Floating Photovoltaic System (FPV) on Kranji Reservoir

Environmental Impact Assessment (EIA): **Non-Technical Summary (NTS)**

May 2024

Version 1.0 (Final)

This Non-Technical Summary presents a summarised overview of the content of the EIA, see the "Floating Photovoltaic System (FPV) on Kranji Reservoir Environmental Impact Assessment (EIA)" for further details of the Project overview, EIA approach and methodology, existing baseline conditions, impact assessments and mitigation, environmental monitoring and management plan and conclusions.

Sustainability is our business

ERM

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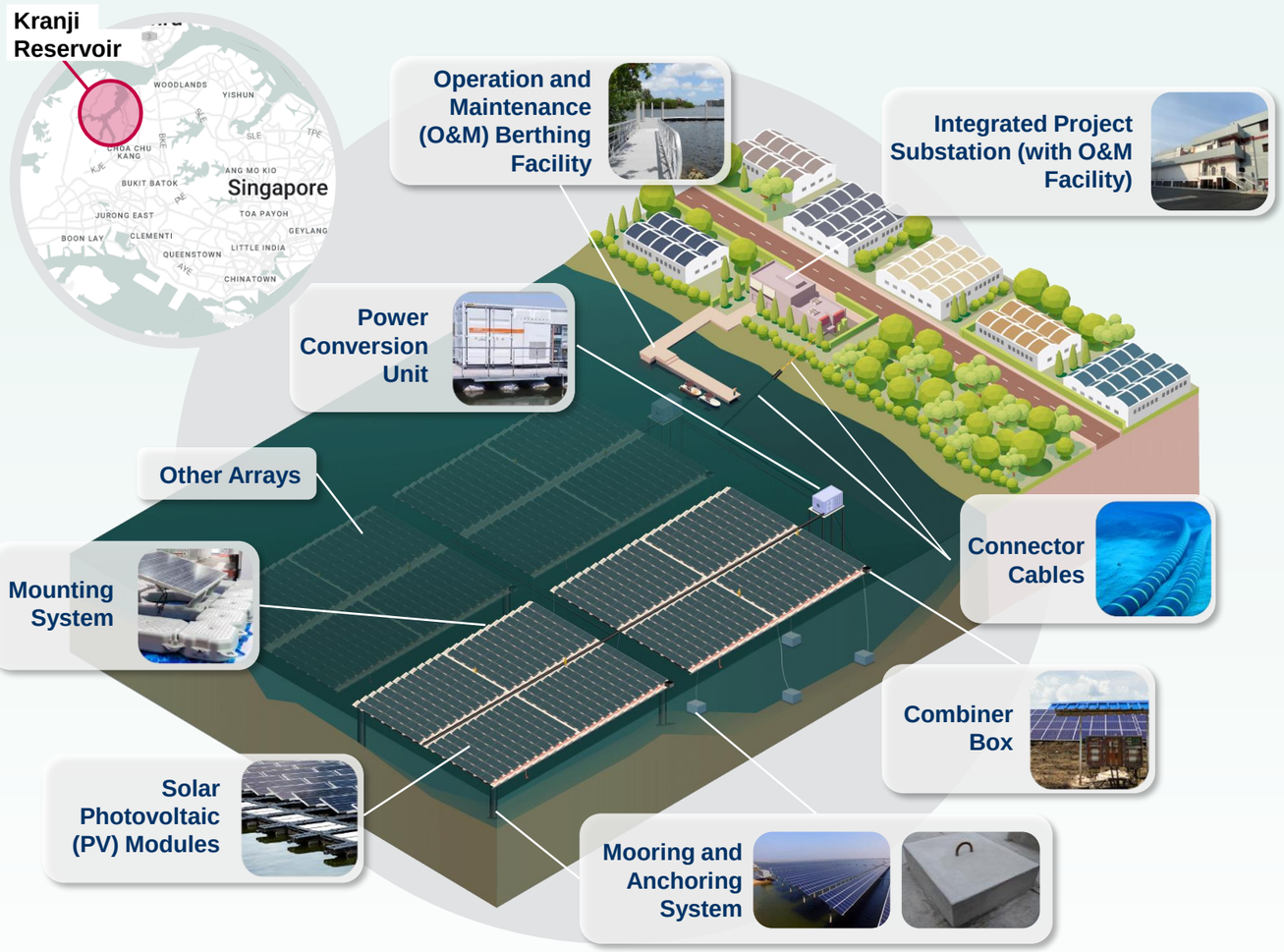
An Overview of the Project and Kranji Reservoir

1. Illustration of the Components of a Floating Photovoltaic (FPV) System:



Project Capacity: 112.5 MWac
(or 141 MWp) (+/- 10%)

Note: MWp (or MWdc) is a measure of the Direct Current (DC) output of PV panels. MWac is a measure of the power output from PV panels after its DC output has been converted to Alternating Current (AC). This conversion is necessary as Singapore's power grid and most of Singapore's equipment/ systems/ appliances run on AC.

2. Kranji Reservoir Status:

- Created by damming former river estuary in 1972
- High nutrient content, resulting in high growth of algae and non-native aquatic vegetation

3. Current Kranji Reservoir Uses/ Activities:

- Important drinking water source (treated at PUB water treatment plant)
- Regular (daily) reservoir management – vessel and machinery operations for aquatic vegetation removal
- Recreational fishing
- Tidal gate operations to manage water levels

4. Potential Positive Benefits of the Project:

Will contribute to 7.1% of Singapore's target of achieving 2 GWp (2,000 MWp) of solar generation by 2030.

Avoided Greenhouse Gases (GHG)

Offsets **76,785 tonnes** of carbon emissions annually

Offsets **1,919,625 tonnes** of carbon emissions over 25 years of operation

Equivalent to reducing

10,138 Motor vehicles' emissions annually

253,450 Motor vehicles' emissions over 25 years of operation

Note: indicative, based on GHG accounting guidance and methodologies from International Financial Institutions (IFI) for grid connected renewables and grid emissions factors, and 2018 motor vehicle statistics from Singapore's National Environment Agency.

5. Project Timeline:

2018:
Economic Development Board (EDB) Request for Information (RFI) to explore Kranji FPV for Renewable Energy User (or Project Proponent)

2019:
EDB selection of Malkoha Pte Ltd as the Renewable Energy User/ Project Proponent, who were to determine the technical feasibility and environmental impacts of the project

2020:
Commencement of EIA, 20 months of baseline surveys and studies & engagements with relevant Government Agencies by Renewable Energy User/ Project Proponent selected by EDB

2021 to 2023:
Five EIA engagements with Nature Groups and ongoing engagements with relevant Government Agencies

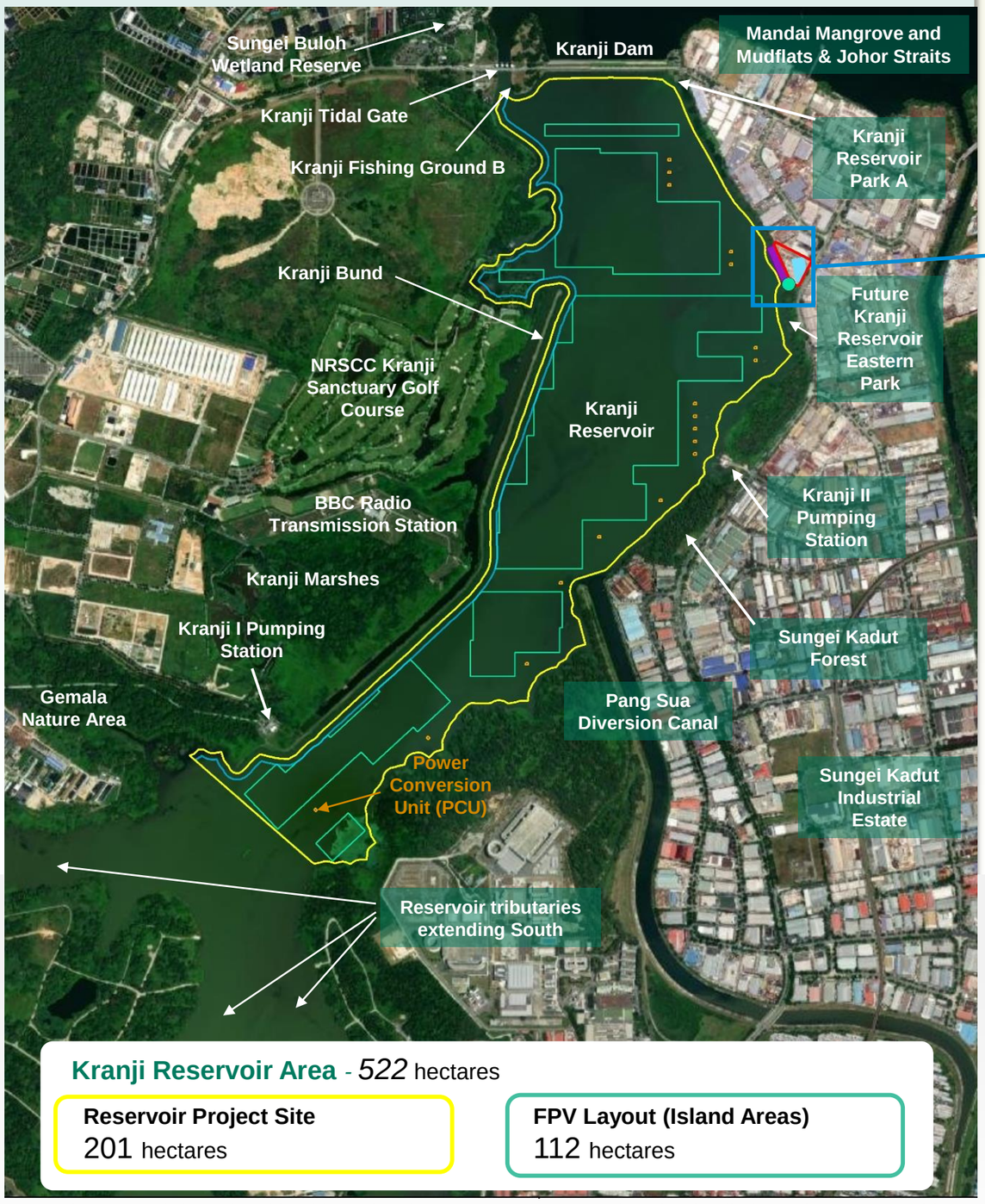
2024:
- Public Gazette of EIA
- Following Public Gazette of EIA: selection of Developer/ Owner who will own, design, install, operate and maintain the FPV System
- Following EIA approval: Developer/ Owner formally appointed and announced

