Low-lying Singapore:
Reimagining our coastal landscape for sea-level rise adaptation

text by
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Rising sea level in singapore

Singapore, as a coastal city-state, is especially susceptible to the effects of climate change and, in particular, rising sea levels. The National Climate Change Secretariat has projected the mean sea level to rise by up to 1 meter by 2100 (NCCS[1]). Any additional increase caused by heavier and more frequent rains would be an immediate threat to a third of the city sitting less than 5m above sea level. At the same time, coastal areas can be expected to be more intensively utilized as mixed-use developments, as gazetted in Singapore’s 2030 Master (URA[2]). From previous trends, it can be estimated that by 2030, up to 86% of coastal protection will employ man-made infrastructures (Samantha, 2014[3]), thus increasing coastal erosion and negatively impacting the natural environment. Singapore’s coastal ecosystem has also been drastically altered over the past few decades with a significant loss of natural coastal habitats - 83% of the total shoreline have been transformed from mangrove forests, natural sandy shores, and mudflats into seawalls or artificial beaches (WildSingapore[4]). This trend towards a mono-functional, static and disconnected sea-land interface must not be ignored.

Ongoing efforts on sea level rise adaptation

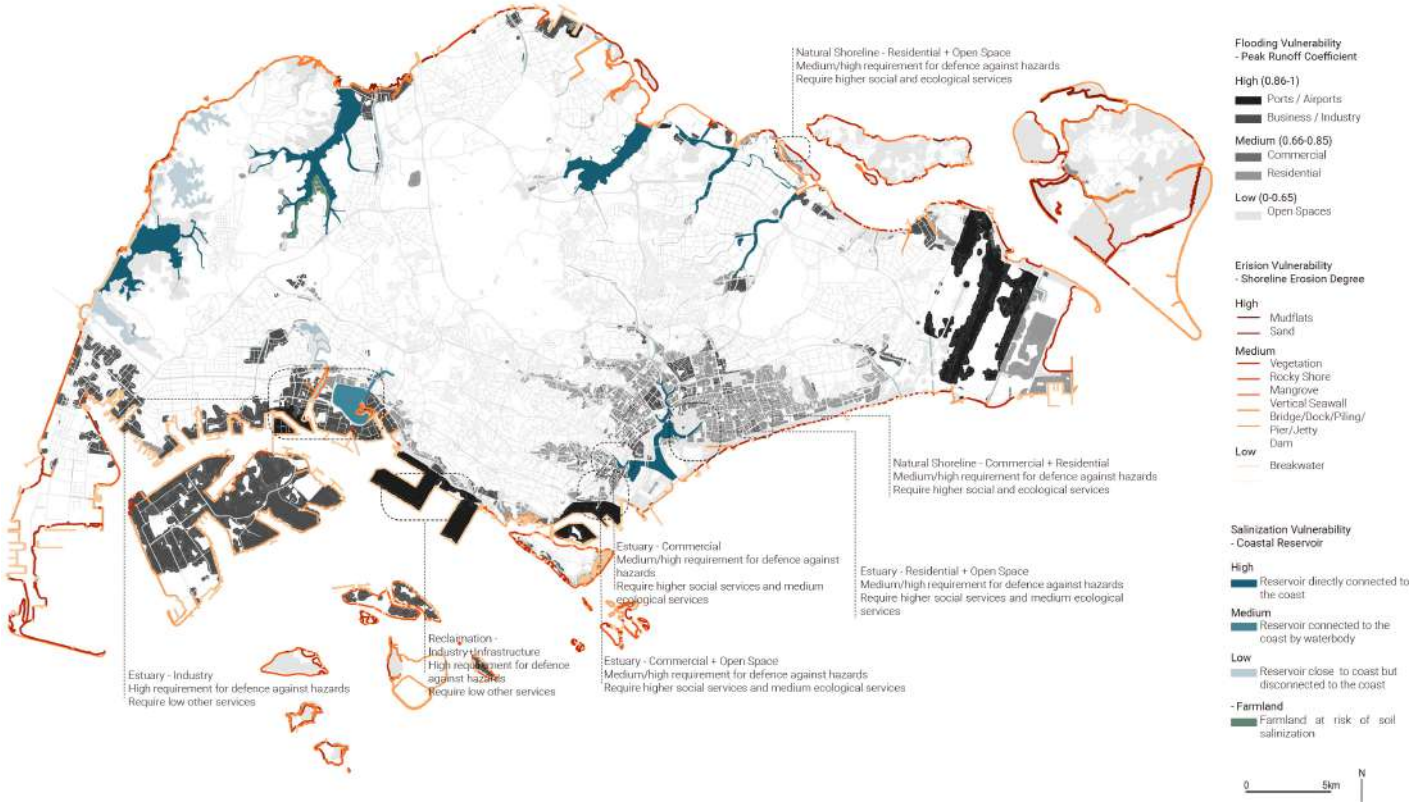
The government has made sea-level rise adaptation a vital agenda to Singapore’s existence. Their plans include port relocation, flood mitigation and inclusive large-scale coastal development planning strategies. Port operations will be consolidated to Tuas by 2040, freeing up land for future coastal development. The Public Utilities Board (PUB) has been encouraging the implementation of flood-mitigation structures and strategies, including flood-proof buildings, elevated buildings, elevated roads, flood gates, and water sensitive urban design (WSUD). The Greater Southern Waterfront, Northern agri-tech and food corridor, and the Greater Rustic Coast along the northern shoreline are URA’s coastal development masterplans geared towards sea level rise adaptation. On the eastern shoreline, coastal protection plans include the use of polders, dykes, a series of reclaimed islands, barrages and a coastal reservoir as buffers against inundation.

