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The Netherlands and the U.S. Upper Texas Coast

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CHAPTER 18

Integrated urban flood design in the United States and the Netherlands

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Introduction

Delta landscapes are characterized by a dynamic relation between land and water in which floodplains play a crucial function in sustaining an integrated balance of soil and water systems. In the Netherlands, a highly advanced water defense system has tamed, and controls the delta dynamic since 1798 (the establishment of the National Water Department *Rijkswaterstaat*) with a focus on strengthening the line between land and water through dike systems. However, while spatial planning was formalized in the Housing Act in 1902 (Anonymous, n.d.), flood defense and urban planning have traditionally been treated as two separate fields. This has been perpetuated by the idea that flood management is fundamental in offering the primary safety condition to urban development. Van der Woud (1987) calls this the *conditio* sine qua non, meaning, without dikes there is no spatial order. Technical interventions make the Dutch territory livable, and the government has a strong and coordinated responsibility for both safety and spatial planning (Hooimeijer, 2014).

In the United States, the flood risk management paradigm is somewhat inverted compared to the Netherlands; it is not focused on flood defense by a line of dikes, but rather on the reduction of consequences by evacuation and insurance (Van Hugten, Huijsman, Kok, & Rooze, 2018). In the United States, the Federal Emergency Management Agency (FEMA) is responsible for emergency preparedness and response during a disaster, and recovery is managed by the USACE (US Army Corps of Engineers). In contrast to the Netherlands, which is a welfare state with high governmental trust, Americans (especially Texans) have a large distrust in the government and are more willing to tolerate a high level of personal flood risk (Kim & Newman, 2020; Malecha, Kirsch, Karaye, Newman, & Horney, 2020; Woodruff et al., 2020). Also, the rate of risk awareness in the Netherlands is low, while it is high in the United States. This affects US planning policies in which the role of the government is limited, increasing counterproductivity in creating new public amenities. Therefore, the choice for flood safety levels in the two countries is quite different. In the Netherlands, protection ranges between 1/4000 and 1/10,000, and in the United States, there is a maximum protection of 1/100 years regardless of vulnerability level (Merrell, 2015).

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The Netherlands has an increasing concern for the impacts of climate change, subsidence, and urbanization and the current flood defense paradigm is highly questioned (Van Doorn-Hoekveld & Groothuijse, 2017). This doubt is also fed by the reality that sometimes heightening a dike is spatially complicated because there are already land uses. Also, the rising awareness for ecology and socioeconomic changes related to ongoing urbanization make the Netherlands turn away from the focus on a primary flood defense line (Kaufmann, Van Doorn-Hoekveld, Gilissen, & Van Rijswick, 2015). The Multi-Layered Safety approach (RWS, 2009) and the Vulnerability approach (De Graaf, 2009) are both Netherland-based frameworks used to understand other ways of reducing risk that are including the urban area behind the dike.

The Netherlands focuses on the primary flood defense line (believed to be the most cost-effective solution), but broadening the scope of flood protection to a wider zone is now required. While the Netherlands is moving toward accepting consequence reduction as a method of risk reduction, the United States is moving toward the probability reduction paradigm. Since Hurricane Katrina (2005), the US national policy of reliance on recovery from flooding was severed through the construction of the Greater New Orleans Barrier (Merrell, 2015). The role of space and design has been part of this new paradigm, where public value is adopted as part of reducing flood risk. This was exemplified in the Dutch Dialogues (Meyer, Morris, Waggonner, Nijhuis, & Pouderoijen, 2009) and Rebuild by Design programs (Bisker, Chester, & Eisenberg, 2015).

This chapter examines the change in perspective in which spatial design integrates flood defense for the Dutch case of Vlissingen with the focus on the reduction of consequences and of the US case in Galveston as an example to expand on the current evacuation approach with spatial adaptation. In order to understand the connectivity between flood risk reduction and the spatial approach, four concepts are used: Probability Approach, Multi-Layered Safety approach, Vulnerability approach, and the Dutch Layers approach explained in the following section.

Spatial design approach

From a hydraulic engineering perspective, the main goal for flood protection is to create a safe defense line and reduce uncertainties using a dike (Van den Hoek, Brugnach, & Hoekstra, 2012). However, in spatial design, safety is but one of the aims among others to balance ecological and cultural values and interests. Ecological and cultural aims can be translated into spatial order characteristics such as site spatial and environmental quality or functionality (Dammers, Bregt, Edelenbos, Meyer, & Pel, 2014). A key to spatial design is the ability to achieve multifunctionality through the integration of the values of multiple stakeholders synthesized in a complex and interdisciplinary project (Reed, van Vianen, Barlow, & Sunderland, 2017).

