Rijkswaterstaat
Ministry of Infrastructure and the Environment

The storm surge barrier

in the Eastern Scheldt

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Rijkswaterstaat Zee en Delta
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Historical introduction

The battle with the sea started the day the first migrants settled in the Netherlands. They built their homes on the high embankments near the shore and provided for themselves by hunting, fishing and farming. They built mounds on which they took refuge at high water. It was not until the arrival of the Romans that the first real hydraulic engineering works in our country appeared.

It was not until approximately the tenth century that the inhabitants started to build flood defences against the sea. The first dykes to appear along the coast were simple, low walls, made using spades and baskets and collapsing whenever the sea launched a serious attack. The monasteries were among the first to build dykes, which created excess water that had to be drained off. To start with, sluices were built so that water could be released from the polders at ebb tide. The windmill, invented about 600 years ago, made it possible to drain many more and deeper polders.

The dyke has broken through at February 1th, 1953

The Dutch are fighting constantly against the water

The primitive dykes of the early Middle Ages provided very poor protection against the sea. Each century had its floods. There were 111 serious or very serious floods in the West Netherlands between 1000 and 1953. Many of these floods were named after the saint's days on which they occurred. They included the St. Agatha flood (1288), the St. Elizabeth flood (1421), the St. Felix flood (1530) and the All Saints' flood (1570). These floods claimed many lives, as well as large areas of land, shaping the contours of the country.

There were floods well into the 20th century – in 1906, in 1916 and again in 1953, when from Saturday night through until Sunday morning the biggest flood of the last couple of centuries occurred. A northwester had raged for many hours, producing a surge four to five meters higher than AOD (Amsterdam Ordnance Datum, mean sea level as defined for Amsterdam). In the middle of the night, while most people slept, the sea poured over the dykes, destroying them completely in 67 places and breaching them in 400 others.

The sea engulfed 200,000 hectares of fertile land and many towns and villages in the southwest Netherlands. 1,835 people and over 200,000 head of cattle drowned, some 72,000 people had to be evacuated and more than 47,000 homes, factories and offices were damaged or destroyed.

The Delta Project

Parliament debates the Delta Act

A disaster of the scale that occurred in 1953 had to be prevented in the future. That was something everyone agreed on. The specially appointed Delta Committee came up with a plan in the same year. They recommended strengthening the flood defences and cutting the coastline by 700 kilometers. The shorter the coastline, the easier it would be to protect it. An excellent example was the construction in 1932 of the Afsluitdijk, a 32 km dike damming the Zuiderzee from the North Sea, and in the process creating the freshwater IJsselmeer. Then the Dutch coastline was shortened by 360 kilometers and the danger of flooding was considerably reduced.

1. Hollandse IJssel storm surge barrier 1958
2. Zandkreekdam 1960
3. Veersedam 1961
4. Grevelingendam 1965
5. Volkerakdam 1969
6. Haringvlietdam 1971
7. Brouwersdam 1971
8. Markiezaatskade 1983
9. Oesterdam 1986
10. Eastern Scheldt storm surge barrier 1986
11. Bath Discharge Canal 1987
12. Philipsdam 1987
13. Maeslant storm surge barrier 1997

The Delta Committee proposed closing off all the inlets in the delta area and raising all flood defences to delta level, five meters above AOD at Hoek van Holland. This would reduce the risk of flooding to 1:4,000 a year in the delta area and the north and 1:10,000 a year in the Randstad (the central and dense populated area of The Netherlands).
The Delta Act, based on the plans put forward by the Committee, was finally approved by Parliament in 1958. Besides providing protection against the sea, the Delta Project would improve watermanagement in many parts of the country, reduce salination, produce freshwater reservoirs and create new recreational areas, while the new dams would greatly improve access to the southwest Netherlands.

The Delta project presented Dutch hydraulic engineers with an enormous challenge. No other nation in the world had ever closed off tidal inlets of this size and depths before, and the know-how and technologies needed to do so did not, as yet, exist. Swiftly, the various parts of the Delta Plan were addressed in turn, each with its own challenges and unique hydraulic engineering solutions increasing in complexity.

