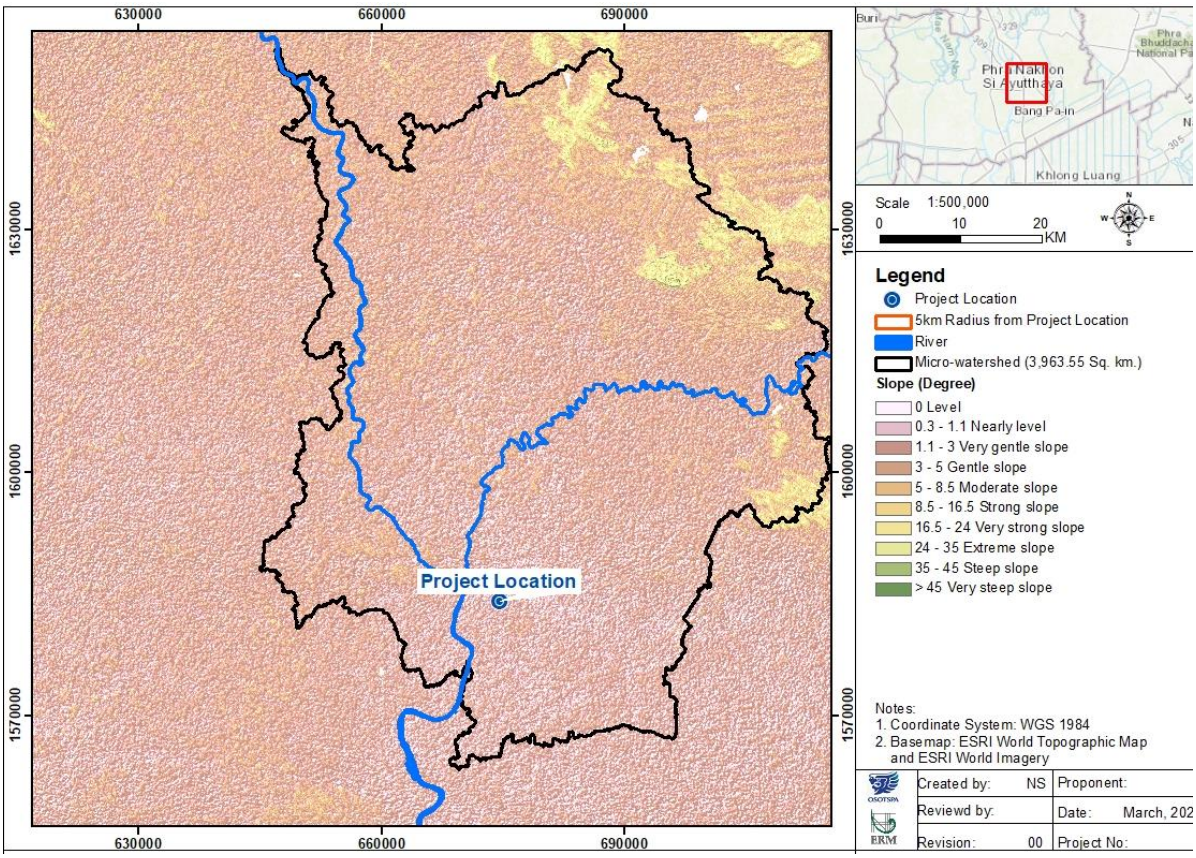


Figure 5-3 Slope and Watershed Delineation Map

5.5 Groundwater Direction Map

To determine groundwater flow direction, depth of the water from the ground level was collected from Department of Groundwater Resources, government of Thailand[4].The data was available from year 2013 to 2022 on a monthly temporal scale for multiple wells which were classified into various zones. The co-ordinates of multiple zones are provided with the data. The data has many missing values hence to get correct representation of depth, the data was averaged for a long-term period.

The groundwater depth level ranges from 3.9 m to 43.79 m within the micro-watershed. The elevation (ground level) data is collected from USGS SRTM DEM, the ground level for each zone was interpolated from the contour. The groundwater elevation from mean sea level (msl) was calculated by subtracting the interpolated groundwater level from ground level for each zone.

The watershed geology is consisting of tidal flat deposits of clay, silty clay sediments and extended almost homogeneously over the area. Later the flow direction is determined based on the higher groundwater elevation to lower groundwater elevation flow. The groundwater flow direction was found to be from east to west in the upper part of the micro-watershed while it is towards south in the lower part of the micro-watershed as shown in **Figure 5-4.**

[4] Department of Groundwater Resources (dgr.go.th)

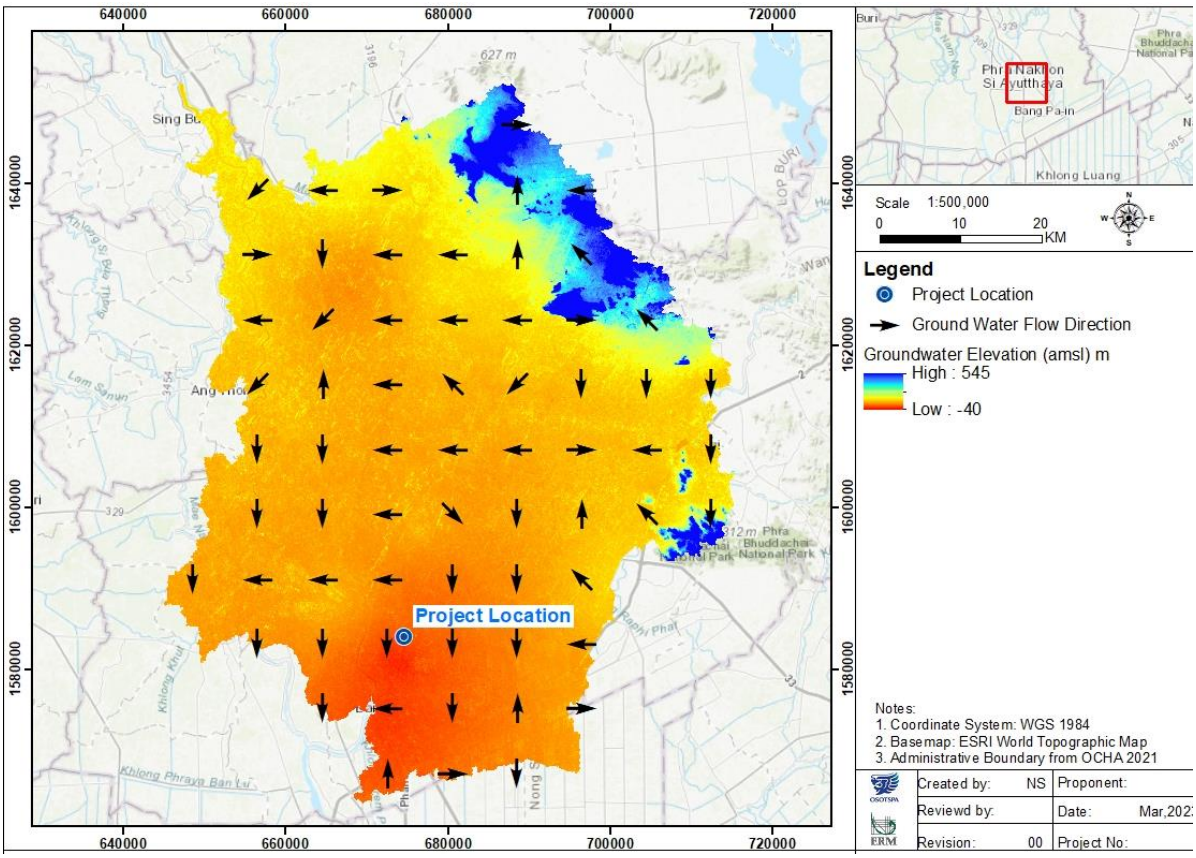


Figure 5-4 Groundwater Direction Map

5.6 Decadal Land Use Change within the Study Area 2008 to 2018

Agriculture was discovered to be the most prevalent land use pattern within the study area (5 km radius), followed by urban/built-up, industrial, miscellaneous, river/water bodies, and forest (Land Development Department, 2018). The industrial land in the study area is approximately 1,028 hectares, which includes Osotspa's factory area. The land use within the study was as shown in **Figure 5-5**.

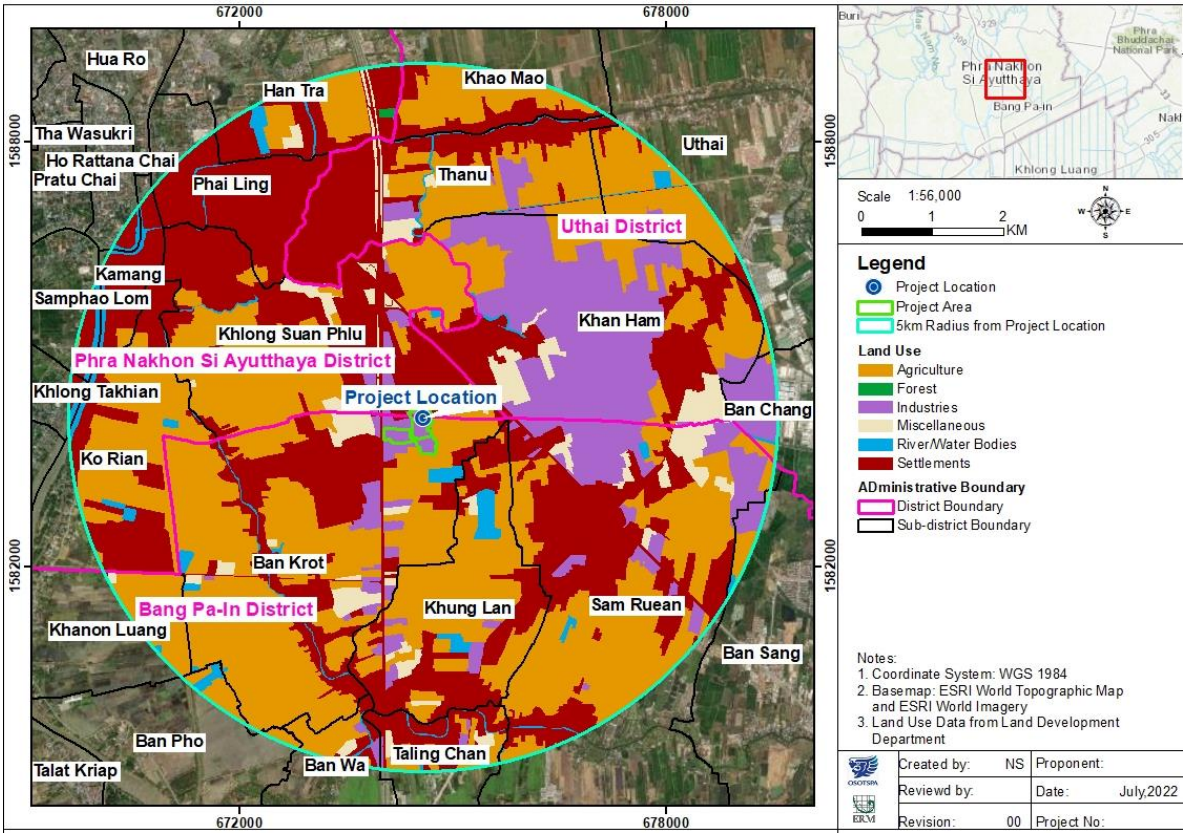


Figure 5-5 Land use nd Land cover map within 5 km radius from the project location in 2018

According to an analysis of land use data from 2008 to 2018 as shown in **Table 5-2**, the agricultural area decreased the most, by -18.32%, or approximately 1,439.18 Hectares. The urban/built-up area increased by 16.31%, or about 1,280.72 Hectares. According to additional research, agricultural areas have changed to most residential areas, followed by industrial areas, other areas, water resources, and forest areas.

Increased urbanization is likely to stress water resources and social infrastructure, as well as degrade soil and water (surface and groundwater) quality due to sewage and solid waste discharge and disposal. However, due to water resources in the area, water availability risks associated with high urbanization are deemed insignificant. Water quality degradation, on the other hand, is regarded as a major concern within communities.

The land use/ land cover map representing decadal change between 2008 – 2018 is presented in the **Table 5-2** and **Figure 5-6**.

Table 5-2 Urban/Built-up area comparison between 2008 - 2018

Description	Area (Ha) in 2008	Area (%)	Area (Ha) in 2018	Area (%)	Decadal Change (Ha)	Decadal Change (%)
Agriculture	4950.66	63.03	3511.48	44.71	-1439.18	-18.32
Miscellaneous	235.23	3.00	312.48	3.98	77.25	0.98
Urban/Built up	2526.56	32.17	3807.28	48.48	1280.72	16.31
River/Water Bodies	141.52	1.80	219.95	2.80	78.43	1.00
Deciduous Forest	-	0.00	2.79	0.04	2.79	0.04

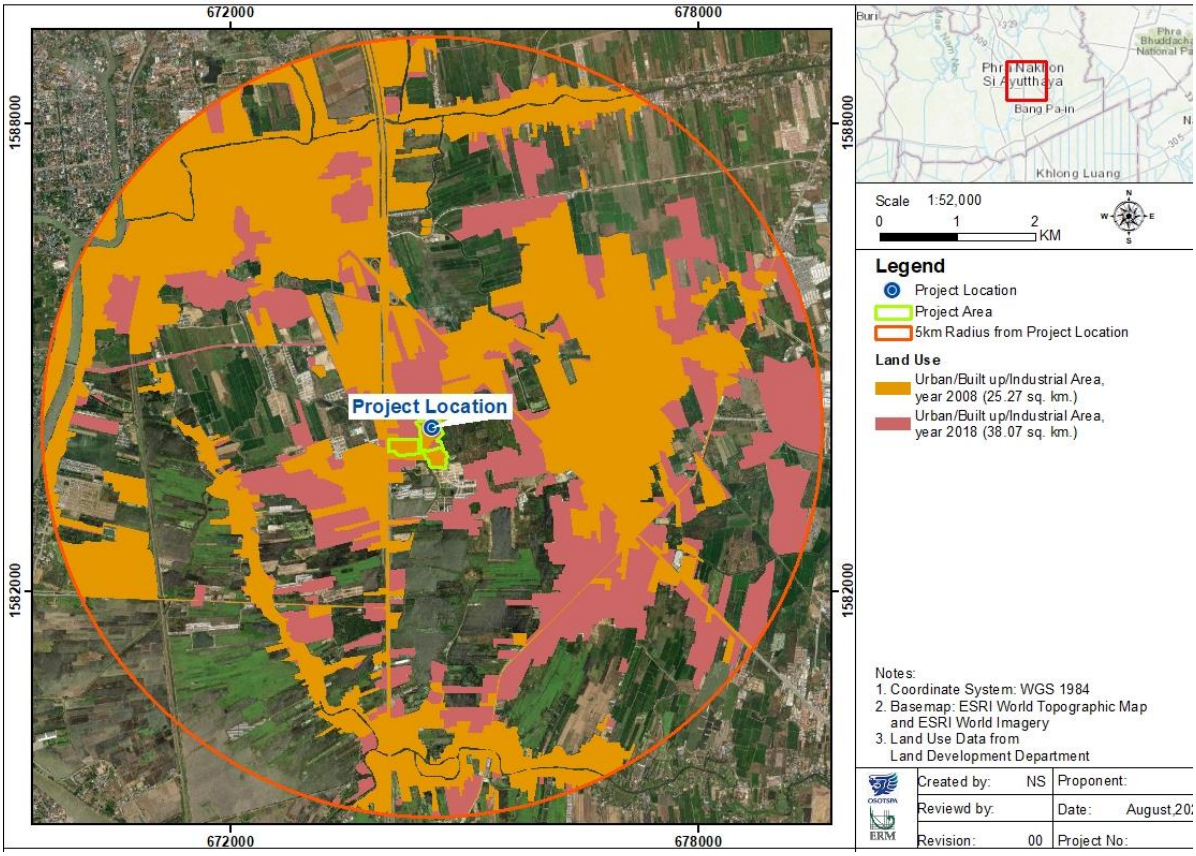


Figure 5-6 Land Use/ Land Cover Changed between 2008 – 2018

Key Findings

- The micro-watershed within which the Site is located extends up to an area of ~3,963.55 Sq.km
- The topography in the study area surrounding the Site is mostly flat plain, but there is a very strong slope to the northeast of the watershed. The elevation in the watershed ranges from 0 m amsl to 563 m amsl, with the highest point in the northeast of the Site.
- The watershed's natural gradient is observed to be southwestern, with natural drainage (streams and canals) and falls in the Chao Phraya River located southwest of the watershed.
- Groundwater flow direction was calculated and it is found to be from east to west in the upper part of the micro-watershed while it is towards south in the lower part of the micro-watershed direction.
- Within the study area, agriculture was discovered to be the most prevalent land use pattern, followed by urban/built-up, industrial, miscellaneous, river/water bodies, and forest.
- Agricultural areas have become the majority of settlement areas over the last ten years (2008-2018), followed by industrial areas, other areas, water resources, and forest areas.
- A review of historical land use data from 2008 to 2018 revealed that the area's settlement land use/land cover increased by approximately 16.31% over the past decade.
- Increased urbanization is likely to put a pressure on water resources and social infrastructure, as well as degrade soil and water quality (surface and groundwater) as a result of sewage and solid waste discharge and disposal. However, because water resources are plentiful in the area, the risks of water scarcity associated with high urbanization are deemed insignificant. Degradation of water quality, on the other hand, is regarded as a major concern within communities.

6. ENVIRONMENTAL SURVEY

The overall objective of conducting an Environmental Survey was to identify any gross areas of concern/issues within the Site, its immediate vicinity and within the micro watershed of the Site that can impact the water (surface water and groundwater) quality. On 25 August 2022, ERM assessors conducted an Environmental Survey to identify possible areas of concern or improvement present at the Site and its immediate vicinity and within the micro watershed of the study area. Potentially impacting the water (surface and/or groundwater) quality. Hence, the following tasks were conducted as part of the survey:

An observational Site visit was conducted by ERM assessors to the following plants operated under Osotspa Ayutthaya Company Limited premises to visually inspect the land use pattern and significant environmental concerns:

- Osotspa Beverage Company (OSP-AY)
- Osotspa Glass Manufacturing (SGI-AY)
- Siam Beverage Manufacturing (SBM)

Identifying the potential contaminants associated with potential pollutant sources;

- Review of readily and publicly available current water quality and related trends within the watershed and groundwater basin; and
- Review of publicly and readily available regulatory database search with concerned regulatory authorities to identify the environmental concerns/ issues that have been brought to the attention of the regulatory agencies about the micro-watershed.

6.1 On-Site Environmental Survey

Based on the plant layout provided for review and data reported by the Site representative it was stated that the total premises occupy an area of 208,456 m^2 parcel of land, whereby the built-up area accounts for 62,400 m^2 parcel of land. Reportedly, the breakdown of the land use for the three facilities operating under Osotspa Ayutthaya is as follows:

- OSP-AY: 93,456 m^2 (built-up area of 35,099 m^2)
- SGI-AY: 56,548 m^2 (built-up area of 17,586 m^2)
- SBM: 19,952 m^2 (built-up area of 4,376 m^2)
- Warehouse: 38,500 m^2 (built-up area of 23,900 m^2)

Facilities at the Site include a production area, warehouses, concrete yard, utilities (e.g. natural gas station, chiller and boiler), hazardous container storage, wastewater treatment plant, treated water pond, canteen and security house.

The facility has clearly demarcated boundaries on all sides of the plant area. Based on the information provided by the Site's representative, the plant covers an area of approximately 208,456 m^2, including the production building, warehouse, water treatment area, wastewater treatment plant, utility area, retention ponds, greenbelt area and vacant land.

6.1.1 On-Site Utilities

The Site houses the following utilities:

Utility Description	Total Number & Capacity	Comments
Air Compressors	1 No.x 37 kW, 2 No. x 55 kW, 1 No. x 75 kW, 2 No. x 90 kW and 1 No. x 110 kW – Total seven(7)	--

Utility Description	Total Number & Capacity	Comments
Chillers	2 No.x 168.7 kW, 1 No. x 284.9 kW, and 1 No x 338 kW	
Cooling Towers	1 No. x 7.4 kW, 1 No. x 11 kW and 2 No. x 16.5 kW	--
Boilers	3 No. x 6 tonne/hour, and 1 No. x 8 tonne/hour capacities;	--
Natural Gas Tanks	NA	Purchased from PTT Public Company Limited
Liquefied Petroleum Gas Cylinders	NA	Placed in the canteen of both the facilities

Note: NA – Not Available

The cooling tower and boiler blowdown water is reportedly conveyed to the onsite WWTP for further treatment prior to disposal.

The two main utilities shared across operating facilities include the boiler and wastewater treatment plant. It was observed that the boiler operates on an alternating basis, supplying to both SBM and OSP-AY. Whilst wastewater generated at SBM is directed through existing drains to the wastewater treatment plant operated by OSP-AY for further processing. As observed during the Site visit, all key utilities are located on paved concrete with roofing. According to the regulatory requirements for SGI-AY, wastewater is not permitted to be discharged from the facility, hence, generated wastewater is directed to the 16,425 m^3 pond located in the west direction of the operating facility.

6.1.2 Storage tanks

Based on the information obtained the Sites contain the following Above Ground Storage Tanks (ASTs) and Under Ground Storage Tanks (USTs) as follows;

- **OSP-AY**
  - One (1) 300 m^3 UST of abstracted groundwater;
  - Two (2) 1,500 m^3 AST tanks- one tank used for the storage of water from PWA and; the other for mixing of PWA water and Birm filtration process water and supply water;
  - One (1) 1,200 m^3 treated wastewater pond (open and with concrete lining); and
  - One (1) 46,500 m^3 retention pond of treated wastewater prior to discharging off-Site.
- **SBM**
  - One (1) 30 m^3 UST (sump pit) of process wastewater to be treated at OSP-AY wastewater facilities.
- **SGI-AY**
  - One (1) 100 m^3 UST of treated raw water from the OSP-AY Plant;
  - Two (2) 1 m^3 AST of supply water directly from PWA; and
  - One (1) 16,425 m^3 pond of treated wastewater without discharging off-Site.

It was reported that all storage tanks and ponds were lined with concrete except the treated wastewater pond located in the SGI-AY plant. The condition of the concrete storage was unknown due to limited access to the area. No information on the raw water storage tanks in the SBM Plant was available.

6.1.3 On-Site Bore wells

Based on the documents provided for review and interview with the Site representatives, it was identified that approximately 75 % of the total water consumption is sourced from bore wells present on site whilst the remaining 25% is sourced from municipal water. All five bore wells (i.e. Well ID: 3804-0289, 4101-0031, 4403-0013, 731059-002, and 730463-0015) are located on site of which four (4) are operating and one (1) is in standby. The bore wells were reported to be registered with the local Office of the Ministry of Natural Resource and Environment, however, the evidence of such documents was not available for review. Reportedly, the aforementioned bore wells were installed in 2001-2020 with depths of 100-190 meters below ground level. It is approximated that the yield per bore well is shown in **Table 6-1**.

Table 6-1 Onsite Groundwater bore wells and yields

Bore well ID	Yield (KL/hour)
3804-0289	1,280
4101-0031	1,280
4403-0013	800
731059-002	3,200
730463-0015	3,200

As per the Site bore well operation plan, groundwater abstraction is not solely done from one bore well, rather the abstraction is rotated amongst the bore wells on-Site. In addition, the Plant has installed mechanical flow meters for the measurement of daily withdrawal on all bore wells. It was reported that groundwater abstractions have never exceeded the groundwater usage permits. During the document review, the daily usage of groundwater from each bore well together with the daily groundwater quality results were provided. The results indicated no exceedances in any of the parameters from the standard and were safe to be used for consumption.

During the Site visit, the assessors visited one bore well station located at the far-east direction of the OSP-AY Site, behind the canteen area. It was observed that the bore well was installed within a fencing area to restrict access and was provided with proper enclosures to protect the wellhead from physical damage or sabotage. Additionally, the Site reported that the remaining bore wells were also maintained within a fenced area with appropriate enclosures. However, based on the observation made during the Site walk, the surrounding area at which one of the bore well is located was observed to store bulky waste and scraps from site construction. It was reported that the Site was undergoing construction work and waste was temporarily stored in the area before being transported and disposed by verified third parties.

It was also informed during the Site visit, that there are no piezometers installed on-site to monitor the groundwater level as it is not required by local regulation. As reported by the Site personnel, the Site has never experienced water shortage or drought. Owing to this, the impact on the Plant's source water availability is considered to be Low.

6.1.4 Water Treatment Process (WTP)

OSP-AY Plant has three (3) on-site Water Treatment Plants (WTP) located in each production building for the treatment of raw water abstracted from on-Site bore wells and municipal water. The WTP treats water via several processes including filtration (multimedia filters and ultrafiltration), softener resin filter, UV treatment, and reverse osmosis (RO) system for all three plants within the Site boundary. The steps involved in the treatment of raw water from its abstraction and reception at the Site is listed as follows:

- Groundwater is abstracted from one operating well at a time and stored in the 300 m^3 raw water tank. It is later transferred to the Birm filtration process for further processing.
- In parallel, the municipal water together with RO cooldown water which was reported to be cooling water from production processes and RO rejected water from RO water treatment process are received via pipelines and stored in a 1,500 m^3 tank No.1.

- The water from the Birm filtration process and mixed water from the 1500 m^3 tank No.1 are transferred to a storage tank No.2 of capacity 1500 m^3. The combined water is then processed via the following methods;
  - Four (4) multi-media filters and two (2) ultrafilter;
  - Three (3) softener resin filters with a capacity of 120 m^3/h for each unit; and
  - Three (3) RO systems with a capacity of 30 m^3/h for each unit.

According to the interview with the responsible Site operator, the Site subjects the RO reject to further treatment, thereby, minimizing the amount of rejected water to 12.5 m^3 per hour per unit. A total of 17.5 m^3/h is required to be discharged into the on-Site wastewater treatment plant for further treatment. The Site optimizes water use in the Site by reusing the RO reject to reduce freshwater consumption. However, no information about the areas/process where RO reject is reused was not available.

Raw water received at the SBM Plant undergoes treatment through an additional filter with a capacity of 20,000L prior to utilization in the processes. The Site also reported that SBM Plant also receives raw water from PWA directly in addition to the treated raw water received from OSP-AY Plant.

6.1.5 Wastewater Treatment Plant

The Site has one wastewater treatment plant (WWTP) to treat wastewater generated from OSP-AY and SBM operations. Wastewater from both Plants is generated through the bottle-cleaning process. While as per regulatory requirements and conditions of the factory activities, wastewater generated from SGI-AY is disposed of in the pond located in the western direction where it is left to evaporate. No wastewater discharge is permitted at the SGI-AY plant.

