Development of an Offshore Wind Farm in Hong Kong: Application for Variation of Environmental Permit

Environmental Review Report

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Environmental Review Report

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1. INTRODUCTION

1.1 Project Background

The Hongkong Electric Company, Limited (hereinafter referred to as HK Electric), is proposing the development of an offshore wind farm in the Hong Kong SAR (the Project). The original intent of the Project was to produce around 100 MW of electricity, which will be connected to the HK Electric grid network to contribute the HKSAR Government commitments to renewable energy generation and the 2050 goals of a net zero economy. The EIA Report for the Project was approved on 14th May 2010 (AEIAR-152/2010) and an Environmental Permit (EP-394/2010) issued on 8th June 2010. The location and the proposed layout of the Project from the EP and the approved EIA Report are shown in **Figures 1.1.1** and **1.2.1**.

Since the EIA Report was approved there has been significant advancements in the technology of offshore wind turbines. The original design was for turbines that could generate between 2.3 and 3.6 MW, but these are now considered obsolete since the market now provides for turbines from 6.45 MW to 16 MW.

1.2 Purpose of this Report

This *Environmental Review Report* (this *Report*) provides information to describe the potential impacts on the environment due to the proposed variations and provides an evaluation of the potential impacts. The information presented herein will form part of the submission to the EPD for an Application for Variation of an Environmental Permit (VEP). In accordance with Section 13(5) of the EIAO, a VEP application has to demonstrate (a) no material change to the environmental impact of the project with mitigation measures in place; and (b) the project complies with the requirements described in the *Technical Memorandum on Environmental Impact Assessment Process* (EIAO-TM).

The purpose of this *Report* is to demonstrate that there is no material change to the environmental impact as stipulated in Schedule 1 of the EIAO and Section 6.2 of the EIAO-TM.

In this *Report*, certain assessments in the previous EIA have been revisited such as the water quality, waste management, terrestrial ecology, marine ecology, fisheries, landscape & visual impact (L&VIA), cultural heritage, and noise impact, etc. Underwater noise associated with pile driving leading to potential impact on fisheries and marine ecology (particularly marine mammals and green turtles) have also been addressed in this *Report*.

1.3 Benefits in Revisiting the Development

Due to the significant advancements in the technology of offshore wind turbines, the unit capacity of the wind turbines in the market increases significantly associated with larger rotor diameter and overall wind turbine height. Deploying larger wind turbines will significantly reduce the number of turbines and foundation structures required, and significantly increase the renewable energy generation from the same project area. By revisiting this Project, while the number of turbines will be reduced (details refer to **Section 2**), the overall capacity of the proposed wind farm will be increased from around 100 MW to around 150 MW within the same wind farm boundary. As compared with the annual energy production of 175 GWh mentioned in the approved EIA report, the current offshore wind farm is anticipated to generate around 400 GWh renewable electricity annually. The increase in the green electricity generation can further help decarbonisation, reduce depletion of non-renewable resource and combat global climate change. In addition, the increase of green electricity generation can also help to offset the air pollutant emission of sulphur dioxide, nitrogen oxides and particulate matters generated from traditional power plants. The revisiting of the Project will reinforce the supporting to Hong Kong's renewable energy target.

As fewer wind turbines will be installed, the duration of wind farm construction is expected to be shortened which is beneficial to the environment, including ecology and fisheries. With less construction work load, it is more flexible to plan the piling works during the day time, to avoid peak occurrence season of finless porpoise from December to May, and to implement marine mammal exclusion zone. Marine ecological and fisheries resources, if any impacted during construction of the Project, could also be recovered and return to the Project Area sooner with the shortened construction time.

Besides, according to the *Final Technical Report of Socio-economic impact study of offshore wind* published by Danish Shipping, Wind Denmark and Danish Energy with support from the Danish Maritime Foundation (1),the increase in turbine size and rating will reduce the operation and maintenance costs, and ultimately leading to lower levelized costs of electricity. The operation and maintenance costs of the Project will be reviewed at later stage by taking into account the technology advancements to confirm the positive socio-economic impact.

(1) Danish Shipping, Wind Denmark and Danish Energy with support from the Danish Maritime Foundation (2020). Final Technical Report of Socio-economic impact study of offshore wind.

2. PROPOSED VARIATIONS

2.1 Reasons for Variations

The approved EIA Report has only covered models of 2.3 – 3.6 MW of turbine with a tip height capped at 136 m. As mentioned in **Section 1.1** of this *Report*, wind turbines that could generate between 2.3 and 3.6 MW are found obsolete in the market since the market now provides for offshore wind turbines from 6.45 MW to 16 MW.

2.2 Proposed Variations and Comparison with the Approved EIA Report

A comparison of the assumptions given in the approved EIA Report and the updated parameters provided by HK Electric for the Project are summarized in **Table 2.1**. At the time of preparing this *Report*, there is no change in the landing point at the onshore Substation and cable route from offshore wind farm to land. Based on the above, there is no change in the grab dredging volume and jetting area/volume.

The construction of meteorological monitoring mast commenced in 2011 and started for collecting wind data in March 2012. Recently, the meteorological monitoring mast has been demolished in view that the main structure has deteriorated extensively to an extent which is beyond repair in a safe manner. The data collected is sufficient for project design. In case the meteorological monitoring mast is required in operational phase, subject to the recommendation of the wind turbine manufacturer, the associated construction and operation will fulfil the requirements from the approved EIA report and EP.

Table 2.1 Comparison of Assumptions in EP-394/2010 / the Approved EIA Report and Proposed Variations

Parameters	EP-394/2010 and Approved EIA Report	Proposed Variations
Wind Farm Parameters		
Overall Capacity of the Wind Farm	100 MW	Around 150 MW
Wind Farm Boundary	EP Figure 1 (see **Figure 1.1.1**)	Same as approved EIA and EP
No. of Wind Turbines (WTG)	Around 35 nos.	Around 10 nos. (higher unit capacity) to around 24 nos. (lower unit capacity)
Unit Capacity of the WTG	2.3 to 3.6 MW (If 3.6 MW, nos. of WTG reduce to 28-30)	6.45 MW to 16 MW
Rotor radius	Max 55.5 m	89 m to 121 m [(1)]
Overall WTG Height	maximum tip height of +136mPD (Section 5.2.1 of EIA Report) LVIA: viewshed analysis based on 136m, photomontages based on 125m	Maximum tip height of 198 m to 271 m above mean sea level [(1)]
Development Site		
Development Site Area	600 ha	Same as approved EIA
Laydown area	Within the existing Lamma Power Station (see **Figure 1.1.1**)	The laydown area will be located outside Hong Kong and the exact location will be determined during the project execution phase. No water quality impact is anticipated. The removal of the proposed laydown area from Lamma Power Station is considered as a positive change from the environmental point of view.

Parameters	EP-394/2010 and Approved EIA Report	Proposed Variations
Construction Method		
Submarine cable route trench (inter-array & offshore wind farm to landing point)	Approximately 14.6 km + 33.7 km	Approximately 14.6 km + 33.7 km as the worst scenario
Construction works involving dredging activities	Grab dredgers will be utilised in the nearshore cable landing area to construct a short underwater trench. Dredging involves the removal of marine sediments from the seabed to form the trench, into which the cable is laid. Except for the about 100m nearshore submarine electricity cables (see **Figure 2.2.1**), no dredging works shall be carried out for construction of other parts of the Project. Only closed grab dredger shall be used for laying the about 100m nearshore submarine electricity cables. (EP Condition 3.7)	Same assumption as approved EIA and EP
Grab dredging volume	13,125 m^3	13,125 m^3
Grab dredging rate	2,500 m^3/day (EP Condition 3.7)	2,500 m^3/day
Construction works involving jetting activities	Except for the about 100m nearshore submarine electricity cables, cable installation will be undertaken using jetting methods. Only jetting technique shall be used for laying the offshore submarine electricity cables (see **Figure 2.2.1**). (EP Condition 3.10)	Same assumption as approved EIA and EP
Jetting area/ volume	37,000 m^3	37,000 m^3
Jetting rate	360 m/hour (EP Condition 3.10)	360 m/hour
Foundation Type	Turbines: Tripod / tetrapod and monopile foundations were considered in the EIA with monopile foundation taken as the worst case scenario. Wind monitoring mast: 8 nos. of steel tubular piles	Monopile, or tetrapod (or namely jacket) foundation which will likely be adopted for the offshore wind turbine with capacity of 10 MW or above. Tetrapod will be lifted and installed at the Site using a crane barge. The barge will progressively install all of the tetrapods. Once each tetrapod is placed on the seabed, at its required position/ angle, the open-ended steel tubular piles are inserted in turn into each of the tetrapod legs, and the hydraulic vibrator/ hammer is placed on the pile head by the crane barge and the pile is pushed/ driven into its required penetration depth. **Figure 2.2.2** (Figures 4.4 and 4.6 from the approved EIA report) shows typical structure of monopile and tetrapod foundation.

Parameters	EP-394/2010 and Approved EIA Report	Proposed Variations
Pile diameter	Monopile diameter of 5 to 7 m	The monopile diameter above the seabed level will be limited to 7 m while the diameter for the portion below the seabed level can reach 9 m. Based on the conceptual design, a total of 4 piles (diameter of around 2-3 m each) will be installed for each tetrapod.
Scour protection footprint area	900 m^3 for each wind turbine (EP Condition 2.9)	900 m^3 for each wind turbine
Construction Programme and Logistics		
Wind Turbine Foundation Installation	3rd quarter of Year 3 to 1st quarter of Year 4	mid-2025 / mid-2026
Wind Turbine Onshore Assembly and Site Installation	1st to 3rd quarter of Year 4	mid-2026
Land Cable Installation and Switchgear Works	4th quarter of Year 3 to 4th quarter of Year 4	early 2026
Testing and Commissioning	3rd quarter of Year 4 to 1st quarter to Year 5	end 2026
Operations and Maintenance		
Monitoring and control of wind turbines	The turbines are monitored and controlled by microprocessors installed within the turbine tower. A central Supervisory Control and Data Acquisition (SCADA) system is linked to turbine microprocessor. This will be controlled by an operational base at the Lamma Power Station.	Same assumption as approved EIA
Maintenance of support structures and submarine cables	Inspections will be performed regularly as will ad hoc visits for surveillance. Should cables are found to be un-earthed, they will be re-buried using jetting techniques. Maintenance crew will use vessels to access the turbines via the platforms. An inbuilt crainage system within the turbine nacelle allows heavy equipment to be lowered to sea level should major work be needed.	Same assumption as approved EIA
Exclusion arrangement	Non-Project vessels (excluding fishery vessels): operational safety zone of 50m radius from the turbine and monitoring mast. Fishing activity or anchoring: not allowed within the wind turbine array or within 500 m of any turbine or offshore monitoring mast. During maintenance work: exclusion from access to the wind farm.	Same assumption as approved EIA

Note:
(1) The rotor radius of the 15 MW WTG is 118 m. The maximum tip height is 265 m above mean sea level with the same lower tip height of 16 MW WTG at 29 m above sea level.

While details of the wind farm layout including the number of wind turbines, wind turbine location, unit capacity of the wind turbine, the specific information on the wind turbine machine and array cable will only be available at later stage. The number of wind turbines will be fine-tuned, which depends on the appropriate unit capacity / size of the wind turbines to be selected in the future optimized layout.

2.3 Details of Variations

With the significant advancements in the technology of offshore wind turbines, the size of the turbines becomes larger and the unit capacity of the turbines becomes higher, resulting in the increase of the overall capacity of the proposed wind farm from 100 MW to around 150 MW, even with the significantly reduced number of turbines and associated foundations.

For assessment purpose, Lower Bound – unit capacity of the wind turbines of ~6.45MW and Upper Bound – unit capacity of the wind turbines of ~15/16 MW are adopted in this *Report* to represent the design envelope for the proposed variations as listed in **Table 2.1**. The proposed project layouts of Lower Bound with 24 wind turbines and Upper Bound with 10 turbines are illustrated in **Figures 1.2.2** and **1.2.3** respectively.

Given the very fast technology development in turbine design for use in offshore wind farms, this envelope is essential to provide flexibility for model selection at the time of detailed design and construction of the proposed wind farm. This will allow the Project to optimise wind energy generation, manage costs to customers and achieve the same or better environmental outcome as predicted in the approved EIA Report.

2.4 Proposed Variations to the Conditions of the Current EP

In view of the proposed changes to the Project, a number of condition(s) in the current Environmental Permit (EP-394/2010) shall be varied; these conditions, the proposed variations and the reason for variation are summarised in **Table 2.2**.

Table 2.2 Proposed Variations to Conditions of the EP

Condition	Current EP	Proposed Variation	Reason for Variation
Part B Title of Designated Project	Development of a 100MW Offshore Wind Farm in Hong Kong	Development of an around 150MW Offshore Wind Farm in Hong Kong	■ The 2.3 – 3.6 MW wind turbines are no longer commonly used for offshore wind farm projects; ■ Deploying larger wind turbines with larger rotor swept areas will significantly reduce the number of turbines and foundations required; and ■ Significantly more renewable energy generation from the same project area, with significantly fewer turbines.
Part B Scale and Scope of Designated Project	The Project is to construct and operate an offshore wind farm with capacity of about 100MW and the following major components :	The Project is to construct and operate an offshore wind farm with capacity of around 150MW and the following major components:	
Part B Scale and Scope of Designated Project	1. around 35 numbers of wind turbines;	1. up to 24 numbers of wind turbines;	
Figure 1	Label showing the location of Laydown Area and Quayside for Material Storage and Pre-assembly Works	To be replaced with **Figure 1.1.2** of the ERR.	Laydown area and quayside for material storage and pre-assembly works are no longer required.
Condition 3.2	Laydown area and quayside for material storage and pre-assembly works for construction of the Project shall only be located onshore and within the	To remove Condition 3.2.	Laydown area and quayside for material storage and pre-assembly works are no longer required.

Condition	Current EP	Proposed Variation	Reason for Variation
	existing Lamma Power Station as indicated in Figure 1 of this Permit.		

3. POSSIBLE IMPACT ON THE ENVIRONMENT

3.1 Water Quality Impact

3.1.1 Construction Phase

3.1.1.1 Elevation of Suspended Sediments

The key concern on water quality impacts during the construction phase identified in the approved EIA Report is sediment dispersion from dredging, jetting works and turbine foundation construction. Summary of the design parameters in the approved EIA Report and the latest design in ERR is presented in **Table 3.1**.

Table 3.1 Construction Work Designs and Arrangements adopted in EP-394/2010 / the Approved EIA Report and the Latest Update

Design Parameters	EP-394/2010 and Approved EIA Report	Latest Design in this ERR
Dredging - Grab dredgers will be utilised in the nearshore cable landing area to construct a short underwater trench. Dredging involves the removal of marine sediments from the seabed to form the trench, into which the cable is laid		
Dredging area	around 100 m (EP Condition 3.7)	Remains unchanged in the latest design
Dredging trench cross-sectional area	trapezium shape with bottom width of 9 m, upper width of 12 to 16 m and the trench depth of 1.5 – 3.5 m deep	
Dredging volume	13,125 m^3	
Plant used	Grab dredgers	
Dredging rate	2,500 m^3 per day (EP Condition 3.7)	
Mitigation measure	Silt curtains will be deployed during dredging at the seawall area. Closed grab dredgers should be used	
Jetting - Except for the about 100m nearshore submarine electricity cables, cable installation will be undertaken using jetting methods		
Jetting area	For entire cable alignment except at the landing area, cable route trench length totalled 48.3 km including: 14.6 km for inter-array route 33.7 km for the six cables to the grab dredging area.	Remains unchanged in the latest design
Jetting trench cross-sectional area	0.75 m^2 (0.5 x 5 m x 0.3 m)	
Jetting volume	37,000 m^3	
Peak jetting rate	360 m/hr (EP Condition 3.10)	
Turbine Foundation Construction		
Scour protection footprint area per wind turbine	900 m^2 (EP Condition 2.9)	Remains unchanged in the latest design

Design Parameters	EP-394/2010 and Approved EIA Report	Latest Design in this ERR
Number of wind turbines	35	Up to 24

Sediment release rate for dredging in the approved EIA Report was estimated based on the peak production rate of the grab dredger. Since the dredging area, peak dredging rate, use of plants and mitigation measures in the latest design will be same as the approved EIA Report, it is, therefore, expected the potential level of suspended solids (SS) elevation associated with dredging would not be worse than the level predicted in the approved EIA Report.

Sediment release rate for jetting in the approved EIA report was estimated based on peak jetting rate, and the cross-sectional area of jetting trench, which both remain unchanged in the latest design. Also, given the reduced number of wind turbines, the cable length required to be installed (and the associated sediment impact) would be shorter than the onshore substation case in the approved EIA. Overall, it is expected the potential level of SS elevation associated with jetting would not be worse than the level predicted in in the approved EIA Report.

Sediment loss related to foundation construction mainly comes from disturbance of seabed surface from installation of scouring protection. In the approved EIA, it was conservatively assumed that there was a total of 35 no. wind turbines with diameter of the monopile foundation of 5-7 m. In the latest design, there would be up to 24 nos. of wind turbines subject to the overall wind farm capacity and the unit capacity of the wind turbine. Given the overall scour protection footprint area of 900 m^2 (width of 30m and length of 30m) for each wind turbine remains the same as that the approved EIA report, the total amount of sediment released during the installation of scour protection would be reduced. Therefore, it is expected the potential level of SS elevation associated with foundation construction would not be worse than the level predicted in the approved EIA Report.

Based on the analysis above, the potential level of SS elevation from all sources of construction in the latest construction design and arrangement is expected to similar to or less than that in the assessed scenario in the approved EIA. No unacceptable SS impact from project construction is expected from the latest construction design and arrangement.

3.1.1.2 Oxygen Depletion and Release of Nutrients and Contaminants

The potential water quality impact associated with release of sediment-bounded contaminants has been assessed in the approved EIA Report. It is stated in **Section 3.1.1.1** that the SS impact from the latest construction design and arrangement would not be worse than that assessed in the approved EIA Report. Since the amount of nutrients and contaminants from disturbed sediment is proportional to the amount of sediment dredged/ jetted/ disturbed, it is concluded the release of nutrients and contaminants based on the latest construction design and arrangement would not be worse than that assessed in the approved EIA Report. Similarly, the release of sediment-bounded organics (which can be consumed by microbe and lead to dissolved oxygen depletion) is also proportional to the amount of sediment released from marine works. Therefore, no unacceptable nutrient, contaminant and dissolved oxygen depletion impact is expected from the latest construction design and arrangement.

3.1.1.3 Vessels Discharges

Key liquid discharges identified in the approved EIA Report include,

- Uncontaminated deck drainage;
- Ballast water (in emergency situations only);
- Potentially contaminated drainage from machinery spaces; and
- Sewage/grey water.

The same list of liquid discharges is deemed applicable to the latest construction design and arrangement. Applicable mitigation measures identified in the approved EIA Report would still be implemented. No unacceptable water quality impact associated with vessel discharges from marine construction is expected.

3.1.1.4 Other Discharges

Grouting is still required during the construction of wind turbines in the latest construction design and arrangement. It is anticipated the amount of grout required remains ~70 m^3 per turbine. Same applicable mitigation/ precautionary measures, including selection of grout that conform to the relevant environmental standards, as well as adoption of appropriate operational management by the contractor to minimize risk of leakage during the pumping phase, would be implemented. No unacceptable water quality impact associated with the use of grout from turbine construction is expected.

3.1.1.5 Land Based Construction Activities

It is stated in the approved EIA Report that the primary source of water quality impact from land-based construction activities would be pollutants runoff from the laydown area. The approved EIA Report indicated that with proper implementation of mitigation and waste management measures, adverse water quality impacts from land based works is not anticipated. In the latest design, although the lay down area will be changed and the exact location will be determined during the project execution phase, the laydown area will likely locate outside Hong Kong. In view of the above, potential water quality impact from onshore activities is not expected to be worse than that in the approved EIA Report. No unacceptable water quality impact would be expected from land-based construction activities under the latest construction design and arrangement

3.1.2 Operation Phase

3.1.2.1 Suspended Sediments from Scouring of Seabed around the Base of Foundations

As stated in the approved EIA Report, the provision of scour protection at the base of foundations of offshore structures would control the erosion of seabed sediments and the impacts associated with the increased suspended sediment levels during the operational phase are expected to be negligible. In the latest design, the construction of scour protection will be retained at the base of each offshore wind turbine. In addition, compared with the design in the approved EIA where maximum 35 no. of wind turbines are estimated to be constructed, the latest design only involves a maximum 24 no. of wind turbines. In view of the above, the potential water quality impact from suspended sediments is deemed similar or less significant than that in the approved EIA Report. Since loss of sediment due to scouring occur at around the wind turbine foundations, a reduction of number of wind turbines means less potential area for scouring and thus less sediment loss. No unacceptable water quality impact would be expected from the scouring of seabed around the base of wind turbine foundations under the latest design.

3.1.2.2 Vessel discharges

Increased vessel activities at project site is expected during the operational phase (including maintenance). Given the reduction on number of wind turbines for the project, vessel activities at the project site for operation phase would unlikely be higher than that assessed in the approved EIA. Potential water quality impact associated with operation phase vessel discharge is expected to be similar to or less than that assessed in the approved EIA under the latest design. No unacceptable water quality impact would be expected from operation phase vessel discharge under the latest design.

3.1.2.3 Other discharges

In case of vessel collision with wind turbine(s) under this project, there would be risk of release of lubricants and hydraulic oils. The approved EIA Report concluded that the water quality impact due to release of fluids and oils is negligible given the implementation of measures to reduce navigation risks. In the latest design, there would be increased height and reduced number of wind turbines under the latest design, the risk of vessel collision with wind turbine (due to omission, poor visibility or other reasons) should be lower than that in the approved EIA. No unacceptable water quality impact would be expected from the vessel collision under the latest design.

3.1.2.4 Hydrodynamics

The potential changes to the hydrodynamic regime was assessed with hydrodynamic modelling exercise in the approved EIA Report. Given the wind turbine structures were significantly smaller than the model grid size, the loss of kinetic energy from the tidal current due to friction of the wind turbine structures was taken into account in the modelling exercise by the “bridge pier” features of the adopted Delft3D model. In estimating the frictional coefficient to be implemented, both the number of wind turbines within each model grid as well as the cross-section obstructed by the wind turbine was taken into account in the approved EIA Report. It was conservatively assumed in the approved EIA that there was a total of 35 no. wind turbines with cross-section of 16-20 m from seabed to sea surface. In the latest design, there are around 10 nos. to around 24 nos. of wind turbines subject to the overall wind farm capacity and the unit capacity of the wind turbine. Based on the latest design, the monopile diameter of each wind turbine will be 7m at the upper end and 9 m at the lower end. The lower end with diameter > 7 m would be entirely buried in sediment and the submerged part within the water column is not expected to be larger than 7 m. Additional scenarios with tetrapod foundation are considered as well based on recent information provided by wind turbine manufacturer. Typically, each turbine with tetrapod foundation would consist of 4 piles and each with diameter of 2 - 3 m. For Lower Bound and Upper Bound, the diameters of the individual tetrapod pile was assumed to be 2 m and 3 m, respectively. Assuming these piles do not overlap in the incoming current direction, the total cross section for each tetrapod foundation is 8 m and 12 m wide respectively for the Lower Bound and Upper Bound scenarios. The typical structures of monopile and tetrapod foundations are shown in **Figure 2.2.2** (extracted from Figures 4.4 and 4.6 from the approved EIA report).

Comparison of submerged cross section area of wind farm in the approved EIA and in the proposed variations are provided below in **Table 3.2**. For the proposed Upper Bound scenario, 24 numbers and 20 numbers of wind turbine with Monopiles and tetrapod have been assessed as worst case to allow flexibility to fine-tune the number of wind turbines based on appropriate unit size in the future optimized design. **Table 3.2** only illustrated the Upper Bound number of wind turbines associated with the water quality impact assessment by comparing the submerged cross section area. The maximum numbers of wind turbines that can be installed with respect to the unit capacity should be referred to **Table 2.1**.

As shown, there would be a decrease in total submerged cross section area in the proposed scenarios as compared with the approved EIA. Since the change in flow regime depends on the overall energy loss of tidal current flowing through the area, an overall reduction of total submerged cross section area would result in less energy loss and thus less change in flow regime. It is therefore expected that the latest design, including the Lower Bound scenarios (both monopiles and tetrapod design), the Upper Bound scenario (monopiles up to 24 sets and tetrapod up to 20 sets) would exert less change on flow regime than that of the design assessed in the approved EIA Report. No unacceptable change in flow regime would be expected based on the latest design.

Table 3.2 Comparison of Submerged Cross Section Area of Wind Farm in the Approved EIA and the Latest Design

	Design in Approved EIA		Proposed Lower Bound Wind Turbine (Monopiles)	Proposed Lower Bound Wind Turbine (Tetrapod))-	Proposed Upper Bound Wind Turbine (Monopiles)	Proposed Upper Bound Wind Turbine (Tetrapod)
	Lower Limit for Turbine Diameter	Upper Limit for Turbine Diameter				
(a) Number of Wind Turbines	35	35	24	24	10 - 24	10 - 20
(b) Water Depth (Note 1)	18 m	18 m	18 m	18 m	18 m	18 m
(c) Pile Diameter	5 m	7 m	7 m	2 m × 4	7 m	3 m × 4
(d) Submerged Cross Section Area for 1 Wind Turbine	90 m^2	126 m^2	126 m^2	144 m^2	126 m^2	216 m^2
(e) Total Submerged Cross Section Area for all Wind Turbines	3,150 m^2	4,410 m^2	3,024 m^2	3,456 m^2	1,260 – 3,024 m^2	2,160 – 4,320 m^2

Note 1: Water depth of the project site ranged from 16-20 m. Average value of 18 m was used for calculation. The selection of water depth does not affect the conclusion.
Note 2: **Table 3.2** only illustrated the Upper Bound number of wind turbines associated with the water quality impact assessment by comparing the submerged cross section area. The maximum numbers of wind turbines that can be installed with respect to the unit capacity should be referred to **Table 2.1**.

3.2 Waste Management

The typical waste identified during the construction and operational phase of the Project in the approved EIA Report are summarised as follows:

- Dredged marine sediment associated with underwater trench for cable landing;
- Construction and demolition (C&D) materials, including rock revetment material and excavated materials, from removal of the existing seawall at the LPS Extension;
- Chemical waste from the construction and maintenance activities;
- Sewage from the construction and maintenance workforce;
- General refuse associated with construction and maintenance activities.

As concluded in the approved EIA Report, no adverse impacts on waste management were predicted during the construction and operational of the Project.

Since there will be no change in the construction method and installation works for the Project with fewer wind turbines to be installed, the quantities of wastes from dredged marine sediment, C&D materials, chemical waste, sewage and general refuse during construction and operation phase of the Project are expected to be less than those assessed in the approved EIA Report. With proper implementation of mitigation measures recommended in Section 7.6 of the approved EIA Report, no unacceptable environmental impacts arising from storage, handling, transport and disposal of wastes are expected.

3.3 Terrestrial Ecology

According to the avifauna impact assessment in the approved EIA Report, significant adverse impacts will not be expected from the result of construction and operation of the proposed wind farm. Significant adverse collision risks was not identified for all the key concerned species in the Assessment Area as predicted by the Scottish Natural Heritage bird collision risk model (Band et al, 2000) (2) with the use of bird distribution and abundance information obtained from boat-based field surveys in the baseline studies. The significance of construction and operation impacts on avifauna is anticipated to be low.

However, considering the proposed change of the turbine specification and reduced number of WTGs, the potential collision risk may differ. Therefore, the bird collision assessment has been updated for the newly proposed wind farm design envelope, from Lower Bound - 6.45 MW to Upper Bound – 15 MW/ 16 MW. To support the assessment, the validity of the baseline data has been reviewed considering the intervening time since the EIA Study in **Appendix A**.

In the review of publicly available data, significant changes in the population of most species recorded in the approved EIA have not been observed since the baseline data collection in 2008. Therefore, it is reasonable to conclude that the baseline avifauna bird collected in 2008 remains largely valid.

However, among the nine key concerned species mentioned in the approved EIA, evidence from the review has indicated that the populations of Aleutian Tern, Black-naped Tern, Common Tern, Red-necked Phalarope and White-winged Tern populations have shown a clear change since 2008. The populations have increased by approximately 3.5 times for Aleutian Tern; 2.5 times (in north-eastern waters) for Black-naped Tern; 3 times for Common Tern; 2 times for Red-necked Phalarope; and 2 times for White-winged Tern. Consequently, the density of these species adopted in the updated bird collision risk model was multiplied proportionally to assess the potential collision risk.

Over the years, the bird collision risk model has been revised and updated to provide a more accurate assessment for collision risks. The bird collision risk model employed in the approved EIA Report, Band *et al.* (2000) was reviewed with the internationally available collision risk prediction models to identify the prevailing industry approach that could be adopted for this *Report*. Further to this review the Band Model 2012 (3) has been adopted and follows in general terms that developed by Band (2000) (1) and Band *et al* (2007) (4) and is promoted in guidance published by Scottish Natural Heritage. The Band Model has been updated to facilitate application in the offshore environment (3). Consequently, Band Model 2012 is used for the assessment of bird collision risks for the newly proposed Lower Bound (i.e 6.45 MW) and Upper Bound (i.e. 15/ 16 MW), in order to evaluate and compare the risk to avifauna among all scenarios.

In the approved EIA Report, Bird Collision Risk Assessment has been conducted for nine key concerned species, including Aleutian Tern *Sterna aleutica*, Black Kite *Milvus migrans*, Black-legged Kittiwake *Rissa tridactyla*, Black-naped Tern *Sterna sumatrana*, Common Tern *Sterna hirundo*, Heuglin's Gull *Larus heuglini*, Red-necked Phalarope *Phalaropus lobatus*, White-bellied Sea Eagle *Haliaeetus leucogaster* and White-winged Tern *Chlidonias leucopterus*. Based on the proposed variations, an updated Bird Collision Risk Assessment has been conducted by using Band Model 2012 as detailed in **Appendices B and C**.

It is concluded that the magnitude of collision risk for some species in the proposed design envelope are low/ negligible since the species, including Black-naped Tern and White-bellied Sea Eagle, do not fall within the risk height of both Lower Bound and Upper Bound; as well as Red-necked Phalarope and White-winged Tern falling outside the risk height of Upper Bound. For the remaining scenarios,

(2) Band, W. (2000). Windfarms and Birds: calculating a theoretical collision risk assuming no avoiding action. Scottish Natural Heritage Guidance Note.

(3) Band, 2012. Using a Collision Risk Model to Assess Bird Collision Risks for Offshore Windfarms.

(4) Band, W., Madders, M. and Whitfield, D.P. (2007). Developing field and analytical methods to assess avian collision risk at windfarms.

the magnitude of all potential impacts resulted from operation of the proposed wind farm are predicted to be low, which is considered to be comparable with the findings in the approved EIA.

Overall, it is anticipated that the overall collision risk from all scenarios due to the operation of the wind farm of around 150MW capacity is low and will not cause any unacceptable impacts to the nine key concerned species. In comparison, Lower Bound - 6.45 MW has higher collision rates than the original turbine scenario, whereas Upper Bound – 15/16 MW has the lowest collision rate for all assessed bird species.

3.4 Marine Ecology

A baseline review of marine ecological resources within, and in the vicinity of, the Project has been conducted (see **Appendix A**). Based on the review, there are no apparent significant changes in marine ecological resources within and in the vicinity of the Project over time since the approval of the EIA report of the Project. No information gap has been identified and therefore no further marine ecological survey is considered necessary for the further environmental review of the proposed variation of the Project. The environmental review of marine ecology impacts of the proposed variation of the Project is discussed below.

3.4.1 Impact on Marine Intertidal and Subtidal Resources

With the proposed variation, the submarine cable route trench & length, dredging volume & rate, jetting volume & rate for the array cables would not be more than those specified in the approved EIA Report and the EP. In addition, the marine intertidal and subtidal resources at the LPS seawall remain to be of low ecological value with reference to the desktop review findings of recent ecological survey data. Therefore, the impact on marine intertidal and subtidal resources at the LPS seawall during construction phase would remain unchanged and not be greater or worse than those predicted in the approved EIA Report.

With reference to the approved EIA Report, foundation construction of wind turbines and wind monitoring mast will lead to loss of no more than 0.16 ha of low value subtidal soft bottom habitat. With the proposed variation, there will be fewer numbers of wind turbines when compared with the wind farm configurations in the approved EIA Report, the total habitat loss due to wind turbine construction will still be within 0.16 ha. In addition, the new offshore structures and scour protection, if any, will provide hard substrate habitat in the wind farm area. These structures could be colonised by a variety of marine organisms, including corals. Therefore, the impact on marine subtidal resources from the proposed variations would remain unchanged and not be greater or worse than those predicted in the approved EIA Report.

3.4.2 Impact on Marine Mammals

Upon review of recent marine mammal monitoring data, the Project is not located within the habitats utilised by Chinese White Dolphin and consequently impacts to the Chinese White Dolphin during construction and operation phases of the Project is not anticipated. The encounter rate and seasonal distribution of Finless Porpoise (FP) remain to be similar in recent years and the ecological importance of the marine waters at the Project is considered to be medium-high. With the proposed variations, the number of wind turbines to be installed will be reduced while the pile diameter of each monopile below seabed would increase to 7-9 m. A stronger hammer might be necessary to drive the larger monopile for each wind turbine foundation. Studies have shown that major sound energy from piling of larger monopiles is emitted in the low frequency range of about 100-500 Hz (5)(6)(7) while dolphins and porpoises generally use higher frequency clicks at a peak frequency of 142 kHz for FP (8).

FP are high frequency specialists, and sound produced during the short term piling works would be audible and may overlap and mask frequencies including those used for socializing but would not likely mask the ultrasonic frequencies used in echolocation for foraging. The waters around the Project is a FP habitat of medium-high ecological importance with higher sightings in winter and spring. FP would be expected to respond by avoiding a localised works area near the Project and the effect would be limited to behavioural disturbance impacts on affected individuals only. In the context of the size of the range of these animals, the size of the disturbed area would be small, and no significant long-term change in marine mammal distribution, abundance and usage pattern in the wider Hong Kong waters is expected. Furthermore, with the implementation of quieter hydraulic hammers, acoustic decoupling of noisy equipment, use of ramp-up piling procedures, avoidance of piling works for the wind turbines during the peak season of finless porpoise and the implementation of a 500 m radius marine mammal exclusion zone, unacceptable impacts on FP are not anticipated during construction of the Project. Therefore, the assessment made in the approved EIA Report on percussive piling stating that no unacceptable impacts on FP are expected with adoption of mitigation measures, will remain unchanged. Although the piling window will remain unchanged between June to November, the piling works duration will be shortened due to fewer numbers of wind turbines to be installed, and would further reduce the impacts to marine mammals and thus the proposed variation is considered beneficial for the development of the Project.

Overall, with the adoption of mitigation and special measures that has been identified, such as marine mammal exclusion zones and closed periods for piling works during peak season of finless porpoise, impacts on FP would remain unchanged and not be greater or worse than those predicted in the approved EIA Report with the proposed variations.

3.4.3 Impact on Sea Turtles

With reference in the desktop review of recent ecological findings, the nesting population of green turtles in Hong Kong was relatively small, while the potential for occurrences of this species around the Project exist as Hong Kong lies within the wider Pacific region where green turtles use as nesting, inter-nesting and foraging habitats (9)(10), which aligns with the approved EIA findings. The Sham Wan Restricted Area has been expanded since 1 April 2021, yet it is still located more than 4 km away from the Project. There is no timeline for the designation of the potential marine park at Southwest Lamma, locating > 1 km away from the wind farm development site.

With the proposed variations, the maximum area of subtidal habitat loss due to foundation installation would not exceed the size with the wind farm configuration presented in the approved EIA Report (0.16 ha). In addition, the extent of scour materials with the variations remains unchanged.

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(5) Koschinski S, Lüdemann K (2020). Noise mitigation for the construction of increasingly large offshore wind turbines - Technical options for complying with noise limits. Report commissioned by the Federal Agency for Nature Conservation, Isle of Vilm, Germany

(6) Mooney TA, Anderson MH, Stanley J. (2020). Acoustic impacts of offshore wind energy on fishery resources. An evolving source and varied effects across a wind farm's lifetime. Oceanography; 33, p. 82-95.

(7) ICF (2021). Comparison of Environmental Effects from Different Offshore Wind Turbine Foundations. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Headquarters, Sterling, VA. OCS Study BOEM 2021-053. 48 pp.

(8) Goold JC & Jefferson TA (2002) Acoustic signals from free-ranging finless porpoises (*Neophocaena phocaenoides*) in waters around Hong Kong. The Raffles Bulletin of Zoology Supplement 10:131-139.

(9) Ng CKY, Dutton PH, Chan SKF, Cheung KS, Qiu JW, Sun YA (2014) *Op cit.*

(10) Ng CKY (2015) Conservation Implications of the Genetic Structure and Habitat Use of Green Turtles (*Chelonia mydas*) in the South China Region and Baseline Contaminant Levels in Green Turtles and Burmese Pythons (*Python bivittatus*). PhD Thesis.

Considering the habitat quality, species, size, duration, reversibility and magnitude due to the proposed variations of the Project remain unchanged, the impact on sea turtles during construction and operation phases would remain unchanged and not be greater or worse than those predicted in the approved EIA Report. With the implementation of the mitigation measures as stated in the approved EIA Report, including marine mammal exclusion zone monitoring for sea turtles during piling works for the wind turbines and dredging works for the cable, no unacceptable impacts to sea turtles during construction and operation of the wind farm are anticipated. Although the piling window will remain unchanged between June to November, the piling works duration will be shortened due to fewer numbers of wind turbines to be installed, and would further reduce the impacts to sea turtles and thus the proposed variation is considered beneficial for the development of the Project.

3.4.4 Summary

Overall, the proposed variations will not generate adverse impact on marine subtidal and intertidal resources, marine mammals, and sea turtles that is worse than that assessed in the approved EIA Report. With the implementation of the mitigation measures as stated in the approved EIA Report, adverse ecological impacts due to the proposed variations are not anticipated. Although the piling window will remain unchanged between June to November, the piling works duration will be shortened due to fewer numbers of wind turbines to be installed, and would further reduce the impacts to marine mammals and sea turtles and thus the proposed variation is considered beneficial for the development of the Project.

Moreover, tetrapod foundation will likely be adopted for the offshore wind turbine with capacity of 10 MW or above. Since piles with smaller diameter (diameter of around 2-3 m each) will be installed at each tetrapod leg, the sound energy from piling will be lower than that of monopile. The monopile option as assessed in the approved EIA report is still considered as the worst case. Therefore, the underwater sound impact to marine mammals and sea turtles when adopting tetrapod foundation is likely to be lowered when comparing to monopile option.

3.5 Fisheries Impact

A baseline review of latest available information on capture and culture fisheries within and in the vicinity of the Project has been conducted (see **Appendix A**). Based on the review, the fisheries resources and production rates within and adjacent to the wind farm are moderate in terms of catch weight and value. The Project area is within the spawning and nursery areas of commercial fisheries resources. There are no additional FCZs around the Project other than those described in the approved EIA report of the Project. Overall, there are no apparent changes to fisheries resources and fishing operation within and in the vicinity of the Project over time after the approval of the EIA report of the Project. No information gap is identified and therefore no further fisheries survey is considered necessary for further environmental review of the proposed variation of the Project. The environmental review on fisheries of the proposed variation of the Project is discussed below.

With the proposed variations, the number of wind turbines will be reduced (from 35 nos to 10-24 nos). The maximum loss of seabed habitat for the foundations installation due to the proposed variations is expected to be within 0.16 ha which is the same as the wind farm configuration presented in the approved EIA Report. The study area supports moderate fisheries resources and production rates, commercial value of fisheries resources and level of ichthyoplankton and fish post-larvae resources are not high. Overall, there are no apparent changes to fisheries resources within and in the vicinity of the Project over time after the approval of the EIA report. The impact on fishing activity and aquaculture activity would remain unchanged and not be greater or worse than those predicted in the approved EIA report.

There are no changes on the implementation of safety/ exclusion zones for all vessels in the works area and Project site during construction and operation phases with the proposed variations. The impact on access of vessels to the Project site would remain unchanged and not be greater or worse than those predicted in the approved EIA report. The volume of vessel traffic due to the Project is also expected to be similar and unchanged with the proposed variations. With the implementation of safety/ exclusion zones, the increased risk of collision will be very low and not be greater or worse than those predicted in the approved EIA report. Underwater sound is expected to be generated during the marine construction works of the Project. With the proposed variation, the piling works duration will be shortened due to fewer numbers of wind turbines to be installed and thus the impacts to fisheries would be further reduced. Impact to fisheries due to underwater sound is expected to be minor.

With the implementation of the mitigation measures as stated in the approved EIA Report, no unacceptable impacts to fisheries during construction and operation of the wind farm are anticipated. Although the piling window will remain unchanged between June to November, the piling works duration will be shortened due to fewer numbers of wind turbines to be installed, and would further reduce the impacts to fisheries and thus the proposed variation is considered beneficial for the development of the Project.

Moreover, a tetrapod foundation will likely be adopted for the offshore wind turbine with capacity of 10 MW or above. Since piles with smaller diameter (diameter of around 2-3 m each) will be installed at each tetrapod leg, the sound energy from piling will be lower than that of monopile. The monopile option as assessed in the approved EIA report is still considered as the worst case. Therefore, the underwater sound impact to fisheries when adopting tetrapod foundation is likely to be lowered when comparing to monopile option.

In addition, the offshore marine structures and scour protection would provide long term benefits with respect to the creation of an ‘artificial reef’. The reduced fishing pressure could also lead to a long term increased fisheries resources within and adjacent to the wind farm area.

3.6 Landscape and Visual Impact

As the approved EIA Report evaluated, the potential landscape and visual impact was greatly reduced from the outset by conducting a site selection process taking into account potential impacts. It also concluded that landscape and visual impacts are considered acceptable with mitigation. In terms of Landscape Character Areas (LCAs), apart from Offshore Waters Landscape (LCA 1), which had Moderate residual impact during both construction and operational phases, the other three LCAs had residual impacts ranging from Negligible to Slight during both phases. Regarding Landscape Resources (LRs), except Seascape (LR1), which had Slight residual impact during both phases, the other five LRs had negligible residual impacts during both phases.

For visually sensitive receivers (VSRs), Moderate residual visual impacts were identified at four VSRs, including: Silvermine Bay (Mui Wo) (VSR 7), The Peak (VSR 11), Mt Stenhouse (VSR 17) and East Lamma Channel (VSR 19). Slight residual impacts were identified at 12 VSRs, including: Lamma Island (Hung Shing Ye beach) (VSR 1), Lo So Shing Beach (VSR 2), Ferry to Cheung Chau (VSR 4), Cheung Chau (VSR 5), Discovery Bay (VSR 6), Chi Ma Wan Peninsula (VSR 8), Cheung Sha (VSR 9), Lantau Trail (VSR 10), Queen Mary Hospital and Mount Davis (VSR 12), Pok Fu Lam - Pauline Chan Building at HKU (VSR 13), Ocean Park (VSR 16), and Penny’s Bay (VSR 18). Negligible impacts were identified at three VSRs, including: Lamma Ferry Pier (VSR 3), Stanley Waterfront (VSR 14) and Wong Nai Chung Gap and Violet Hill (VSR 15).

The revised designs are unlikely to cause any change of the EIA conclusion from the perspective of landscape context. The LCA and the LR that will be affected by both the Lower Bound and Upper Bound remain as the offshore waters themselves, i.e. Offshore Waters (LCA1) and Seascape (LR1).

The proposed use of smaller number of wind turbines for both the Lower Bound and Upper Bound, ie around 24 nos. to around 10 nos., meets with the Environmental Permit (EP-394/2010) intent of minimising the footprint of the project (see Condition 2.6 of the EP). The revised layout will maintain the same site area with EP (600 ha). It should be noted that some flexibility on the final layout is required to allow the turbine spacing and configuration to be optimised to reduce wake losses and maximise energy generation based on the final turbine selection. The potential changes of the visual impacts due to the new turbine specification and wind farm layout are further evaluated in the following sections.

A comparison of the EP layout and the revised layout is shown in **Table 2.1**. To summarise, there would be fewer but bigger turbines in both Lower Bound and Upper Bound. The tip heights in Lower Bound and Upper Bound are respectively 62m and 135m taller than the design approved in the EIA Report. Likewise, the rotor radius of Lower Bound and Upper Bound are respectively 33.5m and 65.5m larger than the design approved in the EIA Report. On the other hand, the total number of WTGs are reduced from 35 nos. to 24/ 10 nos. The number of blades remain unchanged, i.e. three (3) per wind turbine.

The approved EIA Report provided photomontages from VSR1 to VSR18. The locations of VSRs in relation to Lower Bound / Upper Bound are respectively shown in **Figure 3.6.1** and **Figure 3.6.2**, with description of the VSRs and their distances with the nearest turbines for both Lower Bound and Upper Bound summarised in **Table 3.3**. As such, photomontages of these VSRs with the use of current existing views have been prepared in order to illustrate the proposed variations (**Figures 3.6.3a – 3.6.3c** to **3.6.20a – 3.6.20c**).

Table 3.3 Details of Viewpoints VSR1 to VSR18

VSR No.	VSR Location	Distance to the Nearest Turbine (Lower Bound) (km)	Distance to the Nearest Turbine (Upper Bound) (km)
VSR 1	Lamma Island (Hung Shing Ye Beach)	5.36	5.40
VSR 2	Lo So Shing Beach	4.23	4.27
VSR 3	Lamma Ferry Pier	5.65	5.69
VSR 4	Ferry to Cheung Chau	11.13	11.15
VSR 5	Cheung Chau	5.19	5.25
VSR 6	Discovery Bay	14.23	14.36
VSR 7	Silver Mine Bay (Mui Wo)	13.26	13.29
VSR 8	Chi Ma Wan Peninsula	11.01	11.11
VSR 9	Cheung Sha	14.83	15.05
VSR 10	Lantau Trail	14.90	15.10
VSR 11	The Peak	11.91	11.96
VSR 12	Queen Mary Hospital and Mount Davis	10.81	10.85
VSR 13	Pauline Chan Bldg HKU	10.74	10.78
VSR 14	Stanley Waterfront	13.00	13.04
VSR 15	Wong Nai Chung gap and Violet Hill	13.37	13.42
VSR 16	Ocean Park	10.17	10.21
VSR 17	Mt Stenhouse	3.38	3.42
VSR 18	Penny's Bay	14.82	14.90
VSR 19	East Lamma Channel [1]	1.10	1.14

Note: No photomontage was presented for VSR 19 in the approved EIA Report. As such, it is assumed the same applies in this case, no photomontage required.

3.6.1 Construction Phase

From a landscape and visual perspective, the activities for the construction and installation of the turbines will be largely the same as those discussed in the approved EIA Report.

Since the magnitude of change in landscape and visual impacts will remain the same, their sensitivity is fixed and mitigation measures proposed in the approved EIA Report will remain unchanged. It is expected that the significance of landscape and visual impacts during construction phase caused by the proposed variations with Lower Bound and Upper Bound would not be worse than that assessed in the approved EIA Report. In the approved EIA Report, the mitigated impacts at the VSRs during construction phase are ranged from Negligible to Moderate. For the proposed variations with Lower Bound and Upper Bound, the mitigated visual impacts are also ranged from Negligible to Moderate, given the activities for the construction and installation of the turbines will be largely the same as those discussed in the approved EIA Report.

3.6.2 Operational Phase

Photomontages at VSR 1 to VSR 18 have been updated in order to illustrate the existing site conditions, changes in the visual impacts and to compare with that presented in the approved EIA Report (**Figures 3.6.3a – 3.6.3c** to **3.6.20a – 3.6.20c**). The changes include taller turbines with bigger rotor and higher tip heights, although there would be fewer turbines and fewer rows of turbines in total (i.e. the total number of turbines reduced from smaller turbine of ~35 nos to larger turbine of ~10 to 24 nos.). It should be noted that the parameters of the 16MW turbine are similar with 15MW in terms of visual impact, and the Upper Bound photomontages are considered valid for 16MW as well. Details of how views from these VSRs may change are described in **Table 3.4**. There is a considerable distance between the VSRs and the Development Site. Under the proposed variations, subject to the final layout, the turbines in both Lower Bound and Upper Bound are more scattered [(11)].

As presented in **Table 3.4**, Upper Bound would be relatively more distinctive when viewing from VSR 1, VSR2, VSR 5 and VSR 17 but less compacted with more space between turbines. VSR 1, VSR 2, VSR 5, and VSR 17 respectively refer to recreational VSRs in Hung Shing Ye Beach, Lo So Shing Beach, Cheung Chau and Mt Stenhouse. The increase in rotor diameter and tip height of turbines of Upper Bound would be noticeable from these four viewpoints. However, these four VSRs are limited to few individuals and they have alternative views. The frequency of view is occasional.

The increase in rotor diameter and tip height of turbines would be considered noticeable. However, given there is alternative view for these VSRs, and the view is limited to few individuals, as well as the research findings suggested [(12)] that the public prefer the use of fewer, larger turbines than the use of a greater number of smaller ones, the magnitude of change and residual visual impact experienced from these viewpoints would not be worse when compared to that of the approved EIA Report (i.e. the total number of turbines reduced from smaller turbine of ~35 nos to larger turbine of ~10 to 24 nos.). The overall potential visual impact would not be affected. All mitigation measures proposed in the approved EIA Report (VVM1 – VVM4) will be implemented (**Figure 3.6.21** and **Figure 3.6.22**).

It is anticipated that the landscape and visual impacts brought by the proposed variations with Lower Bound and Upper Bound during the operational phase would not be worse than the conclusion in the approved EIA Report. In the approved EIA Report, the mitigated impacts at the VSRs during operational phase are ranged from Negligible to Moderate. For the proposed variations with Lower Bound and Upper Bound, the mitigated visual impacts are also ranged from Negligible to Moderate (**Table 3.4**), given the distances between the viewpoints and the Development Site.

(11) The layout illustrated in Figures 3.6.3a – 3.6.3c to 3.6.20a – 3.6.20c are only preliminary and the detailed layout will be subject to engineering design at later stage. It should also be noted that the number of wind turbines will be fine-tuned, which depends on the appropriate unit capacity / size of the wind turbines to be selected in the future optimized layout.

(12) Thayer and Freeman. (1987). Altamont: Public perceptions of a wind energy landscape.

Table 3.4 Key Changes to Views from VSR 1 to VSR 18

Viewpoint	Key changes / Significance of change to Magnitude of Change experienced	Mitigated Visual Impacts of the Approved EIA Report	Mitigated Visual Impacts of the Proposed Variations with Lower Bound and Upper Bound	Photomontage Figure
Overview of 18 VSRs	■ The total numbers of turbines reduce from 35 in approved EIA Report to 24/10 for Lower Bound / Upper Bound. ■ The windfarm area of both Lower Bound and Upper Bound maintains the same site area size as the Approved EIA Report (600 ha). Upper Bound would be more distinctive when viewing from VSR 1, VSR2, VSR 5 and VSR 17 but less compacted with more space between turbines. ■ The rotor radius of the turbines increases from 55.5 m in approved EIA Report to 89m/ 118m for Lower Bound / Upper Bound. ■ The tip height of the turbines increases from 136 mPD in approved EIA Report to 198 mPD/ 265 mPD for Lower Bound / Upper Bound. ■ For most of the VSRs (apart from VSR 1, 2, 5 and 17), the increases in the rotor diameter and tip height of the turbines are considered to be insignificant and not noticeable taking into account the considerable distances of 1 km to 15 km between the viewpoints and the Development Site. In addition, according to Thayer and Freeman's research (1987), the increase in size can be offset by the smaller number of turbines. ■ From the landscape and visual perspective, it is anticipated that the impacts to the proposed variations with Lower Bound and Upper Bound would not be worse than that presented in the approved EIA Report.	-	-	<u>VSR 1 to VSR 18:</u> **Figures 3.6.3a – 3.6.3c** to **Figures 3.6.20.a – 3.6.20c** a for approved EIA Report [1] b for Lower Bound c for Upper Bound
VSR 1	It is noticeable that there is more space between turbines in both Lower Bound and Upper Bound. For Upper Bound, in relation to its larger turbine size, the turbines look more distinctive.	Slight	Slight	**Figures 3.6.3a – 3.6.3c**

Viewpoint	Key changes / Significance of change to Magnitude of Change experienced	Mitigated Visual Impacts of the Approved EIA Report	Mitigated Visual Impacts of the Proposed Variations with Lower Bound and Upper Bound	Photomontage Figure
VSR 2	It is noticeable that there is more space between turbines in both Lower Bound and Upper Bound. For Upper Bound, in relation to its larger turbine size, the turbines look more distinctive.	Slight	Slight	**Figures 3.6.4a – 3.6.4c**
VSR 3	In the approved EIA Report, the turbines are blocked by the mountains, hence not visible to the VSR. In both Lower Bound and Upper Bound, turbines are also blocked by the mountains and not visible to this VSR. Therefore, the landscape and visual impact would not be worse than that assessed in the approved EIA Report.	Negligible	Negligible	**Figures 3.6.5a – 3.6.5c**
VSR 4	In the approved EIA Report, since there are 35 turbines, they create a denser view. Whereas in the proposed Lower Bound and Upper Bound, there are fewer turbines, hence the view is less compacted. Although the turbines are larger in both Lower Bound and Upper Bound, due to the large distances between the turbines and the viewpoint, (11 km away from the nearest turbine of both Lower Bound and Upper Bound, the difference would be largely imperceptible to the viewer, and the landscape and visual impact would not be worse than that assessed in the approved EIA Report.	Slight	Slight	**Figures 3.6.6a – 3.6.6c**
VSR 5	It is noticeable that there is more space between turbines in both Lower Bound and Upper Bound. For Upper Bound, in relation to its larger turbine size, the turbines look more distinctive.	Slight	Slight	**Figures 3.6.7a – 3.6.7c**
VSR 6	In the approved EIA Report, there were two turbines visible from this VSR. Whereas in the proposed Lower Bound and Upper Bound, only one turbine will be visible from this VSR. In addition to the large distances between the turbine and the viewpoint, (14 km away from the nearest turbine of both Lower Bound and Upper Bound, the difference would be largely imperceptible to the viewer, and the landscape and visual impact would not be worse than that assessed in the approved EIA Report.	Slight	Slight	**Figures 3.6.8a – 3.6.8c**

Viewpoint	Key changes / Significance of change to Magnitude of Change experienced	Mitigated Visual Impacts of the Approved EIA Report	Mitigated Visual Impacts of the Proposed Variations with Lower Bound and Upper Bound	Photomontage Figure
VSR 7	In the approved EIA Report, since there are 35 turbines, they create a denser view. Whereas in the proposed Lower Bound and Upper Bound, there are fewer turbines, hence the view is less compacted. Although the turbines are larger in both Lower Bound and Upper Bound, due to the large distances between the turbines and the viewpoint, (13 km away from the nearest turbine of both Lower Bound and Upper Bound), the difference would be largely imperceptible to the viewer, and the landscape and visual impacts would not be worse than that assessed in the approved EIA Report.	Moderate	Moderate	**Figures 3.6.9a – 3.6.9c**
VSR 8	In the approved EIA Report, since there are 35 turbines, they create a denser view. Whereas in the proposed Lower Bound and Upper Bound, there are fewer turbines, hence the view is less compacted. Although the turbines are larger in both Lower Bound and Upper Bound, due to the large distances between the turbines and the viewpoint, (11 km away from the nearest turbine of both Lower Bound and Upper Bound), and the turbines are partly blocked by the mountains on the left, the difference would be largely imperceptible to the viewer, and the landscape and visual impacts would not be worse than that assessed in the approved EIA Report.	Slight	Slight	**Figures 3.6.10a – 3.6.10c**
VSR 9	In the approved EIA Report, since there are 35 turbines, they create a denser view. Whereas in the proposed Lower Bound and Upper Bound, there are fewer turbines, hence the view is less compacted. Although the turbines are larger in both Lower Bound and Upper Bound, due to the large distances between the turbines and the viewpoint, (14 km away from the nearest turbine of both Lower Bound and Upper Bound), the difference would be largely imperceptible to the viewer, and the landscape and visual impact would not be worse than that assessed in the approved EIA Report.	Slight	Slight	**Figures 3.6.11a – 3.6.11c**
VSR 10	In the approved EIA Report, since there are 35 turbines, they create a denser view. Whereas in the proposed Lower Bound and Upper Bound, there are	Slight	Slight	**Figures 3.6.12a – 3.6.12c**

Viewpoint	Key changes / Significance of change to Magnitude of Change experienced	Mitigated Visual Impacts of the Approved EIA Report	Mitigated Visual Impacts of the Proposed Variations with Lower Bound and Upper Bound	Photomontage Figure
	fewer turbines, hence the view is less compacted. Although the turbines are larger in both Lower Bound and Upper Bound, due to the large distances between the turbines and the viewpoint, (14 km away from the nearest turbine of both Lower Bound and Upper Bound), and the turbines are partly blocked by mountains on the left, the difference would be largely imperceptible to the viewer, and the landscape and visual impacts would not be worse than that assessed in the approved EIA Report.			
VSR 11	In the approved EIA Report, since there are 35 turbines, they create a denser view. Whereas in the proposed Lower Bound and Upper Bound, there are fewer turbines, hence the view is less compacted. Although the turbines are larger in both Lower Bound and Upper Bound, due to the large distances between the turbines and the viewpoint, (11 km away from the nearest turbine of both Lower Bound and Upper Bound), the difference would be largely imperceptible to the viewer, and the landscape and visual impact would not be worse than that assessed in the approved EIA Report.	Moderate	Moderate	**Figures 3.6.13a – 3.6.13c**
VSR 12	In the approved EIA Report, since there are 35 turbines, they create a denser view. Whereas in the proposed Lower Bound and Upper Bound, there are fewer turbines, hence the view is less compacted. Although the turbines are larger in both Lower Bound and Upper Bound, due to the large distances between the turbines and the viewpoint, (10 km away from the nearest turbine of both Lower Bound and Upper Bound), and the turbines are partly blocked by the mountains and the power station’s chimneys in Lamma Island, the difference would be largely imperceptible to the viewer, and the landscape and visual impact would not be worse than that assessed in the approved EIA Report.	Slight	Slight	**Figures 3.6.14a – 3.6.14c**

Viewpoint	Key changes / Significance of change to Magnitude of Change experienced	Mitigated Visual Impacts of the Approved EIA Report	Mitigated Visual Impacts of the Proposed Variations with Lower Bound and Upper Bound	Photomontage Figure
VSR 13	In the approved EIA Report, since there are 35 turbines, they create a denser view. Whereas in the proposed Lower Bound and Upper Bound, there are fewer turbines, hence the view is less compacted. Although the turbines are larger in both Lower Bound and Upper Bound, due to the large distances between the turbines and the viewpoint, (10 km away from the nearest turbine of both Lower Bound and Upper Bound), and the turbines are partly blocked by the mountains and the power station's chimneys in Lamma Island, the difference would be largely imperceptible to the viewer, and the landscape and visual impact would not be worse than that assessed in the approved EIA Report.	Slight	Slight	**Figures 3.6.15a – 3.6.15c**
VSR 14	In the approved EIA Report, the turbines are blocked by the mountains on the right, hence not visible to the VSR. In both Lower Bound and Upper Bound, turbines are also blocked by the mountains on the right and not visible to this VSR. Therefore, the landscape and visual impact would not be worse than that assessed in the approved EIA Report.	Negligible	Negligible	**Figures 3.6.16a – 3.6.16c**
VSR 15	In the approved EIA Report, the turbines are blocked by the mountains, hence not visible to the VSR. In both Lower Bound and Upper Bound, turbines are also blocked by the mountains, hence not visible to this VSR. Therefore, the landscape and visual impact would not be worse than that assessed in the approved EIA Report.	Negligible	Negligible	**Figures 3.6.17a – 3.6.17c**
VSR 16	Comparing to the approved EIA Report, turbines in both Lower Bound and Upper Bound are more scattered. The number of visible turbines from this VSR is also reduced. Although the turbines are bigger in both Scenarios, due to the large distances between the turbines and the viewpoint, (10 km from the nearest turbine of both Scenarios), and some of them are blocked by the mountains, the difference would be largely imperceptible to the viewer, and	Slight	Slight	**Figures 3.6.18a – 3.6.18c**

Viewpoint	Key changes / Significance of change to Magnitude of Change experienced	Mitigated Visual Impacts of the Approved EIA Report	Mitigated Visual Impacts of the Proposed Variations with Lower Bound and Upper Bound	Photomontage Figure
	the landscape and visual impact would not be worse than that assessed in the approved EIA Report.			
VSR 17	It is noticeable that there is more space between turbines in both Lower Bound and Upper Bound. For Upper Bound, in relation to its larger turbine size, the turbines look more distinctive.	Moderate	Moderate	**Figures 3.6.19a – 3.6.19c**
VSR 18	Comparing to the approved EIA Report, turbines in both Lower Bound and Upper Bound are more scattered. The number of visible turbines from this VSR is also reduced. Although the turbines are bigger in both Scenarios, due to the large distances between the turbines and the viewpoint, (14 km from the nearest turbine of both Scenarios), the difference would be largely imperceptible to the viewer, and the landscape and visual impacts would not be worse than that assessed in the approved EIA Report.	Slight	Slight	**Figures 3.6.20a – 3.6.20c**

Note:

[1] Photomontages are extracted from the approved EIA Report.

