STORM SURGE BARRIERS

integral part of the Coastal Defences in the Netherlands

and

I-STORM

Historical perspective, lessons learned and personal experiences

Marc Walraven, Tokyo, 8th of May 2024

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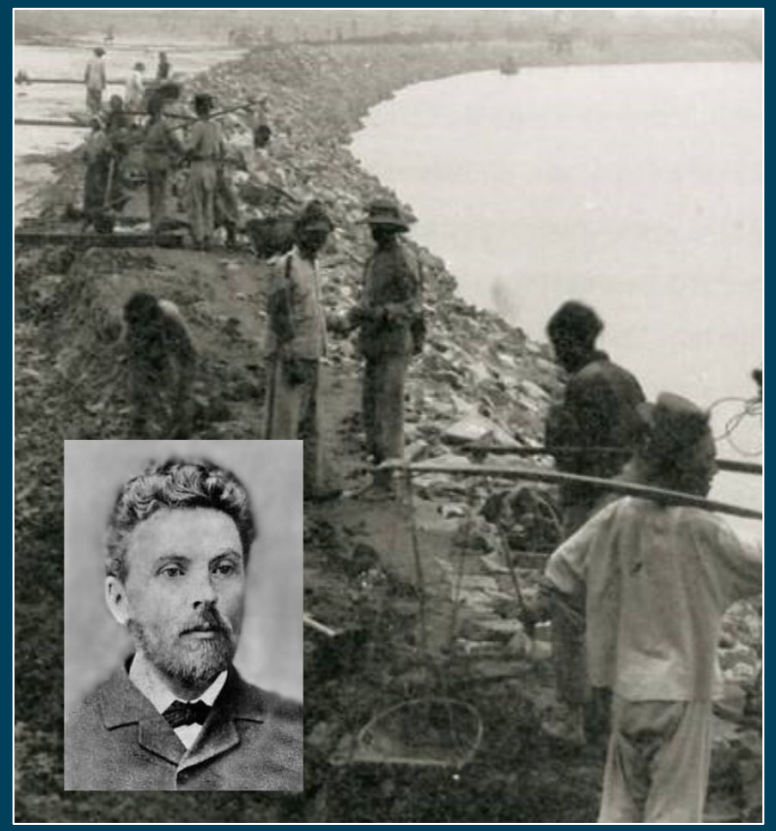
I-STORM

Japan – the Netherlands

Long lasting relation on trade and knowledge sharing

Deshima

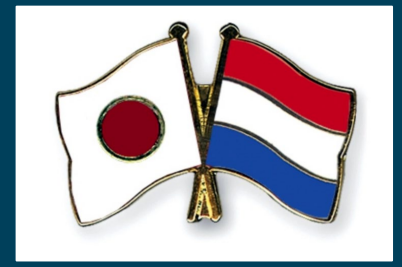


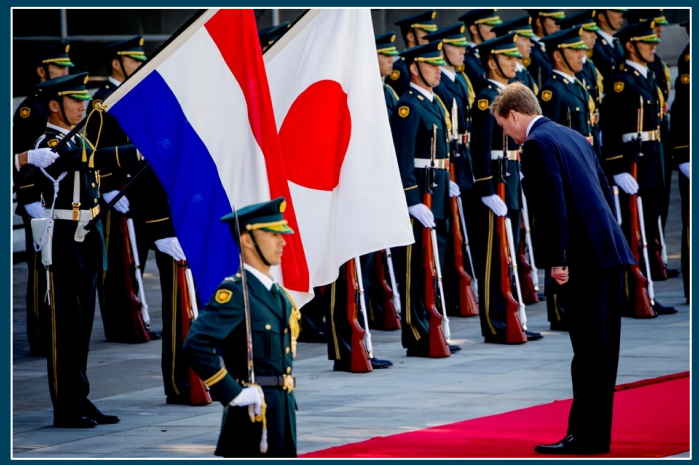
From 1641 – 1853 Japan and the Netherlands had an intensive relationship in trade and knowledge exchange

Johannes de Rijke (1842-1913) and others helped with river management and building dikes

Japan – the Netherlands

Long lasting relation on trade and knowledge sharing

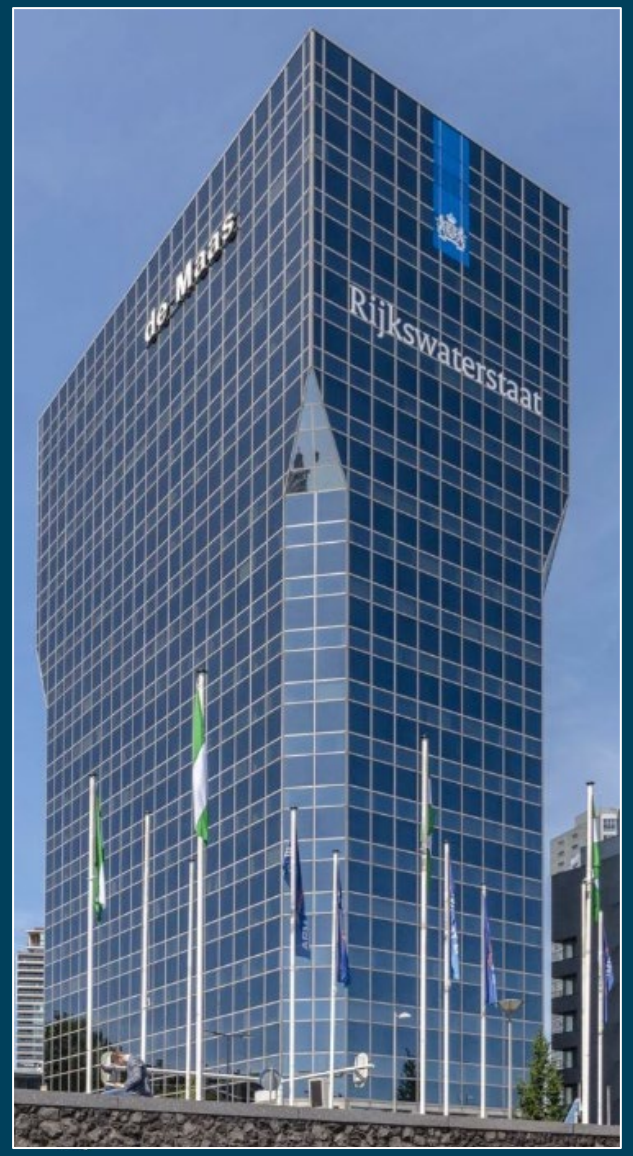




Part 1: Introduction

Rijkswaterstaat & personal introduction

Rijkswaterstaat



Rijkswaterstaat (RWS) is the operational agency of the Ministry of Infrastructure and Water Management

Rijkswaterstaat is responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands. This includes the main road network, the main waterway network and watersystems

Personal introduction

Marc Walraven, M.Sc.

(Ministry of Infrastructure and Water Management)

- Formerly District Manager and responsible for management and operations storm surge barriers in Rotterdam Region
- Senior advisor Storm Surge Barriers
- Leader Operational Closure Team Maeslant- and Hartel Barrier
- Co-founder and Member of the Board of I-STORM network
- Living at 3m below Mean Sea Level

