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a case study of the Port-Industrial Complex Kuala Tanjung**

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From Building *in* Nature to Building *with* Nature©: a case study of the Port-Industrial Complex Kuala Tanjung

Large scale infrastructure, of which ports and related industrial complexes are a major part, can help to unlock the economic, social and ecological potential of delta regions. Large scale infrastructure planning traditionally follows a “building in nature” approach, focussing on impact minimization, mitigation and compensation. “Building with Nature” constitutes a radical shift from “building in nature”, by focussing on opportunities for ecosystem services development and the utilization of natural processes in realizing (part of) the functionality of the design. This paper investigates the potential of the Building with Nature approach for the development of sustainable ports by comparing an ‘in’ and ‘with’ nature master plan for the Kuala Tanjung port-industrial complex. By **Alexander van der Hoek**, **Poonam Taneja** and **Mark van Koningsveld**

Developing sustainable ports

Building with Nature provides guidance to develop ports in a sustainable manner. Where the traditional “building in nature” approach conducts an Environmental and Social Impact Assessment (ESIA) after identifying alternatives, Building with Nature begins by studying and understanding the physical and ecological system before developing alternative solutions and the ESIA is conducted in parallel to the design process. Building with Nature widens the solution space and is more likely to identify win-win situations for businesses and society as well as for nature, which might otherwise be overlooked.

For a port, it is vital to attract international investors and multinationals. It is therefore important to develop and operate ports in accordance with the international environmental and ecological standards that influence investments decisions. At the same time, adaptability has become increasingly important in our fast changing and uncertain world while respect for local nature and society in port development and operation is of growing concern in attracting port investments. Incorporating the wide scope of international environmental and social standards in port design is becoming increasingly challenging. Building with Nature offers an alternative approach to traditional port development by taking a wider scope by considering international environmental and social standards, stakeholder objectives, and port functional requirements as a starting point.

This paper revisits the existing master plan for the development of the Port of Kuala Tanjung in Indonesia. The Port of Rotterdam together with the local port authority Pelindo 1 are working together in a joint venture to realise this project. The development of the master plan is driven by functional requirements and follows a traditional Building in Nature approach. The Building with Nature approach is used to guide a redesign of the Port of Kuala Tanjung in following steps. First, a general evaluation framework is set up in order to embed the redesign in international environmental and social standards. Second, the natural system of Kuala Tanjung is studied, and third a global inventory of Building with Nature solutions related to port development is drawn up from the available Building with Nature literature. The general framework, understanding of the local ecosystem and the inventory of Building with Nature solutions are then applied to the Port of Kuala Tanjung project to identify opportunities to improve the current master plan. The redesign includes the growth of mangroves along the breakwaters. Studying the feasibility of mangrove development along the breakwaters resulted in a checklist with biotic and abiotic conditions for applying mangrove-based protection that is also applicable in other port development projects.

General evaluation framework for port development

The ambition to build a world-class port implies that world-class standards must be applied in contracts and rules & regulations. Also, the Port of Rotterdam, a major partner in more such projects around the world, has its own mission and vision and Corporate Social Responsibility statement for both their port activities in Rotterdam and international port projects. Based on a wide range of relevant international standards, and the Port of Rotterdam vision and Corporate Social Responsibility statement, a general framework for the evaluation of port developments is drawn up. The framework consists of 36 standards in the categories financial, social, environmental and governance, abstracted from 12 international documents applicable to port development, among which the OECD Guidelines for Multinationals (OECD, 2011), United Nations Sustainable Development Goals (UN, 2015), Port Vision 2030 (Port of Rotterdam, 2011) and the Ecoshape Building with Nature Guidelines (Ecoshape, 2018). Some relevant requirements for port development mentioned in various standards are presented in Table 1 for each of the categories.

