DHI CASE STORY

MODELLING THE 180 KILOMETRE LIMFJORD

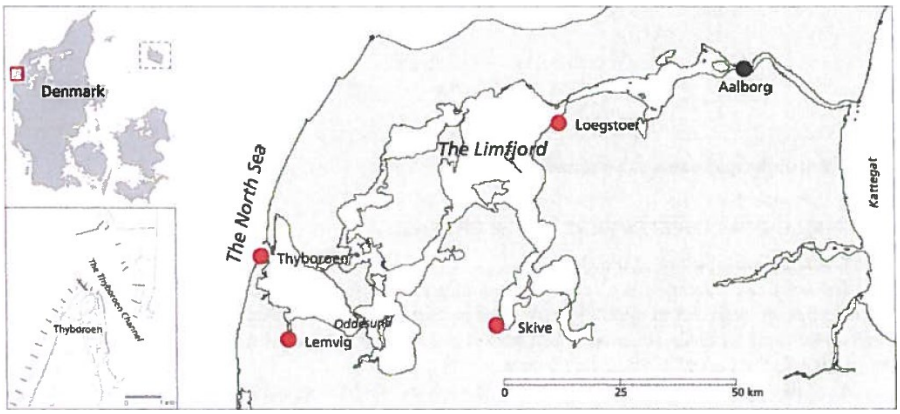
Studying storm surges to prevent damage and protect lives

Following a severe storm in 1862, a breach at the present city of Thyborøn opened a new outlet to the sea for the 180 kilometre Limfjord in Northern Denmark. The new inlet developed rapidly, with the surrounding coast eroding by half a kilometre. Over the years, continued erosion in the Thyborøn Channel has led to increased flooding in the Limfjord. This puts cities situated around the fjord, with a total population of over 60,000 people, at risk. We used MIKE 21 to determine the correlation between erosion and storm surges, as well as the possible impact of climate change. We gave the Danish Costal Authority the tools needed to examine future problems involving flooding in the Limfjord and advised them on possible solutions.

BREACH TO THE NORTH SEA

The Limfjord is an estuary in Northern Denmark. It separates the island of Vendsyssel-Thy from the rest of the Jutland Peninsula. Connected to the North Sea by the Thyborøn Channel, the Limfjord has numerous bays, narrow areas and islands.

For centuries, the Limfjord had only one opening on the east coast at Hals. But in 1862, a severe storm breached the barrier between the Limfjord and the North Sea at Thyborøn. This created two entrances: one on the west coast leading to the North Sea and one on the east coast leading to the Kattegat. Eventually, the inlet was used for navigation, leading to the construction of the Thyborøn Harbour.



The Limfjord system with inlets to the North Sea and Kattegat.

SUMMARY

CLIENT

Danish Coastal Authority

CHALLENGE

- Cities with a total population of more than 60,000 people face an increased risk of flooding
- A 0.5m increase in storm surge levels will increase the damage potential in the Limfjord by EUR 500 million

SOLUTION

- Modelling past, present and future storm surges to gain a better understanding of how changing conditions in the Limfjord will affect flooding
- Consultation with our client on several possible solutions to reducing storm surges in the Limfjord in the future

VALUE

- Obtaining a clear idea of how several factors are affecting storm surges the Limfjord
- Enabling our client to implement the best solution to prevent flooding based on a comprehensive modelling toolbox

LOCATION / COUNTRY

Limfjord, Denmark

OVER 60,000 PEOPLE AT RISK

The area around the western part of the Limfjord is generally rural. But there are six cities west of Løgstør with a total population of over 60,000 inhabitants. These cities have previously experienced flooding during storms. This was caused by a combination of wind set-up in the fjord and an inflow of water though the channel from storm surges in the North Sea.

Over the last 100 years, there has been a dramatic increase in the cross sectional area of the Thyborøn Channel. How has this affected surge levels in the Limfjord? The Danish Costal Authority (DCA) asked us to investigate.

MODELLING THE STORM SURGE: PAST, PRESENT AND FUTURE

We investigated the effects of the increase in the cross sectional area in the Thyborøn Channel on the high water levels in the Limfjord. How much higher are the maximum water levels today in an extreme storm compared to the same storm 50 years ago? How much higher will the water levels be in the future?

With the DCA, we studied the conditions in the Limfjord. Using MIKE21 HD (our two-dimensional hydrodynamic modelling software) we established new high water statistics in the Limfjord based on:

- simulated surge conditions for 31 storms over a 33-year period
- the configuration of Thyborøn Channel in the present (2005), in the past (1958) and in future (2060)

We also ran a number of sensitivity tests to better understand how changes in the bathymetry of the channel affect high water levels in the Limfjord. We included several parameters, including changes in storm duration, intensity and wind direction, as well as an increase in the mean sea level. This allowed us to predict future storm surge conditions if the erosion is allowed to continue.

FIGHTING INCREASED FLOODING

According to our study, the change in the Thyborøn Channel from 1958 to 2005 has increased the maximum water level up to 26 cm during storms in the western Limfjord. We found that 100 years of erosion of the Thyborøn Channel will increase the storm surge levels in the western part of the Limfjord by 15 -60 cm. In addition, a relative sea level rise of 24 cm is expected 2060.

The DCA estimates that an increase in the storm surge level by just 0.5 m increases the damage potential to cities along the Limfjord by 500 million EUR. The most westerly basin, Nissum Bredning, will experience the highest impact.

Based on our modelling, the DCA examined feasible solutions to combat the storm surges. They evaluated several options, taking into account multiple factors like the effect on extreme water levels, the environmental impact, the navigational changes, the need for maintenance dredging and the influence on sediment transport.

They settled on seven options to present to the Danish Ministry of Transport, including:

- building 180 kilometres of new dikes and increasing the height of the 90 kilometres of existing dikes to protect against higher water levels up to 0.6m (EUR 70 million)
- narrowing the Thyborøn Channel by extending a corner groyne at the west end to stop most of the longshore sediment from going into the channel (EUR 37 million)
- extending a groyne at the beginning of the Thyborøn Channel (EUR 25 million)
- advancing the port entrance of the Thyborøn Channel to reduce the channel's cross sectional area (EUR 33 million)
- building a 3.2 kilometre long stone reef to help reduce water flow into the Limfjord at the Thyborøn Channel (EUR 50 million)
- building a dam with sluices, which would prevent longshore sediment from accumulating in the channel (EUR 150 million)
- building a high water barrier to be raised only when there is a high storm risk (EUR 1 billion)

Ultimately, the DCA decided to recommend narrowing the west end of the Thyborøn Channel by extending a corner groyne. This would reduce water levels in the fjord and in the city of Thyborøn. Additionally, this would ensure that conditions in the Limfjord remain unchanged. This solution would also reduce the amount of maintenance dredging at the port entrance – a precursor to improved navigational

REFERENCE

Knudsen, S.B., Ingvardsen, S.M., Toxvig Madsen, H., Sørensen, C. and Christensen, B.B. (2012): Increased water levels due to morphodynamic changes; The Limfjord, Denmark. Proc. 33rd Int. Conf. on Coastal Engineering (ASCE), Santander, Spain, 12. pp.

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CLIENT TESTIMONIAL

"Being able to model former storms gives us great confidence. By using MIKE21 to model future storms influenced by climate change, we can use the results for sustainable planning to control the risk of flooding in the Limfjord."
Per Sørensen Head of Coastal Research—Danish Coastal Authority

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