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Venice, November 1966

New Orleans, after Katrina in 2005

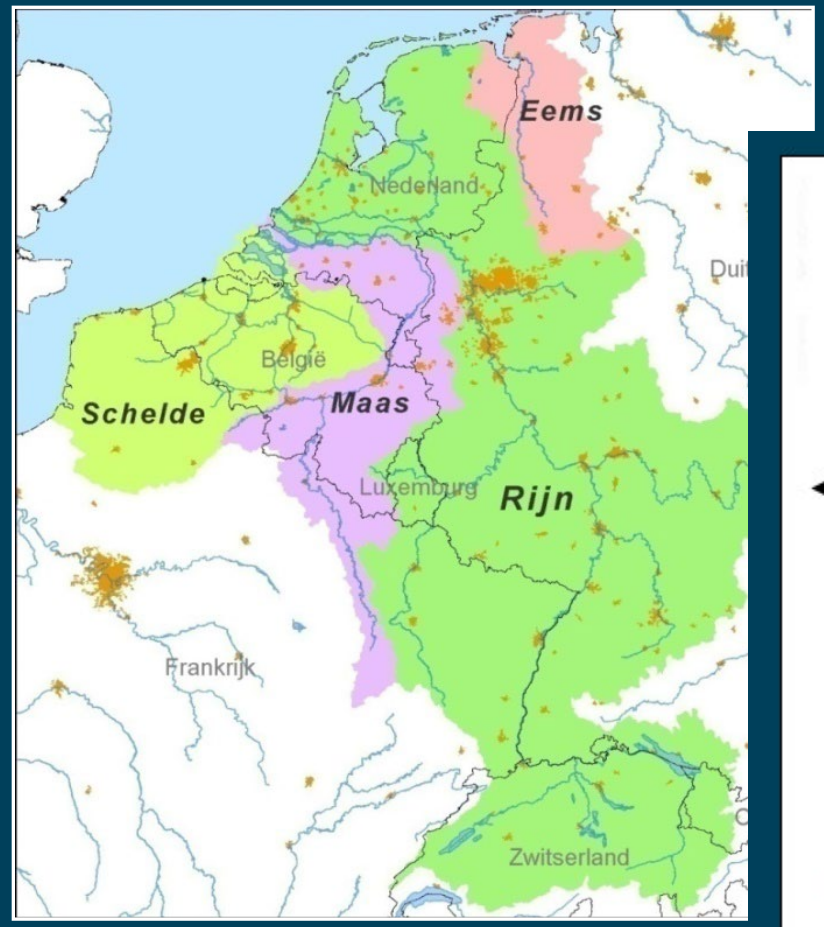
Tokyo, after Typhoon Vera 1959

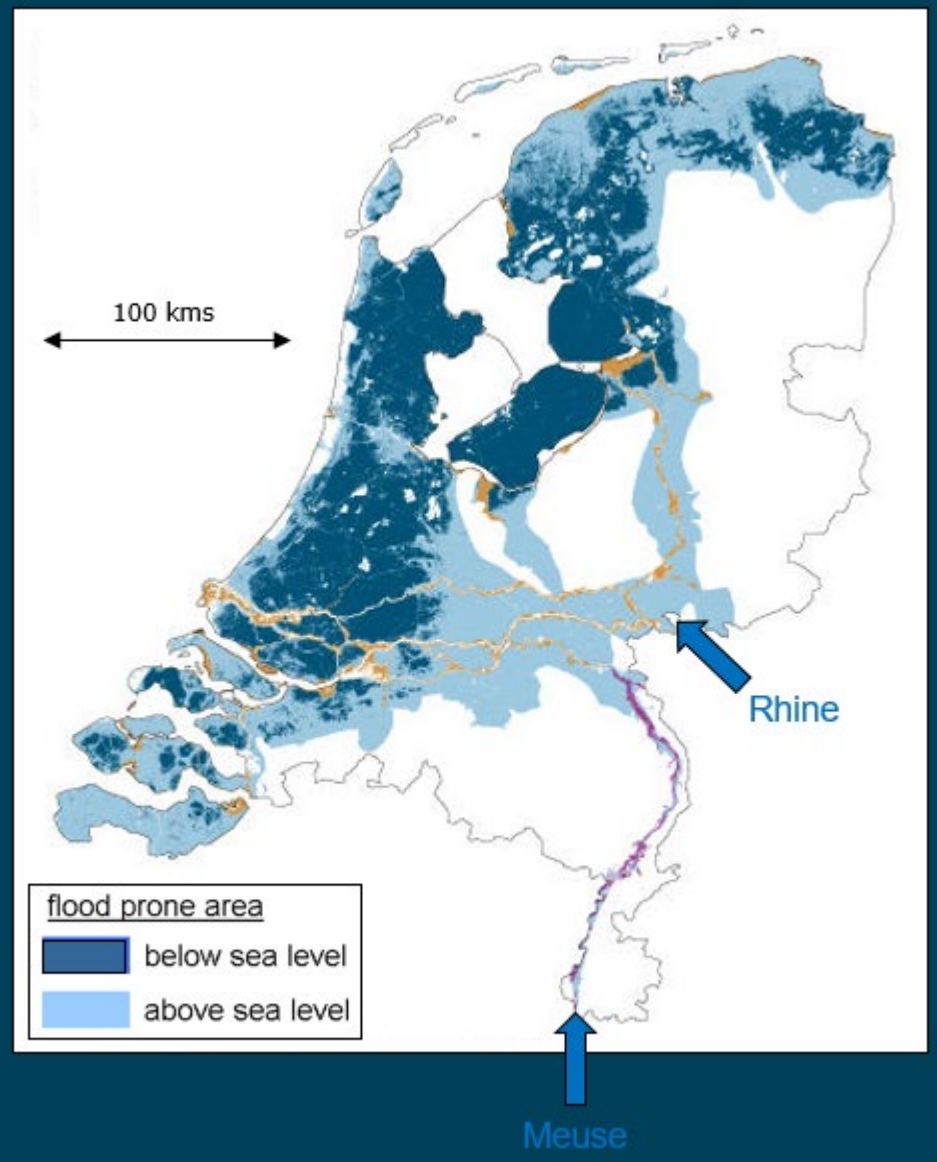
Netherlands, Februari 1953

Part 2: Introduction

The Netherlands, Historical floodings & Lessons learned

The Netherlands





- 17 million inhabitants
- Flat country with deep polders
- Coastal Delta of Northwest Europe with European rivers discharge in the North Sea
- 45% of Dutch borders is coastal
- 55-60% of the country is in floodplain (by sea and rivers)
- Subsidence is an increasing challenge too

Holocene Marine and fluvial sediments

Pre-holocene Glacial and Aeolian sediments

-30 -20 -10 0 10

Norden
Emden
Dörpen
Mep
ordhorn
Ochtrup
Coesfeld
Dülm
Kleve
Raesfeld
Moers
Essen
Bochum
Wuppertal
Dusseldorf
Brecht
Turnhout
Antwerp

I-STORM

The Netherlands: A long history with flooding

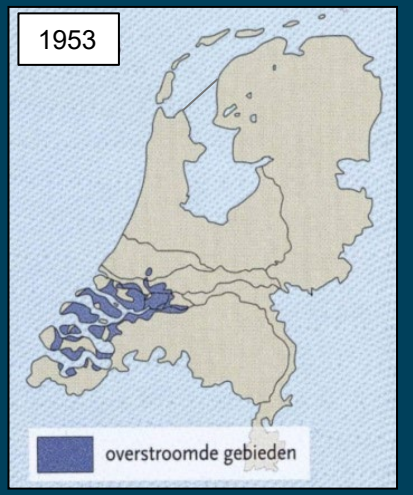
Historical floods

- Early ages: swamps, regular flooding, houses on mounds
- Dynamic landscape with erosion & sedimentation
- Fertile, productive and accessible for ships

But also . . .

- Major floods caused thousands of death people and wetlands (some are still nature reserves)
- Still regular flooding continued: 25 major floods between 1500 and 1953!

➢ Floods always led to new protection measures



Major floods in the last 100 years & Lessons Learned

1916 - North

1953 - South West

1993/1995 - Center

2021 - South East

1916
North

Closure dam ‘Afsluitdijk’ of 32 kms offered many advantages, such as:

- Safety
- Fresh water reservoir
- New land for agricultural use and cities
- Better road connections

1953
South West

The Delta Plan provided:

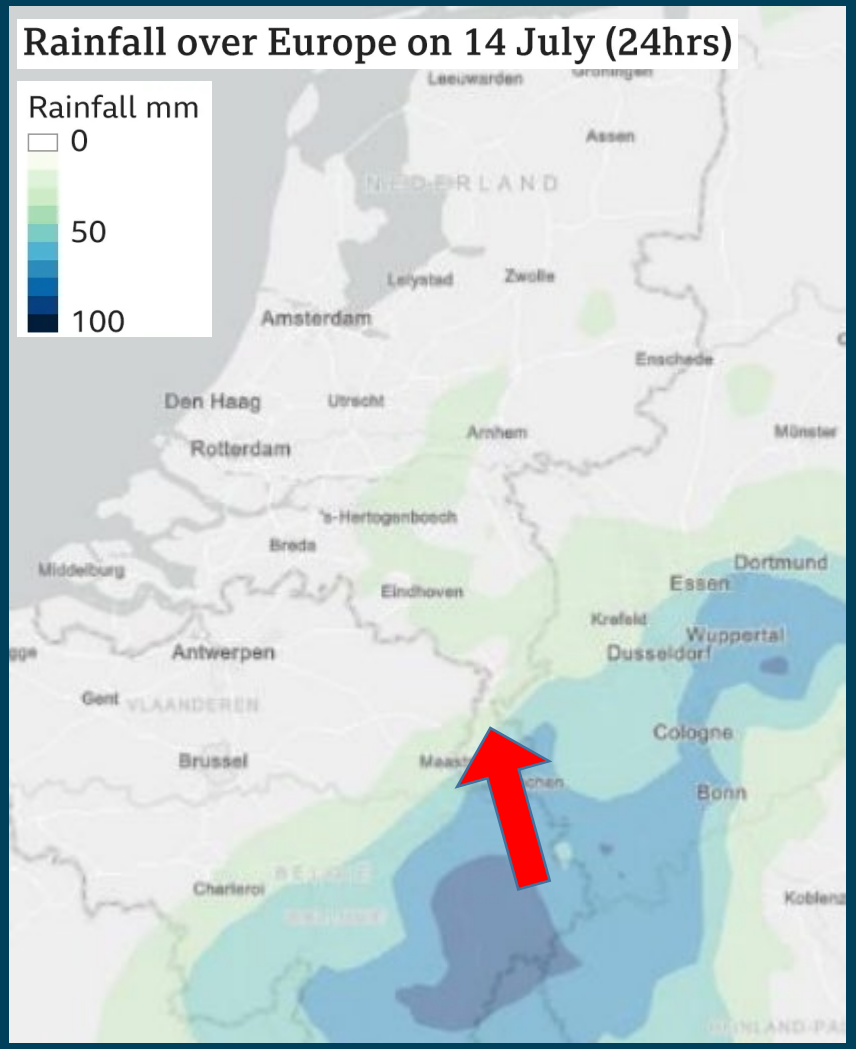
- Safety law and regulations
- Dams and raised dikes
- Storm Surge Barriers

1993/95
Center

Nature Based Solutions introduced

Room For The River Concept

2021
South East



New policies and measures for creeks in hilly region are being developed

Effect of the 20th Century floods

- Every flood got it's response with dikes, Storm Surge Barriers and Nature Based Solutions
- And, apart from the disasterous effects, every flood brought new opportunities as well:
  - Road Infrastructure
  - Fresh water reservoirs
  - New land for agricultural use and new cities
  - Innovations such as movable Storm Surge Barriers
  - New policies regarding river space 'Room for the River'
  - A more integral approach to design for multipurpose use

And last but not least we learned that:

- Adaptation of a more integrated approach to water management is essential
- Flood protection demands a balanced combination of Nature Based Solutions ánd mechanical structures such as dikes, dams and Storm Surge Barriers