On the next page the entire Delta project is presented including the Eastern Scheldt storm surge barrier and the Maeslant storm surge barrier.

"Keep the Eastern Scheldt open!"

The beautiful nature in the Eastern Scheldt.

The last part of the Delta Plan was to close off the Eastern Scheldt by a dam. This was regarded as the hardest part of the Delta Plan, but with the experience gained by other closures, it was not considered insurmountable.
The Eastern Scheldt was and is a unique natural habitat. The clean seawater provides a rich source of food for wildlife of all kinds. Fish use the inlet as a breeding ground and oysters and mussels are farmed there. The inlet's mud flats, salt marshes and sandbanks provide a habitat for many species of birds.

If the Eastern Scheldt had been closed off by a dam, the seawater flora and fauna would have disappeared, and with it sea fishing and mussel and oyster farming would no longer have been possible.

However, soon voices were heard to keep The Eastern Scheldt open and maintain the original estuarine environment. The pressure of the public opinion was so fierce that the Dutch government initiated new studies to investigate if an open Eastern Scheldt was technically viable. The minimum criterion was that the safety of the people in Zeeland could be guaranteed under all circumstances, but also that the original environment could be maintained.

The studies concluded that it was possible protect Zeeland whilst maintaining the existing habitat, and a storm surge barrier with movable gates was chosen as the preferred solution. Another alternative that would satisfy the criterion was to raise the 150 km dykes along the islands to the so called 'Deltahight', however this was not accepted. Works to close the Eastern Scheldt estuary had already commenced, so construction had to be stopped and contracts terminated. The Eastern Scheldt stayed open, but in the event of a storm surge it could be closed off.

With the decision to build a storm surge barrier it was also decided to build the Philipsdam and the Oesterdam as ancillary works. These dams were to be completed together with the storm surge barrier. Their aim was twofold: Firstly, they would reduce the size of the basin behind the barrier limiting the impact of the barrier on the tidal range at Yerseke. Secondly, a tide less shipping route between Antwerp and the Rhine was created, as was agreed on in the covenant between The Netherlands and Belgium in 1963.

