Resilient architecture
the water management think-tank

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RESILIENT ARCHITECTURE

THE WATER MANAGEMENT THINK-TANK

TECHNICAL UNIVERSITY OF EINDHOVEN

RESILIENT ARCHITECTURE
The Water Management Think-Tank

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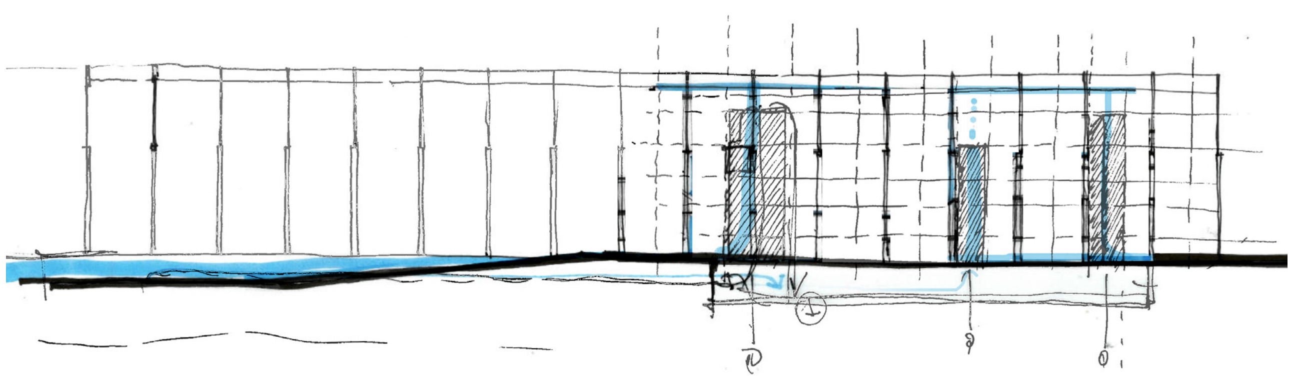
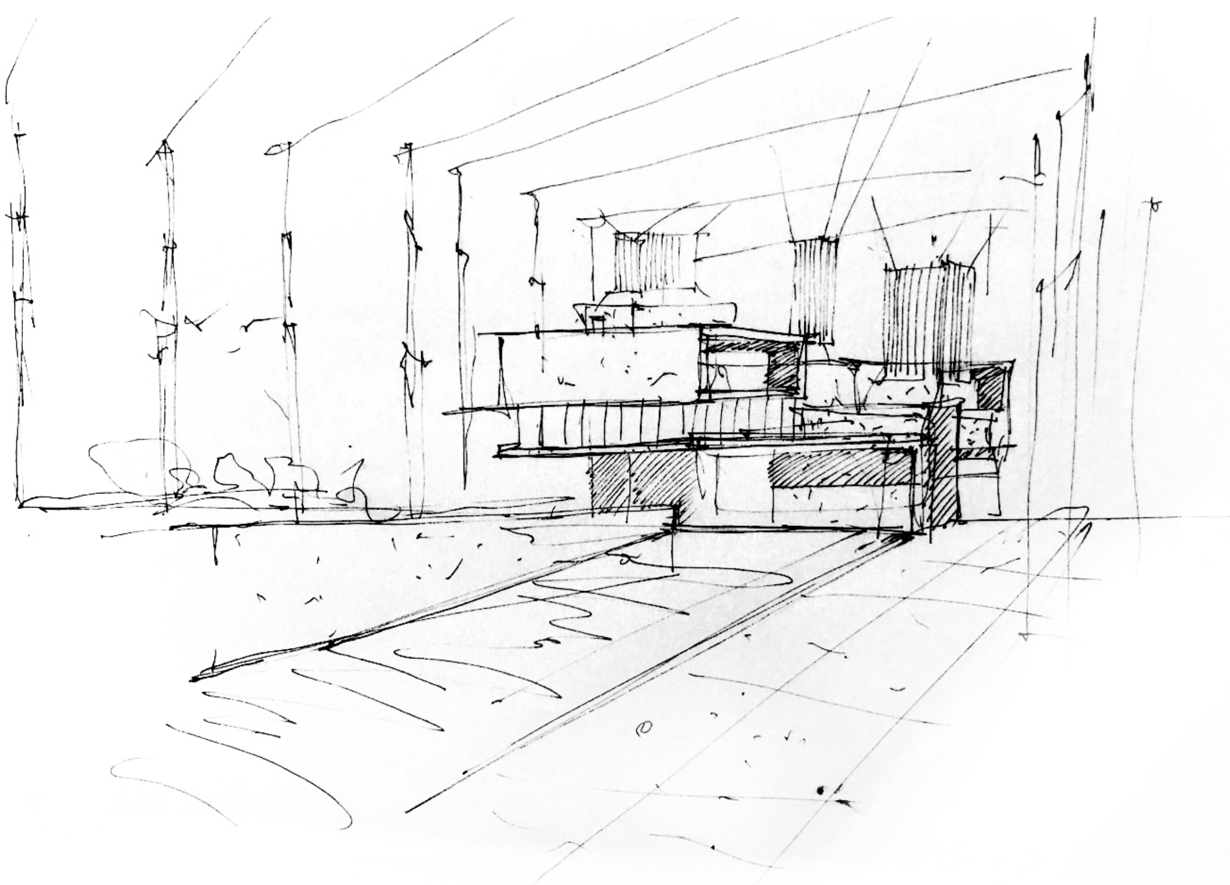


SUMMARY

This graduation builds on resilience, exploring possibilities and limits of a design structured on water.
The latter is the linchpin of the project, shaping landscape and crossing the entire building as a nervous system, lending space dynamism.
The final outcome of this research is a resilience strategy, carried out through a water-based ecological infrastructure, able to connect natural and built environment, to simplify the intricacy of water management, putting in contact research users and public users. Thus, the bond between resilience and design is crucial.
The Water Management Think-Tank is an open port for anyone with a mind, with or without scientific background, that can be used to discover new frontiers.
This design aims to provide an instrument where spaces and events collide increasing the exchange between building and neighbourhood, industry and city, twisting the concept of the office environment creating spatial interactions by means of physical and visual connections that occur through water.
This project represents a whole system where environment and architecture are connected, providing the concept for a building influenced by climate and not vice versa.



INTRODUCTION

Case study

"Resilient Architecture" is a graduation studio focusing on the reuse of dismissed shipyards and water dynamics in the Delta of the Netherlands.
This area has always been characterized by multiple large floods, especially between 1740 and 1860. These events led, during the 19th century, to the optimizations of water distribution, in order to discharge it faster and more efficiently.
Despite of that, the history of the Delta is marked by a catastrophic flood occurred in 1953 (fig. 1). Around 1800 people died, 72,000 lost their homes and 200,000 hectares of land were flooded. This event gave start to the "Delta works" where islands were dammed, sea and river dikes strengthened, opening barriers created to face emergency scenarios.
So, the Netherlands became one of the greatest and more representative examples of environmental engineering, thus resilience.

Among the numerous implication derived from the term "resilience", the relationship between architecture and context is one of the most important. Many are the definitions one can give of this word, and too often it has been linked to terms such as "high-tech", forgetting the importance of the dialogue with tradition, the bond with past and connection with the natural system.
This project starts precisely from the latter, developing a design from the study of the environment and the use of its main elements. Water is used to explore and investigate a resilience strategy able to create a synergy between

Fig. 1: Breach at Ouderkerk aan de IJssel, upstream along the tidal reach of the river Hollandse IJssel, at the time of tidal low water (from Van Veen 1962).

industrial areas (built environment) and natural system (natural environment), providing new spaces and activities for people to gather, turning from threat into utility. This dissertation tries to investigate whether this hypothesis could work or not and how to use water as connector for the project, allowing users, research and environment to interact as a only one resilient system.
Thus, the research question is as follows:

How can water lead the design process as a unifying element able to bring together research and public awareness in a resilient design?

The following chapters will introduce the reader to the general issues related to climate change, analysing causes and consequences and their implications in the case study location.
Afterwards, the concept of "resilience" will be further analysed laying foundations for the subsequent design strategies that structure the project.
In the end, after describing the entire building's system, conclusions will be deduced to comprehend whether the research question has been answered or not.

Fig. 2: Kinderdijk

About complexity

"The flood system is dynamic and complex and affected by continuous changing of natural and human induced processes, such as climate change, urban growth and economic development" [1]

Flood risk represents a design challenge, strictly connected to climate change.
Sea levels rising, rivers discharging, soil is drying out, greater risks of tidal or inland flooding and surface water run-off are just some of the reasons that are pushing man to provide responses to the risk.
Actions must be taken promptly in order to guide the human environment towards a more resilient stage.
Raising the dykes is not an answer anymore: the soil level is going down while the water level is increasing. Thus, new strategies and approaches are required in order to avoid problems such as casualties, contaminated water and destruction.
According to the ""Climate Change and Water" technical paper of the intergovernmental panel on climate change, Bates et al. state the alarming consequences of climate change on the world's water resources. For instance, changing in patterns of precipitation, soil runoff, ice melting, increased risk of rain-generated flooding, drought and aridity in sub-tropics.
Increasing temperature will affect water quality causing pollution from sediments, pathogens or pesticides, with consequences on human health, agriculture and food security.
Furthermore, sea level rise will cause a decrease of freshwater availability, extending areas of salinization of groundwater and estuaries. This will result in changing ecosystem in coastal areas.

The 30% of Netherlands is below the NAP level (Normaal Amsterdams Peil). For each meter water rises, the 5% more of land is flooded, resulting in a doubled economical damage within 30 years [2]. Furthermore, by 2050 sea levels are expected to rise between 15cm and 35cm, doubling the chances of flooding, thus the amount of damages: tangible ones, such as water entering the construction via brickwork, cracks or expansion joists between walls erosion and scours; non-tangible ones such as casualties.

"A delta is a land that forms from deposition of sediment carried by a river as the flow leaves its mouth and enters slower-moving or standing water" [3]

The case study location is one of the most vulnerable areas of the Netherlands: the Delta.
The basins of the Rhine and Meuse rivers occupy this area and are sensitive targets that need a precise programme in order to asses the impact of flood risk, safety measures and to support the spatial planning [4]. Indeed, as showed in fig. 3, the water system can be divided into three areas: sea dominated, river dominated and transitional areas.
In the first one the water level is determined by the sea level and the primary strategies of intervention are based on dykes improvements and storm surge barriers.
In the second one the peak of discharge of the rivers influences the water level of the area; in this case, besides strengthening of dykes, river-widening measures should be taken.
The third case is the transitional region where a combination of both sea and river related problems influence water levels and where the study case is settled.

In light of this, it is therefore clear that the solution cannot be one. Different bodies must be involved both from the design, engineering and water management realms.
The answer resides in a "multi-disciplinary sequential approach" [6] that involves the different parties articulated in three stages. The first one concerns the "Analysis": this phase is structured on the F.R.A. (Flood Risk Assessment), and L.U.P. (Land Use Planning), to individuate risk areas.
F.R.A. is a methodology to determine areas of high, medium and low risk by analysing potential hazards and evaluating existing conditions of vulnerability that might harm people, services and environment. It also studies types and sources of flooding and estimates the current capacity of the site to store flood water [7].
L.U.P. contributes to sustainable development using natural topography. It provides new spaces for activities according to analysis of economic, environmental and hazard data.
Land use planning can help to mitigate disasters and reduce risks thanks to key installation of transport, power, water, sewage and other critical facilities.

[1] Escaramela, Stone et al. (2013)

[2] www.ruimtevoorrivieren.nl

[3] www.wikipedia.com

[4] n A. Hooijer, F. Klijn, B. M. Pedroli and AD G. Van Os (2004)

[5] National Water Plan 2016-2021, www.government.nl

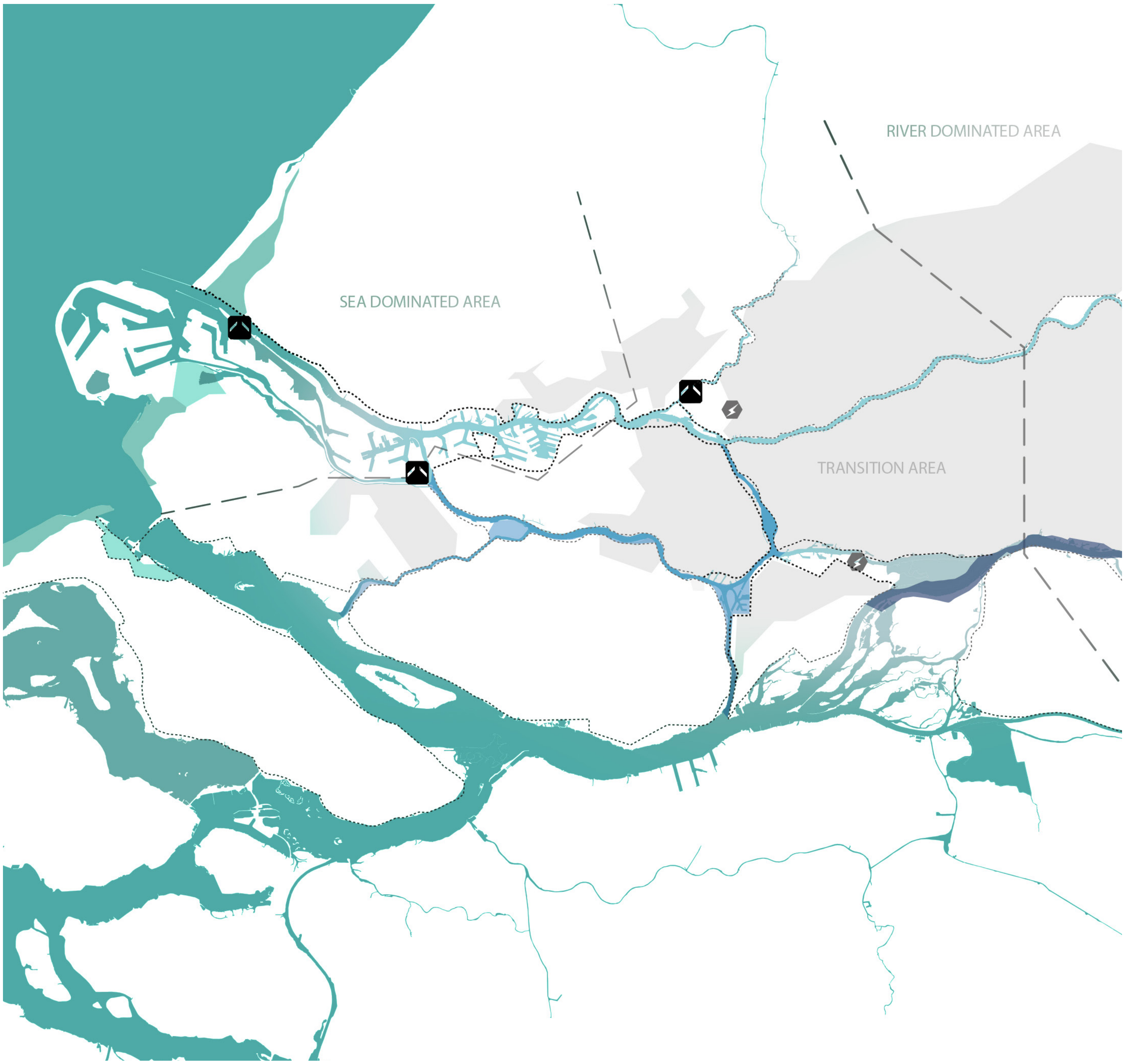
[6] K. Curtis et al. (2009)

[7] "International Strategy for Disaster Reduction" ISDR Secretariat, 2009. www.unisdr.org/eng/library/lib-terminology-eng.home.htm

The second step is the “Control” phase: the aim is to provide new strategies to minimize the probability and severity of a flood, thus its consequences.
Among the primary actions are the integration of coastal flood defences, creation of wildlife corridors, providing of additional flood storage capacity, safe refuge on site and design resilient buildings to minimize internal damages.
To conclude, the third stage is called “Re-assessment”: it is meant to check the impact of the proposals made during the second “Control” phase in regards to future inhabitants, surrounding neighbourhoods, safety, climate change and environmental impact

Thus, it is clear that water management is a complex matter: there is no single solution for one problem, rather strategies that should be adaptable to changing scenarios.
The number of bodies and professionals involved results in a complicated organization and this intricacy makes the communication with the public more difficult and less appealing, causing a lack of awareness.
Complexity is also present in the features of the area and its previously mentioned partition in three zones.
The vulnerability of the local environment is potentially high and results in many areas in danger of flooding, among which is present the case study location.
Indeed, the latter, as showed in the study model in fig. 5, is placed outside of the dyke, making the future desing choices even more challenging.
Zooming into the site (fig. 6), a shipyard run by “Royal IHC”, next by the Kinderdijk, the theme of complexity strikes back, expressed by the variety of the surroundings: rural and more natural environment coexist with industrial sites, commercial activities and residential areas.
This dynamic environment is characterized by the rivers Maas and Noord joining together.
Their water brushes the area and enters it through a ramp in correspondence of a huge ship building, 230 meters long (fig 7).
The features of this gigantic box express the industrial character in all its power and strength.
Steel beams extend over a 50 meters gap, cranes easily lift and move sections of boats through this cage of steel.
The human scale is lost and “bigness” has taken over.
Precisely the relationship with water led to the choice of re-using this building to host the Water Management Think-Tank.
Resilience means also learning from the past, thus the relationship old and new is a crucial point in this research.
Indeed, as it will be further explained in chapter 4.2, the refurbishment of some of the pre-existing buildings is fundamental in the approach to the building.
They relate to the new context and landscape, interacting with it and providing users with a preliminary experience throughout the area.

Fig. 8: Regional map of the most vulnerable zones in the Delta Area.

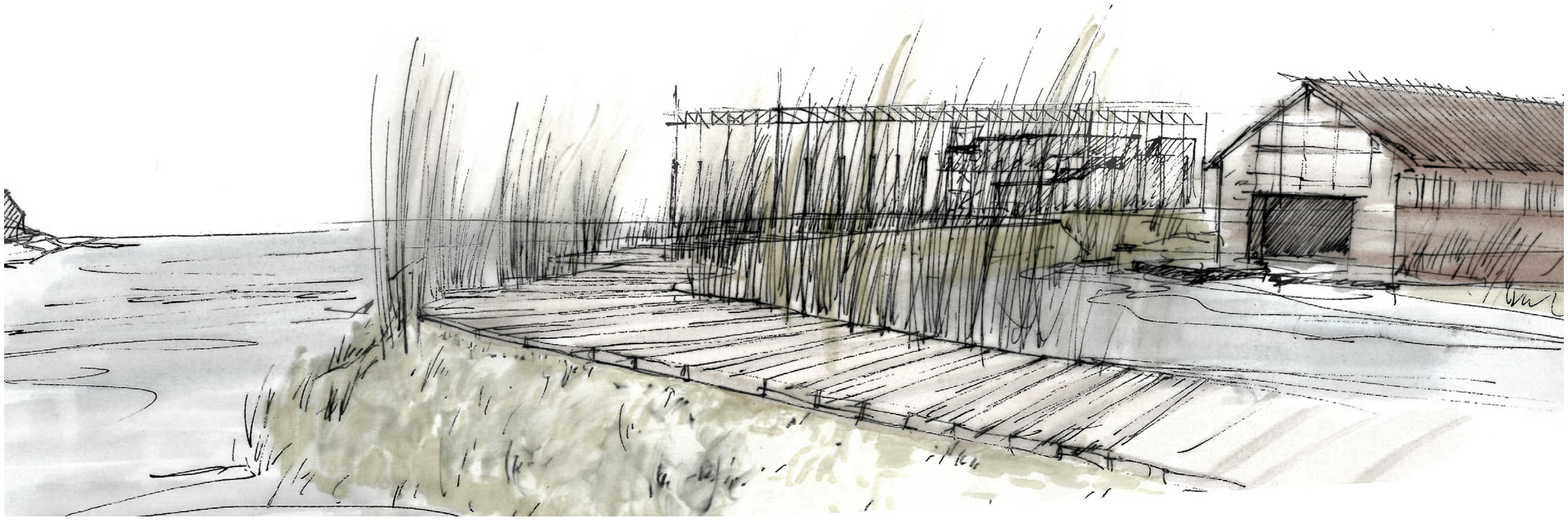

RIVER DOMINATED AREA
SEA DOMINATED AREA
TRANSITION AREA

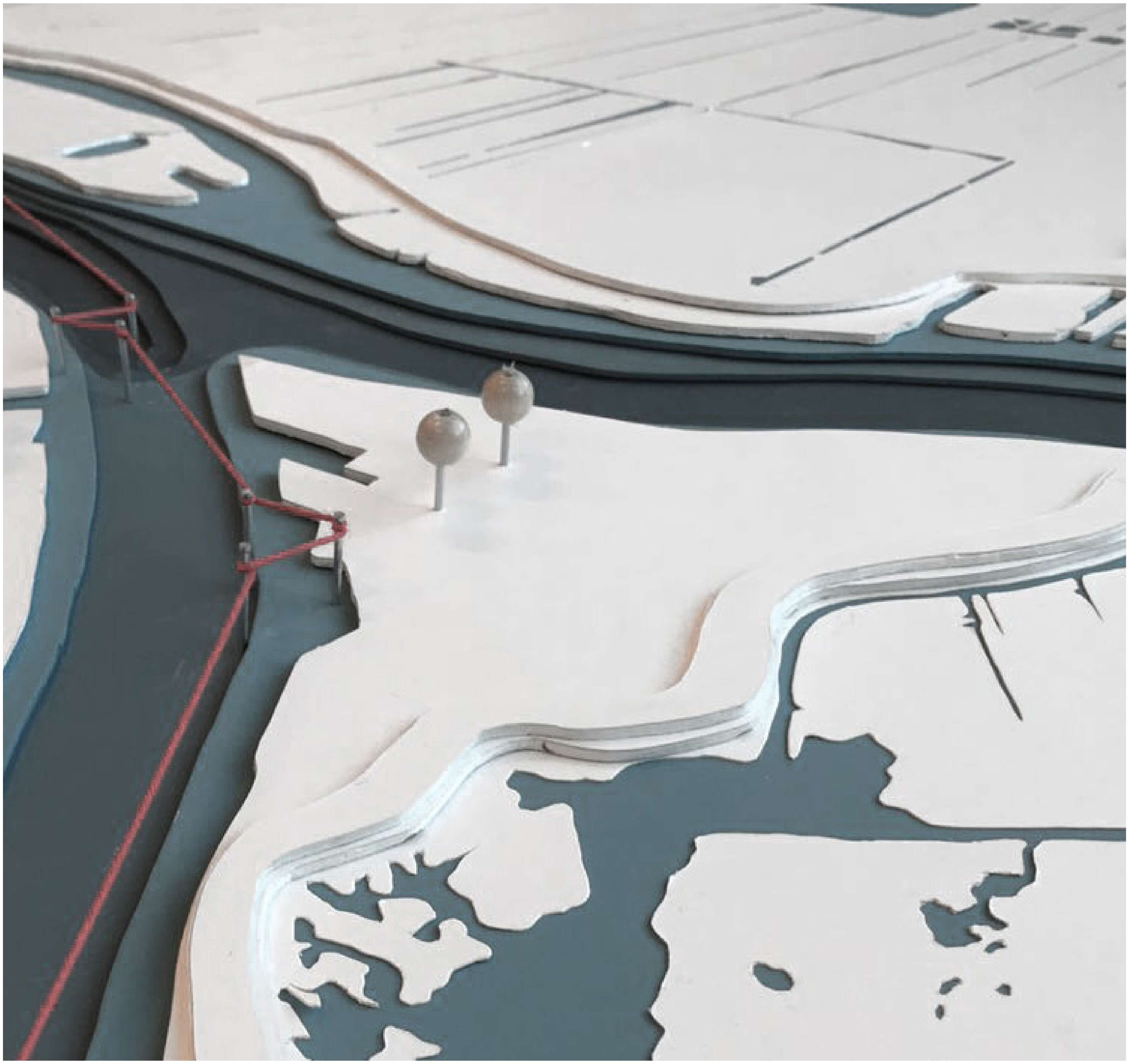
Primary urban defence
Secondary urban defence
Vulnerable area
Sandy engine
River widening before 2050
River widening after 2050
Electricity grid
Storm surge barrier

Fig. 3: Regional map of the most vulnerable zones in the Delta Area.

