

AR3A010 - Research plan
2024/2025

Amphibious living in the Polders

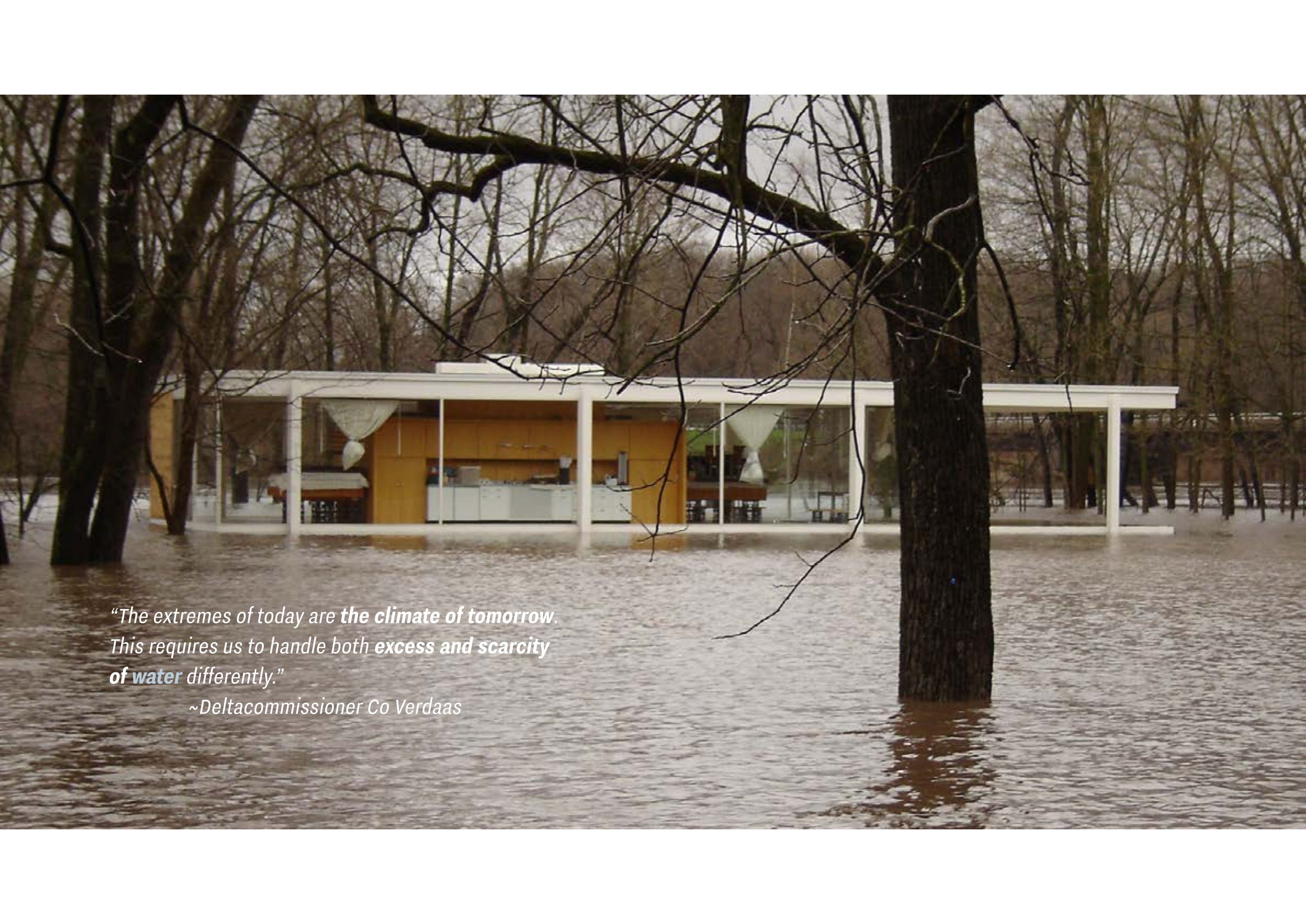
Feasible Implementation of **Amphibious Constructions**
in **Buffer Polders**: A Case Study of Rijnenburg*, Netherlands



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A photograph of a modern, single-story glass house with a white frame, partially submerged in floodwater. The house is surrounded by bare trees, and the water reflects the sky and the building. The scene is overcast and somber, illustrating the impact of climate change.

*“The extremes of today are **the climate of tomorrow**.
This requires us to handle both **excess and scarcity
of water** differently.”*

~Deltacommissioner Co Verdaas

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Motivation, Research Topic and Graduation Studio

I. Studio choice

Keywords

Amphibious Constructions, Dutch Housing Shortage, Adapting Rising-Water Levels, Hybrid Self-Sufficiency, Wetland integration, Climate Change Adaptation

After my bachelor, I decided to take a gap year to gain more experience at an architecture firm before starting my degree. What frustrated me immensely during that year was the limited space for innovation within the designs—there was little thought given to “how can it be improved or made more interesting”. This is when I figured that during my masters, I wanted to find the limits within possibilities of architecture. Graduating offers a final opportunity to delve deeply into personally chosen material and thoroughly explore theoretical topics without the constraints of cost or limitations.

And then the topic: for my own small visualization company, I received an email from a woman who needed visualizations for a particular design. She explained to me the potential of how architecture and water could go hand in hand, and this planted a seed: I had to learn more about this topic. More and more, I noticed around me how people talked about how we

must change our way of living in response to climate change, but also that land is limited, and we need to build almost one million homes. The conversation with the woman came back to mind: there had to be a solution that combined these issues.

When choosing the graduation studio, I stumbled upon “Explore Lab” due to the freedom it offered and the possibility of choosing my own thesis topic. However, in the introductory conversation, Elise van Dooren pointed out that what I wanted to investigate closely aligned with Architectural Engineering: I could choose my own topic as long as it focused on innovations in architecture. This led me to apply to this studio. One last time I can research what interests me the most and contribute to tackling societal challenges, while innovating within architecture. That is my motivation for this studio.