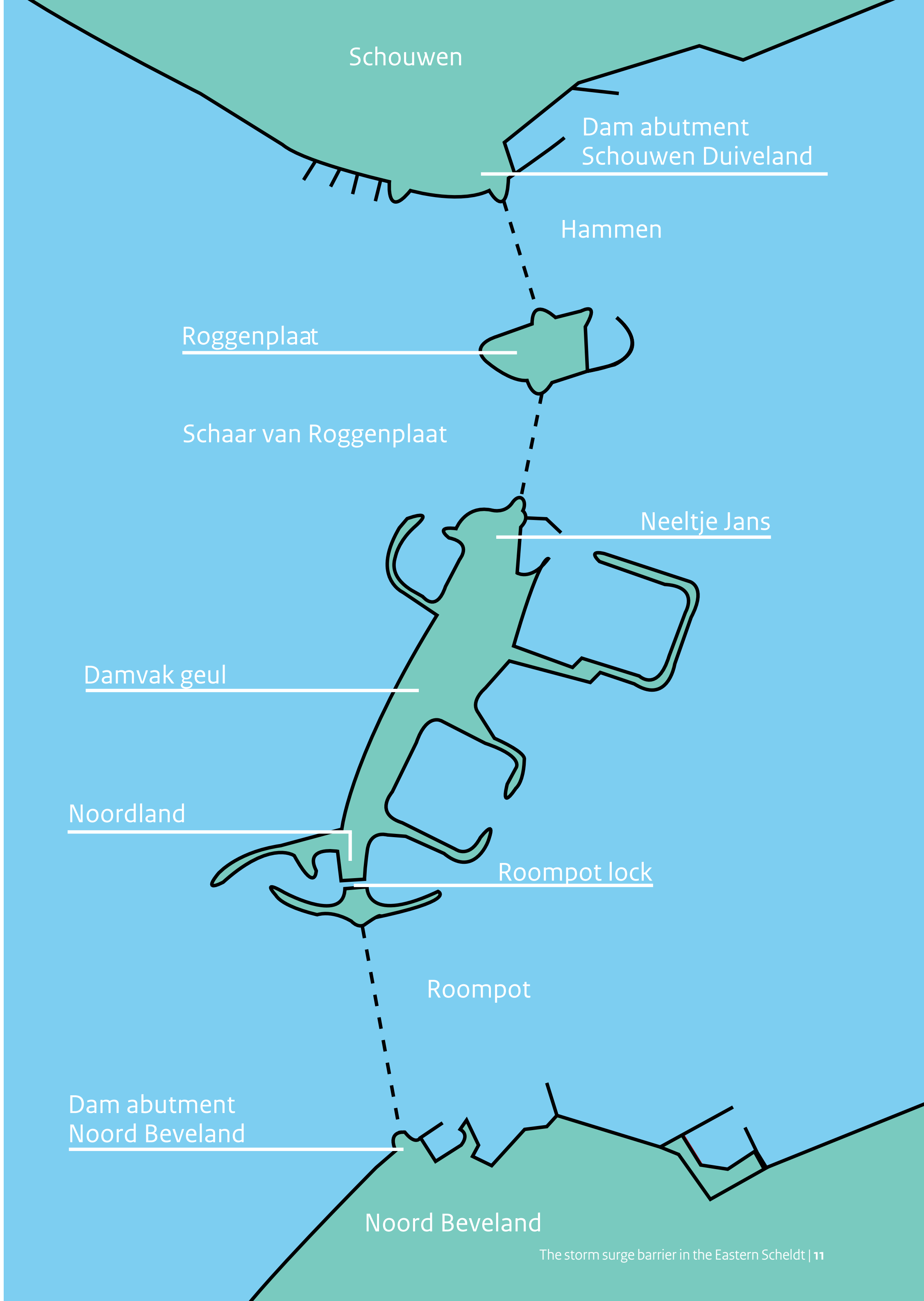
Fishers from Zeeland protest against closure of the Eastern Scheldt

The Eastern Scheldt storm surge barrier

The decision to build a storm surge barrier in one of the most challenging areas along the Dutch coastline had many implications. Instead of a dam a barrier had to be built without changing the course of the existing river channels, this meant that the barrier superstructure would have to be located in the deepest parts of the Eastern Scheldt Estuary. Engineers could not only rely on the experience gained building the other dams in the Delta Plan. New techniques, which had never been applied before, had to be developed. In order to reduce the effect on tidal flow in the river channels, and to limit the construction risks, it was decided to prefabricate as much of the barrier structure as possible. The different prefabricated units were then assembled on site.

The overall plan for building the storm surge barrier can be described roughly as follows: In the flow channels Hammen, Schaar van Roggenplaat and Roompot a barrier was to be built with a total length of about 3000 meters. A number of 65 pre-fabricated concrete piers will be put in place and in between these piers 62 movable steel gates that can be raised or lowered. When the gates are up, the Eastern Scheldt is open to the sea, so that the tidal range in the estuary behind the barrier is approximately three quarters of its natural range; which is sufficient to sustain the environment. When storm surges and exceptionally high water levels are forecast, the movable gates are lowered and the Eastern Scheldt is closed off from the North Sea, guaranteeing the safety of the hinterland.

Because the original plan was to build a dam; the shallow parts in the mouth of the Eastern Scheldt had already been raised to provide working islands. These parts were the Roggenplaat and damvak Geul. Damvak Geul connects the working islands Neeltje Jans and Noordland. Today these raised parts form the dyke section of the Eastern Scheldt storm surge barrier. During construction the prefabricated elements such as the piers, the threshold beams and the foundation mattresses and also the rock armour were built and stored on the artificial islands.