Fig 4: early conceptual impression of the area

Fig 5: dyke system model





	Site
	Industries
	Commercial activities
	Residential areas
	Natural environment

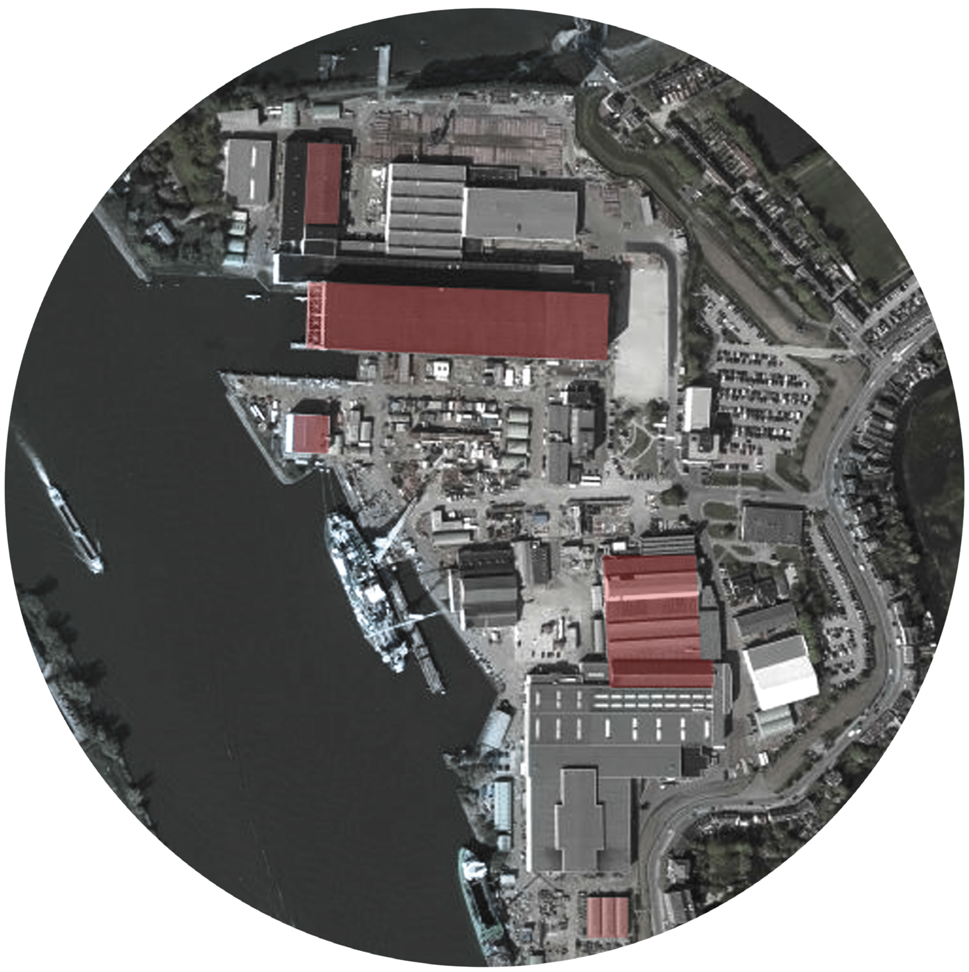


Fig. 6: aerial view and analysis of the case study location

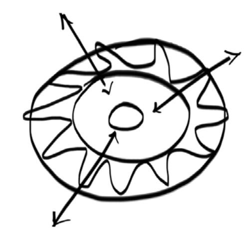
Fig. 7: aerial view of the main building and the surrounding omnes

About interaction

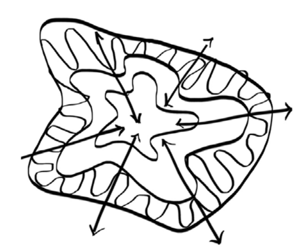
Water is what characterizes the context. The latter, together with sky, stresses the features of a flat landscape, asserting itself as predominant element of the environment. It flows inevitably, brushing lands that appear as a narrow stripe punctuated with elements from the natural and built realm.
Trees, marshlands, industries, cranes, electricity grids, towers and entire cities, together with water and sky, merge in an only one image.
Thus, complexity results in a series of overlapped layers interacting together and providing a clear and understandable picture. Interaction is indeed the keyword to sort out the intricacy that lays between environment (built and natural), public users and research (water management knowledge).
Exchange, interaction and buffering (fig. 9) are the main stages through which is possible to generate interaction. The first step pictures environment, public users and research users: the three system exchanging information. Generating more convoluted boundaries allows to obtain more interaction among the systems (second step).
In order to make good use of this interaction, a tool able to process and buffer this interaction is needed. The black belt in the third step represents the *buffering zone*. According to Darmstad et al., the boundaries between an area and the other become distinctive and may act as buffer zone [8]. The more convoluted the edges of a system the more points of exchange between them will emerge. Precisely, The concept of the building builds on this idea in order to generate interaction.
Therefore, the aim of this research is to provide a clearer, simplified and efficient tool to buffer this exchange; in other words to better comprehend the dynamics of the water management. In this case, this instrument should be represented by a design reflecting complexity and expressing the seek of order in it [9]; able to improve the interaction between public, research and environment through "buffering elements", and to ease the contact and interaction.
The aforementioned elements can cover different roles and tailor to specific requirements or needs.
The project builds on two different types of buffering components to improve and stimulate interaction amongst realms.
The first one is the buffering space: a lecture hall or exhibition space are "learning spaces" that allow different targets of people (students, professionals or general users) to gather and be introduced to the discipline of water management, even though they have no specialized knowledge. While the second one is the buffering activity: thanks to different activities involving sports, experiments and workshops, it is possible to encourage a wider range of people to learn in an informal way, thus experience the building.

[8] W. Dramstad, J. D. Olson, and R. T.T. Forman, (1996)

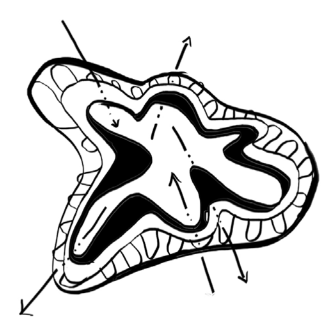
[9] B. Tschumi (1996)



EXCHANGE



INTERACTION



BUFFERING

Fig 9: Exchange, Interaction and Buffering.

Fig. 10: Nieuwe Maas river

RESILIENCE

[10] D. Watson, M. Adams (2010)

[11] "International Strategy for Disaster Reduction" ISDR Secretariat, (2009)

The history of human settlements has always been a response to social, economical and climatic conditions of the time [10].
The above mentioned issues related to climate change are a clear sign that is time to adopt a different approach and stop human behave from being detrimental to the planet.

"Resilience is the capacity of a system, community, or society potentially exposed to hazards to adapt, by resisting or changing, in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures." [11]

Flooding is a natural process depending on weather and water. The concept of resiliency is inspired by natural systems to design for extreme conditions using strategies of buffering zone separation, redundancy, rapid feedback and decentralization. Indeed, a design should aim to restore and improve water resources and mitigate the consequences of extreme weather patterns.
Resilience means thinking about the environment: natural landscapes provide clean air, fresh water storage, groundwater recharge and biodiversity.
That is why is crucial to know how to make use of nature. Wetlands help controlling erosion and flooding, remove pollutants from water and recharge the groundwater reservoirs for the water supply; coastal marshes, wetlands, and mangroves provide important buffers to coastal storms and storm surge.

Thus, design for resilience is strictly linked to the natural processes of the hydrologic cycle and the role of soil, plants, and use of water. The enhancement of the environment must aim to limit and mitigate flooding. A resilient design should be able to preserve local water balance and water supply to sustain region and community [10] and let different scenarios occur in a safe and controlled way.

Water is the element that has the greater impact in the Netherlands at every scale and can be used as a core element of a resilient design.
Water is no longer a renewable resource and it is necessary to learn how to take advantage of natural events such as flooding and extreme weather in order to benefit.
Resilient design can turn threat into opportunity and utility, controlling waterways, natural and built environment.

Being said this, the resilience strategy on which this project is founded, is structured on two maxims:

Absorb and re-direct the threat into utility or benefit

Social cooperation and awareness to deal with changing conditions

The first one concerns the decision of using water as element able to produce a benefit and interaction. Water is a buffering element and is let into the area. Here, a flexible and diverse system, allows to control it in a safe way and is able to respond to changes.
While the second one states the importance of the interaction users/knowledge and the need for awareness. Indeed, public awareness is part of resilience as well. The extent of common knowledge can help reduce vulnerability to hazards.
Rising awareness is possible thanks to diffusion of information through media and educational channels, networks, participation actions and support from authorities.

Thus, the strategy of resilience is concerning this research at different scales. First, the ecosystem scale consists of services to protect or restore environment: maintain and protect aquifers, water filtration, protect riverbanks, control natural erosion and keep forests healthy to purify and replenish air.
Second, the community scale: providing social structures to strengthen community's fabric, design rainwater bioswales and create more room for rivers reducing heat in cities, build infrastructure to handle floods, create resilience hubs to function as emergency shelter during floods and last but not least, spread knowledge through education programs.
Third, the building scale: it means designing or renovating buildings, making them able to withstand climatic events, thus emergency scenarios; create a durable building carrying out rain water collection and providing more room for water to be stored.

Therefore, the decision of keeping some of the indutrial blocks in the area.

This thesis investigates resilience through architecture, trying to answer the impelling demand for a new approach that does not harm environment and natural resources and is able to rise awareness in the public. This book suggests a new way of building, based on a sensitive and aware use of land to take advantage of the natural benefits of flooding, using water as mean to achieve resilience.

Again, in light of all these reason, the research question is as follows:

How can water lead the design process as a unifying element able to bring together research and public awareness in a resilient design?

Fig. 11: "Resilience", collage.

DESIGN CONCEPT

The design concept starts from the aforementioned maxims and research question.
Thus, it can be divided in two strategies: water=energy and users + research.

Water = energy

Water is the predominant element in this environment and can be turned into a benefit if combined with other forces such as wind. The aim is to take advantage of natural agents to produce energy. In fact, it is possible to generate it not only from waves or tides, but also from free-flowing rivers and even constructed waterways, such as irrigation canals or small streams.
To achieve this goal, it is necessary to implement the architecture with technologies able to convey the natural movement of the elements into energy to improve the building's performances and become part of the design.

Netherlands is recognized as one of the most advanced countries worldwide in regard to flood risk. With a past marked by important engineering achievements, nowadays is considered a hotbed for new technologies and techniques to improve safety measures.
Many and different are the instruments use to handle sea or river related problems. For instance, hydrokinetic technologies produce renewable electricity by harnessing the kinetic energy of a body of water, the energy that results from its motion. Or else through "hydro power" it is possible to extract energy from water using generators.
The Integrated Roof Wind Energy System (IRWES) designed by Alexander Suma (CEO and founder of the IBIS Power) uses the wind colliding with a high building (fig. 12). The latter should be minimum 5 level high in urban areas and located within 50 km from the coast line [12]. Based on the Venturi effect, this technology lifts the roof surface of 4 meters using the 120% of the area available for solar.
The top of this unit is implemented with solar panels and underneath it a lined up installation of funnels and turbines, placed along the edge, captures the wind flow accelerating it towards the turbines by 15 times. This makes a weak breeze already usable.
Located within 35 km from the coast in a wide open area, characterized by a wind speed between 5 and 6 m/s, the Water Management Think-Tank presents the ground for an optimal use of this technology.
The purpose is to create a self-sufficient building that uses water and wind, able to function even in case of a severe flood or emergency scenario, and integrate those technologies in the design process.
Water is the nervous system of the building and its process is articulated in different steps concerning how to collect it from the river, its vertical movement and its distribution throughout the design and use.
Two are the elements considered of primary importance for the water cycle: the pre-existing building and the core elements. These two work in symbiosis collecting and distributing water using some of the above mentioned techniques.
The first step is to collect water from the river. This happens thanks to the old building that is in direct contact with it. Implementing the old structure with a system of pipes or Archimede's screws (fig. 13) it is possible to control the amount of water poured on the ground level. By doing so, stagnancy of water can be avoided flushing it back into the river.
Water is then pumped up through the core elements. These are load bearing units of 80cm- thickness walls that function both as serving spaces (elevators, staircases ecc..) and containers for the water pumps, as well as water storage.
They drag water up from the ground level to the different floors, redirecting it horizontally; thereafter, water can be used for the cooling system, improving building's performances, or analyzed in labs, and crosses the entire building through a small canal carved in concrete. The sloped floors let water flow from the highest levels. Its kinetic movement is harnessed by rolling fluid turbines, designed by Miroslav Sedláček (fig. 14). These turbines are not equipped with blades but use a small rotor, connected to a generator able to convert the energy produced by water into electricity. Their small dimension allow them to float under the water surface and are able to function with less than 2 lt/s or even with a drop of just 20 cm, producing an amount of electricity of 10KW/h per day [13].
This technology may be used in the building to provide electricity to workshops, atelier, offices and so on.
Then water finally comes back to the ground level where the cycle can start again.

[12] reference http://www.ibispower.eu/products/powernest-2/

[13] https://www.epo.org/learning-events/european-inventor/finalists/2016/sedlacek.html

In this process the structure of the shipbuilding plays its role in terms of resilience. Its ability to cope with change resides in its use as mean to harvest rainwater. Indeed, it provides an extended surface that allows to collect a huge amount of rain water. This can happen implementing the steel structure with polycarbonate slabs that re-direct rain water into suspended tanks. Once these are full, they let water naturally drop onto the cores and later inside their water storage. By doing so a greater amount of space can be provided to harvest water that can be re-used for building's purposes.

So, the aim is to turn water into the leading element of the design. It is the connector between past and present, between old and new building, shaping space, creating atmospheres. Water is not kept out of the safe area anymore but is let in, becoming an essential part of design and landscape, turned into a benefit able to enhance and improve the building's features.

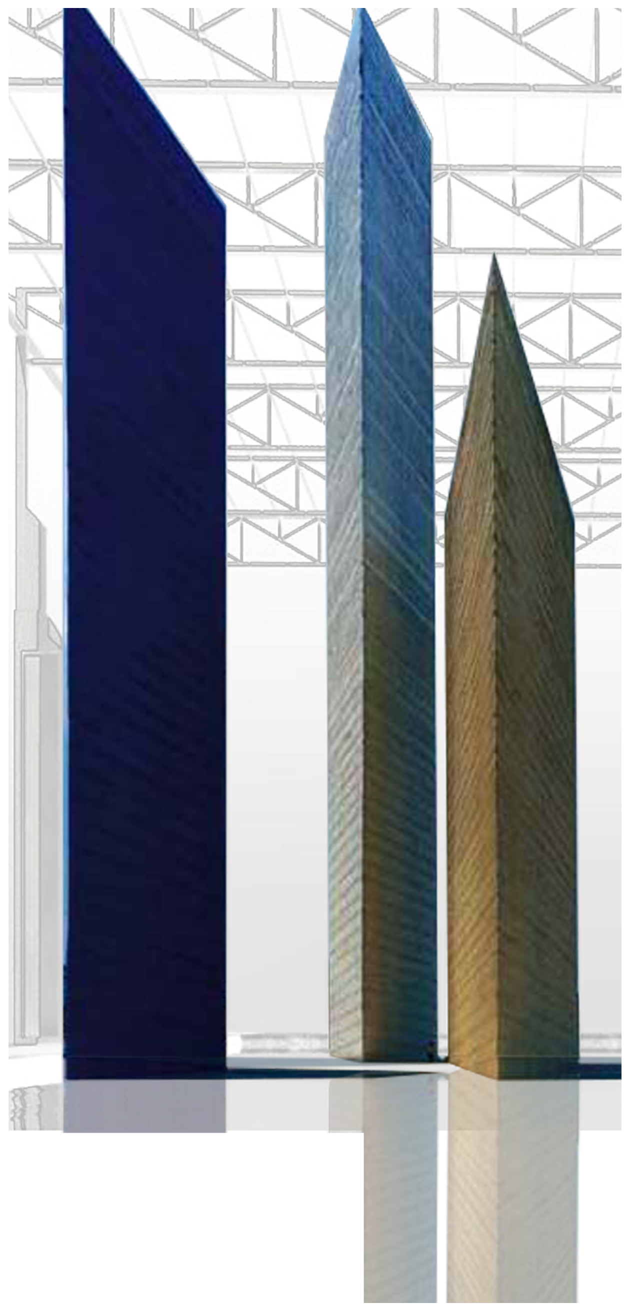


Fig. 11: "Cores", collage.

Fig. 12: IRWES turbine.

Fig. 13: Archimede's screw. Is an idraulic machine used to move a fluid using the kinetic energy generated by its descend. When the machine is not moved by a man it's called screw turbine. In this case the fluid flows spontaneously from the bottom to the top and its descending movement activates the archimede's screw. Thus, energy is produced and it can be harvested to generate electric energy.

Fig. 14: rolling fluid turbine.

Fig. 15: Smart Hydro Power turbine. Is a smart turbine for rivers and canals that allow for the introduction of a base load supply, providing a complete renewable energy solution for the best cost-benefit possible. Because it is powered by kinetic energy no dams and/or head differential are necessary for the operation of this device; the course of a river remains in its natural state and no high investments in infrastructure are required. Since the amount of kinetic energy (velocity) varies from river to river, a greater amount of energy is generated with a higher velocity of water flow.

Fig. 16: attenuator. Also called as heave-surge device, it's a long, jointed floating structure aligned parallel to the wave direction and generates electricity by riding the waves.
Being a rotating device it captures the kinetic energy of a flow of water (tidal stream, ocean current or rivers) as it passes across a rotor. The rotor turns with the current, creating rotational energy that is converted into electricity by a generator. Tidal turbine is one of these devices. This technology can be placed in the river and provide energy to the building.

Fig. 17: system designed by the dutch company Tocardo. The eastern Scheldt is a combination of a storm surge barrier and turbines (capacity: 1.15 megawatt – Generation: for 1000 dutch households) that uses tides to generate energy. Tocardo turbines are very well suited to be combined with electricity from wind turbines, solar pv panels, battery storage and aggregates to bring electrification to remote and offgrid areas.

Fig. 18: tidal current turbine SeaGen

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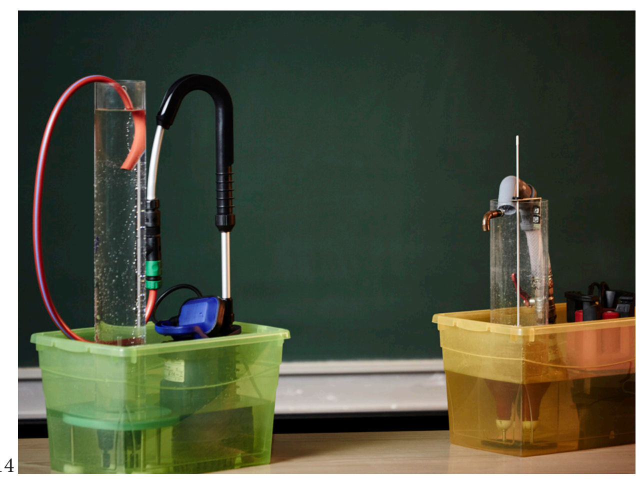

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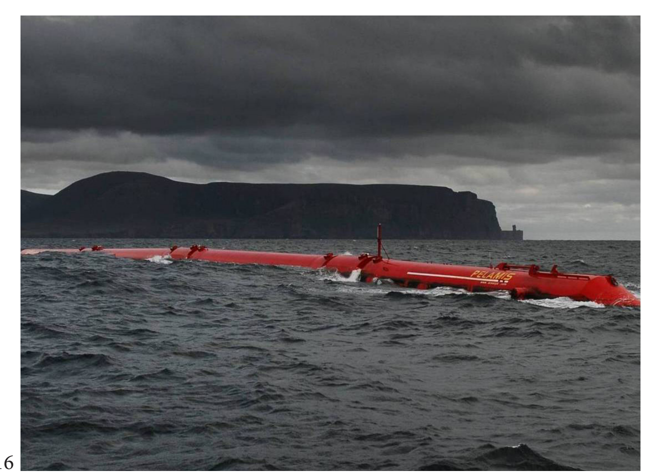

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Water cycle

Hereby is described the water cycle (fig. 19).

1. Rainwater harvesting: system of polycarbonate slabs placed on the pre-existing structure to collect rainwater.

2. Rainwater flow: once collected, water is directed towards openings that let it fall into hanging tanks.

3. Pre-existing structure: it holds up the rainwater harvesting system and provides a support for the suspended tanks.

4. Rainwater harvesting tanks: composed by a system of steel trusses wrapped in polycarbonate panels, these tanks are hooked by mean of steel wires to the main structure and to the concrete core. They harvest rainwater falling from the slabs above.
Water can be released into the core thanks to a system of bulkheads to prevent it from stagnancy.

5. Rooftop level:provides more space to store water and hosts wind turbines.

6. Horizontal water flow: consist of water re-directed horizontally throughout the entire building. A small canal, "carved" in concrete and sloped, hosts micro turbines able to generate a certain amount of energy that can be used for building performances.

7. Cores: are the primary element of the design together with the steel structure. Formed by 80-cm walls, they are load bearing elements which purpose is to store water and distribute it through a system of water pumps. Energy will be provided by water turbines that will harness the kinetic movement of the adjacent rivers.

8. Vertical water flow: water is drag, thanks to water pumps, from the river into the underground level of the building, thus stored inside of the cores. Thereafter, it can be re-directed vertically and used for different purposes such as cooling system, to flush toilets and so on.

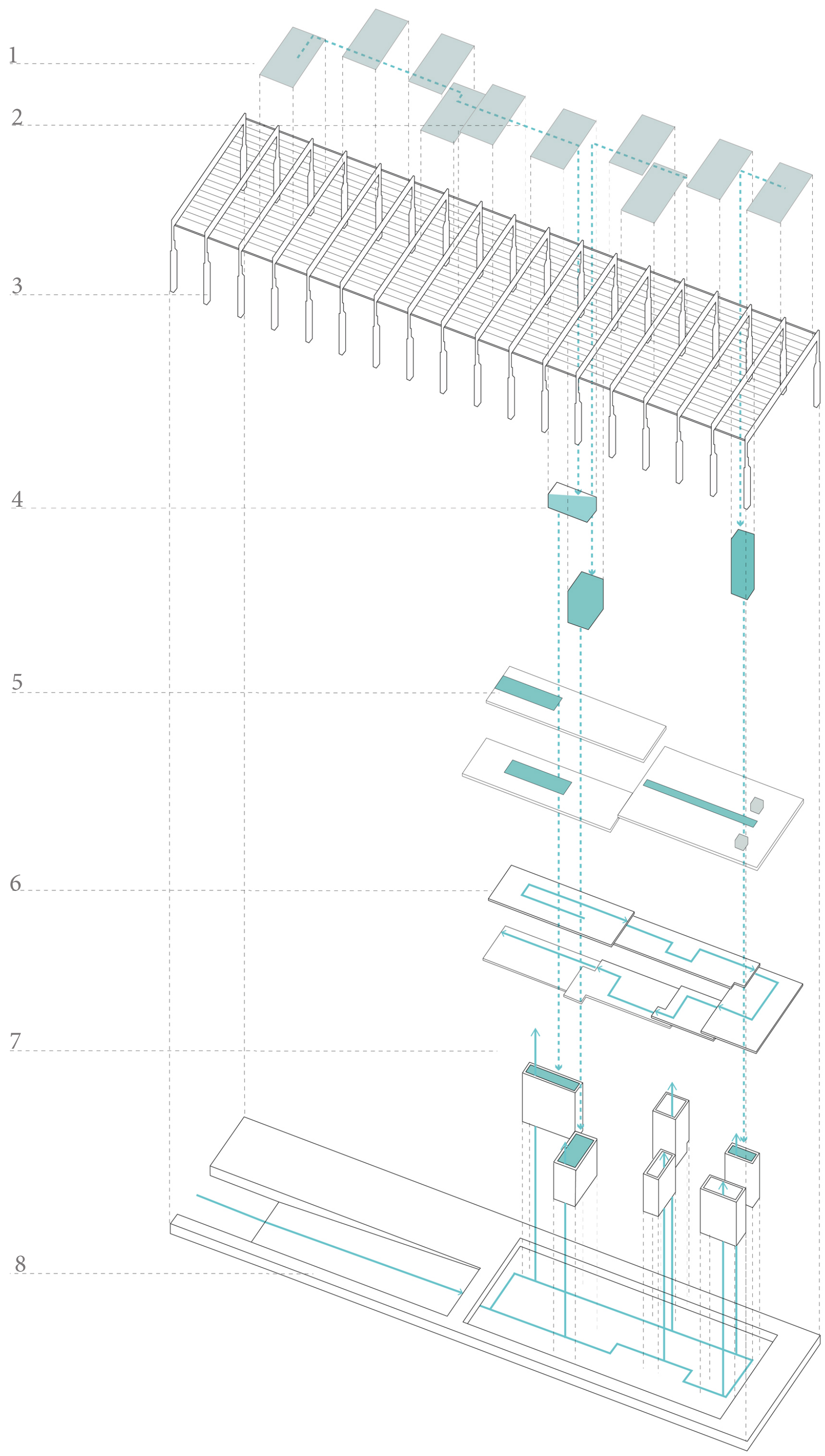
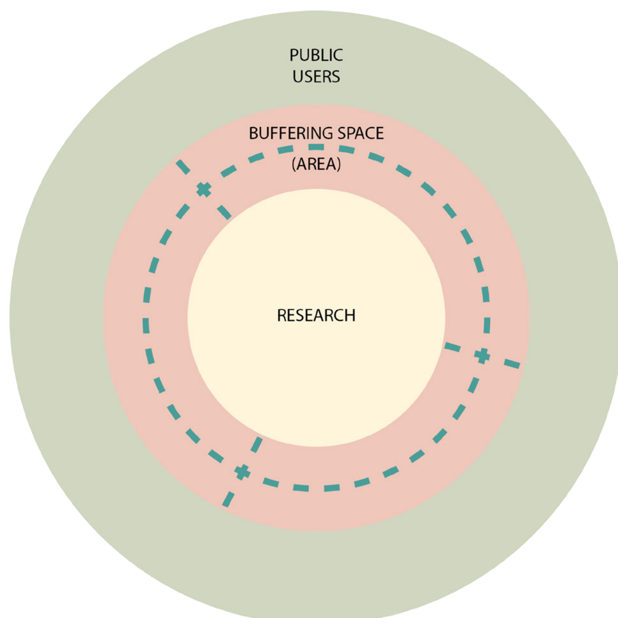