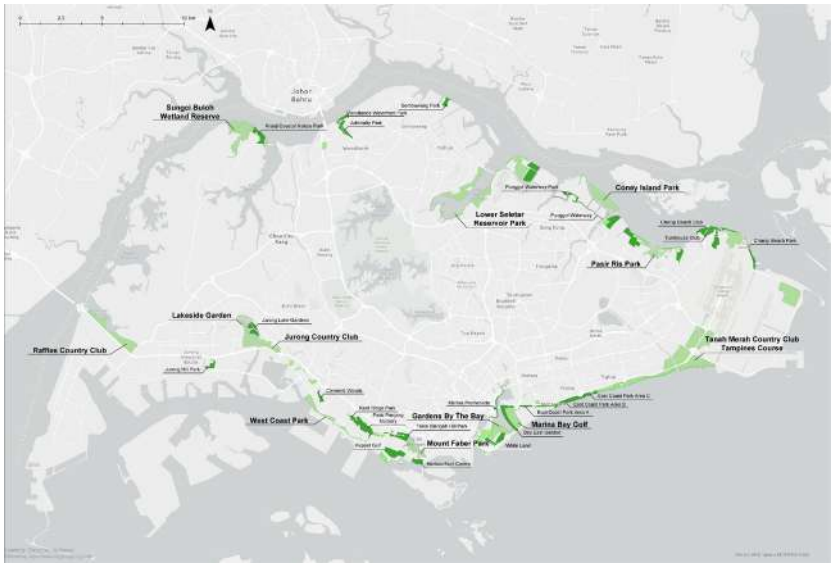
Design studio

In line with these efforts, the low-lying Singapore studio, a course module at the National University of Singapore[5], was set up as a platform for design instructors, students, practitioners and other professionals to collaboratively investigate the following questions. What existing coastal landscape typologies and developments are vulnerable to sea-level rise? How can they be retrofitted to not only ensure sufficient coastal protection but also uncover creative and unexpected land development methods that would otherwise be eclipsed by conventional planning processes? How can these new design approaches facilitate multi-functional land-use and cohabitation of human and coastal ecosystems?

The design studio uses the extreme challenge of planning for the next 100 years in anticipation of a 3-metres sea-level rise to elicit bold, imaginative and innovative ideas that would, hopefully and in turn, catalyse new approaches in the industry. A wide range of analyses were done to form a basis for further investigation. The analyses include coastal vulnerability of land-use within 3km inland from the coastline (Figure 1); locations and landscape typologies of recreational spaces (Figure 2); and coastal accessibility and pollution maps (Figure 3 and 4).

Fig 1.
Coastal Vulnerability and Hazards Analysis.
This map overlays land use and built-up density along the coast with topography and shoreline typologies to reveal areas of flooding, erosion and salinization vulnerability.
(Image credit: Li Wanying)





Top & Bottom / Fig 2.
Locations of coastal recreational spaces (top) and categorization of coastal recreational spaces into spectrums of soft to hard structures, versus high to low accessibility (bottom).
(Image credit: Top - Zhang Liao Judy, Bottom - He Xiaowei Ceama, Lam Ching Hang Adam, Li Xi Emily, Zhang Liao Judy)

Seemingly unrelated land-uses, when analysed in overlays, reveal unexpected opportunities for design intervention. This comprises topics that may appear remote to some, such as land freight (in relation to shipping), naval defence, oil refinery (in relation to water pollution), as well as vistas from sea to land and vice versa. For example, one of the most biologically diverse coral reefs in Singapore, the Cyrene Reef, is found off the southern coast of Singapore. One condominium, for instance, included a marine viewing deck to encourage coral colonization while redefining lifestyle enhancement as part of its response. Likewise, development in the north-western coast could benefit from a more symbiotic relationship between agricultural productivity and coastal biodiversity. Several of our students' work directly address some of the above-described potentials. These, as well as their analyses, can be viewed at the studio book[6].