3.7 Cultural Heritage Impact

The approved EIA Report identified no declared monuments, graded historic buildings, government historic sites, sites of archaeological interest and other built heritage items in the vicinity of the proposed on shore cable route. The reclaimed land where the cable circuit will be located is of no archaeological potential, the assessment concluded that no construction impacts are expected. The change in the wind farm parameters will not lead to additional adverse impacts to any of the cultural heritage resources discussed above. Therefore, the impact assessment presented in the approved EIA Report is still valid.

The approved EIA Report identified one shipwreck within the proposed development layout that may potentially be impacted by the proposed array cable jetting/ turbine foundation (see **Figures 3.7.1** and **3.7.2**). The number of turbines presented in the approved EIA Report has been reduced from around 35 nos. to 10-24 nos. The updated Project layouts for Lower Bound – 6.45MW and Upper Bound – 15/16MW respectively were designed to avoid and minimise the potential impacts to the shipwreck due to construction of the turbine foundation and have taken into account the mitigation measure recommended in the approved EIA Report by allowing a 50m no works area from the shipwreck. The EM&A recommendations in the approved EIA Report remain valid.

During detailed design stage of the Project, the routing of the array cable and the cable route alignment will seek to provide a 50m no works area from the shipwreck to avoid the potential impact. In case the routing of array cable and the cable route alignment are located outside previously surveyed area, further survey and subsequent marine archaeological impact assessment will be conducted in consultation with the Antiquities and Monuments Office.

3.8 Operational Noise Impact

3.8.1 Noise Source Term

Based on the latest design, wind turbines with the capacity of Lower Bound (i.e. 6.45MW) to Upper Bound (i.e. 15/16MW) will be installed for the Project. The total of 35 nos. wind turbines assumed in the approved EIA Report will be reduced to 10 to 24 nos. of wind turbines with capacity between Lower Bound and Upper Bound. According to the information from wind turbine supplier, the maximum sound power level (SWL) of wind turbine with capacity of 15MW is 118dB(A), and has been adopted in the calculation of Upper Bound. Specification of the wind turbine is presented in **Appendix D1**. The maximum SWL of 16MW wind turbine is expected to be similar to the maximum SWL of 15MW wind turbine.

Noise data of the 6.45MW is not available at this stage. Maximum allowable SWL has been calculated based on the methodology presented in **Section 3.8.2.3**. With reference to the approved EIA Report, no tonal, impulsive and intermittent characteristics have been assumed for the wind turbines in the operational noise assessments.

3.8.2 Noise Calculation Methodology

3.8.2.1 Noise Sensitive Receiver

The Project will be located in the marine waters to the southwest of Lamma Island. The nearest representative noise sensitive receivers (NSRs) have been reviewed and found remained the same as that identified in the approved EIA Report. The details and locations of the representative NSRs are presented in **Table 3.5** and **Figures 3.8.1-3.8.2**.

Table 3.5 Identified Representative NSRs

NSR ID	Description	Use	Approximate Distance to nearest Project Site Boundary (m)
N1	Lamma Island – Lo So Shing	Existing Residential	4,280
N2	Cheung Chau – Seascape Peninsula	Existing Residential	4,750

3.8.2.2 Baseline Conditions

Noise measurements were taken at Concerto Inn near NSR N1 and NSR N2 on 29 May 2021 and 9 July 2021, respectively, to investigate the prevailing background noise levels during night-time period (2300 to 0700 hrs on the next day). The noise measurements were conducted using a Rion NL-52 Sound Level Meter (Type 1), which had been calibrated using a 01dB-Stell CAL21 Sound Calibrator with a calibration signal of 94.0 dB(A) at 1kHz. The microphone was set at 1.2m above floor level with façade reflection. The measurements were conducted in accordance with the calibration and measurement procedures stated in the *IND-TM*.

Two (2) sets of 30-minute baseline noise measurements have been conducted during each of the night-time period. The average of the measured noise levels are taken as the prevailing background noise levels during night-time period. Averaged L_{90} has been adopted as prevailing background noise levels.

The measurement locations for Lower Bound and Upper Bound are shown in **Figures 3.8.1-3.8.2**. The measured prevailing background noise levels and applicable operational noise criteria are summarised in **Table 3.6** with details shown in **Appendix D2**.

Table 3.6 Measured Prevailing Background Noise Levels

Location	Time Periods	Averaged Measured Noise Levels (Measured Noise Levels), $L_{90\ (30min)}$ dB(A) [(b)]	ANL-5 for ASR "A", dB(A) [(a)]	Operational Noise Criteria, dB(A) [(a)]
Concerto Inn near N1 [(c)]	Night-time	50	45	45
N2 [(d)]	Night-time	50	45	45

Notes:

(a) *IND-TM* specifies the applicable Acceptable Noise Levels (ANLs) for the operation of the Project. The noise criteria for planning and design of Designated Projects are set out in the *EIAO-TM* as follows:
- the noise level at the facade of the nearest NSR is at least 5 dB(A) below the appropriate ANL as specified in the IND-TM; or,
- the prevailing background noise level (for quiet areas with a noise level 5 dB(A) below the appropriate ANL).

(b) The background noise is mainly dominated by the sound of sea waves/insects

(c) Due to safety concern and accessibility, background noise measurement could not be carried out at NSR N1. The background noise environment is considered similar at Concerto Inn and NSR N1.

(d) Façade correction of 3dB(A) has been applied for the free-field noise measurement at N2.

Based on the above, noise levels of $L_{eq,\ 30min}$ 45 dB(A) was assigned as the noise criterion for the assessment of operational noise impact from the Project during daytime and night-time periods for the NSRs at Lamma Island and Cheung Chau, respectively.

3.8.2.3 Noise Calculation Procedures

The operation noise assessment has been carried in accordance with the methodology adopted in approved EIA Report. The operational noise to be generated by the wind turbines of the Project has been calculated in accordance with standard acoustic principles and the procedures outlined in ISO

9613-1 [(13)] and ISO 9613-2 [(14)]. The calculations have taken into account distance attenuation and atmospheric absorption. No corrections for tonality, impulsiveness and intermittency are considered necessary as HK Electric has confirmed that the wind turbine procurement tender will specify only equipment without such acoustic characteristics.

3.8.3 Results and Discussions

The predicted noise levels at the representative NSRs are summarised in **Table 3.7** with detailed calculation presented in **Appendix D3**.

Table 3.7 Predicted Façade Noise Levels at Representative NSRs

NSR	SWL of each Turbine, dB(A)	Predicted Noise Level, dB(A) [(a)]	Noise Criteria, dB(A)
Lower Bound – 6.45MW (24 nos. of wind turbines)			
N1 (Lamma)	117.5[(b)]	40.5	45
N2 (Cheung Chau)		45.0	
Upper Bound – 15/16MW (10 nos. of wind turbines)			
N1 (Lamma)	118.0	37.4	45
N2 (Cheung Chau)		41.6	

Notes:

(a) The predicted noise levels from the offshore wind farm (of around 150MW) at the representative NSRs would not exceed the noise criteria (assuming up to around 20 nos. of 15/16MW wind turbines). The final detailed layout will be determined by engineering design at later stage.

(b) The maximum allowable SWL of each turbine of Lower Bound has been carried out based on work-back approach.

Based on the maximum allowable SWL for each wind turbine, the predicted noise levels at the representative NSRs comply with the noise criteria for both Lower Bound and Upper Bound. Therefore, adverse noise impact due to operation of the Project is not anticipated.

(13) ISO 9613-1: 1993 Acoustics - Attenuation of sound during propagation outdoors – Part 1: Calculation of the absorption of sound by the atmosphere.

(14) ISO 9613-2: 1996 Acoustics - Attenuation of Sound during Propagation Outdoors – Part 2: General method of calculation.

4. REVIEW OF ENVIRONMENTAL MONITORING AND AUDIT REQUIREMENTS

The review of the potential environmental impacts associated with the proposed changes indicated that no unacceptable environmental impacts would be anticipated. However, monitoring for water quality should be carried out to ensure no water quality impact to nearby WSRs from the Project in accordance with the Environmental Monitoring and Audit (EM&A) requirements from the approved EIA Report.

Review of potential change in water quality impact due to construction works under **Section 3.1** indicated that notable change in water quality impact is not anticipated due to the updates in the project design and working rate (particularly for water pumping). Therefore, the proposed water quality monitoring requirements (i.e. baseline monitoring and construction phase monitoring) stipulated in the EM&A Manual are still deemed applicable and sufficient.

Other EM&A measures and requirements listed in the approved EIA Report would be carried out accordingly.

5. REVIEW OF POTENTIAL MATERIAL CHANGE

In accordance with Schedule 1 of the EIAO:

> *"**material change**" means a physical addition or alteration to a designated project which results in an adverse environmental impact as defined in the technical memorandum*;

And Section 6.2 of the EIAO-TM:

> *The environmental impact of a designated project, for which an environmental permit has been issued, is considered to be materially changed if the environmental performance requirements set out in the EIA report for this project may be exceeded or violated, even with the mitigation measures in place*.

The potential environmental impacts, including water quality, waste management, terrestrial ecology, marine ecology, fisheries, landscape & visual, cultural heritage and operational noise, associated with the proposed changes in the turbine design have been assessed with results presented in *Section 3* of this *Report.* It is demonstrated that the potential environmental impacts are not considered to be materially changed. The environmental performance requirements set out in the approved EIA Report for this Project are not exceeded or violated, with the implementation of the mitigation measures proposed in the approved EIA Report. The potential environmental impacts comply with the requirements and criteria stipulated in EIAO-TM.

6. CONCLUSION

A review against the approved EIA Report has been conducted for the proposed variations and the findings show that there are not predicted to be any adverse environmental impacts as a result of the variations. Changes under the circumstances specified in Schedule 1 of the EIAO and Section 6.2 of the EIAO-TM regarding material changes to a designated project have been evaluated and it is confirmed that the proposed variations will not constitute a material change to the Project.

In addition, it has been evaluated that some positive environmental impacts as compared with the approved EIA Report will arise from the proposed variations. These can be expected to include:

- water quality impact from laydown area eliminated as it will be located outside Hong Kong;
- less change in current flow regime than that of the design assessed in the approved EIA report due to fewer number of wind turbines;
- reduced quantities of wastes generated with fewer wind turbines to be installed;
- reduced impacts to marine mammals, sea turtles and fisheries due to the shorter duration of piling works (the piling window will remain unchanged between June to November); and
- the public's preference of the use of fewer, larger turbines than the use of a greater number of smaller ones as suggested in research findings [(15)] for landscape and visual impact aspect.

With the proposed variation, the current offshore wind farm is anticipated to generate around 400 GWh of renewable electricity annually, as compared with the annual energy production of 175 GWh mentioned in the approved EIA report. The increase in renewable electricity generation can further contribute to managing emissions of air pollutants and climate change, providing diversity of fuel supply, and supporting Hong Kong's renewable energy target. This will also provide positive contribution to meet the Government's decarbonization initiative.

(15) Thayer and Freeman. (1987). Altamont: Public perceptions of a wind energy landscape.

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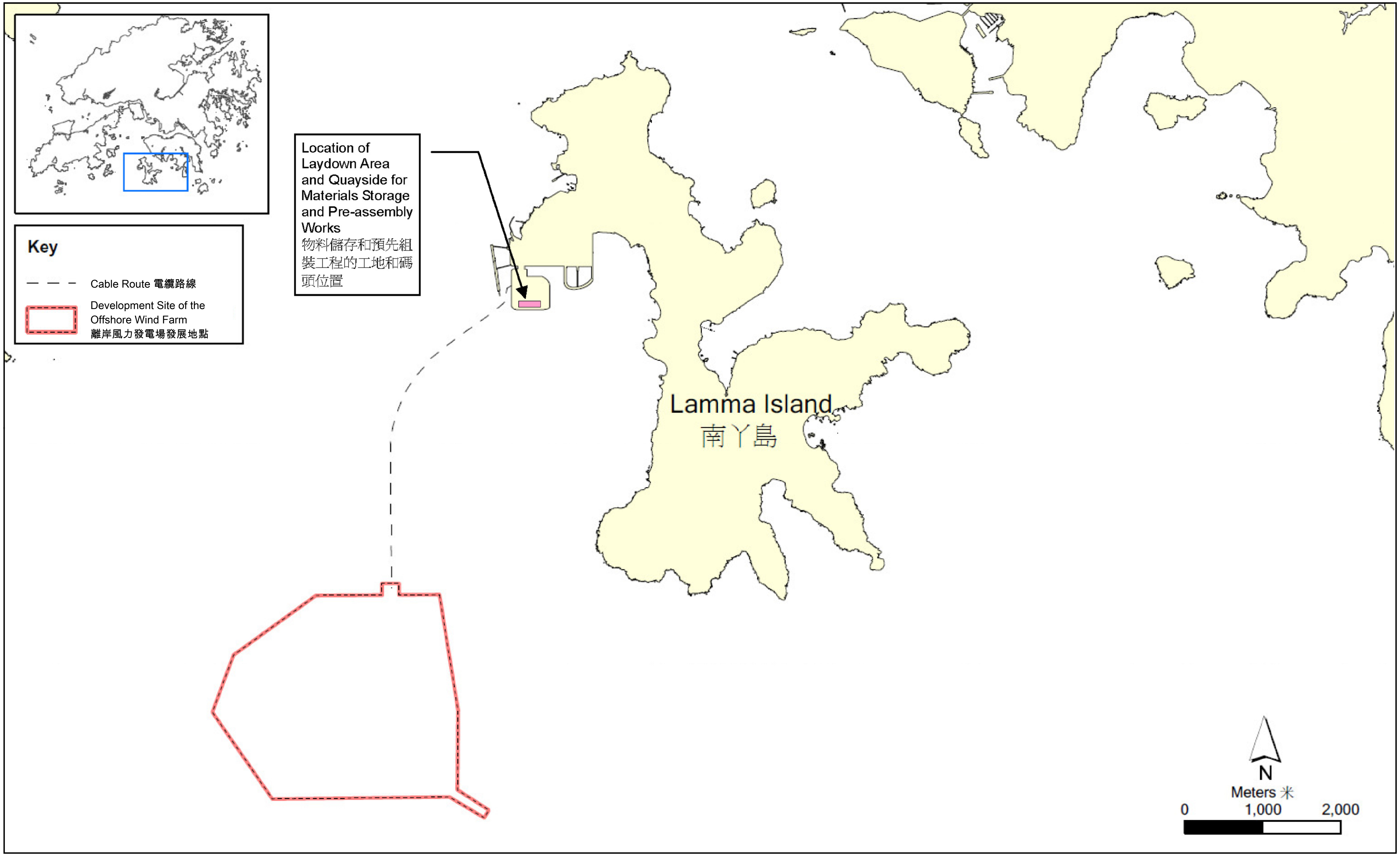

Figure 1.1.1

Location of the Project
(Figure 1 from Environmental Permit No.: EP-394/2010)

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Date: 5/8/2021

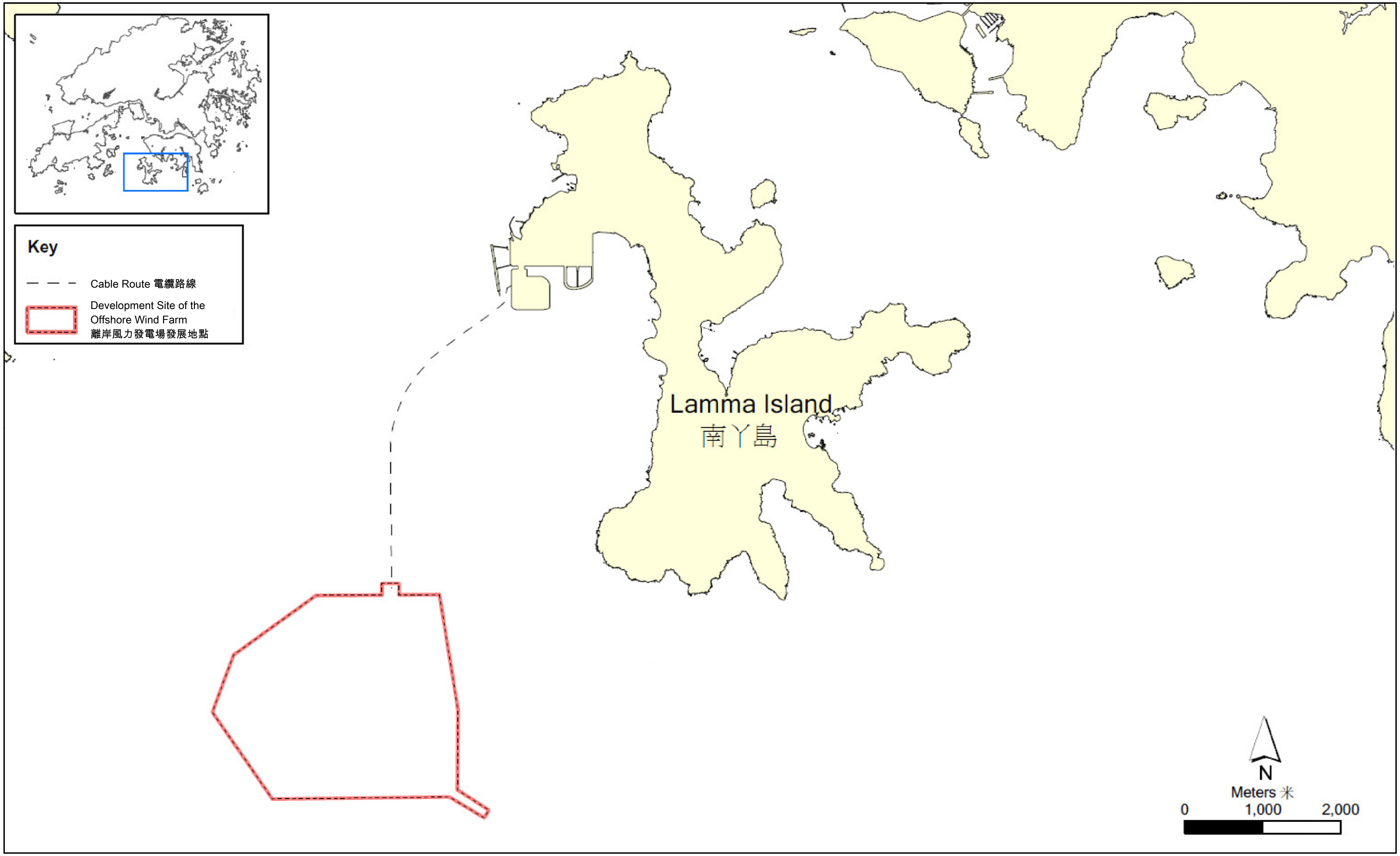

Figure 1.1.2

Location of the Project
(Updated)

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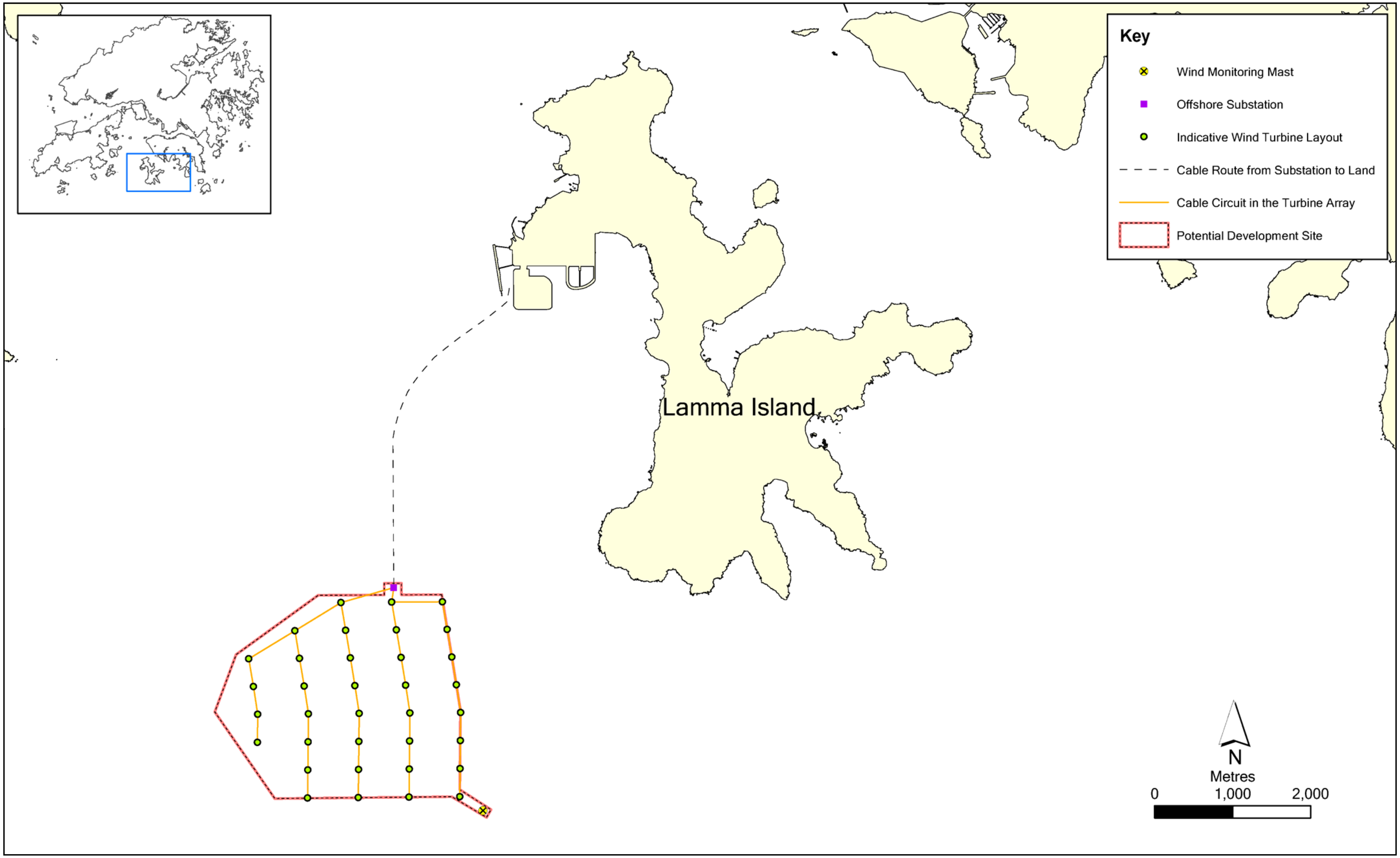

Figure 1.2.1

Location of Project Components
(Figure 5.1 from the Approved EIA Report)

File: T:\GIS\CONTRACT\0607209\mxd\0607209_Windfarm_Layout_from_EIA.mxd
Date: 13/8/2021

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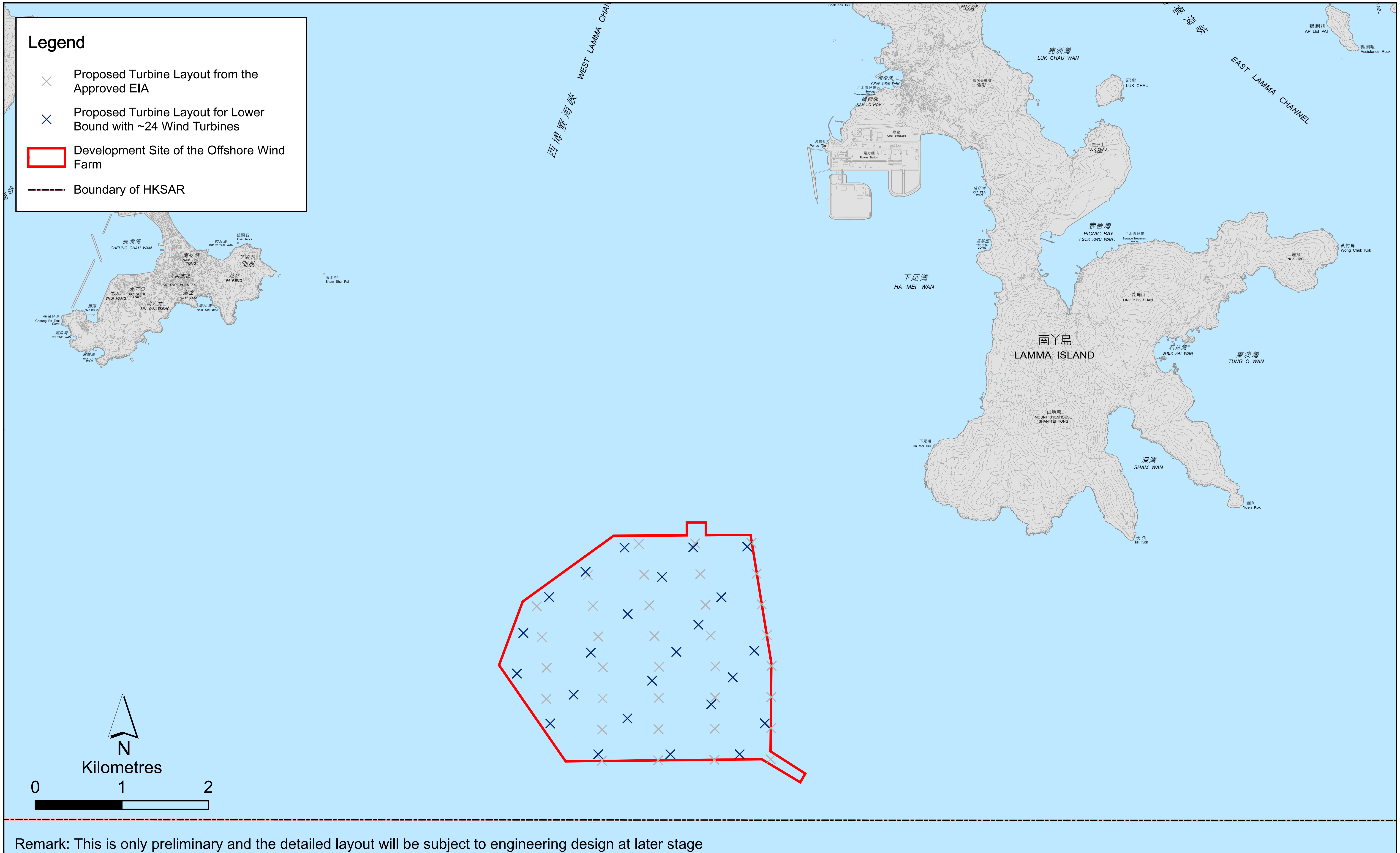

Figure 1.2.2

Proposed Project Layout (Lower Bound)

File: T:\GIS\CONTRACT\0607209\mxd\0607209_6.45MW_Project_Layout.mxd
Date: 7/12/2021

Environmental Resources Management

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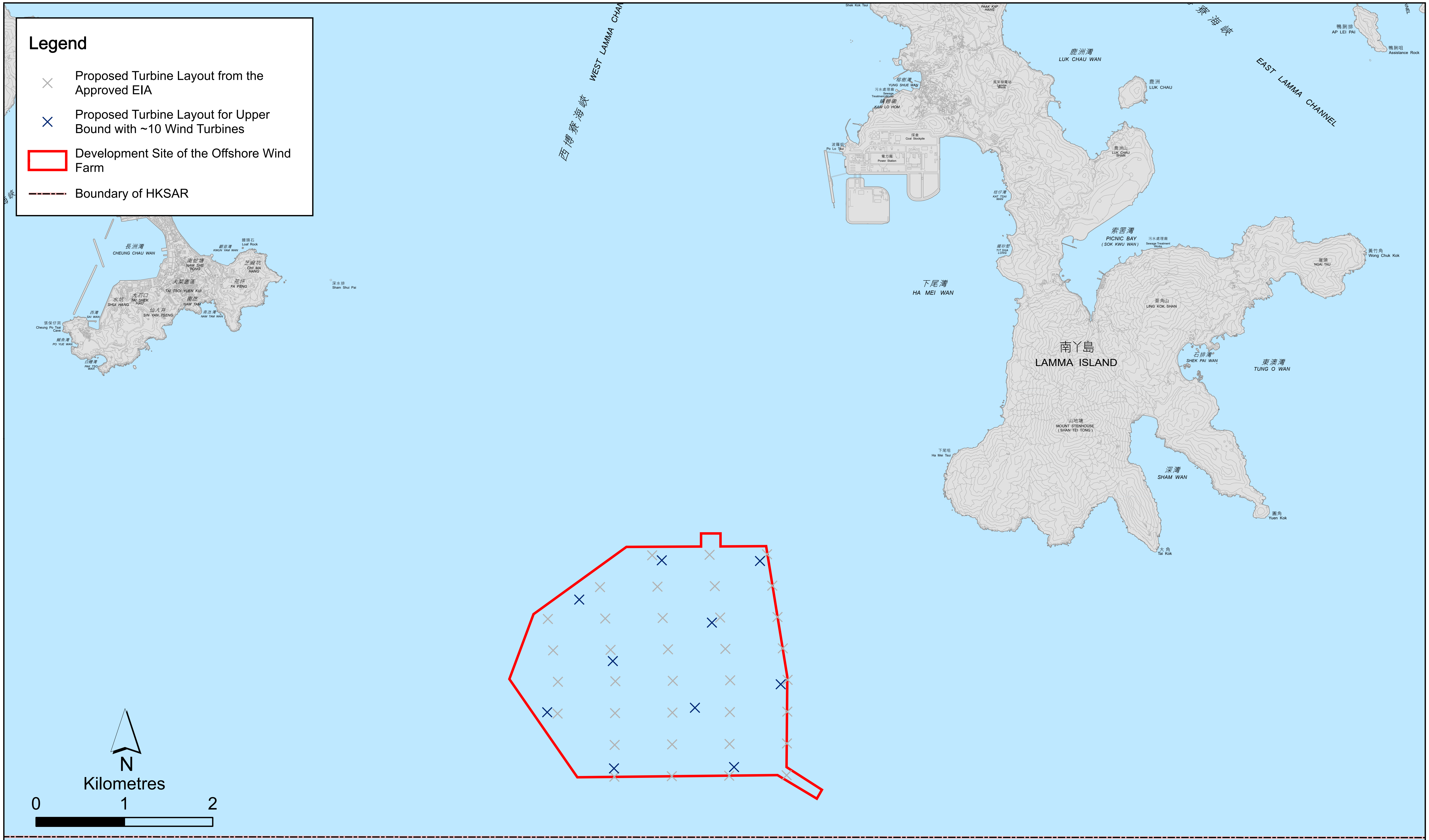

Remark: This is only preliminary and the detailed layout will be subject to engineering design at later stage

Figure 1.2.3

Proposed Project Layout (Upper Bound)

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Date: 7/12/2021

Environmental Resources Management

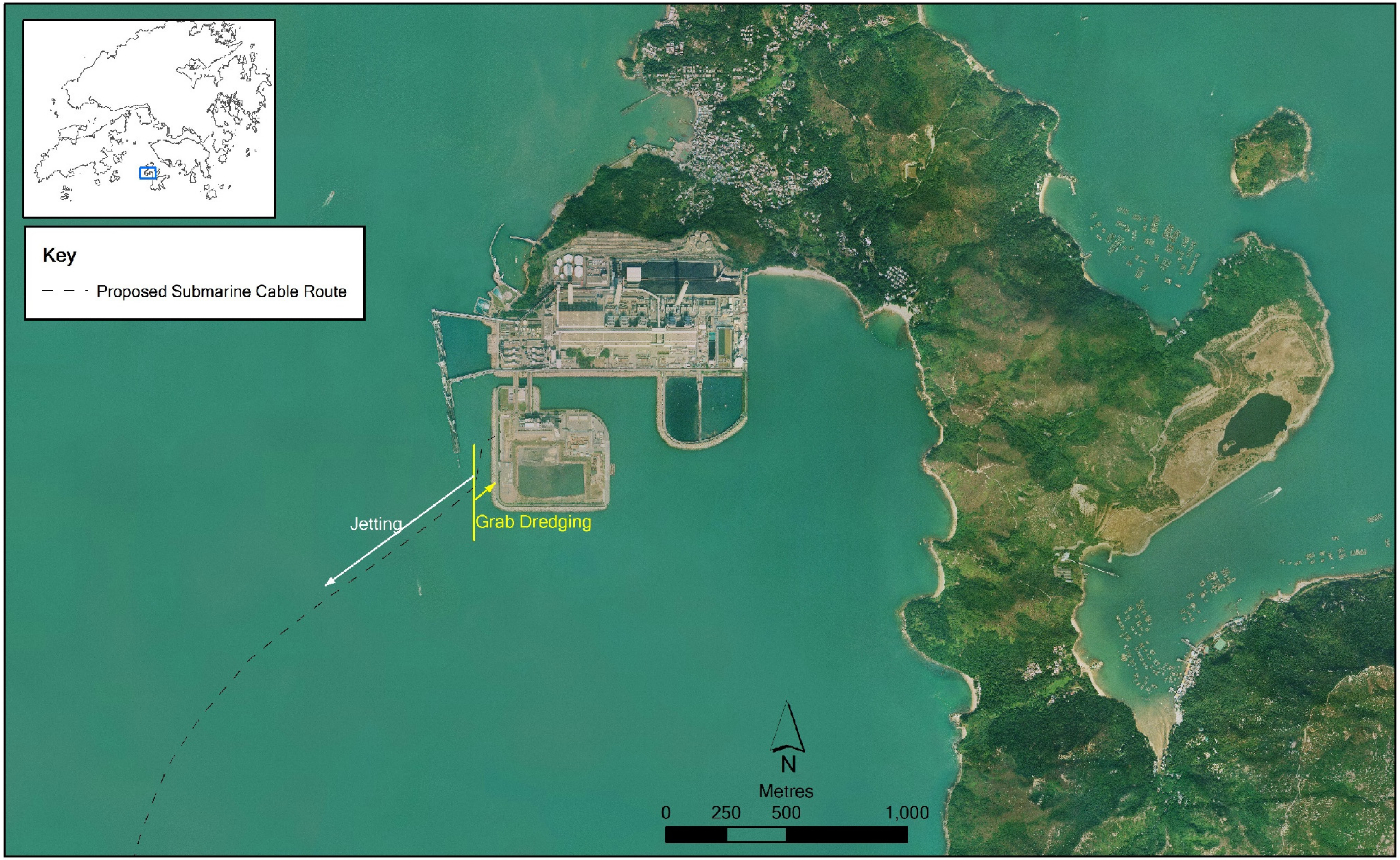

Figure 2.2.1

Zones of Dredging and Jetting
(Figure 2 from Environmental Permit No.: EP-394/2010)

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Date: 24/1/2022

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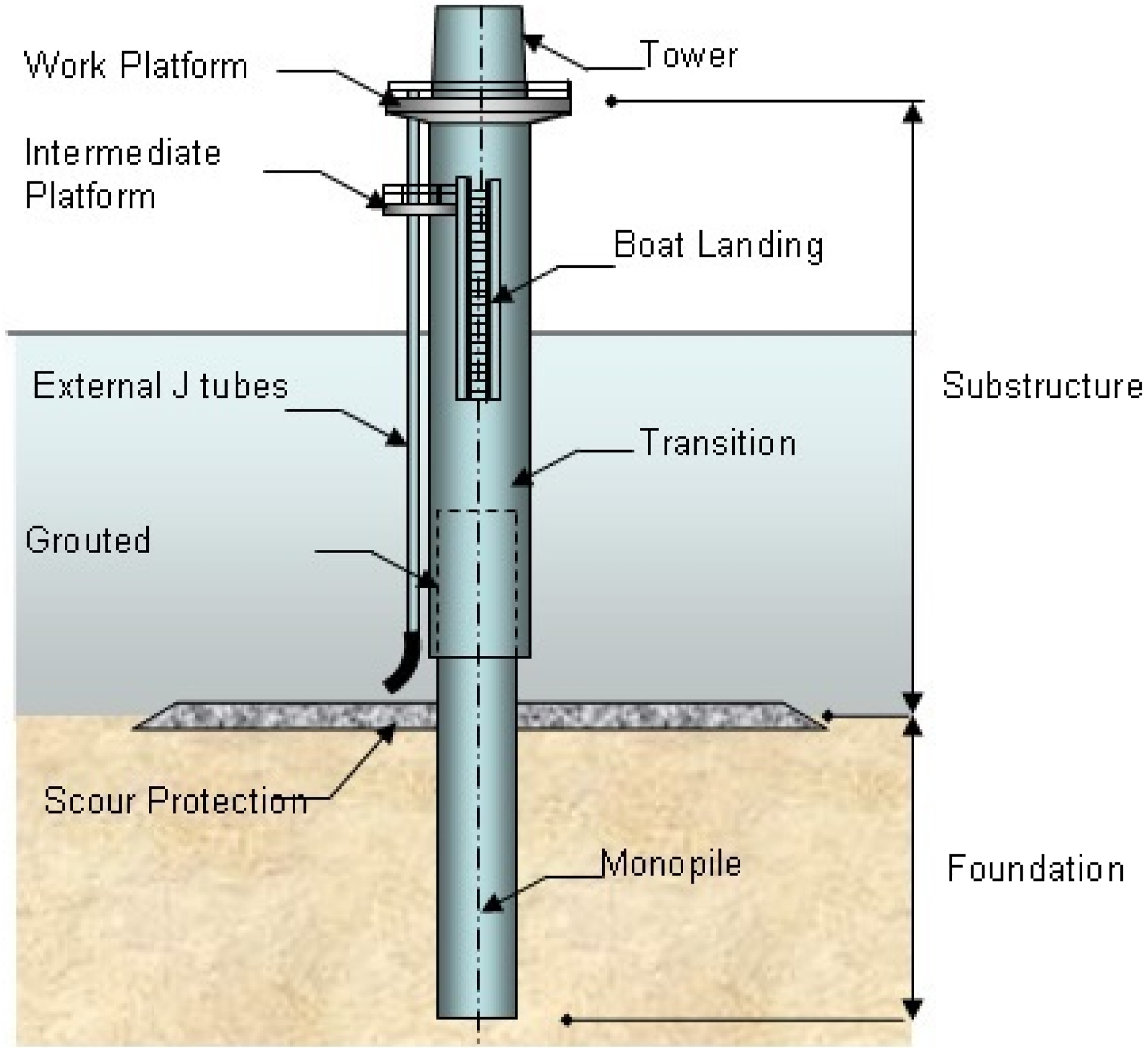
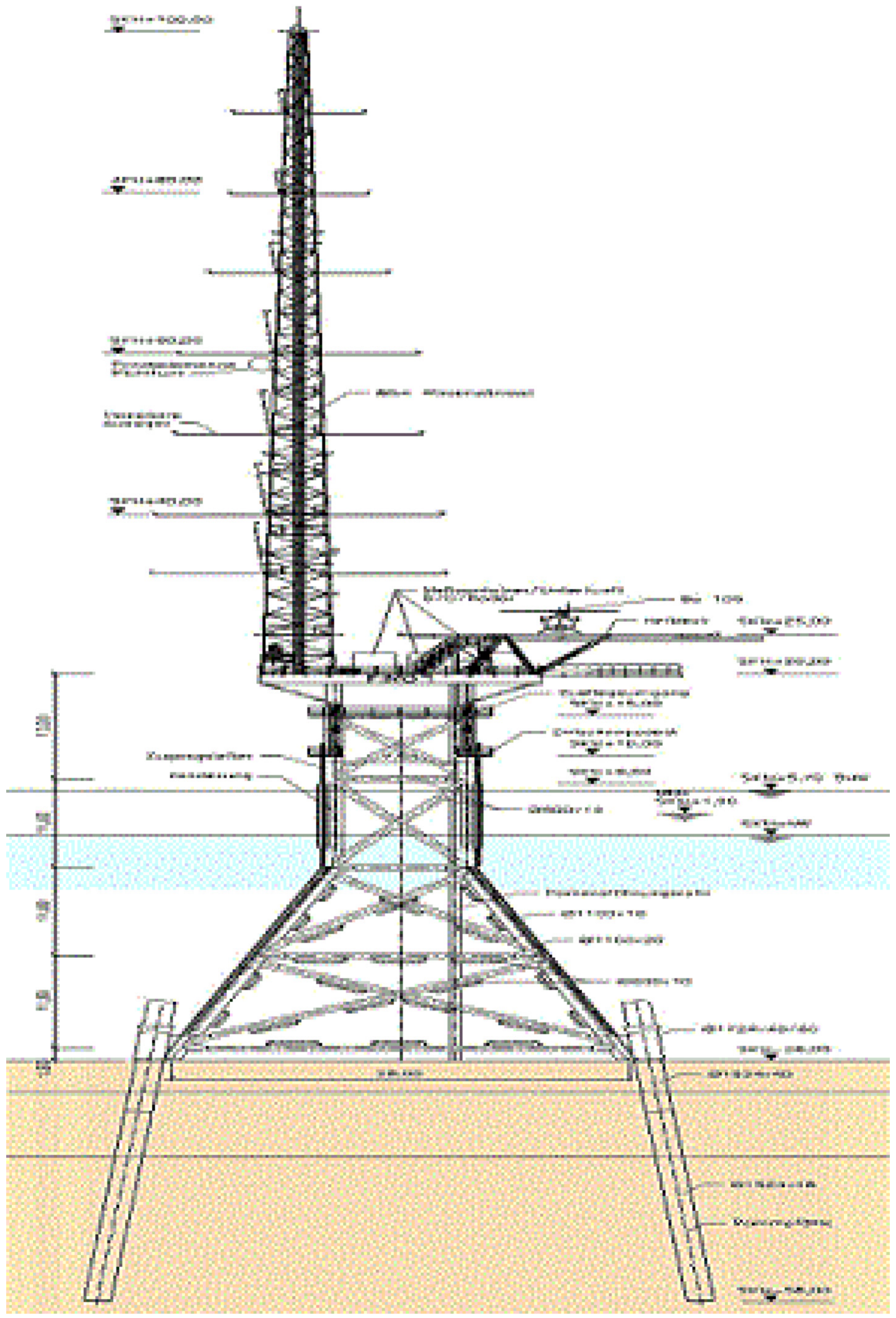


Monopile Foundation



Tetrapod Foundation

Figure 2.2.2

Typical Structure of Monopile and Tetrapod Foundation
(Figures 4.4 and 4.6 from the Approved EIA Report)

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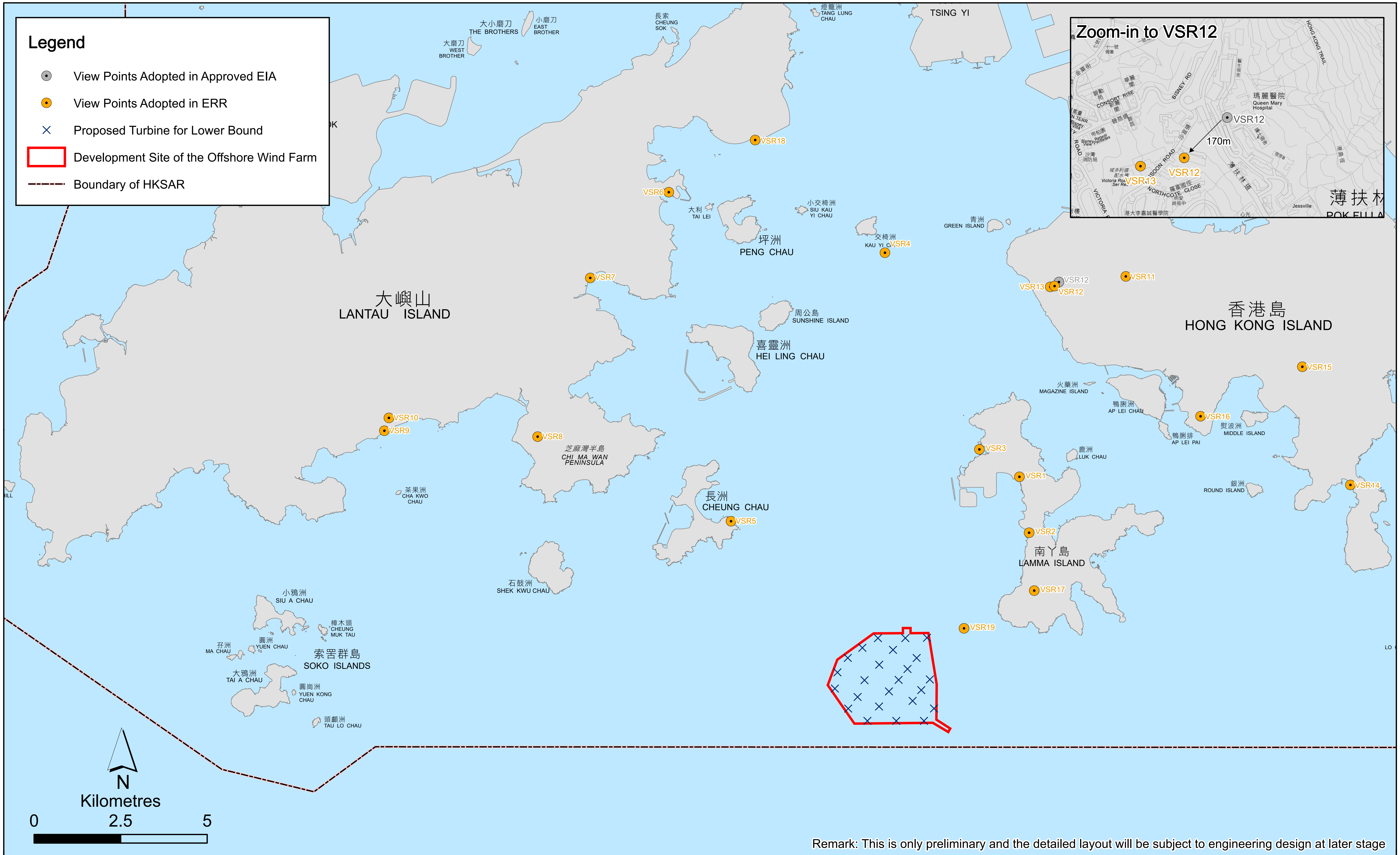

Figure 3.6.1

View Points and Proposed Project Layout (Lower Bound)

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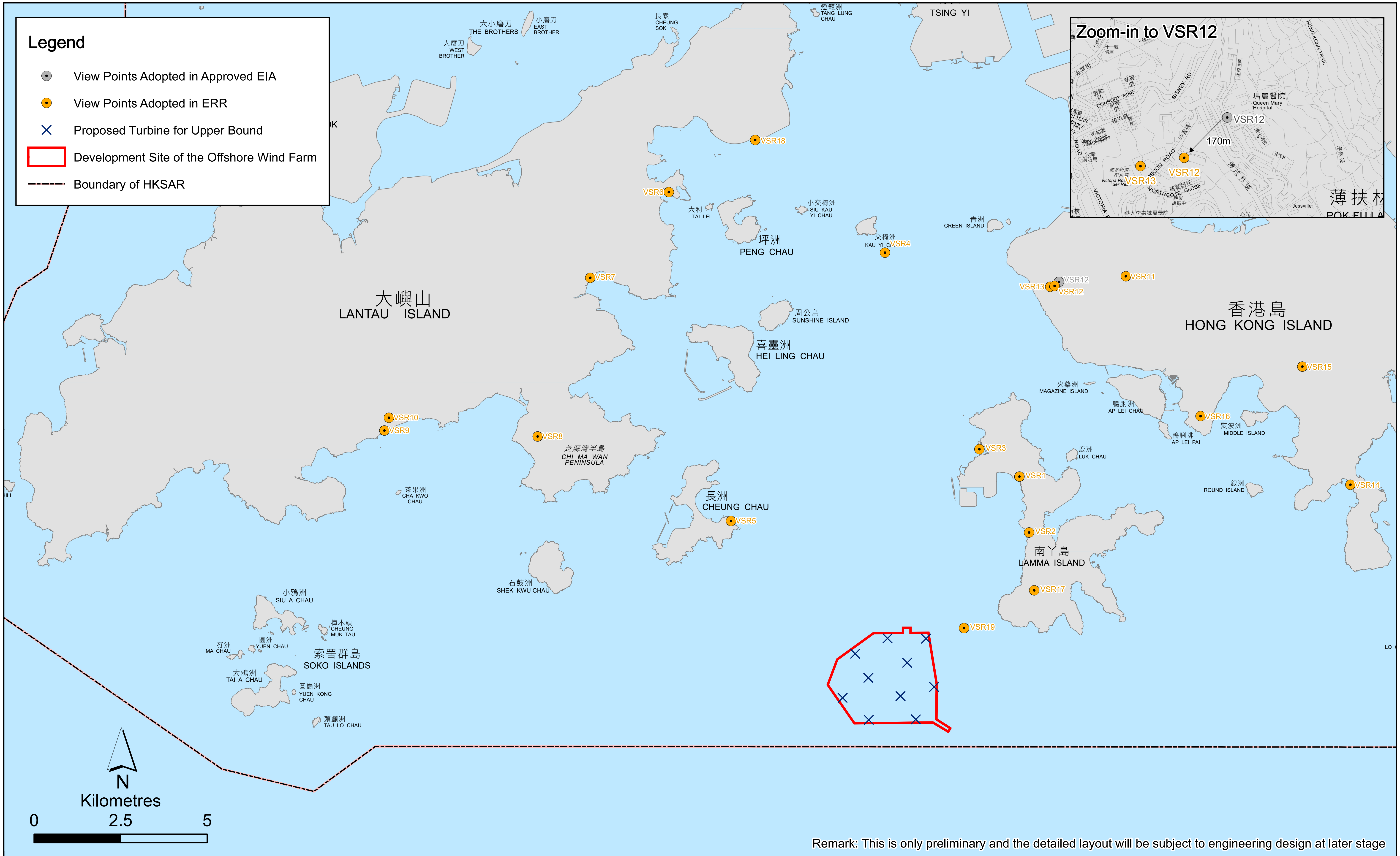

Figure 3.6.2

View Points and Proposed Project Layout (Upper Bound)

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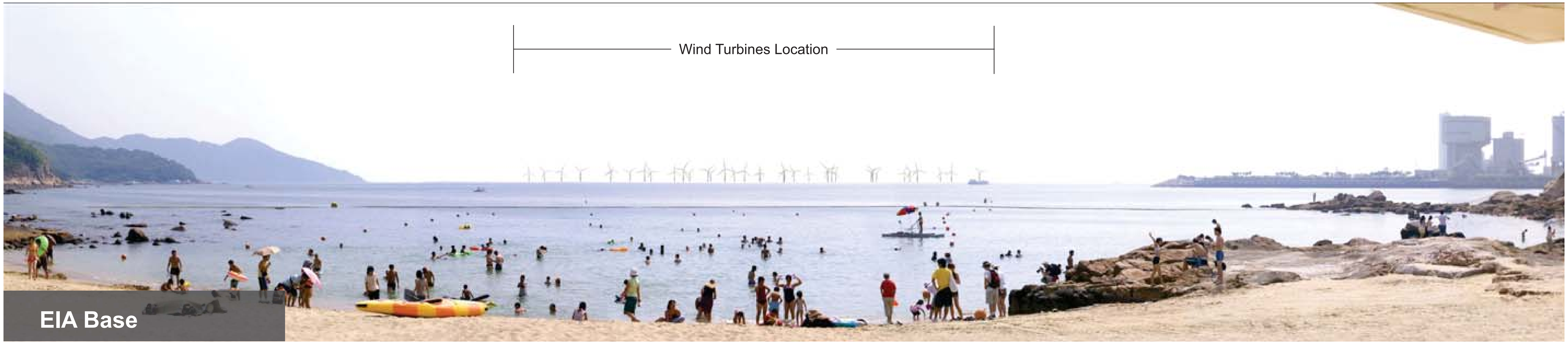

Date Photograph Taken: May 2009

Figure 3.6.3a Viewpoint 1 - Hung Shing Ye Beach (EIA Base)

FILE: 0607209_vsr1.cdr DATE: 23/08/2021

Date Photograph Taken: June 2021

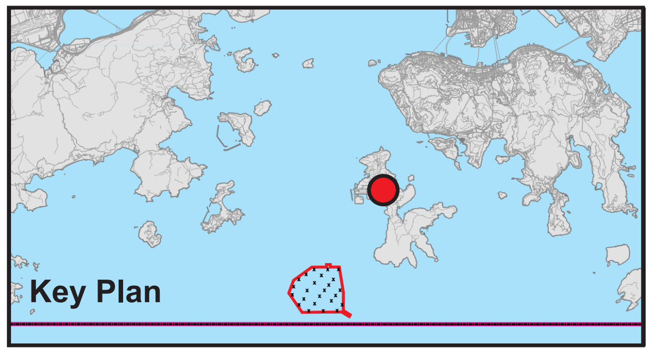

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Figure 3.6.3b | **Viewpoint 1 - Hung Shing Ye Beach (Lower Bound - 6.45MW Layout)**

FILE: 0607209_vsr1.cdr DATE: 23/08/2021

Date Photograph Taken: June 2021

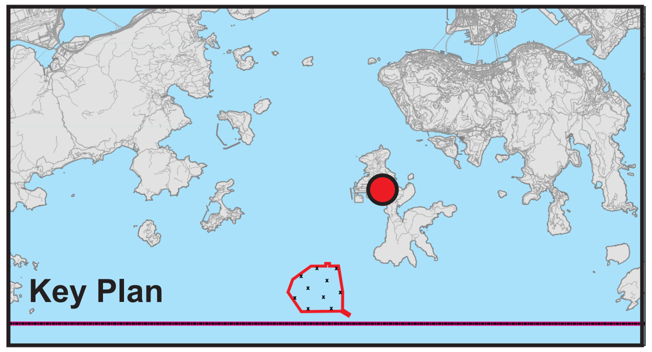

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Figure 3.6.3c **Viewpoint 1 - Hung Shing Ye Beach (Upper Bound - 15MW Layout)**

FILE: 0607209_vsr1.cdr DATE: 23/08/2021

Date Photograph Taken: May 2009

Figure 3.6.4a

Viewpoint 2 - Lo So Shing Beach (EIA Base)

FILE: 0607209_vsr2.cdr DATE: 23/08/2021

Date Photograph Taken: June 2021

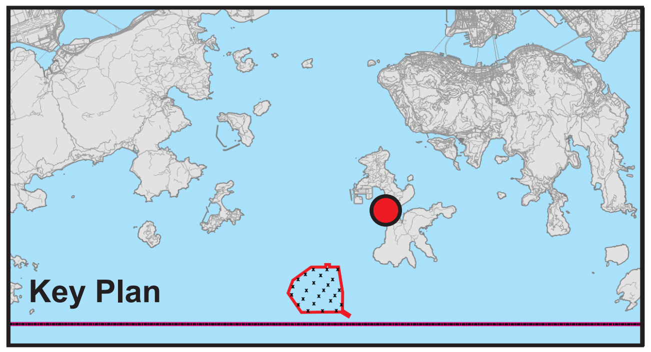

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Figure 3.6.4b

Viewpoint 2 - Lo So Shing Beach (Lower Bound - 6.45MW Layout)

FILE: 0607209_vsr2.cdr DATE: 23/08/2021

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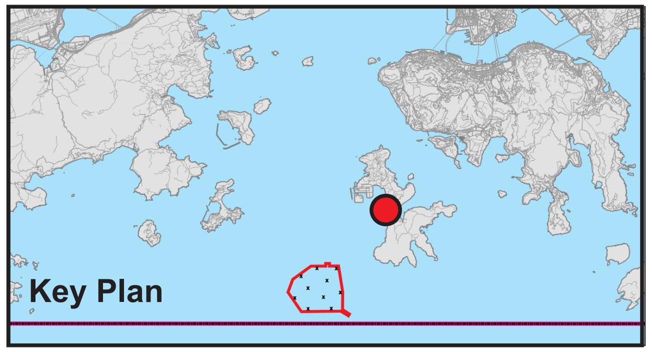

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Figure 3.6.4c

Viewpoint 2 - Lo So Shing Beach (Upper Bound - 15MW Layout)

FILE: 0607209_vsr2.cdr DATE: 23/08/2021

Note: Turbines are blocked by the mountains on the left and not visible to this VSR.

Date Photograph Taken: May 2009

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Figure 3.6.5a

Viewpoint 3 - Yung Shue Wan Ferry Pier (EIA Base)

FILE: 0607209_vsr3.cdr DATE: 18/08/2021

Note: Turbines are blocked by the mountains on the left and not visible to this VSR.

Date Photograph Taken: June 2021

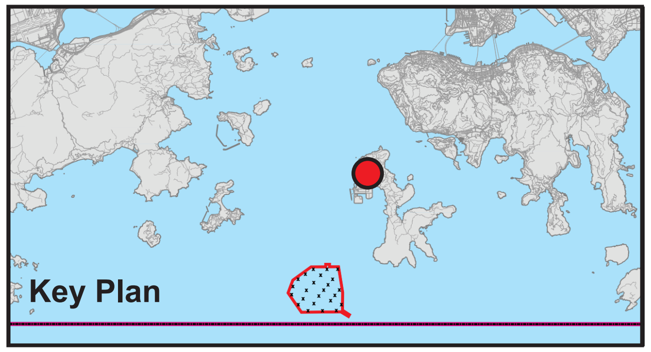

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Figure 3.6.5b

Viewpoint 3 - Yung Shue Wan Ferry Pier (Lower Bound - 6.45MW Layout)

FILE: 0607209_vsr3.cdr DATE: 18/08/2021

Note: Turbines are blocked by the mountains on the left and not visible to this VSR.