Fig. 19: Water cycle diagram
(Water=Energy)

As mentioned above, the building should work as an environmental machine using water for performance purposes and be able to sensitively respond to its environmental and social context. In doing so, it is possible to create a building that is a part of nature rather than dominate it.
The Water Management Think-Tank proposes a research and educational center to provide strategies to face the threat and increase people's awareness.
The building system is based on the relationship water-energy. The aim is to bring the community closer to the benefits of water and its multiple uses, and raise questions about climate change and sustainability.
Water can be filtered from the roof or from the river and used for educational purposes, with the aim to visualize the process for visitors. If they understand how the building system works they can better appreciate the importance of sustainable design inspired by water.
The project not only focuses on the research about the water management but also on the informal learning through a lively, creative and active experience for visitors to witness the water cycle.
This concept is expressed and developed through the use of the buffering elements. Taking a step back to the three system it is possible to understand the concept standing behind masterplan and design.(Fig. 20). Indeed, the aim is to ease the contact between research and public users. In order to do that it is necessary to use a "buffering element" to filter and process the exchange between the two realms.
Again, water plays the main role as connector, guiding visitors throughout a cognitive experience and enhancing the spatial qualities, providing ever changing moments.
It can become a thin vertical membrane dividing spaces through noise, can turn into a floor or create visual connections between different levels or spaces. (Fig. 21,22)

The landscape surrounding the design should actively interact with it and follow the same principles adopted in plan. However this time the three systems are inverted: the public user is the outer realm, heading towards the fulcrum (the research). In between them the area functions as a buffering element, creating a preliminary experience guiding visitors towards the building. Once again, in a larger scale, the movement of water shapes the space and atmosphere of the surroundings flooding areas and routes. This can happen thanks to an efficient use of land where soil, water and plants interact with each other through the design of a water system for nature, using water storage, water reuse and an efficient coordination of landscape functions.
The experience of the natural environment surrounding the Water Management Think-Tank should represent a visible and interactive way for visitors to witness the water cycle, guiding them through an interactive and lively route towards the building. (fig. 23)



Water

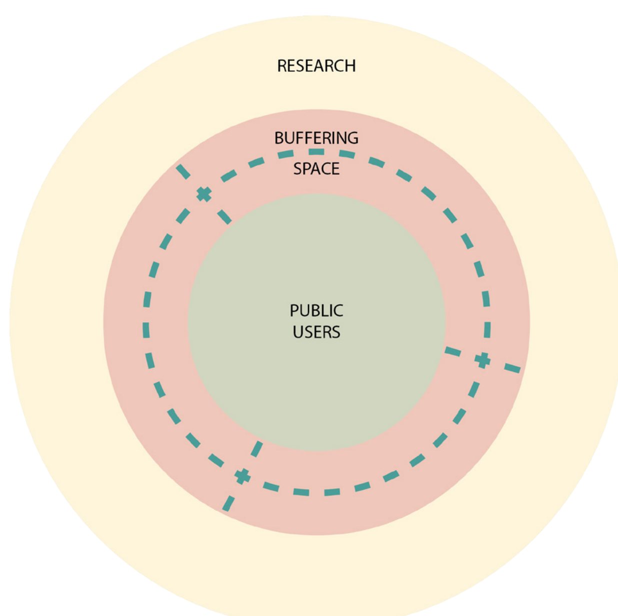
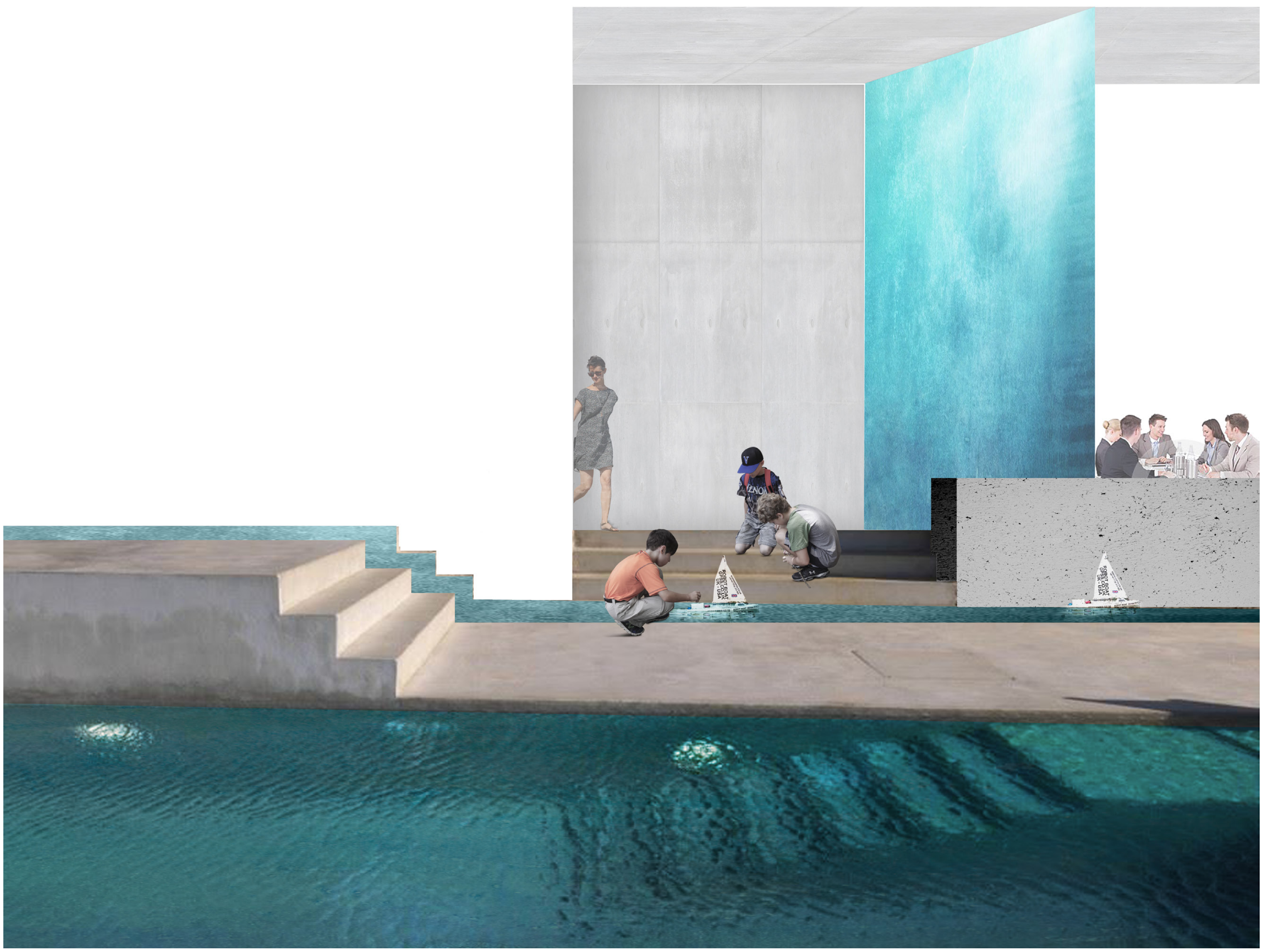
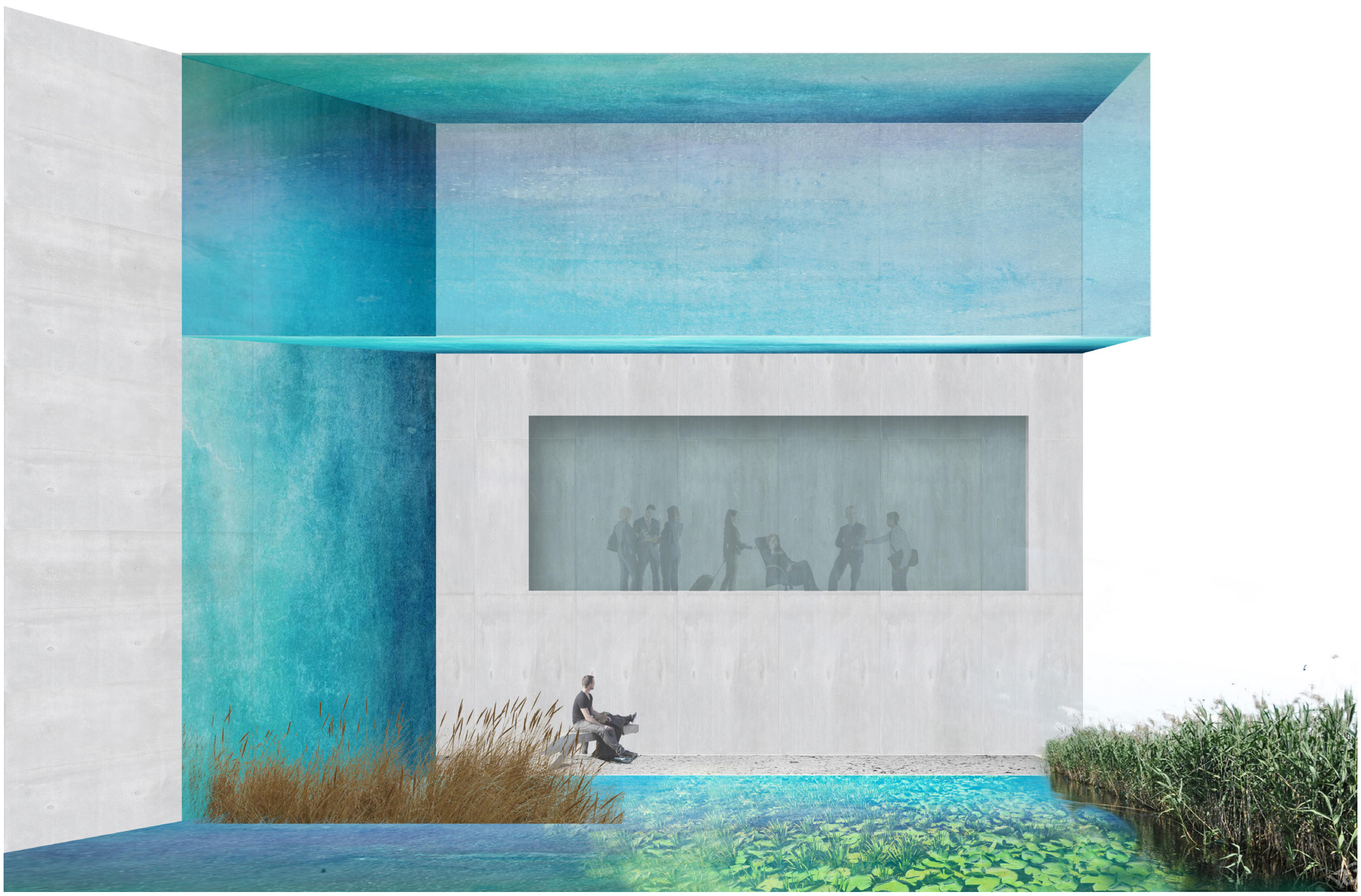


Fig. 20: masterplan and building's plan conceptual diagrams (Users+Research)

Fig. 21,22: conceptual interaction between architecture and water, early collages.





The masterplan reflects the complexity of the environment combining together different layers in order to respond to changes and likely scenarios.
Focusing on storm and river water management, the area is turned into a floodable public urban park that lets invade its spaces by the nearby Noord and Maas rivers. This way the landscape is flexible and depending on the water level, forming ponds and marshy “islands” with various environment.

Three are threee main layers overlapping (fig. 24). The first one is the water system: it is composed by a water flow that runs throughout the entire area connecting water storages, activities and floodable zones, to provide more room for rivers and shape the landscape. Then, on the north-west side of the plot a waterfront gently lower towards the river, connecting area and water.
The second layer is the natural environment: nature surrounding the area visually isolate it from the neighbourhoods, raising curiosity for the discover of this “oasis” characterized by bio-diversity. Marshland, willow woods, open fields are all featuring water, providing a more gradual access to the area and different suggestions until the centre of the former shipyard. Here the landscape turns into an expanse with a terraced route ending into the river, providing a more formal approach to the building.
The third layer is given by the pre-existing buildings. Activities and leisure spaces are now filling these former industrial buildings combining more resilient features.

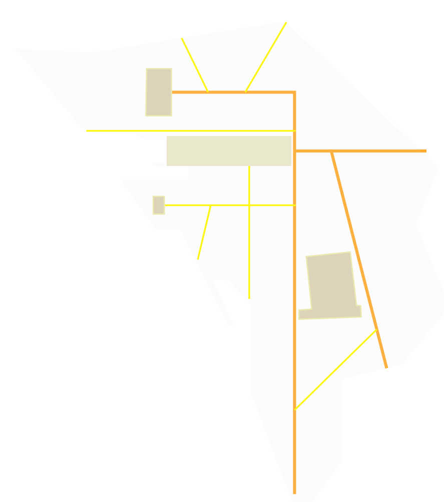


Fig. 23: landscape impression, collage

Fig. 24: landscape layers

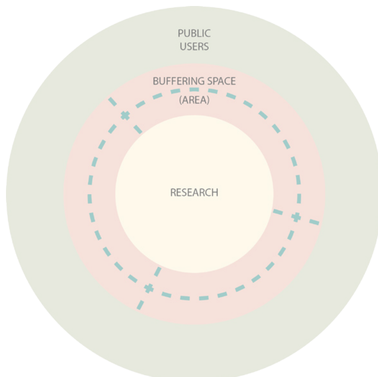


Fig. 25: “Water storage”, collage

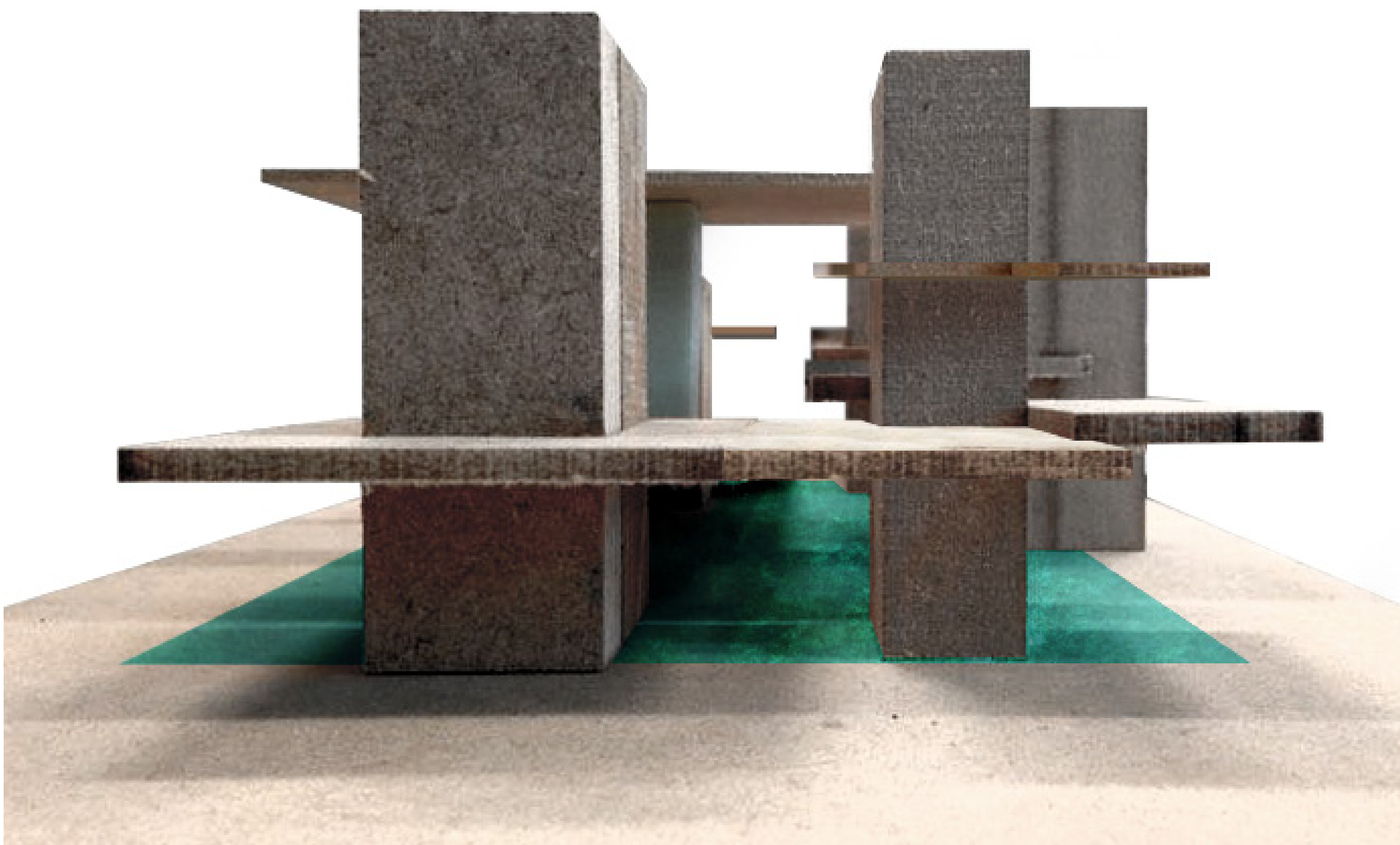
Fig. 26: masterplan

1. Waterfront
2. Water storage
3. Leisure
4. Water flow
5. Marshland
6. Woods
7. Building
8. Water turbines
9. Parking
10. Wave machine pool
11. Main square
12. Ice skating
13. Experiments Hangar
14. Pool/Diving
15. Willow forest

PROGRAMME

The Water Management Think-Tank's programme occupies around 10.000 sqm and expects an average of 800 – 1000 visitors per day. Its proximity to the Kinderdijk and to cities like Dordrecht or Rotterdam makes of it a point of attraction for many activities to collide.
As previously mentioned, the programme extends to the entire area creating a synergy between the latter and the building itself, with the aim to provide an entertaining and relaxing experience to reach as many people as possible.
The functional organization of the Think-Tank goes according to the different stages of water management mentioned in the first chapter: flood risk assessment, land use planning, control and re-assessment. Therefore, the staff is composed by a wide range of experts: geologists, mathematicians, water boards, architects, engineers, landscapers and so on.
In order to generate more interaction between professionals, many of them work on several stages. By doing so researchers are not clustered in only one sector and are aware of the work of their colleagues.
This strategy is reflected also in the organization of the working spaces. Indeed, space is structured as a continuous open plan on different levels (fig. 27). The only exception is made for labs or meeting rooms. Despite of that, even these spaces keep into account the importance of the interaction among people, researchers and water, by means of views and translucent or opaque materials.
As previously showed in the plan diagram, "buffering elements" filter the contact between researchers and users: people have the chance to experience learning activities such as the wave machine pool, combined together with surfing; a climbing wall (fig. 28) connecting outside and inside, allowing climbers to glance at the interior of the core to see its functioning; also, the underground level when flooded provides a place for many water related activities.
Furthermore, the open space facing the river, part of the pre-existing ship building, works as "convertible" space for events or open air activities to happen.

Fig. 27: sketch model



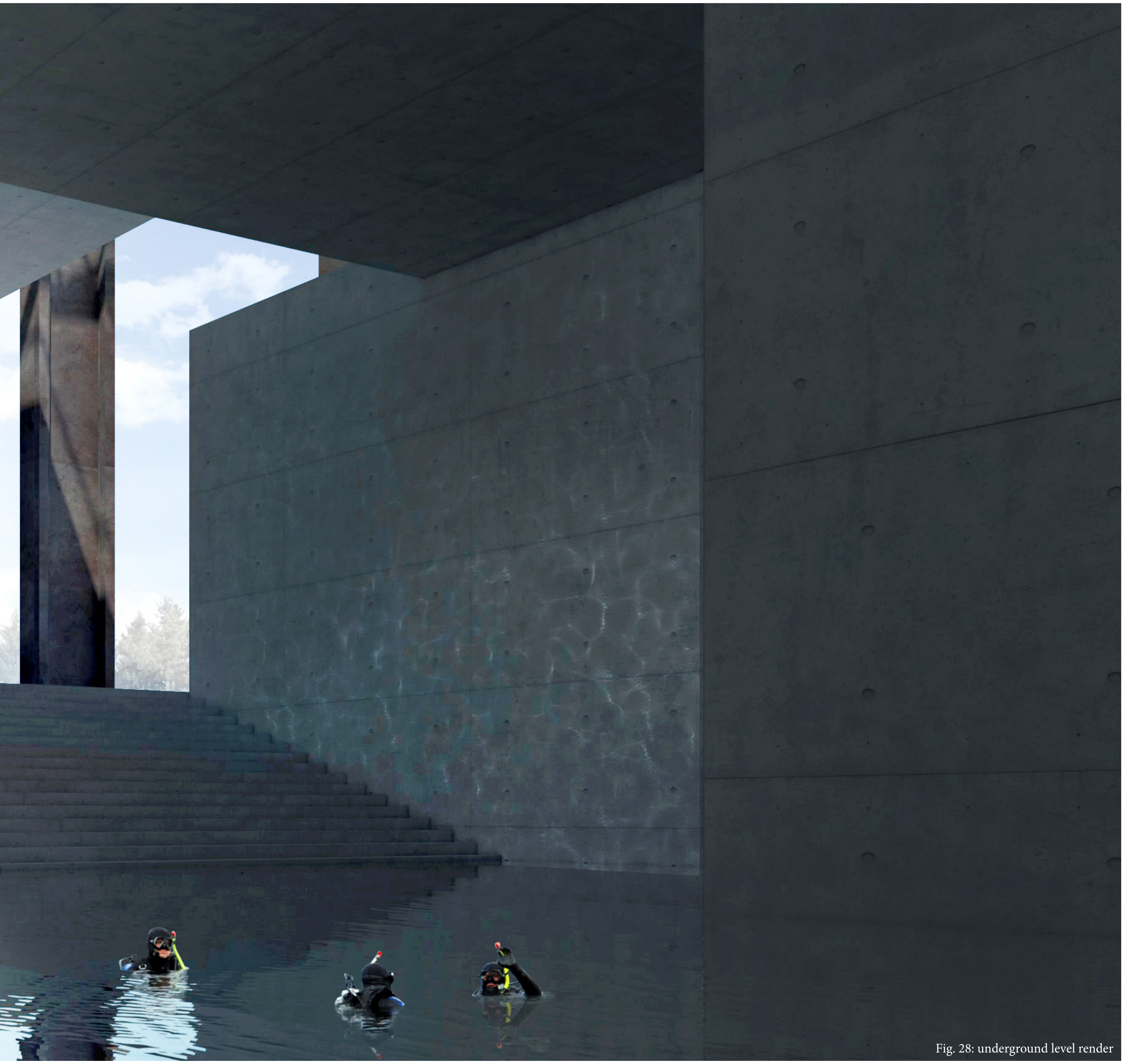
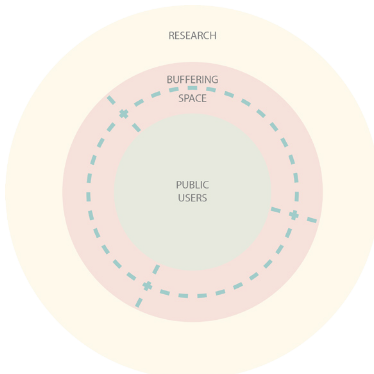


Fig. 28: underground level render



1. Event space
2. Conference Hall
3. Multimedia
4. Staff/Wardrobe
5. Reception
6. Foyer
7. Workshop
8. Underground square