Extreme Water Levels and Housing Shortage

II. Introduction & Problem Statement

Our world is warming up, leading to extreme water levels; low levels in summer, resulting in drought and freshwater scarcity, and high levels in winter, leading to river flooding and increased pressure on dikes, as reported in the most recent IPCC report (2023). The Dutch have a long history of innovative water management. However, with the new extremes in water levels expected in the coming decades, a new approach to water is necessary: one in which water and soil (water en bodem sturend) dictate the course of action (Nationale Deltaprogramma, 2024). At the same time, the Netherlands are facing a housing crisis (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2023), driven by urbanization and population growth, further complicating the situation. There is an urgent need for new housing locations, whereas there is also a need for extra land to store and buffer water. Is there a solution that combines these two societal challenges?

In response to these intertwined challenges, this research explores the potential of amphibious constructions as a solution (figure 1). Amphibious buildings, which can function with fluctuating water levels (Piątek et al., 2024), offer a promising alternative to traditional flood protection measures. They also present a sustainable way to develop housing in flood-prone areas without significantly altering the natural environment. By investigating how amphibious principles can be applied at a larger, neighborhood scale in the polders of Gnephoek, this study seeks to contribute to innovative, climate-adaptive urban development solutions in areas vulnerable for floodings.

Hybrid Adapting strategy - National Delta Program (2024)

This research investigates topics of the National Delta Program (2024) that works on: protecting against floodings, sufficient fresh water and a climate-proof environment. Deltares (2019) has outlined four different strategies for the Netherlands to protect itself against water. This thesis builds on the ‘adapting’ strategy, as exploratory investigated in ‘Oplossingsrichting Meebewegen’ in the form of ‘hybrid adaptation’ (Ministerie van Infrastructuur en Waterstaat, 2024). This strategy explains reducing vulnerability to changing water levels through water-tolerant land use. Four characteristic regions are distinguished (figure 2), where the characteristics of a region strongly determine the nature of the approach. However, each region implements using ‘natte natuur - wet nature’ (figure 4) and ‘buffer polders’ (figure 5) for controlled flooding and water storage in times of drought. These landscapes present a unique opportunity to explore amphibious construction, turning occasional flood zones into viable residential areas that increase the fresh water supply.

Housing crisis - Peat as soil

The housing crisis aggravates the climate challenge, with nearly one million homes to be build by 2030 (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2023). As urban areas become more populated, finding suitable land for new construction has become an issue. The in-depth research by PosadMaxwan & PasBV (2024) identified 420,000 hectares of land in the Netherlands that are at high risk of flooding (Figure 2). Most of these areas consist of peat, which are known to be inferior to other soils in terms to build on (Segeren & Hengeveld, 1984). However, by adopting amphibious construction techniques, just 3% of this flood-prone land could be used to build enough housing—at a density of 65 homes per hectare—to address the current shortage and bypass the inferior soil properties of peat.

REGIONS AND POTENTIAL LOCATIONS

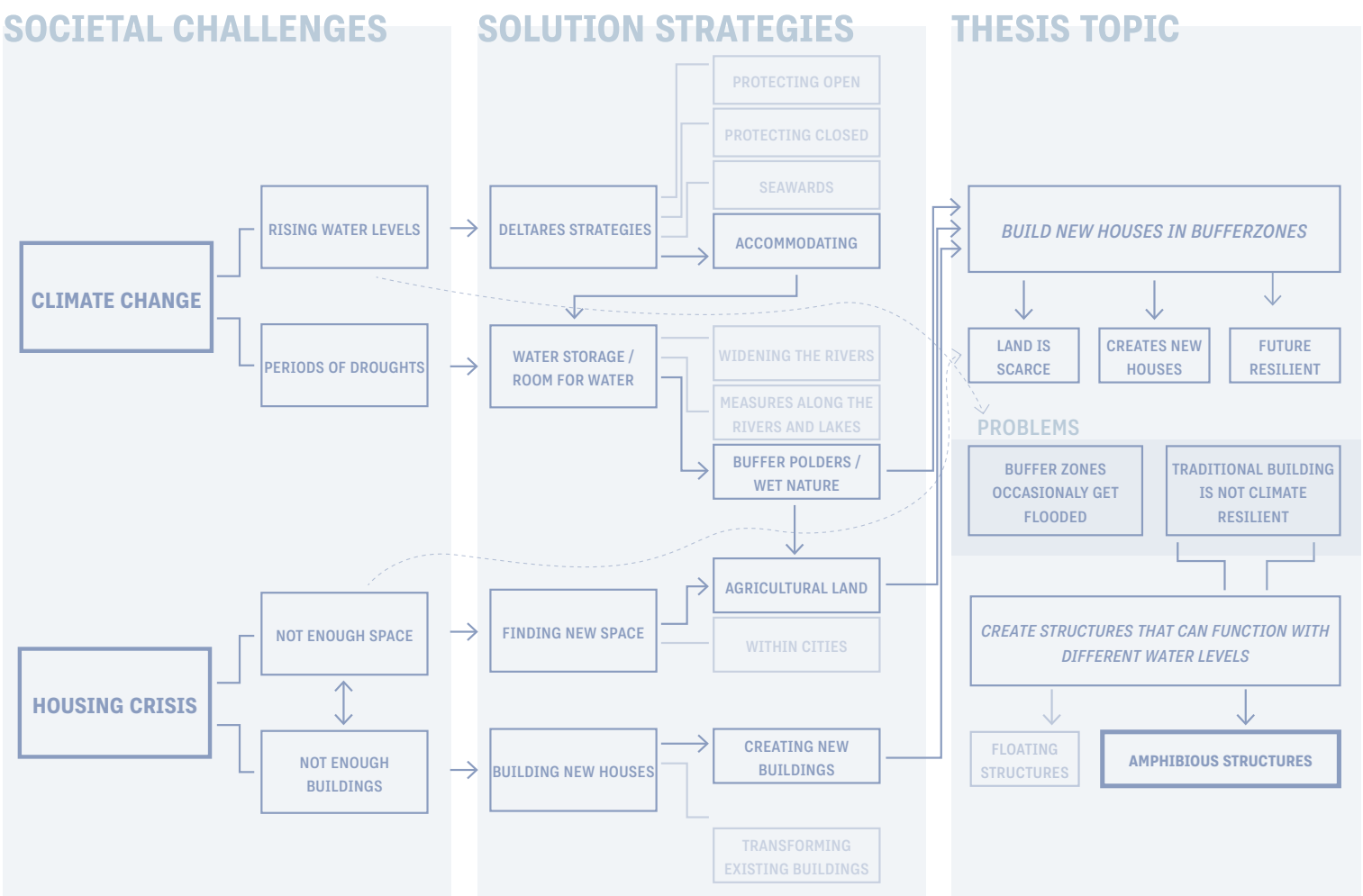
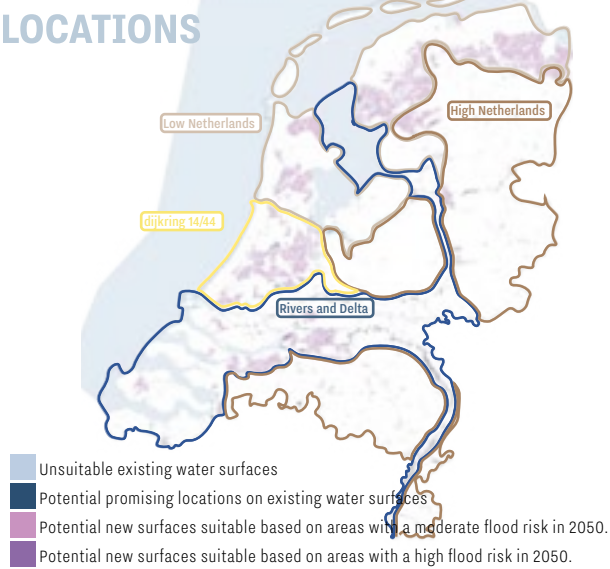
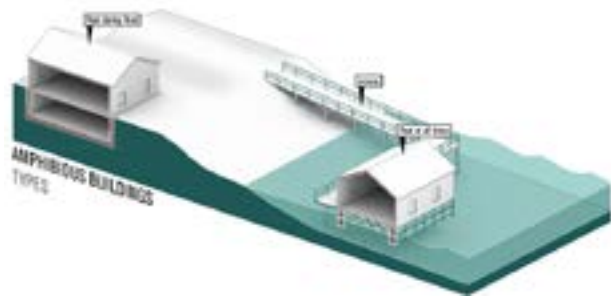