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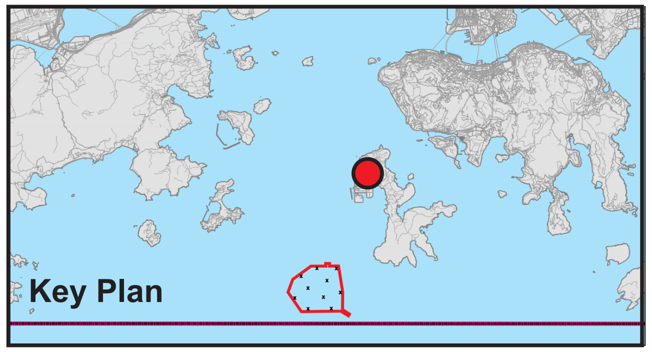

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Figure 3.6.5c

Viewpoint 3 - Yung Shue Wan Ferry Pier (Upper Bound - 15MW Layout)

FILE: 0607209_vsr3.cdr DATE: 16/08/2021

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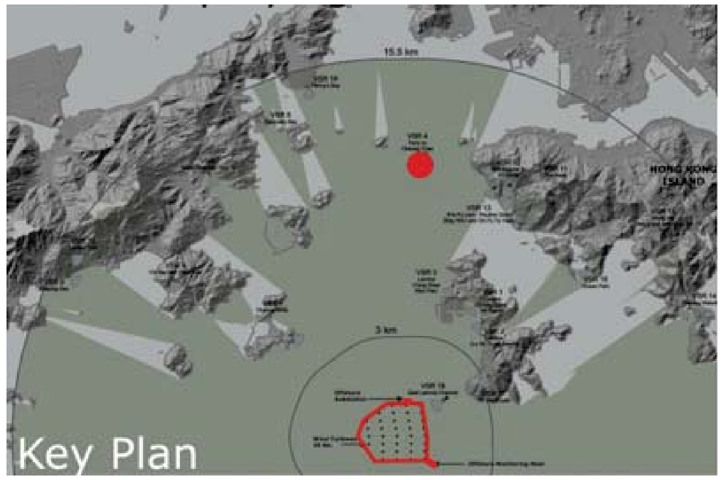
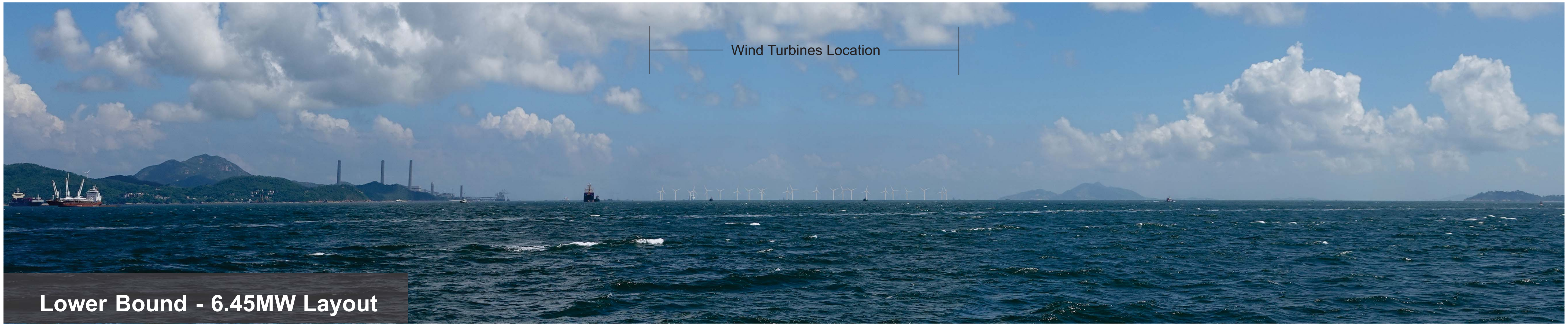


Figure 3.6.6a

Viewpoint 4 - From ferry to Cheung Chau (EIA Base)

FILE: 0607209_vsr4.cdr DATE: 23/08/2021



Date Photograph Taken: July 2021

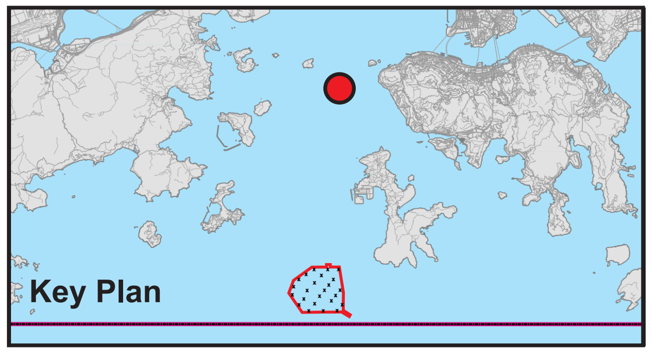


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Figure 3.6.6b

Viewpoint 4 - From ferry to Cheung Chau (Lower Bound - 6.45MW Layout)

FILE: 0607209_vsr4.cdr DATE: 23/08/2021

Date Photograph Taken: July 2021

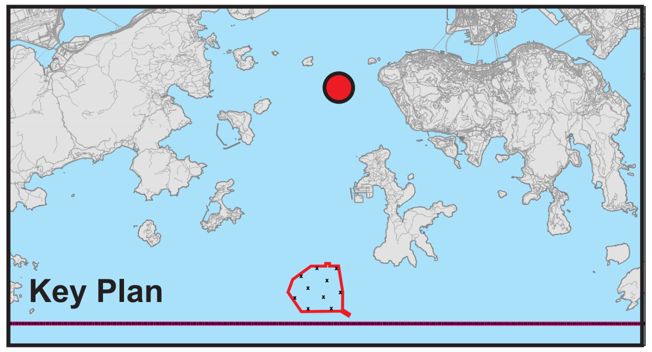

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Figure 3.6.6c

Viewpoint 4 - From ferry to Cheung Chau (Upper Bound - 15MW Layout)

FILE: 0607209_vsr4.cdr

DATE: 23/08/2021

Date Photograph Taken: May 2009

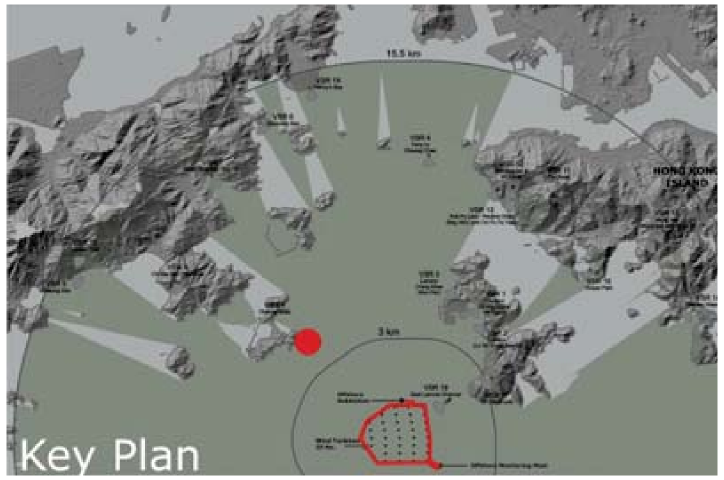
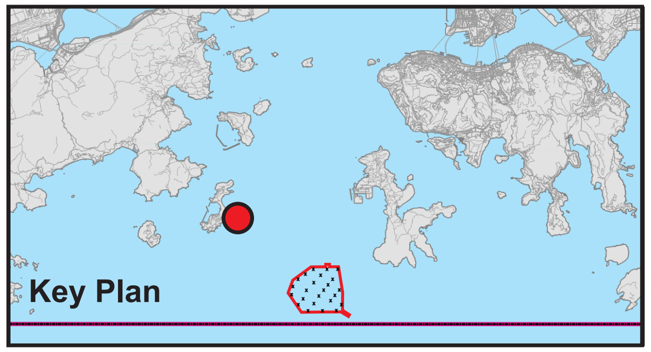


Figure 3.6.7a

Viewpoint 5 - Cheung Chau Lookout (EIA Base)

FILE: 0607209_vsr5.cdr DATE: 23/08/2021

Date Photograph Taken: July 2021



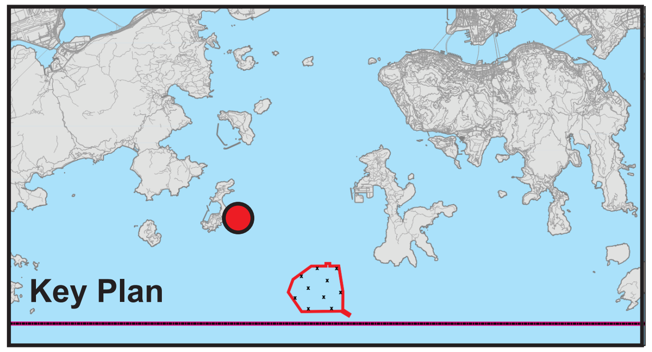
ERM

Figure 3.6.7b

Viewpoint 5 - Cheung Chau Lookout (Lower Bound - 6.45MW Layout)

FILE: 0607209_vsr5.cdr DATE: 23/08/2021

Date Photograph Taken: July 2021

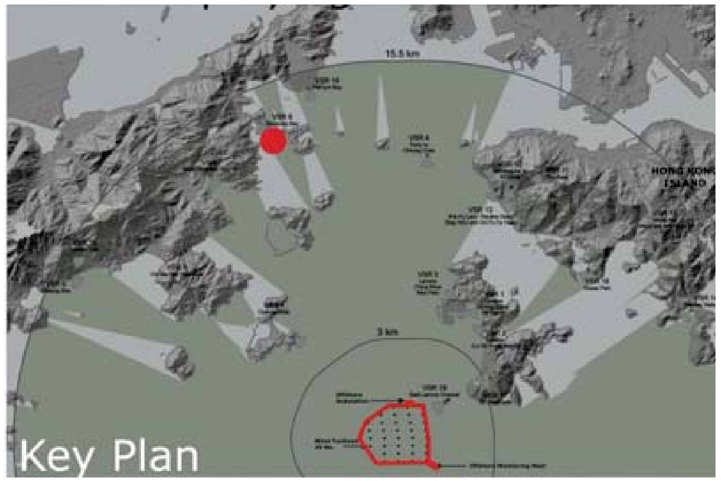


ERM

Figure 3.6.7c

Viewpoint 5 - Cheung Chau Lookout (Upper Bound - 15MW Layout)

FILE: 0607209_vsr5.cdr DATE: 23/08/2021

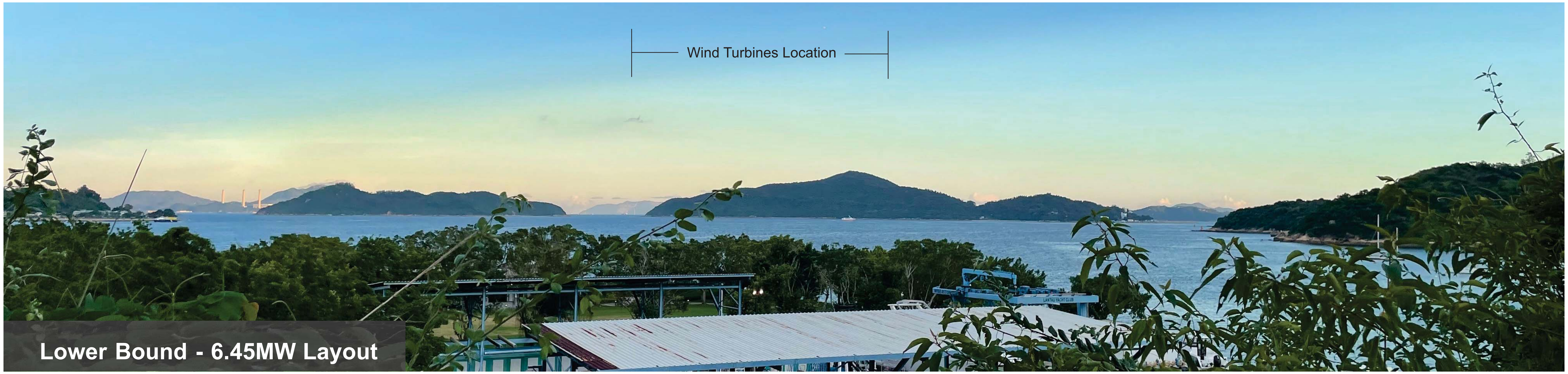


ERM

Figure 3.6.8a

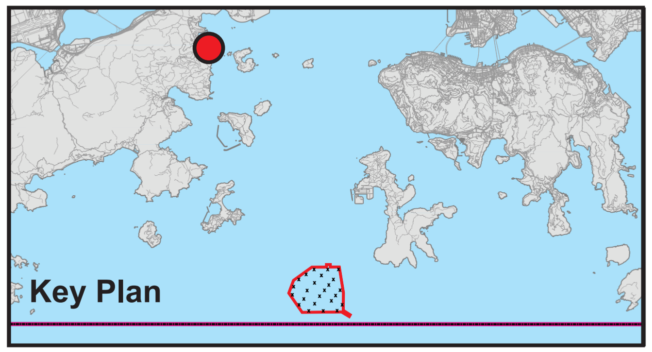
Viewpoint 6 - Coastline Villa, Discovery Bay (EIA Base)

FILE: 0607209_vsr6_v2.cdr DATE: 18/08/2021



Date Photograph Taken: July 2021

Note:
Seaview from the original VSR 6 is blocked by dense vegetation at the time of writing the Report. In accordance with the approved EIA Report, this VSR represents the residents in Discover Bay. The new viewpoint location is slightly adjusted but it can be considered as representative for the original purpose



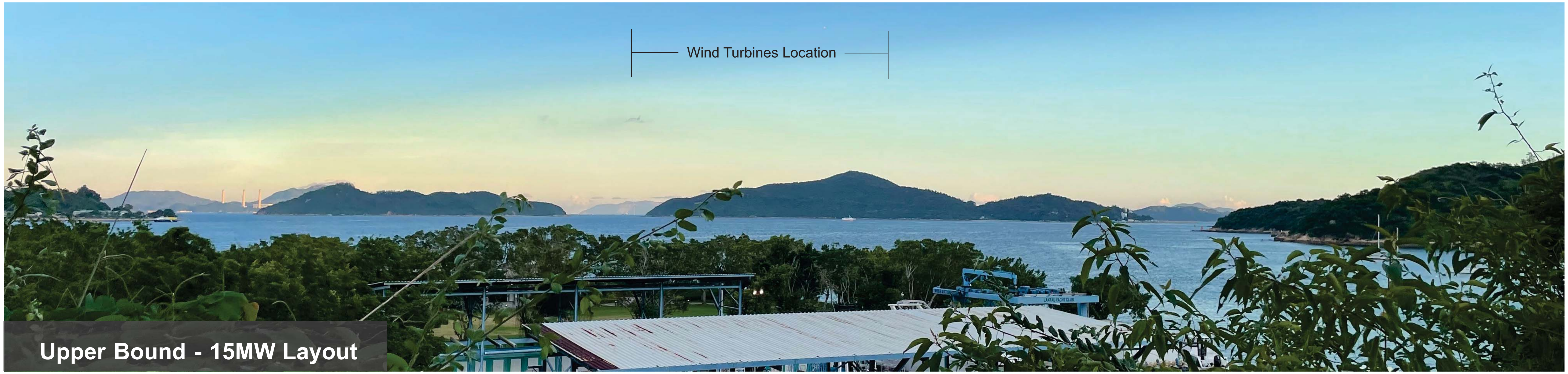
ERM

Figure 3.6.8b

Viewpoint 6 - Discovery Bay (Lower Bound - 6.45MW Layout)

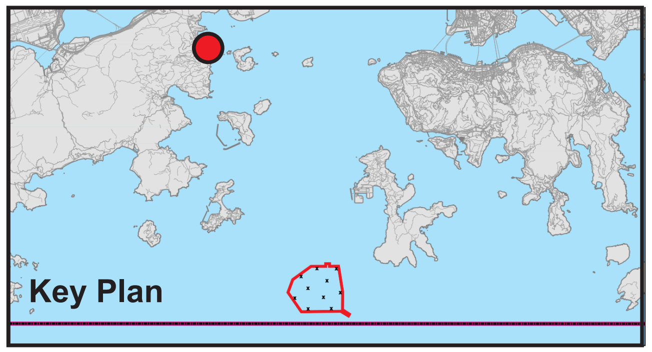
FILE: 0607209_vsr6_v2.cdr

DATE: 18/08/2021



Date Photograph Taken: July 2021

Note:
Seaview from the original VSR 6 is blocked by dense vegetation at the time of writing the Report. In accordance with the approved EIA Report, this VSR represents the residents in Discover Bay. The new viewpoint location is slightly adjusted but it can be considered as representative for the original purpose



ERM

Figure 3.6.8c

Viewpoint 6 - Discovery Bay (Upper Bound - 15MW Layout)

FILE: 0607209_vsr6_v2.cdr

DATE: 18/08/2021

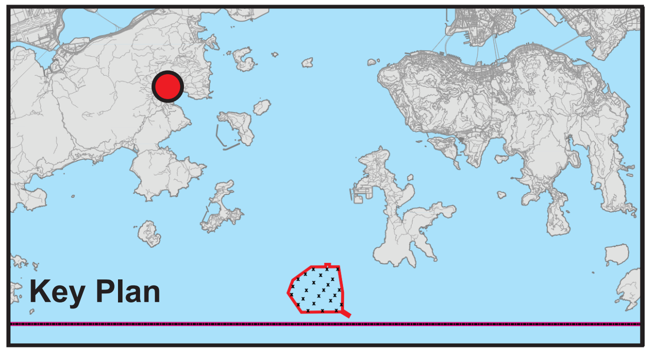
Date Photograph Taken: May 2009

Figure 3.6.9a

Viewpoint 7 - Silver Mine Bay (EIA Base)

FILE: 0607209_vsr7.cdr DATE: 23/08/2021

Date Photograph Taken: July 2021



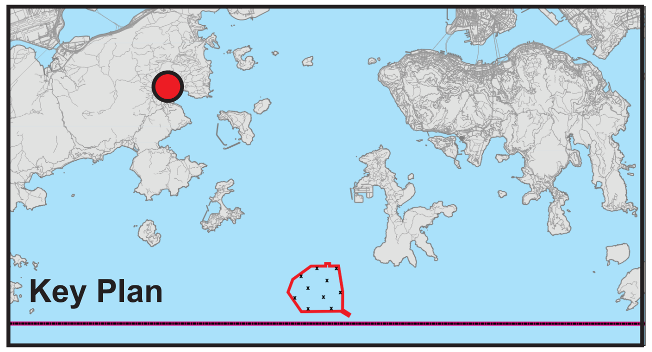
ERM

Figure 3.6.9b

Viewpoint 7 - Silver Mine Bay (Lower Bound - 6.45MW Layout)

FILE: 0607209_vsr7.cdr DATE: 23/08/2021

Date Photograph Taken: July 2021



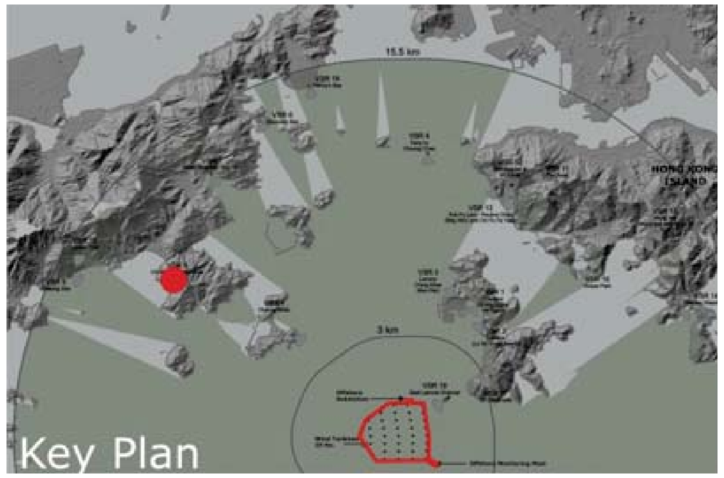
ERM

Figure 3.6.9c

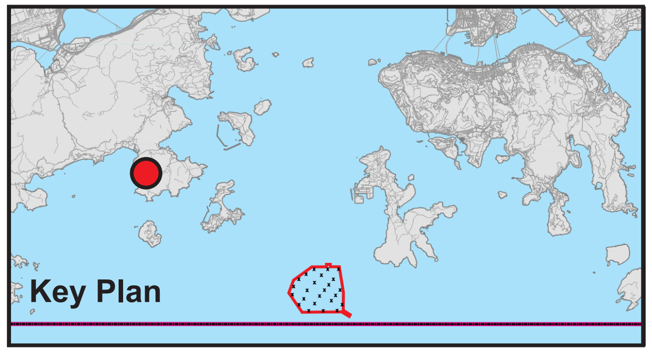
Viewpoint 7 - Silver Mine Bay (Upper Bound - 15MW Layout)

FILE: 0607209_vsr7.cdr DATE: 23/08/2021

Date Photograph Taken: May 2009



Date Photograph Taken: July 2021

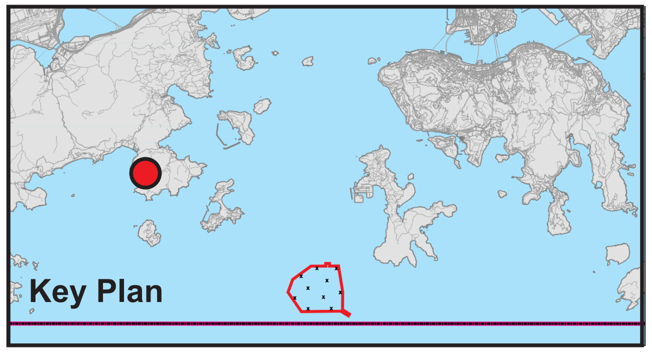


ERM

Figure 3.6.10b Viewpoint 8 - Chi Ma Wan Peninsula (Lower Bound - 6.45MW Layout)

FILE: 0607209_vsr8.cdr DATE: 23/08/2021

Date Photograph Taken: July 2021



ERM

Figure 3.6.10c

Viewpoint 8 - Chi Ma Wan Peninsula (Upper Bound - 15MW Layout)

FILE: 0607209_vsr8.cdr DATE: 23/08/2021

Date Photograph Taken: May 2009

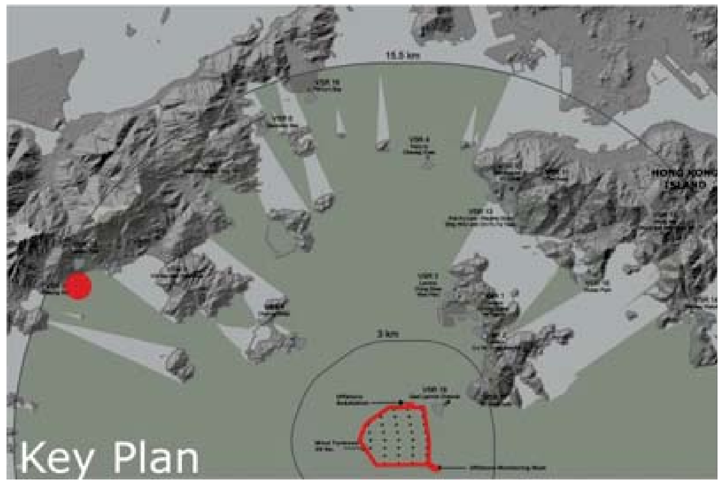
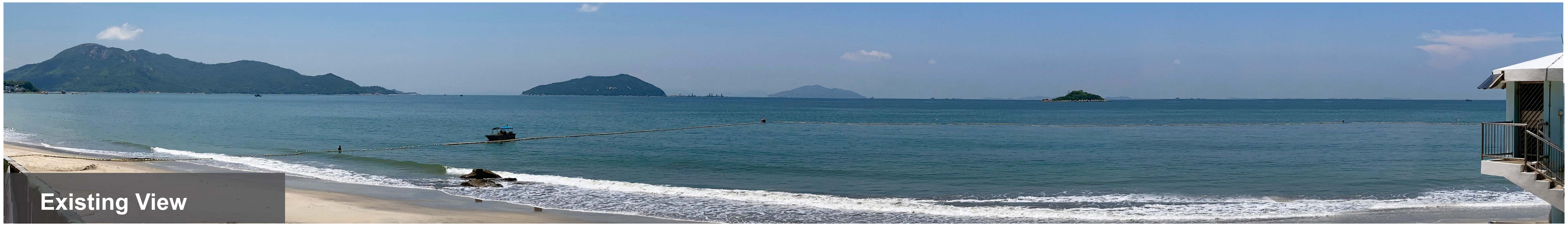


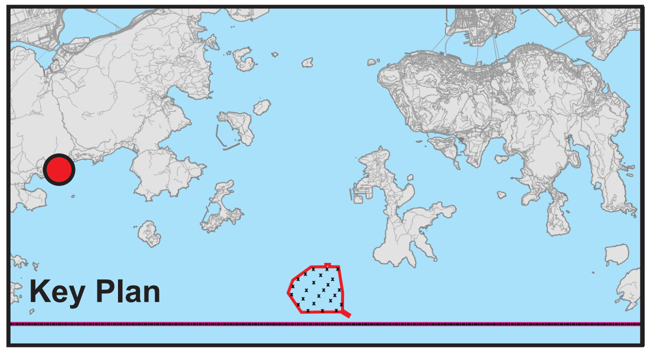
Figure 3.6.11a

Viewpoint 9 - Cheung Sha Beach (EIA Base)

FILE: 0607209_vsr9.cdr DATE: 23/08/2021

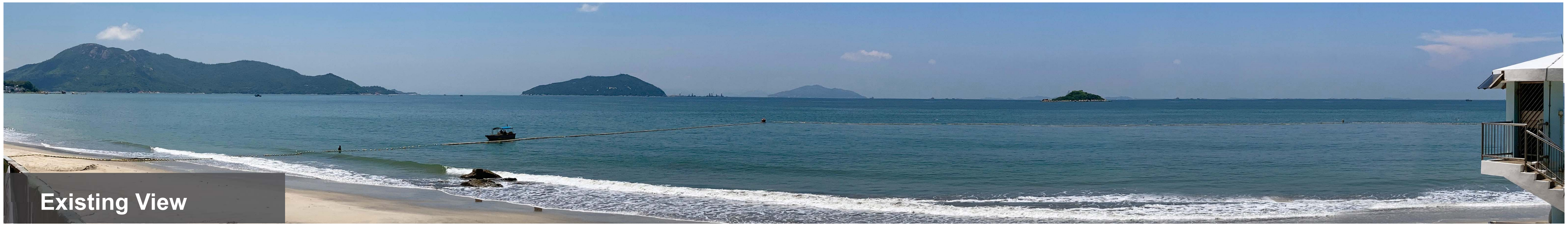


Date Photograph Taken: July 2021

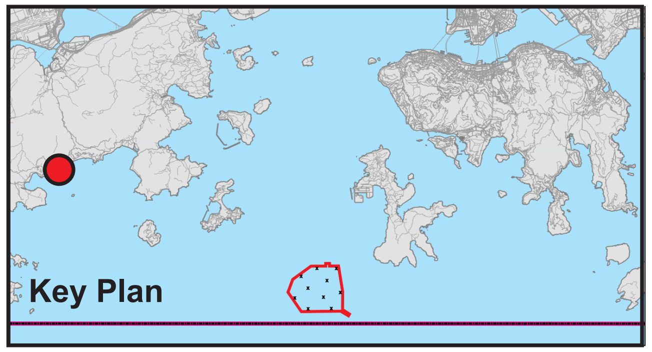


ERM

Figure 3.6.11b **Viewpoint 9 - Cheung Sha Beach (Lower Bound - 6.45MW Layout)**



Date Photograph Taken: July 2021



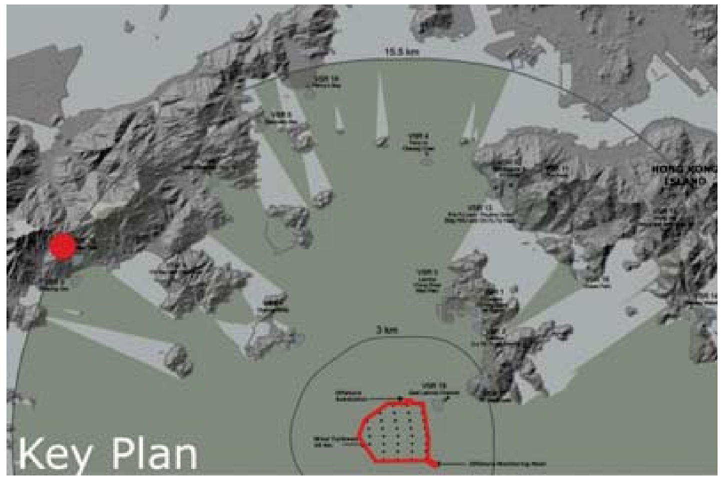
ERM

Figure 3.6.11c

Viewpoint 9 - Cheung Sha Beach (Upper Bound - 15MW Layout)

FILE: 0607209_vsr9.cdr DATE: 23/08/2021

Date Photograph Taken: May 2009



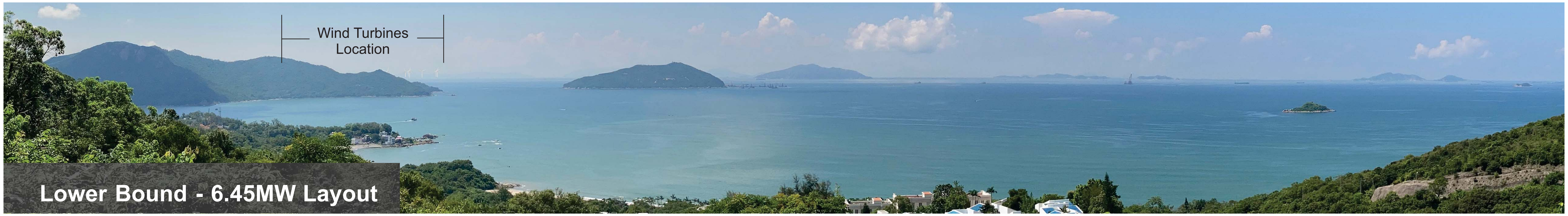
ERM

Figure 3.6.12a

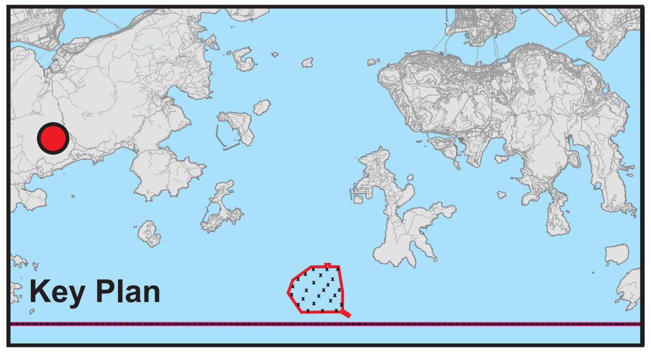
Viewpoint 10 - Lantau Trail (EIA Base)

FILE: 0607209_vsr10.cdr

DATE: 23/08/2021



Date Photograph Taken: July 2021



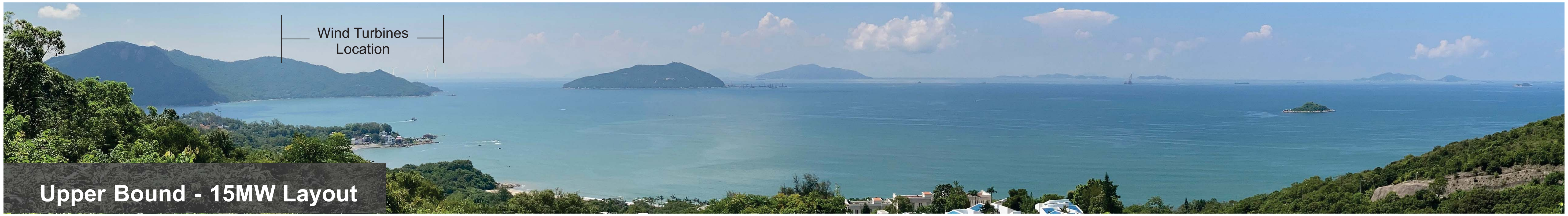
ERM

Figure 3.6.12b

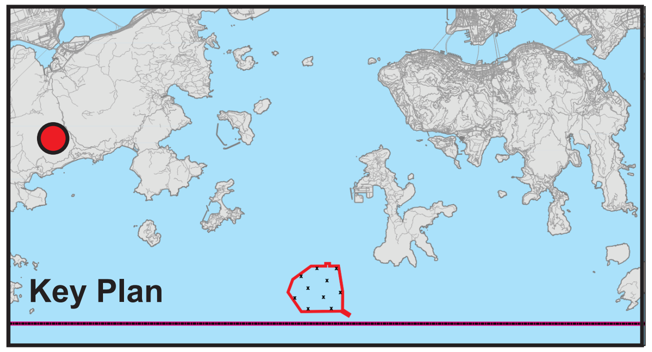
Viewpoint 10 - Lantau Trail (Lower Bound - 6.45MW Layout)

FILE: 0607209_vsr10.cdr

DATE: 23/08/2021



Date Photograph Taken: July 2021



ERM

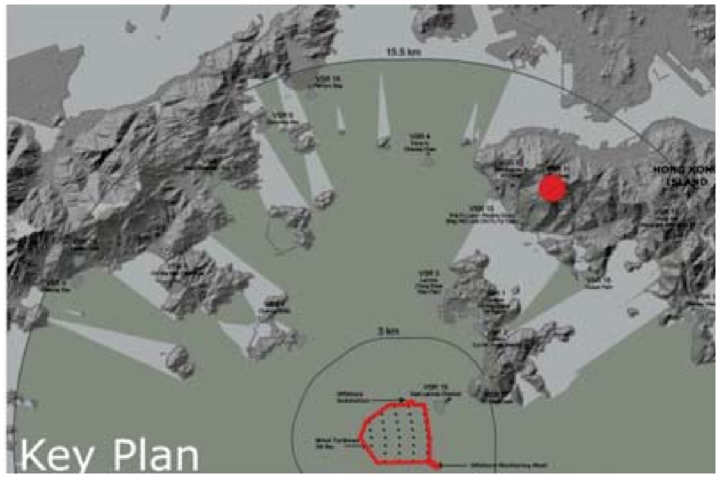
Figure 3.6.12c

Viewpoint 10 - Lantau Trail (Upper Bound - 15MW Layout)

FILE: 0607209_vsr10.cdr

DATE: 23/08/2021

Date Photograph Taken: May 2009



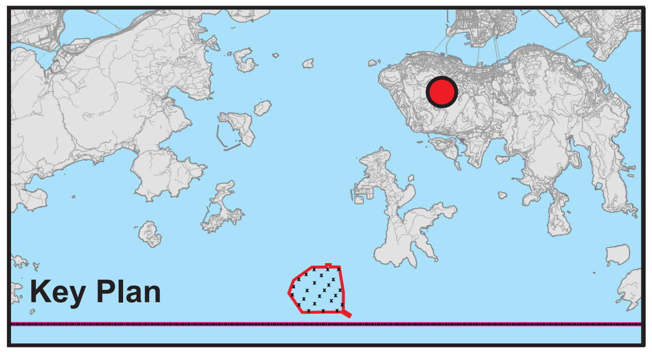
ERM

Figure 3.6.13a

Viewpoint 11 - The Peak (EIA Base)

FILE: 0607209_vsr11.cdr DATE: 16/08/2021

Date Photograph Taken: July 2021

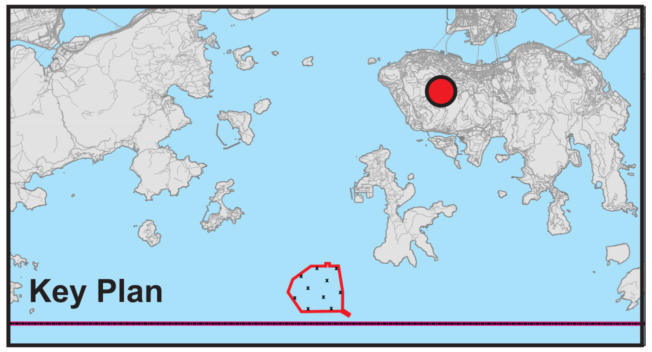


ERM

Figure 3.6.13b **Viewpoint 11 - The Peak (Lower Bound - 6.45MW Layout)**

FILE: 0607209_vsr11.cdr DATE: 16/08/2021

Date Photograph Taken: July 2021

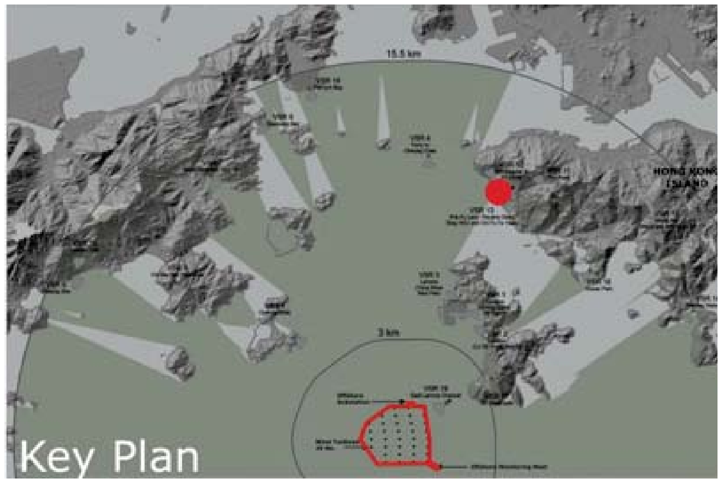


ERM

Figure 3.6.13c **Viewpoint 11 - The Peak (Upper Bound - 15MW Layout)**

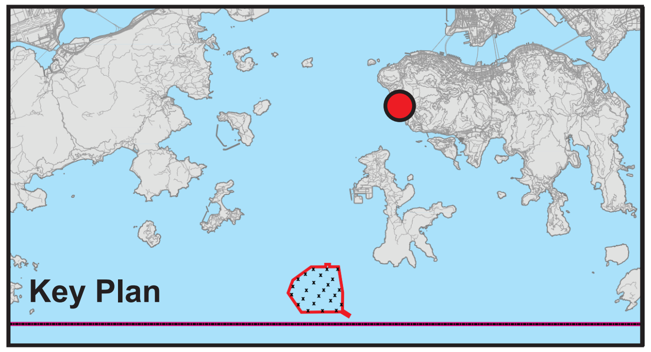
FILE: 0607209_vsr11.cdr DATE: 16/08/2021

Date Photograph Taken: May 2009



Date Photograph Taken: July 2021

Note: Seaview from the original VSR 12 (Queen Mary Hospital and Mt Davis) is blocked by new buildings at the time of writing the Report. In accordance with the approved EIA Report, this VSR represents a mix of workers at hospital, patients at the hospital, visitors at the hospital site, and the recreational visitors of Mt Davis. The new viewpoint location, University of Hong Kong – Hong Kong Jockey Club Building for Interdisciplinary Research, is slightly adjusted but it can be considered as representative for the original purpose.



ERM

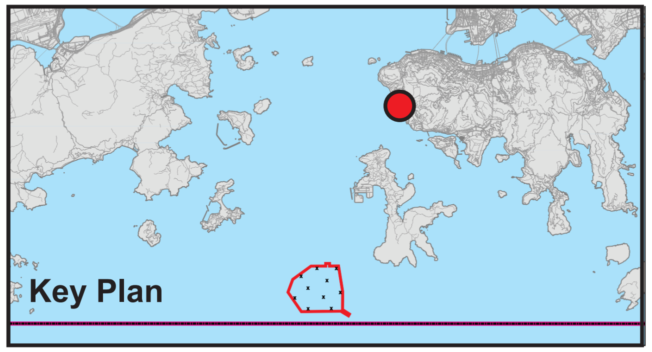
Figure 3.6.14b

Viewpoint 12 - University of Hong Kong – Hong Kong Jockey Club Building for Interdisciplinary Research (Lower Bound - 6.45MW Layout)

FILE: 0607209_vsr12.cdr DATE: 27/08/2021

Date Photograph Taken: July 2021

Note: Seaview from the original VSR 12 (Queen Mary Hospital and Mt Davis) is blocked by new buildings at the time of writing the Report. In accordance with the approved EIA Report, this VSR represents a mix of workers at hospital, patients at the hospital, visitors at the hospital site, and the recreational visitors of Mt Davis. The new viewpoint location, University of Hong Kong – Hong Kong Jockey Club Building for Interdisciplinary Research, is slightly adjusted but it can be considered as representative for the original purpose.



ERM

Figure 3.6.14c

Viewpoint 12 - University of Hong Kong – Hong Kong Jockey Club Building for Interdisciplinary Research (Upper Bound - 15MW Layout)

FILE: 0607209_vsr12.cdr DATE: 27/08/2021

Date Photograph Taken: May 2009

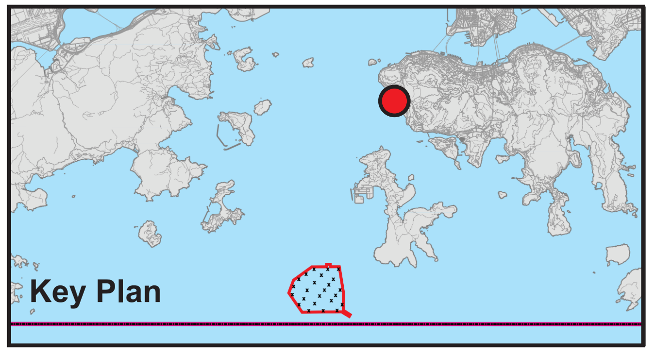
Figure 3.6.15a

Viewpoint 13 - Pauline Chan Building, University of Hong Kong and Chi Fu Fa Yuen, Pok Fu Lam (EIA Base)

FILE: 0607209_vsr13.cdr

DATE: 18/08/2021

Date Photograph Taken: July 2021



ERM

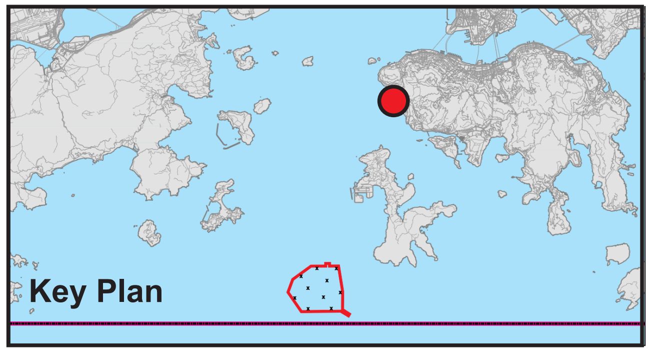
Figure 3.6.15b

Viewpoint 13 - Pauline Chan Building, University of Hong Kong and Chi Fu Fa Yuen, Pok Fu Lam (Lower Bound - 6.45MW Layout)

FILE: 0607209_vsr13.cdr

DATE: 18/08/2021

Date Photograph Taken: July 2021



ERM

Figure 3.6.15c

Viewpoint 13 - Pauline Chan Building, University of Hong Kong and Chi Fu Fa Yuen, Pok Fu Lam (Upper Bound - 15MW Layout)

FILE: 0607209_vsr13.cdr

DATE: 18/08/2021

Date Photograph Taken: May 2009

Note: Turbines are blocked by the mountains on the right and not visible to this VSR.

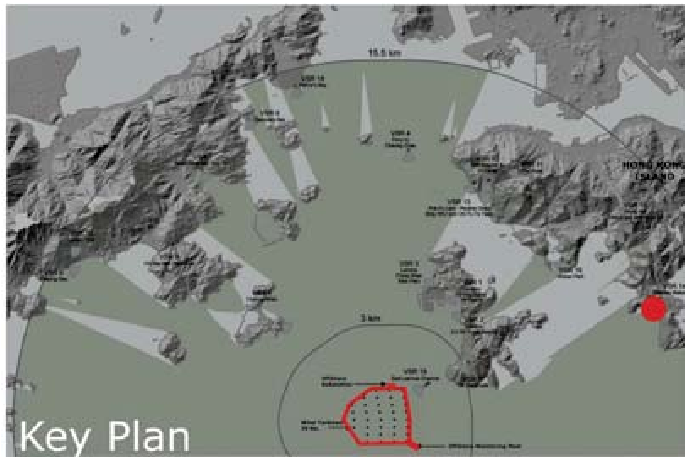
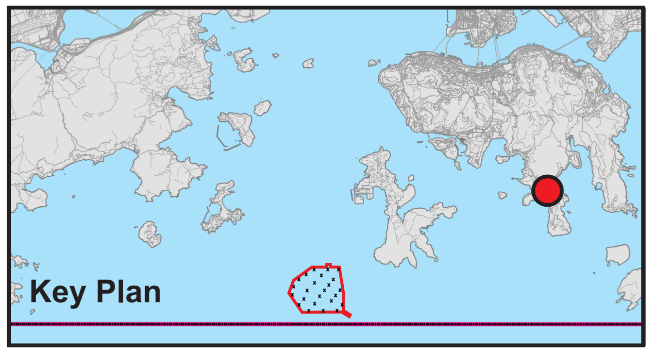


Figure 3.6.16a Viewpoint 14 - Stanley Waterfront (EIA Base)

Note: Turbines are blocked by the mountains on the right and not visible to this VSR.

Date Photograph Taken: July 2021



ERM

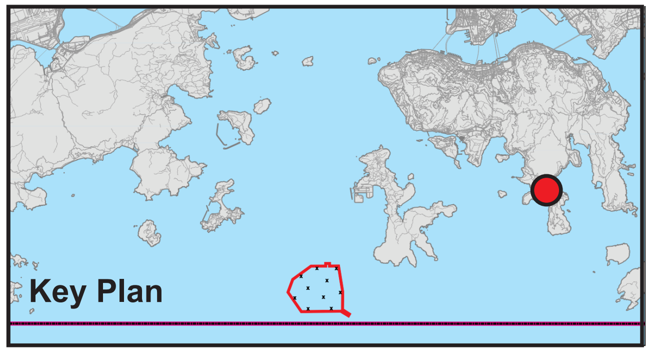
Figure 3.6.16b

Viewpoint 14 - Stanley Waterfront (Lower Bound - 6.45MW Layout)

FILE: 0607209_vsr14.cdr DATE: 18/08/2021

Note: Turbines are blocked by the mountains on the right and not visible to this VSR.

Date Photograph Taken: July 2021



ERM

Figure 3.6.16c

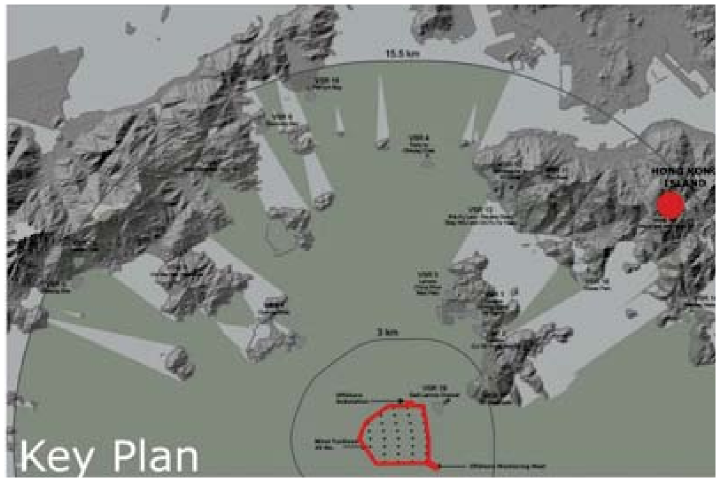
Viewpoint 14 - Stanley Waterfront (Upper Bound - 15MW Layout)

FILE: 0607209_vsr14.cdr

DATE: 18/08/2021

Date Photograph Taken: May 2009

Note: Turbines are blocked by the mountains on the right and not visible to this VSR.



ERM

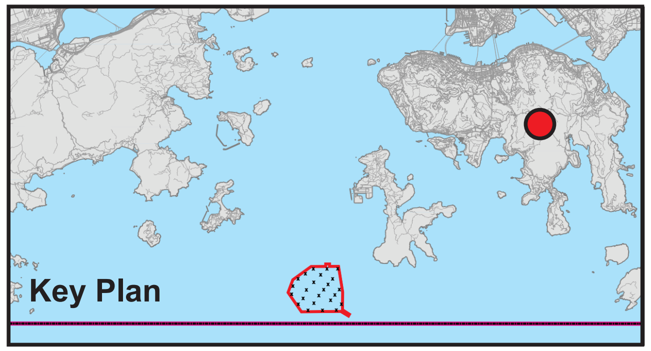
Figure 3.6.17a

Viewpoint 15 - Wong Nai Chung Gap (EIA Base)

FILE: 0607209_vsr15.cdr DATE: 18/08/2021

Note: Turbines are blocked by the mountains on the right and not visible to this VSR.

Date Photograph Taken: July 2021



ERM

Figure 3.6.17b

Viewpoint 15 - Wong Nai Chung Gap (Lower Bound - 6.45MW Layout)

FILE: 0607209_vsr15.cdr DATE: 18/08/2021

Note: Turbines are blocked by the mountains on the right and not visible to this VSR.

Date Photograph Taken: July 2021

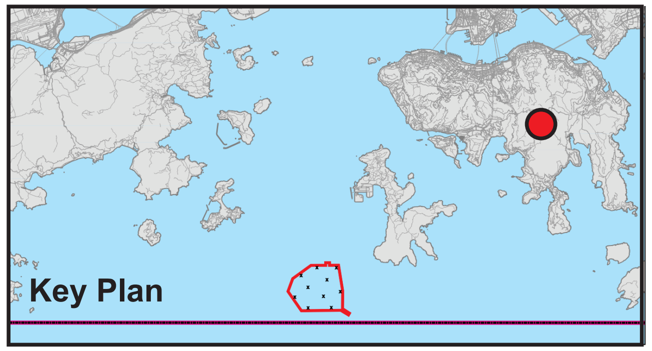
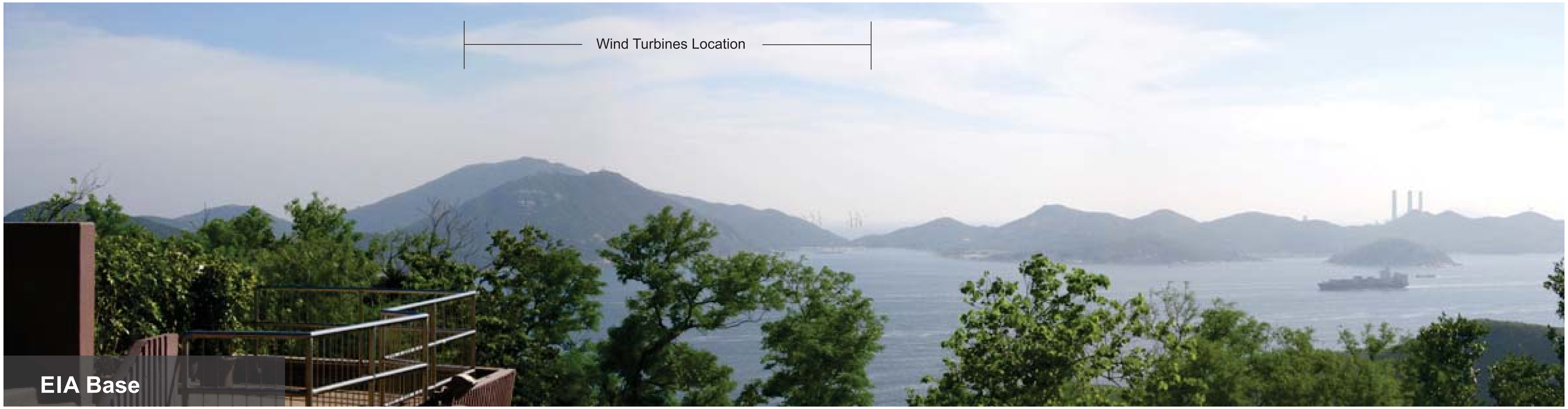


Figure 3.6.17c Viewpoint 15 - Wong Nai Chung Gap (Upper Bound - 15MW Layout)



Date Photograph Taken: May 2009

Note: Turbines are blocked by the mountains on the right and not visible to this VSR.

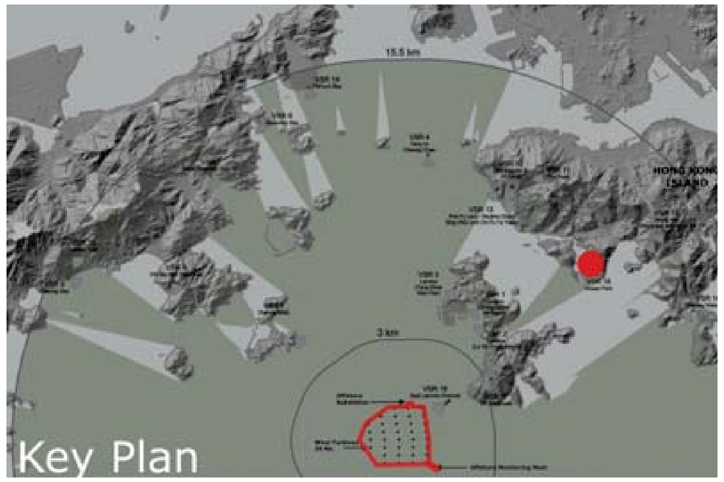


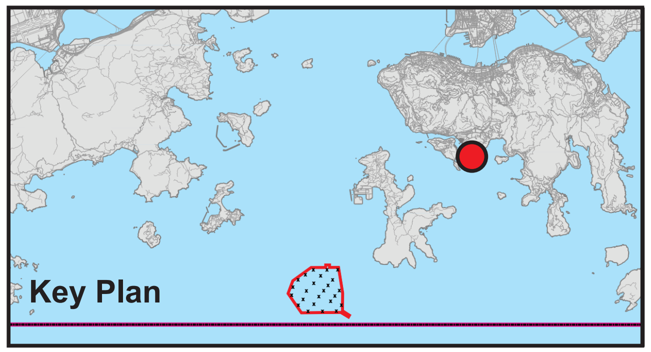
Figure 3.6.18a

Viewpoint 16 - Ocean Park (EIA Base)

FILE: 0607209_vsr16.cdr DATE: 25/08/2021

Note: Turbines are blocked by the mountains on the right and not visible to this VSR.

Date Photograph Taken: July 2021



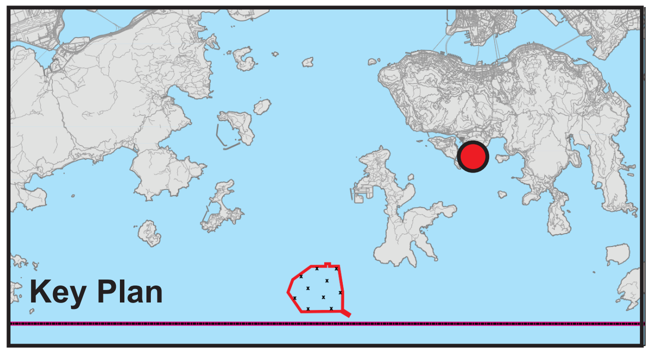
ERM

Figure 3.6.18b **Viewpoint 16 - Ocean Park (Lower Bound - 6.45MW Layout)**

FILE: 0607209_vsr16.cdr DATE: 25/08/2021

Note: Turbines are blocked by the mountains on the right and not visible to this VSR.

