

Rain Chain

Exploring the Opportunities of Rainwater
Through Architecture

Ellen Linder

Master Thesis, Chalmers University of
Technology, spring 2017

Examiner: Daniel Norell
Supervisor: Jonas Lundberg and Karin Hedlund
Department of Architecture and Civil Engineering

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Abstract

Gothenburg has between 160-200 rainy days every year. The main part of this rain is wasted, running down the gutters and into the sewage system. Recent predictions tell us that the future holds even more rain and Gothenburg, like many other cities, is already struggling with the problem of flooding.

In this master thesis, a new type of rainwater harvest system is explored. The aim is to develop a solution where technology and design work together to create a holistic, sustainable concept. This harvesting system state an example of how rainwater can be turned into an asset. At the same time it displays the opportunities and qualities of water.

The research started with literature studies and investigations of already existing methods such as green architecture, storm water strategies and rain harvesting systems. These studies created a base knowledge of rain harvesting. Based on the research, different experiments were conducted to investigate and map the qualities, possibilities and attributes of the water. These experiments laid the ground for a design.

The result is a contemporary water tower that collects and purifies rain water. This

tower is open to the public and visitors can participate and learn from the solutions that have been implemented. In addition to the tower, a strategy was developed to distribute water in Majorna, Gothenburg. The tower states an example of how we can take the next step in rain harvesting systems by using architecture.

By creating an example of a new type of rainwater harvesting system this master thesis will be a contribution to sustainable architecture. The next step in sustainable architecture is to make these kinds of solutions customary. It is therefore vital to present research and visionary designs like this to key stakeholders such as architects, contractors and municipalities. This would demonstrate a modern approach to rainwater harvesting in architecture.

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Introduction

Introduction

Why?

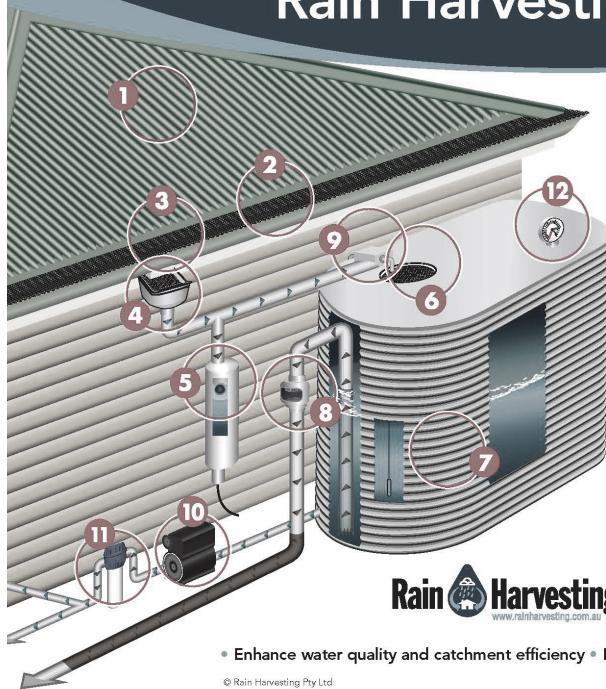
It falls, on average, 1,000mm of rain in Gothenburg every year ("SMHI" 2013). According to Östberg (1999) the future holds even more rain and today Gothenburg, like many other cities, is already struggling with the problem of flooding from storm water. (Länsstyrelsen Västra Götaland, 2015)

We often look upon rainy days as grey, dull (weather pal, 2015) and a future problem but is it maybe an asset that we allow to slip down to the sewage system?

Example:

If all rain that falls upon Chalmers student Union house were to be collected it would add up to around 5000m³ every year. This water would be enough to fill two Olympic swimming pools ("fina", n.d) or run a dishwasher 7 15 000 times ("vi i villa", 2004) or provide all water needed for 100 people for an entire year ("Svenskt vatten", 2017). Instead of looking upon the rainy days as gray and dull they could be turned into an asset in both a sustainable and an artistic way.

How to Create the Complete Rain Harvesting System



1. Check **ROOF SURFACE** is suitable for collecting quality rainwater.
2. Install **GUTTER MESH** (such as Blue Mountain Mesh*) to prevent leaves and debris from blocking gutters.
3. Fit **GUTTER OUTLETS** from the underside of the gutter to prevent obstruction of water flow.
4. Fit Leaf Eater® or Leaf Beater® **RAIN HEADS** to downpipes to prevent blocking. Rain heads deflect leaves and debris and keep mosquitoes out of pipes that hold water ('wet' systems).
5. Install **FIRST FLUSH DIVERTER/S** to help prevent the most contaminated rainwater from entering the tank.
6. Ensure a **TANK SCREEN** is installed at tank entry point to keep mosquitoes and pests out.
7. Choose a **WATER TANK**. Consider annual rainfall, roof catchment area and water usage when determining its size.
8. Attach **INSECT PROOF SCREENS** or **FLAP VALVES** to the end of all pipes to the tank screen to keep mosquitoes and pests out and ensure the tank is vented properly. Install an **AIR GAP** to **TANK OVERFLOW OUTLETS** to prevent stormwater backflow into your tank.
9. Utilise a **TANK TOP UP** system (if required) to automatically top up the tank with mains water when levels fall to a designated minimum level.
10. Select a **PUMP SYSTEM** (if required) to distribute water for use inside or outside the home.
11. **RAINWATER FILTER**. Fit a purpose designed rainwater filter after the pump to help reduce residual sediment, colour and odour.
12. **WATER LEVEL INDICATOR**. Install a Tank Gauge water level indicator to your rainwater tank to monitor your water level and usage.

• Enhance water quality and catchment efficiency • Reduce tank maintenance • Protect pumps and household appliances

© Rain Harvesting Pty Ltd

*Consider local council requirements and have a plumber complete installation where required.

This figure shows the general setup for a rain harvesting system.

Figure: Rain harvesting. (n.d) How to create the complete Rain Harvesting System.

Retrieved 6 mars 2017 from <http://rainharvesting.com.au>

Gap

There are many ways of using rainwater already established. (Rainharvesting, n.d) However, there is a lack of integration between technical solutions and design. The solutions often result in a large, plastic tank and in plain pipe systems. This thesis will be an investigation of how this gap could be narrowed.

Most harvesting solutions are implemented on a small scale. This thesis will be implemented on a larger scale to research how rain water harvesting could be a part of a larger network of infrastructure. The thesis could therefore be an contribution to overall strategies for sustainable development.

This design will not only integrate rain in the design but also display its benefits. By doing so the public can take part of it and be inspired and educated in the opportunities on rainwater.

Purpose

The purpose of this master thesis is to investigate how rain could be a more useful asset in architectural planning and design.

Thesis question:

How can rain harvesting systems be introduced into an architectural design in a sustainable, educating and aesthetically pleasing way?

Contribution

A vision has been created for the future water-strategy of Gothenburg.

No new technical solutions has been developed. Instead existing ones has been redefined and redesigned.

The rainwater system must become a natural part of the architecture and therefore also the design-process.

The aim is that the finished result will state an example of how we can take the next step in rain harvesting systems using architecture. The goal is to display the possibilities of the rain water and inspire and teach the spectator.

Where?

Gothenburg

The city has two water treatment plants.

Both harvest surface water which means that it needs to be chemically cleaned. (Göteborg stad, n.d) Therefore, Gothenburg is a good site to implement a new type of rain harvesting system.

Gothenburg, like many other cities, also struggles with flooding and would therefore benefit from a system that relieves the pressure from heavy rain.

Delimitation

This master thesis has not been focused on re-inventing solutions for rain harvesting. Knowledge has been collected to build the thesis on. The thesis does not revolve around inventing entirely new solutions. It combines already existing solutions and use them in a new perspective.

The thesis was conducted at the department of architecture and is therefore developed with this in mind. The thesis is not a technical one but rather an investigation of how rainwater harvesting could be better integrated within architecture.

Result

The thesis consists of two parts:

First a strategy on a larger scale was developed in order to allow the creation of a holistic concept of future rain harvesting. The rain water is purified, collected and distributed within this strategy.

The second part and the main focus is a design that is focusing on a smaller cycle within this strategy.

The result is a public water center that educates the visitor in rain harvesting and sustainability. At the same time it underlines the importance of being resourceful with water and respecting it.

Background

Terms

Black water - Water contaminated by feces. (From flushing toilet) This water must go directly to water treatment.

Grey water - Water not contaminated by feces. Primarily the term is used to describe water that comes from showers, washing machines and so on. In this thesis the term will, addition to this, be used as a term for water that is clean enough to use for these activities but not clean enough for drinking, simply filtered trough for example a green roof.

White water - Clean water (from springs, wells, purified) May be used for cooking and drinking.¹

Storm water - Rainwater, melted water that is not soaked up by the earth. (EPA .2017). May be used for watering garden and such.

The system in place.

Water treatment plants

Approximately 8,4 million of Sweden's inhabitants get their water from water treatment plants². ("Livsmedelverket", 2017) This means that the water has gone through several steps of cleansing before

it is clean enough for us to drink. Among these steps are filtering away particles and remove dangerous bacteria ("Svenskt vatten", 2017).

60 % of all water produced³ goes to Sweden's households. Around 20% is used within the industry, by hospitals and so on and 20% is reused by the water treatment plant ("Svenskt vatten", 2017).

There are two main methods to obtain the water that the water treatment plant's needs. Around half of the water comes from so called groundwater which is found deep under the surface. This water is generally very clean as it has gone through earths natural cleansing system of for example gravel and sand. Therefore, fewer steps are needed in the treatment of this water before it goes to our taps. The rest of the water however is so called surface water and is obtained from lakes and rivers. This water needs more steps before it is clean enough for us to drink. The last step, which is usually always needed for surface water, is a chemical cleanse where chlorine is added ("Svenskt vatten", 2017).

The Chlorine is added in such small doses that it is unlikely to hurt us however this chemical is dangerous for the environment and can have effect on those who are extra sensitive. ("Sjukdom.online". n.d)

Only 6% of the water we get from our tap is actually used for drinking and cooking. The rest is used for personal hygiene, cleaning, watering our gardens etc ("Svenskt vatten", 2017).

Waste water treatment plants

After we have used the water it is sent to a waste water treatment plant. Here the water goes through several important steps before it can be "released" back in nature. This treatment is very effective and uses most of the waste products, that the water brings from the civilization, for energy. (A large part of this waste is unnecessary items that we flush down our toilets or sinks.) One of the most important treatment is the removal of phosphor and nitrogen to prevent over-fertilization in lakes and oceans. ("Gryab". 2017)

Reservoirs

The water treatment plants are designed to keep an even distribution of water. This means that it produces the same amount of water around the clock but the need for water in a city changes during the day. For example: during the morning a lot more water is used when many people go up to take a shower before beginning their day. To compensate for this a city needs water reserves. These are often places high in either a water-tower or on a hill to be able to distribute water using gravity. These reserve also function as a backup if the power goes out and water can't be pumped. (Nationalencyklopedin,, 2017)

Gothenburg has 13 water-reservoirs spread out over the city. (En Värld utan soror, 2017).

¹ These definitions are based on Josh Robinsons (2015) article What is greywater? In Ecology Artisans.

² The remaining 1,2 million get their water from private wells

³ Produced = water that has gone through a water treatment plant



System in place

Reality

1. (Grey) Water is taken from the natural system.

2. (White) The water is purified using filtering and chemicals and then distributed to the city and to water towers and used.

3. (Black) The water is sent to a waste water treatment plant. (However it is important to notice that this does not mean that all water is black water. The main part is actually grey but all water is treated as black)

4. (White) The water is purified before let out in the natural water system again.

(5.) The rainwater is for the most part an isolated cycle. However the water still has to be handled by the sewage system and this might cause an overload of the system which can lead to some contaminated water leaking out in nature. ("Svenskt vatten", 2017).



Warner brothers placed their logo high on the tower. Today the tower is almost a part of the logo. Picture: Crawfish Head. (n.d) Retrieved 31 mars 2017 from Flickr, https://www.flickr.com/photos/crawfish_head/2766353089



Bräckes water reserve. Picture: En Värld utan sopor, 2017



The mushroom tower in Helsinki. Picture: Water tower Helsinki Finland. (n.d) Retrieved 31 mars from Wikimedia, https://commons.wikimedia.org/wiki/File:Roihuvuori_water_tower_-_Helsinki_Finland.jpg



Grabergets water reservoir Picture: En Värld utan sopor, 2017

Water towers



Gudhedstornet by Nils Einar Ericsson. Picture: En Värld utan sopor, 2017



The blue spider by Nils Einar Ericsson. Picture: En Värld utan sopor, 2017

Water towers has trough history not only served as water reserves they have also been important landmarks. Much care and effort has gone into designing them and many of them has become symbols for cities or, in some cases even for companies. The towers were often an occasion for a society to mark them self on the map. At the same time the towers symbolizes the true importance of water. (Dori M. Penny, 2011)

However when the population of cities grew so did the need for water. The infrastructure of the water and the technology behind the transportation of the water became in many cases the main focus when building new reservoirs and the architecture and design was forgotten. (Andersson, A, 1971)

In Gothenburg we can however find several beautiful and important towers. The water tower of Guldheden and the blue spider in Biskopsgården are both beautiful contributions to their surroundings and both designed by the very important architect Nils Einar Ericsson. (Hisingenftw, 2014) During the last century these structures has little by little been replaced by simpler reservoirs. Such as. Bräckes water reservoir built 1947 or gråbergets water reservoir built in 1940 (En Värld utan sopor, 2017)

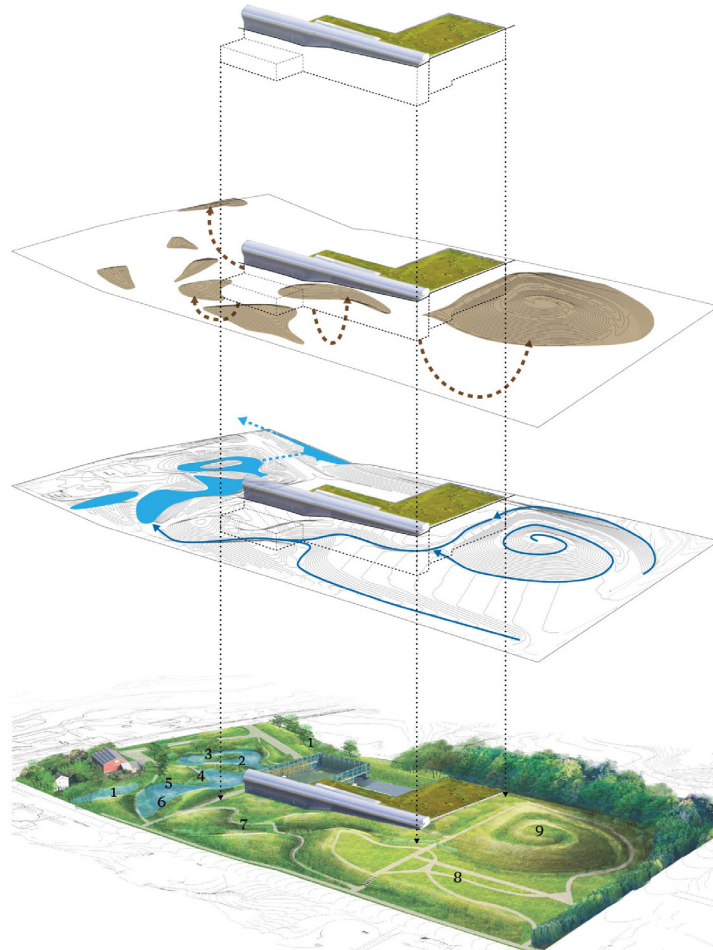
Collaborative landscape strategy places 70% of building below grade

40,000 cubic yards of displaced soil from building excavation creates new topography

Topography harnesses natural hydrological processes to improve water quality

A diverse landscape becomes a neighborhood amenity

- 1 Pre-existing Wetlands
- 2 Lake
- 3 Island
- 4 Peninsula
- 5 Beach
- 6 Gorge
- 7 Valley & Stream
- 8 Agricultural Garden
- 9 Mountain & Intermittent Stream



Picture: General design, 2010

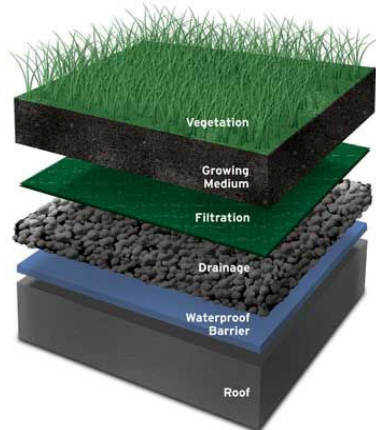
Green architecture

Nature is very good at cleaning water. By passing through layers of dirt, soil, sand and so on the water is freed from small particles and even from bacteria. This method is used more and more in green roofs however the water that goes through the roof is not taken care of. (Rainharvesting, n.d)

A great example of where this method has been taken advantage of is the Whitney water purification facility. In this project the water is taken care of and used. The project is a reserve of water for the South Central Connecticut Regional. It draws water from nearby Lake Whitney. By using elements in the landscape and architectural tools the design filters water and at the same time it creates a topographical variety. (General design, 2010)



Picture: Bara vanligt vatten. (n.d) Retrieved 31 mars from Svenskprepper. <http://svenskprepper.se/2015/03/29/bara-vanligt-vatten/>



Picture: Applications Green roofs. (n.d) Retrieved 31 mars from Safeguardeurope. http://www.safeguardeurope.com/applications/green_roofs_flat

Conclusions

Looking upon the system that we have put in place there are some points that are troubling

- A large amount of water is cleaned only to be flushed down to the waste plant again. (94% of the water we use is unnecessary clean for the task. Since all water is cleaned for drinking)
- The long and complex process and transportation of water from plant to tap.
- The need for chemical purification.
- The cities inability to cop with heavy rain
- The decline of the groundwater

There is a more logical way of providing and cleaning the water without having to transport it.