figure 1: Problem to topic diagram (own source)

EXAMPLE OF AMPHIBIOUS CONSTRUCTIONS



EXAMPLE OF WET NATURE



EMISSION SCENARIOS

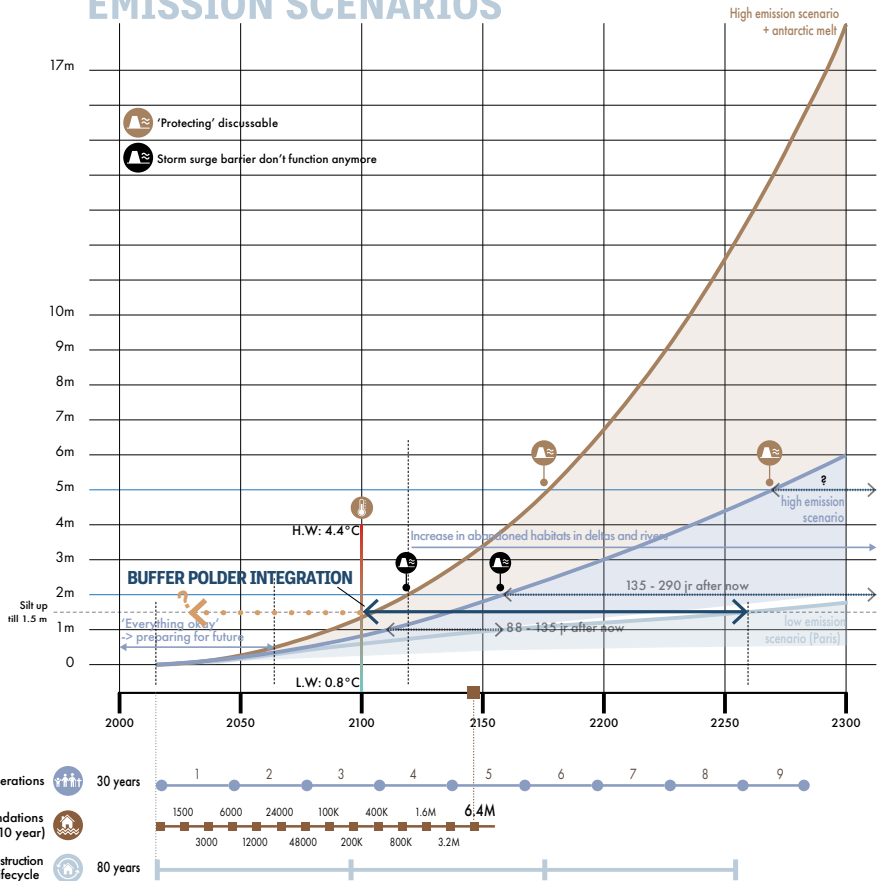


figure 3 : Types of amphibious constructions (Pacific Institute for Climatic Solutions, 2024)
figure 4: Example of wet nature (Redesigning Deltas, 2022)

figure 5: Buffer polder integration with emission scenarios, simplified for this research (Ministerie van Infrastructuur en Waterstaat, 2024)

Researching the Possibilities of Amphibious Living

III. Thematic Research

Thematic Research Objective

The objective of this research is to explore **the feasibility of implementing amphibious constructions within peatlands as a sustainable system for extreme water levels and the Dutch housing crisis**. The system focuses on how amphibious constructions, in combination with a self-sufficient water system for peat, can be integrated into modern urban development, with a case study on an amphibious neighborhood in Gnephoek, the Netherlands.

To start with, the research contextualizes the principles of amphibious living in the Netherlands, where historically seen there is a culture of living with water (P. J. E. M. Van Dam, 2012). By understanding the context, it becomes clear if these principles can be applied in contemporary designs. Then, by comparing amphibious structures with groundbound -and floating structures, a clear overview can be provided on how amphibious constructions can be validated for contemporary design.

In the first research topic, an in-depth research is made of how the amphibious principles, as researched by de Vries in her thesis on amphibious living (De Vries, 2024), can be clustered to larger buildings or entire neighborhoods. This topic investigates the challenges that come with building on peat (Baron, 2004). The outcome of this chapter can be used for further urban development.