Category	Statement of requirements	Source
<i>Financial</i>	The project generates extra cargo flow to Rotterdam and strengthens the competitive position of the Netherlands.	Port Vision 2030 (Port of Rotterdam, 2011)
	The project stimulates the national economy of the host country.	Expert opinion PoR (2018), Annual Report PoR (2017), IFC (2012)
<i>Social</i>	Close co-operation with the local community is encouraged.	OECD Guidelines for Multinationals (2011), Expert opinion PoR (2018), Annual Report PoR (2017)
	Human rights (of workers) are supported and protected in doing business.	UN Global Compact (2015), Annual Report PoR (2017), UN-SDG (2015), OECD Guidelines for Multinationals (2011), IFC-PS 2 (2012)
<i>Environmental</i>	The project is sustainable according to the Paris Agreement to combat climate change.	Port Vision 2030, Annual Report PoR (2017), Expert opinion PoR (2018), UN-SDG 13 (2015)
	The ecosystem services provided by the system are identified before the design phase is initiated and possible new ecosystem services are explored.	Building with Nature Guidelines (2018)
<i>Governance</i>	Abstain from any improper involvement in local political activities. Local political stability is needed.	OECD Guidelines for Multinationals (2011), Expert opinion PoR (2018), Annual Report PoR (2017), Strategy PoRint (2018)
	The project is executed according to the host countries rules and regulations.	EHS-IFC (2012), Annual Report PoR (2017), Expert opinion PoR (2018), UN-SDG 16 (2015)

Table 1 Some examples of requirements for port development in various standards

The framework is applied to both the current Building in Nature master plan and the Building with Nature redesign by simply checking adherence to the requirement with a yes or a no. Strictly adhering to all the requirements is not possible; the framework is therefore to be used as a tool to improve and guide the design process towards a more sustainable and inclusive design.

Port of Kuala Tanjung

Kuala Tanjung is a large port-industrial complex situated in North Sumatra, Indonesia, north west of Singapore on the heavily shipped strait of Malacca (figure 1). Further development of Kuala Tanjung has a high potential to stimulate local and national economy and is bound to have major impact on the surrounding social and ecological environment. Indonesia is already South East Asia's largest economy and is expected to be the 4th biggest economy in the world in 2050. Indonesia counts an estimated 17.000 islands and its economic functioning depends on efficient ports and large scale industrial development. In December 2017 a plan was presented for the extension of the Port of Kuala Tanjung, which would become the country's largest international hub once finished. The dense shipping traffic of the Malacca Strait and the populous hinterland (over 50 million inhabitants in 2014) make this port project attractive for international investors.