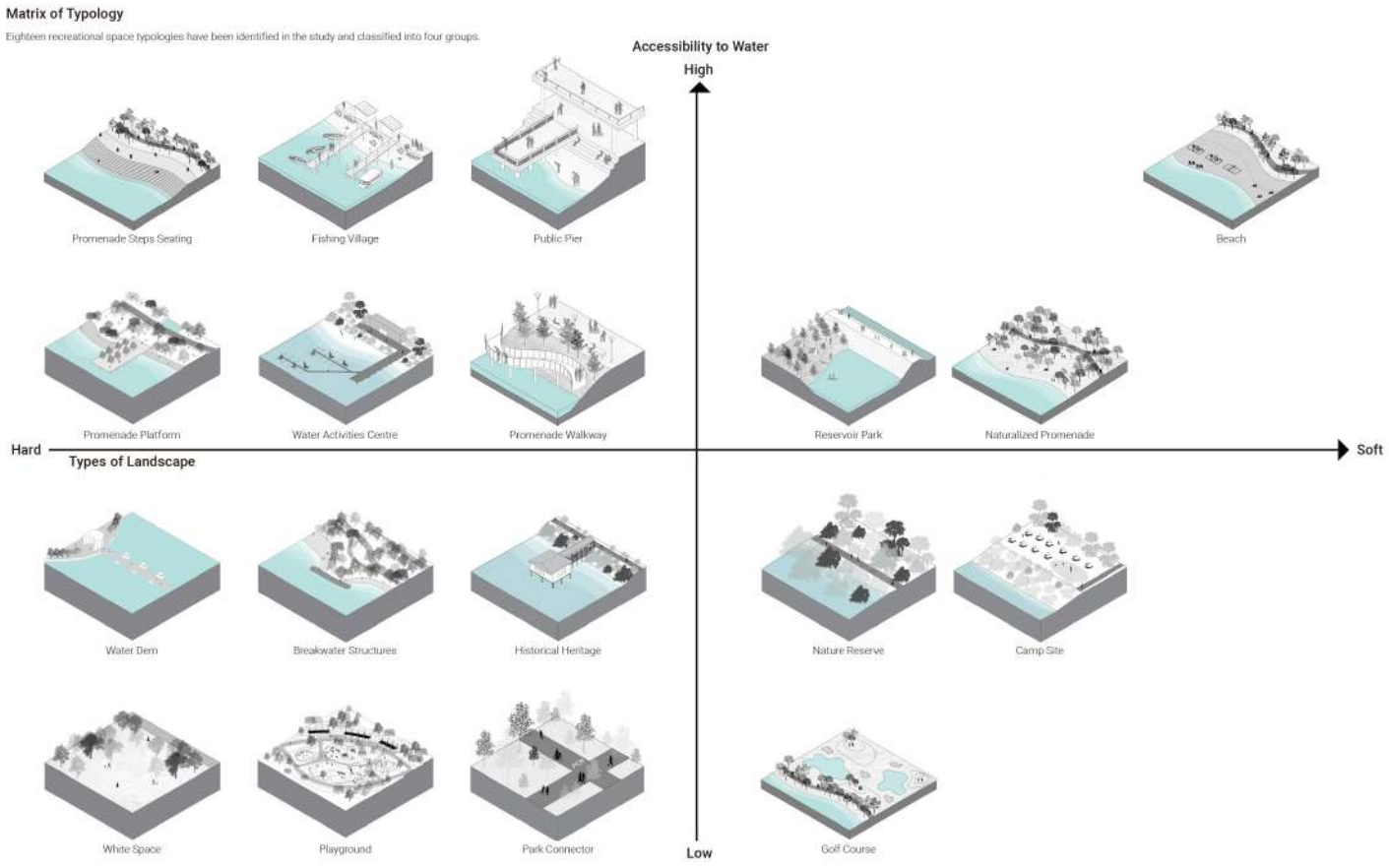


Fig 3.
Mapping different types of land use and pollution (types and intensity) is also crucial for understanding where public access is safe and appropriate. The southwestern coast of Singapore is set aside for industrial use and will remain so for the foreseeable future. As the northern coastline transforms into an agricultural / ecological conservation / recreational band, the industrial zones there will also slowly move to the southwest. So will shipyards and oil refineries along the southern coast as it makes way for more waterfront living spaces.
(Image credit: Hao Jun, Long Di)

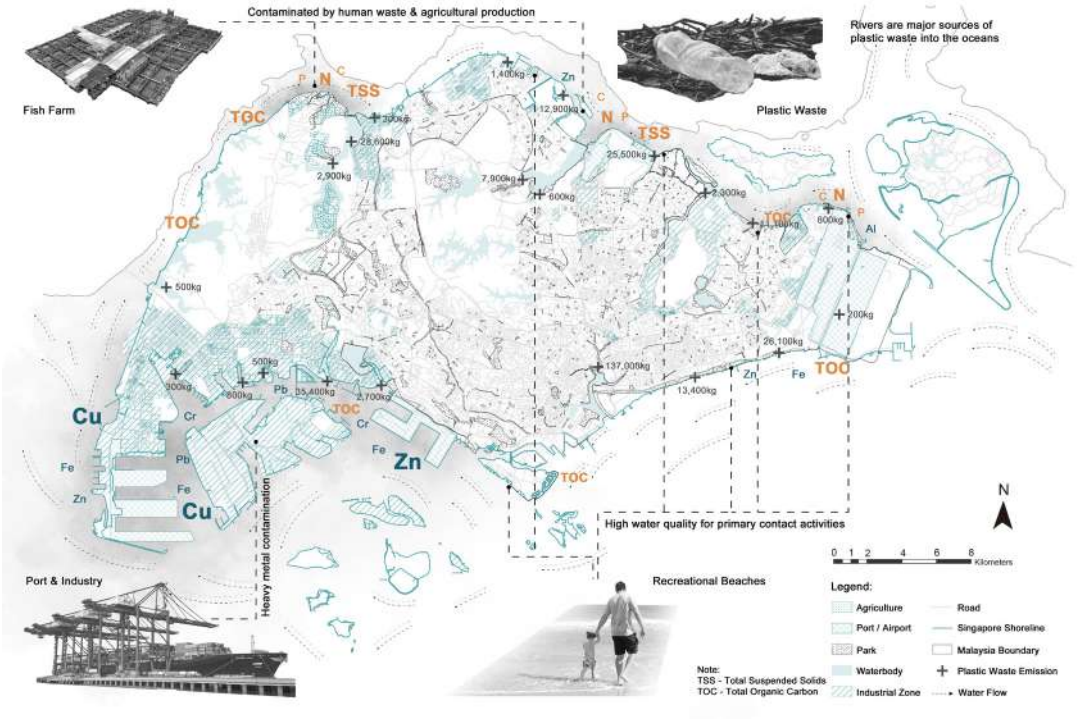
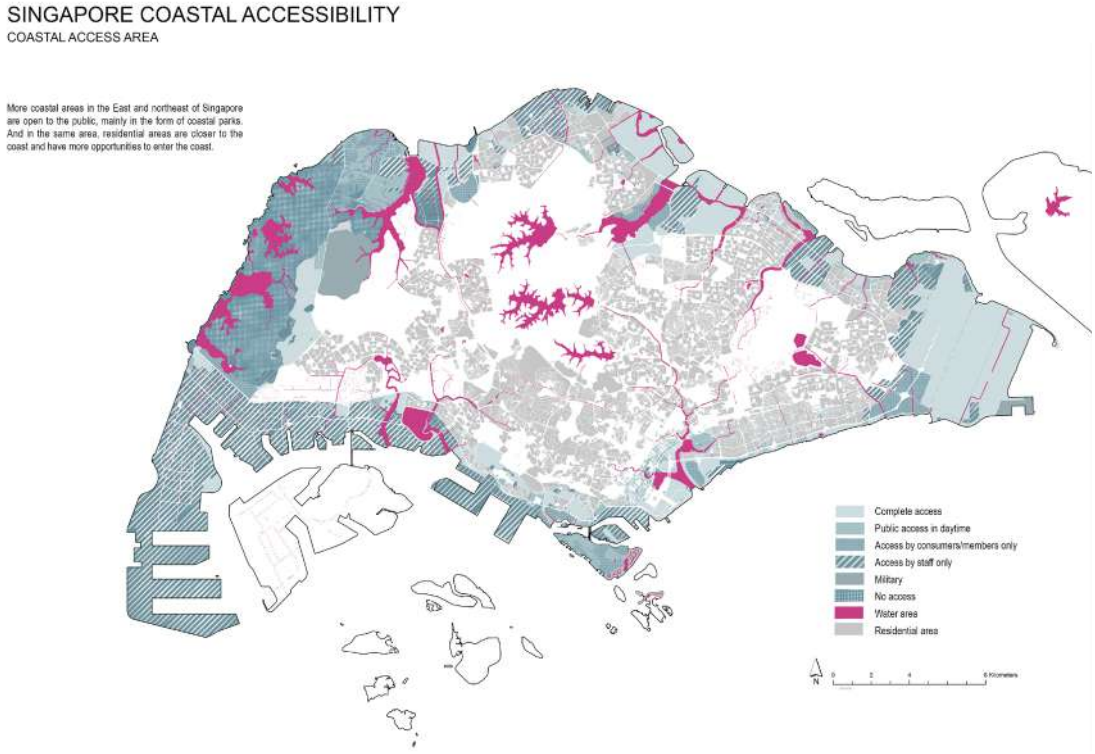