2025:
Commencement of Construction (~3 years)

2027/ 2028:
Commencement of Operation (~25 years)

An Overview of Project Location and Components

1. Reservoir-based Project Components

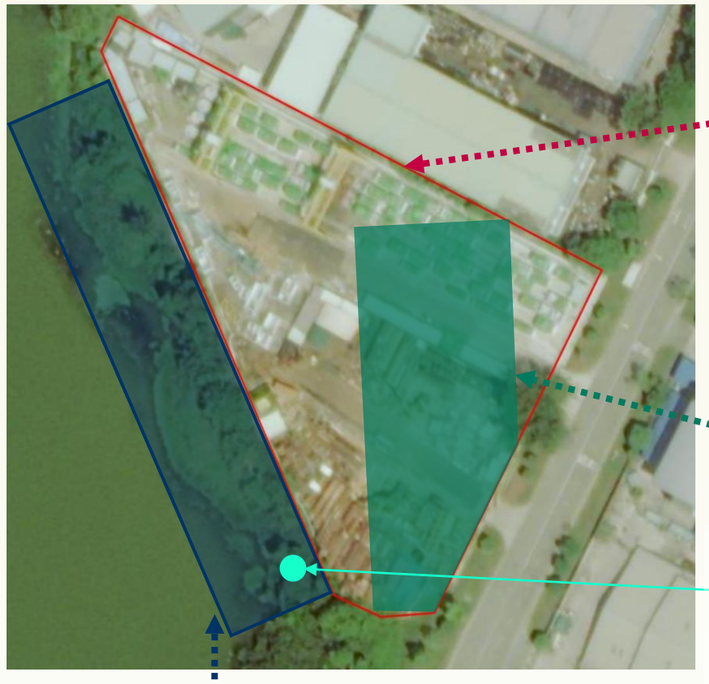


Kranji Reservoir Area - *522* hectares

Reservoir Project Site
201 hectares

FPV Layout (Island Areas)
112 hectares

2. Land-based Project Components



~1.1 hectares
Temporary Staging/ Launching Area

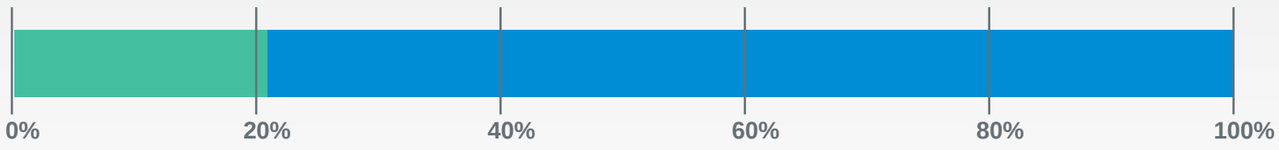
~0.44 hectares
Permanent Integrated Project Substation (and O&M Facility)

Proposed Cable Landing Point (Indicative)

~150 m long
Temporary Launching Ramp

~5 x 20 m long
Permanent Operation & Maintenance Berthing Facility

Up to 21.5% of the Kranji Reservoir area is proposed to be covered by the FPV islands



Area of Kranji Reservoir covered by permanent FPV islands = 21.5% (112 hectares)

Area of Kranji Reservoir not covered by permanent FPV islands = 78.5% (410 hectares)

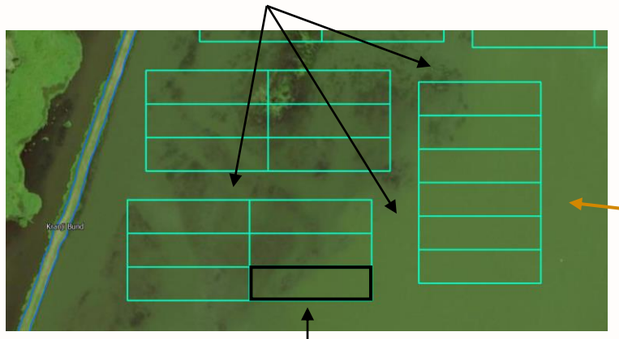
Note: The reservoir-based and land-based project components, as well as the detailed FPV layout, are subject to detailed deign (by the selected Developer/ Owner) and Planning Approval.

FPV Layout Considerations

Break up large FPV islands with 30 - 40 metres vessel corridors

30 - 40 m

Large FPV Islands will be broken up into smaller islands with internal operational and SCDF emergency vessel access corridors (for illustration purposes, subject to final design)



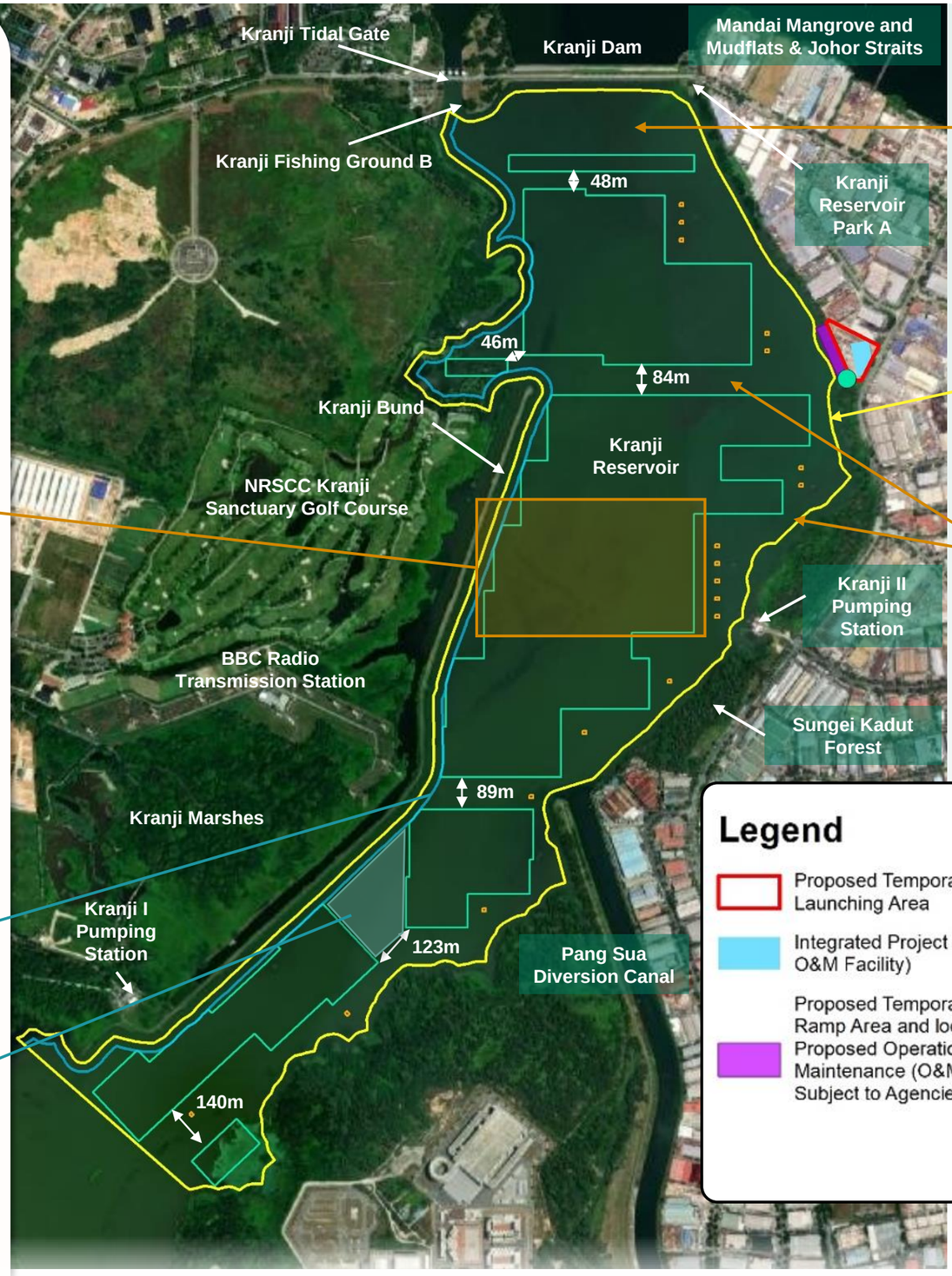
FPV panel blocks forming the FPV islands are assumed to be 170 x 50 m (to maximise capacity, 600W modules, includes row spacing and perimeter floats etc)

