REinventing FLOOD CONTROL

Urban integration of a dike park with special regard to integrated flood control in Deggendorf, Germany

Master thesis in Sustainable Urban Design 2017

Hanna- Celine Rauschkolb

Reinventing Flood Control
Urban integration of a dike park with special regard to integrated flood control in Deggendorf, Germany

Lund, September 2017

Master thesis in Sustainable Urban Design
Master of Science in Architecture with a specialisation in Sustainable Urban Design,
Facultiy of Engineering, Lund University

Author:	Hanna- Celine Rauschkolb	
Supervisor:	Louise Lövenstierne	Architect MSA, Course Leader in Sustainable Urban Design, Lund University
Examiner:	Peter Sjöström	Programme Director in Sustainable Urban Design, Lund University
Jury:	Harrison Fraker	Professor in Architecture and Urban Design, Dean of the UC Berkeley College of Environmental Design, U.S.A.
	Jenny B. Osuldsen	Partner Snøhetta, Professor in Landscape Architecture Oslo, Norway

SUDes
Sustainable Urban Design

Lund University
School of Architecture

AxSUD
Axson Johnson Institute for
Sustainable Urban Design

CONTENTS

PREFACE

The thesis deals with the concept of flood control in Germany and how more frequent events of heavy rainfall influence flood control in urban environments. It highlights the importance of integrated flood control within urban development and spatial planning in order to become more flood resilient.
The aim of thesis is to show how adapted, site-specific integrated flood control helps to integrate a dike into the urban context and how it can be used as a tool for flood resilient urban design.

The thesis is divided into three parts. From a scientific research, over analysis into strategies and a design proposal the thesis zooms in into the topic from one part to another.

The following questions are guiding the thesis:

How can a city grow within its urban boundaries and develop simultaneously a resilience to floods?

How can one overcome a dike as a barrier between a city and a river and use it at the same time as an asset for the city?

How can you combine technical flood protection, water sensitive urban design and flood- proofed building design and increase the living quality at the same time?

Which design possibilities offer integrated flood control measures and how can you arrange a new type of living with it?

How can adapted integrated flood control improve environmental, social and economic sustainability within a city?

The first part investigates climate change and its impact of floods that threaten our cities. This will be demonstrated by the flood catastrophe in Deggendorf, which is the chosen city of this thesis. Additionally, flood control is explained and new trends and needs presented. This part examines scientific background information about the topic and reveals critical aspects of it.

The second part focuses on the city Deggendorf and its connection with flood control. It contains analysis of the city and the site and summarizes site conditions.

In the third part strategies are stated to overcome the problems on site. The concept of integrated flood control is demonstrated and applied to the site. This part presents the design proposal and how the findings and strategies are integrated into the design of the site.
A conclusion is drawn to answer the research questions, stated at the beginning.

ABSTRACT

The thesis discusses the problem of extreme rainwater events and areas behind flood defences not being addressed appropriately within urban planning in Germany. It argues for the need of integrated flood control within urban development in order to make cities more sustainable and flood resilient in times of climate change.

Deggendorf, a city in southeast Germany, although protected through flood defence systems has suffered from severe flooding. A dike burst in 2013 resulted in an inundation of an area in Deggendorf for two weeks and leaking oil tanks caused serious environmental damage. Millions of Euros have been invested into reconstruction and flood control measures.

One year later the city was hosting a state horticultural show for which the city has made large investments into the design of the dike into a park. Although being a huge success for the city, the dike design has still not reached full potential and neglects some areas around it.

Like in many cities along rivers a dike creates a barrier between the city and the river. Additionally, the dike is not designed for extreme rainwater events and there are no building regulations for some areas behind the flood defence, such as in many cases in Germany.

The thesis gives a design proposal for a mostly unbuilt area next to this dike park by addressing the problems stated above. It develops strategies to overcome the dike as a barrier and use it as an asset for the city instead. The strategies connect, activate and integrate are applied to the site and the city.

In order to develop a water resilient design, integrated flood control is adapted to the site and used as design guidelines. Integrated flood control involves the combination of decentral and central flood control measures which are divided into technical flood control, land use management and (building) precaution.
Adapted to the site, a toolbox for the dike, water sensitive urban designs and buildings is created.

The design proposal shows how one can combine technical flood defence (dike) with water sensitive urban design and flood proofed building types while increasing the living quality at the same time. The area is designed in a way to retain water on site in order to reduce the peak of flood flows and ease the pumping stations. Therefore a large retention basin creates the centre of the site and offers multifunctional usage throughout the year.

Since the area is affected by not only flood water and storm water but also groundwater flooding, permeable surfaces play an important role in the design process in order to let the water come and go while not disturbing the natural water flows.
Therefore most buildings are elevated on stilts which gives the site a new identity. Platforms that connect the dike with the site or surround the buildings are easily accessible through stairs and ramps and activate the public space. These wooden platforms create a transition between built and unbuilt area on the site, of which approximately half is designed as green expansion of the dike park and also provides a platform for festivals that have a big tradition in this area.
The design is resilient against ground water floods, storm water and extreme flood water and makes an occupation of public and private space possible during various flood scenarios.

Finally the thesis shows how the design proposal can be used as an experimental pilot project and demonstrates in which way it is environmental, economically and social sustainable for the city.

Overall the site becomes part of an urban integration of the dike and promotes flood resilient urban design. It shows that areas behind flood defences should not be neglected but designed in a flood proofed way that is resilient against extreme rain water events and that integrated flood control can be used as a guidance to do so.

INTRODUCTION

Climate change adaption is becoming more and more crucial within sustainable urban design. Global warming has an effect on an increase of heavy rainfall events in Europe and especially in Germany. In fact global warming in Germany is higher than the global average and one result of this climate phenomena can be floods.

While 100- years floods occur more frequently in Germany, which can cause many flood defence and urban drainage systems to exceeds its capacity, there is a so called "extreme" rain event that has not been integrated into spatial planning policies in Germany appropriately. These extreme rain events mean even more heavy rainfall in a short period of time that cities have to prepare for. But this design category has no legal boundaries and is interpreted differently within Germany.

In order to make urban environments more flood resilient this extreme rainwater design event has to be more integrated within flood control and more buildings and public places designed accordingly.
Overall, climate adaption is still not incorporated appropriately within urban design.

Dikes are a common flood defence system to protect urban environments in Germany and the rest of the world. Despite the fact that they cannot guarantee 100% flood protection, they also create a visual and geographical barrier between the river and the city. This barrier has not been addressed a lot within urban design and flood defence systems often bring challenges to the city in terms of integration and design. It raises the question if there is a way to use a dike as an asset for the city rather than a problem.

(Integrated) Flood control is often the matter of spatial planning and water departments of authorities. But the question rises if it can or should be more adapted in smaller scale developments with a shorter planning period to have immediate and efficient outcome. Can it become an obligatory part of the design process of our cities with flood hazard or simply a lot of storm water and create a guideline for flood resilient urban design for urban designers and (landscape) architects?

1
RESEARCH

1.1. Floods as a consequence of climate change in Germany?

Global warming causes more extreme rainfall events!

Global warming in Germany is higher than the global average!

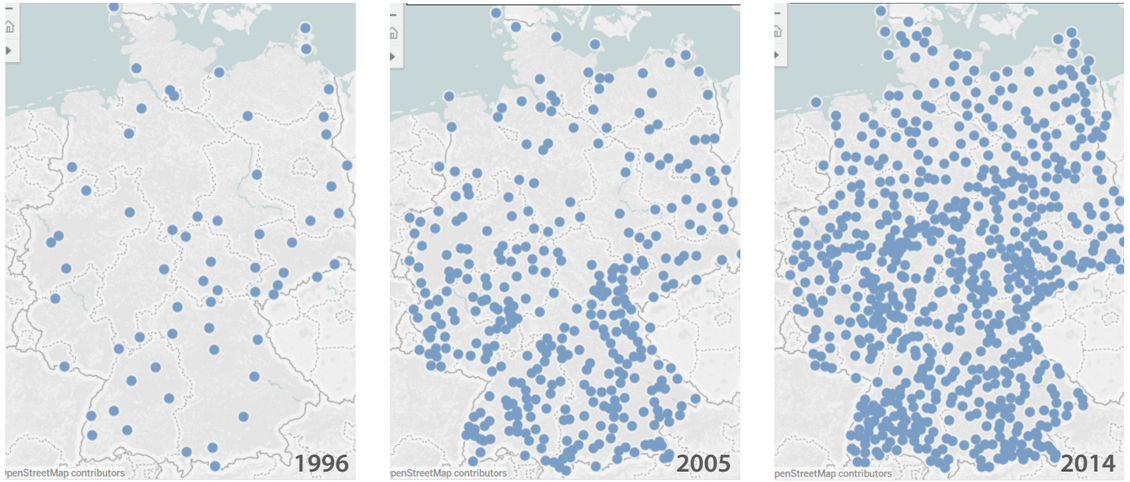
While scientists cannot see a direct connection between global warming and the average amount of rainfall, there is an increase of extrem rainfall events. Within extreme rainfall events a lot of rain occurs within a short period of time. (Reimer, N. and Lüdemann, D. 2017)

Flooding occurs more commonly from heavy rainfall, when the soil can´t infiltrate anymore rainwater and and natural water courses don´t have the capacity to convey excess water (ga.gov.au, 2017).

