Artificial island in the North Sea and options for coastal development

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Abstract

A large-scale project such as the construction of an offshore island requires careful consideration not only of the direct effects of such intervention, but also of the implications for the further evolution of the Dutch coast. It is found that the construction of an offshore island is technically possible and - if optimally shaped and carefully placed - would have only limited effects on the marine and coastal environment which could be compensated for. If only the island were built, the already limited resilience of the Dutch coast would be even further decreased, because more coastal maintenance will be necessary. But if the island is combined with other measures, like locally increasing the nearshore sand volumes by e.g. seaward-protruding sand hooks, the resilience of the coast will improve. For this reason an in-depth discussion is recommended about the long-term future of the Dutch coast.

Introduction

On its own initiative, WL|DELFT HYDRAULICS has performed a study on the feasibility of building an artificial island off the coast of the Netherlands, to be used for an expansion of the national airport. WL|DELFT HYDRAULICS does not aim to participate in the political discussion regarding the need and benefit of the airport expansion to an offshore island. However, if such an expansion is chosen, WL|DELFT HYDRAULICS does want to make a technical contribution concerning the possible island location and lay-out, consequences for morphology and ecology, and best options for mitigating negative effects. The effect of the island on tides and currents, sand and silt transports, water quality, marine ecosystems, and the use of the North Sea and the coastal zone were all examined. Finally, the contribution of the island to the morphological dynamics was studied.

Island design

For the island design, a triangular island with rounded corners is proposed, surrounded by a high dike with a sea defence. This island shape has a sufficiently large area (24 million square metres) and a relatively short perimeter, while it also limits the effect on the coastal currents. The orientation of the island is such that the runways can be aligned optimally with the predominant wind directions, whereby one runway can also be aligned with the Dutch coast.

In order to minimise costs and detrimental effects on the environment, a "hard" sea defence consisting of concrete blocks is chosen over a soft (sandy) one. Using a Bermuda sea defence on the north-west and south-west sides of the island and on the corners, the dimensions of the concrete blocks can be reduced to a manageable size.

Water and salt spray, which is harmful to aircraft, is also limited in this way. The construction of berms using hard materials has the added advantage that it will support a large variety and number of marine plant and animal species. The east side of the island is oriented towards the Dutch coast and is more sheltered from wave and storm action, which means that on this side a bermed sea defence is not necessary.

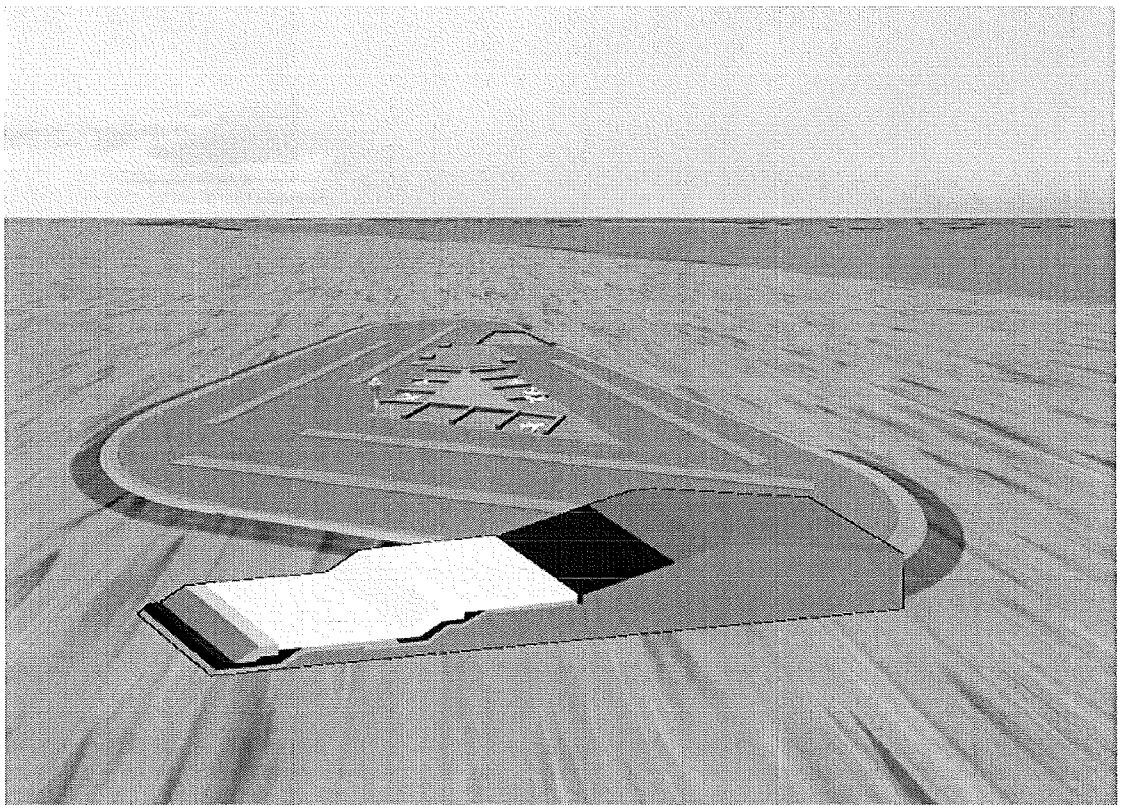

Figure 1. The western tip of the island (top berm at MSL +2 m)

