# 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.

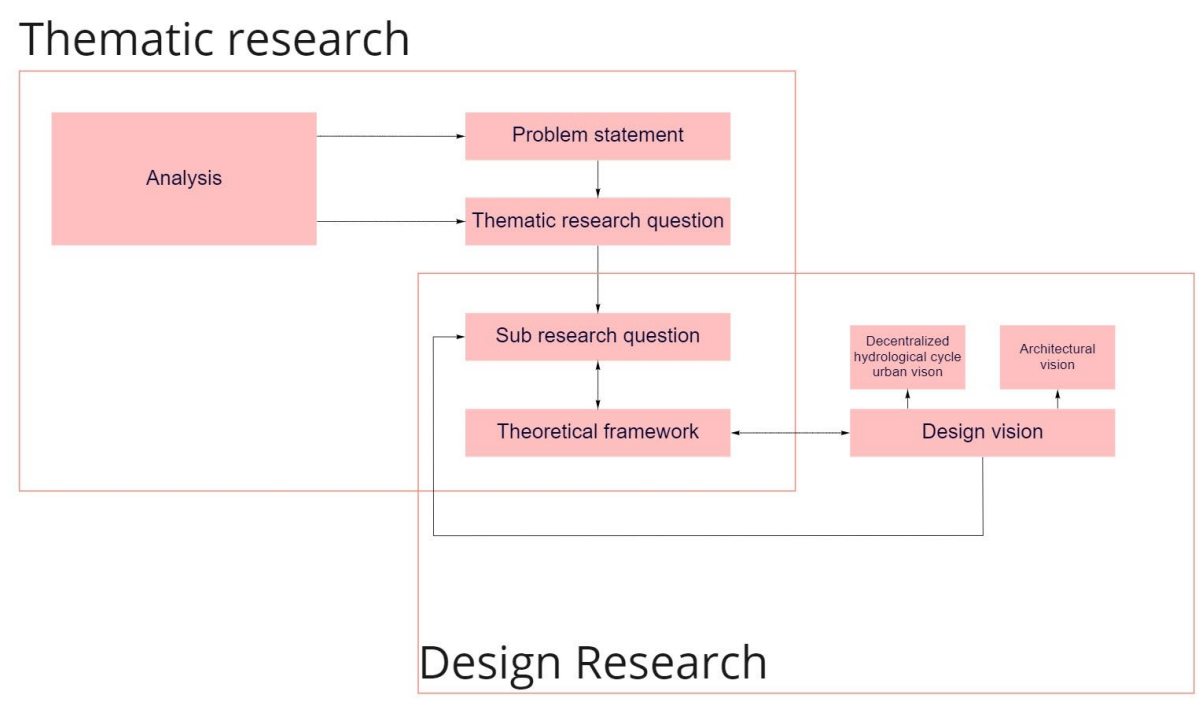
The graduation plan consists of at least the following data/segments:

| **Personal information** | |
|---|---|
| Name | Alexander Justin Da Costa Gomez |
| Student number | 4287967 |

| **Studio** | | |
|---|---|---|
| Name / Theme | Architectural Engineering | |
| Main mentor | Mo Smit | *Design tutor* |
| Second mentor | Jos de Krieger | *Research tutor* |
| Argumentation of choice of the studio | For me architecture must *serve people*. Conventional building constructions tend to deplete the natural environment and its resources. Researching what technological solutions in the built environment exist in supporting, by for example harvesting freshwater, these depleting recourses in order to relieve the pressure in order to create resiliency for communities. | |

| **Graduation project** | |
|---|---|
| Title of the graduation project | Thirsty Monument: re-evaluating the historical and natural fresh water system for the urban context of Willemstad, Curaçao |
| **Goal** | |
| Location: | Urban area of Willemstad, Curaçao |
| The posed problem, | As water scarcity has become one of the most important environmental and social issues of the 21st century, the way the built environment interacts with water must be reconsidered. Today's urban water cycle in Curaçao is characterized by linear, centralized, polluting, costly, time and energy consuming and does not contribute to cultural value. |
| research questions and | *How can a decentralized, circular water system (inspired by Closed city concept, HIDS and NBS) be implemented to* |

| | |
|---|---|
| | *provide freshwater in a urban neighbourhood in Willemstad, Curaçao?*<br><br>Developed further via **sub questions**:<br>○ *What are the current situations and potentials of the natural water cycle and water chains of Willemstad, Curaçao?*<br>○ *What are the requirements for a closed city concept?*<br>○ *What decentralized systems and technologies, inspired by HIDS and NBS, are available?*<br>○ *How can these systems and technologies be integrated on neighbourhood or building scale?*<br>○ *What are the spatial and architectural impacts of these systems and technologies?*<br>○ |
| design assignment in which these result. | *How can a decentralized water management system, on neighbourhood scale, in the urban area of Willemstad be implemented on delipidated monument sites and be connected to a public program to increase the communal awareness of the finite resource of freshwater?* |



