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Jonkman, Sebastiaan N.; Merrell, William J.

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Discussion of "Coastal Defense Megaprojects in an Era of Sea-Level Rise: Politically Feasible Strategies or Army Corps Fantasies?"

Sebastiaan N. Jonkman

Professor, Dept. of Hydraulic Engineering, Delft Univ. of Technology, Delft 2611 WE, Netherlands; Texas A&M Galveston, Institute for a Disaster Resilient Texas, Houston, TX 77002 (corresponding author). ORCID: https://orcid.org/0000-0003-0162-8281. Email: s.n.jonkman@tudelft.nl

William J. Merrell

Professor, Texas A&M Galveston, Institute for a Disaster Resilient Texas, Galveston, TX 77554.

This paper presents a discussion of "Coastal Defense Megaprojects in an Era of Sea-Level Rise: Politically Feasible Strategies or Army Corps Fantasies?" by D. J. Rasmussen, Robert E. Kopp, and Michael Oppenheimer. https://doi.org/10.1061/(ASCE)WR.1943-5452.0001613.

Introduction and Key Issues

The authors provide a valuable review of coastal defense megaprojects with storm surge barriers in the United States over the past decades. This review comes at an important moment: an increasing number of coastal regions are considering such solutions. Examples from the original paper are Houston, Miami, New York, Boston, and Norfolk in the US, Götenborg (Sweden), Shanghai, and Singapore (Tan 2022). A new barrier is under construction in Nieuwpoort (Belgium) (AMDK 2023). In addition, countries with existing barriers (the Netherlands, UK) are making plans to adapt, upgrade or replace surge barriers.

The reasons for consideration of these novel megaprojects are the rapid increase in exposed value and potential damages in coastal regions (Bouwer 2013; Hallegatte et al. 2013), leading to increasing demand for protection against coastal disasters (Brown et al. 2021). Another major driver is planning for adaptation to future sea-level rise. In light of these developments and the increasing demand for coastal adaptation and risk reduction, it is striking that the authors of the original paper "are pessimistic that storm surge barriers will be politically feasible climate adaptation options" in a US context for three main reasons:

1. modern environmental laws that provide avenues for expression of oppositional views within the decision process;
2. the allure of alternative options that are more aesthetically pleasing and cheaper and faster to implement (even when they do not offer equivalent levels of protection—e.g., green/nature-based solutions).
3. a shift in water resources planning that adds considerable complexity by considering multiple objectives that are sometimes in conflict.

In this short contribution, we compare and sometimes contrast the findings of the original paper based on experiences from the implementation of coastal megaprojects with storm surge barriers in the Netherlands. It is found that these are feasible if the following conditions apply:

- When alternative shoreline-based strategies have too much impact on the areas that they protect, their cost is too high, or they cannot provide sufficient protection (addressing Reason 2 above).
- Multifunctionality: meaning that functions and objectives other than flood protection are an integral part of the broader plan formulation (Reason 3).
- Environmental goals and functions integrated in the barrier design (Reason 1).
- A broadly felt urgency, as well as sufficient funding and support, to build and maintain the coastal megaproject during its lifetime (Reasons 1 and 3).

The four points just listed address one or more of the reasons for pessimism regarding the feasibility of future barriers that the authors present in their original paper. Further details and information are presented in the following section.

Coastal Megaprojects and Barriers in the Netherlands

Coastal megaprojects generally include various structural measures including levees, barriers, and dams, as well as nature-based and nonstructural solutions such as placement of dredged materials. A storm surge barrier or dam is a key intervention to shorten the length of coastline that is directly exposed to flooding. These interventions limit the need to reinforce shoreline defenses along an estuary, bay, or the downstream of a river. The first large (closed) dam in the Netherlands was the 32.5-km-long Afsluitdijk (Closure Dam) that was finalized in 1933 (Fig. 1). A storm surge barrier is a fully or partly movable coastal barrier that is normally open but can be closed temporarily to limit water levels and prevent flooding in the basin behind the barrier (Mooyaart and Jonkman 2017). The first storm surge barrier in the world was the Hollandse IJssel Barrier in the

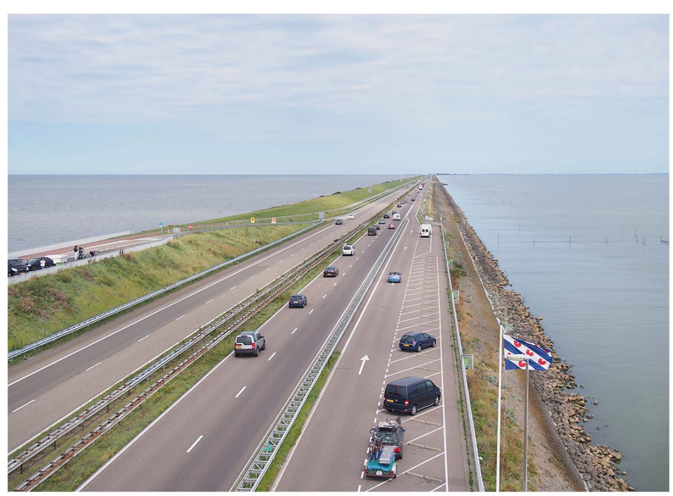

Fig. 1. Afsluitdijk (Closure Dam). (Image courtesy of Wikimedia Commons/C messier.)

