Redesigning deltas: The Delta Works of the future

Bas Jonkman, Dies Natalis TU Delft, January 12, 2024

A recording of the lecture which includes the presentation and visuals is found at: https://vimeo.com/896924896/55e68b3551; The lecture starts around 23:45

Introduction

Today we celebrate the Dies Natalis of our university. In the year 1842 it was founded as the Royal Academy in Delft. It had the mission to educate civil engineers for the needs of our nation.

Here in Delft, many famous civil and hydraulic engineers were educated, who have changed and shaped the map of our country.

Cornelis Lely graduated in the year 1875. He became famous for reshaping the Zuiderzee area. He proposed a 30km long closure dam, now known as the Afsluitdijk, to provide protection and shorten the coastline exposed to storm surges. This project also served multiple other functions: water storage and the development of polders for agriculture. It was decided to construct his plan after the 1916 flood disaster that struck the Zuiderzee region.

Another famous Delft graduate - Johan van Veen – was the founder of the Deltaworks. These provide protection to the Southwest of our country and shorten the coastline exposed to storm surges by a series of dams. Despite earlier warnings by van Veen, his ideas only implemented after the largest flood of the 20th century, the 1953 storm surge disaster – Watersnoodramp.

When thinking about the future of our delta we are standing on the shoulders of these giants – Lely and van Veen. But their projects to dam and close estuaries would probably no longer be feasible in current times. A main reason is the increased importance of nature.

In more recent decades, the Dutch have found new solutions for flood management that are combined with nature and other societal functions. Well-known examples are the construction of the sand engine and the Room for Rivers program.

Given our changing needs and the challenges ahead, we can ask ourselves: how will the map of the Netherlands change in this century? What are then the solutions and Delta Works of the future? For our country and other regions around the world.

Dealing with uncertain sea level rise

These last weeks are characterized by a storm surge at the North Sea and the closure of our storm surge barriers. There were also high discharges in our rivers - the IJssel, Rhine) and the Meuse – and a high lake level in the IJsselmeer and Markermeer. Although these events occur every 5 to 10 years, their simultaneous occurrence is more rare. This reminds us that flooding is an ever-present threat for our low-lying country. Therefore, we need to continue investments in flood management: in nature-based and spatial measures. But, make no mistake, as we live in manmade lowlands, technical measures such as dikes, dams and pumps will remain crucial.

Let us look at the challenges ahead. There is concern about the future of the Netherlands because of sea level rise.

In the worst case scenario - In case of the highest possible melt of Antarctic ice - sea level could rise more than 10 meters in 2300. The statue of Lely on the Afsluitdijk and most parts of the west of our country would be permanently under water. Because of this focus on the worst case scenario several experts advocate to stop building houses and business in polders, and to move activities to higher ground, the so-called retreat strategies – an example is shown here.

However, these worst case scenarios are very unlikely. Therefore, you can ask the question if planning mainly on these worst case scenarios is a balanced approach.

Getting a better grip on the sea level rise is important for our country. As questions have come up: Is the Netherlands still a safe place to live and develop, also for international investors?

To come to a more constructive debate and decision-making on how to deal with rising sea levels, three things should happen.

First, we should shift the focus from the very long term of 2300 to a more realistic planning period of about a century ahead. This is already a very long planning horizon, as if Lely would plan for our current times.

Let's take a look at the sea level projections for this period. In case of low emissions and a 1 degree warmer world, sea level rise will be less than 1 meter in the year 2150. In case of high emissions and a 5 degrees warmer world, sea level would rise a maximum of 2 meters.

A recent report by the Dutch Delta Program indicated that adaptation of our flood defences and water management systems is technically and economically feasible for at least another 3 meters of sea level rise.

So it is not all gloom and doom. This means that we can adapt to sea level rise in the 21st and 22nd century, also in the higher emission scenarios, but it will be a large effort. This is also in line with Dutch history: as over centuries we have been able to adapt to changing conditions.

Secondly, in our planning for the future, we should account for the uncertainties in these various scenarios. They key is to estimate their probability, and this information is not provided KNMI and IPCC. The probabilities can be estimated on the basis of observations and predictions of sea level, ice melt and CO2 emissions. Collaboration between climate scientists, hydraulic engineers, statisticians and policy makers is needed to get a better grip on the likelihood of future sea level.

Yet, we made some preliminary estimates of the likelihoods.

We assumed that the low and high emission scenarios are equally likely, and that there is a smaller probability of the worst case scenario.

Combined, this results in a bandwidth (or probability density) showing the uncertainty in sea level rise.

This now becomes our basis for infrastructure and spatial planning: it is the middle scenario with some margin to account for uncertainty. By using this as basis we will balance doing too little and doing too much. Of course we need to monitor sea level and the ice caps to update projections and to adapt our strategy in time if needed.

Thirdly, we need to develop future-proof strategies for each region that fit the physical system and the needs and ambitions for regional development.

What are the solutions for a region like ours? Let's take a look at Rotterdam.

Towards a plan for the Rotterdam region

Let's start near the city at the Maeslant barrier. It is normally open, but it is closed during storm surges on the North Sea to protect the region from coastal flooding. Just a couple of weeks ago, it was closed during storm Pia – the first real storm closure since its construction.

It is already a large challenge to keep it at the required reliability level and the maintenance costs are high. (slide 18) We explore how novel technologies such as a digital twin model can contribute to better management and extension of the lifetime of the barrier. However, The barrier will need to be upgraded or replaced in the second half of this century because of aging of the structure and sea level rise. A similar story applies to the other barriers: such as the Eastern Scheldt, Hollandse IJssel.

