

Architectural design strategies for flood resilience

in Dutch outer dike areas



RESEARCH PLAN

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Architectural design strategies for flood resilience in Dutch outer dike areas		
Research plan		
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Cover page
Figure 01: House standing amidst a flooded area (by author, 2024, AI-generated image)

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Introduction

July 13, 2021. Extreme rainfall caused severe flooding across the Dutch province of Limburg, as well as in parts of Germany and Belgium. Over two days, more than 160 mm of rain fell, pushing the river levels beyond their capacity and leading to a widespread flooding along rivers like the Meuse and Roer. While the primary flood defenses held, unprotected areas, such as outer dike areas and areas along minor rivers were heavily impacted with significant damage in the town of Valkenburg. In total, over 50.000 people were evacuated and approximately 2.500 homes, 6.000 businesses and 5.000 were directly affected. (Task Force Fact-finding Hoogwater 2021, 2021), This incident highlights the ongoing flood risks that challenge multiple regions in the Netherlands.

Flooding is the most frequent natural disaster worldwide (CRED & UNDRR, 2020). While floods have always been a natural part of the hydrologic cycle, bringing new nutrients and supporting biodiversity, they became problematic as human settlement expanded into flood-prone areas. Our built environment encroaches upon rivers, wetlands, and coastal areas that naturally serve as buffers for high water levels (Watson & Adams, 2010). Rather than controlling these natural processes, a more sustainable approach would be to appreciate and adapt to them, developing land and buildings in harmony with natural flood cycles. This perspective drives the need for architectural design strategies that allow for coexistence with floodwater, reducing the impact of extreme flooding events, while preserving the benefits of living or working in flood-prone areas.

The battle against water has been an enduring challenge in the Netherlands, a country where much of the land lies below sea level and is the delta of several major European rivers, including the Rhine and Meuse, carrying rain and snowmelt from upstream countries such as Germany, Belgium, France and Switzerland. This geographical situation has led to a history of severe flood events, with the 1953 North Sea flood being one of the most catastrophic. The river floods of 1993 and 1995 further exposed the vulnerability of the Dutch country, leading

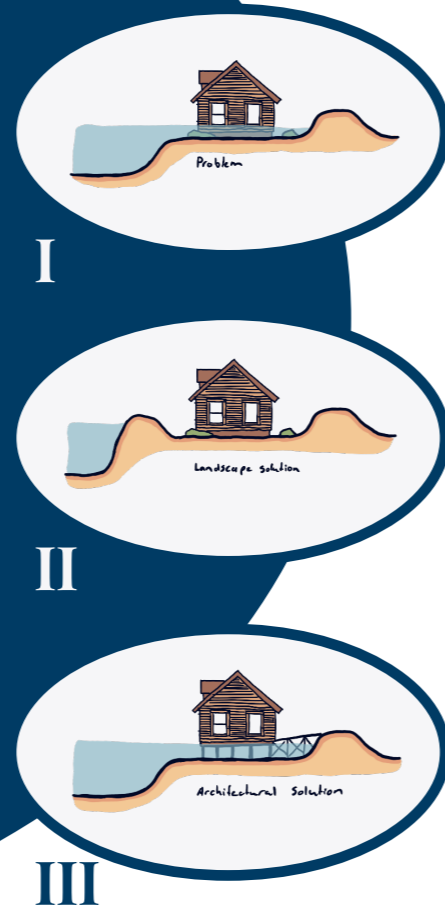
to large-scale evacuations and flood damage. In response, the Dutch Government launched the “Room for the River” program in 2000, a strategic initiative to increase river capacity and manage high water levels through landscape based interventions.

The “Room for the River” program includes a series of spatial landscape adaptations aimed at giving rivers more space to handle peak water levels safely. Key interventions are relocating dikes further inland to widen the riverbed, lowering floodplains to expand water storage, restoring polders to natural river functions and removing barriers that block the water flow (Rijkswaterstaat, n.d.). By creating areas where rivers can overflow without causing immediate damage, the program reduces flood risks for densely populated regions. However, the program focuses exclusively on landscape modifications, which, while being effective at expanding river capacity, are limited in addressing flood risks in developed outer dike regions, where spatial constraints restrict further landscape-based interventions. As a result, even with these interventions, extreme weather events and rising sea levels, driven by climate change are expected to cause more frequent severe floods, reducing the recurrence interval of major flooding in regions like Limburg from once every 500 years to once every 175 years by 2050, and as frequently as once every 85 years by 2085 (Deltares, 2022).