In principle, an offshore island is an attractive habitat for birds, in particular sea gulls. These birds are a risk factor for air traffic (due to collisions). While it is impossible to completely prevent birds from frequenting and inhabiting the island, the risks can be limited by a proper lay-out and some additional measures. The cross-sections of the sea defence, and in particular the height of the berms relative to high and low water, and the island surface are designed such that birds will concentrate in those locations where they will cause the least harm to air traffic. For example, birds are discouraged from congregating around the tips of the runways (where the risk of collisions is greatest) and are tolerated in zones to the sides of the runways. Sea gulls and terns are further discouraged from inhabiting the island by the planting of low brushwood. As an additional measure, fishing boats could be forbidden from throwing fish discards overboard near the island. Further research on the possibilities for limiting the bird population is necessary. For example, the use of trained falcons to decrease the bird population should be studied.

With regard to the island design both a low level island (polder model) and a high level island (above sea level) have been considered. The high cost of sand mining, transport and deposition increases the cost of building a high level island out of sand

and makes the alternative - the polder model - more attractive. However, in the polder model, an impermeable layer of clay covered with filter and sand layers needs to be constructed in order to limit seepage.

Preliminary calculations for different levels of surface elevation indicate that minimum construction costs are obtained for a surface elevation of 5 meters below Mean Sea Level (MSL). This would cost 1 billion guilders (US$ 500 million) less than an island with a surface elevation at MSL. However, the construction of the impermeable clay layer is more labourious and will increase the construction time. Also the risk of such a design to the airport itself (flooding) and to air traffic (due to the height difference between the surface elevation and the top of the dike) should be considered.

The construction costs of an island with an area of 24 million square metres and a surface elevation at MSL are estimated at 6 billion guilders (US$ 3 billion), not including the costs of the airport facilities and the connection to the main land. This estimate corresponds to a land price of 260 guilders per square metre, which is not unfavourable compared to the land price near the Schiphol Amsterdam Airport.

The costs of connecting the island to the main land are estimated at 1 to 4 billion guilders, depending on the choice of a bridge or a tunnel. A further connection to Schiphol Airport will cost a considerable amount extra. It involves building a railway over land or in a tunnel.

Location

Important criteria for determining possible locations for the island were based on its use as an airport, the accessibility and the anticipated noise pollution. Additionally, undesirable effects on the sea and the coast - and the use thereof - should be minimised, and the contribution to morphological dynamics should be maximised. Based on these criteria, the area in which the island could be located was thus narrowed down to the coast between Noordwijk and Zandvoort between 10 and approximately 25 kilometres offshore.

At first three specific locations were considered within the defined area. Two locations are 10 and 17 km from the Zandvoort coast, and the third location is 10 km from the Noordwijk coast. The location 10 km from the Zandvoort coast has local effects on coastal currents, and a greater impact on the coast and shipping than the other two locations. For this reason the other two locations were investigated further: 17 km from Zandvoort (5 km south of the IJgeul shipping channel) and 10 km from Noordwijk.

Consequences for sea and coast

Table 1 gives an overview of the consequences of the construction and presence of an island on the sea and the coast, for the island being at least 10 km offshore. There is less impact if the island is further offshore. This applies, for example, to the morphological effects on the coast (accretion and erosion), the effect on the wind

climate in the dunes, and the visual impact to the landscape ('horizon pollution' due to loss of open sea horizon).

