

Workshop on Urban Mobility & Environment

Green infrastructure design and construction: the Shenzhen Bay Bridge

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Shenzhen Bay Bridge

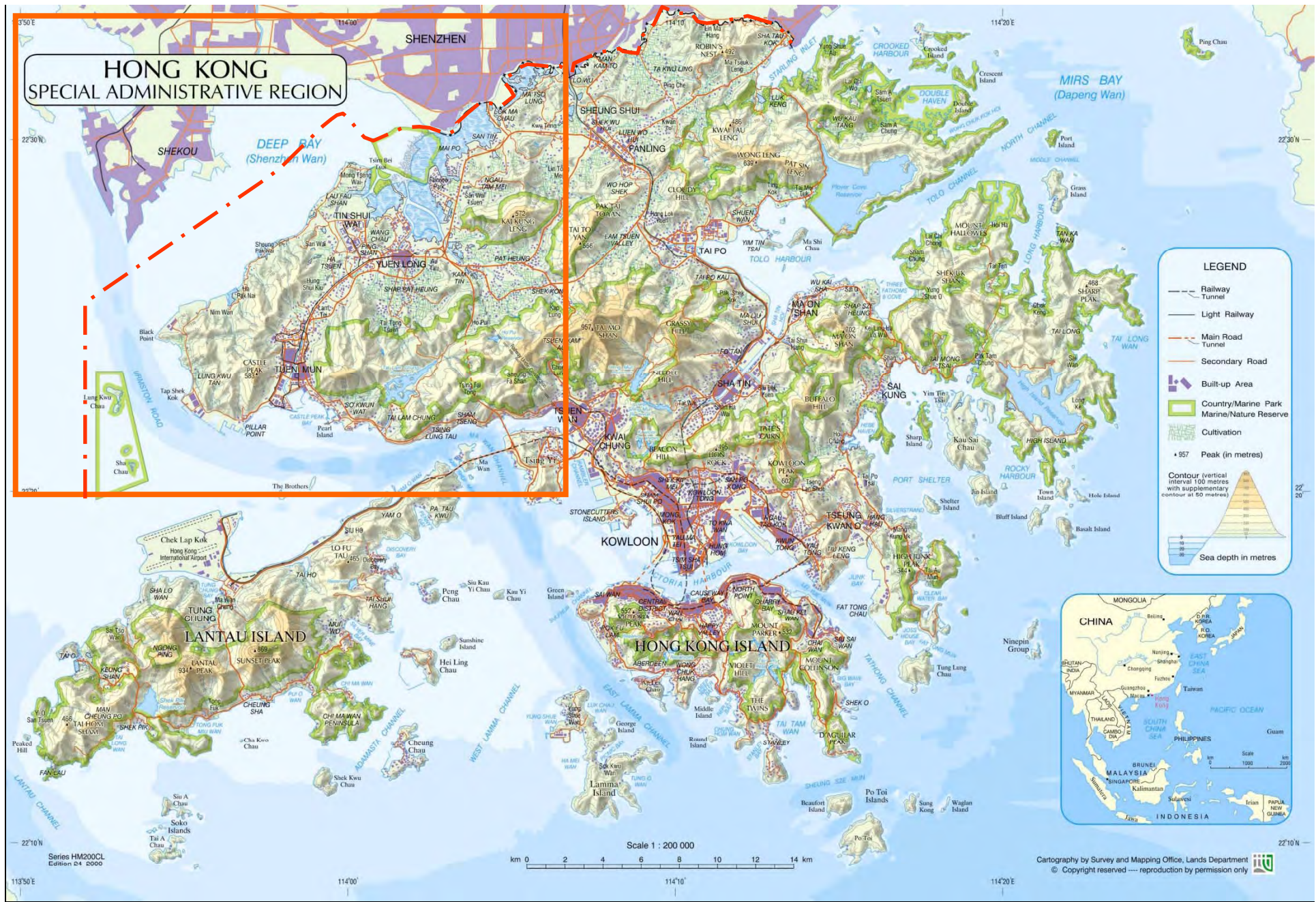
- Background
- Environmental challenges
- Solutions

Background

- The three existing vehicular boundary crossings at Lok Ma Chau, Man Kam To and Sha Tau Kok are nearly saturated.

Background

- Crosslinks Further Study (March 2001) confirmed the need for the fourth land boundary crossing of Hong Kong-Shenzhen Western Corridor (now called Shenzhen Bay Bridge)
- The project will:
 - Alleviate the traffic congestion at the three existing crossings
 - Facilitate the further development of the container port of Hong Kong
 - Enhance trade between Hong Kong and Southern China
 - Facilitate further economic development particularly in areas of finance, logistics and tourism
 - Strengthen the position of Hong Kong as the hub of the Pearl River Delta region