Wastewater generated from SBM production is stored in a 30 m^3 sump pit and subsequently passed through pre-screen at the discharge point before combining with wastewater from OSP-AY lines in WWTP. It was reported by the Site representative that approximately 90% of the wastewater treated comes from OSP-AY and the remaining 10% comes from SBM. Combined wastewater then passes through a screening process, equalization tank (capacity of 980 m^3), neutralization tank (where sodium hydroxide, iron chloride, phosphoric acid and nitrogen is added), then continued separated into two MSBR tanks, filtered and reused or recycled on-site or directed into the retention pond (approximate capacity of 46,500 m^3 lined with concrete). Based on the interview with the Site representatives, the wastewater process flow is shown in **Figure 6-1 O.** The total design capacity of WWTP is 2,500 m^3 per day. Presently, the WWTP treats approximately 1,800 m^3 per day on average. Based on the document available for review, there are a number of days from August to December 2021 that the Site operated WWTP exceeding the maximum designed capacity of 2,500 m^3. The WWTP influent varies up and down day by day due to the operation and reached a maximum of 3,151 m^3 in October 2021. However, it is documented that the exceeding events are sometimes caused by the maintenance of the WWTP system including, cleaning or maintenance of retention pond and re-treating of wastewater from MSBR tanks.

WWTP effluent is then either used for landscaping or cleaning around the Site, reused (in toilets or cooling towers), or stored in a concrete retention pond and subsequently discharged into the local water stream (Thap Taeng Canal) located adjacent to the retention pond (approximately 900 m^3 is discharged per day). Water recycled is required to pass through additional treatment processes including filters, multimedia, carbon, filters, ultraviolet treatment and storage prior to being utilized in the cooling tower.

Sludge generated from the wastewater treatment plant is passed through a thickening process and stored in a waste skip (approximately 10-12 tons). It was reported by the Site representative that sludge is removed from the premises approximately twice a month by a third party, Green Environment Company. However, during the Site walk, it was observed that in the corner of the storage areas few chemicals containers (i.e. approximately 23 containers of chlorine 10% and approximately 14 containers of chlorine solution), as well as approximately four (4) two-hundred-liter drums with funnels in the mouth opening, were present in the area for storing used oil (used in the WWTP). It was

mentioned by the Technical Operator in charge of the Site that oil in the WWTP is replaced bi-annually, hence it is expected that the used oil containers have been stored at the premises for several months. As reported by the Site representative, the containers were temporarily placed in the areas and shall be removed from the Site as per the waste management and disposal procedure. Additionally, the flooring condition was observed to be in good condition without cracks, and therefore the risk of potential contamination to soil and groundwater is considered to be low to moderate. In addition, a regular inspection is recommended to ensure the implementation of site standard operating procedures and waste management system.

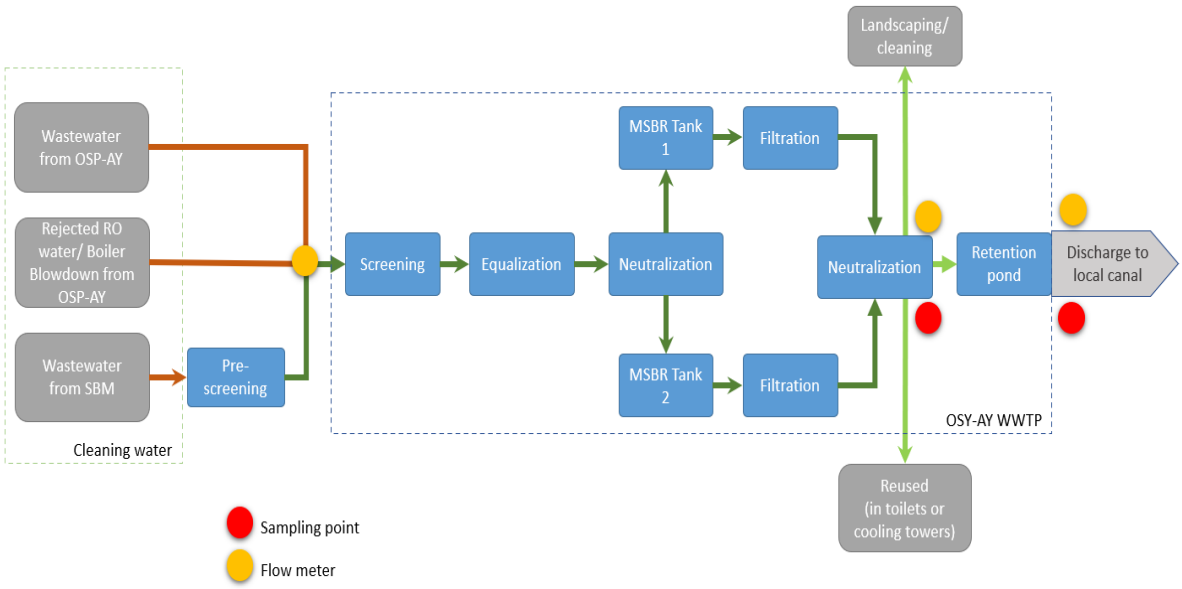


Figure 6-1 OSP-AY and SBM Wastewater process flow

As for SGI-AY, it was reported by the Site representative that due to their operational activities, the Site is prohibited from discharging wastewater out of the Site Boundary. As seen in **Figure 6-2**, wastewater generated at the Site passes through the oil water separator, overflowed into an aeration treatment process (treatment capacity of 50 m^3 per day) and then passed through a filter press machine (where chemicals are added to coagulate sediment and remove sludge). An on-site operator stated that sludge is removed from the Site boundary approximately every 3 months with a capacity of two, one-ton bags. Treated wastewater is then directed to an open pond, located in the western direction of the facility and left to evaporate. The total capacity of the pond was reported to be 16,425 m^3 with no concrete or sealed lining.

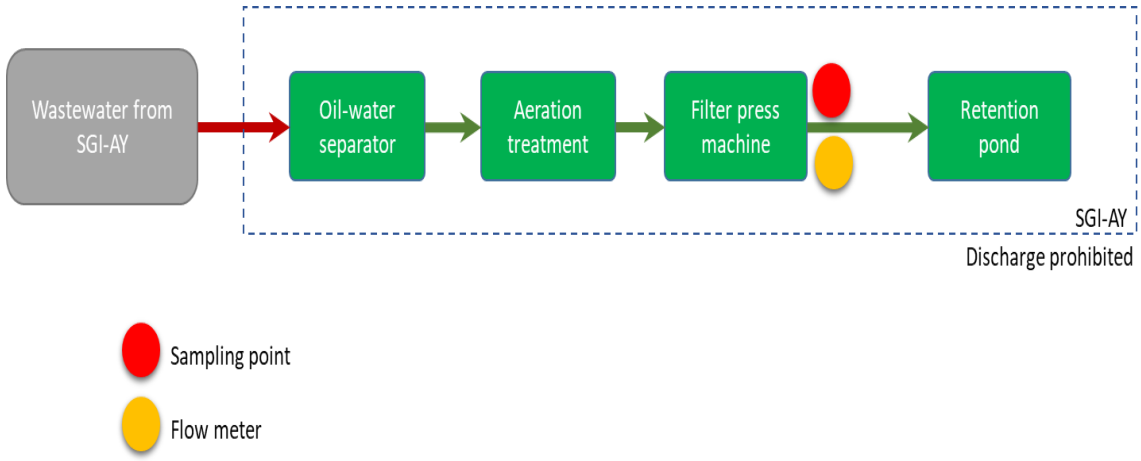


Figure 6-2 SGI-AY Wastewater Process Flow

6.1.6 Hazardous Waste and Chemicals Storage

Each facility has a designated storage area for storing hazardous waste as required by regulations. At OSP-AY, the Site designated the paved area in between the wastewater treatment plant and the production house for receiving waste generated from the production house. A mixture of both hazardous and non-hazardous waste is placed in the middle of the concrete yard. Site representative reported that waste from production lines 4 to 9 is brought out and cleared during the morning while waste from mixing lines 1-3 is brought out and cleared during the afternoon. The waste department is then responsible for segregating the waste into recyclables (i.e. sellable materials), hazardous containers and non-hazardous. Examples of hazardous waste generated at the Site are used chemical containers, contaminated clothes/rugs, ink cartridges and used fluorescent light bulbs.

The frequency of waste removal was reported to be as follows:

- General waste removed by the municipality on a daily basis;
- Hazardous waste removed by the registered waste vendor on a bi-weekly basis (depending on the volume of waste stored); and
- Infectious waste removed within 90 days by Akkhie Prakarn Public Company Limited;

As observed during the Site visit, chemicals stored throughout the Site are in areas where chemicals are used. Chemicals that were mainly used at the wastewater treatment plant (i.e. Ferrous, Phosphoric acid, Chlorine, Sodium Hydroxide, etc.) were observed to be stored on paved ground, with secondary containment, spill kit equipped and roofed. However, it was observed that forklift diesel oil was present in the scrap yard area with no secondary containment and next to an open soil area. As a corrective action, the Site representative stated that the Site is currently procuring a paved new cage for the oil containers with secondary containment and appropriated spill kits provided.

Regarding the operation in SBM, the waste comprises of general office waste, and hazardous waste including contaminated containers, ink cartridges, contaminated fabrics, and used lubricant oil which is reportedly disposed of by third parties on monthly basis. The condition of waste storage was observed to be in good condition with covers and gates restricted to authorized personnel. Chemical use on-site was reported to be gear oil (used for bottle cap opening), lubricants, and cleaning agents. According to the information provided by the Site representative, an appropriate storage room is equipped to keep such chemicals in place.

As for SGI-AY, waste generated is segregated and stored at the designated paved area located to the south of the facility. The main generated wastes include general waste, hazardous waste such as, contaminated fabric, containers and other materials, used spray cans, electronic wastes, mold cleaning

agents, Sulphur-containing scrap and ashes, and wastewater sludge. Similar to OSP-AY, hazardous waste was reported to be transported and handled by authorized waste disposers on regular basis.

6.1.7 Raw Water Storage Pond and Intake Water

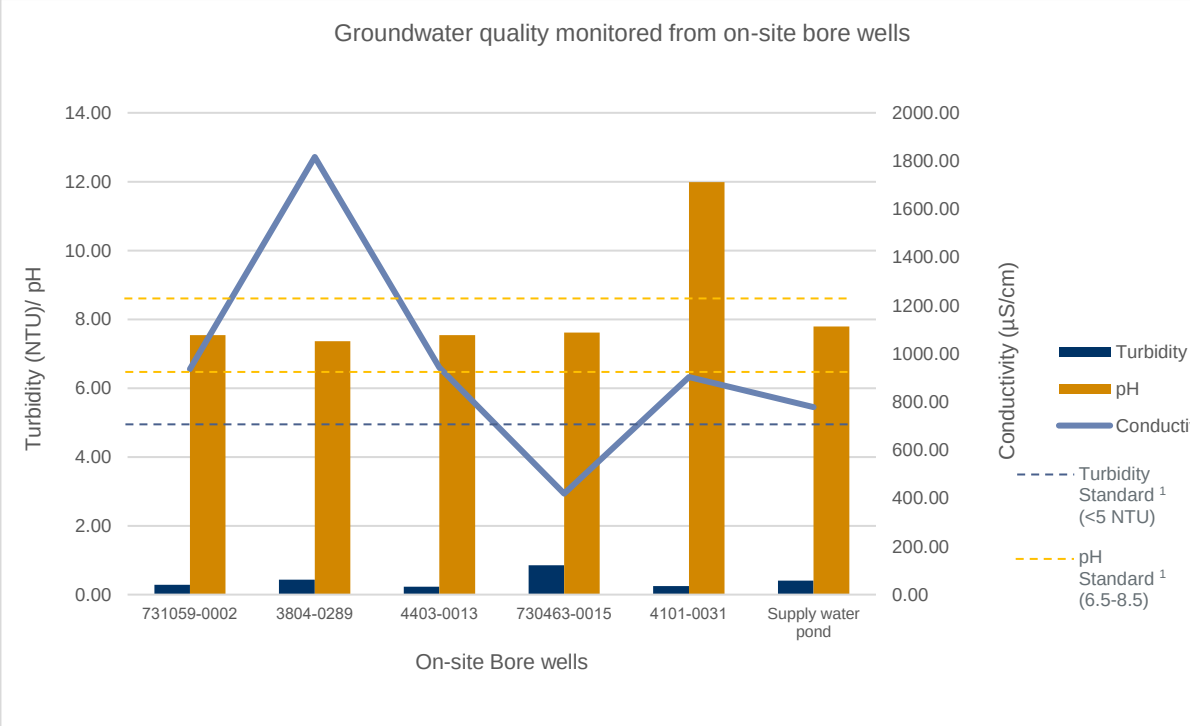
As informed by the Site representatives, water used at the Site is sourced from groundwater and municipal water (PWA). Water consumed in SBM is supplied from water treatment units in OSP-AY. As for OSP-AY, there is no opened raw water pond to store abstracted water from the bore well, rather withdrawn water is collected in a 300 m^3 raw water storage tank prior to treatment. Whilst, municipal water together with reused RO cool-down water enters a 1,500 m^3 intake tank as the first storage and then into treatment processing units.

At SGI-AY, it was reported that the facility has a designated raw water storage container (capacity of 100 m^3) to store water directed from OSP-AY and municipal water. The ratio is approximately 75 to 25 percent respectively.

Based on the information provided, the Site does not have a storage tank to store raw water in case of any disruption to the water supply. Currently, the combined average water withdrawal of the Site from both bore wells and PWA is ~4.5 MLD and the total raw water storage capacity on-site is ~1.8 MLD (1 No.x 300 m^3, 1 No.x 1500 m^3). Thus, in case of unforeseen disruption to existing water supply arrangement, existing on-Site raw water storage capacity/reserves cannot sustain normal operations for even a single day. However, it was reported that the Site has never experienced a water shortage since its commencement.

6.1.8 Raw Water Quality

The groundwater quality of all five (5) bore wells at the Site along with the supply water from PWA was reportedly constantly monitored on a daily basis by the Site's internal laboratory prior to utilization in the processes. The collected groundwater samples were analyzed for three (03) parameters: pH, turbidity, and conductivity. The 6-month average of groundwater quality records for such parameters shows in **Figure 6-3**. The result indicated the pH and turbidity were under drinking water regulatory standards, prescribed under *Thailand Drinking Water Standard Manual, issued by Department of Medical Sciences under Ministry of Public Health, B.E. 2562 (2019)*, except for the pH value from bore well number 4101-0031. There is no prescribed regulatory limit for conductivity.



Note: [1] Drinking water standard is specified under Thailand Drinking Water Standard Manual, issued by Department of Medical Sciences under Ministry of Public Health, B.E. 2562 (2019)

Figure 6-3 **Groundwater Quality Monitored from on-Site Bore Wells**

Currently, the Site performs water quality analysis for only three (03) parameters and not for a comprehensive suite of analytes. This is critical as rapid urbanization and reported domestic wastewater from communities into waterways as informed by the surrounding communities during the environmental survey could introduce contaminants into the aquifer and deteriorate the quality of groundwater as well as surface water.

6.1.9 Wastewater Quality Monitoring

OSP-AY and SBM Plants:

As mentioned in **Section 6.1.5,** wastewater generated from SBM is directed for treatment at OSP-AY WWTP. The factory manager stated that at the connection point between SBM and OSP-AY, SBM monitors pH, temperature, Chemical Oxygen Demand (COD), and suspended solids.

Based on the interview with the Site representative, it was mentioned that the quality of treated wastewater from OSP-AY WWTP is monitored routinely before being discharged into the retention pond. Parameters and monitoring frequency conducted by the internal wastewater management team include:

- pH and temperature on a daily basis;
- Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) on a weekly basis; and
- Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are monitored every 30 minutes;

Furthermore, the OSP-AY engages ALS Laboratory Group (Thailand) Co., Ltd., a third-party laboratory to conduct monitoring of the treated wastewater quality on a monthly basis. The monitoring parameter includes BOD, COD, color, oil & grease, pH, TDS, total Kjeldahl Nitrogen and TSS. Based on the

documents reviewed, no exceedance from the regulatory limit [5] was identified. The highest concentration of both influent and effluent of OSP-AY from the 6-month period from January to June 2022 was reported to be in April 2022 as indicated in **Table 6-2**.

Table 6-2 Wastewater quality of influent and effluent of OSP-AY WWTP in April 2022

Measuring parameter	Unit	Influent	Effluent	Standard[2]
BOD (5 days at 20 degree C)	mg/L	124	2	≤20
COD	mg/L	781	5	≤120
Color (at Original pH)	ADMI	-	10	≤300
Color (at pH 7.0)	ADMI	-	10	≤300
Oil and grease	mg/L	5	3	≤5
pH		8	8.3	5.5-9
Total Dissolved solids Dried at 180 °C	mg/L	1,116	908	≤3,000
Total Kjeldahl Nitrogen as N	mg/L	42.4	1	≤100
Total Suspended Solids Dried at 103-105 °C	mg/L	630	5	≤50

Note: [2] Effluent standard for factories, industrial estate and industrial park set by Notification of the Ministry of Natural Resource and Environment and effluent standard for factories and industrial park set by Notification of The Ministry of Industry dated June 07, B.E.2560 (2017).

The effluent standard for factories/industries set by the Ministry of Natural Resource and Environment includes a total of sixteen (16) parameters including heavy metals, microbiology and pesticides. However, the Site is monitoring only nine (09) parameters. The treated wastewater is recycled for landscaping green areas on-site. However, the Site has never conducted an assessment to identify the hydraulic loading rate for the soil in the greenbelt area.

Prior to discharging into the local canal, the Site monitors BOD and COD at the discharge point once again. Based on the interview with the Site representative, no exceedances of wastewater concentration was reported during the years but the evidence of monitoring result was not provided for review.

SGI-AY Plant:

As for SGI-AY, it was reported that the quality of treated wastewater in the retention pond is monitored bi-annually for pH, color, temperature, odor, BOD, COD, TDS, TSS, oil and grease and TKN. The monitoring result dated 12 October 2022 was available for review, and no exceedance of any measuring parameter from effluent standard for factories was identified. The Site has not measured the water level in the retention pond located to the west-eastern sector of the SGI-AY plant nor the evaporation rate since the Site commencement. However, the Site representative reported that the water level is consistent throughout the year.

6.1.10 Soil and Groundwater (Quality) Monitoring

Based on the review of the Factory Permit, the Site is classified as a factory type 20 (3) which does not qualify under the *Ministerial Regulation, B.E. 2559 (2016), Re: Control of Soil and Groundwater Quality within Factory Premise* to conduct soil and groundwater monitoring. As a result, the Site has never conducted any investigation for establishing a baseline for soil and groundwater quality to evaluate potential impacts imposed by its operating activities. Therefore, the overall potential of soil and groundwater contamination due to on-site operational activities, inclusive of waste and wastewater management practices, cannot be ruled out.

[5] Effluent standard for factories, industrial estate and industrial park set by Notification of the Ministry of Natural Resource and Environment and effluent standard for factories and industrial park set by Notification of The Ministry of Industry dated June 07, B.E.2560 (2017).

6.2 Off-Site Environmental Survey

The majority of the land use within the larger watershed was observed to be industries, built-up community areas to accommodate employees working in the industries, and vacant land used for agricultural purposes. No field study with the neighboring communities was conducted, hence, the details below are based on the aerial imagery. The following were identified as areas of environmental importance/ concerns within the Site surroundings:

- Industrial factories adjacent to the Site;
- Petrol stations located within 500 meters of the Site (e.g. PTT Station located in the west direction, PTT Gas Station and Bangchak Petrol Station located in the west direction);
- Chao Phraya River located approximately ~4.7 kilometers in the west direction of the Site; and
- Waste and wastewater management practices conducted by communities around the Site.

It was observed that approximately 30% of the land area is dedicated to agricultural purposes, therefore risks of contamination due to agricultural run-off to the shallow groundwater or surface water (i.e. the Chao Phraya River) are considered to be low-medium.

6.2.1 Industries within the Study Area

The study area (~5 km radius of the Site) is comprised of multiple industrial factories due to the presence of Rojana Industrial Park. Located ~1.3 kilometers from the Site in the east direction are factories mainly engaged in the electronics, automobile, chemical, rubber, and frozen food sectors.

North

- NMB-Minebea Thai Ltd. (Ayutthaya Factory), the manufacturer of electronics, is located approximately 3 kilometers to the north of the Site.
- Other occupancies within the area were observed to be vacant land and community areas.

South

- Not applicable (based on aerial imagery it was observed that the south direction comprised of vacant agricultural land areas and small community clusters).

East

- Rojana Industrial Park, covering a total area of 56 square kilometers, housing numerous manufacturing facilities.
- Fujikura Electronics (Thailand) Co., Ltd, manufacturer and assembler of electronics, located approximately 1.5 km to the east of the Site.
- NIDEC Mobility (Thailand) Co., Ltd, manufacturer of automotive electronic components and systems located approximately 1.6 km to the east of the Site.
- Nippon Steel Thai Sumilox (Thailand) Company Limited, manufacturer of non-oriented electrical steel coil and sheets, located approximately 1.7 km to the east of the Site.
- Pioneer Manufacturing (Thailand) Company Limited, manufacturer of car stereo and home audio products, located approximately 2.0 km to the east of the Site.
- OKI (Thailand) Company Limited, manufacturer of printing and multifunction equipment, located approximately 2.7 km to the east of the Site.
- Thai Nippon Food Company Limited, manufacturer of frozen and chilled foods, located approximately 2.7 km to the east of the Site.

- Thai Indo Kordsa Company Limited, manufacturer of chemicals, plastics and paper, located 2.9 km to the east of the Site.
- Nikon (Thailand) Company Limited, manufacturer of cameras and electronic components, located approximately, 3.0 km to the east of the Site.
- Nakashima Rubber (Thailand) Company Limited, manufacturer of rubber, located approximately 3.3 km to the east of the Site.
- Techman Electronics (Thailand) Company Limited, manufacturer of hard disks, located approximately 3.5 km to the east of the Site.

West

- Not applicable (based on aerial imagery it was observed that the west direction comprised of two residential villages, commercial offices and shops).

Both ERM and Osotspa representatives did not physically enter any of the facilities as part of this assessment. An assessment based on readily available information was conducted instead.

The majority (approximately 95%) of the industries identified around the Study area are located within Rojana Industrial Park. The source of water to the industrial park is not known. It is expected that the wastewater generated in industries/factories is treated either via facilities on-site wastewater treatment process or in combined industrial estate treatment plants.

ccording to the review of the Google Earth Imagery, it was observed that the central sanitary landfill for Ayutthaya province is located approximately 14 kilometers west of the Site. The Phra Nakhon Sri Ayutthaya Provincial Sanitary Landfill has a total area of approximately 1,556.64 square kilometers. The sanitary landfill consists of three landfills, a wastewater treatment plant, three evaporation ponds, a weighing scale, an office area, a security office, fourteen mechanical vehicles, and five groundwater monitoring wells. It was reported by the Pollution Control Department that the Ayutthaya Sanitary Landfill monitors the following qualities for treated wastewater: pH, Arsenic, Cadmium, Lead, Manganese, Zinc, Mercury, Nitrogen, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS) and Total Suspended Solids (TSS). It was reported that groundwater quality is monitored every 6 months to ensure the quality of groundwater is in accordance with the *Notification of the National Environment Board, Issue 20 (B.E. 2543) released under the Environmental Promotion and Conservation Act, B.E. 2535 (1992), Re: Prescribing Groundwater Standards*. No monitoring results or complaints were identified on public sources.

6.2.2 Waste and Wastewater Management in the Villages around the Site

Based on the 2021 Ayutthaya Provincial Report prepared by the Strategy and Information for Provincial Development Unit, Governor's Office of Phra Nakhon Si Ayutthaya Province, the district comprises of 34,845 households. According to the Provincial Department, Bangpa-in district generates an average of 5.96 tons of waste per day. Whereby, domestic waste generated from households and factories is collected and disposed by municipal waste disposers.

According to the aerial map reviewed, it was observed that the nearest landfill is located approximately 14 kilometers in the west direction of the Site. The Pollution Control Department reports the landfill to be a sanitary landfill, with no leachate treatment plant or groundwater monitoring well. The sanitary landfill reportedly covers a total area of 595,200 square kilometers.

The communities do not have a dedicated wastewater treatment system. Domestic wastewater from communities is directly discharged into waterways which eventually leads to the Chao Phraya River and thereby resulting in its contamination. Due to practice, this is likely to lead to shallow groundwater and surface water contamination. No quality-related data in the immediate vicinity were available for review in the public domain.

6.2.3 Agriculture practices within area

Agricultural practices were observed within the study area (approximately 2 kilometers in the west direction of the Site. No primary details were provided regarding the occupation of the local authority, however, based on the 2021 Ayutthaya Provincial Report prepared by the Strategy and Information for Provincial Development Unit, Governor's Office of Phra Nakhon Si Ayutthaya Province, it was reported that the top five occupations in the province include industrial job (approximately 25%), commercial and market (approximately 20%), handicraft (approximately 14%), retails (approximately 10%) and agriculture (approximately 7%). Due to these statistics, it is expected that the groundwater and surface water vulnerability due to the unscientific application of agrochemicals via agricultural run-off is considered to be 'low'.

Environmental Implications of Surrounding Land Use

Details of the major land use and their environmental implications within the micro watershed around the facility are presented below:

Land Use		
Observation	There is an industrial park (i.e. Rojana Industrial Park Public Co., Ltd) located within the Study Area, covering a land area of more than 56 square kilometers. Rojana Industrial Park houses numerous industrial units/ factories. Mainly conducting manufacturing such as electronic devices, automobile parts, chemical processing, rubber processing and the frozen food sectors. Wastewater treatment, water usage and environmental management practices engaged by these industrial units were not studied under this assessment. Additionally, the Site is not located within the Rojana Industrial Park. Therefore, it is presumed that each factory within the industrial park treats wastewater generated from processes with their individual wastewater treatment plant. Then directs the water into the industrial park's central wastewater treatment unit for secondary treatment. Hence, due to the industrial operations activities and their waste and wastewater management practices that cannot be confirmed, impacts on shallow groundwater and surface water cannot be ruled out.	The study area is comprised of several villages, and settlements, mainly accommodation for employees working in the factories and industrial park located nearby. Water supply for households is expected to be supplied by municipal water for domestic use. Drinking water is expected to be purchased from filter stands or bottled water. Wastewater generated by households is expected to be either directly disposed into municipal wastewater, and septic tanks or discharged into public water ways without treatment. In which the water will eventually discharge into the Chao Phraya River. The municipal solid waste generated is disposed and placed in designated locations (e.g. in front of houses) for municipal waste collectors to gather and dispose of. The nearest landfill (i.e. sanitary landfill) was located to be approximately 14 kilometers in the west direction of the Site.
Likely Environmental Implication	Potential impacts to soil and water due to industrial operations, waste and wastewater management practices and disposal cannot be ruled out and are considered to be *'Low' to 'Moderate'*.	Potential impact to soil and water due to disposal of sanitary and domestic wastewater and solid waste cannot be ruled out and are considered to be *'Moderate' to 'High'*.

