Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	**Pim Braakhuis**
Student number	4811305

Studio		
Name / Theme	Architectural Engineering	
Main mentor	Mo Smit	Architectural tutor
Second mentor	Fransje Hooimeijer	Research tutor
Argumentation of choice of the studio	When choosing the graduation studio, I stumbled upon "Explore Lab" due to the freedom it offered and the possibility of choosing my own 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.	

Graduation project	
Title of the graduation project	Amphibious Living in the Polders – Feasible implementation of Amphibious Constructions in Buffer Polders: A case-study of Gnephoek, Alphen aan den Rijn, the Netherlands.
Goal	
Location:	Gnephoek, Alphen aan den Rijn
The posed problem,	The posed problem is the increasing challenge of managing water levels due to climate change, which causes droughts in summer and floods in winter, placing pressure on dikes and water systems. Simultaneously, the Netherlands faces a housing crisis, requiring nearly a million new homes by 2030, while land availability is limited and many potential sites are at high flood risk. This dual challenge of housing demand and water management necessitates innovative solutions that balance urbanization with climate adaptation.
research questions and	**Main question:** *How can amphibious principles be developed in peatlands in an ecologically responsible and climate-resilient manner, so that they contribute both to effective water management and to addressing the housing crisis?* **Sub questions:** - *What makes amphibious housing a realistic solution for the challenges in peatlands?* - *What specific characteristics of peatlands must be considered when developing amphibious principles in a climate-adaptive way?*

	- *How can peatlands be designed to be climate-resilient through the integration of water management systems?* - *How can peatlands be prepared for the construction of amphibious neighborhoods, focusing on foundation, construction, infrastructure, and groundwater management?*
design assignment in which these result.	*To explore and design viable, resilient neighborhoods that integrate amphibious and water management principles, aligned with sustainable urban design standards in a polder landscape.*

Our planet is warming up, leading to extreme water levels: low levels in summer result in droughts and freshwater shortages, while high levels in winter cause river floods and increased pressure on dikes (IPCC, 2023). The Dutch have a rich history of innovative water management. However, with the new extremes in water levels expected in the coming decades, a new vision for water management is essential—one where water and soil play a guiding role (Ministerie van Infrastructuur en Waterstaat et al., 2024). At the same time, the Netherlands is facing a housing crisis due to urbanization and population growth (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2023), further complicating the situation. There is an urgent need for new housing, but also for water storage, while land is scarce (PosadMaxwan & PasBV, 2024).

This graduation builds on the adaptation strategy aligned with the Nationaal Deltaprogramma 2025 and further explored in the report *'Oplossingsrichting Meebewegen'* in the form of hybrid adaptation (Ministerie van Infrastructuur en Waterstaat, 2024). Hybrid adaptation explains, among other things, how the vulnerability of the soil can be reduced by using "bufferpolders" for controlled water storage and water reserves during drought periods. These polders, often consisting of peat soil (Verhagen et al., 2009), offer a unique opportunity to enhance the buffer capacity of the Netherlands.

In addition to climate change, the housing crisis adds to the challenge, with nearly one million homes needing to be built by 2030 (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2023). Limited land availability and future flood risks make finding suitable locations for construction projects more difficult. Research by PosadMaxwan & PasBV (2024) identified 420,000 hectares of land in the Netherlands at high risk of flooding, most of which consists of peat—a soil type less suitable for construction (Segeren & Hengeveld, 1984).

Amphibious construction techniques, which bypass the disadvantages of peat soils and function in wet conditions, offer a solution. By developing just 3% of the identified flood-prone areas using this method—with a density of 65 homes per hectare—it is possible to address both the housing shortage and the need for new water storage options.

As a solution to these two societal challenges, the thematic paper explores the potential of amphibious constructions in pealands. By investigating how these peatlands can be designed to be climate-resilient using amphibious principles, this research aims to contribute to innovative solutions for urban development in flood-prone areas.

The main research question is: *"How can amphibious principles in peatlands be developed in an ecologically responsible and climate-resilient manner, so that they contribute both to effective water management and to addressing the housing crisis?"*

To answer this question, the research is divided into several sub-questions. Each sub-question highlights a specific aspect of the main question, thereby contributing to its ultimate resolution:

1. **Context**: *"What makes amphibious housing a realistic solution for the challenges in peatlands?"*
2. **Landscape**: *"What specific characteristics of peatlands must be considered when developing amphibious principles in a climate-adaptive way?"*
3. **Water Management**: *"How can peatlands be designed to be climate-resilient through the integration of water management systems?"*

4. **Development**: *"How can peatlands be prepared for the construction of amphibious neighborhoods, focusing on foundation, construction, infrastructure, and groundwater management?"*

With the conclusions from the thematic paper, the base for the design assignment is laid. The assignment aims to design sustainable neighborhood layouts that integrate amphibious construction and watermanagement principles while addressing the unique challenges of building in peatlands. Peatlands present ecological benefits like water and carbon storage but are also fragile, with low load-bearing capacity and vulnerability to subsidence and CO_2 emissions when drained.