Biodiversity Mitigation Measures (identified through the EIA process to reduce Project impacts, particularly to birds):

50 m setback from western shoreline to FPV panels (resulting from stakeholder feedback) = blue line

FPV coverage area reduced and FPV islands re-orientated to avoid observed relatively higher foraging area (based on baseline surveys)

Avoidance of southern reservoir which was observed to have relatively higher bird foraging (based on baseline surveys)



Kranji tidal gate/ dam

100 metres

Setback from Kranji Tidal Gate and Dam (PUB requirement)

FPV

Reservoir Project Site
(i.e. project boundary) = yellow line.
Shorelines observed to have relatively higher bird foraging (based on baseline surveys)

> 50 metre wide vessel corridors
(at assigned depths) from North-to-South and East-to-West (to Kranji bund inlet) as PUB operational requirement – means majority of FPV panels are >50 m from eastern shoreline

Project Construction and Operation Activities

Note: construction and operation to be carried out by Developer/ Owner who will own, design, install, operate and maintain the FPV System

Step 1:

Geotechnical (ground condition) Investigation

On land at Temporary Staging/ Launching Area, and within Reservoir Project Site

Step 2:

Construction Preparation and Set up

On land at Temporary Staging/ Launching Area and adjacent shoreline

Step 3:

Assembly of modular FPV System

On land at Temporary Staging/ Launching Area

Step 4:

Phased installation of Anchoring and Mooring System (a combination of piles and/ or anchor blocks)

Within Reservoir

Step 5:

Launching and Arrangement of FPV, Power Conversion Units & Connector Cables

Within Reservoir

Step 6:

Construction of Integrated Project Substation (with Operation and Maintenance (O&M) Facility) and O&M Berthing Facility

On land at Temporary Staging/ Launching Area and adjacent shoreline

Operation & Maintenance (O&M)

Operation, monitoring, inspection and maintenance of FPV System

Photo of Existing FPV System on Tengeh Reservoir in Singapore

Permanent sites on land and within Reservoir

Note: Construction activities (Step 1 to 6) may happen concurrently and in a phased manner.

2025:
(~3 years)

Construction

Operation

2027/ 2028:
(~25 years)

Environmental Impact Assessment (EIA) Approach and Methodology

Impact Assessment Process Steps

1. Screening & Scoping
2. Project & Existing Baseline Definition
3. Impact Significance & Assessment
4. Mitigation, Monitoring & Adaptive Management

1. Screening and Scoping the EIA

Assessing the impacts to the following environmental aspects during the construction and/ or operation phases of the Project:

- **Surface Water Quality**
- **Airborne Noise and Vibration**
- **Biodiversity**
- **Air Quality**
- **Vectors**
- **Soil and Groundwater**

Stakeholders we engaged:
Relevant Government Agencies, in addition to five EIA engagements with the Nature Groups.

What we engaged with Stakeholders on:
EIA scope, baseline surveys scope and methods, initial baseline findings, the Kranji Reservoir ecosystem approach and EIA mitigation and outcomes.

When we engaged with our Stakeholders:
2020 to 2024.

The EIA scope, including baseline surveys and assessment approaches, has been agreed and aligned with Government and Technical Agencies and Nature Groups.

2. Existing Baseline Definition and Environmental Aspects Considered

Physical

- Surface Water Quality (including Reservoir Sediment Quality)
- Light Penetration into Reservoir
- Air Quality
- Airborne Noise & Vibration
- Soil & Groundwater

Biological

- Terrestrial Flora & Fauna (including birds)
- Aquatic Flora & Fauna
- Terrestrial (Land-based) Habitats
- Aquatic (Reservoir-based) Habitats
- Protected Areas
- Vectors (mosquitos and rats)

3. Impact Significance and Assessment

Determining Impact Significance

Impact significance is assessed with and without mitigation:

A. Initial Impact (pre-mitigation) Significance *takes into account:*

- **Embedded Controls** – physical or procedural controls planned into the Project from the start.
- **Impact Magnitude** – considers the impact's type, duration, extent, scale and frequency.
- **Receptor Sensitivity** – defined by legal protection, regulations, policy, amongst others.

*…and are mapped in an **Impact Significance Matrix***

B. Residual Impact (post-mitigation) Significance *additionally takes into account:*

- **Mitigation** and **Adaptive Management Measures** identified through the EIA process to reduce Project impacts.

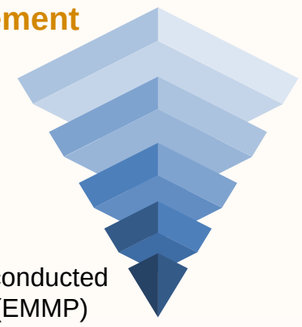
Magnitude of Impact \ Sensitivity/ Vulnerability/ Importance of Resource/ Receptor	Low	Medium	High
Negligible	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE
Small	NEGLIGIBLE	MINOR	MODERATE
Medium	MINOR	MODERATE	MAJOR
Large	MODERATE	MAJOR	MAJOR

Impact Significance Matrix

4. Mitigation, Monitoring and Adaptive Management

Mitigation Hierarchy

The objective of mitigation measures is to **reduce impacts as low as reasonably practicable** (ALARP).



- Avoid or reduce at source
- Abate on site
- Abate at receptor
- Repair or remedy
- Compensate

Monitoring

Comprehensive monitoring programme is proposed to be conducted through the Environmental Management and Monitoring Plan (EMMP) during pre-construction, construction and post-construction to address compliance (e.g. water quality) and trend analysis (e.g. for biodiversity).

Adaptive Management

The EIA has adopted a practical approach to managing uncertainty, where implementation of mitigation and management measures are **responsive** to **changing conditions** and the **results of monitoring** throughout the Project. This is known as 'Adaptive Management'. Adaptive management actions may include, in addition to physical mitigation measures: refinement of thresholds/ criteria, initiation of remedial action, continued monitoring, ceasing monitoring, etc.

Establishing an Understanding of the Existing Environmental Baseline Conditions

An extensive range of surveys (both spatial and temporal) was carried out within and surrounding the proposed Project Sites:

1,771
hours
(236 days)
of baseline surveys

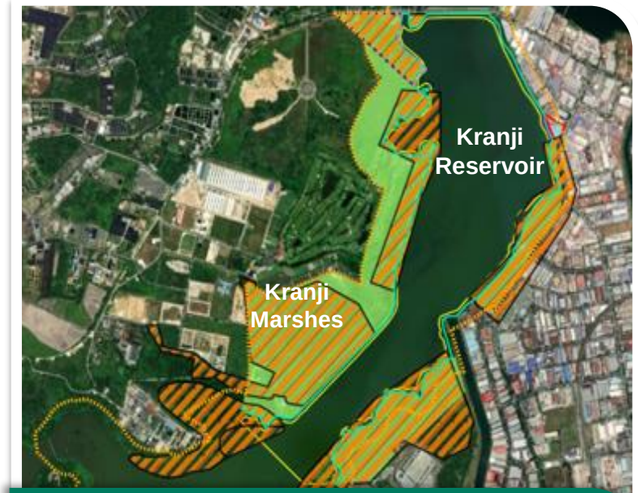
Over
20 months
from Oct 2020 to May 2022

Other baseline surveys included airborne noise and air quality.