Project location

ARUP E5



Constraints at landing point

ARUP E6

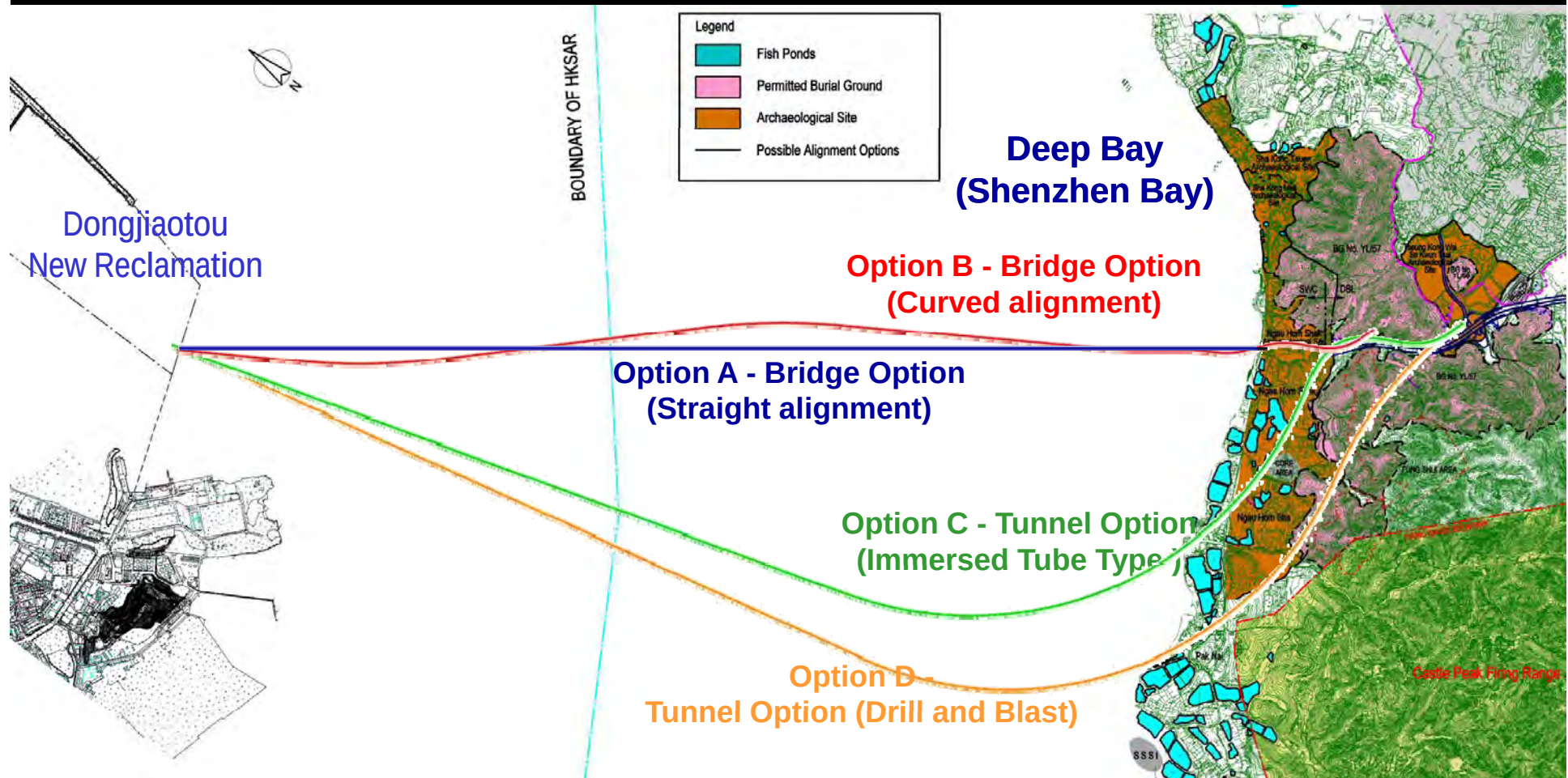
Shenzhen Bay Bridge

- Fourth vehicular boundary crossing between Hong Kong Special Administrative Region (HKSAR) and the Mainland
- Total length: 5.5 km (divided by Boundary of HKSAR)
- HKSAR section: 3.5 km & Shenzhen section: 2 km
- Dual 3-lane elevated carriageway with hard shoulders
- Cable-stayed bridge at navigation channel
- Jointly implemented by both governments of HKSAR and Shenzhen

Consultations with stakeholders

- Investigation & planning consultancy commenced 21 Aug 01
- Tuen Mun Rural Committee (1st) 31 Aug 01
- Tuen Mun District Council (1st) 03 Sep 01
- ACE EIA Subcommittee 17 Sep 01
- Green Groups (1st round) 27 Sep 01 – 12 Oct 01
- ACE discussion paper on options selection Oct 01
- Ha Tsuen Rural Committee 05 Feb 02
- Tuen Mun Rural Committee (2nd) 07 Feb 02
- Green Groups (2nd round) 27 Feb 02 – 11 Mar 02
- Liaison Group with Oyster Farmers (1st) 01 Mar 02
- Tuen Mun District Council (2nd) 15 Mar 02
- Yuen Long District Council (TT comm) 19 Mar 02
- Liaison Group with Oyster Farmers (2nd) 10 Apr 02
- Green Groups (3rd round) 29 May 02 – 04 Jun 02

Select proper alignment to minimise overall impacts



Legend

-  Fish Ponds
-  Permitted Burial Ground
-  Archaeological Site

1. Engineering

f1 Highway alignment

f2 Drainage impact

f3 Utilities impact

f4 Construction practicability

f5 Construction traffic management

f6 Traffic Operation

Factors Considered

2. Environmental

f7 Noise impact

f8 Air quality impact

f9 Water quality impact

f10 Ecology impact

f11 Fisheries impact

f12 Waste

f13 Cultural Heritage

f14 Hazard to life

f15 Landscape and Visual Impact

3. Marine

f16 Marine Impact

4. Land Use

f17 Land Use Impact

5. Programme

f18 Programme

6. Cost

f19 Cost

7. Public Perception

f20 Public perception

8. HSK NDA

f21 HSK NDA

46.9%

- Ratings are given on a 5-point scale to each alignment option under each of the above factors, with higher scores for better options.
- Relative importance of the factors is taken into consideration by applying weights to the rating factors.

Alignment Options - Ranking Exercise



Highest Score → Option B : 247.8
Curved Bridge Option, Landing at Ngau Hom Shek

Preferred Option

Environmental Challenges

- Deep Bay (also called Shenzhen Bay)
 - sedimentation rate
 - first foul flush of road runoffs after dry season
 - accidental chemical spillage from vehicles
 - oyster farming
- Disturbance zone
- Bird collision with man-made structures
- Compensation for loss of mudflats

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Deep Bay



Mai Po at Inner Deep Bay

ARUP E15



Mai Po at Inner Deep Bay

ARUP E16

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Mai Po at Inner Deep Bay

Sedimentation Rate

- WWF expressed deep concerns that the Shenzhen Bay Bridge project would accelerate the sedimentation rate and cause drying-up of the 'Gei-Wai's at Mai Po
- In the early stage of the project, WWF Hong Kong had stated that they would object to any bridge option of the crossing, as they were worried that the numerous bridge supports in the waters of Deep Bay would slow down the water current at the inter-tidal mudflats and hence accelerate the sedimentation rate. They voiced out that they would only accept a tunnel option.
- However, our assignment as stated in the consultancy brief is that the crossing shall be a bridge.