The focus is on developing climate-resilient housing that adapts to fluctuating water levels, preserves the ecological functions of peatlands, and aligns with sustainable urban design principles (PosadMaxwan, 2024). The design must address two key questions: *"How can peatlands be developed in an ecologically responsible and climate-resilient manner with the aid of amphibious principles, so that they contribute both to effective water management and to addressing the housing crisis?"*

The output is a holistic design on how peatlands can be preserved and enhanced through innovative housing solutions that balance ecological, social, and economic needs while utilizing the landscape's natural characteristics for water management and carbon storage.

Process

Method description

This project is structured into three phases: research, concept development, and validation, each progressing logically from the previous stage to create a comprehensive and feasible design.

The **research phase** focuses on understanding the feasibility of implementing amphibious constructions in peatlands. It includes case studies of existing amphibious projects, comparative analyses of construction methods and materials , as well as in-depth interviews with experts. This phase examines how amphibious housing can function under varying water levels while preserving the ecological value of peatlands. Additionally, innovative water management systems, such as the APSSI, are analyzed for their potential integration. The conclusions identify key opportunities and challenges, laying the groundwork for the next phase.

The **concept phase** builds on the thematic paper and implements insights from the *Contourenplan Gnephoek*. This phase uses the plan's principles, such as *water en bodem sturend*, as a framework for designing sustainable neighborhoods in the Gnephoek that align with national goals for water and soil management. A preliminary neighborhood layout is developed, integrating amphibious housing principles and self-sufficient systems while looking at the spatial and ecological guidelines set out in the *contourenplan*. A circular plan for the neighborhood is developed is developed as well (paludiculture, watermanagement, waste management and construction materials).

The **validation phase** focuses on working out one of the neighborhoods as described in the contourenplan to a detailed architectural plan. This involves developing both the technical and spatial challenges specific to the area, such as water management, site preparation, and integration with the surrounding landscape on a smaller scale. The design includes detailed housing layouts, infrastructure plans, and public space designs that fit within the larger neighborhood framework. A step-by-step plan for site preparation and the construction on peatlands will be given as well.

Literature and general practical preference

For my graduation project, I will consult a variety of literature, research data, and practical examples to build a strong foundation.

Policy is key, as it validates the approach of spatial development in which water and soil are leading. Reports like those from the Intergovernmental Panel on Climate Change (IPCC, 2023) will help me understand how changing water levels affect urban planning, while reports from the Dutch government

like '*Nationaal Deltaprogramma 2025' and* '*Oplossingsrichting Meebewegen'* will give me insights into hybrid adaptation strategies. These strategies combine the need for water storage and urban development, which is directly relevant to my project.

Secondly, understanding the characteristics of peat will give insight into the ecological importance of peatlands and how they function as a building soil. It explains their role in carbon storage, water retention, and the challenges of subsidence and CO_2 emissions when drained. The CNK (Coalitie Natuurlijke Klimaatbuffers) (A&W ecologisch onderzoek et al., 2022), has developed a vision with measures how peatlands can be restored and maintained to improve the biodiversity and carbon-and water storage capacity. Other rapports like '*Dalende Bodems, Stijgende Kosten'* by Planbureau voor de Leefomgeving (2016) further elaborates these measures.

Methods of how to prepare peatlands as a building soil are described in the report '*beter bouw-en woonrijp maken'* written by Baron (2004). The measures and materials to improve the soil properties are however a bit outdated, which led to implementing more recent rapports and papers in the research paper. The use of amphibious foundations has been concepted by A. De Vries in her thesis at the TU Delft last year on which I have elaborated my own findings.

For my research data, I will analyze a case study with projects that have different building methods. This will validate why amphibious constructions are more suitable compared to groundbound and floating foundations when building on weak soil. Multiple comparative analysis will further examine construction techniques and material choices. For the water management system, I have used three different pilots that all have proven to be working to combine them into a new system on which I have checked if the specifications were compatible with each other.

Reflection

I believe my graduation topic is a good example of Architectural Engineering and fits well within the Architecture track. Architectural Engineering focuses on innovation in architecture, addressing both personal and societal challenges. In my case, I had a vision of how we could expand cities using amphibious concepts to ensure that, with climate change, buildings wouldn't experience water damage.

As I explored this idea, I realized that amphibious construction has barely been applied in the Netherlands, mainly because the need for it wasn't urgent until now. Only the last years has the awareness of water-related risks started to influence development plans, making this topic more and more relevant. The challenge is that amphibious concepts have mostly been explored on a urban conceptual scale, rather than at the level of architectural design. This makes it an good opportunity for me as an Architecture student to create a concrete design.

By exploring how we can build on peatlands using amphibious techniques—looking at both soil preparation and the construction process—I believe I can provide valuable insights for both the professional field as for scientific research. This approach offers a way to tackle two major challenges: the impacts of climate change and the housing shortage. If handled separately, these issues can stand in each other's way, but with the right approach, we can address both at the same time.