Terrestrial (Land-based) Fauna Surveys:
- Terrestrial transects (T) / point counts - diurnal & nocturnal, for 12 months
- Boat transects (B) = diurnal & nocturnal, for 6 months
- Camera traps (CT)

Bird Vantage Point (VP) Surveys
(12 months):
- Twice monthly during migration (Sept-Feb)
- Once monthly during non-migration (Mar-Aug)
- Recording foraging & flight activities over reservoir at different time-periods

Bat Surveys:
- Terrestrial bat detectors (BAT)/ surveys
- Boat based point count surveys over reservoir



Flora Surveys (single survey event):
- Flora along reservoir edge

Terrestrial Habitat Surveys
(single survey event)
- Including forest and Kranji Marsh Core Area

Aquatic Flora & Fauna Surveys
(single survey events):
- Sonar, Hydroacoustic, eDNA, grab surveys
- Fish, macroinvertebrates and plankton
- Aquatic habitat mapping
- Aquatic vegetation sampling

Reservoir Water Quality Surveys
(6 months):
- Across 3 water depths
- Extensive range of parameters analysed

Sediment Quality Surveys (one-off surveys)

Surface Water Quality

Existing Baseline Conditions, Sensitive Receptors and Modelling Output Findings

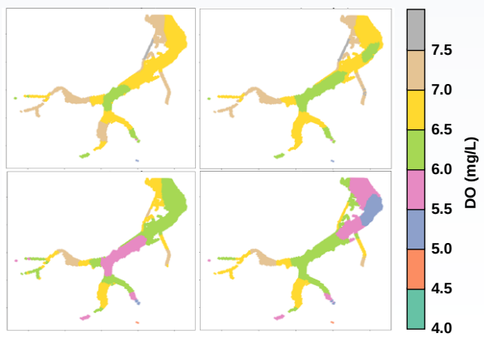
1. Baseline Conditions:

Water quality – generally within guideline values, with some exceedances, e.g. for dissolved oxygen.

Sediment quality – various exceedances of 2009 Dutch Soil Quality Standard across sampling locations, e.g. for antimony, arsenic, copper, zinc.

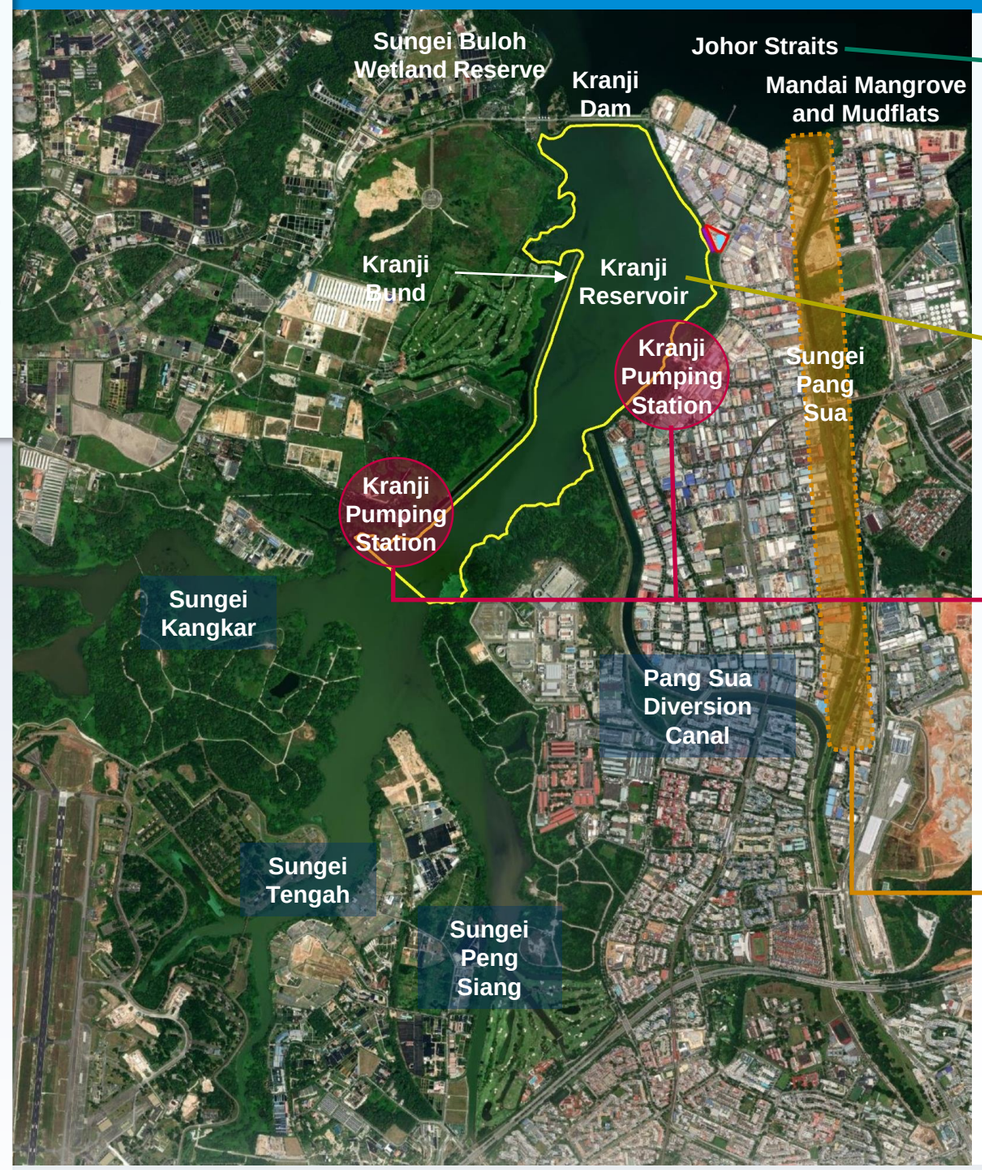
2. Water Quality Model:

- Conservative (larger) FPV footprint was modelled to understand FPV implications to water quality.
- Model validated against PUB's 2019 in-reservoir water quality monitoring data.
- Model outcomes measured against 2019 baseline and future climate scenarios (2030, 2040, 2050) with and without FPV in place.



Example of Model Output

3. Water Quality Sensitive Receptors:



Johor Straits
Medium Sensitivity

Kranji Reservoir
Medium to High Sensitivity

PUB Drinking Water Intake Points
High Sensitivity

Sungei Pang Sua and other minor connected canals/ drains
Low to Medium Sensitivity

4. Water Quality Model Findings:

With FPV in place, across all scenario years (2019, 2030, 2040, 2050):

- **Temperature:** temperature changes are within the water quality guidelines, i.e. less than 0.3°C increase in temperature.
- **Dissolved Oxygen (DO):** decreases (deterioration), however, median level is within water quality guidelines for more than 97% of the time (more than 354 days in a year).
- **Total Phosphorous (TP):**
  - Without FPV: TP concentration exceeds the water quality guideline parameters of 0.06 mg/L.
  - With FPV: TP concentration increases slightly (deterioration) and continues to exceed the water quality guideline.
- **Total Nitrogen (TN), Total Organic Carbon (TOC), Chlorophyll-a (Chl-A):**
  - Without FPV: All parameters exceed water quality guidelines
  - With FPV: Decreased concentrations (which is positive) and reduced time of non-compliance by at least 30%.

Note: Water quality guidelines levels agreed with PUB.

5. Other Water Quality Assessment Findings:

- **In-reservoir piling (where required)** for the FPV floats and infrastructure:
  - Is expected to result in temporary elevated levels of suspended solids within 100m of active piling worksites only.
  - Nutrient release from reservoir bed sediments is expected to be less than 0.25% of overall Kranji catchment nutrient loads.
- **Aquatic vegetation trimming** (within top 1m of the water column within Reservoir Project Site to enable construction vessel movement) and subsequent in-reservoir decomposition:
  - Is expected to equate to less than 3% of existing nutrient changes in the reservoir.

Surface Water Quality

Embedded Controls and Impacts during Construction and Operation

6. Embedded Controls: physical and procedural controls planned into the Project from the start.

Construction Phase

- Establish an **Earth Control Measures (ECM) Plan**.
- **No dredging and excavation** of reservoir sediment.
- In-reservoir **construction will be phased** to limit spatial and temporal extent of impacts.
- Conservative analysis of:
  - **Sediment suspension and nutrient release from piling**.
  - **Nutrient release from aquatic vegetation decomposition**.

Operation Phase

- Conservative **surface water quality modelling of larger FPV layout**, and modelling of climate change scenarios up to 2050.
- Conservative analysis of **nutrient release from aquatic vegetation decomposition**
- **Cleaning of panels/ bird droppings on FPVs** using reservoir water.

7. Impacts (those assessed as Moderate or above)

Impact significance was assessed both pre-mitigation (with embedded controls), and then with mitigation in place (residual impact).