In the second research topic, the focus shifts to the environmental context of buffer polders. The characteristics of these landscapes change (A&W ecologisch onderzoek et al., 2022) are essential to understand when planning amphibious constructions, as they are closely connected to the design. Is it possible to employ the strong soil properties of peat while creating new land to build on?

In the third research topic, the scope is on supply: using the water in the environment for water self-sufficiency and peat preservation. Is it possible to implement the water of the landscape into a water management system and purify it to reuse it in the neighborhood, as conceived by B plus B architects (B+B, 2021)?

The conclusions of the prior research topics will be combined in the next topic: guidelines. With these guidelines, propositions of lay outs for self-sufficient amphibious neighborhoods can be generated that will get tested with different scenarios.

At last, one of these layouts will be tested in the Validation by performing a feasibility study. The chapter investigates an amphibious neighborhood in Rijnenburg*, primarily taking the environmental and technical factors into account to test the feasibility of the project. The economic feasibility will be examined via a model that is developed by Watertorenberaad (2023).

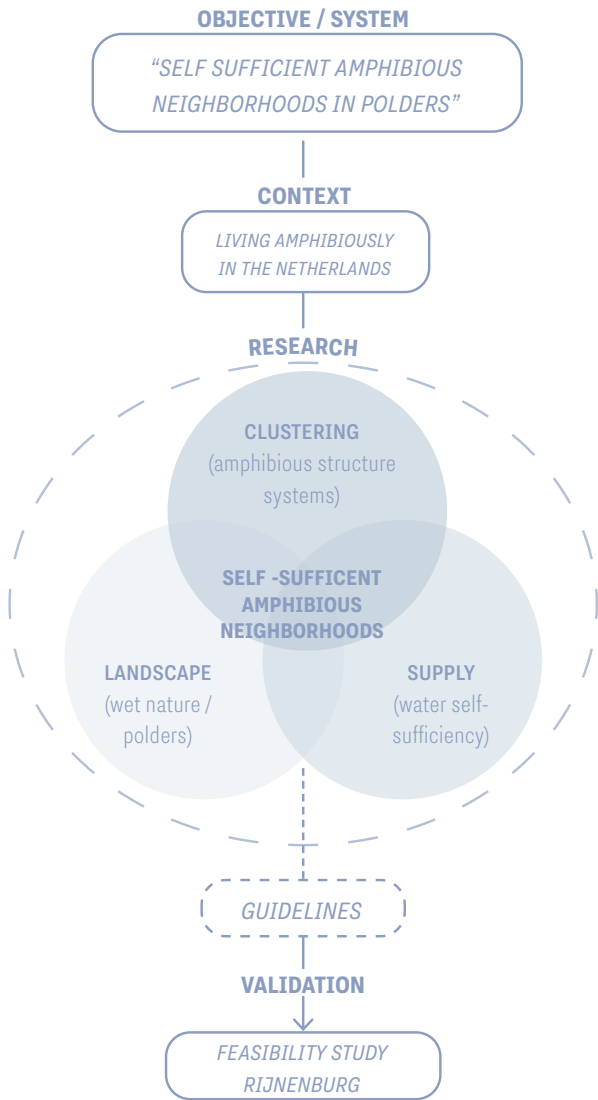


figure 10: Thesis topics structure (own source)

SUBQUESTIONS

QUESTION 1 (CONTEXT): <i>What are the principles of amphibious living in the Dutch context, and how can they be adapted for modern neighborhood development while enhancing sustainability?</i>		
QUESTION 2 (RESEARCH): <i>What challenges and oppotunities arise when clustering amphibious principles to neighborhood developments?</i>	QUESTION 3 (RESEARCH): <i>What specific characteristics of wet nature and buffer polders must be considered to ensure ecological compatibility?</i>	QUESTION 4 (RESEARCH): <i>How can the water of wet nature and buffer polders be integrated in a water management system for amphibious neighborhoods along with energy self-sufficiency?</i>
QUESTION 5 (GUIDELINES): <i>How can amphibious and self-sufficiency principles be combined to create viable, resilient neighborhood layouts that align with sustainable urban design?</i>		
QUESTION 6 (VALIDATION): <i>What is the feasibility of developing self-sufficient amphibious neighborhoods in Rijnenburg*?</i>		

RESEARCH QUESTION

“How can amphibious constructions be feasibly implemented on a larger scale in a way that harmonizes with nature in buffer polders?”

figure 11: Subquestions which conclusions can answer the Research question (own source)

Technical research question

If done correctly, my thesis question will look as followed:

*“How can **amphibious constructions** be **feasibly implemented on a larger scale** in a way that **harmonizes with nature** in **buffer polders**?”*

To answer this question, the sub questions are defined in figure 11.

Hypothesis

My first hypothesis of this research will be that people can learn from the past in terms of living amphibiously. The willingness to live with water has to increase throughout the decennia to come. Historically seen, people always were able to live in harmony with water, only in the last hundred years we have figured how to defend us against it.

With answering the first subquestion, I expect that the second and third chapter are easier to visualize in terms of possibilities. With preliminary research I already figured out that theoretically both subquestions can be answered. However, what I hope to get out of these topics are suiting guidelines and new insights on how to effectively and ecologically combine both outcomes into a concrete way

that is useful for providing guidelines. My hypothesis for these topics is that it is possible to implement amphibious structures on a larger scale but that there are a lot of what if's and further research is needed. The question might be to big to be answered directly.

My third hypothesis is that the feasibility study of Rijnenburg can only be validated if costs are not implemented via traditional investing models. Only if we implement benefits that are not financial in the investments (such as CO2 storage, lower water treatment costs, lower disposal costs, less damage due to water nuisance/flooding that save costs) the area will be feasible for amphibious structures.

Antithesis

The antithesis of this project is that it is not feasible to implement amphibious constructions on a larger scale for a couple of reasons:

- Too large constructions could cost astronomically more than floating foundations which make it simply not worth investing in, certainly not with the current area development model.
- Secondly is there the aspect of water that stands still: it is a breeding spot for bacteria and mosquitoes, which makes it not an attractive place for people to live in.
- Lastly is that it is not possible to purify the water of the wetlands for water storage so that it can be integrated in buildings in a way that harmonizes with nature.