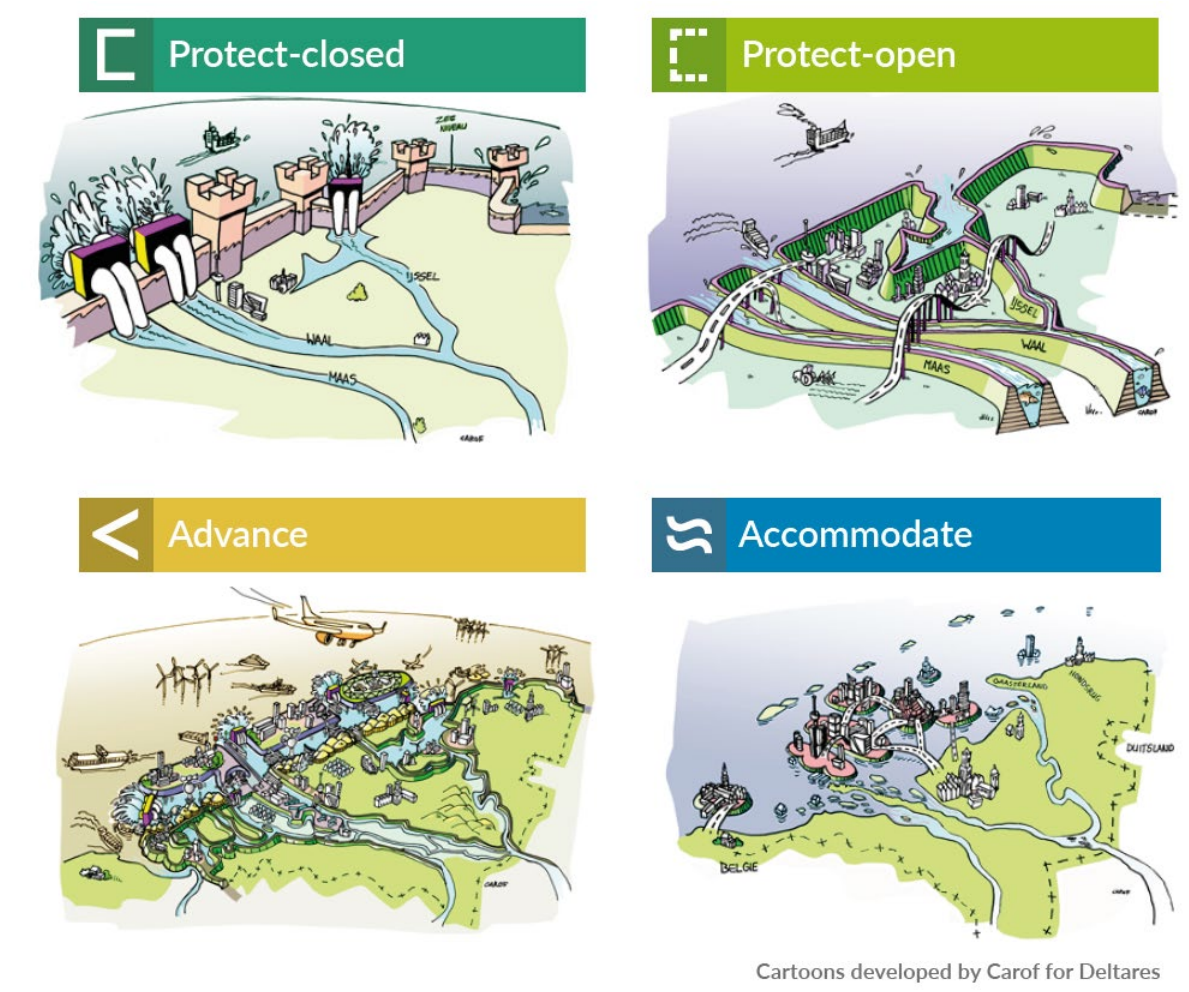
Part 3: Into the future

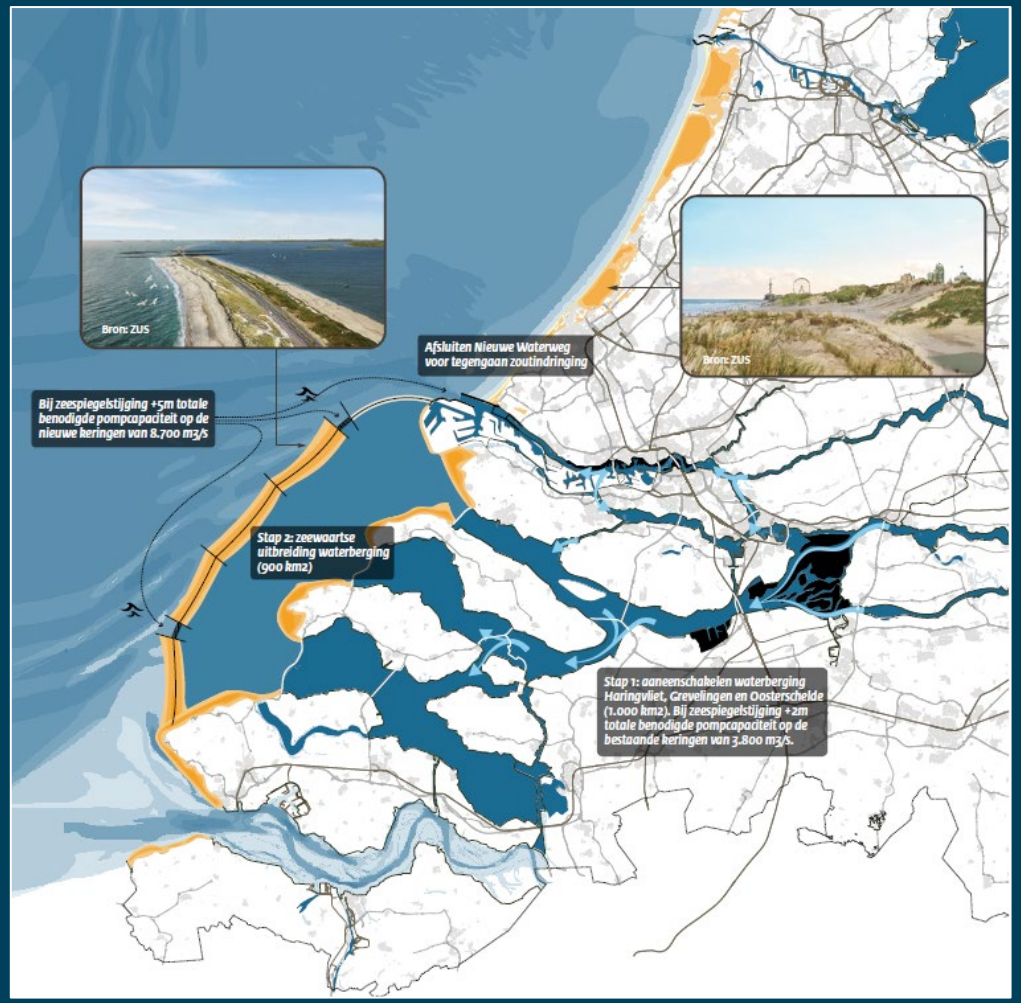
Delta Programme
Long Term Strategies
For the Netherlands

Delta Programme – 2100 and beyond

The Delta Programme protects the Netherlands against high water and flooding, ensures there is enough fresh water, and contributes to climate-resilient and water-robust planning for our country

Delta Programme – 2100 and beyond





https://english.deltaprogramma.nl/documents/publications/2023/09/19/delta-programme-2024-english