Construction	Pre-Mitigation Impact	Residual (with mitigation) Impact

• Site runoff, wastewater, and sediment disturbance from preparation of the Temporary Staging/ Launching Area
• Sediment disturbance from works within the reservoir, such as:
  • Geotechnical/ site (ground condition) investigation
  • Launching, towing and installation of FPV and ancillary equipment
  • Installation of connector cables (between FPV islands and to shore)
  • Construction of O&M berthing facility
	NEGLIGIBLE TO MODERATE	NEGLIGIBLE

• Sediment disturbance from deployment of anchors/ piles and mooring lines within reservoir • Degradation/ changes in water quality from trimming of aquatic vegetation	MAJOR	NEGLIGIBLE TO MODERATE
Operation		
• Wastewater and sediment disturbance from the O&M of FPV facilities (including cleaning of PV panels) within reservoir	NEGLIGIBLE TO MODERATE	NEGLIGIBLE
• Change of hydrodynamics and surface water quality from presence of FPV within reservoir	MAJOR	MODERATE

Surface Water Quality

Mitigation Measures, Monitoring and Adaptive Management

8. Mitigation Measures

a) Reservoir-based:

- **Controlled and phased lowering of anchors, piles, weights and cables** (construction).
- Establish an **Aquatic Vegetation/ Invasive Species Management Plan** (construction/ operation).
- **Aquatic vegetation management** – collect and remove trimmings for off-site disposal (construction/ operation).
- **Vessel operating procedures** – for shallow water, heavy loads, navigation aides and traffic routes (construction/ operation).
- **Review of piling anchoring** and **aquatic vegetation trimming options and analysis** (construction).

b) Land-based:

- **Silt fencing** on land near waters edge at Temporary Staging/ Launching Area (construction).
- **Work boats to be refuelled at specified locations** (construction/ operation).

c) FPV Design:

- Detailed design, FPV layout and construction methodology to optimise/ **minimise** extent of the Project **footprint** and **sediment disturbance**, including **anchoring options and phasing/ sequencing of work** (construction/ operation).

9. Monitoring and Adaptive Management

- **Re-run models (hydrodynamic, water quality and hydraulic)** and confirm results to be within impacts evaluated in EIA based on the final FPV layout (pre-construction).
- **Locate initial phase of anchoring/ piling away from water intakes** and monitor (construction).
- Agree **surface water quality threshold criteria** with PUB (construction/ operation).
- **Surface water quality monitoring programme,** including **continuous online monitoring** (construction/ operation/ decommissioning).
- If notable deterioration trends in surface water quality, **investigate the cause, review and identify further monitoring and/ or mitigation in close liaison with relevant Government Agencies** (construction/ operation).

Biodiversity

Existing Baseline Conditions (General) and the Kranji Reservoir Ecosystem

1. Existing Baseline Conditions (General)

Generally, Kranji reservoir is in a **relatively stable, deteriorated ecological state**.

The eutrophic conditions of the Reservoir are one of the causes of low species diversity. These conditions can result in high nutrients, which results in high growth of algae and aquatic vegetation (i.e. primary production) and large fluctuations of dissolved oxygen.

Terrestrial Flora: No species of conservation concern were located within the land-based Project Site.

Terrestrial Fauna: Species of conservation concern were all located outside the land- and reservoir-based Project Site (e.g. at Forested area beside Carpark B, Sungei Kadut Forest, Kranji Marshes & bund). Smooth-coated otter and monitor lizards were recorded in/ around reservoir.

Fish: More than 88% species are non-native.

Plankton: (microscopic organisms that provide the base for the food web, i.e. food source for larger animals): low species richness and high abundance.

Macroinvertebrate: (organisms visible to the eye, and that do not have a backbone): overall diversity ranged from very low to medium.

2. An Ecosystem Approach to Kranji Reservoir was adopted, following an international framework, to better understand:

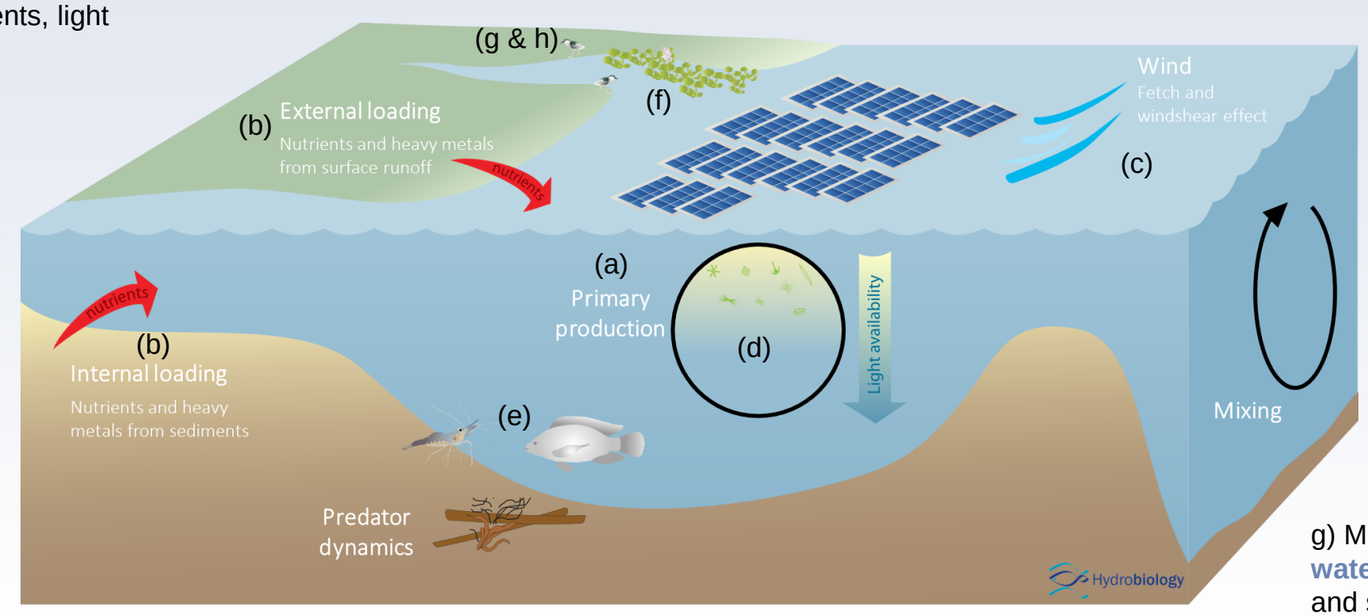
- **Current ecosystem baseline** conditions.
- **Inter-relationships of the important and supporting biotic (living, e.g. flora/ fauna) and abiotic (non-living, e.g. water quality) components.**
- **Key drivers of change in the current ecosystem.**
- **How the deployment of FPV could drive changes in the ecosystem.**
- **Thresholds of change beyond which may cause a deterioration** – whether from natural (e.g. climate change) or human pressures (FPV or otherwise).
- **Application of adaptive management.**

3. Understanding the Kranji Reservoir Ecosystem – Components, Process and Drivers of Change

a) **Primary productivity** (phytoplankton and macrophytes) **supports the food web** and is largely driven by nutrients, light penetration, and water column mixing.

b) **Nutrients** are an important determinant of primary production.

c) **Reservoir water temperature** governs the kinds and types of aquatic life.



h) Terrestrial **species of conservation concern** utilise the reservoir.

g) Migratory and resident **waterbirds** use the reservoir and surroundings as a foraging (feeding)/ nesting/ roosting (resting) ground.

d) **Plankton** serve as indicators of environmental conditions.

e) **Fish populations** are a food source for species of conservation concern.

f) **Aquatic vegetation** (submerged/ floating) provides a food source and habitat.

Biodiversity

Existing Baseline Conditions (Birds) and Sensitive Receptors

4. High Sensitivity Biodiversity Areas, all outside the Project Sites

Sungei Buloh Wetland Reserve
High Sensitivity

Mandai Mangrove and Mudflat
High Sensitivity

Sungei Kadut Forest
High Sensitivity (not a designated Protected Area)

Kranji Marshes
High Sensitivity

Gemala Nature Area
High Sensitivity

Little Tern

5. Recorded Flora and Fauna of Conservation Concern

	Globally Threatened Species	Nationally Threatened Species
Birds	3	10
Non-flying mammals	1	1
Fish	1	-
Reptiles	2	1
Invertebrates	-	4
Bats	1	1
Terrestrial Plants	-	19
Aquatic Vegetation	None	

Note: Threatened species include those designated as CR = Critically Endangered; EN = Endangered; and VU = Vulnerable.

6. Existing Baseline Condition (Birds)

- Bird community was dominated by native waterbirds (i.e. wading or swimming bird species).
- Native species and some birds of conservation concern globally and/ or nationally utilise the reservoir.
- In-reservoir bird foraging (feeding) activity was observed to be very low: 35.4 foraging events per hour in total for all focal species (of which 23 foraging events per hour were contributed by little terns) across the whole bird survey area.
- Foraging was observed particularly in the shoreline edges, central western area and south (outside) of the Reservoir Project Site.
- Very few raptors were observed foraging in the reservoir.