The Program, Context and Technical interest of the Design

v. Objective / Design

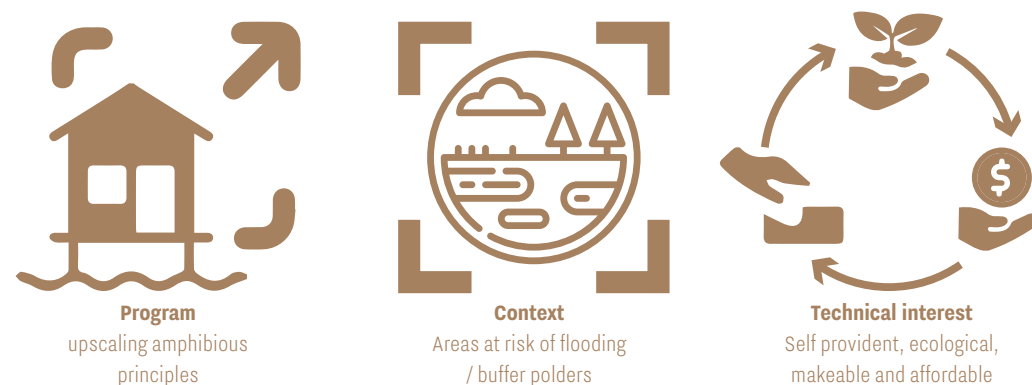
The focus of the project will be on upscaling amphibious buildings to a neighborhood scale. The research agency PosadMaxwan has conducted a study and developed a handbook exploring the possibilities of 'floating cities' in the Netherlands. This handbook outlines six ambitions that such a city should meet (figure 6). This thesis explores if it possible to utilize these ambitions for **amphibious neighborhoods**. Secondly, Redesigning Deltas (2022) conceptualized a new boezem-system that: "will support nearby urban areas through designated zones for various types of production and innovative land use, based on underground morphology. These landscape zones will function as water buffers and filters, foster new agriculture and nature conservation methods, and maintain recreational spaces" (Redesigning Deltas et al., 2022). This thesis aims to adapt and integrate this self-sufficiency model with amphibious neighborhoods implemented, using the boezem-system as a foundation (figure 7).

The research will focus on how we can scale up our amphibious ambitions in areas that can be both wet and dry. Is it possible to create neighborhoods or communities within the so called '**wet nature or buffer polders**' as in line with the hybrid-adaptation (Ministerie van Infrastructuur en Waterstaat, 2024). An area where such a bufferpolder could be introduced is in **Utrecht**, where the development of **Rijnenburg** is being explored (Gemeente Utrecht, 2024). The program includes approximately 25,000 homes and a new light rail connection. The municipality has also outlined in the programmatic exploration a desire for water storage in the Green-blue framework (figure 9). What if we use this water storage to implement the program of amphibious neighbourhoods with the boezem-system.

One of the reasons that there are no amphibious neighborhoods yet is partly due to financial feasibility. Within this graduation, the design is going to explore if it is possible to create these buildings in an affordable way that also functions harmonious with nature. Can the water of the landscape be used to make the building self provident? De Vries (2024) graduated with a thesis about small scale amphibious projects where she looked into researchable factors for amphibious housing. This thesis delves deeper into the **scalability** and **self-providency** of amphibious constuctions, as seen in figure 8. Furthermore are the ambitions of PosadMaxwan taken into account: The design must be ecological, affordable, attractive and makeable.

Taking the previous paragraph into account, the design question is formulated as:

*"How can we create an **attractive amphibious housing project** in a **polder** that is **self provident, ecological, makeable and affordable**?"*



Research Plan

POSAD MAXWAN' AMBITIONS



figure 6: Ambitions of a floating city according to PosadMaxwan (PosadMaxwan, 2023)

MODIFIED BOEZEM-SYSTEM SCHEME

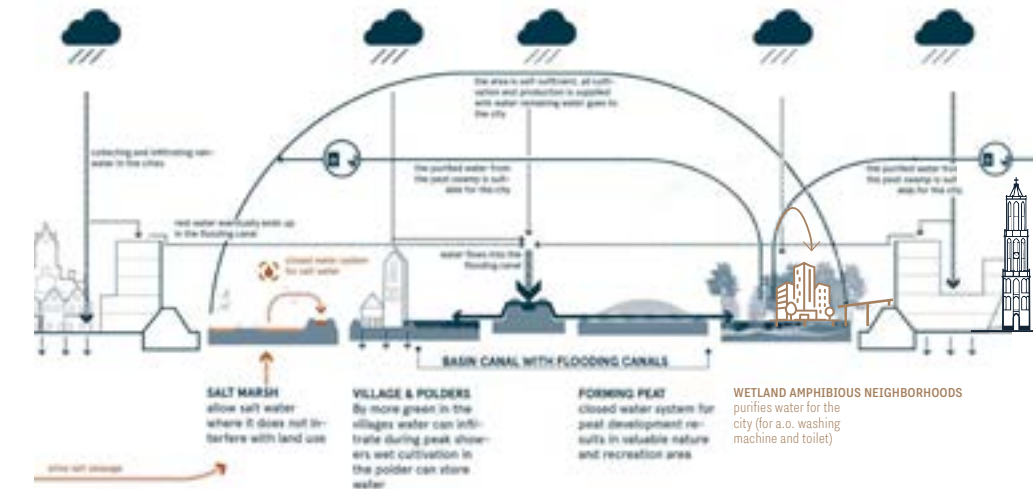


figure 7: Integrated amphibious neighborhoods in the Boezem-system (FLUX, ZUS and Sweco, 2023)