Key Findings

1. On-Site

- All onsite utilities were reportedly stored within designated locations with covered roofs and concrete paved floorings. The two main utilities shared across operating facilities include the boiler and wastewater treatment plant, supplying to both SBM and OSP-AY.
- The proportion of ground water and supply water consumption is reported to be 75:25% (reducing from 80:20 in the previous year)
- There are a total of five (5) bore wells installed within the Site premise. Four of which were reported to be in operation and another was reported as no longer utilized.
- The bore wells are reportedly installed up a depth of ~ 100-190 m below ground level.
- It was reported that the Site operates only one bore well at a time for an average of 10 hours per time, chosen based on the locational distance between each well and their groundwater yield.
- One of the bore wells was observed that the Site has installed a fencing area to restrict access. The aforementioned bore well was observed installed on a paved area with proper enclosures to protect the wellhead from physical damages or sabotages.
- However, based on the observation made during the Site walk, the surrounding area at which one of the bore well is located was observed to store bulky waste and scraps without appropriate management.
- Groundwater quality monitoring of each bore well are conducted by the Site personnel on daily basis using automatic probes for measuring the following parameter, conductivity, turbidity and pH. The analysis of physical and chemical parameters is conducted by an external laboratory under the Department of Groundwater on monthly basis. In addition, the Plant has installed mechanical flow meters for the measurement of daily withdrawal on all bore wells.
- The facility maintains groundwater abstraction logs on a daily basis from individual wells
- There are three (3) on-Site Water Treatment Plants (WTP) to treat raw water and supply it to the whole plant.
- Based on the interview, the Site has a program to reduce rejected RO water to WWTP by recirculating in the treatment process.
- Water used in SGI-AY was observed passing through another set of the filter prior to utilize in the processes.
- Wastewater generated at SBM is directed through existing drains to the wastewater treatment plant operated by OSP-AY for further process.
- WWTP-treated effluent is either used for landscaping or cleaning around the Site, reused (in toilets or cooling towers), or stored in a retention pond and subsequently discharged into the local water stream (Thap Taeng Canal)
- On a monthly basis, the OSP-AY engages with the third-party laboratory to conduct monitoring of the treated wastewater quality. The result showed no exceedance of wastewater parameters above the regulatory limits.
- Prior to being discharged into the local canal, the Site monitors BOD and COD once again. According to the operator in charge, it was reported that in 2021, an exceedance of COD was identified. The Site representative mentioned that this was due to a large volume of reverse osmosis (RO) water being disposed directly into the WWTP, causing the treatment capacity to be insufficient. As a corrective action, the Site has recycled the rejected RO in the system to reduce the volume of RO water being directed to the WWTP. No other exceedances were reported.

- Sludge generated from the wastewater treatment plant is directed passed through a thickening process and stored in a waste skip which is transported and disposed of by a third party twice a month.
- It was observed that chemical containers and used oil drums were stored in the corner of the storage areas in WWTP. As mentioned by the Technical Operator in charge of the Site, oil in the WWTP is replaced bi-annually, hence it is expected that the used oil containers have been stored at the premises for several months without appropriated containments.
- According to the regulatory requirements for SGI-AY, wastewater is not permitted to be discharged from the facility, hence, generated wastewater is treated on-site and directed to the 16,425 m3 retention pond with no concrete and lining. Sludge is removed from the Site boundary approximately every 3 months.
- As for SGI-AY, it was reported that the quality of treated wastewater in the evaporation pond is monitored on a bi-annual basis for the concentration of TDS. No other wastewater quality parameters were monitored nor the water level in the pond, however, the Site representative reported that the water level is consistent throughout the year.
- Chemicals were observed stored throughout the Site on the paved concrete.
- It was observed that the forklift diesel oil drum was present in the scrap yard area with no secondary containment and next to an open soil area.
- There are designated storage areas for storing hazardous waste as required by regulation. The areas were observed to be paved and roofed and are in good condition without cracks.
- Wastes generated on-Site are transported and disposed of by third parties on regular basis.
- According to Ministerial Regulation, the Site which is classified as a type 20 (3) factory is not required to conduct soil and groundwater monitoring. Therefore, the Site has never conducted an investigation to establish a baseline for soil and groundwater quality.
- Based on the interview, groundwater quality was reported to be monitored daily prior to utilization in the processes.
- The Site also has never conducted groundwater level monitoring, hence, the groundwater level and water availability are unknown.
- The overall potential of soil and groundwater contamination due to on-Site operational activities, inclusive of waste and wastewater management practices, cannot be ruled out.
- The likelihood of potential impact to soil and groundwater due to on-Site activities is considered '**Moderate**'.

2. Off-Site

- The majority of the land use within the larger watershed was observed to be industries, built-up community areas to accommodate employees working in the industries and vacant land used for agricultural purposes.
- The majority (approximately 95%) of the industries identified around the Study area are located within Rojana Industrial Park, hence it is expected that wastewater generated from the industries within the industrial park are treated internally and then disposed to Rojana Industrial Park's central wastewater treatment system.
- It is expected that wastewater generated in industrial factories is treated either via facilities on-site wastewater treatment process or combined industrial estate treatment plants.
- Potential impacts to soil and water due to industrial operations, waste and wastewater management practices and disposal cannot be ruled out and are considered to be '**Low**' to '**Moderate**'

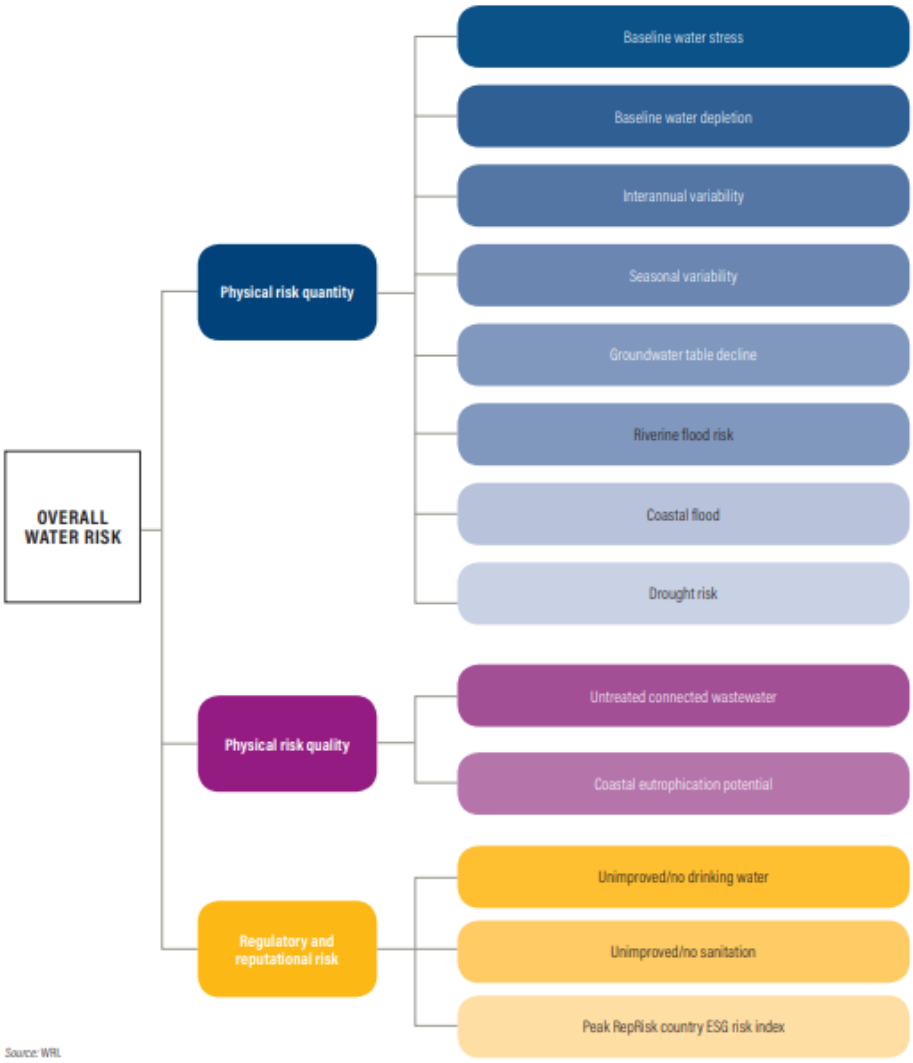
- The central sanitary landfill for Ayutthaya province is located approximately 14 kilometers to the west direction of the Site with a total area of approximately 1,556.64 km2 and is reportedly in accordance with regulatory standards.
- Domestic waste generated from households and factories is collected and disposed by municipal waste disposers.
- The communities do not have a dedicated wastewater treatment system.
- Domestic wastewater from communities is directly discharged into waterways without proper treatment. This could lead to shallow groundwater and surface contamination.
- Potential impact on soil and water due to disposal of sanitary and domestic wastewater and solid waste cannot be ruled out and are considered to be '**Moderate'** to '**High**'.
- Agricultural practices were observed within the study area (approximately 2 kilometers in the west direction of the Site.
- Based on the 2021 Ayutthaya Provincial Report prepared by the Strategy and Information for Provincial Development Unit, the top five occupations in the province include industrially related job (approximately 25%), commercial and market (approximately 20%), handicraft (approximately 14%), retails (approximately 10%) and agriculture (approximately 7%).
- Due to these statistics, it is expected that the groundwater and surface water vulnerability due to the unscientific application of agrochemicals via agricultural run-off is considered to be '**low**'.

7. SOURCE WATER ASSESSMENT – GROUNDWATER

7.1 Assessment of Groundwater Resource Using Aqueduct Tool

7.1.1 Introduction to Aqueduct

Aqueduct was developed by the World Resources Institute (WRI) which used a Water Risk Framework as presented in the following figure that includes thirteen (13) global indicators grouped into three (3) categories of risk and one (1) overall score.



Source: Aqueduct metadata document: Aqueduct Global Atlas 3.0; World Resource Institute

Figure 7-1 Aqueduct Water Risk Framework

Aqueduct is an online global database of local water risk indicators and a global water risk mapping tool for measuring and reporting geographic water risk. It assesses risk based on water supply and quality, regulatory pressure, governance, climate change, socio-economics, and others.

Aqueduct Global Atlas 3.0 includes indicators of water quantity, water variability, water quality, public awareness of water issues, access to water, and ecosystem vulnerability. Thus, it allows stakeholders to assess current and future challenges in terms of water on a broad level. In this assessment, Aqueduct Global Atlas 3.0 were used for:

1. Baseline Water Stress: To understand current status of water use;
2. Projected Change in Water Stress: To gain some perspective on future water stress
3. Seasonal Variability: To understand current intra-annual variation in water availability; and
4. Projected Seasonal Variability: To understand projected intra-annual variation in water availability.

7.1.2 Baseline Water Stress

Baseline water stress measures the ratio of total water withdrawals to available renewable surface and groundwater supplies. Water withdrawals include domestic, industrial, irrigation, and livestock consumptive and non-consumptive uses. Available renewable water supplies include the impact of upstream consumptive water users and large dams on downstream water availability. Higher values indicate more competition among users.

Accordingly, as presented in **Figure 7-2**, the water stress at the Site is reported to be 'High', which may be considered to indicate high competition among multiple stakeholders dependent on common water resources.

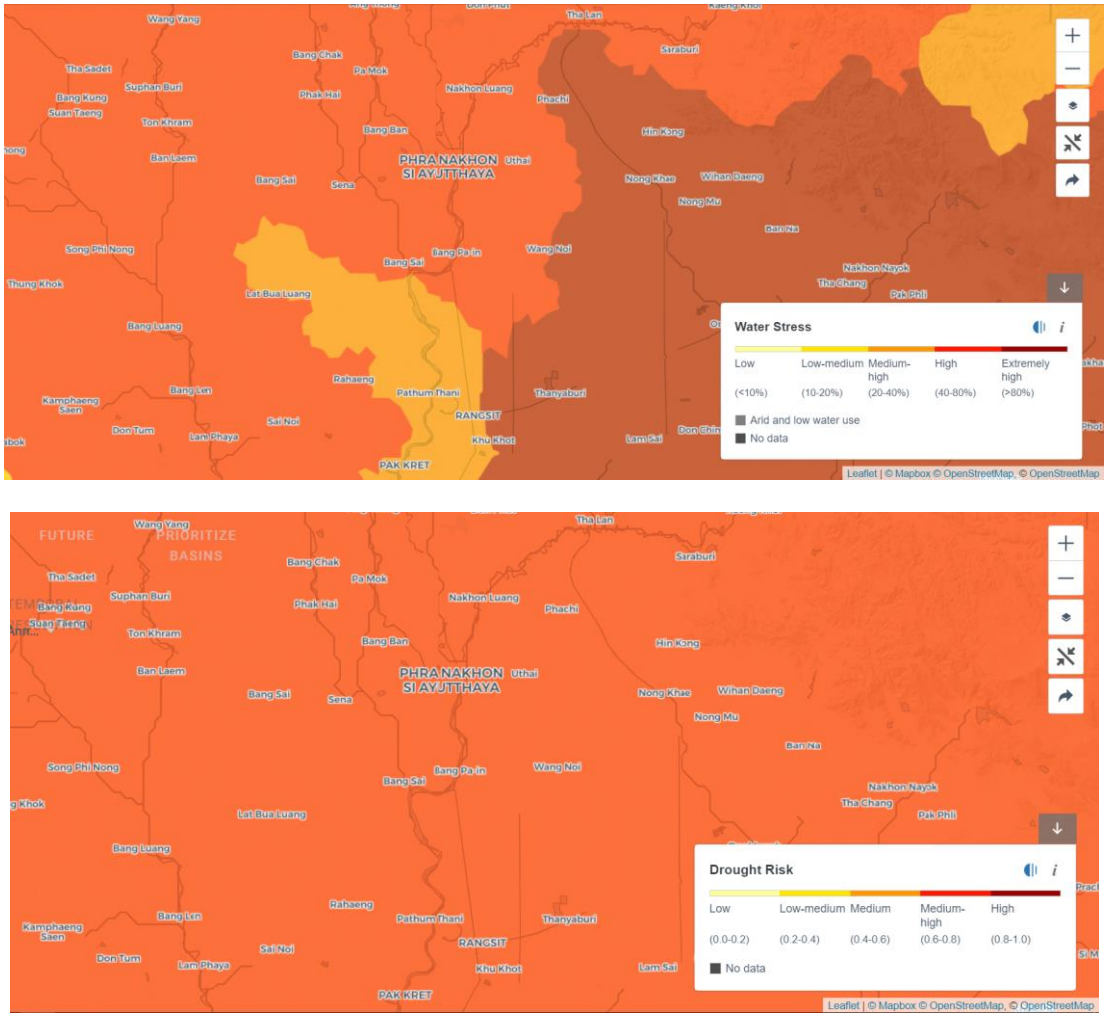


Figure 7-2 Water Risk Assessment for the Site property region using Aqueduct.

7.1.3 Projected Water Stress

As presented in **Figure 7-3** and **Figure 7-4** show the water stress by year 2030 and 2040 under RCP 8.5 and RCP 4.5, respectively. It can be seen that water stress is projected to remain 'Medium-High', reduction in projected water stress under both climate change conditions. This may be due to projected increased rainfall in future. However, the availability of water should also be evaluated on seasonal basis, as the higher annual availability of water can be due to higher rainfall over a short duration of time in a year, and this may lead to water scarcity during dry period of the year in the absence of sufficient storage capacity.

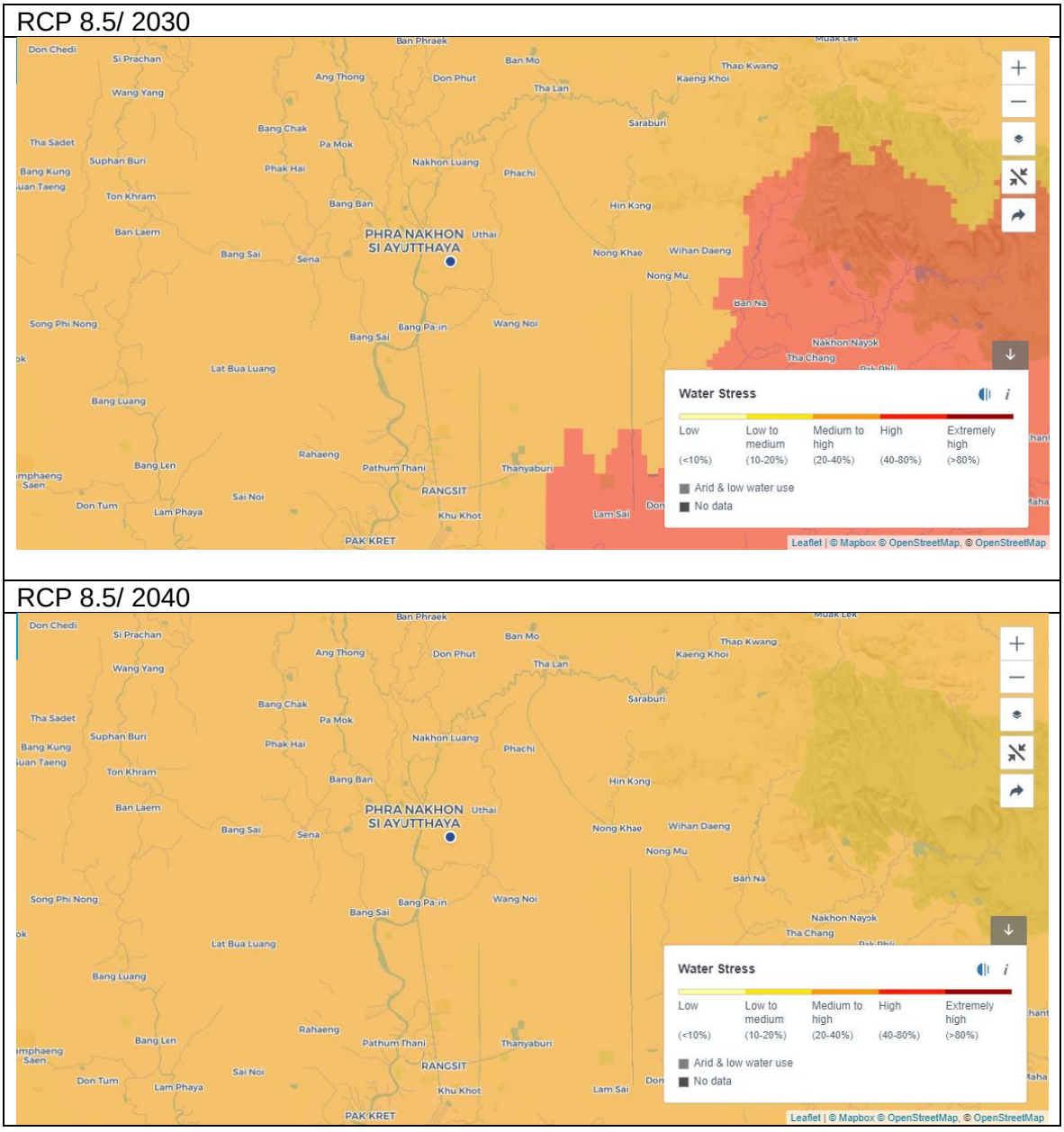


Figure 7-3 Projected Water Stress for the Site property region using Aqueduct for RCP 8.5 Climate Change Scenario.

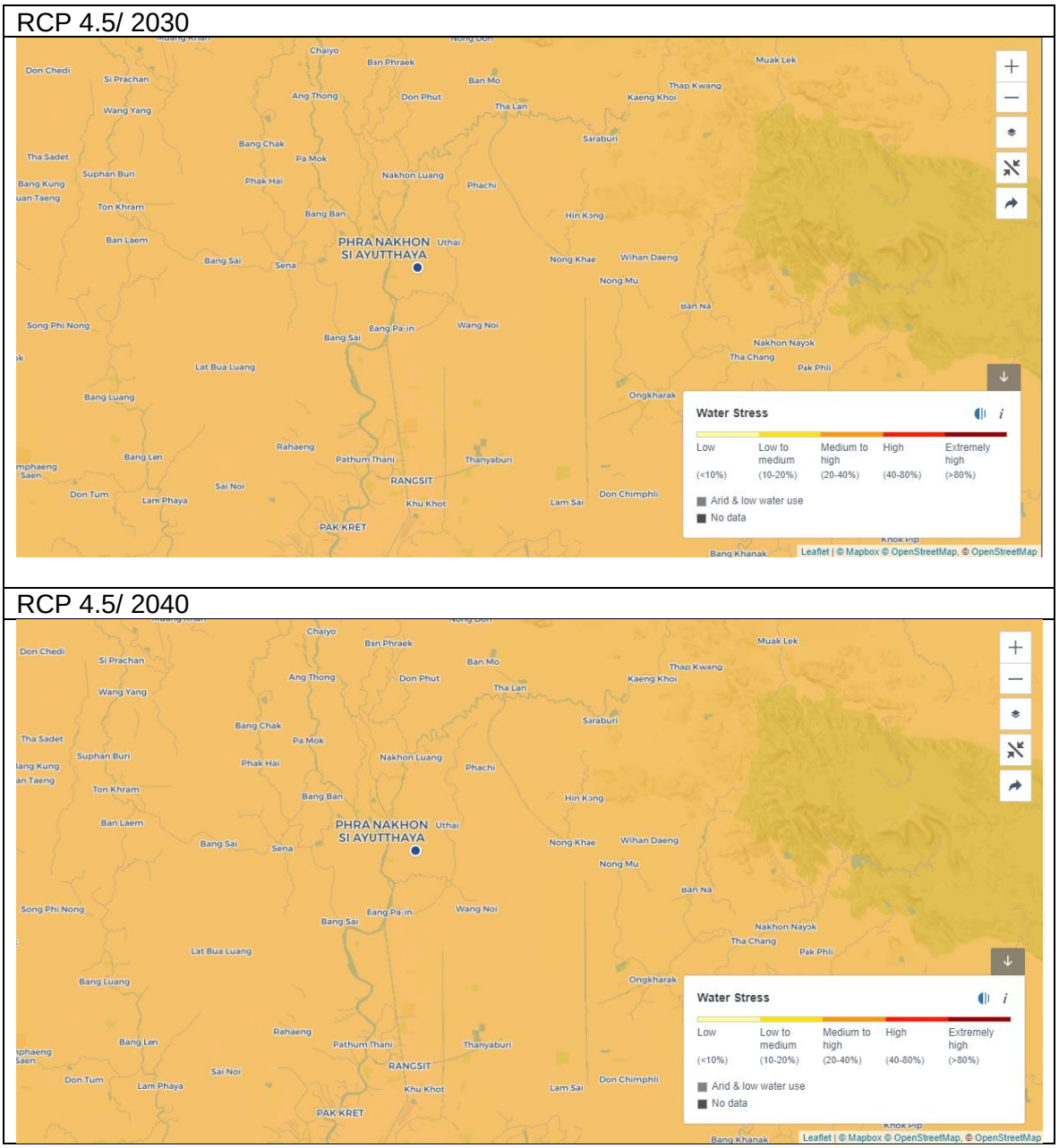


Figure 7-4 Projected Water Stress for the Site property region using Aqueduct for RCP 4.5 Climate Change Scenario.

7.1.4 Seasonal Variability

It should be noted that although the water stress indicates the 'High' risk towards average annual availability of water, water availability may vary significantly over different seasons with no (insignificant) change in water demand in region. This may lead to acute water scarcity during the dry period of the year. Therefore, it is important to understand the risk due to seasonal variability in addition to the water stress. As per Aqueduct, 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.

Accordingly, as presented in **Figure 7-5** below, the seasonal variability at the Site is reported to be 'High'.

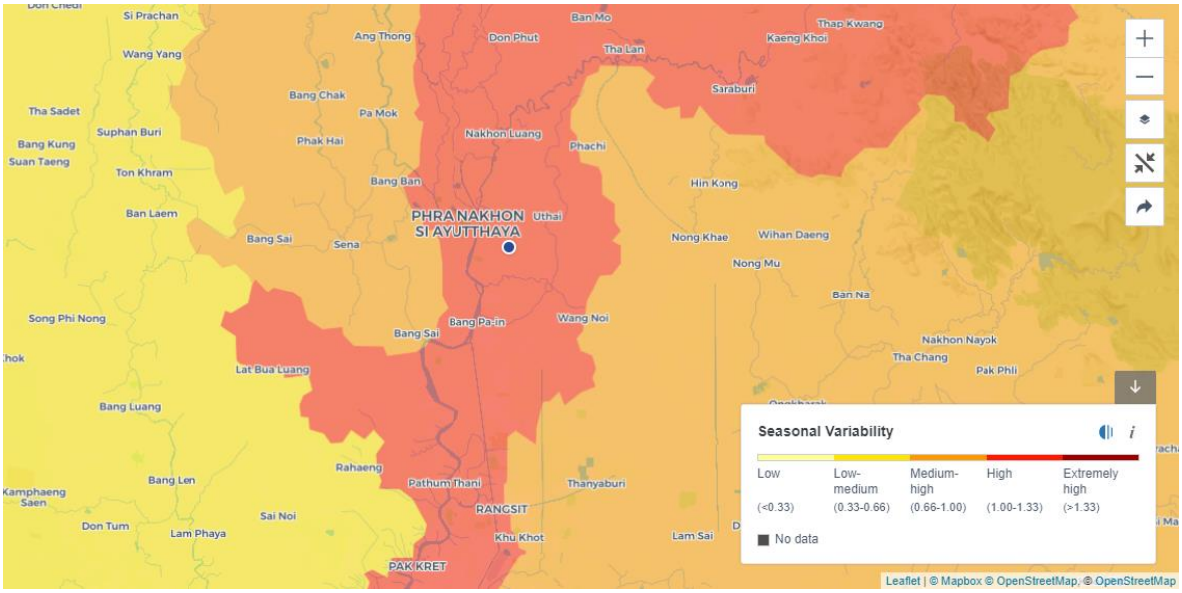


Figure 7-5 Baseline Seasonal Variability for the Site property region using Aqueduct.

7.1.5 Projected Seasonal Variability

As presented in the seasonal variability by year 2030 and 2040 under RCP 8.5 and RCP 4.5 is projected to increase to High, indicating increased seasonal variability in future as shown in **Figure 7-6**. Increased seasonal variability may result in availability of excess amount of water leading to flood like situation during wet season, and acute water scarcity during dry seasons.