7. Bird Species of Conservation Concern Observed Foraging in Reservoir

Birds observed to forage (feed) in the reservoir and water edges (though amount of foraging varies):

- Little tern – nationally Endangered (EN)
- Purple heron – nationally EN
- White-winged tern – nationally EN
- Grey-headed fish eagle - Global Near Threatened (NT), Nationally Vulnerable (VU)
- Great egret – nationally VU
- Eastern cattle egret – nationally VU
- Yellow bittern – nationally VU
- Striated heron – nationally NT
- Other raptors, egrets and herons

Biodiversity

Embedded Controls and Impacts during Construction and Operation

8. Embedded Controls: physical and procedural controls planned into the Project from the start.

Construction Phase

- **No trenching** (dredging) for laying cables in reservoir.
- Integrated Project Substation **set back** from the Kranji Reservoir shoreline and to follow **Urban Design Guidelines and greening/ planting principles**.

- **Shoreline setbacks and vessel access corridors:**
  - Reservoir Project Site (i.e. project boundary) is setback from shoreline by at least 25 m.
  - 100 m setback from the Kranji tidal gate and dam.
  - 50 m vessel corridors (at assigned depths) – north to south and east to west (PUB operational requirements).
  - Avoidance of area south of the Reservoir Project Site.
  - Breaking up of large FPV islands with 30-40 m corridors for operational and SCDF emergency access.
  - FPV panels to have anti-reflective surface.

Operation Phase

- Maximum **vessel speed limit** of 5 knots.
- **No detergent or soap** for cleaning of FPVs.
- **Directional/ minimise light** at night (land-based).

9. Impacts (those assessed as Moderate or above)

Impact significance was assessed both pre-mitigation (with embedded controls), and then with mitigation in place (residual impact).

Construction	Pre-Mitigation Impacts	Residual (with mitigation) Impacts
• Elevation of pollutants and/ or nutrients within the reservoir affecting aquatic fauna • Disturbance to aquatic fauna from piling & boat movements	MODERATE	MINOR

• Disturbance to terrestrial fauna from:
  • Land-based worksite & night lighting
  • Vessel movements and use of helicopters
• Dust from land-based worksite disturbing terrestrial flora/ fauna
• Loss/ degradation of integrity of Protected Areas
• Benthic habitat/ fauna (at bottom of reservoir) loss/ disturbance
• Elevation of suspended sediments in-reservoir affecting aquatic biodiversity
• Changes in aquatic biodiversity due to trimming of aquatic vegetation
	MINOR TO MODERATE	NEGLIGIBLE

• Disturbance to terrestrial fauna from in-reservoir piling	MODERATE	NEGLIGIBLE TO MODERATE ON A PRECAUTIONARY BASIS
Operation		
• Changes to the planktonic and/ or benthic communities affecting food web • Reduced foraging opportunities on reservoir surface for terrestrial fauna, particularly birds	MODERATE	MODERATE ON A PRECAUTIONARY BASIS
• Loss/ degradation of integrity of Protected Areas • Changes to fish community affecting food web	MINOR TO MODERATE	NEGLIGIBLE

A precautionary approach was taken (i.e. residual impact magnitude and significance retained at pre-mitigation levels) in some cases, for example, subject to final design, or due to limited data or long-term uncertainties.

Biodiversity

Mitigation Measures, Monitoring and Adaptive Management

10. Mitigation Measures

a) FPV Layout (Construction / Operation):

- Embedded controls (see previous page), avoids observed relatively higher bird foraging areas (along shorelines and in the area south of the Reservoir Project Site).
- Mitigation measures are recommended to:

Further reduce FPV layout footprint at:

- Observed relatively higher bird foraging area within the Reservoir Project Site, on the central west edge (adjacent to Kranji Marshes).
- Western shoreline – setback distance of 50 m from the FPV panels (originally 25 m), as suggested by stakeholders.

Mitigated biodiversity FPV layout will:

Occupy **112 ha or 21.5%** of the Kranji Reservoir surface area.

410 ha or 78.5% of the Kranji Reservoir surface area **will remain not covered by permanent FPV islands**.

FPV island layout has been reduced and re-orientated to avoid observed relatively higher foraging area thus **reducing the loss of bird foraging caused by the FPV**.

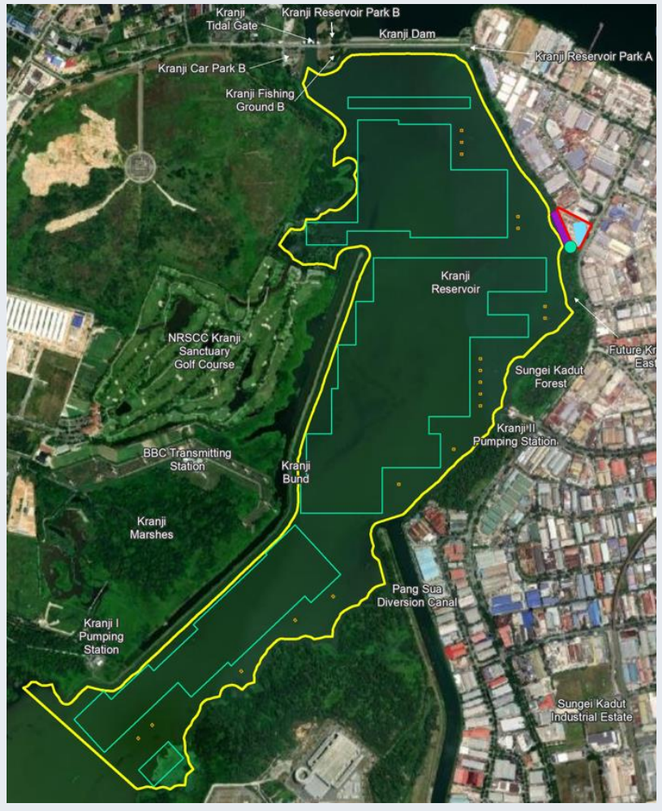
Achieves **fewer foraging events and foraging areas lost** compared to the unmitigated maximum FPV layout.

Thus, providing greater confidence in the ability of the “mitigated biodiversity FPV layout” to reduce impacts on biodiversity associated with disturbance and displacement along the western shoreline.

The FPV layout mitigation will also support minimizing biodiversity impacts from:

- Reservoir-based geotechnical/ site investigations, aquatic vegetation trimming, piling and connector cables.
- Piling – subject to locations, phasing, and requirements for simultaneous piling workstations.

Unmitigated Maximum FPV Layout



Mitigated Biodiversity FPV Layout

50 m setback (blue line) from western shoreline to FPV panels (resulting from engagement with stakeholders)

Avoided areas, observed to have relatively higher bird foraging (from baseline survey results)

Biodiversity

Mitigation Measures, Monitoring and Adaptive Management

b) Other Biodiversity Mitigation Measures:

Noise – within reservoir **ramp up piling gradually** and install **enclosed piling shrouds**; at land-based worksite install **4m noise barrier** around boundaries (construction).

Avoid felling trees and land-based vegetation clearing during the peak bird breeding season (March to July) (construction).

Early re-planting of shoreline vegetation at Temporary Staging/ Launching Area (construction).

Minimise construction works during **sunrise and sunset** periods (construction).

Regular inspections to ensure environmental compliance and identify impacts to biodiversity (construction).

Site personnel **biodiversity awareness training** (construction).

No works outside of Project worksites (construction).

No fly zone for project helicopters (if required) near specific locations (construction).

Establish and implement an **Aquatic Vegetation/ Invasive Species Management Plan** (construction/ operation).

Minimise number and duration of lighting use (operation).

11. Monitoring and Adaptive Management

- **Wildlife Incident Response Plan and Reporting** (construction/ operation).
- **Biodiversity monitoring programme** (construction/ operation).
- If notable deterioration in trends of biodiversity, **investigate the cause, review and identify further monitoring and/ or mitigation/ management in close liaison with relevant Government Agencies** (construction/ operation).

Bird Species Observed at Kranji Reservoir

Purple Heron

Black Crowned Night Heron

White-bellied Sea Eagle

Great Egret

Little Tern

Grey-headed Fish Eagle

Airborne Noise and Vibration Impact Assessment Summary

Baseline Findings, Sensitive Receptors, Impacts, Mitigation Measures and Monitoring

1. Baseline Findings

- Localised noise sources include: vehicular traffic, military aircraft, animal vocalisations along the western shoreline and Temporary Staging/ Launching Area.
- Background noise is highest on eastern boundary of Temporary Staging/ Launching Area due to vehicles on the adjacent road, given its proximity of the Sungei Kadut Industrial Estate.

2. Sensitive Receptors

Human sensitive receptors within **150 m** from the source may be affected by noise and vibration from construction and/ or operation at the land-based Temporary Staging/ Launching Area and/ or integrated Project Substation (with O&M Facility).

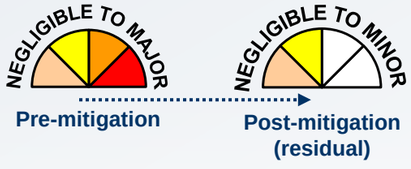
No sensitive receptors (hospitals, schools, institutions) or residential areas are located within 150 m of the Project Sites.