*Figure 02:
River flooding in
Limburg in 2021
(Rijkswaterstaat, 2023)*

Landscape and architectural design strategies

Outer dike areas are vulnerable to flooding as they are located outside the primary flood defenses (I). While most flood risk management strategies focus on landscape-based adaptations (II), this research will focus on architectural design strategies for buildings (III).



Given the limitations of additional landscape-based adaptations in densely populated areas, architectural interventions are essential for strengthening flood resilience in outer dike regions. Located outside the primary dike system, these areas are intentionally exposed to floodwater during high-water events to alleviate pressure on protected zones. However, as many outer dike areas have been developed into residential, industrial, or recreational spaces, there is a need for buildings that can accommodate periodic flooding. Isolating these areas from rivers would further restrict river capacity, leading to increased flood risks elsewhere, highlighting the importance of architectural design solutions that integrate with natural water cycles.

To ensure water safety in the Dutch delta, the government has developed the “Nationaal Deltaprogramma” which aims at safeguarding the country from flooding and ensuring a reliable supply of drinking water (Nationaal Deltaprogramma, 2024). However, in outer dike areas, the program’s focus remains on

minimizing casualty risk rather than protecting against material losses. As the program states: *“In general, the risk of casualties in the event of flooding in an area outside the dikes is low, but depending on the function of the areas, significant material and economic damage can still occur”* (Deltaprogramma Rijnmond-Drechtsteden, 2020). Consequently, flood risk management in outer dike areas is left to residents and developers, with no legal standards for flood protection (Elshof et al., 2014). This research aims to find architectural design strategies that can provide guidance for flood resilient redevelopment in outer dike areas, where landscape adaptations are limited.

Figure 03: Problem statement with different solutions (by author, 2024).

Design location

This research has a “research for design” approach, where the findings of the research will directly inform a design. The selected site is an outer dike area along the Beneden Merwede River on the eastern edge of Sliedrecht, a town with a strong maritime history. Historically, this area served as an industrial area, and although the industry has moved on, remnants of the past are still visible. The old shipyard, partially standing, hints at the shipbuilding activities that once happened at this riverside location. Beside it stands an iconic water tower, a monument amidst an evolving landscape. As Sliedrecht looks to redevelop this site, the project aims to create a design that not only respect this heritage, but also address the growing challenges of climate change and river flooding. Situated outside the primary dike protection, this area is particularly vulnerable to river flooding. Therefore, this research will explore architectural design strategies that enhance the flood resilience of the proposed buildings.



Figure 04: Sketch of the Water tower area in Sliedrecht (by author, 2024).

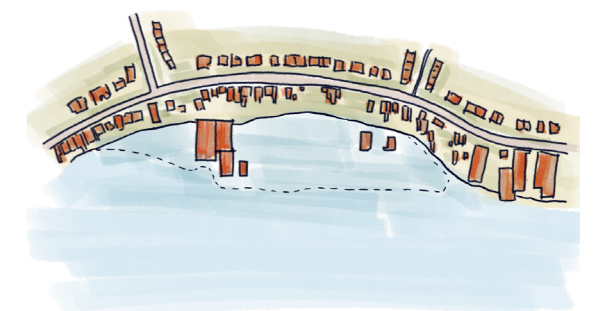


Figure 05: Sketch of the Water tower area in Sliedrecht being flooded (by author, 2024).



Figure 06: Water tower area in Sliedrecht (Google Earth, 2024)

Research objectives

Given the inherent vulnerability of outer dike areas, there is a pressing need for flood resilient architecture that can withstand these risks. By exploring innovative architectural approaches, this study aims to propose practical solutions that enhance flood resilience while supporting sustainable redevelopment in the outer dike area of Sliedrecht.

The research is divided into two phases. Phase I will focus more general on different architectural design strategies for flood resilient buildings, to find out which strategy will be most suitable for the outer dike area of Sliedrecht.