In making these regional plans we need to consider broader issues: The functionality of the Maeslant barrier has a major influence on the water system, the possibilities for developing houses on the waterfront, port and inland navigation and nature. Moreover, in our country, big decisions and large changes take decades. Completing the Deltaworks took more than 40 years. That is why it is important to start now with a plan for Rotterdam.

What we need is realistic regional design strategies. Luckily, there are already some great ideas.

One of the options if we want to keep the system open is a new storm surge barrier. Here you see the Holland barrier, a structure to replace or add to the Maeslant barrier. This so-called arch gate would have a width of over 300m and a height over 100m. It is lowered

during storm surge conditions to provide flood protection. At the same time it could serve as a landmark, and a new icon for Dutch delta-engineering. Such a structure by itself comes with many technical challenges, the foundation and driving mechanism, the structural design and material use etc.

Another strategy is a closed dam at Rotterdam. It would offer direct flood protection to the city and opportunities development of waterfront houses in the city. It would also allow to store fresh water of rivers behind the dam in dry summers. However, the dam would be a barrier for inland shipping and nature.

A third strategy is a more “open an natural” approach. This plan would focus on a gradual sedimentation and undeepening of the New Waterway and nature development on the river banks. This would affect shipping and it is effect on flood risk and dike raising has yet to be investigated.

As you can see there is something to choose. Further “research and design” of these plans is really needed, for example in our Redesign the Delta Initiative.

But there are more challenges in the Netherlands. In the low-lying parts of our country several issues come together. Reinforcing dikes in densely populated areas with soft soils is challenging. With sea level rise, salt intrusion will increase. Also, there are subsidence, heavy rainfall, drought and heat stress.

100,000’s of houses will be developed in the low-lying areas of country, and the question is not if this will happen but how. New developments need to be climate adaptive. These buildings are designed to cope with local risks of subsidence, heat and drought, and flooding from heavy rainfall and other sources.

The previously discussed challenges require a multidisciplinary approach involving civil engineers, architects and planners, financial and policy experts and others. Here at TU Delft we will strengthen the collaboration between these disciplines in the field of deltas, also by developing future education programs. Moreover, our region and our campus will serve as a living lab to show the solutions. We will do all this in collaboration with our key partners such as Deltares, IHE, Rijkswaterstaat and many others from government and the private sector.

We need to involve the next generation, our students: and that is what we do within our Delta Futures Lab, where students, researchers and practitioners collaborate.

After the catastrophic 2021 summer floods in Limburg, they focussed on studying the causes and solutions. Let's hear directly from these talented minds. {Video Limburg Delta Futures Lab}

I'm excited that this next generation of engineers, is helping to shape a resilient future. Their work really makes an impact for a better society.

International deltas and coastal areas

We talked about Rotterdam and Limburg. But of course many global delta cities face similar challenges: rapid development and population growth, subsidence and sea level rise. There are many examples: Shanghai, New York and so on.

Many countries are therefore actively investing in risk reduction and adaptation, and considering multiple types of interventions: From wetlands to flood defences and adaptation of buildings. Over the last decades, investments in these measures have been successful to reduce the frequency and impacts of floods across the globe. The challenge is to find the right combination of measures that fits in the local conditions and ambitions

One of the regions where such large-scale interventions are in preparation is the coastal region near Houston, Texas, where I have worked and lived with my family for half a year.

This area is home to around 6 million people and a large energy industry. Similar to New Orleans, this region is threatened by hurricanes, which lead to storm surge on the coast, as well as wind set up in the Galveston bay – which is similar in size to our IJsselmeer. Houston is known as the flood capital of the US and it suffered several coastal and inland floods over the last decades.

Around ten years ago, a professor from Texas A&M proposed a Delta Works project for Texas. It would protect Houston and shorten the coastline exposed to hurricane surge. Over the last decade a successful collaboration with Delft and others has developed. The "research by design" work from more than 80 TU Delft students formed a basis for the official government plan. This coastal protection plan has received approval from Washington DC. With a total price tag of over 34 Billion US Dollars it would the largest civil works program in the US history. As you know everything is bigger in Texas!

Key elements include nature based solutions: New wetlands within Galveston bay can help to reduce local wave attack and restore the bay ecosystem. Together with Texas A&M we also study innovative coastal protection that combines hard structures with dunes. This solution will have a minimal impact on the many houses present on the coast.

The most challenging and costly element is the storm surge barrier in Bolivar Roads, a 3 km wide inlet into the Bay and a busy shipping channel. It would require a combination of the Maeslant and Eastern Scheldt barriers, but there is debate whether this is the best solution for shipping and nature. We study alternative solutions, such as the previously presented arch gate.

These future Delta Works 2.0 have to be better than the existing ones. Extensive monitoring of the bay and coastal systems is needed to understand and minimize the environmental impact of interventions. Just like our delta works, this program will take decades to implement and will be a catalyst for innovation. The expertise and solutions developed in Texas, will also be implemented in our own country and other regions.

Closure

Ladies and gentlemen, we return to the Afsluitdijk. It has just been reinforced for another century. The inscription on the statue of Lely at the Afsluitdijk reads “A nation that lives builds its future”. What does that imply for us?

Firstly, we must adapt our delta to sea level rise and changing conditions. We have the solutions to do this, but “cannot take it for granted”. This is a very large effort, with large costs and implications for society. We should shift the focus from worst case sea level rise on the very long term, to expected sea level rise in the coming century. Quantifying the uncertainties in sea level rise will make these more manageable for planning and decision making.

Secondly, we need to start now to design and plan regional strategies, starting with the Rotterdam region. We at this university are committed to educate the next generation of delta engineers to do so. Engineers who understand the system, and design, engineer and implement solutions.

We have to be pro-active and prevent that we are surprised by disasters and act too late.

It is time to start now to plan and realize the Delta Works of the 21st century.

I thank you for your attention.

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