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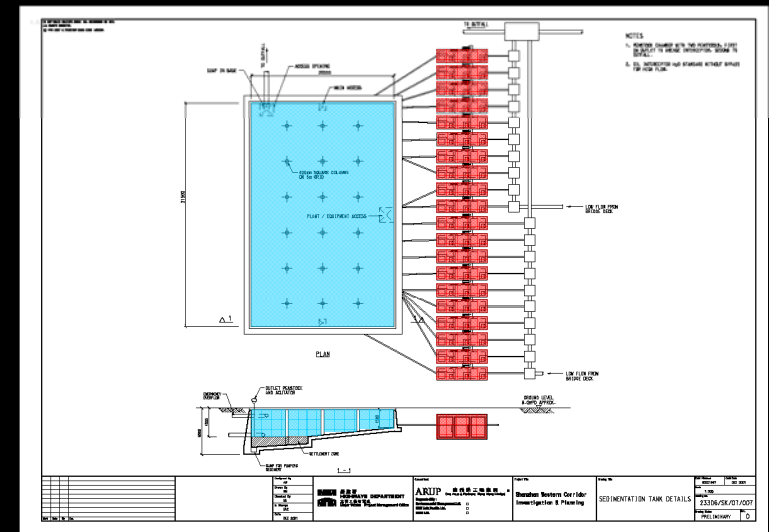
First foul flush after dry seasons

- Vehicles generate road sludge:
 - directly, through frictional wear and normal combustion by-products
 - indirectly, through transport of contaminants from parking lots, construction sites, farms, and dirt roads



First foul flush after dry seasons

- Isolated drainage system to collect all road runoff to treatment tank:
 - Requires large size drainage pipe inside deck void
 - Requires large space on shore for the treatment tank
 - High operating and maintenance costs
 - In event of long duration of heavy rainfall that exceeds storage capacity of treatment tank, untreated runoff would over-flow from treatment tank to Deep Bay



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Accidental chemical spillage from vehicles

- Green groups raised concern of ecological disaster in Deep Bay in the event of car accident involving Dangerous Goods Vehicles (DGVs):
 - when whole truck carrying hazardous chemicals crushed into the sea,
 - when chemical containers on the DGV fell off the DGV into the sea, or
 - when chemical containers on the DGV got damaged and the contents leak to road surface and enter the bridge drainage gullies that discharge to the sea
- Green groups preferred tunnel option of the boundary crossing, as this would eliminate this problem
- However, DGVs of categories 1, 2 and 5 are prohibited from entering tunnels in Hong Kong, but the crossing should be designed to serve also the DGVs

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Oyster farming in Deep Bay



Oyster farming in Deep Bay

Oyster rafts in deeper waters



Oyster farming in Deep Bay

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Disturbance zone

- In Feb/Mar 02, green group representatives stated that Lok Ma Chau Spur Line EIA set precedent by depicting an 'Exclusion Zone' of 50m on both sides of the bridge alignment
 - any mitigation measure within 50m from the alignment would not be counted
 - serious impact to Shenzhen Bay Bridge as project site limit would have to be extended to beyond 50m each side in order to have any 'effective' on-site compensation/mitigation measure
- Road gazette plans already have site limit set at 50m clearance from each side of Shenzhen Bay Bridge for gazettal on 15th March 2002

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Bird collision with man-made structures

- Shenzhen side expressed very strong desire of having landmark cable-stayed bridges for Shenzhen Bay Bridge.
- Green groups concerned that the towers and stay cables of the bridges would cause bird mortality, especially as Shenzhen Bay Bridge would cross the flight paths of migratory birds which fly from Southern hemisphere to Mai Po.
- If this matter is not resolved quickly, the project could not proceed any further.

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Compensation for loss of mudflats

- Shenzhen Bay Bridge would result in loss of mudflats during the construction and operation stages
- Green group members commented that loss of mudflats should be compensated on a like-for-like basis, i.e. inter-tidal mudflat lost must be compensated by an equal area of inter-tidal mudflat, no matter how small the quantity would be
- How to create new inter-tidal mudflats ???

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Sedimentation rate

- Computer modelling used in the assessment of water quality and sedimentation rate

Oyster beds on inter-tidal mudflat

- reduce flushing capacity
- bird feeding activities much lower than in areas without oyster beds



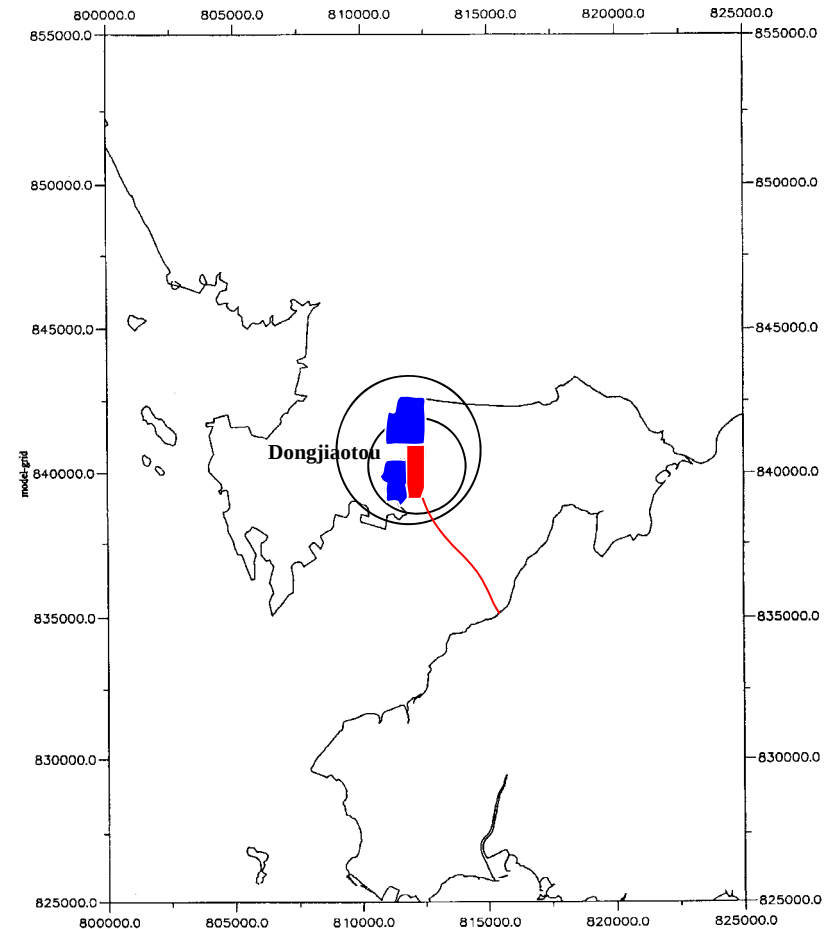


Sedimentation rate and water quality in Deep Bay

Water Quality Modeling

Coastline Configuration for Different Scenarios:

- **Scenario 1: Existing baseline (2002)**
- **Scenario 2: Baseline with SWC Reclamation (2003)**
- **Scenario 3: With SWC bridge (end of 2005)**
- **Scenario 4: With SWC bridge and future SZ reclamation (2010)**



Concern: • **Impact on flushing capacity and water quality during operational phase**

• **Sedimentation and erosion of inter-tidal mudflat**

Findings: • **Model prediction showed small reduction in flushing capacity (0.76% from bridge only)**

- **2.6% from HKSWC reclamation (Scenario 2)**
- **3.3% from HKSWC reclamation & bridge (Scenario 3)**

• **Minor water quality changes in Deep Bay (0.21 – 2.2%)**

• **Small increases in sedimentation rate (Scenario 3):**

- **Mai Po: + 0.5 mm/yr**
- **Ramsar Site: + 0.3 to 0.5 mm/yr**
- **Pak Nai SSSI: + 0.4 mm/yr**
- **Tsim Bei Tsui: + 0.9 mm/yr**

• **Natural processes dominate the sedimentation and erosion conditions in Deep Bay**

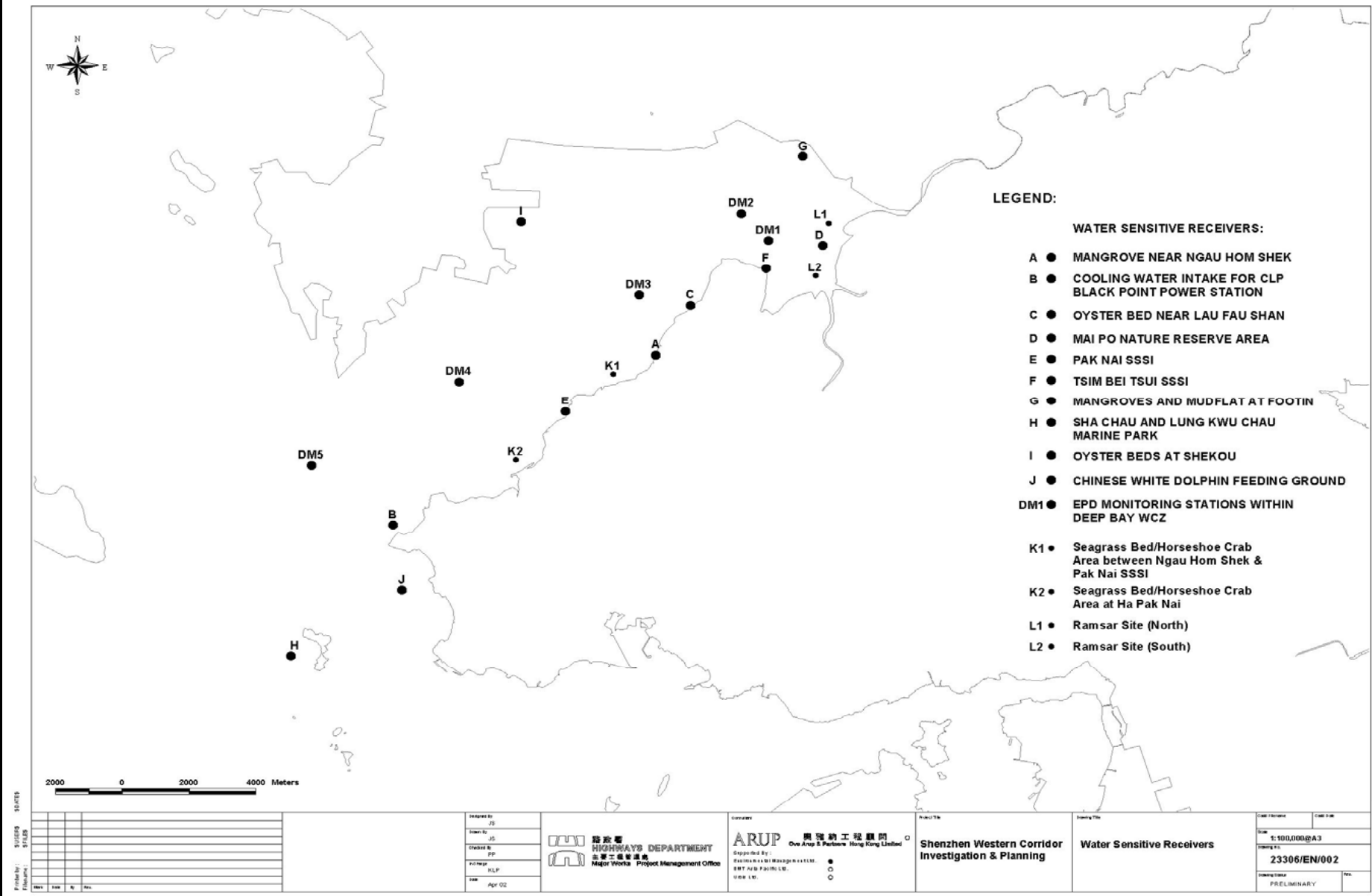
Mitigation:

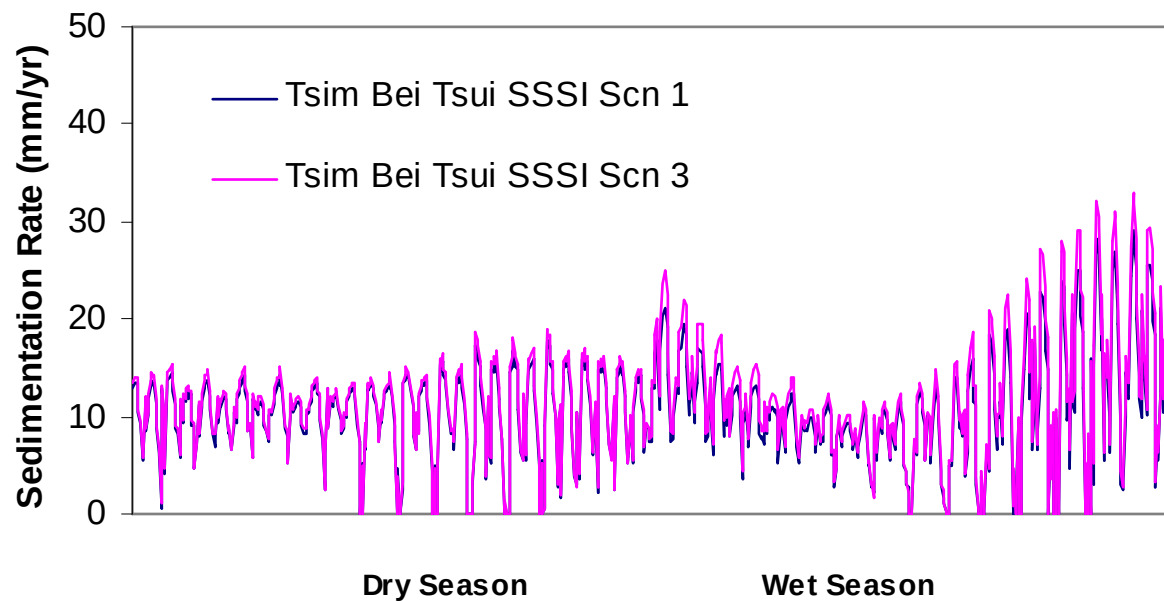
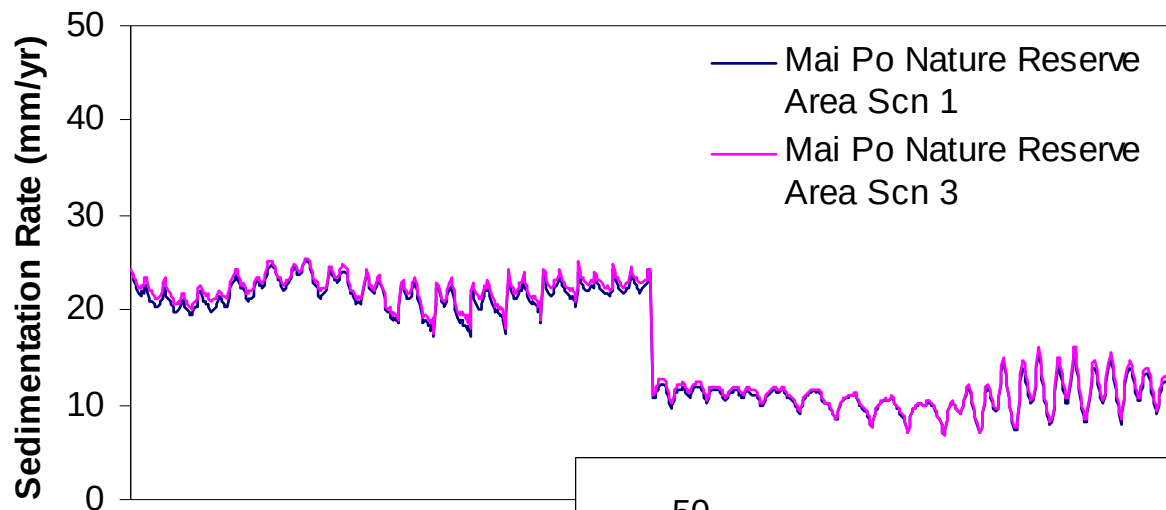
- Minimize reduction in flushing capacity through the design of a longer span spacing (75m)
- Streamline shaped bridge pier
- Submerged pile cap
- Clearance of oyster beds within works limit (could potentially restore up to 0.38% of flushing capacity)