POTENTIAL CONSEQUENCES OF ACCELERATED SEA-LEVEL RISE

ANTARCTICA

Coast
more sand needed

10 mm/year ~

14 mm/year ~

60 mm/year ~

Drought risk

Increase water demand to lake IJssel ~

At 1m: permanent alternative needed for supply route via Gouda ~

Flood risk
pumping capacity lake IJssel

From 0.65 m ~ structurally needed

From 1.75 m ~

Flood risk
Maeslant Barrier

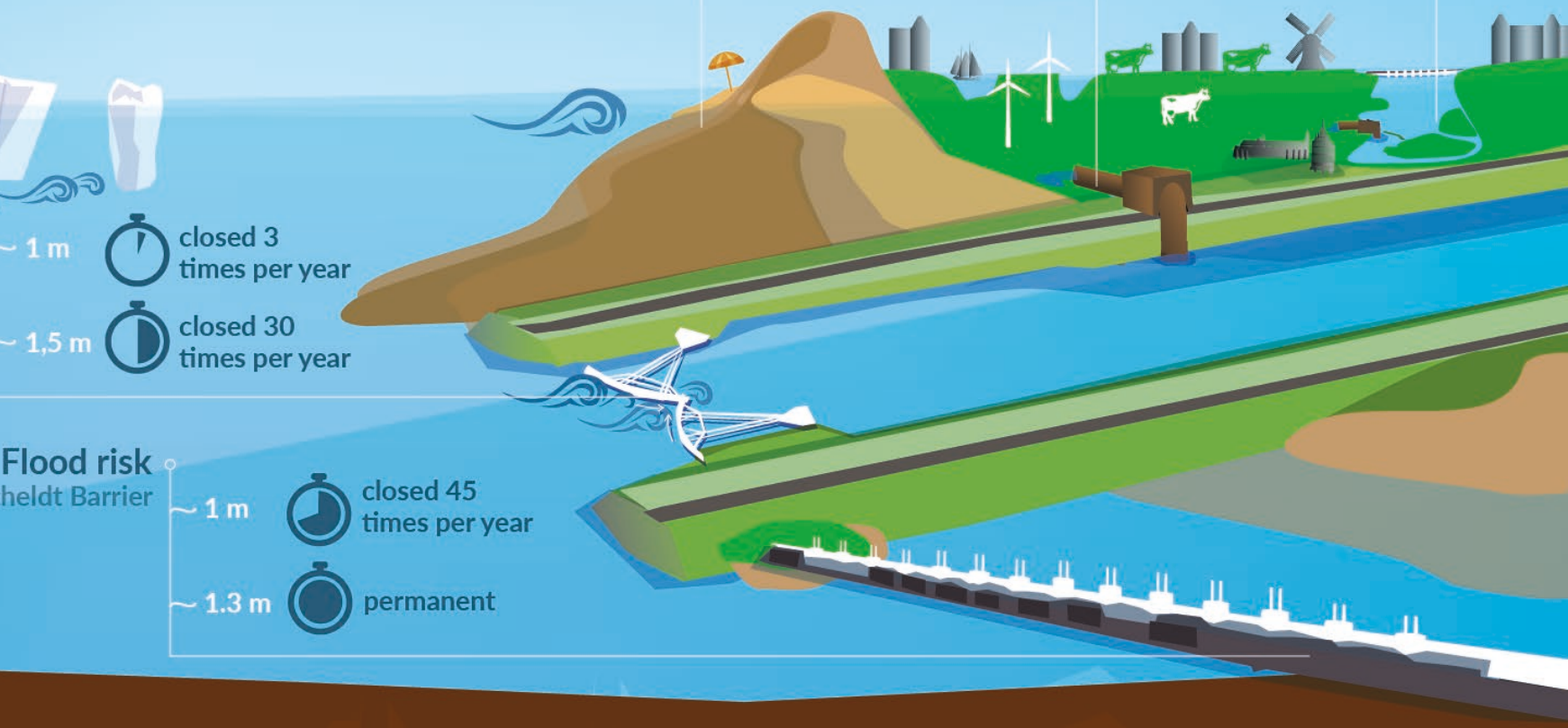
~ 1 m — closed 3 times per year

~ 1,5 m — closed 30 times per year

Flood risk
Eastern Scheldt Barrier

~ 1 m — closed 45 times per year

~ 1.3 m — permanent



Deltares
Enabling Delta Life

2018 https://bit.ly/2OArzxX

Part 4: Storm Surge Barriers

Overview of Dutch Storm Surge Barriers

Maeslant Barrier - 1997

Haringvliet Sluices / Barrier - 1971

Eastern Scheldt Barrier - 1986

Ramspol Barrier - 2002

Hollandse IJssel Barrier - 1958

Hartel Barrier - 1997

Hollandse IJssel Barrier - 1958

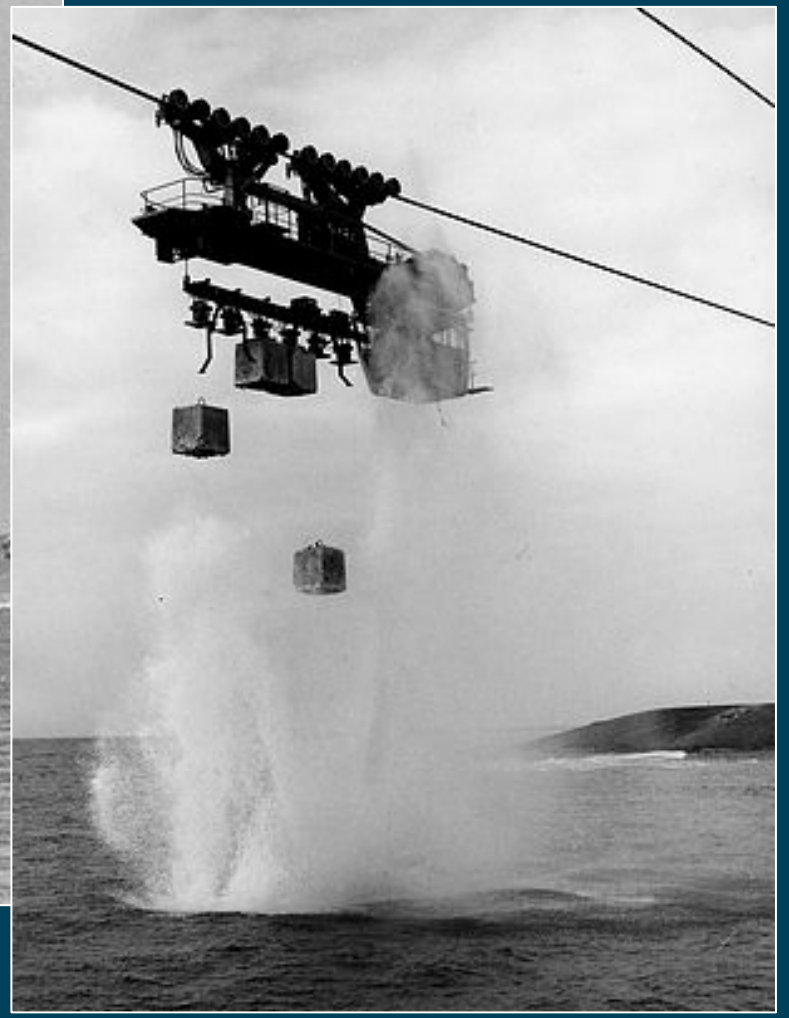
Lowest point of the Netherlands: -6,74m / -22 ft

- 1st of Delta Works
- 2 vertical lift gates
- 1 sluice
- 80m / 250ft width

Eastern Scheldt Barrier - 1986

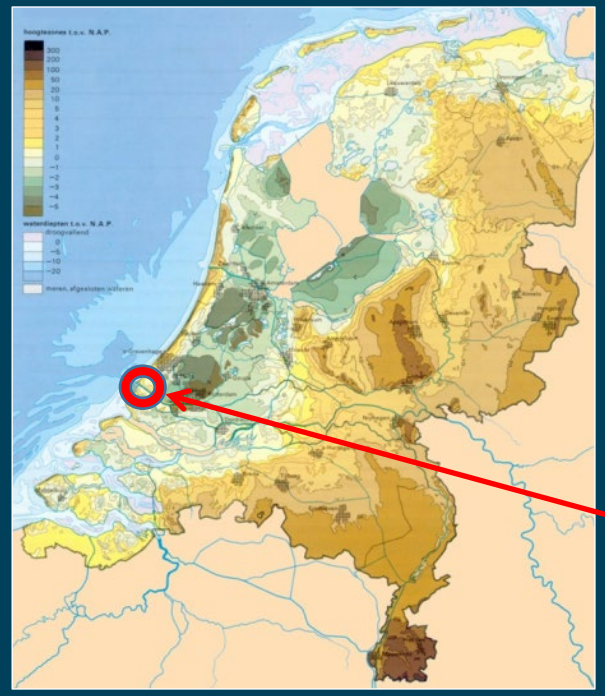
- 62 gates
- 42m / 138ft width per gate
- 6-12m/ 20-40ft height per gate
- 1 sluice
- 2 artificial islands
- Total stretch 9km/5.6mi

Construction 1976-1986

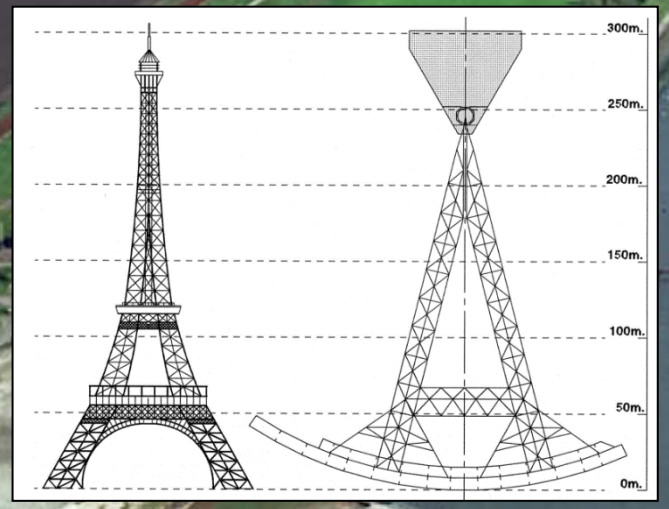



750 m / 2460 ft
750 m / 2460 ft
1500 m / 4920 ft

Maeslant Barrier - 1997



- 2 horizontal floating gates
- No sluice
- 360m / 1180ft width
- 22m / 72ft height



238 m / 780 ft

210 m / 689 ft

360 m / 1,180 ft

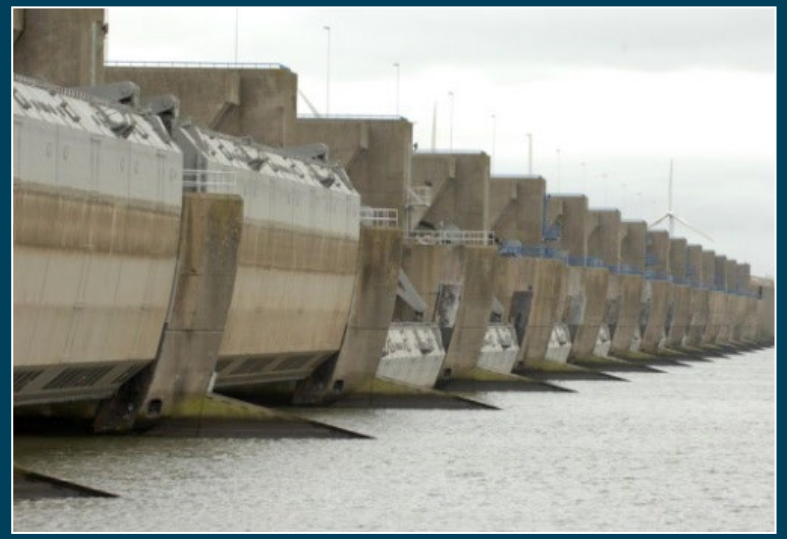
17 m / 57 ft

22 m / 72 ft

Ramspol Barrier - 2002

- 3 Inflatable gates
- No sluice
- 80m / 260ft per gate
- 10m / 33ft diameter

Each Storm Surge Barrier is different



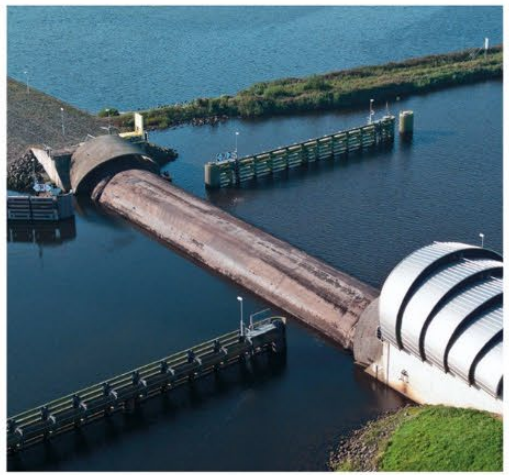
Storm Surge Barriers do have typical characteristics

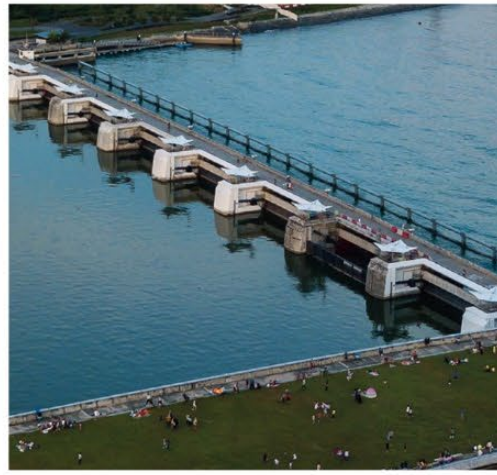
- Mostly unique design and one of a kind
- Sub systems mostly designed for other use (i.e. frequent use) than used in a storm surge barrier
- Low frequency of closures or full tests
- Full test is difficult (shipping, required water levels)
- High reliability requirements (no possibility to close a lane or lower speed like on other assets)
- Low chance on a failure required, extreme high risk
- Governmental organisations are mostly fully responsible
- Operations team and trained staff have a crucial role in achieving level of reliability – though knowledge and experience are crucial!