The design of flood defenses has impacts on natural and cultural landscape features and people's lives both on and behind the dike (Van Loon-Steensma & Kok, 2016). Flood defense is, therefore, also "a symbol of the relationship between man and nature, an identity of people, landscapes and countries" (Palmboom, 2017). The conscious inclusion of the urban area behind the dike as a part of flood defense (e.g., Integrated urban flood design) will integrate flood defense into the urban fabric. This fabric is a complex interwoven spatial structure of systems, like infrastructure and parks, and objects, like buildings and bridges, that houses the necessary urban functions. There are multiple examples of integrated urban flood design in the Netherlands, such as the "Room for the River" project (Van den Brink et al., 2019) and the integration of parking into the dike in Katwijk (Voorendt, 2017). However, integrated urban flood design into the larger urban zone, outside of the dike itself, is still underdeveloped.

One important aspect of the spatial design approach is understanding the spatial order, in order to prioritize and organize the spatial claims and interests. An influential methodology is the Dutch Layers Approach (De Hoog, Sijmons, & Verschuuren, 1998) in which the spatial organization of the landscape is defined by three layers: the substratum, the networks and the occupation. The substratum includes water, drainage canals, soil, etc.; networks include the infrastructure, nodes, regional public transport, etc.; and the occupation layer refers to how humans build on top of both layers. These layers all have different timescales to physically transform themselves, making time a crucial planning factor. The Dutch Layers Approach was inspired by the "layer cake" approach by US landscape architect Ian McHarg (1969) in which ecology is considered the *condition* sine qua non for urban development (Whiston Spirn, 2000). Design using scales of time and a process of landscape development is operationalized through thinking in layers to negotiate between low and high dynamics in landscape development.

The Netherlands, since the Housing Act of 1901 (Anonymous, n.d.) and via a tradition of National Spatial Reports from the 1960s, has had a stronger spatial approach (Ministerie VROM, 1991). As noted, the Netherlands is both small and geographically vulnerable and the control over spatial order in which public and private interests are balanced needed to be extremely high. In contrast, the US spatial order is not controlled by a spatial approach but generally characterized by the urban grid as a means of territorial organization of land use and mobility. The grid also allowed for the rapid subdivision of large parcels of land during centuries of rapid growth (Reps, 1965). It creates a simple and straightforward division between public and private land. Spatial planning and design from the era of industrialization in the United States is very much based on a regional landscape architecture approach reflected in the current Landscape Urbanism discourse, in which natural systems are put forth as the leading operational logic (Corner, 2006; Waldheim, 2006).

The spatial design potentials of the risk approach

The primary aim of flood defense anywhere should be managing and reducing the impacts of flooding on people (including health and life), the economy, cultural heritage, and the environment (Priest et al., 2016). The question is, how the risk approach (risk = probability × consequences) can be understood spatially, not only in casualties and damage, but how probability and consequence reduction can be done by spatial design. In order to integrate flood defense (the risk approach) within a spatial approach (the Dutch Layers Approach) the concepts of vulnerability and the Multi-Layered Safety approach are needed to make clear connections.

The concept of vulnerability is a useful link to spatial components and measures. Vulnerability is the extent to which both social and physical systems at risk are able to sustain damage and to return to their initial state, or further enhance their performance (Adger & Kelly, 1999). Many authors discuss the components of vulnerability to climate change; hence, there are many opposing views on its definition and understanding. For the purpose of this work, the Vulnerability approach by De Graaf (2009) is used because it explains the components of vulnerability through the sequence of four building capacities—threshold, coping, recovery, and adaptivity.

The objective of the threshold capacity is to reduce the probability by a primary defense line. The objective of the coping and recovery capacities are related to damage reduction, coping during, and recovery after an event. These two capacities can be taken into the spatial approach. Coping can not only be done through evacuation of people but also by building housing on piles. Recovering can be supported by not only having an insurance to rebuild after the hazard but also making structures flood-proof so they will not be damaged as well. The objective of adaptive capacity is to build both an understanding and an ability to foresee development for the future in which the main goal is to establish a robust and healthy living environment, making use of all three other capacities as an ensemble (De Graaf, 2009).

