INTRODUCTION

For coastal development, artificial seawalls are commonly deployed to protect shorelines and reclamations. For quite a long time, considerations of artificial seawall designs are mainly given on the safety and reliability for shoreline protection. Artificial shorelines are mostly formed by concrete vertical seawall, or sloping seawall covered with boulders or protected by other structures (such as the armour 'Dolosse' on the east main cofferdam of High Island Reservoir).

Major types of artificial shoreline are as follows:
- Vertical Seawalls
- Sloping Rubble Seawalls
- Dam/breakwaters
- Artificial Beach
- Marine structures: piers, wharf, quay, etc.

It is known that the subtidal portion of these types of artificial shorelines could provide hard substrates for colonization of corals or other epibenthos. The east main cofferdam of the High Island Reservoir is known for the diverse coral communities and is now one of the 33 locations for Reef Check in Hong Kong, with a coral coverage of 53.1% (see Annex 1).

For the intertidal zone, however, due to the constraints of the hard substrates posed on seawall constructions (concrete or boulders), the intertidal communities on artificial seawalls are usually of low diversity or abundance. It is known that many soft shores in intertidal habitats support higher diversity and abundance of intertidal communities than hard shores do. However, there are very few examples that soft substrates materials are included as part of the artificial seawalls.

With the awareness on balancing nature conservation and development, there are trends/examples on taking into account the natural habitats when designing or constructing man-made structures, such as designing naturalised drainage channels, or providing habitats for wildlife in residential areas. For marine structures/projects, the concept of "eco-shoreline" has been introduced.

CONSIDERATIONS WHEN DESIGNING ECO-SHORELINE

Eco-Shoreline Concept

An "Eco Shoreline" is a kind of shoreline which provides beneficial functions to the local ecosystem through a range of active or passive solutions, whilst providing coastal protection. It represents a paradigm shift in the fundamental approach to sustainable and environmentally friendly construction, from "minimizing impact" to "creating ecological benefit". Eco-shorelines can also provide beautiful and natural public open space. The concept of Eco-shoreline was proposed in the Land Supply Study (Increasing Land Supply by Reclamation and Rock Cavern Development cum Public Engagement – Feasibility Study) as one of potential mitigation/enhancement measures for future coastal developments and was discussed in public engagement process. In a recent review on the ecological engineering to mitigate impacts of coastal structures published by local researchers (Perkins 2015), after comparing literatures and examples on the conventional hard engineering approaches for coastal structures and those on the "soft" engineering approaches with considerations of preserving ecology and biodiversity, it is proposed that "the greater adoption of soft approaches as default for coastal defence infrastructure policy when engineering is required".

Constraints and Challenges

Natural shorelines are constantly modified by coastal processes, driven by tides, currents, wind, waves, storms and sea level changes, leading to erosion, siltation and littoral drift. Like natural shoreline, artificial shorelines would also be subject to a variety of coastal processes. Some of them may be powerful and destructive. Engineering safety is still a key consideration even for eco-shorelines, though general public may be sceptical of the protection provided by 'invisible' defences such as submerged artificial reefs or groins.

Eco-shoreline however is a relatively new concept/technology. So far, no pilot project has been undertaken in Hong Kong.

Opportunities

The scenarios suitable for application of eco-shoreline could be diverse. It could mitigate the impacts, or part of the impacts, caused by the developments, such as loss or degradation of habitats. In some circumstances, with careful considerations and suitable design, some of the techniques of eco-shoreline could be even used for conservation and enhancement of natural shorelines.

ECO-SHORELINE AS A MITIGAITON MEASURE FOR TUNG CHUNG EAST RECLAMATION

There will be a reclamation of about 120.5 ha for TCE PDA and about 8.6 ha reclamation for Road P1. When taking into account the additional space occupied by the seawalls, it will totally cause a loss of about 145 ha of seabed. The ecological impact assessment has evaluated the impact of this loss of marine habitats and ranked as Minor to Moderate. As the waters within the reclamation footprints are of very low usage by Chinese White Dolphin (CWD), and it is concluded that the impact would be mostly on the loss of general marine habitats. Though the habitat type impacted is common in the western Hong Kong and contains no species of special conservation importance, given the size of the reclamation, it is recommended in the EcoIA that eco-shoreline should be introduced in the artificial shoreline of future TCE PDA and Road P1 as mitigation measure to enhance ecological functions for marine habitats.