Phase I

- To analyze existing architectural design strategies for flood resilient buildings in flood-prone regions, both historical and current solutions.
- To analyze the strengths and weaknesses of each strategy.
- To assess the applicability of the design strategies in the outer dike area of Sliedrecht.

Phase II will focus on a specific strategy to find out how this strategy can be implemented in a design.

Phase II

- To have a more in-depth study of a selected strategy of phase I.

Figure 07:
The Kentish Classics
(The DHaus Company,
n.d.)



Research questions

To achieve these objectives, the following research question has been developed:

What architectural design strategies can be developed and implemented to enhance flood resilience in the outer dike area of Sliedrecht?

To find a suitable answer to this question, the following subquestions are developed:

Phase I

- *What existing architectural design strategies have been implemented in flood-prone regions?*
- *What are the strengths and weaknesses of each identified strategy?*
- *What strategy is most suitable for the outer dike area in Sliedrecht?*

Phase II

- *How can the identified solution be implemented in the redevelopment of the outer dike area in Sliedrecht?*

Theoretical framework

In the Netherlands, flood risk management has become an urgent priority due to increasing extreme weather and climate-induced changes, particularly in outer dike areas that lack primary flood defenses such as dikes. Outer dike areas are described as the regions between the dike and the river (Elshof et al., 2014), leaving them unprotected and at higher flood risk, as shown in figure 11.

A dedicated government department, known as the Nationaal Deltaprogramma, is responsible for overseeing water management and assessing flood risks across various regions in the Netherlands (Nationaal Deltaprogramma, 2024). The outer dike area of Sliedrecht lies in the region Rijnmond-Drechtsteden. In 2014, a document was set up to make it clear which choices there were made to ensure water safety in the area, called the Synthesedocument Rijnmond-Drechtsteden. This document gives advice for outer dike areas in the region. It states: *“For most of the outer dike areas, the chance of casualties due to flooding is very small. Therefore, these areas are not nationally regulated. However, the economic or environmental damage from a flood can be relatively large”* (Programmateam Rijnmond-Drechtsteden, 2014). In 2020, a recalibration of the previous document was issued. This reassessment did not identify any justification for changing the principle that households and businesses are personally responsible for damages incurred outside the dike, nor for establishing a minimum safety standard through government intervention (Programmateam Rijnmond-Drechtsteden, 2020).

In response to increasing flood risks, the Netherlands has implemented large-scale landscape-based interventions, such as those in the “Room for the River” program. These measures have focused on restoring floodplains, expanding water storage capacity and creating green infrastructure to manage water flows (Rijkswaterstaat, n.d.). While effective on a

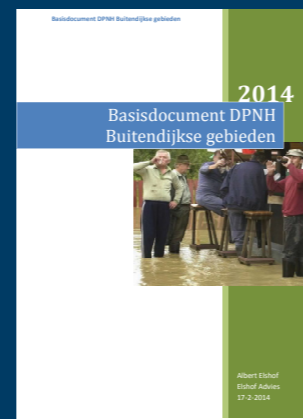


Figure 08: Basisdocument DPNH Buitendijkse gebieden (Elshof et al., 2014)

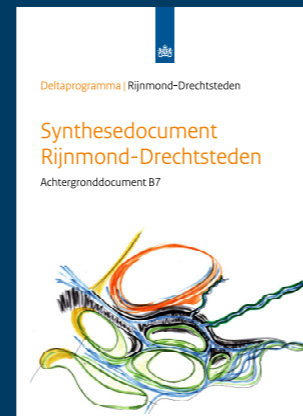


Figure 09: Synthesedocument Rijnmond-Drechtsteden (Programmateam Rijnmond-Drechtsteden, 2014)

regional scale, these landscape interventions may fall short in highly populated outer dike areas. In these areas, architecture plays a crucial role in providing immediate, building level resilience against floods. This study, therefore, shifts focus from landscape interventions to architectural design strategies that aim to protect communities in outer dike areas, such as the outer dike area in Sliedrecht. Architectural interventions can complement the regional landscape measures, offering local protection for residents and businesses.