3. Embedded Controls (Construction and Operation)

- Airborne Noise: integrated Project Substation's louvres (angled openings to allow air to pass through) are orientated to face the road to the east to minimise noise to Kranji Reservoir and future park to the west during operation.
- Vibration: applicable international standards and limits to be applied.

4. Impacts – Description

Construction

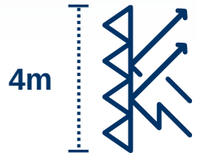


Airborne noise and vibration impacts (to humans) from the various land-based construction activities, is assessed to be **Negligible** to **Major** pre-mitigation, based on applicable standards. These are all reduced to **Negligible** to **Minor** with mitigation in place.

Operation

With the above embedded controls for the operation of the integrated Project Substation, the noise impact is assessed to be **Negligible**.

5. Mitigation and Monitoring (Construction)



- **Temporary 4 metre high noise barrier** along the boundaries of Temporary Staging/ Launching Area.
- **Minimise extent and duration** of noisy activities, and greater distance to vibration sensitive activities (e.g. minimum 4 m), where feasible.
- **Noise monitoring surveys** regularly throughout construction.

Air Quality Impact Assessment Summary

Baseline Findings, Sensitive Receptors, Impacts, Mitigation Measures

1. Baseline Findings

PM2.5 exceedances from local Ambient Air Quality Targets found at Temporary Staging/ Launching Area (likely due to high volume of vehicles on the adjacent road).

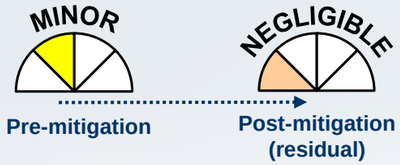
2. Sensitive Receptors

Industrial receptors within 350 m from the source (typically land-based construction site) may be affected by dust.

3. Embedded Controls (Construction)

- Covering of temporary stockpiles.
- Paved vehicular access/ egress with truck wash bay.
- Watering and covering of aggregate and sand storage.
- Machinery to comply with the USEPA Tier 4 emission standards.
- Regular equipment and machinery maintenance.

4. Impacts – Description (Construction)



Impacts from the generation of dust from land-based construction at the Temporary Staging/ Launching Area and integrated Project Substation is assessed to be **Minor** pre-mitigation.

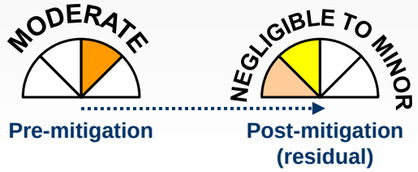
This is reduced to **Negligible** with mitigation in place.

5. Mitigation – FPV Design Related (Construction)

Detailed design and construction methodology and scheduling to **minimise extent and duration of dusty activities**.

Soil and Groundwater and Vectors Impact Assessment Summary

Impacts have also been assessed related to soil and groundwater and vectors (mosquitos and rats):



Soil & Groundwater Baseline Findings: land-based worksite is located within predominantly urbanised and industrial area, and was occupied by temporary industrial uses and reinstated to vacant land as of September 2022.

Soil & Groundwater Embedded Controls and Mitigation:

- All hazardous materials stored and handled in compliance with relevant regulations.
- Spill Prevention and Emergency Response Plan.
- Worker training, and annual joint exercises with SCDF on fire and spill emergency preparedness.

Vectors Baseline Findings: No existing dengue clusters identified by NEA's portal and no identified potential rodent hotspots at the time of writing.

Vectors Embedded Controls and Mitigation:

- Ensure good housekeeping controls (no conditions favourable to breeding, have designated food consumption areas, and wildlife proof bins and regular bin collection).
- Abide by notice served to spray or fog with pesticides.
- Establish complaint mechanism.

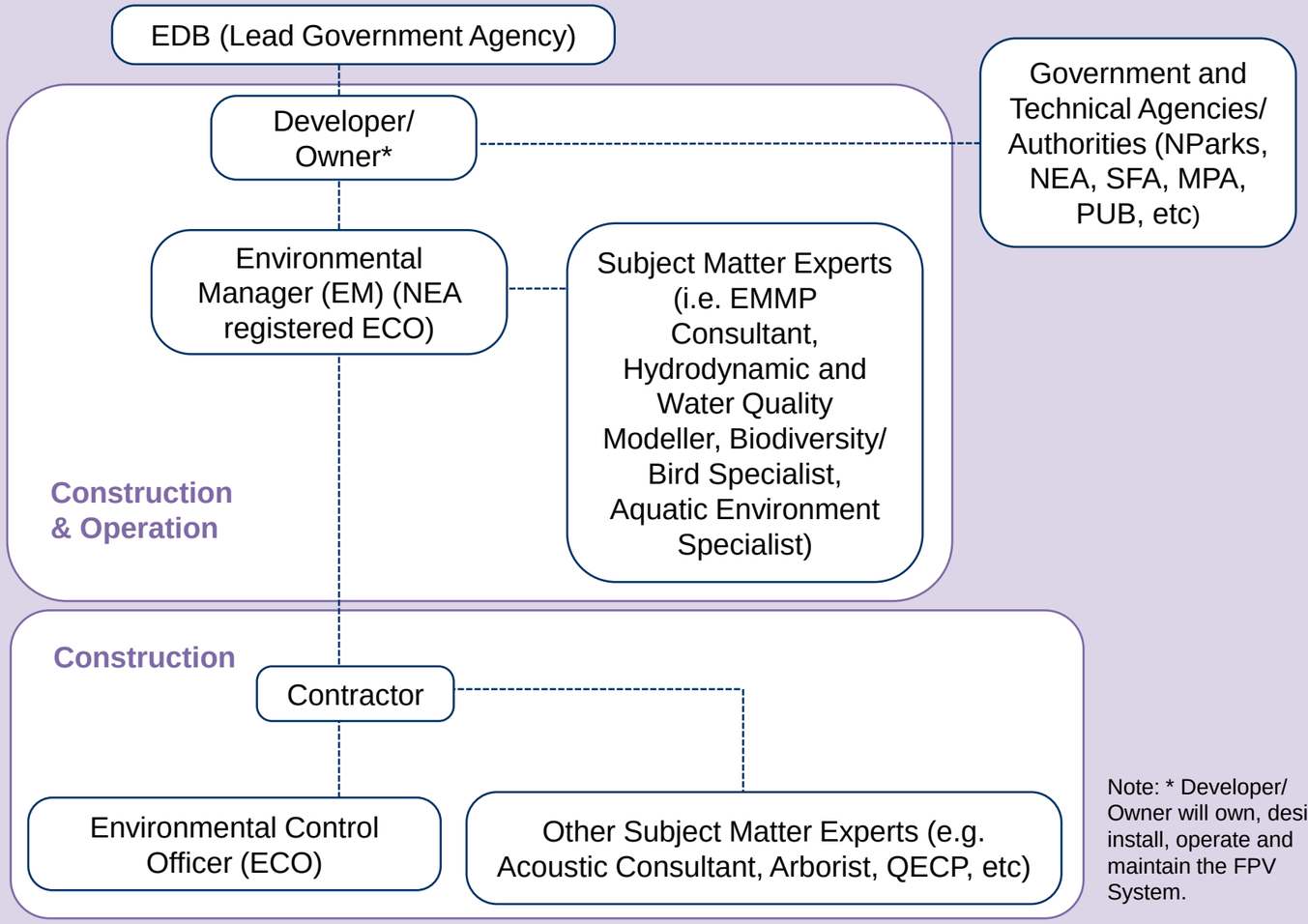
Environmental Monitoring and Management Plan (EMMP) for Construction and Operation Phases

EMMP Objectives, Organisation, Reporting and Monitoring Approach

1. EMMP Objectives

- **Verify environmental impacts** defined during the EIA.
- Monitor performance of mitigation and their effectiveness.
- Database to determine **short term or long-term environmental impacts**.
- **Identify sources** of pollution, impact and nuisance from the works.
- **Compliance** with regulatory and EIA mitigations and monitoring requirements.
- Early **indication of failure** to achieve acceptable standards.
- Take **remedial action** if required.
- Provide basis for adaptive management, whenever necessary, identifying need for additional or alternative measures.
- **Audit environmental performance**.

2. EMMP Organisation



Note: * Developer/ Owner will own, design, install, operate and maintain the FPV System.

3. EMMP Reporting

During Construction and Operational Phase:

- Monthly Construction EMMP reporting.
- Quarterly Operational EMMP reporting.

4. Monitoring Approach

Monitoring (details to be agreed with relevant Government Agencies/ Authorities) to take place:

- Pre-construction.
- During construction.
- Post-construction: initial three years post-construction (i.e. initial operation) – thereafter, a review of monitoring requirements is to be undertaken in consultation with relevant Government Agencies/ Authorities, and stakeholders, where appropriate considering the monitoring results obtained.
- Surface water quality monitoring will occur throughout the operational lifespan of the Project (including decommissioning).