Date Photograph Taken: July 2021



ERM

Figure 3.6.18c | **Viewpoint 16 - Ocean Park (Upper Bound - 15MW Layout)**

FILE: 0607209_vsr16.cdr DATE: 25/08/2021

Date Photograph Taken: May 2009

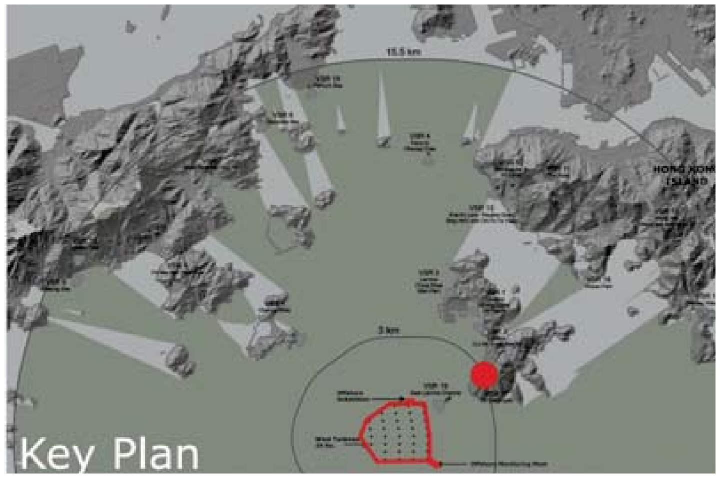
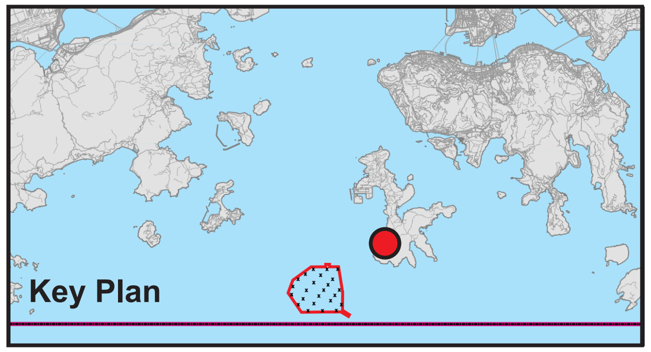


Figure 3.6.19a

Viewpoint 17 - Mt Stenhouse (EIA Base)

FILE: 0607209_vsr17.cdr DATE: 27/08/2021

Date Photograph Taken: June 2021



ERM

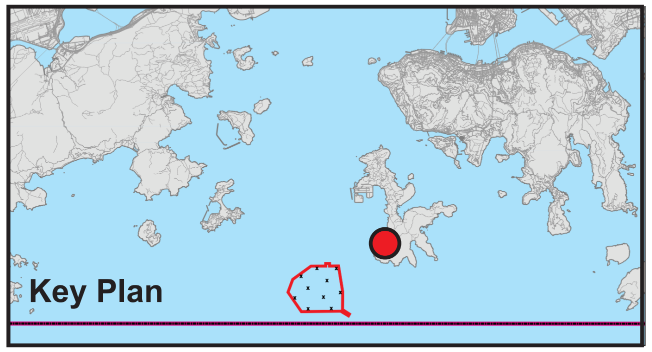
Figure 3.6.19b

Viewpoint 17 - Mt Stenhouse (Lower Bound - 6.45MW Layout)

FILE: 0607209_vsr17.cdr

DATE: 27/08/2021

Date Photograph Taken: June 2021



ERM

Figure 3.6.19c

Viewpoint 17 - Mt Stenhouse (Upper Bound - 15MW Layout)

FILE: 0607209_vsr17.cdr

DATE: 27/08/2021

Date Photograph Taken: May 2009

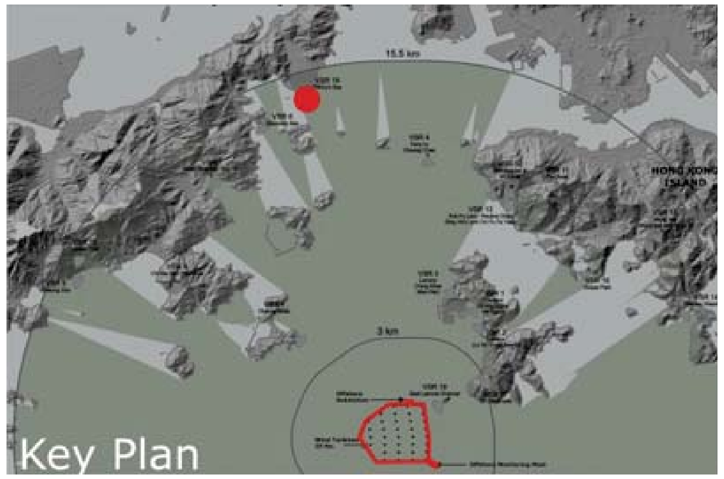


Figure 3.6.20a

Viewpoint 18 - Disneyland Resort Pier, Penny's Bay (EIA Base)

FILE: 0607209_vsr18.cdr

DATE: 21/08/2021

Date Photograph Taken: June 2021

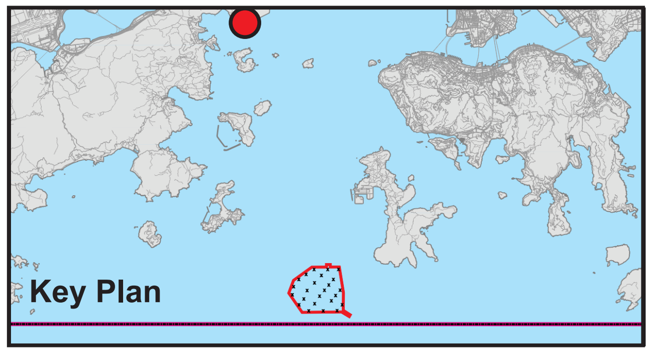


Figure 3.6.20b

Viewpoint 18 - Disneyland Resort Pier, Penny's Bay (Lower Bound - 6.45MW Layout)

FILE: 0607209_vsr18.cdr DATE: 21/08/2021

Date Photograph Taken: June 2021

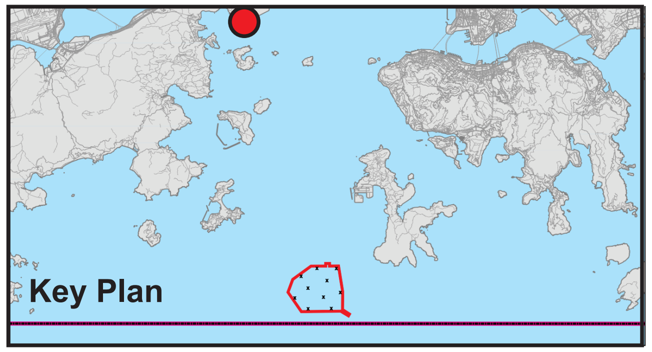
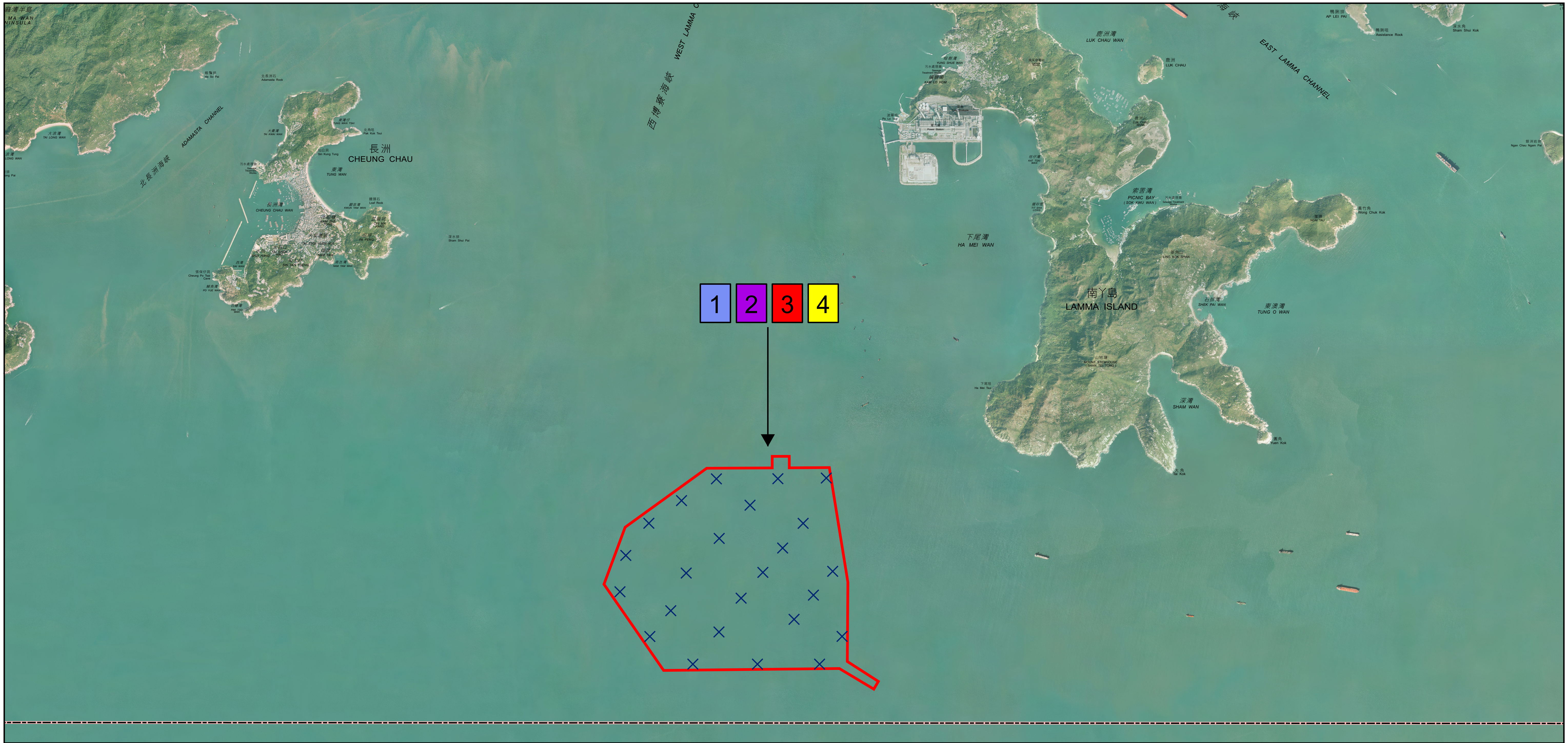


Figure 3.6.20c

Viewpoint 18 - Disneyland Resort Pier, Penny's Bay (Upper Bound - 15MW Layout)

FILE: 0607209_vsr18.cdr

DATE: 21/08/2021



LANDSCAPE MITIGATION MEASURES

1 **VMM 1 Site Selection**
A detailed site selection process has been undertaken. One of the key considerations was to select a site that would the potential visual impacts associated with the Project.

2 **VMM 2 Array Layout**
The array of wind turbines shown in this study is preliminary only. There is an opportunity to amend the layout of the array to reduce the number of turbines visible for the most sensitive viewpoints. It must be noted that visual impacts are only one consideration when determining the layout of the array. Changes to the array are only possible when other technical details such as optimum sea floor and wind flow conditions are achievable.

3 **VMM 3 Colours.**
Appropriate colours for the wind turbines should be selected to reduce their visibility.

4 **VMM 4 Blade Rotation.**
To create a more harmonious visual pattern the blades for all turbines should rotate in the same direction.

Legend

- Proposed Turbine for Lower Bound
- Development Site of the Offshore Wind Farm
- Boundary of HKSAR

Remark: This is only preliminary and the detailed layout will be subject to engineering design at later stage

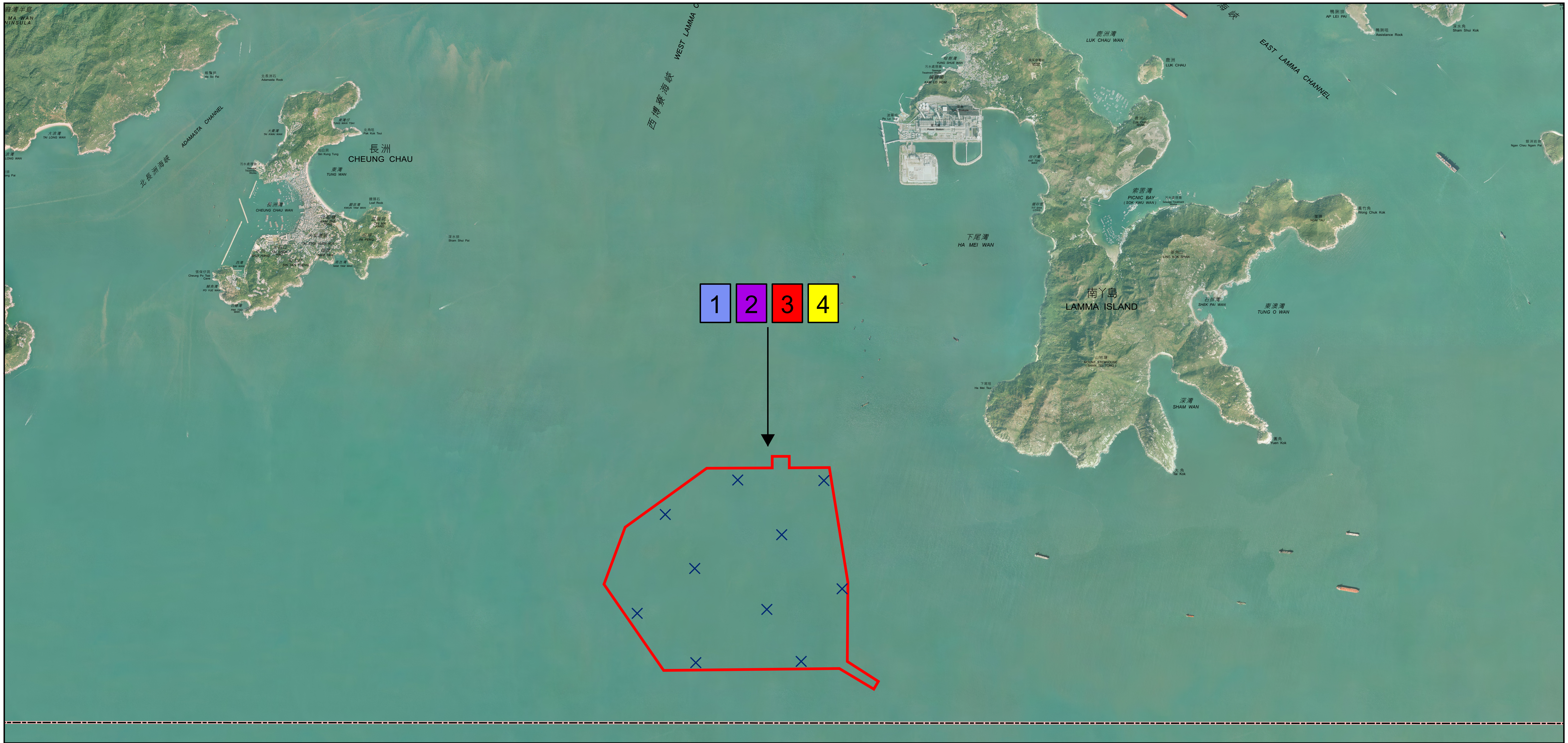
Figure 3.6.21

Visual Mitigation Measures (Lower Bound)

File: T:\GIS\CONTRACT\0607209\mxd\0607209_Visual_Mitigation_6.45MW.mxd
Date: 30/1/2022

Environmental Resources Management

ERM



LANDSCAPE MITIGATION MEASURES

1 **VMM 1 Site Selection**
A detailed site selection process has been undertaken. One of the key considerations was to select a site that would the potential visual impacts associated with the Project.

2 **VMM 2 Array Layout**
The array of wind turbines shown in this study is preliminary only. There is an opportunity to amend the layout of the array to reduce the number of turbines visible for the most sensitive viewpoints. It must be noted that visual impacts are only one consideration when determining the layout of the array. Changes to the array are only possible when other technical details such as optimum sea floor and wind flow conditions are achievable.

3 **VMM 3 Colours.**
Appropriate colours for the wind turbines should be selected to reduce their visibility.

4 **VMM 4 Blade Rotation.**
To create a more harmonious visual pattern the blades for all turbines should rotate in the same direction.

Legend

- Proposed Turbine for Upper Bound
- Development Site of the Offshore Wind Farm
- Boundary of HKSAR

Remark: This is only preliminary and the detailed layout will be subject to engineering design at later stage

Figure 3.6.22

Visual Mitigation Measures (Upper Bound)

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Date: 30/1/2022

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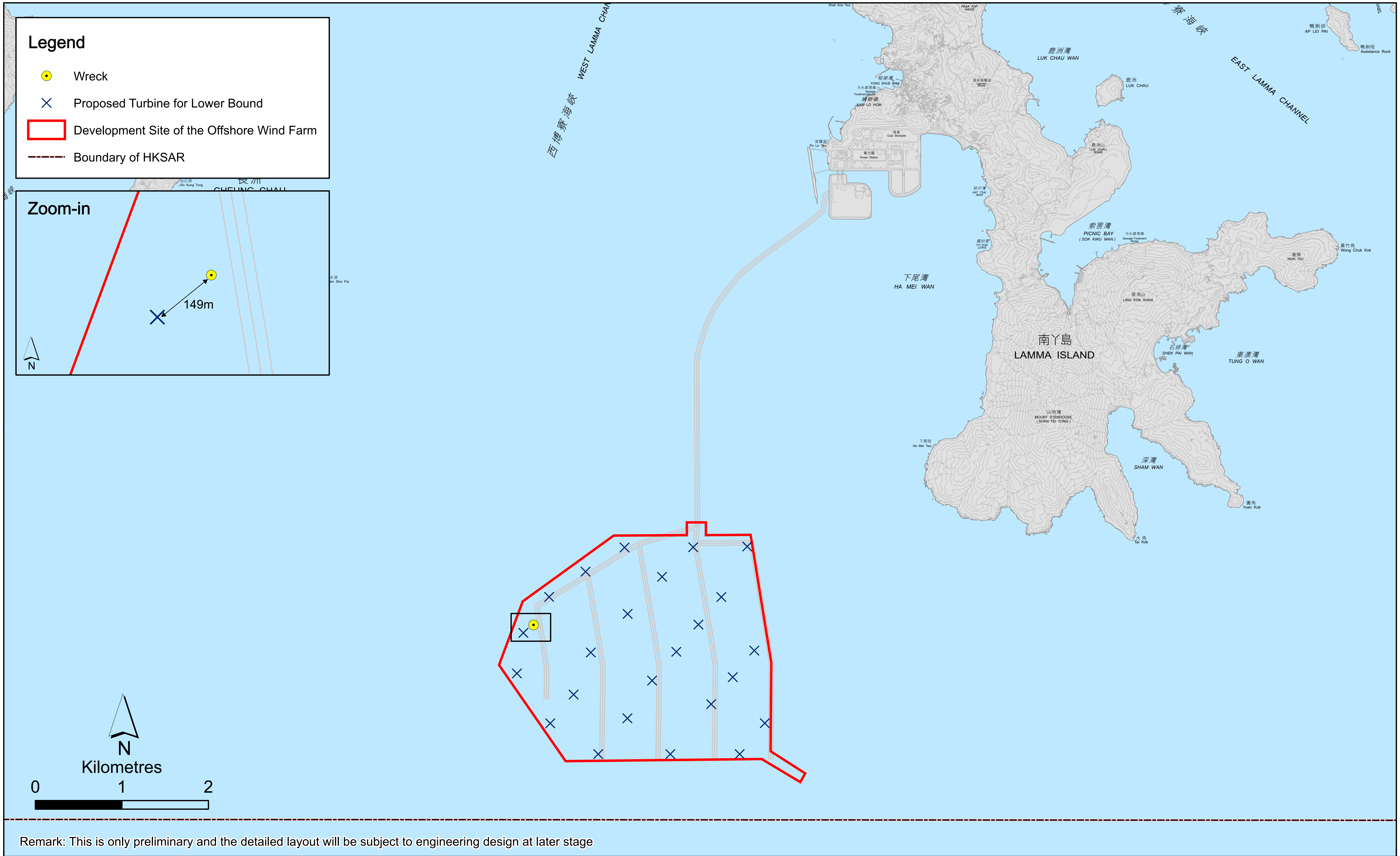

Figure 3.7.1

Location of Wrecks Found during Geophysical Survey and Proposed Project Layout (Lower Bound)

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File: T:\GIS\CONTRACT\0607209\mxd\0607209_Wreck_and_6.45MW.mxd
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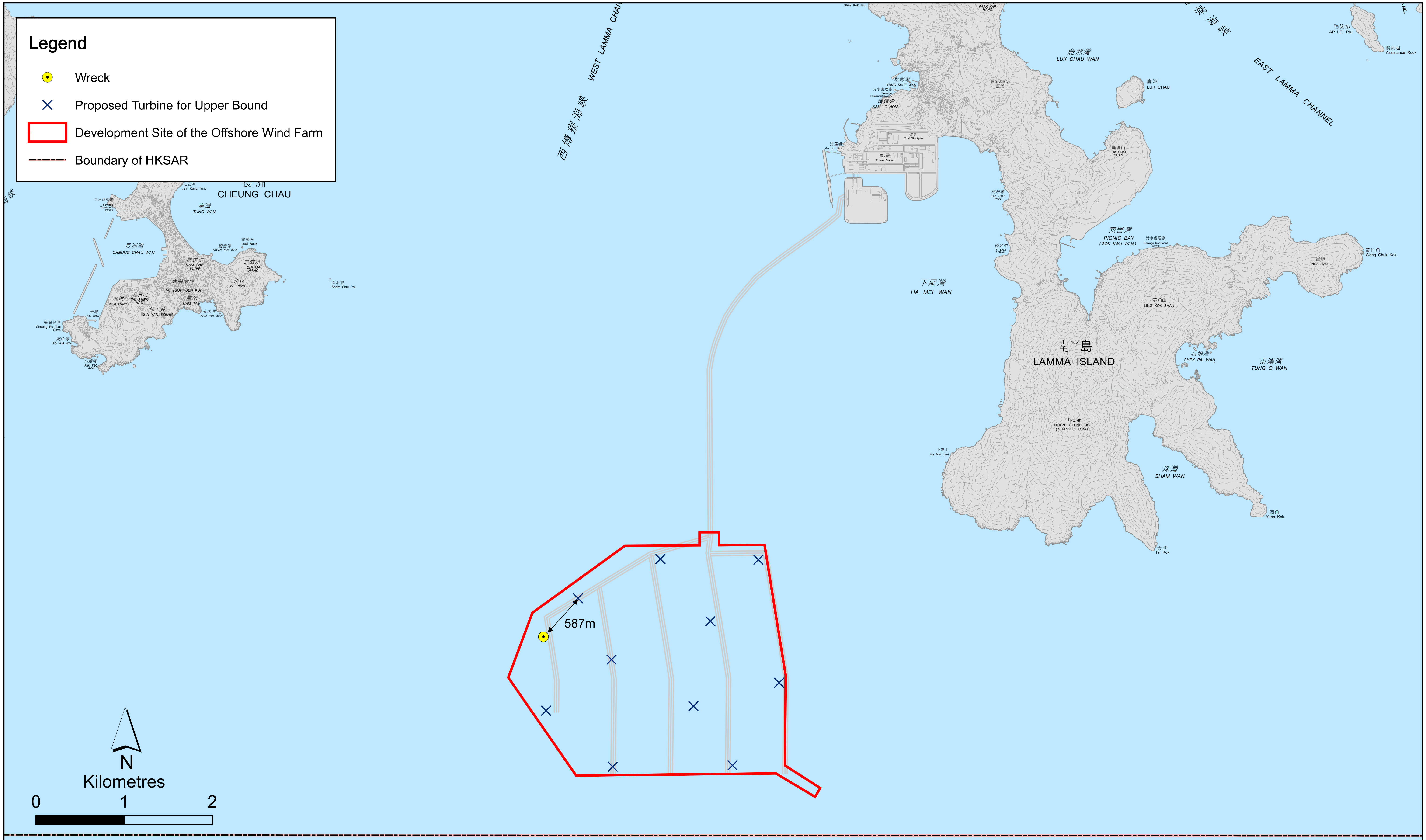

Remark: This is only preliminary and the detailed layout will be subject to engineering design at later stage

Figure 3.7.2

Location of Wrecks Found during Geophysical Survey and Proposed Project Layout (Upper Bound)

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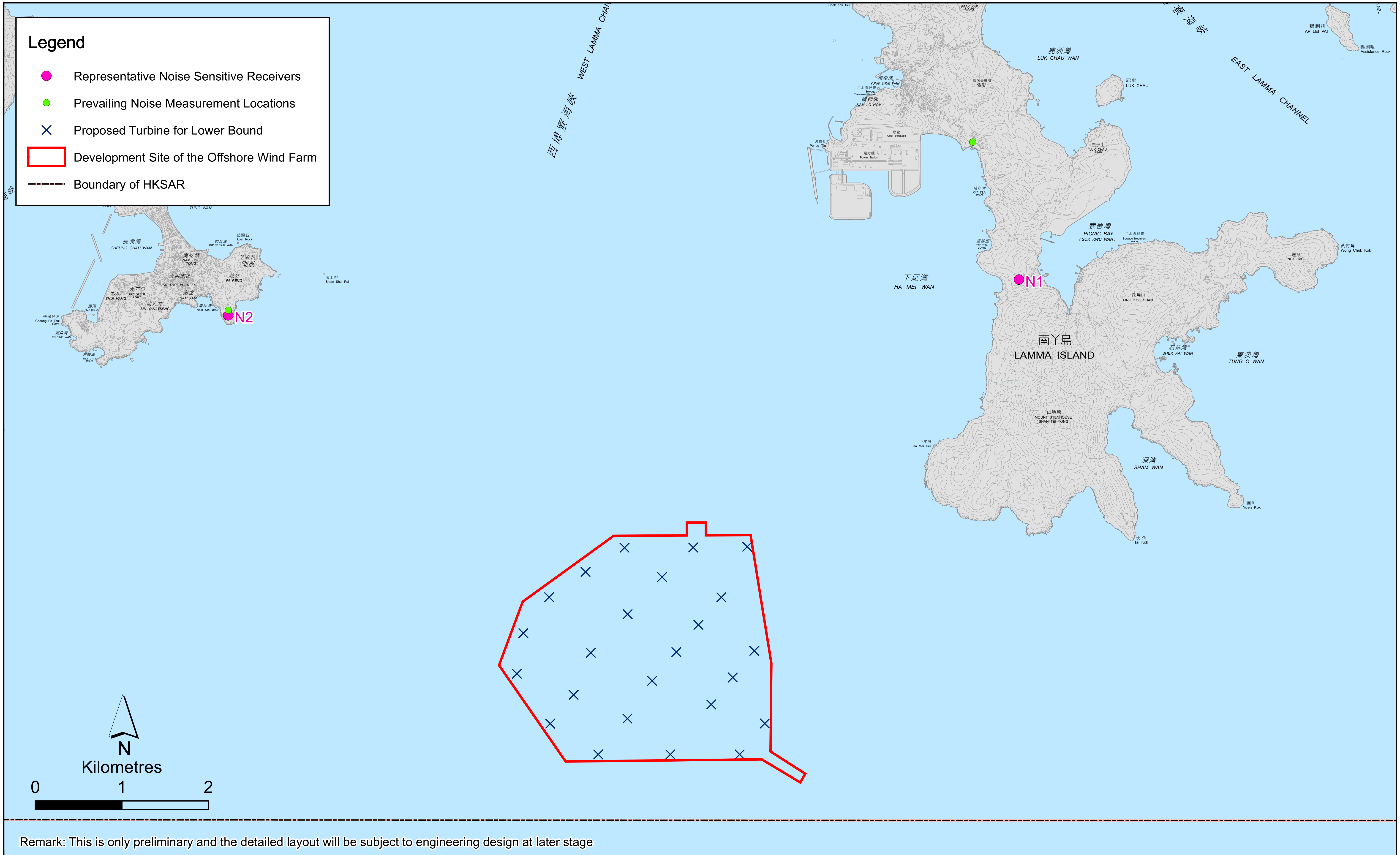

Figure 3.8.1

Locations of Representative Noise Sensitive Receivers and Proposed Project Layout (Lower Bound)

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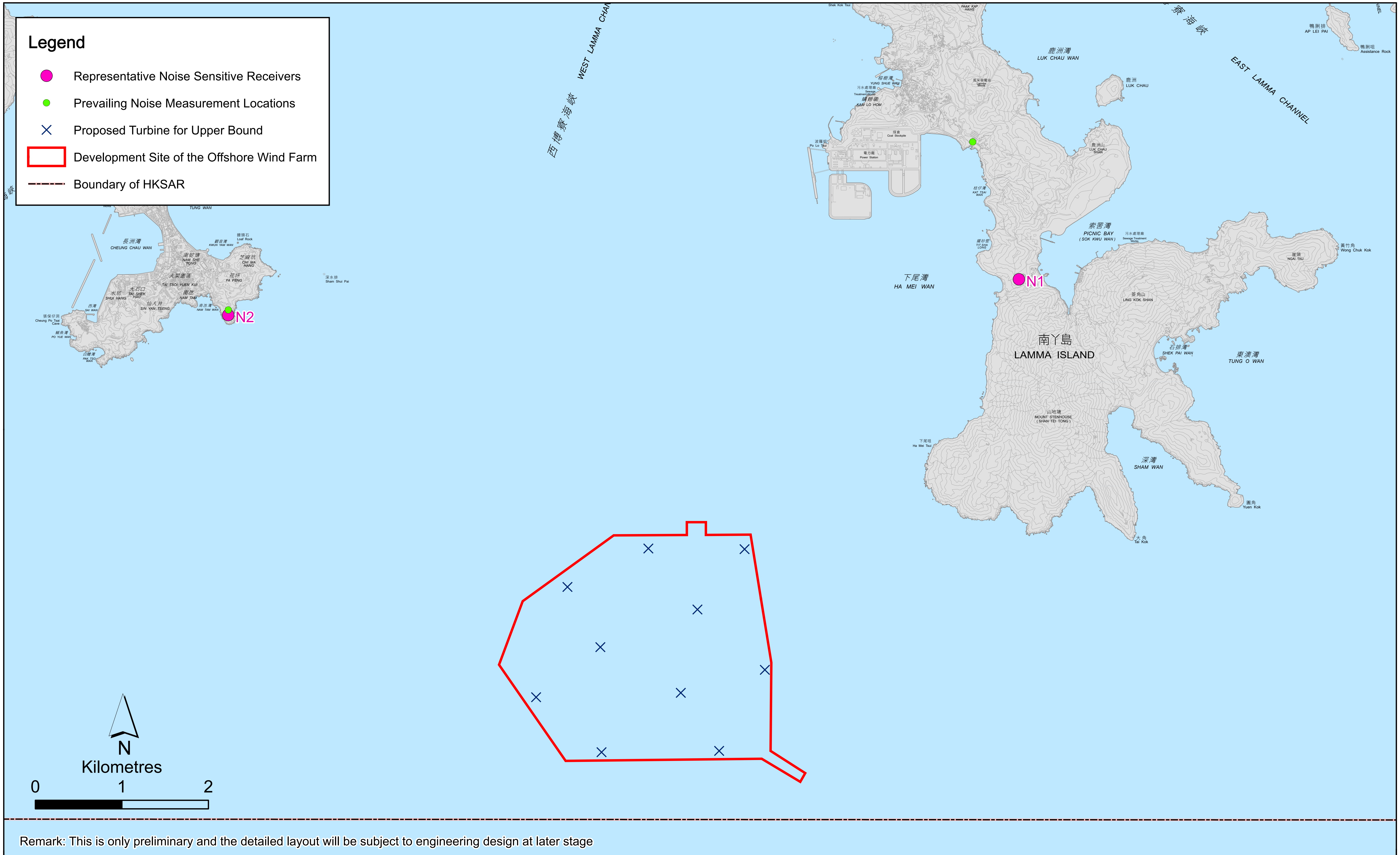

Remark: This is only preliminary and the detailed layout will be subject to engineering design at later stage

Figure 3.8.2

Locations of Representative Noise Sensitive Receivers and Proposed Project Layout (Upper Bound)

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Date: 30/1/2022

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APPENDIX A BASELINE DATA NOTE

CONTENTS

A1. INTRODUCTION

A1.1 Project Background

The Hongkong Electric Company, Limited (hereinafter referred to as HK Electric), is proposing the development of an offshore wind farm in the Hong Kong SAR (the Project). The original intent of the Project was to produce around 100 MW of electricity, which will be applied directly to the HK Electric grid network to help meet the HKSAR Government commitments to renewable energy generation and the 2050 goals of a net zero economy. The EIA for the Project was approved on 14th May 2010 (AEIAR-152/2010 and an Environmental Permit issued (EP-394/2010) on 8th June 2010. The location of the Project is shown in **Figure A1.1**.

Since the EIA was approved there has been significant advancements in the technology of offshore wind turbines. The original design was for turbines that could generate between 2.3 and 3.6 MW but these are now considered outdated since the market now provides for turbines from 6.45 MW to 16 MW. These higher capacity turbines are larger with tip heights of up to 271m above mean sea level.

A1.2 Proposed Variations

The approved EIA has only covered models of 2.3 – 3.6 MW of turbine with a tip height capped at 136 m. Consequently, an application for Variation of EP (VEP) is required to vary the conditions and/or project parameters presented in the existing EP. To support the VEP application, an Environmental Review Report (ERR) is required to be prepared and certain assessments in the previous EIA are required to be revisited such as the Landscape & Visual Impact Assessment (L&VIA), water quality, noise impact, terrestrial ecological impact (avifauna), marine ecology, fisheries and cultural heritage, etc. Underwater noise associated with pile driving leading to potential impact on fisheries and marine ecology (particularly marine mammals and green turtles) would needed to be addressed as part of the ERR. The updated parameters provided by HK Electric for the Project are summarized in **Table A1.1**:

Table A1.1 Wind Farm Parameters

Parameters	EP-394/2010 and Approved EIA Report	Proposed Variations
Overall Capacity of the Wind Farm	100 MW	At least 150 MW
Wind Farm Boundary	EP Figure 1	No change
No. of Wind Turbines (WTG)	Around 35 nos.	Around 10 nos. to around 24 nos.
Unit Capacity of the WTG	2.3 to 3.6MW (If 3.6MW, nos. of WTG reduce to 28-30)	6.45MW to 16MW
Overall WTG Height	maximum tip height of +136mPD (Section 5.2.1 of EIA Report) LVIA: viewshed analysis based on 136m, photomontages based on 125m	Maximum tip height of 198 m to 271 m above mean sea level (1)
Foundation Type	Turbines: Tripod / tetrapod and monopile foundations were considered in the EIA with monopole foundation taken as the worst case scenario.	Monopile or Jacket with tubular piles in each of jacket legs driven by percussive piling

Parameters	EP-394/2010 and Approved EIA Report	Proposed Variations
	Wind monitoring mast: 8 nos. of steel tubular piles	

Note:
(1) The maximum tip height of 15 MW WTG is 265 m above mean sea level with the same lower tip height of 16 MW WTG at 29 m above sea level.

While details of the wind farm layout including the number of wind turbines, wind turbine location, unit capacity of the wind turbine, the specific information on the wind turbine machine and array cable will only be available at later stage. The number of wind turbines will be fine-tuned, which depends on the appropriate unit capacity / size of the wind turbines to be selected in the future optimized layout.

A1.3 Purpose of this Document

The baseline data adopted in the impact assessments for terrestrial and marine ecology as well as fisheries that were presented in the EIA were gathered more than 10 years ago. Consequently, a *Baseline Data Note* has been prepared which presents a review of the currently available data and status of the data versus changes that have taken place to verify that the assumptions used in the assessment remain appropriate. The key purpose of this *Baseline Data Note* is to review the baseline avifauna data for use in the collision risk assessment and baseline marine mammal data for use in the qualitative underwater noise impact assessment which will be carried out in the next stage as part of the ERR.

In this *Baseline Data Note,* ERM has also reviewed the validity of the EIA baseline bird data (Bird Counts of Boat Surveys (Appendix 8 of in the original approved EIA, all data collected in year 2008-2009), and checked against the current available HK territory-wide bird data (i.e. Hong Kong Bird Watching Society Waterbird monitoring data and Hong Kong Bird Reports).

Quantitative vessel based surveys for the EIA study were conducted in year 2008 - 2009. Marine mammal annual surveys and the latest marine mammal baseline data available from AFCD have been reviewed for use in the impact assessment which will be carried out in the next stage.

A2. TERRESTRIAL ECOLOGY

An extensive baseline avifauna database exists for the Hong Kong Offshore Wind Farm in Southern Waters (the Project) from boat-based surveys conducted in 2008-2009 as part of baseline studies for the approved EIA (EIA-177/2009). Potential impacts on birds identified in the approved EIA include habitat loss/ avoidance/ disturbance; creation of a barrier effect to bird movement including displacement or exclusion; and collision mortality. An in-depth review has been conducted to check the validity of the data considering the intervening time since the EIA Study.

This review aims to inform the Terrestrial Ecology Assessment for the Project through comparison with bird population trends that are available from other data sources for Hong Kong. Under this baseline review, a total of 93 identified bird species (there were also 4 unidentified bird species), including 88 species recorded in the EIA literature review and 33 identified species recorded during the EIA baseline survey were reviewed, and the applicability of the available information are reviewed. In the case where species are considered to have a significant population increase since the EIA Study, the parameters for the Collision Risk Assessment would be adjusted accordingly to reflect the potential impact with consideration of latest available population information.

Further review of the Project Site has been conducted to verify the existing conditions of the wind farm site. There have been no development activities in the proposed wind farm site and its close vicinity (i.e. within 5km), and the review indicate that environmental conditions described in the approved EIA continue to prevail. Furthermore, review of fisheries resource as detailed in **Section A4** shows that there are no evidence of any marked changes in fisheries resource in the area, i.e. potential food source to birds. Therefore, significant changes in bird usage of the wind farm site are not anticipated given there are no major changes in the local environment.

A2.1 EIA Baseline Survey Data

A full account of the baseline avifauna is available in the approved EIA (EIA-177/2009). In summary, in total 27 days of avifauna vessel surveys were conducted within nine months in the Study Area using the quantitative line transect method, three times per month from July to October 2008 and from February to June 2009. During each survey, which was conducted during daytime hours, avifauna observations were recorded as the vessel traversed along a pre-defined fixed transect route designed to cover the proposed wind farm and adjacent areas. The selected transect lines were the same as the marine mammal survey transects which are standardised in Hong Kong and adopted by AFCD (**Figure A2.1**). The survey periods were designed to cover mainly the migratory and breeding seasons. Seasonality of birds in Hong Kong follows the HKBWS:

- Spring (March to May) – Migratory Season
- Summer (June to August) – Breeding Season
- Autumn (September to November) – Migratory Season
- Winter (December to February)

Table A2.1 presents all of the bird species that were recorded during in the EIA literature review and from the EIA baseline surveys (88 from the literature review and 33 from the baseline surveys). During the course of the surveys, a total of 2,214 individuals in 899 bird sighting records from 33 identified species and 4 unidentified species were recorded. The total mean and abundance (number of individuals per survey trip) of bird species in each season recorded during EIA baseline study are shown in **Table A2.2**. The recorded species from the EIA baseline study were discussed in bird species groups including birds of prey (723 individuals), egrets and herons (351 individuals), shorebirds (230 individuals), gulls and terns (792 individuals), seabirds (15 individuals) and others (103 individuals).

Of the species groups recorded, gulls and terns were found to represent the largest proportion (i.e. 792 individuals, ~36% of total recorded birds) of the total bird abundance recorded within the Study

Area. Among this bird group, the most abundant species are Heuglin's Gull (183 individuals) and White-winged Tern (178 individuals).

The bird group of birds of prey was also found to represent a large proportion (i.e. 723 individuals, ~32% of total recorded birds) of the total bird abundance recorded within the Study Area. In this bird group, 3 species were recorded, in which the most abundant species is Black Kite (712 individuals).

On the basis of potential sensitivity to wind farm operation as well as their relative prevalence in the Study Area, nine were selected for detailed collision risk assessment in the approved EIA. The nine selected species were:

- Aleutian Tern
- Black Kite
- Black-legged Kittiwake
- Black-naped Tern
- Common Tern
- Heuglin's Gull
- Red-necked Phalarope
- White-bellied Sea Eagle
- White-winged Tern

Table A2.1 Summary of Identified Species in Literature Review and During EIA Baseline Survey

Species Group	Common Name	Literature Review	EIA Baseline Survey
Birds of Prey	Black Kite	✓	✓
	Bonelli's Eagle	✓	
	Chinese Sparrowhawk	✓	
	Common Kestrel	✓	
	Crested Goshawk	✓	
	Eastern Buzzard	✓	✓
	Eurasian Hobby	✓	
	Grey-faced Buzzard	✓	
	Peregrine Falcon	✓	
	Western Osprey	✓	
	White-bellied Sea Eagle	✓	✓
Egrets & Herons	Black-crowned Night Heron	✓	
	Chinese Pond Heron	✓	✓
	Eastern Cattle Egret	✓	✓

Species Group	Common Name	Literature Review	EIA Baseline Survey
	Great Egret	✓	✓
	Grey Heron	✓	
	Little Egret	✓	✓
	Pacific Reef Heron	✓	✓
	Von Schrenck's Bittern		✓
Shorebirds (excluded Egrets & Herons)	Eurasian Curlew	✓	
	Far Eastern Curlew		✓
	Greater Sand Plover	✓	
	Green Sandpiper	✓	
	Oriental Pratincole		✓
	Pacific Golden Plover	✓	
	Red Knot	✓	
	Red Phalarope	✓	
	Red-necked Phalarope	✓	✓
	Ruddy Turnstone	✓	
	Whimbrel	✓	
	Wood Sandpiper	✓	
Gulls & Terns	Aleutian Tern	✓	✓
	Black-headed Gull	✓	✓
	Black-legged Kittiwake	✓	✓
	Black-naped Tern	✓	✓
	Black-tailed Gull	✓	✓
	Bridled Tern	✓	✓
	Brown-headed Gull	✓	
	Caspian Tern	✓	
	Common Tern	✓	✓
	Glaucous Gull	✓	
	Glaucous-winged Gull	✓	
	Greater Crested Tern	✓	✓
	Gull-billed Tern	✓	

Species Group	Common Name	Literature Review	EIA Baseline Survey
	Heuglin's Gull	✓	✓
	Little Gull	✓	
	Little Tern	✓	✓
	Mew Gull	✓	
	Pallas's Gull	✓	
	Relict Gull	✓	
	Roseate Tern	✓	✓
	Saunders's Gull	✓	
	Slaty-backed Gull	✓	
	Slender-billed Gull	✓	
	Sooty Tern	✓	
	Whiskered Tern	✓	✓
	White-winged Tern	✓	✓
	Yellow-legged Gull	✓	
Seabirds (excluded Gulls & Terns)	Ancient Murrelet	✓	✓
	Brown Booby	✓	
	Christmas Frigatebird	✓	
	Great Frigatebird	✓	
	Japanese Murrelet	✓	
	Lesser Frigatebird	✓	✓
	Long-tailed Jaeger	✓	
	Masked Booby	✓	
	Parasitic Jaeger	✓	✓
	Pomarine Jaeger	✓	
	Red-footed Booby	✓	
	Short-tailed Shearwater	✓	
	Streaked Shearwater	✓	
	Wedge-tailed Shearwater	✓	
Others	Barn Swallow	✓	✓
	Black Drongo	✓	

Species Group	Common Name	Literature Review	EIA Baseline Survey
	Blue Rock Thrush	√	
	Chinese Bulbul	√	
	Collared Crow	√	
	Common Emerald Dove	√	
	Common Kingfisher	√	
	Crested Myna	√	√
	Domestic Pigeon		√
	Greater Coucal	√	
	House Swift	√	
	Large-billed Crow	√	√
	Lesser Coucal	√	
	Northern Shoveler	√	
	Oriental Dollarbird	√	
	Oriental Turtle Dove	√	
	Pacific Swift	√	
	White-breasted Kingfisher	√	
	White-tailed Tropicbird	√	
	Western Yellow Wagtail		√
	Yellow-bellied Prinia	√	
	Total	**88**	**33**

Table A2.2 Total Mean and Abundance (Number of Individuals per Survey Trip) of Bird Species in Each Season Recorded During EIA Baseline Study (2008-2009)

Species Group	Mean Abundance (Total Abundance)						
	Effective Survey Trips	9 trips	9 trips	6 trips	3 trips	27 trips	%
	Common Name	Spring	Summer	Autumn	Winter	Overall	
Birds of Prey	Black Kite [1]	35.7 (321)	20.2 (182)	12.2 (73)	45.3 (136)	26.4 (712)	32%
	Eastern Buzzard	0.1 (1)	0 (0)	0 (0)	0 (0)	0 (1)	0%
	White-bellied Sea Eagle [1]	0.7 (6)	0.2 (2)	0.3 (2)	0 (0)	0.4 (10)	0%
Egrets & Herons	Eastern Cattle Egret	2.1 (19)	0 (0)	0.3 (2)	0 (0)	0.8 (21)	1%
	Chinese Pond Heron	0 (0)	0 (0)	1 (6)	0 (0)	0.2 (6)	0%
	Great Egret	0.1 (1)	0.3 (3)	0 (0)	0 (0)	0.1 (4)	0%
	Little Egret	8.2 (74)	10.9 (98)	11.2 (67)	3 (9)	9.2 (248)	11%
	Pacific Reef Heron	0.6 (5)	0.6 (5)	0.5 (3)	2 (6)	0.7 (19)	1%
	Unidentified Egrets	0.8 (7)	0 (0)	5 (30)	0 (0)	1.4 (37)	2%
	Von Schrenck's Bittern	1.8 (16)	0 (0)	0 (0)	0 (0)	0.6 (16)	1%
Shorebirds (excluded Egrets & Herons)	Far Eastern Curlew	2.4 (22)	0 (0)	0 (0)	0 (0)	0.8 (22)	1%
	Oriental Pratincole	0.1 (1)	0 (0)	0 (0)	0 (0)	0 (1)	0%
	Red-necked Phalarope [1]	22.9 (206)	0 (0)	0.2 (1)	0 (0)	7.7 (207)	9%
Gulls & Terns	Aleutian Tern [1]	1.2 (11)	1 (9)	10.8 (65)	0 (0)	3.1 (85)	4%
	Black-headed Gull	0 (0)	0 (0)	0 (0)	0.7 (2)	0.1 (2)	0%
	Black-legged Kittiwake [1]	0 (0)	0 (0)	0 (0)	0.3 (1)	0 (1)	0%
	Black-naped Tern [1]	5.6 (50)	5.7 (51)	0 (0)	0 (0)	3.7 (101)	5%
	Black-tailed Gull	0.1 (1)	0 (0)	0 (0)	0 (0)	0 (1)	0%
	Bridled Tern	0.2 (2)	11 (99)	0 (0)	0 (0)	3.7 (101)	5%
	Common Tern [1]	2.3 (21)	4.2 (38)	8 (48)	0 (0)	4 (107)	5%
	Greater Crested Tern	0.1 (1)	0 (0)	0 (0)	0 (0)	0 (1)	0%
	Heuglin's Gull [1]	5.2 (47)	0 (0)	0 (0)	45.3 (136)	6.8 (183)	8%
	Little Tern	0.1 (1)	0 (0)	0 (0)	0 (0)	0 (1)	0%
	Roseate Tern	1.1 (10)	0.9 (8)	0 (0)	0 (0)	0.7 (18)	1%
	Whiskered Tern	0 (0)	0 (0)	0.7 (4)	0 (0)	0.1 (4)	0%

	White-winged Tern [1]	19.8 (178)	0 (0)	0 (0)	0 (0)	6.6 (178)	8%
	Unidentified Terns	0.6 (5)	0.3 (3)	0.2 (1)	0 (0)	0.3 (9)	0%
Seabirds (excluded Gulls & Terns)	Ancient Murrelet	0.8 (7)	0 (0)	0 (0)	0 (0)	0.3 (7)	0%
	Parasitic Jaeger	0.8 (7)	0 (0)	0 (0)	0 (0)	0.3 (7)	0%
	Lesser Frigatebird	0 (0)	0.1 (1)	0 (0)	0 (0)	0 (1)	0%
Others	Barn Swallow	2.9 (26)	3.8 (34)	2.8 (17)	0.7 (2)	2.9 (79)	4%
	Crested Myna	0 (0)	0 (0)	0 (0)	4.7 (14)	0.5 (14)	1%
	Domestic Pigeon	0 (0)	0 (0)	0 (0)	0.3 (1)	0 (1)	0%
	Large-billed Crow	0.1 (1)	0.2 (2)	0.5 (3)	0 (0)	0.2 (6)	0%
	Western Yellow Wagtail	0 (0)	0 (0)	0.2 (1)	0 (0)	0 (1)	0%
	Unidentified Pipit	0 (0)	0 (0)	0.2 (1)	0 (0)	0 (1)	0%
	Unidentified Crow	0 (0)	0 (0)	0 (0)	0.3 (1)	0 (1)	0%
	Total	**116.3 (1,047)**	**59.4 (535)**	**54 (324)**	**102.7 (308)**	**82 (2,214)**	**100%**

Note: (1) This species was among the nine species selected for detailed collision risk assessment

A2.2 Information Sources Used to Review Validity of EIA Baseline Avifauna Dataset

There is a substantial amount of annually published information that are specifically focused on monitoring trends in different Hong Kong bird populations over time, and it is these long-term records that can be used as the basis to review the validity of the EIA baseline data for this Project. In general, these publicly available data can be used to establish trends of bird groups of interest in terms of whether bird populations are stable or have seen increases or declines since the time of EIA bird surveys, and thus inform on whether material changes in bird populations have occurred in the intervening years since the time of the EIA bird surveys.

In order to review the validity of using the EIA baseline bird data, which was collected in the years 2008 and 2009, a detailed review of population trends since 2008 (year of EIA baseline data collection) has been conducted by collating publically available information contained in the *Monthly Waterbird Monitoring Winter Reports*, *Monthly Waterbird Monitoring Summer Reports* and *Hong Kong Bird Reports* published by Hong Kong Bird Watching Society (HKBWS). A total of 93 species was reviewed (including 88 species recorded in the EIA literature review; 33 identified species recorded in the EIA baseline survey). The applicability of the available information for the review is discussed as follows.

The HKBWS *Monthly Waterbird Monitoring Summer Reports* [1] and *Monthly Waterbird Monitoring Winter Reports* [2], from year 2008 to 2021 (latest available data), were reviewed with a view to informing population trends over time. These reports were found to provide local regional data on bird abundance for analysis and covered the majority of migratory waterbird species, which was deemed useful for the review even though the monitoring data is primarily focused in Deep Bay area. Although terns present in southern waters in Hong Kong are likely summer breeding population but

(1) Hong Kong Bird Watching Society. Monthly Waterbird Monitoring Summer Report (2008-2009 to 2020-2021).
(2) Hong Kong Bird Watching Society. Monthly Waterbird Monitoring Winter Report (2008-2009 to 2020-2021).

not those wintering in Deep Bay, the review of the summer and winter reports still provides insights on the population trends of ardeids, shorebirds and waterbirds (as listed in **Table A2.2** above). The winter monitoring conducted by the HKBWS since 1997 serves as valuable resource that provide insights into the bird usage, health of wetlands and the entire ecosystem etc. in the Deep Bay area. Notably, since 2004, summer monitoring has seen increased observation effort during migration seasons and includes egretry surveys during the breeding season. Population trends based on review of these winter and summer monitoring reports are presented in **Section A2.3**). As mentioned previously, given that these reports focus on the Deep Bay area, further review of *Hong Kong Bird Reports* was conducted to understand the presence/ distribution/ usage of birds across Hong Kong.

The *HKBWS Hong Kong Bird Reports* are also an important published data resource that provide information for a range of bird species including their occurrence, distribution and habitat use across Hong Kong (and not only focused on the Deep Bay area). As part of the review, the *Hong Kong Bird Reports* from 2008 to 2018 [(3)] (latest available data) have also been examined so as to investigate population trends for other species groups, including gulls and terns, shorebirds, as well as other landbirds and waterbirds. From the review it is noted, the *Hong Kong Bird Reports* provide more general data in comparison to the summer and winter monitoring reports, such that abundance data or population trends are not available for some species. Population trends based on review of these Hong Kong Bird Reports are presented in **Section A2.4**.

It is also noted that the HKBWS published the *Hong Kong Bird Atlas 2016 – 2019* in 2020 [(4)]. This publication showed species distribution changes in Hong Kong by comparing data from 1993 – 1996 and 2001 - 2005. This reference has not been adopted for the review since it does not provide relevant information on changes from 2008 to present.

Apart from the Monthly Waterbird Monitoring Summer Reports, Monthly Waterbird Monitoring Winter Reports and HKBWS Hong Kong Bird Reports, no other publically available information were considered useful.

A2.3 Review of Summer and Winter Waterbird Data at Deep Bay

An examination of the winter and summer peak data in Deep Bay from 2008 to 2021 has shown an overall decline of waterbirds since 2008. **Table A2.3** and **Figure A2.2** shows the comparison of peak monthly number of waterbirds recorded at Deep Bay between 2008 and 2021. The total monthly peak count in Deep Bay was 106,821 birds in 2008-2009. The peak count declined gradually and reached 56,168 birds in 2016-2017, which is ~53% of that recorded in 2008-2009. Although the population increased slightly to 76,143 in 2017-2018, it can be seen in general there is a continuous decreasing trend since 2008. Although another slight increase in waterbirds is evident from the latest peak count data, overall it can be seen monthly peak counts have become lower since 2008-2009, while a further decline is observed and reached 55,519 birds in 2020-2021.

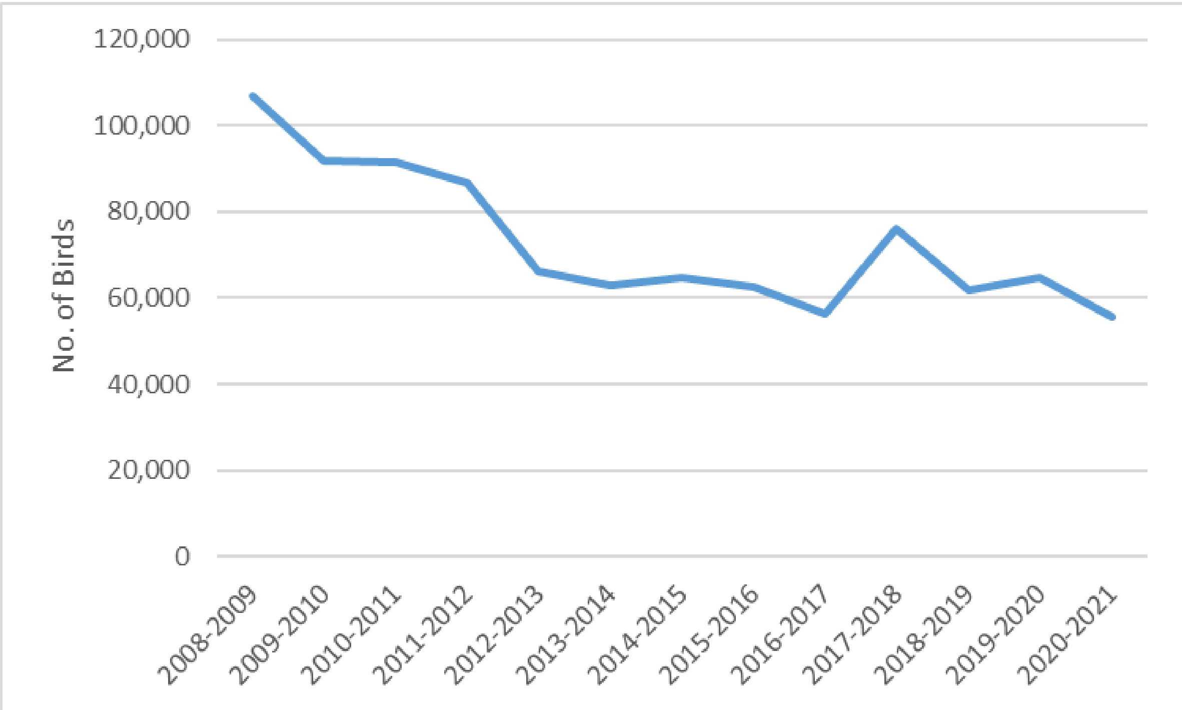
(3) Hong Kong Bird Watching Society. Hong Kong Bird Report (2008 – 2018).

(4) Hong Kong Bird Watching Society (2020). Hong Kong Bird Atlas 2016 – 2019.

Table A2.3 Comparison of the Peak Monthly Number of Waterbirds Recorded at Deep Bay between 2008 and 2021

Year	Peak Monthly Count of Summer Waterbirds (Apr – Sep)	Peak Monthly Count of Winter Waterbirds (Oct – Mar)	Total of Peak Winter and Summer Monthly Count (Apr – Mar)
2008-2009	28,666	78,155	106,821
2009-2010	14,865	76,882	91,747
2010-2011	22,884	68,635	91,519
2011-2012	18,759	68,080	86,839
2012-2013	10,131	56,043	66,174
2013-2014	19,191	43,874	63,065
2014-2015	12,221	52,584	64,805
2015-2016	15,610	46,792	62,402
2016-2017	10,877	45,291	56,168
2017-2018	14,176	61,967	76,143
2018-2019	14,119	47,714	61,833
2019-2020	16,893	47,651	64,544
2020-2021	13,614	41,905	55,519

Figure A2.2 Total of Deep Bay Peak Winter and Summer Monthly Count from 2008 – 2021 (Apr – Mar)



Apart from investigation of the trend in total waterbirds based on peak count data, the available information was also analysed to examine trends in wintering birds for each of the different bird species groups. Details on population trend of wintering birds (Dec – Feb) in Deep Bay for the different species groups between 2008 and 2021 are shown in **Table A2.4** and **Figure A2.3**. Overall, a key review finding is that most bird groups showed a decline when comparing the latest available data for winter 2020 with winter 2008. The reasons for long term decline in bird populations is reported to be complex as migratory species travel to multiple regions along their respective migratory routes.

In the Hong Kong Bird Report 2014 by HKBWS [(5)], it was suggested some potential causes for the decline in some species in Hong Kong may include local habitat changes, habitat changes outside of Hong Kong, trapping/ hunting outside of Hong Kong and climate change impacts. It was also noted migratory species require sufficient habitat outside Hong Kong at their breeding or wintering sites, or at migration stopover sites. As such, HKBWS reported loss of habitat elsewhere in the region could account for some of the observed population changes within Hong Kong.

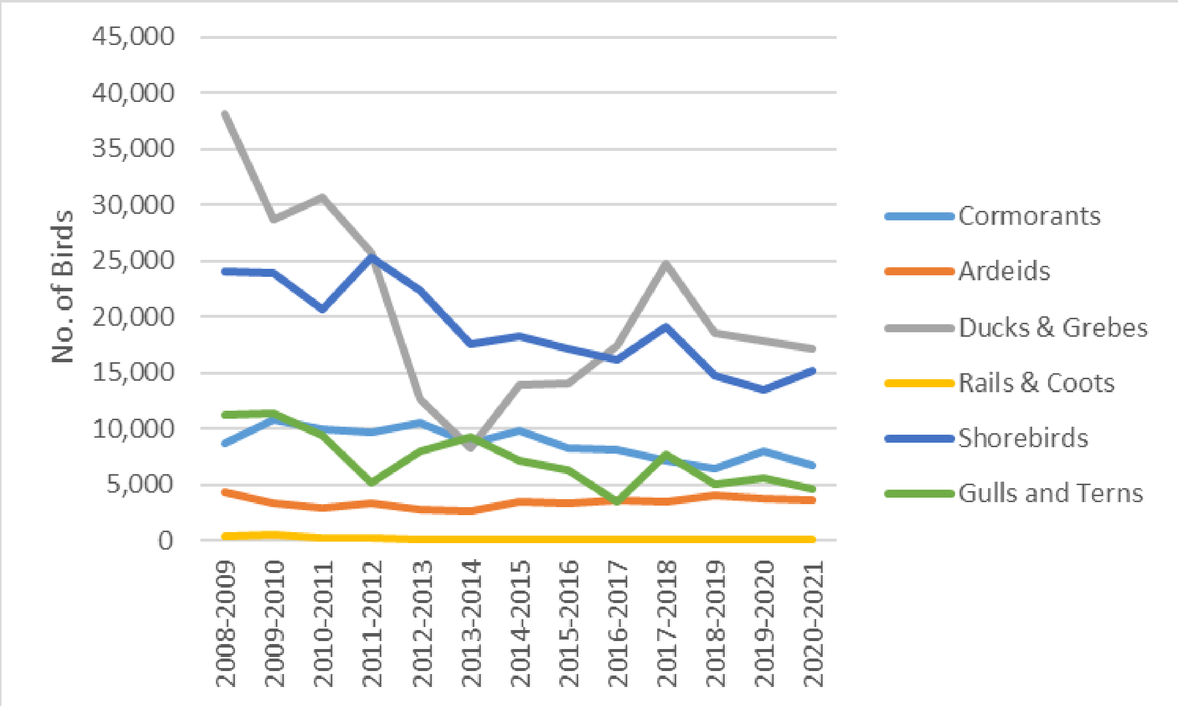
Table A2.4 Comparison of the Peak Monthly Number of Mid-Winter (Dec – Feb) Waterbirds by Groups Recorded at Deep Bay between 2008 and 2021

Year	Cormorants	Ardeids	Ducks & Grebes	Rails & Coots	Shorebirds	Gulls and Terns
2008-2009	8,736	4,384	38,099	460	24,069	11,212
2009-2010	10,758	3,357	28,700	523	23,926	11,331
2010-2011	10,023	3,006	30,628	332	20,708	9,393
2011-2012	9,636	3,384	25,739	206	25,299	5,128
2012-2013	10,569	2,773	12,693	182	22,380	8,048
2013-2014	8,761	2,728	8,259	199	17,573	9,216
2014-2015	9,891	3,569	13,985	179	18,261	7,129
2015-2016	8,247	3,433	14,024	156	17,146	6,322
2016-2017	8,217	3,706	17,477	151	16,127	3,578
2017-2018	7,218	3,470	24,736	138	19,070	7,774
2018-2019	6,484	4,089	18,599	108	14,772	5,059
2019-2020	8,033	3,726	17,911	150	13,478	5,687
2020-2021	6,739	3,694	17,163	99	15,161	4,587

Notes: The highlighted columns indicate the key review species group in the summer and winter monitoring report.

(5) Hong Kong Bird Watching Society, 2016. Hong Kong Bird Report 2014.

Figure A2.3 Peak Number of Different Waterbird Groups in the Deep Bay area during mid-winter period (December to February) from 2008 – 2021



Among the waterbird groups, the peak number of wintering shorebirds over time has seen some marked fluctuation since 2008; however overall the trend has been a decline. The peak number of wintering shorebirds was found to be markedly lower comparing to the data from winter 2008 and winter 2020. On the other hand, peak number of ardeids recorded in winter can be seen to have fluctuated little over time since 2008 with similar numbers recorded including from the latest monitoring. For the gulls and tern species group, the population trend based on peak winter numbers in Deep Bay has been declined. For instance, the peak number of gulls and terns were reported to be 6,625 sightings less in winter 2020 compared to winter 2008, which equates to about a halving of sightings (**Table A2.4**).

A2.4 Review of Hong Kong Bird Reports

As discussed previously, *Hong Kong Bird Report's* data come from observations from a wider Study Area (rather than focused on the Deep Bay) and are useful for describing the general trend of bird populations across Hong Kong. In the following sections, review findings are presented for the species recorded by species groups (refer **Section A2.5.1**) and the nine key concerned species as identified in the approved EIA, including two birds of prey species Black Kite and White-bellied Eaglie; six gull and tern species Aleutian Tern, Black-legged Kittiwake, Black-naped Tern, Common Tern, Heuglin's Gull and White-winged Tern; and the waterbird species Red-necked Phalarope (refer **Section A2.4.2**).

A2.4.1 Review of Recorded Species by Groups

A2.4.1.1 Birds of Prey

Birds of prey recorded in the literature review and the approved EIA include Black Kite, Bonelli's Eagle, Chinese Sparrowhawk, Eastern Buzzard, Common Kestrel, Crested Goshawk, Eurasian Hobby, Grey-faced Buzzard, Western Osprey, Peregrine Falcon and White-bellied Sea Eagle. Significant change in population trend of most specie has not been described by the Hong Kong Bird Reports, except the number of Common Kestrel autumn migrants and Bonelli's Eagle reported to be declining. The number of Grey-faced Buzzard may also be declining according to the Hong Kong Bird Report in 2014, while the peak counts recorded in the year of 2008 and 2018 are 98 and 5 individuals, respectively.