9. Workshop
10. Offices

11. Green House
12. Laboratory
13. Cafè

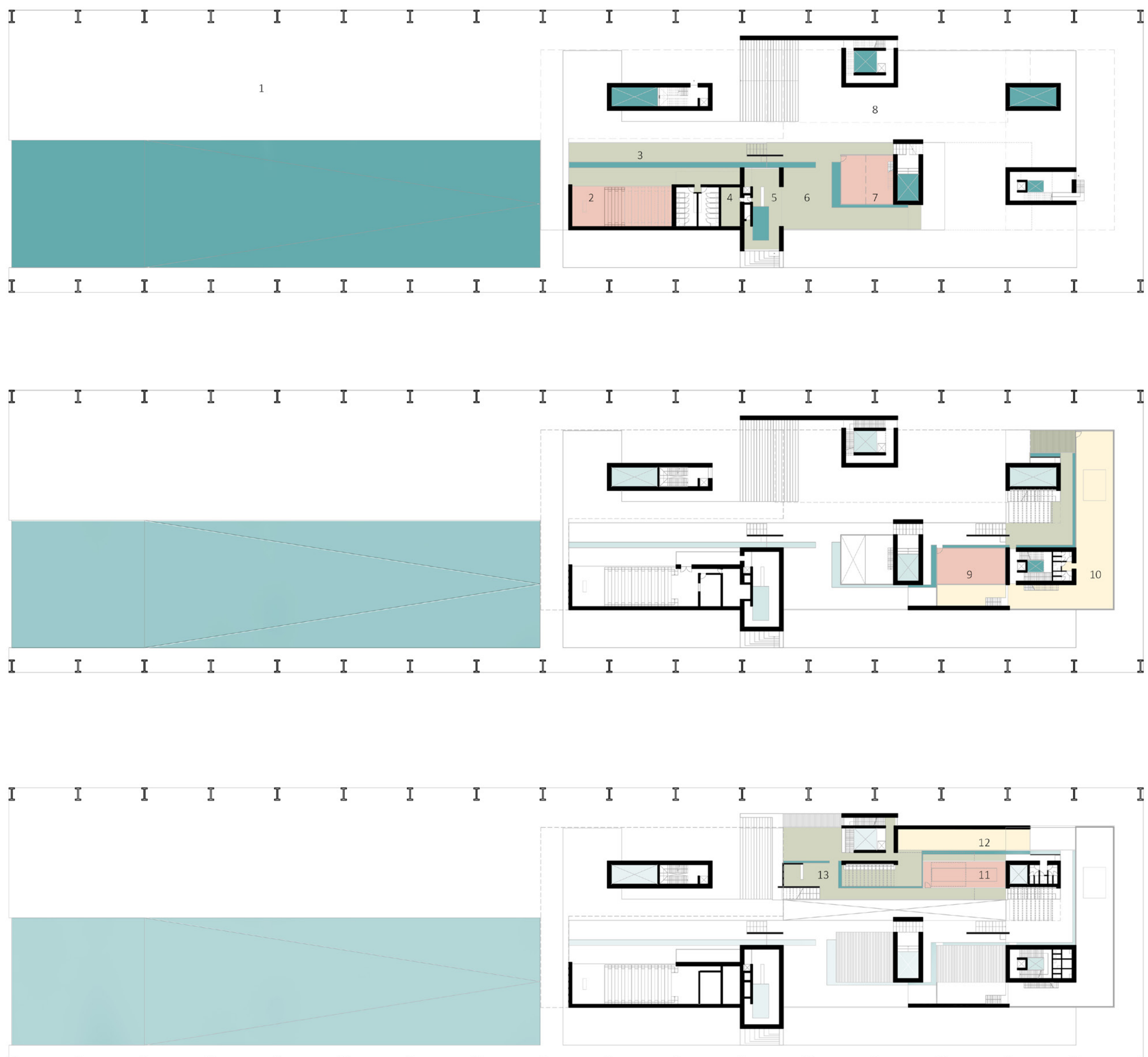
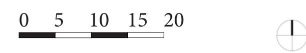
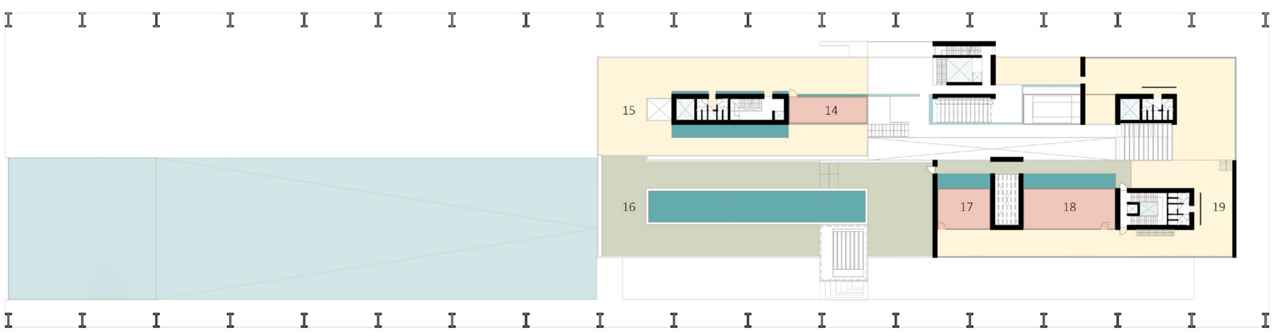
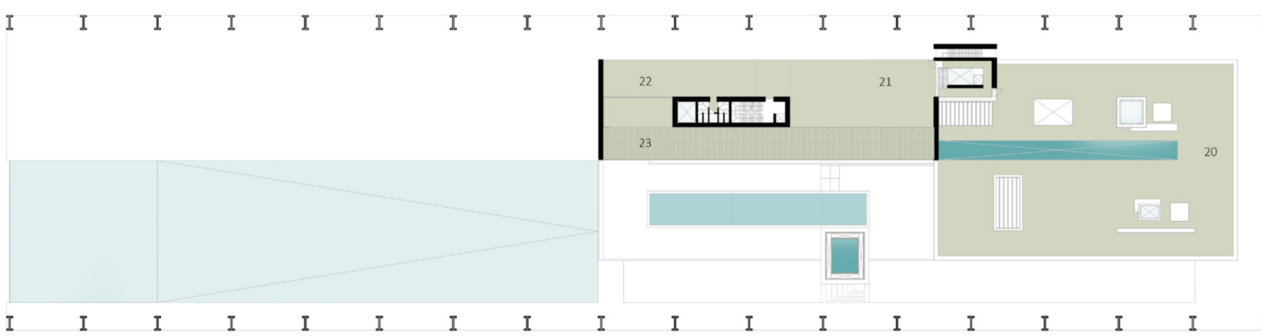


Fig. 29: functional plans

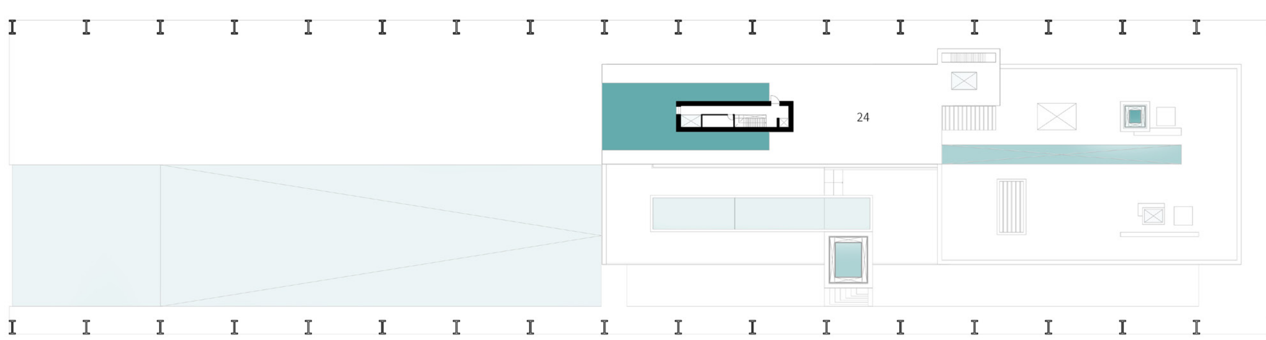




14. Workshop
15. Exhibition Space
16. Terrace
17. Laboratory
18. Workshop
19. Offices



20. Terrace
21. Reading/Lounge area
22. Restaurant
23. Terrace



24. Rooftop

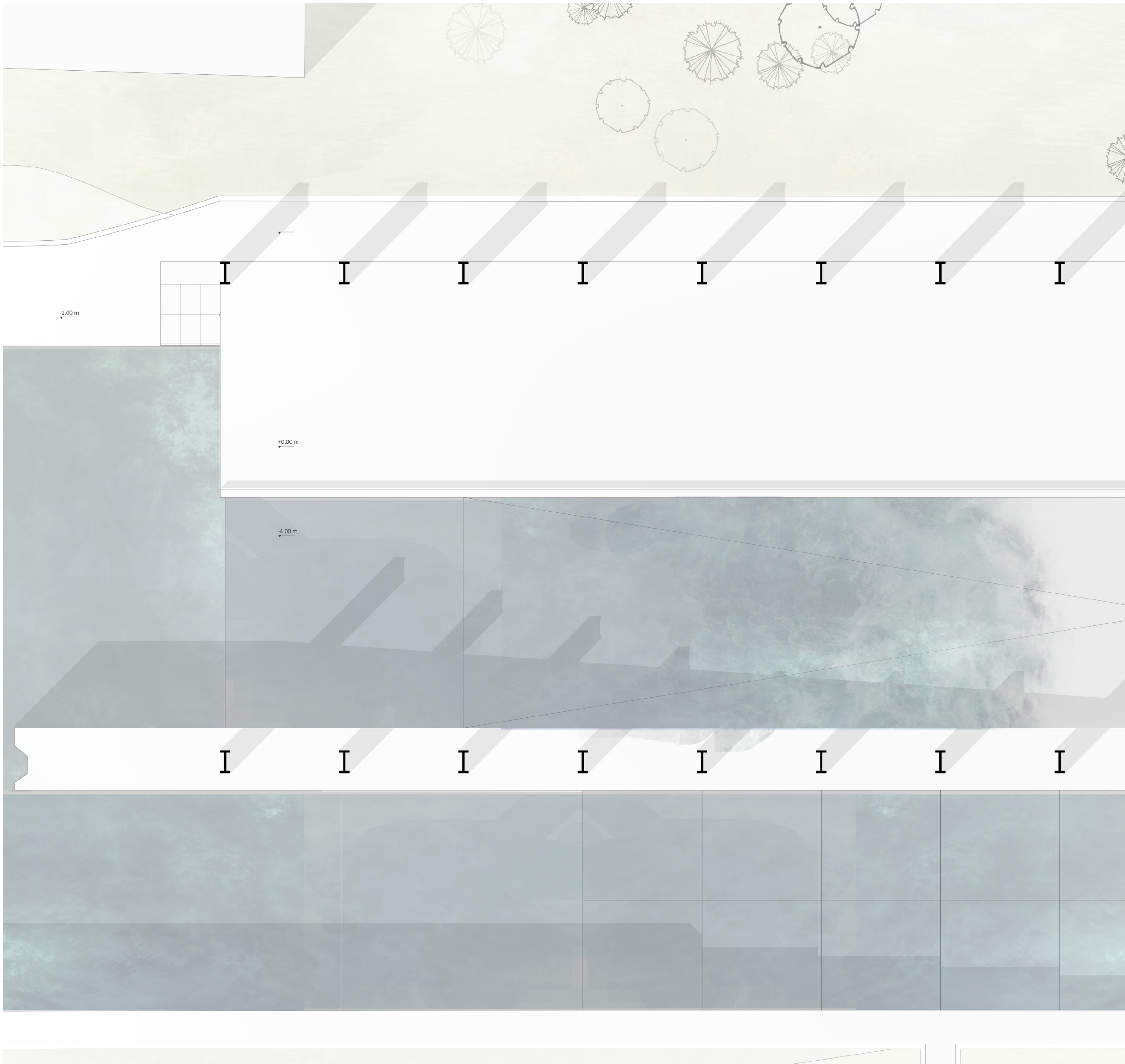
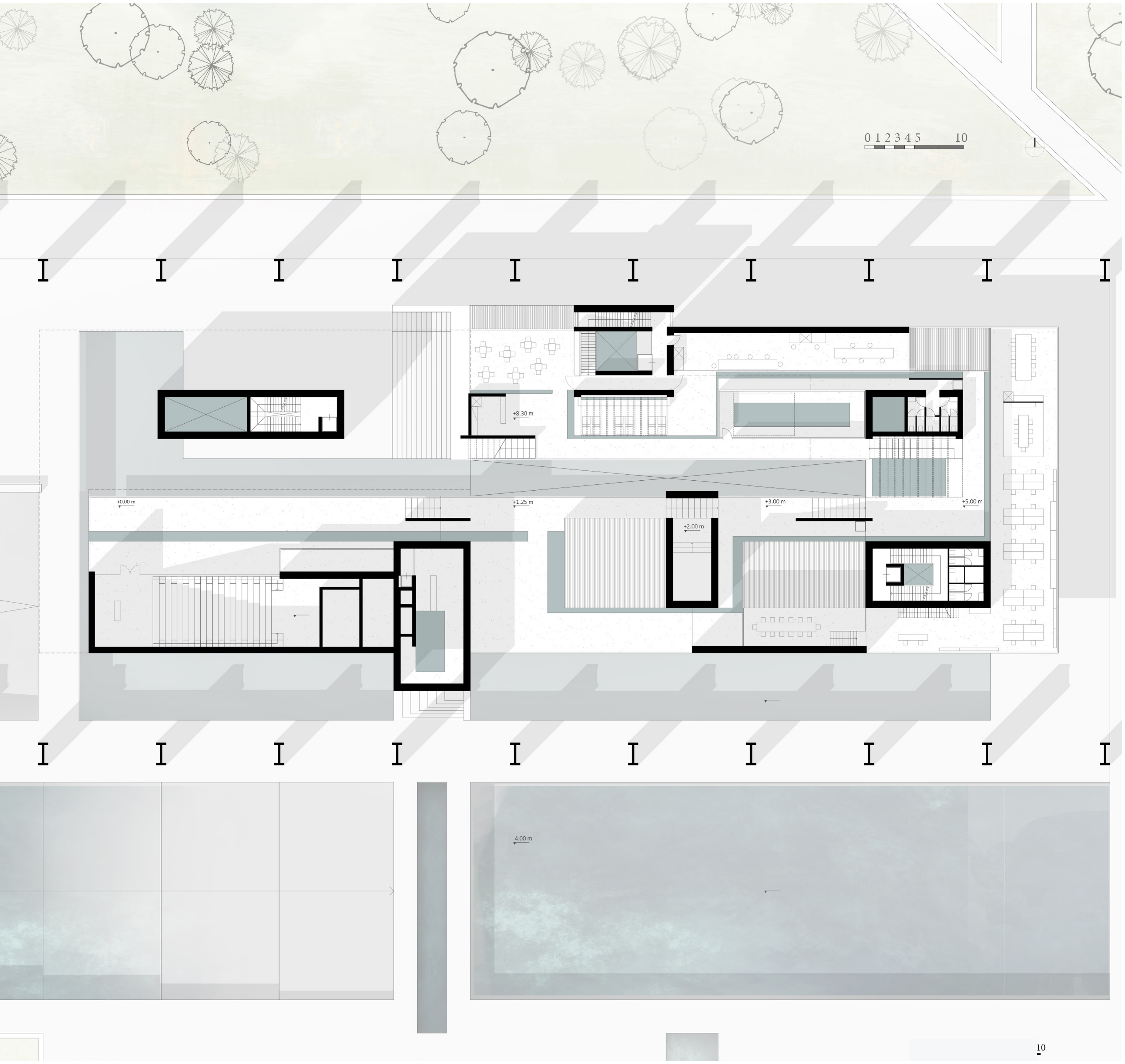


Fig. 30: floor plan


0 1 2 3 4 5 10
+8.30 m
+0.00 m
+1.25 m
+3.00 m
+5.00 m
+2.00 m
-4.00 m
10

SPATIAL EXPERIENCE AND ROUTING

Each core has its specific characteristic. Some of them work exclusively as water storage or mean to transport water vertically; some others help circulation throughout inside and outside space.
Starting from Louis Kahn's definition of servant and served spaces, the core element is designed.
It contains elements for vertical connections and services but it is, at the same time, a crucial component of the design. Cores represent a fulcrum, merging together functional and aesthetic qualities.
The access to the building is different for users and researchers. On the one hand employees may use two cores to get directly to their working spaces: the first one does not get in contact with public routing while the second one does.
On the other hand, users' access happens through the core facing the main square. Here is made use of a more formal staircase to point out its difference and importance.
Once entered, the main route begins, guiding visitors to discover the design. This path is a sequence of moments and interactions between levels. Space shrinks or widens providing an ever changing experience from the entrance to the top floors.
Hallways are almost missing. The main path follows the sequence of stairs that goes up to the higher terraced level where is possible to enjoy great views of the surroundings. Here are placed laboratories, overtopped by a glazed surface covered in water. Users interact with a space which rigour is interrupted by shining greenish polycarbonate boxes, pointing out the different activities.
Water management is experienced in many ways, such as lessons, workshops and multimedia. Exploring the building, it is possible to glance into these activities, into offices and meeting rooms, or, through "learning activities" to observe the design from a different perspective, interacting with it on a whole different level.
The upper levels of the building developed around the highest core, host a restaurant and a reading space with a terrace facing the main square. From this level is possible to access the roof, placed above 14 meters, which provides a 360 degrees view on the entire area and allows people to directly experience technologies featuring the design.
The core ends in a space filled with light and water reflection passing through a glass ceiling where water flows (fig. 31). Above, on the outside, a water tank is hanging, releasing the collected rainwater on the the skylight.
The space conveys towards its only opening, a window facing the river Noord, from which is possible to see Rotterdam and the surrounding environment. Also, a drop of 25 meters allows users to look down into the core.
A third terrace at 19.5 meters is reachable through this core but is not accessible to public.

Thus, water is what guides users. It points out buffering elements, directions and interactions with researchers. The stream carved in concrete changes in width, becoming narrower when users are supposed to walk or wider when they are meant to contemplate. Water is the tool that involves people to stop, observe and interact.

Fig. 31: core skylight

Sequence of spaces

Hereby is presented a sequence of spaces following a routing diagram (fig. 32). The intend is to explain the way users would experience the building, from the entrance to the top levels.

The main route users can walk, runs along the interior facade of the building. This way is possible for them to experience space in the best way.
Water flowing in the opposite direction, features this path. As stated previously, its movement and sound suggest visitors alternative itineraries guiding them in the discover of the design.

The first level, or "zero level" hosts a conference hall and a multimedia area (fig. 33). Here is possible to collect information and exchange them.
Walking towards the next floor visitors encounter a huge waterfall featuring the foyer of the main entrance (fig. 34). Ahead space shrinks in a narrow cut where a feeble light pours from above, pointing out the way towards the intermediate level of the building (fig. 35).
Here, a pond is filled with small boats that harness the kinetic movement of water turning on their light bulbs. Above, the ceiling lets light in, illuminating the water dripping on the wall of a core. In this point, where users and researchers cross their paths, it is possible to glance at the river Noord on the opposite side.
A concrete stair brings users to a sort of hallway.
Space shrinks again between transparent and diaphanous surfaces that extend up to the ceiling. The polycarbonate box on the right is one of the workshop, a buffering element (fig. 36). Inside of it, different types of plants, typical of the area, are grown, and can be observed and studied.
Out of the "Green Workshop", the building widens in an open space filled with light. A waterfall flowing on a huge concrete wall dominates the café, capturing the attention of users and characterizing the environment (fig.37). This core connects with the "tech-terrace" and it is used both from researchers and visitors to move fast through levels.
From the café the open plan extends towards the exhibition space (fig. 38) located on the only one concrete slab which is completely cantilevered and hanging on the highest core. Here, the continuity of the polished concrete floor, blurs the distinction between inside and outside space.
On the outside a terrace features suspended water tanks and a long pool that looks like reaching out towards horizon and the nearby river (fig. 39)
From this outer space, users can access again the building and glance into the more formal and intimate atmosphere of the labs (fig. 40), completing the tour of the building.
The levels above the exhibition space are detached from this main route on purpose and have their own access. This way is still possible to use them even when the building is closed. A terraced restaurant and reading/relax area (fig. 41) are placed on this floor and are directly connected with the tech-terrace (fig. 42)

researcher
user
point of view

Fig. 32: routing diagram

Fig. 33: conference hall and multimedia space

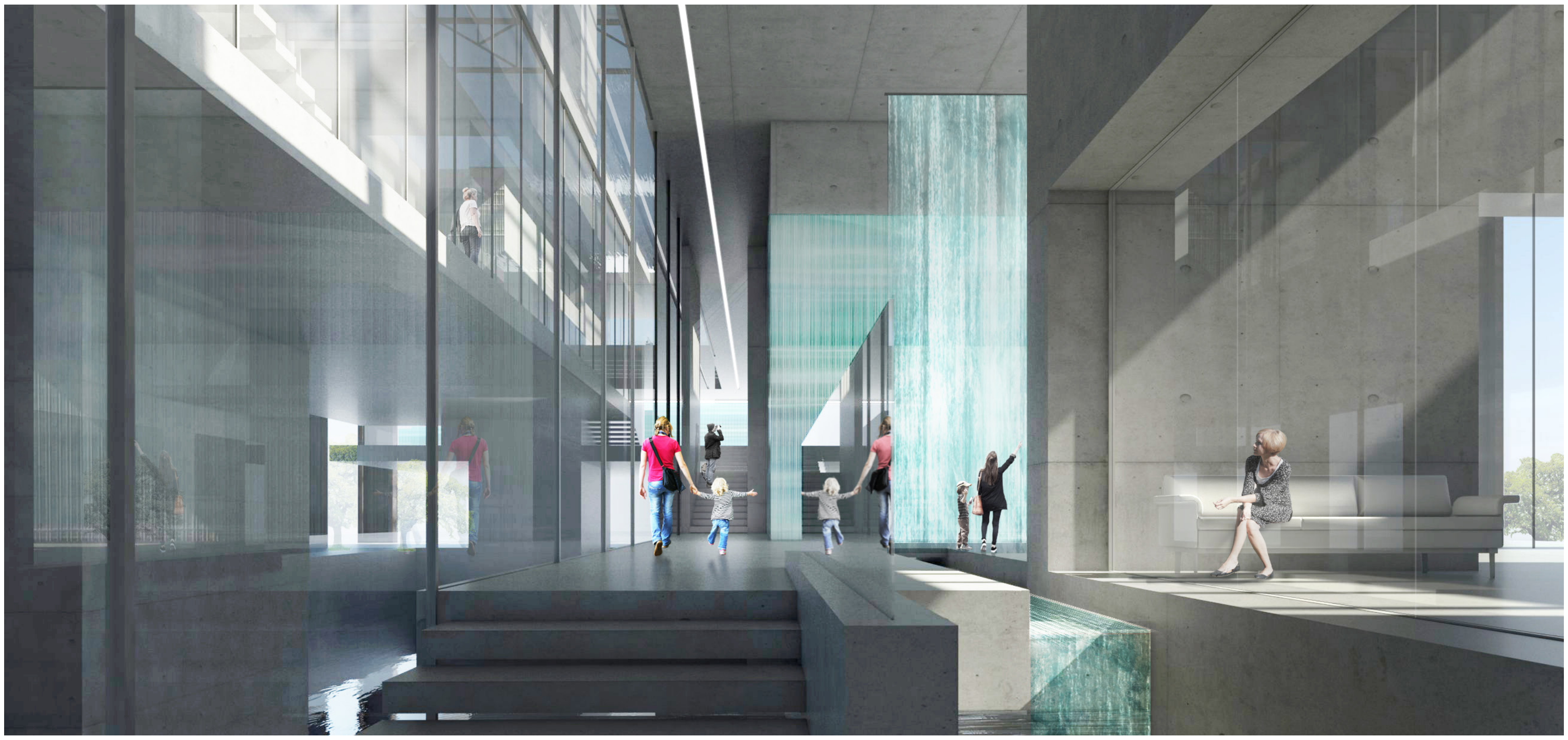


Fig. 34: foyer

Fig. 35: intermediate concrete slab towards
the river Noord.