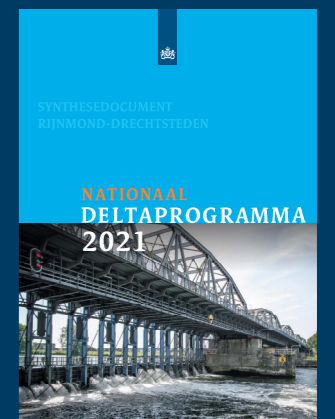
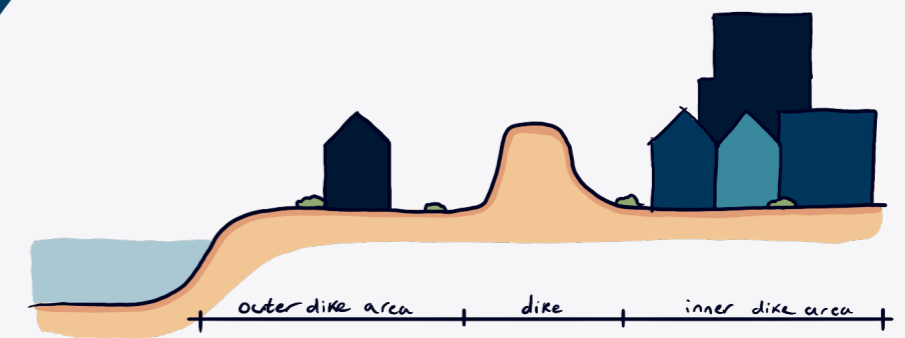


Figure 10: Synthesedocument van herijking voorkeursstrategie deltaprogramma Rijnmond-Drechtsteden (Programmateam Rijnmond-Drechtsteden, 2020)

Figure 11: Inner and outer dike areas (by author, 2024)



Methodology

This research will be conducted in two main phases, structured to allow for iterative feedback between research findings and design decisions. This approach ensures that insights gained from both general and specific investigations into flood-resilient buildings will directly inform the development of a design for the outer dike area in Sliedrecht.

Phase I: Identification of suitable architectural strategies for flood resilient buildings.

The first phase focuses on exploring general architectural design strategies for flood resilience, aiming to identify the strategy best suited to the specific conditions of the design location. This phase consists of three main steps:

1. Literature review of flood resilient architectural strategies

A literature review will be conducted to establish a baseline understanding of existing architectural strategies that enhance flood resilience. The review will cover both historical and contemporary approaches.

2. Case study analysis (selection criteria on page 14)

Following the literature review, a series of case studies will be examined to showcase how different flood resilient strategies have been implemented in real world contexts. Each case study will be analyzed to assess the strategy's strengths and weaknesses.

3. Comparative analysis of strategies and suitability for Sliedrecht

A comparative analysis of these strategies will be conducted, highlighting the advantages and limitations of each. This outcome will be compared to the context of Sliedrecht's specific flood risk, environmental conditions and intended uses. This analysis will enable the selection of a strategy that aligns with Sliedrecht's unique conditions, bridging the gap between theoretical approaches and practical application.

Phase II: In-depth analysis and integration of selected strategy.

Once the most suitable strategy is identified, the second phase will involve a detailed exploration of the chosen approach, focusing on technical and material specifics. This phase consists of two key steps:

1. Detailed analysis of materiality and technical application

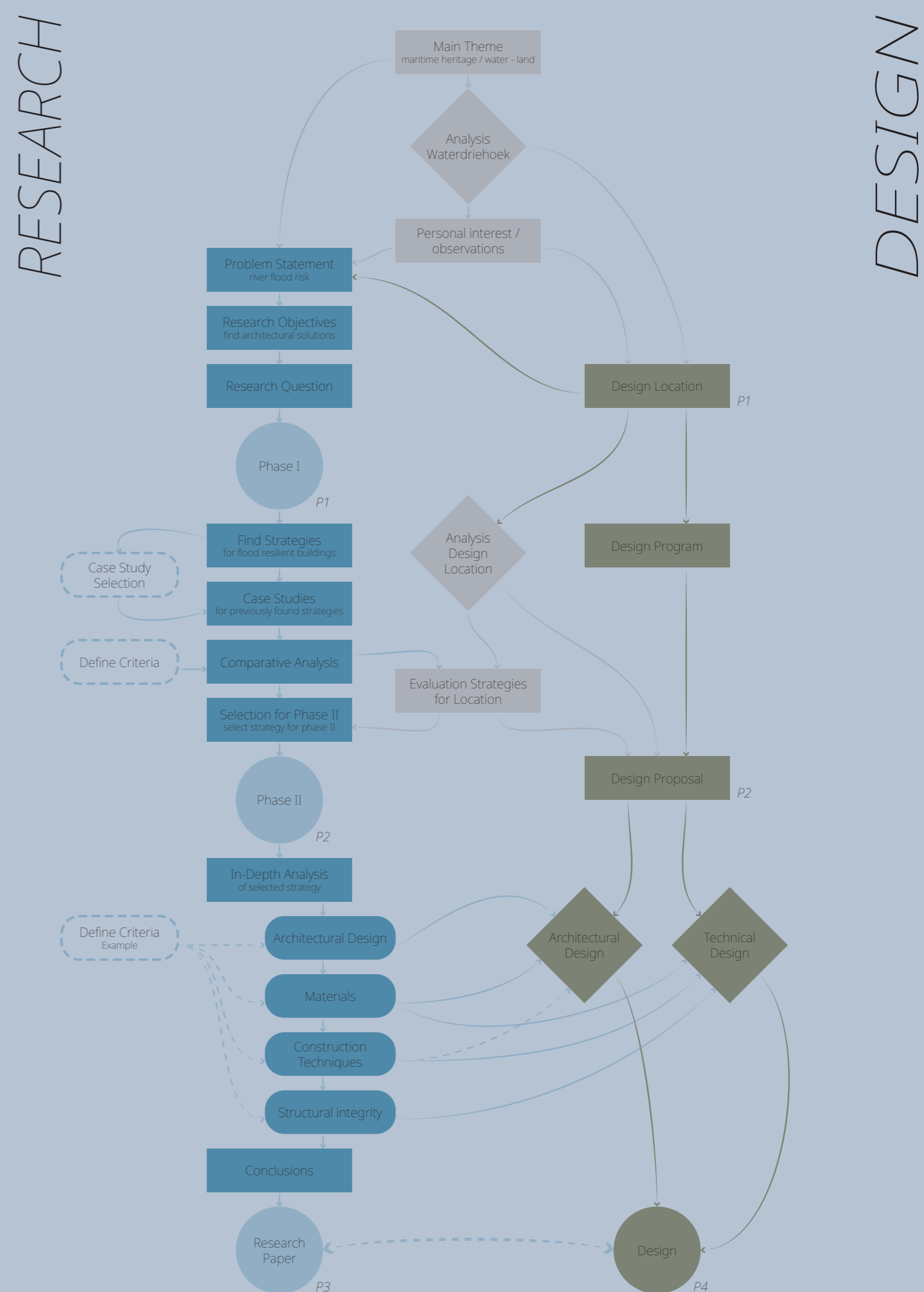
Using a literature based approach, this step will delve into specific material properties, construction methods and waterproofing techniques, relevant to the chosen architectural design strategy.

2. Integration of findings into the design process

The technical insights gained from the detailed analysis will then be directly applied to the design, allowing for adjustments to accommodate specific requirements of the Sliedrecht site, to ensure that the final design is not only theoretically resilient, but practically viable, considering spatial limitations and the needs of future occupants.

A visual representations of this methodology is provided in figure 12, illustrating the iterative process between research and design. The diagram outlines each research step, highlighting how each phase informs and influences subsequent design decisions to ensure that the final architectural solution is both resilient and context-specific.

Figure 12:
Research and Design
(by author, 2024).



Case study selection criteria

To ensure relevant and applicable insights, the case studies will be selected based on the following criteria:

1. Practical application from literature-based strategies

The literature research will provide a series of architectural design strategies for flood resilient buildings. The case studies need to show the practical applications of these strategies.

2. Demonstrated effectiveness

Preference will be given to cases with proven success in minimizing flood impact.

3. Diverse architectural approaches

Selected case studies will represent a range of

architectural strategies for flood resilience. By analyzing diverse approaches, the study can identify the strengths and weaknesses of each strategy and assess which elements may be suitable for Sliedrecht.