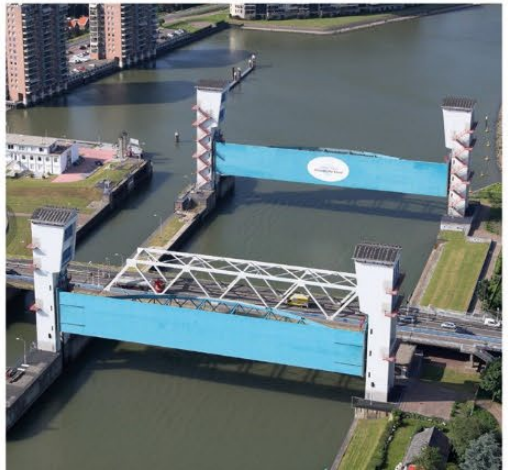


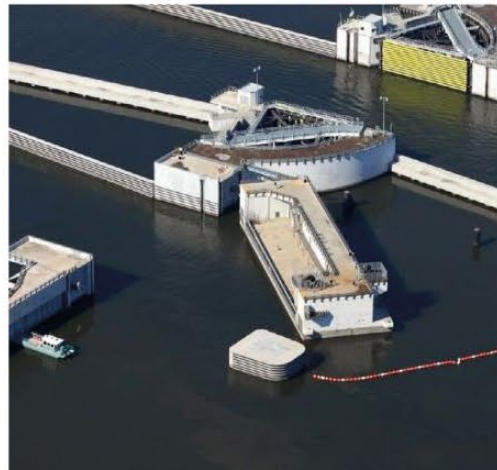








Part 5: Storm Surge Barriers

Examples of unforeseen experiences & introduction to lessons learned

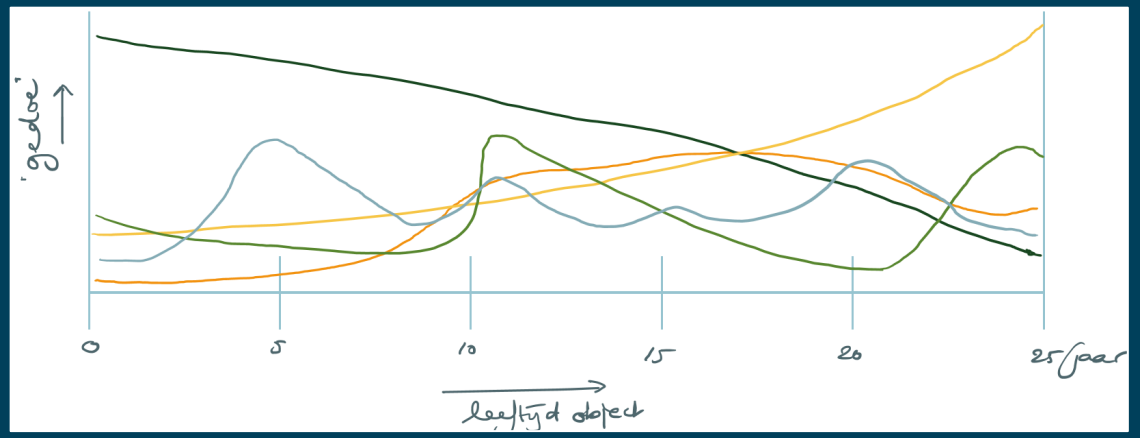
Worldwide focus is on optimising costs in design and construction,
but the reliability of a storm surge barrier is determined by

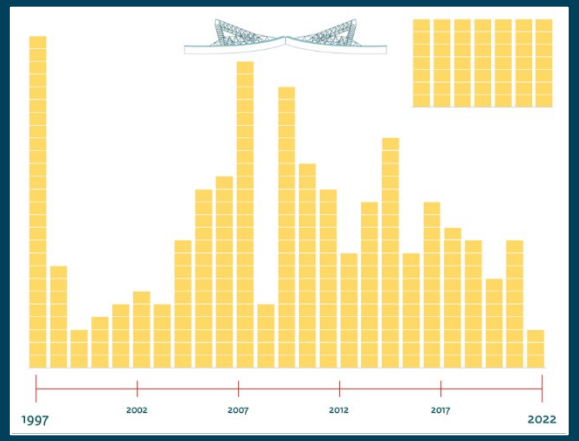
Management, Maintenance & Operations (MMO)
as a daily business

for another 100-200 years

Some examples as an introduction to lessons learned

Lessons Learned – 25 years Maeslant Barrier



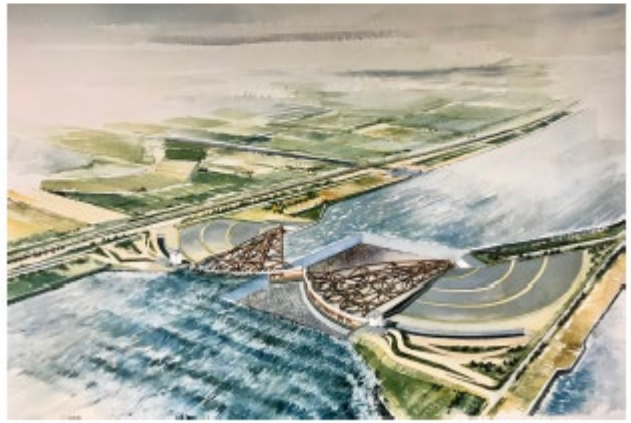


Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

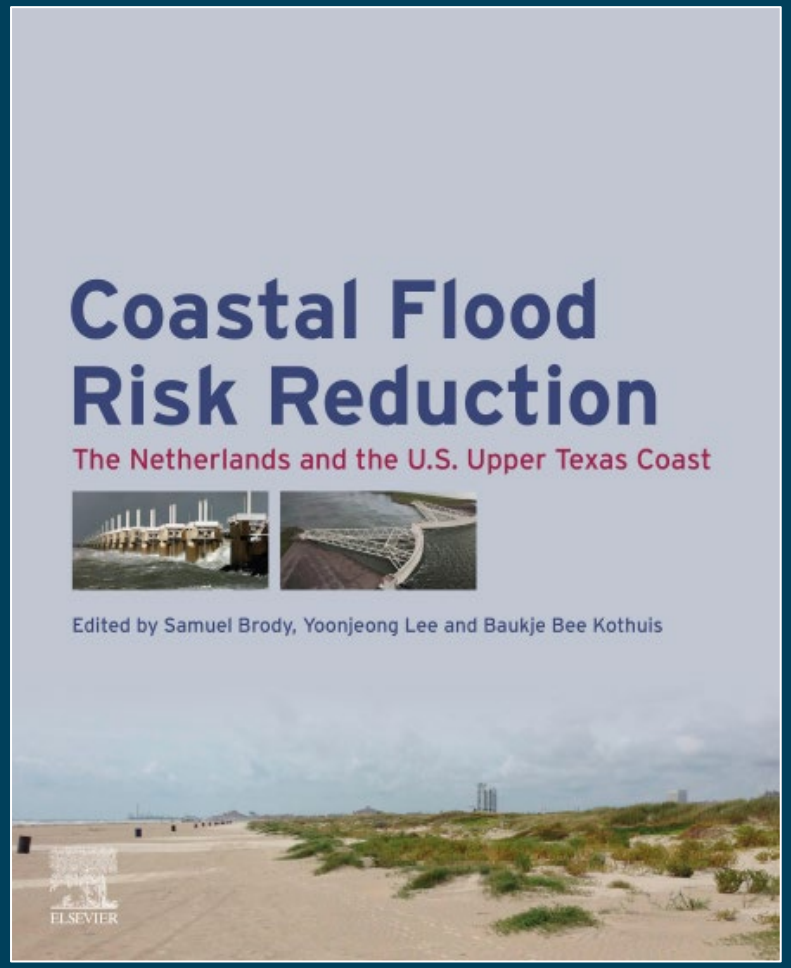
DWS BEDRIJFSINFORMATIE

Achtergronden ontwerp Maeslantkering

Reflecties in een tactisch verbindend perspectief



Lessons Learned



Book

CHAPTER 20

Design, maintain and operate movable storm surge barriers for flood risk reduction

Marc Walraven[a], Koos Vrolijk[a], and Baukje Bee Kothuis[b,c]
[a]Ministry of Infrastructure and Water Management, Rijkswaterstaat, Rotterdam, Netherlands
[b]Department of Hydraulic Engineering and Flood Risk, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands
[c]Netherlands Business Support Office, Houston, TX, United States

Introduction

After the flood disaster of 1953 in the Netherlands, it was clear that a new form of coastal defense was urgently needed. The Dutch chose to shorten the coastline, whereby part of the coastal inlet was completely closed off with dams and another part was provided with movable storm surge barriers. The so-called Delta Works were implemented, and in a period of about 45 years, six movable barriers were constructed. They were all the first of their kind prototypes of which by now various features have been applied in some form or another in several places around the globe (a.o. Daniel & Paulus, 2019). At multiple locations, possibilities for building a barrier or upgrading an existing barrier are currently being considered to protect coastal areas against storms, sea-level rise, and possible future consequences of climate change. For example, in Rotterdam, the Maeslant barrier faces a range of challenges caused by potential sea-level rise (Deltares, 2019). Similarly, in the Houston Galveston Bay region, shortening of the coastline by means of a Coastal Spine is being considered following Hurricane Ike (2008), and a movable storm surge barrier in the Houston Ship Channel has been included in the preliminary design (USACE & TGLO, 2020).

Over the years, storm surge barriers have proven to incorporate a number of very specific characteristics that have a significant impact on their management, maintenance, and operations (MMO). In the process, many lessons have been learned worldwide about the use of several types of barriers similar to those in the Delta Works, and a number of new designs have also been developed. Sharing these valuable lessons amongst barriers, worldwide, is one of the main aims of the I-STORM* network (I-STORM, 2020).

* I-STORM is the international knowledge-sharing network for all those working in the storm surge barrier profession. See also www.i-storm.org.

Coastal Flood Risk Reduction
https://doi.org/10.1016/B978-0-323-85251-7.00020-2

Chapter about
Storm Surge Barriers

Table 2 Dynamic environment of storm surge barriers.