If a system, that takes care of and clean the rainwater directly, could be implemented into the architecture, within the city, we could achieve a simple cycle of the water and get rid of much of the complex, and environmentally dangerous water infrastructure.

In order to create a new better and sustainable cycle several factors other than the technical ones needs to be included,

Natural filtering:

Nature has a very clever way of filtering water. In this thesis these methods will be mimicked.

Information:

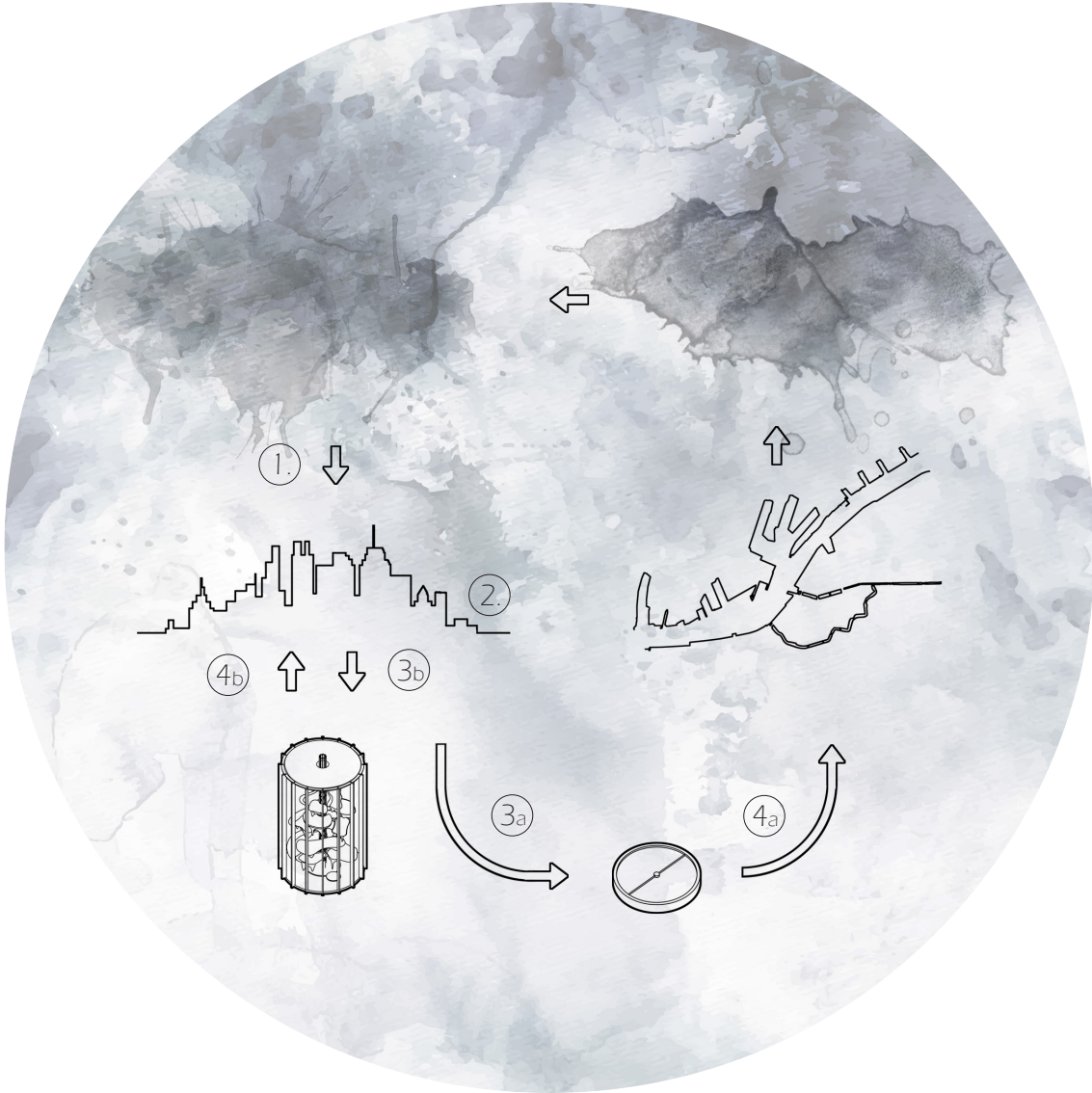
It is important to create awareness. All factors indicate that water, in many different ways, will be a future problem. We will face shortage but also flooding and contamination. Making people aware of this problem is one part but a more important part is to let people know that there are many good alternatives that could help us face these problems. This thesis will therefore also display and teach people of the cleaning process.

Respect:

Over time the respect for the water has been forgotten and we also seem to have forgotten the true importance water.

The expression of the high-rise water towers will be an inspiration for the final design in the thesis. An iconic, monumental expression will be created. The result will therefore be a tower that inflict an iconic expression that will awake curiosity for the topic and also bring back the respect for the water.

Strategy



Vision

Proposal - Strategy

With all the information gathered in mind, a new strategy for the infrastructure of water has been created.

1. (Storm) Rain falls on city roofs

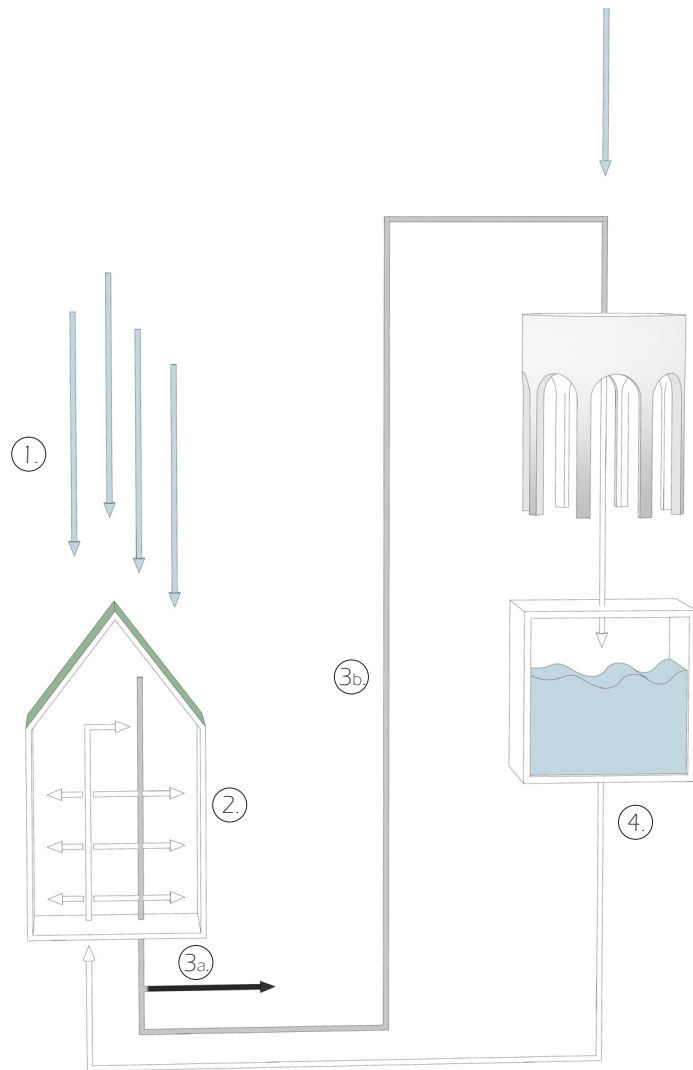
2. (Grey) The water is partly purified by green roofs and used for purposes that don't require white water such as showering or flushing the toilet..

3a. (Black) Water that is used for flushing the toilet become contaminated by feces and must be sent directly to a waste water treatment plant.

4a (White)purified water is released into nature again.

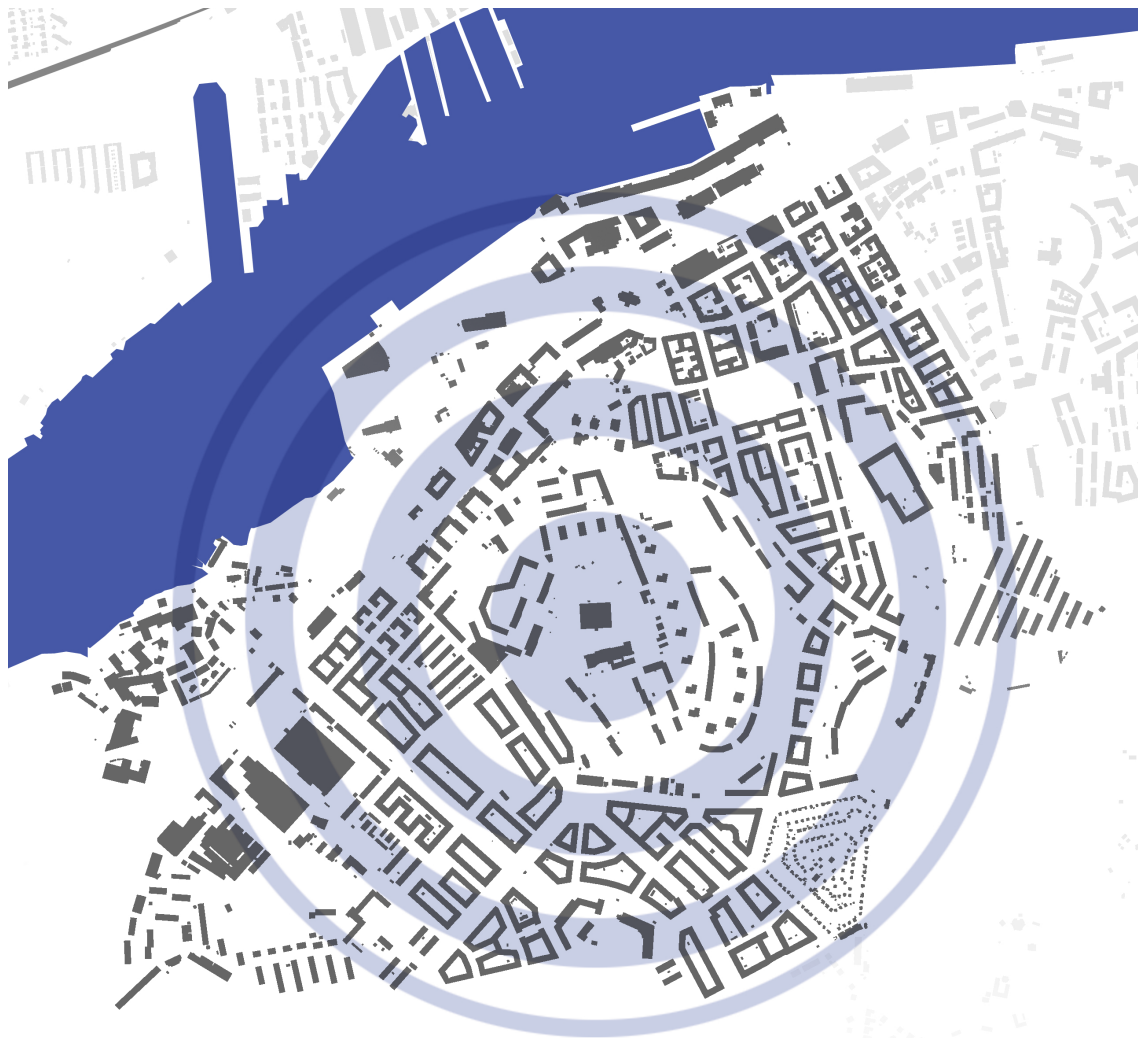
3b. (Grey) Water that is used for washing, showering and so on is transported to the new water tower.

4b. (White) The tower purifies the water and it is send back to the city where is primarily used for drinking and cocking, which requires white water, and secondary for other water needs.



Small cycle

- 1. (Storm)** Water rains down on green roofs.
- 2. (Grey)** The water from the roof is used for washing, showering and so on.
- 3a. (Black)** Water that has been contaminated is transported to a waste treatment plant.
- 3b. (Grey)** The superfluous water is lead to the water tower.
- 4. (White)** Within the tower the water is purified, stored and sent back to the households.



Location

Gråberget - Kulturtemplet

Gråberget water reservoir was designed by Adrian C. Peterson and finished 1901. In 1940 it was replaced by a new modern reservoir that is still in use. However the old reservoir was not demolished but simply bolted and forgotten. Until Jorge Alcaide, a music teacher, went by and decided to unravel the mystery. After a lot of phone calls, emails and nagging the municipality finally opened up the reservoir, put in a door and gave Jorge a key. What he found was an architectural, acoustic treasure and today he is running "kulturtemplet" - the temple of culture. (Kulturtemplar.org)

The location of the reservoir is no coincidence. It is situated high on a hill overlooking the port of Gothenburg and the cityscape of western Gothenburg.

Gråberget has a lot of opportunities. The new reservoir provides the water-network needed. The old reservoir is an exiting space where the water's potential can be displayed in a different environment than we are used to. The surrounding with its hills and cliffs may also be used for many different harvesting systems and an open display of the systems and experiments.

Majorna

The district is situated in the west of Gothenburg and has around 10 000 inhabitants. (Göteborg, n.d)

Calculations

The strategy depends on the collection of water from the surroundings. The roofs of the houses within a 1 km radius has an area of 500 000m². During a year, these roofs will collect around 500 000 000 liters of water. One person uses approximately 65 000 liters of water a year. By collecting this water the system could then provide 7 500 people with water. The system must therefore purify and store over 1 350 000 liters of water every day.



The old reservoir looking out over the city
Photo: Ellen Linder



The old reservoir lies almost as a hidden gem on the top of the hill.
Photo: Ellen Linder



Below ground is the old storage hall that is now empty.
Picture: Kulturtemplet.org



The new reservoir is still in use and is situated right next to the old one.
Picture: Ellen Linder

Process

Process

Two stages of design

- Preparation stage
- Design stage

Preparation stage

In the first weeks of the thesis three subjects were researched. Simultaneously designs were brainstormed in quick workshops and design experiments were conducted. After the first quick research the scope was narrowed and focused on the most interesting subjects/aspects. The rest of the time up until the midterm was spent researching and developing experiments for these subjects/aspects. All work was carefully documented in a portfolio.

Topics:

- Patina
 - How does the water affect the building over time? How does the water move? Can it be an asset?
- Green architecture - roof- wall - algae
 - What types are there? Possibilities? How may it be used Limitations?
- Storage
 - How much storage is needed? How can it be something more than a simple tank in the backyard?

Research

Parallel with the design, basic research was done about the basic facts of rain and the water infrastructural system put in place.