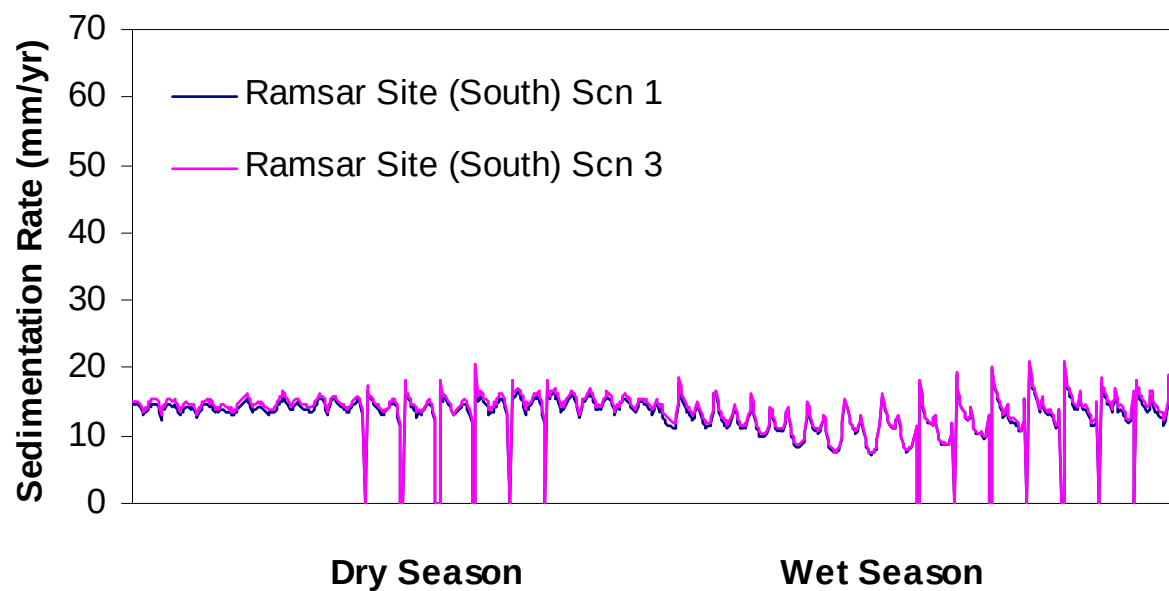
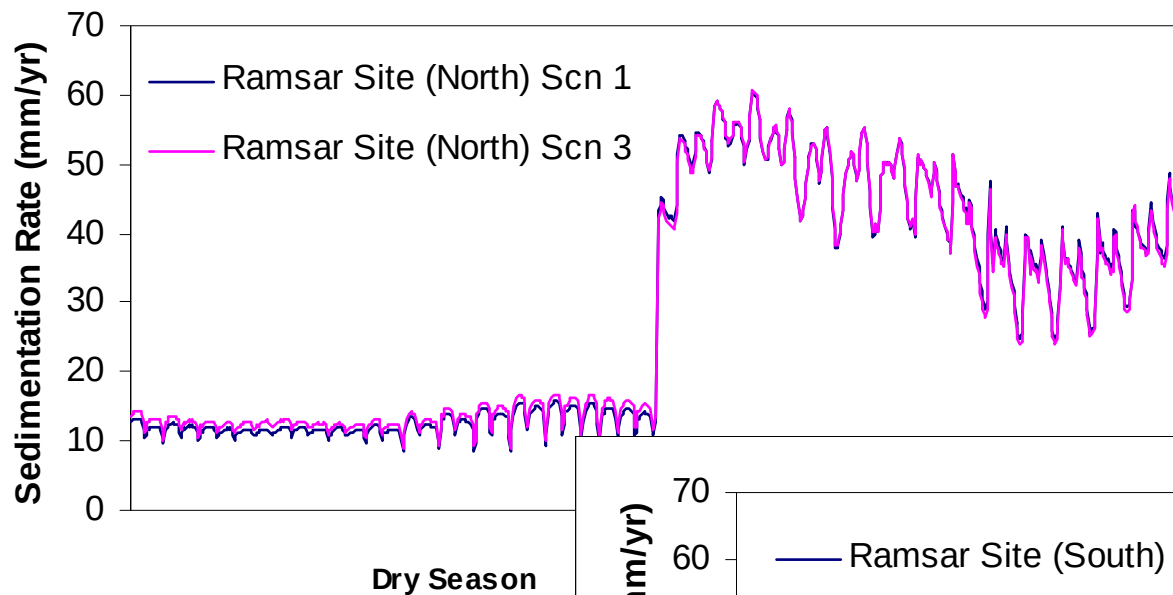
Residual:

- Natural processes dominate the sedimentation and erosion in Deep Bay and residual impact due to SWC is not noticeable









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First foul flush of road runoffs after dry season

- The University of New South Wales (UNSW) Research Report No. 204 entitled 'Stormwater Quality from road Surfaces – Monitoring of Hume Highway at South Strathfield' has the following key findings:
 - Dry weather build-up of contaminants on road surface reaches equilibrium after 10 days. It was found that after 10 days contaminant deposition rates were similar to removal rates caused by air turbulence.
 - The contaminant equilibrium would be maintained until a cleansing event, such as wind exceeding 21 km/hr or rain exceeding 7 mm/hr.



First foul flush of road runoffs after dry season

- A research by Barrett et al (1998) on the characteristics of highway runoff supported that contaminant concentration in highway runoff was not significantly high.
- Mitigation measures:
 - Regular removal of pollutants from the road surface by vacuum air sweeper (initially at twice every week subject to review in operational stage)
 - Use standard highway road gullies that contain silt traps
 - Monitor road runoff during operational stage and adjust road cleaning frequency if necessary



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Accidental chemical spillage from vehicles

- Low traffic accident rate on major bridges in Hong Kong (approx. 0.7 to 7.7 accident/year)
- Main concern is spillage of corrosive or poisonous chemicals from container of dangerous goods vehicles (DGVs) involved in traffic accidents.
- There is tight statutory control under the Dangerous Goods Ordinance (Cap. 295) on the conveyance of dangerous goods by vehicles:
 - Drivers of DGVs are required to possess certificate of training course on transportation of dangerous goods
 - Stringent requirements on design of vehicle and container

Accidental chemical spillage from vehicles

- Based on Hong Kong traffic accident statistics and the estimated traffic flow on the boundary crossing, the return period of DGV accident on the crossing is 1 in 33 years indicating that the potential DGV accident on the crossing is extremely low.
- There were existing emergency response plans being implemented by Government to deal with chemical spillage due to vehicle accidents on roads. In the event of oil pollution at sea, there was a maritime oil spill response plan developed by Marine Department to deal with oil spillage in Hong Kong waters. With these plans in mind, a detailed emergency response plan has been developed for chemical spillage on Shenzhen Bay Bridge.

Accidental chemical spillage from vehicles

- Clean up materials including saw dust, dry sand, absorbents and neutralising agents are stored at a weigh-station managed by Hong Kong Police Force near Shenzhen Bay Bridge so that in case of DGV accident on the crossing, Hong Kong Police Force will provide assistance to transport the clean up materials to the accident scene within a short time.
- With the above measures, the potential impacts due to chemical spillage will be reduced to acceptable levels.

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Oyster farming

- Early liaison with oyster farmers was carried out to identify their concerns and requirements.
- Information on existing extent of oyster farming in the vicinity of the bridge alignment was obtained by aerial photos and supplemented with field visits and side-scan sonar survey.
- Oyster beds within 50m both sides of the bridge alignment were cleared to provide the necessary works area and compensation was paid to affected farmers.