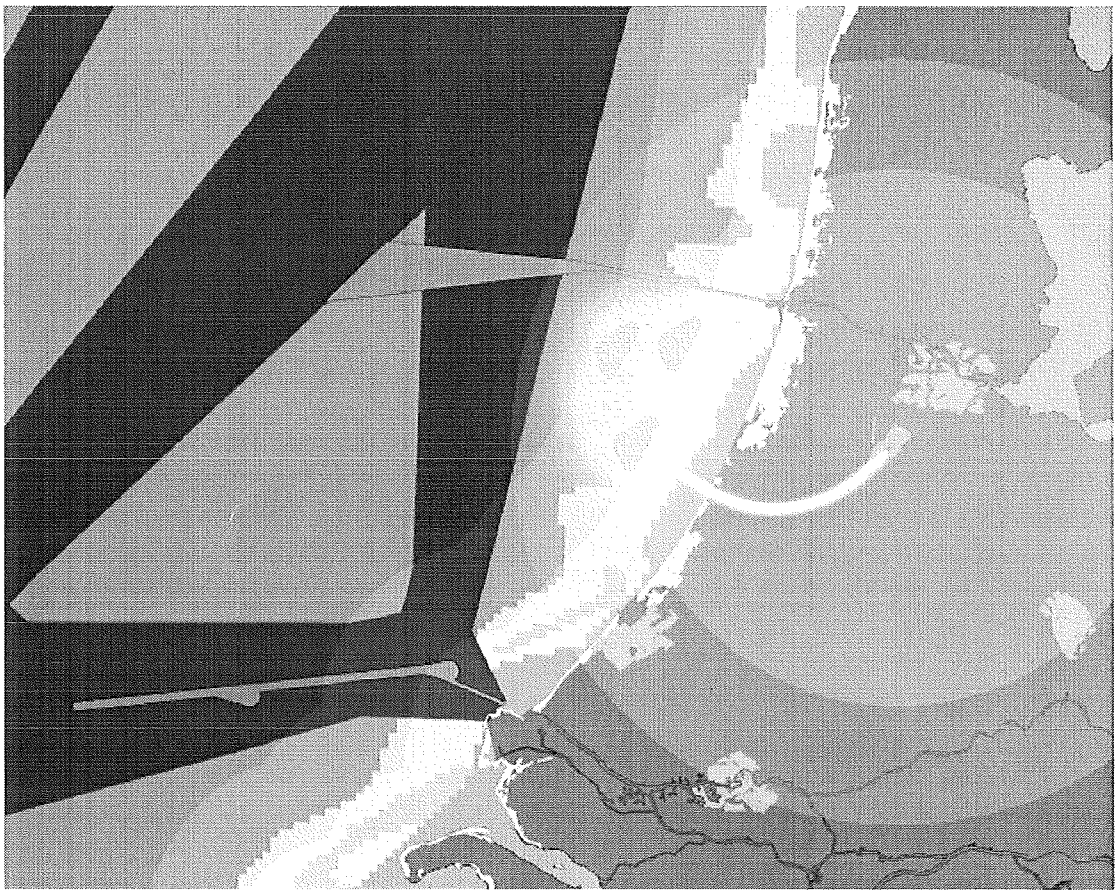

Figure 2. Spatial use in the North Sea and alternative island locations.

Table 1 Overview of consequences of construction and presence of an offshore island

Consequences on	Nature and seriousness of the consequences
tides and currents	• change of flow pattern in an area of 15 to 40 km around the island • small influence on the large scale hydrodynamics
morphology	• accretion at the northern tip of the island[1] • intermittent pattern of accretion (about 10 m/yr) and erosion (about 6 m/yr) along the coast sheltered by the island
water turbidity and suspended matter transport	• temporary increase of suspended matter during construction (in Winter 10-40%, in Summer 30-60%, due to the large natural variation only noticeable in the Summer) • probably no significant effect on the suspended matter supply to the Wadden Sea
water quality	• around the island a 5% increase in PAH concentration • minimal effect on the large scale transport of substances

algae growth	• temporary, small (less than 10%) decrease of algae growth during construction but only a minimum influence on larger organisms • small increase of algae growth North-west of Texel island due to presence of the artificial island (falls within range of natural variation)
marine ecosystems	• temporary loss of at most 2,800 metric tons of biomass (ash-free dry weight) due to sand mining; restoration of the population within a few years • permanent loss of 400 metric tons of biomass due to loss of sea bottom area • increase of 500 to 800 metric tons of biomass on hard substrate of sea defence and increase of biodiversity
birds	• small decrease of marine feeding areas • creation of rest and feeding areas for migratory and sedentary birds
coastal dunes	• slight influence on wind climate and salt spray • fragmentation of dune area and possible detrimental effect on ground water table due to construction of Schiphol connection
marine and coastal area use	• no detrimental effects on shipping traffic • some hindrance to recreational boating • financial damage to fishing industry due to loss of fishing grounds and additional damages if restrictions are applied in the area surrounding the island • detrimental effect on the open sea horizon (horizon pollution) • some noise pollution for inhabitants and tourists in the coastal zone

[1] For this reason the island will be located at a distance of at least 5 km from the IJgeul shipping channel

The island's presence has little impact on large-scale hydrodynamics. The sea bed will change in the vicinity of the island, including accretion on the north side. On the lee-side of the island the coast will accrete, while elsewhere more erosion will occur. This erosion can easily be compensated for with extra beach replenishments, approximately 10% more than the currently applied amounts.