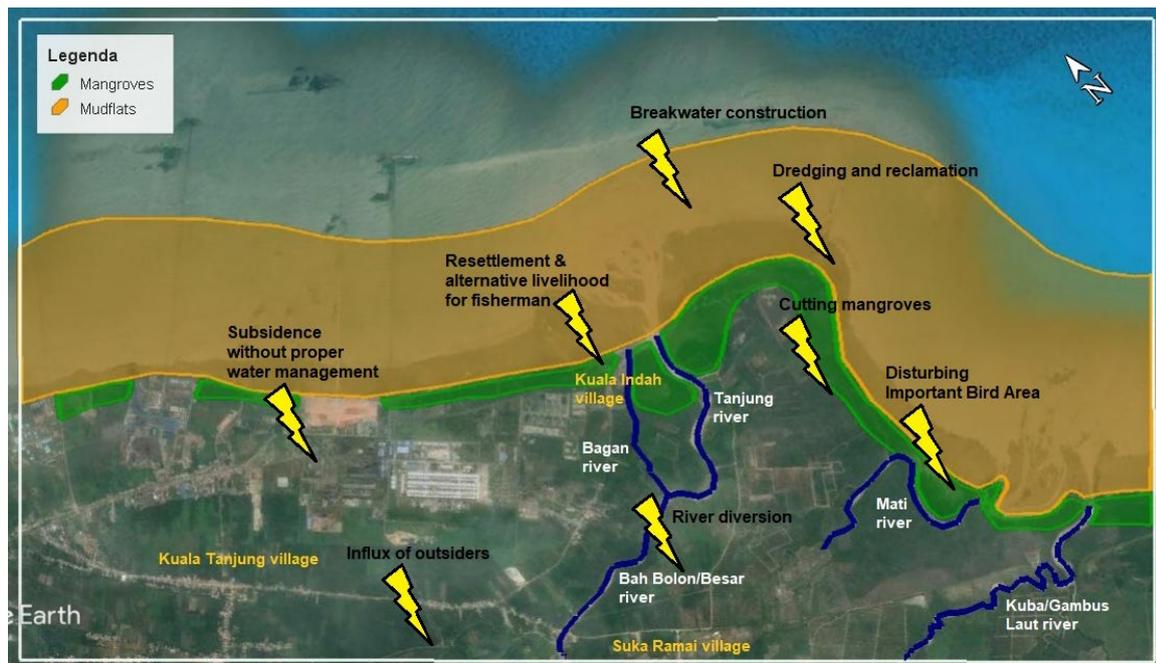


Figure 1 Location, natural system and impacts of Kuala Tanjung port development

Master plan: in nature

The impacts of the current master plan of the Port of Kuala Tanjung on the natural system is illustrated in figure 1. In keeping with a traditional approach, an Environmental and Social Impact Assessment (ESIA) was conducted after a preliminary functional design of the port development and subsequently mitigation and compensation measures were proposed. The master plan is not in accordance with the Building with Nature guidelines and the international standards in the evaluation framework. The current design only adheres to 15 of the 36 requirements. For example, to make room for the project a village of fisherman needs to be resettled and the main Bah Bolon river needs to be diverted. Moreover, it is still unclear whether there is enough sand available for the planned reclamations. Most of the suggested measures to mitigate the impact of the port development are compensation measures. The importance of the delta, which forms the interface between salt and fresh water, is mentioned several times and so are the mangrove areas as sources for biodiversity and coastal protection. The proposed compensation for destroying the present mangroves is a replanting program which gives the requirements for mangrove replanting in general terms: replanting should not be a one-time deal, it should involve multiple species, and follow natural

succession of mangrove habitat. Replanting mangroves is however not elaborated upon in the current master plan, nor is it incorporated in the design. In addition, beneficial use for the material dredged during the Bah Bolon river diversion, the approach channel, and harbour basins are not incorporated in the current master plan.

Based on the evaluation, it is concluded that the master plan of the Port of Kuala Tanjung was mainly driven by functional requirements and economic growth, while trying to mitigate and compensate the negative consequences. The evaluation of the current master plan and relating its weaknesses to their root causes in the design of the breakwater, river diversion, and required land acquisition, helps to identify opportunities to improve the master plan, not only by including mitigation and compensation measures but by adapting the entire design.

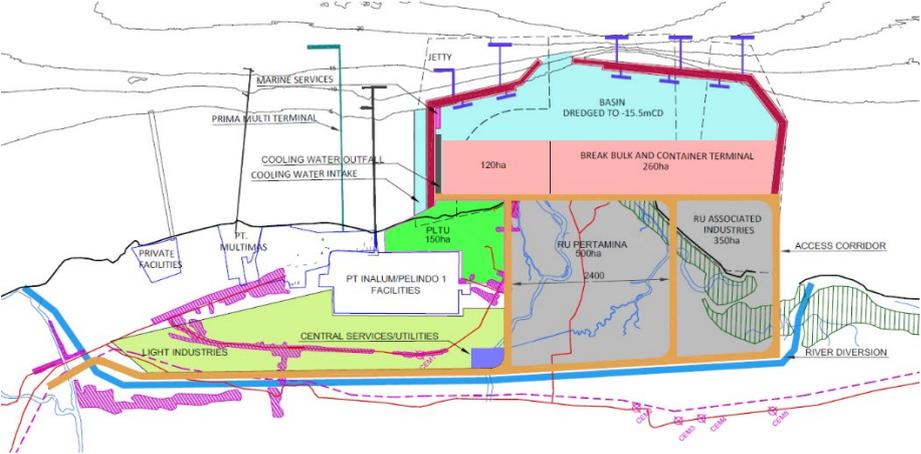


Figure 2 Proposed final phase technical design with internationally competitive container terminal (RHDHV, 2017)