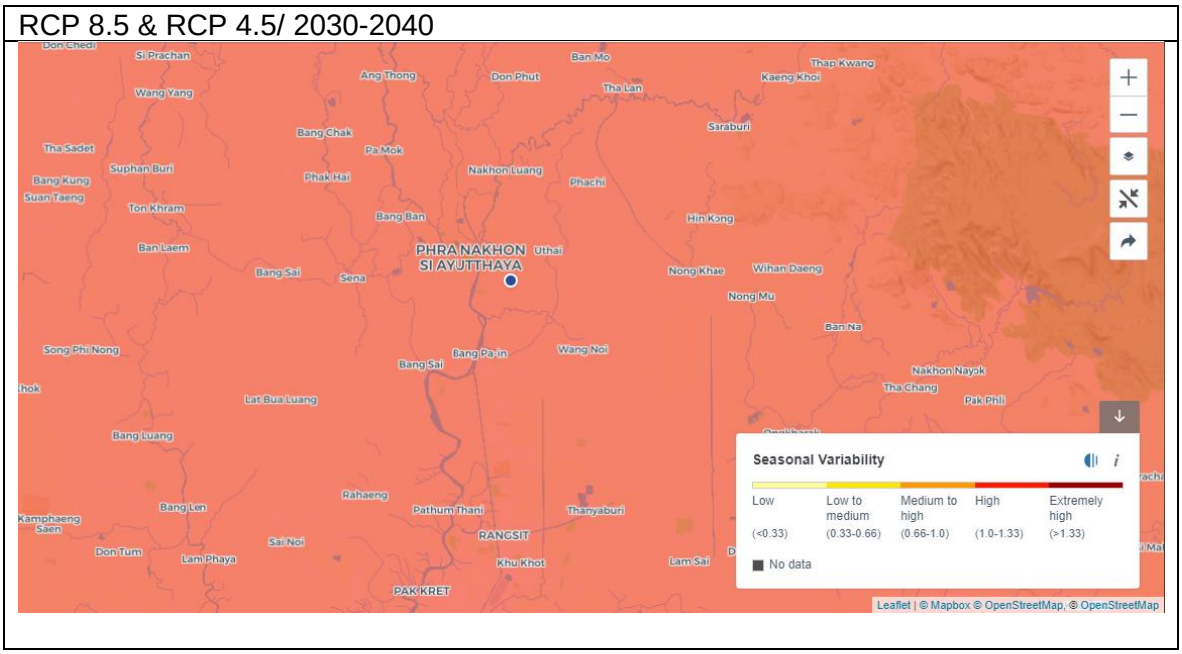


Figure 7-6 Projected Seasonal Variability for the Site property region using Aqueduct

7.2 Status of Groundwater as a Resource

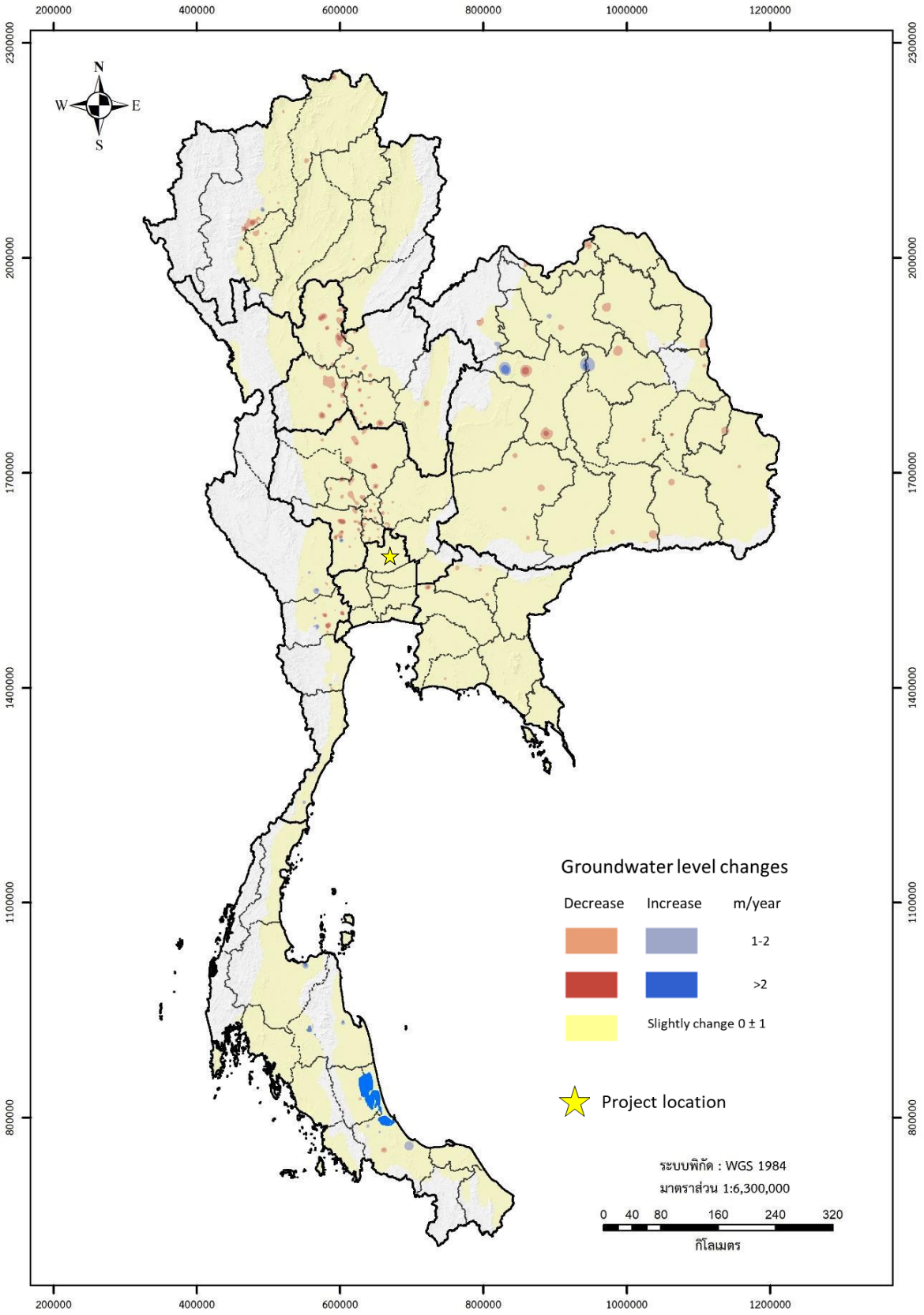
Thailand is blessed with abundant water supplies due to rainfall patterns that it receives annually. Surface water has been used as the main source of water for irrigation, domestic water supply, industrial processes and other purposes. However, water demand has drastically increased every year due to

population growth and rapid economic development. As a result, groundwater utilization is considered an alternative water supply for domestic, industrial and agricultural activities.

Thailand reportedly receives an average rainfall of 900 - 2000 mm per year. According to Groundwater report in 2019 prepared DGR, it was reported annual groundwater recharge from rainfall is approximately 72,987 Mm^3/year in which the quantity available for use is up to (abstraction) ~45,385 Mm^3/year. The current groundwater abstraction in the whole country is 14,741 Mm^3/year, which is equivalent to 33% of the annual available abstraction water that is available for use, meaning that there is still 30,645 Mm^3/year excess of groundwater available for use. Based on information in 2019, the total approximate quantity of groundwater availability in Thailand is 1,137,713 Mm^3; namely 166,860 Mm^3 in the Northern region, 241,312 Mm^3 in the Northeastern region, 412,856 Mm^3 in the Central region, 53,195 Mm^3 in the Eastern region, 63,710 Mm^3 in the Western region and 199,779 Mm^3 in the Southern region of Thailand. Additionally, the country has a surface water storage of approximately 76,000 Mm^3. As for Phra Nakhon Ayutthaya Province, groundwater availability was reported to be 221.13 Mm^3/year, while groundwater consumption in 2019 was 125.57 Mm^3/year.

Groundwater abstraction is utilized for the following purposes; 44% for agricultural purposes, 37% for industrial usage, and 19% for domestic use (Source: Juan & Kriangsak, Groundwater in Thailand).

Department of Groundwater Resource reported that the demand for groundwater has increased in the past years as Thailand faces more severe and prolonged droughts as well as the deterioration of surface water quality which may be suitable for consumption. As a result, groundwater levels tend to decrease in some areas during the year as shown in During the past year, there are a number of areas encountering a decrease in groundwater level (as shown in red and light red spot in **Figure 7-7**) with the range of 1 to 2 meters. However, the groundwater level in Phra Nakorn Si Ayutthaya province is reported to be unchanged or slightly changed due to the amount of rainfall with no more than 1 meter per year.



Source: Summary report on groundwater situation in Thailand for the year 2021, Department of Groundwater Resource

Figure 7-7 Changes in Groundwater Level in Thailand

In addition, several regulatory measures are initiated to preserve groundwater resources. Under the Groundwater Act, the government initiated licensing for the installation of bore wells and groundwater usage. Prior to groundwater extraction, users are required to acquire a license and adhere to the pumping limits that are instated in the Permit. These Permits shall be renewed annually. Groundwater usage was charged since 1985 when 1.00 Baht was charged for every cubic meter of groundwater used. Groundwater tariffs have been updated periodically until 2014 except for provinces in the Critical zone which are obliged to pay a groundwater tariff of 13 THB/m^3, other provinces in the Kingdom are required to pay the 3.5 THB/m^3 fee.

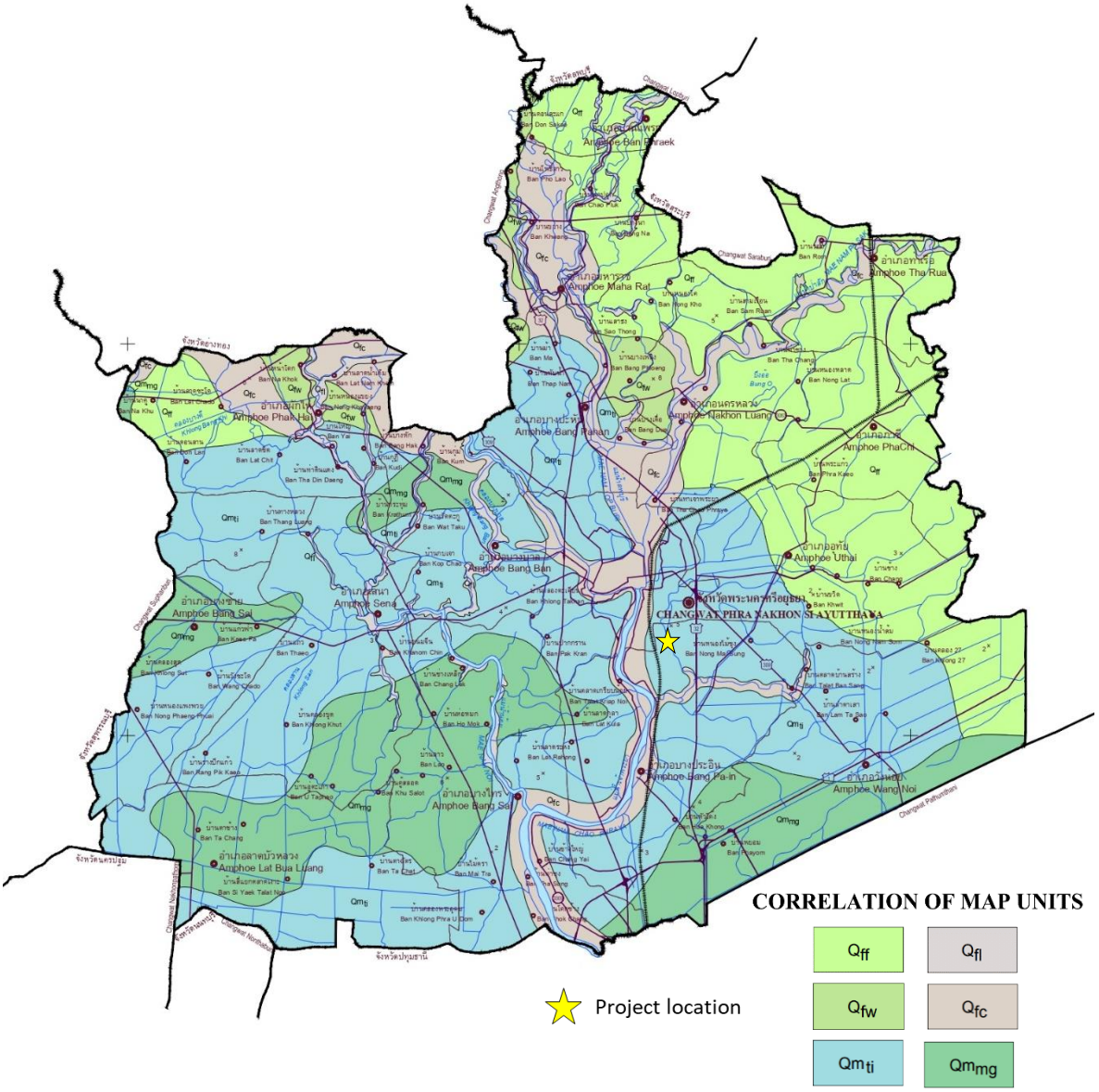
Intensive extraction of groundwater over a long period of time may lead to serious problems, including, land subsidence, groundwater depletion, and seawater intrusion (in coastal areas). To control groundwater use and mitigate environmental problems associated with it, areas that have the potential to be severely affected by groundwater-related problems are designated as Critical Zones by the Department of Groundwater Resources. According to the *Notification of the Ministry of Natural Resources and Environment, B.E. 2546 (2003), Re: Critical Groundwater Zone*, Phra Nakorn Si Ayutthaya Province is classified as a Critical Zone. As prescribed in the aforementioned Notification, the critical zone is considered the area where groundwater is withdrawn in excess of the amount of groundwater replenishment resulting in a decrease in the groundwater level, land subsidence and diffusion of saltwater into the groundwater in coastal areas.

7.2.1 Geology

Pra Nakorn Si Ayutthaya is located at the Central Plains of Thailand. Geologically, Ayuttaya consists of sediments primarily from the Quaternary Age, and is obscured with two types of sedimentary rocks, as portrayed herewith. Majority of Pra Nakorn Si Ayutthaya, typically the west side of the area, is composed of alluvial sedimentary deposit, whereas, the east's geology is marine clay deposits. Note that the Site and the watershed of concern are situated on the marine deposit geological characteristics.

The Site lies in Muang Pra Nakorn Si Ayutthaya district; surrounded by Bang Pahan and Nakhon Luang district toward the North, Uthai districts to the East, Bang Pa-In district towards the South, and Bang Ban district toward the West of the Site. The Site lies within a watershed area of approximately 3,963.55 km^2. The area is part of the Chao Phraya River Basin that extends to 20,865.53 km^2. The Chao Phraya River Basin is considered as the largest basin in Thailand housing some of the most important industrial and urban areas, the basin is also known to have the highest population density. The basin stretches from the slightly elevated northern plains to the low alluvial plains where the Chao Phraya River eventually flows into the Gulf of Thailand.

The geological map of Pra Nakorn Si Ayutthaya, prepared by the Department of Mineral Resources Thailand (DMR) as shown in the following Figure, portrays the rock formations of the area. Details of such information are described in the following **Figure 7-8** and **Table 7-1** below.



Source: https://coop.dmr.go.th/map/pdf/250k_Geo%20Province/%แผนที่ธรณี_อยุธยา_1st_2558.pdf

Figure 7-8 Geology Characteristics of Pra Nakorn Si Ayutthaya

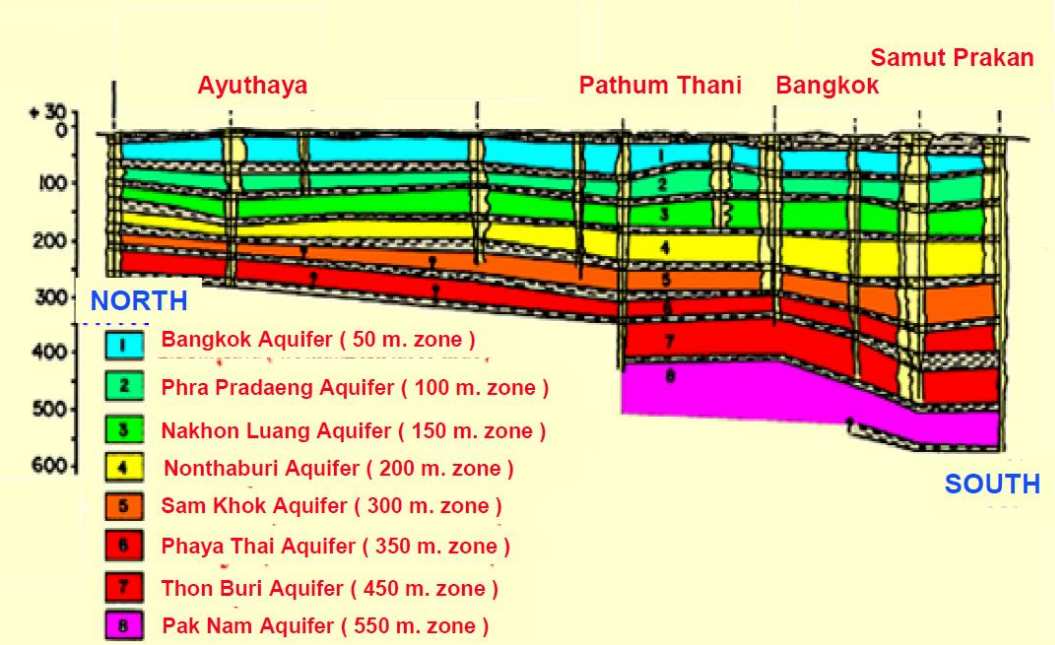
Table 7-1 Simplified Geology of Pra Nakorn Si Ayutthaya

Unit	Rock Type	Description
Q_{ff}	Flood plain deposits	Clay, gray, brown, abundant mottles, yellowish brown, reddish brown, very firm, thick-bedded, with thin lamination of fine sand
Q_{fl}	Natural levee deposits	Silt, very fine sandy, brown to light brown, loose, well sorted, thin-bedded, composed of quartz, mica, overlay on thick clay bed.

Q_{fw}	Swamp deposits	Clay, gray, brown and black, very firm, thick-bedded, abundant mottles, yellowish brown, reddish brown, with abundant plant remain or humus in some layer.
Q_{fc}	Abandoned channel deposits	Sand, gray, fine-to very coarse-grained, well sorted, well rounded, loose, thick-bedded, composed of quartz and rock fragments, overlay by thick clay bed.
Q_{mti}	Tidal flat deposits	Clay, silty clay, light olive gray to light greenish gray, very stiff, sparse to common olive yellow to yellowish, brown cloudy mottles, common lime nodules.
Q_{mmg}	Mangrove swamp deposits	Peat, brownish black, brittle; Peaty clay, brownish gray, brittle, decomposed of stem and branches; Clay, gray, fine plant remains, on mottle

7.2.2 Hydrogeology

The Site lies in Pra Nakorn Si Ayutthaya Province that falls within the lower Chao Phraya River Basin. The Chao Phraya River Basin is the largest basin in Thailand that originates from four (4) major rivers (Ping, Wang, Yom and Nan Rivers) flowing from the Northern region of the country. The four rivers merge to form Chao Phraya River before flowing through the Central Plains of the country and finally drains into the Gulf of Thailand. The basin's multi-aquifer system is composed of a soft to stiff topmost clay layer (approximately 20-30 m thick) and eight water-bearing layers underneath as shown in the following **Figure 7-9**.



Source:
https://www.researchgate.net/publication/265650600_Groundwater_Situation_in_Bangkok_and_Its_Vicinity

Figure 7-9 Aquifer System of Lower Chao Phraya River Basin

The **Table 7-2** summarizes the major hydrogeological units within the Chao Phraya River Basin from a groundwater abstraction standpoint.

Table 7-2 Major Aquifer Systems in Chao Praya Basin

Geological Unit	Aquifer Name	Average Depth to Aquifer (m)
Sand and Gravel	Bangkok	0-50
Sand and Gravel	Phra Pradaeng	50-100
Sand and Gravel	Nakhorn Luang	150-200
Sand and Gravel	Nonthaburi	200-300
Sand and Gravel	Sam Khok	300-350
Sand and Gravel	Phaya Thai	300-350
Sand and Gravel	Thon Buri	350-450
Sand and Gravel	Pak Nam	>450

Groundwater in the study area, Pra Nakorn Si Ayutthaya, are mostly trapped in voids between gravel and sand grains of the flood plain and lower terrace deposits that consist of multiple aquifers from the depth of 40 meters onward. The characteristics of the aquifer is as follows: gravel and sand that are light brown to brown in color, fine to course texture, angular to sub-rounded shape, poor sorted and composing of quartz, feldspar, chert and rock fragments. Each aquifers are confined between aquicludes. As shown in the **Figure 7-9**, the aquifer system in Pra Nakorn Si Ayutthaya consists of the topmost clay layer and 6 other layers including:

1. Bangkok Aquifer: This is the topmost aquifer in Pra Nakorn Si Ayutthaya that is covered with Bangkok Clay (~22 meters thick). The characteristics of Bangkok Aquifer is sand and gravel. There are high volume of groundwater trapped in this aquifer, however, it is not suitable for consuming as it is brackish in nature.
2. Phra Pradaeng Aquifer: Following the Bangkok Aquifer, there is an aquiclude (not less than 10 meters in thickness) that overlies the Phra Pradaeng Aquifer. The aquifer is situated at 60-80 meters below ground level, being ~20-50 meters in thickness. The aquifer is composed of a mixture of gray/light brown sand and gravel. High volume of groundwater can be found in this aquifer, however, it contains high salinity.
3. Nakorn Luang Aquifer: There is an aquiclude (~3-10 meters in thickness) integrated between the Phra Pradaeng and Nakorn Luang Aquifers. This aquifer is ~50-70 meters thick, situated at ~100-150 meters below ground level. The aquifer is composed of sand and gravel.
4. Nonthaburi Aquifer: This underlies the Nakorn Luang Aquifer. Its hydrogeological characteristics are similar to that of the Phra Pradaeng Aquifer's that is sand and gravel integrated with aquicludes in some areas. The aquifer is ~30-70 meters thick, situated at ~170-200 meters below ground level. Groundwater abstraction capacity is at ~150-300 m^3/hour.
5. Sam Khok Aquifer: This aquifer underlies the Nonthaburi Aquifer, which lies at 240-250 meters below ground level. The aquifer is ~40-80 meters in thickness, composing of sand and gravel. Groundwater characteristics are similar to that of the Nonthaburi Aquifer but in less volume.
6. Phaya Thai Aquifer: The hydrogeological characteristics of this aquifer is similar to that of the Sam Khok Aquifer, which is composed of sand and gravel. The aquifer is found at ~275-350 meters below ground level, and ~40-60 meters in thickness.
7. Thon Buri Aquifer: Following the Phaya Thai Aquifer, there is an aquiclude (~1-30 m in thickness) that overlies the Thon Buri Aquifer. This aquifer is found at ~350-400 m below ground level and ~50-100 m in thickness.

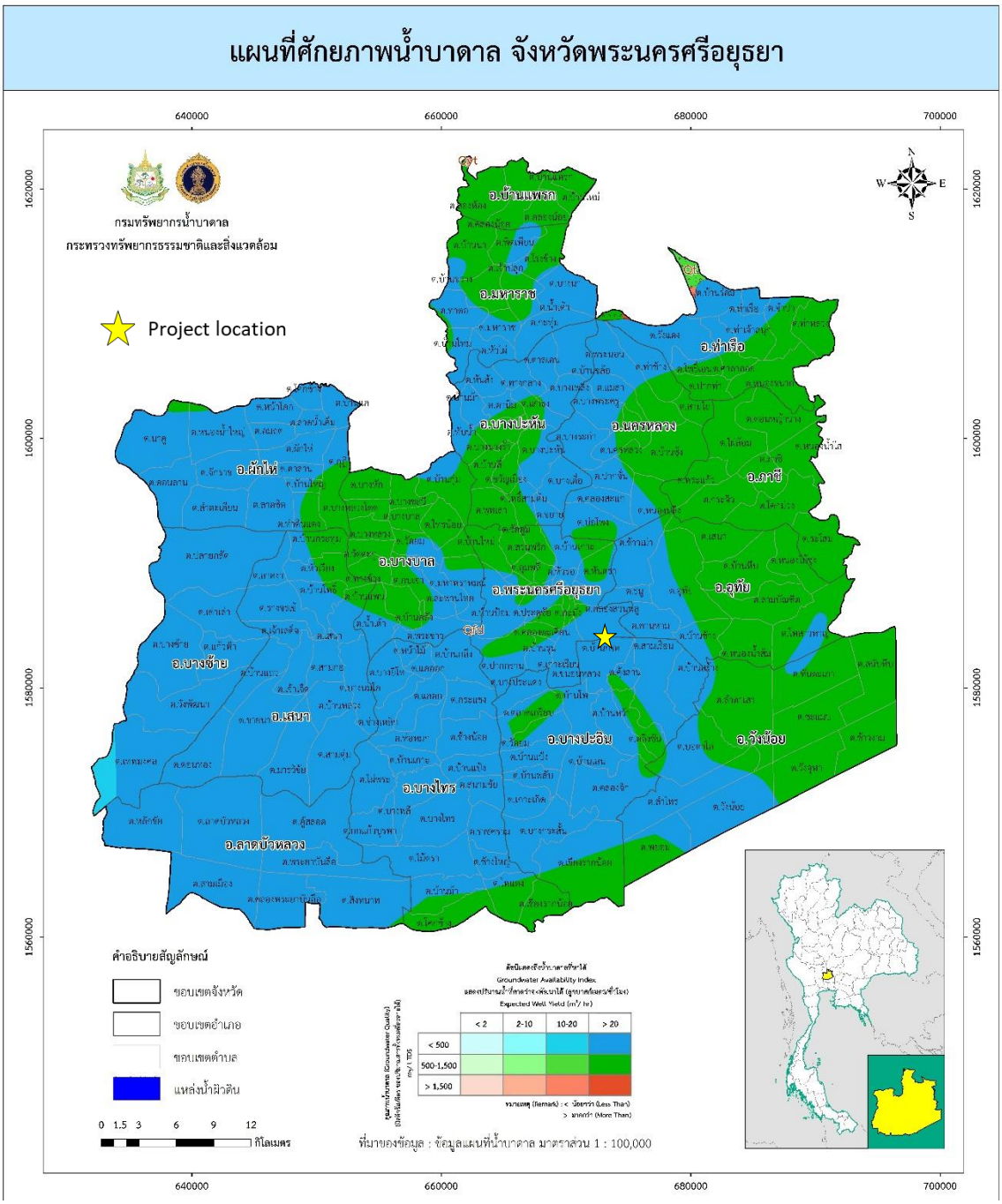
8. Pak Nam Aquifer: The Pak Nam Aquifer is situated at ~420-500 m below ground level, and its thickness is approximately ~50-150 m. Groundwater trapped within this aquifer is considered good quality, with high temperature at 50 degree Celsius.