Sand mining and deposition into the sea for the construction of the island will lead to a temporary increase in the water turbidity along the Dutch coast. The consequences for algae growth along the coast and transport of suspended matter to the Wadden Sea appear to be limited. Nonetheless, more investigation into the suspended matter transport to the Wadden Sea is recommended. Due to the mining of sand from the sea bottom for building the island at most 2,800 metric tons of biomass is lost. This biomass will recover after the mining has finished.

Approximately 27 million square metres of sea bed will be permanently lost as a result of the construction of the island. This results in a loss of approximately 400 metric tons of biomass of species, which live on the sandy bottom. However, construction of the berms could result in an increase of 500-800 metric tons of biomass of species that live on the hard substrate. If the island is intentionally made unappealing for birds, the consequences for bird populations are limited. At the same time, the island will create a good resting place for migratory birds which cross the North Sea.

An island located at least 10 km offshore is not expected to have a significant effect on the wind in the dunes. The consequences of an island with an airport on the use of the North Sea and coast appear limited, but this topic deserves more attention, especially because of the expected impact of the horizon pollution (loss of open sea horizon) on recreation and tourism. The way the mainland connection will be constructed (underground or above ground) has great consequences for, among other things, the dunes, and the landscape in the route to Schiphol. The choice of a route and the method of construction require careful consideration.

The island within the framework of long-term coastal development

WL|DELFT HYDRAULICS concludes that construction of an offshore island for use as an airport is possible with limited effects on the sea and coastal environment. The localised increase in coastal erosion can be compensated for in the classical method of beach replenishment. Additionally, the offshore island could play an important role in future dynamic morphological development of the coast.

WL|DELFT HYDRAULICS believes that in the present coastal management practices not enough consideration is given to the fact that the Dutch coast, seen as a whole, has become a rigid system which is very narrow in certain places and has little buffer capacity landwards. In the long term WL|DELFT HYDRAULICS envisions a resilient coast, a coast that can 'survive' such events as extreme storms and sea level rise. To become resilient a coast needs space for dynamic morphological and ecological processes to occur. Given the high population density in the western Netherlands more space can only be realised by a seaward expansion. This can be achieved by supplying extra sand to the coastal system through the construction of seaward-protruding sand hooks. The new dynamical equilibrium created can be maintained by natural coastal processes.

The offshore island can fill the function of a detached beachhead in a new resilient coast. At the sheltered side of the island sediment can accumulate, leading to coastal growth. But for this to0 occur, large sand displacements are necessary. Therefore, also smaller scale coastal expansions are proposed in places where, given the effect of an island on the accretion and erosion of the coast, they are most effective. These are experimental procedures and the results are not completely certain. However, if the large, localised beach nourishments does not work as planned the suppletion of sand will be ended. Then the sand will simply be redistributed along the coast by natural processes. This form of coastal expansion offers the advantage of experimenting with the innovative concept of increased resilience without risks. Coastal dynamics perpendicular to the coast can be allowed again without having to take compensating

measures of beach nourishment. Of course, such a coastal expansion can be used independently of the island to strengthen the Dutch coastal system.

Constructing sand buffers and increasing and/or allowing the natural dynamics to take place also offers possibilities for nature to develop, by broadening the land-sea transition zone among other things. Possible uses (e.g. recreation) of the coast could also increase.

Consideration of the two alternative locations

For the two selected island locations coastal expansion has been examined as a supporting measure to help compensate for the negative effects for the coast (erosion).

For an island near Noordwijk, compensating measures are necessary near Noordwijkerhout and at Katwijk. Near Noordwijkerhout a north-facing sand hook is proposed. At Katwijk a more drastic coastal expansion is considered, a "Katwijk Lagoon," which not only has morphological and ecological functions, but also makes modest economic (recreation-touristic) development possible. The sea defence of the lagoon, which provides space for a marina and beach and water recreation, is low enough that the view from the promenade is uninterrupted.

For an island near Zandvoort, the coast will be reinforced through construction of a sand hook near Noordwijkerhout. A second sand hook near IJmuiden is not necessary. South of the harbour piers there is enough sand to absorb possible erosion caused by the island.

Conclusion

A large-scale project such as the construction of an offshore island requires careful consideration not only of the direct effects of such intervention, but also of the implications for the further evolution of the Dutch coast. WL|DELFT HYDRAULICS concludes on the basis of the results of the investigation that the construction of an offshore island is technically possible and - if optimally shaped and carefully placed - would have only limited effects on the sea and coastal environment which could be compensated for. If only the island were built, the already limited resilience of the Dutch coast would be even further decreased, because more coastal maintenance will be necessary. But if the island is combined with other measures, like locally increasing the nearshore sand volumes by e.g. seaward-protruding sand hooks, the resilience of the coast will improve. For this reason an in-depth discussion is recommended about the long-term future of the Dutch coast.

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[1)] See http://www.wldelft.nl for an illustrated and animated summary