Master plan: with nature

The potential impact of implementing the Building with Nature approach in the ‘traditional’ master plan of the Port of Kuala Tanjung could be large since this project is still in the initiation phase. However, there are some limitations in applying the Building with Nature philosophy, the most important being the project location, which has been selected for strategic and financial reasons. Compared to other ports at the strait of Malacca, the Port of Kuala Tanjung does not have a large inland waterway (like the port of Medan), natural protection from waves by an island (harbour of Kuala Lumpur) or a good existing infrastructural network and sandy environment (port of Singapore). Nevertheless, there are enough degrees of freedom to adapt the existing master plan and develop a more sustainable and inclusive design including society’s need for infrastructural functionality by following a Building with Nature approach.

The current port activities at Kuala Tanjung employs jetties to reach deep water, which are exposed to waves, resulting in operational downtime. Onshore port development generally requires dredging, but the breakwaters can be constructed at relative shallow locations resulting in lower downtime and higher terminal efficiency. Based on this, it could be concluded that breakwaters are needed to create a world-class container terminal, which is a goal of the Indonesian government. In the short-term, offshore development (exposed jetties) is acceptable because the type of ships expected in the first two phases of the project, can handle higher wave conditions than container ships (last phase). Two alternatives to the existing master plan, both with sheltered berths in the final phase, are proposed: the onshore and the offshore alternative. In the onshore alternative, the focus lies on the stimulation and

use of the ecosystem services provided by mangroves. The offshore alternative limits the impact on the ecology of the estuary. The latter alternative deviates more from the current master plan, while the onshore alternative only requires some modifications in port planning and design.

In keeping with the Building with Nature approach, the physical and ecological system at Kuala Tanjung is studied before developing the on and off shore alternatives solutions.

A large number of the 17.000 islands of Indonesia are protected from the sea by mangroves which attenuate waves and can trap sediments. However, at least 35% of the world's mangroves have been lost in the past two decades¹. This underlines the relevance of protecting and stimulating the growth of mangroves. If all 24 future port developments announced by the Indonesian government (President Joko Widodo – APEC Summit, 2014) consider incorporating mangroves in the port development project, it will contribute to the United Nations Sustainable Development Goals.

The social and environmental impact would be the least when working offshore. However, creating effective hinterland connections is difficult. While the offshore solution preserves a number of ecosystem services, the onshore solution too makes use of the ecosystem services, for instance, by using the currents to nourish the muddy breakwater.

The bathymetry in figure 3 indicates a deep trench located a couple of hundred meters in front of the coast, making this location suitable for serving large ships. The first hundred meters perpendicular to the coast are shallow and muddy, however, resulting in tidal mudflats.