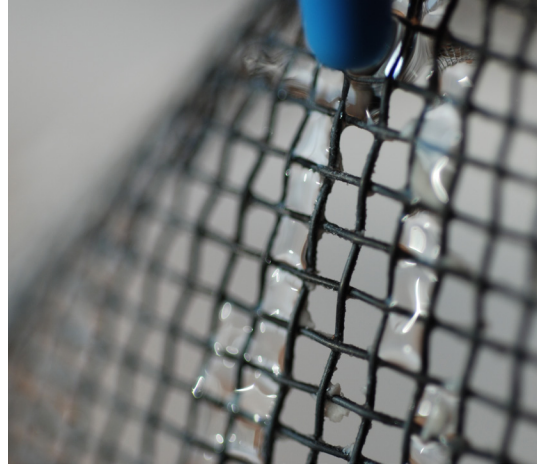
- Water infrastructure
- Water shortage
- Water purification
- Iconography

Design stage

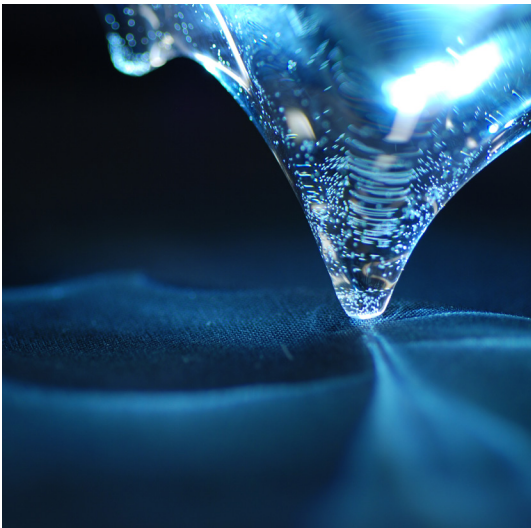
The research and workshops in the preparation stage will provide a broad platform of ideas and knowledge. After the midterm the scope was narrowed drastically when a fixed program was created. In this stage the portfolio was an important base for the thesis. The most important aspects and qualities were taken from the portfolio and from the research.



Capillary action



Patina -The mark of the water

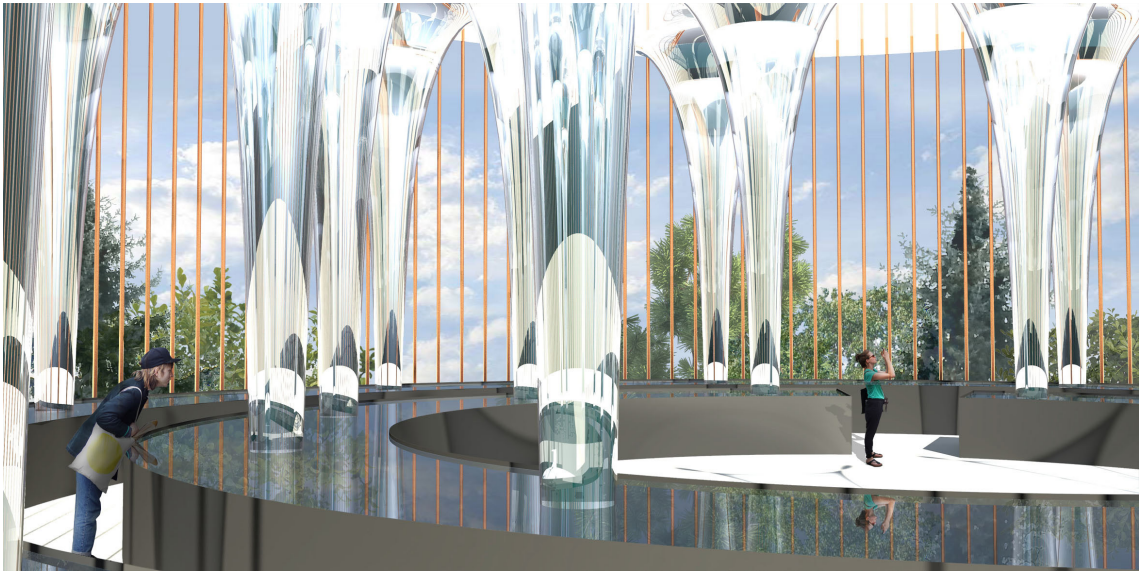


Caustic effect

Experiments:

In the research many interesting factors were found. These were selected and brought into the design.

- Capillary action
- Caustic effects
- Traveling water



Design proposal

On the hill of Gråberget a new water center will be developed and this will be the main focus of the thesis.

The result is a contemporary water tower that collects and purifies rain water. This tower will be open to the public and visitors can participate and learn from the solutions that have been implemented.

In this design the knowledge gained from the research of rain harvesting will be implement. The methods that has been studied will be used i new ways that incorporates design. The rain harvesting system should be a part of creating the design instead of being an addition to the design.

The project will as well inspire and teach visitors to use rainwater themselves. The visitor will be able to follow the waters way trough the tower and see the filtering stages. In this center the visitor can interact with the water in for example a water-playground, "water-allotments" or a meditative relaxing garden.

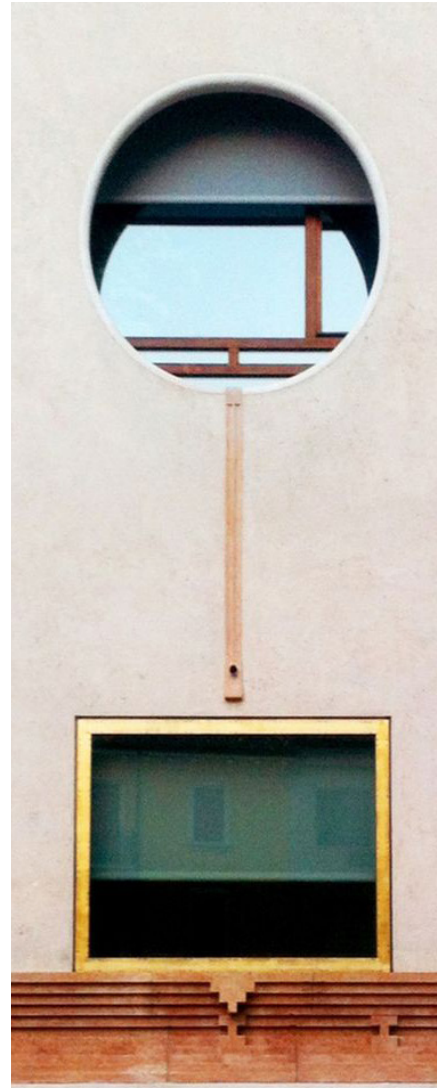
Experiments

Traveling water



Santa Maria dei Miracoli.

Picture: Monumentos. (n.d) Retrieved 31 mars from Arthehistoria. <http://www.artehistoria.com/v2/monumentos/1312.htm>



Banca Popolare di Verona

Picture: Italian architect carlo scarpa. (n.d) Retrieved 31 Mars from Brooketestoni, <http://www.brooketestoni.com/2015/10/italian-architect-carlo-scarpa/>

Scar or patina?

Carlo Scarpa saw the effect rainwater had to a window in Santa Maria dei Miracoli. He took this as a source of inspiration when he later designed Banca Popolare di Verona. The line demonstrates the possible effect that rainwater may have on the facade. The weathering is accepted and the development of the design will continue even after it is finished.

Plaster

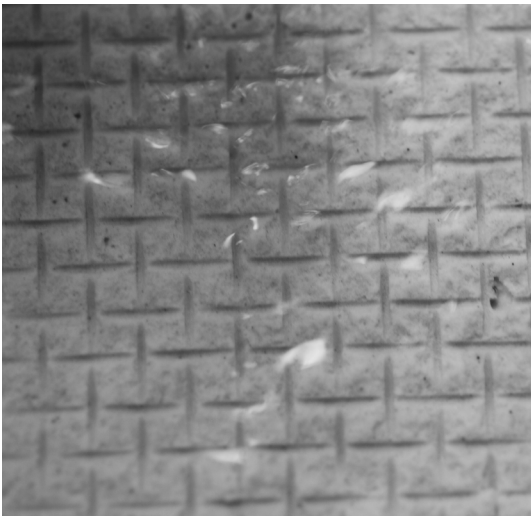
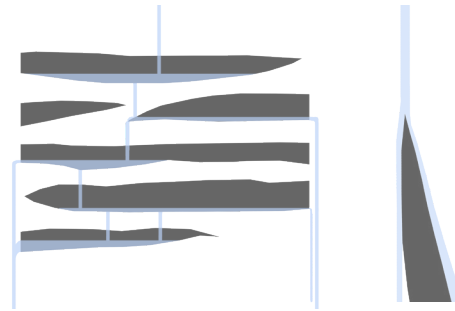
For the first experiment I used plaster and molds. I used plaster partly because it is fast and I could begin immediately. It also imitates surfaces very well and makes it easy to create different textures. Another benefit is that it also imitates concrete pretty well and allows me to investigate concrete as a building material at the same time.

I molded the plaster in five different molds and then introduce water to see how the water moves over different surfaces and textures.



Cracks

The surface tension either lead the water past the crackles or trapped the water within it.



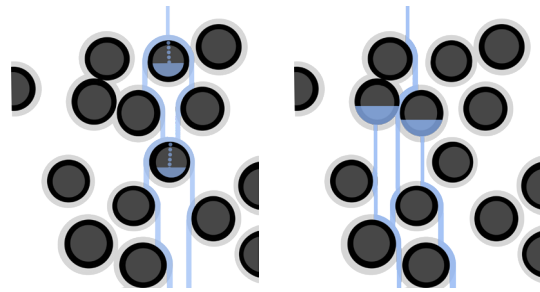
Steel net

The pattern created various play in the water surface.



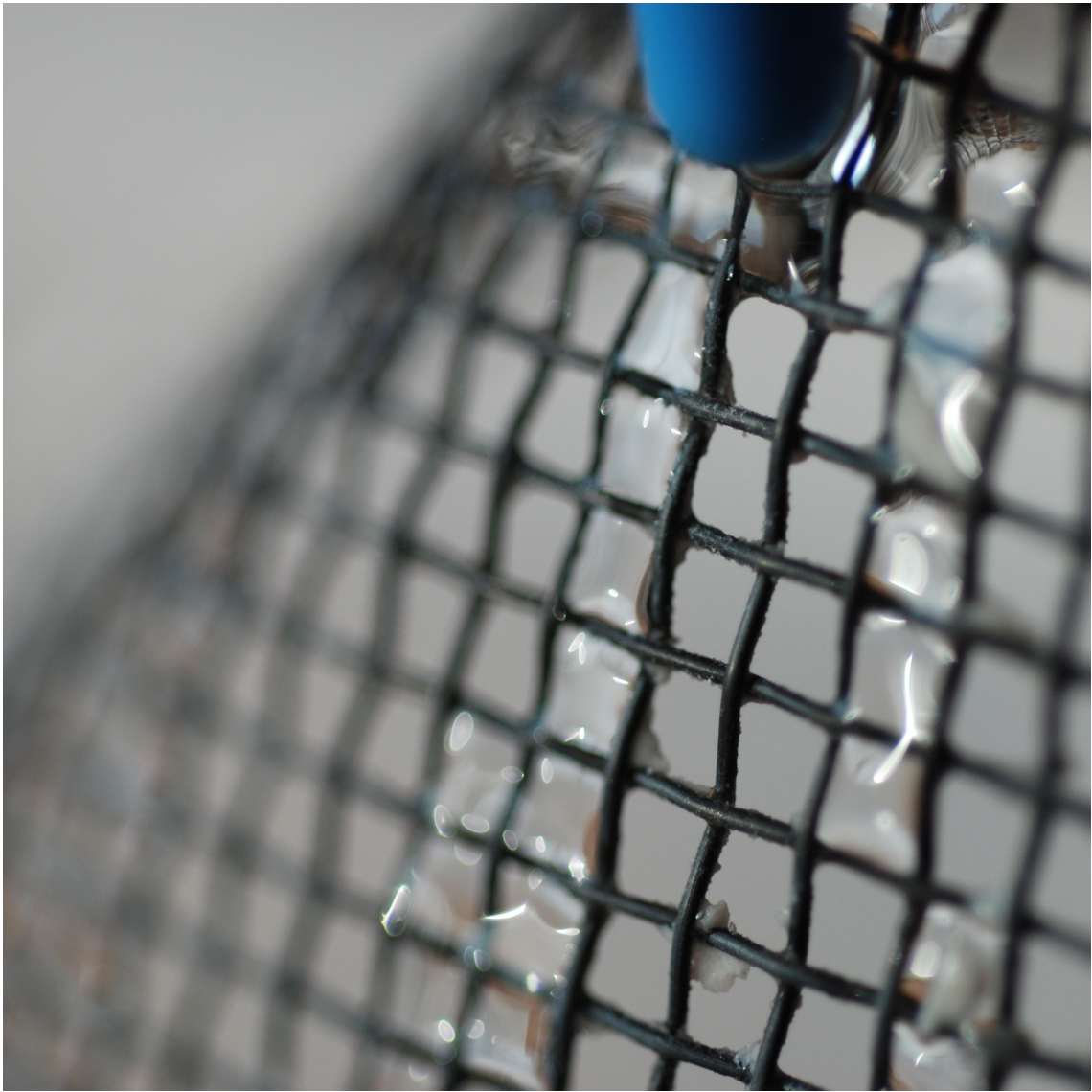
Bubbles

The surface tension created a path for the water, making it almost bounce from bubble to bubble.



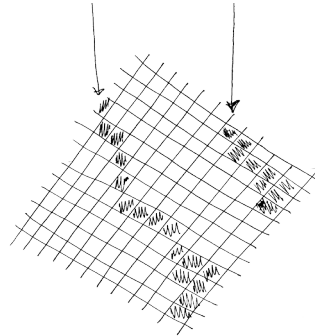
Fabric

The plaster mimic the fabric and created small curves for the water to follow.



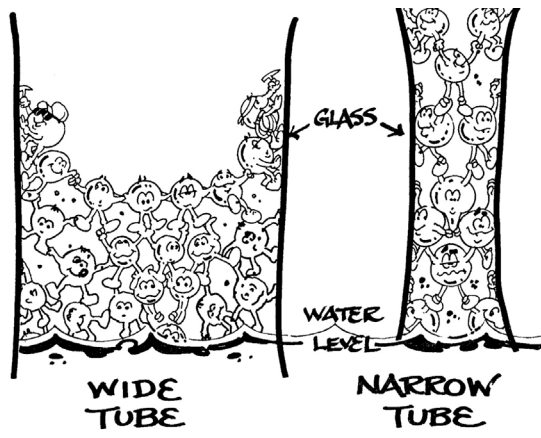
Steel net II

The water chooses different ways down depending on where you pour it.



This was the most important discovery and inspiration. The water will always find the easiest way and follow it. It may even create its own way over time. The design should be adapted and created to follow the natural way of the water and not force the water where it does not want to go.

Capillary action



Picture: (Rieson, 2012)

Capillarity action

Capillarity action is the ability of a liquid to flow upward in narrow spaces without the assistance of, or even in opposition to, external forces. (Rieson, 2012)

Capillary action is present everywhere in nature and in architecture. Vegetation is made up from small tubes that allow the water to travel upwards. (Rieson, 2012) However in architecture it is seen as something dangerous and many methods has been developed to stop the action. I will have investigated how the action can be used in a beneficial way,

The capillary action might be beneficial in many ways: Transportation of water. Self watering systems, filtering of water.



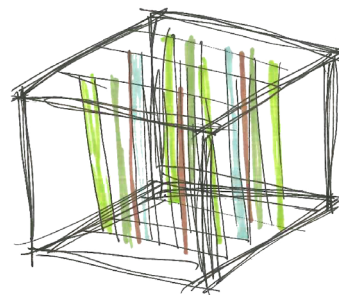
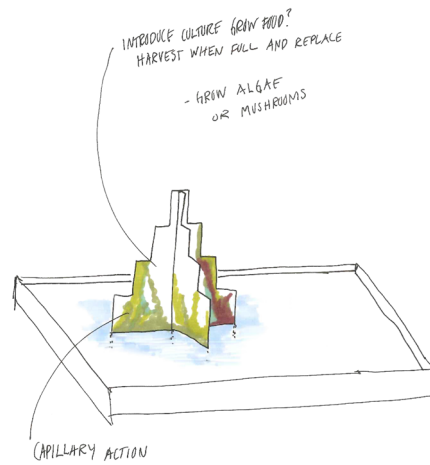
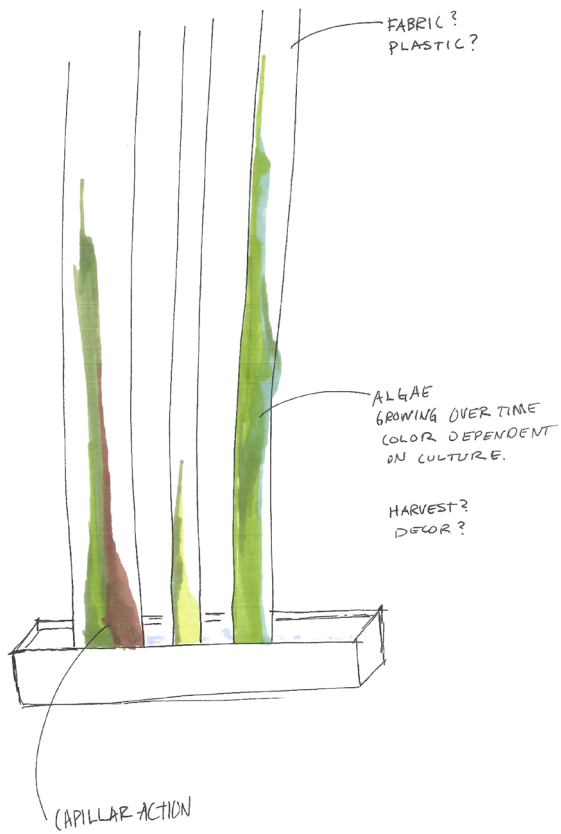
Laban house. Picture: Laban Dance Theater, (n.d) Retrieved 31 mars from Architektura, <http://www.architektura.pb.edu.pl/arch-wsp/index>.