The problem statement is derived out of 3 components from more generic to site specific:

1. Water treatment issue in the urbanized regions in SIDS
2. Water treatment issue in Curaçao
3. Urban area of the city Willemstad, Curaçao

**1) Water treatment issue in urbanized regions and SIDS:**

According to Gurera and Bhushan (2020) it is estimated that 2 billion people live in countries that are experiencing problems related to high water stress. These problems are often found in urbanized areas around the world. The increases in population and building density that occur in these progressively urbanized areas can have a far-reaching effect on the *hydrological cycle* and therefore on both the quantity and quality of water resources (Hall & Ellis, 1985).

A trend to live in urbanized area has developed greatly in Curaçao. According to the Government of Curaçao et al (2019) 75% of the population on Curaçao lives in urbanized regions, that makes up of a quarter of the total area of the island. This classifies Curaçaos as a highly urbanized countries. Looking at the hydrological cycle of SIDS numerous challenges occur due to their biophysical settings (Figure 2). SIDS are at the forefront of climate change and its consequences, particularly with regards to their freshwater resources, where 91% is threatened by water shortages (UNESCO, 2019). Also problems relating to the pollution of ground water and surface water due to saline intrusion can be found on these types of islands. As stated in UNESCO (2019), SIDS are often surrounded by the ocean, making their ground prone to saline intrusion, causing 73% risking groundwater pollution.

As mentioned above there are many resident living in urbanized areas facing the issue of the quantity and quality of freshwater resources. Researchers like Pawlyn and Safari (2019) state that our standard approaches to water have an inherent technological laziness to them that has developed from the same assumptions of limitless supply that characterised our attitude to resources at the start of the Industrial Revolution. By introducing the hydrological cycle in our built environment, buildings and public space could be seen as the connection between the natural water systems, water chains and its inhabitants.

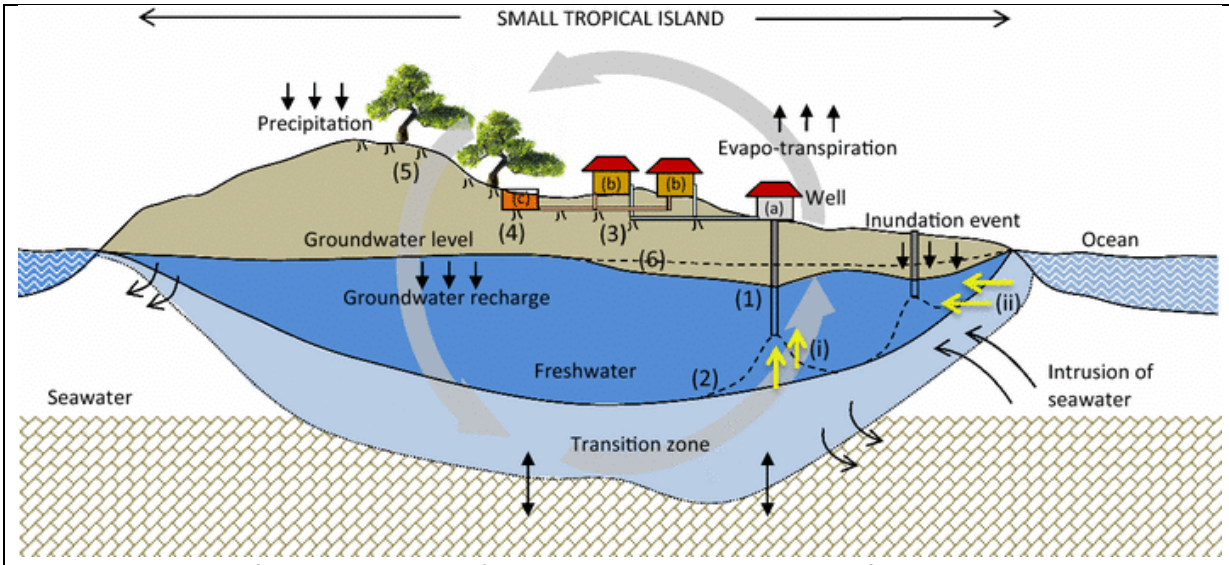



Figure 2. Overview of small tropical island's conceptual model showing simplified hydrological cycle and hydro geochemistry mechanisms (Mohd Isa et al., 2017)

## 2) Current water production and treatment in Curaçao:

On Curaçao the importance of freshwater is tangible (GSO, 2017). One of the main problems on the island is the lack that management and infrastructure of freshwater have in order to cope with the natural water system and water chains. This main problem can be divided into the following: 2.1) issues in the catching and managing of rainwater and groundwater, 2.2) issues in the harvesting of freshwater and 3.3) the lack of treating wastewater.