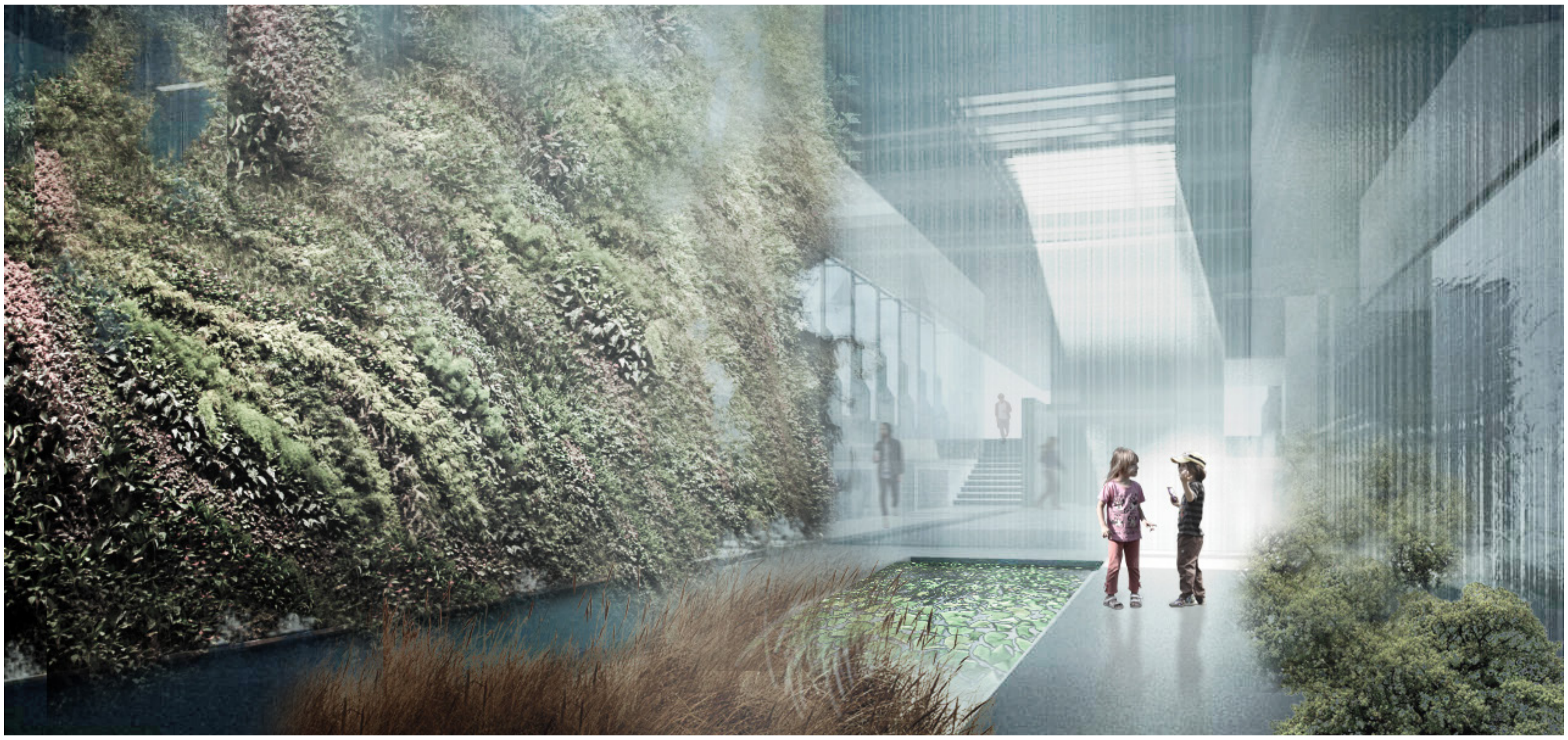


Fig. 36: “GreenHouse Workshop”

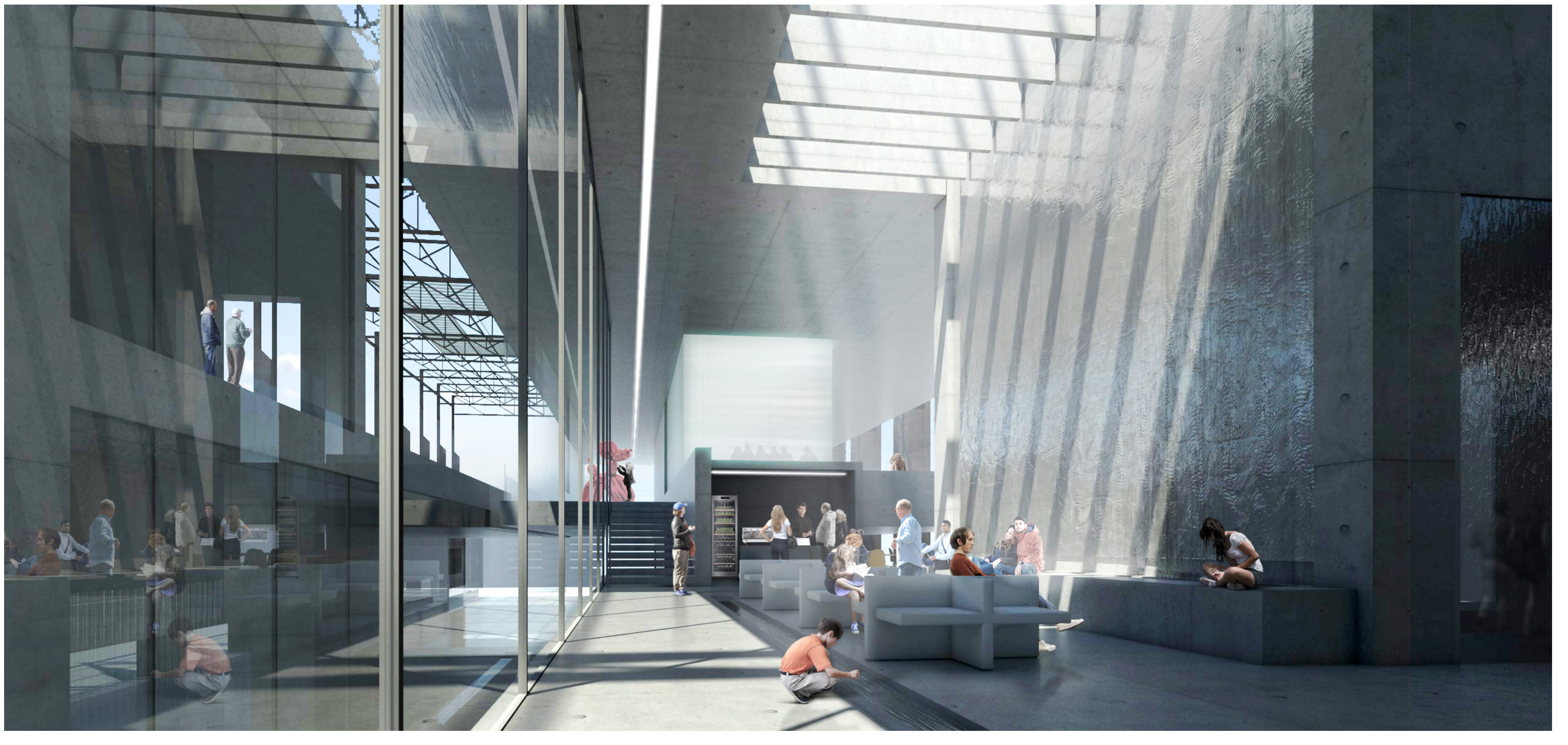


Fig. 37: café and lounge area.

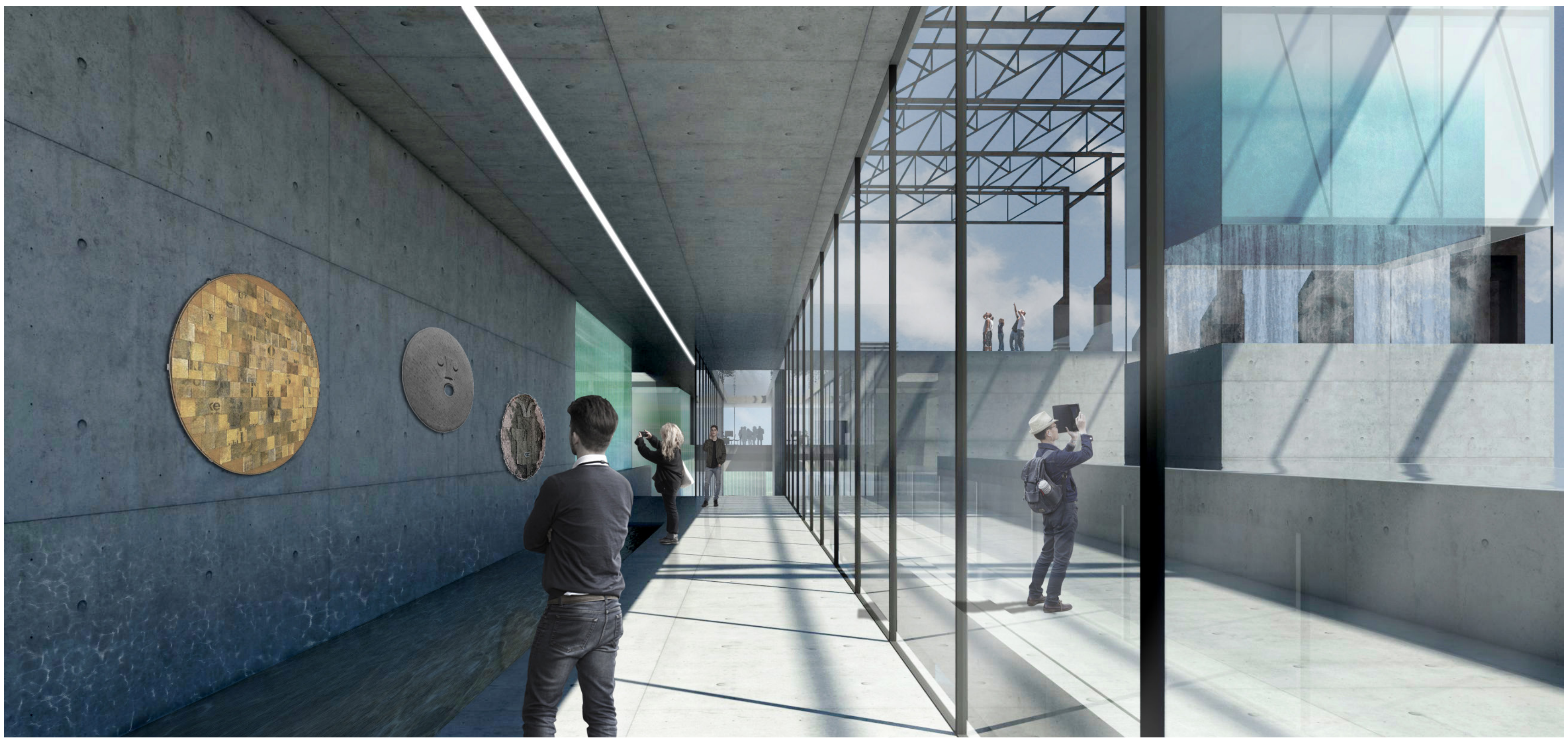


Fig. 38: exhibition space

Fig. 39: exhibition space terrace.

Fig. 40: laboratories

Fig. 41: restaurant and reading space terrace

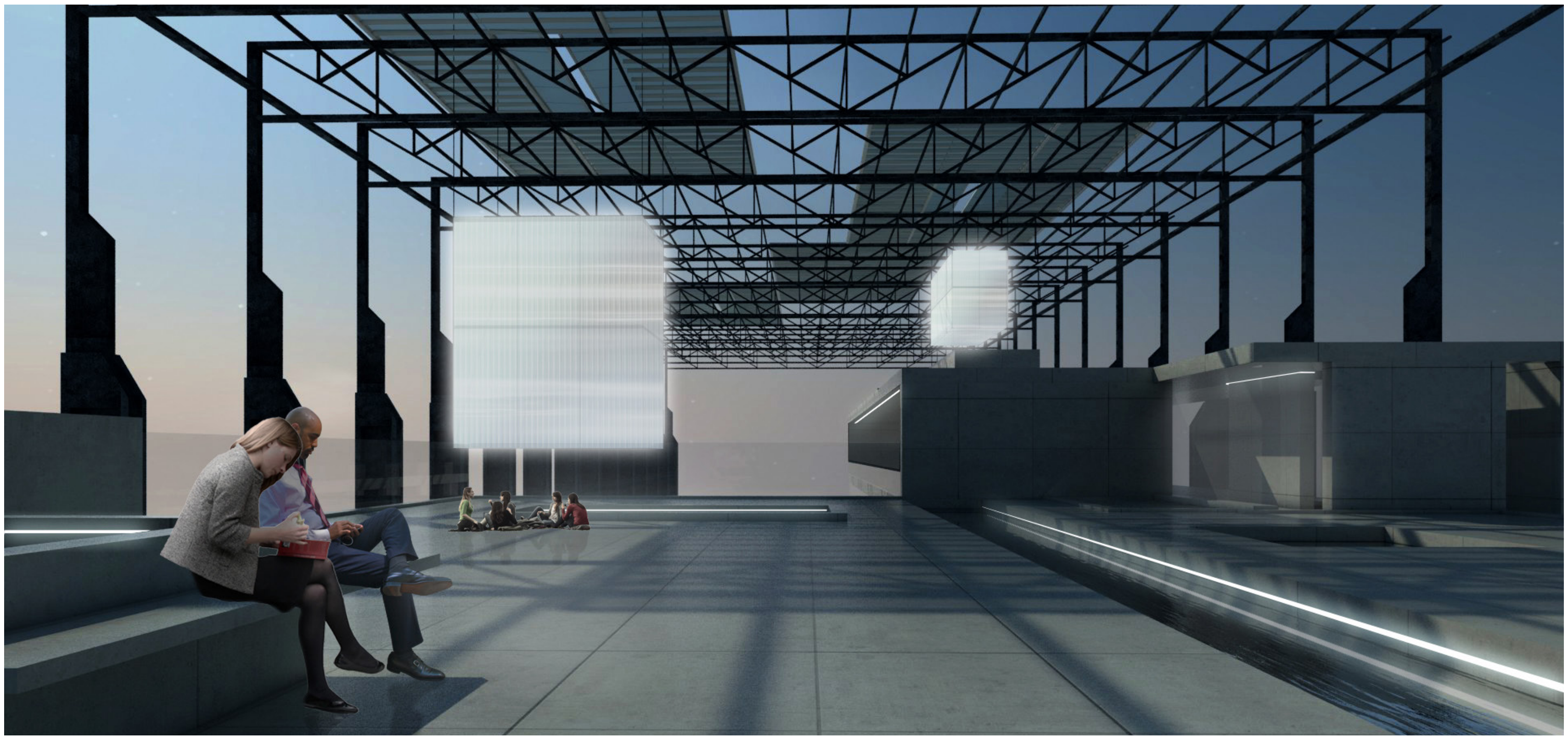


Fig. 42: “Tech-terrace”

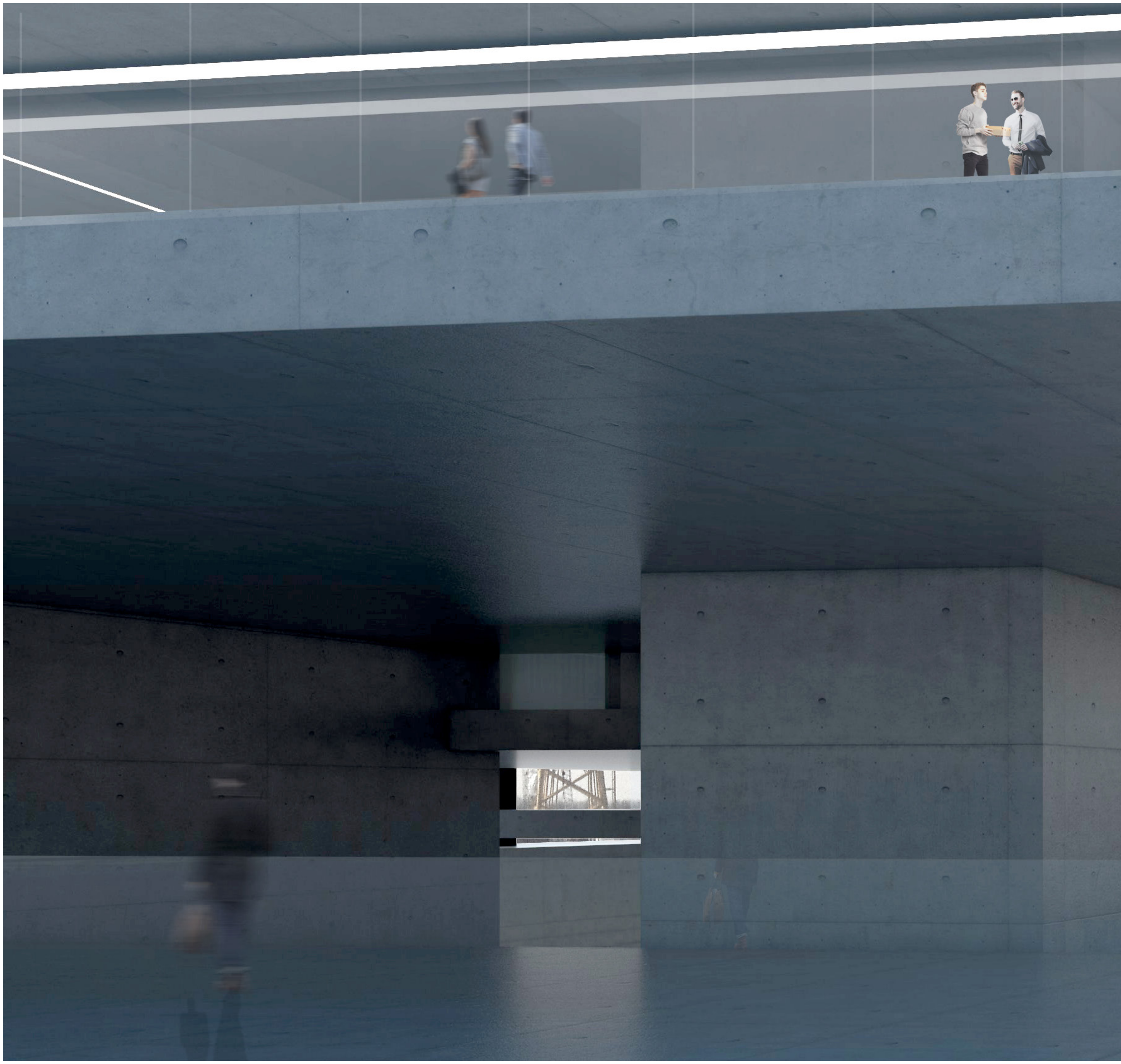
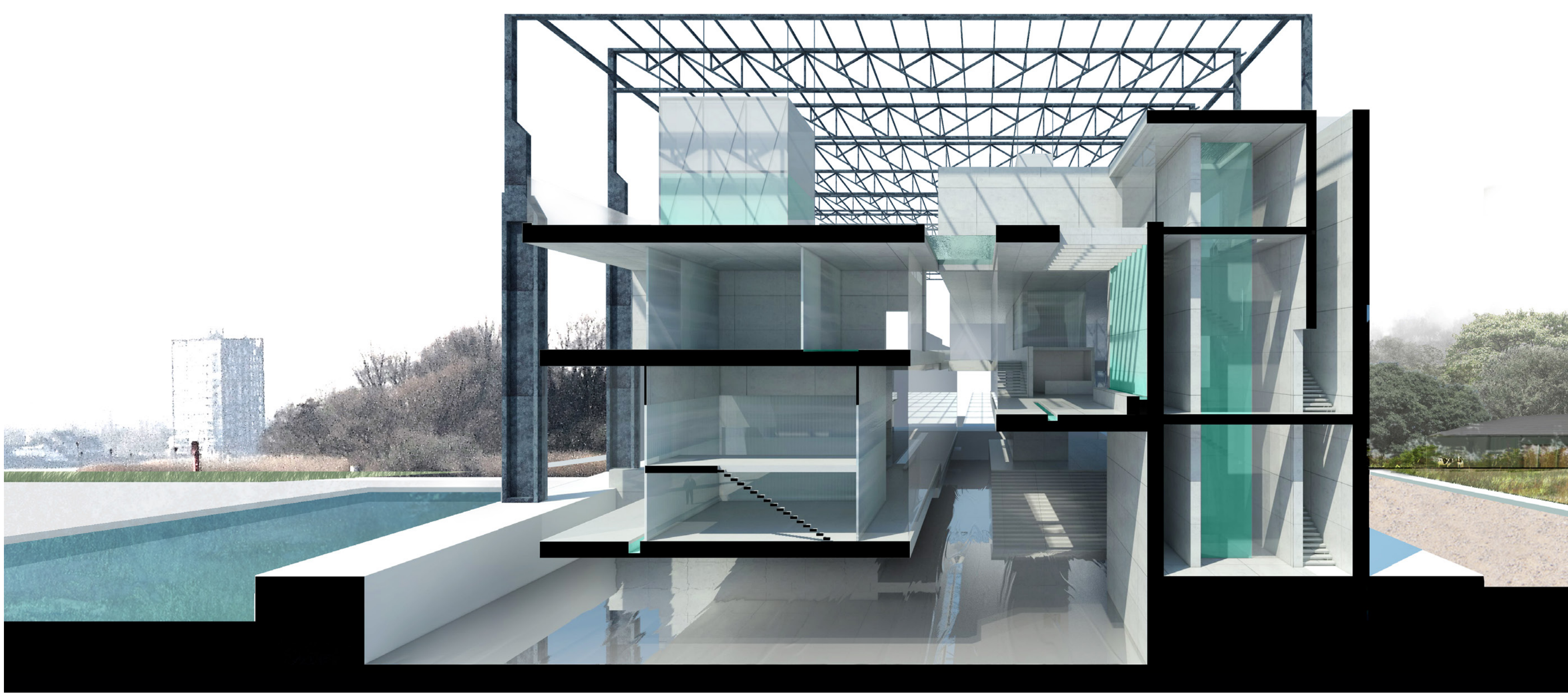



Fig. 43: view towards the river/researchers' access



SPATIAL QUALITIES

Old and new

By now, it is clear the significance of water in every single aspect of this project. Once again, it plays a crucial role in defining the spatial qualities and composition choices. Once again, water is the connector between old and new. The will of keeping the pre-existing building lies in its capacity to ease the contact with it: it represents an "organism" co-existing with water, which aim is now to drag it towards the "new" where its movements are structured around horizontal and vertical axis.
This process, the water cycle, is fundamental for the resilience strategy and is translated into architectural language: indeed, the steady and calm rhythm of the steel structure resembles the incessant course of water, while the new building, featuring an articulated volumetric game, declares the complexity of the water cycle happening inside of it (Fig. 44).

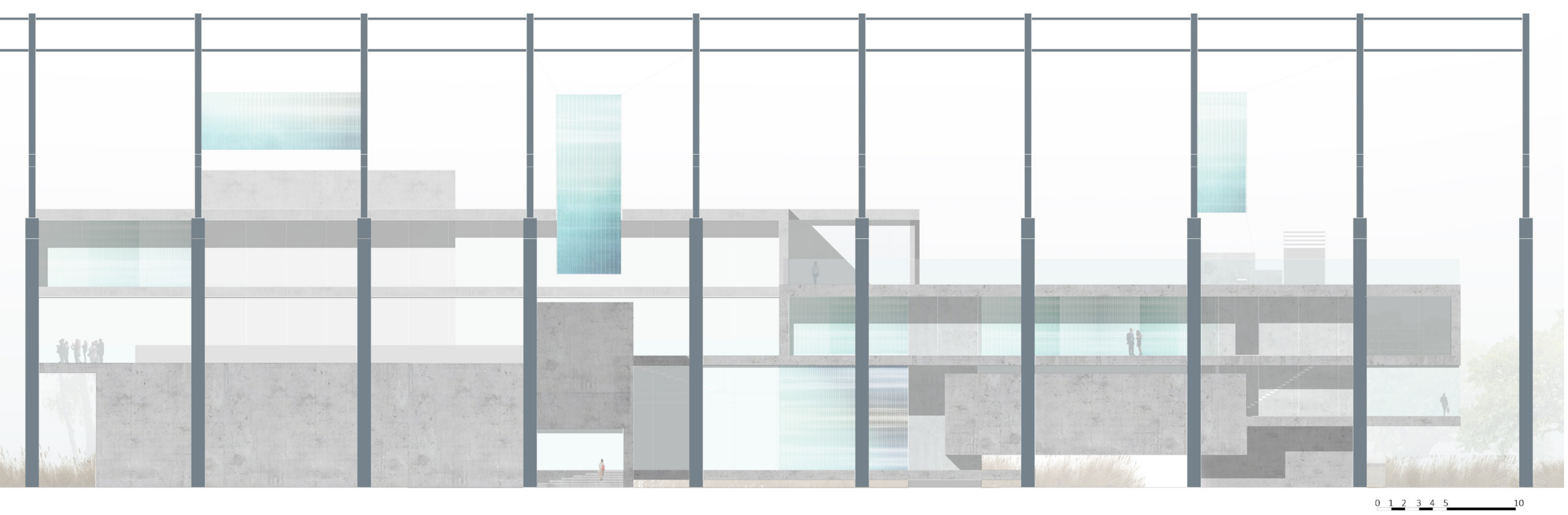
Therefore, there is no structural connection among the two, but it is clear their exchange in terms of proportions, visual interactions and contrasts between heaviness, complexity and horizontal development of the concrete volume and lightness, clearness and soar of the steel structure.
The latter is a buffering element, filtering the contact between area and research, and reference to the industrial context in which the programme integrates with all its features. Scale, proportions and materials land a sense of bigness to the structure. This immense nave is now unveiled to users and observable from new points of view provided by the new design.