Environmental Monitoring and Management Plan (EMMP) for Construction and Operation Phases

Monitoring Parameters and Protocols

5. Monitoring Parameters

Monitoring Parameters	Parameters/ Methods	Frequency
1) Surface Water Quality (physio-chemical)	Water sampling & online monitoring, both in-situ and laboratory analysis of: - Numerous parameters, including temperature, DO, TSS, pH, Chl-a, metals etc	In-situ and laboratory analysis: - Monthly (pre-/ construction) - Monthly/ Quarterly (initial operation) Also, continuous throughout project duration (pre-/ construction & operation, including decommissioning) by online continuous sensors
2) Nutrients	Water sampling and laboratory analysis of: - TP, TN, TOC, Dissolved Oxygen Carbon (DOC) ammonia and nitrate (both as N) and phosphate (as P)	
3) Light penetration into water column	Photosynthetic Active Radiation (PAR) loggers	Continuous (pre-/construction & initial operation)
4) Plankton	Water sampling & laboratory analysis (to be aligned with PUB's methods)	- Monthly (pre-/ construction) - Quarterly (initial operation)
5) Focal bird species and waterbird community	Point counts via 6 Vantage Point locations and flight path mapping	Monthly (pre-/ construction & initial operation)
6) Focal species of high conservation concern	- Birds: Vantage Point surveys and observations - Otters: incidental observations	- Birds: monthly (pre-/ construction & initial operation) - Otters: incidental during bird surveys
7) Fish	Hydroacoustic survey of fish biomass & size class	Annually (pre-/ construction & initial operation)
8) Sediment Quality	Grab sampling & laboratory analysis of: - Nutrients, contaminants/ metals, hydrocarbons	Single sampling events (pre-construction & after unplanned events)
9) Airborne Noise (biodiversity)	- Noise meters	Monthly, when piling activities within specified distances of Kranji Marshes and Black-crowned night heron roosts (pre-/ construction)
10) Airborne Noise (humans)		Quarterly (pre-/ construction)

Note: initial operation = 3 years post-construction, thereafter a review of monitoring requirements is to be carried out. TSS = Total Suspended Solids, Chl-a = Chlorophyll-a, TP = Total Phosphorous, TN = Total Nitrogen, TOC = Total Organic Carbon

6. Monitoring Protocol (if deterioration of monitoring parameters is identified)

a) If notable deterioration or adverse trend in the parameters and monitoring data observed:
- Notify relevant Government Agencies.
- Investigate the cause, and duration (e.g. single event, trending or permanent shift).
- Determine if cause is attributed to the construction or operation of the Project.

b) If cause **is attributable to the Project**:
- Review cause, consider if natural variability (or not), and if adaptive management is required.
- Developer/ Owner to liaise with relevant Government Agencies closely on monitoring results, investigation findings and adaptive management action(s) which may include potential layout changes, or removal of the FPV, where appropriately agreed.

c) If cause **is not attributable to the Project**:
- Developer/ Owner to liaise further with relevant Government Agencies responsible for managing the identified effect for their action.

Conclusion

1 Baseline Surveys

EIA draws on 20 months of environmental baseline field surveys including:

- Ambient air quality.
- Airborne noise.
- Reservoir water quality, light penetration and reservoir bed sediment quality.
- Biodiversity (terrestrial and aquatic flora and fauna, including birds).

2 Precautionary Approach

The EIA has considered conservative scenarios in the undertaking of the impact assessments. In some cases a precautionary approach was taken (i.e. residual impact magnitude and significance retained at pre-mitigation levels), for example, where subject to final design, or due to limited data or long-term uncertainties.

3 Ecosystem Level Approach

Developed to understand the Kranji Reservoir ecosystem across a range of both abiotic (non-living) and biotic (living) elements of the waterbody, as well as an understanding of human use and existing environmental stresses, to inform limits of acceptable change beyond which a deterioration may be observed within the Kranji Reservoir ecosystem.

4 Comprehensive Monitoring Programme (EMMP) to Support Adaptive Management

Project will put in place extensive long term monitoring. Datasets and trend analysis through pre-construction, construction and post-construction to be carried out to validate impacts, monitor short and long term data trends and allow for adaptive mitigation and management, if required.

5 Summary of EIA Outcomes

Environmental Aspect	Pre-mitigation Impact Significance	Residual (with mitigation) Impact Significance
Construction		
Surface Water Quality	NEGLIGIBLE TO MAJOR	NEGLIGIBLE TO MODERATE
Biodiversity	NEGLIGIBLE TO MODERATE	NEGLIGIBLE TO MODERATE ON A PRECAUTIONARY BASIS
Air Quality	NEGLIGIBLE TO MINOR	NEGLIGIBLE
Airborne Noise and Vibration	NEGLIGIBLE TO MAJOR	NEGLIGIBLE TO MINOR
Soil and Groundwater	NEGLIGIBLE TO MODERATE	NEGLIGIBLE TO MINOR
Vector	NEGLIGIBLE TO MODERATE	NEGLIGIBLE
Operation		
Surface Water Quality	NEGLIGIBLE TO MAJOR	NEGLIGIBLE TO MODERATE
Biodiversity	NEGLIGIBLE TO MODERATE	NEGLIGIBLE TO MODERATE ON A PRECAUTIONARY BASIS
Airborne Noise and Vibration	NEGLIGIBLE	NEGLIGIBLE

Images

Cover Page

Solar Panels
Green Trees Blue Sky Reflection On Stock Photo 35680300 | Shutterstock

Tengeh FPV
https://www.ies.org.sg/Tenant/C0000005/00000001/Images/TSE/TSE%20Aug%2021_web.pdf

Project Construction and Operation Activities
Geotechnical (ground condition) Investigation
https://www.gie.com.sg/

FOSTA Pte Ltd

Floating Solar Panels, Construction Preparation and Set-up, and Modular FPV system
Home - Ciel et Terre (ciel-et-terre.net)

Floating solar - Ciel et Terre (ciel-et-terre.net)

PV Panels in Fish Pond
Double-Glazed Modules, Reliable for “Complementation between Fishery and PV” (raytech-energy.com)

Mooring Block
Mooring Blocks West Cork | Single & Double Ring Mooring Block Manufacturers near Glengarriff (dcwl.ie)

Construction Barges Deployed in Reservoir
Construction Journey of Sembcorp Tengeh Floating Solar Farm - Sembcorp Energy Singapore

Solar Panels in Reservoir
Europe's largest floating solar farm to open - BBC News

Power Conversion Unit
Construction Journey of Sembcorp Tengeh Floating Solar Farm - Sembcorp Energy Singapore

Under-water Connection Cables
3d Rendering Submarine Cables Stock Illustration 1372606610 | Shutterstock

Floating Dock System
Aluminum Floating Dock Systems - Bellingham Marine (bellingham-marine.com)

Integrated Project Substation
Industrial-Projects-2021.pdf (ecas.com.sg)

Existing FPV in Tengeh Reservoir, Singapore
Trina Solar 210 Vertex Modules Provides Backbone for 60MW Solar Farm in Singapore, One of World’s Largest Inland Floating Solar PV Systems | Trina Solar

Floating Solar Cell Equipment
Premium Photo | Floating solar cell equipment (freepik.com)

Floating Solar Power Station
Solar Power Station Float on Water Stock Image - Image of photovoltaic, pattern: 129600587 (dreamstime.com)

Combiner Box
Row of Installed Photovoltaic Solar Panels or Modules, Solar Street Light and String Combiner Box, String Monitoring Box with Stock Photo - Image of cell, generator: 196249576 (dreamstime.com)

Species
Little Tern
https://www.nparks.gov.sg/florafaunaweb/fauna/6/7/677

Great Egret
NParks | Great Egret

Pictures of Purple Heron, Black Crowned Night Heron, White-bellied Sea Eagle and Grey-headed Fish Eagle provided by Camphora Pte. Ltd.

Notes

See the “Floating Photovoltaic System (FPV) on Kranji Reservoir Environmental Impact Assessment (EIA)” for further details of the Project overview, EIA approach and methodology, existing baseline conditions, impact assessments and mitigation, environmental monitoring and management plan and conclusions.

The EIA was undertaken at the technical feasibility stage of the Project, and therefore assesses the site layout and features of the concept design available at the time of preparing the EIA. Where necessary, reasonably conservative assumptions were made.

The EIA has considered the conservative scenarios in the undertaking of the impact assessment, and the development of mitigation measures and monitoring plans for the construction and operation stages of the Project. A precautionary approach was taken (i.e. residual impact magnitude and significance retained at pre-mitigation levels) in some cases, for example, subject to final design, or due to limited data or long-term uncertainties..

All maps, illustrations, figures etc in this report are purely illustrative and are to be used solely for the purpose of assessing the environmental impact of the Project, and not for any other purpose.