Laban House

When looking at the building one might think that the facade has been infested with some sort of algae but the facade is actually colored. However this expression lead me to investigate capillary Action as a possible way to make green architecture.

The capillary action will soak the material. What could this be used for? In this scenario I imagine a sort of farming. The capillary action would automatically supply the "crop" with water.

The crop could be a number of things such as algae or mushrooms. Maybe the effect could be used for coloring of fabric or maybe it could just be a beautiful installation to display rain in a new way.



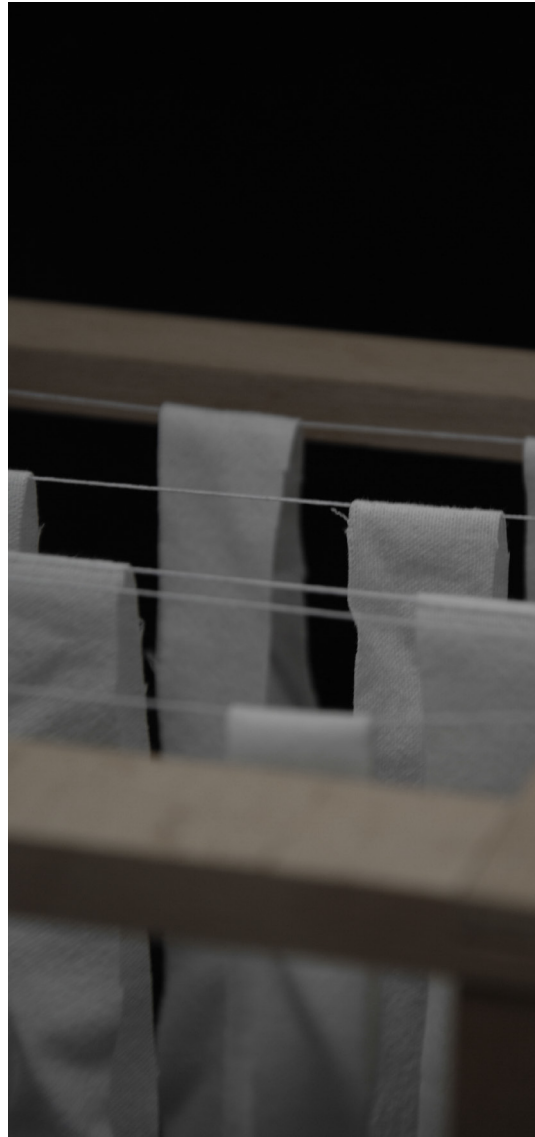
Modeling

I started to investigate which material would be beneficial. Most material are capable of capillary action but for building a model i decided on fabric. The benefits of this is that it works quickly and it is also similar to many material that can be used on a larger scale. (Material that is woven toughener)

To make the water and effect visible I used watercolor. The color could also represent something growing.

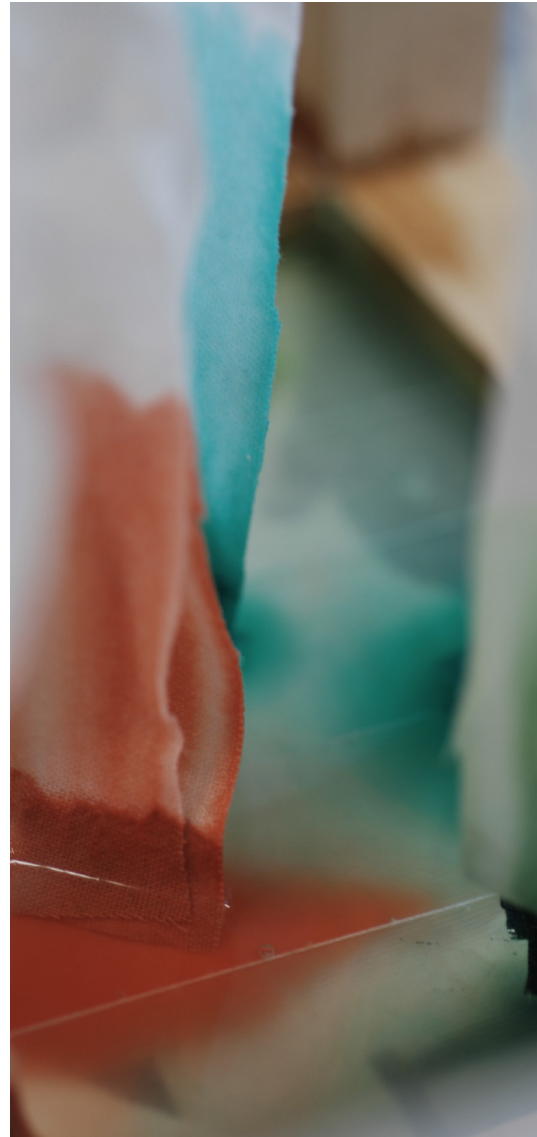
Idea for modeling: A module that supports the capillary material. When the "crop" is ready the frame will be removed and "harvested" and the put back for a new harvest to grow on.

The capillary system could also be a device put directly into the water and the be harvest like a pine tree.



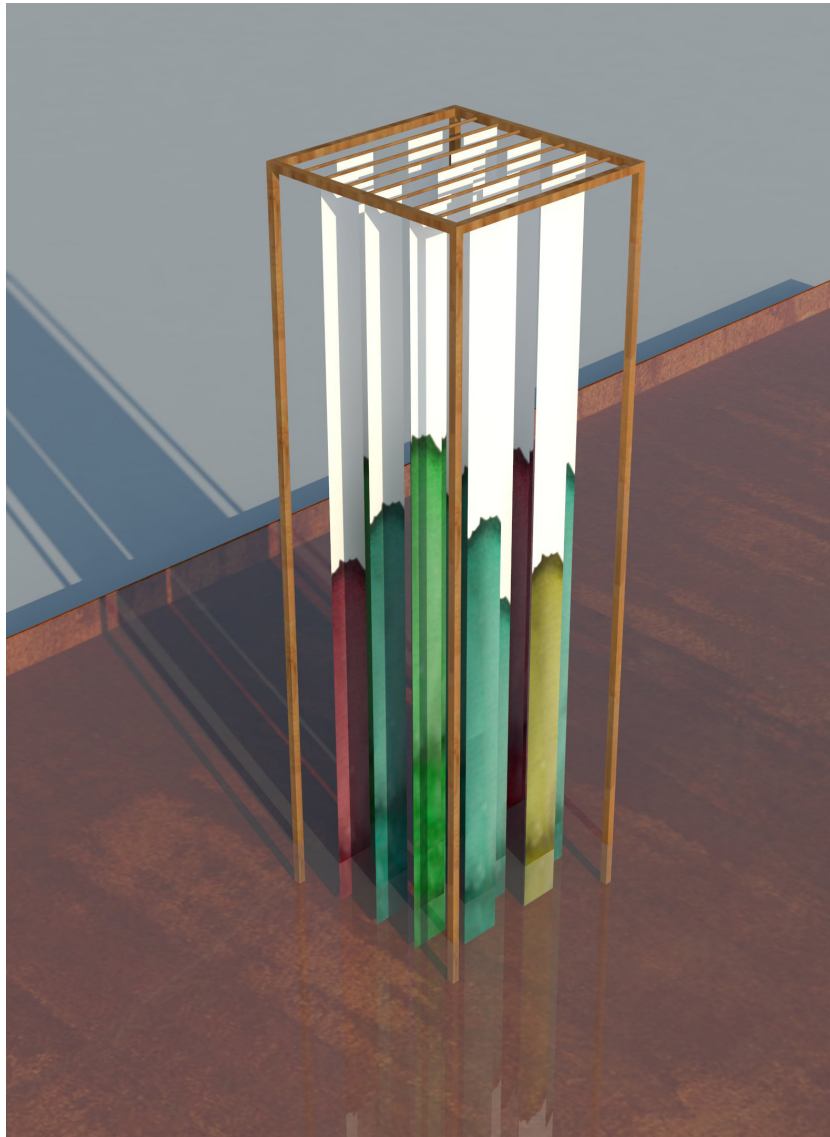


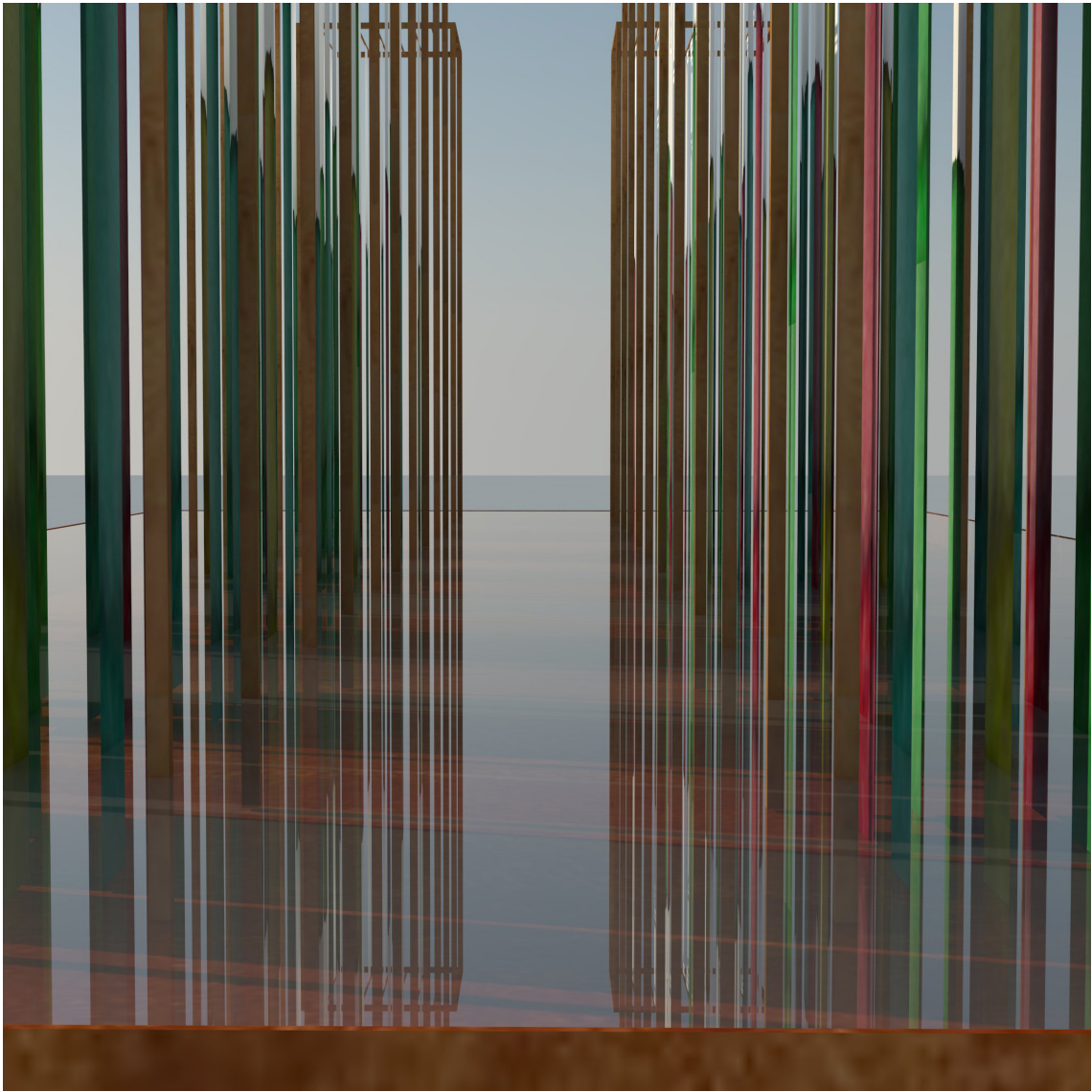
A frame was built and white fabric was hung over it.



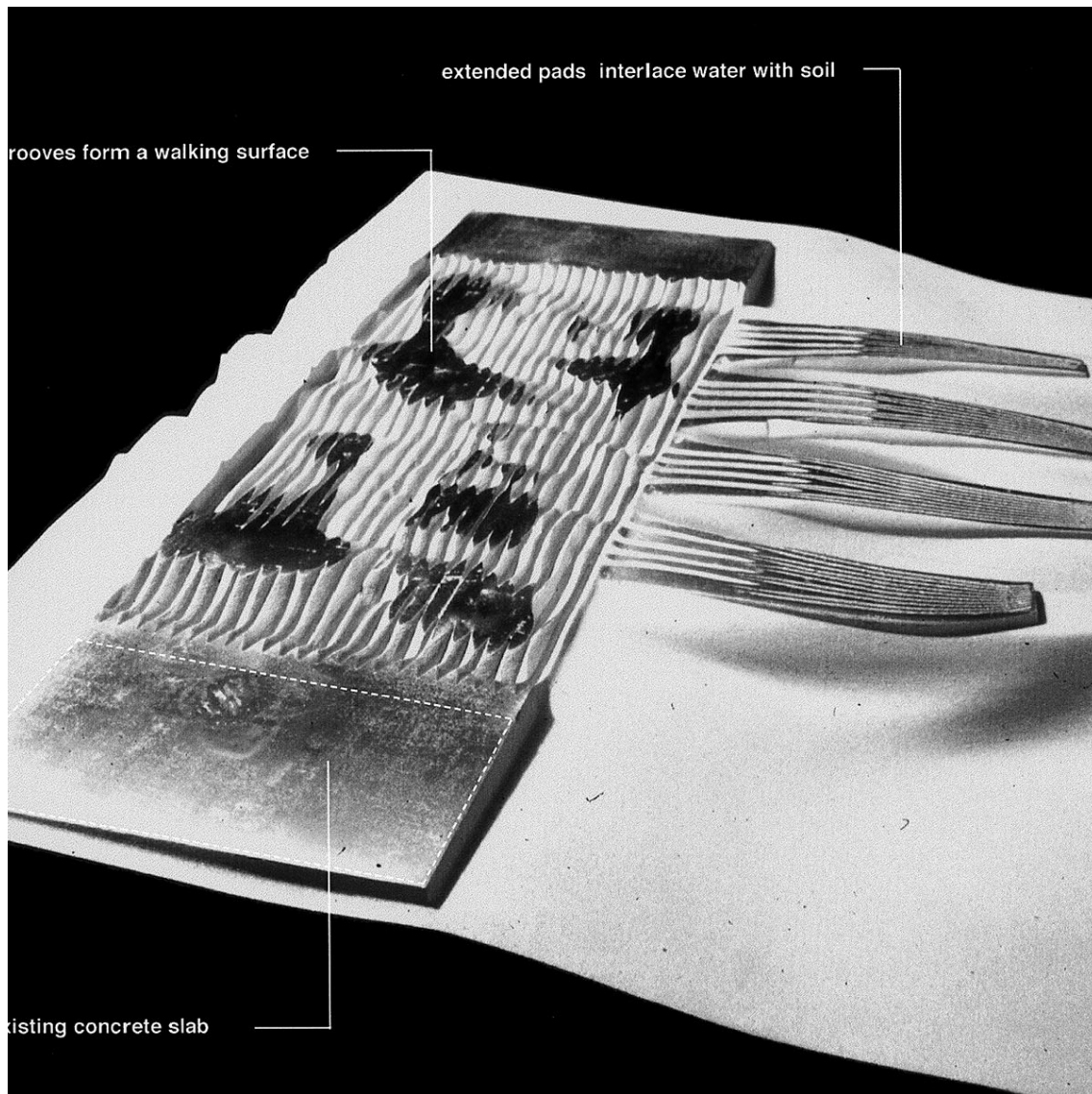


The stripes of fabric is dipped in water color.
The small spaces within the fabric allows the water to travel upwards, brining the color with it as it goes.