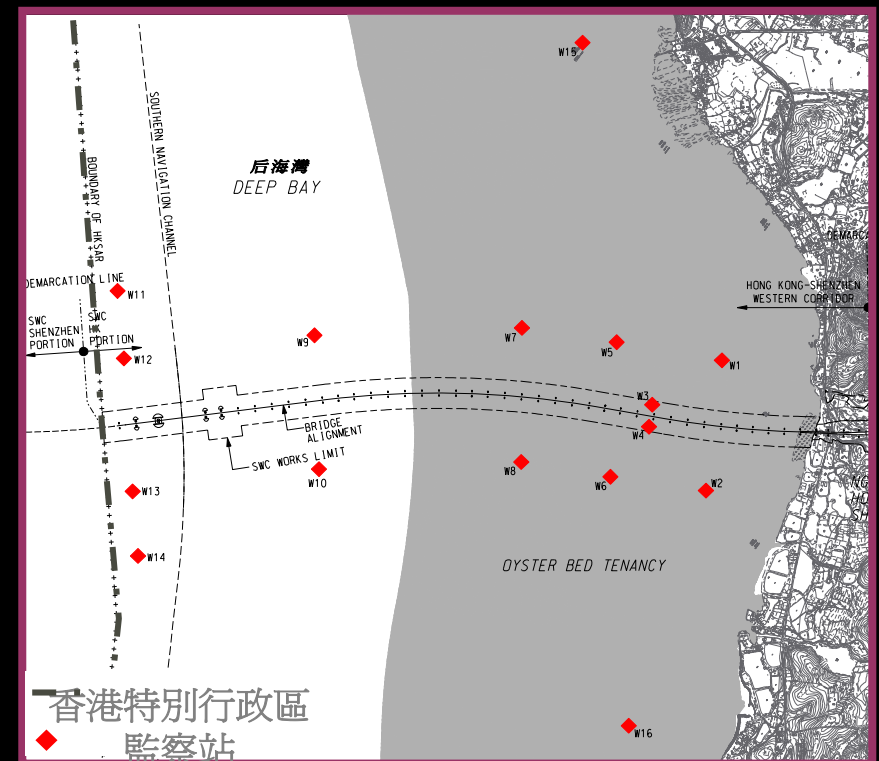


Oyster farming

- City University of Hong Kong was commissioned to carry out an independent investigation to assess the impact of SWC construction works to oyster farming in Deep Bay.
- The study by City University of Hong Kong revealed that the construction works would not cause any significant impact to the oyster farming in Deep Bay and the results were accepted by the Yuen Long District Council.

Oyster farming

- To alleviate the concerns of oyster farmers in the vicinity, additional water quality monitoring was carried out along both sides of the site boundary during construction stage.



Oyster farming

- An inter-department task force comprising representatives of Highways Department, Environmental Protection Department and Agriculture, Fisheries and Conservation Department of HKSAR Government has been formed to carry out routine site inspection with special focus on the water quality in the vicinity of the site.



Oyster farming

- With the concerted efforts of the project team and Government departments, good relationship was maintained with the oyster farmers during the construction stage.

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Disturbance zone

- 10 species of birds of conservation concern are relevant to Shenzhen Bay Bridge:
 - Ardeids (4 of the 10 species) are known to be tolerant to noise and disturbance
 - Curlew, Wood Sandpiper, Redshank, Osprey and Little Ringed Plover were rare in the location of the crossing
 - Outer Deep Bay is NOT an important feeding habitat for the ardeids and Black-faced Spoonbills
- Elevation of Shenzhen Bay Bridge over inter-tidal mudflats is about 18m
- There is no cable-stay in the inter-tidal zone

Disturbance zone

- Field surveys of birds in Macau & HK bridges with similar inter-tidal habitats as Shenzhen Bay Bridge were carried out:
 - Birds can fly over or under the bridges
 - All birds were able to detect and not collide with the bridges
 - Ardeids were observed feeding underneath the Route 3 bridge
 - Black-faced Spoonbills were observed feeding at close distance (30~40m) from disturbance sources (speedboat and heavy equipment).
 - Birds nest under Route 3 flyover.
- The surveys demonstrated that there is no barrier effect nor physical disturbance of these bridges on birds.



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Bird collision with man-made structures

- The project team carried out extensive literature review of over 1500 documents spanning the last 117 years and discussed with professionals round the world on the subject.

Bird collision with man-made structures

- Key findings are:

- From statistics in North America, less than 0.02% of total annual bird mortality is attributable to bird collisions with tall, man-made structures
- Characteristics of tall structures causing bird fatalities are:
 - Height of tower structure (some over 600m, most threatening over 250m);
 - Siting of tower on prominent topographic feature that may be used by birds as navigation guide;
 - Isolated tower;
 - Tower using floodlights;
 - Tower with guy-wires that are hardly seen at night

Bird collision with man-made structures

- For Shenzhen Bay Bridge:
 - Height of cable-stayed bridge tower is much lower, only about 150m
 - Bridge location is not on prominent topographic features (ridges, mountain peaks)
 - The cable-stayed bridge is remote from intertidal zone which is the area of major bird activities
 - The stay cables are relatively large in size (about 30cm diameter, much larger than guy wires of 1cm diameter), and painted with white colour making them visible at night
 - The lighting scheme of Shenzhen Bay Bridge was carefully designed to minimise disturbance to bird flights

Bird collision with man-made structures

- Highways Department (which maintains all public bridges in Hong Kong) has no record of any bird kills due to collision with bridges. There were bird kills due to collision with transparent noise barrier panels but Shenzhen Bay Bridge has no noise barriers.
- Conclusion: bridges do not cause significant bird mortality.
- Additional precautionary measures:
 - No power lines suspended above the bridge deck
 - Cable-stayed bridge tower and stay cables should be provided with suitable lighting to increase their visibility at night to birds
 - Bridge management and maintenance personnel are required to report all cases of bird mortality on Shenzhen Bay Bridge

Solutions

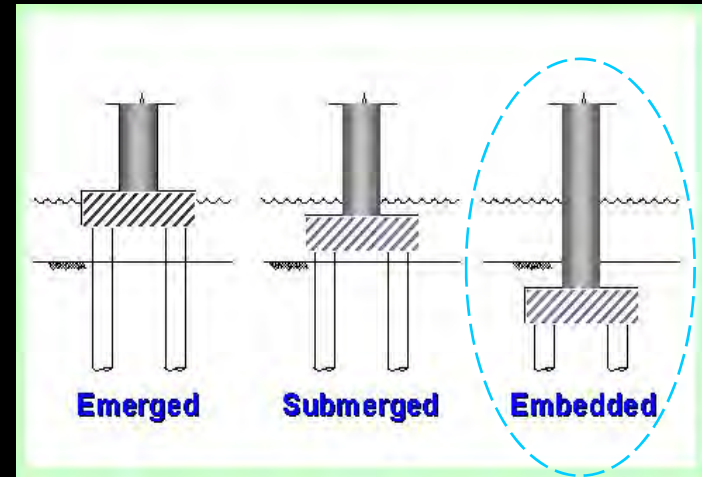
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Compensation for loss of mudflats