It is recommended in the EcoIA that the detailed design of the eco-shoreline will be submitted for the approval of the authority before the commencement of reclamation works. This appendix aims to provide some basic information of eco-shoreline and examples of design or conceptual design, to demonstrate the feasibility of the proposed mitigation, but will not form any constraints for the future design of eco-shoreline on TCE PDA and Road P1, which will be the objectives of the future detailed design study.

Current Conditions of Tung Chung existing shoreline

Currently the shorelines in North Lantau from Tung Chung to To Kau Wan are dominated by artificial sloping boulder seawalls, mostly along the North Lantau Expressway and railway tracks for Airport Express and Tung Chung Line.

The marine waters in western Hong Kong including North Lantau are basically brackish, of lower salinity than the waters in other areas of Hong Kong, due to the influence of Pearl River discharge. In the water quality chapter, a Summary of EPD's Routine Marine Water Quality Data for North Western Water Quality Control Zone in 2013 is provided. The salinity at all monitoring stations in North Lantau waters shows a large fluctuation range. Taking NM3 as an example, the salinity ranges from 18.2 to 32.8 ppt, with an average of 27.7 ppt. Other stations also show a similar pattern.

Under the brackish environment, estuarine fauna dominate the ecosystems in north Lantau waters. CWD is the key concerned species in North Lantau waters but their occurrence near Tung Chung is very low. Currently the artificial seawalls are of low ecological value. During the ecological survey for the present study, only very low diversity and abundance of intertidal fauna and subtidal fauna were recorded. For subtidal fauna, low coverage of cup coral and gorgonians, both common in western Hong Kong waters, were found. Low abundance of shorebirds such as Pacific Reef Heron was also recorded on the seawalls

Opportunities and constraints in Tung Chung

Currently the majority of shoreline in North Lantau comprises sloping artificial seawall for North Lantau Highway. It is expected that the original shorelines before the construction of North Lantau Highway would be natural and should be of higher ecological value than its present conditions. Provisions of eco-shoreline in the area would serve an opportunity to revitalise the shoreline.

Though the existing seawalls and the reclamation footprints are not of high ecological value or potential, two estuarine bays are considered of conservation importance, i.e. Tai Ho Wan and Tung Chung Bay, which are located in two directions from the reclamation (to the east and to the west of TCE PDA). Provisions of habitats in between these two bays with ecological functions might help to establish linkage between the two estuaries.

But there are some constraints for implementation of eco-shoreline along the entire shoreline at TCE PDA. The western side of the TCE PDA is facing Airport Island and the opening of Airport Channel. It would need to reserve a navigation channel of sufficient width for the piers at Tung Chung to allow vessels including ferries to access the piers. There would not be enough space for any additional structures required for eco-shoreline on the seawalls at this area. And the vessel traffic to-and-fro the piers would also cause turbulence flow and would affect the eco-shoreline. These factors would constrain the application of Eco-shoreline on the seawall at the western side of TCE PDA.

LOCAL EXAMPLES OF ECO-SHORELINE

While there has been no precedent example of eco-shoreline with specifically purposed-oriented design features on reclamation in Hong Kong, similar environmentally friendly designs on other types of wetland have been adopted in previous development projects in Hong Kong.

For instance, Green Channel designs have been adopted/proposed in some local drainage channels. Some of them are located in estuarine areas and could be taken as a reference for eco-shoreline especially for reclamation in waters of lower salinity.

In the Main Drainage Channel in Shan Pui River of Yuen Long, a special design was adopted for mangrove planting in brackish environment near the channel outlet to Inner Deep Bay.

In the lower part of the channelised section of Shan Pui River (or Main Drainage Channel MDC 60), a platform extended from the lower part of the sloping rubble man-made channel bank to hold muddy substrates for mangrove planting. The planted mangrove trees and the naturally colonised benthic communities were successfully established, which demonstrated that these types of designs are feasible in Hong Kong and effective in enhancing the ecological functions of the area.