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Fig. 2. Hollandse IJssel Barrier. (Image © Rijkswaterstaat, used with permission.)

Fig. 3. Eastern Scheldt Barrier. (Image © Rijkswaterstaat, used with permission.)

Netherlands, which was finished in 1958. In total, there are 19 storm surge barriers around the world (Kluijver et al. 2019). The main Dutch barriers are summarized in the Appendix and shown in Figs. 1–6.

We summarize a number of findings based on the experiences of Dutch coastal megaprojects, and we identify four key factors crucial for their feasibility and realization:

- *Alternatives*: the authors suggest that "alternative risk reduction measures that are more environmentally friendly and faster to implement are often preferred over storm surge barriers and other megaprojects." A main argument for choosing the barriers in the Netherlands was that other alternatives—mostly shoreline-based reinforcements in areas behind the barrier—were too difficult, time-consuming, and/or intrusive to be feasible. As an example, it became clear in the 1980s that reinforcing the inland defenses of Rotterdam and Dordrecht would take decades and would affect historic city centers. It was therefore decided to construct the Maeslant storm surge barrier (Fig. 4), as it could be realized faster and with less societal impact (Rohde 1993). Particularly in densely populated areas, barriers have less impact than "perimeter protection" on environment, economy, and population.

Fig. 4. Maeslant Barrier. (Image © Rijkswaterstaat | Bart van Eyck, used with permission.)

Fig. 5. Hartel Barrier. (Image © Rijkswaterstaat, used with permission.)

Fig. 6. Ramspol Barrier. (Image © Rijkswaterstaat, used with permission.)

- *Multifunctionality*: in developing the Dutch coastal megaprojects, co-benefits besides flood risk reduction included freshwater storage and land reclamation behind the Afsluitdijk, and improvement of transportation networks and the regional economy for the Delta Works. Also, a more recent program, Room for Rivers, had a clear multifunctional approach as it focused on flood risk reduction and environmental landscape quality (Rijke et al. 2012). Although multifunctionality increases cost and planning complexity, it has broad support among various stakeholders and contributes to project approval and feasibility. It thereby also reduces legal objections. Several methods are available to support risk-based and multifunction optimization and planning (e.g., Woodward et al. 2014; Zhu and Lund 2009; Rijcken et al. 2012).
- *Environmental functions and requirements*: such considerations have driven the design of the more recent Dutch barriers. The Eastern Scheldt Barrier (Fig. 3) was initially planned as a closed dam. Environmental concerns and opposition have resulted in a change in design to a storm surge barrier which allows a more open estuary. Since the completion of the Eastern Scheldt Barrier, decades of environmental research and monitoring have been performed to understand the effects of the intervention. Also, for future barriers interdisciplinary research and monitoring efforts are critical to understanding and predicting the environmental effects of barrier systems (Orton et al. 2023).
- *Urgency, decision-making, and implementation time*: decisions to construct most of the Dutch barriers were made after disasters—for example, the Afsluitdijk after the 1916 flood disaster and the Delta Works after the 1953 storm surge. These disasters highlighted the urgency of intervention and resulted in broad societal and political support and funding for barriers, and even dedicated legislation for realization. However, the actual plans had been prepared before the 1916 and 1953 disasters by engineers Cornelis Lely and Johan van Veen, respectively. This confirms that megaproject plans can take many decades before they are accepted and approved.

An often-heard related concern is lengthy construction time as pointed out by the authors. A few examples show that design and construction can be realized within a limited number of years once the decision has been made—possibly faster than large-scale reinforcement of defenses in urban areas. The first barrier of the Dutch Delta Works was the Hollandse IJssel Barrier, finished in 1958—only five years after the 1953 storm surge disaster. The hurricane protection system of New Orleans was finished in the year 2013, only eight years after Hurricane Katrina. It includes over 200 km of flood defenses and multiple surge barriers at a total cost of $14.5 billion. An important factor in the expedited construction of the New Orleans barrier was that Congress appropriated all the construction funds needed soon after the disaster. This allowed USACE to work in design/build mode and prevented costly project delays and stoppages when annual appropriations were not sufficient for continued progress.