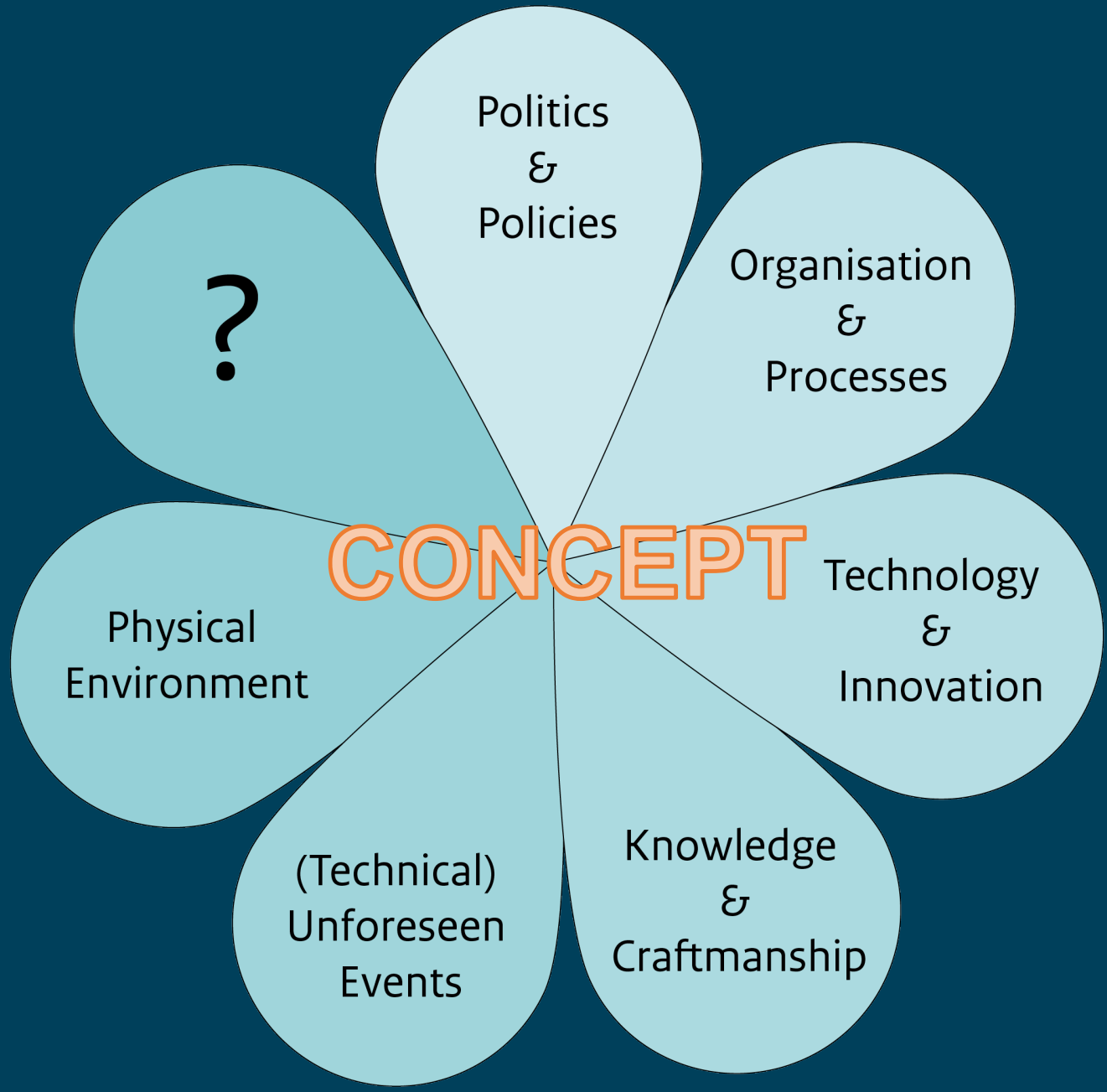
Type of dynamic environment	Example of dynamics
Politics, policy, law and regulation changes	• Shift from mainly focus on managing flood risk to also include attention to environmental aspects. • Awareness of the need for flood safety measures decreases the longer no flood disasters occur; this leads to paradoxical feature: high flood safety level because of high flood risk means less attention and thus (political) support for flood risk reduction measures.
Organizational and process changes	• Changing relationship between market and government. Shift from 'all technical knowledge in-house at government level' to 'obtaining technical knowledge from market parties' to 'part of the technical knowledge in-house and partly from the market'.
Technological changes and innovation	• Application of new types of materials and new design processes. For example, hydraulic laboratories used to be built and operated manually (e.g., the Mississippi River Model in Vicksburg; and Waterloopkundig Laboratory in Flevopolder) and are now built and operated mainly by computerized systems (e.g., the Lower Mississippi River Physical Model at LSU Baton Rouge, LA; and the Delta Flume at Deltares in Delft). • Shift from structural safety (on construction and material knowledge basis) to intelligent safety (including probabilistic knowledge), driven by the development of ICT technology. • New potential threats and needs for security: e.g., cyber security.
Knowledge and craftsmanship changes	• Additional requirements, for example resulting from the demand for multifunctionality, require additional and different types of knowledge. • In the Netherlands, many barriers were built after the 1953 disaster, a strong new knowledge impulse. The level of safety became so high, that for decades no new barriers have been built: knowledge and (human) knowledge carriers become obsolete or even disappear.
Physical environment changes	• Sea level rise, climate change, higher/lower levels of river discharge • Increasing amount of shipping, for example resulting in a higher chance of colliding with a storm surge barrier.

increasing amount of (potential) additional functions is becoming relevant, mostly related to creating economic, recreational, ecological, or sustainable energy benefits. Think of additional design to enable fish migration (e.g., at the Haringvliet Barrier) or to incorporate turbines to generate energy from tidal motion (e.g., at the Eastern Scheldt Barrier). For MMO, this means for the first case monitoring and maintaining an extra opening in

First conceptual model of
'Lessons Learned'

Conceptual model

Topics with impact on the reliability of a storm surge barrier during its lifetime



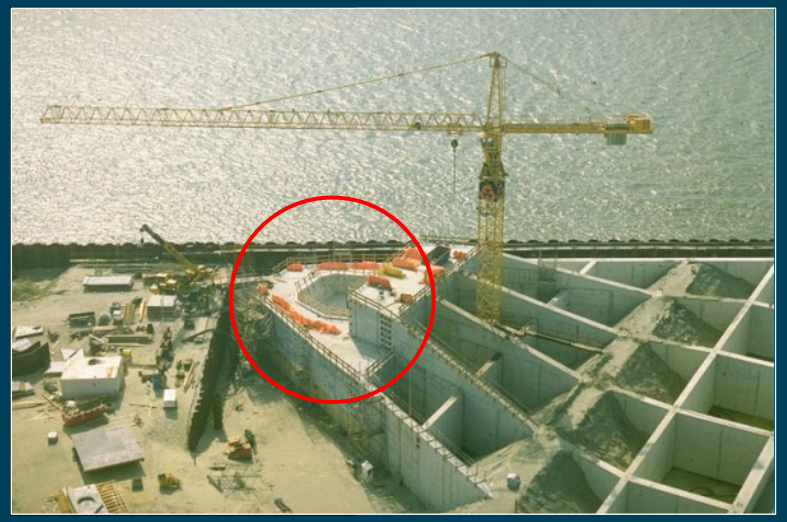
Two examples

Example 1

Ball Joint
Maeslant Barrier

Example 1:
Ball Joint Maeslant Barrier

Example 1: Ball Joint

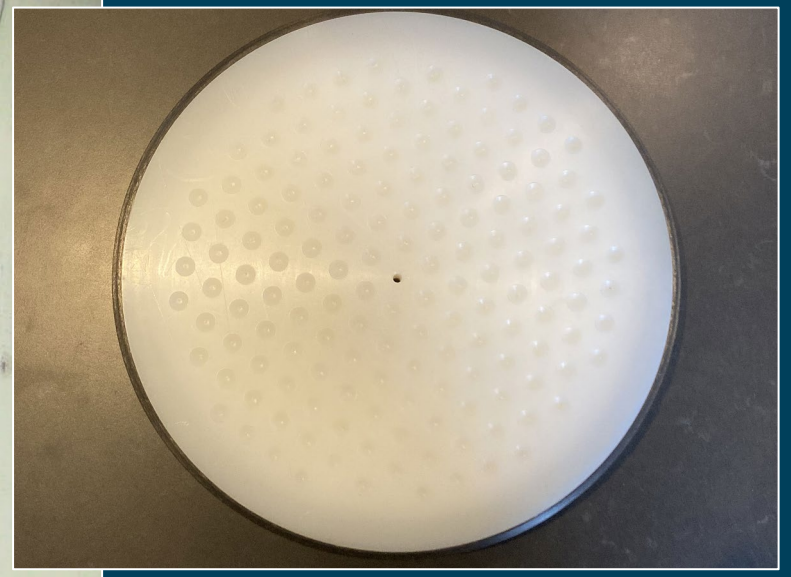


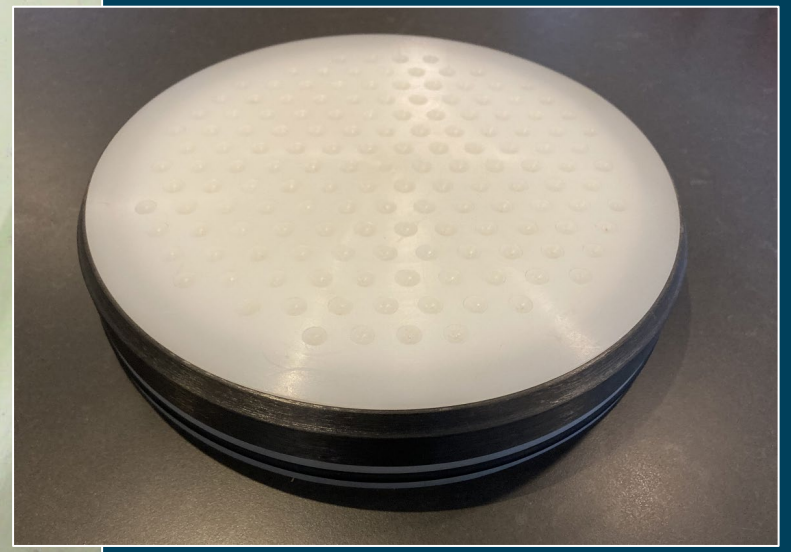
The ball joint: a 10 m steel ball rotating in a steel hollow. Designed to be ‘maintenance friendly’

Already after 5 years (and only test closures)

- Technical problem: Unexpected rapidly wear of the coating of the steel hollow
- Additional environmental problem: New laws blocked the use of specialized coating
- Short term: Additional maintenance turned out to be no permanent solution
- Longer term: Alteration of design with hard plastic disks (cost ¥ 653.480.000,- / € 4.000.000,- 2002 rate)