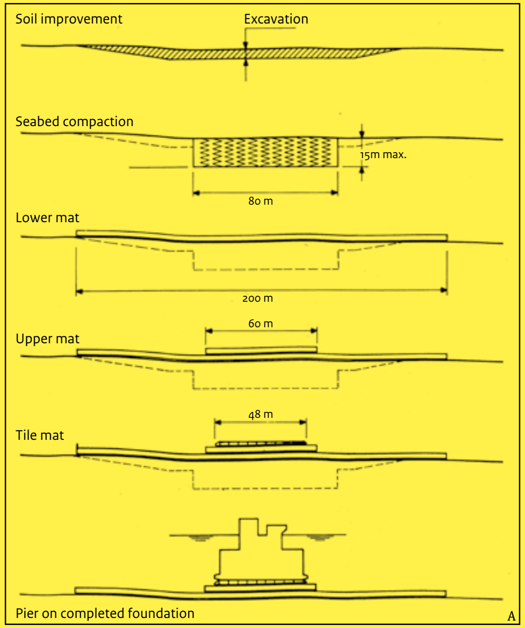


The storm surge barrier in the Eastern Scheldt

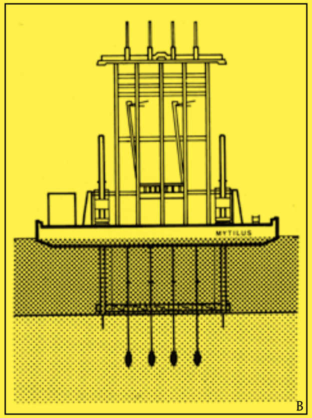
1. Schouwen
2. Flow channel Hammen
3. Working island Roggeplaat
4. Flow channel Schaar van Roggeplaat
5. Service building
6. Outer harbour Neeltje Jans
7. Former construction docks for piers
8. Former construction docks for mats
9. Inner harbour Roompot lock
10. Outer harbour Roompot lock
11. Roompot lock
12. Flow channel Roompot
13. Noord Beveland

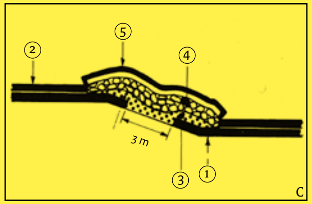
Construction of the Eastern Scheldt storm surge barrier

A. Construction of the foundation



B. Schematic presentation of the bed compaction by the vibrating rods of the Mytilus





C. Sealing the seams between two mattresses
1. Lower mat
2. Upper mat
3. Sea gravel
4. Rubble
5. Gravel mat

The Eastern Scheldt storm surge barrier was such an exceptional and unique project that a new approach had to be taken to every part of its construction. A consortium of Dutch contractors (De Oosterschelde Stormvloedkering BOUWcombinatie [DOSBOUW]) was formed, and cutting-edge methods and materials were developed and used.

The Mytilus sea-bed compression vessel

Step by step

First, the foundation for the piers was built up step by step. The sands of the Eastern Scheldt are constantly shifting, and with no bedrock the foundations had to be solid and flexible. Polypropylene mattresses, with concrete blocks attached to them, were used to protect the bed on which the barrier would stand. The silt was dredged and replaced by sand. Then the “Mytilus”, a ship specifically built to compact the seabed in the Eastern Scheldt, inserted four enormous steel rods into the bed. By vibrating the rods, grains of sand up to a depth of fifteen meters could be compacted. The sea bed became solid ground.

A carpet in the sea

To prevent sand being flushed away when the barrier was closed and to make sure the piers were standing on a level surface, an even firmer foundation was needed. Mattresses were used for this purpose, made up of polypropylene filled with sand and grit. A separate factory was built to manufacture these mattresses, from which they were rolled around huge, floating cylinders. The mattresses were then unrolled on to the seabed. The rough waters in the inlet made this extremely painstaking work. The mattresses had to be rolled out quickly in exactly the right place. The work could only be done at slack water, when the tide turned, which lasted for just one hour. If a mattress had not been fully unrolled before the tide turned, it would have been destroyed by the force of the ebb tide. Fortunately, this never occurred.