Mangrove plantation at Shan Pui River

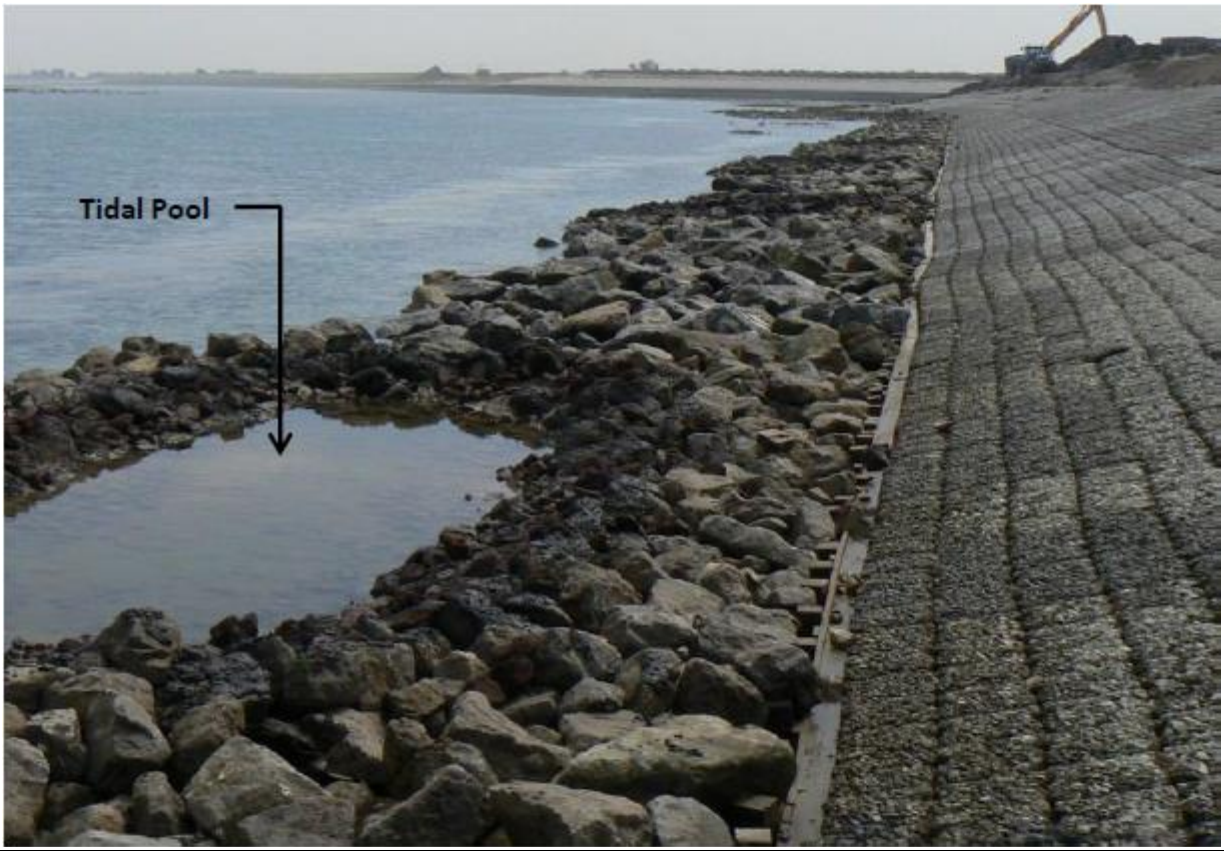
OVERSEAS EXAMPLES OF ECO-SHORELINE

There are overseas examples of eco-shoreline designs, differing in materials and structures, to be adopted instead of traditional shorelines in order to increase the ecological value of the seawall.

If the horizontal surface is of soft substrate, riparian vegetation or mangroves might colonise and help rehabilitation. In Australia, some areas subject to continual erosion have seawalls with benched rock and seawall revetments, and mangroves or salt marsh plants were established on the soft substrates in between.