Fig 4.
Coastal accessibility map, indicating that less than 50% of the coast is completely accessible to the public. Overlaid with Figures 2 and 3, it reveals a potential for the development of more and a wider variety of public recreational spaces along the shoreline.
(Image credit: Xiang Wenqin)



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One condominium, for instance, included a marine viewing deck to encourage coral colonization while redefining lifestyle enhancement as part of its response.

The following four lessons are derived after surveying the students' completed works. It reveals paradigm shifts, as well as new approaches and skills that the landscape design industry would need to embrace in order to address sea-level rise in a compelling manner.

Lessons from design outcomes

1. The new aquatic terrain

Landscape architects pride themselves in the intimate relationship that we have with the land. Home ground thus far is terra firma - the ground as distinct from the sea. Undoubtedly, we embrace riparian and coastal habitats and study them attentively. However, it seems necessary to delve into deeper waters and venture further offshore to break away from expected outcomes. We need to imagine beyond current engineering limitations and explore not only different types of floating or drifting structures, but also submerged ones.

In this way, instead of losing ground, we are potentially gaining real estate in the form of marine landscapes. Studio projects showcase this paradigm shift. To design realistically, we depended not only on conventional topographical maps, but also marine cartographic charts, tapping into information and technology that the nautical industry is more typically familiar with. This delineated the appropriate underwater levels where while sensible and seamless vertical connections to on-land structures can be choreographed.

The following three projects proposed such marine landscape typologies. "Amphibious sports park' leverages sea-level rise as an opportunity to remodel the terrain into a triple-level terraced buffer. It provides flood-protection while encouraging habitat development and ecological diversity. The spaces created also facilitate exploration of a wider variety of human aquatic activities. "Revival" brings art galleries and performance venues underwater, offering a rare oceanarium experience. Meanwhile, underwater structures interrupt the flow of incoming waves, thus protecting the coast. "Dockscape" proposed the relocation of an existing ferry terminal anticipated to be submerged by sea-level rise. The existing ferry terminal is allowed submersion and eventual preservation as an underwater cultural artifact, where divers can explore like a shipwreck (Figure 5, 6, 7).

Left / Fig 5.
"Dockscape" proposed the relocation of an existing ferry terminal anticipated to be submerged by sea-level rise. The existing ferry terminal is allowed submersion and eventual preservation as an underwater cultural artifact, where divers can explore like a shipwreck (Image credit: Fang Ting).

Right / Fig 6.
"Amphibious sports park' leverages sea-level rise as an opportunity to remodel the terrain into a triple level terraced buffer. It provides flood-protection while encouraging habitat development and ecological diversity. The spaces created also facilitate exploration of a wider variety of human aquatic activities. (Image credit: Hao Jun)