Fig. 44: perspective section

North-east facade


0 1 2 3 4 5 10

South-west facade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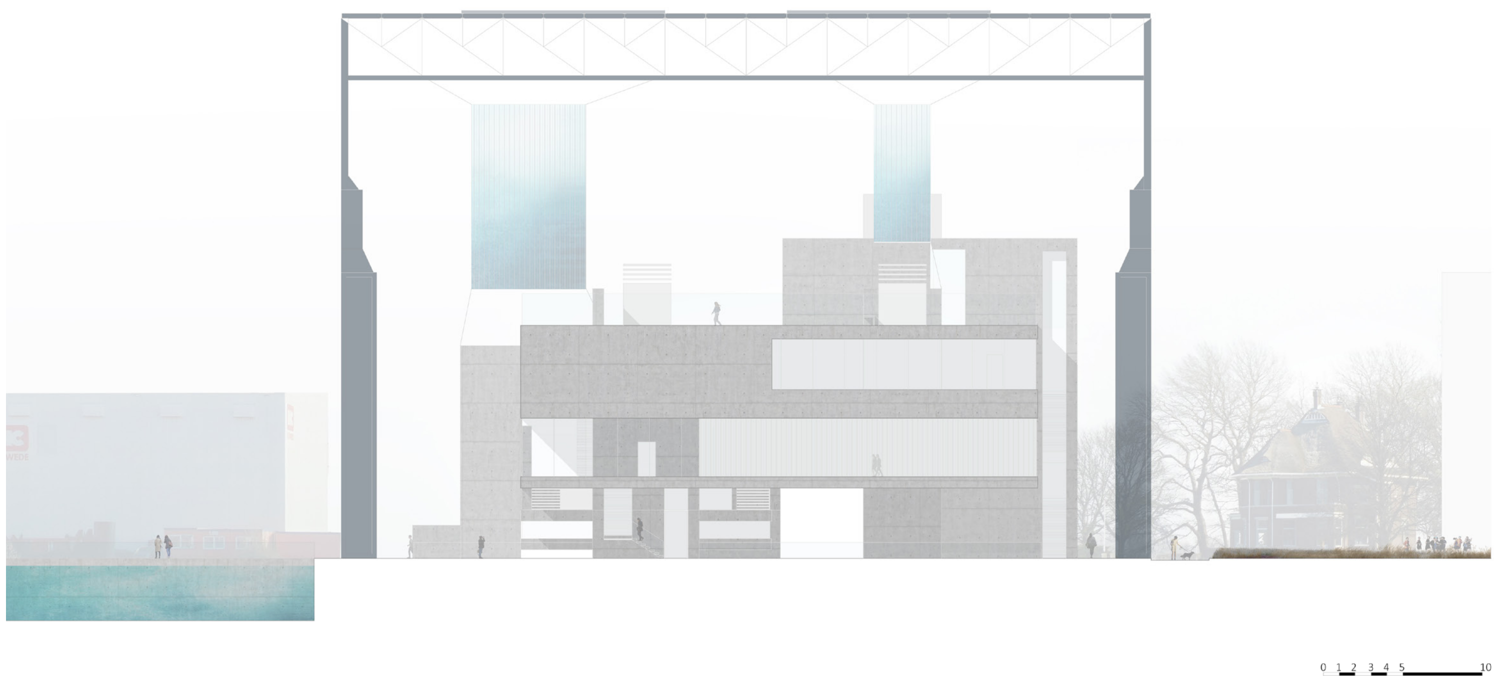
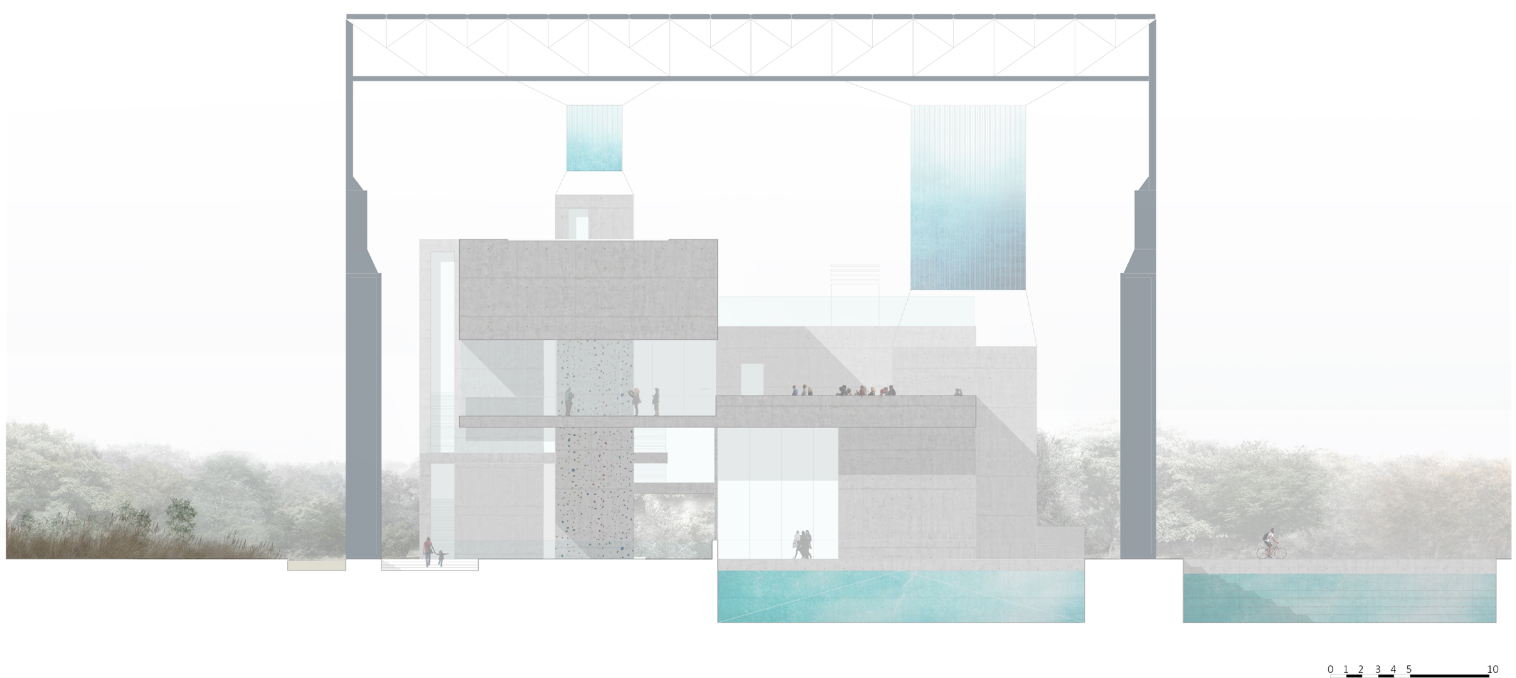


South-east facade



North-west facade

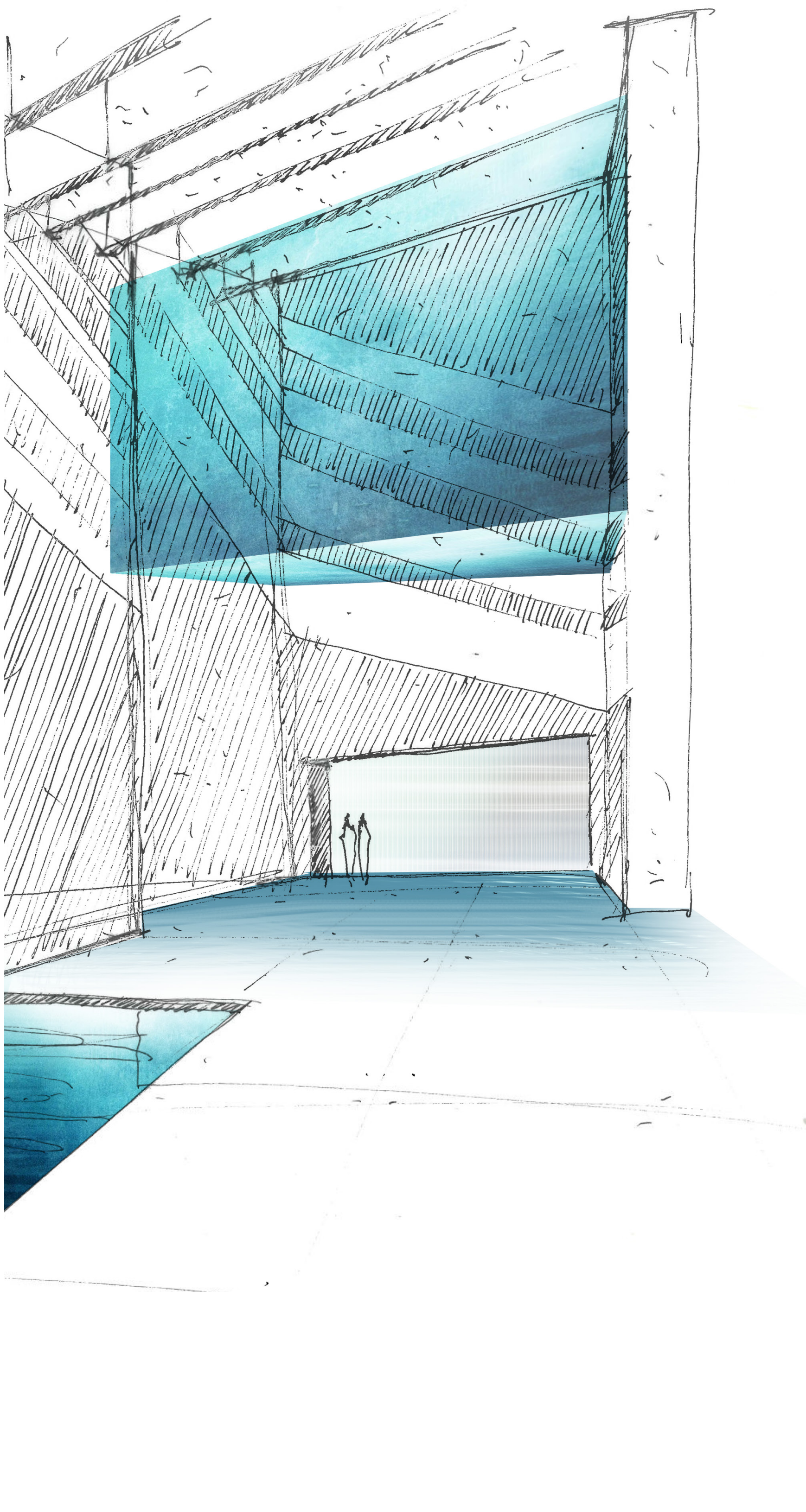
Complexity and contrast

The Water Management Think-Tank stands out for its solidity and strength inside of the steel envelope. Floors appear as thick floating layers overlapping each others, landing tension to the mass of the building.
These cantilevered elements play with the cores, creating enlargement or contraction of space, thus visual interactions among levels placed at different heights. By doing so, users are witness of a continuously changing spatial experience.
Wide glass surfaces overlap with polycarbonate panels altering the transparency of space, holding or releasing light, to let users and researchers interact between themselves and the design.
By means of views and openings viewers are constantly experiencing the presence of the outside steel structure, that helps them gain in awareness of the proportions of space. The latter are stressed by the 80-cm-thick floors, connected by a thin glass that looks like is bearing their load.
Precisely on these contrasts the aesthetic language is based: continuous or syncopated rhythm, vertical and horizontal axis, heaviness and lightness, opacity and transparency.

Water is a constant. It runs throughout the entire building bringing it to life and shaping its spaces.
The terraced development of the plan, composed by progressively higher levels, allows water to flow from higher to lower heights landing dynamism to architecture.

The experience provided to users is reach, not only in terms of views and light but of soundscapes as well.
The noise of water features architecture entirely, adding one more dimension to perceive and experience space.
The calm rustling coming from the stream, the calm dripping on concrete walls and waterfalls used as walls all contribute to enhance the spatial qualities and stress the importance of water as leading element for the design.

Water is not just a “threat” turned into utility or benefit, but has finally become part of an architectural vocabulary.



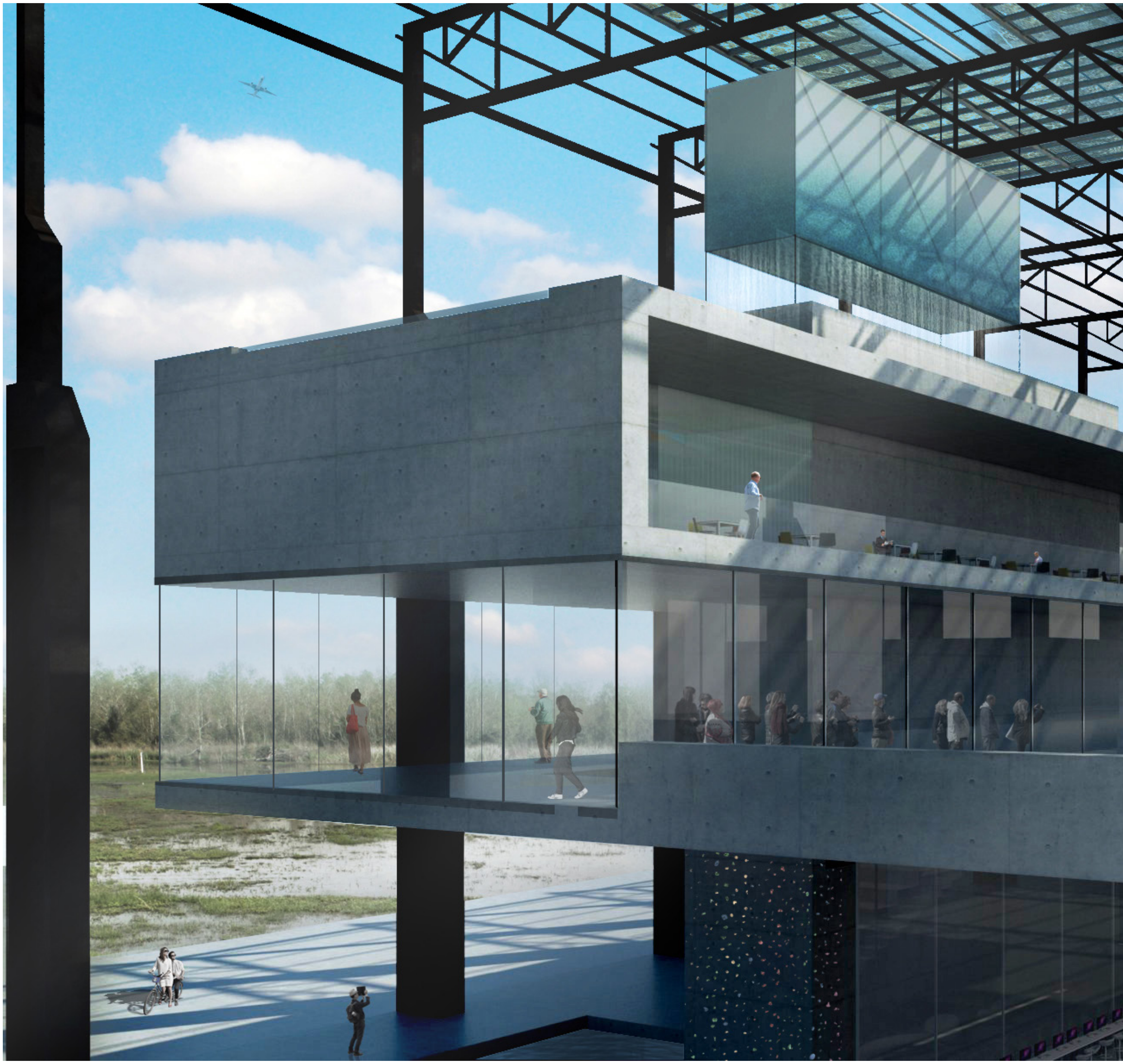
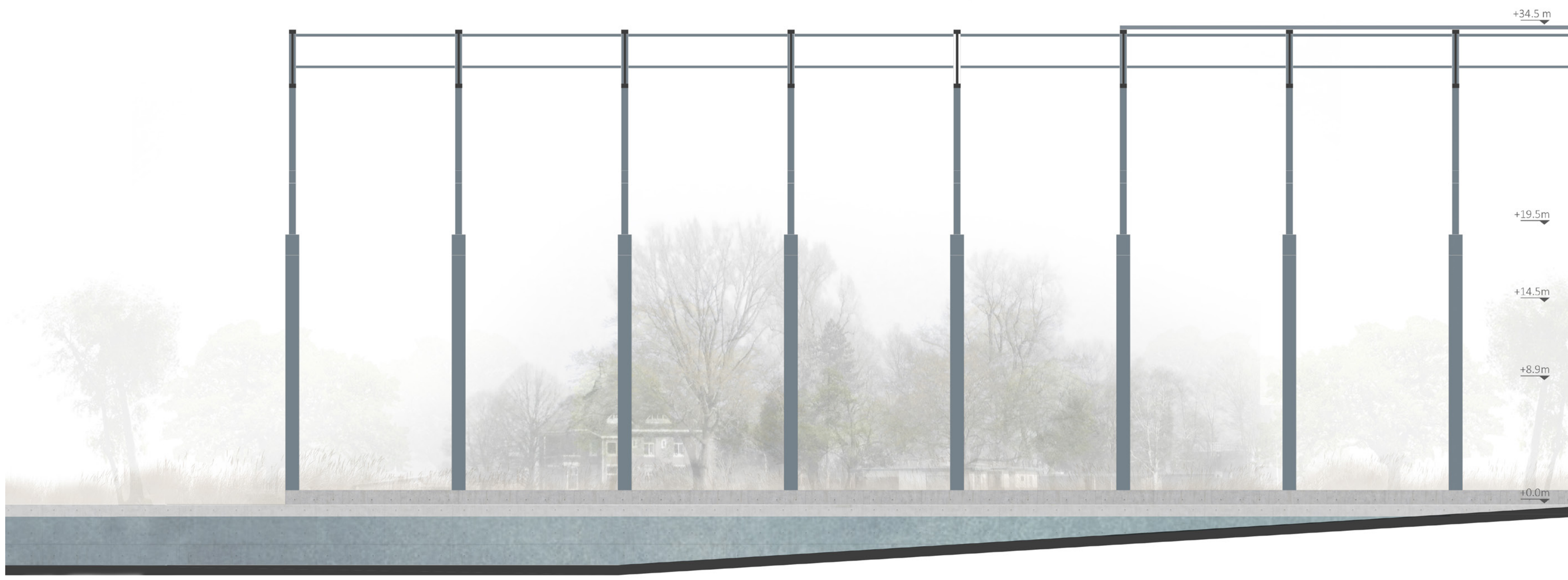
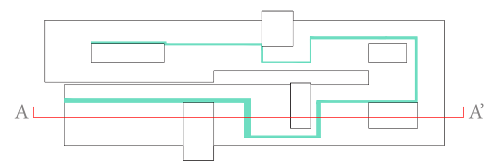


Fig. 45 : view from the river



Section A-A'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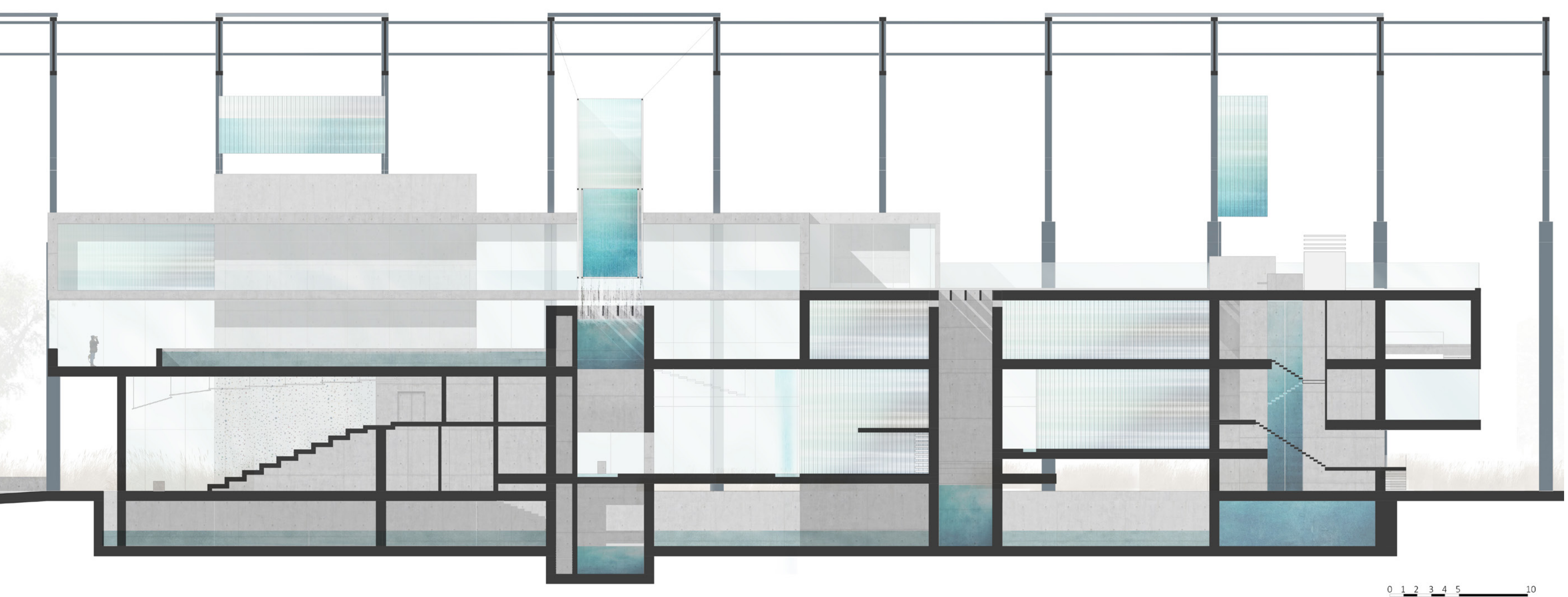
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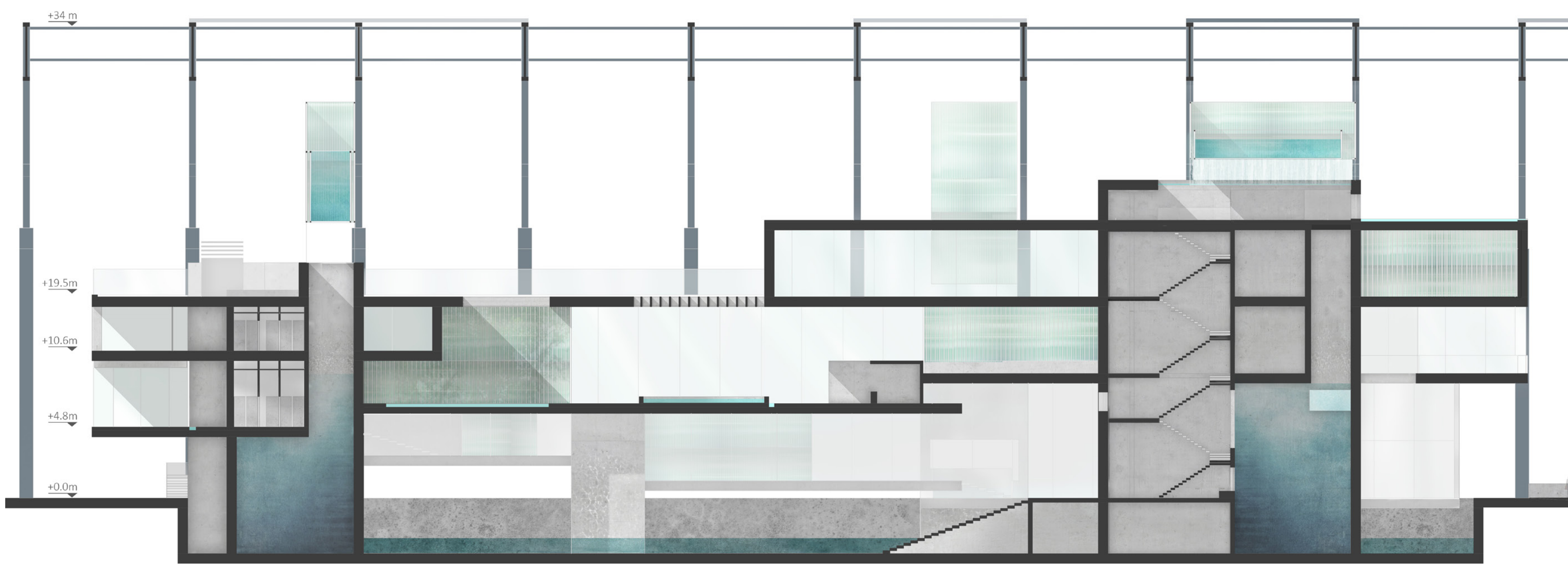

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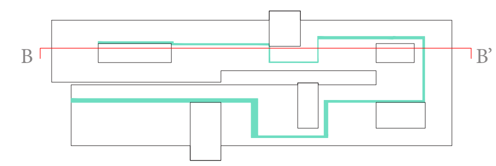
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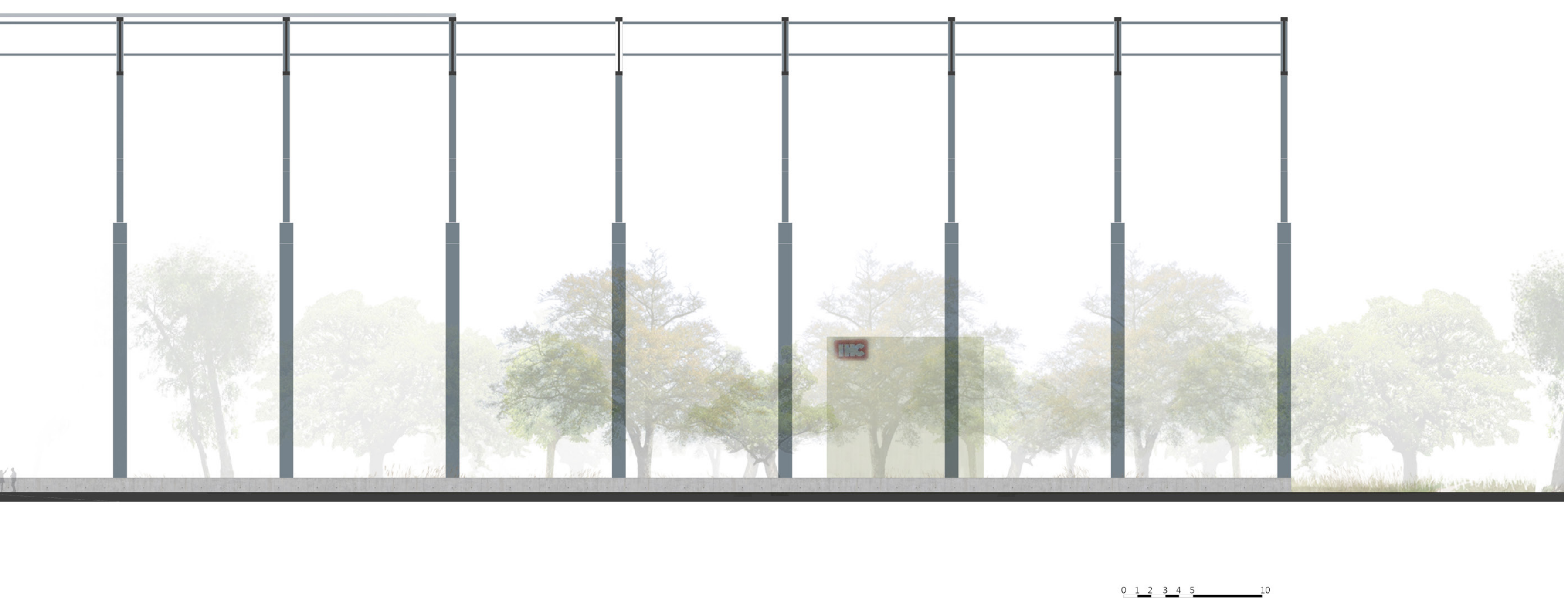
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Inside and outside

The building provides users with a new point of view towards the surroundings. It is the fulcrum of the area from which is possible to observe the complexity of the environment and comprehend the interactions between its layers.
Therefore, exchanging with context is a matter of primary importance. This dialogue happens through the use of primary elements such as water or biodiversities featuring the location, becoming object of study and tools to create architecture.