Caustics



Picture: Watergarden, (n.d) retrieved 31 mars from Reiser-umemoto, <http://www.reiser-umemoto.com/projects/landscape/watergarden.html>

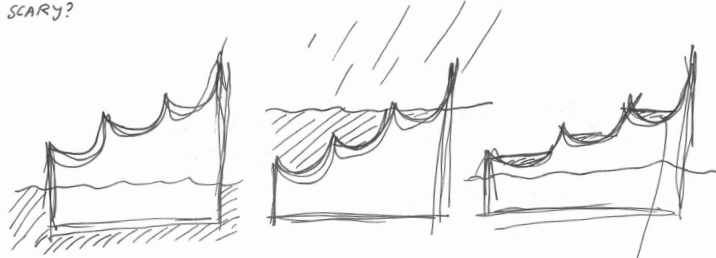
Storage

“First, architecture as a stable and unchanging framework within which, and against which, the temporal unfolds; and second, how the mutable nature of nature can be made to approach or deviate from a certain ideal”

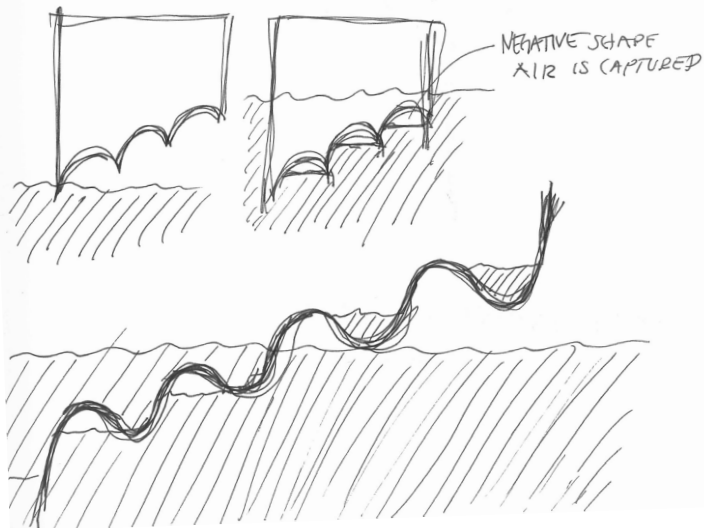
- Jesse Reiser + Nanako Umemoto in collaboration
with Jeff Kipnis and David Ruy

FLOOD

SUDDEN CHANGE OF LANDSCAPE. HOW MAY IT BE USED?
SCARY?



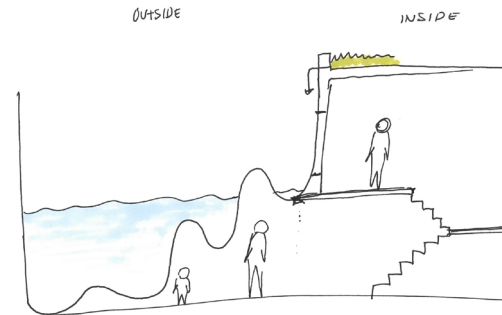
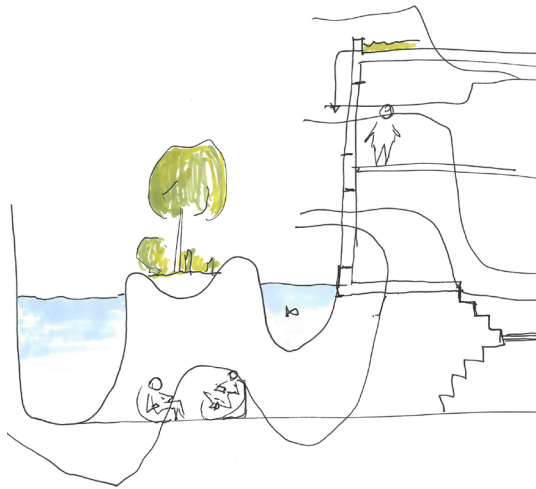
- May be used as a measuring
 - May be used for security. plan for flood.
- POSITIVE
SHAPE
WATER
IS CAPTURED



NEGATIVE SHAPE
AIR IS CAPTURED

Water as an active element in architecture

The next experiment looked upon new ways of storing the water. Does it just have to be a tank? Could there be more than one perspective? Could this change as the water level change?

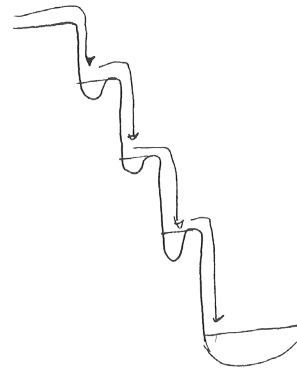


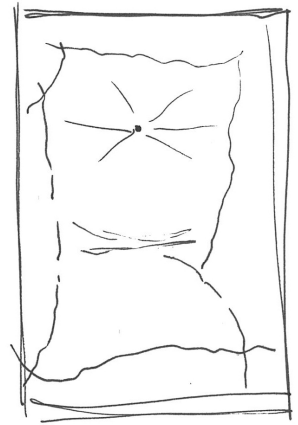
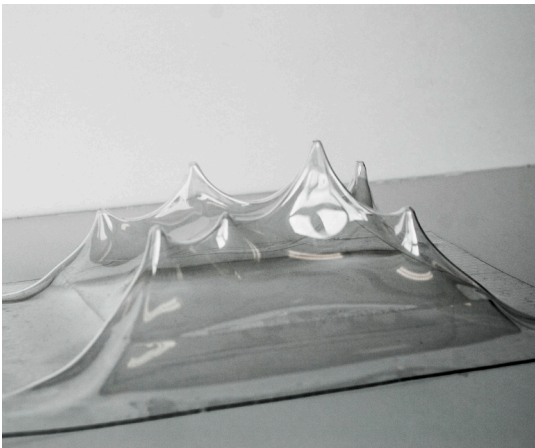
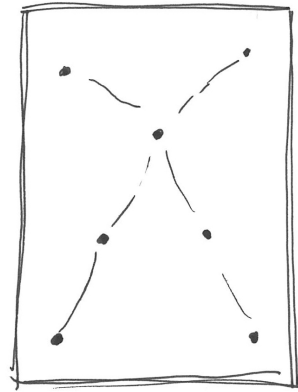
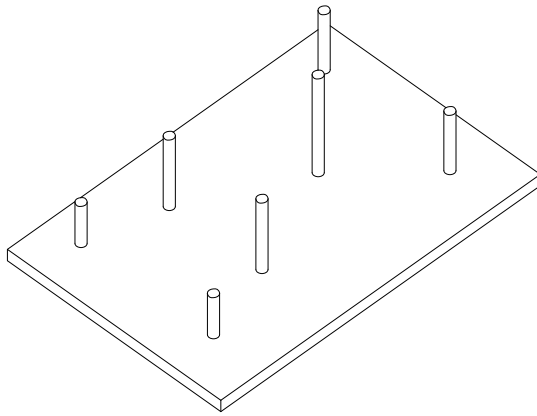


Picture: Pamukkale naturschoenheit tuerkei, (n.d) Retrieved 31 Mars from Urlaubsguru <https://www.urlaubsguru.de/reisemagazin/pamukkale-naturschoenheit-tuerkei/>

Pamukkalle Turkey

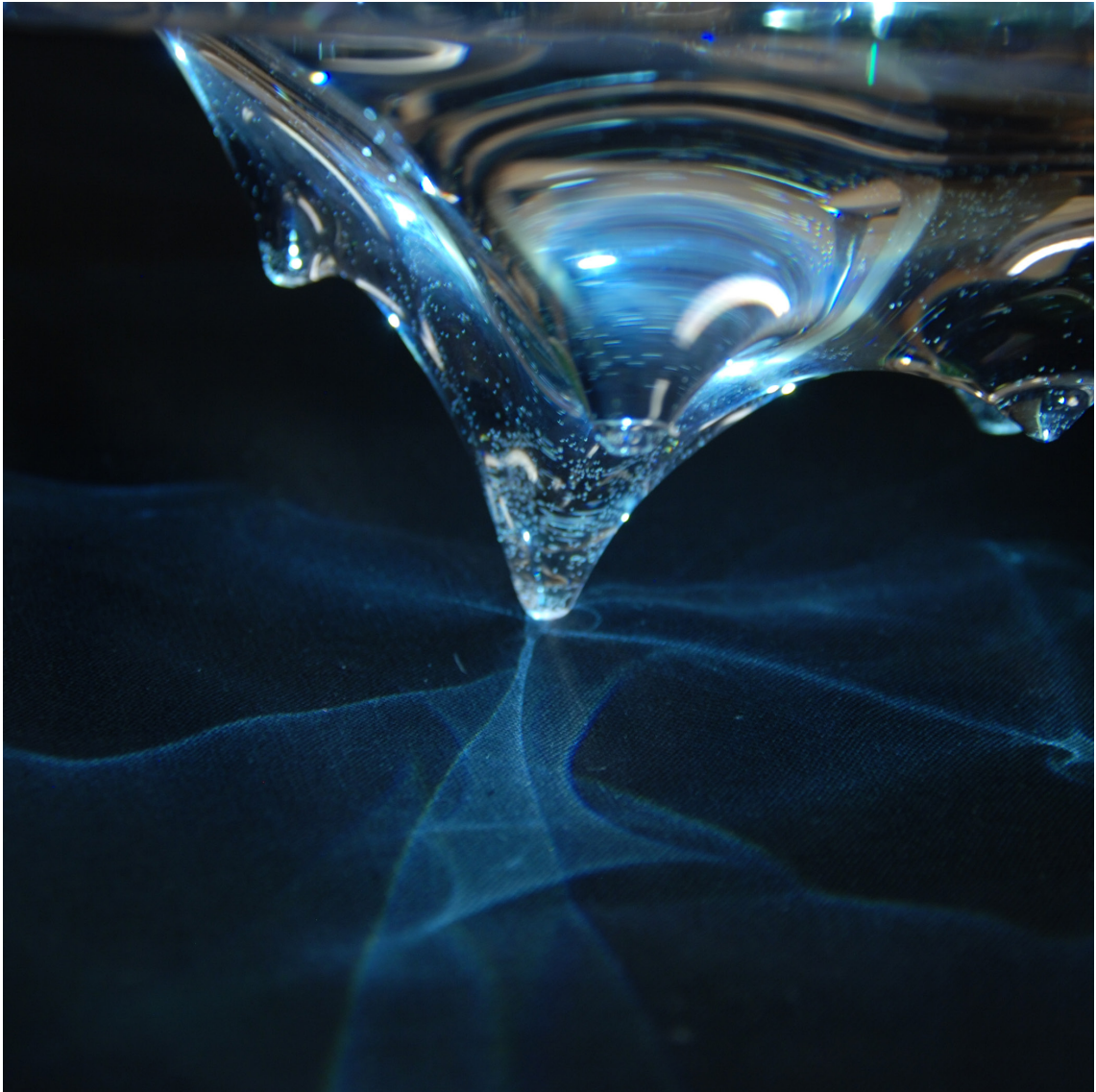
The natural pools in Pamukkalle is a great inspiration. The water is transferred from one level to another and creates a fantastic landscape. Could these levels be given cleansing features and then be implemented in a design.





Model

By using the vacuum machine i created a surface that is see trough. By placing different shapes in the machine i could get different surfaces to investigate. The one that worked best with my vision was however the one where i simply used sticks as a mold.





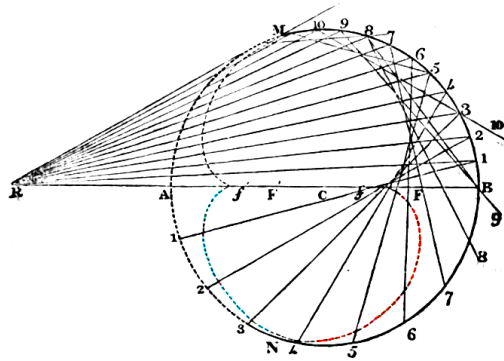


Figure: Wienstein lev Albertovich. (1969)



Picture: Gibby Zobel (2013) Alfredo Moser: Bottle light inventor proud to be poor, Retrieved 31 mars from BBC <http://www.bbc.com/news/magazine-23536914>

Light

The beautiful light that emerge from the model is an effect called caustic light. This is a phenomena that occurs when light bounces inside a shape and becomes concentrated. (Wienstein lev Albertovich, 1969)

There could be many types of usage for this phenomena

Light:

The concentration of light can create a light source using only natural light. An example are exposed areas where there is no electricity such as war-zones or poor parts of the world. (Gibby Zobel, 2013)

Filtering:

Another way to clean and filter water is to let UV-light pass trough it. (espwaterproducts, n.d) This could therefore be more than a light source. It could also be part of the filtering system.

Beauty:

When both light and filtering is combined a beautiful side effect is created that could be taken care of within the design.

3C



SMALL

3D



LARGE

By creating several molds with different appearance a register was created. This registered later worked as a catalogue when designing. Different types of caustics were chosen to create the effect that was intended.