There has been a lot of debates about whether climate change is the reason for environmental catastrophes such as floods or not. There is no right answer to this question as usually many factors play a role to cause such an event. One major factor is the way we have been building our cities and continue to design them.

Floods within cities are not necessarily the result of climate change but also inappropriate urban design and land use management (Kelman, I. 2017).

While climate mitigation involves actions to reduce climate change, climate adaption refers to the ability of systems to adjust to climate change (Global Greenhouse Warming.com, 2017).



Increase of heavy rainfall in Germany
(Rösing, P. 2017)

Climate mitigation strategies are often determined by higher authorities and requires long term planning while climate adaption can often be more feasible or faster to address. In the field of climate adaption, urban design has possibilities to counteract climate change but it also reveals failures in climate adaption.
These failures become most evident after a climate catastrophe like floods or hurricanes. But is the function of climate adaptive urban design not to increase resilience to natural weather conditions and avoid environmental disasters?

Flood resilient urban design can be seen as a climate adaption strategy that has to be promoted more in order to avoid or reduce climate environmental disasters and prepare cities for these scenarios.

1.2. The flood catastrophy in Deggendorf in June 2013

In June 2013 widespread flooding occurred in central Europe and in particularly in Germany, where this event can be regarded as the most severe flood over the last 60 years. This flood caused a total damage of 6 to 8 billion Euros and the lifes of fourteen people in Germany. Spatially extended and very intense rainfall during the month of may in the Danube catchment in the alpine areas of southern Bavaria caused the floodings. Due to high catchment wetness the water level of the river was already increased and the conveyance capacity of river sections had been strained. The discharge contribution of the river Isar just a few kilometres located south of Deggendorf caused the high water in Deggendorf (Thieken et al., 2016).

On the 4th of June 2013 dikes breached eventually due to this hydraulic load along the Danube River and the Isar estuary. This caused polders to be flooded from the behind and led to a 3 m high inundation of 24 km^2.
The discharge of the flood water was disturbed by the dikes which led to the water say in the district "Fischerdorf" for two weeks. The structural damage was not as severe as the environmental damage due to private oil tanks leaking into the water (Deutsches Komitee Katastrophenvorsorge e.V., 2015, 27) .

The Danube river reached a level of 8,08 m and thus exceed the record of 7, 48m. Disaster alert was exclaimed and many people had to be evacuated from their houses. Additionally, Deggendorf was isolated from the surrounding cities as the main highway was flooded.

The flooding caused extreme structural damage. 150 Buildings had to be demolished and clearing work required a lot of time and helpers. The county Deggendorf had to report a total damage of 500 Million Euros (Hochwasser 2013, 2014).
The city Deggendorf invested 47 Million Euros in reconstruction and flood control measures (Wasserwirtschaftsamt Deggendorf).

1.3. Flood control in Germany

Flood control refers to all methods used to reduce or prevent effects of flood waters.

1.3.1 Decentral and central flood measures

Centralized flood measures

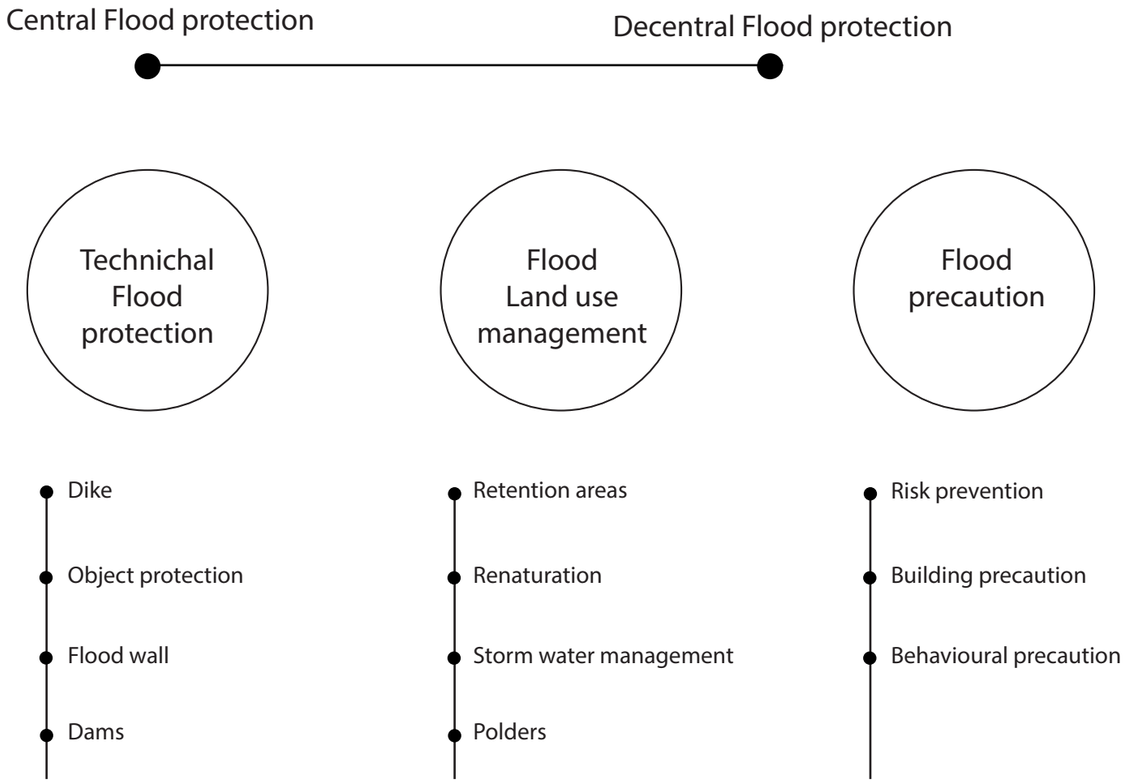
Centralized flood measures are applied to buildings or unbuilt areas.
In settlement areas, dikes and flood walls along the water front protect buildings from flooding, while dams retain the water in undeveloped areas.

Decentralized flood measures

Land use management is applied to settlement areas, agriculture and forest land as well as water bodies. This paper studies only the measures in settlement areas and built areas along water bodies, which are also known under: Sustainable urban drainage system (SUDS) or Water sensitive urban design (WSUD):

- Rainwater infiltration
- (Bio) swales and channels
- Detention and retention ponds
- Wetlands
- Permeable surfaces and desealing measures
- ...

Flood precaution is relevant for the private sector but policies are made on government level.
The technical flood proofing applications for buildings are illustrated in the Design chapter.
(Röttcher, K., 2015)



1.3.2. The importance of integrated flood control

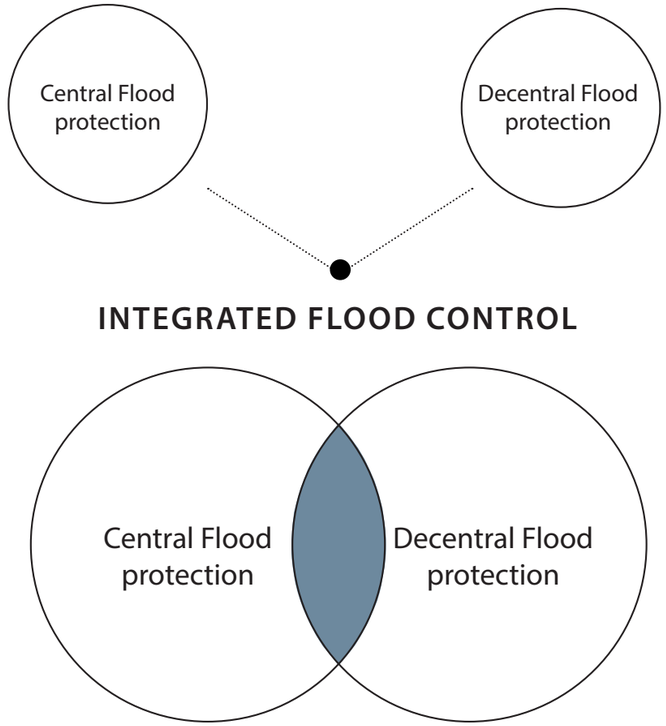
An Integrated flood risk management requires the use of centralized and decentralized flood measures and balances the current protection needs with future sustainability (Abhas K.,Bloch, R. and Lamond, J., 2012, 198).

But the truth is that centralized and decentralized flood measures are often viewed separately and an integrated flood management is missing. A common thought is that retention areas for example become unnecessary when an area is already protected through a flood defence such as a dike. But in fact centralized and decentralised flood measures complement each other and together provide a comprehensive flood protection (Röttcher, K., 2015).

Any storage through decentralized flood measures has the effect of reducing the peak of flood flows (Abhas K.,Bloch, R. and Lamond, J., 2012, 213). A retention pond behind a dike for instance retains the storm water on site and relieves the pumping station, which lowers the water pressure in front of the dike.

For both measures, discharge capacities have to be maintained and supported in order to restore the natural water balance and prevent floods and damages. It is very important that both flood control means don't interfere but complement each other and are site-specific. Retention areas become more effective when different catchment sizes and flood intensities are regarded (Thieken et al., 2016).