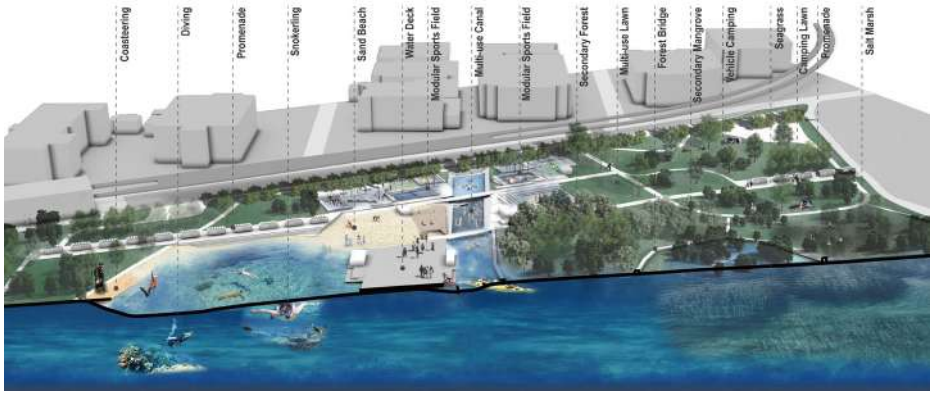
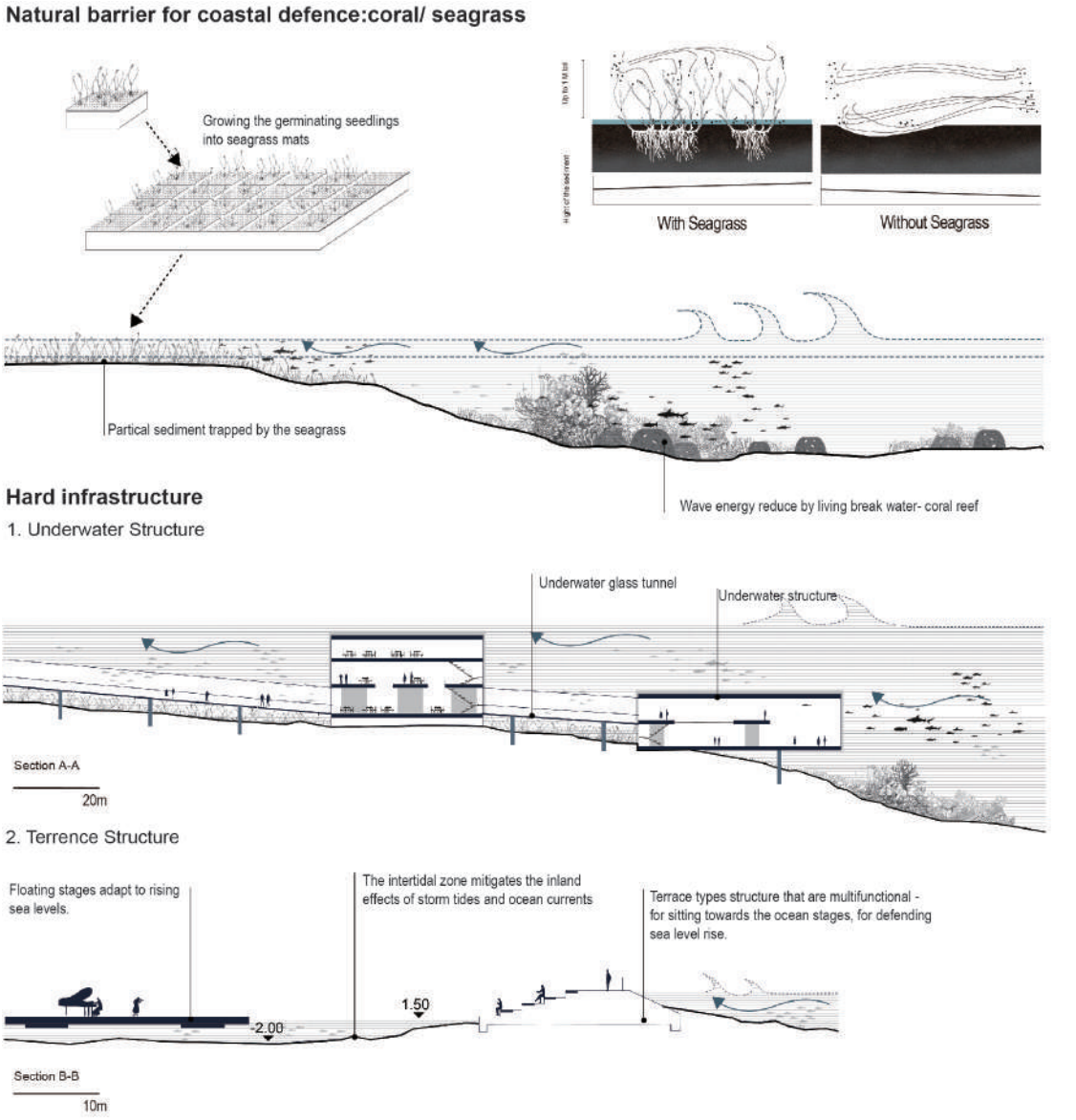
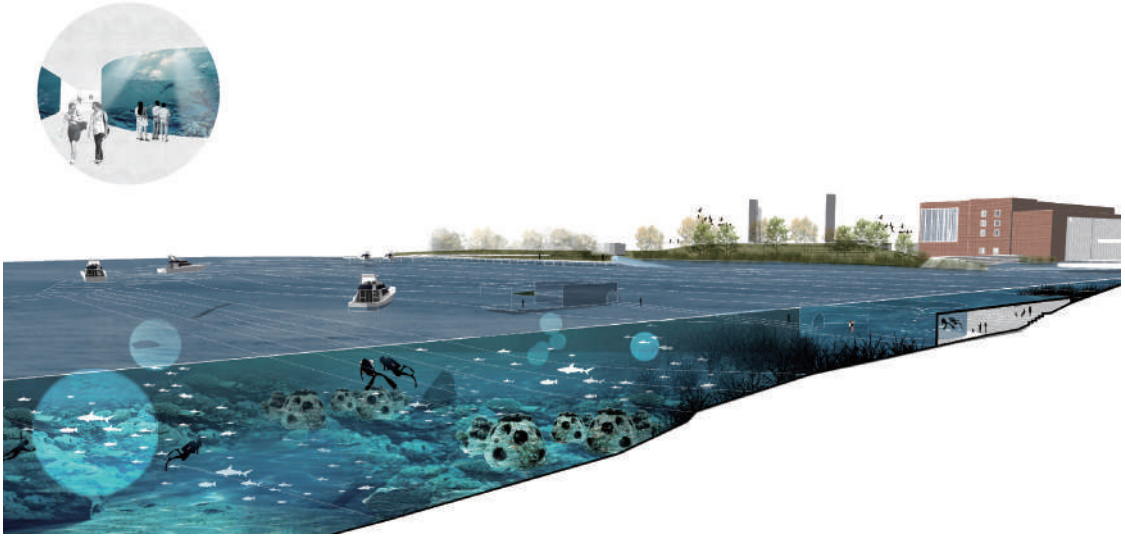


Fig 7.
"Revival" brings art galleries and performance venues underwater, offering a rare oceanarium experience. Meanwhile, underwater structures interrupt the flow of incoming waves, thus protecting the coast. (Image credit: Hong Mengyi)