4. Availability of detailed documentation

To conduct a thorough analysis, only case studies with comprehensive documentation (architectural plans, materials used, etc.) will be selected.

These criteria will guide the selection of case studies, ensuring that each one contributes valuable insights for developing a flood-resilient design in Sliedrecht.

References

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List of figures

Figure 01: By author. (2024). House standing amidst a flooded area.

Figure 02: Rijkswaterstaat. (2023). River flooding in Limburg in 2021.
https://www.magazinesrijkswaterstaat.nl/binaries/widescreen/content/gallery/magazines-rijkswaterstaat/mer-nieuws/mer-nieuws-103-beeld/evaluatie-hoogwaterveiligheid/1775_12394-55-1920.jpg

Figure 03: By author. (2024). Problem statement with different solutions.

Figure 04: By author. (2024). Sketch of the Water tower area in Sliedrecht.

Figure 05: By author. (2024). Sketch of the Water tower area in Sliedrecht being flooded.

Figure 06: Google Earth. (2024). Water tower area in Sliedrecht.

Figure 07: The DHaus Company. (n.d.). The Kentish Classics.
<https://www.thedhaus.com/dhaus-shortlisted-dezeen-miniliving-future-home-competition-final-15/>

Figure 08: Elshof, A., De Graaff, R., & Van de Veerdonk, C. (2014). *Basisdocument DPNH Bijtendijkse gebieden*

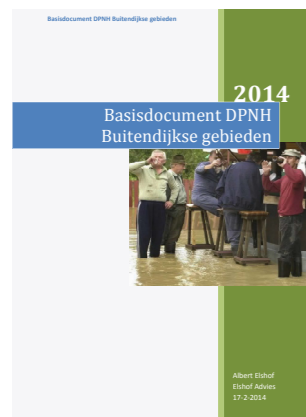
Figure 09: Programmateam Rijnmond-Drechtsteden. (2014). *Synthesedocument Rijnmond-Drechtsteden*.

Figure 10: Programmateam Rijnmond-Drechtsteden. (2020). *Synthesedocument van herijking voorkeursstrategie deltaprogramma Rijnmond-Drechtsteden*.

Figure 11: By author. (2024). Inner and outer dike areas.

Figure 12: By author. (2024). Research and Design.

Annotated bibliography



Basisdocument DPNH Buitendijkse gebieden

Topic: Flooding / outer dike areas

Content: Advice about flood safety in outer dike areas

Relevance: Shows specific characteristics of outer dike areas and their safety



Overstromingsrisico's in Nederland

Topic: Flooding

Content: Flood risk assessment for the Netherlands

Relevance: Shows the flood risk in different areas in the Netherlands



Overstromingsrisicozonering in Nederland

Topic: Flooding / spatial planning

Content: Flood risk assessment and spatial planning

Relevance: Gives advice on how flood risks can be addressed in spatial planning



Voorkeursstrategie Deltaprogramma Rijnmond-Drechtsteden 2020

Topic: Flooding / flood risk management

Content: Flood risk management strategy for the region Rijnmond-Drechtsteden

Relevance: Gives an overview of the flood risk management that is already used in the project location

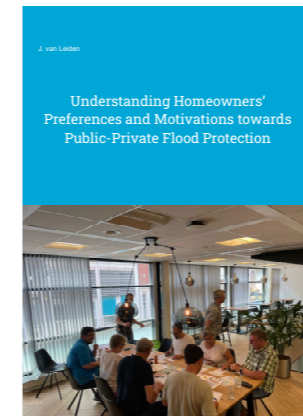


Exploration of spatial adaptation strategies for mitigating future coastal flood risk in the Netherlands

Topic: Flooding / spatial planning

Content: Thesis about spatial adaptation strategies for mitigating flood risk

Relevance: Shows different spatial adaptation strategies that can be used for mitigating floods. Gives an understanding of spatial adaptation.