When the mattresses were being laid by the “Cardium”, this vessel was assisted by another specially-designed vessel, the “Jan Heijmans”, a stone and asphalt tripper. This vessel held the ends of the mattresses in place and sealed the seams between them with layers of stone.

The final result was a foundation that was more level than many football pitches. Right across the mouth of the Eastern Scheldt, a smooth carpet, two hundred meters wide, awaited the construction of the piers.

The construction of a pier

A backbone of piers

65 colossal piers form the backbone of the barrier. They were built at three enormous construction docks. Each pier is a hollow concrete form, thirty to forty meters high and weighing 18,000 tons. The exact height of each pier depended on its place in the channel. A special unit was set up to produce the concrete and it took nearly a year and a half to produce each pier. Production was staggered, with work on a new pier starting every two weeks. When all the piers in a construction dock were finished, the dock was submerged and the surrounding dyke was opened so that they could be transported to one of the three channels in the Eastern Scheldt.

Putting the piers in place

Two vessels were positioned in the mouth of the Eastern Scheldt and they worked together to sink the piers in the right place. The “Ostrea” lifted the huge piers out of the construction dock and transported them to the channel, placing them onto the mats within a tolerance of just a few centimeters. This specific operation had to take place at slack water and it took a year to sink all 65 piers. Once they were in place, the space between the foot of the pier and the mats was sealed off with grout, a mixture of sand, cement and water. The lower sections of the hollow piers were then filled with sand to make them more stable.

Five million tons of stone

For even greater stability and protection from the powerful currents that would arise if one of the gates refused to open, the piers were embedded in sills made up of blocks of stone weighing up to ten thousand kilograms, since dropping these heavy stones into position could damage the piers, the “Trias” was specially designed to lay the top layer. This vessel was equipped with a long, extendable arm that could place the heaviest stones accurately. Five million tons of stone were needed and since it was not available in the Netherlands it was shipped over a four-year period from Germany, Finland, Sweden and Belgium.

The finishing touches

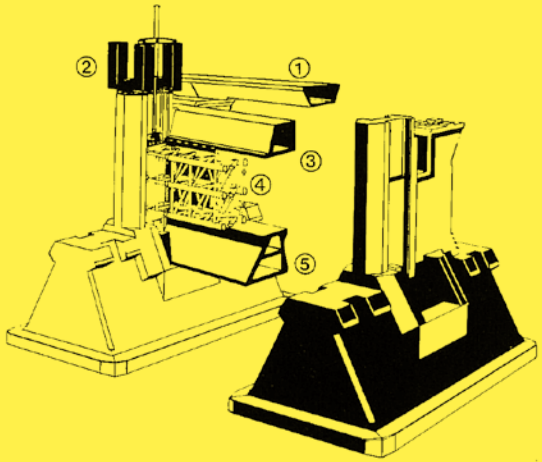
When the main part of the storm surge barrier was complete. The final stage was the installation of the service ducts, pier capping units, gates, threshold beams and upper beams had to be put in place. The hollow service ducts, which would later be covered by a road, were laid on top of the piers. The ducts contain the operating and control equipment for the gates.

The steel gates, varying in height from six to twelve meters, were suspended between the piers. Their strength comes tubular steel truss structure that supports a flat steel face on the Eastern Scheldt side of the barrier. Each is equipped with two hydraulic cylinders to control its movements. The biggest gate weighs 480 tons and hangs in the deepest channel, the Roompot. It takes 82 minutes to close.
The Roompot lock was constructed in the southern section of the work island to allow shipping through.