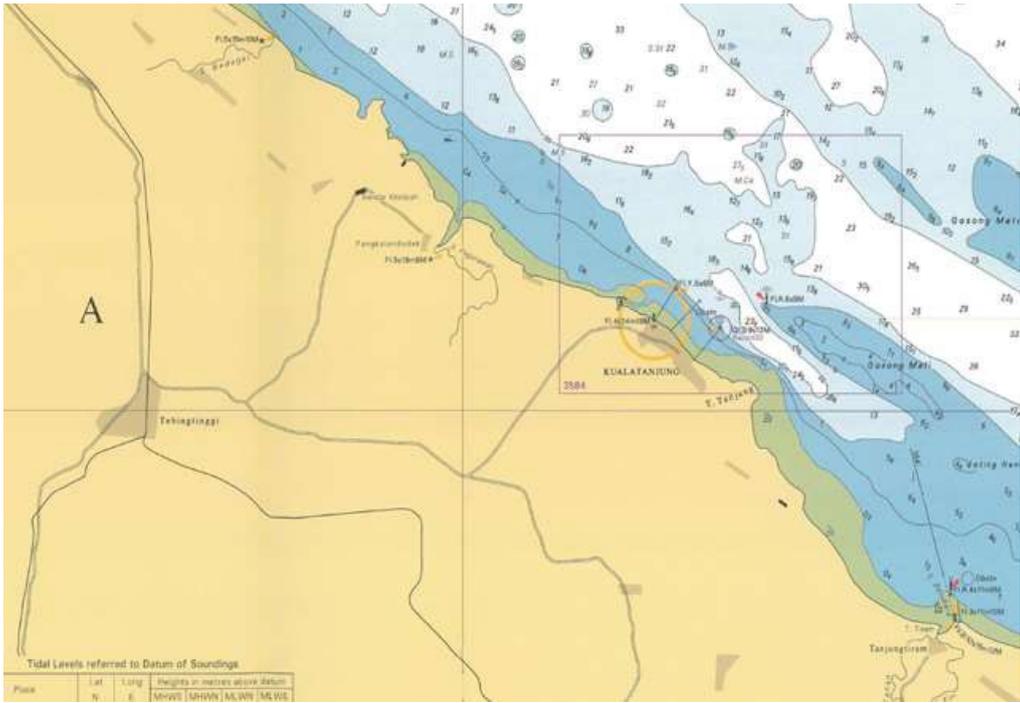


Figure 3 Nautical chart showing bathymetry at Kuala Tanjung (RHDHV ESIA, 2017)

¹ Valiela, I., Bowen, J. L., & York, J. K. (2001). Mangrove Forests: One of the World's Threatened Major Tropical Environments: At least 35% of the area of mangrove forests has been lost in the past two decades, losses that exceed those for tropical rain forests and coral reefs, two other well-known threatened environments. *Bioscience*, 51(10), 807-815.

By applying the Building with Nature approach to the Port of Kuala Tanjung project, the emphasis lies on the positive impact instead of the negative impact. By communicating this innovative approach to stakeholders, involving them and connecting to political agendas, the Port of Kuala Tanjung development is likely to gain more support. The alternative designs developed underneath, followed the Building with Nature design steps, incorporated the standards of the evaluation framework described above and include an active search for opportunities to use or create new ecosystem services using the knowledge from globally applied Building with Nature solutions.

The offshore alternative does not only consist of jetties but also includes offshore concrete decks on piles. In this way, offshore terminals are created connected to the land by bridges and the impact on the ecology of the estuary is limited. Underneath the decks, life under water can continue and even be stimulated in a Building with Nature way by applying E-concrete and other materials on which shellfish can grow. Since the onshore alternative offers more opportunities to apply the Building with Nature philosophy, the onshore alternative will be described more extensively underneath.

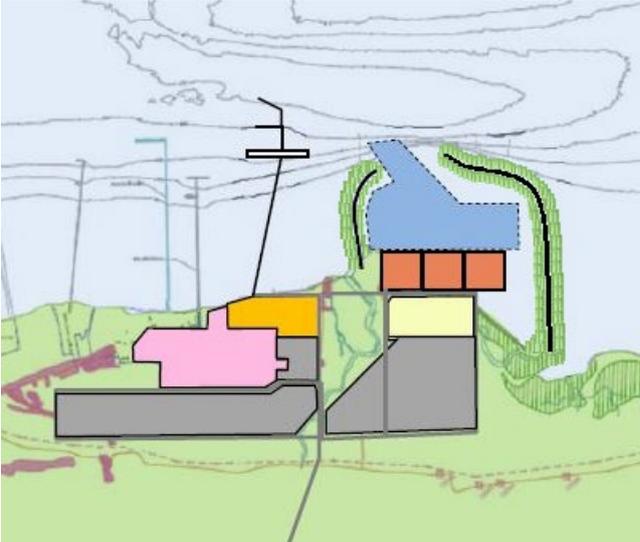


Figure 4 The onshore Building with Nature alternative master plan with mangrove breakwaters