Flood precaution also plays an important role for an integrated flood control and has to be promoted more. Due to the dike burst in June 2013 in Deggendorf, oil tanks that were stored in basements leaked into the water and caused enormous environmental damage. This could have been prevented through building and appropriate behavioural precaution at comparatively low costs.
The dike burst also shows once again that technical flood defences alone are not enough to prevent extreme floods and highlights the importance of an integrated flood control (Thieken et al., 2016).



Where flood defences fail, other approaches, such as retention and building regulations have to be further improved and integrated.
To achieve a sustainable reduction of damage, preventive measures have to be more implemented, also in areas behind dikes.

The interconnection between technical flood protection, land use management and flood precaution increase the relation between the protected people and the measure itself, highlighting the importance of flood control and making flood risk more evident (Röttcher, K., 2015).

Neither retention measures nor protection measures are a universal remedy, but should be incorporated into integrated, locally adapted concepts (Thieken et al., 2016).

1.4. Flood hazard and its importance for building regulations

Flood hazard maps show flood hazard areas using design flood levels. These maps provide important information for flood risk and precautional measures and form the base for regulatory flood plains.
German flood hazard maps differ between three different design flood levels:

Frequent highwater event

(high probability of occurrence, every 5- 20 years)

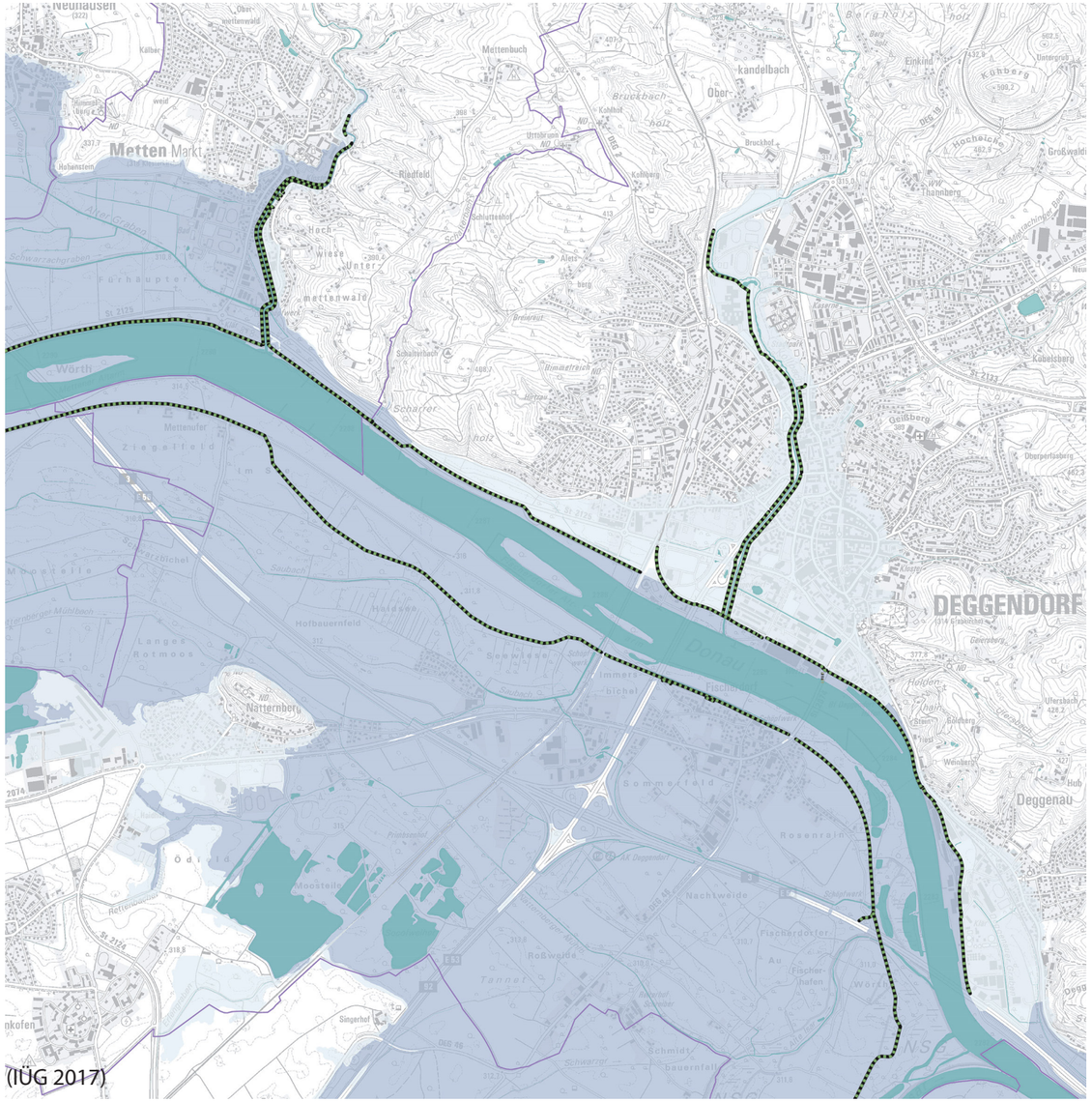
100- years flood

(medium probability of occurrence, at least once every 100 years)

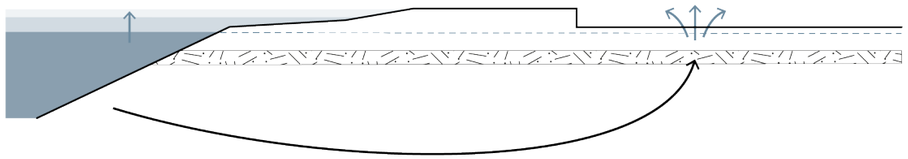
Extreme high water event

(low probability of occurrence, flow rate is 1,5 times higher than the one of the 100 years flood)

(StMUV, 2015, 50)



(IÜG 2017)



Groundwater flooding

"Groundwater flooding occurs when the water table level of the underlying aquifer in a particular zone rises until it reaches the surface level."

This usually happens after long or heavy rain periods and in low- lying areas with permeable soil structure or areas with a general high groundwater level.

Groundwater usually rises and falls with the water level in rivers or other water bodies.
Hence, high water pushes the groundwater to the surface causing flooding, basement or sewage surcharge and urban infrastructure disruption. Groundwater flooding during heavy rainfall can disrupt sustainable urban drainage systems, which increase surface flooding further more.
Since groundwater usually responds slower compared to water bodies, it can take weeks or months for the water to discharge and can become very costly.

Groundwater floodings are hard to predict and strategies to reduce surface flooding, such as infiltration can often not be applied, as they would cause the water-table to rise again and result in more water flowing into rivers.

A common method to deal with groundwater flooding is by pumping. The groundwater will be pumped to a location where it does not infiltrate into the aquifer directly. In some cases this water can be reused for industrial purposes.
The energy for pumping and treatment if necessary can be very expensive (Abhas K.,Bloch, R. and Lamond, J., 2012, 61).

1.4.1. Extreme high water events as a new design flood level and the need for building regulations behind flood defence measures

In contrast to frequent high water events and 100-years floods, the extreme high water event has no legal boundaries and differs between states. That means that there are no building regulations for areas that are affected by this design flood level, which is why it is very important for private building precaution.

Extreme high water design level shows that flood defence has a limit and does not provide complete protection but depends on the high water level. There is always a remaining risk, which has not been declared enough in the public (StMUV, 2015, 50).

There is a need to determine more regulatory provisions in order to strengthen the flood control in spatial planning. There is a lack of legal policies when it comes to the designation of new building areas and the densification of existing built- up areas, even in declared statutory flood plains. Especially areas behind flood defences have no buildings restrictions. Saxony is the only state in Germany that determines these areas with use and buildings restrictions for flood proved planning, construction and rehabilitation.

Overall there is a stronger need for information and policies, especially in areas that are rarely effected by floods or that are located behind flood defence systems.
The flood catastrophe in June 2013 confirmed that technical measures protect urban areas up to the design event and that building precaution has to be aligned.

The fact that extreme high water is not statutory and is interpreted differently needs to be changed in order to achieve comprehensive flood adapted spatial planning (Thieken et al., 2016).

1.4.2. Flood proofed buildings

As mentioned in the chapter before, building regulations are very much needed in areas that are affected by extreme high water events.

Flood adapted design of buildings can reduce the vulnerability of them to flood damage and hence can enable occupation of floodplain areas within cities. There are three main approaches

- Flood resilience (wet flood proofing)
- Flood resistance (dry flood proofing)
- Flood avoidance (elevated buildings)

These approaches are design solutions depending on the level of risk, environmental conditions of the location, climate, soil etc.

Wet flood proofing reduces damages through allowing waters to easily enter and exit a structure. It can also involve the use of resistant materials and elevating important utilities.

Dry flood proofing seeks to prevent water from entering the building by making it impermeable to flood waters up to the expected flood event.

Flood avoidance aims at avoiding the flood water entirely, by locating or elevating the buildings above the flood level or to allow them to rise with the flood water (Abhas K.,Bloch, R. and Lamond, J., 2012, 254-256).