DESIGN FACTORS

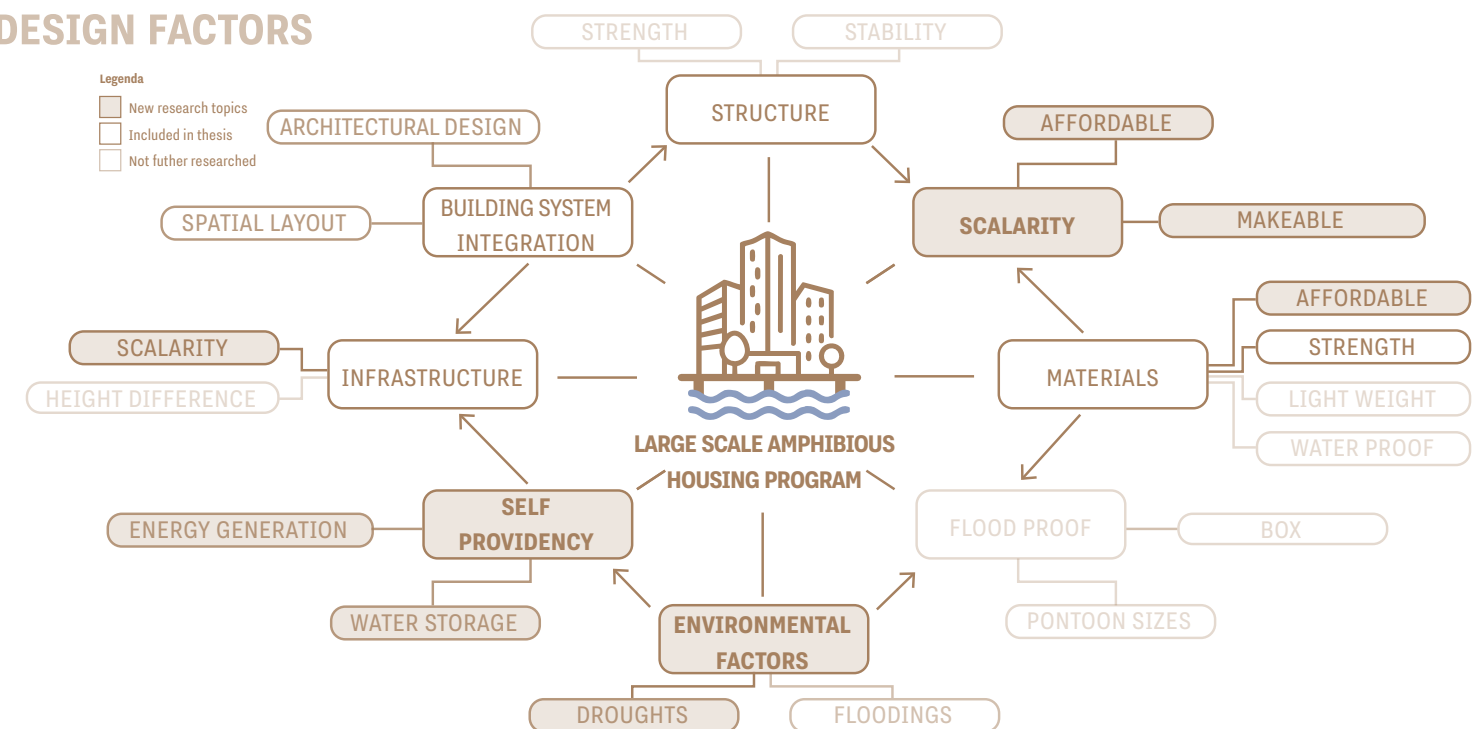


figure 8: Design factors as given by Anouk de Vries in her thesis, with an addition for my thesis (own source)

KEY AREAS OF RIJNENBURG



POTENTIAL CASE STUDY

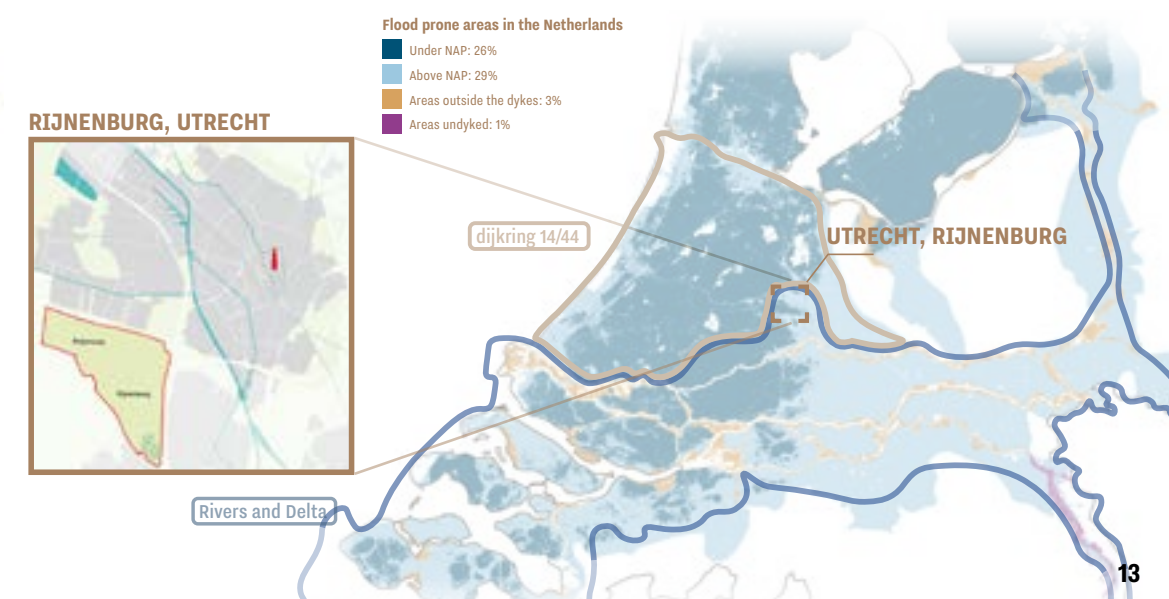


figure 9: Key areas of Rijnenburg (Gemeente Utrecht, 2024)

figure 10: Map of the Netherlands with the locations given by the Program Room for the River and Rijnenburg, Utrecht (own source)

SITUATION IN TIMES OF DROUGHT



SITUATION IN TIMES OF FLOODINGS



Thesis Relevance

VI. Relevance

Anno 2024, I think that the societal relevance of my project is getting more significant. The Dutch are becoming increasingly aware of the consequences of climate change and rising water levels. There is not one concrete solution available which makes the research in essence more generic. However, besides climatic issues and housing crisis, we need to remember the necessity of affordable and sustainable architecture. Simply building concrete amphibious buildings isn't going to do the trick. Sustainability, even within amphibious buildings (which can be defined as sustainable due to their ability to cope with floods) are necessary to develop to live up to our current building regulations.

Finding a solution for high-water levels is the bare minimum. Creating places where people actually want to live and what can be seen as a valid investment is what will make this design relevant. The design should trigger people to be aware of the opportunities that water can bring, instead of solely seeing it as a threat.