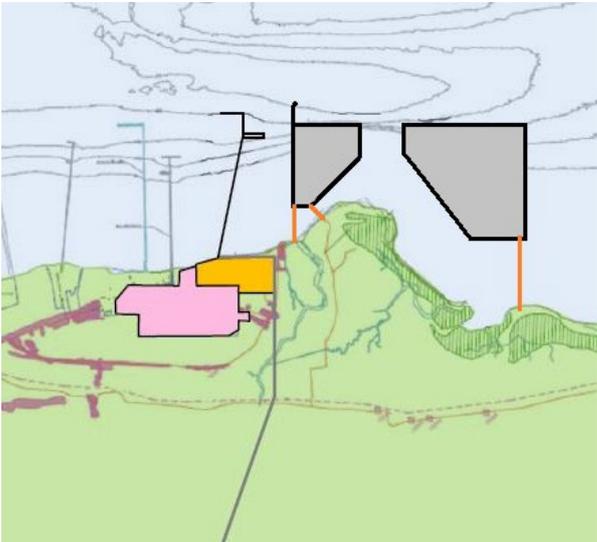


Figure 5 The offshore Building with Nature alternative master plan

Because of the shallower depths near shore, the onshore design (figure 5) offers the opportunity to include mangrove breakwaters. In the current natural system, the mangroves offer various important ecosystem services. In addition, it is noted that the hard breakwaters proposed in the current master plan, form a large part of the total capital expenditure. Consequently, a solution is proposed where mangroves are integrated in the design to attenuate waves and enhance nature at the same time. The checklist for habitat requirements for mangroves resulted in a preliminary design of the mangrove breakwater, which consisted of a mild slope around MSL of muddy soil with permeable dams to retain the sediment and initiate the natural process of accretion (figure 6). The breakwater will naturally grow by accretion behind the permeable dams. To initiate the sedimentation process, a stretch of 150 m wide should be artificially elevated up to + 1,6 m CD to be able to construct permeable dams. The dredged material (silty sand) is reused to create the right conditions for mangroves to grow. At the deepest locations of the breakwater, the original design of the

breakwater is used but E-concrete blocks are applied to support habitat for crabs, shellfish and fish. According to the preliminary feasibility study, for deep sea ports like the Port of Kuala Tanjung, this Building with Nature solution will only be partially applicable since large depths require large amounts of fill material. However, reuse of dredged material can limit the costs of this alternative design.

Attractive alternative housing (including piped water and electricity) is proposed in later stages of port development to offer housing for dockworkers (influx of outsiders) and residents of Kuala Indah who are willing to leave their homes. A water treatment plant is added to the master plan to ensure clean (piped) water for the villages nearby and to prevent subsidence because of deep-water subtraction. The port can only be sustainable when industries will be prohibited to extract deep groundwater as a source for fresh water. In Indonesia it is common practice to extract deep ground water resulting in large amounts of settlement up to 10 cm/year in densely populated areas.

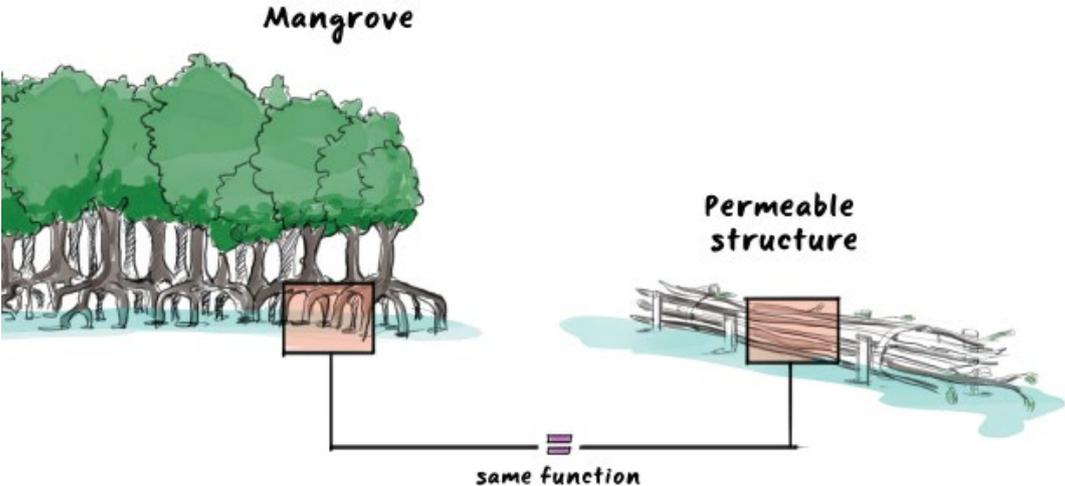


Figure 6 Permeable structures mimic the root system of mangroves that breaks incoming waves, reduce orbital velocities and turbulences and trap sediments (Ecoshape Demak, 2018)