- To minimise permanent loss of mudflat habitat, the pile caps are buried below the mudflat



Mudflat
Reinstated



Compensation for loss of mudflats

- To minimise disturbance of mudflat habitat during construction period, construction equipment were prohibited from treading of mudflat and the Contractor was required to construct a temporary access bridge (1.8km long) over the mudflat

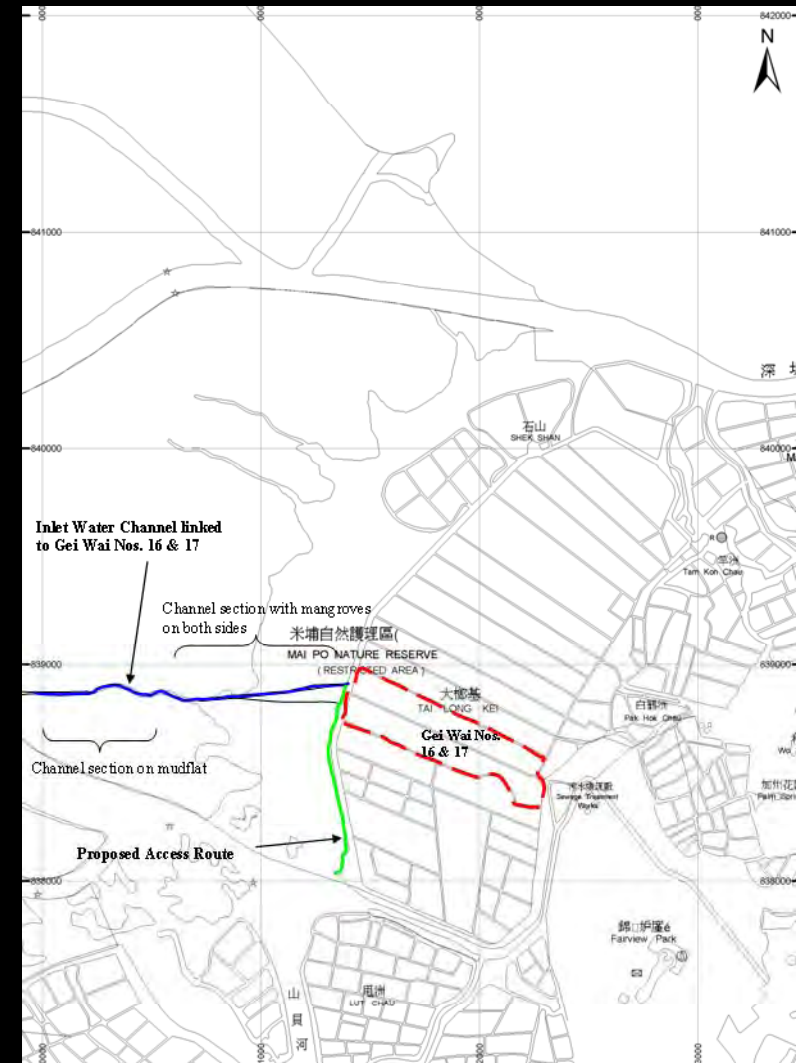


Compensation for loss of mudflats

- Our ecological survey revealed that mudflats occupied with oyster beds have a much lower bird density, indicating that the oyster clutches and the oyster farmer activities would affect bird feeding behaviour.
- As part of the site clearance exercise, a 139m wide corridor along the bridge alignment was cleared of oyster beds. This restored the feeding habitat for birds, over and above the loss of mudflat habitat during the construction stage as well as the operation stage.

Compensation for loss of mudflats

- As additional enhancement measure, we restored the function of two 'Gei Wai's (which are traditionally operated shrimp ponds) at Mai Po as core feeding ground for birds by dredging of the 1.9 km long inlet water channel linking between these Gei Wai and Inner Deep Bay



Compensation for loss of mudflats

- Dredging of inlet water channel linking Mai Po 'Gei Wai's No. 16 & 17 with Inner Deep Bay



Construction photos

- Bridge foundation construction within cofferdam and silt curtain



Working Platform



Closed grab



Cofferdam for pile cap construction



Dredging within Cofferdam

Construction photos

- Watertight temporary access bridge



Construction photos

- Watertight temporary access bridge



Watertight working platform



Drainage system



Sedimentation tanks



Wastewater treatment system

Construction photos

- Large flocks of birds fly over the construction site



Construction photos

- The mudflats and mangrove area in close vicinity to the construction site were frequently utilised by birds



News from media during construction period

- ‘A record-breaking number (262 out of world population of about 1000) of black-faced spoonbills are visiting Hong Kong this winter, proving that the Mai Po wetlands remain attractive to the rare visitors, according to the World Wide Fund for Nature’ – South China Morning Post 3rd Jan 2004.

News from media during construction period

- There was a record high of 311 Black-faced Spoonbills, which amounted to one quarter of the world population of this endangered species, recorded in Deep Bay in January 2005, based on the International Black-faced Spoonbill Census 2005. This is good demonstration that the construction of Shenzhen Bay Bridge has no adverse impact to this species.



News from media during construction period

- Oyster farmers at Lau Fau Shan announced that they have big harvest of oysters, in an article entitled ‘建西部通道水質不變，蠔情再現過肥年’ (meaning: construction of Shenzhen Bay Bridge has no change to water quality; big oyster harvest for the new year) in Express Weekly 27th January 2004.

Awards :

- The First Prize winner of Civil Engineering Paper of the Year Award 2005 organised by the Hong Kong Institution of Engineers Civil Division
- The Champion Prize winner of the 2005 Environmental Paper Award organised by the Hong Kong Institution of Engineers Environmental Division and Hong Kong Construction Association
- Winner of UK IStructE Structural Awards 2006 (Sustainability category)



Postscript :

- **Green measures of Shenzhen Bay Bridge include:**
 - **Preservation of the existing natural environment**
 - **Produced cost-effective solutions**
- **The project demonstrated that a mega scale infrastructure development can harmonise with an ecologically sensitive environment**



Thank You