Example 1: Ball Joint



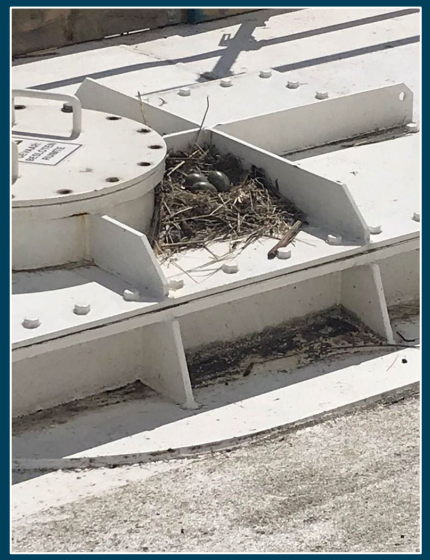


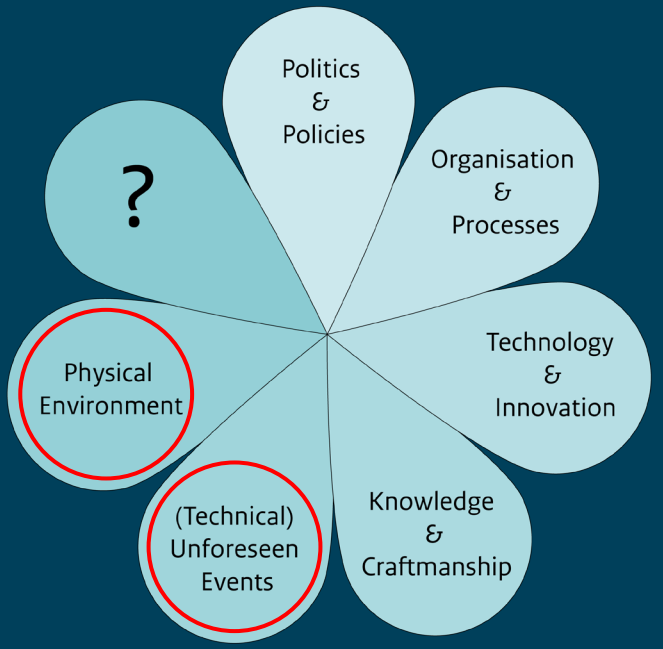
Example 2:

Gulls have recently been declared being endangered species

Example 2:

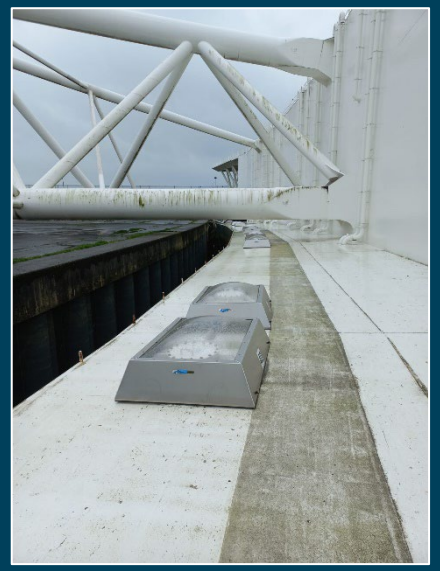
Gulls have recently been declared being endangered species

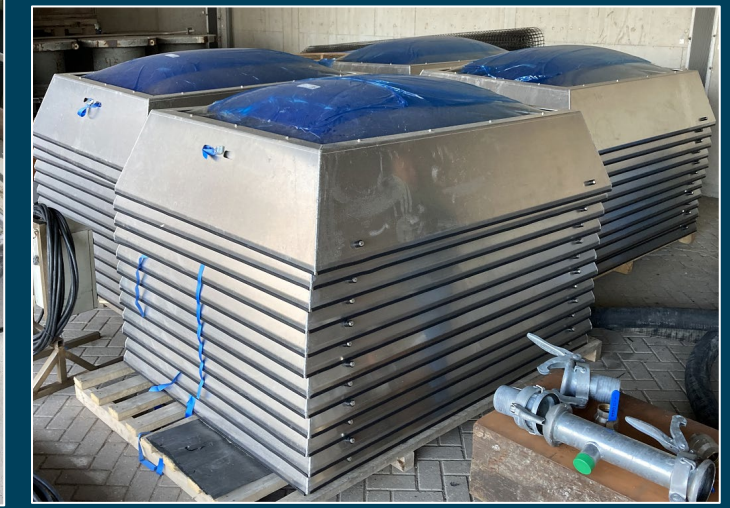




- Nests are not allowed to be disturbed
- Interfering with Maintenance Season
- Prevention is crucial, but costly

Effect: Developing urgent but costly measurements





- Special covers were designed
- These have to be placed and removed by contractor every year
- And ‘last but not least’ . . . .

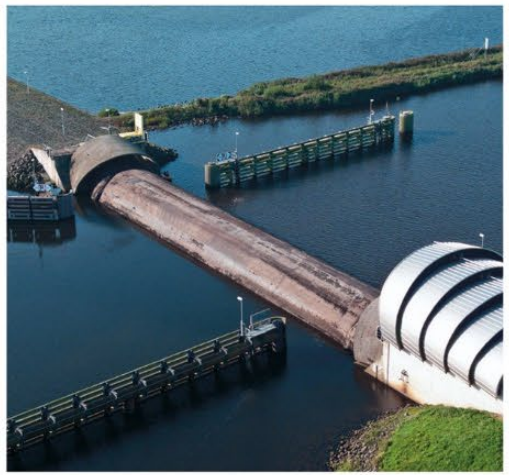
These experiences aren’t unique, but occur all over the world due to the unique nature and characteristics of storm surge barriers

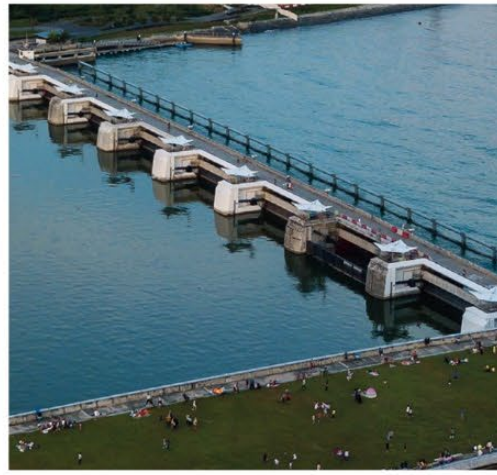
これらの経験は特別なものではありませんが、防潮堰の特殊性と特徴性により、すべての世界中で発生します。

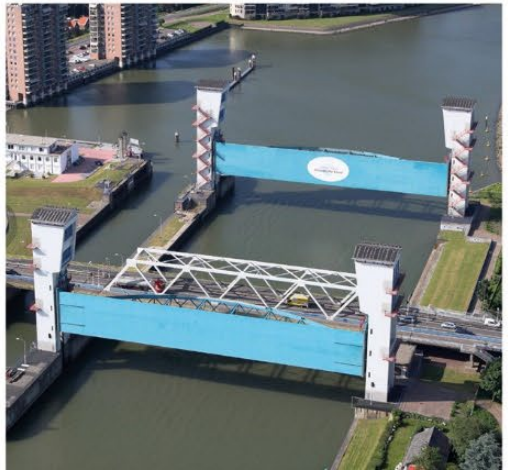


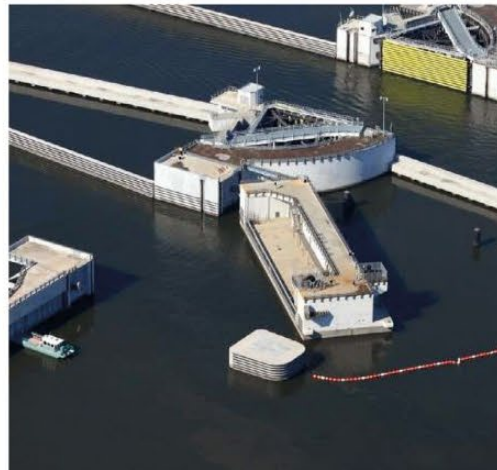








Part 6: International

I-STORM

Introduction to I-STORM

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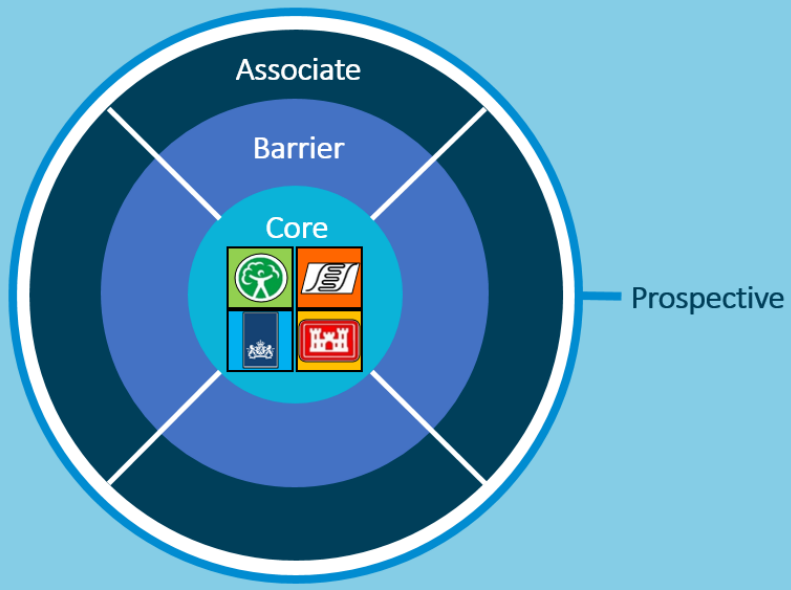
An international knowledge sharing network

- For Storm Surge Barrier (SSB) professionals around the world
- Sharing knowledge and experience to improve management, maintenance and operation of SSBs
- To better protect people, places and property from flooding
- Established in 2006

Introduction to I-STORM



We share Knowledge and experience of SSB's to

- Continuously improve barrier operations, management and performance
- Optimise SSB's performance within Flood Risk Systems
- Inform concept and development of new barriers
- Understand the impacts of environmental factors such as climate change on SSB's to help us to adept in future
- Collaborate on research and development

Awareness Meetings Denmark, 2018

Annual Meetings
Rotterdam June 2022

Peer Reviews & Other Reviews

Peer Reviews

- Thames Barrier, UK (2010)
- Eastern Scheldt Barrier, NL (2011)
- Ramspol Barrier, NL (2012)
- Maeslant Barrier, NL (2014)
- New Orleans Barriers, US (2018)
- Venice, IT (2023)

Document Reviews

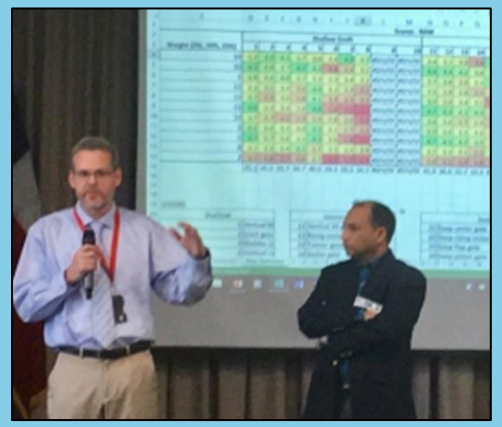
- Venice (2012)
- New Orleans (2013)