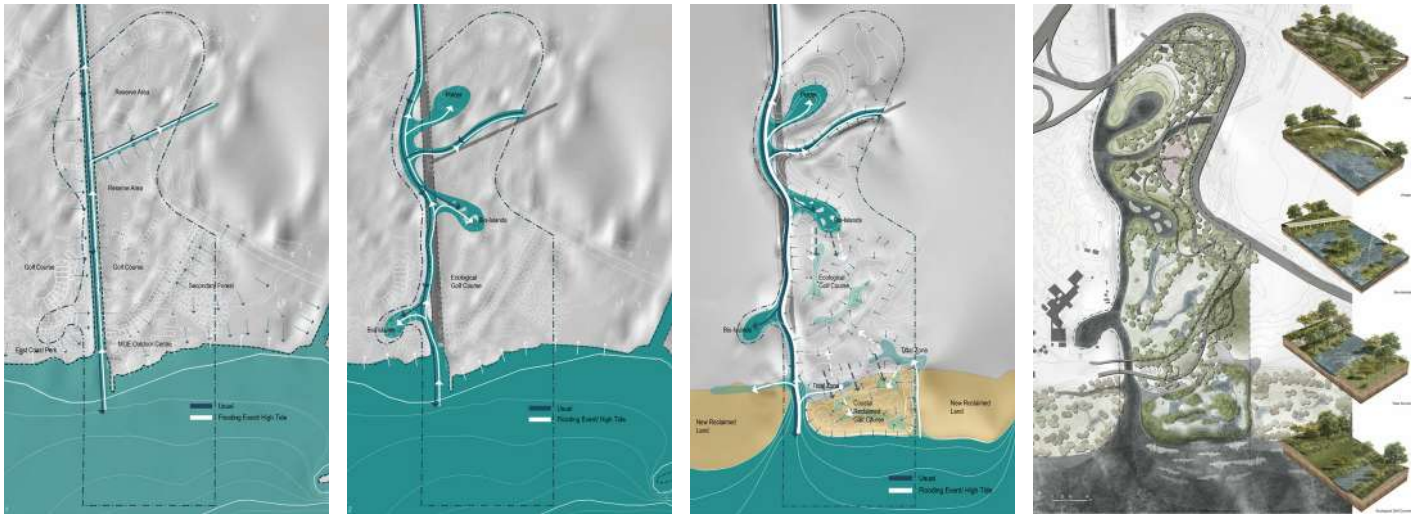


Fig 8.
"Guardian of the City". (Image credit: Zhang Liao)

2. WSUD on steroids

The main algorithmic operators in a typical in-land WSUD project are water quality, water velocity and water retention/detention capacity. In the coastal context, however, one is forced to ask some pressing and complex questions. How far inland can storm surges be expected to go? In what direction and at what velocity do the ocean currents hit the coast and what patterns of turbulence occurs thereafter, both in the X-Y planes and the Z plane? If retention / detention must be catered for in both the seaward and land-ward directions, can they be one and the same? Closer working relationships with coastal engineers and coastal geologists, as well as basic understandings of typical coastal geological formations are indispensable tools in tackling sea-level rise.

"Guardian of the City," is a studio project proposing the conversion of reclaimed land, currently threatened by sea-level rise inundation, along east coast park into an ecological golf course. The terrain was shaped to not only guide water along dedicated streams outflowing to the sea, but also back inland during high tides. Longer-term sea-level rise backflow is also catered for. Water will also be detained in polders for sustainable irrigation of the golf course (Figure 8). "In-between landscapes" demonstrates an elegant shaping of the land to facilitate a robust application of WSUD for stormwater management and water purification while preventing contamination from sea-level rise and cultivating brackish ecological habitats (Figure 9).

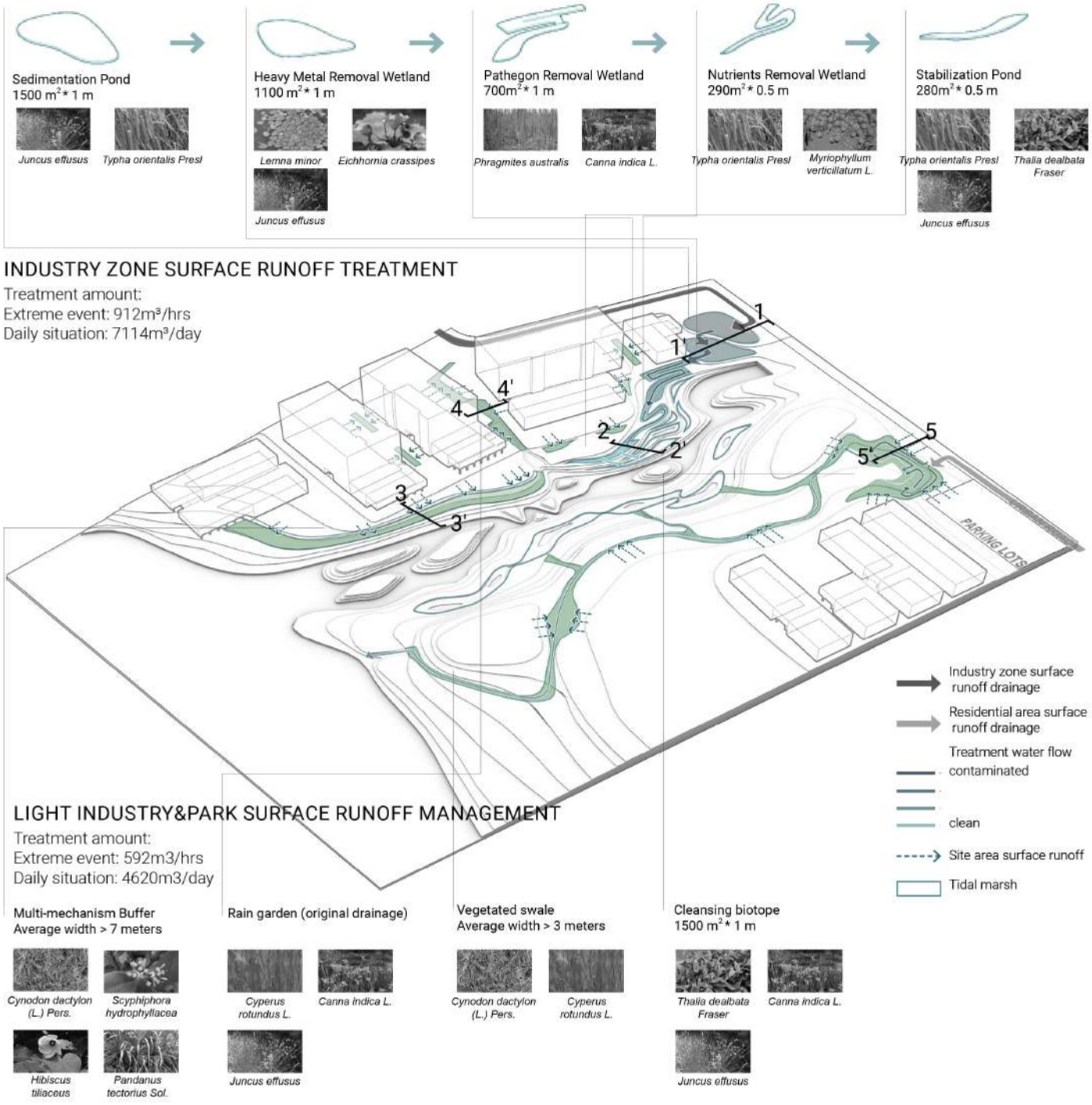


Fig 9.
"In-between landscape" proposes an open space mitigation between industrial and recreational spaces at the edge of West Coast Park. (Image credit: Li Wanying)