4A

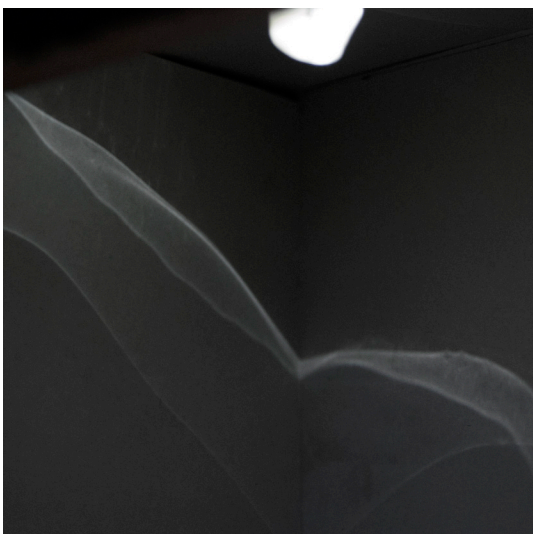


4B



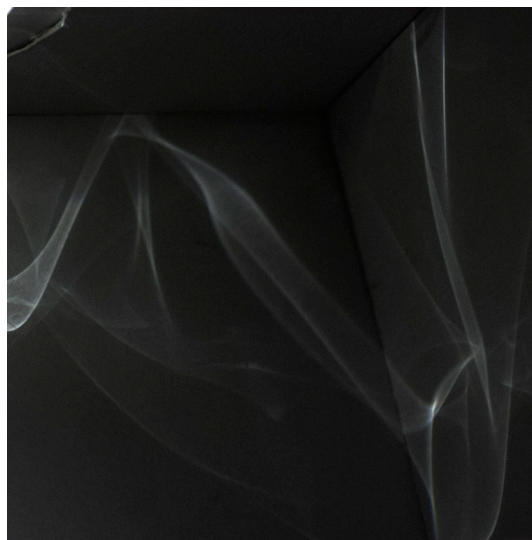
3C

SMALL

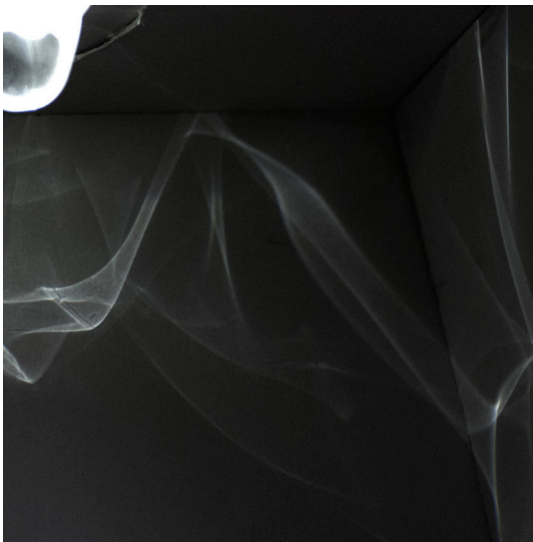


LARGE

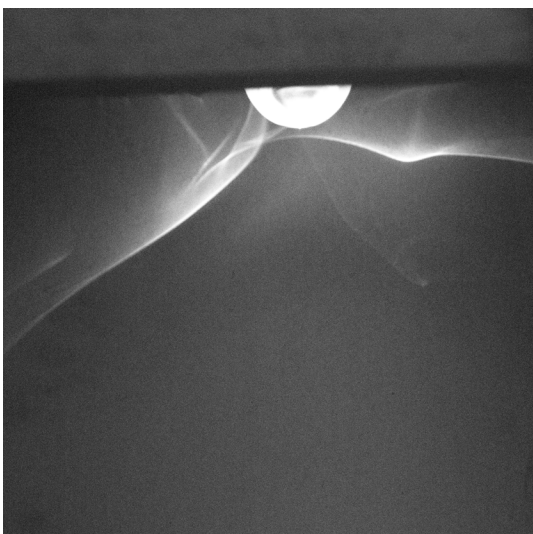
3D



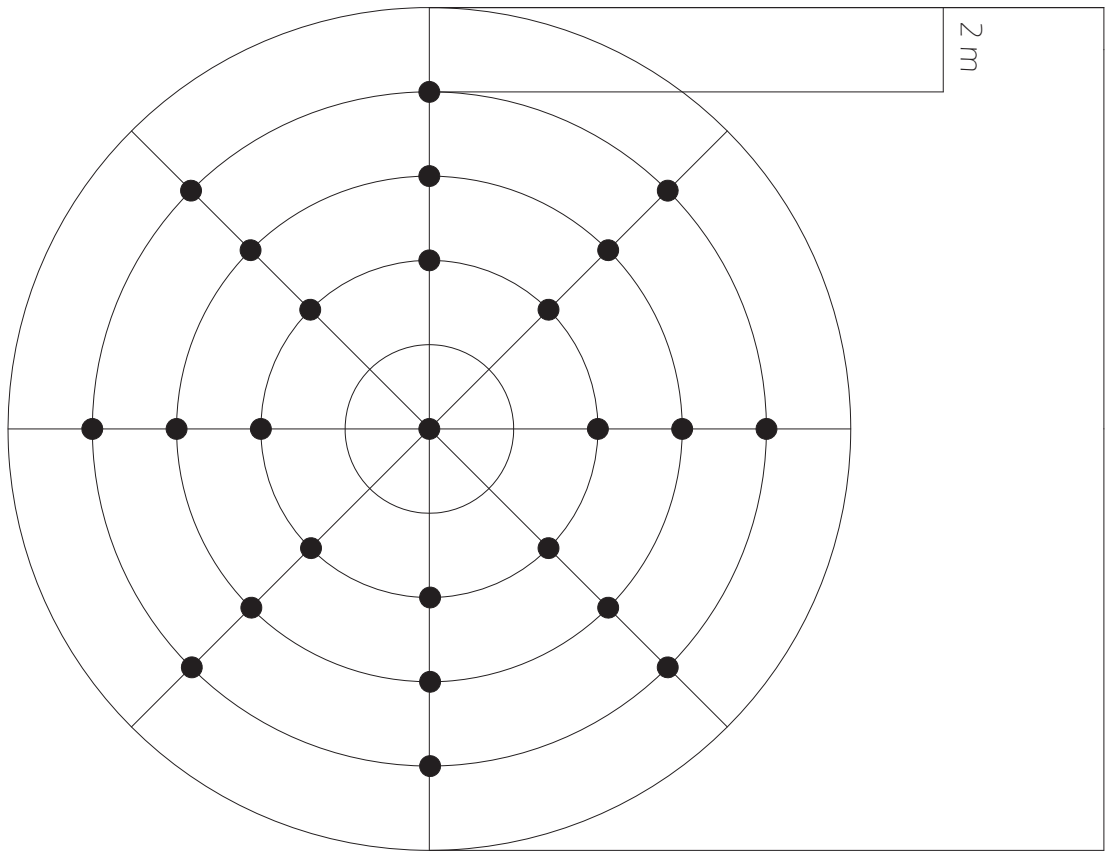
4A

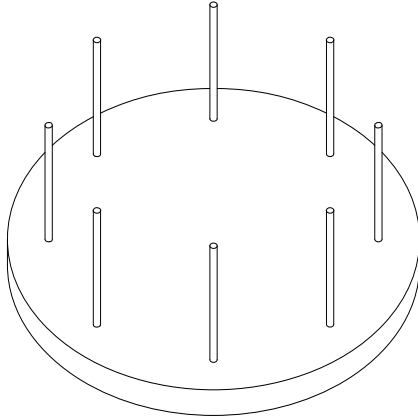


4B



Design





A mold was created that could be used over and over again. The sticks can be removed and placed in different patterns creation different layers.

Design system

The experiments are the building stones for the project. The next phase of the project was to create the design based on them.

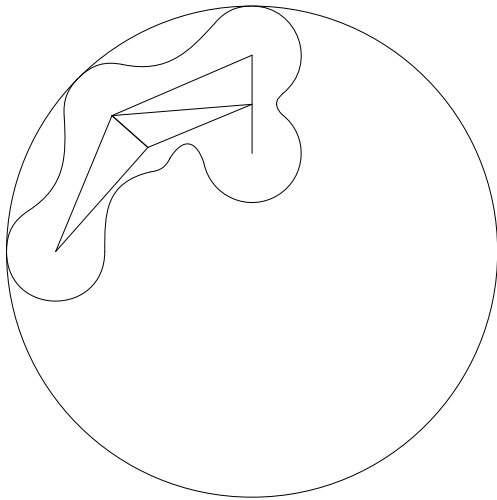
Based on the research and the experiments the design should incorporate several aspects.

The path of the water should be part of the design

The purification should be developed with the natural system in mind.

The design should be open to the public and teach and inspire them.

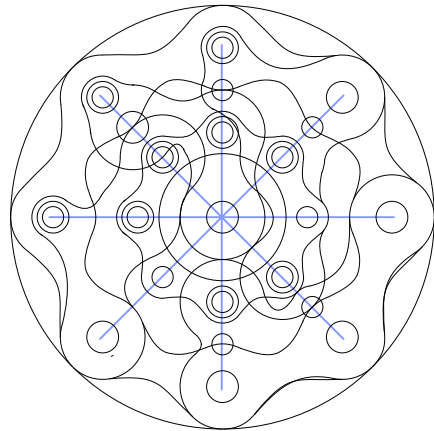
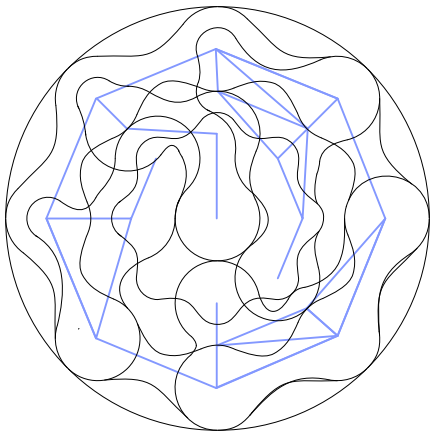
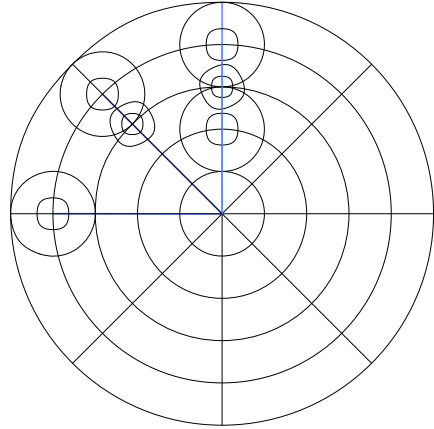
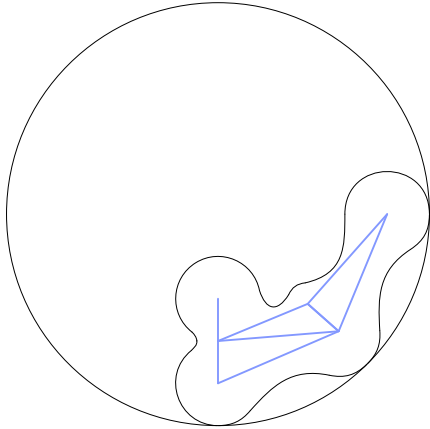
In order to incorporate these aspect a design system was created inspired by the natural paths of the water. The system takes into account how the water wants to move and works in a way so that the water is naturally steered at the desired direction.

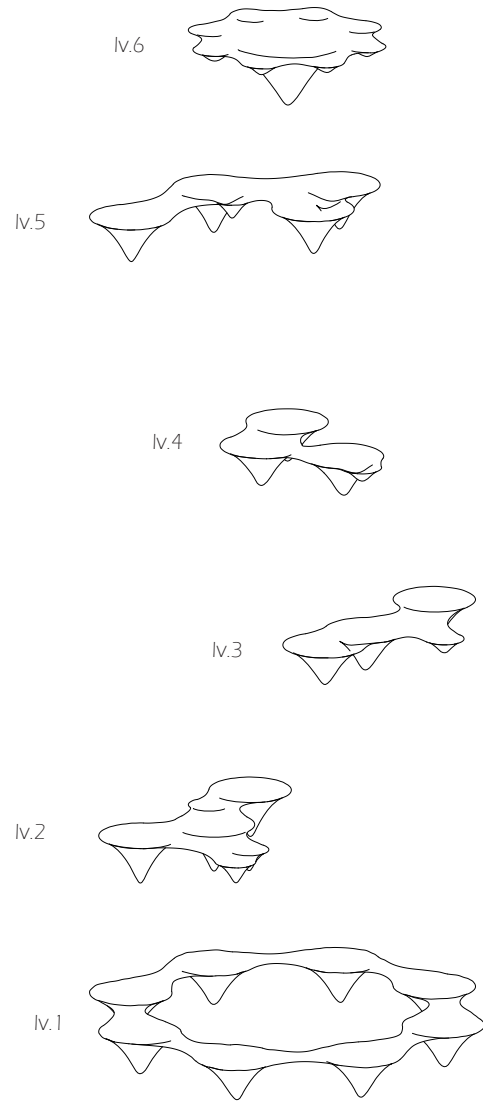
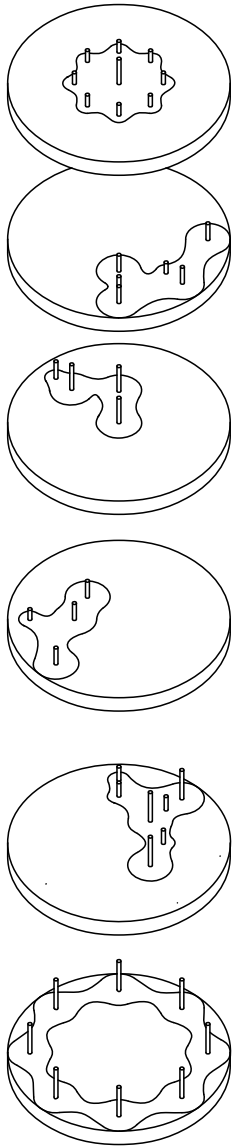


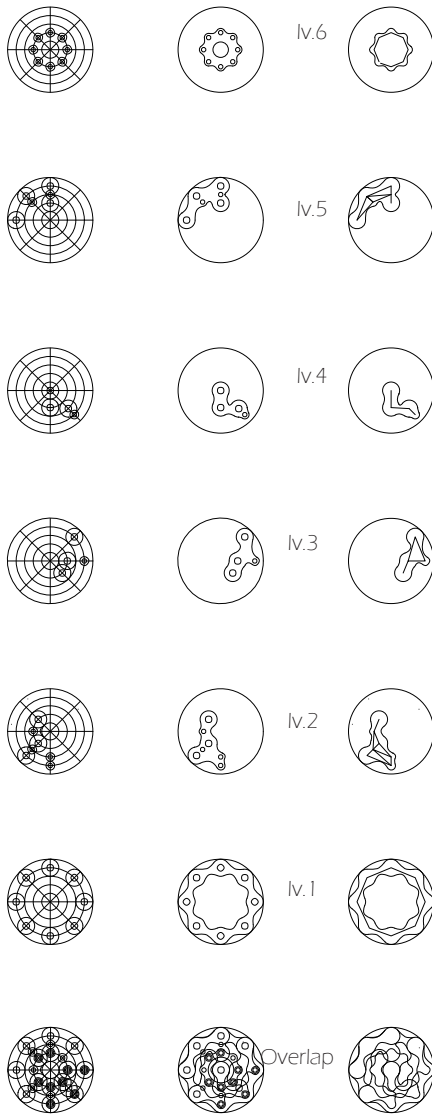
By planning the position of the sticks several levels were created. The layer beneath will collect the water from the one above and so on until the water reaches the bottom. Each level will have a purpose in the line of filtering.

The position of the sticks is one aspect that decides the parameter of the level. Another is the height of the stick that is put into the mold. A higher stick creates a larger circle and therefore a larger level.









These islands and levels will be the core of the design. In order to fully understand and control the method. Several iterations were made before the final design.



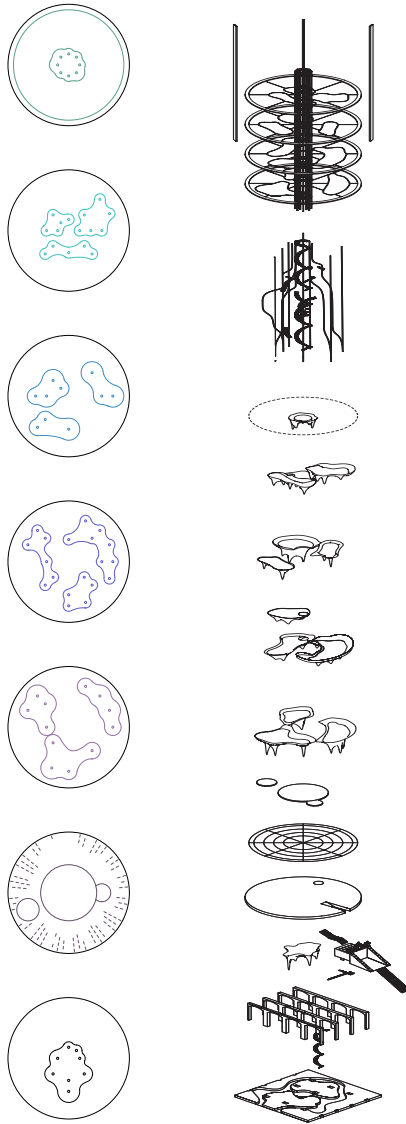
Iterations

By using this method several iterations was made. Each one gave new knowledge.



Final iteration



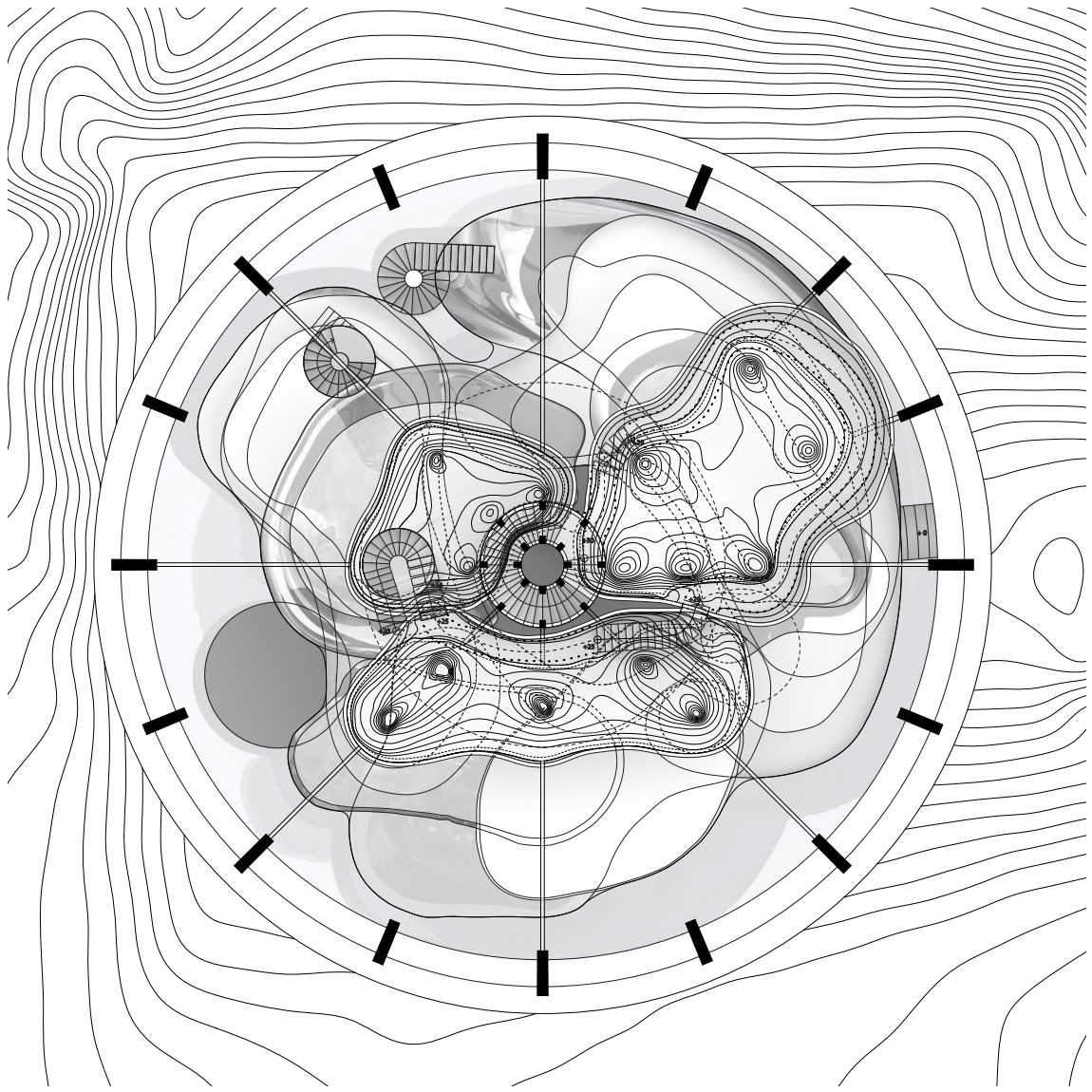


Design

From afar you see the tower as a simple structure in the skyline but when you come closer you will see that the tower is actually made up of several levels. Each level has a specific purpose and is designed according to this. The water travels from level to level similar as the landscape in Pamukkalle. Turkey. The water is brought up by the pipes or by raining directly on top of it. These pipes will also be used to lead the water down again.