2.1) Despite imminent shortages, Curaçao allows rainwater to drain unused into the sea (GSO, 2017), which not only effects the quantity of freshwater resources on land but also pollutes the ecosystems in the ocean. This inadequate management contributes to the pressure of harvesting enough freshwater for the inhabitants and tourists, but also for flora, fauna and agriculture.

2.2) To produce freshwater, a land based reverse osmoses production plant, named Aqualectra, was built on the island. This plant produces freshwater for 98% of the households (Central Bureau of Statistics, 2018). However, the production is a time and energy consuming process which makes the production of freshwater expensive. According to Wesselink (2015) the cost per cubic meter of freshwater in Curaçao is seven times more expensive than that of the Netherlands. In addition to this, Curaçao faces the pressure of producing enough freshwater for the inhabitants and tourists (Antilliaans Dagblad, 2019). Although the population growth on the island has flattened, there is still a big growth in tourists visiting it. According to Antilliaans Dagblad (2019), tourists use up to 300% more water than inhabitants of the island. Another problem the plant faces is the loss of produced water, due to deteriorated pipe lines and illegal tapping of freshwater. It has been stated in the 2019 Annual Report of Aqualectra (2019) that 27% of the produced water of Aqualectra is lost in the process of distributing it to the people naming it 'Non-revenue'.

2.3) Another challenge facing Curaçao is the lack of infrastructure and treatment of domestic and industrial wastewater. Stated by UNOPS et al (2018) , around 16% of

wastewater produced in Curaçaos is treated due to deficiency in sewage treatment facilities. The remaining untreated wastewater is discharged into the terrestrial and marine environment. According to Hendriksen (2019) 1.6 million guilders was invested to build a new WWTP, specially designed to treat polluted water in order to dump it back in the ocean. Linear solutions like these are implemented even though 2% of the people on the island can't afford their monthly water bill (Ministry of Economic Development, 2021). Currently, there are four different WWTP's on Curaçao built by the government, but these do not function well due to inadequate machinery and treatment techniques (UNOPS et al, 2018).

To conclude, there is a high freshwater demand on the island which is currently provided by an expensive, energy consuming production method (reverse-osmoses desalination method), while much water is lost due to inadequate water management.

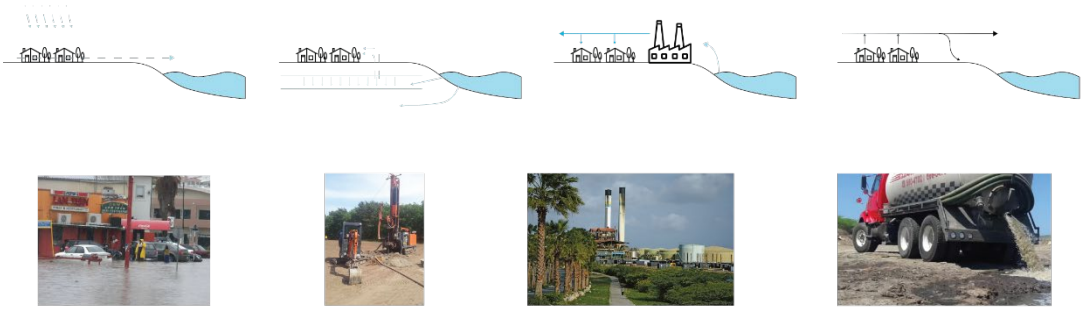


Figure 3. Diagrams that summarizes the current lack Curaçao has on the that management and infrastructure of freshwater and wastewater, in order to cope with the natural water system and water chains (Authors image)

### 3) Urban neighbourhoods 'barios' of Willemstad, Curaçao

The urban region of Curaçao is concentrated in the city called Willemstad (center and periphery). This part of the island is in transition from a unsustainable developed urban area, that grew out of new neighbourhoods built for the labour class during the early days of the prosperous oil refinery and 20th century modernist suburban expansion (Ministry of Economic Development, 2021), into a green and healthy living environment. In the past, water reservoirs and greenery where depleted in order to build these scattered neighbourhoods and car infrastructures. Due to this depleting of natural environment, problems related to quality and quantity of freshwater started increasing. Therefore, in the Objectives for the community-based vision 2030 of the New Urban Agenda, it is stated that the drainage system, wastewater collection and treatment system functions would be optimized and integrated in a sustainable water management cycle (Government of Curaçao et al., 2019).