Most Dutch barriers have been in place for decades. There are a number of current and future challenges. Firstly, actions are taken to further mitigate environmental impacts, such as nourishments in the Eastern Scheldt Estuary and the construction of a fish migration river in the Afsluitdijk. Secondly, the management and maintenance of barriers is demanding. Annual barrier maintenance costs are a high percentage of construction costs (de Ruig et al. 2021). Moreover, it appears to be difficult to quantitatively determine the reliability of these complex structures. Finally, there are concerns about future performance. Rising sea levels with increasing closure frequencies are expected and affect reliability (van Alphen et al. 2022), and they may accelerate structural degradation. Alternative plans for barrier replacement have been prepared, such as a second barrier (the Holland Barrier) next to the Maeslant Barrier to provide additional redundancy for the Rotterdam (Rijcken et al. 2023).

Discussion and Future Perspective

Because we live, according to the authors, in an "era of sea level rise," and populations in coastal zones are growing, the demand for adaptation and risk reduction will increase. The analysis and case histories in the original paper provide a number of insights and three recommendations that are crucial for future programs and are also in line with experiences from the Netherlands. The review in the original paper zooms in on two project histories from the 1960s. With modern expertise and technology, it is expected that better and more broadly acceptable coastal projects with fewer environmental impacts will be realized.

Given uncertainties in the performance of interventions and future conditions, a system for adaptive management should be part of every program. This would include maintenance, operation, monitoring, and adaptation to ensure that the system is able to function at high reliability levels in the decades after initial delivery. Such longer-term challenges are illustrated by the environmental mitigation provided by Dutch barriers and by the New Orleans hurricane protection system. The New Orleans system has proven its value in the years after completion, as it already prevented billions of dollars in flood damage during Hurricane Isaac in 2012. Yet for the longer term there are concerns about decreasing protection because of subsidence (Frank 2019) and marsh degradation (Seminara et al. 2011).

In the Dutch cases, obtaining broad support from the public, nongovernmental organizations, and different levels of government has proven to be complex and time-consuming. An important difference between the Netherlands and the US is that in the Netherlands a single federal government agency (Rijkswaterstaat, as part of the Ministry of Infrastructure and Water) is responsible for plan development, construction, and maintenance. This agency is also structurally tasked and funded to build and maintain water infrastructure. In the US, responsibilities and funding arrangements are distributed over various federal and local government agencies. The design of effective and sustainable public policy arrangements for longer-term barrier management is a key issue.

The Texas Coastal Project yields information on how current projects might progress in the present political environment in the US. The project features a large coastal spine protecting the Houston/Galveston region. It recently received a Congressional authorization of $34.4 billion despite its largely being developed in response to Hurricane Ike in 2008. Local interest in protection during the 15 years since Ike has not waned. Frequent near misses by other hurricanes kept the possibility of hurricane-induced catastrophic damages before the public and decision-makers. Ultimately, USACE chose the megabarrier concept as the tentative plan. Although alternatives were most likely faster to build and less expensive, they did not offer the same level of protection and in most cases protected only a part of the region.

To conclude, based on experiences from the Netherlands and from other regions (New Orleans, Houston/Galveston), we are more positive than the authors of the original paper that coastal megaprojects with barriers are feasible and will be needed for future coastal protection and adaptation. A key question is whether societies and governments will build these megaprojects only reactively after catastrophes, or will take action proactively before new coastal disasters strike.

Appendix. Storm Surge Barriers in the Netherlands

Barrier	Trigger/flood	Program	Construction period	Type	Length[a] (m)	Main design and multifunctional considerations
Afsluitdijk (Closure Dam)	1916	Zuiderzee Works	1927–1933	Closed dam with sluices	32,500	Freshwater supply by new lake behind barrier; land reclamation
Hollandse IJssel	1953	Delta Works	1954–1958	Double vertical lift gates	200	Better for flood protection than dike reinforcement; allows shipping and tidal flow
Eastern Scheldt	1953	Delta Works	1976–1986	64 vertical lift gates and island in middle	9,000	Initial plan for closed dam changed to open dam during construction for fisheries and environment
Maeslant	1953	Delta Works	1989–1997	Floating sector gates	360	Barrier considered better than dike reinforcement, accounting for shipping in Rotterdam port area
Hartel	1953	Delta Works	1993–1997	2 vertical lift gates	147	Combined system with Maeslant barrier; navigation
Ramspol	—	—	1996–2002	3 Inflatable gates	450	Flood protection against storm surge on Lake IJssel, open to discharge river flow under normal conditions

Source: Data from Mooyaart and Jonkman (2017).
[a]Includes both gated and permanent sections.

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