Dutch flood-risk policy has broadened its scope to a Multi-Layered Safety approach (RWS, 2009). The first layer is the threshold capacity; the second layer is the reduction of vulnerability by spatial planning tools and building codes to increase coping capability, recovery, and adaptive capacity; and the third and final layer is crisis management, represented by recovery capacity. The first layer of protection has traditionally been dominant in the construction of flood defense systems. Given that the United States often prioritizes the crisis management layer, an interesting case is created to explore how the first and second layers of the Multi-Layered Safety approach could be applied in TX (Kok & Brand, 2017) (Table 1).

These concepts show how spatial design of the area behind the dike can contribute to reducing the overall risk to flooding by reducing the consequences. Simultaneously, spatial development of the urban area behind the dike increases consequences because with new housing there is increase in real estate value and number of people. This is oftentimes referred to as "the spiral of risk" (Rijcken, 2017) and needs therefore to be part of spatial planning. The measures for spatial design in integrated urban flood design can be ordered in two groups: *integration with the urban fabric and reintegration with the ecological system*.

Table 1 Relation between the risk equation, the Vulnerability Framework, Multi-Layer Safety strategy, and Dutch Layers Approach.

risk =	probability see Fig. 1A, B, C, E	x consequences see Fig. 1F and G		
Vulnerability framework (De Graaf ,(2009)	threshold	coping - recovery		adaptation
Multi-Layered Safety (RWS , 2009)	first layer	second layer		
			third layer	
Dutch Layers Approach (De Hoog et al., 1998)	infrastructure			
		occupation		
	substratum			

The spatial impacts of probability and consequence reduction are linked to Fig. 1.

Integration with the urban fabric

At first, this new risk approach considers a broader flood defense system as well as the dikes and the urban area behind the dikes that are impacted. As shown in Fig. 1, the scope of the flood defense system is extended to the urban area, dike, and foreshore, and not merely focused on the line created by a dike. By increasing safety measures in the urban fabric such as improving evacuation routes or raising the ground level of buildings, there is a reduction in the number of casualties and/or economic damage. This contributes to reducing overall consequences and could lead to a reduction of overall flood risk (Nillesen & Kok, 2015).

Reintegration with the ecological system

The "spiral of risk" can also be an opportunity to make a difference in the way flood defense is planned in dense urban areas and how it is in rural areas. The rural areas could be planned and designed as natural areas where the occasional flooding is welcome to nurture the natural system. Thus, it can impact the land use and design of landscapes on the larger scale. Reintegration with the ecological system creates a potential to use nature-based solutions for risk reduction, such as planting a willow forest in a foreshore area to dissipate energy from surge waves and unload this pressure on the dike or dune. This allows for greater possibilities to incorporate nature-based solutions as an alternative or additional strategy to the conventional gray (or nonnature based) infrastructure flood defense systems (see Fig. 1D and E).