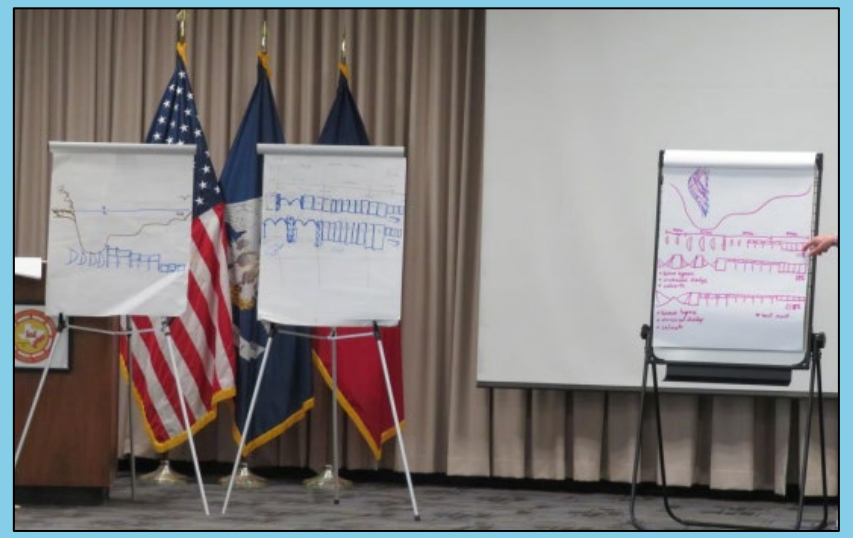
Operational Review

- Venice, IT (2019)

Gate Design Workshops

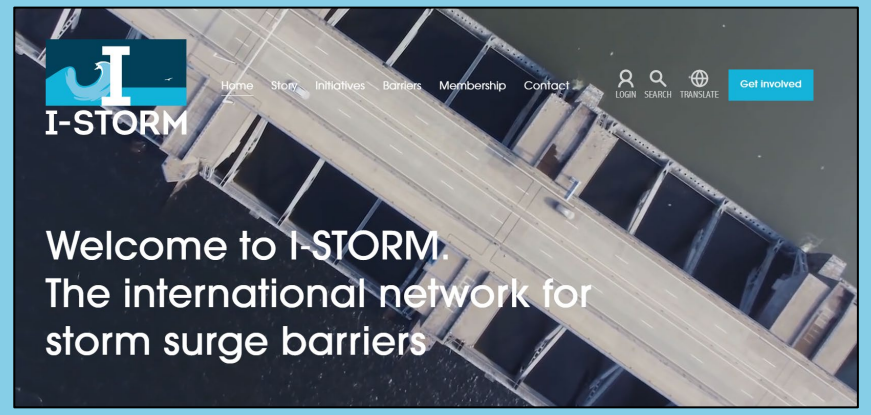
- Galveston, US (2019)
- Philadelphia, US (2022)
- London, Thames Barrier II, UK (2023)
- Copenhagen, Denmark (2024)





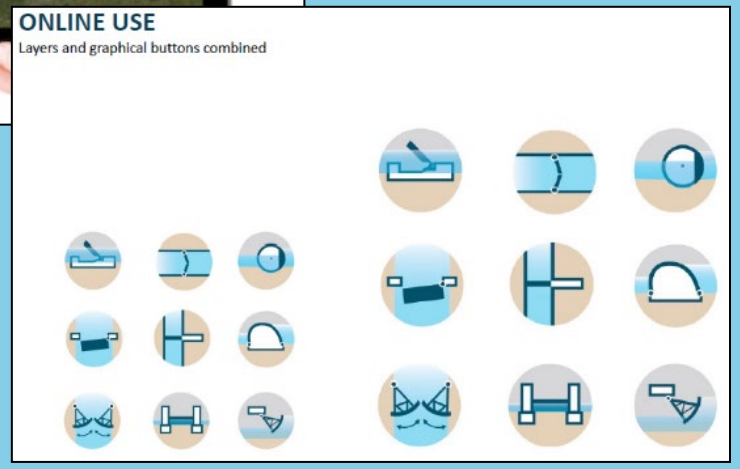
I-STORM Communications

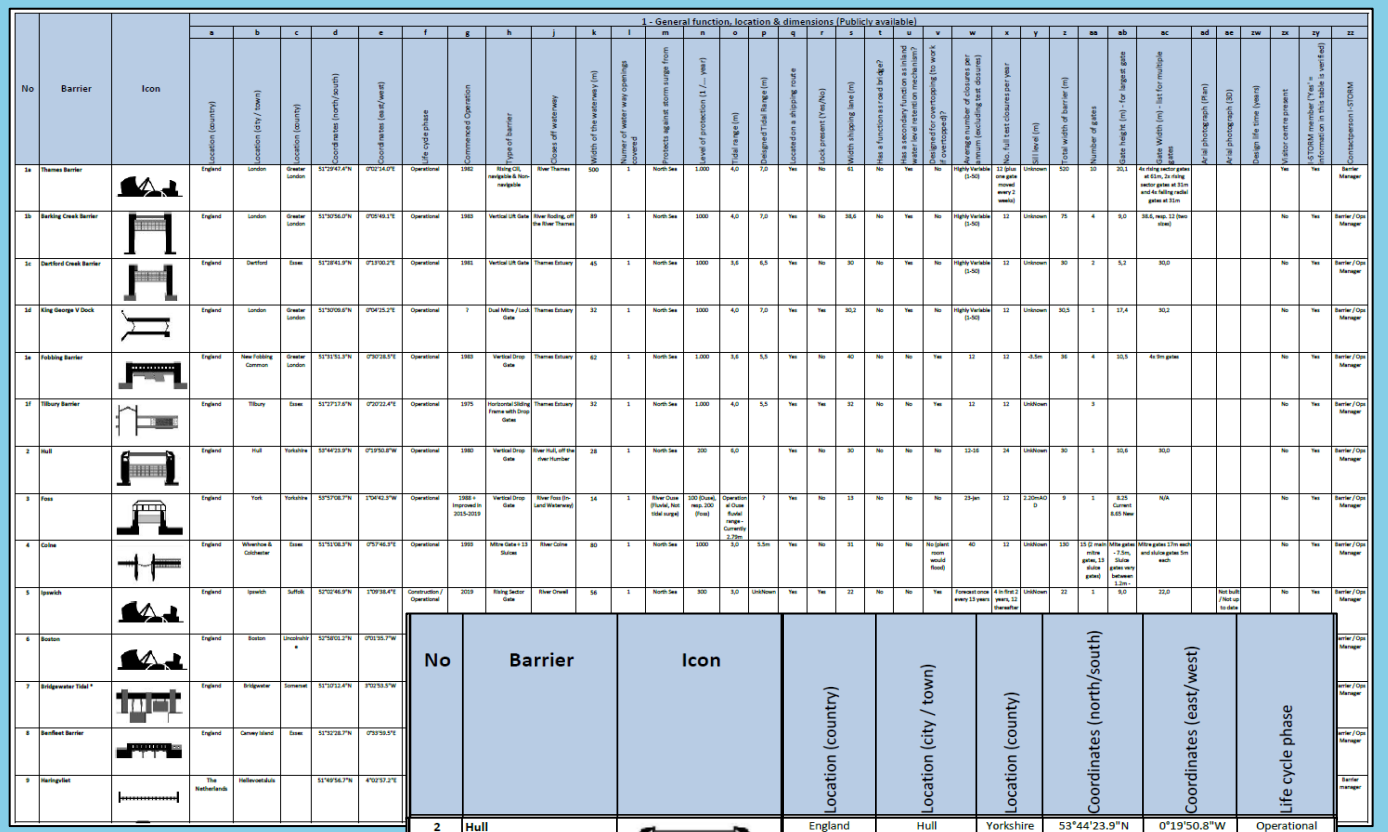
- Surge newsletter
- Webinars
- Website (www.i-storm.org)
- Twitter (twitter.com/ISTORMnetwork)
- LinkedIn (https://www.linkedin.com/groups/8959685/
- I-STORM international team: enquiries@i-storm.org



I-STORM Communications

- Characteristics Table
- Icons





No	Barrier	Icon	Location (country)	Location (city / town)	Location (county)	Coordinates (north/south)	Coordinates (east/west)	Life cycle phase
2	**Hull**		England	Hull	Yorkshire	53°44'23.9"N	0°19'50.8"W	Operational
3	**Foss**		England	York	Yorkshire	53°57'08.7"N	1°04'42.3"W	Operational
4	**Colne**		England	Wivenhoe & Colchester	Essex	51°51'08.3"N	0°57'46.3"E	Operational
5	**Ipswich**		England	Ipswich	Suffolk	52°02'46.9"N	1°09'38.4"E	Construction / Operational
6	**Boston**		England	Boston	Lincolnshire	52°58'01.2"N	0°01'35.7"W	Construction

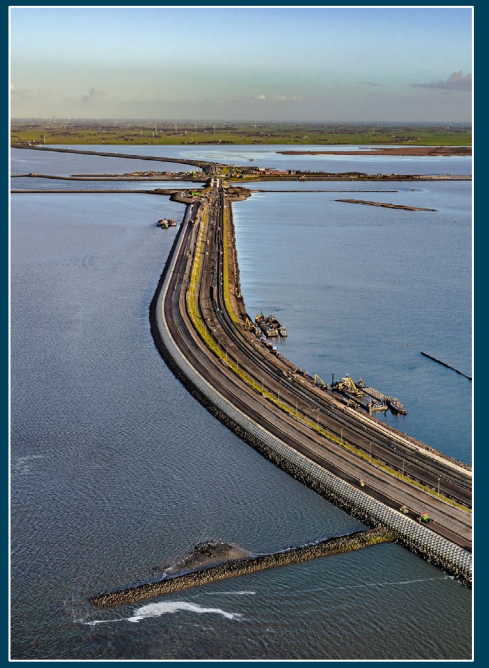
Part 7: Conclusive note

Sharing and collaboration is to the benefit of all

Two conclusive notes
２つの結論的なメモ

1. *Nature Based Solutions and structures like Storm Surge Barriers as a balanced combination provide the solutions to climate change in the future*

1. 自然に基づく解決策と防潮堰などの構造物をバランスよく組み合わせることで、将来の気候変動に対する解決法を与えます。

Two conclusive notes
２つの結論的なメモ

2. *Adaptability is crucial. We can learn from each others experiences in maintenance and operations of Storm Surge Barriers. It would be my pleasure to learn from and with you*

2. 適応力が重要です。防潮堰の維持管理や運用の経験をお互いに学ぶことができます。皆様から、そして皆様と一緒に学ぶことができれば幸いです。

THANK YOU
どうもありがとうございます