Collect and distribute

The first level is where all water is gathered. This level consists of only one broad island that will collect water that rains on top of it and water that is pumped up to it. The water is then distributed and guided down different paths through the tower.

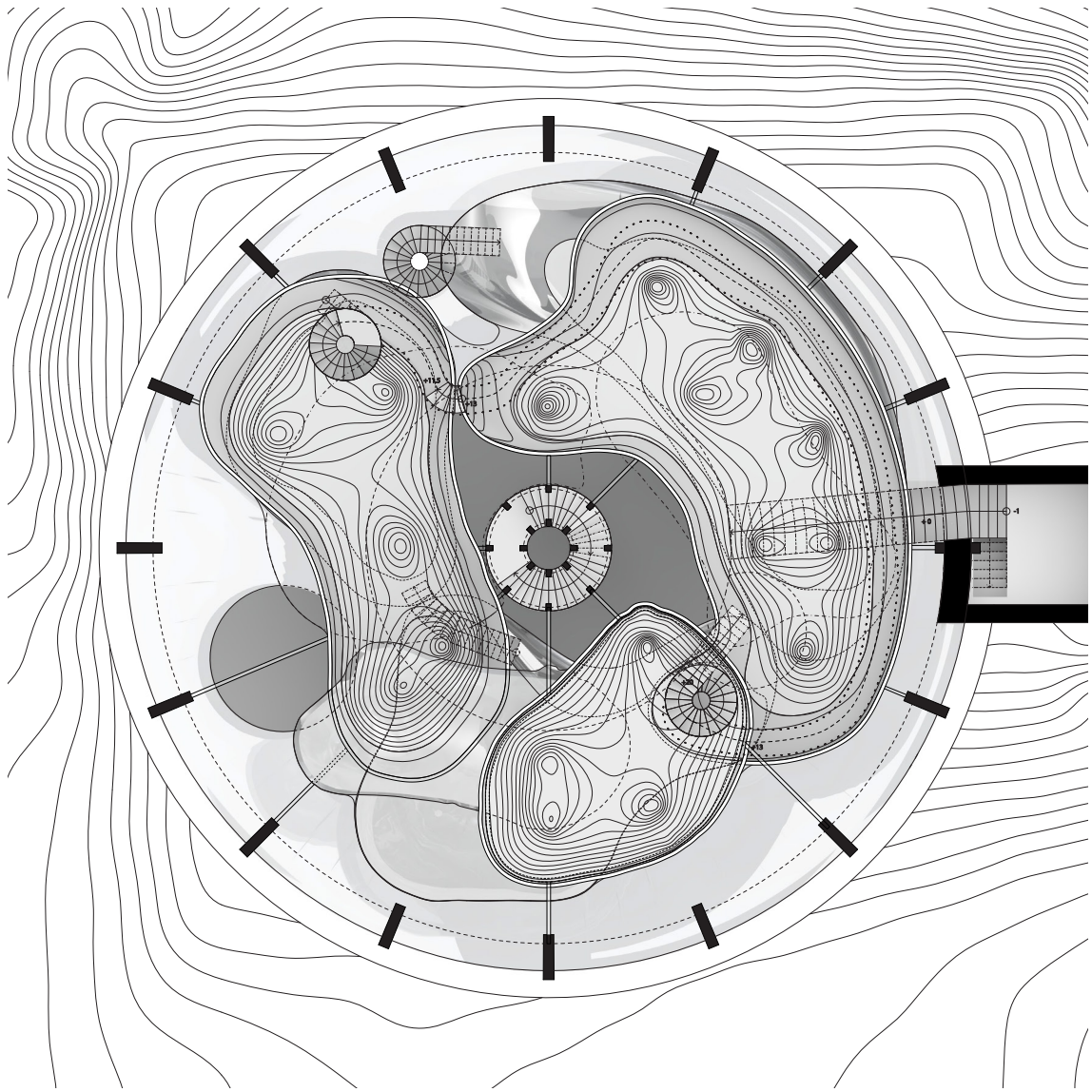


Greenery

This level will do a basic filtering of the water. The method is inspired by green roofs. Large particles are caught in the soil and the water is freed of the worst dirt. It takes a long time for the water to find its way through the soil therefore the level is broad and shallow with many exits to distribute the water faster.

Obstruction

This level was created to make sure that there is always a flow of water in the tower and to keep the flow of water at an even pace. It works as reserve of water within the tower. These islands are much higher to hold more water and have fewer exits to make the water flow evenly.



Sand

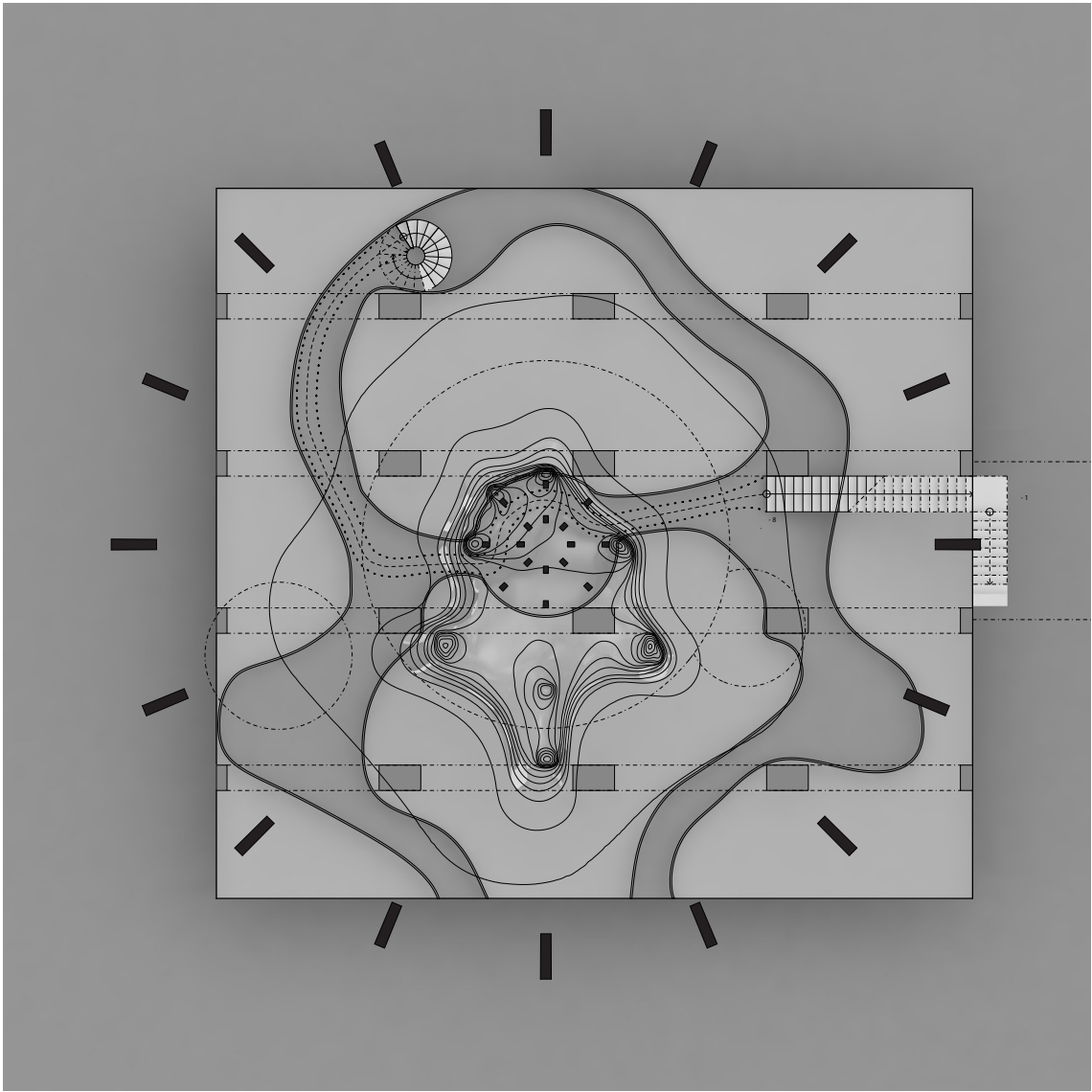
The next level has the task of filtering away the smallest particles. It is therefore filled with layers of sand, gravel and charcoal. This method of purifying is a mimic of nature's own system and is often used in gardens as a way of taking care of rainwater.

Bypass

This level of islands is the last above ground. It guides the water down to the entrance level and opens up a space for the visitor in the middle of the tower. These islands are designed to create the entering space. They rise high and create pillars that visitors can pass under.

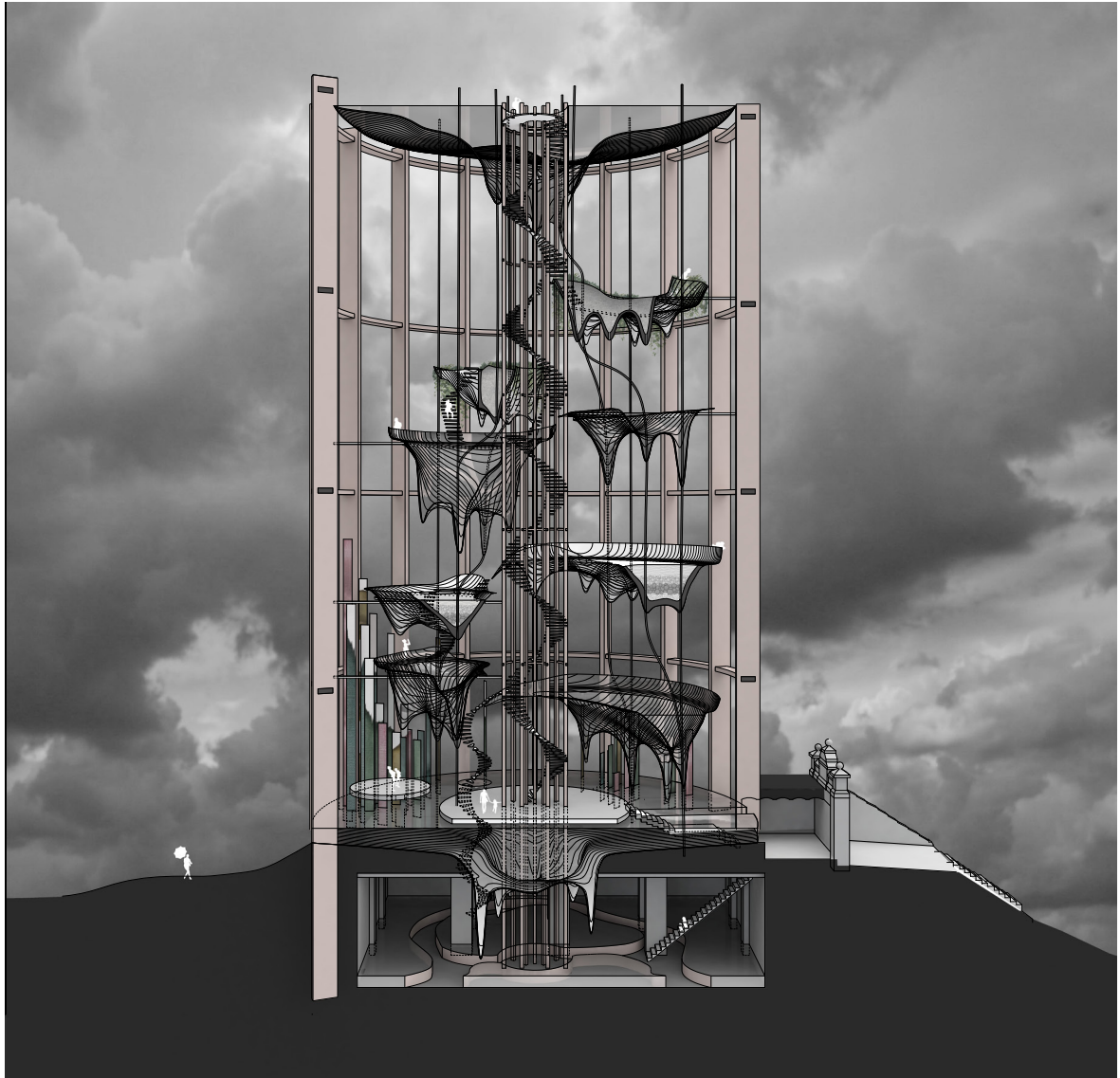
Capillary action

At this level, the visitor enters. Surrounding a platform are pillars of fabric displaying capillary action in an explosion of color. The capillary action is a phenomenon where the surface tension allows the water to travel upwards. This can be used for many things for example it is often used as a self-watering system. In the tower, it is displayed using color.



Caustics

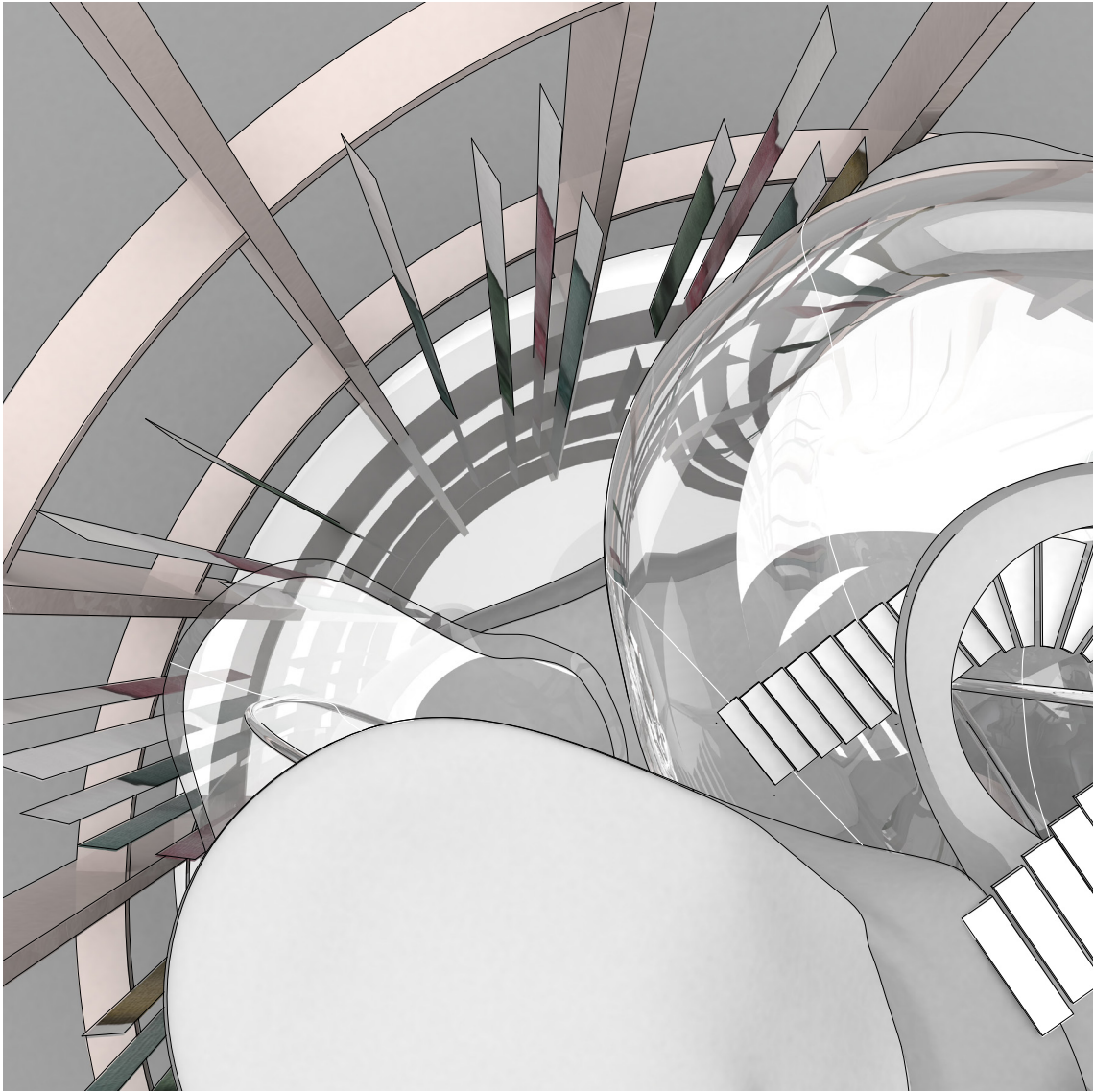
Underground is the last step of the purifying system. By using UV- light bacteria and viruses are killed. This method is being used more frequently in waste water treatment plants as an alternative to chlorine. It is also used in contaminated lakes. The light is an important aspect for the purifying. But is also have a beautiful side effect – Caustics. By bending the surfaces of the level varied waves of caustics falls over the walls of the old reservoir.