Wet flood- proofing and elevated buildings allow internal and external hydrostatic pressures to equalise during a flood and therefore lessen the loads on walls and floors.
While the occupation of wet flood proofed buildings are not given during flood events, the elevated buildings can still function. Also wet flood-proofed buildings need a clean up after the flood event.
In general, wet flood proofed buildings and elevated buildings are less expensive than dry flood proofed buildings but always depending on the measurement (Linham, M. and Nichols, R., 2017).

Every building project affect the natural ground water flows and water systems. This involves general infrastructure measures, landscaping and every kind of on grade and under grade building project that interrupt the ground conditions (Striffler, H. and Heiland, P., 2015).

Therefore elevated buildings have only little risk of structural damage due to hydrostatic pressures being released. Dry flood- proofed buildings instead increase the hydrostatic pressure underneath the building and hence allocate the problem instead of solving it (challengeforsustainability, 2017).

Elevated buildings require a structural integrity of the soil and foundation. Materiality, columns and accessibility have to be considered (Abhas K.,Bloch, R. and Lamond, J., 2012, 255).

2
ANALYSIS

DEGGENDORF


2014
GINALAURA
Jack Wolfskin
FLEISCHWAREN
zero
SUROS
ANTONIUS

2.1. Location and the Danube river

Deggendorf is a town in southeast Germany and capital of the "Deggendorf district". With around 36.000 habitants is Deggendorf one of the four major cities in the region lower Bavaria.

It is located on the left bank of the Danube river and surrounded by the Bavarian forest, which gave it the name "The door to the Bavarian forest". Deggendorf also lies next to the confluence of the river Isar with the Danube. Due to its location within the flat river valley and the surrounding hilly forest, Deggendorf is characterised through significant height differences ranging from 311m to 863m (see page 40). Its topography has also an effect on the climate. Although Deggendorf is located on the south side of the forest, spring arrives in the lower areas before the higher lying districts (Deggendorf, 2017).

Danube river

The Danube River has its origin in Germany and flows through 10 countries, more than any other river in the world. It is the second largest river in Europe and 2860 km long (Donau, 2017).

There have always been floodings in the history of the river.

Deggendorf lies next of the Danube river in Southeast Germany

Deggendorf (city and county) in the context of Bavaria and the region lover Bavaria.

2.2. History

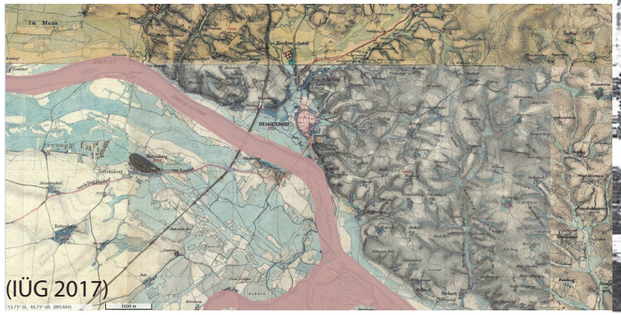
The first written mention of Deggendorf was in the year 1002 by Henry II, Holy Roman Emperor. Later in 1212 received Deggendorf the town privilege.

Deggendorf developed quickly into an expanding market town with commerce and trade in the early 1330s. Despite an immense population loss during the Thirty Year´s War and several fire damages due to many conflicts, the city recovered quickly with the help of regional resources. This led to a self confidence of the city which was demonstrated through the baroque steeple of the "Grabkirchenturm" 1772. This church steeple is known as one of the most beautiful ones in Bavaria and gives the old city centre its character.

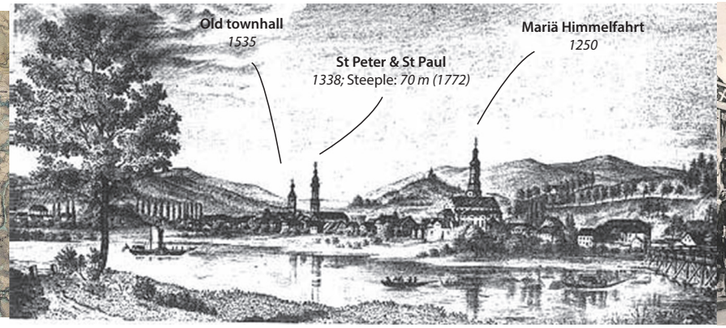
In the 19th´s century, train connections over the Danube river and in the Bavarian forest as well as stable iron bridges and roads to the surrounding settlements were established to connect the city further with its surrounding. In line with the expanding city, the medieval view of the city slowly disappeared with only the layout of 500 years old city centre together with a 27m long peace of the old city wall remaining.

Only in the 20th century, Deggendorf gained a lot of habitants through incorporating the neighbouring communities and is growing continuously since then (Deggendorf, 2017).

"Where the Isar enters the Danube river"

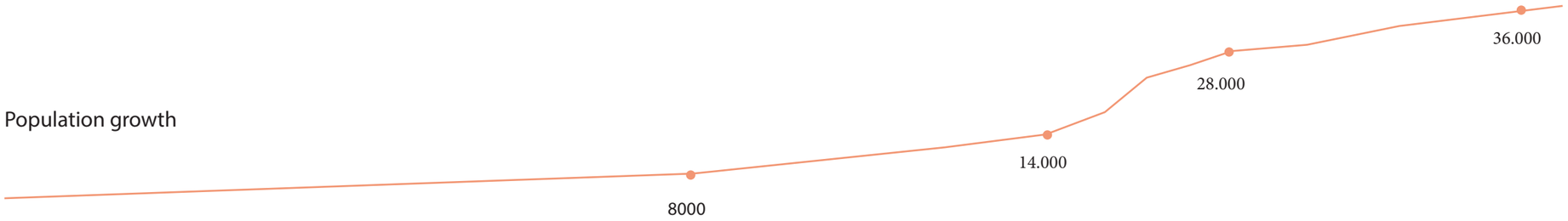


"The door to the bavarian forest"



1212	1330	19th century	20th century	2013/14
Town rights	Develops into a market town with commerce and trade	Train connections and stabile iron bridges over the Danube river follow	Gains a lot of inhabitants through incorporating the neighbouring communities	Economy grows. Establishment of technical university (one of many administrative institutions) and host of popular state horticultural show

Population growth



2.3. City development

Population

As you can see on page 33 the population is growing. There is also a slight increase within the age group 18- 25, 25 – 30 and 30- 40 since the year 2011. The city is known for a growing middle class, but just like the overall trend in Germany and Bavaria, the group of elderlies are growing the strongest. Also the number of immigrants outweighs the number of emigrants since 2004 with a positive future trend (Bayrisches Landesamt für Statistik, 2015).
Deggendorf is a very traditional city with 65 % Catholics and a strong political party, the Christian social Union (CSU). 7 % of the habitants are immigrants and the city is hosting approximately 500 Asylum seekers since 2015 (Deggendorf, 2017).

Economy

Deggendorf has a good, trans regional economy that is steadily growing. For its pro-business attitude, Deggendorf has received already several prices within Bavaria, such as "community of the year". Besides services, many industries are located in Deggendorf, which makes it member of the economy region Danube cities (Deggendorf, 2017).

The figure of unemployment is decreasing steadily from 1100 in 2009 to less than 700 in 2015 (Bayrisches Landesamt für Statistik, 2015).
Because of its trans regional importance there are some public and administrative authorities and since 1994 a college that transformed into a Technical university since 2013 with 5200 students in Deggendorf.
These public institutions are attracting many people from the region to the city, which forms the need to expand steadily (Deggendorf, 2017).

Transport

Deggendorf is well connected through nationwide and transnational highways due to its proximity to Czech Republic. Parallel through the river Danube and through the city passes a regionally important state street.
The city owns a cargo port and a pier for passenger ships.
There is one train station in Deggendorf with connections to other cities and the Bavarian Forest until Czech Republic passing through a beautiful scenery.
The train section (Deggendorf – Hengersberg) is currently only used for carrying goods to the port.
There is a trans regional and national bicycle path passing through Deggendorf, which follows the Danube river and is very popular. On many bicycle tracks E- bikes and mountain bikes are rentable (Deggendorf, 2017).

Tourism and Culture

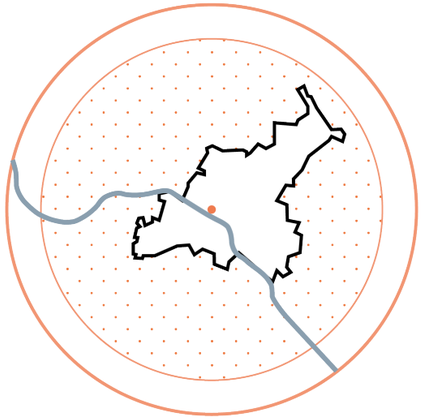
The characteristic city centre and the three unique church steeples represent the panorama in front of the Bavarian forest and form the city´s recognizable character and identity.

"The door to the Bavarian Forest" is therefore attracting many tourists. Many tourists choose Deggendorf as a starting point to explore the Danube river and the Bavarian forest, with many hiking and mountain biking and even skiing opportunities. The city is surrounded by recreational areas.

Museums, a city hall with concert and exhibition facilities and churches that host cultural events create the city´s cultural life. Some organisations are contributing in a growing art and music scene (Deggendorf, 2017).
Since 2014 many tourists and citizens are coming to the dike promenade, which was platform of the state horticultural show. This show takes place in a different city every year and in every state of Germany. The horticultural show in Deggendorf was a huge success for the city, turning the dike and its green space into a park with many activities and hence attracting many people. Its popularity didn't decrease up until now.