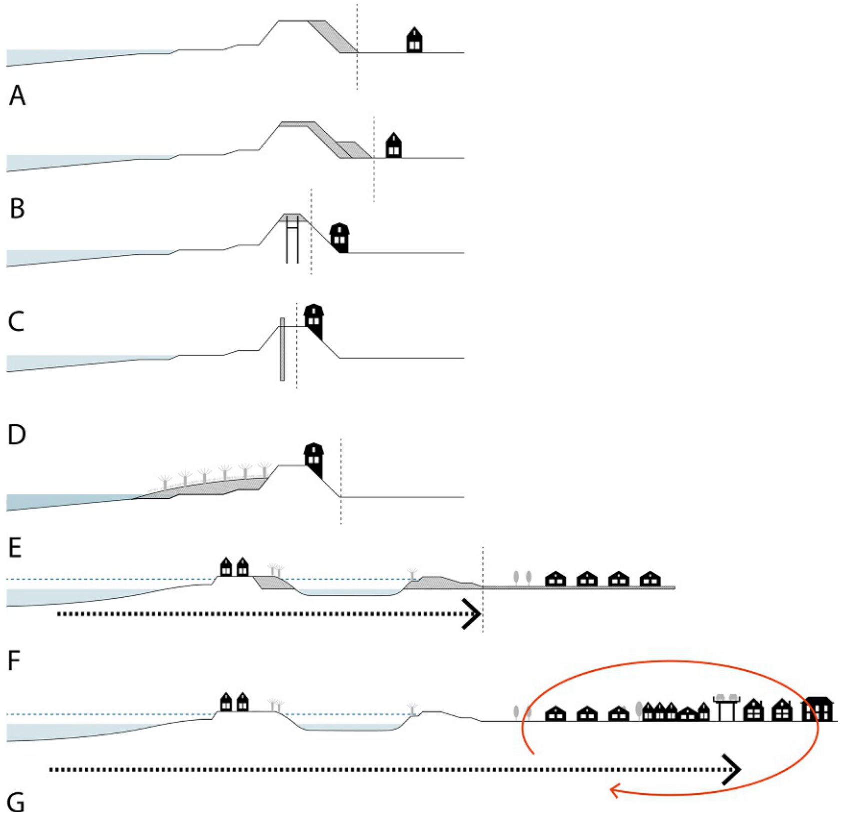


Fig. 1 (A–D) Scope of dike reinforcement; (E) wave attenuating willow forest; (F) room for the River; (G) broader scope by the new safety standard. *(Drawn by Y. Yoshida.)*

Case study: Vlissingen (Flushing)

Vlissingen is a cape town located on the coast where the North Sea and the Scheldt River intersect. The estuary acts as a funnel, which increases sea levels and flood risk. The current protection level is 1/30,000 years. This dike protecting the city is completely fixed, with buildings constructed atop it. Due to the proximity to the North Sea—Antwerp shipping route, seaward reinforcement in the foreshore is not possible. For this reason, the municipality developed the so-called "Vlissings Model" (Vlissingen & Ma.an, 2010), which includes the adaptation of the building code to allow for the possible raising of the dike.

The Vlissings Model regulates since the 1990s that new construction along the coastal boulevard must anticipate future flood risks, requiring that their foundations and ground floors be designed in such a way that are part of the future raised dike system. Some existing construction along the Boulevard (mainly hotels) has been built according to this

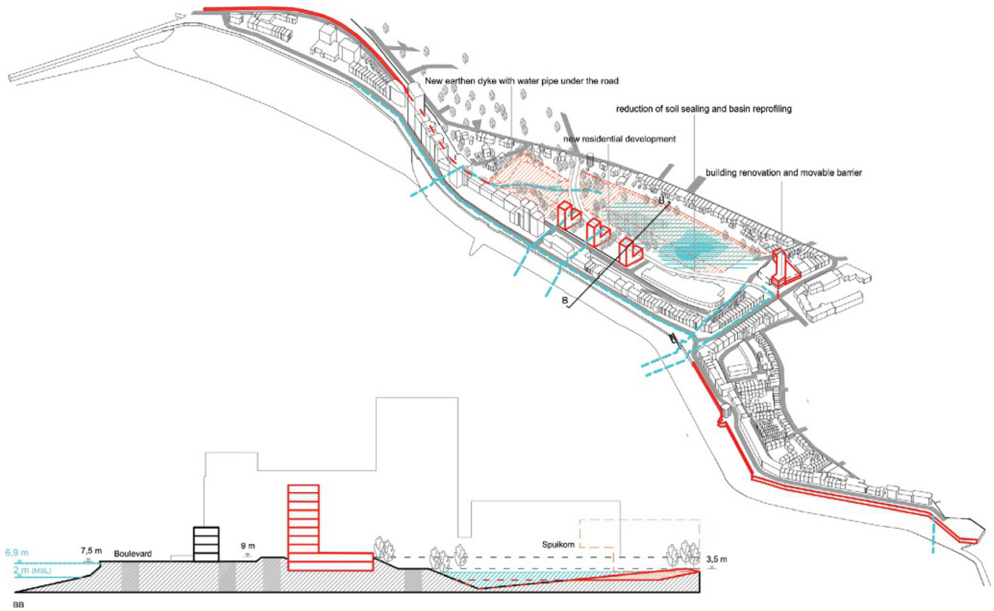


Fig. 2 The Overtopping Sump Model, making space for water (with estimated still water level at 2100 with 100,000 years RP). *(Drawn by A. Bortolotti.)*