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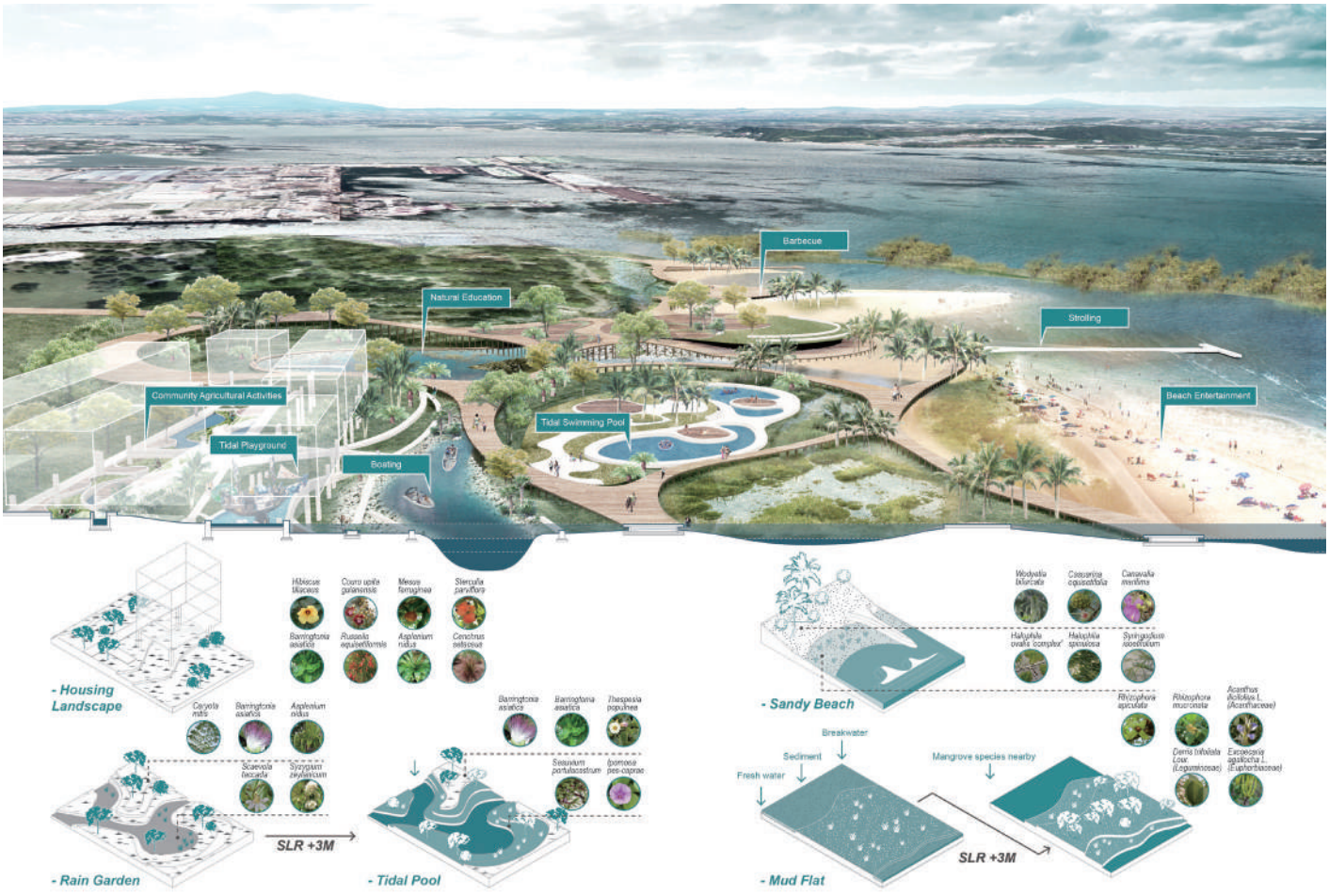
3. Brackish ecology

Tropical seascapes consist of a great diversity of coastal habitats - mangrove, seagrass, coral reef, mudflats, sandy shores, rocky shores, estuaries, sea walls, and subtidal benthic habitats. Each of these habitats have specific preferred conditions in which they thrive - depth of water, level of pollution and oxygenation, sunlight penetration and water velocity etc.

A student analysis indicated that beaches in Singapore have exceptionally low biodiversity and are very narrow, with none on the main island wider than 50m. As a response, a beach restoration proposal, “futuristic is past” boldly extended the beach to an unprecedented width. A variety of ecological habitats were created along this beach and a lost kampung heritage is evoked by bringing the beach right up to the existing modern housing stock (Figure 10), thus creating a coastal building typology non-existent in Singapore. Residential green spaces, recreational open spaces, and urban parks work as multiple buffers of coastal protection (Figure 10).

Fig 10.
“Futuristic is past” restores a degenerated beach typology to increase biodiversity and facilitate complex multi-functionality of space.
(Image credit: Huang Xi)



In dense urban conditions, mangrove forests have no space to retreat backwards when sea-level rise, thus relegating it to eradication. To address this problem, “Retreat forward” explores land reclamation further offshore beyond the mangrove forests as a method of not only protecting them against sea-level rise, but also eventually extending their width. Meandering water channels form linked pools of prawn farms that guide sedimentation, slowly transforming them into mudflats, suitable for mangrove propagation (Figure 11).