The bore wells operated within the Site are installed at 100-190 meters below ground level, tapping the Phra Pradaeng and further beyond Nakhorn Luang Aquifer of the Chao Phraya River Basin.

The Groundwater Map of Phra Nakorn Si Ayutthaya, prepared by the Department of Mineral Resources, is further analyzed for hydrogeological characteristics of Phra Nakorn Si Ayutthaya District. According to the Map, “excellent” groundwater (meaning, high availability and good quality) are located approximately 90-140 meters below ground level. Therefore, it can be concluded that groundwater in Phra Nakorn Si Ayutthaya District are mainly trapped within Phra Pradaeng and Nakorn Luang Aquifers of the Chao Phraya River Basin.

According to the groundwater map of Phra Nakorn Si Ayutthaya by the Department of groundwater, Ministry of Natural Resources and Environment in Thailand, it was observed that Phra Nakorn Si Ayutthaya district at which the Site is located yields more than 20 m^3/hour with groundwater quality of less than 500 mg/L TDS as illustrated in below.

In addition, According to the aforementioned map of groundwater, in the study area, Phra Nakorn Si Ayutthaya district are mostly trapped in voids between gravel and sand grains of multiple aquifers from the depth of 90 to 100 meters on some areas. The characteristics of the rock types that forms the aquifers are summarized in the following **Table 7-3** and **Figure 7-10**.



Source: http://app.dgr.go.th/newpasutara/xml/show3.php?ddlGeo=5&btn2=

Figure 7-10 Groundwater map of Phra Nakhon Si Ayutthaya

Table 7-3 Groundwater Characteristics in Phra Nakorn Si Ayutthaya District

Area (District)	Rock Types	Average Depth to Aquifer (m)	Average Static Water Level (m)
Phra Nakorn Si Ayutthaya	Sand and Gravel	90-100	10-30 (<10 and 30-40 in some areas)

7.2.3 Groundwater Potential and Abstraction in Study Area

Thailand has ~30,645 Mm^3/year of groundwater potential for use per year. Based on 2022 information obtained from the Groundwater Information Technology Center of the Department of Groundwater Resources (DGR), Thailand 115,012 municipal bore wells with total groundwater availability at 932,126 m^3/hour for both domestic use and agricultural purposes. In addition, there are 121,851 private-owned bore wells in Thailand with groundwater availability at 13,557,301 m^3/month.

According to DGR available information, 1,199 municipal bore wells were reported operating in Phra Nakhon Si Ayutthaya of which three (3) bore wells are within Khlong Suan Plu Sub-district where the Project Site is located. These wells supply water to the residents living around the near vicinity of the Site for domestic purposed. These wells generally tap into the aquifer at a depth range of 121-126 meters below ground level with the yield of 9-72 m^3/h. However, The station insists of 4 monitoring wells with 78-124 meters below ground level and the yield of 10-45 m^3/h.

According to the information reported by the Coordinating Committee for Geoscience Programs in East and Southeast Asia (CCOP) in 2019, it was reported that the DGR has constructed multiple groundwater monitoring networks in order to address the vulnerable groundwater resource whereby currently 334 monitoring stations and 1,001 observation wells are located in lower central region. Data provided by the DGR illustrated that Phra Nakorn Si Ayutthaya has in total of 58 observation wells, none of which is located in Khlong Suan Plu Sub-district where properties are located. However, it is reported that the nearest monitoring station to the Site is located in Ban Krot Sub-district, Phra Nakhon Si Ayutthaya at which four (4) monitoring wells are installed. The depth of these bore well ranged from 198-270 m below ground level and water level of 19-39 m.

The field survey conducted by ERM (within the 5 km buffer/ study area) indicated that the Site is surrounded by agricultural lands, settlements and industries. There are several industrial units including the Rojana Industrial Park Ayutthaya covered the area of approximately 6,000 acres and a number of factories scattered along the highway within 5 km to the Site. It was observed that build-ups cover an area of ~50% of the total land use within the study area. While information regarding their water use for industrial purposes was not identified, communities were reported to mainly consume village water (groundwater) and municipal water supply, provided by the local municipal for domestic purposes.

7.2.4 Groundwater Level Fluctuation

Based on various literature reviews, it was reported that the demand for groundwater has increased over the past decades. This is due to a variety of factors including increased population and economic growth, resulting in further demand for groundwater.
It was reported that Thailand only extracts about 33% of the total volume of groundwater aquifer that is recharged in a year. Therefore, groundwater availability in aquifers fluctuates with seasonal variability and the region's annual precipitation.

The figure illustrates the water level in four observation wells available in Ban Krot Sub-district including GWA110, GWA111, GWA112, and GWA113 with 270, 233, 233, and 198 m in depth, respectively. As shown in **Figure 7-11**, the groundwater level was observed with an decreasing trend from 2003 to 2022 by 6 meters. It is observed that groundwater levels, specifically within these wells, have decreasing trends over the study period. However, according to the below figure, borewell number GWA110 may be considered an outliner after the year 2017 with a dramatic decrease in groundwater level. The evidence of such decreasing trend was not identified.

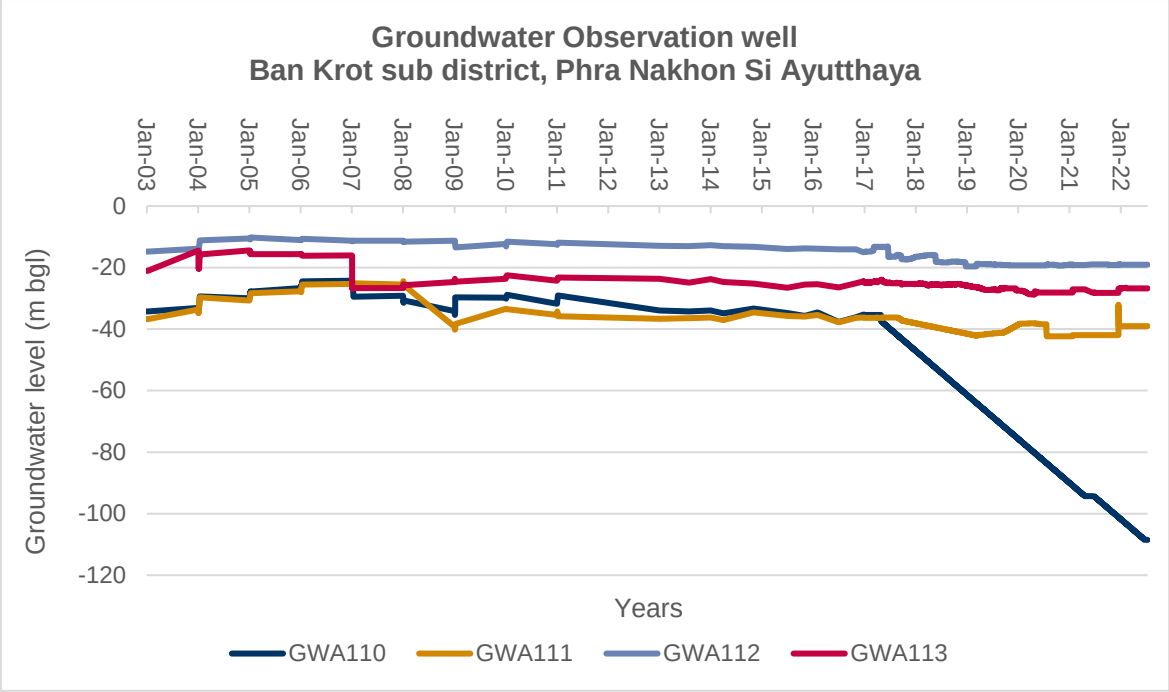


Figure 7-11 Groundwater Level Observation wells in Ban Krot Sub-district, Phra Nakorn Si Ayutthaya during 2003 - 2022

7.2.5 Groundwater Recharge and Replenishment

Groundwater aquifers underlying water basins in Thailand are recharged by rainfall and seepage from rivers. In 2019, Thailand's reported annual groundwater recharge from rainfall is approximately 72,987 Mm^3/year in which the quantity available for use is up to ~45,385 Mm^3/year.

The government authorities have recognized the significance of groundwater recharge to augment the water resources and groundwater recharge. Over the years, several recharge structures including dams have been constructed by the government across the country and within the basin. There are currently nine operational dams within Chao Phraya River Basin, namely, Bhumibol Dam, Sirikit Dam, Pa Sak Dam, etc. The dams are also constructed to exploit the agricultural and hydroelectric potential of the basin, as well as, to tackle the region's repetitive flooding occurrences.

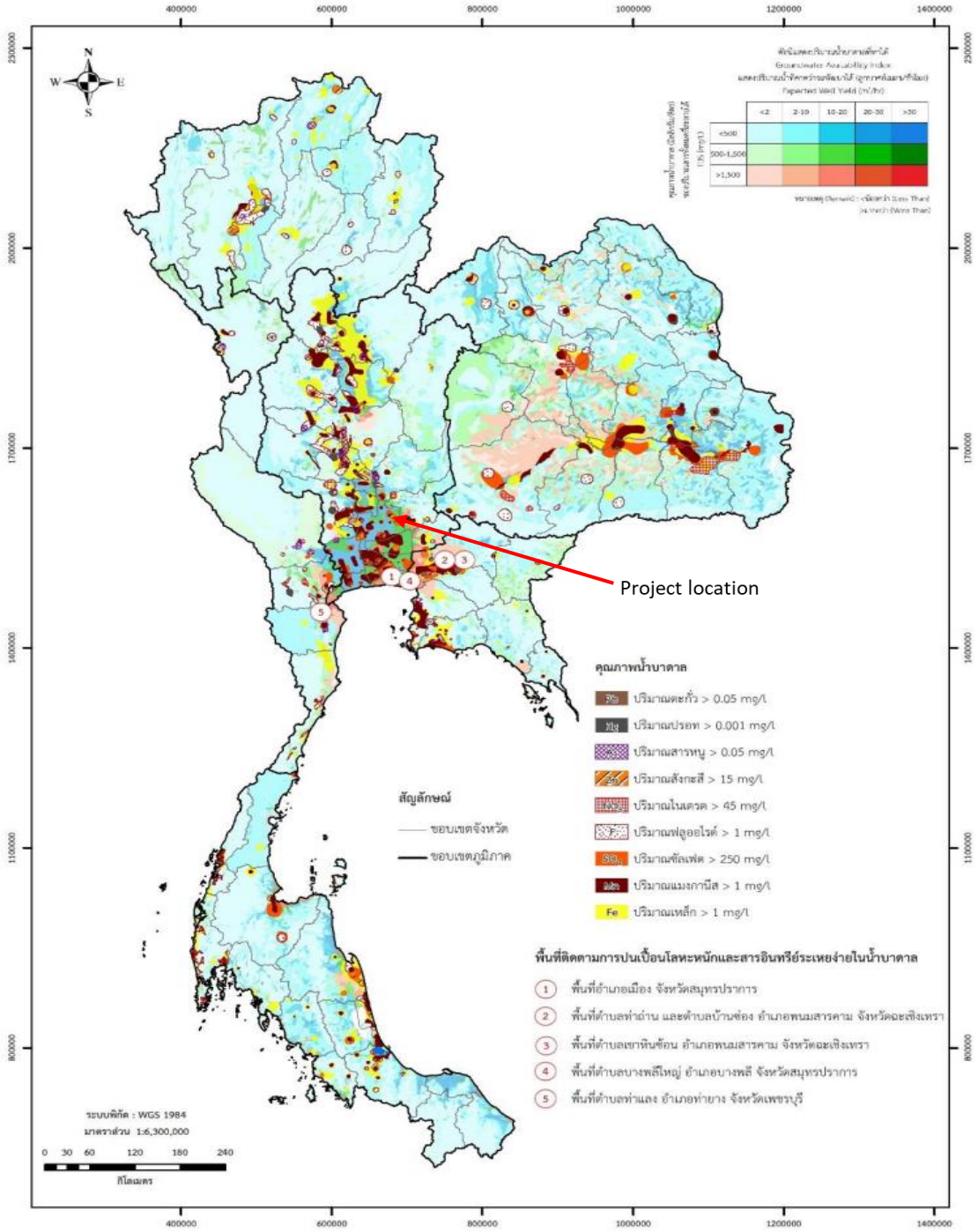
Climate change is identified as one of the factors that may affect groundwater resources. Researches are conducted to understand how climate variability and change can affect the availability and sustainability of groundwater resources in Thailand (Korrakoch et al., 2018). Climate change has effects on many matters including: increase in global average air and ocean temperatures, rising sea levels, changes in precipitation amounts, wind patterns, etc. Scientific studies portray that climate variability and change can affect the quantity and quality of various factors in the global hydrologic cycle, including atmospheric water vapour content, precipitation and evapotranspiration patterns, soil temperature and moisture, and surface runoff and streamflow.

These factors will likely influence the subsurface hydrologic cycle in terms of the amount of soil infiltration, deeper percolation, and hence groundwater recharge (Wen-Ying et al, 2020). Climate change may cause changes to Thailand's annual rainfall volume or the soil infiltration capacity, thus, affecting the multi-system aquifers of the Chao Phraya River Basin. Additional research are being conducted to gain further details regarding climate change in order to manage groundwater resources in an efficient and sustainable matter in the future (U.S. Geological Survey, 2009).

7.2.6 Groundwater Quality

Water pollution is one of Thailand's most severe environmental problems. As one of the major water sources in Thailand. Industrial wastewater, agricultural run-off and domestic sewage discharges are known to be a major source of contamination within the basin. As shown in **Figure 7-12**, the Department of Groundwater Resource reveals that groundwater quality on average in Thailand is still within the

standard threshold as stated in Groundwater Act, B.E. 2520 (1997). However, some areas have experienced high iron or manganese concentrations due to geological and hydrogeological conditions. In community dumping areas, industrial waste disposal sites and some industrial estates, the amount of toxic heavy metals and volatile organic compounds are reported to exceed the groundwater standards. The figure below also indicated that the quality of groundwater in Thailand is generally high in iron (> 1mg/L), and the western area adjacent to the igneous rock has an elevated concentration of fluoride values of more than 1mg/L.

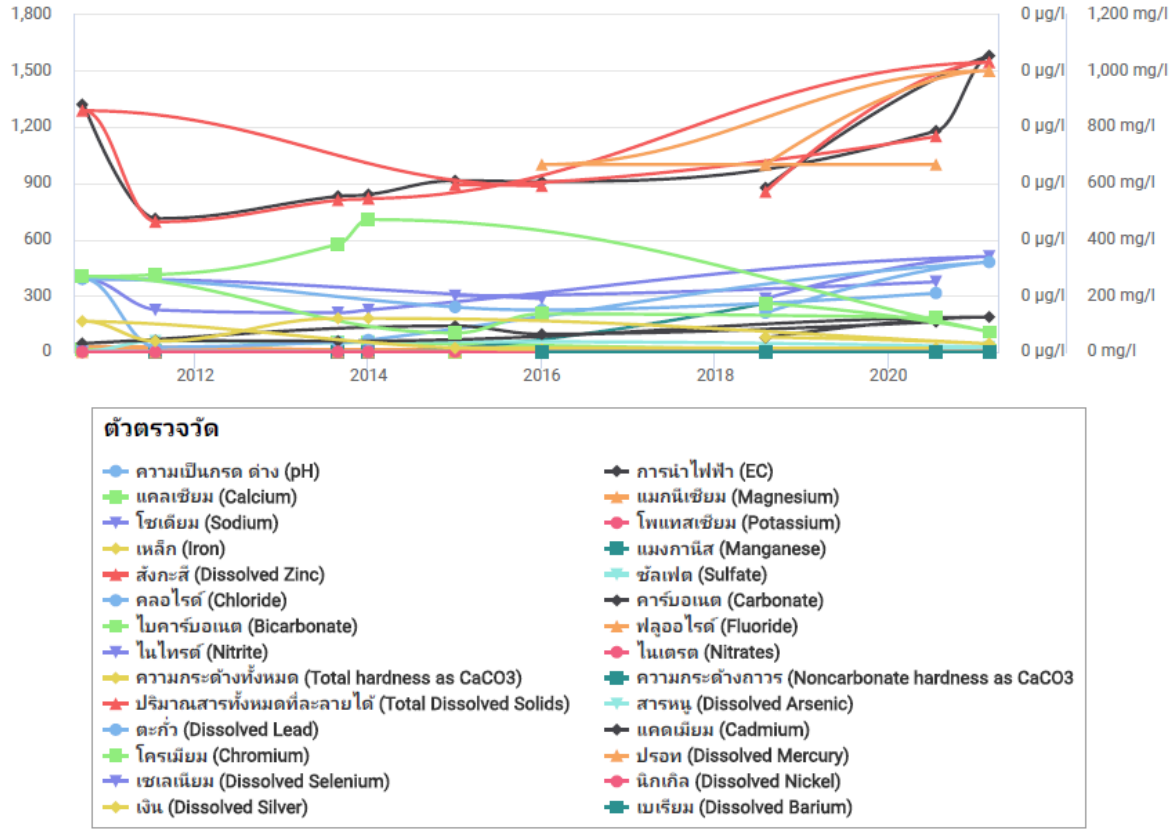


Source: Summary report on groundwater situation in Thailand for the year B.E. 2564 (2021), Department of Groundwater Resource

Figure 7-12 of Quality of groundwater in Thailand during 2021

The groundwater quality monitoring for physical and chemical parameters within the Study Area is assessed by an external laboratory under the Department of Groundwater on monthly basis. However, the results were not available for review. In terms of the study area, results of groundwater monitoring at an observatory well in Ban Krot Sub-district was obtained from the Department of Groundwater Resources as shown in **Figure 7-13**. Several parameters were monitored including pH, electrical conductivity, metals, ions, TSS, TDS, total hardness, and non-carbonate hardness. The quality of groundwater fluctuates throughout the years with slightly upward trends yet still lies within the acceptable range and is in compliance with the regulatory standards stated in *Groundwater Act, B.E. 2520 (1997)*.

Groundwater quality GWA111



Source: Department of Groundwater Resource, 2022

Figure 7-13 Groundwater quality of observatory well GWA111 located in Ban Krot Sub-district, Phra Nakhon Si Ayutthaya from 2011 to 2021

Key Findings:

- It was reported that the Site has never conducted groundwater level monitoring as it is not required by the local regulation.
- According to the Site activities, it is expected that the groundwater vulnerability due to unscientific application of agrochemicals via agricultural run-off is considered to be '**low**' to '**moderate**'.
- There are 121,851 private-owned bore wells in Thailand with groundwater availability at 45,385 Mm^3/year.
- Phra Nakorn Si Ayutthaya Province is classified as a Critical Zone where groundwater is withdrawn in excess of the amount of groundwater replenishment resulting in a decrease in the groundwater level, land subsidence and diffusion of saltwater into the groundwater in coastal areas.
- To track the changes in groundwater level and quality, public owned observation bore wells are installed throughout Thailand.
- The nearest monitoring station to the Site is located in Ban Krot Sub-district at which four (4) monitoring wells are installed. The depth of these bore well ranged from 198-270 m below ground level and water level of 19-39 m.
- Department of Groundwater Resource reported that the demand for groundwater has increased in the past years as Thailand faces more severe and prolonged droughts as well as the deterioration of surface water surface quality which may be suitable for consumption. As a result, groundwater levels tend to decrease in some areas during the year.
- During the past year, there are a number of areas encountering a decrease in ground water level (as shown in red and light red spot) with the range of 1 to 2 meter. However, groundwater level in Phra Nakorn Si Ayutthaya province is reported to be unchanged or slightly changed due to amount of rainfall with no more than 1 meter per year.
- There are no reports on drastic decline on groundwater resources as Thailand receives abundant rainfall. Therefore, groundwater availability in aquifers fluctuates with seasonal variability and the region's annual precipitation.
- Groundwater level was observed with an increasing trend from 2003 to 2022 by 6 meters. It is observed that groundwater levels, specifically within these wells, have increasing trends over the study period.
- Groundwater aquifers underlying water basins in Thailand are recharged by rainfall and seepage from rivers. In 2019, Thailand's reported annual groundwater recharge from rainfall is approximately 72,987 Mm3/year in which the quantity available for use is up to ~45,385 Mm^3/year.
- It was reported that Thailand only extracts about 33% of the total volume of groundwater aquifer that is recharged in a year.
- Climate change is identified as one of the factors that may affect groundwater resources. Climate change has effects on many matters including: increase in global average air and ocean temperatures, rising sea levels, changes in precipitation amounts, wind patterns, etc. Scientific studies portray that climate variability and change can affect the quantity and quality of various factors in the global hydrologic cycle, including: atmospheric water vapour content, precipitation and evapotranspiration patterns, soil temperature and moisture, and surface runoff and streamflow.
- Water pollution is one of Thailand's most severe environmental problems. As one of the major water sources in Thailand.
- The figure indicated that the quality of groundwater in Thailand is generally high in iron (> 1mg/L), and the western area adjacent to the igneous rock has an elevated concentration of fluoride values of more than 1mg/L.

- The location where the Site is located is reported the have high Manganese concentration on groundwater.
- Based on the output from Global Atlas 3.0, the baseline water stress is reported to be "**High**" due to the competition among multiple stakeholders dependent on common water resource. Projected water stress is also classified as "**Medium-High**" due to the increase project rainfall. Seasonal variability is classified as "**High**" and the project seasonal variability is classified as "**High**" resulting in flooding in the wet season or acute water scarcity during the dry season.

8. REVIEW OF WATER AND WASTE WATER RELATED REGULATORY REQUIREMENTS

8.1 Emerging Legislation Related to Water Resource

Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description
(Draft) Notification of the Ministry of Natural Resource and Environment, Re: Prescribing Types of Factories and Industrial Estate that are Classified as a Pollution Source to Control Effluent Discharged to Public Water Courses or Environment	Ministry of Natural Resource and Environment	Wastewater	This emerging Notification aims to cancel two following Notifications: ■ Notification of the Ministry of Science, Technology and Environment, No. 4, B.E. 2539 (1996), Re: Prescribing Types of Factories and Industrial Estate classified as Pollution Sources to Control Effluent Discharged to Public Water Courses or Environment ■ Notification of Ministry of Natural Resources and Environment, B.E. 2560 (2017), Re: Prescribing Types of Factories and Industrial Estate classified as Pollution Sources to Control Effluent Discharged to Public Water Courses or Environment This emerging Notification classifies factories and industrial estates that are defined as "Factory" under the *Factory Act, No. 2, B.E. 2562 (2019)*, to be a pollution source that shall be under control for its effluent discharged into public water courses or to the environment.
Water Environment Policy on Polluter Pays Principle	Ministry of Natural Resource and Environment	Water, Wastewater	Based on consultation with the authority, it was revealed that the National Water Environment Policy will apply Polluter Pays Principle (PPP) to any individual or facilities that produce wastewater that pose an impact towards the environment are responsible to pay additional fee for restoration of the affected environment. This Principle will influence and drive the polluters to develop internalization of environmental costs; therefore, reducing the amount of generated wastewater.
(Draft) Economic Instruments for Environmental Management Act	Ministry of Finance	Wastewater	This Draft aims to propose a framework for comprehensive environmental management based on economic instruments together with an implementation plan on water pollution tax. The two (2) pollutants, biological oxygen demand (BOD) and total suspended solids (TSS) be first targeted in the initial phase of implementing a water pollution tax.
(Draft) Notification of the Pollution Control Department, Re: Guideline for Prescribing Communal Wastewater Treatment Fees	Pollution Control Department	Wastewater	(Draft) Notification of the Pollution Control Department, Re: Guideline for Prescribing Communal Wastewater Treatment Fees aims to propose that the Polluter Pays Principle will be adopted for calculating the communal wastewater treatment fee as it is seen that taking into account the treated characteristics of

Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description
			wastewater will over complicate the calculations. Wastewater treatment fee will be equal to 80% of the total municipal water consumption volume.
(Draft) Climate Change Act	Ministry of Natural Resource and Environment	Water	This Draft aims to propose a framework for comprehensive management regarding climate change based on the Paris Agreement within the United Nations Framework Convention on Climate Change in which Thailand signed in 2016. Water management approaches particularly on data in water-stressed area will be governed by this Act.