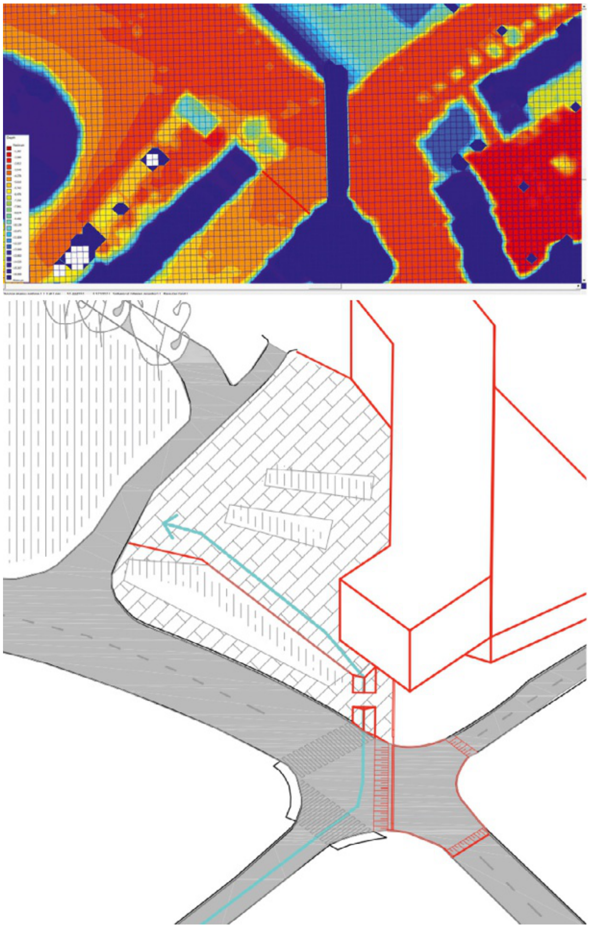
principle, with higher ceilings on the ground floors to enable the incorporation of the ground floor into the new dike (Fig. 2).

However, the Vlissings Model may eventually lead to the replacement for the entire historical urban waterfront, an important part of the identity of the city. Therefore, a second option has been investigated to accept overtopping of seawater in the future and preserve the historical identity. The water would be conveyed to—and stored in—a former water reservoir located behind the dike, a green space called the Spuikom. This approach involves the rerouting of overtopping water from the seafront boulevard toward the Spuikom, street redesign, and basin reprofiling.

Design evaluation

Analyzed through the lens of the vulnerability concept, the Vlissings Model aims to increase the threshold capacity with spatial adaptation of the dike. The Overtopping Sump Model aims to maintain the threshold capacity and introduces the adaptive capacity of the area behind the dike. This integrated urban design is based on fine-grained and spatially explicit hydraulic models that support design decisions (e.g., the location of mobile barriers, the layout of new development, etc.). As such, it requires interdisciplinary engagement and a close collaboration between spatial designers and hydraulic engineers. Not only are hydraulic models necessary to project flood events (their extension and intensity) to suggest where to take spatial adaptation measures, but they are also an essential tool for assessing the effectiveness of such interventions within the timeframe of a flood event.

The Vlissings Model, considering the Multi-Layer Safety strategy and Dutch Layers approach, respectively, combines the first and second infrastructure and occupation layers by including private property as a part of the flood defense strategy. The Overtopping Sump Model is a new step in shifting the paradigm in which flood defense becomes part of spatial design (Fig. 3).



Time	10000 Years	100 000 Years
	Q[m³/s]	Q[m³/s]
13/12/2019 08:30	0,000	0,000
13/12/2019 09:00	0,000	13,286
13/12/2019 09:30	6,095	41,282
13/12/2019 10:00	12,212	58,994
13/12/2019 10:30	13,462	56,740
13/12/2019 11:00	10,222	47,369
13/12/2019 11:30	6,698	35,114
13/12/2019 12:00	4,517	23,728
13/12/2019 12:30	3,031	13,617
13/12/2019 13:00	1,732	5,948
13/12/2019 13:30	0,977	2,195
13/12/2019 14:00	0,610	1,243
13/12/2019 14:30	0,532	0,779
13/12/2019 15:00	0,443	0,493
13/12/2019 15:30	0,398	0,454
13/12/2019 16:00	0,342	0,409
13/12/2019 16:30	0,307	0,350
13/12/2019 17:00	0,285	0,328
13/12/2019 17:30	0,246	0,301
13/12/2019 18:00	0,239	0,257
13/12/2019 18:30	0,269	0,230
13/12/2019 19:00	0,259	0,211
13/12/2019 19:30	0,000	0,202
13/12/2019 20:00	0,000	0,195
13/12/2019 20:30	0,196	0,159

Fig. 3 Detail of the HydroNL Model for understanding volume and time sequence of the overtopping to design the street with for a probability of 1:10,000 years and 1:100,000 years in the W+ climate scenario. In the image, there is a barrier taken up in the public space design to guide the water flow to the Spuikom.