The Water Management Think-Tank integrates in the context whilst declaring its unusual nature. It is clear what is pre-existing and what has come at a later time.
Again, complexity and contrast rule the design, establishing a synergy that connects all these aspects. Thus, the relationship inside/outside becomes relevant.
The internal space is defined by a transparent glass envelope. The six cores are placed in between the two realms, holding floors that slowly cross space. In some points the slab continues beyond the envelope, which blurs the distinction between internal and external space.
The inside recalls the concept of "rhythmic space" by Swiss scenographer Adolphe Appia. Space is precisely three-dimensional and abstract. It develops in a statuary scene made of big stereometric surfaces, structured on vertical and horizontal planes where the only oblique line is traced by stairs. Even their unconnected steps let the outside flow into the inside.
The building lets the eye penetrate through it into the surrounding, becoming part of a whole.

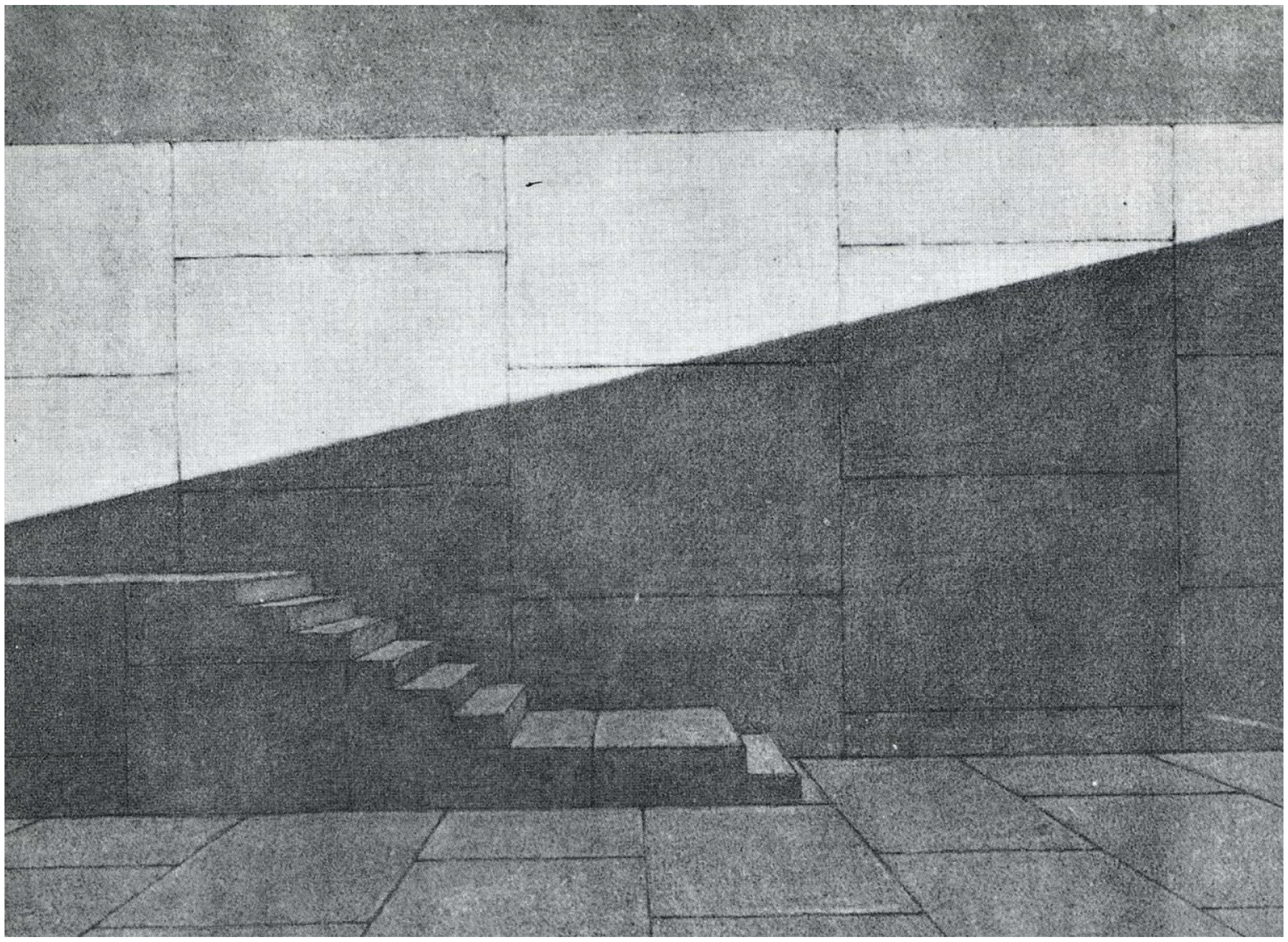


Fig. 46: “Rhythmic spaces” A. Appia

Materials and light

Glass, concrete, steel and polycarbonate are used as the primary materials to create complexity through a simple language.
Concrete expresses solidity, weight and solemnity. It is the primary material in the construction of these spaces and presents rich spatial expressions in conjunction with water and natural shadows. There is no ornament in composition or superfluous decorations so that the building can reveal its simple geometry (fig. 47)
Furthermore, the steel structure wrapping the new design, becomes an element lending character and richness in composition to it. The void it generates, is filled on the interior by the new mass of glass and concrete.
The latter is also used as homogeneous surfaces to let light beams fall across it, dramatizing and enriching the spatial experience. Thus, light is used as a connector of space and form [14].

[14] T. Ando (1990)

Daylight pours down from above, landing interiors a quiet and sacred atmosphere. This character is stressed by the presence of water, mirroring images and casting a mosaic of reflections on the spare concrete walls.
The widening and shrinking of space affects the way light diffuses. Narrower spaces produce darkness, thus a sense of uncertainty of not being able to see. Yet, light, contraform of shadow, guides users through a complex space of polished concrete floors and grey concrete walls.
A three-dimensional canvas for the play of light and shadow, spaced out by frosted glass and polycarbonate surfaces.
Wide surfaces liberate light, taking the distance from the concept of the conventional "opening" that pierces the interior of architecture, catching the movement of light with precision. Despite of that, the primary source of light of the inner space is given by skylights, breaking the continuity of the huge concrete slabs. This, combined with recesses in the facades, allows to filter light and not to let it scatter ineffectually and be lost in an homogeneous light, devoid of darkness.
The openness of space becomes a point of strength, allowing users to feel its power and experience the effects of sky, light and water on the concrete.

Fig. 47: core

STRUCTURE, MATERIALS AND DETAILS

A sequence of eighteen portals, covering a span of 50 meters and placed at 12 meters from each other, becomes a landmark in the masterplan of the former shipyard, and, as previously mentioned, a buffering element.
Its 1-meter thick columns have a length of 2.5 meters and get thinner on the top, where a structure of steel trusses extends from one pillar to the other.
The new design is contained inside of this steel cage. Here, the six cores rise as towers, reaching out towards the outer structure.
These concrete blocks are composed by a load bearing structure recalling the "wall-frame" technique [15]. This envelope is composed of 80-cm thick precasted concrete walls, and bears the weight of six alike concrete slabs, of which one is cantilevered on both sides for 12 meters.
Due to long spans, precast prestressed concrete is used. The same reason led to the use of hollow core slabs for floors. Indeed, they offer high durable units and fast erection of long spans.
Many are the advantages of this prestressed structures. For instance: extended length without central supports, can be easily changed to include electrical wiring, plumbing and other facilities within the building. Thus, avoiding a floating floor that might attenuate the sense of solidity while walking on it. Furthermore they can provide ventilation throughout the building, have excellent fire resistance and their voids act as insulator for sound as well.
On the other hand, non bearing walls, are composed by an outer layer of precast concrete and a structure of concrete panels on the inside. The space in between is filled with thermal and acoustic insulation plus a cavity for installations and pipes.
The choice of concrete was due to different reasons. Water was for sure the main one. Indeed, the constant relationship and contact with it, made necessary to pick a material able to resist water throughout years. Obviously, changes in the appearance of the material over time are taken into account.

[15] K. Elliott (2002)

As previously mentioned in the "Complexity and contrast" paragraph (Chap. 7.2), the relationship between steel structure and new building is mainly visual. Despite of that, a connection is necessary to create a continuous water cycle throughout the entire project.
Indeed, the pre-existing structure provides a gigantic surface to harvest rainwater. In order to make use of it, a secondary thin structure of steel is laid on top of the old one to provide stiffness, and combined with polycarbonate slabs to direct rain towards collection points. From here water is let fall down into cores or rooftop's ponds to be harvested and re-use for building performances.
Nevertheless, the drop from the harvesting slabs to the core is too high. An average of 11 meters separate them. Thus, due to strong winds, it would be impossible to move water without wasting it.
To solve this problem polycarbonate tanks for rainwater harvesting have been designed. Their function is to reduce the water drop up to only three meters, providing more room for rain and minimizing waste. Oblique steel cables, connected both to steel structure and concrete core, hold these tanks and shall prevent them from swinging. In the end, a system of bulkheads design within the tanks allows to control the amount of collected water.

These "boxes" provide the joining link to close the water cycle. One more time, the accent is put on the role of water as a connector. In this case through its fall, it visually conjoins steel structure and building, thus old and new. Furthermore the properties of polycarbonate create interesting plays between light and water, turning the tanks into floating landmarks.

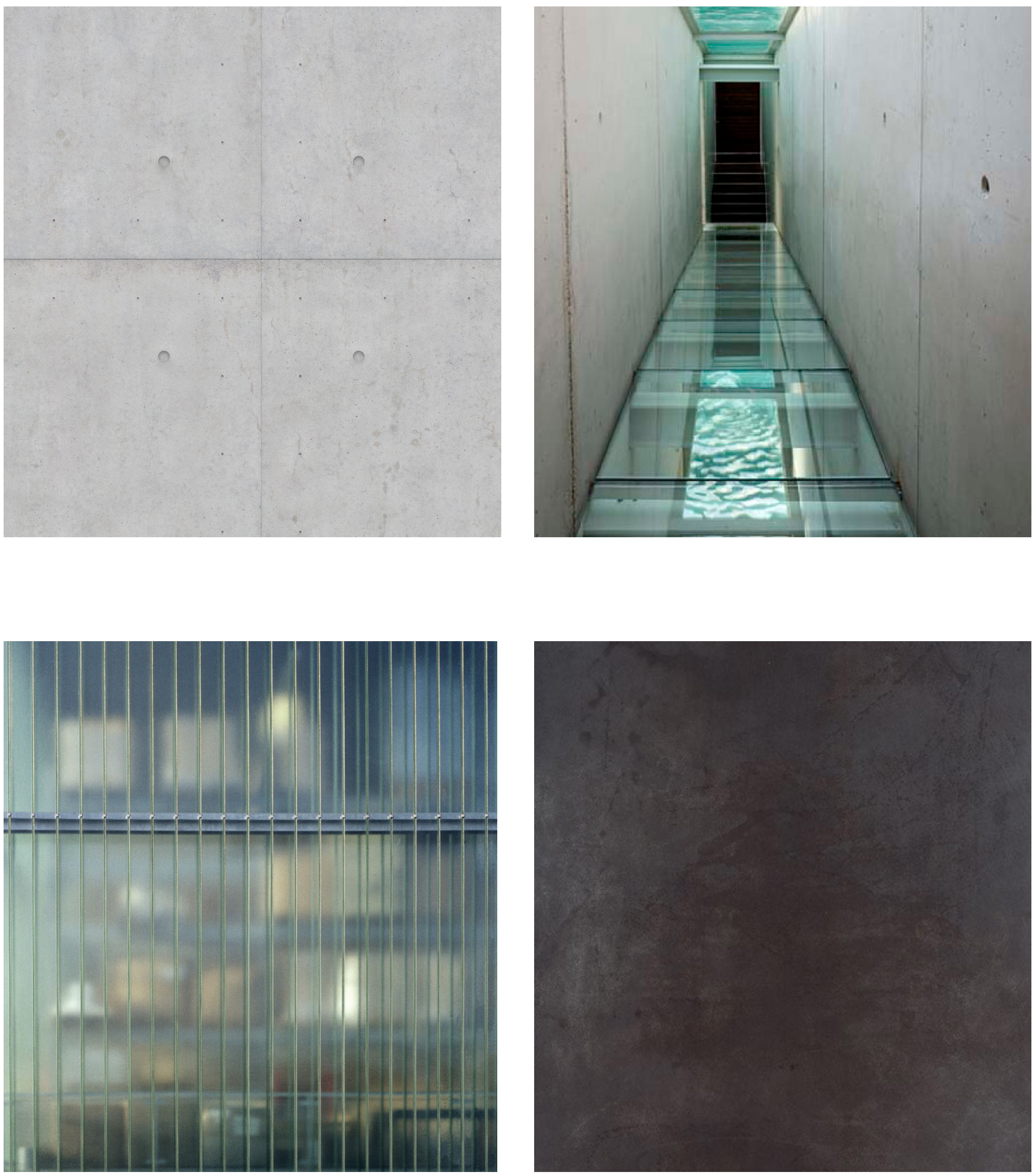
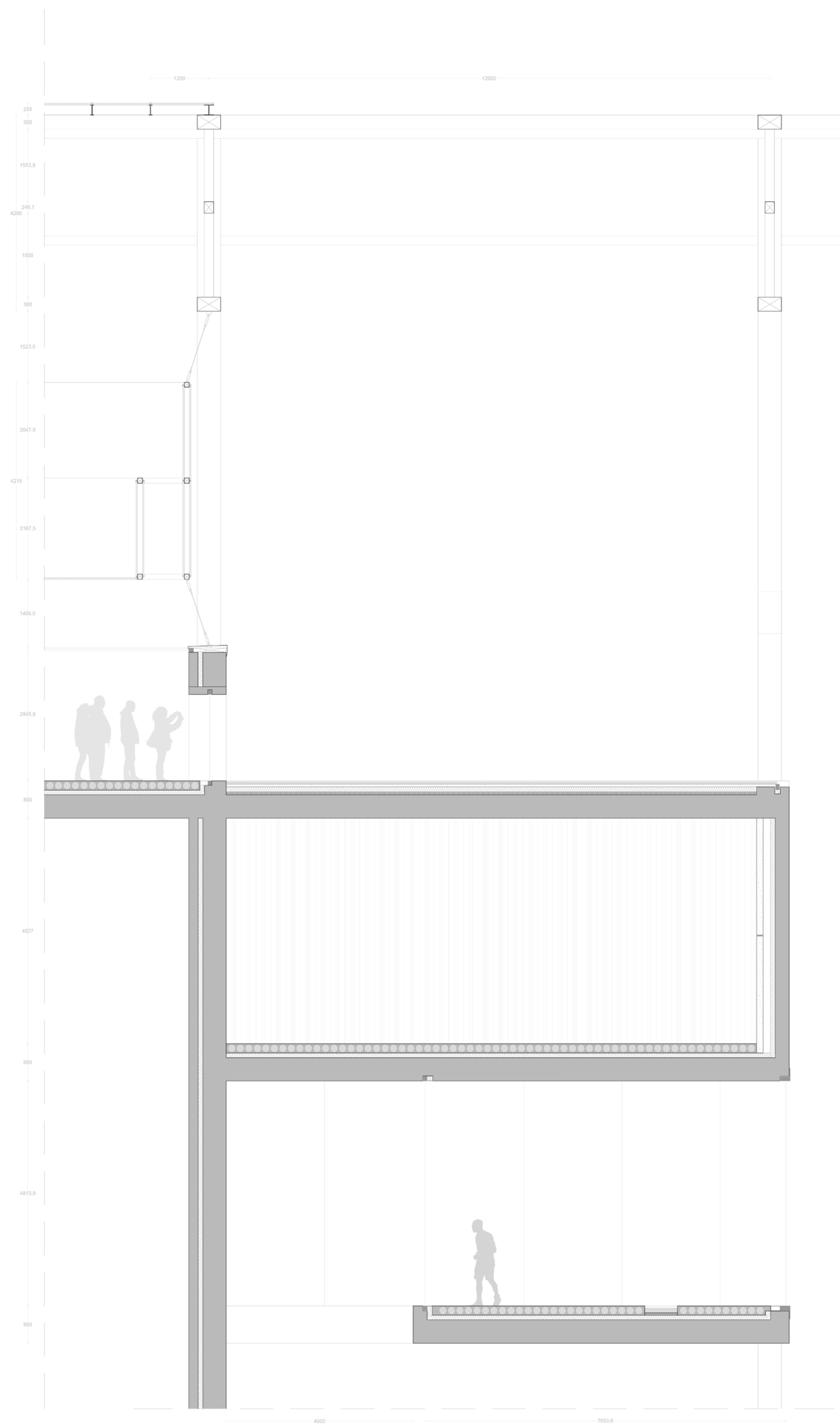
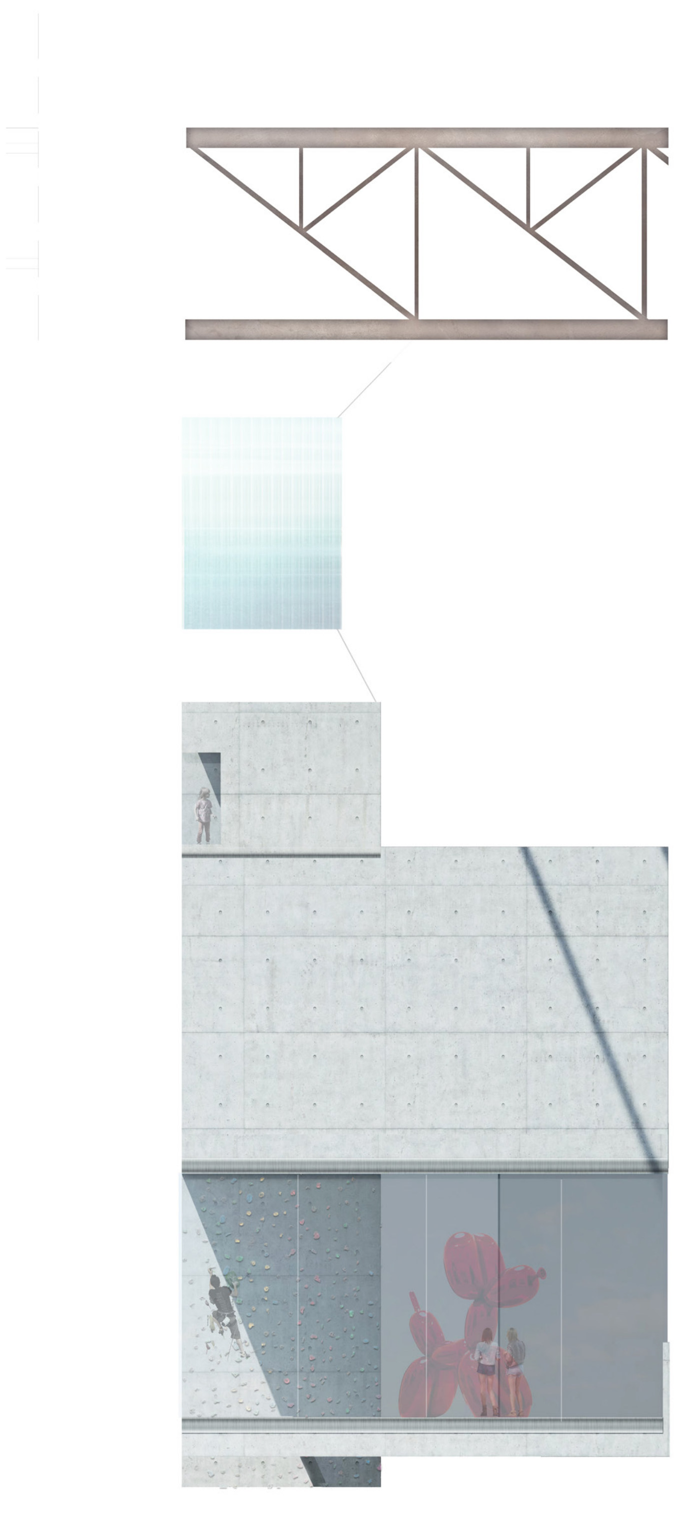


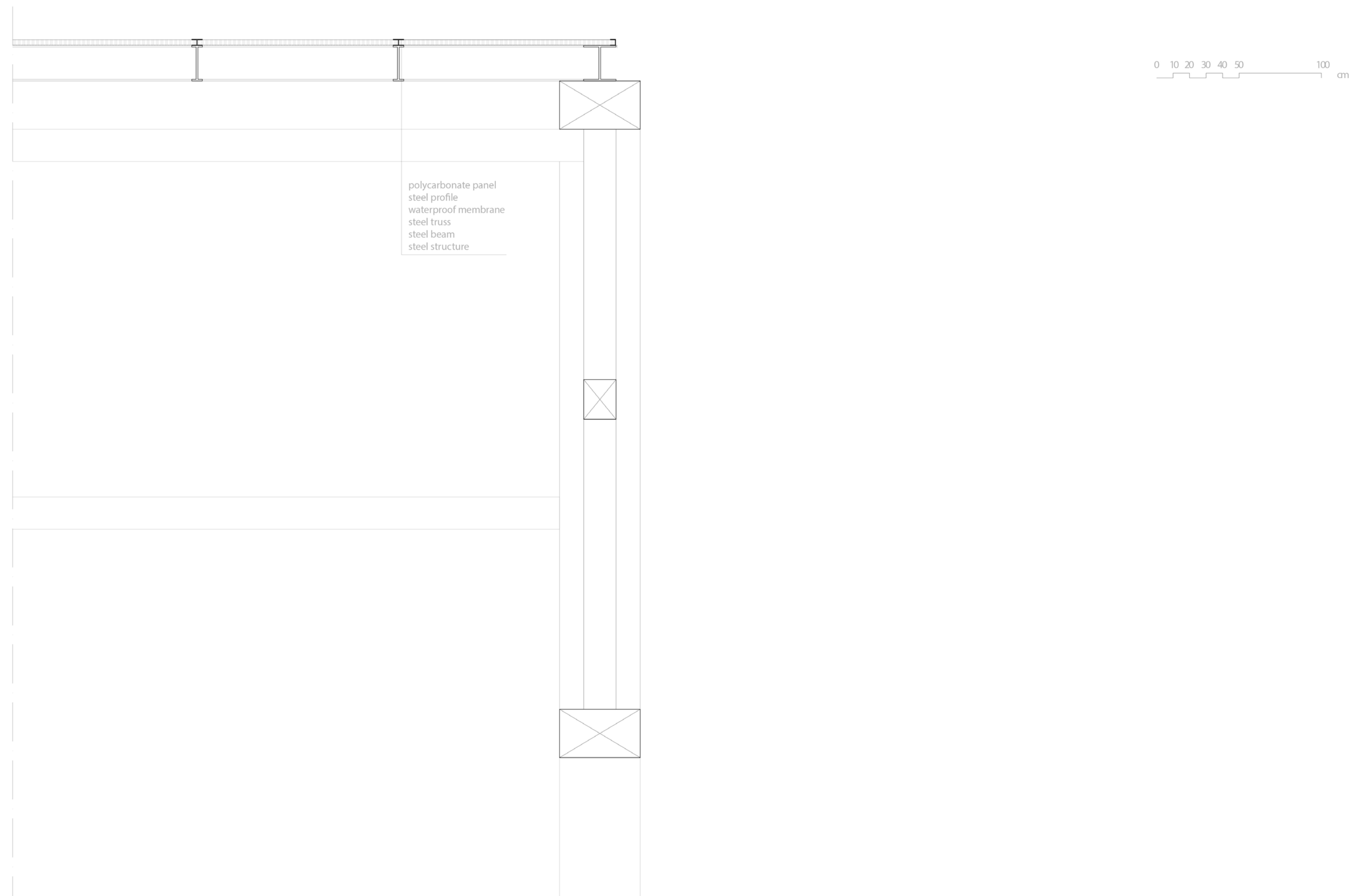
Fig. 48, 49, 50, 51 : concrete, glass, polycarbonate and steel.