The storm surge barrier in detail

1. Pier
2. Rubble dam in front of main construction
3. Beam supporting operation machinery
4. Hydraulic cylinders
5. Stand beam (pier capping unit)
6. Upper beam
7. Sliding gate
8. Threshold beam
9. Road for traffic
10. Transport tunnel
11. Service duct
12. Sand filling
13. Upper layer threshold
14. Threshold core
15. Sand filling of pier
16. Bearing of threshold beam
17. Upper mat
18. Grout filling
19. Tile mat
20. Lower mat
21. Compacted sand
22. Gravel bag

1. Transport tunnel
2. Stand beam
3. Upper beam
4. Sliding gate
5. Threshold beam



Managing the storm surge barrier

The operation panel in the control room of the ir. J.W. Topshuis

The Eastern Scheldt storm surge barrier is operated from the service building "Topshuis" on Neeltje Jans. The gates have to be closed at extremely high water – once a year on average. In normal conditions the sliding gates are fully open. Only when water levels of more than 3 meters above AOD are forecasted will they be closed, well in advance. Also a warning system has been developed, that responds to multi-day weather forecasts. When a water level of 2.75 meters above AOD is expected, the required barrier staff (decision team, operating team and design expert) is summoned to the barrier.
Based on weather forecasts in combination with local data and forecasted water levels on the North-sea, the barrier staff decides if the storm surge barrier will be closed.
When making the decision when to close, a 1-2-1 strategy is adopted. This means that in the event of multiple consecutive high-waters, the closure aim to achieve of: 1 meter above AOD on the first tide, 2 meters above AOD on the second and 1 meter above AOD on the third. The objective of this strategy is to distribute the wave action on the dike face.

In the period that the storm surge barrier is operational, it has been closed 26 times [counter at 1 July 2015], because of higher water levels.
If something goes wrong either in operating the gates or sounding the alert, an emergency system closes the gates automatically based on measured water levels.
The situation in the Eastern Scheldt basin is factored into any decision to open or close the gates. Operating the barrier effects the environment, fisheries and the water-management system as well as the safety of the dykes that surround the Eastern Scheldt.

The service building (ir. J.W. Topshuis) in front of the Eastern Scheldt storm surge barrier

Eastern Scheldt storm surge barrier
District Zee en Delta Noord

Two parallel processes

Emergency closing system (Automatic and unmanned)	Decision team (Closure based on human intervention)
Storm surge barrier closes automatic if the measured water level reaches 3 meters above AOD.	Storm surge barrier closes based on expected water level. 1-2-1 strategy

The Delta Project completed

The bold programme of hydraulic engineering works in the Delta produced enormous changes affecting people, animal's plants and the landscape. Dams, locks and roads were constructed and new lakes and residential and recreational areas were created. Sweeping changes have occurred in the age-old rhythm of ebb and flow. The environment has altered in many places and in many ways. In addition to protecting the Southwest Netherlands from flooding and producing economic benefits, the implementation of the Delta Project increasingly took account of ecological requirements. A Delta is a very rich and varied system of plant and animal communities: an ecosystem that is also economically important and very sensitive to human intervention.

The Netherlands was willing to spend a lot of money on the Delta Project. The cost of ensuring protection from flooding, radically improving the communications network, distributing the scarce supplies of fresh water more efficiently and preserving the unique ecosystem came to Fl. 12,000 m. [Dutch guilders]. The work in the Eastern Scheldt was the most expensive part of the Delta Project, costing Fl. 7,000 m.

During the official opening ceremony of the storm surge barrier, Queen Beatrix declared the Delta Project completed. The work in the Southwest Netherlands may be over, but there is still a lot of work for the hydraulic engineers.
Shallows and sandbars are developing in front of the dams and headlands and gradually becoming higher, promoting the formation of new channels. This area can offer new opportunities to the fishing industry and the environment. Plans are therefore already being considered with regards to the future of the Delta Project for this area. The steady rise of the sea level also indicates that the protection of the Netherlands against the sea will remain a permanent struggle. Dutch hydraulic engineers believe that the knowledge and expertise they gained in the thirty years it took to complete the Delta Project should also benefit other countries in addition to the Netherlands.

The storm surge barrier in the Eastern Scheldt |

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Rijkswaterstaat

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