Case study: Galveston

Galveston Island, Texas, is located on a sand barrier island on the southeast coast of Texas, within the Gulf of Mexico. Surrounding the island, several bays provide important habitat, options for recreation, and access to the port of Houston. Galveston has suffered greatly during many past hurricanes (e.g., Ike, 2008; Harvey, 2017); excessive rainfall cannot always be drained, causing common local flooding complications called "nuisance flooding" (Van Hugten et al., 2018).

When a hurricane is expected, the National Weather Service (NWS) activates to recommend evacuation directions and supply essential needs (water, food, light). The USACE organizes temporary housing, and debris removal. FEMA leads the recovery afterwards for the reconstruction of properties and primary infrastructure. Due to the increasing occurrence of extreme weather events, evacuation recovery activities are becoming more complex and expensive, highlighting the need for a comprehensive strategy to mitigate the impact of urban flooding.

After Hurricane Ike in 2008, the concept of a coastal spine inspired by the Dutch Delta Works was intended to protect the Houston-Galveston area from a 10,000-year storm (Houston Chronicle, 2009; Kothuis, Brand, Sebastian, Nillesen, & Jonkman, 2015; Merrell, 2015). The so-called "Ike-Dike" raised several controversies related to its environmental impact, the economic investment (23–31 billion dollar), and the navigability of the channel (AP News, 2018). For Galveston, the strategy consists of raising the historical sea wall (built after the 1900 Great Storm) and creating new protective structures to encircle the urban development. The plan, known as the "Galveston Ring Barrier," risks could generate a "bathtub effect," which means that water would be trapped inside the barrier, creating more severe floods (Coastal Texas Study, 2020). This infrastructure is still in the early stages of planning (Powell, 2020) and open to public scrutiny, offering opportunities to think for measures, which may have a lower impact on the ecological and hydraulic balance of the bay as well as on the spatial development.

In response to the Galveston Ring Barrier, a project of TU Delft students named "Floodproof Galveston" (Van Hugten et al., 2018) was setup. Overall, 13 projects have been designed as a synergetic plan of local designs to reduce nuisance flooding and damage during hurricanes in Galveston. All designs focus on five general purposes: (1) protect evacuation infrastructure from flooding, (2) prevent inundation, when gravity discharge does not occur, (3) reduce the impact of waves, (4) facilitate recovery interventions, and (5) avoid hard infrastructure and prioritize natural solutions.

Evaluation of the design for Galveston

The plan (Fig. 4) by Van Hugten et al. (2018) for Galveston aims to mitigate nuisance flooding. Design proposals work together involving the transformation of the substratum and infrastructure layers, in order to increase the adaptation capacity of urban

Fig. 4 Integral design of mitigation measures (Van Hugten et al., 2018).

development. Coping and recovery are promoted by raising mobility hubs, installing pumps, and combining discharge and water storage measures. The probability of flood risk can be decreased by the integrated projects of partially raising the historic seawall, implementing coastal protection with dunes, sand bars, and building new wetlands.

The plan is composed from the interaction between all layers of the Multi-Layer Safety strategy and considers all components of the Dutch Layers approach, demonstrating the need for a multiscale design environment for water management. The outlined strategy examines the possibility to approach Galveston's flood issues by conceiving a more inclusive plan, where situational design proposals result from a collaboration between engineers, architects, and urban planners. The approach can be representative for a paradigm shift in the United States wherein they can move from nonspatial measures (evacuation and insurance) to the inclusion of spatial assets of coping and recovery capacities that impact and shape the urban fabric in order to improve urban sustainability.

Discussion

After introducing a spatial design strategy and defining its potential within the risk approach, two cases were studied considering the Vulnerability Concept, Multi-Layered Safety strategy, and the Dutch Layers approach. The overview shows how the two models for Vlissingen clearly differ on how to reduce vulnerability, the safety approaches, and layers of spatial dynamics. The Overtopping Sump Model is a step beyond the traditional line-based defense of Dutch flood risk management. In the Galveston case, rather than building the Ike Dike and encircling the island with sea walls (in the Dutch manner) the design demonstrates the potential for expanding the focus beyond recovery toward adaptation, which is about including all levels of the Multi-Layer Safety and Dutch Layers approaches.