8.2 Existing Legislation Related to Water Resource

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
1	Enhancement and Conservation of National Environment Quality Act, B.E. 2535 (1992)	Ministry of Natural Resource and Environment	Water, Wastewater, Soil and Groundwater Contamination	This Act prescribes the factory owners to install wastewater treatment system in order to treat their generated wastewater to be in compliance with the industrial effluent standards, and a wastewater treatment system shall be approved by an authorized officer; otherwise the wastewater has to be directed to and treated by the existing central wastewater treatment system to meet the legal compliance.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2535/A/037/1.PDF*
2	Regulation of the Ministry of Industry, No.2, B.E. 2535 (1992), issued under the Factory Act B.E. 2535 (1992)	Ministry of Industry	Wastewater	This Regulation prescribed that the factories are not allowed to direct discharge any wastewater out of their boundaries, unless they are treated and/or are within the industrial effluent standards. Dilution of wastewater is strictly prohibited. In case of provision of the wastewater treatment system, it is required to install an electrical gauge and daily record electricity consumption of the system. Records of chemical and biological usage for treatment and evidence of chemical and biological procurement shall be maintained onsite.	*http://web.krisdika.go.th/data/law/law2/%c332/%c332-2b-2556-a0002.pdf*
3	Regulation of the Ministry of Industry, No. 11, B.E. 2539 (1996), issued under the Factory Act B.E. 2535 (1992).	Ministry of Industry	Wastewater	This Regulation is established to control and prohibit factories from discharging untreated wastewater. It prescribes control instrument that shall be installed at the wastewater treatment system.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2539/A/033/32.PDF*

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
4	Notification of the Ministry of Science, Technology and Environment, No. 4, B.E. 2539 (1996), Re: Prescribing Types of Factories and Industrial Estate classified as Pollution Sources to be controlled the Discharge of Effluent into Public Water Courses or Environment	Ministry of Natural Resource and Environment	Wastewater	This Notification prescribes industrial factory, industrial estate and industrial park/land as pollutant generator which are prohibited from discharging wastewater unless it has properties that meet the standards as specified in the *Notification of Ministry of Natural Resources and Environment, B.E. 2559 (2016), Re: Prescribing Standard of Discharging Effluent from Factories, Industrial Estates, and Industrial Land/Park*. Both Type 2 and Type 3 factories are defined as a pollutant generator, discharges to the environment, have to be controlled. Dilution of wastewater is strictly prohibited.	http://www.ratchakitcha.soc.go.th/DATA/PDF/2560/E/222/24.PDF
5	Notification of Ministry of Natural Resources and Environment, B.E.2560 (2017), Re: Prescribing Types of Factories and Industrial Estate classified as Pollution Sources to be controlled the Discharge of Effluent into Public Water Courses or Environment	Ministry of Natural Resource and Environment			http://www.ratchakitcha.soc.go.th/DATA/PDF/2539/D/013/27.PDF

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
6	Notification of Ministry of Natural Resources and Environment, B.E. 2559 (2016), Re: Prescribing Standard of Discharging Effluent from Factories, Industrial Estates, and Industrial Land/Park	Ministry of Natural Resource and Environment	Wastewater	This Notification prescribes that wastewater effluent discharged from a factory shall be treated, except by dilution, to be in compliance with the standards, as defined in this Notification. Moreover, the factory shall use the prescribed methods to analyse the quality of discharged effluent. In order to discharge such wastewater into public waterways (i.e. lake, reservoir, pond, stream, river, sea within the coast of Thailand), the factory shall acquire an annual wastewater discharge permit from the Marine Department.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2559/E/129/17.PDF*
7	Notification of Ministry of Industry, B.E.2560 (2017), Re: Prescribing Quality Standard of Wastewater from Factory	Ministry of Industry			*http://www.ratchakitcha.soc.go.th/DATA/PDF/2560/E/153/11.PDF*
8	Notification of Marine Department, No. 164, B.E. 2560 (2017), Re: Prescribing Standard for Wastewater from Industrial Factory, Industrial Estate, and Industrial Land/Zone as Pollutant Generator	Marine Department			*http://www.ratchakitcha.soc.go.th/DATA/PDF/2560/E/246/10.PDF*
9	Order of Marine Department, B.E.2557 (2014), Re: Criteria and Permission for Discharging Wastewater into Public Body of Water	Marine Department	Wastewater	This Order prescribes the requirements for permission to discharge wastewater into public body of water. The factory that wish to discharge wastewater into public waterways shall submit an Application Form, as annexed to this Order, to the Marine Safety and Environment Bureau or the Provincial Marine Office. The Permit is valid for 12 months from the date of issuance, therefore, the factory shall submit for renewal within 30 days prior to expiration date.	*http://www.md.go.th/app/mdadmin/images/upload/news/1689-001.pdf*

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
10	Notification of Ministry of Industry, B.E. 2558 (2015), Re: Reporting Type and Quantity of Pollution Generated from Factory.	Ministry of Industry	Wastewater	The Notification prescribes that the factory generating water and air pollution shall develop a report, which states the type and quantity of such pollution. Additional reporting requirements include required parameters for measurement of water and air pollution, reporting forms, submission frequency and sampling location.	http://www.ratchakitcha.soc.go.th/DATA/PDF/2558/E/193/8.PDF
11	Notification of the Department of Industrial Works, B.E. 2559 (2016), Re: Reporting Forms of Type and Quantity of Pollution Generated from Factory.	Ministry of Industry		In case the factory is required to submit a report stating the type and quantity of generated water pollution, it shall use the reporting Forms as annexed to this Notification for Environmental Pollution Reporting Form (Ror Vor. 1), Wastewater Pollution Reporting Form (RorVor.2), and Air Pollution Reporting Form (Ror Vor.3).	http://www.ratchakitcha.soc.go.th/DATA/PDF/2559/E/048/25.PDF
12	Regulations of Ministry of Natural Resources and Environment, B.E. 2555 (2012), Re: Prescribing Criteria, Methods and Forms for Statistical Data Collection, Detail Record, and Summary Report of Wastewater Treatment System	Ministry of Natural Resource and Environment	Wastewater	This Regulation prescribes the criteria and form for recording and reporting of wastewater treatment system. This regulation is applicable to the facility that has wastewater treatment systems and directly discharges it to the environment only. It prescribes that any facility with a wastewater treatment system shall keep a record of the daily performances of such system following the annexed Form, Tor Sor. 1, and conduct a monthly report summarizing the obtained data following the annexed Form, Tor Sor. 2, and submit to local authority within the fifth of the following month.	http://www.ratchakitcha.soc.go.th/DATA/PDF/2555/A/039/4.PDF
13	Notification of the Port Authority of Thailand, B.E. 2558 (2013), Re: Prohibition of Discharging Oil, Contaminated Water, Chemical Substances, Wastewater, Ballasts or	Ministry of Natural Resource and Environment	Wastewater	The Notification prohibits the disposal of oil, contaminated water, chemical substances, wastewater, ballasts or hazardous substances (including waste, solid waste, hazardous waste) into the river or sea within the boundary of the Port Authority of Thailand. Violation of this will result in legal action including imprisonment or fines and in the event of requiring restoration, associated fees will be imposed.	http://www.ratchakitcha.soc.go.th/DATA/PDF/2558/D/094/102.PDF

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
	Hazardous Substance Including Waste, Solid Waste or Hazardous Waste in the River or Sea within the Boundary of the Port Authority of Thailand				
14	Notification of Pollution Control Department, B.E. 2557 (2014), Re: Submission of Wastewater Treatment Summary Report via Electronic	Pollution Control Department	Wastewater	This Notification prescribes the method for submitting wastewater treatment summary report to be done via electronic mean; URL of submission page is provided.	*http://infofile.pcd.go.th/law/Elec_M80.pdf?CFID=4217360&CFTOKEN=71037742*
15	Notification of Ministry of Industry, B.E. 2547 (2004), Re: Prescribing the Factory having Wastewater Treatment System to Install Special and Additional Equipment	Ministry of Industry	Wastewater	These Notifications prescribe the type of factory that needs to install special or additional tools or equipment (e.g. BOD or/and COD meter, flow meter, and electricity power meter) to report effluent quality via online system of DIW as the following; 1. Factory that discharge wastewater exceed 10,000 m2/day. 2. Factory that discharge wastewater from 3,000-10,000 m2/day or has Influent BOD Load from 4,000 kg/day or more. 3. Factory that discharge wastewater from 1,000 but not exceed 3,000 m2/day. 4. Factory that discharge wastewater from 500 but not exceed 1,000 m2/day. Except for factory with no discharging the effluent or factory that treat the wastewater at Central Waste Treatment Plant.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/0E/00145776.PDF*
16	Notification of Ministry of Industry, No. 2, B.E. 2548 (2005), Re: Prescribing the Factory having Wastewater Treatment System to Install Special and Additional Equipment	Ministry of Industry	Wastewater		*http://www.ratchakitcha.soc.go.th/DATA/PDF/2548/00154187.PDF*

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
17	Notification of Ministry of Industry, No. 3, B.E. 2549 (2006), Re: Prescribing the Factory having Wastewater Treatment System to Install Special and Additional Equipment	Ministry of Industry	Wastewater	This Notification prescribes the extension for installing special or additional tools or equipment at the wastewater treatment system (e.g. BOD or/and COD meter, flow meter, and electricity power meter) for these factories as follow: 1. Factory that discharges wastewater from 3,000-10,000 m^3/day or has influent BOD Load from 4,000 kg/day or more. 2. Factory that discharges wastewater from 1,000 but not exceeding 3,000 m^3/day. 3. Factory that discharges wastewater from 500 but not exceeding 1,000 m^3/day. The duration for installing special or additional tools or equipment is extended to 31 December 2008.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2549/D/110/11.PDF*
18	Notification of Ministry of Industry, No. 4, B.E. 2552 (2009), Re: Prescribing the Factory having Wastewater Treatment System to Install Special and Additional Equipment	Ministry of Industry	Wastewater	This Notification amended the extension for installing special or additional tools or equipment at the wastewater treatment system (e.g. BOD or/and COD meter, flow meter, and electricity power meter) regarding to the Notification of Ministry of Industry, No. 3, B.E. 2549 (2006), Re: Prescribing the Factory having Wastewater Treatment System to Install Special and Additional Equipment. The duration for installing special or additional tools or equipment is extended to 31 December 2010.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2552/E/159/55.PDF*

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
19	Notification of Department of Industrial Works, B.E. 2550 (2007), Re: Criteria for Approval Factory Having Wastewater Treatment System to Install Special and Additional Equipment	Ministry of Industry	Wastewater	This Notification prescribes the requirement for specific types of factory operation to install a BOD monitoring device. This includes Type 4 (operation involving live stock), Type 6 (operation involving aquatic animal), Type 8 (operation involving vegetable, plant, or fruit), Type 9 (operation involving plant seed or knolle), Type 10 (operation involving food producing from starch), Type 16 (operation involving distillery or brewing liquor), Type 19 (operation involving malt or beer), and Type 20 (operation involving drinking water, non-alcohol beverage, soft drink, or mineral water)	*www.ratchakitcha.soc.go.th/DATA/PDF/2550/E/181/23.PDF*
20	Notification of the Department of Industrial Works, B.E. 2554 (2011), Re: Qualification, Training and Qualification Evaluation for Environmental Personnel of Factory	Department of Industrial Works	Wastewater	This Notification prescribes the requirements for the following: ■ Qualifications of appointed environmental personnel; ■ Qualifications of eligible person for receiving environmental personnel training and examination; ■ Qualifications of training institute and examination agency; ■ Registration of qualified training institute and examination agency; and ■ Training course and examination. The factory shall ensure that their appointed Environmental Personnel has the qualifications as prescribed.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2556/E/074/17.PDF*
21	Notification of the Department of Industrial Works, B.E. 2556 (2013), Re: Notification for Environmental Personnel of Factory	Department of Industrial Works	Wastewater	Factory shall ensure that all appointed Environmental Personnel are registered and notified to the Department of Industrial Works through the Forms as annexed to this Notification. Factory shall also follow the conditions of renewal, increasing, revoking or changing of the personnel as prescribed in this Notification.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2556/E/074/21.PDF*
22	Notification of the Department of Industrial Works, B.E. 2556 (2013), Re: Registration	Department of Industrial Works	Wastewater	Factory shall ensure that all appointed Environmental Personnel are registered and notified to the Department of Industrial Works through the Forms as annexed to this Notification. Registration Forms shall be submitted for	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2556/E/074/17.PDF*

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
	for Wastewater Treatment Supervisor, Air Pollution Control Supervisor, and Industrial Waste Management Supervisor			renewal every three years, within 30 days prior to the expiry date.	
23	Notification of Ministry of Industry, B.E. 2546 (2003), Re: Criteria for Prohibiting Operation in case of Wastewater Discharged from the Factory	Ministry of Industry	Wastewater	This Notification prescribes the conditions that the factory will be prohibited from discharging wastewater (i.e. no wastewater treatment system, insufficient wastewater treatment capacity, wastewater condition not in compliance with prescribed standards, etc.).	*http://www.ratchakitcha.soc.go.th/DATA/PDF/00130238.PDF*
24	Order of Marine Department, B.E. 2557 (2014), Re: Criteria and Permission Procedure for Wastewater Dumpling or Discharging to Public Water Source	Marine Department	Wastewater	This Order prescribes the criteria for requesting permission and consideration procedure for wastewater dumpling or discharging to the public water source.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2557/E/273/3.PDF*
25	Notification of Pollution Control Department, B.E. 2539 (1996), Re: Prescribing Methods, Frequency, and Period for Collecting Wastewater Discharged from Factory and Industrial Estate	Pollution Control Department	Wastewater	This Notification prescribes methods, frequency, and period for wastewater collection for factory type 2 and 3.	*www.ratchakitcha.soc.go.th/DATA/PDF/2539/D/091/23.PDF*

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
26	Notification of Ministry of Industry, B.E. 2545 (2002), Re: Prescribing Factory Types and Sizes, Procedure for the Control of Discharges of Wastes, Pollutants, or Any Substances that Cause Adverse Effects on the Environment, Qualifications of Supervisors and Operators, and Criteria for Registration of the Supervisors of Pollution Prevention Systems	Ministry of Industry	Wastewater	1. This Notification prescribes factory types and sizes which required environmental supervisors in the factory including; ▪ Factory which have contaminated organic substances wastewater more than 500 m^3 per day or have BOD load of influent more than 100 kg per day. ▪ Factory using prescribed substances (as shown in the regulation) in production process and releasing wastewater more than 50 m^3 per day. 2. This Notification prescribes responsibility of environmental supervisors in factory and manufacturer. 3. This Notification prescribes the procedure and criteria for environmental control supervisor registration	http://www.ratchakitcha.soc.go.th/DATA/PDF/00054468.PDF
27	Notification of Ministry of Industry, No.2, B.E. 2545 (2002), Re: Prescribing Factory Types and Sizes, Procedure for the Control of Discharges of Wastes, Pollutants, or Any Substances that Cause Adverse Effects on the Environment, Qualifications of Supervisors and Operators, and Criteria for Registration of the	Ministry of Industry	Wastewater	This Notification was announced to amend the *Notification of Ministry of Industry, No.2, B.E. 2545 (2002), Re: Prescribing Factory Types and Sizes, Procedure for the Control of Discharges of Wastes, Pollutants, or Any Substances that Cause Adverse Effects on the Environment, Qualifications of Supervisors and Operators, and Criteria for Registration of the Supervisors of Pollution Prevention Systems*. Key summary of this regulation can be described as follow: 1. The additional factory types and sizes which required environmental supervisors in the factory including; ▪ Factory which operation involving distillery or brewing liquor, which have production capacity more than 40,000 L per month.	http://www.ratchakitcha.soc.go.th/DATA/PDF/2555/E/026/38.PDF

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
	Supervisors of Pollution Prevention Systems			▪ Factory which operation involving with wine, which have production capacity more than 600,000 L per month. ▪ Factory which operation involving with beer, which have production capacity more than 600,000 L per month. 2. Responsibility of environmental supervisors in the factory is prescribed 3. The procedure and criteria for environmental control supervisor registration is prescribed.	
28	Notification of Ministry of Industry, B.E. 2551 (2008), Re: Control Measures for Wastewater Discharged from Industry in order to Recovering Water Quality in Chao Praya River	Ministry of Industry	Wastewater	This Notification prescribes the factory in 9 provinces located near Chao Praya River, which generate wastewater from operation, shall install high efficiency wastewater treatment plant, which can treat wastewater from operation until treated wastewater can be recycled, or install storage system, which can store all wastewater and prevent wastewater leaking to groundwater. In addition, wastewater shall not be directly or indirectly discharged to Chao Praya river.	*https://www.diw.go.th/hawk/law/water/WATER17.pdf*
29	Notification of the Department of Industrial Works, released under the Factory Act B.E. 2535 (1992), Re: Prescribing Fines for Discharging Wastewater from Factory incompliant to Characteristics Notified by DIW	Department of Industrial Works	Wastewater	This Notification prescribes the fines for discharging wastewater from factories which are incompliant to wastewater quality prescribed by the Department of Industrial Works. This is to promote environmental protection and protect local communities from impacts caused by factory operations.	*http://www2.diw.go.th/PIC/download/water/%WWFee.2535.pdf*
30	Regulation of the Ministry of Public	Ministry of Public Health	Wastewater, Waste	This Notification prescribes criteria and conditions for controlling harmful business as follow:	*http://www.ratchakitcha.soc.go.th/DA*

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
	Health, B.E. 2560, Re: Harmful Business Control			■ The harmful business shall implement the water pollution control according to the water quality standard. ■ The harmful business shall collect or dispose solid waste according to the procedures prescribed in this Notification (i.e. providing containers for solid waste, comply with regulations in case of solid waste self disposal or hazardous substances disposal).	*TA/PDF/2560/A/080/15.PDF*
31	Public Health Act., B.E. 2535 (1992)	Ministry of Public Health	Waste	The operator shall not abandon or generate solid waste in the public. The container for waste shall be provided in public and private area. In addition, the operator shall develop the procedure for sewage or waste collection, transportation, and disposal.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2535/A/038/27.PDF*
32	Public Health Act., No. 2, B.E. 2535 (1992)	Ministry of Public Health	Waste	The operator who wishes to collect, transport, or dispose sewage or solid waste shall implement the permission with local authority where the operation is located (except the operation relating to hazardous waste disposal). In addition, the operator relating to hazardous substances shall report about the operation to the authority.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2550/A/028/1.PDF*
33	Royal Irrigation Act., No. 4, B.E. 2518	Ministry of Natural Resource and Environment	Waste	The factory shall not abandon solid waste, animal or plant remains, ash, or sewage to the irrigation water, and shall not discharge wastewater or toxic chemical substances to the irrigation water, which may cause hazard to agriculture, water consumption, water usage, or public health.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2518/A/033/1.PDF*
34	Regulation of the Ministry of Industry, No. 22, B.E. 2556, issued under the Factory Act B.E. 2535 (1992)	Ministry of Industry	Waste	This Notification amends the *Regulation of Ministry of Industry, No. 2, B.E. 2535, issued under the Factory Act B.E. 2535 (1992)*. The operator having sewage or waste shall implement the sewage or unused material management as follow: ■ The operator shall not abandon sewage or unused material outside the factory boundary, except for dispose, recycling, or burying. ■ The operator shall inform about types, volume or weight, characteristics, and storage of sewage or	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2556/A/016/8.PDF*

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
				unused material including methods for disposal, recycling, bury, transfer, and transportation.	
35	Notification of Ministry of Industry, B.E. 2547 (2004), Re: Criteria and Methods for Notifying the Information of Sewage or Unused Material via Internet	Ministry of Industry	Waste	This Notification prescribes criteria and methods to inform about sewage and unused material from the factory via internet system of the Department of Industrial Works. The operator shall inform the information about sewage and unused material from the factory via website (http://www2.diw.go.th/e-license/login.asp) immediately when the sewage and unused material from the factory is transported to the waste disposer.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2547/E/145/001.PDF*
36	Notification of Ministry of Industry, B.E. 2548 (2005), Re: Criteria for Consideration of Waste Collector and Waste Transporter Designation	Ministry of Industry	Waste	This Notification prescribes criteria for considering waste collector and transporter designation. The operator who wishes to designate waste collector and transporter shall submit Thai Form Code: Sor Kor 6.1, Sor Kor 6.2, and Sor Kor 6.3 as annexed in this Notification for waste collector and transporter designation.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2549/D/080/8.PDF*
37	Notification of Ministry of Public Health, B.E. 2561 (2018), Re: Prescribing the Document for Sewage Transportation	Ministry of Public Health	Waste	This Notification requires person who provide sewage transportation service and person who requests for the service shall develop the record of sewage transporter 1 as annexed in this Notification. The master document will be kept by sewage transporter, and the copy will be kept by person who requests for the service.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2562/E/003/T_0029.PDF*
38	Notification of Ministry of Industry, B.E. 2548 (2005), Re: Disposal of Wastes and Unusable Materials	Department of Industrial Works	Waste	The Notification prescribes list of hazardous and non-hazardous wastes; and unusable including coding system for 19 categories of hazardous and non-hazardous wastes and unusable materials (e.g. waste from confectionery industry, used fluorescent bulbs). In some waste categories, further analysis may be required to identify type of the hazardous waste depending on their characteristics and contents of hazardous substances contained in those wastes.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2549/00180774.PDF*

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
39	Notification of Ministry of Industry, No.2, B.E.2560 (2017) Re: Disposal of Waste and Unusable Materials.	Ministry of Industry	Waste	This Notification updates the requirement for submission of offsite waste disposal permit (Thai Form Code: Sor Gor.2) and permission of onsite storage exceeding 90 days (Thai Form Code: Sor Gor.1) to the DIW via Internet.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2560/E/190/143.PDF*

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
40	Order of Ministry of Industry, B.E. 2561 (2018), Re: Criteria, Conditions and Methods for Permission to Dispose Wastes or Unused Materials Outside Factory Boundary through Electronic System.	Ministry of Industry	Waste	The Order prescribes the criteria, conditions and methods that waste generator shall follow for permission application and approval to dispose waste or unused materials via electronic system.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2561/E/088/1.PDF*
41	Notification of Ministry of Industry, B.E. 2561 (2018), Re: Prescribing the Type and Characteristics of Waste or Unused Materials and Disposal Method for Permission to Dispose Outside Factory Boundary via Electronic System.	Ministry of Industry	Waste	The Notification prescribes the disposal methods appropriate for different types and characteristics of waste or unused materials that the waste generators have submitted application permission for disposal via the electronic system.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2561/E/095/8.PDF*
42	Notification of Ministry of Industry, B.E. 2561 (2018), Re: Prescribing Non-Hazardous Wastes and Unused Materials that are Exempted From Acquiring Permission to be Disposed Outside Factory Premises.	Ministry of Industry	Waste	This Notification prescribes the list of non-hazardous wastes or unused materials, which can be further recycled, to be exempted from permission for off-site disposal permit (Thai Form Code: Sor. Gor.2). Furthermore, the listed non-hazardous wastes or unused materials shall not be contaminated by hazardous substances or other hazardous waste.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2561/E/125/6.PDF*

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
43	Notification of Ministry of Public Health, B.E. 2561 (2018), Re: Prescribing Types, Sizes, Duration for Sewage Pumping, and Standard Methods of Wastewater Discharge for Sewage Disposal System	Ministry of Public Health	Waste	This Notification prescribes types, sizes, duration for sewage pumping, and methods for wastewater discharge for sewage disposal system as follow: ■ In case of building, house, or row house, the owner shall provide on-site disposal system with the total volume more than 1,000 L, and the duratioin for sewage pumping shall be more than once per 4 years. ■ In case of large building (e.g. apartment, school, hospital, hotel, department store,etc.) or public toilet, the owner shall provide on-site disposal system which is enough for sewage volume generated in the building, and the duratioin for sewage pumping shall be once per year.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2562/E/003/T_0033.PDF*
44	Notification of the Ministry of Industry, B.E. 2547 (2004), Re: Hazardous Waste Manifest	Ministry of Industry	Waste	The Notification prescribes the implementation of hazardous waste manifest system for waste generator, transporter, and waste treatment facilities/disposers. In addition, this Notification also defines manifest form. Waste generator who generated 100 kg/ month or more shall follow this Notification.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/0E/00153088.PDF*
45	Regulation of the Ministry of Industry, B.E. 2559 (2016), Re: Soil and Groundwater Contamination Prevention in the Facilities	Ministry of Industry	Soil and Groundwater Contamination	This Regulation prescribes the list of factories that are required to monitor and be ensured that the quality of soil and groundwater within factory premises comply with the threshold standards. Factory shall monitor soil and groundwater following the prescribed monitoring frequency, and conduct a report containing the monitoring results and submit to the Department of Industrial Works or its Provincial Industry Office within 120 days after monitoring date. If the quality of soil and groundwater exceeds the prescribed standards, the factory is required to conduct a report containing mitigation measures, and submit such report to the Department of Industrial Works and the Provincial	*http://web.krisdika.go.th/data/law/law2/%c332/%c332-2b-2559-a0001.pdf*

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
				Industry Office within 180 days of acknowledgment of non-compliance.	
46	Notification of Department of Industrial Works, B.E. 2560 (2017), Re: Additional Analytical Laboratory Approved for Soil and Groundwater Monitoring	Department of Industrial Works	Soil and Groundwater Contamination	In addition to the analytical laboratory prescribe in Article 07 of the Regulation of the Ministry of Industry, B.E. 2559 (2016), Re: Soil and Groundwater Contamination Prevention in the Facilities, this Notification prescribes other laboratories that are approved to conduct soil and groundwater monitoring as follows: ■ Governmental Analytical Laboratory ■ Analytical Laboratory owned by a State University or National University Such laboratories do not have to be registered with the Department of Industrial Works.	http://web.krisdika.go.th/data/law/law2/%c332/%c332-2e-2560-a0004.pdf
47	Notification of Ministry of Industry (MOI), B.E.2559 (2016), Re: Prescribing the Soil and Groundwater Contamination Criteria, Monitoring, Reporting of the Monitoring Results, and Reporting the Control and Mitigation Measures for Soil and Groundwater Contamination	Ministry of Industry	Soil and Groundwater Contamination	The factory shall monitor the quality of soil and groundwater within factory premises in accordance with the methods prescribed in this Notification, and ensure that the quality of its soil and groundwater are in compliance with the threshold limits as annexed to this Notification. The factory shall conduct an analysis report containing the monitoring results, details of the storage location of hazardous substances, and mitigation measures (if the monitoring result exceeds the threshold limits). Such analysis report shall be submitted to the Department of Industrial Works or to the Provincial Industrial Office. In case the factory has installed monitoring wells that comply with the standards, the evidence of installation of such up gradient and down-gradient monitoring wells shall also be disclosed.	http://www.ratchakitcha.soc.go.th/DATA/PDF/2559/E/275/4.PDF
48	Notification of the Department of Industrial Works (DIW), B.E. 2560 (2017), Re: Guideline	Department of Industrial Works	Soil and Groundwater Contamination	The factory follow the guideline on soil and groundwater monitoring as annexed in this Notification.	http://www.ratchakitcha.soc.go.th/DATA/PDF/2560/E/109/2.PDF

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
	for Soil and Groundwater Sampling				
49	Notification of the Department of Industrial Works (DIW), B.E. 2563 (2020), Re: Method for Conducting Soil and Groundwater Monitoring in Factory Boundary approved by Department of Industrial Works	Department of Industrial Works	Soil and Groundwater Contamination	The factory shall use the following method for soil and groundwater monitoring: ■ ASTM Internation for soil monitoring. Test Methods for Evaluating Solid Waste, Physical/ Chemical Methods (SW-846) by the United States Environmental Protection Agency for groundwater monitoring.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2563/E/054/T_0016.PDF*
50	Regulation of the Ministry of Natural Resource and Environment, B.E. 2556 (2013): Re: Prescribing Types of Groundwater Use and Approval Letters Regarding Groundwater Utilization	Ministry of Natural Resource and Environment	Groundwater	The Regulation was announced to cancel Regulation (Issue 1), B.E. 2521 (1978), released under the Groundwater Act, B.E. 2520 (1977 and prescribe new method for seeking approval of groundwater utilization. Sections included in the Regulation are: ■ Requeting permit for groundwater utilization ■ Permit approval process (i.e. standards, methodology and criterias, water-stress area assessment criteria, outside water-stress area assessment criteria and permit to discharge water into groundwater well) ■ Permit renewal process	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2556/A/092/3.PDF*
51	Notification of the Department of Groundwater Resources, B.E. 2562 (2019), Re: Prescribing Request Form for Approval Permit, Request Form for Permit Renewal and	Department of Groundwater Resource	Groundwater	This Notification was announced to cancel: ■ Notification of the Department of Groundwater Resource, B.E. 2557 (2014), Re: Prescribing Request Form for Approval Permit, Request Form for Permit Renewal and Request Form for Utilizing Groundwater; and ■ Notification for the Department of Groundwater Resource, B.E. 2559 (2016), Re: Prescribing Request Form for Approval Permit, Request Form for Permit Renewal and Request From for Utilizing Groundwater (No.2).	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2562/E/142/T_0034.PDF*