In terms of the birds of prey species recorded during the EIA, including Black Kite, Eastern Buzzard and White-bellied Sea Eagle, the number of recorded birds of prey within the EIA Study Area were generally low, except for higher count of Black Kite, where a total of 712 individuals were recorded within the whole EIA Study Area (see **Table A2.2**). White-bellied Sea Eagle were recorded within the Study Area during the baseline study for the approved EIA. Black Kite and White-bellied Sea Eagle are discussed further in **Sections A2.4.2.2** and **A2.4.2.8** respectively.

A2.4.1.2 Egrets and Herons

The recorded egrets and herons in the literature review and the approved EIA include Black-crowned Night Heron, Eastern Cattle Egret, Chinese Pond Heron, Great Egret, Grey Heron, Little Egret, Pacific Reef Heron and Von Schrenck's Bittern.

Based on the review of Hong Kong Bird Reports, an increase in population has only been observed for Chinese Pond Heron (peak of 260 in 2008 to 652 in 2018). The number of Grey Heron was observed slowly declining since the year of 1990 (peak of 930 in 2008 to 827 in 2018). For other egrets and herons, the population trend were not described to have significant change in Hong Kong Bird Reports. Although high counts occasionally occur due to weather, no apparent trend in population was reported, including Black-crowned Night Heron (peak of 361 in 2008 to 156 in 2018), Eastern Cattle Egret (peak of 149 in 2008 to 134 in 2018), Great Egret (peak of 1,167 in 2008 to 1,284 in 2018), Little Egret (peak of 1,675 in 2008 to 1,144 in 2018), Pacific Reef Heron and Von Schrenck's Bittern.

While Chinese Pond Heron has shown an increase over the years, the number recorded within the whole EIA Study Area was very low, where a total of 6 individuals was recorded during the baseline surveys. Furthermore, the recorded individuals were recorded flying below the risk height level (i.e., heights within the rotor zone).

In terms of the egret and heron species recorded during the EIA, including Eastern Cattle Egret, Chinese Pond Heron, Great Egret, Little Egret, Pacific Reef Heron and Von Schrenck's Bittern, the number of recorded egrets and herons within the EIA Study Area were generally low, except for higher count of Little Egret, where a total of 248 individuals was recorded within the Study Area (see **Table A2.2**). Furthermore, most of the recorded individuals were recorded flying below the risk height level (i.e., heights within the rotor zone), where 30 individuals were observed within the rotor height of Lower Bound – 6.45MW and 13 individuals of Upper Bound – 15/16MW.

A2.4.1.3 Shorebirds (excluded Egrets and Herons)

Shorebirds recorded in the literature review and the approved EIA include Far Eastern Curlew, Eurasian Curlew, Greater Sand Plover, Green Sandpiper, Oriental Pratincole, Pacific Golden Plover, Red Knot, Red Phalarope, Red-necked Phalarope, Ruddy Turnstone, Whimbrel and Wood Sandpiper. According to the Hong Kong Bird Reports, two of these species showed an increasing population trend, including Eurasian Curlew (peak of 1,116 in 2008 to 1,341 in 2018) and Pacific Golden Plover (peak of 533 in 2008 to 1,081 in 2018). While Eurasian Curlew and Pacific Golden Plover have shown an increase over the years, they were not recorded within the whole Study Area during the EIA baseline study. In addition, the Hong Kong Bird Report has stated the numbers of Whimbrel have been slowly increasing since the 1990s and fluctuation has been shown over the recent years (peak of 217 in 2008 to 336 in 2018). During the EIA baseline study, Whimbrel was not recorded within the Study Area.

The number of Green Sandpiper was observed slowly declining since 2000 (peak of 34 in 2008 to 25 in 2018). The peak counts have also been low in recent years for Far Eastern Curlew (peak of 15 in

2008 to 8 in 2018). A long period of decline since the 1990s was also observed for Ruddy Turnstone (peak of 46 in 2008 to 8 in 2018).

For the other species, the population trend were not described to have significant change in Hong Kong Bird Reports, including Greater Sand Plover (peak of 500 in 2008 to 437 in 2018), Oriental Pratincole (peak of 32 in 2008 to 26 in 2018), Red Knot (peak of 52 in 2008 to 130 in 2018), Red Phalarope and Wood Sandpiper (peak of 512 in 2008 to 223 in 2018). Although the population trend of Red-necked Phalarope was not described in Hong Kong Bird Reports, a general increase in peak counts were observed (peak of 102 in 2008 to 2,000 in 2018, details about the high peak count are discussed in **Section A2.4.2.7**).

In terms of the shorebird species recorded during the EIA, including Far Eastern Curlew, Oriental Pratincole and Red-necked Phalarope, the number of recorded shorebirds within the EIA Study Area were generally low, except for higher count of Red-necked Phalarope, where a total of 207 individuals was recorded within the Study Area (see **Table A2.2**). Furthermore, most of the recorded individuals were recorded flying below the risk height level (i.e., heights within the rotor zone), where 6 individuals were observed within the rotor height of Lower Bound – 6.45MW and 2 individuals of Upper Bound – 15/16MW. Red-necked Phalarope is discussed further in **Section A2.4.2.7**.

A2.4.1.4 Gulls and Terns

Recorded gulls and terns species in the literature review and the approved EIA include Aleutian Tern, Black-headed Gull, Black-legged Kittiwake, Black-naped Tern, Black-tailed Gull, Bridled Tern, Brown-headed Gull, Caspian Tern, Common Tern, Glaucous Gull, Glaucous-winged Gull, Greater Crested Tern, Gull-billed Tern, Heuglin's Gull, Little Gull, Little Tern, Mew Gull, Pallas's Gull, Relict Gull, Roseate Tern, Saunders's Gull, Slaty-backed Gull, Slender-billed Gull, Sooty Tern, Whiskered Tern, White-winged Tern and Vega Gull.

Based on the review of Hong Kong Bird Reports, the population trend were not described to have significant change, except Black-naped Tern, Gull-billed Tern, Saunder’s Gull, Black-headed Gull, Bridled Tern and Roseate Tern. The number of breeding Black-naped Tern in southern waters have increased substantially according to the description in Hong Kong Bird Report 2014. Increasing peak counts were also observed in Gull-billed Tern (peak of 311 in 2008 to 390 in 2018), Saunder’s Gull (peak of approx. 60 in 2008 to 67 in 2018). The number of Black-headed Gull have been declining (peak of 11,600 in 2008 to 7,564 in 2018). In terms of Bridled Tern and Roseate Tern, although the number of Bridled Tern has shown an increase over the recent years, the number of breeding survey peak count in the southern waters has declined, where Bridled Tern had peak of 85 in 2011 to 6 in 2018, and Roseate Tern peak of 167 in 2011 to 46 in 2018 [(6)].

While peak counts have shown increases over the years for Black-naped Tern, Gull-billed Tern and Saunder’s Gull, only Black-naped Tern was sighted during the EIA baseline Study (Black-naped Tern is further discussed in **Section A2.4.2.4**). In terms of other gulls and terns recorded during the EIA and which significant population change was not described in the Hong Kong Bird Report or reported to be declining, including Aleutian Tern, Black-legged Kittiwake, Black-tailed Gull, Common Tern, Greater Crested Tern, Heuglin's Gull, Little Tern, Roseate Tern, Whiskered Tern and White-winged Tern, the recorded number were generally low, except for higher count of Aleutian Tern, Bridled Tern, Common Tern, Heuglin's Gull and White-winged Tern, where the total of individuals recorded were in the range of 85 – 183 (see **Table A2.2**). For Bridled Tern, among a total of 101 individuals recorded, where 7 individuals were observed within the rotor height of Lower Bound – 6.45MW and 1 individual of Upper Bound – 15/16MW, while the remaining individuals were recorded at sea-level or below the rotor height (see **Table A2.2**). Aleutian Tern, Common Tern, Heuglin’s Gull and White-winged Tern are discussed further in **Sections A2.4.2.1, A2.4.2.5, A2.4.2.6 and A2.4.2.9** respectively.

(6) Breeding survey peak count for Bridled Tern is available since 2011, therefore comparison to 2008-2009 data could not be conducted.

A2.4.1.5 Seabirds (excluded Gulls and Terns)

Seabirds recorded in the literature review and the approved EIA include Ancient Murrelet, Brown Booby, Christmas Frigatebird, Great Frigatebird, Japanese Murrelet, Lesser Frigatebird, Long-tailed Jaeger, Masked Booby, Parasitic Jaeger, Pomarine Jaeger, Red-footed Booby, Short-tailed Shearwater, Streaked Shearwater and Wedge-tailed Shearwater. Based on the review of Hong Kong Bird Reports, significant change in population trend of most specie has not been described.

The seabirds species recorded in the EIA Study Area include Ancient Murrelet, Parasitic Jaeger and Lesser Frigatebird, in which the number recorded were generally low. Furthermore, most of the recorded individuals were recorded flying at sea-level or below the rotor height.

A2.4.1.6 Other Landbirds and Waterbirds

Other landbirds and waterbirds species recorded in the literature review and the approved EIA include Barn Swallow, Black Drongo, Blue Rock Thrush, Chinese Bulbul, Collared Crow, Common Kingfisher, Crested Myna, Northern Shovele, Oriental Dollarbird, Western Yellow Wagtail, Common Emerald Dove, Domestic Pigeon, Greater Coucal, Large-billed Crow, Lesser Coucal, House Swift, Oriental Turtle Dove, Pacific Swift, White-throated Kingfisher, White-tailed Tropicbird and Yellow-bellied Prinia. Western Yellow Wagtail was not described in Hong Kong Bird Reports. Based on the review of Hong Kong Bird Reports, significant change in population trend of most specie has not been described.

The only species with a sign of increase in population is Collared Crow. According to the 2015 Hong Kong Bird Report, the peak count has increased from 100 individuals in 2008 to 163 individuals in 2015. This species is mostly recorded in the Mai Po Nature Reserve and the Deep Bay area. During the EIA baseline survey, no Collared Crow was recorded within the whole EIA Study Area. The number of White-throated Kingfisher was also reported to be declined in Deep Bay (peak of 43 in 2008 to 27 in 2018) while the peak counts have also been low in recent years for and Northern Shoveler (peak of 14,253 in 2008 to 4,612 in 2018).

Other landbirds and waterbirds species recorded in the EIA Study Area include Barn Swallow, Crested Myna, Domestic Pigeon, Large-billed Crow and Western Yellow Wagtail. These species were mostly recorded in small numbers apart from Barn Swallow. According to the Hong Kong Bird Reports, the population of Barn Swallow is considered to be abundant over the years but did not describe any change in population. The recorded Barn Swallows were mostly flying below the rotor height, which is outside of the flight height with collision risk.

A2.4.2 Review of Key Concerned Species Identified by the approved EIA

A2.4.2.1 Aleutian Tern

Aleutian Tern is an uncommon passage migrant through coastal waters, mostly in spring. It was found distributed in Cheung Chau, Lamma Island, Po Toi, D'Aguilar and Ninepins. It is classified as Vulnerable on the IUCN Red List. According to the 2018 Hong Kong Bird Report, most of the records were from the southern waters. The numbers are generally stable with exceptional high peak counts due to weather. Although the peak counts of Aleutian Tern has dropped from 2013 to 2017, a high count of 145 was recorded in southern waters in 2018. As a precautionary approach, the density (based on the EIA baseline survey), to be used for the updated bird collision risk model, will be multiplied by 3.5 times as determined from the increase in the peak count between 2008 and 2018. During the EIA baseline survey, they were mostly seen in autumn along the West Lamma Channel. Within the EIA Study Area, 85 individuals were recorded, where 20 individuals were within the Assessment Area of collision risk and 15 individuals were within the Project Site. With consideration of the new turbine specifications, for Lower Bound – 6.45MW, 8 individuals fall within the risk height level in Study Area, in which 4 individuals are within the Assessment Area and 2 individuals are within the Project Site. For Upper Bound – 15/16MW, 4 individuals fall within the risk height level in Study Area and Assessment Area, in which 2 individuals are within the Project Site.

Table A2.5 Peak Count of Aleutian Tern from 2008 to 2018 (2014 - 2018 Hong Kong Bird Report)

Locations	Peak Count										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Southern waters	44	200	430	21	108	250	117	43	28	23	145

A2.4.2.2 Black Kite

According to AFCD Biodiversity Database, Black Kite is a common resident and winter visitor. It is abundant and presents all year and widely distributed in Hong Kong, with increased numbers in winter between October and March. It is listed on Cap. 586 Protection of Endangered Species of Animals and Plants Ordinance. It is also classified as Least Concern on the IUCN; Red List and Regional Concern by Fellowes *et al*. (2002); Class II protected species in the PRC; and listed in CITES Appendix II. Among 2008 – 2016, the peak count was recorded in the range of 68 – 399, while increase was observed in 2017 and 2018 with peak count of 506 and 972 respectively. Since 2017, peak counts recorded in other large roosting sites were also reported in Hong Kong Bird Reports, including Magazine Gap, Sai Kung and Stonecutter Island. Magazine Gap is known to be a regular roost site of a large number of Black Kites. According to the Hong Kong Bird Report 2013 – 2015, the peak counts are not truly representative of the Hong Kong population as larger numbers are known to use regular roost sites at Magazine Gap and Stonecutter Island. In 2014, the Hong Kong Bird Watching Society estimated that there are 1,300 black kites in Hong Kong while Magazine Gap alone is home to 800 (7). The fluctuation between 2008 and 2018 may possibly due to data of some major roost sites not being available in all years. According to the Hong Kong Bird Report 2018, a peak combined count of 972 was recorded from three roosts (551 at Sai Kung, 305 at Stonecutter Island and 116 at Magazine Gap). In 2019, over 500 Black Kites were recorded in 100 minutes at three fixed locations, including Magazine Gap Road, Tai Kok Tsui Promenade and Sai Kung Pier, in a public census organised by Lung Fu Shan Environmental Education Centre and The Hong Kong Bird Watching Society (8). The shortest distance from the proposed wind farm and Magazine Gap is approximately 12.3 km; Sai Kung is approximately 29.4 km; and Stonecutter Island is approximately 15.8 km. During the EIA baseline survey, they were mainly distributed around the shoreline. Within the EIA Study Area, a total of 712 individuals was recorded, where 31 individuals were within the Assessment Area of collision risk and 16 individuals were within the Project Site. With consideration of the new turbine specifications, 561 individuals fall within the risk height level in the Study Area of Lower Bound – 6.45MW, in which 19 individuals are within the Assessment Area and 6 individuals are within the Project Site. For Upper Bound – 15/16MW, 495 individuals fall within the risk height level in the Study Area, in which 17 individuals are within the Assessment Area and 5 individuals are within the Project Site. Considering the long distance between the Project Site and the key roosting area, as well as the observed distribution of Black Kite during the EIA baseline study, it is considered that the usage by Black Kite would be similar at the Project Site. Therefore, it is considered the use of EIA baseline data in 2008 for further assessment would be appropriate.

Table A2.6 Peak Count of Black Kite from 2008 to 2018 (2008 - 2018 Hong Kong Bird Report)

	Peak Count										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018*
Peak Count	146	399	100	104	264	71	68	79	170	506	972

*Note: 972 is a peak combined count recorded from three roosts (551 at Sai Kung, 305 at Stonecutter Island and 116 at Magazine Gap)

(7) South China Morning Post, 2014. Where eagles nest.
(8) Topick, 2019. 香港首個公眾麻鷹普查 過百人用 100 分鐘數到逾 500 隻麻鷹.

A2.4.2.3 Black-legged Kittiwake

The Black-legged Kittiwake is a rare spring passage migrant. According to AFCD Biodiversity Database, it is a rare winter visitor found in Deep Bay Area and Sha Chau. It is classified as Vulnerable on the IUCN Red List. According to the Hong Kong Bird Report 2009-10, there were ten records of the species before 2009. In the period between 2008 and 2014, only one or two records were reported each year in Po Toi and southern waters and no further record was reported since 2015. One individual was observed flying within the EIA Study Area, as well as the Assessment Area of collision risk, but it was not recorded in the Project Site. With consideration of the new turbine specifications, this individual falls within the risk height level of both Lower Bound – 6.45MW and Upper Bound – 15/16MW. Considering the decreasing population trend of the species, it is considered the use of EIA baseline data in 2008 for further assessment would provide a conservative result.

A2.4.2.4 Black-naped Tern

The Black-naped Tern is a common summer breeder and migrant in southern and eastern waters. According to AFCD Biodiversity Database, it was found distributed in Mirs Bay, Cape D'Aguilar, Waglan Island, Cheung Chau. It was classified as Least Concern on the IUCN Red List and Local Concern on Fellowes *et al*. (2002). The population data for the southern waters, where the proposed wind farm site would be located, was only available since 2011, which has shown an increase in population with some fluctuation from 2011 to 2018. The number of breeding Black-naped Tern in southern waters have increased substantially according to the Hong Kong Bird Report 2014.

With reference to data from the north-eastern waters, the population of the Black-naped Tern has seen an increasing trend between 2008 and 2018 (increased by approximately 2.5 times). This might imply a similar trend in the population in the southern waters since 2008. As a precautionary approach, the density (based on the EIA baseline survey), to be used for the updated bird collision risk model, will be multiplied by 2.5 times as determined from the increase in the peak count in the north-eastern waters between 2008 and 2018. During the EIA baseline study, Black-naped Tern were present in Spring and Summer flying and foraging along West Lamma Channel during the surveys. Black-naped Tern were also found foraging in open sea southeast of Cheung Chau. A total of 101 individuals was recorded in the Study Area, where 8 individuals were within the Assessment Area of collision risk and 7 individuals were within the Project Site. With consideration of the new turbine specifications, 18 individuals fall within the risk height level in the Study Area of Lower Bound – 6.45MW, in which none are within the Assessment Area nor Project Site. For Upper Bound – 15/16MW, none of the recorded Black-naped Tern fall within the risk height level.

Table A2.7 Peak Count of Black-naped Tern from 2008 to 2018 (2018 Hong Kong Bird Report)

Locations	Peak Count										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
North-eastern	81	86	120	182	333	125	121	120	143	148	207
South-eastern	-	-	180	181	170	191	139	212	318	179	116
Southern	-	-	-	291	159	139	182	47	328	390	98
All HK waters	-	-	-	292	422	281	282	332	461	595	383

A2.4.2.5 Common Tern

The Common Tern is an uncommon passage migrant through coastal waters. According to AFCD Biodiversity database, it is a common passage migrant found in Tai O, Mirs Bay, Victoria Harbour, Tolo Harbour, Cape D'Aguilar, Cheung Chau. It is classified as Least Concern on the IUCN Red List. According to the Hong Kong Bird Report 2014, the numbers of Common Tern are generally stable with exceptional high peak counts due to weather. Among 2008 – 2018, the peak count is ranged in 10 – 160 while most of them were recorded in southern waters, where the proposed wind farm would be located. In 2018, peak count 148 was recorded in southeastern waters. As a precautionary approach, the density (based on the EIA baseline survey), to be used for the updated bird collision risk model, will be multiplied by 3 times as determined from the increase in the peak count between 2008 and 2018. During the EIA baseline study, they were found foraging west of the Project Site Boundary and south of Round Island. A total of 107 individuals was recorded in the Study Area, where 41 individuals were within the Assessment Area of collision risk and 17 individuals were within the Project Site. With consideration of the new turbine specifications, 16 individuals fall within the risk height level in the Study Area of Lower Bound – 6.45MW, in which 7 individuals are within the Assessment Area and 2 individuals are within the Project Site. For Upper Bound – 15/16MW, 8 individuals fall within the risk height level in the Study Area, in which 3 individuals are within the Assessment Area, but none are within the Project Site.

Table A2.8 Peak Count of Common Tern from 2008 to 2018 (2014 - 2018 Hong Kong Bird Report)

	Peak Count										
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Peak Count	56	25	38	27	62	41	50	43	10	44	160

A2.4.2.6 Heuglin's Gull

The Heuglin's Gull is a common winter visitor to Deep Bay and spring passage migrant to coastal waters. According to AFCD Biodiversity Database, it was found distributed in Deep Bay area and Cape D'Aguilar. It is classified as Least Concern on the IUCN Red List and Local Concern by Fellowes *et al*. (2002). In the Hong Kong Bird Reports, most of the records were made in the Deep Bay area where it is a winter visitor, and Po Toi where it is a spring migrant through southern waters, mostly in March. The number of Heuglin's Gull are generally stable. With reference to the available data, it is considered the data in 2008 would be comparable. During the EIA baseline study, Heuglin's Gull were usually found flying or resting or foraging within and in the vicinity of the Project Site. A total of 183 individuals was recorded in the Study Area during the EIA baseline survey, where 173 individuals were within the Assessment Area of collision risk and 131 individuals were within the Project Site. With consideration of the new turbine specifications, 33 individuals fall within the risk height level in the Study Area of Lower Bound – 6.45MW, in which 28 individuals are within the Assessment Area and 11 individuals are within the Project Site. For Upper Bound – 15/16MW, 20 individuals fall within the risk height level in the Study Area, in which 15 individuals are within the Assessment Area and 9 individuals are within the Project Site.

Table A2.9 Peak Count of Heuglin's Gull from 2008 to 2018 (2018 Hong Kong Bird Report)

	Peak Count										
	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Peak Count	305	635	700	276	455	410	787	250	278	342	200

A2.4.2.7 Red-necked Phalarope

The Red-necked Phalarope is a common passage migrant, mostly distributed in coastal waters but sometimes inland, with occasionally high counts and rare winter records. It is classified as Least Concern on the IUCN Red List. Based on Hong Kong Bird Reports, the number of Red-necked Phalarope are generally stable with occasionally high counts. The highest record was made in 2012, peak count 2,490 passing northeast offshore from Po Toi. Low counts were also recorded, but partly due to lack of sea-watching activity according to the Hong Kong Bird Report 2015. According to the

Hong Kong Bird Report 2018, a high peak count of 2,000 at Clearwater Bay was recorded due to the Typhoon Mangkhut. Given that the peak count recorded in 2018 was affected by adverse weather condition, the peak count in 2018 is considered as abnormal and therefore not considered in the review. With reference to the available data, it is considered that the population of Red-necked Phalarope has increased by approximately 75% from 102 peak count in 2008 to 179 peak count in 2017. As a precautionary approach, the density (based on the EIA baseline survey), to be used for the updated bird collision risk model, will be multiplied by 2 times as determined from the increase in the peak count between 2008 and 2017. During the EIA baseline study, Red-necked Phalarope spent most of their time swimming or resting over large area of the Study Area. A total of 207 individuals was recorded in the Study Area during the EIA baseline survey, where 41 individuals were within the Assessment Area of collision risk and 7 individuals were within the Project Site. With consideration of the new turbine specifications, 6 individuals fall within the risk height level in the Study Area of Lower Bound – 6.45MW, in which one individual is within the Assessment Area, but none are within the Project Site. For Upper Bound – 15/16MW, 2 individuals fall within the risk height level in the Study Area, but none are within the Assessment Area nor the Project Site.

Table A2.10 Peak Count of Red-necked Phalarope from 2008 to 2018 (2018 Hong Kong Bird Report)

	Peak Count										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018*
Peak count	102	360	128	610	2,490	409	435	20	300	179	2,000

*Note: An abnormal high peak count recorded is due to adverse weather condition, Typhoon Mangkhut. The peak count in 2018 is therefore not considered in the review.

A2.4.2.8 White-bellied Sea Eagle

The White-bellied Sea Eagle is a locally common resident in coastal areas, mainly in the eastern New Territories and islands. According to AFCD Biodiversity Database, it is an uncommon resident. It is listed on Cap. 586. Protection of Endangered Species of Animals and Plants Ordinance. It is also classified as Least Concern on IUCN Red List; Regional Concern on Fellowes et al. *(2002)*; Class II protected species in the PRC; an indeterminate species in the China Red Data Book; and CITES Appendix II. Significant change in population trend of White-bellied Sea Eagle has not been described by the Hong Kong Bird Reports. With reference to the available data, it is considered the data 2008 would be comparable. During the EIA baseline study, most of the bird activities were observed along the East Lamma Channel. A total of 10 individuals was recorded in the Study Area, where one individual was recorded within the Assessment Area of collision risk and none were recorded within the Project Site. With consideration of the new turbine specifications, 6 individuals fall within the risk height level in the Study Area of Lower Bound – 6.45MW and Upper Bound – 15/16MW, but none are within the Assessment Area nor the Project Site.

During the time of EIA study no nests of the White-bellied Sea Eagle were found on Lamma Island. However, according to AFCD publication in 2020 [(9)], the nearest nesting site of White-bellied Sea Eagle is located at Lamma Island, with 4 – 6 breeding years (i.e. since 2013/ 2014), where the shortest distance from the proposed wind farm and the Lamma Island nesting site is approximately 6.1 km (**Figure A2.4**). A study revealed that their foraging distance could reach as far as 2km from nesting locations with the peak foraging period occurring between 5pm and 7pm [(10)]. Considering the large distance between the Lamma Island nesting site and the proposed windfarm, it is considered that there will be no significant impact on the breeding population of White-bellied Sea Eagle.

(9) So *et al.* 2020. A short Note on the Breeding of White-bellied Sea Eagle in Hong Kong. AFCD Biodiversity Newsletter.

(10) Tsim et al (2003) *Op cit*.

Table A2.11 Peak Count of White-bellied Sea Eagle from 2008 to 2018 (2008 - 2018 Hong Kong Bird Report)

	Peak Count										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Peak Count	6	3	3	3	2	3	3	2	2	3	2

A2.4.2.9 White-winged Tern

The White-winged Tern is a common passage migrant, mostly sighted in spring, with some summer records. According to AFCD Biodiversity Database, it is an uncommon passage migrant found distributed in Deep Bay area, Cheung Chau, Po Toi, Long Valley, Cape D'Aguilar and Lamma Island. It occurs at inland wetlands and coastal waters. It is classified as Least Concern on the IUCN Red List. Based on data from Hong Kong Bird Report, the peak counts fluctuate greatly due to occasional large spring flocks with no apparent trend. As a precautionary approach, the density (based on the EIA baseline survey), to be used for the updated bird collision risk model, will be multiplied by 2 times as determined from the increase in the peak count between 2008 and 2018. During the EIA baseline study, they were mainly resting or flying in the vicinity of the Project Site. A total of 178 individuals was recorded in the Study Area, where 49 individuals were within the Assessment Area of collision risk and 20 individuals were within the Project Site. With consideration of the new turbine specifications, 20 individuals fall within the risk height level of Lower Bound – 6.45MW, in which all records are within the Assessment Area and Project Site. For Upper Bound – 15/16MW, none of the recorded White-winged Tern fall within the risk height level.

Table A2.12 Peak Count of White-winged Tern from 2008 to 2018 (2018 Hong Kong Bird Report)

Seasons	Peak Count in Spring and Autumn										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Spring	280	111	700	70	177	68	450	387	128	292	600
Autumn	20	10	28	1	44	4	9	65	6	2	6

A2.5 Summary

In summary, the in-depth review of available data showed that the majority of the species recorded in the approved EIA have not seen an increasing trend in their populations since the baseline data was collected in 2008 and as such, it is reasonable to conclude that the baseline avifauna bird collected in 2008 remains largely valid.

Among the main species of concern, evidence from the review has indicated that Aleutian Tern, Black-naped Tern, Common Tern, Red-necked Phalarope and White-winged Tern populations showed a clear change.

In consideration of the increase in their populations, the density of these species adopted in the updated bird collision risk model will be multiplied to assess the potential collision risk. Given that the environmental conditions of the Project Site remain similar to that described in the approved EIA and the baseline avifauna data collect in 2008 remains largely valid, no further baseline survey for avifauna is considered necessary with the adjustment of the data for specific species.

A3. MARINE ECOLOGY

A3.1 Review of EIA Findings

This Section reviews the findings of the EIA study on marine ecological resources identified within and in the vicinity the Project, including the footprint of the proposed wind farm site and the proposed alignment corridor for the submarine cable connection to the Lamma Power Station Extension as presented in **Figure A1.1**. The marine ecological assessment conducted during the EIA stage was based on the review of available literature and data obtained from field surveys for marine mammals, intertidal assemblages, subtidal benthic assemblages and subtidal hard bottom assemblages conducted between July 2008 and June 2009. The ecological importance of the habitats during EIA stage was evaluated and presented in **Table A3.1**.

Table A3.1 Ecological Importance of the Marine Habitats as presented in the EIA Report

Habitat	Ecological Importance within and in close vicinity of Wind Farm Site	Ecological Importance along Cable Route
Artificial Shoreline	N/A	Low
Subtidal Soft Bottom Habitats	Low	Low
Subtidal Hard Surface Habitat	Low	Low
Marine Waters	**Medium – High** for *Neophocaena phocaenoides* and **Low** for *Chelonia mydas*	**Low – Medium** for *Neophocaena phocaenoides* and **Low** for *Chelonia mydas*

In the following context, the up-to-date information for marine ecological resources within and in the vicinity of the Project have been reviewed based on available literatures and EIA reports.

A3.2 Marine Mammals

A total of 18 (and possibly up to 20) species of marine mammals (mostly cetaceans) have been recorded in Hong Kong waters (including one humpback whale sighted in 2009, one stranding of Omura's whale in 2014, one shortfin pilot whale sighted in 2015 and 2 false killer whale pods sighted in 2014 and 2020). Among these two of which are considered residents, including the Finless Porpoise (FP) *Neophocaena phocaenoides* and the Chinese White Dolphin (CWD) *Sousa chinensis*. FP are mainly distributed in southern and eastern waters of Hong Kong, while CWD are mainly distributed in western and southwestern waters of Hong Kong. As the Project is located in southern waters of Hong Kong within the habitats utilised by FP, the following context will focus on FP.

FP is a tropical/ sub-tropical cetacean widely distributed in coastal marine waters, as well as some river mouths and estuaries, from the Arabian/Persian Gulf eastwards around the rim of the Indian Ocean to the Taiwan Strait area in southern Japan. It is protected locally by the *Wild Animals Protection Ordinance (Cap. 170)*, and is listed as "Vulnerable" in the IUCN Red List of Threatened Species [(11)]. FP is also listed in CITES Appendix I (i.e. highest protection), and is listed as "Grade II National Key Protected Species" in China. As such FP is considered a species of conservation importance, both locally in Hong Kong and regionally in China and across the Asia Pacific.

(11) Wang, J.Y., Reeves, R. (2017). *Neophocaena phocaenoides*. The IUCN Red List of Threatened Species 2017.

Studies on the distribution, abundance, habitat use, life history and behaviour of FP in Hong Kong have been undertaken since 1998. It was estimated that there were at least 147 porpoises occurring in Chinese waters just south of Hong Kong, which makes the minimum population size estimate to be 217 animals [(12)].

In Hong Kong, FP occur year-round, and they can be found primarily in the southern (i.e Po Toi, Lamma, Southeast and Southwest Lantau) and eastern (i.e. Mirs Bay, Sai Kung and Ninepins) waters of the territory [(13)] [(14)]. The majority of porpoise sightings have been made to the south of Soko Islands and Cheung Chau, around Shek Kwu Chau, and between the waters of Soko Islands and Shek Kwu Chau. These areas are thus considered to be the main habitats for FP. The only area where FP and CWD showed overlap in distribution was in South Lantau waters especially around Soko Islands.

Seasonal variation in distribution is evident for FP in Hong Kong. FP move into the waters of south Lantau and Lamma in winter (from December to February), and peak abundance was recorded in spring (from March to May) when significant numbers occurred in southern waters. During summer (from June to August), FP generally vacated the waters of south Lantau and Lamma and moved to Po Toi, Ninepins and Sai Kung, and abundance appears to reach a low point in autumn (from September to November) [(15)]. Their abundance in Hong Kong waters ranges from a high of approximately 152 individuals in spring to approximately 55 in autumn [(16)].

A data review of long-term marine mammal monitoring conducted by AFCD up to the year of 2020 has been conducted [(17)]. The results showed that FP were mainly sighted to the south of Tai A Chau, Shek Kwu Chau, south of Cheung Chau and at the offshore waters between Shek Kwu Chau and the Soko Islands as important porpoise habitats during dry season and at Po Toi Islands and at the juncture of Po Toi and Ninepins areas during wet season. The encounter rate of FP varied over time between 2002-2019 and the FP encounter rate in Lamma waters was slightly lowered in recent years (2017-2019) (**Figure A3.1**). A higher sighting density (SPSE values) of FP in Lamma waters was recorded during winter and spring (December to May) in compared to summer and autumn (June to November) within and in the vicinity of the Project during 2015-2019 (**Figure A3.2**).

Overall, the encounter rate and seasonal distribution of FP remain to be similar in recent years and it is considered that the data from the long-term marine mammal monitoring conducted by AFCD are comprehensive and adequate for further environmental review for the Project. No further baseline survey for marine mammals is considered necessary.

A3.3 Sea Turtles

Of the seven extant species of sea turtles, loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*), olive ridley (*Lepidochelys olivacea*) and green (*Chelonia mydas*) turtles have been reported to occur in the waters of Hong Kong [(18)]. However, the green turtle is the only species confirmed to nest in Hong Kong [(19)].

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(12) AFCD (2020). Finless Porpoise.

(13) Jefferson TA, Braulik G T (1999) Preliminary report on the ecology of the finless porpoise in Hong Kong waters. *IBI Reports* 9: 41-54

(14) Jefferson TA, Hung SK, Law L, Torey M, Tregenza N (2002) Distribution and abundance of finless porpoises in Hong Kong and adjacent waters of China. Raffles Bulletin of Zoology 10: 43-55.

(15) AFCD (2021). Finless Porpoise.

(16) AFCD (2021). Finless Porpoise.

(17) AFCD (2020) Monitoring of Marine Mammals in Hong Kong Waters (2019 -2020). Prepared by Hong Kong Cetacean Research Project.

(18) AFCD (2020) Sea turtles recorded in Hong Kong website.

(19) Nesting refers to the laying of clutches of eggs by female turtles on their natal beaches. Female turtles usually migrate (up to thousands of kilometres) from their resident foraging areas to a coastal area, ie nesting beach, for nesting. Adult

Green turtle *Chelonia mydas* is protected locally by the *Wild Animals Protection Ordinance (Cap. 170)*, and is listed as "Endangered" in the IUCN Red List of Threatened Species [(20)]. It is also listed in CITES Appendix I (i.e. highest protection), and is listed as "Critically Endangered" on the China Species Red List and a "Grade II National Key Protected Species" in China. As such green turtle is considered a species of conservation importance locally, regionally and globally.

The major nesting site for green turtles in Hong Kong is at Sham Wan, southern Lamma Island, which is over 5 km from the Project [(21)(22)(23)]. A small number of green turtles are known to nest at Sham Wan, although nesting does not occur every year. Some five green turtles were observed at Sham Wan in the nesting seasons between 1998 and 2012 [(24)]. The last record of green turtle nesting at Sham Wan was in 2012 when five clutches of eggs were laid, though none hatched [(25)].

Satellite tracking of female green turtles nesting at Sham Wan beach has been undertaken since 2002 to examine their regional migration patterns. Results of the tracking showed that the same nesting female (named "Hong Kong 2") tracked in June 2003, August 2008 and August 2012 used the waters close to Sham Wan, in the south and southeast of Lamma Island, between subsequent clutches (**Figures A3.3-A3.5**). She maintained a distance of within 10 km of the beach during inter-nesting periods for just over two months before migrating back to foraging grounds in the coastal waters of Dao Bach Long Vi, Vietnam [(26)].

Satellite tracking of a foraging green turtle in the Gangkou Sea Turtle National Nature Reserve populations in China indicated that it moved from its foraging grounds in Daya Bay to Wanshan Archipelago [(27)], migrating past or through Hong Kong, by Basalt Island, Tung Lung Chau and other parts of Hong Kong waters, between nesting and foraging grounds. Another tracking study conducted on post-nesting green turtles populations in Taiwan also indicated that the turtles often utilise several coastal areas as temporal residential forging sites as far as to the east coast of China [(28)].

Apart from the nesting records at Sham Wan, nesting of green turtles has been recorded in Shek Pai Wan and Tung O on Lamma Island, Tai Wan in Sai Kung and Tai Long Wan in Shek O in the last two decades [(29)]. The most recent nesting of green turtle was reported on a beach on Lantau Island in

females return to their natal areas for breeding and both males and females show strong fidelity to their nesting and foraging areas

(20) Seminoff, J.A. (Southwest Fisheries Science Center, U.S.). 2004. Chelonia mydas. The IUCN Red List of Threatened Species 2004

(21) McGilvray F, Geermans S (1997) The status of the green turtle in Hong Kong and an action plan for its survival. Hong Kong: The Hong Kong Marine Conservation Society.

(22) Morton B (1999) On turtles, dolphins and, now, Asia's horseshoe crabs. Marine Pollution Bulletin 38: 845-846.

(23) Green turtle nesting was recorded in 2006 to the east of Hong Kong at Tai Long Wan, Sai Kung. However, this is the only record of nesting at this location and it is unlikely to be a major nesting site for green turtles in Hong Kong.

(24) Ng CK, Dutton PH, Chan SK, Cheung K, Qiu J, Sun Y (2014) Characterization and conservation concerns of Green Turtles (*Chelonia mydas*) nesting in Hong Kong, China. Pacific Science, vol. 68, no. 2:231-243.

(25) AFCD (2013) Rescued green turtle returned to the sea.

(26) Hong Kong Wetland Park's website

(27) Song X, Wang H, Wang W, Gu H, Chan SKF, Jiang H (2002) Satellite tracking of post-nesting movements of green turtles, *Chelonia mydas*, from Gangkou Sea Turtle National Nature Reserve, China, 2001. Marine Turtle Newsletter 97: 8-9.

(28) Cheng IJ (2000) Post-nesting migrations of green turtles (*Chelonia mydas*) at Wan-An Island, Penghu Archipelago, Taiwan. Marine Biology 137: 747-754.

(29) Ng CK, Dutton PH, Chan SK, Cheung K, Qiu J, Sun Y (2014) Characterization and conservation concerns of Green Turtles (*Chelonia mydas*) nesting in Hong Kong, China. Pacific Science, vol. 68, no. 2:231-243.

October 2016 (30). It indicated that the turtle may use the sandy shores in South Lantau. However, no systematic survey or satellite tracking survey have been conducted on the turtles that occurred in Lantau Island and in Sai Kung. Recent news records reported green turtles in Northeastern waters and Lantau waters, including a live adult female in Tai Po in December 2012 (31), three juvenile turtles at Pak Lap Beach and Silverstrand Beach in Sai Kung and a refuse collection depot on Tin Hau Temple Street in North Point in 2014 to 2016 (32), a dead individual with marine debris inside its stomach on Pak Lap Beach in Sai Kung in October 2015 (33), a dead juvenile turtle entangled with fishing net in Pui O Wan in January 2016 (34) and a tagged individual (HK303) in Tai She Wan in Sai Kung in November 2017 (35). A green turtle was rescued in the waters of South Lantau in January 2021 and was then released into the southern waters of Hong Kong on 25 June 2021 with satellite transmitter attached to its carapace for tracking the movement and feeding grounds of the green turtle for future identification and monitoring (36).

Overall, it was reported that the nesting population of green turtles in Hong Kong was relatively small, while the potential for occurrences of this species around the Project exist as Hong Kong lies within the wider Pacific region where green turtles use as nesting, inter-nesting and foraging habitats (37)(38), which aligns with the EIA findings. Due to the very occasional occurrence of green turtle in Hong Kong waters consistently over the years, it is considered that the existing information is adequate for further environmental review for the Project.

A3.4 Intertidal Hard Bottom Assemblages

Intertidal hard shores of Hong Kong display characteristic zonation patterns consisting of different algal and invertebrate species along the vertical gradient from terrestrial to marine environments. The areas around the Project mainly consists of hard shores (both natural shores and artificial shores) with some natural shore shores (e.g. sandy shores) as shown in **Figure A3.6**. From the literature review, intertidal assemblages recorded in the vicinity of the Project Area up to 2017 are summarised in **Table A3.2**. The species recorded were all very common and widespread species of Hong Kong which aligns with the EIA findings. Overall, it is expected that the intertidal habitats remain similar over time and the existing information is adequate for further environmental review for the Project.

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(30) EJInsight (2017) Marine garbage likely to keep green turtles from returning to HK.

(31) South China Morning Post (2013) Endangered green turtle caught in Tai Po returned to sea.

(32) AFCD (2016) Three green turtles returned to sea.

(33) WWF (2015) Dead Green Turtle Found Stranded in Sai Kung Shocking quantities of marine litter had accumulated inside its digestive system.

(34) Coconuts Hong Kong (2016) Young sea turtle found dead and entangled in fishing net south of Lantau Island.

(35) 蘋果新聞網 (2017) 瀕危綠蠵龜被海底廢漁網纏身 熱心女救脫險.

(36) AFCD: Press Releases Access on 28 June 2021.

(37) Ng CKY, Dutton PH, Chan SKF, Cheung KS, Qiu JW, Sun YA (2014) *Op cit.*

(38) Ng CKY (2015) Conservation Implications of the Genetic Structure and Habitat Use of Green Turtles (*Chelonia mydas*) in the South China Region and Baseline Contaminant Levels in Green Turtles and Burmese Pythons (*Python bivittatus*). PhD Thesis.

Table A3.2 Summary of Review on Intertidal Assemblages in the vicinity of the Project

Survey Period	Location (see *Figure A3.7*)	Total No. of Species Recorded	Mean Abundance of Mobile Fauna and Sessile Flora and Fauna	Dominant Species
August 1998 (Wet Season)	Natural Rocky Shores (T1 – T6, L1)	37	125.6 individuals m^{-2} (Mobile Fauna) 39.8% m^{-2} (Sessile Flora & Fauna)	Chiton *Liolophura japonica*, the Limpets (*Cellana grata*, C. *toreuma, Patelloida pygmaea, P. saccharina, Siphonaria atra* and *S. sirius*, the snails *Monodonta labio* and *Planaxis sulcatus*, the nerites *Nerita albicilla. N. chamaeleon, N. costata* and *N. lineata,* littorinid snail *Echinolittorina radiata*, *E. trochoides* and *E. vidua*, the common dog whelks *Reishia clavigera* and *Morula musiva*
October 2008 (Wet Season)	Artificial Sloping Seawall (T7, T8 & T9)	23	38 individuals m^{-2} (Mobile Fauna) 13% m^{-2} (Sessile Flora & Fauna)	Littorinid snail *Echinolittorina* spp. in, the topshell *Monodonta labio*, the limpet *Cellana toreuma*, *C. toreuma, Siphonaria japonica* and *Patelloida saccharina*, the common dogwhelk *Reishia clavigera*, barnacle *Tetraclita squamosa*, the oyster *Saccostrea cucullata*
February 2009 (Dry Season)	Artificial Sloping Seawall (T7, T8 & T9)	22	64 individuals m^{-2} (Mobile Fauna) 21% m^{-2} (Sessile Flora & Fauna)	
May 2014 and September 2015 (Wet Season)	Artificial Sloping Seawall	23	60 individuals m^{-2} (Mobile Fauna) 33% m^{-2} (Sessile Flora & Fauna)	The sea roach *Ligia exotica*, the limpet *Patelloida pygmaea*, *Patelloida saccharina*, *Siphonaria japonica* and the encrusting alga *Hildenbrandia rubra*
November 2015 and January 2016 (Dry Season)	Artificial Sloping Seawall	21	37 individuals m^{-2} (Mobile Fauna) 33% m^{-2} (Sessile Flora & Fauna)	Littorinid snail *Echinolittorina radiata*, the topshell *Monodonta labio*, the limpet *Patelloida saccharina*, the chiton *Liolophura japonica* and the encrusting alga *Hildenbrandia rubra*
May 2014 and August 2015 (Wet Season)	Natural Rocky Shores at Lo So Shing and Ha Mei Tsui	47	80 individuals m^{-2} (Mobile Fauna) 30% m^{-2} (Sessile Flora & Fauna)	Littorinid snail *Echinolittorina radiata*

Survey Period	Location (see *Figure A3.7*)	Total No. of Species Recorded	Mean Abundance of Mobile Fauna and Sessile Flora and Fauna	Dominant Species
November 2015 and January 2016 (Dry Season)	Natural Rocky Shores at Lo So Shing and Ha Mei Tsui	34-39	70 individuals m^{-2} (Mobile Fauna) 30% m^{-2} (Sessile Flora & Fauna)	Littorinid snail *Echinolittorina radiata*, topshell *Monodonta labio*, encrusting alga *Hildenbrandia rubra*
August 2016 (Wet Season) and February 2017 (Dry Season)	Artificial Sloping Seawall (T7, T8 & T9)	20-22	10.4 - 14.2 individuals m^{-2} (Mobile Fauna) 13.4 – 18.9% m^{-2} (Sessile Flora & Fanua)	limpets *Patelloida spp.*, barnacles *Capitulum mitella* and *Tetraclita spp.*

A3.5 Subtidal Hard Bottom Assemblages – Corals

Qualitative and semi-quantitative REA surveys were conducted in May 2009 on the artificial seawall of the Lamma Power Station (LPS) Extension and on hard substrate identified along the proposed cable route during the EIA study of the Project. In addition, some further coral surveys were conducted in 2014, 2015 and 2017 for the EIA studies for the Improvement Dredging for Lamma Power Station Navigation Channel and the Hong Kong Offshore LNG Terminal projects. The records of these studies are summarised in **Table A3.3**. The indicative locations of coral communities are presented in **Figure A3.6**.

Table A3.3 Summary of Review on Coral Communities in the vicinity of the Project

Source	Location	Summary of findings
EIA for the Development of an Offshore Wind Farm in Hong Kong	Seawall of LPS Extension and submarine cable route	A total of three (3) hard corals were identified on the seawall, including *Oulastrea crispata, Porites* sp. and ahermatypic cup coral under Family Dendrophyllidae. The coverage are generally low with <5% on the seawall. The seabed along the submarine cable route was mainly comprised of soft substrata and they were only sparsely colonized on the hard substrata. Octocorals *Echinomuricea* sp., *Menella* sp. and *Dendronephthya* sp. and black coral *Cirripathes* sp. were recorded on the dumped materials along the submarine cable route.
EIA for the Improvement Dredging for Lamma Power	Seawall of LPS Extension and natural shores along the	At the sloping artificial seawalls along the LPS Extension, only one hard coral species, *Oulastrea crispata*, was recorded with low coral cover (<1%). Soft corals were also

Source	Location	Summary of findings
Station Navigation Channel	western coast of Lamma Island	recorded including *Dendronephthya gigantea*, *Echinomuricea* spp., *Echinogorgia* sp. and *Carijoa* sp.. A total of 18 hard coral species were recorded at the natural shores along the western coast of Lamma. Coral cover was, however, low in general (<1% to <5% cover).
EIA for the Hong Kong Offshore LNG Terminal	Artificial seawall of LPS	The site comprised of large boulders and the toe of the seawall was covered with a layer of mud. On the hard substrata, algae were absent and sessile benthos comprised of isolated barnacles. Only sparse colonies of hard coral *Turbinaria peltata*, *Porites* sp. and *Oulastrea crispata*, ahermatypic hard coral *Tubastrea* / *Dendrophyllia* sp. and *Balanophyllia* sp. and octocoral colonies *Dendronephthya* sp., *Echinomuricea* sp. and *Menella* sp./ *Paraplexaura* sp. were identified. The coral cover was low (<5%).

The results from these studies showed that the seawalls along LPS Extension, natural shores along the western coast of Lamma and the proposed cable route of the Project supported very low coverage of corals (<5%). The species recorded were common and widespread in Hong Kong.

A3.6 Subtidal Soft Bottom Assemblages - Benthic Assemblages

Site-specific benthic grab surveys within and in proximity to the footprint of the wind farm site and cable route were conducted as part of the EIA study of the Project. In both seasons, infaunal assemblages at the surveyed sites were dominated by polychaete worms, and the species recorded are common and widespread species with no particular conservation importance. The abundance, biomass and taxonomic richness of infauna at these sites are considered as very low in comparison with the Hong Kong average reported in the literature. Thereafter, benthic grab surveys were conducted in west of Lamma in 2014, 2015 and 2017 for the EIA studies for the Improvement Dredging for Lamma Power Station Navigation Channel and the Hong Kong Offshore LNG Terminal project. The relevant sampling locations of these studies are selected for review as presented in **Figure A3.6**. The findings are summarised in **Table A3.4**.

Table A3.4 Summary of Review on Benthic Assemblages in the vicinity of the Project

Source	Summary of findings
EIA for the Development of an Offshore Wind Farm in Hong Kong	Benthic surveys conducted in October 2008 and March 2009 showed that infaunal abundance, biomass and taxonomic richness were very low at all sampling sites. Variation within site (ie among sampling stations) was also considered to be small. The majority of organisms were from the Phylum Annelida and Arthropoda. No rare or uncommon species were recorded in the surveys.
EIA for the Improvement Dredging for Lamma Power Station Navigation Channel	Benthic surveys conducted in May 2014, September and December 2015 showed that bivalves (Mollusca) and polychaetes (Annelida) were the most abundant groups within the navigation channel, while sipunculids and polychaetes were the most abundant groups outside the navigation channel. In general, the diversity and species evenness of benthic communities of survey area were similar amongst various surveys and all recorded species were common with no conservation interest.

Source	Summary of findings
EIA for the Hong Kong Offshore LNG Terminal	Benthic surveys conducted in March and June 2017 showed that infaunal abundance, biomass and taxonomic richness were very low at all sampling sites (Stations B15 and B16). The majority of organisms were from the Phylum Annelida, Arthropoda and Echinodermata. No rare or uncommon species were recorded in the surveys.

The results showed that the subtidal soft bottom habitats in west of Lamma waters supported low abundance, biomass and taxonomic richness of infaunal assemblages and the dominant organisms were polychaete worms and bivalves. The species recorded were common and widespread species with no particular conservation importance. Based on the above review, it is consistently showed that the subtidal soft bottom habitats within and in the vicinity of the Project support low abundance, biomass and taxonomic richness of infaunal assemblages and the dominant organisms were polychaete worms and bivalves. The species recorded were common and widespread species with no particular conservation importance. Overall, it is expected that the subtidal soft bottom habitats would remain broadly similar over time and the existing information is adequate for further environmental review for the Project.

A3.7 Recognized Sites of Conservation Importance

There are no Special Areas or Conservation Areas that are relevant to marine ecology within and in the vicinity of the Project. Recognized sites of conservation importance include potential marine park at South Lamma, Sites of Special Scientific Interest (SSSI) and the Sham Wan Restricted Area. These are further discussed below and their locations are provided in **Figure A3.6**.

A3.7.1 Potential South Lamma Marine Park

A study was conducted in 1999 to investigate the feasibility of designating South Lamma as a marine park [39]. The study concluded that the coastal waters of South Lamma supported marine fauna of ecological value, mainly green turtles and finless porpoises. There is no information on the proposed timeline for designation of South Lamma Marine Park.

A3.7.2 Sham Wan SSSI

Designated in June 1999, the Sham Wan SSSI covers the sandy beach and adjoining shallow shore of about 4 ha at Sham Wan of South Lamma (**Figure A3.6**), for important nesting sites for the locally and regionally rare green turtles. This SSSI is more than 3 km to the east of the Project.

A3.7.3 Sham Wan Restricted Area

The sandy beach at Sham Wan of South Lamma was designated as a Restricted Area under the *Wild Animals Protection Ordinance (Cap. 170)* in July 1999. To strengthen the protection of the Green Turtle, the Restricted Area has been expanded from the beach to the adjacent waters in the inlet of the sea with effect from 1 April 2021. Access to the beach is prohibited between 1 April and 31 October each year during the green turtle nesting season. The location of this Restricted Area is provided in **Figure A3.6** [40].

A3.8 Summary

Overall, there are no apparent significant changes in marine ecological resources within and in the vicinity of the Project over time since the approval of the EIA report of the Project. The existing

(39) AFCD (1999). Study on the Suitability of South Lamma to be Established as Marine Park or Marine Reserve.

(40) AFCD (2021) Conservation of sea turtles in Hong Kong.

information reviewed in this Baseline Data Note is considered adequate for further environmental review of the proposed variation of the Project. No information gap has been identified and therefore no further marine ecological survey is considered necessary for the further environmental review of the proposed variation of the Project.

A4. FISHERIES

A4.1 Review of EIA Findings

This Section reviews the findings of the EIA study on existing fisheries resources, capture and culture fishing operations from the construction and operation of the proposed offshore wind farm development. The EIA study was conducted mainly based on the data of AFCD Port Survey 2006. It was reported that the fisheries resources and production rates within and adjacent to the wind farm range from medium to high in terms of catch weight and value and the Project area is within the spawning and nursery areas of commercial fisheries resources. No fish culture zones (FCZs) were located close to the wind farm site or the proposed cable route. The closest FCZs were located at Lo Tik Wan (> 9 km from the windfarm site, > 6 km from the cable route), Sok Kwu Wan (> 10 km from the windfarm site, > 8 km from the cable route) and Cheung Sha Wan (> 10 km from the windfarm site, > 9 km from the cable route).

In the following context, the up-to-date information for fisheries resources and fishing operations within and in the vicinity of the Project have been reviewed based on available literatures and EIA reports.

A4.2 Fisheries Operation

As of 2020, the Hong Kong fishing industry produced an estimated 116,000 tonnes of fisheries products, the value of these capture fisheries products was around $2.7 billion. AFCD reported that the capture fisheries industries consists of around 5,040 fishing vessels that employ an estimated 10,150 local fishermen [(41)]. The statutory ban on trawling in Hong Kong waters that was implemented on 31 December 2012 [(42)] has resulted in the majority of fishing activities in Hong Kong to be conducted on sampans utilising an array of fishing gear and on other smaller non-trawler vessels such as gill netters, long liners, purse seiners, etc. The latest available information regarding the current type and number of fishing vessels in Hong Kong was produced in AFCD's 2018-2019 Department Annual Report (**Table A4.1**).

Table A4.1 Estimated Number of Fishing Vessels by Type in 2018 (Source: AFCD)

Type of Vessel	Quantity
Pair Trawler	560
Stern Trawler	140
Shrimp Trawler	240
Hang Trawler	40
Gill Netter	270
Long Liner	100
Hand Liner	40
Purse Seiner	100
Miscellaneous	3560
Total	**5050**

The AFCD Port Survey 2016/17 provides the latest available survey information on the current fishing operations and fisheries production in Hong Kong waters. The survey was conducted from 2016 to

(41) AFCD (2021). Overview of Capture Fisheries.

(42) AFCD (2017). Hong Kong Fisheries Resources Monitoring Report (2010-2015) Executive Summary. Accessed on 14 May 2020

2017 through a comprehensive interview survey of local fishermen by AFCD (43). The survey achieved a sampling rate of about 36% which included various fishing vessels from different homeports. The homeports of local fishing vessels that are in the vicinity to the Project include Yung Shue Wan, Lo Tik Wan, Sok Kwu Wan, Cheung Chau, Silver Mine Bay and Peng Chau. The distribution of overall fishing operations in Hong Kong from 2016-2017 is presented in **Figure A4.1**.

The survey results showed that the Project footprint falls within the high fishing activity area with moderate to high (>100-200 vessels to >600-800 vessels) level of fishing operations which are comparable to the Port Survey 2006 findings.

Recent opportunistic vessel-based observations could be referred to fisheries impact assessment conducted for the Hong Kong Offshore LNG Terminal EIA with assessment done in proximity of the Lamma Power Station in 2016-2017 (44). A total of 99 vessels with fishing activities were recorded during the adult fish production surveys with an average of about 3-4 vessels encountered per day. Results showed that some fishing activities by hand-lining and gill-netting were observed during wet season, with a majority of fishing undertaken using P4/7 vessels (also referred to as sampan) at the northern area of wind farm site and in proximity of the proposed cable location. Whereas in dry season, fishing by hand-lining, gill-netting and long-lining were observed, with over half of the activities undertaken by hand-lining and gill-netting using P4/7 vessels. The recent survey results have recorded lower mean number of vessels encountered per day with similar vessel type (except trawlers) observed compared to the results obtained during the EIA study of this project. A mean total number of ~10 vessels were recorded in the study area around Lamma Island per day during the EIA study, in which the majority were small P4s (45) undertaking hand-lining or gill-netting activities, followed by shrimp trawling and stern trawling vessels.

A4.3 Fisheries Production

The status of fisheries production in Hong Kong can be made reference to the latest available fisheries information from AFCD Port Survey 2016/17 conducted through a comprehensive interview survey of local fishermen (46). The survey results showed that the highest fisheries production (>400 to 600 kg ha^{-1}) occurred in Hong Kong was at waters around Shek Kwu Chau and at southern waters of Cheung Chau (**Figure A4.2**). This showed a shifting pattern in the highest fisheries production from southern waters of Hong Kong Island and northeastern waters of Hong Kong to southern waters of Lantau Island when compared to the Port Survey 2006 data, which the highest fisheries production (600 to 1,000 kg ha^{-1} for adult fish) occurred near the Ninepin Island Group, Po Toi and Tap Mun previously. Other areas of high fisheries production as showed in the 2016/17 data include areas around the Soko Islands and Po Toi Island Group extending to waters outside Bluff Head.

From the AFCD Port Survey 2016/17, fisheries production varies from >50 – 100 kg ha^{-1} to >200 – 300 kg ha^{-1} within and adjacent to the wind farm site and cable route, showing a slight decrease of fisheries production when compared to adult fish catches (varying from 200 – 400 kg ha^{-1} to 400 – 600 kg ha^{-1}) as reported in the Port Survey 2006 data. In comparison to other areas of the Hong Kong fishing ground, fisheries production to the east of the proposed wind farm site which was reported to be relatively high (400 – 600 kg ha^{-1}) from the Port Survey 2006 data, appeared to be at moderate level (>200 – 300 kg ha^{-1}) in the latest Port Survey 2016/17.

The top 10 fish catches in Hong Kong recorded in the 2016/17 report (**Table A4.2**) were similar to the 2006 data, however, anchovy (Engraulidae) which previously belonged to the top 10 families/ groups captured was not on the list in the latest 2016/17 report. The distribution of overall fisheries production in Hong Kong from 2016-2017 is presented in **Figure A4.2**. Furthermore, based on the

(43) AFCD Port Survey 2016/17.

(44) ERM (2018). EIA Report for the Hong Kong Offshore LNG Terminal (Register No.: AEIAR-218/2018)

(45) Defined as vessels which are licensed to carry no more than four passengers.

(46) AFCD Port Survey 2016/17. *Op. Cit.*

findings of the Hong Kong Fisheries Resources Monitoring Report (2010-2015) [47], the main commercial families of fisheries resources around the Project are provided in **Table A4.3**.

Table A4.2 The Top 10 Fish Catch in Hong Kong Waters (Source: AFCD Port Survey 2016/17)

Rank	Family/Group	Common Name of Fish Catch
1	Mugilidae	Mullet
2	Clupeidae	Sardine, Shad
3	Carangidae	Scad, Jack
4	Sparidae	Seabream
5	Sciaenidae	Croaker
6	Mixed squid	Squid
7	Mixed crab	Crab
8	Siganidae	Rabbitfish
9	Mixed shrimp	Shrimp
10	Platycephalidae	Flathead

Notes:

(1) Other common fish captured include Muraenesocidae (conger-pike eel), Scombridae (mackerel), Polynemidae (threadfin), Scorpaenidae (common rock fish) and Cynoglossidae (tongue sole), etc.

(2) Ranking is based on the estimated weight of production of each family/group of fish catch.

Table A4.3 Main Commercial Families of Fisheries Resources in Southern Hong Kong waters (Source: AFCD Hong Kong Fisheries Resources Monitoring Report (2010-2015))

Rank	Main Commercial Families from Shrimp Trawl Surveys	Main Commercial Families from Stern Trawl Surveys	Main Commercial Families from Purse-Seine Surveys
1	Leiognathidae	Leiognathidae	Carangidae
2	Sciaenidae	Engraulidae	Clupeidae
3	Platycephalidae	Carangidae	Trichiuridae
4	Squillidae	Sciaenidae	Engraulidae
5	Portunidae	Clupeidae	Leiognathidae
6	Penaeidae	Sparidae	
7	Cynoglossidae	Squillidae	
8	Clupeidae	Stromateidae	
9	Polynemidae	Polynemidae	
10	Sparidae	Trichuridae	

Notes:

(1) Consolidated ranking based on the biomass of each family collected in the surveys.