The number of overnight stays is growing with a peak in the year 2014 (Bayrisches Landesamt für Statistik, 2015).

Deggendorf is a very important regional hub that supplies many small settlements in the Bavarian forest and the rural areas. Because of its economy, public institutions and its proximity to recreational amenities, it attracts a lot of people and is growing continuously. Since the past few years the city has grown significantly with an ongoing trend in the future.



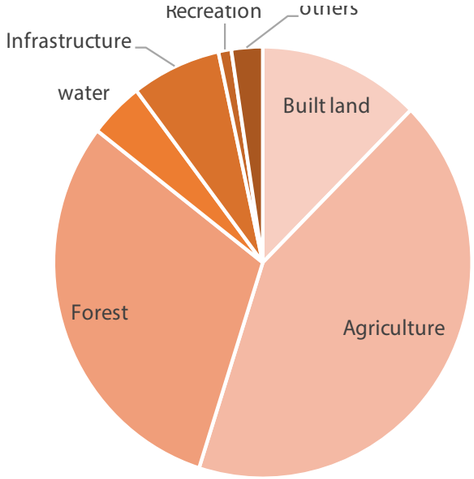
Deggendorf attracts people from the surrounding region

Urban growth boundary and land use

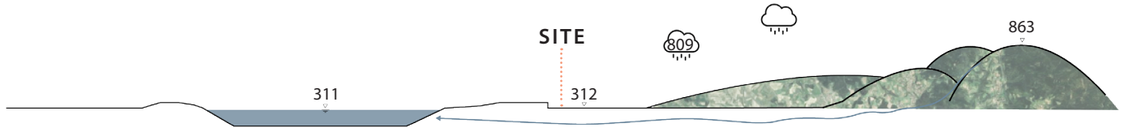
Deggendorf is restricted through the Danube River in the south and the Bavarian forest in North, West and East. Development areas are therefore limited and urban expansion is reaching its limits. More and more open space and agricultural fields along the river are used for retention areas and play an important part in the flood defence for the city and the region. Hence, building in these areas are prohibited. Deggendorf has to build within the city boundaries rather than on the greenfield.

As you can see in the figure, only 12,5 % of the administrative area of Deggendorf is built land, while the forest area takes over 30,5 % and agriculture land even 42 %. Only 1% of the city are recreational areas, like parks (Deggendorf, 2013).

Nevertheless, Deggendorf is growing and the number of building completion is rising (Bayrisches Landesamt für Statistik, 2015).



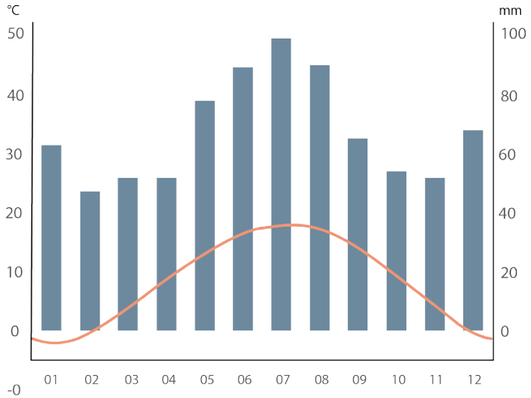
Land use



Section showing geographical conditions of the city and site

As mentioned before, Deggendorf has significant height differences. The landscape is sloping down from the high Bavarian forest to the low lying river bed with agriculture fields.

The climate in Deggendorf is characterized through hot and humid summers and cold winters.
The average rainfall per year is 809mm, which is higher than in Hamburg (738 mm). The rainiest month is July (Climate- Data.org, 2017).



Climate diagramm showing average rainfall and temperature of Deggendorf

Urban growth in Deggendorf is limited thorugh flood plains and forest area

2.4. State horticultural show

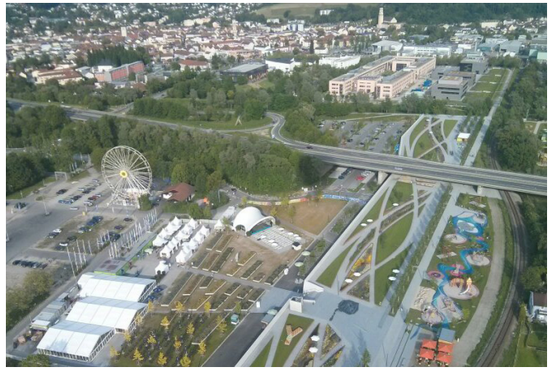
Dike park

As part of the horticultural show, architects designed a parkade that is integrated into the dike. While the parkade provides parking space for the nearby university and park visitors, the roof is designed as a dike garden with flower and grass beds representing the flow of the Danube river.

The dike protects the city against 100- years floods and with the construction of the so called dike garden the flood defence was increased by around 70 cm (through the railing), which is now around 316,8 m above sea level and 5,8 m above river water level.

Other projects that have been developed for the state horticultural show are various playgrounds that also incorporate the theme of the Danube river in its design and a beach bar, just to mention a few (Landesgartenschau Deggendorf 2014 (2017).
Overall, the green space around the dike has been turned into a dike park which is now one of Deggendorf´s most attractive recreational areas.

View over the dike garden that integrates a parkade and adjoins the site to the left

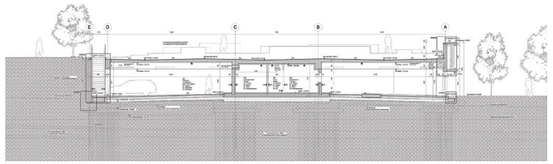


View over the dike garden and site during the state horticultural show

Beach bar and highway bridge over the Danube river in the background (Tourist information Deggendorf)

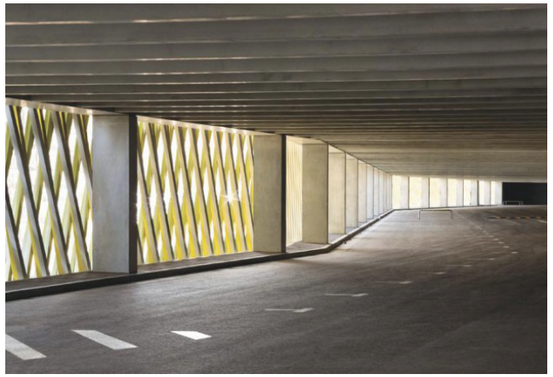
Dike garden (City Council Deggendorf)

Dike garden and playground (City Council Deggendorf)



Section through parkade (K1 Landscape architects)

Car entrance to parkade



Inside the parkade

People using the parkade as emergency space during the flood 2013

New pedestrian and cyclist bridge for the state horticultural show

Stairway to the dike garden from the site

2.5. The Site

The site was chosen because of its proximity to the dike and its unused potential.

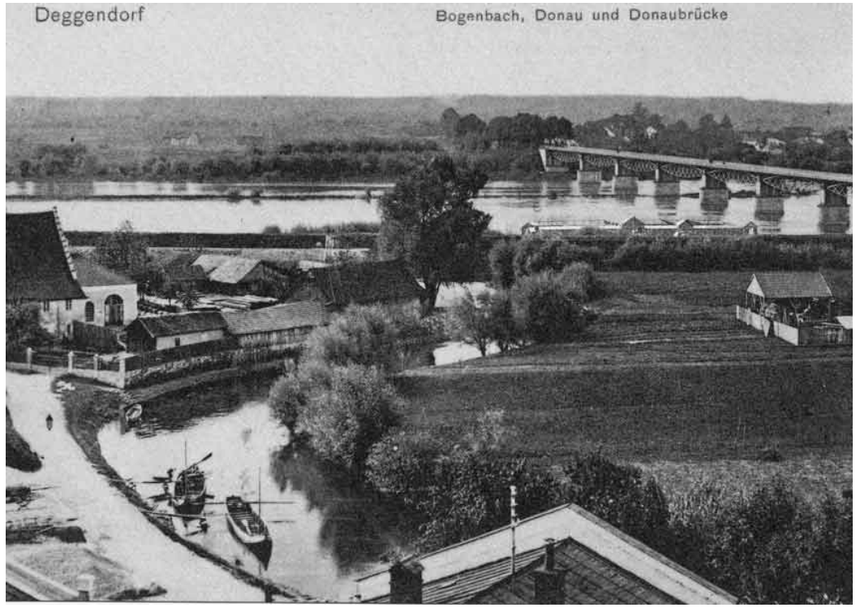
As mentioned before, the city Deggendorf has not many possibilities to grow and in order to counteract urban sprawl and to prevent new development areas on flood plains, the site reveals a perfect location to densify within the city.
Additionally the population growth of the city and the need for further public buildings together with the limited building land argue for a development of areas behind flood defences as long as they are within an existing city and are flood proofed.

The approximately 7,5 ha large site has a high land value due to its proximity to the popular dike park and the river and therefore is highly qualified to be developed and accommodate many uses to make the best value of it and to attract many people and fulfil their needs.

It is used as a pilot project demonstrating a flood resilient development of an abandoned site behind a flood defence and make use of its potential.