Fig 11.
“Retreat forward” proposes a new prototype for nature-based land reclamation.
(Image credit: Long Di)

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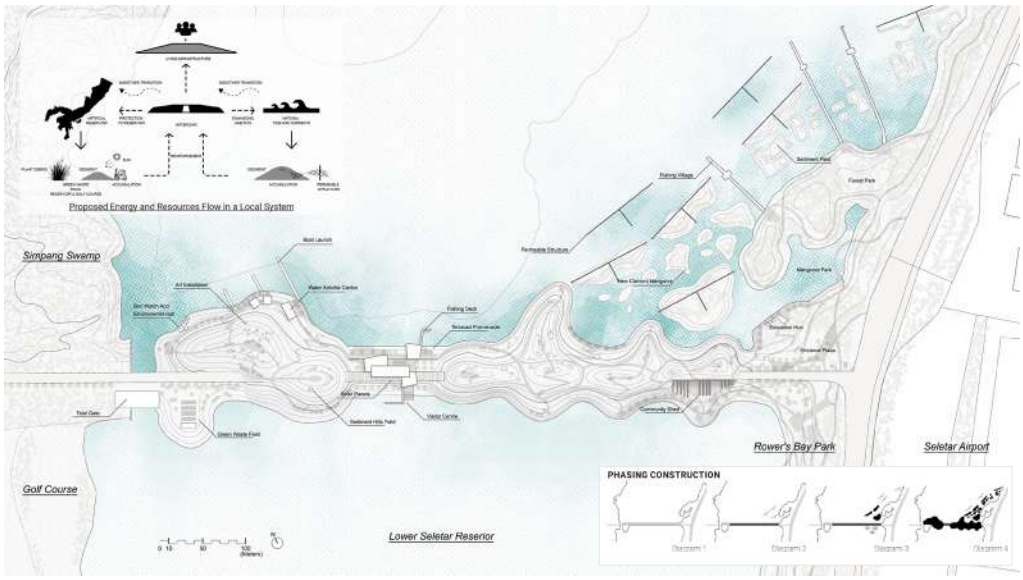

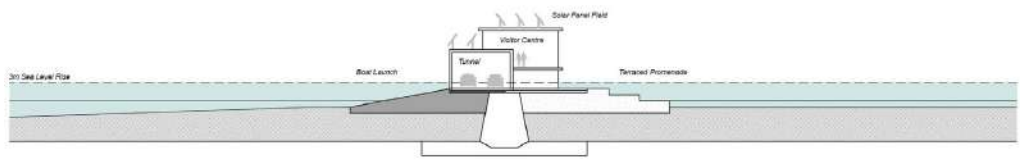

Bottom / Fig 12.
"Living Infrastructure" boldly transforms a transportation infrastructure into an ecological spine that supports, flora, fauna and human recreation while protecting the reservoir from sea-level rise contamination. (Image credit: Lam Ching Hang, Adam)

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The issue of sea-level rise is such a wicked one that it behoves one to not to jump headlong into designing but seek first to understand the complexities of the issues related to sea-level rise in the specific context of Singapore. This is where the interface between academia, practice, and governmental regulation can be more thoughtfully navigated to harness maximum synergy.

4. Inhabiting infrastructures

Traditional coastal protection infrastructures can be colossal, stark and mono-functional as to make urban landscaping that much more challenging. Before even considering how to facilitate the coexistence of ecology and urbanity, the designer must first consider scale and socio-economic functions more thoughtfully. Several infrastructure-retrofit projects, such as the High Line in New York City, or Zollverein Park in Essen, Germany, do this ingeniously. What is less commonly seen is the incorporation of life cycle thinking in both its construction and subsequent ongoing use. The ability to anticipate future modifications facilitate flexibility of change as it becomes outdated, as well as on-site resource management. When multi-functional human- and fauna-friendly experiences are already built into the process of developing the infrastructure, it allows organic morphology.

"Inhabiting infrastructure" takes on the challenge to do just. Anticipating sea-level rise to threaten the integrity of the separation between sea and drinking water at the estuarine Lower Seletar Reservoir, the existing Yishun Dam is envisioned to be retrofitted into a "living" infrastructure. A tunnel was proposed to be constructed over the existing road to increase the platform level, while a new terrain forms around and above it through the accretion of coastal sediments brought by tide and currents, as well as green waste from the reservoir and nearby golf courses. It is envisioned to be multi-layered. The ground surface is used for generating energy, diverse community recreational functions, and coastal habitat enhancement, while the engineering functions such as a heavy road traffic and tidal barrier are kept subterranean. It is also multi-scalar, with visitor centres and comfortably scaled social and recreational spaces embedded into, and coexisting with, mega structures such as tunnels and wind turbines (Figure 12).

ACKNOWLEDGEMENTS

Much of the work here was done by the student participants in Low-lying Singapore studio.

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Conclusion

In his book "Range: Why Generalists Triumph in a specialized world," David Epstein contemplated, "whether chemists, physicists, or political scientists, the most successful problem solvers spend mental energy figuring out what type of problem they are facing before matching a strategy to it, rather than jumping in with memorized procedures." The issue of sea-level rise is such a wicked one that it behoves one to not to jump headlong into designing but seek first to understand the complexities of the issues related to sea-level rise in the specific context of Singapore.

This is where the interface between academia, practice, and governmental regulation can be more thoughtfully navigated to harness maximum synergy. Research and educational organizations could invite practitioners, consultants and government agencies for input and involvement in studios, workshops, symposiums and conferences. Plentiful rounds of such audacious paper projects are necessary in the early stages, to tease out the undetected issues that might arise. They will likely encourage pilot projects, this time initiated by practitioners, to confirm feasibility. When these become commonplace, best practices and case studies can then be consolidated to form the bedrock of a tried and tested set of guidelines galvanized by the governmental bodies.

Such a roadmap is flexible enough to accommodate a curiosity that sparks uncommon solutions, yet robust enough to encourage a conviction towards a viable outworking. May it give us faith that sea-level rise, this Goliath of an issue, is not as arduous as it is intimidating.

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4 http://www.wildsingapore.com/wildfacts/concepts/loss.htm

5 25 master-level graduate students from the architecture and landscape architecture programmes took part in this 14-week long module which began in Jan 2021. In this form, the studio is "a forum for speculative ideas taken through to a degree of resolution", valuable not just as a pedagogical tool, but also as a setting for landscape architecture research.