(2) The data above represent the main commercial families of fisheries resources obtained from South-Western Hong Kong waters from shrimp trawl and stern trawl surveys and from Southern Hong Kong waters from purse-seine surveys.

(47) South China Sea Fisheries Research Institute (SCSFRI) (2017). Hong Kong Fisheries Resources Monitoring Report (2010-2015). Prepared for the Agriculture, Fisheries and Conservation Department

A4.4 Fisheries Resources

Historically, the majority of species captured in the southern waters (South Lamma, South Cheung Chau, Soko Islands, South Lantau, North Lamma) were mantis shrimp (Squillidae). Results of gill-netting surveys indicated high biomass of croaker (Sciaenidae) were recorded at Shek Kwu Chau, South Lamma and Peng Chau (48).

Fisheries surveys were conducted for the Hong Kong Offshore LNG Terminal Project between October 2016 and July 2017 and the survey locations covered Cheung Chau and West Lamma in the vicinity of the Project (49). The results showed that mean biomass, abundance, species richness, species diversity and species evenness of the fisheries resources (including fish and crustaceans) were moderate in both wet and dry seasons, comparing to other stations located in western waters and southern Lantau waters. The dominant fish species recorded in the surveys, in terms of both biomass and abundance, was the croaker *Johnius belangerii* which is of low commercial value (i.e. < 55 HK$/kg) according to the Fish Marketing Organisation (FMO) (50) and other published references (51). The dominant crustacean species recorded in the survey, in terms of both biomass and abundance, was the crab *Charybdis (Charybdis) affinis* which has been identified as of no commercial value (52).

Another gill net and hand line surveys were conducted between February and May 2018 around the Lamma Power Station for the Improvement Dredging for Lamma Power Station Navigation Channel Project. A total of 187 individual fishes, crustaceans and cuttlefish weighing 12.87kg from 26 species of 19 families were collected from the surveys. All the species caught in this study are commonly found and widespread across the waters of Hong Kong. Most of the catches are species with low commercial value (53).

A4.5 Existing Spawning and Nursery Areas of Commercial Fisheries Resources

A4.5.1 Spawning Grounds

The southern Hong Kong waters were previously identified in 1998 as fisheries spawning grounds for high value commercial species (**Figure A4.3**). In Hong Kong, spawning period differs among fisheries species with the majority of commercial species aggregate and spawn in the open waters during the period from June to September (54). Some fish species, including flathead (*Platycephalus indicus*) and shad (*Clupanodon (Konosirus) punctatus*), spawn in the late winter/early spring (i.e. February to April) and a few are known to spawn in January. Shrimp scad (*Alepes djedaba*) spawns in the early summer (around June) whilst pony fish (*Leiognathus brevirostris*) and croakers were found to be reproductive throughout most of the year from May to December. The spawning period of most of the crustacean species was found to be from April to November, with spawning concentrated between June and August.

The recognised spawning ground in southern Hong Kong waters is over 30 km long and approximately 10 km wide, extending across southern waters from Fan Lau Kok all the way east pass Soko Islands and beyond Lamma Island, abutting the southern boundary of the HKSAR. Pony fish (*Leiognathus brevirostris*), croakers (*Johnius belangerii* and *Protonibea diacanthus*), mantis shrimps

(48) ERM (1998). Study of Fisheries Resources and Fishing Operations in Hong Kong Waters, AFCD.

(49) ERM (2018). *Op cit.*

(50) Fish Marketing Organization (FMO). Available at FMO website

(51) Mott MacDonald (2014). Expansion of Hong Kong International Airport into a Three-Runway System: EIA Study (EIA Report Registered No. AEIAR-185/2014).

(52) Mott MacDonald (2014). *Op Cit.*

(53) Mott MacDonald (2018). Fisheries Baseline Review Report for Improvement Dredging for Lamma Power Station Navigation Channel.

(54) ERM (1998). *Op Cit.*

(*Oratosquilla* spp.) and prawn (*Metapenaeus joyneri* and *M. affinis*) were some of the examples of major commercial species recorded in this spawning ground. The Project is located within the recognised southern Lantau spawning ground (**Figure A4.3**).

Ichthyoplankton and fish post-larvae surveys were conducted from July 2005 to March 2006 as part of the proposed LNG receiving terminal and associated facilities EIA study. The survey locations covered Cheung Chau and Lamma Island in the vicinity of the Project. The study found that the fish eggs and fish post-larvae densities were generally low in both western and southern Lantau waters. Results showed that the highest fish densities were obtained between July and September and decreased significantly in October, suggesting that the peak spawning period for most fishes in southern waters of Hong Kong occurred during the summer. Samples were dominated by Ambassidae (glass perches), Engraulidae (anchovies), Gobiidae (gobies) and Sciaenidae (croakers) in the wet season. In the dry season, the major families included Callionymidae, Gobiidae, Scorpaenidae (rockfishes) and Syngnathidae (pipefishes) in the vicinity of southwestern Lantau and Soko Islands. A total of 40 different families have been recorded in the surveys, with mean family richness of 10.8 – 16.8. Even in the wet season when the highest fish densities were obtained, the fish densities recorded were generally low (0.21 – 1.82 larvae m^{-3}) and there were no observable difference in fish or fish egg densities between waters of the identified spawning /nursery grounds for commercial fisheries of the southern waters of Hong Kong and those of western Lantau not identified as important spawning / nursery grounds.

Ichthyoplankton and fish post-larvae surveys were conducted from November 2016 to July 2017 as part of the proposed Hong Kong Offshore LNG Terminal Project. The survey locations covered Cheung Chau and West Lamma in the vicinity of the Project. The study found that the levels of ichthyoplankton and fish post-larvae resources were generally low. The dominant species of fish eggs and fish larvae recorded was the glass perchlet (family Ambassidae) which is of low commercial value [(55)]. Whilst the top ten dominant species of fish eggs included some species with medium to high commercial values, including pony fishes (family Leiognathidae), sole (family Soleidae), sweetlips (family Haemulidae) and sillago (family Sillaginidae), the top ten dominant species of fish larvae were mostly of low commercial value. Fish post-larvae of the Assessment Area were also dominated by species of low commercial value such as scads (family Carangidae), dragonets (family Callionymidae), gobies (family Gobiidae), anchovies (family Engraulidae) and rabbitfish (family Siganidae).

A4.5.2 Nursery Area

The southern Lantau waters extending across southern waters from Fan Lau Kok all the way east pass Soko Islands and beyond Lamma Island and abutting the southern boundary of the HKSAR was also previously identified in 1998 as a fisheries nursery area for high value commercial species (**Figure A4.3**). This recognised nursery area is an important habitat area for a number of commercial juvenile fish and crustacean species, with major species of mantis shrimp (*Oratosquilla anomala*, *Dictyosquilla foveolata*), Sciaenid fry, Serranid fry, *Squilla* fry, prawn (*Metapenaeopsis barbata*, *M. palmensis*) and goby (*Oxyurichthys tentacularis*). Majority of fry and juveniles were recorded during the summer months. The proposed wind farm site encompasses a 600 ha area Southern Waters nursery grounds, which coincides with a small fraction (2.72%) of the previously identified nursery grounds (22,000 ha) (**Figure A4.3**).

A4.6 Culture Fisheries

Mariculture is protected and regulated by the Marine Fish Culture Ordinance (Cap. 353), which stipulates that licenses must be obtained in order for marine fish culture activity to occur and that the activity must occur within designated fish culture zones. AFCD's Departmental Annual Report 2018-2019 outlined that as of 2018 there were 26 fish cultures zones which covered 209 hectares with 931

(55) Mott MacDonald (2014). *Op Cit.*

licensed operators [56]. The most recent estimated production in 2019 from licenced farms was 889 tonnes that accounts for about 5% of local demand for live fish and was valued at $72 million [57].

The nearest designated FCZs to the Project are Cheung Sha Wan FCZ, Lo Tik Wan FCZ and Sou Kwu Wan FCZ which are the same as described in the approved EIA report of the Project (**Figure A4.3**). Within Lo Tik Wan FCZ, eight units of artificial reefs with total volume of 330 m^3 were deployed as biofilter to enhance habitat quality and marine resources.

A4.7 Summary

The latest available information on fisheries resources and fishing operations within and in the vicinity of the Project has been reviewed. The fisheries resources and production rates within and adjacent to the wind farm are moderate in terms of catch weight and value and the Project area is within the spawning and nursery areas of commercial fisheries resources. There are no additional FCZs around the Project other than those described in the approved EIA report of the Project.

Overall, there are no apparent changes to fisheries resources and fishing operation within and in the vicinity of the Project over time after the approval of the EIA report of the Project. The existing information reviewed in this Baseline Data Note is considered adequate for further environmental review of the proposed variation of the Project. No information gap is identified and therefore no further fisheries survey is considered necessary for further environmental review of the proposed variation of the Project.

(56) AFCD (2020) Departmental Annual Report 2018-2019.

(57) AFCD (2020) Marine fish culture, pond fish culture and oyster culture.

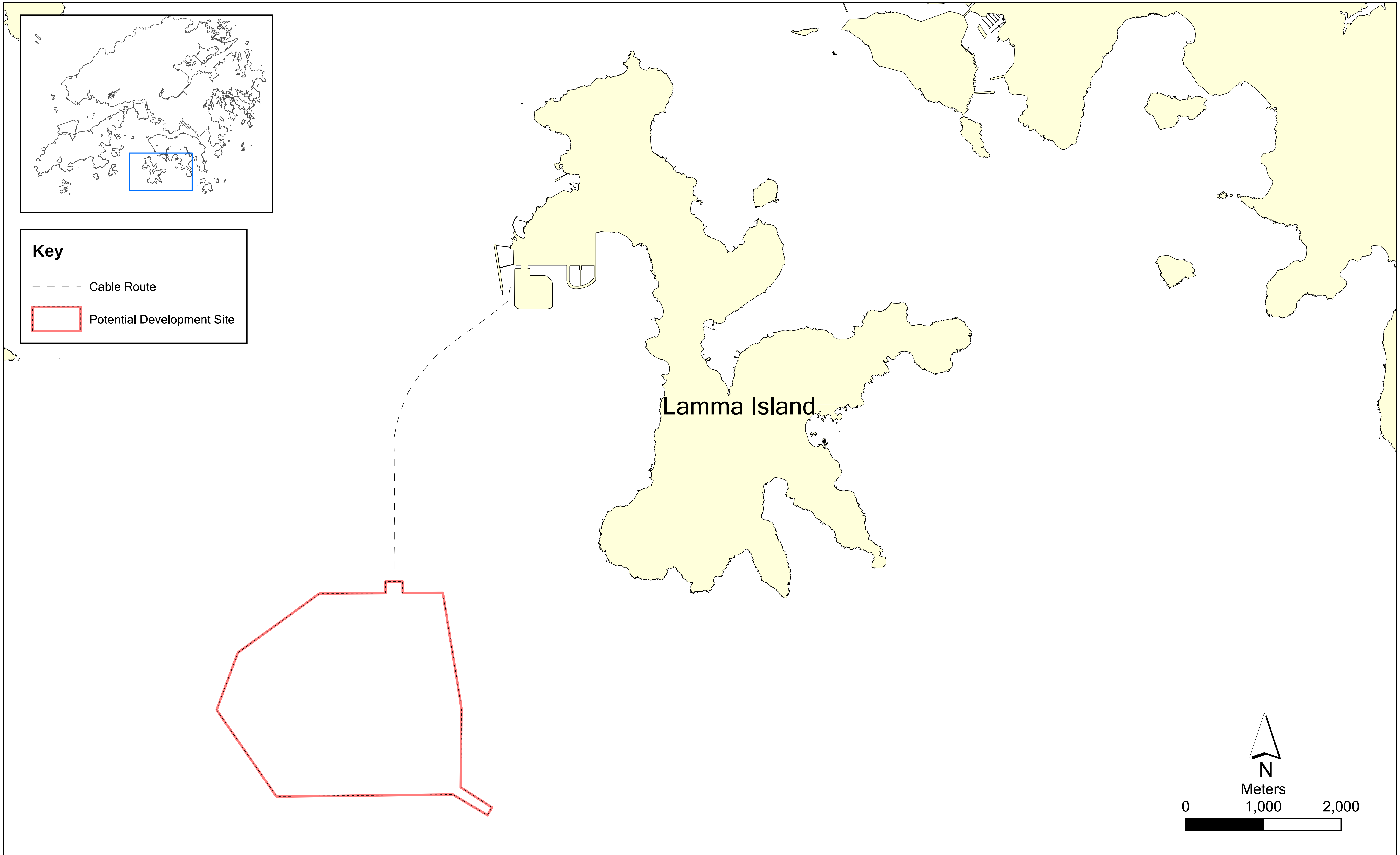

Figure A1.1

Location of the SW Lamma Offshore Windfarm and Cable Route

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Date: 16/04/2009

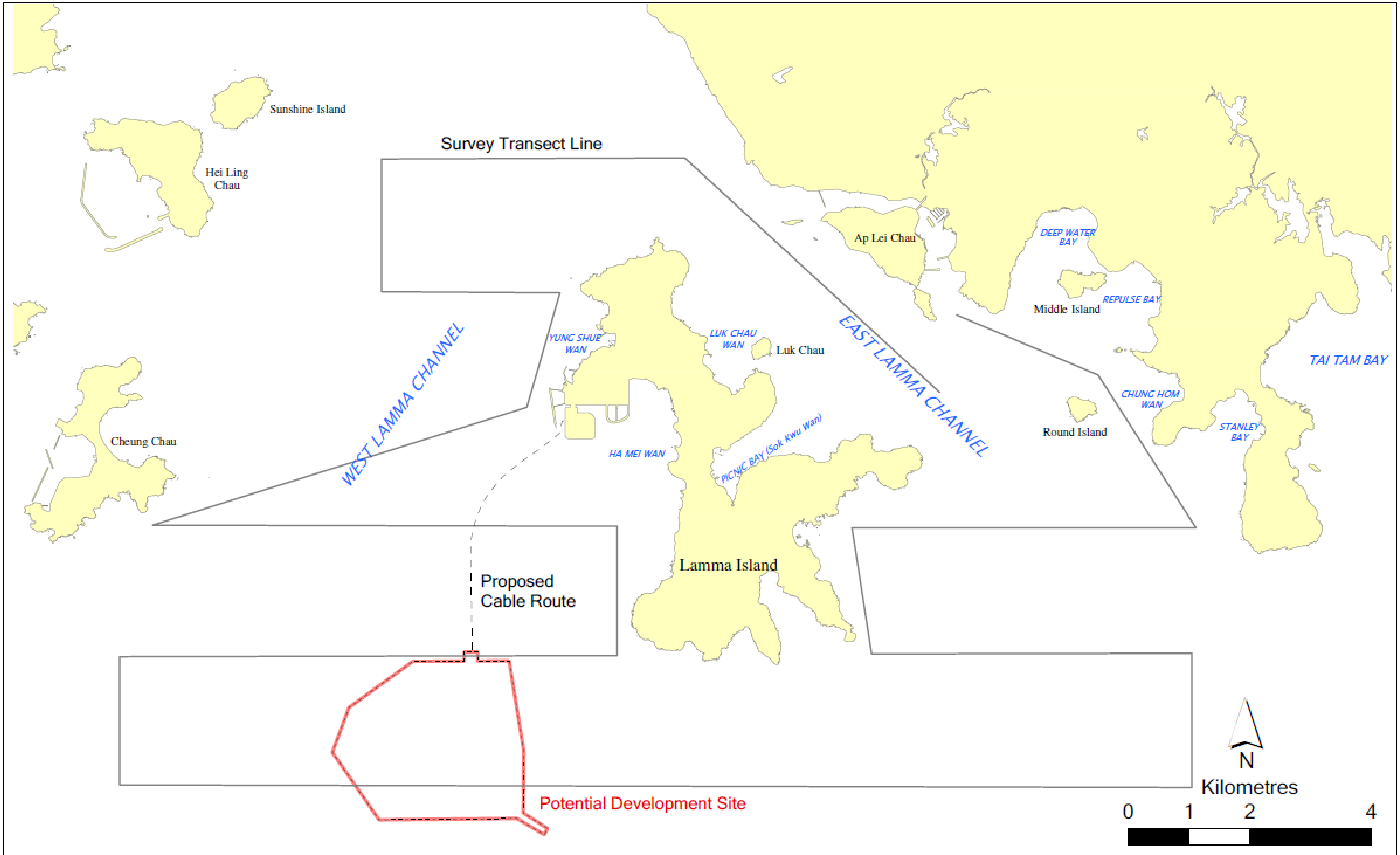

Figure A2.1

Survey Transect of Avifauna Vessel Survey
(Transect location followed marine mammal surveys)

File:Bird Survey\0088440_survey transect_Lamma.mxd
Date: 10/08/2009

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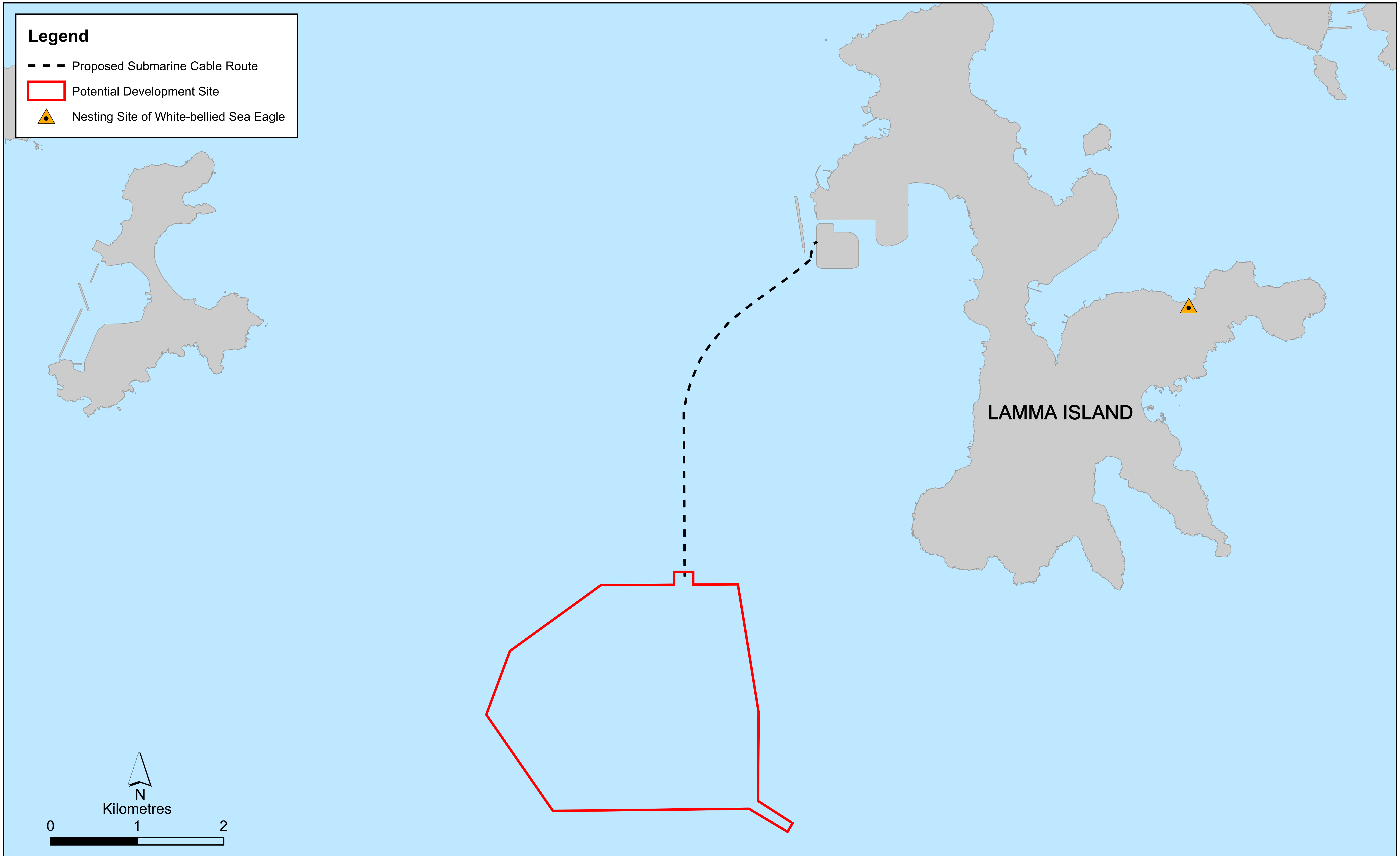

Figure A2.4

Nesting Site of White-bellied Sea Eagle

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Date: 30/6/2021

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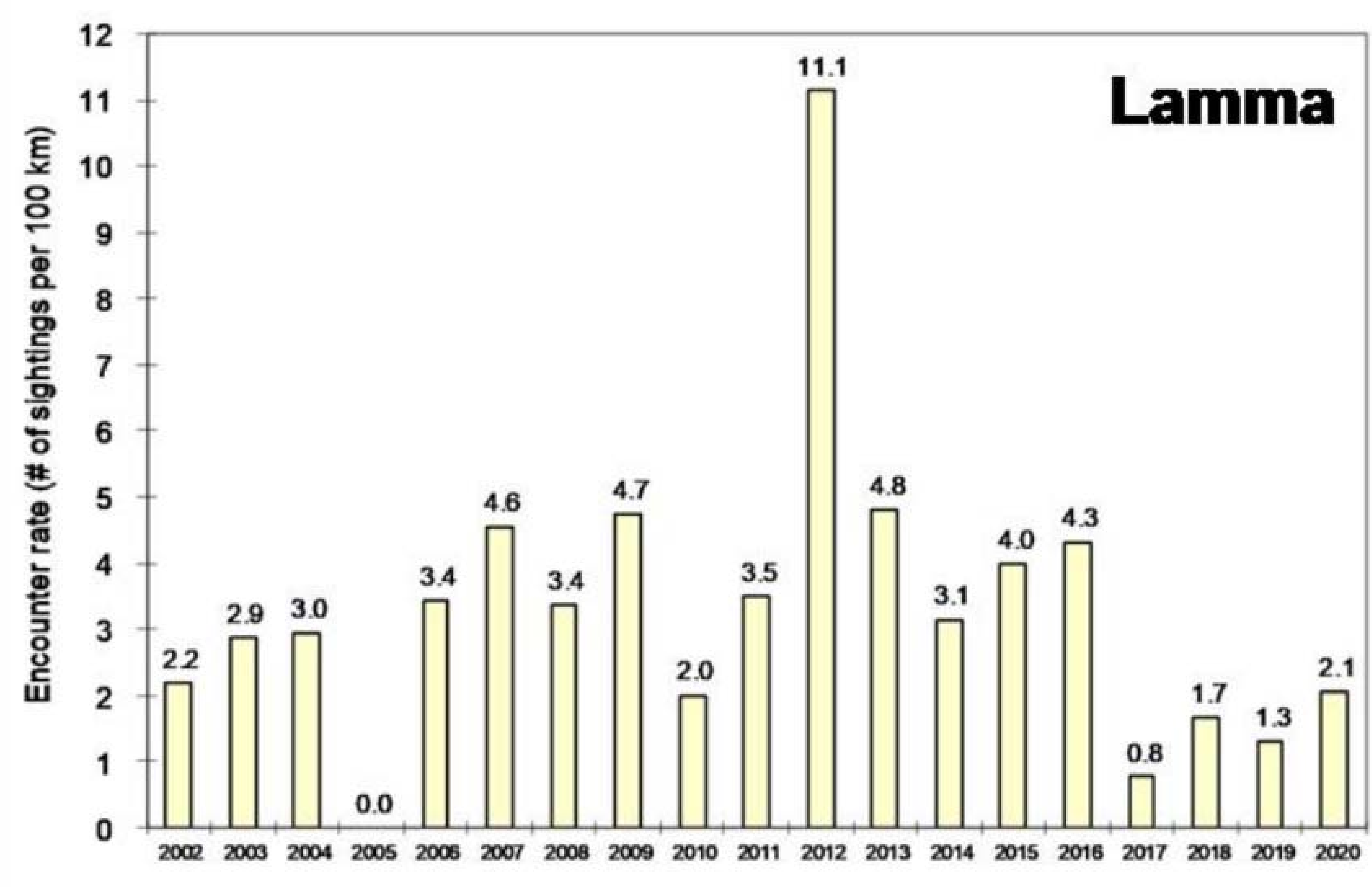

Figure A3.1

Temporal Trends in Annual Encounter Rates of Finless Porpoises in Lamma Survey Area
(Source: AFCD Monitoring of Marine Mammals in Hong Kong Waters 2020/21)

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Date: 6/9/2021

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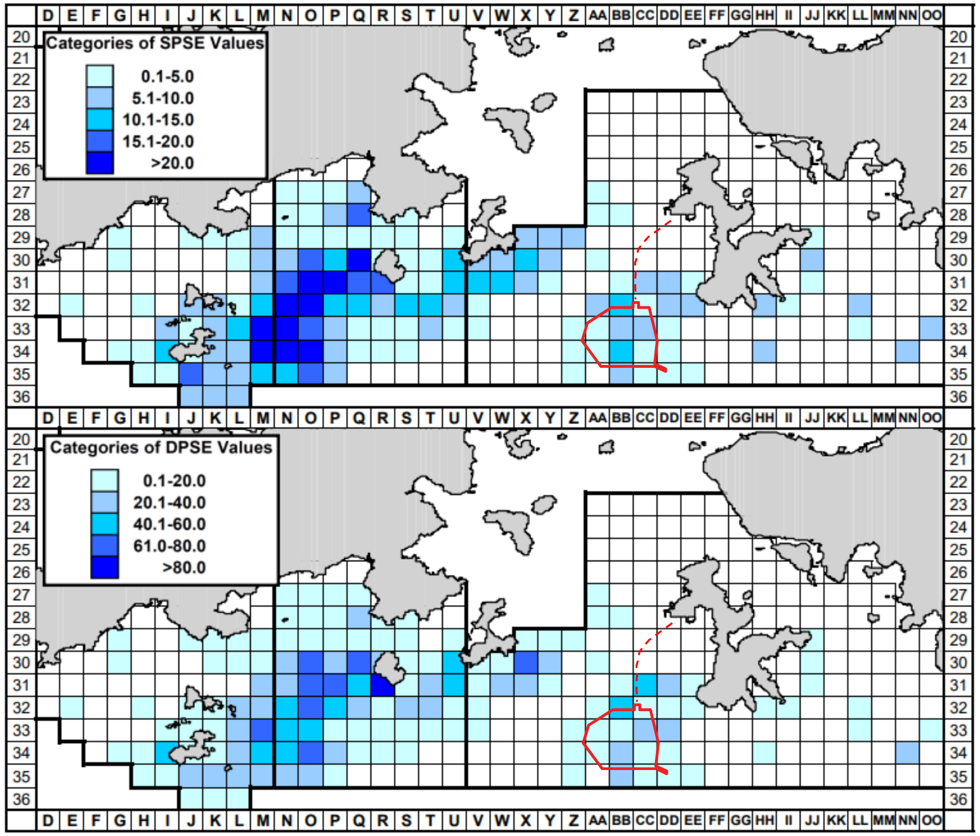
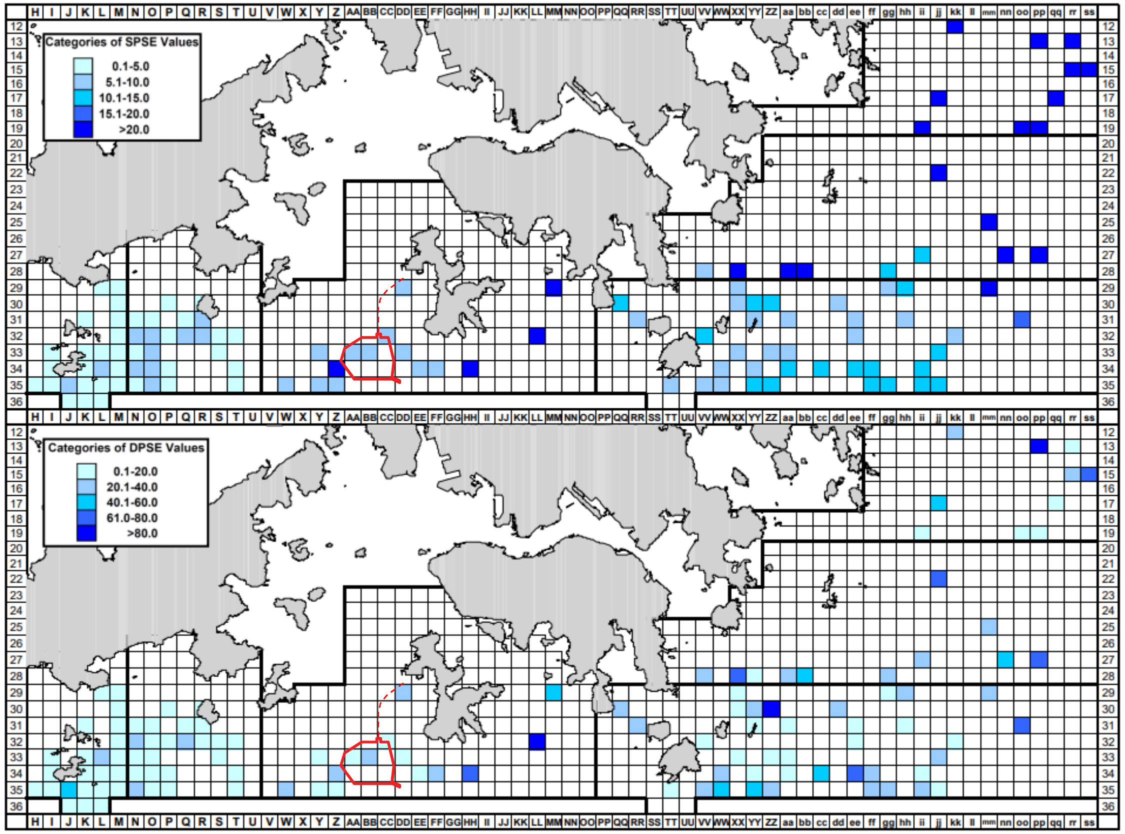


Figure 16. Density of finless porpoises with corrected survey effort per km^2 in southern waters of Hong Kong during dry season (December to May), using data collected during 2016-20 (SPSE = no. of on-effort porpoise sightings per 100 units of survey effort; DPSE = no. of porpoises per 100 units of survey effort)



Density of finless porpoises with corrected survey effort per km^2 in southern and eastern waters of Hong Kong during wet season (June to November), using data collected during 2016-20 (SPSE = no. of on-effort porpoise sightings per 100 units of survey effort; DPSE = no. of porpoises per 100 units of survey effort)

Figure A3.2

Density of Finless Porpoises in Dry and Wet Seasons during 2016-2020
(Source: AFCD Monitoring of Marine Mammals in Hong Kong Waters 2020/21)

File: 0607209
Date: 6/9/2021

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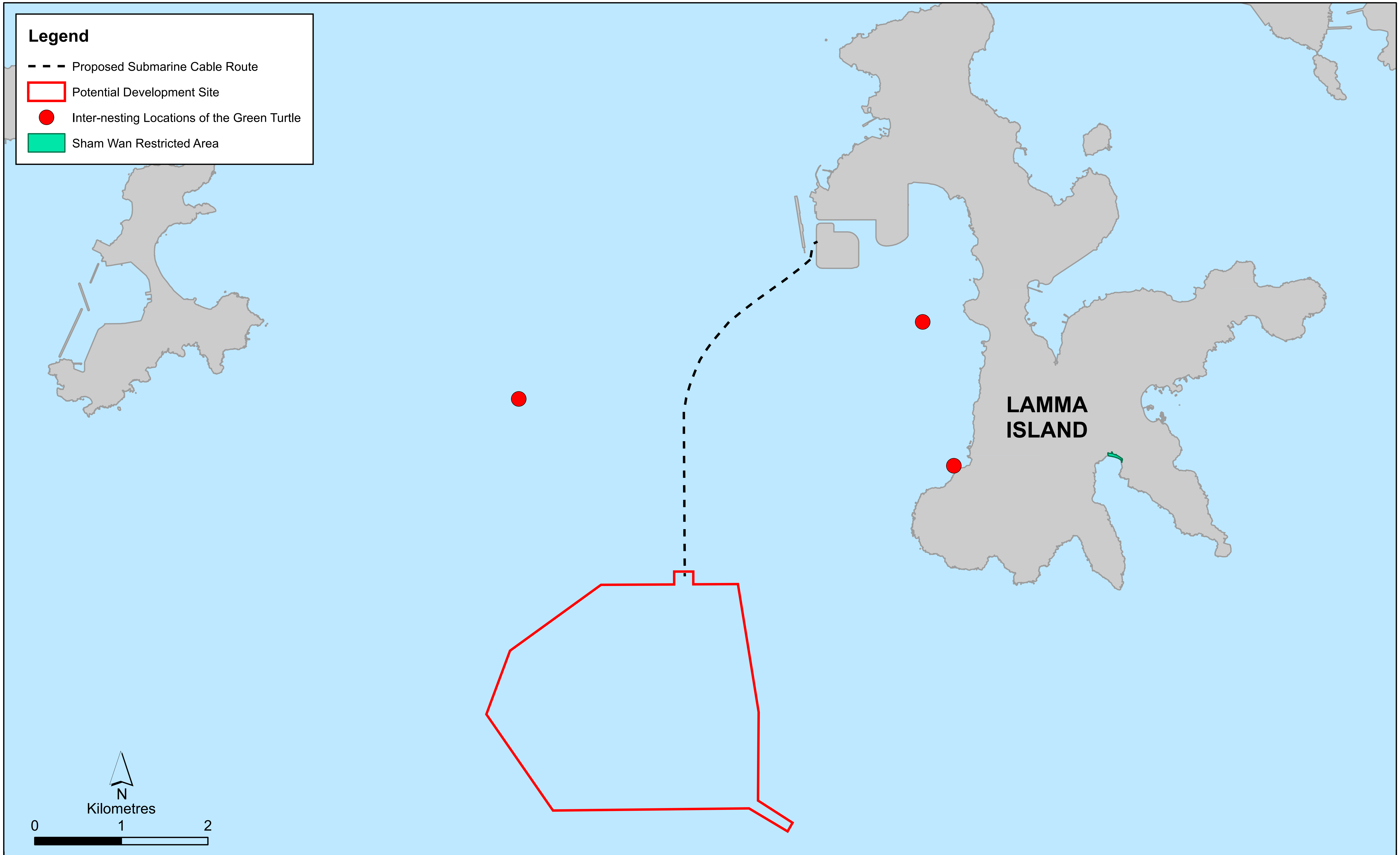

Figure A3.3

Inter-nesting locations (red dots) from June 25 to September 4, 2003 of the green turtle (named "Hong Kong 2") that nested on Sham Wan, Lamma Island. Map provided by AFCD

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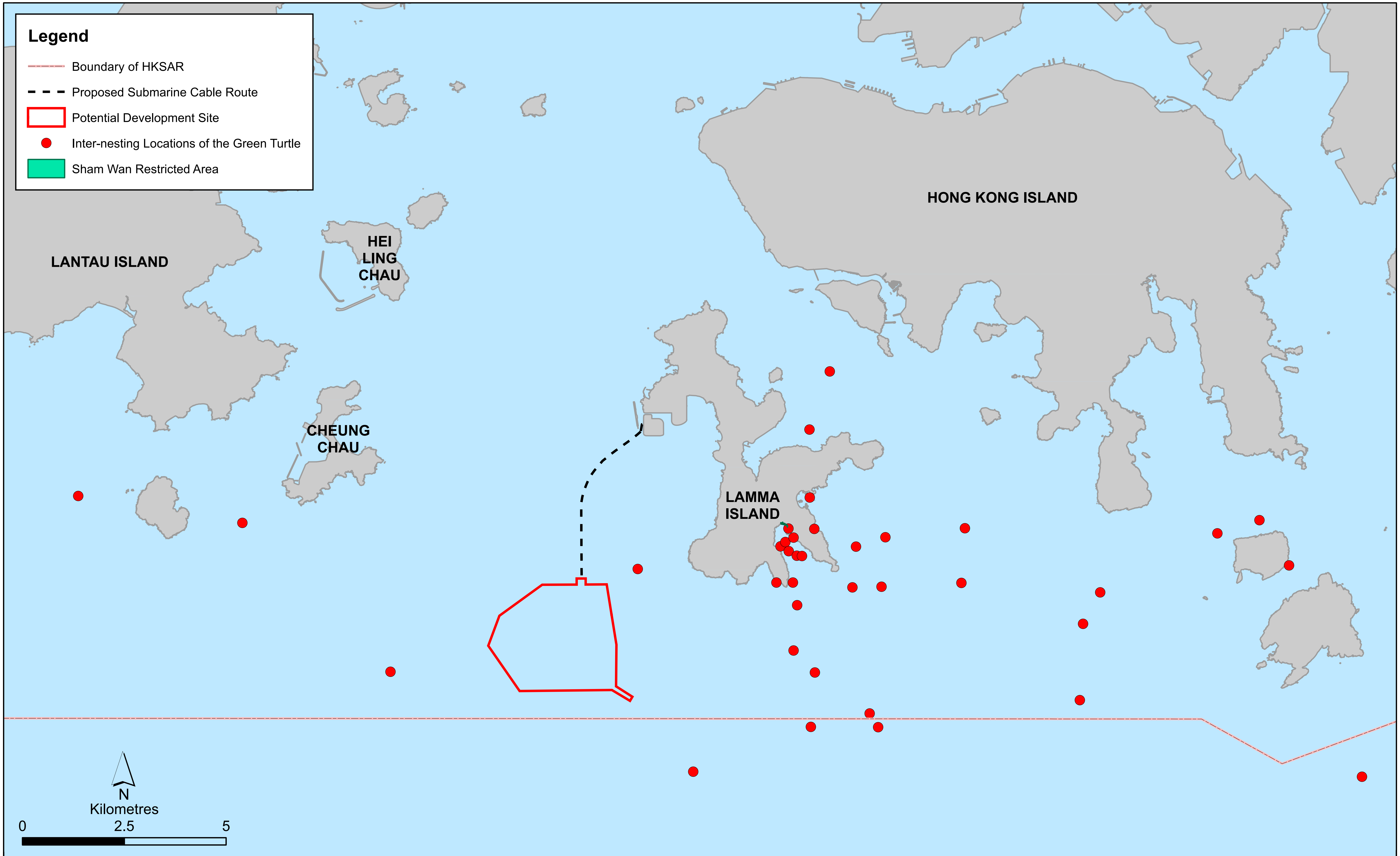

Figure A3.4

Inter-nesting locations (red dots) from August 9 to October 12, 2008 of the green turtle (named "Hong Kong 2") that nested on Sham Wan, Lamma Island. Map provided by AFCD

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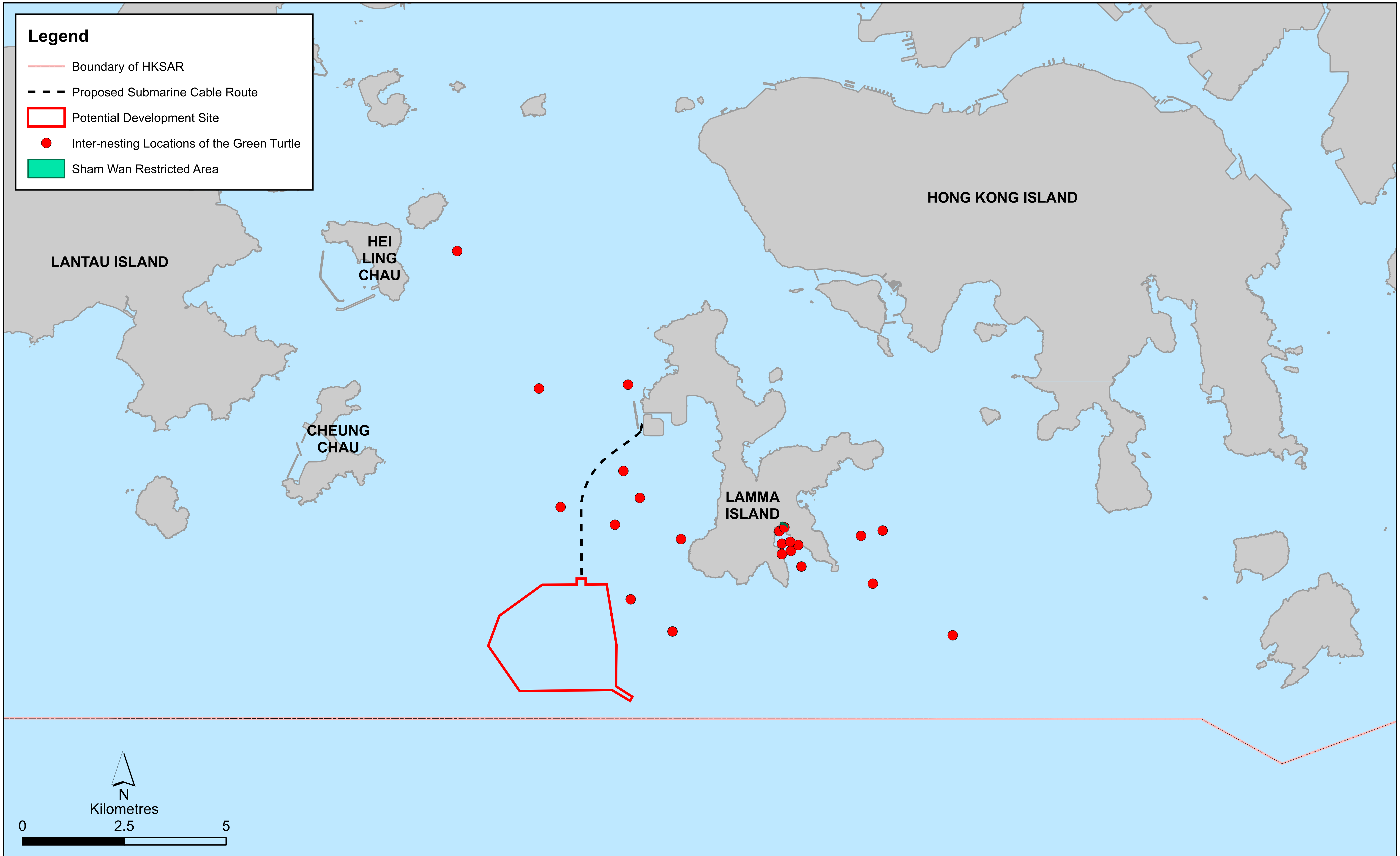

Figure A3.5

Inter-nesting locations (red dots) from August 14 to September 30, 2012 of the green turtle that nested on Sham Wan, Lamma Island. Map provided by AFCD

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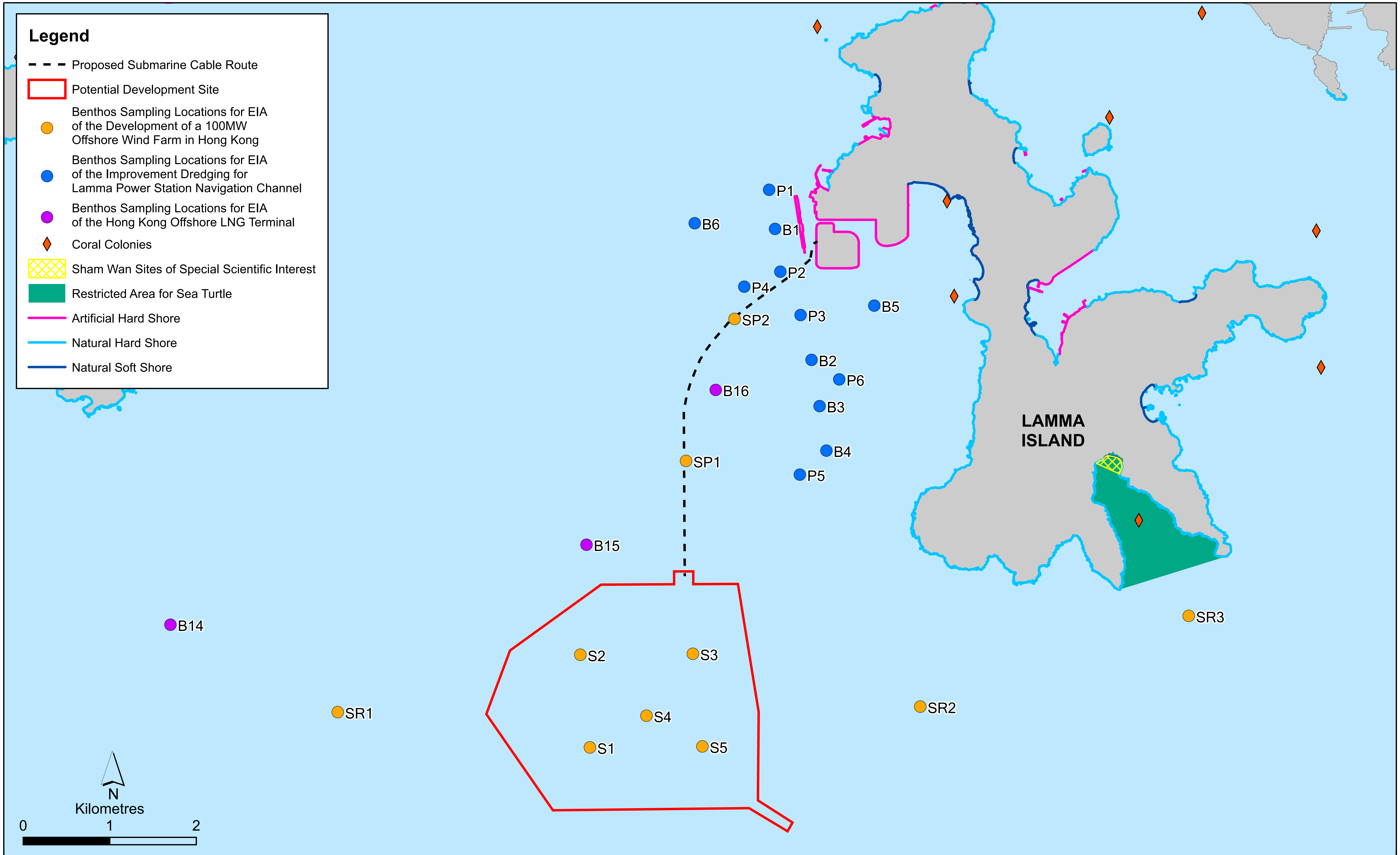

Figure A3.6

Marine Habitats in the vicinity of the Project

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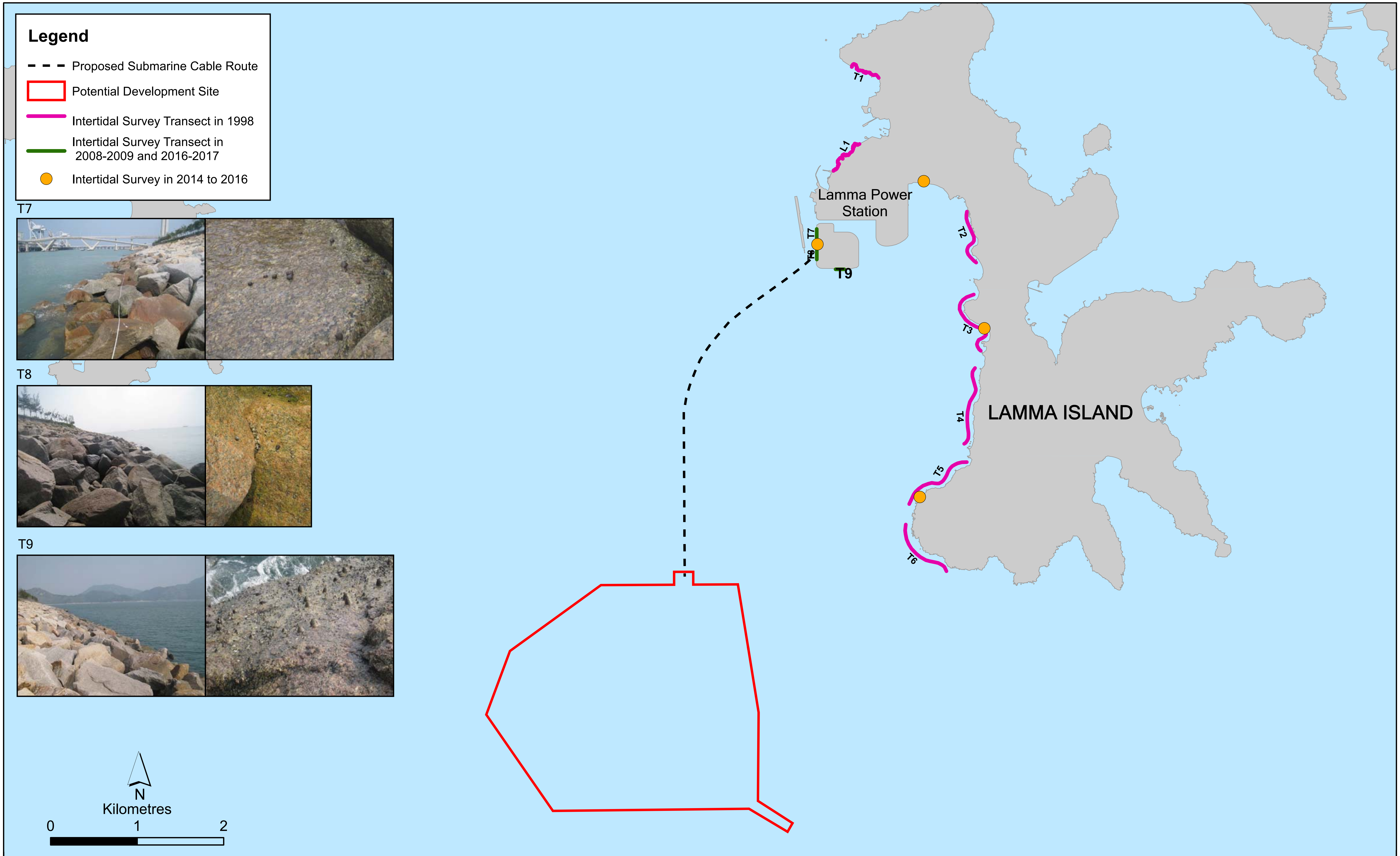

Figure A3.7

Previous Intertidal Survey Transect in Lamma Power Station
(Reproduced from ERM (1998, 2008 to 2009 and 2014 to 2017))

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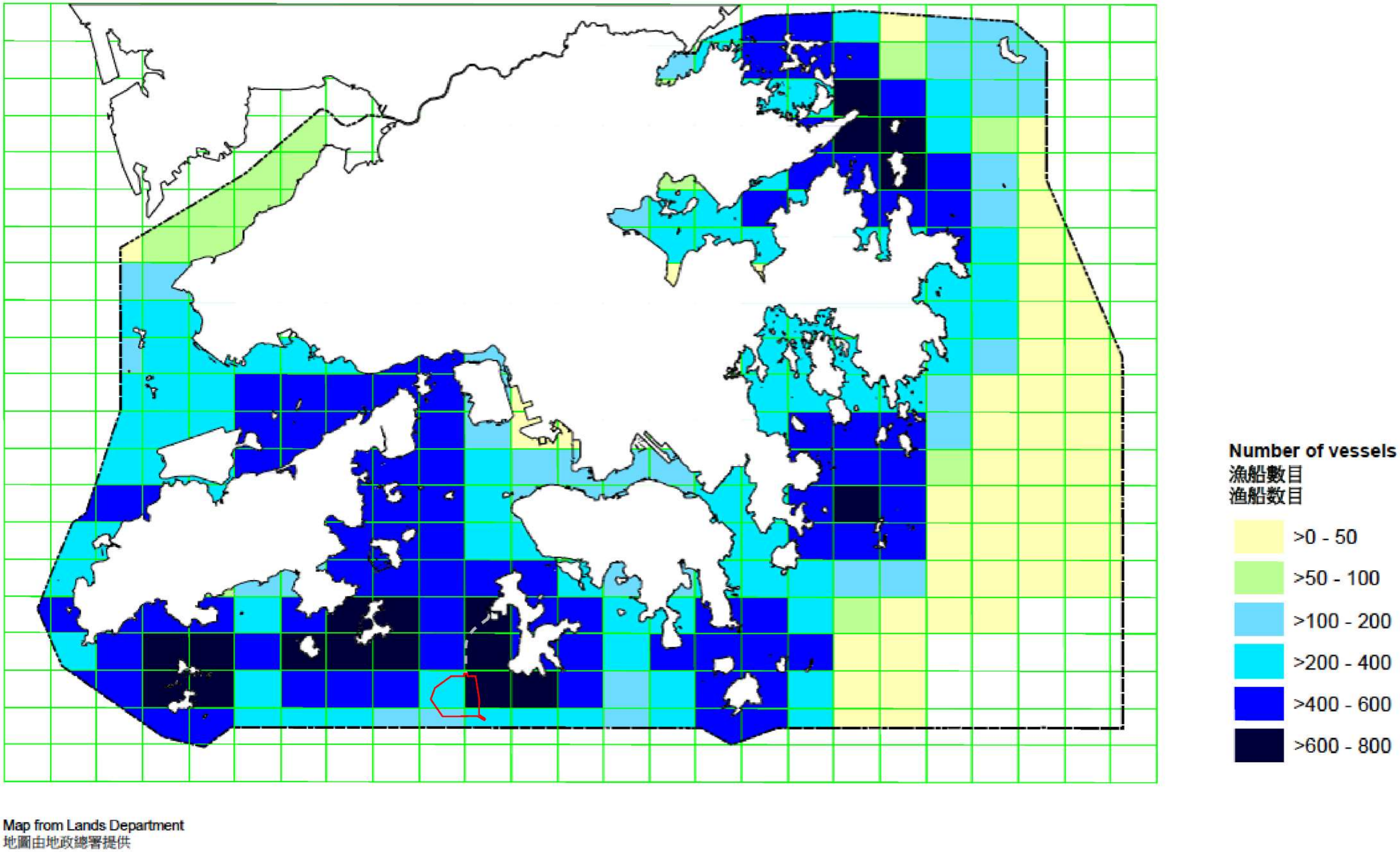

Figure A4.1

Distribution of Fishing Operation (Overall) in Hong Kong
(Source: AFCD Port Survey 2016/17)

File: T:\GIS\PROPOSAL\P0589670\P0589670_AFCD_Fishing_Figures.mxd
Date: 29/6/2021

Environmental Resources Management

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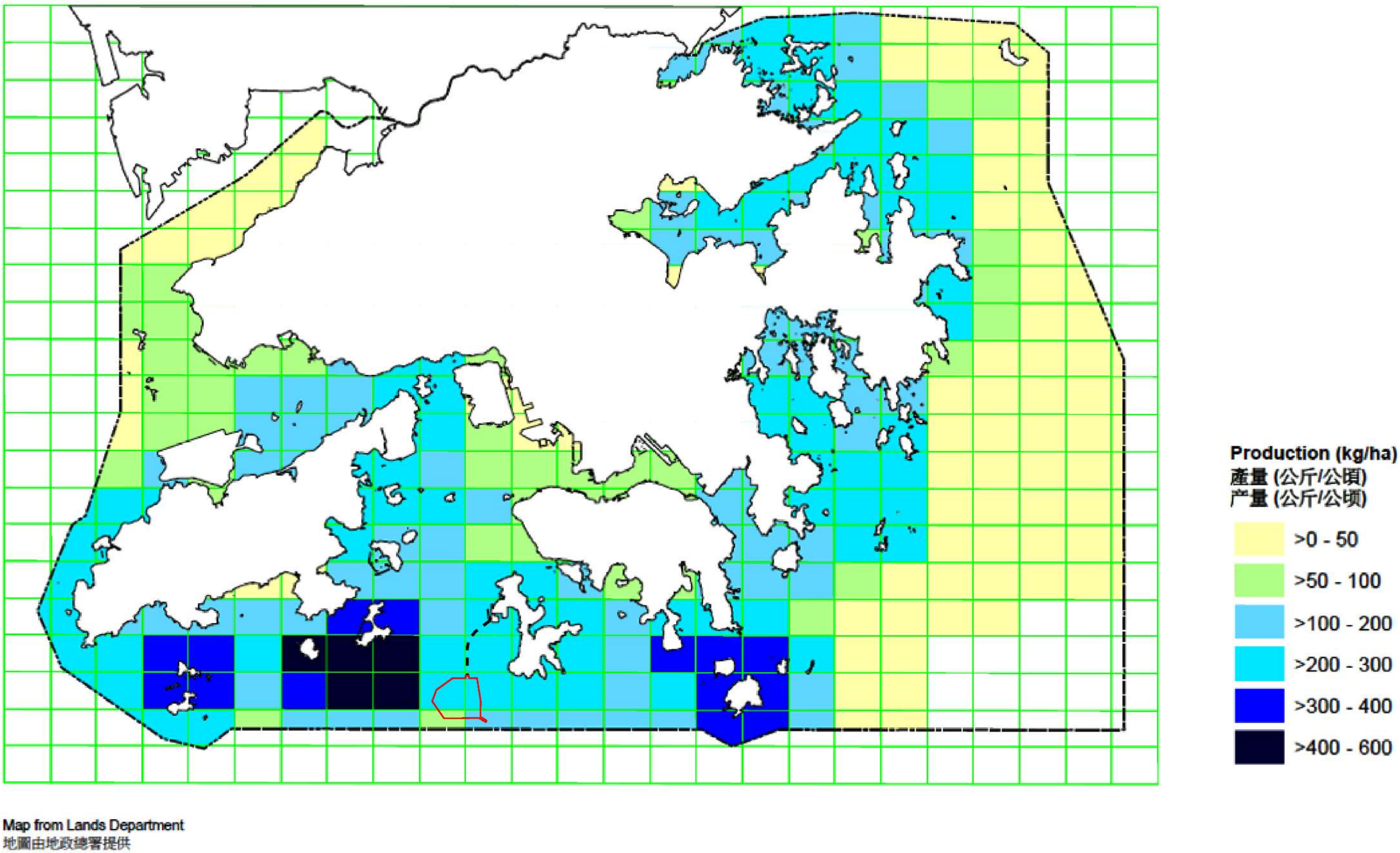

Figure A4.2

Distribution of Fisheries Production (Overall) in Hong Kong
(Source: AFCD Port Survey 2016/17)

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Date: 29/6/2021

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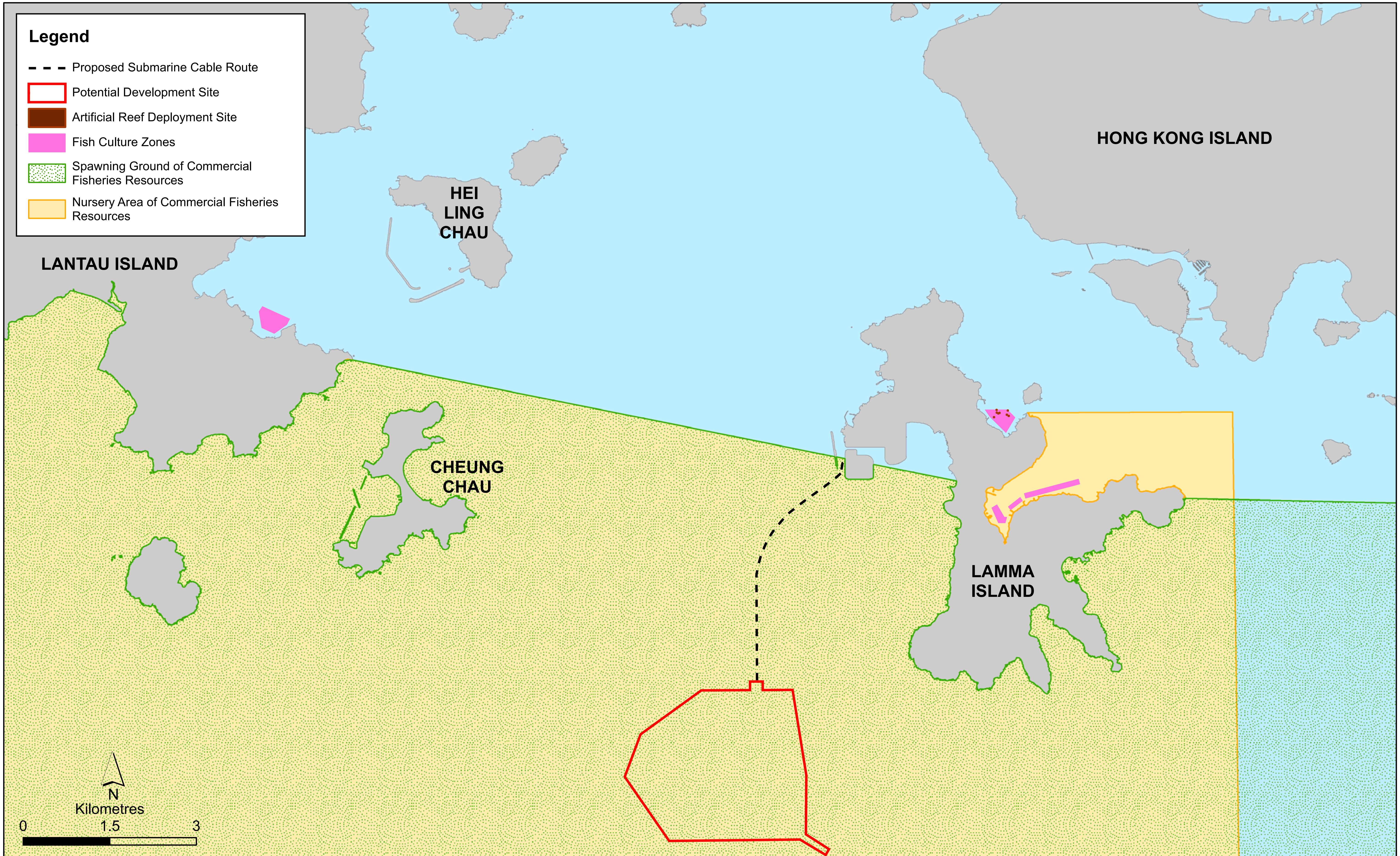

Figure A4.3

Fisheries Sensitive Receivers

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Date: 28/6/2021

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APPENDIX B UPDATED BIRD COLLISION RISK ASSESSMENT

CONTENTS

List of Tables

B1 Review of Bird Collision Risk Model

During the EIA stage, Scottish Natural Heritage (SNH) bird collision risk model Band (2000) (1) was adopted to quantify the collision risk from the proposed offshore windfarm. Over the years, the bird collision risk model has been revised and updated to provide a more accurate assessment for collision risks. ERM reviewed the bird collision risk model employed in the approved EIA Report and the internationally available collision risk prediction models, in order to identify the current industry best-practice approach that could be adopted for this *Environmental Review Report*.