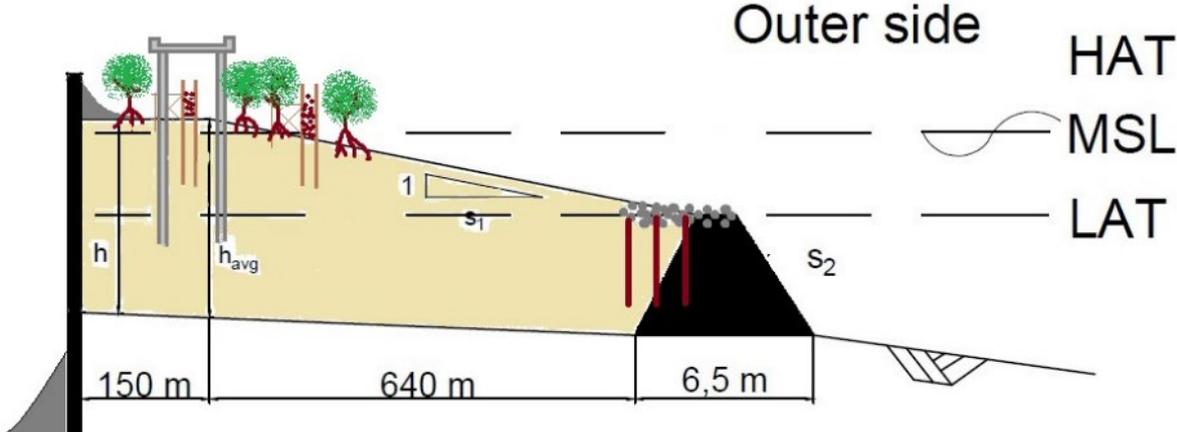


Figure 7 Final phase mangrove breakwater

After evaluation of the alternatives together with experts involved in the Kuala Tanjung project, it was concluded that the onshore alternative is more realistic from a functional point of view, while still offering opportunities for applying the Building with Nature philosophy. The main advantage of developing the port onshore is the possibility to create a port-industrial complex where utilities can be easily shared. A preliminary feasibility study will determine to what extent the mangroves can be implemented in the breakwater design.

After applying the evaluation framework to the onshore Building with Nature alternative (with a mangrove breakwater), it could be concluded that it has the potential to meet the international standards. The on-shore Building with Nature alternative adheres to 26 out of the 36 requirements of the evaluation framework proposed.

Implementing sustainable port standards through Building with Nature

In this research, the Building with Nature philosophy provided the guidance to identify opportunities for sustainable port development of the Port of Kuala Tanjung. This resulted in a Building with Nature solution for the breakwaters. Instead of a traditional 'hard' breakwater, a breakwater is proposed with a mild slope of dredged material around MSL which 'grows' naturally by accretion behind permeable dams creating the right conditions for mangrove trees to establish. This mangrove protection can develop into a sustainable barrier which grows with (relative) sea level rise by trapping sediments.

The key lessons learnt from this research are that a combination of a thorough understanding of the physical, socio-economic and governmental system and early stakeholder involvement results in higher vital benefits, reduces costs and provides the setting for sustainable design solutions.

The aim of the checklist with habitat requirements for mangroves is to provide an indication of whether mangroves can be considered as an ecosystem service for a Building with Nature design at a site. Ideally, this is checked in an early stage of the design process in such a way that an optimal habitat for mangroves can be created. Later in the process, the design is locked in and the possibilities for adaptation decrease. Nevertheless, the possibility to incorporate mangroves in the final design can still be considered using the checklist mentioned above.

January 2019

Link to youtube project video made by port of rotterdam:

https://youtu.be/8gxro4_ykxk

Link to master thesis:

<https://repository.tudelft.nl/islandora/object/uuid%3a7754d39f-b744-4421-b07b-bed6c58a62cf>