Estuarine Vegetation in front of seawall in Parramatta River Estuary, Australia

Instead of having one single sloping surface, horizontal surfaces can be incorporated in the intertidal zone. In the case of a dike section in the Netherlands, tidal pools were incorporated into the design of artificial seawall. The pools at the lower part of the seawall could increase complexity of seawall, provide additional habitat for intertidal organisms and attract foraging birds, and enhance the biodiversity of the area.



Tidal Pool during low tide along Shoreline of Dike Section in Yerseke, the Netherlands

The gradient of a seawall would affect the surface area subjected to tidal influences. Usually seawall with a gentler slope seawall would have a higher resemblance to a natural foreshore, but the footing of the seawall will be increased in size and the footprint will be expanded. In Hawkesbury River Estuary of Sydney, steps and benches are incorporated into different sections of the seawall to produce a terraced seawall. The habitat diversity is increased by including both vertical and horizontal surfaces. (NSW DECC, 2009).

Terraced Seawall in Hawkesbury River, Sydney Australia

POTENTIAL TYPES/DESIGN OF ECO-SHORELINE IN TCE

1. Tidal pools and protrusions on vertical seawalls

In the The Cumulative Environmental Impact Assessment Study for the Three Potential Nearshore Reclamation Sites in the Western Waters of Hong Kong (CEIA Study), the application of Eco-shoreline design in the three potential nearshore reclamation sites was investigated. For the Siu Ho Wan Site located to the east of the Tung Chung PDA and Road P1, it is anticipated that vertical seawall design might be adopted at this site. It is suggested in the study that tidal pools could be considered to be incorporated on the future vertical seawall at the intertidal zone. In the subtidal zone, protrusions such as vertical reef balls and horizontal reef units are suggested.

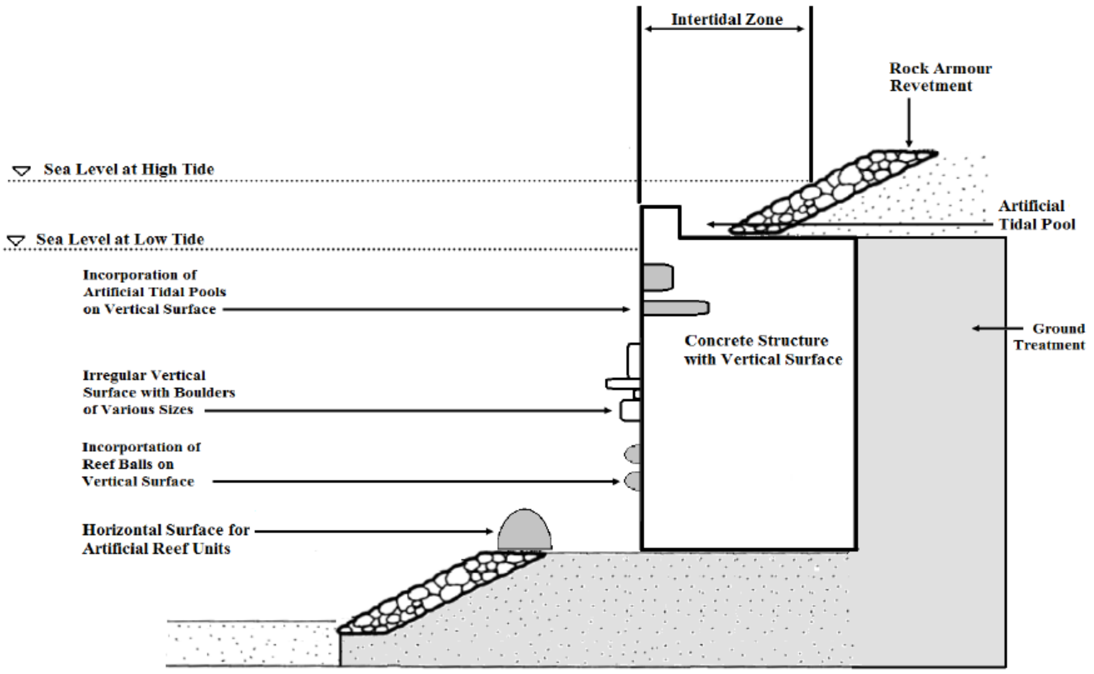


Plate 2: Schematic Diagram for Eco-shoreline Design (Vertical seawall) at Siu Ho Wan PRS, Sunny Bay PRS and Site Trial Location 2

Conceptual design of vertical eco-shoreline with tidal pools and protrusions (sources: CEIA Study)

The conceptual design of vertical eco-shoreline suggested in the CEIA Study could be incorporated where appropriate as part of the design of the future eco-shoreline for TCE and Road P1 for the portion of vertical seawall.