## Process

### Method description

**Overarching methodology:**

For this project is *scenario planning*. Inspired by the 'Closed City concept' described by Hooimeijer et al (2019), scenarios are imagined relying on the ideas of decentralized water management system and circular economies. In order to formulate scenarios that will assist me in gaining knowledge for the research, as well

as for the design, the theory of biomimicry in architectural design principles (Pawlyn & Safari, 2019) is also studied.

**Defined scenario for the thematic research:**
Where decentralized closed water systems are implemented as part of an advanced circular approach to relieve the pressure on freshwater availability in Curaçao. This scenario shifts the emphasis from current conventional centralized water management to technical and practical challenges of the transition into a decentralized closed water system where building construction are needed to be designed as part of an advanced regenerative circular economy. Allowing exploration in techniques of freshwater harvesting and wastewater treatment.

**Thematic research methods:**

**Literature review**: academic literature and scientific articles providing an overview of existing knowledge on:

- Hydrological cycle: definition, flows, challenges.
- Closed City concept: definition, economic challenges, environmental and social benefits.
- Circular water systems: definition, economic challenges, environmental and social benefits.
- Biomimicry in architecture: definition, economic challenges, environmental and social benefits.
- Biomimetics in harvesting, capturing, storing, transporting and reusing water.
- Different plant species and there capacities of extracting, storing and transporting water in semi-arid or arid climates.
- Different biomimetic and non-biomimetic technical solutions in the built-environment which create smart ways of harvesting, capturing, storing, transporting and reusing water

**Interviews**:

- Stakeholder interviews that are in the business of creating and improving techniques of built structures in order to play a role in water harvesting.
- Stakeholder interviews in the business of reusing wastewater

**Case studies**: Case study analysis of different examples that show interventions and biomimetic solutions for storing, capturing, harvesting, transporting and reusing (waste)water.

**Experimentation**: This part is used to bridge the gap between the academic an practical work. I would like to do experimentation with creating forms to better understand the physical challenges in creating a space that both tackles social aspect and technical aspect of harvesting, capturing, storing transporting and reusing water.

**Quantitative analysis:** the hypothetical case of the decentralized water treatment machine, placed in periphery of Willemstad, is tested further with a quantitative analysis of potential saving in energy and cost in the renewable used water.

**Contextual-research methods:**

This part will be done parallel to the thematic research in order to compliment the architectural program that will be added on a dilapidated monumental plot in Willemstad. The added program should boost the concept of decentralized circular water treatment in order to re-establish the hydrological cycle in the area.

**Literature and general practical preference**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## Reflection

**1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?**

Graduation topic: Water harvesting technologies in the built environment
Studio topic AE: Engineering solutions in the built environment
Master programme: Architecture

Relationship between the three above mentioned aspects is:

➔ Researching challenges in the current built environment and building methods
➔ Analyse different engineering solutions in order to tackle the problem that is stated within these challenges
➔ Implementing the found solutions in the current built environment using architectural principals (making architecture with the technological solutions)

2. **What is the relevance of your graduation work in the larger social, professional and scientific framework?**

**Disciplinary relevance:**
Circular water treatment is one of the key elements in order to tackle the contemporary issue of climate change and consequent changing of the hydrological cycle in urban areas. In Curaçao water processing companies and wastewater treatment facilities have already made steps in order to down the pressure on freshwater resources, like desalination reverse osmoses plant and wastewater treatment plants. However, there remains problems in the urban hydrological cycle in SIDS on how to collect and treat water properly and efficiently.

Allot of research is done on how to create closed water cycles that inspired by mimicking solutions found in nature and heritage. For the building level there has been allot of research done based on biomimetic approaches for freshwater treatment and wastewater reuse.
Thus, based on the existing knowledge on decentralized closed water cycles and freshwater harvesting and wastewater treatment technologies, this research tries to get an insight into the feasibility of managing the natural water system and water chain on the scale of a building.

**Societal relevance:**
This research is also of great societal relevance because currently, many residents of SIDS are not aware of the importance of creating closed urban water cycles. In order to realize the circular hydrological cycle in urban areas, community involvement and awareness can be a crucial part. A closed urban hydrological cycle is not only beneficial for the quantity and quality of freshwater resources but also beneficial for providing a healthy living environment for residents. Residents will have more possibilities to work together with their communities on treating the freshwater from their neighbourhoods. This would enhance the cohesion in the sprawled neighbourhoods of Curaçao which is missing at this moment.