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
	Request Form for Utilizing Groundwater			The factory intending to utilize groundwater are required to submit the following request form along with supporting documents and evidence as indicated in Thai Form Code NorBor 1. ■ Use Thai Form Code NorBor.4 for permit to drill groundwater well; ■ Use Thai Form Code NorBor.5 for permit to use groundwater well; and ■ Use Thai Form Code NorBor.2 for permit renewal.	
52	Notification of the Department of Groundwater Resource, B.E. 2552, Re: Prescribing Standards, Methodology and Conditions for Backfilling Ceased Use of Groundwater Wells	Department of Groundwater Resource	Groundwater	The Notification requires groundwater wells that are not in used to be backfilled with cement or pure soil. Backfilling of the groundwater well will be monitored by a controller approved by the Department of Groundwater Resources. The factory is required to follow the steps detailed in this Notification for backfilling the groundwater. Examples of the steps include: cleaning, pressure for backfilling and reporting process.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2552/E/120/31.PDF*
53	Notification of National Environmental Board, No. 8, B.E. 2537 (1994), issued under Enhancement and Conservation of National Environment Quality Act, B.E. 2535 (1992), Re: Prescribing Surface Water Quality Standards	Ministry of Natural Resource and Environment	Water Resource	This Notification prescribes surface water quality standard and methods for surface water analysis.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2537/D/016/73.PDF*

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
54	Water Resources Act, B.E. 2561 (2018)	Ministry of Natural Resource and Environment	Water Resource	The Act prescribes the appointment of Water Usage Committee in the National and Local levels to issue protocols and policies regarding water resource management, flood/drought preventive and mitigation and water conservation plans. In addition, the Water Usage Committee is responsible for prescribing the volume of water that can be used by users and prioritize water usage types. As per the requirement stipulated under this Act, the factory is classified as water user type 2 for industrial purposes that shall obtain Water Usage Permits and install equipment/ instruments to monitor water usage.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2561/A/112/T_0044.PDF*
55	Regulation of the Ministry of Industry, No.25, B.E. 2559 (2016), issued under the Factory Act B.E. 2535 (1992)	Ministry of Industry	Water Resource	The Regulation revised requirements stated in the Regulation of the Ministry of Industry, No.2, B.E. 2535 (1992), issued under the Factory Act B.E. 2535 (1992). Requires amended included: ■ In order to protect the safety and environment of a public water course, factories type 3 of all types, size and capacity within a 100 meter boundary are prohibited to expand. ■ Factories must also be established in an appropriate location.	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2559/A/113/3.PDF*
56	Ministerial Regulation, B.E. 2565 (2022), Re: Prescribe Engineering Profession and Control Engineer Profession.	Ministry of Interior	Water, Wastewater, Groundwater	This Ministerial Rule prescribes the engineering professions as control engineer profession and assigns roles and responsibilities of the control engineers including supervising and operating of the equipment and systems. As prescribed in this Rule, the environmental engineering shall be responsible for the following: ■ 1) Tap water production system with capacity from 500 cubic meters per day ■ 2) Clean water production system (for factory) ■ 3) Wastewater system (for factory) ■ 4) Water reclaimation system (for factory) ■ 5) Drainage system (serving from 10,000 cubic meters per day)	*http://www.ratchakitcha.soc.go.th/DATA/PDF/2565/A/042/T_0017.PDF*

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
				■ 8) Remidiation system of soil or contaminated water system occupying at least 3,000 square meters ■ 11) Fire response and prevention system worth at least 3 million baht per system or serving an area at least 2,000 square meters. 12) Groundwater system or subsurface water filling system with minimum capacity of 1,000 cubic meters per day	
57	Notification of the Department of Water Resources, B.E. 2565 (2022), Re: Application Form for Type II and Type III Water Use Permits and Water Management Plan.	Department of Water Resources	Water Resources	This Notification prescribes the forms for Category II (government or small business) and Category III (state enterprise, Industry, large business) water use permit applications in its annex. The applicant for a water use permit Type II and Type III shall prepare water management plans to be in accordance with the guidelines as specified in the annex of this Notification. Documents annexed in this Notification includes: ■ Application for Category II of water use permit for an individual (Form Tor Nor. 1) ■ Application for a Category II of water use permit for a legal entity or a government agency (Form Tor Nor. 2) ■ Application for a Category III of water use permit for an individual (Form Tor Nor. 3) ■ Application for a Category III of water use permit for a legal entity or a government agency (Form Tor Nor. 4) Water Management Plan	http://www.ratchakitcha.soc.go.th/DATA/PDF/2565/E/179/T_0012.PDF
58	Notification of the Department of Water Resources, B.E. 2565 (2022), Re: Criteria and Method for Installing Instruments to Measure Water Usage Volume and Collecting Necessary Data for Monitoring And			This Notification prescribes the method of equipment installation for measuring or estimating amount of water used and collecting data necessary for the purpose of monitoring and controlling the use of non-irrigated and non-ground water public water resources by Category II and Category III water use permit holders. Holder of water use permit mentioned in this Notification shall install the flow measuring equipment according to the criteria and method prescribed in this Notification and report the data to Department of Water Resources every 3 months via electronic platform.	http://www.ratchakitcha.soc.go.th/DATA/PDF/2565/E/179/T_0013.PDF

No.	Laws and Regulations	Authority	Applicable Matrix	Brief Applicability Description	Link
	Controlling the Use of Public Water Resources that Are Not Irrigation Water, Nor Groundwater By Permit Holders of Category II and Category III Water Use.			Documents annexed in this Notification includes: ■ Criteria and Method for Installing Instruments to Measure Water Usage Volume ■ Request Form for Water Flow Measurement Equipment Installation (Form Tor Nor. 13) Acknowledgement Document for Water Flow Measurement Equipment Installation Request (Form Tor Nor. 14)	

9. PRELIMINARY BROAD LEVEL PERCEPTION SURVEY

A preliminary broad level perception survey was conducted within the subject area to understand peoples' perception on water availability around each subject water sources. The survey was conducted in focus groups of community representatives with the assumption that each of these groups have a different perception on the issue. The survey was be supplemented by one consultation that will be undertaken with Local Authority. The output of the survey was:

- broad socio-economic profile of the area;
- the socio-political scenario of the area;
- history of the community coming together for action;
- potential for opposition;
- perception about water availability; and
- Analysis of State Government's and Union Government's policies and prospective plans.

Based on ERM's past experience, we cannot guarantee that these efforts will necessarily yield complete information. In that information requested for Client under this assignment may in certain circumstances be derived from or based on verbal communications with various stakeholders (rather than official written sources), there can be no assurance that the said information is complete, representative or will not change over time. Also, please note that this survey should not be considered as an alternative to a detailed need assessment/ social impact assessment.

9.1 Site Visit and Consultations

The purpose of the consultations was to develop an understanding of the stakeholder perceptions and views regarding Osotspa beverage filling plant and glass factories in Khlong Suan Plu Sub-District, Phra Nakhon Si Ayutthaya Province, and other industries' activities (pertinent to surface water, groundwater, and wastewater) within the area, history of drought/floods, water availability and water quality in the area, the impact of factories to the community, and communities' expectations from industries. This survey was conducted considering the objective and scope of work proposed to Osotspa under a limited timeframe. ERM carried out a reconnaissance survey and consultations by random sampling in 19 villages and settlements within a 5 km radius around the plant and factories with an average group size of 2-4 persons per group as shown in **Figure 9-1**.

Figure 9-1 Reconnaissance Survey with Community Residing the Study Area

9.2 Key Socio-Economic Indicators and Their Implications On The Project

Indicator	Description	Implication
Population and density	• Osotspa beverage filling plant and glass factories are located in Moo 7, Khlong Suan Plu sub-district, Phra Nakhon Si Ayutthaya district, Phra Nakhon Si Ayutthaya province. The area is administrative by Ko Rian Sub-district Administration Organization (SAO). The population under Ko Rian SAO administration consists of 7,080 persons with an average density of 496.87 persons per sq.km (Ko Rian SAO, 2022). • The study scope of a 5 km radius from the Osotspa plant and factories covers 3 districts (including Phra Nakhon Si Ayutthaya, Bang Pa-in, and Uthai district) and 21 sub-districts. Regarding the data from Official statistics registration systems, the number of populations in the three districts has increased slightly over the past decade (5.4% and 10.4% increased in the past 5 and 10 years, respectively) (Official statistics registration systems, 2022). The increased population is mainly caused by the increment of housing estates and local employment from the industrial park in the study area (so-called Rojana). • Phra Nakhon Si Ayutthaya province is the alluvial area in which the Chao Phraya River – the country's main river – has flowed through. The Chao Phraya River directly flows through Phra Nakhon Si Ayutthaya and Bang Pa-In district, while the river branches (e.g., Kaomao, Chong Sa Dao, and Nong Nam Som canal) flow through Uthai district. Thus, Phra Nakhon Si Ayutthaya province is suitable for agriculture and industrial expansion.	• The growing number of populations neither significantly increases the amount of water used and consumption nor creates a water shortage within the area. Because most households in the study area have access to water via village water (groundwater and surface water) supplied by Sub-district Administration Organization or Municipality. At the same time, some households have access to water provided by Provincial Waterworks Authority. Therefore, the water availability in that source is adequate for use throughout the year. • Most wastewater issues in the study area come from households draining wastewater into public water sources (i.e. rivers, canals). Consistent wastewater drainage into the river and canal might result in further degradation of water quality in the present and future. • Furthermore, the industrial park near the communities is one of the main reasons the percentage of local members' participation in the workforce is increasing.
Land use and livelihoods	• **Land Use** - By comparing the situations of 3 districts (Bang Pa-in, Phra Nakhon Si Ayutthaya, and Uthai) in the past (5 - 10 years back) and in the present, there is no indication of significant changes in land uses. The estimated distribution of the land use is evaluated to be over 60% of agricultural area. • **Living conditions related to water sources and water usage** - Public water resources in the study are the Chao Phraya River, canals, and groundwater. The tradition and cultures related to the river/canal are the Loy Krathong festival, Songkran festival, traditional candle festival, and Long Boat Racing. In the past, people used water from rivers and canals	• In the past, people typically settled down to live nearby water sources with rivers and canals passing through the provinces, creating a suitable area for farming; hence, most people were rice farmers. The surrounding environmental condition promotes other agricultural activities such as farming and orcharding. During that period, the primary sources of water in the area were the Chao Phraya River and local canals since these water bodies are spread throughout the province, reaching every village. The quantity and quality of these water sources used to be sufficient and considerably clean for uses throughout the year. Moreover, the community

Indicator	Description	Implication
	for living, farming, and transportation. Currently, those sources are mainly used for agricultural and cultural activities.	utilized rivers and canals as major transportation routes. Over the years, the technological changes have influenced transportation channel from traveling via rivers and canals to on-ground roads. • Lately, there has been a significant shift in occupation from agricultural-related to non-agricultural activities of the local community members. More and more farmers shifted to non-agricultural occupations. The reason of shifted is from the current industrial and metropolis expansion in and surrounding the study area. Another reason for this alternation is that working in non-agricultural jobs (e.g., freelance, self-employed, and employee) ensures a stable revenue compared to working as a farmer. However, at the moment, the proportion of agricultural and non-agricultural households is still at a similar level in the area. And although the local occupation has been shifted, a large proportion of land is still utilized for agricultural activities. Only a minor part of the land was changed from agricultural purposes to factories and dwellings. • Currently, agricultural activities in the area are related to on and off-season rice productions throughout the year. Local people regularly cultivate off-season rice twice a year in compliance with the Royal Irrigation Department's water management to ensure sufficient water for agricultural activities throughout the year. Most farmers have used chemical fertilizers, pesticides, and insecticides to reach the expected yield for paddy cultivation in the area. These chemicals increase the risk of contaminating surface water and groundwater. However, in some areas, farmers are persuaded and encouraged to change from chemical fertilizer to organic fertilizer and bio-pesticide for farming instead.
Water Availability	• Village water (groundwater) and water supplied by Provincial Waterworks Authority have become a major source of households' water consumption. However, purchasing bottled water and water filtration is the primary source of drinking water. At the same time, the water sources for agricultural activities come from rivers and canals. The	• Due to the fact that the lands in the study area are mostly used for farming and agricultural activities, rivers and canals in the area are hence an essential water source for agriculture. Within the study area, those water sources provide enough water for agricultural activities. But nearly half of the farmers and almost seventy percent of villagers

Indicator	Description	Implication
	factories in the area use groundwater, water supplied by the Provincial Waterworks Authority, and Pasak River in the production activities. • Based on consultations with local communities, almost seventy percent experienced water pollution, such as odors from the canal, especially during the dry season. Aside from the natural effects, the household is the primary cause of water pollution since their wastewater drainage is direct to canals, followed by factories and restaurants.	face the negative effects of bad quality water from the canal. The reasons for polluted water in the view of villagers are the drainage of wastewater from the housing estate to the canal, followed by wastewater from factories and restaurants. Also, the Royal Irrigation Department will occasionally close the floodgate for a short period, which will cause the water flow to stop temporarily. Consequently, the still water becomes polluted water. • The two primary sources of domestic water supply to the household are 1) village water (groundwater) and 2) water supplied by Provincial Waterworks Authority, while only a small number of household use water from the canal. As stated by interviewees, those sources provide enough water, but a minority have complained about the quality (colored water, sedimentary water, slow-flowing water). Most households gain access to drinking water by purchasing bottled water, while a certain number of households use self or public water filter machines. • Industrial factories in the area use Pasak River, groundwater, and water supplied by the Provincial Waterworks Authority for their production processes without impacting local people's water sources. Generally, industrial factories will conduct wastewater treatment in compliance with relevant standards and laws before draining into public water sources.

9.3 Key Stakeholders in the Project Area

9.3.1 Local Community

Stakeholders in the local community consist of village leaders and villagers who live within a 5 km radius of Osotspa plant and factories. Henceforth, the study scope for Osotspa plant and factories covers 3 districts and 21 sub-districts within a 5 km radius of Osotspa plant and factories, as shown in the **Table 9-1** below:

Table 9-1 List of sub-districts within a 5 km radius of Osotspa plant in perception study

District	Sub-district	
Phra Nakorn Si Ayutthaya	1) Khlong Suan Phlu 2) Ko Rian 3) Khlong Takhian 4) Samphao Lom	5) Phai Ling 6) Hantra 7) Kamang 8) Ho Rattanachai
Bang Pa-In	1) Sam Ruean 2) Ban Krot 3) Khung Lan 4)Taling Chan	5) Khanon Luang 6)Ban Pho 7) Ban Wa 8) Ban Sang
Uthai	1) Khan Ham 2) Ban Chang 3) Uthai 4) Thanu	5) Khao Mao

Based on data in 2022 from Official statistics registration systems, the total population in the study area (Phra Nakhon Si Ayutthaya, Bang Pa-In, and Uthai district) is 170,478. According to the interview of local communities, the largest proportion of citizens works as a freelance, self-employed, employee, and farmer, respectively. Although there were shifts in occupation, expansion of villages, and additional establishment of habitats, the area is primarily agricultural and farming fields. While most population of farmer work in paddy fields inside and outside irrigation areas, a certain number of citizens cultivate coconut, corn, oil palm, and other plant-based products (Department of Land Development, 2021).

Based on the opinions and statements of interviewees in the study area, the water used in household consumption is sufficient. Water shortage does not occur in communities because the village water (groundwater) and water supplied by Provincial Waterworks Authority make the amount of water to be sufficiently available in communities throughout the year. However, the household has minor complaints about the water quality (e.g., colored water, sedimentary water, slow-flowing water). The water sources for farming, mainly from rivers and canals, are sufficient and available throughout the year. But almost seventy percent of households and nearly half of the farmers in the study area complained about the water quality of the river and canal that affected the household and farms. From the affected villager's and farmers' perception, draining wastewater from the housing estate to the canal is the primary cause of a polluted canal, followed by wastewater drainage from factories and restaurants, respectively. The closing of the floodgate from September to December, causing less water flow, is another reason for polluted canal.

Primary water resources for Osotspa plant and factories are groundwater (75%) and water supplied by Provincial Waterworks Authority (25%). And since most of the water provided to the village, which is from the same sources used in the plants, is sufficient, therefore, it can conclude that the establishment of Osotspa plant and factories does not impact the water usage of local people in the surrounding communities in terms of availability. The communities believed that the bad water quality in the canal resulted from housing estates, factories, and restaurants, respectively. However, no specific factory was mentioned. But since Osotspa plant and factories have wastewater treatment and are operating in

compliance with the law requirements, the plant thus legally generates no impact on water sources within the local river/canal.

Local communities' overall perception of the nearby factories is ‘natural to positive’. According to the opinions and statements of interviewees, most believed that having a factory located in a community area, overall, generates more benefits than negative impacts to the community.

However, there are minor concerns about dust, noise, and wastewater that believed caused by the factories, but no protest or any activities against factories have occurred. Local communities also request support in terms of charitable donations, promoting job opportunities, and canal wastewater management.

9.3.2 Local Administration within 5 km radius around the plant

Local Municipalities and Sub-district Administrative Organizations (SAO) are responsible for ensuring peace and cleanliness, providing and enhancing public utility systems/services, and promoting social, educational, and environmental activities for the benefit of people. Municipalities and SAO that are selected as a target group for perception surveys include Sam Ruean SAO, Ban Krot SAO, Taling Chan SAO, Ko Rian SAO, Khan Ham SAO, and Ayothaya Town Municipality. Furthermore, the study selected two local government agencies as the target group to gain reliable information on water-related aspects in the area, including Phra Nakhon Si Ayutthaya Provincial Irrigation Office and Provincial Office of Natural Resources and Environment Phra Nakhon Si Ayutthaya.

The opinions of the Municipality and SAO disclose that households in the area access non-drinking water from the village water supply (which can be pumped from groundwater and surface water) and water supplied by the Provincial Waterworks Authority. The amount of water from those sources is adequately available in compliance with households’ needs. While some of the households that settled near the water sources resort non-drinking water from nearby canals. And bottled water is the primary source of households’ drinking water. Furthermore, the amount of water in natural water sources (Chao Phraya River, the river branches and canals) is sufficient for farming and agricultural activities throughout the year; hence water shortage rarely happens within these areas, according to the opinions of Municipality and SAO. However, certain locations in the study area may encounter floods every year.

The municipality and SAO indicate a sewage water problem with the river and canal in the area. But the impact of wastewater on the communities is considered low impact level. However, unlike the opinion of the local communities, they disclose that the problems are mainly from wastewater drainage from factories.

While the local governments in the area indicated that the sewage water in canals is from the drainage of wastewater from the housing estates and the drainage of wastewater which contained chemical fertilizer from paddy fields. The impact of sewage water to community is considered mid-level.

9.3.3 Local Labourers

Data from the Municipality, SAO, and community leaders point out that the most significant proportion of the population in the study area is working as freelance and rice farmers, followed by self-employed and employees. And there is a tendency for the occupation transformation from agricultural to non-agricultural since the prices and yields of crops are uncertain, and factories create jobs for local communities nearby.

9.3.4 Village Institutions

Data from SAO, The Secondary Educational Service Area Office Phra Nakhon Si Ayutthaya, Phra Nakhon Si Ayutthaya Primary Educationl Service Area Office 1 and 2, and Office of the Private Education Commission shows that within study area, there are total 42 schools as listed below:

- 24 educational opportunity expansion schools (kindergarten until elementary school);
- 15 educational opportunity expansion schools (kindergarten until high school); and

- 3 high schools

Within the study area, there are 1 district hospital, 4 private hospitals, and 18 sub-district health promoting hospitals.

9.3.5 CSR Activities

Osotspa has undertaken Corporate Social Responsibility (CSR) activities with the communities surrounding the plant and occasionally visit community leaders and related government agency on various occasions as appropriate to maintain a good relationship with the communities.

9.3.6 Local NGO's

There was no active NGO's operating in the area as per local consultations and secondary data search.

9.3.7 Media

There have been no reports by the media on environmental concerns with respect to Osotspa plant and factories in the area.

Key Findings:

- Based on the review of the secondary information and consultations undertaken during the Site visit, no major social conflicts between factory and local community in terms of water availability are found. Main indicators of this conclusion, which is based on perceptions of local people as informed during consultations, are as below:
- Most households in the Study Area have sufficient access to tap water and Ping River for domestic use, purchase bottled water for consumption. The agricultural community utilizes from the groundwater, Ping River, tap water and canal network. The average depth of groundwater wells in the area are reportedly 184.13 meters.
- Most households in surrounding areas (Phra Nakhon Si Ayutthaya, Bang Pa-in, and Uthai district) of Osotspa plant and factories have sufficient water from village water (groundwater) and water supplied by Provincial Waterworks Authority. Bottled water and filtered water are the primary sources of drinking water. The farmer also has sufficient water for agricultural activities from the canal networks passing through the area. And there is no major drought in the area reported by communities.
- However, a minority of households have complained about the quality of water used for household purposes (colored water, sedimentary water, slow-flowing water), and the majority have complained about canal water quality. Almost seventy percent of households faced waste canal water issues that directly affected the living condition in the community. Most communities realize that industrial plants and factories in the area have a standard wastewater treatment system that complies with the regulations. They believe the sewage might be generated from wastewater drainage of housing estates without an appropriate treatment system. In most communities' opinions, industrial plants are not the major cause of the degraded water quality.
- The overall perception of the communities towards the factories is 'neutral to positive'. The communities did not report any grievances against the factories. And there is no history of protests against the plant or other industries regarding water or wastewater issues since the communities do not consider the plant and other industries in the area as competitive water users. Hence, water consumption from industrial factories does not affect people's way of life in the communities. Furthermore, local communities think the nearby factories generate more benefits than negative impacts for the community.
- According to the communities' opinions, the industry development approach that will not affect the environment, especially the water source, is that the factories have a standard wastewater

treatment system. The factories also should operate canal wastewater treatment projects and let the community be part of it. Furthermore, the factories should give a budget or be part of local community development and promote job opportunities to maintain the development of industry and the local economy.

- Osotspa needs to publicize relevant information about its operation to communities around its plant and factories to ensure that the community will not have any misunderstandings about wastewater. In addition, doing so can provide a better understanding that the company has a standard wastewater treatment and has obtained monitoring results on water quality measurement. From the survey, the most common channels for receiving news of the local villagers consist of community news distribution towers and social media such as websites, LINE, and Facebook. Thus, before the publicization, the company may start coordinating with village leaders to shape their understanding and then help pass the publicizing information to the villagers.
- There is no CSR activity, related to water issue. Thus, Osotsoa should plan additional CSR activities, regarding to water and water reservation in the study area. Some examples of these CSR program are projects/activities listed below:

    1) Collecting garbage around canals projects/activities;

    2) Promote cultural activities related to canal; and

    3) Encourage the awareness of the river and canal.

10. RISK EVALUATION CRITERIA AND QUALITATIVE RISK EVALUATION

10.1 Risk Evaluation Criteria

Based on the observations made during the secondary data review and findings of the assessment, a qualitative risk assessment was carried out on each of the tasks. Approach for hazard identification, risk, likelihood/probability analysis, risk evaluation is developed based on International Standard for Risk Management (ISO 31000) [1] and International Standard: Guidelines for Risk Management - Risk Assessment Techniques (ISO 31010)[2]. ERM identified potential risks and vulnerabilities associated with source water, and categorized them considering the likelihood and severity of the impact.

Risk = Likelihood of an impact occurring x Severity of the impact.

Potential Likelihood		Potential Severity				
		1	2	3	4	5
		Negligible	Minor	Moderate	Significant	Severe
5	Almost Certain (81-100%)	5	10	15	20	25
4	Likely (61-80%)	4	8	12	16	25
3	Possible (41-60%)	3	6	9	12	15
2	Unlikely (21-40%)	2	4	6	8	10
1	Rare (1-20%)	1	2	3	4	5

Figure 10-1 Probability-Consequence Matrix for Risk Categorization

10.1.1 Qualitative Definition of Risk Severity Specific to Current Assessment

Following definition was developed by ERM for this assessment as a reference for analysis and interpretation of categorization of hazards and risks and for prioritization of mitigation action.

Severe: Likely to cause shutdown of operations or severe disruption of business for extended period (>1 week); Will cause direct and/or indirect financial and/or reputational impact on the business.

Significant: Likely to cause shutdown of operations or disruption to normal business up to 1 week. Will cause direct and/or indirect financial and/or reputational impact on the business.

Moderate: Has potential to cause shutdown of operations or disruption to normal business; May require considerable resources and planning to mitigate the risk from escalating in future; Direct or indirect financial and/or reputational impact on business is not evident. May require further evaluation.

Minor: May cause temporary inconvenience, impact performance of operations, requires allocation of resources to mitigation the risk from escalating further; Must be monitored and reviewed on periodic basis; and

Insignificant: Direct or indirect impact are not evident. Impact may be insignificant in case it occurs. Monitoring and review is recommended for all cases other than “Not Applicable”.