In some drainage channels, hides for fish and aquatic fauna (referred as in-stream refugia) are provided on the vertical walls of the channels as shelters when the flow is fast. These hides could also be utilised by waterbirds as roosting place. These design features could be considered for vertical seawalls.

In-stream refugia (source: DSD website)

2. Tidal pools on sloping seawalls

In CEIA Study, eco-shoreline features on sloping seawalls are also investigated. Tidal pools with concrete base are suggested in the intertidal zone on sloping boulder seawalls. To facilitate tidal pools in this form, the basic design and structures of the sloping seawalls could follow those existing sloping seawalls, but the gradient or the extent of the seawalls might need to be adjusted to accommodate the tidal pools. Subject to the detailed design and sizes of the tidal pools, there may be potential increase in the footprints of the seawalls.

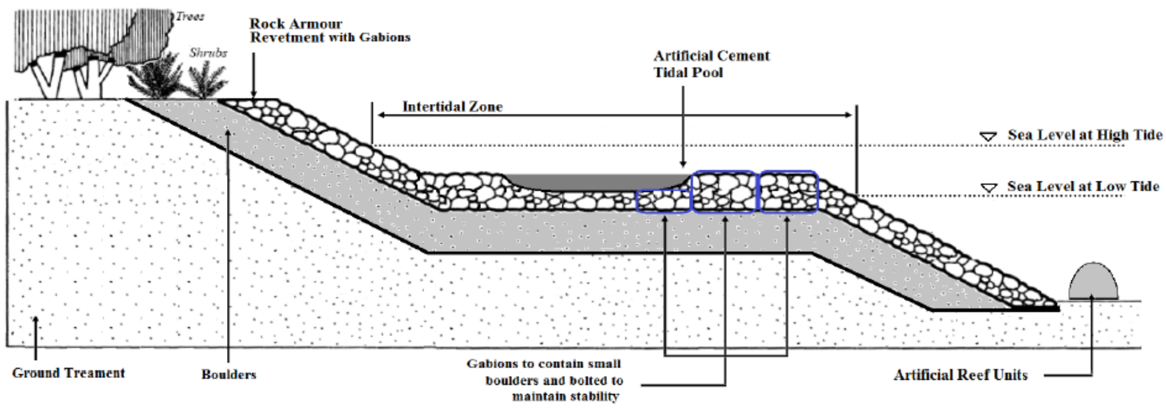


Plate 1: Schematic Diagram for Eco-shoreline Design (Sloping artificial seawall) at Lung Kwu Tan PRS and Site Trial Location 1

Conceptual design of sloping eco-shoreline with tidal pools (sources: CEIA Study)

3. Sandy Shore on sloping seawalls

Sandy shores on sloping seawalls was also proposed, mainly for Lung Kwu Tan site, in the CEIA Study. Sandy substrates would be hold in front of the sloping seawalls by a subtidal sill. This kind of design would inevitably occupy a larger seabed footprint as the gradient must be kept gentle to allow the sand to naturally retain in the area (different from the tidal pool design above where the tidal pools are concrete lined and more flexible in size). This design thus might not be suitable for TCE PDA and Road P1, in order to avoid the increase in seabed footprint, which will be verified in the detailed design.