In both countries, the planning systems present a challenge for integrating flood risk in spatial design. In the Netherlands, because of greater government control, integrating flood risk into spatial design means that engineers and spatial designers need to codesign, like in the Overtopping Sump Model in Vlissingen. This presents a significant shift in the design and construction of the urban fabric. The United States has the opposite issue; it is difficult to expand flood risk management due to a lack of employed local spatial design strategies. However, the urban fabric is much easier to adapt to the measures proposed.

The opportunities for both cases lie in creating spatial designs that include natural solutions and better anticipate uncertainties. In the Netherlands, this can create more awareness and adaptivity to flood risk, as new urban amenities become possible by taking out gray (engineered) infrastructure. In the United States, the recovery paradigm in which people are individually affected can take on an adaptive approach through the creation of new urban amenities, public spaces, recreational, and ecological areas (Table 2).

Table 2 Relation between the risk equation, the Vulnerability Framework, Multi-Layer Safety strategy, and Dutch Layers Approach.

risk	probability see Fig. 1A, B, C, E	consequences see Fig. 1F and G		
Vulnerability framework (De Graaf ,(2009)	threshold	coping - recovery	adaptation	adaptation
Multi-Layered Safety (RWS, 2009)	first layer		second layer	
	first	second	third layer	
Dutch Layers Approach (De Hoog et al., 1998)	infrastructure			
	occupation	occupation		
	substratum			
	infrastructure		occupation	substratum

The position of the Vlissings Model is in *light blue*, Galveston in *green*, and Overtopping Sump Model in *dark blue*.

Generally, an interdisciplinary approach in which goals, information, and measures are merged is key to integrating flood defense into spatial planning. Particularly, in the Overtopping Sump Model, the spatial design process is done in close collaboration with hydraulic engineering knowledge and tools in order to understand spatial dimensions, the volume of the water coming over the dike that needs to be stored or conveyed, and the temporal dimensions of water overtopping the dike. The result is a spatial strategy in which the consequence reduction goes hand in hand with spatial upgrading because of the re-design of public space and real estate development. Spatial design in Galveston is not necessarily about the design of public space, but it is about the design of the urban fabric as a system in which the proposed measures are integrated. This was done with the perspective of flood defense as a zone rather than just a line of defense provided by a single dike.

Conclusions

The integration of flood protection in urban development is currently undergoing a paradigm shift in which flood defense is no longer the *conditio* sine qua non, but instead urban development becomes also the *conditio* sine qua non for flood defense. This is due to the urgency caused by the environmental crises, and, in the Dutch case, related to the natural processes of subsidence, which increasingly makes the country vulnerable to floods. To keep on defending land by a dike in the Netherlands, or keep on recovering from events in the United States is too costly and missing out on the option for sustainable urban development. For the Netherlands, the paradigm shift is moving from reducing probability (the threshold capacity) to foreseeing consequences and focusing on adaptive capacity. For the United States, the shift is going from dealing with the consequences and a high recovery capacity to a spatial approach in which design is used to define a set of adaptive measures. The two shifts basically meet in the middle where integration with the urban fabric and reintegration with the ecological system are both achieved.

This study found five principles for future action in integrated urban flood design:

1. Spatial design strategies should include flood risk and consequence reduction, related to environmental conditions and vulnerabilities. This usually goes hand in hand with staying close to the *genius loci* (original natural identity) and using parameters to balance the conditions of the landscape with urban use.
2. Repurpose spatial design to prioritize ways in which to live with water. Design can create awareness and thus carry capacity; also cost and benefits of flood defense and other urban developments can be synergized.
3. Incorporate the notion of deep uncertainty like climate change into planning and design by integrating no-regret solutions, which are solutions serving multiple purposes, as a part of urban development.
4. Acknowledge and design with the natural landscape and local ecosystems as part of the sustainable development process.

5. Integrate innovative dike reinforcement with urban programs on the larger scale and supportive to the paradigm shift wherein urban development becomes also the *conditio* sine qua non for flood defense.

The integration of flood defense in urban development needs bridging. This is bridging of concepts and integrating goals, strategies, and measures. The bridging of the risk approach with the Dutch Layers approach by use of the vulnerability concept and the Multi-Layered Safety approach is very helpful to understand the integration of flood defense in urban development because it navigates through the complexity. The cases are meeting in the middle of two very different (national) approaches and thus revealing opportunities of integration and a new road to a resilient future.

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