Photos from the site during spring (City Council Deggendorf)

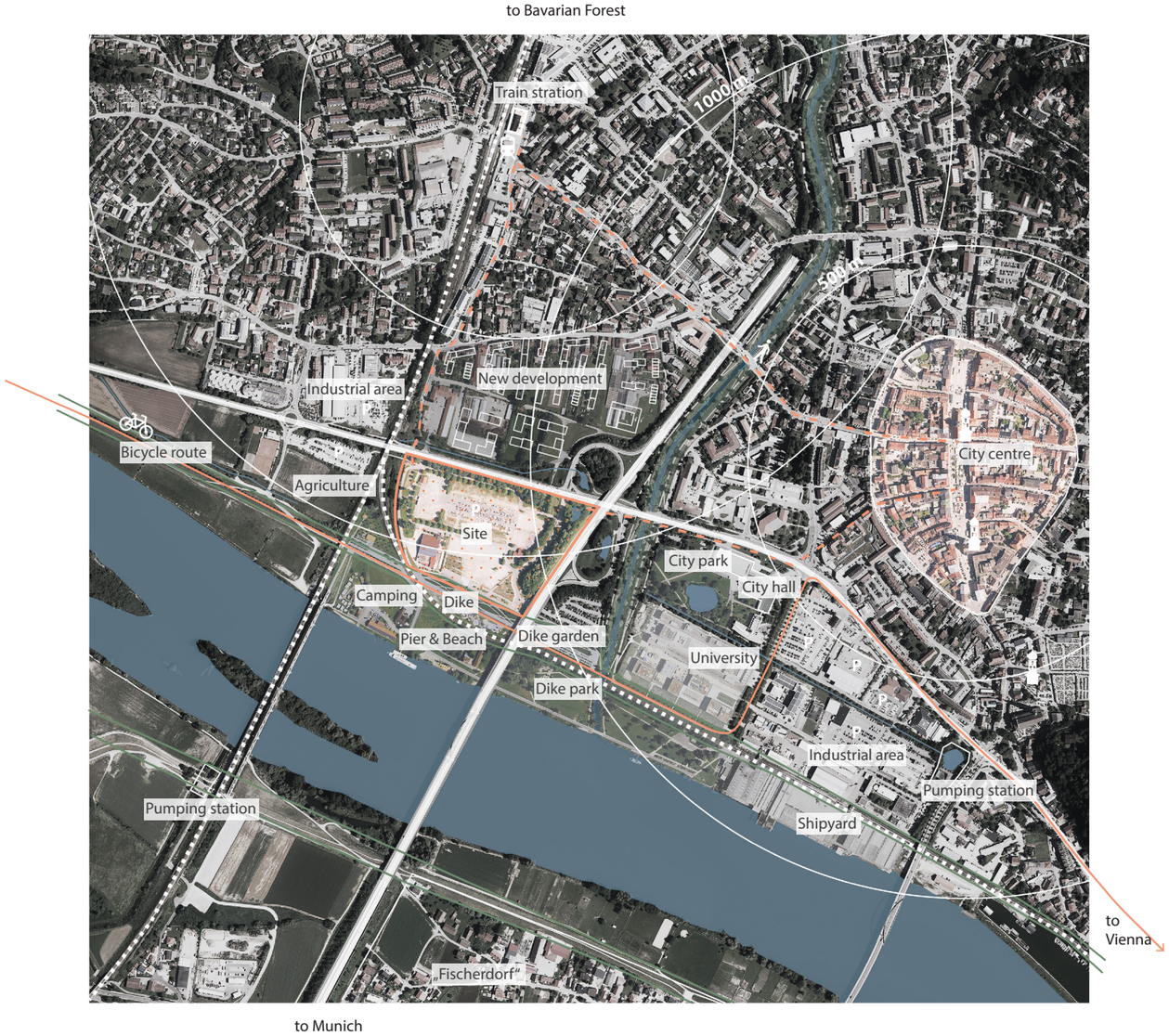
Photos from the site during winter (own photos)



History of the site

Up until 1935 the site was located in the neighbouring village "Schaching".
Deggendorf and Schaching were arguing a lot about grazing rights on the valuable pastures in Schaching. Especially the pasture "Bogenwiese", which is the site today, was of high interest in Deggendorf. This fight lastet around 250 years until they came to an agreement that Deggendorf can use this area in 1855. In order to celebrate this agreement, they celebrated a "pasture fest", which takes place on the site until now and is called "Volksfest". Volksfest is still Deggendorf´s biggest festival and attracts a lot of people to the site.

While Deggendorf was growing fast, Schaching had three times more land available than Deggendorf. Hence, Deggendorf was planning to expand its urban boundaries and tried to incorporate "Bogenwiese", as it was the perfect location to establish a railway bridge, a train station and a pier plus facilities for shipping. But only in 1935 Schaching became a city district of Deggendorf (Deggendorf.de, 2017).



Analysis

The land use plan for Deggendorf foresees no residential area beneath the locally important state road which goes parallel to the dike and creates another barrier between the city and the river.
The site lies beneath this road and is zoned as recreational green space with cultural purposes that is most used for parking (see page 53).

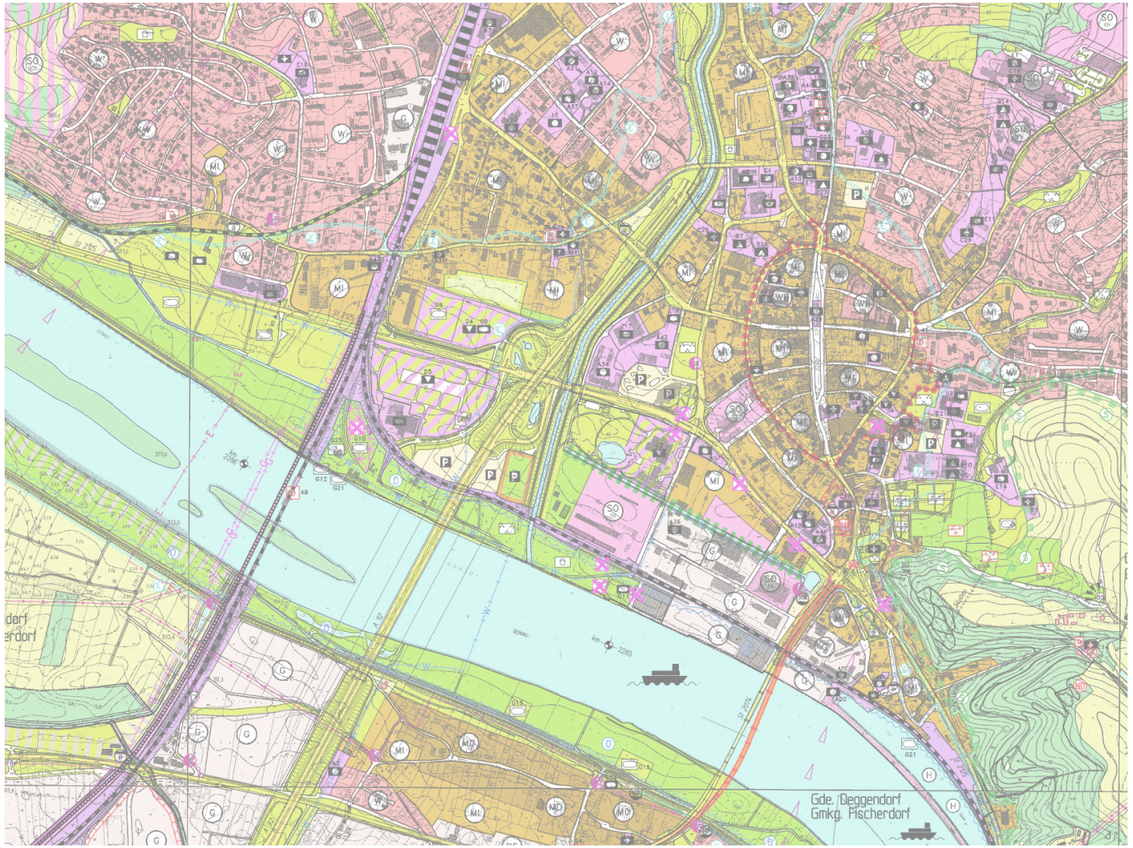
The area between the dike and this state road, where the site is located, is mostly used for green spaces, parking and industrial or commercial space. There is also a city hall and park and the technical university in the east of the site. Between the site and university is a stream flowing from north towards the Danube river in the south, that is also protected through flood defence system which creates another barrier.
To the west side of the site are agriculture fields, a tennis court and yet more parking places. The municipality is currently planning a new residential area with mixed uses adjacent to the north of the site. The dike park with the integrated park house adjoins the site in the south.

Two times a year the site together with the dike park are platform of a festival. Apart from the festival, there is a bowling centre that is the only permanently used building on site. Temporary uses include a flea market and other events. The predominantly use is parking.