[1] https://www.iso.org/obp/ui/#iso:std:iso:31000:ed-1:v1:en

[2] https://bambangkesit.files.wordpress.com/2015/12/iso-31010_risk-management-risk-assessment-techniques.pdf

10.2 Risk Summary: Qualitative Risk Matrix

Table 10-1 presents a summary of risk attributes and their risk factor qualitatively evaluated and categorized in a risk matrix. Residual risk indicated in the last column represents the existing level of risk at the time of this assessment. Mitigation measures to address these risks are presented in **Section 1111.**

Table 10-1 Risk Summary: Qualitative Risk Matrix

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
Climate and Natural Hazard	Drought: Impact on Source and Water Supply: Present (Baseline)	■ As per the baseline 10 years of recorded rainfall data of TMD, 7 years of which were observed to be normal rainfall, 2 years were observed to be deficient, and 1 scanty rainfall year was observed in 2019. ■ According to the Water Crisis Prevention Center in Thailand, Phra Nakhon Si Ayutthaya Province is not at risk of drought. ■ As per the WRI aqueduct, the baseline drought risk for the area in which the Site is located is medium-high (0.6-0.8). ■ As per the Site representative, the Site has never experienced a water drought event since the Site commencement.	**Minor**	**Unlikely**	The Site planned to increase the ratio of supply water from PWA to reduce utilization of un-predicted groundwater sources.	**4**
	Flooding: Impact on Off-Site Water Infrastructure	■ Flooding is a common disaster in the Phra Nakhon Si Ayutthaya province caused by water run-off. ■ According to the disaster Risk Management Plan, 2015 (Revision, 2020) report, Phra Nakhon Si Ayutthaya province has been affected by water run-off in 2011 and 2021 due to the water overflow.	**Moderate**	**Likely**	-	**12**

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
	Flooding: Within the Site premises	■ The areas at which the Site located is considered as high flood risk area ■ Based on Site representative, the Site did not affected by great flooding event occurred in 2011	**Moderate**	**Likely**	The Site has conducted a flooding impact assessment and a mitigation plan has been developed at the Site level to reduce the impact from flooding. However, no flooding mitigation is implemented on Site.	**12**
	Seismic Risk: Impact on Off-Site Water Infrastructure	■ The Thailand Seismic Hazard Map is used to assess the severity and intensity of earthquakes with a 10% chance of occurring within the next 50 years, according to the Mercalli Scale. ■ Based on Thailand's Department of Disaster Prevention and Mitigation, there is no record of an earthquake in Phra Nakon Si Ayutthaya Province. ■ Phra Nakon Si Ayutthaya Province is considered to have a low risk of seismic activity.	**Moderate**	**Rare**	None	**3**
	Land subsidence Risk: Impact	■ According to the UNESCO LaSII, the Project is located in an area with "High" susceptibility of subsidence. ■ Overall, the entire basin of the Chao Phraya is categorized between "Medium-High" to "High" susceptibility.	**Significant**	**Likely**	None	**16**

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
		■ Considering smaller scale studies focused on the Bangkok metropolitan area, it is possible to observe that the northern portion of the Chao Phraya River has lower rates of subsidence than the southern stretch of the river. According to Aobpaet et al. (2012), the subsidence rate in the north Chao Phraya can vary between -7 mm/year to -18 mm/year. ■ According to the Global Subsidence susceptibility map from Herrera and Ezquerro, 2020, subsidence susceptibility is high at the Site and surrounding region. Currently, the subsidence rate is not monitored at the Site. However, the Site has never faced any disruption due to land subsidence. But the continuous extraction of groundwater can aggravate the land subsidence and Site may get impacted in the future.				
Water Availability/Supply /Quality/Cost/Water Balance	Water Available at Source: Present	■ The water source to the Site is groundwater supplied from bore wells within the Site premises and the municipal water from PWA. ■ Proportion of groundwater and PWA water consumption is reported to be 75:25 ■ No information on the water source for municipal water was available. Hence, commenting on water availability for the source of PWA water is not possible. ■ The Site reported that they have obtained the permit for the	**Significant**	**Possible**	The following steps are followed to reduce the freshwater consumption on-site: ■ Treated wastewater from on-site WWTP is used for gardening and cleaning purposes.	**12**

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
		installation and groundwater abstraction (consented volume). However, the document was not available for review. It was informed by the Site that they have never exceeded the consented volume of groundwater abstraction. ■ As per the 2021 water consumption report, the average groundwater withdrawal and raw water supplied from PWA are ~3,770 and 765 m3/day, respectively. The trend of water use depends highly on production rate which is expected to increase in several years. ■ As per the WRI Aqueduct baseline water stress for the district is reported to be “Medium to High”. ■ Phra Nakon Si Ayutthaya Province is classified as a “Critical” Zone where groundwater is withdrawn in excess of the amount of groundwater replenishment resulting in a decrease in the groundwater level, land subsidence and diffusion of saltwater into the groundwater in coastal areas. ■ Based on groundwater level record from DGR, groundwater level in observation wells in Ban Krot Sub-district nearby to the Site observed a decreasing trend of 6-10 meters from 2003 to 2022. ■ According to DGR, during the past year, groundwater level in Phra Nakorn Si Ayutthaya province is reported to be unchanged or slightly			■ Treated wastewater is recycled for cooling tower to reduce the dependency of fresh water consumption ■ RO rejected water is re-treated in water treatment processes to divert rejected RO water from discharging	

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
		changed due to amount of rainfall with no more than 1 meter per year. ■ Overall groundwater recharge and availability in Thailand is reported to be around 45,385 Mm3/year which is considered sufficient compared to groundwater abstraction rate nation-wide. However, no specific information for Site location is available. ■ The Site has never conducted groundwater level monitoring for operating bore wells as it is not required by the local regulation.There are no piezometers installed on-site to monitor the fluctuations in groundwater levels. ■ In addition, baseline water stress at the Site using Aqueduct tool is reported to be 'Medium to High', which may be considered to indicate high competition among multiple stakeholders dependent on common water resources. ■ No issues with groundwater availability were reported during the perception survey.				
	Water Available at Source: Projected	■ As reported by the Site, there are plans to increase the production volume by 15 percent in the next five years. Therefore, there will be an increase in water withdrawal in the next five years. ■ Based on the decadal land use (2008-2018) in the study area, it is found that there is a considerable	**Significant**	**Possible**	The Site has planned to increase the ratio of supply water from PWA to reduce utilization of un-predicted groundwater sources. However,	**12**

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
		increase in urban or built-up areas resulting in water stress on water resources and social infrastructure in the area. ■ However, due to the presence of abundant water resources in the area, water availability risks associated with high urbanization are deemed insignificant. ■ Furthermore, the estimated water stress for 2030 and 2040 based on climate change scenarios RCP 8.5 and RCP 4.5 is projected to remain a “medium to high” risk of water stress. ■ However, the availability of water should also be evaluated on a seasonal basis which is also projected to increase to “High”, indicating increased seasonal variability in the future.			no measures are currently in place	
	Water Quality at the Source	■ Based on the information obtained during the site visit, the Site acquired the permits for five (5) on-site bore well to abstract groundwater without exceeding the permitted volume which varies depending on drilling characteristics and hydrogeological data, however, the evidence of groundwater withdrawal permits were not available for review. ■ As per the Thailand groundwater quality map, the area where the Site is located is indicated to have an elevated sulphate concentration of more than 250 mg/l.	**Moderate**	**Possible**	At present, the abstracted bore well water is monitored for only three (3) parameters	**9**

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
		■ 10-year record of groundwater monitoring at a public observatory well in Ban Krot Sub-district was obtained from the DGR. Several parameters were monitored including pH, electricity conductivity, metals, ions, TSS, TDS, total hardness, and non-carbonate hardness. The quality of groundwater fluctuates throughout the years with slightly upward trends yet still lies within the acceptable range and is in compliance with the regulatory standards. ■ As for on-site bore well, the groundwater quality of each bore wells at the Site were constantly monitored on daily basis by the Site's internal laboratory prior to be utilized in the processes for the following parameters: pH, turbidity, conductivity. The result of 6-month average of groundwater quality indicated the pH and turbidity to be under drinking water regulatory standard (*Thailand Drinking Water Standard Manual, issued by Department of Medical Sciences under Ministry of Public Health)* except pH value from one bore well numbered 4101-0031. ■ During the Site visit, one bore well station located at the far-east direction of OSP-AY Site, behind the canteen area was observed installed on paved area with proper enclosures to protect the wellhead from physical damages or				

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
		sabotages and installed fencing area to restrict access installed. However, the surrounding area at which the bore well is located was observed to store bulky waste and scraps from site construction. It was reported that the Site was undergoing construction work and construction waste was temporary stored at the area prior to being transported and disposed by verified third parties. ■ As per the environmental and perception survey carried out by ERM following observations were made: ○ The two primary sources of domestic water supply to the household are 1) village water (groundwater) and 2) water supplied by PWA, while only a small number of household use water from the canal. As stated by interviewees, those sources provide enough water, but a minority have complained about the quality (coloured water, sedimentary water, slow-flowing water). ○ Within the study area, water sources for farming and agricultural provide enough water for agricultural activities. But nearly half of the farmers and almost seventy percent of villagers face the negative effects of bad quality water from the canal. The reasons for polluted water in the view of villagers are				

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
		the drainage of wastewater from the housing estate to the canal, followed by wastewater from factories and restaurants. Also, the Royal Irrigation Department will occasionally close the floodgate for a short period, which will cause the water flow to stop temporarily. ○ Industrial factories in the area use Pasak River, groundwater, and water supplied by the PWA for their production processes without impacting local people's water sources. Generally, industrial factories will conduct wastewater treatment in compliance with relevant standards and laws before draining into public water sources. ■ Currently, the Site performs water quality analysis for only three (03) parameters and not for a comprehensive suits of analytes. This is critical as rapid urbanization and reported domestic wastewater from communities into waterways as informed by the surrounding communities during the environmental survey could introduce contaminants into the aquifer and deteriorate the quality of groundwater as well as surface water.				
	Supplied Water Quality: Present	■ Supply water from PWA together with reused RO cool down water to	Minor	Possible	At present, the supply water from PWA is monitored	**6**

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
		enter a 1,500 m3 intake tank as the first storage. ■ Site reportedly constantly monitored water quality in the 1,500 m3 intake tank on daily basis by the Site's internal laboratory for the following parameters: pH, turbidity, and conductivity. The 6-month record of supply water and reused RO cool-down water was indicated to be under drinking water regulatory standards. ■ Site does not perform water quality analysis for a comprehensive suite of analytes. As per the environmental and perception survey, the discharge of domestic sewage from communities in the study area directly into the waterways eventually lead to the Chao Phraya River and thereby causing pollution of surface water.			three (3) parameters	
	Water Quality of Supplied Raw Water: Future	■ A 10-year record of observation well for several parameters were monitored. The overall trend of groundwater quality fluctuates throughout the years with slightly upward trends, therefore, considering the constant water utilization and discharge behavior, groundwater quality in the study area is projected to increase over years.	Moderate	Possible	None	**9**
	Wastewater Quality Prior to Discharge	■ The Site undertakes monitoring and analysis of treated effluent from OSP-AY by an internal laboratory for the following parameters	**Minor**	**Possible**	The Site undertakes monitoring and analysis of treated	**6**

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
		○ pH and temperature on a daily basis; ○ Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) on a weekly basis; and; ○ Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) monitored every 30 minutes; ■ In addition, on a monthly basis, the OSP-AY engages ALS Laboratory Group (Thailand) Co., Ltd., a third-party laboratory to conduct monitoring of the treated wastewater quality. The monitoring parameter includes BOD, COD, color, oil & grease, pH, TDS, total Kjeldahl Nitrogen, and TSS. A review of the treated effluent quality reports (January - June 2022) indicated no exceedance above the regulatory limit. ■ The effluent standard for factories/industries set by the Ministry of Natural Resource and Environment includes a total of sixteen (16) parameters including heavy metals, microbiology, and pesticides. However, the Site is monitoring only nine (09) parameters. ■ Plants (OSP-AY and SBM) discharge a certain volume of their treated wastewater into the canal-Khlong Thap Taeng. However, the water quality of the canal is not known.			effluent from OSP-AY and SGI-AY	

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
		■ As for SGI-AY Plant, which is not allowed to discharge wastewater off-site, the quality of treated wastewater in the retention pond is monitored based on bi-annually basis for pH, color, temperature, odor, and concentration BOD, COD, TDS, TSS, oil and grease and TKN. The monitoring result dated 12 October 2022 was available for review, yet no exceedance of any measuring parameter identified. ■ Although, quality of treated wastewater from SGI-AY has been monitored, there is no record of water level or evaporation rate from its retention pond.				
	Water-related Emergencies/Incident Response	■ Based on an interview with Site representatives, no event of leakage or spillage which could potentially impact soil and groundwater contamination has been reported. ■ Site has spill kits on-site to handle oil/chemical spills on-site ■ An emergency response plan for flood cases has been developed. However, implementation is still underway. ■ Site does not have a dedicated Stormwater Management Plan and Stormwater Pollution Prevention Plan ■ As per the document provided for review, there are a number of days in the past year where the Site operated WWTP exceeding the	Minor	Unlikely	None	**4**

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
		maximum design capacity of 2,500 m3. It is documented that the exceeding events are sometimes caused by the maintenance of the WWTP system including, cleaning or maintenance of retention pond and re-treating of wastewater from MSBR tanks. However, no corrective action was reported in response to such events.				
	Water Cost	■ The Site falls under the "Critical" zone for groundwater withdrawal. Provinces categorized as Critical have to pay a groundwater tariff of 13 THB/m3 whereas other provinces in the Kingdom are required to pay the 3.5 THB/m3 fee. Site is currently paying four (4) times the price for groundwater as it is located in an area where groundwater is overexploited. ■ In the case that the Site diverts water source from abstraction bore wells to supply water from PWA, a massive utility cost shall be added to the Site operating expense. ■ The Site has not provided a detailed break-up of the costs as water infrastructure maintenance, WTP and ETP operational costs, electrical costs, and payroll of the team managing the water and cooling and heating costs.	Significant	Possible	None	**12**
	Site Water Balance	■ Site has shared the water balance based on actual usage/discharge in 2021	Significant	Possible	None	**12**

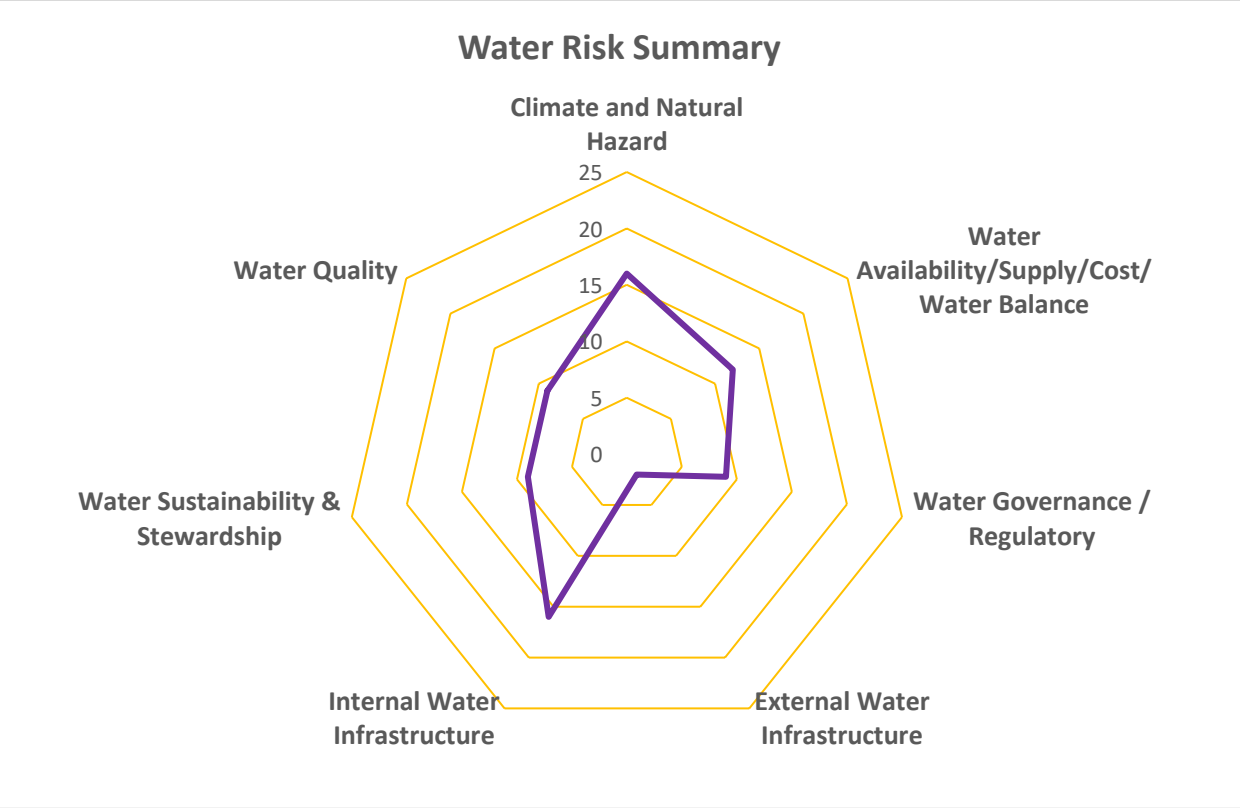
Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
		■ In the water balance schematic shared by the Site, the volume of treated wastewater evaporated from on-site retention ponds nor treated water used for gardening green areas has been accounted for. ■ The break-up of actual water (fresh + recycled) used for the boiler, cooling tower, process, and domestic purposes. ■ The break-up of fresh water supplied to the SBM and SGI-AY Plant after treatment at the OSP-AY was not available for review. ■ Site has not developed a scientific water balance since all the water losses are not quantified ■ Due to a lack of information on treated water usage, water losses from Site activities cannot be identified at the current stage. A record of treated water usage should be identified to determine water loss and improve water footprint.				
Water Governance / Regulatory	Compliance with water and wastewater-related regulations	■ Based on the document reviewed, the Site has conformed to local registration regarding permitting, monitoring and reporting. ■ The bore wells were reported to be registered with the local Office of the Ministry of Natural Resource and Environment, however, the evidence of such documents was not available for review. ■ As per the permit for groundwater abstraction from the bore well, only	Moderate	Possible	None	**9**

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
		a consented volume is allowed to be abstracted from the bore wells. However, this information was not available for review ■ The Site (only for Plants OSP-AY and SBM) has permission to discharge treated wastewater into the local canal. SGI-AY is restricted from discharging treated effluent into the canal.				
External Water Infrastructure	Off-Site Water Infrastructure	■ There is no concern identified for external water infrastructure as raw water and wastewater generated are treated by on-site water production units and an on-site WWTP, thus, the Site's activities related to water do not rely on off-Site infrastructure. ■ The Site also receives municipal water from PWA. However, the source of water for PWA is unknown. Therefore, identifying the risks to the water infrastructure of PWA wasn't possible.	Negligible	Unlikely	None	**2**
Internal water Infrastructure	On-site Water Infrastructure	■ Currently, the combined average water withdrawal of the Site from both bore wells and PWA is ~4.5 MLD. The total on-site raw water storage capacity is ~1.8 MLD (1 No.x 300 m3, 1 No.x 1500 m3, and 1 No.x 2m3). ■ In case of an unforeseen disruption to the existing water supply arrangement, existing on-Site raw water storage capacity/reserves cannot sustain normal operations for even a single day. In case of	Significant	Likely	Existing on-site raw water storage capacity/reserves cannot sustain normal operations for even a single day.	**16**

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
		disruption of the established water supply arrangement for an extended period, the Site may experience a business interruption.				
	Wastewater Treatment Practices	■ As For SGI-AY, due to their operational activities, the Site is prohibited from discharging wastewater out of the Site Boundary. ■ Treated effluent is therefore directed to the SGI-AY open pond located in the area where the treated wastewater is allowed to evaporate. However, it was reported that the ponds have no concrete or sealed lining. Also, it was reported that the Site does not monitor the evaporation rate. Thus, contamination of aquifer from the contaminants if present in the treated wastewater stored in the retention pond cannot be ruled out. ■ The amount of treated wastewater discharged into the retention pond is not known. There are no flowmeters installed in the WWTP of SGI-AY. ■ In the case of OSP-AY and SBM, the treated wastewater from the WWTP is used for gardening, toilets and in cooling tower (after subjecting the treated wastewater to additional treatment). ■ The treated wastewater from OSP-AY and SBM Plant is used for irrigating the green-belt. However, it was reported that the Site has not	Significant	Likely	None	**16**

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
		determined the acceptable hydraulic loading rate for the land within its own boundaries to estimate the optimum land application/discharge rate. Excessive land application of recycled water is likely to result in run-off and infiltration of applied wastewater into the nearby soils and shallow groundwater, in turn resulting in potential soil and groundwater impacts. ■ As per document provided for review, there are a number of days in the past year that the Site operated WWTP exceeding the maximum designed capacity of 2,500 m3. It is documented that the exceeding events are sometimes caused by the maintenance of WWTP system including, cleaning or maintenance of retention pond and re-treating of wastewater from MSBR tanks.				
Water Sustainability & Stewardship	**On-Site Initiatives**	■ Significant opportunity exists to optimize Water Use Ratio (WUR) of the Site through recovery, reuse, and recycle.	Moderate	Possible	Following steps are followed to reduce the freshwater consumption on-site: ■ Treated wastewater from on-site WWTP is used for gardening and cleaning purposes. ■ Treated wastewater is	**9**

Risk Attribute	Risk Factor	Brief Description of Risk Triggers	Risk Severity	Likelihood	Mitigation Measure Currently in Place	Risk at the time of Assessment
					recycled for cooling tower to reduce the dependency of fresh water consumption ■ RO rejected water is re-treated in water treatment processes to divert rejected RO water from discharging.	
	Off-Site Catchment Level Initiatives	■ Catchment refers to 1) catchment of the primary water source; 2) catchment of the water source of the communities; and 3) catchment which may be impacted by operations at the Site and its supply chain. In the current case, the primary water source for the Site is the groundwater and supply from PWA. The surrounding communities also get water from the supply of PWA. Both, the groundwater and PWA get recharged from the Chao Praya River Micro-watershed directly or indirectly.	Moderate	Unlikely	Significant opportunity exists for undertaking water sustainability initiatives at the catchment level.	**6**


Water Risk Summary
Climate and Natural Hazard
Water Availability/Supply/Cost/ Water Balance
Water Governance / Regulatory
External Water Infrastructure
Internal Water Infrastructure
Water Sustainability & Stewardship
Water Quality
25
20
15
10
5
0

11. WATER RISK MITIGATION AND RESOURCE MANAGEMENT PLAN

Based on a broad level understanding of the Site's water usage pattern, concerns associated with water security, and the current level of water-related action beyond the Site boundary, ERM has developed a holistic approach towards water resources management, which includes a combination of water use optimization, emergency preparedness, and long-term sustainability. A water risk mitigation and resource management plan are developed based on risks summarized in **Table 11-1Table 11-1.**

Table 11-1 Water Risk Mitigation and Resource Management Plan

Risk Factor	Mitigation Measure	Action Tasks	Recommended Timeline
Unforeseen emergency resulting from major repair or maintenance work of existing on-site source well(s) or land subsidence risk	Establish standby alternate water supply arrangement – Rainwater Reuse On-Site	■ Develop a scientifically designed rainwater harvesting plan and system considering rooftop areas at the Sites. ■ Identify a suitable vendor/contractor for constructing the system. ■ Install new rooftop rainwater harvesting systems	6 months
Water Availability: (Sustainability of Water Source in Long-term)	Water conservation to reduce groundwater withdrawal volume	■ Undertake a detailed water audit of the Site to identify gaps and opportunities for the conservation of water and optimization of overall water use at the Site. ■ Install piezometers on-site to monitor the groundwater table. ■ Introduce more water and energy-efficient process in place of the water production unit and recovery of RO-rejected water.	3 years
	Plan and prepare alternate water sources and supply arrangements to the Sites during the non-emergency period.	■ Identify various scenarios which may prompt the need for sourcing water from an alternate water source (AWS) other than the existing established water supply arrangement. Identify all available water sources in the region which has the potential to serve as an AWS. ■ Evaluate the feasibility of securing a supply arrangement from the identified alternate source by undertaking a SWOT (Strength, Weakness, Opportunity, Threat) analysis. The objective is to understand whether the identified options can be implemented	36 to 48 months

Risk Factor	Mitigation Measure	Action Tasks	Recommended Timeline
		pragmatically to achieve the desired water security goal and cater to the Site's present and projected water demands.	
	Water supply from PWA	■ The Site is planning to increase the percentage of water withdrawal from PWA and reduce its consumption of groundwater. ■ Engage with PWA/ agencies responsible to identify the source of PWA water and the risks associated with it. ■ Engage with PWA/agencies responsible to increase the amount of water supplied to the Site and to develop the necessary infrastructure for water supply(if required) ■ Engage with PWA/specific Water Treatment plant to monitor the quality of raw water received at the Site	
Water Storage	Raw Water storage	■ Build additional raw water storage tanks on-site to store water abstracted from the bore wells as well as municipality water in case there is any unseen disruption to the current water supply. Currently, the capacity of raw water storage tanks on-site cannot sustain the operations for a single day.	3 months
Water Balance	Develop scientific water balance for the Site water usage	■ Quantify daily or yearly estimates of water consumption/losses from processes and utilities which would aid the Site to reduce its water abstraction in the next few years. ■ Track treated wastewater reused for gardening greenbelt area and identify the evaporation rate of the OSP-AY retention pond and SGI-AY retention pond. ■ Develop a scientific water balance with the actual water usage data.	6 months
Water Quality	Testing of the incoming water through an external/third-party laboratory for a comprehensive suite of analytes	Perform raw water (both groundwater and PWA water) quality analysis for the comprehensive suite of analytes (currently, only 3 are tested). This is critical as rapid urbanization and reported discharge of industrial and domestic wastewater into the nearby canals and ponds as informed by the surrounding communities during the environmental survey could introduce contaminants into the aquifer and surface water, thereby deteriorating the quality of water sources and cause a reputational impact on the business.	Long-term Continual

Risk Factor	Mitigation Measure	Action Tasks	Recommended Timeline
Water Cost (Possible increase in water tariffs)	Internal Measure: Sensitivity Analysis	■ As the Site is situated in the "***Critical***" zone, it is currently paying 13 THB/m^3 for groundwater abstraction which is 4 times more than the standard (non-critical) users. With rapid urbanization, an increase in groundwater withdrawal can be expected in the near future which could also result in per m^3 cost for groundwater. ■ In case of significant impact on business, mobilize internal stakeholder(s) to engage with concerned authorities and strategically negotiate an acceptable level of revision in tariffs (preferential rates rather than standardized rates).	Subjective
Wastewater Treatment Facility	Treated wastewater from OSP-AY and SBM Plants	Determine the acceptable hydraulic loading rate for the treated wastewater used for irrigating the green belt. The objective is to estimate the optimum land application/discharge rate of the treated wastewater as excessive land application of recycled water is likely to result in run-off and infiltration of applied wastewater into the nearby soils and shallow groundwater, in turn resulting in potential soil and groundwater impacts.	6 months
Wastewater Treatment Facility	Improve wastewater infrastructure at SGI-AY Plant	■ Re-construct retention pond in SGI-AY to be paved with the concrete or appropriate liner to prevent contamination of groundwater and surface water sources in the area. ■ Track water level in SGI-AY pond to identify potential risks from wastewater containment. ■ Install flow meters to record the amount of water being discharged into the retention pond ■ Undertake the feasibility assessment to evaluate treatment requirements, and cost implications associated with the reuse of treated wastewater from the SGI-AY Plant	6 months
	Design Capacity of OSP-AY WWTP	■ Conduct an adequacy study of the on-site WWTP to cater to the current effluent characteristics and plant load	6 months
Site Incidence Response	Establish spill prevention and stormwater management plan	■ Provide roles and responsibilities for the person-in-charge in case of any kind of water-related emergencies ■ Develop a dedicated stormwater management plan and stormwater pollution prevention plan	6 months Continual

Risk Factor	Mitigation Measure	Action Tasks	Recommended Timeline
Water Sustainability & Stewardship	External Measure: Catchment level groundwater replenishment action	Assess at the catchment level to identify potential opportunities for engagement and intervention to implementing artificial aquifer recharge measures. The objective is to contribute to enhancing the replenishment of groundwater in deeper aquifer zones and enable long-term sustainability of the groundwater resources.	Long-term Continual
		■ Engage with suppliers, surrounding industries and communities to gain support and enable successful implementation of the envisioned project(s). ■ Select and engage a technical partner to assist in the implementation of the project(s) ■ Establish physical assets to harvest rainwater at the catchment level and replenish groundwater. ■ Engage with communities/NGO to participate in CSR initiatives	Long-term Continual

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