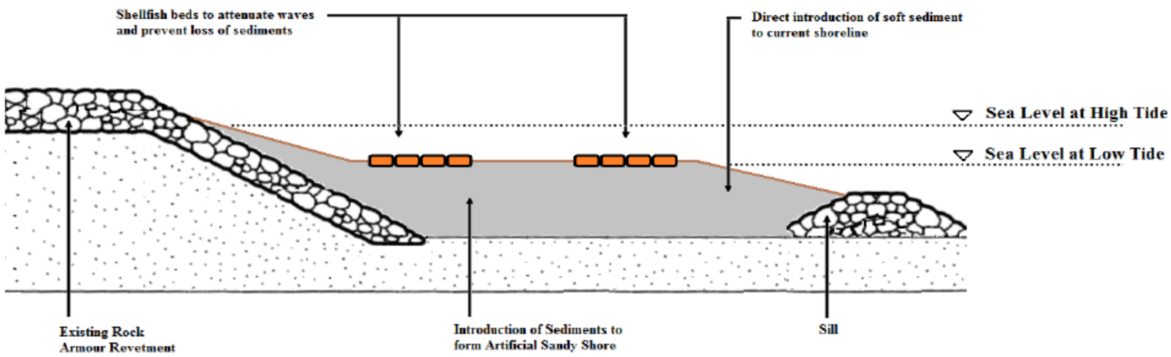


Plate 3: Schematic Diagram for Eco-shoreline Design (Artificial sandy shore) at Lung Kwu Tan PRS, Sunny Bay PRS and Site Trial Location 3

Conceptual design of sloping eco-shoreline with sandy beaches (sources: CEIA Study)

4. Platform with muddy substrates for mangrove planting/colonisation

Considerations could also be given to the design adopted in MDC 60 Shan Pui River by providing a platform on sloping or vertical seawalls for holding muddy substrates to allow colonisation of intertidal fauna. Mangrove might also be able to colonise the platform, if the salinity is suitable. There are studies indicating that the growth rate and survival of seedling of Kandelia was impeded when salinity was over 20 ppt (Zheng & Lin 1992, Liao et al. 1996). For the waters in North Lantau, the salinity fluctuates a lot with seasons, and the average salinity is over 20ppt (see above sections on current conditions around TCE PDA and Road P1). Therefore the implementation of this design, if adopted, should be selected at locations near freshwater discharge, such as surface runoff drainage discharge points of the new reclamations, or near the Tai Ho inlet which is the discharge point of Tai Ho Stream.

References:

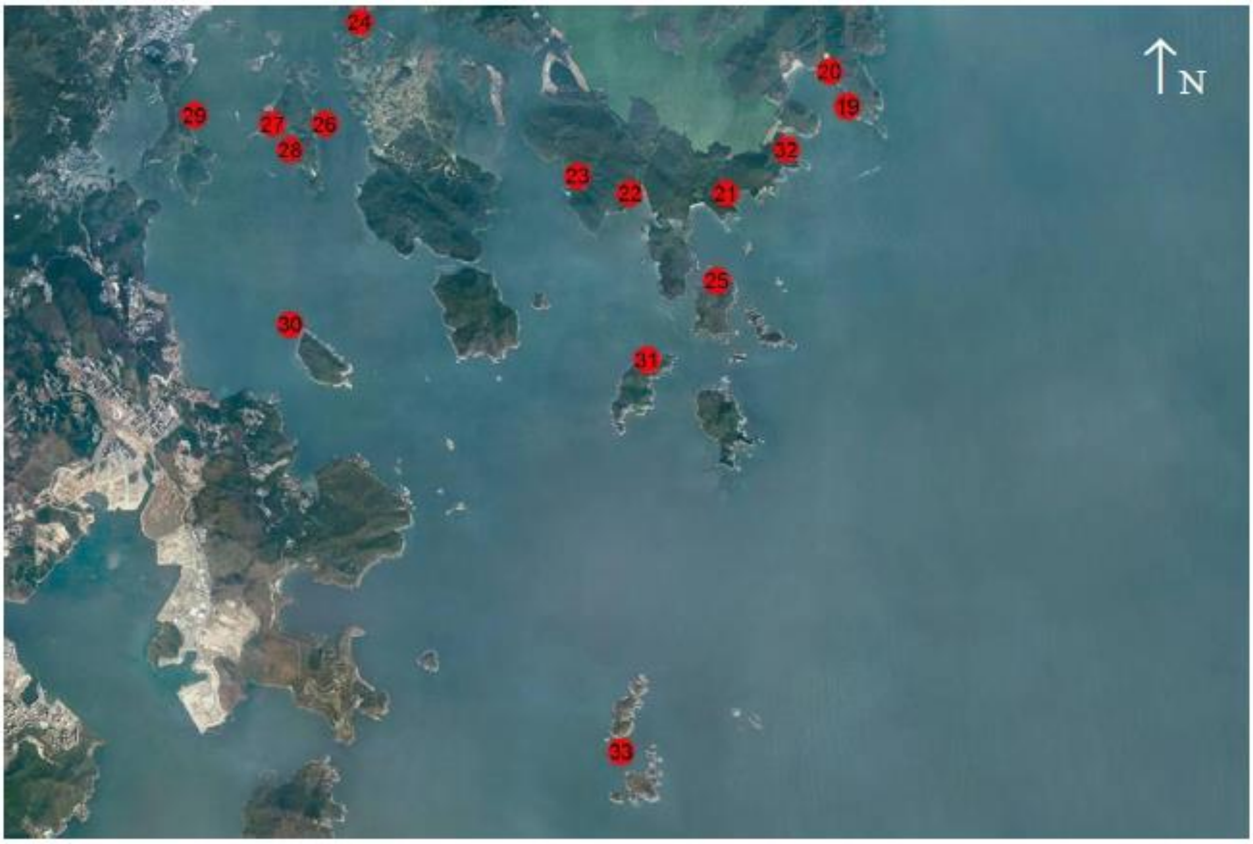
Liao, B.W. et al. 1996. Studies on the Primary Character and Storage Method of Mangrove *Kandelia candel Forest Research* 9(1): 58-63.