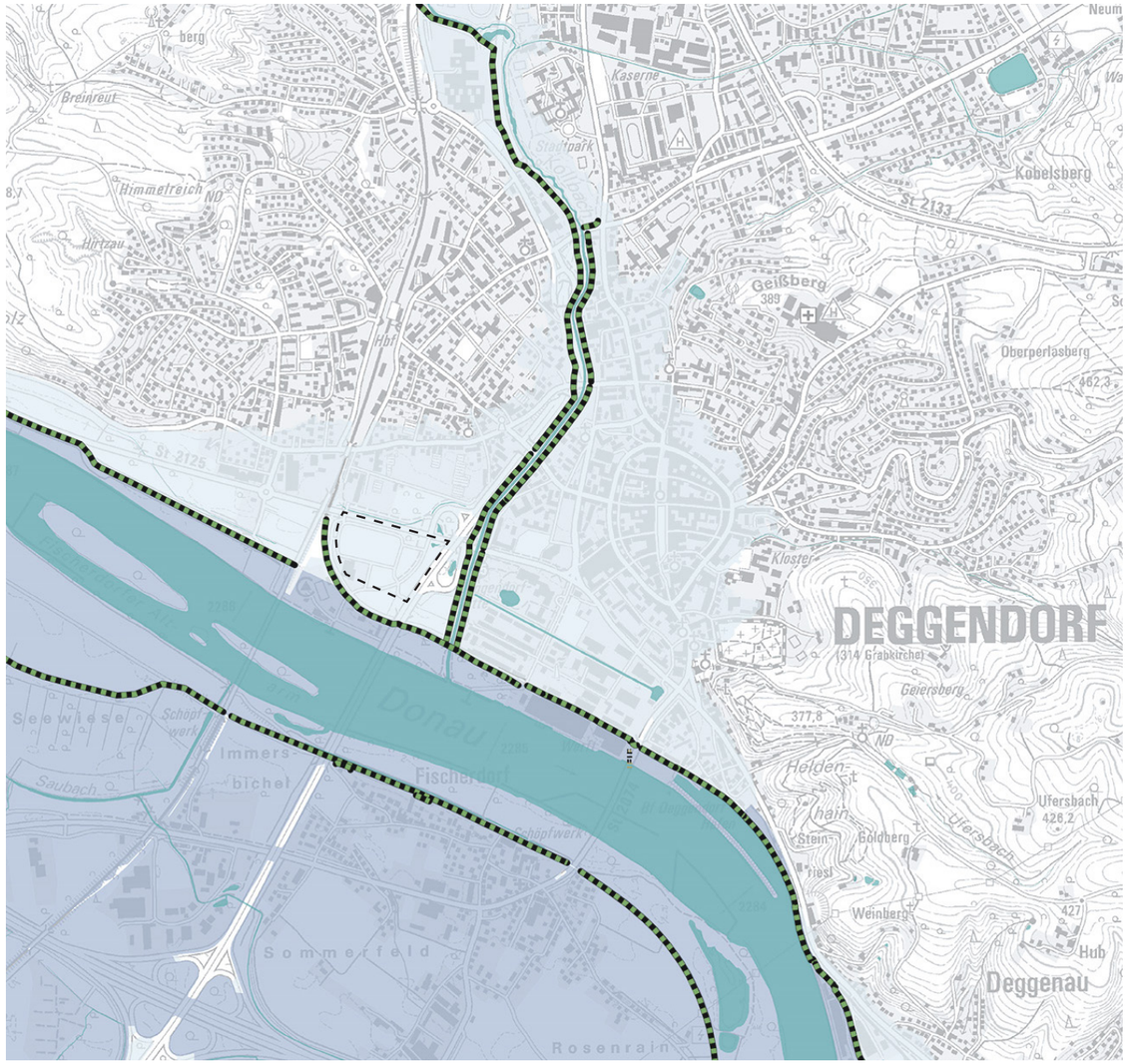
Currently the site is not connected to any public transport system, which is lacking in general in Deggendorf. It is accessible by car in the north, which leads to the parking space and the park house integrated within the dike park.
The transnational bicycle track goes along the dike park and hence is in close proximity and is connected through a small path with the site.
The site is directly connected through stairs to the newly created dike park (see page 45).
Overall, the site is surrounded by the dike, elevated highway, train tracks and noise barrier which isolate the site visually and geographically. Nevertheless, there are some pedestrian and bicycle paths which connects the site with is surrounding, including a pedestrian tunnel in the north.

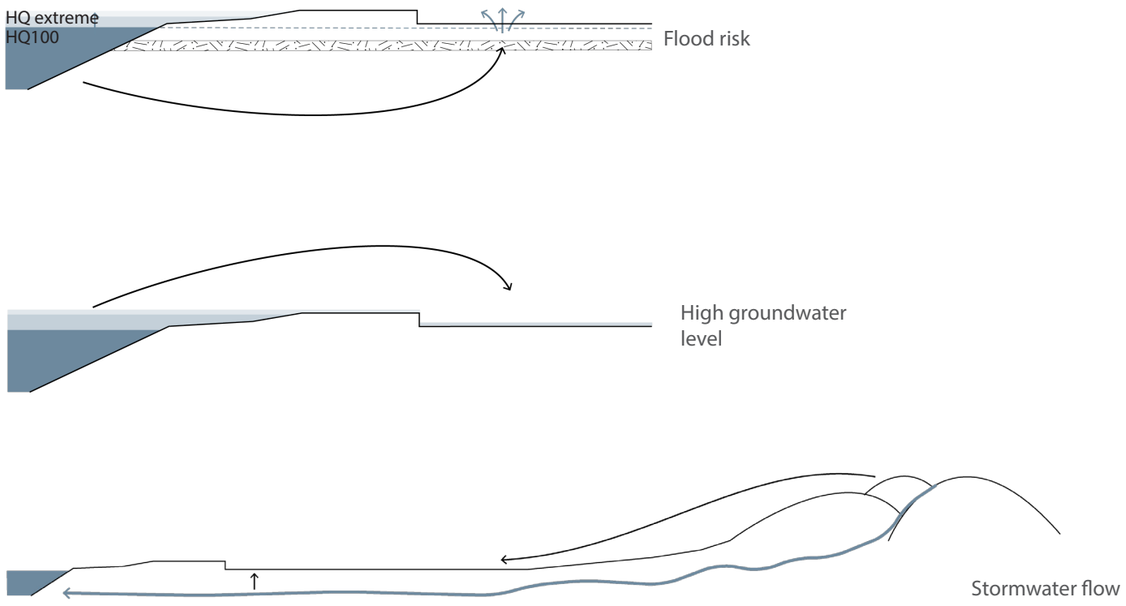
Unlike most cities the main train station of Deggendorf is not situated in the city centre but around 1 km away. The city centre itself is somehow isolated and almost 1 km away from the river and the site. All together, the distance between the site, city centre and train station is equally long and not very clearly accessible for pedestrians and cyclists.

All in all the city of Deggendorf is separated from the river and the area south of the state road is rather homogenous.



Land use plan of Deggendorf (City Council Deggendorf)