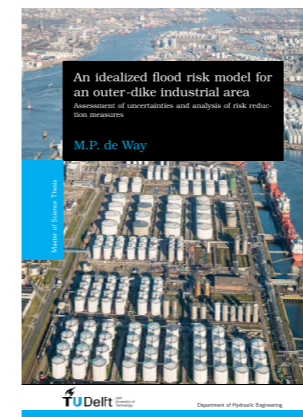


Understanding homeowners' preferences and motivations towards public-private flood protection

Topic: Flood protection / participation

Content: Thesis about the participation of homeowners in flood protection

Relevance: Gives an overview of the reasons people have to invest in flood protection.



An idealized flood risk model for an outer-dike industrial area

Topic: Flooding / outer dike areas

Content: Assessment of uncertainties and analysis of risk reduction measures

Relevance: Gives an example of a risk assessment in an outer dike area and an analysis on how to reduce this risk.



Design for flooding

Topic: Flooding / design

Content: A guide to planning and design for water sustainability, as well as flooding and natural disasters

Relevance: Guides the planning and design process for flood-resilient buildings

Annotated bibliography



Retrofitting for flood resilience

Topic: Flooding / design

Content: A guide to building and community design

Relevance: Gives an overview of different flood risks and mitigating strategies

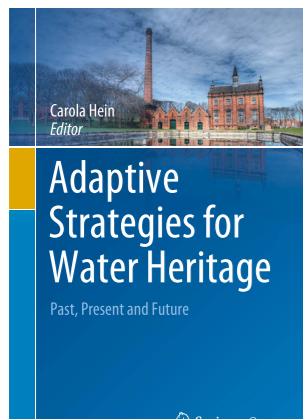


A practical approach to development of housing on floodplain land in the UK

Topic: Outer dike areas / design

Content: Examples and evaluation of flood-resistant technology

Relevance: Gives an overview of how to reduce flood risks. Examples can be used for case studies



Adaptive strategies for water heritage

Topic: River planning / waterfronts

Content: Contains a collection of research papers about water

Relevance: Some research papers floods may be relevant to the research topic



Flood-resilient urban design based on the indigenous landscape in the city of Can Tho, Vietnam

Topic: Flood resilience / design

Content: Exploration of spatial design and flood resilient buildings in the city of Can Tho.

Relevance: Case study about flood resilient building

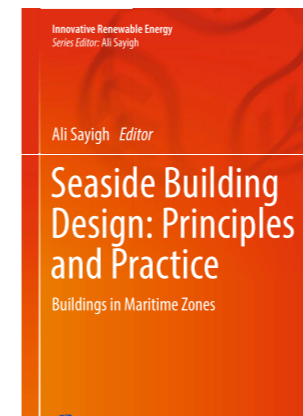


Transition as condition: toward flood resilience through flexible architecture

Topic: Flood resilience / design

Content: Thesis about flood resilient building design. Contains multiple examples

Relevance: Examples of flood resilient building design can be used to identify different strategies

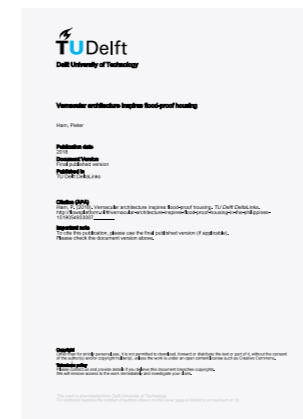


Seaside building design: Principles and practice

Topic: Maritime zones / design

Content: Contains an overview of architectural features and building design in various coastal zones.

Relevance: Although not directly related to flooding, coastal buildings may be inspiring for flood resilient design

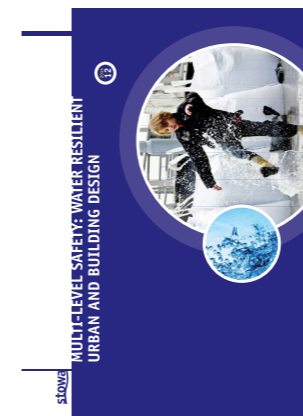


Vernacular architecture inspires flood-proof housing

Topic: Flood resilience / design

Content: Analysis of vernacular flood-proof housing in Asia

Relevance: Vernacular principles may be relevant to contemporary designs



Multi-level safety: Water resilient urban and building design

Topic: Flood resilience / design

Content: Examples of flood resilient urban and building design

Relevance: Provides examples of flood resilient buildings that can be used to identify strategies

RESEARCH PLAN