NSW DECC, 2009. Hawkesbury-Nepean River Environmental Monitoring Programme – Final Technical Report.

Perkins, M.J., T.P.T. Ng, D. Dudgeon, T.C. Bonebrake, and K.M.Y. Leung 2015. Conserving intertidal habitats: What is the potential of ecological engineering to mitigate impacts of coastal structures? *Estuarine, Coastal and Shelf Science (2015)*.

Zheng, W.J. & Lin, P. 1992. Effect of Salinity on the Growth and Some Ecophysiological characteristics of Mangrove *Bruguiera sexangula* Sseedlings. *Chinese Journal of Applied Ecology*. 3(1): 9-14.

Annex 1 East Dam location and coral coverage percentage



The location of East Dam (Source: AFCD Website)

Table 1: Hard coral coverage at 33 sites

Site	Coral Cover (%)
1. A Ma Wan, Tung Ping Chau	68.8
2. A Ye Wan, Tung Ping Chau	43.8
3.Wong Ye Kwok,Tung Ping Chau	61.3
4. Kai Kung Tau, Kat O	21.9
5. Tau Tun, Kat O	28.8
6. Lai Chi Wo, Yau Chau Tong	58.1
7. Au Yue Tsui, Yau Chau Tong	48.8
8. Ngau Shi Wu Wan	38.1
9. Wu Pai, Crescent Island	66.9
10. Cresent Island West	62.5
11. Crescent Island South	61.9
12. Tung Wan, Double Island	31.3
13. Wong Chuk Kok Hoi	34.4
14. Port Island	54.4
15. Moon Island, Hoi Ha Wan	31.9
16. Coral Beach, Hoi Ha Wan	79.4
17. Pier, Hoi Ha Wan	72.5
18. Gruff Head, Hoi Ha Wan	71.9
19. Long Ke Wan	49.4
20. Siu Long Ke	37.5
21. Pak Lap Tsai	53.1
22. Pak A	43.1
23. Tai She Wan	53.8
24. Tai Mong Tsai	60.6
25. Town Island	56.3
26. Sharp Island East	70.0
27. Sharp Island North	78.8
28. Sharp Island South	34.4
29. Pak Ma Tsui	45.0
30. Shelter Island	59.4
31. Bluff Island	72.5
32. East Dam	53.1
33. South Ninepin	23.1

Percentage of coral coverage at different reef check site including East Dam (Source: AFCD Website)