Two paths

The water is guided naturally down this path and is cleaned in the process however there is another path to travel by trough this tower. The visitors path.

The visitor follow mainly the same way as the water. But the experience is much different. The aim is for the visitor to be inspired and clearly experience how long and complicated the process of purification is and to understand that the water that we get from our taps have a much higher value.



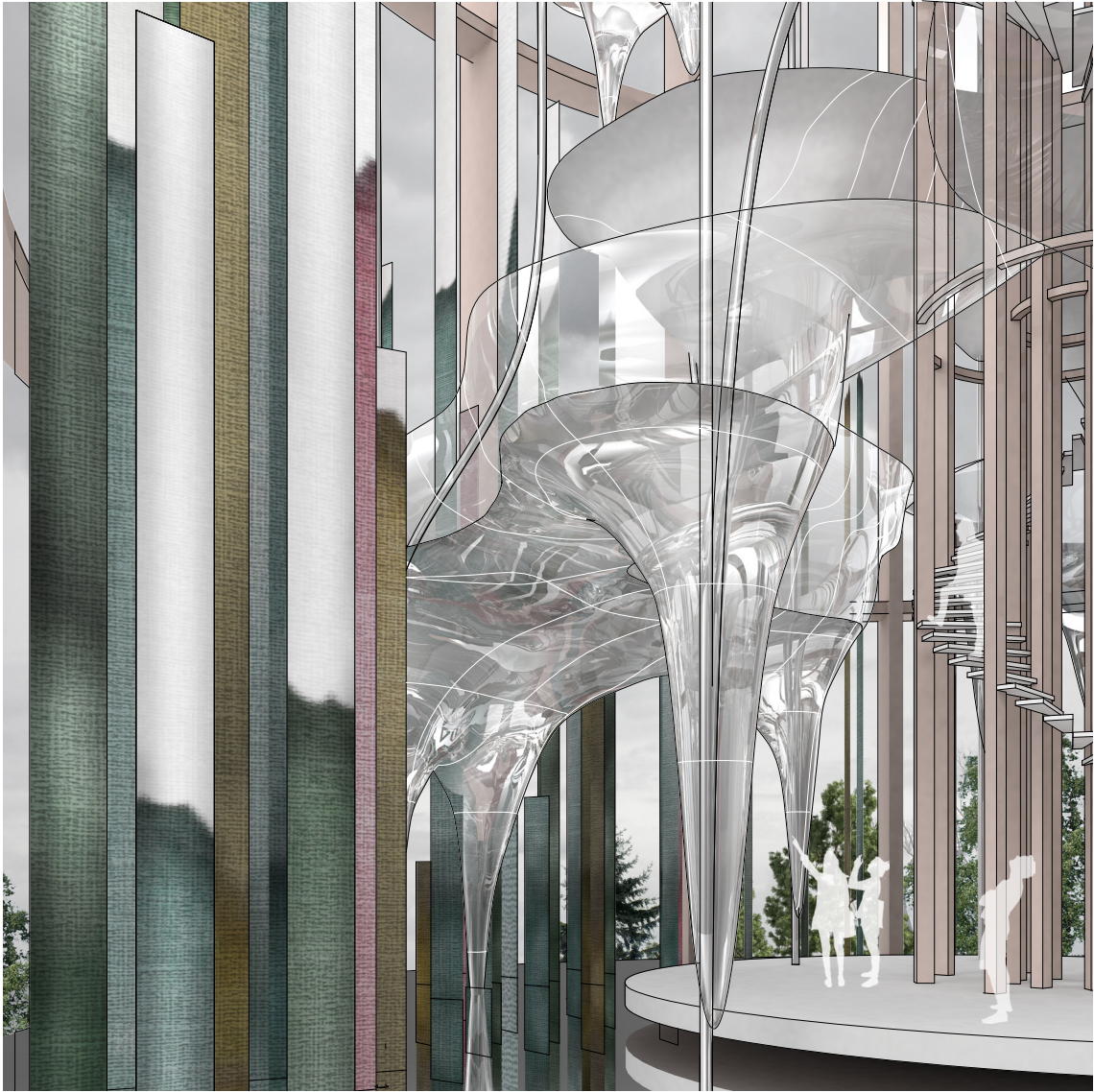
From top...

The visitor enters from the portal off the old reservoir and then travel all the way up to the top.

It is here where all starts in the sky.

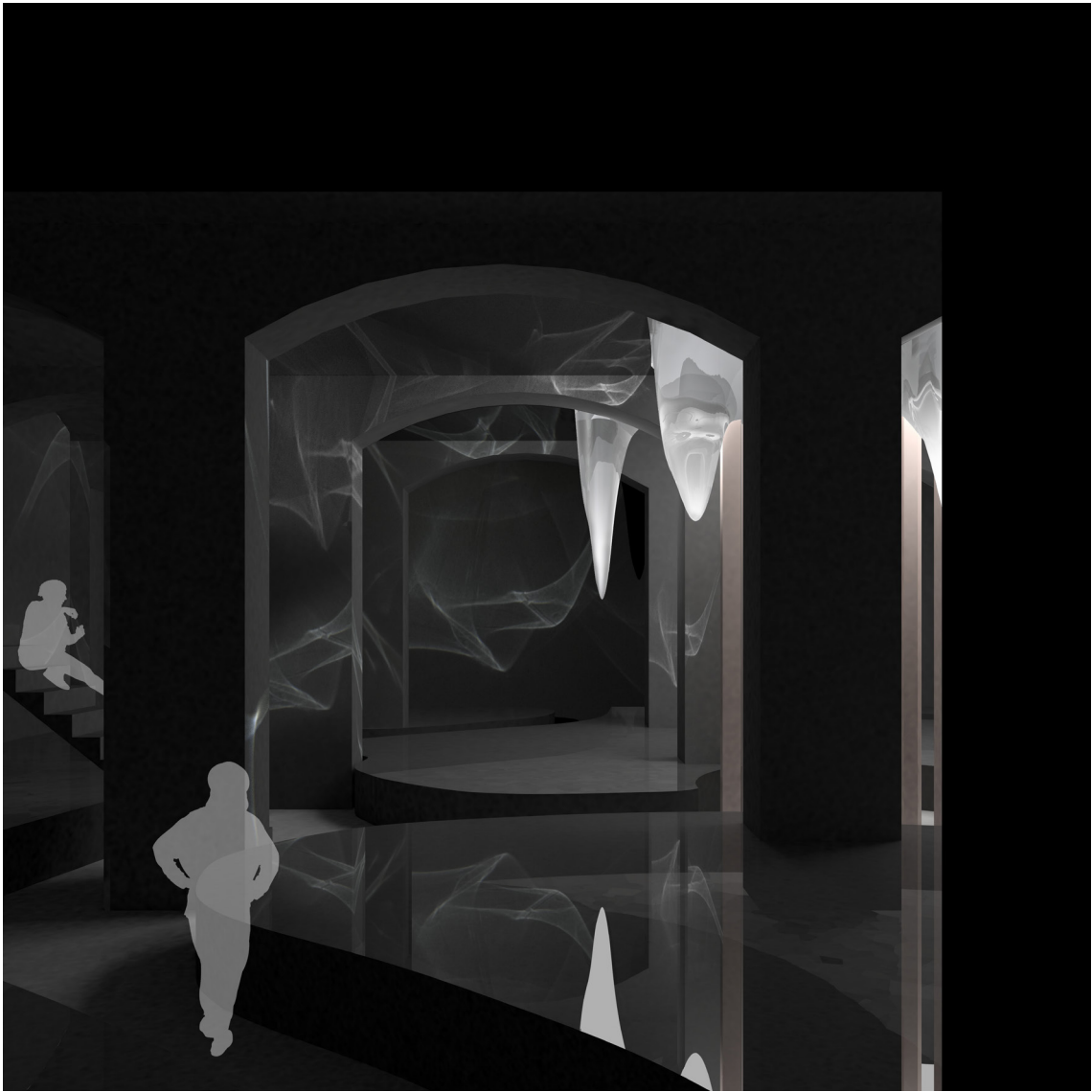
Then the visitor is guided down through the various levels. The different tasks of the levels creates diverse landscapes.

First you go through the green islands where vegetation grows freely. Water is constantly flowing down on the foliage and an almost jungle like landscape is created. Suddenly you are lead down to a landscape of tanks where water is stored. The green islands have slowed the water down and now it is flowing carefully into the storage tanks. This landscape is simple and dominated by the see-through water islands. Next comes a rough landscape full of gravel and sand. The water flows more heavily here but slows down when passing through the dense layers of sand.



When reaching the bypass layer the water once again runs calmly.

The entrance level explodes in color and light as the capillary effect is taken advantage of here. Tall pillars of colors reaches towards the sky. The water pillars and the pillars of color creates a feeling of being in a cathedral and it is all created by water and rain. This builds a contrast to the final underground level.



to bottom

The last stage leads you underground. Here all is still and dark. In the center of the room is the only light source which is the level that connects surface with underground this level is lit up and cast a caustic effect over the old reservoir. Here the visitor can pause and reflect over what he or she has just experienced. Here a meditative almost sacred space is created and maybe after seeing the process and learned about it the visitor can start to respect and appreciate the water as the true treasure it is!







Conclusion

How can rain harvesting systems be introduced into an architectural design in a sustainable, educating and aesthetically pleasing way?

There are many ways of integrating architecture and rain harvesting systems. Only our imagination will be the limitation of the future designs of rain harvesting. During this thesis however much more important facts were discovered.

While doing research on the subject I was at first very worried and pessimistic about the future. It seems very gray when you look upon the facts. However when I started to do research about rain and water and discovered the possibilities that are hidden in this very curious element, The future was no longer so dull, it was full opportunities. There are many features within rain that we can use and turn into something useful, sustainable and at the same time beautiful. All we have to do is realize that it is possible.

The aim with this thesis was to design solutions for rain harvesting in smaller dwellings but as I got to know the water better I realized that a crucial step towards

our rain harvesting future is to create an interest for harvesting and show the possibilities. By awakening an interest I am also confident that we will start to appreciate and respect the water like it deserves to.

My hope is that this thesis and its design will be a vision, a little sneak peak, of how the future might look if we take advantage of the opportunities in rainwater.

- Ellen Linder

References

- Andersson, A (1971). Svenska vattenledningar och vattenreservoarer, 1860-1910. Retrieved 31 Mars from Eber <http://www.eber.se/litt/bil/svenska-vattenledningar-och-vattenreservoarer.pdf>
- Bågler Pros, H. (2015). Gatans poesi: Gråberget och dess hemligheter. Retrieved 18 February 2017 from Djungeltrumman, i <http://blogg.djungeltrumman.se/thismustbetheplace/grabergets-hemligheter/>
- Dori M. Penny. (2011) Retrieved 31 Mars from Encyclopedia of the great plains. <http://plainshumanities.unl.edu/encyclopedia/doc/egp.wat.037>
- Egefur, C. (2016). Ett tempel fyllt med tomhet. Retrieved 18 February 2017 from ETC Göteborg, <http://goteborg.etc.se/kultur-noje/ett-tempel-fyllt-med-tomhet>
- En Värld utan sopor. (2017). Göteborgs vattentorn. Retrieved 18 February 2017 from En värld utan sopor, <http://www.envarldutansopor.nu/vattentorn>
- ESP Water products. (n.d) Understanding UV. Retrieved 18 February from ESP water Products. <https://www.espwaterproducts.com/understanding-uv/>
- Fahlgren, M. (2014) Spana in Göteborgsvattentorn. Retrieved 18 February 2017 from Vårt göteborg, <http://www.vartgoteborg.se>
- Fina. (2017). Swimming. Retrieved 17 February, 2017 from Fina, <http://www.fina.org>
- Gibby Zobel (2013) Alfredo Moser: Bottle light inventor proud to be poor, Retrieved 31 Mars from BBC <http://www.bbc.com/news/magazine-23536914>
- Gryab. (2017).vattenbehandling. Retrieved 17 February, 2017 from Gryab, <http://www.gryaab.se/vad-vi-gor/avloppsvattenrening/vattenbehandling/>
- Göteborg stad. (n.d). Vartifrån kommer ditt dricksvatten? Retrieved 6 Mars 2017 from, <http://goteborg.se/wps/portal/start/vatten-och-avlopp/dricksvatten/varifran-kommer-ditt-dricksvatten/Hisingenftw.> (2014). Hisingens sju underverk. Hämtad 17 mars från Hisingen ftw. <http://hisingenftw.se/2014/03/31/hisingens-sju-underverk-den-bla-spindeln/>
- Göteborg, (n.d). Stadsdelar. Retrieved 18 Mars from Goteborg.om. (<http://www.goteborg.com/stadsdelar/>)
- Kulturtemplet. (2017) <http://www.kulturtemplet.org/>

Livsmedelverket. (2017). Egen brunn. Retrieved 17 February from Livsmedelsverket, <https://www.livsmedelsverket.se/matvanor-halsa-miljo/egen-brunn/>

Länsstyrelsen Västra Götaland. (2015). Riskhanteringsplan för översvämningar i Göteborg. Retrieved 1 Mars 2017 from länsstyrelsen, <http://www.lansstyrelsen.se/vastragotaland/SiteCollectionDocuments/Sv/manniska-och-samhalle/krisberedskap/oversvamningsdirektivet/riskhanteringsplan-goteborg-beslutsdokument.pdf>

Nationalencyklopedin. (2015). Vattenreservoar. Retrieved 18 February 2017 from, <http://www.ne.se/uppslagsverk/encyklopedi/lang/vattenreservoar>

Rieson. (2012). Capillary action. Retrieved 18 February from Rieson Blogspot. <http://rieson.blogspot.se/2012/12/capillary-action.html>

Robinson, J. (2015). What is greywater? Retrieved 1 Mars 2017 from ecology artisans, <https://ecologyartisans.com/what-is-greywater/>

Roos, J. (2016). Från dold vattenreservoar till klingande kulturtempel. Retrieved 18 February 2017 from Göteborg direkt, <http://www.goteborgdirekt.se/nyheter/fran-dold->

[vattenreservoar-till-klingande-kulturtempel](#)

Sjukdom.online. (n.d). Klor effekter på miljö & människor. Retrieved 17 January from Sjukdom online, <http://www.sjukdom.online>

SMHI. (2013). Hur var vädret. Retrieved 17 February, 2017, from SMHI, <http://www.hurvarvadret.se/stationer/92#2000>

Svenskt vatten. (2017). Fakta om vatten. Hämtat 17 februari 2017 från Svenskt vatten, <http://www.svenskvatten.se/fakta-om-vatten/dricksvattenfakta/>

United States Environmental Protection Agency (2017). <https://www.epa.gov/npdes/npdes-stormwater-program>

Vi i villa. (2004). Bästa hushållsslaven. Retrieved 17 February, 2017 from Vi i Villa, <http://www.viivilla.se/kok/vitvaror/basta-hushallsslaven>

weatherpal, (2015) Hur mår vi av vädret? Retrieved 6 Mars 2017 from weatherpal, http://www.weatherpal.se/artiklar/Hur_mar_vi_av_vadret-8406

Östberg, K. (1999). Medelhavsklimat i sverige om hundra år. Retrieved 17 February, 2017 from Ny teknik, <http://www.nyteknik.se/innovation/medelhavsklimat-i-sverige-om-hundra-ar>