Further to an international review of the currently available bird collision risk models, Band Model 2012 (2) was selected for the collision risk assessment. Band Model 2012 follows in general terms that developed by Band (2000) (1) and Band (2007) (3) and promoted in guidance published by SNH, but it has been updated to facilitate application in the offshore environment (2). And therefore it is more appropriate to use Band Model 2012 for the assessment of bird collision risks to compare the differences among the original turbine scenario and the two newly proposed turbine scenario (Lower Bound, 6.45MW and Upper Bound, 15/16MW).

B2 Updated Bird Collision Assessment

The updated bird collision assessment results below have adopted a different collision risk model of using the later version of Band Model 2012 as detailed in **Section B1**. Collision risks are calculated for nine bird species, including Aleutian Tern *Sterna aleutica*, Black Kite *Milvus migrans*, Black-legged Kittiwake *Rissa tridactyla*, Black-naped Tern *Sterna sumatrana*, Common Tern *Sterna hirundo*, Heuglin's Gull *Larus heuglini*, Red-necked Phalarope *Phalaropus lobatus*, White-bellied Sea Eagle *Haliaeetus leucogaster* and White-winged Tern *Chlidonias leucopterus*. The predicted numbers of collisions for the nine bird species per season are listed in **Table B2.1** – **Table B2.27**. The collision assessment result of no avoidance and 98% avoidance action (where a probability of 98% is that an individual bird, or individuals within a flock, has a 98% chance to successfully avoid collision with the turbine when it make a transit past it) are presented in the following to demonstrate the conditions for the worst case (no avoidance) and the typical (98%) assumption for real situations respectively. According to SNH, 98% is a recommended avoidance rate for most of the bird species, hence 98% avoidance rate has been adopted (4).

B.2.1 Aleutian Tern

Aleutian Tern was recorded within the Assessment Area during the summer breeding season and the autumn migratory season in 2008, in which the highest predicted collision rate occurs in the autumn migratory season. Since the population of Aleutian Tern has been increased since 2008 as detailed in **Appendix A**, the bird density has been multiplied by 3.5 times in the collision risk model. Assuming 98% avoidance rate, the maximum collision rate in autumn is approximately 5.88, 7.84 and 3.36 for the original, 6.45MW (Lower Bound) and 15MW (Upper Bound) turbine scenario respectively. For the Upper Bound turbine scenario, collision rates for 16MW scenario have also been assessed while the predicted collision rates are similar with that of 15MW scenario. In comparison, the use of newly proposed 15/16MW (Upper Bound) turbine scenario has shown the lowest collision rate among three scenarios, whereas another newly proposed turbine scenario, 6.45MW (Lower Bound), has shown a relatively higher collision rate than the original turbine scenario but still of low magnitude. Considering the low collision rate under 98% avoidance rate, the impact of collision to Aleutian Tern is not considered adverse for all scenarios.

(1) Band, W. (2000). Windfarms and Birds: calculating a theoretical collision risk assuming no avoiding action. Scottish Natural Heritage Guidance Note.

(2) Band, 2012. Using a Collision Risk Model to Assess Bird Collision Risks for Offshore Windfarms.

(3) Band, W., Madders, M. and Whitfield, D.P. (2007). Developing field and analytical methods to assess avian collision risk at windfarms.

(4) Scottish Natural Heritage, 2018. Avoidance Rates for the onshore SNH Wing Farm Collision Risk Model.

The predicted collision rate of Aleutian Tern, under the original and 6.45MW (Lower Bound) turbine scenario, may affect a small portion of their overall population. Additional Potential Biological Removal (PBR) [(5)(6)(7)(8)] analysis was undertaken to assess if this predicted collision risk would have a potential population level effect.

The PBR for Aleutian Tern is estimated to be more than 144 individuals [(9)], therefore collision rate of 8 and 11 per year for the original and 6.45MW (Lower Bound) turbine scenario, respectively, would not be expected to cause significant impact to the Aleutian Tern overall population.

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(5) Wade, P. R. 1998. Calculating Limits to the Allowable Human-Caused Mortality of Cetaceans and Pinnipeds. Marine Mammal Science 14(1): 1-37.

(6) Niel, C. and J. D. Lebreton. 2005. Using Demographic Invariants to Detect Overharvested Bird Populations from Incomplete Data. Conservation Biology 19(3): 826-835.

(7) Dillingham, P.W. and Fletcher, D. 2008. Estimating the ability of birds to sustain additional human-caused mortalities using a simple decision rule and allometric relationships. Biological Conservation 141 (2008) 1783 –1792.

(8) Cooke *et al.* 2012. Management rules for marine mammal populations: a response to Longeran. Marine Policy 36: 389-392.

(9) PBR was developed by Wade (1998) as a simple means to estimate levels of incidental harvest of marine mammals which would permit populations to be maintained at, or restored to, an optimum sustainable size, and which can be computed even in the absence of demographic data about the population in question (Cooke *et al.* 2012).
The PBR equation is:

$$PBR = N_{min} \times \frac{R_{max}}{2} \times F_R$$

Where:
PBR = the number of additional animals which can be removed safely;
N_{min} = the minimum population estimate;
R_{max} = the maximum net recruitment rate; and
F_R = the recovery factor.

Wade (1998) conducted simulations on the sensitivity of results to the value of N_{min} used. This led to a recommendation that the lower 60th percentile (~ p = 0.2) of the assumed population distribution be used. This was further modified with an estimate of the coefficient of variation (Dillingham and Fletcher 2008):
N_{min} is

$$N_{min} = \hat{N}e^{(Z_p CV_{\hat{N}})}$$

Where:

N = population estimate;
Z_p = the *p*th standard normal variate; and,
CV_N = coefficient of variation for N
The value for Z_p, at p = 0.2 is -0.842 and CV is typically set at 10%.

Maximum rates (R_{max}) of population growth are predicted to occur at small population densities, and are rarely observable in nature. Using an allometric relationship, Niel and Lebreton (2005) derived a method to estimate the maximum population growth rate (λ_{max}) using only adult survival (s) and age at first reproduction (α):

$$\lambda_{max} = \frac{(s\alpha - s + \alpha + 1) + \sqrt{(s - s\alpha - \alpha - 1)^2 - 4s\alpha^2}}{2\alpha}$$

R_{max} is then found as:

$$R_{max} = \lambda_{max} - 1$$

Aleutian Tern's Adult Survival Rate (s) = 91.3% (Due to the limited study available on Aleutian Tern, Sooty Tern *Onychoprion fuscatus* is used as a proxy species, considering they are in the same family https://marineornithology.org/~marineor/PDF/39_2/39_2_221-226.pdf);
Aleutian Tern's Age at first production (α) = 5 year (Sooty Tern *Onychoprion fuscatus* is used as a proxy species https://marineornithology.org/~marineor/PDF/39_2/39_2_221-226.pdf) ;
f (or F_R)= 1.0 for populations of 'least concern' species that are known to be increasing or stable;
f (or F_R)= 0.5 for populations of 'least concern' species that are declining or of uncertain trend;
f (or F_R)= 0.3 for populations of 'near threatened' species; and,
f (or F_R)= 0.1 for populations of 'vulnerable' and 'endangered' species.
On this basis R_{max} ≈ 0.1, N_{min} (N=31000; Due to limited data of Aleutian Tern's average coordinated counts in Asia and Australasia between 2008 and 2015, calculation is based on Aleutian Tern's global population available on Bird Life Data Zone http://datazone.birdlife.org/species/factsheet/aleutian-tern-onychoprion-aleuticus) ≈ 28496.7, f = 0.1 (recovery factor, as the species is of "vulnerable" status). Therefore, PBR = 28496.7x 0.1 x 0.5 x 0.1 ≈ 144.8.

Table B2.1 Collision Rates of Aleutian Tern for the Original Turbine Scenario

Aleutian Tern	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	0.00	625.61	2019.44	0.00
Proportion at rotor height (Band collision risk)	44.4%	44.4%	44.4%	44.4%
Collision per season (no avoidance)	0.00	91.11	294.09	0.00
Collision per season (98% avoidance)	**0.00**	**1.82**	**5.88**	**0.00**

Table B2.2 Collision Rates of Aleutian Tern for Lower Bound - 6.45MW

Aleutian Tern	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	0.00	687.93	2220.60	0.00
Proportion at rotor height (Band collision risk)	44.4%	44.4%	44.4%	44.4%
Collision per season (no avoidance)	0.00	121.44	392.00	0.00
Collision per season (98% avoidance)	**0.00**	**2.43**	**7.84**	**0.00**

Table B2.3 Collision Rates of Aleutian Tern for Upper Bound - 15MW*

Aleutian Tern	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	0.00	380.03	1226.74	0.00
Proportion at rotor height (Band collision risk)	44.4%	44.4%	44.4%	44.4%
Collision per season (no avoidance)	0.00	51.97	167.76	0.00
Collision per season (98% avoidance)	**0.00**	**1.04**	**3.36**	**0.00**

*Note: Collision rates of Aleutian Tern for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

B.2.2 Black Kite

Black Kite was recorded within the Assessment Area during the spring migratory season and winter in 2009, in which the highest predicted collision rate occurs in the spring migratory season. Assuming 98% avoidance rate, the maximum collision rate is approximately 8.97, 10.31 and 3.94 for the original, 6.45MW (Lower Bound) and 15MW (Upper Bound) turbine scenario respectively. For the Upper Bound turbine scenario, collision rates for 16MW scenario have also been assessed while the predicted collision rates are similar with that of 15MW scenario. In comparison, the use of newly proposed 15/16MW (Upper Bound) turbine scenario has shown the lowest collision rate among three scenarios, whereas another newly proposed turbine scenario, 6.45MW (Lower Bound) has shown a similar collision rate to the original turbine scenario. Considering the low collision rate under 98% avoidance rate, the impact of collision to Black Kite is not considered adverse for all scenarios.

Table B2.4 Collision Rates of Black Kite for the Original Turbine Scenario

Black Kite	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	3534.40	0.00	0.00	2095.43
Proportion at rotor height (Band collision risk)	61.3%	61.3%	61.3%	61.3%
Collision per season (no avoidance)	448.31	0.00	0.00	265.79
Collision per season (98% avoidance)	**8.97**	**0.00**	**0.00**	**5.32**

Table B2.5 Collision Rates of Black Kite for Lower Bound - 6.45MW

Black Kite	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	3886.47	0.00	0.00	2304.17
Proportion at rotor height (Band collision risk)	61.3%	61.3%	61.3%	61.3%
Collision per season (no avoidance)	515.40	0.00	0.00	305.56
Collision per season (98% avoidance)	**10.31**	**0.00**	**0.00**	**6.11**

Table B2.6 Collision Rates of Black Kite for Upper Bound - 15MW*

Black Kite	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	1921.02	0.00	0.00	1138.91
Proportion at rotor height (Band collision risk)	54.8%	54.8%	54.8%	54.8%
Collision per season (no avoidance)	197.14	0.00	0.00	116.88
Collision per season (98% avoidance)	**3.94**	**0.00**	**0.00**	**2.34**

*Note: Collision rates of Black Kite for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

B.2.3 Black-legged Kittiwake

Black-legged Kittiwake was recorded within the Assessment Area during the winter period. Assuming 98% avoidance rate, the collision rate is approximately 0.81, 1.05 and 0.45 for the original, 6.45MW (Lower Bound) and 15MW (Upper Bound) turbine scenario respectively. For the Upper Bound turbine scenario, collision rates for 16MW scenario have also been assessed while the predicted collision rates are similar with that of 15MW scenario. In comparison, the use of newly proposed 15/16MW (Upper Bound) turbine scenario has shown the lowest collision rate among three scenarios, whereas the 6.45MW (Lower Bound) turbine scenario has shown a relatively higher collision rate than the original turbine scenario but still in low magnitude. Considering the low collision rate under 98% avoidance, the impact of collision to Black-legged Kittiwake is not considered adverse for all scenarios.

Table B2.7 Collision Rates of Black-legged Kittiwake for the Original Turbine Scenario

Black-legged Kittiwake	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	0.00	0.00	0.00	594.31
Proportion at rotor height (Band collision risk)	100.0%	100.0%	100.0%	100.0%
Collision per season (no avoidance)	0.00	0.00	0.00	40.65
Collision per season (98% avoidance)	**0.00**	**0.00**	**0.00**	**0.81**

Table B2.8 Collision Rates of Black-legged Kittiwake for Lower Bound - 6.45MW

Black-legged Kittiwake	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	0.00	0.00	0.00	653.51
Proportion at rotor height (Band collision risk)	100.0%	100.0%	100.0%	100.0%
Collision per season (no avoidance)	0.00	0.00	0.00	52.61
Collision per season (98% avoidance)	**0.00**	**0.00**	**0.00**	**1.05**

Table B2.9 Collision Rates of Black-legged Kittiwake for Upper Bound - 15MW*

Black-legged Kittiwake	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	0.00	0.00	0.00	361.02
Proportion at rotor height (Band collision risk)	100.0%	100.0%	100.0%	100.0%
Collision per season (no avoidance)	0.00	0.00	0.00	22.45
Collision per season (98% avoidance)	**0.00**	**0.00**	**0.00**	**0.45**

*Note: Collision rates of Black-legged Kittiwake for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

B.2.4 Black-naped Tern

Black-naped Tern was recorded within the Assessment Area during the summer breeding season in 2008 and spring migratory season in 2009, in which the highest predicted collision rate occurs in the summer breeding season. During the baseline survey, eight Black-naped Tern were recorded above sea level within the Assessment Area, while six of them were recorded flying below 10m and two of them were flying at 15m. All of the records do not fall into the risk height of 6.45MW turbine scenario (Lower Bound, 20m to 198m) and 15/16MW scenario (Upper Bound, 29m to 265m/271m), while two of them fall into the risk height of original turbine scenario (14m to 136m). Since the population of Black-naped Tern has been increased since 2008 as detailed in **Appendix A**, the bird density has been multiplied by 2.5 times in the collision risk model. Assuming 98% avoidance rate, the collision rate is approximately 2.30 for the original turbine scenario. Considering the low collision rate under 98% avoidance rate, the impact of collision to Black-naped Tern is not considered adverse for the original turbine scenario. Given that all records in the baseline survey are out of the risk height of 6.45MW (Lower Bound) and 15/16MW (Upper Bound) turbine scenarios, the impact of collision is considered low/ negligible for these two scenarios.

Table B2.10 Collision Rates of Black-naped Tern for the Original Turbine Scenario

Black-naped Tern	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	449.11	1348.38	0.00	0.00
Proportion at rotor height (Band collision risk)	25.0%	25.0%	25.0%	25.0%
Collision per season (no avoidance)	38.29	114.96	0.00	0.00
Collision per season (98% avoidance)	**0.77**	**2.30**	**0.00**	**0.00**

Table B2.11 Collision Rates of Black-naped Tern for Lower Bound - 6.45MW

Black-naped Tern	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	0.00	0.00	0.00	0.00
Proportion at rotor height (Band collision risk)	0.0%	0.0%	0.0%	0.0%
Collision per season (no avoidance)	0.00	0.00	0.00	0.00
Collision per season (98% avoidance)	**0.00**	**0.00**	**0.00**	**0.00**

Table B2.12 Collision Rates of Black-naped Tern for Upper Bound - 15MW*

Black-naped Tern	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	0.00	0.00	0.00	0.00
Proportion at rotor height (Band collision risk)	0.0%	0.0%	0.0%	0.0%
Collision per season (no avoidance)	0.00	0.00	0.00	0.00
Collision per season (98% avoidance)	**0.00**	**0.00**	**0.00**	**0.00**

*Note: Collision rates of Black-naped Tern for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

B.2.5 Common Tern

Common Tern was recorded within the Assessment Area during the summer breeding season and autumn migratory season in 2008, as well as the spring migratory season in 2009, in which the highest predicted collision rate occurs in the autumn migratory season. Since the population of Common Tern has been increased since 2008 as detailed in **Appendix A**, the bird density has been multiplied by 3 times in the collision risk model. Assuming 98% avoidance rate, the maximum collision rate is approximately 7.89, 7.30 and 1.34 for the original, 6.45MW (Lower Bound) and 15MW (Upper Bound) turbine scenario respectively. For the Upper Bound turbine scenario, collision rates for 16MW scenario have also been assessed while the predicted collision rates are similar with that of 15MW scenario. In comparison, the use of the newly proposed 6.45MW (Lower Bound) and 15/16MW (Upper Bound) turbine scenario has shown a lower collision rate than the original turbine scenario, while 15/16WM (Upper Bound) has shown the lowest collision rate among the three scenarios. Considering the low collision rate under 98% avoidance rate, the impact of collision to Common Tern is not considered adverse for all scenarios.

The predicted collision rate of Common Tern's, under the original and 6.45MW (Lower Bound) turbine scenario, may affect a small portion of their overall population. Additional Potential Biological Removal (PBR) analysis was undertaken to assess if this predicted collision risk would have a potential population level effect.

The PBR for Common Tern is estimated to be more than 358 individuals [(10)], therefore collision rate of 18 and 17 per year for original and 6.45MW (Lower Bound) turbine scenario, respectively, would not be expected to cause significant impact to the Common Tern overall population.

(10) PBR was developed by Wade (1998) as a simple means to estimate levels of incidental harvest of marine mammals which would permit populations to be maintained at, or restored to, an optimum sustainable size, and which can be computed even in the absence of demographic data about the population in question (Cooke *et al.* 2012).
The PBR equation is:

$$PBR = N_{min} \times \frac{R_{max}}{2} \times F_R$$

Where:
PBR = the number of additional animals which can be removed safely;
N_{min} = the minimum population estimate;
R_{max} = the maximum net recruitment rate; and
F_R = the recovery factor.

Wade (1998) conducted simulations on the sensitivity of results to the value of N_{min} used. This led to a recommendation that the lower 60th percentile (~ p = 0.2) of the assumed population distribution be used. This was further modified with an estimate of the coefficient of variation (Dillingham and Fletcher 2008):
N_{min} is

$$N_{min} = \hat{N} e^{(Z_p CV_{\hat{N}})}$$

Where:

N = population estimate;
Z_p = the *p*th standard normal variate; and,
CV_N = coefficient of variation for N
The value for Z_p, at p = 0.2 is -0.842 and CV is typically set at 10%.

Maximum rates (R_{max}) of population growth are predicted to occur at small population densities, and are rarely observable in nature. Using an allometric relationship, Niel and Lebreton (2005) derived a method to estimate the maximum population growth rate (λ_{max}) using only adult survival (s) and age at first reproduction (α):

$$\lambda_{max} = \frac{(s\alpha - s + \alpha + 1) + \sqrt{(s - s\alpha - \alpha - 1)^2 - 4s\alpha^2}}{2\alpha}$$

R_{max} is then found as:

$$R_{max} = \lambda_{max} - 1$$

Common Tern's Adult Survival Rate (s) = 90.0% (https://app.bto.org/birdfacts/results/bob6150.htm);
Common Tern's Age at first production (α) = 3-4 year (To be conservative, 4 year is used for Common Tern's Age at first production for the worst case scenario) (https://www.audubon.org/field-guide/bird/common-tern) ;
f (or F_R)= 1.0 for populations of 'least concern' species that are known to be increasing or stable;
f (or F_R)= 0.5 for populations of 'least concern' species that are declining or of uncertain trend;
f (or F_R)= 0.3 for populations of 'near threatened' species; and,
f (or F_R)= 0.1 for populations of 'vulnerable' and 'endangered' species.
On this basis R_{max} ≈ 0.13, N_{min} (N=12472.4, N is calculated based on average of Common Tern's coordinated counts in Asia and Australasia from 2008 to 2015 https://www.eaaflyway.net/documents/resources/aewa%20ref/AWC_2008_2015_Summary_Report_31Mar17.pdf) ≈

Table B2.13 Collision Rates of Common Tern for the Original Turbine Scenario

Common Tern	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	1843.71	2704.41	3741.31	0.00
Proportion at rotor height (Band collision risk)	26.3%	26.3%	26.3%	26.3%
Collision per season (no avoidance)	194.42	285.18	394.53	0.00
Collision per season (98% avoidance)	**3.89**	**5.70**	**7.89**	**0.00**

Table B2.14 Collision Rates of Common Tern for Lower Bound - 6.45MW

Common Tern	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	1419.08	2081.54	2879.64	0.00
Proportion at rotor height (Band collision risk)	18.4%	18.4%	18.4%	18.4%
Collision per season (no avoidance)	179.95	263.96	365.17	0.00
Collision per season (98% avoidance)	**3.60**	**5.28**	**7.30**	**0.00**

Table B2.15 Collision Rates of Common Tern for Upper Bound - 15MW*

Common Tern	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	335.79	492.55	681.41	0.00
Proportion at rotor height (Band collision risk)	7.9%	7.9%	7.9%	7.9%
Collision per season (no avoidance)	32.96	48.35	66.89	0.00
Collision per season (98% avoidance)	**0.66**	**0.97**	**1.34**	**0.00**

*Note: Collision rates of Common Tern for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

11465.2, f = 0.5 (recovery factor, as the population of 'least concern' Common Tern is declining). Therefore, PBR = 11465.2x 0.13 x 0.5 x 0.5 ≈ 358.3.

B.2.6 Heuglin's Gull

Heuglin's Gull was recorded within the Assessment Area during the spring migratory season and winter in 2009, in which the highest predicted collision rate occurs in the spring migratory season. Assuming 98% avoidance rate, the maximum collision rate is approximately 17.75, 20.96 and 4.80 for the original, 6.45MW (Lower Bound) and 15MW (Upper Bound) turbine scenario respectively. For the Upper Bound turbine scenario, collision rates for 16MW scenario have also been assessed while the predicted collision rates are similar with that of 15MW scenario. In comparison, the use of newly proposed 15/16MW turbine scenario (Upper Bound) has shown the lowest collision rate among three scenarios, whereas the 6.45MW turbine scenario (Lower Bound) has shown similar collision rate to the original turbine scenario. Considering the low collision rate under 98% avoidance rate for the 15/16MW (Upper Bound) turbine scenario, the impact of collision to Heuglin's Gull is not considered adverse for the 15/16MW (Upper Bound) turbine scenario.

The predicted collision rate of Heuglin's Gull, under the original and 6.45MW (Lower Bound) turbine scenario, may affect a small portion of their overall population. Additional Potential Biological Removal (PBR) analysis was undertaken to assess if this predicted collision risk would have a potential population level effect.

The PBR for Heuglin's Gull is estimated to be more than 261 individuals [11], therefore collision rate of 30 and 35 per year for the original and 6.45MW (Lower Bound) turbine scenario, respectively, would not be expected to cause significant impact to the Heuglin's Gull overall population.

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(11) PBR was developed by Wade (1998) as a simple means to estimate levels of incidental harvest of marine mammals which would permit populations to be maintained at, or restored to, an optimum sustainable size, and which can be computed even in the absence of demographic data about the population in question (Cooke *et al.* 2012).
The PBR equation is:

$$PBR = N_{min} \times \frac{R_{max}}{2} \times F_R$$

Where:
PBR = the number of additional animals which can be removed safely;
N_{min} = the minimum population estimate;
R_{max} = the maximum net recruitment rate; and
F_R = the recovery factor.

Wade (1998) conducted simulations on the sensitivity of results to the value of N_{min} used. This led to a recommendation that the lower 60th percentile (~ p = 0.2) of the assumed population distribution be used. This was further modified with an estimate of the coefficient of variation (Dillingham and Fletcher 2008):
N_{min} is

$$N_{min} = \hat{N} e^{(Z_p CV_{\hat{N}})}$$

Where:

N = population estimate;
Z_p = the *p*th standard normal variate; and,
CV_N = coefficient of variation for N
The value for Z_p, at p = 0.2 is -0.842 and CV is typically set at 10%.

Maximum rates (R_{max}) of population growth are predicted to occur at small population densities, and are rarely observable in nature. Using an allometric relationship, Niel and Lebreton (2005) derived a method to estimate the maximum population growth rate (λ_{max}) using only adult survival (s) and age at first reproduction (α):

$$\lambda_{max} = \frac{(s\alpha - s + \alpha + 1) + \sqrt{(s - s\alpha - \alpha - 1)^2 - 4s\alpha^2}}{2\alpha}$$

R_{max} is then found as:

$$R_{max} = \lambda_{max} - 1$$

Heuglin's Gull's Adult Survival Rate (s) = 88.1% (Due to the limited study available on Heuglin's Gull, Lesser Black-backed Gull *Larus fuscus* is used as a proxy species, considering they are in the same family and Heuglin's Gull is the subspecies of Lesser Black-backed Gull, https://www.welshwildlife.org/wp-content/uploads/2019/10/Skomer-Seabird-Report-2019.pdf);
Heuglin's Gull's Age at first production (α) = 4 year (Lesser Black-backed Gull is used as a proxy species, http://www.cheshireandwirralbirdatlas.org/species/lesser-black-backed-gull-breeding.htm);
f (or F_R)= 1.0 for populations of 'least concern' species that are known to be increasing or stable;
f (or F_R)= 0.5 for populations of 'least concern' species that are declining or of uncertain trend;
f (or F_R)= 0.3 for populations of 'near threatened' species; and,
f (or F_R)= 0.1 for populations of 'vulnerable' and 'endangered' species.
On this basis R_{max} ≈ 0.13, N_{min} (N=4255.4; N is calculated based on average of Heuglin's Gull's coordinated counts in Asia and Australasia from 2008 to 2015, https://www.eaaflyway.net/documents/resources/aewa%20ref/AWC_2008-2015_Summary_Report_31Mar17.pdf) ≈ 3911.7, f = 1 (Lesser Black-backed Gull is used as a proxy species,

The magnitude of collision risk for Heuglin's Gull under all scenarios is considered to be negligible.

Table B2.16 Collision Rates of Heuglin's Gull for the Original Turbine Scenario

Heuglin's Gull	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	7475.67	0.00	0.00	4794.30
Proportion at rotor height (Band collision risk)	90.3%	90.3%	90.3%	90.3%
Collision per season (no avoidance)	887.73	0.00	0.00	569.32
Collision per season (98% avoidance)	**17.75**	**0.00**	**0.00**	**11.39**

Table B2.17 Collision Rates of Heuglin's Gull for Lower Bound - 6.45MW

Heuglin's Gull	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	8220.35	0.00	0.00	5271.88
Proportion at rotor height (Band collision risk)	90.3%	90.3%	90.3%	90.3%
Collision per season (no avoidance)	1048.05	0.00	0.00	672.13
Collision per season (98% avoidance)	**20.96**	**0.00**	**0.00**	**13.44**

Table B2.18 Collision Rates of Heuglin's Gull for Upper Bound - 15MW*

Heuglin's Gull	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	2432.79	0.00	0.00	1560.20
Proportion at rotor height (Band collision risk)	48.4%	48.4%	48.4%	48.4%
Collision per season (no avoidance)	239.97	0.00	0.00	153.90
Collision per season (98% avoidance)	**4.80**	**0.00**	**0.00**	**3.08**

*Note: Collision rates of Heuglin's Gull for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

recovery factor, as the population of 'least concern' Lesser Black-backed Gull is increasing). Therefore PBR = 3911.7 x 0.13 x 0.5 x 1 ≈ 261.2.

B.2.7 Red-necked Phalarope

Rad-necked Phalarope was recorded within the Assessment Area only in the spring migratory season in 2009. During the baseline survey, seven Red-necked Phalarope were recorded above sea level within the Assessment Area, while six of them were recorded at 1m, which does not fall into the risk height of the original turbine scenario (14m to 136m), 6.45MW turbine scenario (Lower Bound, 20m to 198m) and 15/16MW scenario (Upper Bound, 29m to 265m/271m), one Red-necked Phalarope was recorded flying at 20m, which falls into the risk height of the original (14m to 136m) and 6.45MW turbine scenario (Lower Bound, 20m to 198m). Since the population of Red-necked Phalarope has been increased since 2008 as detailed in **Appendix A**, the bird density has been multiplied by 2 times in the collision risk model. Assuming 98% avoidance rate, the collision rate is approximately 1.13 and 1.66 for the original and 6.45MW turbine scenario (Lower Bound) respectively. Considering the low collision rate under 98% avoidance rate, the impact of collision to Red-necked Phalarope is not considered adverse for the original and 6.45MW turbine scenario (Lower Bound). Given that all records in the baseline survey are out of the risk height of 15/16MW turbine scenario (Upper Bound), the impact of collision is considered low/ negligible for this scenario.

Table B2.19 Collision Rates of Red-necked Phalarope for the Original Turbine Scenario

Red-necked Phalarope	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	446.12	0.00	0.00	0.00
Proportion at rotor height (Band collision risk)	14.3%	14.3%	14.3%	14.3%
Collision per season (no avoidance)	56.30	0.00	0.00	0.00
Collision per season (98% avoidance)	**1.13**	**0.00**	**0.00**	**0.00**

Table B2.20 Collision Rates of Red-necked Phalarope for Lower Bound - 6.45MW

Red-necked Phalarope	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	490.56	0.00	0.00	0.00
Proportion at rotor height (Band collision risk)	14.3%	14.3%	14.3%	14.3%
Collision per season (no avoidance)	82.94	0.00	0.00	0.00
Collision per season (98% avoidance)	**1.66**	**0.00**	**0.00**	**0.00**

Table B2.21 Collision Rates of Red-necked Phalarope for Upper Bound - 15MW*

Red-necked Phalarope	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	0.00	0.00	0.00	0.00
Proportion at rotor height (Band collision risk)	0.0%	0.0%	0.0%	0.0%
Collision per season (no avoidance)	0.00	0.00	0.00	0.00
Collision per season (98% avoidance)	**0.00**	**0.00**	**0.00**	**0.00**

*Note: Collision rates of Red-necked Phalarope for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

White-bellied Sea Eagle

White-bellied Sea Eagle was recorded within the Assessment Area only in the spring migratory season in 2009. During the baseline survey, one White-bellied Sea Eagle was recorded within the Assessment Area flying at 15m, which fall within the risk height of the original turbine scenario (14m to 136m), but outside the risk height of 6.45MW turbine scenario (Lower Bound, 20m to 198m) and 15/16MW scenario (Upper Bound, 29m to 265m/271m). Assuming 98% avoidance rate, the collision rate is approximately 0.92 for the original turbine scenario. Considering the low collision rate under 98% avoidance rate, the impact of collision to White-bellied Sea Eagle is not considered adverse for the original turbine scenario. Given that all records in the baseline survey are out of the risk height of 6.45MW (Lower Bound) and 15/16MW turbine scenarios (Upper Bound), the impact of collision is considered low/ negligible for these two scenarios.

Table B2.22 Collision Rates of White-bellied Sea Eagle for the Original Turbine Scenario

White-bellied Sea Eagle	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	569.07	0.00	0.00	0.00
Proportion at rotor height (Band collision risk)	100.0%	100.0%	100.0%	100.0%
Collision per season (no avoidance)	46.24	0.00	0.00	0.00
Collision per season (98% avoidance)	**0.92**	**0.00**	**0.00**	**0.00**

Table B2.23 Collision Rates of White-bellied Sea Eagle for Lower Bound - 6.45MW

White-bellied Sea Eagle	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	0.00	0.00	0.00	0.00
Proportion at rotor height (Band collision risk)	0.0%	0.0%	0.0%	0.0%
Collision per season (no avoidance)	0.00	0.00	0.00	0.00
Collision per season (98% avoidance)	**0.00**	**0.00**	**0.00**	**0.00**

Table B2.24 Collision Rates of White-bellied Sea Eagle for Upper Bound - 15MW*

White-bellied Sea Eagle	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	0.00	0.00	0.00	0.00
Proportion at rotor height (Band collision risk)	0.0%	0.0%	0.0%	0.0%
Collision per season (no avoidance)	0.00	0.00	0.00	0.00
Collision per season (98% avoidance)	**0.00**	**0.00**	**0.00**	**0.00**

*Note: Collision rates of White-bellied Sea Eagle for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

B.2.8 White-winged Tern

White-winged Tern was recorded within the Assessment Area only in the spring migratory season in 2009. During the baseline survey, 47 White-winged Tern were recorded above sea level within the Assessment Area, a group of 20 White-winged Terns was recorded flying at 20m, which falls into the risk height of the original (14m to 136m) and 6.45MW turbine scenario (Lower Bound, 20m to 198m). Since the population of White-winged Tern has been increased since 2008 as detailed in **Appendix A**, the bird density has been multiplied by 2 times in the collision risk model. Assuming 98% avoidance rate, the collision rate is approximately 22.92 and 32.43 for the original and 6.45MW turbine scenario (Lower Bound) respectively. Given that all records in the baseline survey are out of the risk height of 15/16MW turbine scenario (Upper Bound), the impact of collision is considered low/ negligible for this scenario.

The predicted collision rate of White-winged Tern, under the original and 6.45MW (Lower Bound) turbine scenario, may affect a small portion of their overall population. Additional PBR analysis was undertaken to assess if this predicted collision risk would have a potential population level effect.

The PBR for White-winged Tern is estimated to be more than 121 individuals (12), therefore collision rate of 23 and 33 per year for the original and 6.45MW (Lower Bound) turbine scenario, respectively, would not be expected to cause significant impact to the White-winged Tern overall population.

The magnitude of collision risk for White-winged Tern under all scenarios is considered to be negligible.

(12) PBR was developed by Wade (1998) as a simple means to estimate levels of incidental harvest of marine mammals which would permit populations to be maintained at, or restored to, an optimum sustainable size, and which can be computed even in the absence of demographic data about the population in question (Cooke *et al.* 2012).
The PBR equation is:

$$PBR = N_{min} \times \frac{R_{max}}{2} \times F_R$$

Where:
PBR = the number of additional animals which can be removed safely;
N_{min} = the minimum population estimate;
R_{max} = the maximum net recruitment rate; and
F_R = the recovery factor.

Wade (1998) conducted simulations on the sensitivity of results to the value of N_{min} used. This led to a recommendation that the lower 60th percentile (~ p = 0.2) of the assumed population distribution be used. This was further modified with an estimate of the coefficient of variation (Dillingham and Fletcher 2008):
N_{min} is

$$N_{min} = \hat{N} e^{(Z_p CV_{\hat{N}})}$$

Where:

N = population estimate;
Z_p = the *p*th standard normal variate; and,
CV_N = coefficient of variation for N
The value for Z_p, at p = 0.2 is -0.842 and CV is typically set at 10%.

Maximum rates (R_{max}) of population growth are predicted to occur at small population densities, and are rarely observable in nature. Using an allometric relationship, Niel and Lebreton (2005) derived a method to estimate the maximum population growth rate (λ_{max}) using only adult survival (s) and age at first reproduction (α):

$$\lambda_{max} = \frac{(s\alpha - s + \alpha + 1) + \sqrt{(s - s\alpha - \alpha - 1)^2 - 4s\alpha^2}}{2\alpha}$$

R_{max} is then found as:

$$R_{max} = \lambda_{max} - 1$$

White-winged Tern's Adult Survival Rate (s) = 80.0% (Due to the limited study available on White-winged Tern, Whiskered Tern *Chlidonias hybrid* is used as a proxy species, considering they are in the same family, https://www.researchgate.net/publication/237100971_Adult_and_pre-breeding_survival_estimates_of_the_Whiskered_Tern_Chlidonias_hybrida_breeding_in_southern_Poland);
White-winged Tern's Age at first production (α) = 4 year (Whiskered Tern is used as a proxy species, https://www.researchgate.net/publication/237100971_Adult_and_pre-breeding_survival_estimates_of_the_Whiskered_Tern_Chlidonias_hybrida_breeding_in_southern_Poland);
f (or F_R)= 1.0 for populations of 'least concern' species that are known to be increasing or stable;
f (or F_R)= 0.5 for populations of 'least concern' species that are declining or of uncertain trend;
f (or F_R)= 0.3 for populations of 'near threatened' species; and,
f (or F_R)= 0.1 for populations of 'vulnerable' and 'endangered' species.
On this basis R_{max} ≈ 0.16, N_{min} (N= 1647.4; N is calculated based on average of White-winged Tern's coordinated counts in Asia and Australasia from 2008 to 2015, https://www.eaaflyway.net/documents/resources/aewa%20ref/AWC_2008-2015_Summary_Report_31Mar17.pdf) ≈ 1514.3, f = 1 (recovery factor, as the population of 'least concern' White-winged Tern is stable). Therefore, PBR = 1514.3x 0.16 x 0.5 x 1 ≈ 121.8.

Table B2.25 Collision Rates of White-winged Tern for the Original Turbine Scenario

White-winged Tern	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	23203.94	0.00	0.00	0.00
Proportion at rotor height (Band collision risk)	42.6%	42.6%	42.6%	42.6%
Collision per season (no avoidance)	1146.12	0.00	0.00	0.00
Collision per season (98% avoidance)	**22.92**	**0.00**	**0.00**	**0.00**

Table B2.26 Collision Rates of White-winged Tern for Lower Bound - 6.45MW

White-winged Tern	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	25515.37	0.00	0.00	0.00
Proportion at rotor height (Band collision risk)	42.6%	42.6%	42.6%	42.6%
Collision per season (no avoidance)	1621.43	0.00	0.00	0.00
Collision per season (98% avoidance)	**32.43**	**0.00**	**0.00**	**0.00**

Table B2.27 Collision Rates of White-winged Tern for Upper Bound - 15MW*

White-winged Tern	Spring Migratory Period (Mar to May)	Summer Breeding Period (Jun to Aug)	Autumn Migratory Period (Sep to Nov)	Winter Period (Dec to Feb)
Number of bird transits through rotor (per season)	0.00	0.00	0.00	0.00
Proportion at rotor height (Band collision risk)	0.0%	0.0%	0.0%	0.0%
Collision per season (no avoidance)	0.00	0.00	0.00	0.00
Collision per season (98% avoidance)	**0.00**	**0.00**	**0.00**	**0.00**

*Note: Collision rates of White-winged Tern for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

B3 Summary of Significance of Impacts on Avifauna

It is concluded that the magnitude of collision risk for some species in the new scenarios are considered to be low/ negligible since the species do not fall within the risk height, including Black-naped Tern and White-bellied Sea Eagle in both Lower Bound (i.e. 6.45MW) and Upper Bound (i.e. 15/16MW) turbine scenarios; as well as Red-necked Phalarope and White-winged Tern in 15/16MW turbine scenario (Upper Bound). For the remaining scenarios, the magnitude of all potential impacts resulted from operation of the proposed wind farm are predicted to be low, which is considered to be comparable with the findings in the approved EIA.

Overall, it is anticipated that the collision risk from all three turbine scenarios due to the operation of the wind farm of at least 150MW capacity is low and will not cause any unacceptable impacts to the nine key concerned species. In comparison, the Lower Bound scenario has relatively higher collision rates than the original turbine scenario, whereas the Upper Bound scenario has the lowest collision rate for all assessed bird species.

APPENDIX C COLLISION PROBABILITIES OF SELECTED SPECIES

List of Tables

Table C1 Collision Probability Calculation for Aleutian Tern (Original Scenario)

NoBlades	3	
MaxBladeWidth	2.00	m
Pitch (degrees)	27.5	
Species name	Aleutian Tern	
BirdLength	0.34	m
Wingspan	0.80	m
F: flapping (0) or gliding (+1)	0	
Proportion of flights upwind	50%	%
Bird speed	5.5	m/sec
Rotor Radius	55.5	m
Rotation Speed	19	rpm
Rotation Period	3.16	sec
Bird aspect ratio: β	0.43	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	1.00	2.76	0.477	1.41	0.244
0.10	0.79	0.50	1.83	0.315	0.43	0.074
0.15	0.88	0.33	1.67	0.289	0.63	0.110
0.20	0.96	0.25	1.65	0.285	0.80	0.139
0.25	1.00	0.20	1.62	0.279	0.91	0.157
0.30	0.98	0.17	1.53	0.265	0.96	0.165
0.35	0.92	0.14	1.42	0.246	0.96	0.165
0.40	0.85	0.12	1.31	0.227	0.94	0.162
0.45	0.80	0.11	1.24	0.213	0.92	0.159
0.50	0.75	0.10	1.17	0.201	0.90	0.155
0.55	0.70	0.09	1.10	0.190	0.87	0.151
0.60	0.64	0.08	1.03	0.177	0.84	0.145
0.65	0.58	0.08	0.95	0.165	0.80	0.138
0.70	0.52	0.07	0.89	0.153	0.75	0.130
0.75	0.47	0.07	0.83	0.143	0.72	0.124
0.80	0.41	0.06	0.76	0.132	0.67	0.116
0.85	0.37	0.06	0.72	0.124	0.64	0.111
0.90	0.30	0.06	0.65	0.112	0.59	0.101
0.95	0.24	0.05	0.58	0.101	0.54	0.093
1.00	0.00	0.05	0.34	0.059	0.34	0.059

Overall p(collision) integrated over disk

Upwind **16.5%** **Downwind** **12.6%**

Proportion	upwind:	downwind
	50%	50%

Average **14.6%**

Table C2 Collision Probability Calculation for Aleutian Tern (Lower Bound - 6.45MW)

NoBlades	3	
MaxBladeWidth	5.10	m
Pitch (degrees)	27.5	
Species name	Aleutian Tern	
BirdLength	0.34	m
Wingspan	0.80	m
F: flapping (0) or gliding (+1)	0	
Proportion of flights upwind	50%	%
Bird speed	5.5	m/sec
Rotor Radius	89	m
Rotation Speed	12	rpm
Rotation Period	5.00	sec
Bird aspect ratio: β	0.43	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

			Upwind:		Downwind:	
r/R	c/C	α	collide		collide	
radius	chord	alpha	length	p(collision)	length	p(collision)
0.00				1.000		1.000
0.05	0.73	0.98	5.75	0.628	2.32	0.253
0.10	0.79	0.49	4.01	0.438	0.50	0.054
0.15	0.88	0.33	3.72	0.406	1.11	0.121
0.20	0.96	0.25	3.67	0.400	1.53	0.167
0.25	1.00	0.20	3.58	0.391	1.81	0.197
0.30	0.98	0.16	3.37	0.368	1.92	0.210
0.35	0.92	0.14	3.09	0.337	1.92	0.210
0.40	0.85	0.12	2.81	0.307	1.87	0.204
0.45	0.80	0.11	2.62	0.286	1.83	0.199
0.50	0.75	0.10	2.44	0.266	1.77	0.193
0.55	0.70	0.09	2.27	0.248	1.71	0.186
0.60	0.64	0.08	2.08	0.227	1.61	0.176
0.65	0.58	0.08	1.90	0.208	1.51	0.164
0.70	0.52	0.07	1.73	0.189	1.40	0.153
0.75	0.47	0.07	1.59	0.173	1.31	0.143
0.80	0.41	0.06	1.42	0.155	1.19	0.130
0.85	0.37	0.06	1.31	0.143	1.11	0.122
0.90	0.30	0.05	1.12	0.122	0.97	0.106
0.95	0.24	0.05	0.96	0.105	0.85	0.093
1.00	0.00	0.05	0.34	0.037	0.34	0.037

Overall p(collision) integrated over disk

			Upwind	**20.7%**	**Downwind**	**14.6%**
Proportion	upwind: downwind					
50%	50%		**Average**	**17.7%**		

Table C3 Collision Probability Calculation for Aleutian Tern (Upper Bound - 15MW)*

Calculation of alpha and p(collision) as a function of radius

NoBlades	3					**Upwind:**			**Downwind:**	
MaxBladeWidth	5.10	m	r/R	c/C	α	collide			collide	
Pitch (degrees)	27.5		radius	chord	alpha	length	p(collision)		length	p(collision)
Species name	Aleutian Tern		0.00				1.000			1.000
BirdLength	0.34	m	0.05	0.73	0.96	5.65	0.477		2.21	0.187
Wingspan	0.80	m	0.10	0.79	0.48	3.95	0.334		0.53	0.045
F: flapping (0) or gliding (+1)	0		0.15	0.88	0.32	3.68	0.311		1.14	0.097
Proportion of flights upwind	50%	%	0.20	0.96	0.24	3.64	0.308		1.56	0.132
Bird speed	5.5	m/sec	0.25	1.00	0.19	3.56	0.301		1.83	0.155
Rotor Radius	118	m	0.30	0.98	0.16	3.36	0.284		1.94	0.164
Rotation Speed	9.3	rpm	0.35	0.92	0.14	3.08	0.260		1.94	0.164
Rotation Period	6.45	sec	0.40	0.85	0.12	2.80	0.237		1.88	0.159
			0.45	0.80	0.11	2.61	0.221		1.84	0.155
			0.50	0.75	0.10	2.43	0.206		1.78	0.151
Bird aspect ratio: β	0.43		0.55	0.70	0.09	2.26	0.191		1.71	0.145
			0.60	0.64	0.08	2.08	0.176		1.62	0.137
Integration interval	0.05		0.65	0.58	0.07	1.90	0.161		1.51	0.128
			0.70	0.52	0.07	1.73	0.146		1.40	0.119
			0.75	0.47	0.06	1.58	0.134		1.31	0.111
			0.80	0.41	0.06	1.42	0.120		1.19	0.101
			0.85	0.37	0.06	1.31	0.110		1.12	0.094
			0.90	0.30	0.05	1.12	0.095		0.97	0.082
			0.95	0.24	0.05	0.96	0.081		0.85	0.072
			1.00	0.00	0.05	0.34	0.029		0.34	0.029

Overall p(collision) integrated over disk

			Upwind	**16.0%**	**Downwind**	**11.4%**
Proportion	upwind:	downwind				
	50%	50%	**Average**	**13.7%**		

*Note: Collision rates of Aleutian Tern for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

Table C4 Collision Probability Calculation for Black Kite (Original Scenario)

NoBlades	3	
MaxBladeWidth	2.00	m
Pitch (degrees)	27.5	
Species name	Black Kite	
BirdLength	0.69	m
Wingspan	1.50	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	9	m/sec
Rotor Radius	55.5	m
Rotation Speed	19	rpm
Rotation Period	3.16	sec
Bird aspect ratio: β	0.46	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R	c/C	α	**Upwind:**		**Downwind:**	
radius	chord	alpha	collide length	p(collision)	collide length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.63	4.34	0.458	2.99	0.316
0.10	0.79	0.82	2.65	0.280	1.19	0.126
0.15	0.88	0.54	2.18	0.230	0.55	0.059
0.20	0.96	0.41	2.27	0.240	0.88	0.093
0.25	1.00	0.33	2.19	0.231	1.04	0.109
0.30	0.98	0.27	2.07	0.218	1.12	0.119
0.35	0.92	0.23	1.92	0.203	1.16	0.122
0.40	0.85	0.20	1.78	0.188	1.17	0.123
0.45	0.80	0.18	1.69	0.178	1.17	0.124
0.50	0.75	0.16	1.60	0.169	1.17	0.123
0.55	0.70	0.15	1.52	0.160	1.15	0.122
0.60	0.64	0.14	1.44	0.152	1.13	0.119
0.65	0.58	0.13	1.35	0.143	1.10	0.116
0.70	0.52	0.12	1.28	0.135	1.06	0.112
0.75	0.47	0.11	1.21	0.128	1.03	0.109
0.80	0.41	0.10	1.14	0.121	0.99	0.105
0.85	0.37	0.10	1.09	0.116	0.97	0.102
0.90	0.30	0.09	1.02	0.107	0.92	0.097
0.95	0.24	0.09	0.95	0.100	0.88	0.092
1.00	0.00	0.08	0.69	0.073	0.69	0.073

Overall p(collision) integrated over disk

		Upwind	**14.5%**	**Downwind**	**10.8%**
Proportion	upwind: downwind				
50%	50%	**Average**	**12.7%**		

Table C5 Collision Probability Calculation for Black Kite (Lower Bound - 6.45MW)

NoBlades	3	
MaxBladeWidth	5.10	m
Pitch (degrees)	27.5	
Species name	Black Kite	
BirdLength	0.69	m
Wingspan	1.50	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	9	m/sec
Rotor Radius	89	m
Rotation Speed	12	rpm
Rotation Period	5.00	sec
Bird aspect ratio: β	0.46	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	1.61	8.57	0.571	5.13	0.342
0.10	0.79	0.80	5.50	0.367	1.78	0.119
0.15	0.88	0.54	4.72	0.315	0.58	0.038
0.20	0.96	0.40	4.70	0.313	1.20	0.080
0.25	1.00	0.32	4.50	0.300	1.59	0.106
0.30	0.98	0.27	4.19	0.279	1.81	0.121
0.35	0.92	0.23	3.81	0.254	1.90	0.127
0.40	0.85	0.20	3.47	0.231	1.92	0.128
0.45	0.80	0.18	3.22	0.215	1.93	0.128
0.50	0.75	0.16	3.00	0.200	1.91	0.127
0.55	0.70	0.15	2.80	0.187	1.88	0.125
0.60	0.64	0.13	2.59	0.172	1.81	0.121
0.65	0.58	0.12	2.38	0.159	1.73	0.115
0.70	0.52	0.11	2.18	0.146	1.64	0.110
0.75	0.47	0.11	2.02	0.135	1.57	0.105
0.80	0.41	0.10	1.84	0.123	1.47	0.098
0.85	0.37	0.09	1.72	0.115	1.40	0.094
0.90	0.30	0.09	1.52	0.101	1.28	0.085
0.95	0.24	0.08	1.35	0.090	1.16	0.078
1.00	0.00	0.08	0.69	0.046	0.69	0.046

Overall p(collision) integrated over disk

Upwind **16.2%** **Downwind** **10.3%**

Proportion upwind: downwind
50% 50% **Average** **13.3%**

Table C6 Collision Probability Calculation for Black Kite (Upper Bound - 15MW)*

NoBlades	3	
MaxBladeWidth	5.10	m
Pitch (degrees)	27.5	
Species name	Black Kite	
BirdLength	0.69	m
Wingspan	1.50	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	9	m/sec
Rotor Radius	118	m
Rotation Speed	9.3	rpm
Rotation Period	6.45	sec
Bird aspect ratio: β	0.46	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

			Upwind:		**Downwind:**	
r/R radius	c/C chord	α alpha	collide length	p(collision)	collide length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.57	8.39	0.433	4.95	0.256
0.10	0.79	0.78	5.41	0.279	1.69	0.087
0.15	0.88	0.52	4.65	0.240	0.50	0.026
0.20	0.96	0.39	4.65	0.240	1.25	0.065
0.25	1.00	0.31	4.46	0.231	1.63	0.084
0.30	0.98	0.26	4.16	0.215	1.84	0.095
0.35	0.92	0.22	3.79	0.196	1.93	0.099
0.40	0.85	0.20	3.44	0.178	1.94	0.100
0.45	0.80	0.17	3.20	0.166	1.94	0.100
0.50	0.75	0.16	2.99	0.154	1.92	0.099
0.55	0.70	0.14	2.79	0.144	1.89	0.098
0.60	0.64	0.13	2.58	0.133	1.82	0.094
0.65	0.58	0.12	2.37	0.123	1.74	0.090
0.70	0.52	0.11	2.18	0.113	1.65	0.085
0.75	0.47	0.10	2.02	0.104	1.57	0.081
0.80	0.41	0.10	1.84	0.095	1.47	0.076
0.85	0.37	0.09	1.72	0.089	1.41	0.073
0.90	0.30	0.09	1.51	0.078	1.28	0.066
0.95	0.24	0.08	1.34	0.069	1.17	0.060
1.00	0.00	0.08	0.69	0.036	0.69	0.036

Overall p(collision) integrated over disk

		Upwind	**12.5%**	**Downwind**	**8.0%**
Proportion	upwind: downwind				
50%	50%	**Average**	**10.3%**		

*Note: Collision rates of Black Kite for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

Table C7 Collision Probability Calculation for Black-legged Kittiwake (Original Scenario)

NoBlades	3	
MaxBladeWidth	2.00	m
Pitch (degrees)	27.5	
Species name	Black-legged Kittiwake	
BirdLength	0.41	m
Wingspan	0.97	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	13.1	m/sec
Rotor Radius	55.5	m
Rotation Speed	19	rpm
Rotation Period	3.16	sec
Bird aspect ratio: β	0.42	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	2.37	5.21	0.378	3.86	0.280
0.10	0.79	1.19	3.12	0.227	1.67	0.121
0.15	0.88	0.79	2.54	0.184	0.91	0.066
0.20	0.96	0.59	2.26	0.164	0.49	0.036
0.25	1.00	0.47	2.06	0.149	0.37	0.027
0.30	0.98	0.40	2.00	0.145	0.63	0.046
0.35	0.92	0.34	1.81	0.131	0.71	0.051
0.40	0.85	0.30	1.64	0.119	0.75	0.054
0.45	0.80	0.26	1.52	0.110	0.77	0.056
0.50	0.75	0.24	1.42	0.103	0.79	0.057
0.55	0.70	0.22	1.32	0.096	0.79	0.057
0.60	0.64	0.20	1.23	0.089	0.78	0.056
0.65	0.58	0.18	1.13	0.082	0.76	0.055
0.70	0.52	0.17	1.05	0.076	0.73	0.053
0.75	0.47	0.16	0.98	0.071	0.71	0.052
0.80	0.41	0.15	0.90	0.065	0.68	0.049
0.85	0.37	0.14	0.84	0.061	0.66	0.048
0.90	0.30	0.13	0.76	0.055	0.62	0.045
0.95	0.24	0.12	0.68	0.050	0.58	0.042
1.00	0.00	0.12	0.41	0.030	0.41	0.030
0.00				1.000		1.000

Overall p(collision) integrated over disk

		Upwind	**8.6%**	
		Downwind	**5.1%**	
Proportion upwind: downwind	50%	50%	**Average**	**6.8%**

Table C8 Collision Probability Calculation for Black-legged Kittiwake (Lower Bound - 6.45MW)

Calculation of alpha and p(collision) as a function of radius

Parameter	Value	Unit	r/R radius	c/C chord	α alpha	**Upwind:** collide length	**Upwind:** p(collision)	**Downwind:** collide length	**Downwind:** p(collision)
NoBlades	3								
MaxBladeWidth	5.10	m							
Pitch (degrees)	27.5								
Species name	Black-legged Kittiwake		0.00				1.000		1.000
BirdLength	0.41	m	0.05	0.73	2.34	10.90	0.499	7.46	0.342
Wingspan	0.97	m	0.10	0.79	1.17	6.77	0.310	3.05	0.140
F: flapping (0) or gliding (+1)	1		0.15	0.88	0.78	5.66	0.259	1.52	0.070
Proportion of flights upwind	50%	%	0.20	0.96	0.59	5.17	0.237	0.64	0.030
Bird speed	13.1	m/sec	0.25	1.00	0.47	4.76	0.218	0.52	0.024
Rotor Radius	89	m	0.30	0.98	0.39	4.45	0.204	0.99	0.045
Rotation Speed	12	rpm	0.35	0.92	0.33	3.97	0.182	1.18	0.054
Rotation Period	5.00	sec	0.40	0.85	0.29	3.54	0.162	1.29	0.059
			0.45	0.80	0.26	3.24	0.148	1.35	0.062
			0.50	0.75	0.23	2.97	0.136	1.38	0.063
Bird aspect ratio: β	0.42		0.55	0.70	0.21	2.73	0.125	1.38	0.063
			0.60	0.64	0.20	2.48	0.114	1.35	0.062
Integration interval	0.05		0.65	0.58	0.18	2.25	0.103	1.30	0.060
			0.70	0.52	0.17	2.03	0.093	1.24	0.057
			0.75	0.47	0.16	1.85	0.085	1.18	0.054
			0.80	0.41	0.15	1.65	0.075	1.10	0.051
			0.85	0.37	0.14	1.51	0.069	1.05	0.048
			0.90	0.30	0.13	1.29	0.059	0.94	0.043
			0.95	0.24	0.12	1.11	0.051	0.84	0.039
			1.00	0.00	0.12	0.41	0.019	0.41	0.019

Overall p(collision) integrated over disk

		Upwind	**10.8%**		**Downwind**	**5.3%**
Proportion upwind: downwind						
50%	50%		**Average**	**8.1%**		

Table C9 Collision Probability Calculation for Black-legged Kittiwake (Upper Bound - 15MW)*