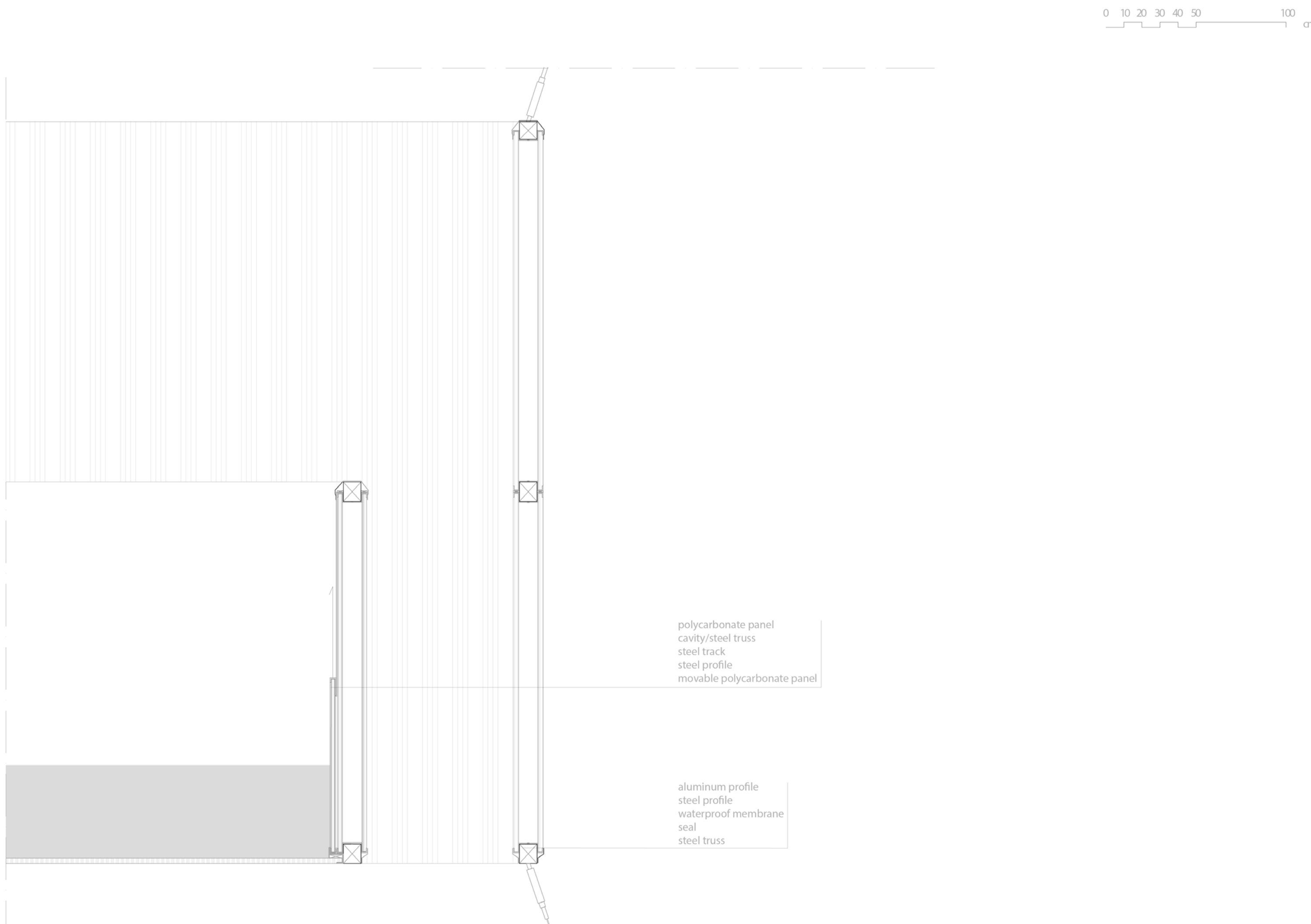
Exhibition space core section



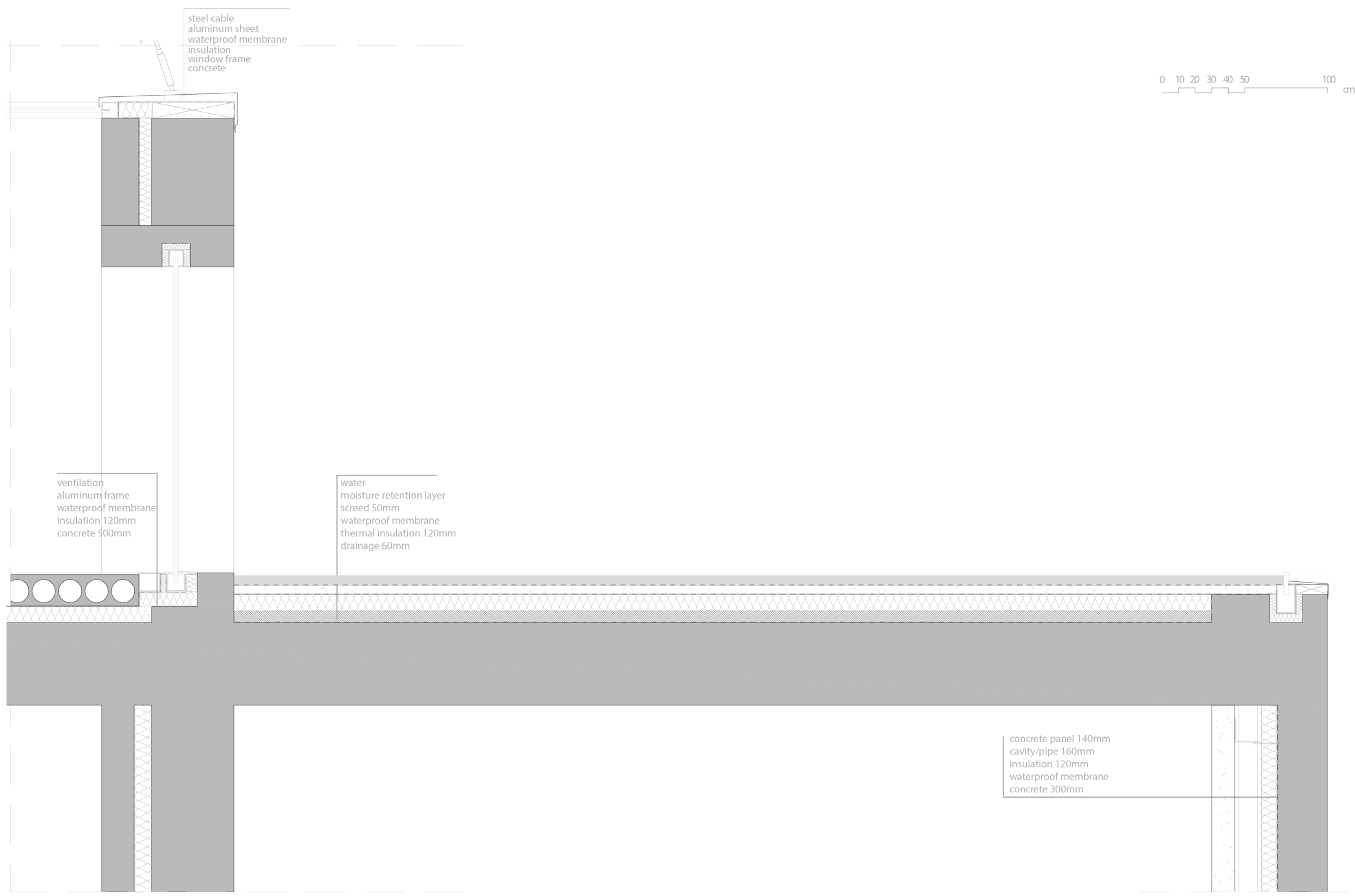
Material impression of the facade



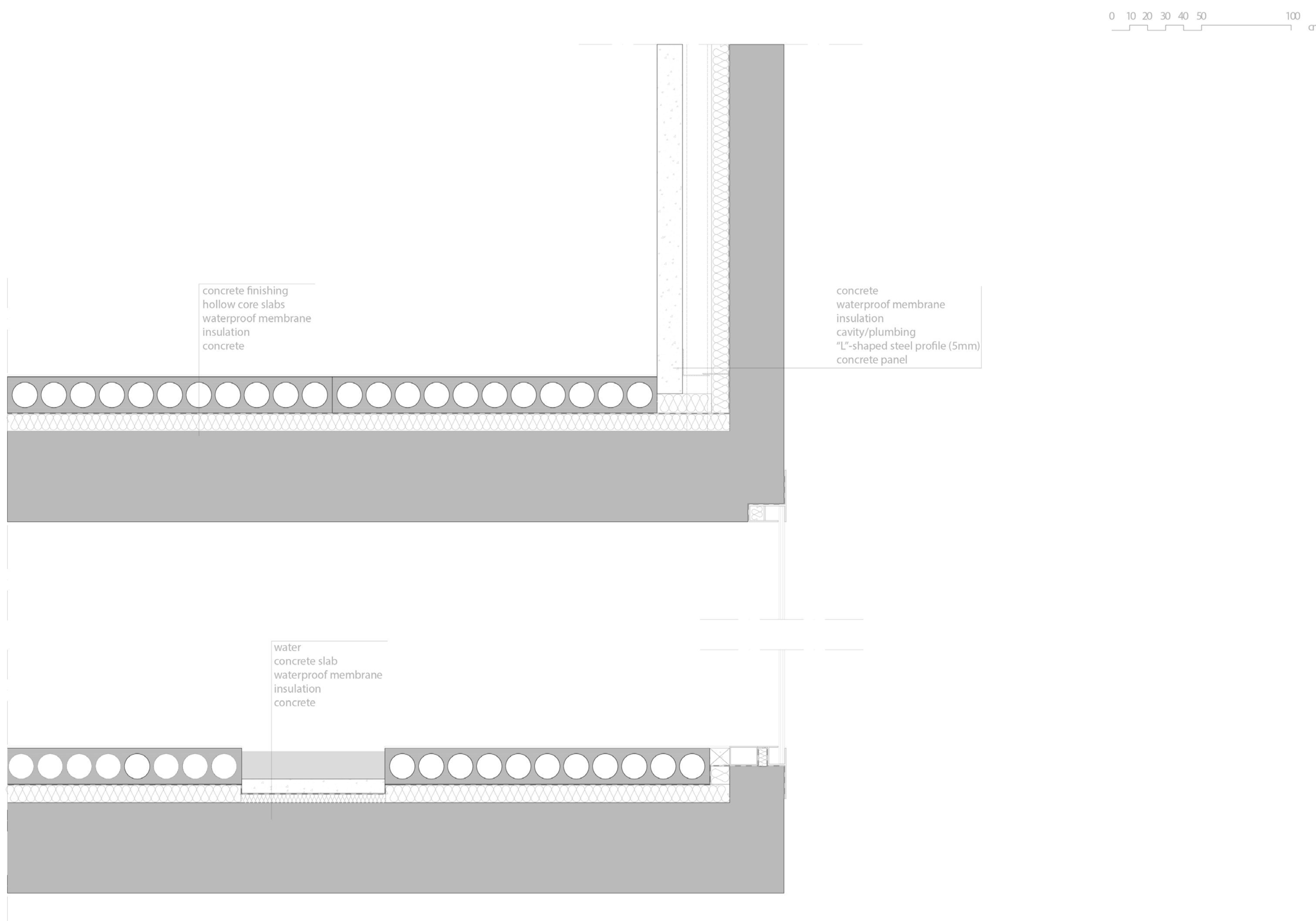
Pre-existing structure detail



Rainwater harvesting tank detail



Rooftop hub detail



Concrete floor and wall details

CONCLUSION

The evidence from this book confirms that resilience is not any single solution. Already its definition is hard to grasp or circumscribe to a certain extent.
Resilience is the capacity to bounce back after a disturbance or interruption; it is adaptation, redundancy, flexibility, durability, equity and dynamism [16]. It is a multi-faceted concept that does not relate just to strategies to survive climate change-related events or coexist with future scenarios.
Indeed, resilience has expanded in the multi-dimensionality of urban life. Infrastructure, emergency response systems and the making of communities are key elements to reach a new level of wealth [17].

This thesis tries to test the solidity of a proposal (a strategy for resilience) through combination of different approaches. It highlights the importance of water for urban settlements and how they can be expression of resilience and adaptability in contemporary approaches to urbanism [18].
Throughout history rivers have provided industry with power and sewers and characterized locations for new urban settlements. Urban rivers have a major role in providing sustainable places to live in and mitigating climate change's impact on cities and environment.
Here, is stated their importance as instruments of urban regeneration and resilience, and fertile ground for innovative approaches to flooding.

As above mentioned, resilience is multi-faceted, and requires a multi-disciplinary approach. Thus, it is necessary to find a common language to let different methods from different disciplines merge together.
This book tries to elaborate it, focusing on facilitating the linkage of landscape and urban design to promote resilience in the urban system, and involving users and researchers to rise awareness.
This project follows the concept of "water-based urbanism" [19], that is, the design of urban settlements around dynamics of water. It could not be any different, since water urbanism is a crucial part of dutch cities' past and present. However, climate change and rising sea level, require an enhancement in order to improve urban resilience, using key elements to develop new strategies.
The Water Management Think-Tank is not an attempt to convert an industrial riverbank into a commercial leisure playground. On the contrary it wants to stand as a prototype for new urban forms strictly in relation to water, which aim is to stimulate interaction among parties.
What is proposed here, is a design that merges together engineering and environment, taking into account dynamics of the context, strengthening and using them as solid foundation.
The project is not an extreme work of engineering, rather it falls within the definition of soft-engineering.
It endorses a design that works together with forces of nature, with the aim of mitigating consequences of natural disasters; reconstructing wetlands, creating landscapes able to withstand floods, in order to develop a resilient water-based strategy.
Water has been a cornerstone of urban design [19] and it is now keystone of this project, combining together natural and artificial water structures to enrich bio-diversities, recreate habitat for native wildlife or develop water-cultures. These are some of the benefits that define this project a water-based ecological infrastructure.

Despite the constant need of humankind to prevail over and master nature, yet the latter proved us how detrimental consequences of our actions could be. Netherlands has realized this and is moving towards different approaches.
As stated at the beginning of this book, raising dykes is not a solution anymore and, according to Pickett, Cadenasso et al., it is necessary to maximize natural flows.
This project points towards this direction, leaving the dyke system untouched and increasing flow capacities, reducing flow resistance and removing obstacles.
Water is not a threat anymore. It can be rather considered a medium to integrate engineering and planning approaches to re-establish a balance between city and nature.

The Water Management Think-Tank embodies a possible way to reach resilience but, like an organism, each part of it relies on the other ones.
If one of them collapses then the entire system ceases to function. In other terms, it would be impossible to generate exchange between the layers of environment, users and research, mentioned in chapter 2.1.
That applies especially to the building. Indeed, the new

[14] http://www.resilientdesign.org/what-is-resilience/

[15] I. Bauman et al. (2015)

[16] De Meulder and Shannon (2008)

[17] Picket, Cadenasso et al. (2013)

design is in synergy with its context to which is connected by means of technologies implemented in the architecture and landscape.
This book lays the groundwork for further investigation concerning the feasibility of some choices, to verify whether the performances of installations such as wind turbines, water pumps and water turbines, can actually turn into reality the concept of "water=energy". Therefore, would be interesting to lead a more accurate research to estimate the efficiency of the building and the amount of energy required to fulfil all the goals. Thus, what changes or improvements would the design be subjected to.

It might be concluded that resilience is a mechanism to achieve a new level of adjustment to changing conditions, where social, economic and environmental factors are involved.
This thesis proves that, in this open process, water can play a major role in defining strategies to face the different scenarios. It is able not only to influence environment and the way it responds to climate changes but also architecture, thus social dynamics. Through water is possible to bring people together, guide them towards a more resilient mentality and rise awareness, enhancing the urban system we live in and encouraging interaction and exchange.

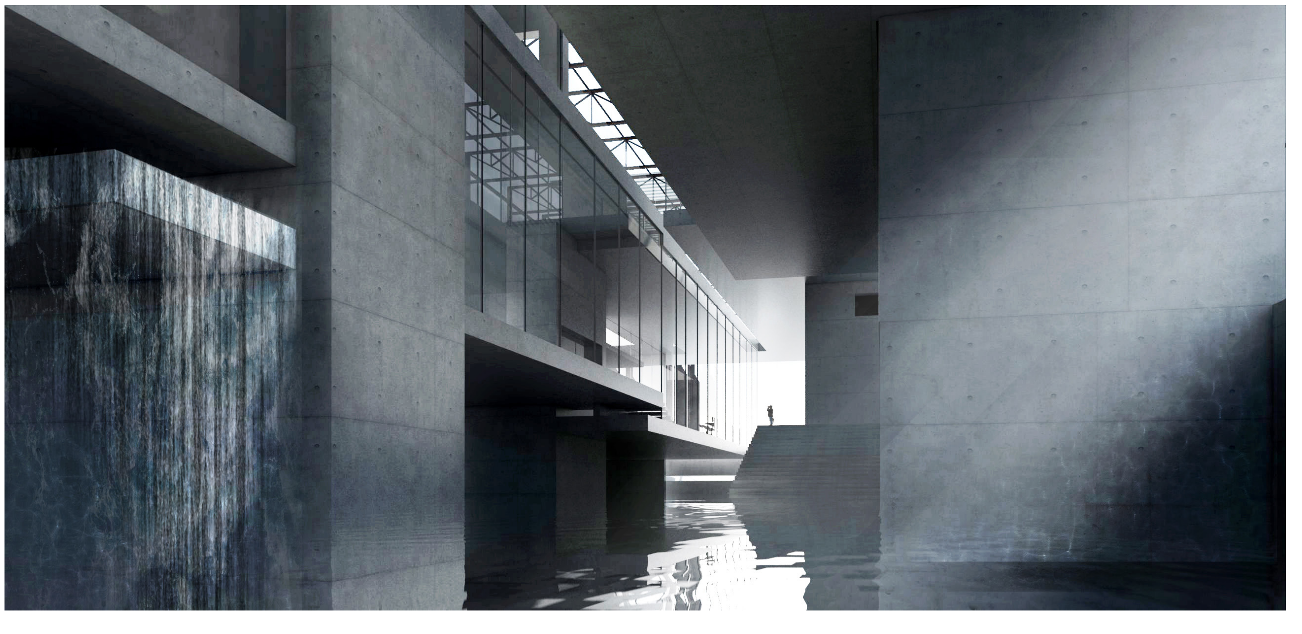


Fig. 52: undergound level


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Fig. 53: view from the area

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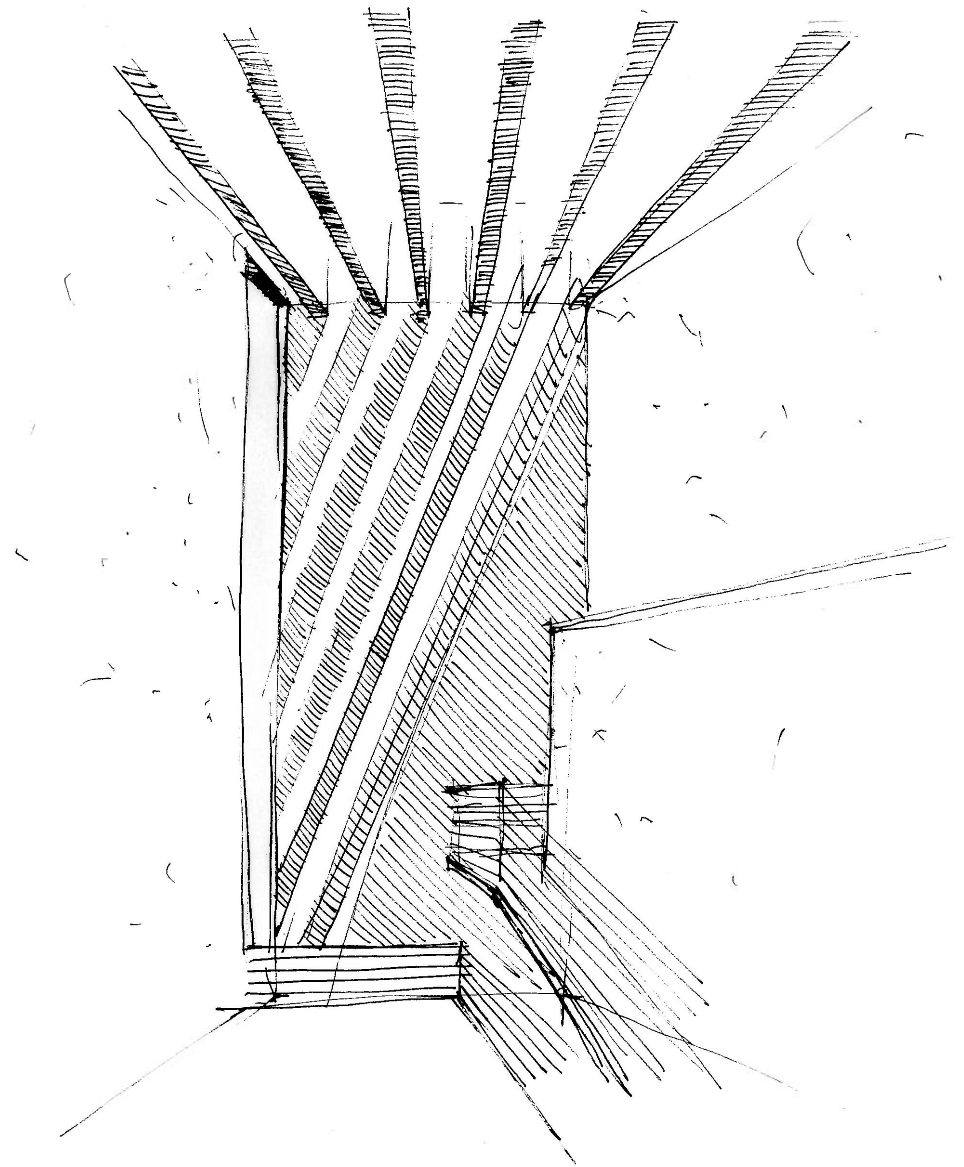

IMAGES

The images that are not mentioned in this index are produced and designed by Andrea Somma.

Fig. 1: Breach at Ouderkerk aan de IJssel, upstream along the tidal reach of the river Hollandse IJssel, at the time of tidal low water (from Van Veen 1962). Retrieved on https://beeldbank.rws.nl, Rijkswaterstaat / Afdeling Multimedia Rijkswaterstaat

Fig. 3: regional map of the Regional map of the most vulnerable zones in the Delta Area. Made by Andrea Somma, 2016

Fig. 6: aerial view retrieved from www.google/maps.com

Fig. 7: aerial view retrieved from www.google/maps.com

Fig. 8: Launch of the trailing suction hopper dredger Willem van Oranje - See more at: http://www.motorship.com/news101/industry-news/queen-launches-boskalis-dredger#sthash.Dx7Mv120.dpuf, retrieved on http://www.motorship.com/news101/industry-news/queen-launches-boskalis-dredger

Fig. 12: IRWES Turbine. Retrieved on http://www.ibispower.eu/

Fig. 13: Archimede's screw. Retrieved on http://www.panoramio.com/photo/41996370. Uploaded October10, 2010 © all rights reserved, ©Jpix

Fig 14: Rolling fluid turbine. Retrieved on https://www.epo.org/news-issues/press/european-inventor-award/sedlacek.html

Fig. 15: "Cores", collage. Made by Andrea Somma, 2016

Fig. 13: Smart Hydro Power turbine. Retrieved on https://re-publica.com/en/16/news/explore-future-making-things-autodesk-gallery

Fig. 16: Attenuator. Pelamis Wave Machine Public Domain via Wikipedia. Retrieved on https://miningawareness.wordpress.com/2016/09/06/celtic-union-of-renewable-energy-launched-by-scotland-ireland-and-northern-ireland/#jp-carousel-30595

Fig. 17: The eastern Scheldt. Retrieved on

Fig. 18 Tidal current turbine installation SeaGen. Retrieved on http://www.siemens.com/press/en/presspicture/index.php?content=E&sheet=4

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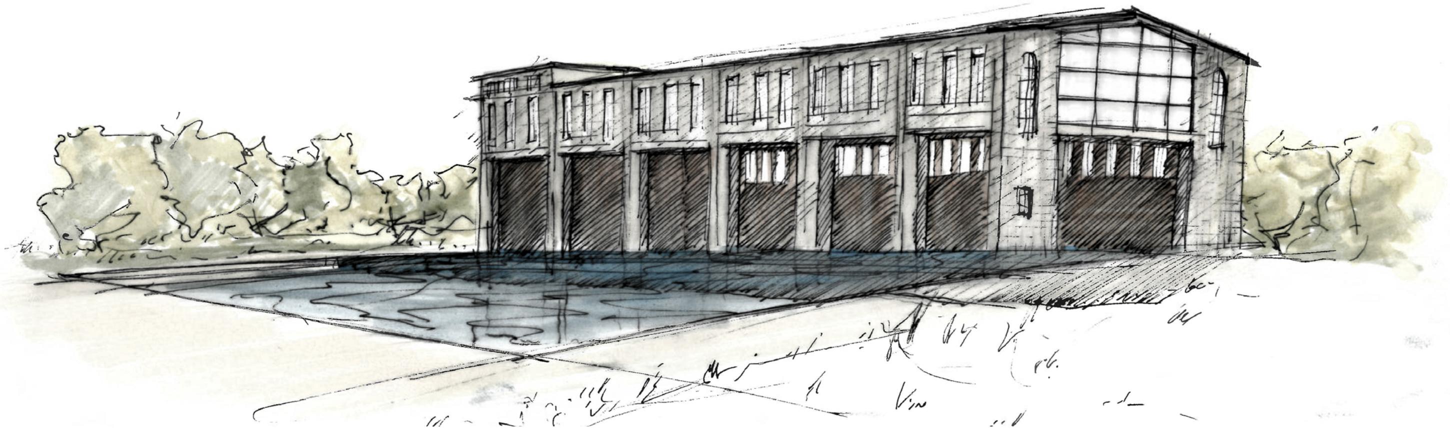

RESILIENT ARCHITECTURE

THE WATER MANAGEMENT THINK-TANK

Graduation thesis of Andrea Somma

Technical University of Eindhoven, January 2017