Research Activities and Products up until P2

VII. Planning

Outline of research

The schedule provides a rough outline of how the different chapters of the research are organized and how the design and research processes are interwoven. It's important to note that this schedule is a **preliminary sketch**, and adjustments are likely to be made in the second quarter as new insights emerge.

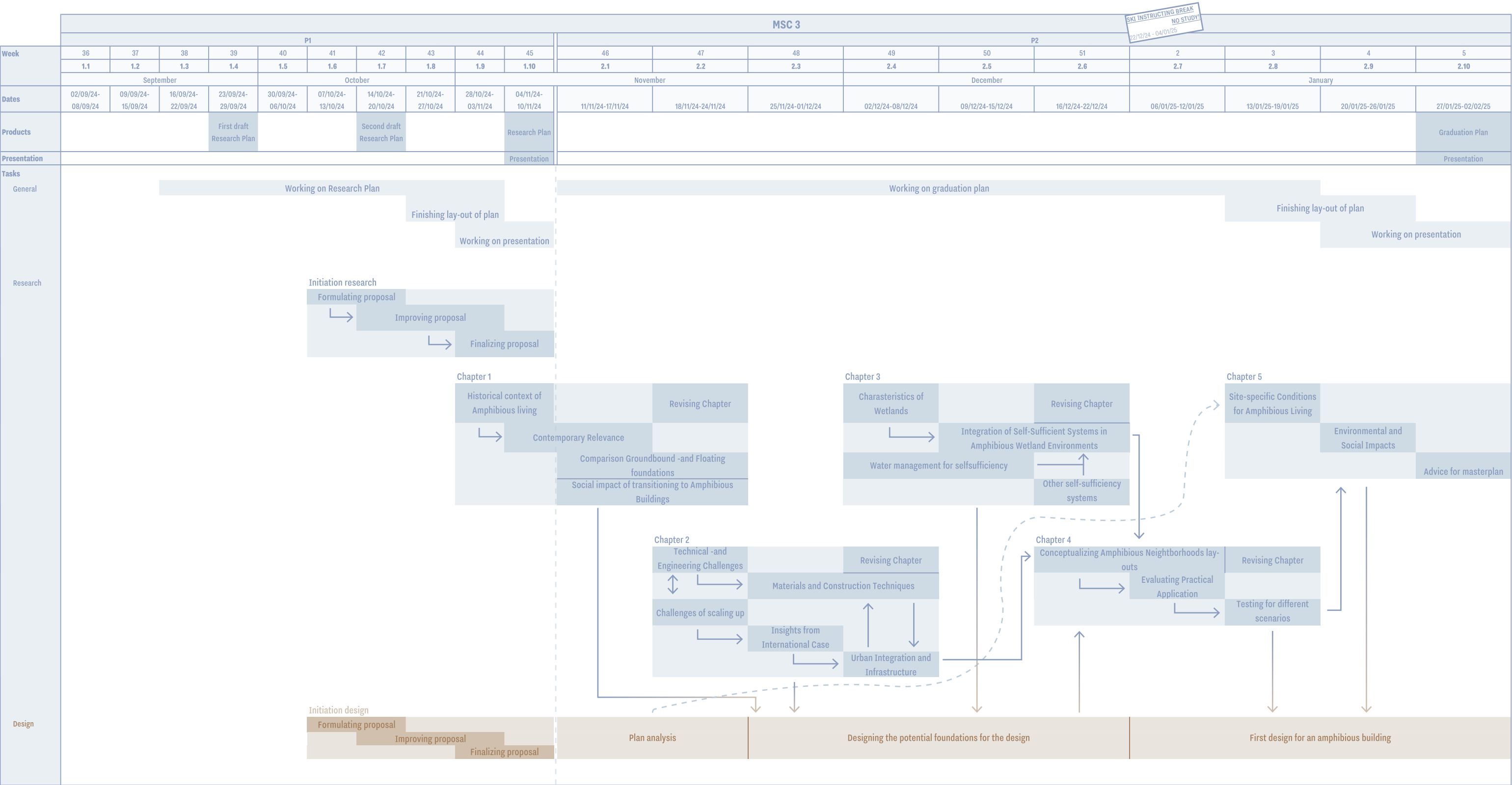
Sequence of Topics

The schedule clearly shows the relationships between the various topics and why they are put in this sequence with the

aid of arrows. The arrows **illustrate the conclusions** from each topic and how these gets used into further research or design.

Research methods

What isn't specified in the schedule is the timing of the research methods (e.g., when expert feedback sessions or interviews will take place). The intention is for the methods within each topic to be **implemented within the allocated timeframe**.



Terms used in this proposal

VIII. Key Terms Glossary

Used in this research as an adaptation strategy in which structures can function with different water levels. Understood as defined by Hangler (2024): “*Amphibious architecture is an adaptation strategy where structures are designed to adapt to flooding. Some amphibious buildings are built on elevated foundations. Other buildings are constructed on foundations that under normal circumstances rest firmly on a solid surface. However, during periods of flooding, the building floats.*”

Refers to the current housing shortage of the Netherlands which states that almost one million homes still have to be built by 2030 while land to built on is scarce. (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2023)

Refers to the rising sea -and river levels as assumed by the IPCC (2021) and how the the ‘accommodating’ option from Defacto (2024), which explains reducing vulnerability to water level rise through water- or salt-tolerant land use, will be used as base for this research

Understood in this research as an integration of self-sufficient systems while being assisted by the main grid. The term emphasizes that the building is designed to operate independently for certain systems (energy and wastewater) while staying connected for others (like potable water) and back-up when needed, hence the term ‘hybrid’.

Used in this research as the integration of buffer polders in sustainable water management to support the hybrid self-sufficiency of buildings. Natural Climate buffers are defined by Veraart et al. (2019) as: *areas where natural processes are given space to flourish. This allows them to adapt to climate change, helping to retain and absorb water, prevent water shortages, moderate heat, and reduce carbon dioxide in the atmosphere.*

As defined by The Global Center on Adaptation (2024): Climate adaptation means taking action to prepare for and adjust to the current and projected impacts of climate change. With climate change bringing more frequent and intense extreme weather events such as heatwaves, droughts and floods.