Calculation of alpha and p(collision) as a function of radius

NoBlades	3				**Upwind:**		**Downwind:**	
MaxBladeWidth	5.10 m	r/R	c/C	α	collide		collide	
Pitch (degrees)	27.5	radius	chord	alpha	length	p(collision)	length	p(collision)
	Black-legged							
Species name	Kittiwake	0.00				1.000		1.000
BirdLength	0.41 m	0.05	0.73	2.28	10.66	0.378	7.22	0.256
Wingspan	0.97 m	0.10	0.79	1.14	6.64	0.236	2.92	0.104
F: flapping (0) or gliding (+1)	1	0.15	0.88	0.76	5.57	0.198	1.42	0.050
Proportion of flights upwind	50%%	0.20	0.96	0.57	5.09	0.181	0.57	0.020
Bird speed	13.1 m/sec	0.25	1.00	0.46	4.70	0.167	0.57	0.020
Rotor Radius	118 m	0.30	0.98	0.38	4.40	0.156	1.03	0.037
Rotation Speed	9.3rpm	0.35	0.92	0.33	3.93	0.140	1.22	0.043
Rotation Period	6.45 sec	0.40	0.85	0.28	3.51	0.125	1.32	0.047
		0.45	0.80	0.25	3.21	0.114	1.38	0.049
		0.50	0.75	0.23	2.95	0.105	1.40	0.050
Bird aspect ratio: β	0.42	0.55	0.70	0.21	2.71	0.096	1.40	0.050
		0.60	0.64	0.19	2.47	0.088	1.37	0.049
Integration interval	0.05	0.65	0.58	0.18	2.24	0.079	1.32	0.047
		0.70	0.52	0.16	2.02	0.072	1.25	0.044
		0.75	0.47	0.15	1.84	0.065	1.19	0.042
		0.80	0.41	0.14	1.64	0.058	1.11	0.039
		0.85	0.37	0.13	1.51	0.053	1.06	0.038
		0.90	0.30	0.13	1.29	0.046	0.94	0.034
		0.95	0.24	0.12	1.11	0.039	0.84	0.030
		1.00	0.00	0.11	0.41	0.015	0.41	0.015

Overall p(collision) integrated over disk

		Upwind	**8.3%**	**Downwind**	**4.1%**
Proportion upwind: downwind					
50%	50%	**Average**		**6.2%**	

*Note: Collision rates of Black-legged Kittiwake for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

Table C10 Collision Probability Calculation for Black-naped Tern (Original Scenario)

NoBlades	3	
MaxBladeWidth	2.00	m
Pitch (degrees)	27.5	
Species name	Black-naped Tern	
BirdLength	0.35	m
Wingspan	0.23	m
F: flapping (0) or gliding (+1)	0	
Proportion of flights upwind	50%	%
Bird speed	9.6	m/sec
Rotor Radius	55.5	m
Rotation Speed	19	rpm
Rotation Period	3.16	sec
Bird aspect ratio: β	1.52	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R	c/C	α	Upwind: collide		Downwind: collide	
radius	chord	alpha	length	p(collision)	length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.74	3.33	0.329	1.98	0.196
0.10	0.79	0.87	2.30	0.227	0.84	0.083
0.15	0.88	0.58	2.07	0.205	0.44	0.044
0.20	0.96	0.43	1.98	0.196	0.50	0.049
0.25	1.00	0.35	1.89	0.187	0.66	0.065
0.30	0.98	0.29	1.76	0.174	0.75	0.074
0.35	0.92	0.25	1.61	0.159	0.79	0.079
0.40	0.85	0.22	1.46	0.145	0.81	0.080
0.45	0.80	0.19	1.36	0.135	0.81	0.081
0.50	0.75	0.17	1.27	0.126	0.81	0.080
0.55	0.70	0.16	1.19	0.118	0.80	0.079
0.60	0.64	0.14	1.11	0.109	0.78	0.077
0.65	0.58	0.13	1.02	0.101	0.75	0.074
0.70	0.52	0.12	0.94	0.093	0.72	0.071
0.75	0.47	0.12	0.88	0.087	0.69	0.068
0.80	0.41	0.11	0.81	0.080	0.65	0.064
0.85	0.37	0.10	0.76	0.075	0.62	0.062
0.90	0.30	0.10	0.68	0.067	0.58	0.057
0.95	0.24	0.09	0.61	0.060	0.53	0.053
1.00	0.00	0.09	0.35	0.035	0.35	0.035

Overall p(collision) integrated over disk

		Upwind	**10.4%**	**Downwind**	**6.7%**
Proportion upwind:	downwind				
50%	50%	**Average**	**8.5%**		

Table C11 Collision Probability Calculation for Black-naped Tern (Lower Bound - 6.45MW)

NoBlades	3	
MaxBladeWidth	5.10	m
Pitch (degrees)	27.5	
Species name	Black-naped Tern	
BirdLength	0.35	m
Wingspan	0.23	m
F: flapping (0) or gliding (+1)	0	
Proportion of flights upwind	50%	%
Bird speed	9.6	m/sec
Rotor Radius	89	m
Rotation Speed	12	rpm
Rotation Period	5.00	sec
Bird aspect ratio: β	1.52	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	1.72	7.78	0.486	4.34	0.272
0.10	0.79	0.86	5.28	0.330	1.56	0.097
0.15	0.88	0.57	4.70	0.294	0.56	0.035
0.20	0.96	0.43	4.47	0.280	0.75	0.047
0.25	1.00	0.34	4.26	0.266	1.15	0.072
0.30	0.98	0.29	3.93	0.245	1.39	0.087
0.35	0.92	0.25	3.54	0.221	1.50	0.093
0.40	0.85	0.21	3.18	0.199	1.53	0.095
0.45	0.80	0.19	2.92	0.183	1.54	0.096
0.50	0.75	0.17	2.70	0.169	1.53	0.096
0.55	0.70	0.16	2.49	0.156	1.50	0.094
0.60	0.64	0.14	2.27	0.142	1.44	0.090
0.65	0.58	0.13	2.06	0.129	1.37	0.086
0.70	0.52	0.12	1.86	0.116	1.29	0.080
0.75	0.47	0.11	1.70	0.106	1.21	0.076
0.80	0.41	0.11	1.51	0.095	1.12	0.070
0.85	0.37	0.10	1.39	0.087	1.05	0.066
0.90	0.30	0.10	1.19	0.074	0.93	0.058
0.95	0.24	0.09	1.01	0.063	0.82	0.051
1.00	0.00	0.09	0.35	0.022	0.35	0.022

Overall p(collision) integrated over disk

Upwind **13.2%** **Downwind** **7.4%**

Proportion upwind: downwind
50% 50%

Average **10.3%**

Table C12 Collision Probability Calculation for Black-naped Tern (Upper Bound - 15MW)*

Calculation of alpha and p(collision) as a function of radius

NoBlades	3	
MaxBladeWidth	5.10	m
Pitch (degrees)	27.5	
Species name	Black-naped Tern	
BirdLength	0.35	m
Wingspan	0.23	m
F: flapping (0) or gliding (+1)	0	
Proportion of flights upwind	50%	%
Bird speed	9.6	m/sec
Rotor Radius	118	m
Rotation Speed	9.3	rpm
Rotation Period	6.45	sec
Bird aspect ratio: β	1.52	
Integration interval	0.05	

			Upwind:		**Downwind:**	
r/R radius	c/C chord	α alpha	collide length	p(collision)	collide length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.67	7.62	0.369	4.18	0.203
0.10	0.79	0.84	5.20	0.252	1.48	0.071
0.15	0.88	0.56	4.64	0.225	0.49	0.024
0.20	0.96	0.42	4.42	0.214	0.80	0.039
0.25	1.00	0.33	4.22	0.204	1.19	0.058
0.30	0.98	0.28	3.89	0.189	1.42	0.069
0.35	0.92	0.24	3.51	0.170	1.52	0.074
0.40	0.85	0.21	3.15	0.153	1.55	0.075
0.45	0.80	0.19	2.91	0.141	1.56	0.076
0.50	0.75	0.17	2.68	0.130	1.55	0.075
0.55	0.70	0.15	2.48	0.120	1.52	0.074
0.60	0.64	0.14	2.26	0.109	1.45	0.070
0.65	0.58	0.13	2.05	0.099	1.38	0.067
0.70	0.52	0.12	1.86	0.090	1.29	0.063
0.75	0.47	0.11	1.69	0.082	1.22	0.059
0.80	0.41	0.10	1.51	0.073	1.12	0.054
0.85	0.37	0.10	1.39	0.067	1.06	0.051
0.90	0.30	0.09	1.18	0.057	0.93	0.045
0.95	0.24	0.09	1.01	0.049	0.82	0.040
1.00	0.00	0.08	0.35	0.017	0.35	0.017

Overall p(collision) integrated over disk

Upwind	**10.2%**	**Downwind**	**5.8%**

Proportion	upwind:	downwind		
	50%	50%	**Average**	**8.0%**

*Note: Collision rates of Black-naped Tern for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

Table C13 Collision Probability Calculation for Common Tern (Original Scenario)

			r/R	c/C	α	Upwind: collide		Downwind: collide	
			radius	chord	alpha	length	p(collision)	length	p(collision)
NoBlades	3								
MaxBladeWidth	2.00	m							
Pitch (degrees)	27.5								
Species name	Common Tern		0.00				1.000		1.000
BirdLength	0.35	m	0.05	0.73	1.41	3.89	0.474	2.54	0.309
Wingspan	0.98	m	0.10	0.79	0.71	2.41	0.294	0.95	0.116
F: flapping (0) or gliding (+1)	0		0.15	0.88	0.47	2.01	0.245	0.54	0.066
Proportion of flights upwind	50%	%	0.20	0.96	0.35	1.84	0.224	0.64	0.077
Bird speed	7.8	m/sec	0.25	1.00	0.28	1.77	0.216	0.77	0.094
Rotor Radius	55.5	m	0.30	0.98	0.24	1.66	0.203	0.85	0.103
Rotation Speed	19	rpm	0.35	0.92	0.20	1.53	0.186	0.87	0.106
Rotation Period	3.16	sec	0.40	0.85	0.18	1.40	0.171	0.87	0.106
			0.45	0.80	0.16	1.31	0.160	0.87	0.105
			0.50	0.75	0.14	1.23	0.150	0.85	0.104
Bird aspect ratio: β	0.36		0.55	0.70	0.13	1.16	0.141	0.84	0.102
			0.60	0.64	0.12	1.07	0.131	0.81	0.098
Integration interval	0.05		0.65	0.58	0.11	1.00	0.121	0.77	0.094
			0.70	0.52	0.10	0.92	0.112	0.74	0.090
			0.75	0.47	0.09	0.86	0.105	0.71	0.086
			0.80	0.41	0.09	0.79	0.097	0.66	0.081
			0.85	0.37	0.08	0.75	0.091	0.64	0.078
			0.90	0.30	0.08	0.67	0.081	0.59	0.071
			0.95	0.24	0.07	0.60	0.073	0.54	0.066
			1.00	0.00	0.07	0.35	0.043	0.35	0.043

Calculation of alpha and p(collision) as a function of radius

Overall p(collision) integrated over disk

		Upwind	**12.4%**	**Downwind**	**8.7%**
Proportion	upwind: downwind				
50%	50%	**Average**	**10.5%**		

Table C14 Collision Probability Calculation for Common Tern (Lower Bound - 6.45MW)

NoBlades	3	
MaxBladeWidth	5.10	m
Pitch (degrees)	27.5	
Species name	Common Tern	
BirdLength	0.35	m
Wingspan	0.98	m
F: flapping (0) or gliding (+1)	0	
Proportion of flights upwind	50%	%
Bird speed	7.8	m/sec
Rotor Radius	89	m
Rotation Speed	12	rpm
Rotation Period	5.00	sec
Bird aspect ratio: β	0.36	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R	c/C	α	Upwind: collide		Downwind: collide	
radius	chord	alpha	length	p(collision)	length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.39	7.69	0.592	4.25	0.327
0.10	0.79	0.70	5.04	0.387	1.32	0.101
0.15	0.88	0.46	4.38	0.337	0.68	0.052
0.20	0.96	0.35	4.13	0.317	1.10	0.084
0.25	1.00	0.28	3.97	0.305	1.44	0.111
0.30	0.98	0.23	3.69	0.284	1.63	0.125
0.35	0.92	0.20	3.35	0.257	1.69	0.130
0.40	0.85	0.17	3.02	0.232	1.68	0.129
0.45	0.80	0.15	2.79	0.215	1.67	0.129
0.50	0.75	0.14	2.59	0.199	1.64	0.126
0.55	0.70	0.13	2.40	0.185	1.60	0.123
0.60	0.64	0.12	2.19	0.169	1.52	0.117
0.65	0.58	0.11	2.00	0.154	1.43	0.110
0.70	0.52	0.10	1.81	0.139	1.34	0.103
0.75	0.47	0.09	1.65	0.127	1.26	0.097
0.80	0.41	0.09	1.48	0.114	1.15	0.089
0.85	0.37	0.08	1.36	0.105	1.08	0.083
0.90	0.30	0.08	1.16	0.089	0.95	0.073
0.95	0.24	0.07	0.99	0.077	0.84	0.064
1.00	0.00	0.07	0.35	0.027	0.35	0.027

Overall p(collision) integrated over disk

		Upwind	**15.6%**	**Downwind**	**9.7%**
Proportion	upwind: downwind				
50%	50%	**Average**	**12.7%**		

Table C15 Collision Probability Calculation for Common Tern (Upper Bound - 15MW)*

Calculation of alpha and p(collision) as a function of radius

NoBlades	3	
MaxBladeWidth	5.10	m
Pitch (degrees)	27.5	
Species name	Common Tern	
BirdLength	0.35	m
Wingspan	0.98	m
F: flapping (0) or gliding (+1)	0	
Proportion of flights upwind	50%	%
Bird speed	7.8	m/sec
Rotor Radius	118	m
Rotation Speed	9.3	rpm
Rotation Period	6.45	sec
Bird aspect ratio: β	0.36	
Integration interval	0.05	

			Upwind:		**Downwind:**	
r/R	c/C	α	collide		collide	
radius	chord	alpha	length	p(collision)	length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.36	7.53	0.449	4.09	0.244
0.10	0.79	0.68	4.95	0.295	1.23	0.073
0.15	0.88	0.45	4.32	0.257	0.71	0.043
0.20	0.96	0.34	4.08	0.244	1.14	0.068
0.25	1.00	0.27	3.93	0.234	1.48	0.088
0.30	0.98	0.23	3.66	0.218	1.65	0.099
0.35	0.92	0.19	3.32	0.198	1.71	0.102
0.40	0.85	0.17	3.00	0.179	1.70	0.101
0.45	0.80	0.15	2.78	0.166	1.69	0.101
0.50	0.75	0.14	2.58	0.154	1.66	0.099
0.55	0.70	0.12	2.39	0.142	1.61	0.096
0.60	0.64	0.11	2.18	0.130	1.53	0.091
0.65	0.58	0.10	1.99	0.119	1.44	0.086
0.70	0.52	0.10	1.80	0.107	1.35	0.080
0.75	0.47	0.09	1.65	0.098	1.26	0.075
0.80	0.41	0.08	1.47	0.088	1.16	0.069
0.85	0.37	0.08	1.35	0.081	1.09	0.065
0.90	0.30	0.08	1.16	0.069	0.95	0.057
0.95	0.24	0.07	0.99	0.059	0.84	0.050
1.00	0.00	0.07	0.35	0.021	0.35	0.021

Overall p(collision) integrated over disk

		Upwind	**12.1%**	**Downwind**	**7.6%**
Proportion	upwind: downwind				
50%	50%		**Average**	**9.8%**	

*Note: Collision rates of Common Tern for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

Table C16 Collision Probability Calculation for Heuglin's Gull (Original Scenario)

NoBlades	3	
MaxBladeWidth	2.00	m
Pitch (degrees)	27.5	
Species name	Heuglin's Gull	
BirdLength	0.60	m
Wingspan	1.39	m
F: flapping (0) or gliding (+1)	0	
Proportion of flights upwind	50%	%
Bird speed	9	m/sec
Rotor Radius	55.5	m
Rotation Speed	19	rpm
Rotation Period	3.16	sec
Bird aspect ratio: β	0.43	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	**Upwind:** collide length	p(collision)	**Downwind:** collide length	p(collision)
0.00				1.000		1.000
0.05	0.73	1.63	5.05	0.533	3.70	0.391
0.10	0.79	0.82	3.00	0.317	1.55	0.163
0.15	0.88	0.54	2.42	0.255	0.79	0.083
0.20	0.96	0.41	2.18	0.230	0.79	0.084
0.25	1.00	0.33	2.10	0.222	0.95	0.100
0.30	0.98	0.27	1.98	0.209	1.03	0.109
0.35	0.92	0.23	1.83	0.193	1.07	0.113
0.40	0.85	0.20	1.69	0.179	1.08	0.114
0.45	0.80	0.18	1.60	0.168	1.08	0.114
0.50	0.75	0.16	1.51	0.159	1.08	0.114
0.55	0.70	0.15	1.43	0.151	1.06	0.112
0.60	0.64	0.14	1.35	0.142	1.04	0.109
0.65	0.58	0.13	1.26	0.133	1.01	0.106
0.70	0.52	0.12	1.19	0.125	0.97	0.103
0.75	0.47	0.11	1.12	0.119	0.94	0.100
0.80	0.41	0.10	1.05	0.111	0.90	0.095
0.85	0.37	0.10	1.00	0.106	0.88	0.093
0.90	0.30	0.09	0.93	0.098	0.83	0.087
0.95	0.24	0.09	0.86	0.091	0.79	0.083
1.00	0.00	0.08	0.60	0.063	0.60	0.063

Overall p(collision) integrated over disk

		Upwind	**13.7%**		**Downwind**	**10.0%**
Proportion	upwind: downwind					
50%	50%		**Average**	**11.9%**		

Table C17 Collision Probability Calculation for Heuglin's Gull (Lower Bound - 6.45MW)

Calculation of alpha and p(collision) as a function of radius

NoBlades	3					**Upwind:**		**Downwind:**	
MaxBladeWidth	5.10	m	r/R	c/C	α	collide		collide	
Pitch (degrees)	27.5		radius	chord	alpha	length	p(collision)	length	p(collision)
Species name	Heuglin's Gull		0.00				1.000		1.000
BirdLength	0.60	m	0.05	0.73	1.61	9.27	0.618	5.83	0.389
Wingspan	1.39	m	0.10	0.79	0.80	5.85	0.390	2.13	0.142
F: flapping (0) or gliding (+1)	0		0.15	0.88	0.54	4.95	0.330	0.81	0.054
Proportion of flights upwind	50%	%	0.20	0.96	0.40	4.61	0.307	1.11	0.074
Bird speed	9	m/sec	0.25	1.00	0.32	4.41	0.294	1.50	0.100
Rotor Radius	89	m	0.30	0.98	0.27	4.10	0.273	1.72	0.115
Rotation Speed	12	rpm	0.35	0.92	0.23	3.72	0.248	1.81	0.121
Rotation Period	5.00	sec	0.40	0.85	0.20	3.38	0.225	1.83	0.122
			0.45	0.80	0.18	3.13	0.209	1.84	0.122
			0.50	0.75	0.16	2.91	0.194	1.82	0.121
Bird aspect ratio: β	0.43		0.55	0.70	0.15	2.71	0.181	1.79	0.119
			0.60	0.64	0.13	2.50	0.166	1.72	0.115
Integration interval	0.05		0.65	0.58	0.12	2.29	0.153	1.64	0.109
			0.70	0.52	0.11	2.09	0.140	1.55	0.104
			0.75	0.47	0.11	1.93	0.129	1.48	0.099
			0.80	0.41	0.10	1.75	0.117	1.38	0.092
			0.85	0.37	0.09	1.63	0.109	1.31	0.088
			0.90	0.30	0.09	1.43	0.095	1.19	0.079
			0.95	0.24	0.08	1.26	0.084	1.07	0.072
			1.00	0.00	0.08	0.60	0.040	0.60	0.040

Overall p(collision) integrated over disk

		Upwind	**15.7%**	**Downwind**	**9.8%**
Proportion	upwind: downwind				
50%	50%	**Average**	**12.7%**		

Table C18 Collision Probability Calculation for Heuglin's Gull (Upper Bound - 15MW)*

Calculation of alpha and p(collision) as a function of radius

			r/R	c/C	α	Upwind:		Downwind:	
NoBlades	3								
MaxBladeWidth	5.10	m	r/R	c/C	α	collide		collide	
Pitch (degrees)	27.5		radius	chord	alpha	length	p(collision)	length	p(collision)
Species name	Heuglin's Gull		0.00				1.000		1.000
BirdLength	0.60	m	0.05	0.73	1.57	9.07	0.469	5.63	0.291
Wingspan	1.39	m	0.10	0.79	0.78	5.75	0.297	2.03	0.105
F: flapping (0) or gliding (+1)	0		0.15	0.88	0.52	4.88	0.252	0.73	0.038
Proportion of flights upwind	50%	%	0.20	0.96	0.39	4.56	0.236	1.16	0.060
Bird speed	9	m/sec	0.25	1.00	0.31	4.37	0.226	1.54	0.079
Rotor Radius	118	m	0.30	0.98	0.26	4.07	0.210	1.75	0.090
Rotation Speed	9.3	rpm	0.35	0.92	0.22	3.70	0.191	1.84	0.095
Rotation Period	6.45	sec	0.40	0.85	0.20	3.35	0.173	1.85	0.096
			0.45	0.80	0.17	3.11	0.161	1.85	0.096
			0.50	0.75	0.16	2.90	0.150	1.83	0.095
Bird aspect ratio: β	0.43		0.55	0.70	0.14	2.70	0.139	1.80	0.093
			0.60	0.64	0.13	2.49	0.128	1.73	0.089
Integration interval	0.05		0.65	0.58	0.12	2.28	0.118	1.65	0.085
			0.70	0.52	0.11	2.09	0.108	1.56	0.081
			0.75	0.47	0.10	1.93	0.100	1.48	0.077
			0.80	0.41	0.10	1.75	0.090	1.38	0.072
			0.85	0.37	0.09	1.63	0.084	1.32	0.068
			0.90	0.30	0.09	1.42	0.074	1.19	0.061
			0.95	0.24	0.08	1.25	0.065	1.08	0.056
			1.00	0.00	0.08	0.60	0.031	0.60	0.031

Overall p(collision) integrated over disk

		Upwind	**12.1%**	**Downwind**	**7.6%**
Proportion	upwind: downwind				
50%	50%	**Average**	**9.9%**		

*Note: Collision rates of Heuglin's Gull for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

Table C19 Collision Probability Calculation for Red-nacked Phalarope (Original Scenario)

Calculation of alpha and p(collision) as a function of radius

			r/R	c/C	α	Upwind: collide		Downwind: collide	
			radius	chord	alpha	length	p(collision)	length	p(collision)
NoBlades	3								
MaxBladeWidth	2.00	m							
Pitch (degrees)	27.5								
Species name	Red-necked Phalaarope		0.00				1.000		1.000
BirdLength	0.19	m	0.05	0.73	0.94	2.25	0.411	0.90	0.165
Wingspan	0.38	m	0.10	0.79	0.47	1.58	0.289	0.26	0.047
F: flapping (0) or gliding (+1)	0		0.15	0.88	0.31	1.49	0.273	0.51	0.094
Proportion of flights upwind	50%	%	0.20	0.96	0.24	1.48	0.270	0.68	0.123
Bird speed	5.2	m/sec	0.25	1.00	0.19	1.45	0.264	0.78	0.142
Rotor Radius	55.5	m	0.30	0.98	0.16	1.37	0.250	0.82	0.150
Rotation Speed	19	rpm	0.35	0.92	0.13	1.26	0.230	0.82	0.150
Rotation Period	3.16	sec	0.40	0.85	0.12	1.15	0.211	0.80	0.146
			0.45	0.80	0.10	1.08	0.197	0.78	0.143
			0.50	0.75	0.09	1.01	0.184	0.76	0.138
Bird aspect ratio: β	0.50		0.55	0.70	0.09	0.94	0.172	0.73	0.133
			0.60	0.64	0.08	0.87	0.159	0.69	0.126
Integration interval	0.05		0.65	0.58	0.07	0.80	0.146	0.65	0.119
			0.70	0.52	0.07	0.73	0.134	0.61	0.111
			0.75	0.47	0.06	0.68	0.124	0.57	0.104
			0.80	0.41	0.06	0.61	0.112	0.53	0.096
			0.85	0.37	0.06	0.57	0.104	0.50	0.090
			0.90	0.30	0.05	0.49	0.090	0.44	0.080
			0.95	0.24	0.05	0.43	0.079	0.39	0.071
			1.00	0.00	0.05	0.19	0.035	0.19	0.035

Overall p(collision) integrated over disk

		Upwind	**14.5%**
		Downwind	**10.7%**
Proportion	upwind: downwind		
50%	50%	**Average**	**12.6%**

Table C20 Collision Probability Calculation for Red-nacked Phalarope (Lower Bound - 6.45MW)

Calculation of alpha and p(collision) as a function of radius

						Upwind:		Downwind:	
NoBlades	3								
MaxBladeWidth	5.10	m	r/R	c/C	α	collide		collide	
Pitch (degrees)	27.5		radius	chord	alpha	length	p(collision)	length	p(collision)
Species name	Red-necked Phalaarope		0.00				1.000		1.000
BirdLength	0.19	m	0.05	0.73	0.93	5.14	0.593	1.71	0.197
Wingspan	0.38	m	0.10	0.79	0.46	3.71	0.428	0.39	0.045
F: flapping (0) or gliding (+1)	0		0.15	0.88	0.31	3.50	0.403	1.03	0.119
Proportion of flights upwind	50%	%	0.20	0.96	0.23	3.46	0.399	1.44	0.166
Bird speed	5.2	m/sec	0.25	1.00	0.19	3.39	0.391	1.70	0.197
Rotor Radius	89	m	0.30	0.98	0.15	3.18	0.367	1.81	0.209
Rotation Speed	12	rpm	0.35	0.92	0.13	2.91	0.336	1.80	0.208
Rotation Period	5.00	sec	0.40	0.85	0.12	2.64	0.304	1.74	0.201
			0.45	0.80	0.10	2.45	0.282	1.70	0.196
			0.50	0.75	0.09	2.27	0.262	1.64	0.189
Bird aspect ratio: β	0.50		0.55	0.70	0.08	2.11	0.243	1.57	0.181
			0.60	0.64	0.08	1.92	0.222	1.47	0.170
Integration interval	0.05		0.65	0.58	0.07	1.74	0.201	1.37	0.158
			0.70	0.52	0.07	1.57	0.181	1.26	0.145
			0.75	0.47	0.06	1.43	0.165	1.17	0.134
			0.80	0.41	0.06	1.26	0.146	1.05	0.121
			0.85	0.37	0.05	1.15	0.133	0.97	0.112
			0.90	0.30	0.05	0.97	0.112	0.83	0.095
			0.95	0.24	0.05	0.81	0.093	0.70	0.081
			1.00	0.00	0.05	0.19	0.022	0.19	0.022

Overall p(collision) integrated over disk

		Upwind	**20.0%**	**Downwind**	**13.9%**
Proportion	upwind: downwind				
50%	50%	**Average**	**16.9%**		

Table C21 Collision Probability Calculation for Red-nacked Phalarope (Upper Bound - 15MW)*

Calculation of alpha and p(collision) as a function of radius

			r/R	c/C	α	Upwind: collide		Downwind: collide	
NoBlades	3		radius	chord	alpha	length	p(collision)	length	p(collision)
MaxBladeWidth	5.10	m							
Pitch (degrees)	27.5								
Species name	Red-necked Phalaarope		0.00				1.000		1.000
BirdLength	0.19	m	0.05	0.73	0.90	5.05	0.452	1.61	0.144
Wingspan	0.38	m	0.10	0.79	0.45	3.67	0.328	0.43	0.039
F: flapping (0) or gliding (+1)	0		0.15	0.88	0.30	3.46	0.310	1.06	0.095
Proportion of flights upwind	50%	%	0.20	0.96	0.23	3.43	0.307	1.47	0.131
Bird speed	5.2	m/sec	0.25	1.00	0.18	3.36	0.301	1.73	0.154
Rotor Radius	118	m	0.30	0.98	0.15	3.17	0.283	1.83	0.164
Rotation Speed	9.3	rpm	0.35	0.92	0.13	2.89	0.259	1.82	0.163
Rotation Period	6.45	sec	0.40	0.85	0.11	2.63	0.235	1.76	0.157
			0.45	0.80	0.10	2.44	0.218	1.71	0.153
			0.50	0.75	0.09	2.26	0.202	1.65	0.147
Bird aspect ratio: β	0.50		0.55	0.70	0.08	2.10	0.188	1.58	0.141
			0.60	0.64	0.08	1.92	0.171	1.48	0.132
Integration interval	0.05		0.65	0.58	0.07	1.74	0.155	1.37	0.123
			0.70	0.52	0.06	1.57	0.140	1.26	0.113
			0.75	0.47	0.06	1.43	0.127	1.17	0.104
			0.80	0.41	0.06	1.26	0.113	1.05	0.094
			0.85	0.37	0.05	1.15	0.103	0.97	0.087
			0.90	0.30	0.05	0.96	0.086	0.83	0.074
			0.95	0.24	0.05	0.81	0.072	0.70	0.063
			1.00	0.00	0.05	0.19	0.017	0.19	0.017

Overall p(collision) integrated over disk

		Upwind	**15.4%**	**Downwind** **10.8%**
Proportion	upwind: downwind			
50%	50%	**Average**	**13.1%**	

*Note: Collision rates of Red-necked Phalarope for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

Table C22 Collision Probability Calculation for White-bellied Sea Eagle (Original Scenario)

Parameter	Value	Unit
NoBlades	3	
MaxBladeWidth	2.00	m
Pitch (degrees)	27.5	
Species name	White-bellied Sea Eagle	
BirdLength	0.85	m
Wingspan	2.18	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	16.7	m/sec
Rotor Radius	55.5	m
Rotation Speed	19	rpm
Rotation Period	3.16	sec
Bird aspect ratio: β	0.39	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	3.02	8.79	0.500	7.44	0.423
0.10	0.79	1.51	4.95	0.281	3.49	0.198
0.15	0.88	1.01	3.79	0.215	2.16	0.123
0.20	0.96	0.76	3.22	0.183	1.45	0.083
0.25	1.00	0.60	2.84	0.161	0.99	0.056
0.30	0.98	0.50	2.48	0.141	0.73	0.041
0.35	0.92	0.43	2.15	0.123	0.74	0.042
0.40	0.85	0.38	2.21	0.125	1.06	0.061
0.45	0.80	0.34	2.07	0.118	1.11	0.063
0.50	0.75	0.30	1.95	0.111	1.14	0.065
0.55	0.70	0.27	1.84	0.105	1.15	0.066
0.60	0.64	0.25	1.73	0.098	1.15	0.066
0.65	0.58	0.23	1.63	0.092	1.15	0.065
0.70	0.52	0.22	1.53	0.087	1.13	0.064
0.75	0.47	0.20	1.45	0.083	1.12	0.063
0.80	0.41	0.19	1.37	0.078	1.09	0.062
0.85	0.37	0.18	1.31	0.074	1.07	0.061
0.90	0.30	0.17	1.22	0.069	1.04	0.059
0.95	0.24	0.16	1.14	0.065	1.00	0.057
1.00	0.00	0.15	0.85	0.048	0.85	0.048

Overall p(collision) integrated over disk

		Upwind	**9.8%**	**Downwind**	**6.5%**
Proportion upwind: downwind				
50%	50%	**Average**	**8.1%**	

Table C23 Collision Probability Calculation for White-bellied Sea Eagle (Lower Bound - 6.45MW)

Calculation of alpha and p(collision) as a function of radius

			r/R	c/C	α	Upwind: collide		Downwind: collide	
			radius	chord	alpha	length	p(collision)	length	p(collision)
NoBlades	3								
MaxBladeWidth	5.10	m							
Pitch (degrees)	27.5								
Species name	White-bellied Sea Eagle		0.00				1.000		1.000
BirdLength	0.85	m	0.05	0.73	2.99	15.73	0.565	12.29	0.441
Wingspan	2.18	m	0.10	0.79	1.49	9.27	0.333	5.55	0.199
F: flapping (0) or gliding (+1)	1		0.15	0.88	1.00	7.42	0.266	3.27	0.118
Proportion of flights upwind	50%	%	0.20	0.96	0.75	6.54	0.235	2.02	0.072
Bird speed	16.7	m/sec	0.25	1.00	0.60	5.89	0.211	1.18	0.042
Rotor Radius	89	m	0.30	0.98	0.50	5.21	0.187	0.79	0.028
Rotation Speed	12	rpm	0.35	0.92	0.43	4.53	0.163	0.98	0.035
Rotation Period	5.00	sec	0.40	0.85	0.37	4.29	0.154	1.42	0.051
			0.45	0.80	0.33	3.93	0.141	1.53	0.055
			0.50	0.75	0.30	3.63	0.130	1.60	0.058
Bird aspect ratio: β	0.39		0.55	0.70	0.27	3.36	0.121	1.64	0.059
			0.60	0.64	0.25	3.08	0.111	1.64	0.059
Integration interval	0.05		0.65	0.58	0.23	2.82	0.101	1.61	0.058
			0.70	0.52	0.21	2.58	0.093	1.57	0.057
			0.75	0.47	0.20	2.38	0.086	1.53	0.055
			0.80	0.41	0.19	2.16	0.078	1.47	0.053
			0.85	0.37	0.18	2.02	0.072	1.43	0.051
			0.90	0.30	0.17	1.78	0.064	1.33	0.048
			0.95	0.24	0.16	1.59	0.057	1.24	0.045
			1.00	0.00	0.15	0.85	0.031	0.85	0.031

Overall p(collision) integrated over disk

Upwind	**10.8%**	**Downwind**	**5.5%**

Proportion upwind: downwind

50% 50%

Average **8.2%**

Table C24 Collision Probability Calculation for White-bellied Sea Eagle (Upper Bound - 15MW)*

NoBlades	3	
MaxBladeWidth	5.10	m
Pitch (degrees)	27.5	
Species name	White-bellied Sea Eagle	
BirdLength	0.85	m
Wingspan	2.18	m
F: flapping (0) or gliding (+1)	1	
Proportion of flights upwind	50%	%
Bird speed	16.7	m/sec
Rotor Radius	118	m
Rotation Speed	9.3	rpm
Rotation Period	6.45	sec
Bird aspect ratio: β	0.39	
Integration interval	0.05	
	3	

Calculation of alpha and p(collision) as a function of radius

			Upwind:		Downwind:	
r/R	c/C	α	collide		collide	
radius	chord	alpha	length	p(collision)	length	p(collision)
0.00				1.000		1.000
0.05	0.73	2.91	15.35	0.427	11.91	0.332
0.10	0.79	1.45	9.07	0.253	5.35	0.149
0.15	0.88	0.97	7.27	0.203	3.13	0.087
0.20	0.96	0.73	6.42	0.179	1.90	0.053
0.25	1.00	0.58	5.79	0.161	1.08	0.030
0.30	0.98	0.48	5.13	0.143	0.83	0.023
0.35	0.92	0.42	4.47	0.124	1.01	0.028
0.40	0.85	0.36	4.25	0.118	1.45	0.041
0.45	0.80	0.32	3.90	0.109	1.57	0.044
0.50	0.75	0.29	3.60	0.100	1.63	0.045
0.55	0.70	0.26	3.34	0.093	1.66	0.046
0.60	0.64	0.24	3.06	0.085	1.66	0.046
0.65	0.58	0.22	2.80	0.078	1.63	0.045
0.70	0.52	0.21	2.56	0.071	1.59	0.044
0.75	0.47	0.19	2.37	0.066	1.54	0.043
0.80	0.41	0.18	2.15	0.060	1.48	0.041
0.85	0.37	0.17	2.01	0.056	1.44	0.040
0.90	0.30	0.16	1.78	0.049	1.34	0.037
0.95	0.24	0.15	1.58	0.044	1.25	0.035
1.00	0.00	0.15	0.85	0.024	0.85	0.024

Overall p(collision) integrated over disk

		Upwind	**8.3%**	**Downwind**	**4.3%**
Proportion upwind: downwind					
50%	50%	**Average**	**6.3%**		

*Note: Collision rates of White-bellied Sea Eagle for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

Table C25 Collision Probability Calculation for White-winged Tern (Original Scenario)

Parameter	Value	Unit
NoBlades	3	
MaxBladeWidth	2.00	m
Pitch (degrees)	27.5	
Species name	White-winged Tern	
BirdLength	0.23	m
Wingspan	0.67	m
F: flapping (0) or gliding (+1)	0	
Proportion of flights upwind	50%	%
Bird speed	15.5	m/sec
Rotor Radius	55.5	m
Rotation Speed	19	rpm
Rotation Period	3.16	sec
Bird aspect ratio: β	0.34	
Integration interval	0.05	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Downwind: collide length	Downwind: p(collision)
0.00				1.000		1.000
0.05	0.73	2.81	6.19	0.379	4.84	0.297
0.10	0.79	1.40	3.64	0.223	2.18	0.133
0.15	0.88	0.94	2.90	0.178	1.28	0.078
0.20	0.96	0.70	2.55	0.156	0.78	0.048
0.25	1.00	0.56	2.30	0.141	0.45	0.028
0.30	0.98	0.47	2.03	0.125	0.41	0.025
0.35	0.92	0.40	1.77	0.109	0.46	0.028
0.40	0.85	0.35	1.55	0.095	0.49	0.030
0.45	0.80	0.31	1.41	0.087	0.53	0.032
0.50	0.75	0.28	1.30	0.079	0.55	0.034
0.55	0.70	0.26	1.19	0.073	0.56	0.034
0.60	0.64	0.23	1.09	0.067	0.56	0.034
0.65	0.58	0.22	0.99	0.061	0.54	0.033
0.70	0.52	0.20	0.90	0.055	0.53	0.032
0.75	0.47	0.19	0.82	0.050	0.51	0.031
0.80	0.41	0.18	0.74	0.045	0.48	0.029
0.85	0.37	0.17	0.68	0.042	0.46	0.028
0.90	0.30	0.16	0.59	0.036	0.42	0.026
0.95	0.24	0.15	0.51	0.032	0.39	0.024
1.00	0.00	0.14	0.23	0.014	0.23	0.014

Overall p(collision) integrated over disk

Upwind	**6.6%**	**Downwind**	**3.2%**

Proportion	upwind: downwind		
	50%	50%	
		Average	**4.9%**

Table C26 Collision Probability Calculation for White-winged Tern (Lower Bound - 6.45MW)

Calculation of alpha and p(collision) as a function of radius

NoBlades	3					**Upwind:**		**Downwind:**		
MaxBladeWidth	5.10	m	r/R	c/C	α	collide		collide		
Pitch (degrees)	27.5		radius	chord	alpha	length	p(collision)	length	p(collision)
Species name	White-winged Tern		0.00				1.000		1.000
BirdLength	0.23	m	0.05	0.73	2.77	12.73	0.493	9.29	0.360
Wingspan	0.67	m	0.10	0.79	1.39	7.74	0.300	4.02	0.156
F: flapping (0) or gliding (+1)	0		0.15	0.88	0.92	6.37	0.247	2.22	0.086
Proportion of flights upwind	50%	%	0.20	0.96	0.69	5.73	0.222	1.21	0.047
Bird speed	15.5	m/sec	0.25	1.00	0.55	5.23	0.203	0.52	0.020
Rotor Radius	89	m	0.30	0.98	0.46	4.67	0.181	0.57	0.022
Rotation Speed	12	rpm	0.35	0.92	0.40	4.08	0.158	0.78	0.030
Rotation Period	5.00	sec	0.40	0.85	0.35	3.57	0.138	0.90	0.035
			0.45	0.80	0.31	3.23	0.125	1.00	0.039
			0.50	0.75	0.28	2.94	0.114	1.06	0.041
Bird aspect ratio: β	0.34		0.55	0.70	0.25	2.68	0.104	1.08	0.042
			0.60	0.64	0.23	2.41	0.093	1.07	0.041
Integration interval	0.05		0.65	0.58	0.21	2.16	0.083	1.04	0.040
			0.70	0.52	0.20	1.92	0.074	0.99	0.038
			0.75	0.47	0.18	1.73	0.067	0.94	0.037
			0.80	0.41	0.17	1.52	0.059	0.87	0.034
			0.85	0.37	0.16	1.37	0.053	0.83	0.032
			0.90	0.30	0.15	1.15	0.044	0.73	0.028
			0.95	0.24	0.15	0.95	0.037	0.64	0.025
			1.00	0.00	0.14	0.23	0.009	0.23	0.009

Overall p(collision) integrated over disk

		Upwind	**9.1%**	**Downwind**	**3.7%**
Proportion upwind:	downwind				
50%	50%	**Average**	**6.4%**		

Table C27 Collision Probability Calculation for White-winged Tern (Upper Bound - 15MW)*

Calculation of alpha and p(collision) as a function of radius

			r/R	c/C	α	**Upwind:**		**Downwind:**	
NoBlades	3					collide		collide	
MaxBladeWidth	5.10	m	radius	chord	alpha	length	p(collision)	length	p(collision)
Pitch (degrees)	27.5								
Species name	White-winged Tern		0.00				1.000		1.000
BirdLength	0.23	m	0.05	0.73	2.70	12.43	0.373	9.00	0.270
Wingspan	0.67	m	0.10	0.79	1.35	7.58	0.228	3.86	0.116
F: flapping (0) or gliding (+1)	0		0.15	0.88	0.90	6.25	0.188	2.11	0.063
Proportion of flights upwind	50%	%	0.20	0.96	0.67	5.64	0.169	1.12	0.034
Bird speed	15.5	m/sec	0.25	1.00	0.54	5.16	0.155	0.45	0.013
Rotor Radius	118	m	0.30	0.98	0.45	4.60	0.138	0.62	0.018
Rotation Speed	9.3	rpm	0.35	0.92	0.39	4.03	0.121	0.82	0.025
Rotation Period	6.45	sec	0.40	0.85	0.34	3.53	0.106	0.94	0.028
			0.45	0.80	0.30	3.20	0.096	1.03	0.031
			0.50	0.75	0.27	2.91	0.087	1.08	0.032
Bird aspect ratio: β	0.34		0.55	0.70	0.25	2.65	0.080	1.10	0.033
			0.60	0.64	0.22	2.39	0.072	1.09	0.033
Integration interval	0.05		0.65	0.58	0.21	2.14	0.064	1.05	0.032
			0.70	0.52	0.19	1.91	0.057	1.00	0.030
			0.75	0.47	0.18	1.72	0.052	0.95	0.029
			0.80	0.41	0.17	1.51	0.045	0.88	0.026
			0.85	0.37	0.16	1.37	0.041	0.84	0.025
			0.90	0.30	0.15	1.14	0.034	0.73	0.022
			0.95	0.24	0.14	0.95	0.028	0.64	0.019
			1.00	0.00	0.13	0.23	0.007	0.23	0.007

Overall p(collision) integrated over disk

			Upwind	**6.9%**	**Downwind**	**2.8%**
Proportion	upwind:	downwind				
	50%	50%	**Average**	**4.9%**		

*Note: Collision rates of White-winged Tern for Upper Bound 16MW turbine scenario have also been assessed while the predicted collision rates are similar with that of Upper Bound 15MW turbine scenario.

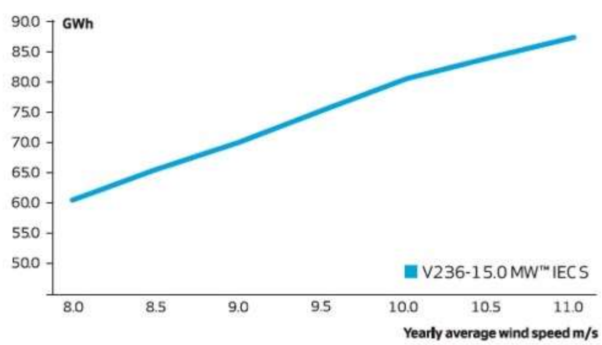
APPENDIX D SUPPORTING DOCUMENTS FOR OPERATION NOISE ASSESSMENT

APPENDIX D1 SPECIFICATION OF WIND TURBINES

V236-15.0 MW™
Facts & figures

POWER REGULATION	Pitch regulated with variable speed
OPERATING DATA	
Rated power	15,000 kW
Cut-in wind speed	3 m/s
Cut-out wind speed	30 m/s
Wind class	IEC S or S,T
Standard operating temperature range	from -10°C to +25°C* with a de-rating interval from +25°C to +45°C
	*high ambient temperature variant available
SOUND POWER	
Maximum	118dB(A)
ROTOR	
Rotor diameter	236 m
Swept area	43,742 m²
Aerodynamic brake	three blades full feathering
ELECTRICAL	
Frequency	50/60Hz
Converter	full scale
GEARBOX	
Type	medium speed
TOWER	
Hub height	site-specific

ANNUAL ENERGY PRODUCTION



Assumptions
One wind turbine, 100% availability, 0% losses, k factor = 2,
Standard air density = 1.225, wind speed at hub height

APPENDIX D2 DETAILS OF BACKGROUND NOISE MEASUREMENT

NSR N1 (Lamma)

NSR N2 (Cheung Chau)

Appendix D2-1

Photographs of Background Noise Measurement Locations

DATE: 24/8/2021

Environmental
Resources
Management

ERM

Appendix D2-2: Detailed Noise Measurement Results

Noise Monitoring Field Record Sheet

Project Name / GMS No.:	0607209 HKE OWF
Date of Monitoring:	29 May 2021 and 9 July 2021
Measurement Location	Concerto Inn (near NSR N1)/Seascape Peninsula (NSR N2)
Noise Monitoring Staff:	Pako Yu
Temperature:	33 °C (29 May 2021)/ 32°C (9 July 2021)
Wind Speed:	<5 m/s
Noise Meter Model / Identification:	Rion NL-52/01298719
Calibrator Model / Identification:	01dB-Stell CAL21/34113606(2011)
Calibration Level before Measurement (dB(A)):	94.0
Calibration Level after Measurement (dB(A)):	94.0

Background Noise Measurement Results (dB(A)):

Location	Date	Time	$L_{eq(30min)}$, dB(A)	$L_{max(30min)}$, dB(A)	$L_{min(30min)}$, dB(A)	$L_{10(30min)}$, dB(A)	$L_{90, 30min}$ (dB(A))	Averaged $L_{90(30min)}$, dB(A)
Night-time Period								
Concerto Inn near NSR N1	29/5/2021	00:00-00:30	51.7	58.2	47.4	54.0	49.6	50.2
	29/5/2021	00:30-01:00	52.2	59.0	49.1	54.1	50.7	
Seascape Peninsula (NSR N2) [(c)]	9/7/2021	00:10-00:40	56.5	69.0	46.9	59.3	51.5	50.2
	9/7/2021	00:40-01:10	53.8	73.2	46.1	56.2	48.4	

Notes:

(a) The instruments used for the noise measurements comply with International Electrotechnical Commission Publications 651:1979 (Type 1) and 804:1985 (Type 1).

(b) The background noise environment is mainly dominant by sea waves/insects.

(c) Façade correction of 3dB(A) has been applied for the free-field noise measurement at N2.

APPENDIX D3 OPERATION NOISE ASSESSMENT

Appendix D3-1A
Coordinates of NSR and Wind Turbines
(Lower Bound - 6.45MW)

NSR: N1
Lamma Island - Lo So Shing
830865 807373.3

	Wind Turbine	x	y	Distance between NSR & Wind Turbine (m)
1	W01	826308.0	804275.3	5510
2	W02	827101.3	804277.8	4873
3	W03	827725.7	804286.5	4403
4	W04	825858.2	803995.8	6039
5	W05	826742.0	803936.5	5368
6	W06	827426.8	803702.0	5030
7	W07	825436.9	803703.7	6552
8	W08	826344.1	803507.8	5948
9	W09	827162.0	803383.8	5443
10	W10	827807.9	803082.8	5268
11	W11	825139.3	803288.0	7034
12	W12	825450.2	802242.5	7460
13	W13	825919.1	803061.1	6562
14	W14	826906.9	803069.3	5847
15	W15	827558.9	802776.0	5663
16	W16	826626.6	802736.9	6282
17	W17	827309.5	802464.1	6061
18	W18	827928.5	802244.1	5910
19	W19	825064.7	802819.1	7375
20	W20	825719.9	802575.1	7035
21	W21	826340.9	802300.9	6797
22	W22	827638.3	801886.4	6365
23	W23	826837.3	801886.4	6806
24	W24	826004.7	801886.4	7330

Appendix D3-1B
Coordinates of NSR and Wind Turbines
(Lower Bound - 6.45MW)

NSR: N2
Cheung Chau - Seascape Peninsula
821728.29 806959.73

	Wind Turbine	x	y	Distance between NSR & Wind Turbine (m)
1	W01	826308.0	804275.3	5308
2	W02	827101.3	804277.8	6005
3	W03	827725.7	804286.5	6566
4	W04	825858.2	803995.8	5083
5	W05	826742.0	803936.5	5855
6	W06	827426.8	803702.0	6564
7	W07	825436.9	803703.7	4935
8	W08	826344.1	803507.8	5764
9	W09	827162.0	803383.8	6505
10	W10	827807.9	803082.8	7211
11	W11	825139.3	803288.0	5012
12	W12	825450.2	802242.5	6009
13	W13	825919.1	803061.1	5724
14	W14	826906.9	803069.3	6477
15	W15	827558.9	802776.0	7176
16	W16	826626.6	802736.9	6467
17	W17	827309.5	802464.1	7167
18	W18	827928.5	802244.1	7790
19	W19	825064.7	802819.1	5318
20	W20	825719.9	802575.1	5929
21	W21	826340.9	802300.9	6556
22	W22	827638.3	801886.4	7789
23	W23	826837.3	801886.4	7200
24	W24	826004.7	801886.4	6635

Appendix D3-1C
Coordinates of NSR and Wind Turbines
(Upper Bound - 15/16MW)

NSR: N1
Lamma Island - Lo So Shing
830865 807373.3

	Wind Turbine	x	y	Distance between NSR & Wind Turbine (m)
1	W01	825649.0	803816.7	6313
2	W02	826583.5	804260.6	5293
3	W03	827695.0	804253.3	4448
4	W04	826028.7	803120.1	6440
5	W05	827151.1	803555.5	5326
6	W06	825286.5	802541.4	7380
7	W07	826958.6	802592.3	6174
8	W08	827930.0	802858.0	5385
9	W09	826042.3	801905.1	7291
10	W10	827401.2	801920.7	6460

Appendix D3-1D
Coordinates of NSR and Wind Turbines
(Upper Bound - 15/16MW)

NSR: N2
Cheung Chau - Seascape Peninsula
821728.3 806959.7

	Wind Turbine	x	y	Distance between NSR & Wind Turbine (m)
1	W01	825649.0	803816.7	5025
2	W02	826583.5	804260.6	5555
3	W03	827695.0	804253.3	6552
4	W04	826028.7	803120.1	5765
5	W05	827151.1	803555.5	6403
6	W06	825286.5	802541.4	5673
7	W07	826958.6	802592.3	6814
8	W08	827930.0	802858.0	7435
9	W09	826042.3	801905.1	6645
10	W10	827401.2	801920.7	7588

Appendix D3-2A

Summary of Predicted Façade Noise Levels (Lower Bound - 6.45MW)

NSR:	N1 Lamma Island - Lo So Shing
Location of Wind Turbine	**Predicted Façade Noise Level, dB(A)**
W01	27.4
W02	28.4
W03	29.3
W04	26.6
W05	27.6
W06	28.2
W07	25.9
W08	26.7
W09	27.5
W10	27.8
W11	25.3
W12	24.7
W13	25.9
W14	26.9
W15	27.1
W16	26.2
W17	26.5
W18	26.8
W19	24.8
W20	25.3
W21	25.6
W22	26.1
W23	25.5
W24	24.9
TOTAL =	**40.5**

Appendix D3-2B

Summary of Predicted Façade Noise Levels (Lower Bound - 6.45MW)

NSR:	**N2** **Cheung Chau - Seascape Peninsula**
Location of Wind Turbine	**Predicted Façade Noise Level, dB(A)**
W01	32.5
W02	31.4
W03	30.6
W04	32.8
W05	31.6
W06	30.6
W07	33.1
W08	31.8
W09	30.7
W10	29.8
W11	33.0
W12	31.4
W13	31.8
W14	30.7
W15	29.9
W16	30.8
W17	29.9
W18	29.1
W19	32.5
W20	31.5
W21	30.6
W22	29.1
W23	29.8
W24	30.5
TOTAL =	**45.0**

Appendix D3-2C

Summary of Predicted Façade Noise Levels (Upper Bound - 15/16MW)

NSR:	N1 Lamma Island - Lo So Shing
Location of Wind Turbine	**Predicted Façade Noise Level, dB(A)**
W01	26.7
W02	28.2
W03	29.7
W04	26.5
W05	28.2
W06	25.3
W07	26.9
W08	28.1
W09	25.4
W10	26.5
TOTAL =	**37.4**

Appendix D3-2D

Summary of Predicted Façade Noise Levels (Upper Bound - 15/16MW)

NSR:	N2 Cheung Chau - Seascape Peninsula
Location of Wind Turbine	**Predicted Façade Noise Level, dB(A)**
W01	33.4
W02	32.6
W03	31.1
W04	32.3
W05	31.3
W06	32.4
W07	30.8
W08	30.0
W09	31.0
W10	29.9
TOTAL =	**41.6**

Appendix D3-3A

Sample Calculation of Noise Level Due to Operation of Wind Turbine

(Lower Bound - 6.45MW)

NSR Location:	**N1**	
	Lamma Island - Lo So Shing	
Noise Source:	W24	
Horizontal Distance:	7330 m	
SWL[(1)], dB(A)		117.5
Distance, m		7330
Distance correction [(2)]		-88
Barrier Attenuation[(4)]		-5
Atmospheric Absorption @ 500Hz[(3)]		-2.5
Predicted Lp, dB(A)		22
Lp, dB(A)		21.9

FACADE CORRECTION= 3 dB(A)

PREDICTED FACADE NOISE LEVEL = 25 dB(A)

Notes:

(1) Specification of the 6.45MW is not available at this stage. Maximum allowable SWL has been calculated based on the methodology presented in Section 3.8.2.3.

(2) Basing on the equation for geometrical divergence A_{div} = -[20 log(d) +11] from ISO 9613:Part 2 for spherical spreading in the free field from a point sound source.

(3) Basing on the equation $A_{ab}(f_m) = A_{at}(f_m)\ [1+0.00533[1-0.2303\ A_{at}(f_m)]]^{1.6}$ from Handbook of Acoustics (where $A_{ab}(f_m)$ is the atmospheric attenuation for broadband at frequency f_m, and $A_{at}(f_m)$ is the atmospheric attenuation for pure tone at frequency fm) and ISO 9613:Part 1 for Atmospheric Absorption at 30°C and relative humidity of 100% as the worse scenario (see Appendix D3-3C).

(4) Basing on the equation $A_{bar}=Dz=10\log[3+(C_2/l)C_3zK_{met})$ from ISO 9613:Part 2 for Barrier Attentuation. (see Appendix D3-3D).

Appendix D3-3B

Sample Calculation of Noise Level Due to Operation of Wind Turbine

(Lower Bound - 6.45MW)

NSR Location:	**N2**	
	Cheung Chau - Seascape Peninsula	
Noise Source:	W24	
Horizontal Distance:	6635 m	
SWL[(1)], dB(A)		117.5
Distance, m		6635
Distance correction [(2)]		-87
Barrier Attenuation		0
Atmospheric Absorption @ 500Hz[(3)]		-2.5
Predicted Lp, dB(A)		28
Lp, dB(A)		27.5

FACADE CORRECTION= 3 dB(A)

PREDICTED FACADE NOISE LEVEL = 31 dB(A)

Notes:

(1) Specification of the 6.45MW is not available at this stage. Maximum allowable SWL has been calculated based on the methodology presented in Section 3.8.2.3.

(2) Basing on the equation for geometrical divergence A_{div} = -[20 log(d) +11] from ISO 9613:Part 2 for spherical spreading in the free field from a point sound source.

(3) Basing on the equation $A_{ab}(f_m) = A_{at}(f_m)\ [1+0.00533[1-0.2303\ A_{at}(f_m)]]^{1.6}$ from Handbook of Acoustics (where $A_{ab}(f_m)$ is the atmospheric attenuation for broadband at frequency f_m, and $A_{at}(f_m)$ is the atmospheric attenuation for pure tone at frequency fm) and ISO 9613:Part 1 for Atmospheric Absorption at 30°C and relative humidity of 100% as the worse scenario (see Appendix D3-3C).

Appendix D3-3C

Pure-tone atmospheric absorption attenuation coefficients ($A_{at}(f_m)$ in decibels per kilometre) and the calculated atmospheric attenuation for broadband ($A_{at}(f_m)$)

Frequency	20°C, 80%		20°C, 40%		20°C, 90%		20°C, 100%		30°C, 100%	
Hz	$A_{at}(f_m)$	$A_{ab}(f_m)$	$A_{at}(f_m)$	$A_{ab}(f_m)$	$A_{at}(f_m)$	$A_{ab}(f_m)$	$A_{at}(f_m)$	$A_{ab}(f_m)$	$A_{at}(f_m)$	$A_{ab}(f_m)$
63	0.079	-0.1	0.15	-0.2	0.0705	-0.1	0.0637	-0.1	0.0462	0.0
125	0.302	-0.3	0.521	-0.5	0.272	-0.3	0.247	-0.2	0.1827	-0.2
250	1.04	-1.0	1.39	-1.4	0.966	-1.0	0.895	-0.9	0.705	-0.7
500	2.77	-2.8	2.63	-2.6	2.71	-2.7	2.63	-2.6	2.52	-2.5
1000	5.15	-5.1	4.65	-4.6	5.3	-5.3	5.42	-5.4	7.17	-7.1
2000	8.98	-8.9	11.2	-11.0	9.06	-9.0	9.21	-9.1	14.2	-13.9
4000	21.3	-20.6	36.1	-33.9	20.2	-19.6	19.4	-18.8	24	-23.1
8000	68.6	-60.1	128	-98.4	62.6	-55.6	58.1	-52.1	51.8	-47.1

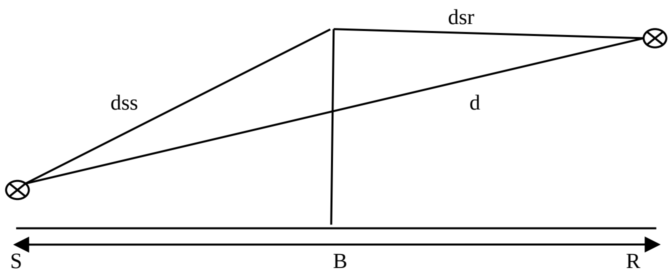
Notes:

1) Basing on the equation $A_{ab}(f_m) = A_{at}(f_m)\ [1+0.00533[1-0.2303\ A_{at}(f_m)]]^{1.6}$ from Handbook of Acoustics (where $A_{ab}(f_m)$ is the atmospheric attenuation for broadband at frequency f_m, and $A_{at}(f_m)$ is the atmospheric attenuation for pure tone at frequency fm reference from ISO 9613:Part 1).

2) Based on the above calculation for various combination of temperature and relative humidity that are applicable to Hong Kong's climate, the worst case for atmospheric absorption is at 30°C and 100%.

Appendix D3-3D

Sample Calculation of Barrier Attenuation [Note]



Wind Turbine: W24

Frequency, Hz	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Source H =	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
Rec Ht =	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
SB =	7280	7280	7280	7280	7280	7280	7280	7280
RB =	50	50	50	50	50	50	50	50
SR =	7330	7330	7330	7330	7330	7330	7330	7330
Barrier Ht =	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
dss =	7280	7280	7280	7280	7280	7280	7280	7280
dsr =	51	51	51	51	51	51	51	51
d =	7330	7330	7330	7330	7330	7330	7330	7330
z =	0.916	0.916	0.916	0.916	0.916	0.916	0.916	0.916
Wavelength, 500Hz	5.40	2.72	1.36	0.68	0.34	0.17	0.09	0.04
Kmet	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
20/0.69*z*Kmet	0.00000001	0.00000003	0.00000006	0.00000012	0.00000023	0.00000046	0.00000093	0.00000185
Dz	-4.77	-4.77	-4.77	-4.77	-4.77	-4.77	-4.77	-4.77

Note:

The barrier attenuation was calculated based on the equation A_{bar}=Dz=10log[3+(C_2/l)C_3zK_{met}) from ISO 9613:Part 2.