AMPHIBIOUS
ARCHITECTURE

DUTCH HOUSING
SHORTAGE

ADAPTING
RISING-WATER
LEVELS

HYBRID
SELF-SUFFICIENCY

NATURAL CLIMATE
BUFFER
INTEGRATION

CLIMATE CHANGE
ADAPTATION

Literature and Figure Overview

IX. Bibliography

A&W ecologisch onderzoek, Bureau Peter de Ruyter landschapsarchitectuur, & Atelier des Hollants. (2022). Visie klimaatbestendige veenlandschappen. In Coalitie Natuurlijke Klimaatbuffers (CNK). <https://www.klimaatbuffers.nl/uploads/visie-klimaatbestendige-veenlandschappen-cnklres.30e240.pdf>

Baron, D. J. (2004). Beter bouw-en woonrijp maken: Een verkennend onderzoek naar het bouw- en woonrijp maken in de Nederlandse praktijk en de problematiek rondom wateroverlast op de bouwplaa. TU Delft. <https://filelist.tudelft.nl/CiTG/Over%20faculteit/Afdelingen/Watermanagement/Education/Completed%20MSc%20theses/2005%20-%202009/BRM2004.pdf>

B+B. (2021, August 3). Tussenwater. <https://bplusb.nl/project/tussenwater/>

De Vries, A. A. H. (2024). Flood-proof living at the riverside | TU Delft Repository. <https://resolver.tudelft.nl/uuid:e2daa03f-7c8e-4639-9a68-4d98c059b2c0>

Ferreira, C. S., Kaşanin-Grubin, M., Solomun, M. K., Sushkova, S., Minkina, T., Zhao, W., & Kalantari, Z. (2023). Wetlands as nature-based solutions for water management in different environments. Current Opinion in Environmental Science & Health, 33, 100476. <https://doi.org/10.1016/j.coesh.2023.100476>

Gemeente Utrecht. (2024). Programmatische verkenning Rijnenburg: Op weg naar een uitgangspuntennotitie. <https://utrecht.bestuurlijkeinformatie.nl/Reports/Item/37a58e41-5192-4284-87ed-b0d0f0777053>

IPCC. (2023). IPCC, 2023: Summary for Policymakers. In Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (No. 1–34). <https://doi.org/10.59327/IPCC/AR6-9789291691647.001>

Ministerie van Binnenlandse Zaken en Koninkrijksrelaties. (2023, July 12). Woningbouwopgave stijgt naar 981.000 tot en met 2030. Nieuwsbericht | Rijksoverheid.nl. <https://www.rijksoverheid.nl/actueel/nieuws/2023/07/12/woningbouwopgave-stijgt-naar-981.000-tot-en-met-2030>

Ministerie van Infrastructuur en Waterstaat en de Deltacommissaris, Zanting, H. A., & Bouw, M. (2024). Eindrapportage oplossingsrichting “meebewegen”: Verkennend onderzoek voor het kennisprogramma zeespiegelstijging. In Deltaprogramma. nl

Ministerie van Infrastructuur en Waterstaat, Ministerie van Landbouw, Visserij, Voedselzekerheid en Natuur, & Ministerie van Volkshuisvesting en Ruimtelijke Ordening. (2024). Nationaal Deltaprogramma 2025: Naar een nieuwe balans in de leefomgeving: ruimte voor leven met water. Nationaal Deltaprogramma. Retrieved October 30, 2024, from <https://dp2025.deltaprogramma.nl/>

Ministerie van Infrastructuur en Waterstaat. (2024, July 3). Ruimte voor de rivieren. <https://www.rijkswaterstaat.nl/water/waterbeheer/bescherming-tegen-het-water/maatregelen-om-overstromingen-te-voorkomen/ruimte-voor-de-rivieren>

Nillesen, A. L., & Singelenberg, J. (2011). Waterwonen in Nederland : architectuur en stedenbouw op het water = Amphibious housing in the Netherlands : architecture and urbanism on the water. In NAI Publishers eBooks. <http://ci.nii.ac.jp/ncid/BB07110267>

Piątek, Ł., Cin, F. D., & Gireesh, N. (2024). Amphibious buildings as a Response to Increased Flood Risk—European Case Study. In Lecture notes in civil engineering (pp. 789–808). https://doi.org/10.1007/978-981-97-0495-8_46

Posad Maxwan, Blue Revolution, Pas BV, Buiting Advies, & Dutch Lotus. (2023). Drijvende steden: inspiratie- en handboek, eerste fase. <https://acrobat.adobe.com/link/track?uri=urn%3Aaaid%3Ascds%3AUS%3Aafaefc0c-132a-354d-a1cf-34c0211f7f82>

PosadMaxwan & PasBV. (2024). Verdiepend onderzoek in de potentie van de drijvende stad. In Posadmwxwan.nl. Retrieved October 8, 2024, from <https://acrobat.adobe.com/id/urn:aaid:sc:EU:29690ba5-0e54-4b7d-8aaa-7528236a4e04>

Redesigning Deltas, ZUS [Zones Urbaines Sensibles], Flux, & Sweco. (2022). National Productive Park Deltland: It is about time in Delta Design to create a new Dutch condition. In Redesigning Delta. https://drive.google.com/file/d/1GD_KUmpgERUh3z9Y9YRDRQN14m6992K6/view?usp=sharing

Segeren, W. A., & Hengeveld, H. (1984). Bouwrijp maken van terreinen. Kluwer Technische Boeken B.V. <https://tudelft.on.worldcat.org/search/detail/63943350?queryString=bouwrijp%20maken%20van%20terreinen>

The Global Center on Adaptation. (2024, July 23). What is climate adaptation? GCA.org -. <https://gca.org/what-is-climate-adaptation/#:~:text=Climate%20adaptation%20means%20taking%20action,projected%20impacts%20of%20climate%20change>.

Van Dam, P. J. E. M. (2012). OVERSTROMINGEN EN CULTURELE AANPASSINGEN IN HISTORISCH PERSPECTIEF. Water Governance. <https://edepot.wur.nl/244222>

Vervaart, J., Kaandorp, V., & Deltafact. (2023). Water vasthouden en bergen in natuurgebieden. STOWA. Retrieved October 30, 2024, from <https://www.stowa.nl/sites/default/files/assets/DELTAFACTS/Deltafacts%20NL%20PDF%20nieuw%20format/Water%20vasthouden%20in%20natuurgebieden%20v1.pdf>