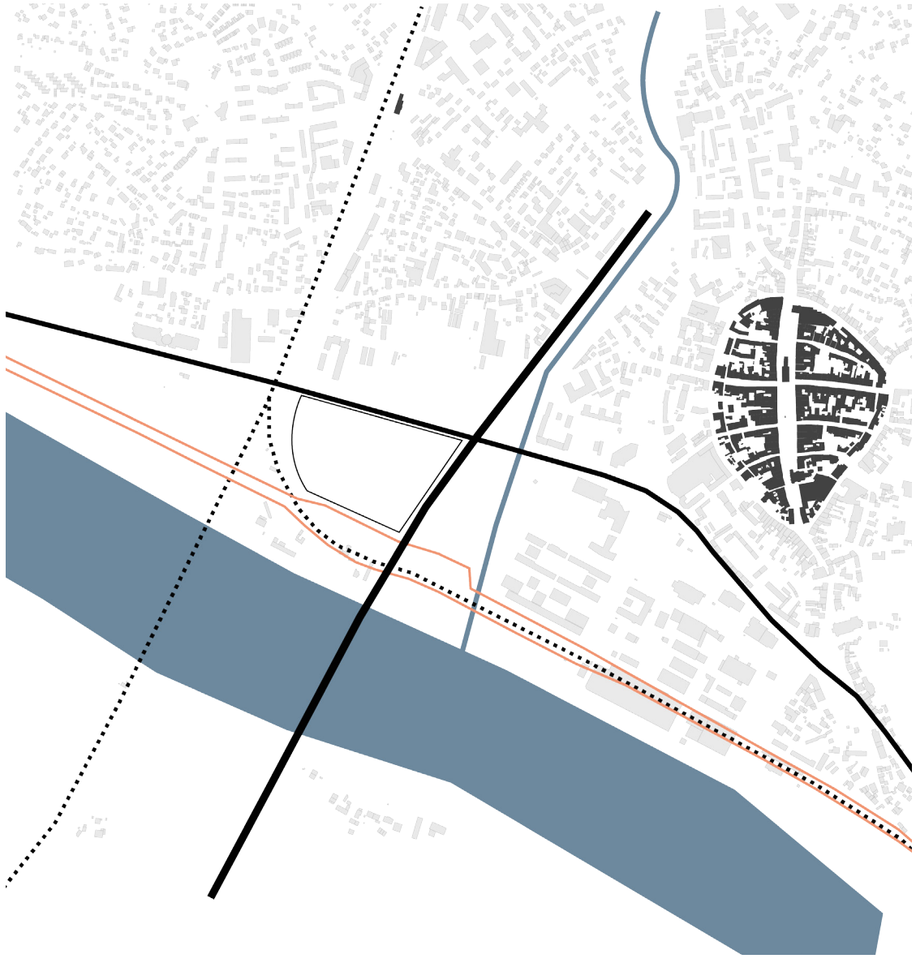




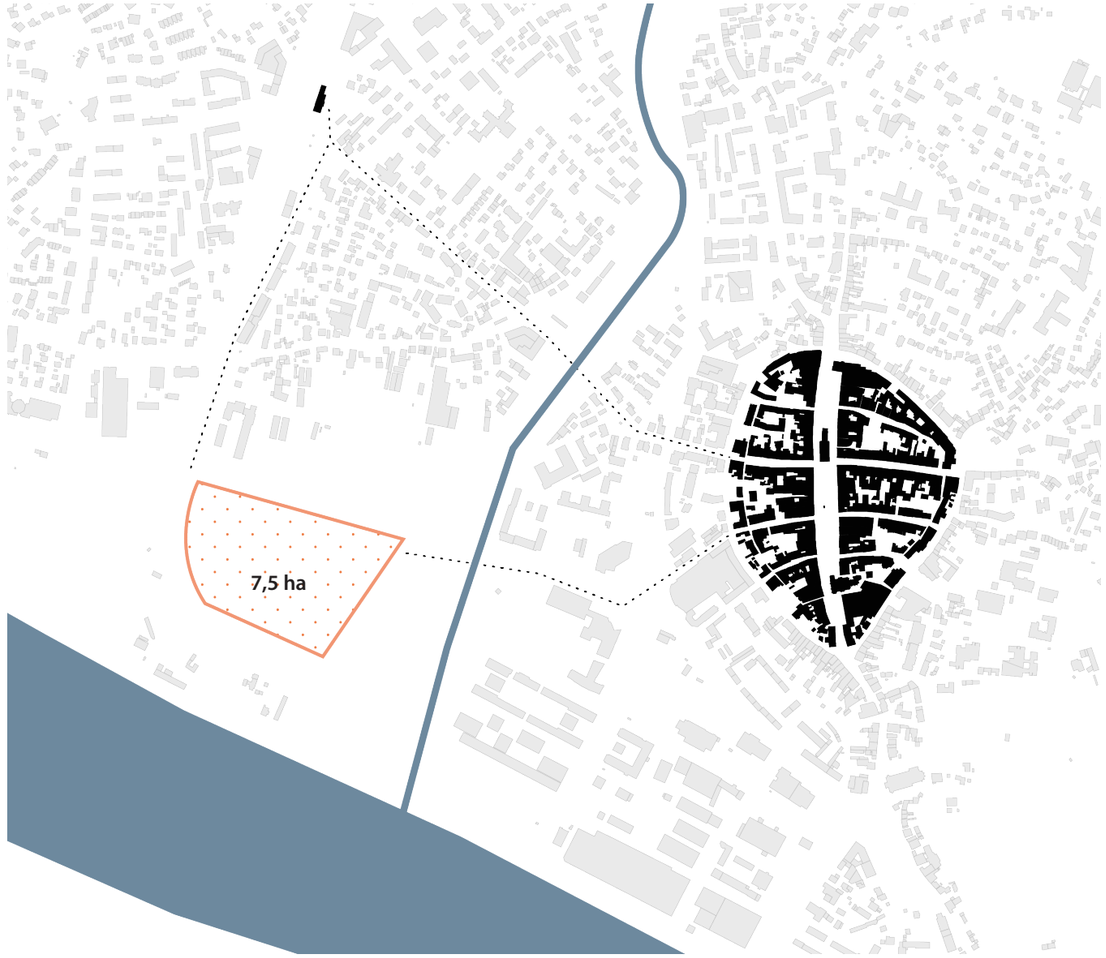
Site conditions

The site is flat and only one meter over the river water level. There is expected run off water predominantly from the hills to the west and east. The area suffers from groundwater flooding's and is not protected against extreme floods that are more likely to occur with the climate changing.

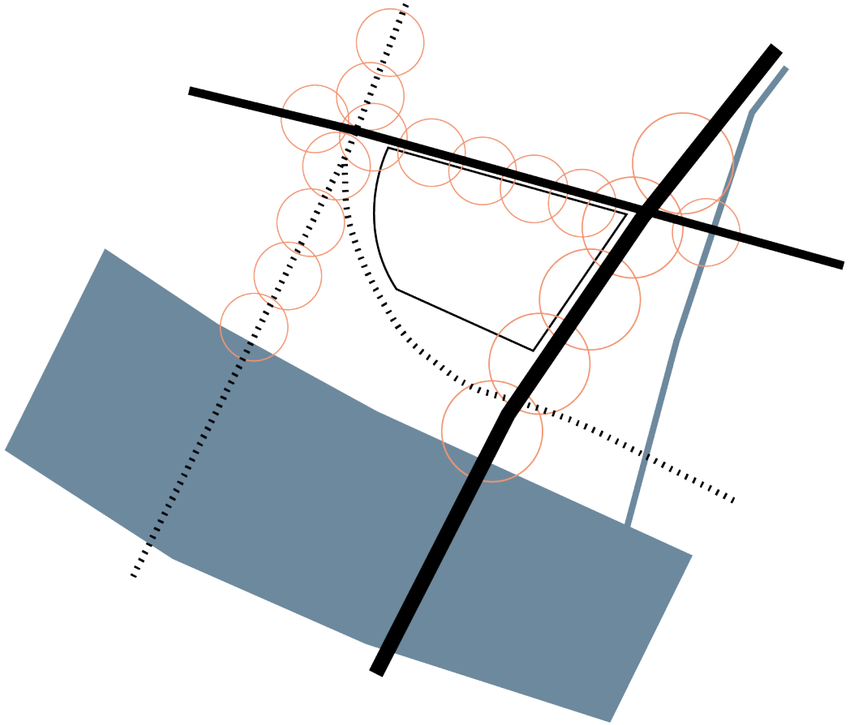
Due to its proximity to the stream and the river, the area is threatend by flood waters from south and east.



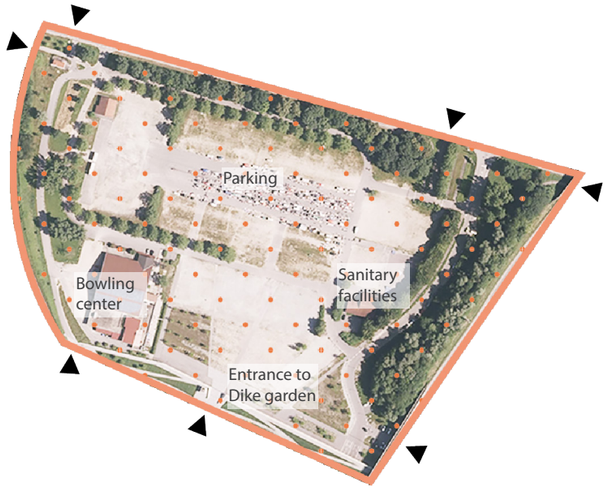
The dike creates a barrier between the city and the river



The site in the city context and scale comparison



Noise problem and isolation of the site



Pedestrian and cyclist accesses of the site and functions

3
DESIGN

3.1. Strategic steps

How can a city grow within its urban boundaries and develop simultaneously a resilience to floods?

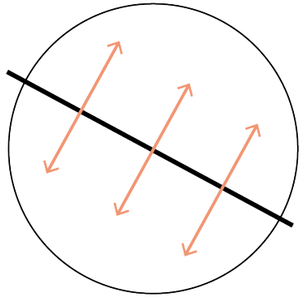
How can one overcome a dike as a barrier between a city and a river and use it at the same time as an asset for the city?

Strategy

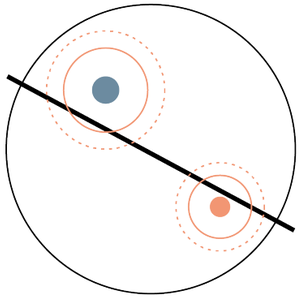
The main strategy for the site is to connect, activate and integrate it with the dike park in order to overcome the barriers and to generate public space.

Bicycle and pedestrian paths are created and connected with existing ones. The public space is activated through multifunctional usage that is also applied to the dike, the buildings and the water sensitive urban design, such as a retention basin.
The dike is integrated into the design through a platform and a cultural building that ease the transition and result in urban expansion of the dike park.

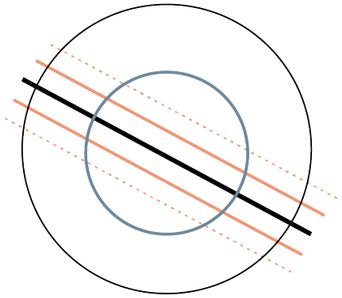
The strategy can be applied to the city in order to reconnect Deggendorf with its river.



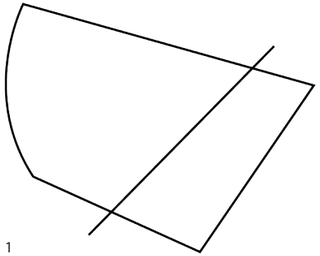
CONNECT



ACTIVATE

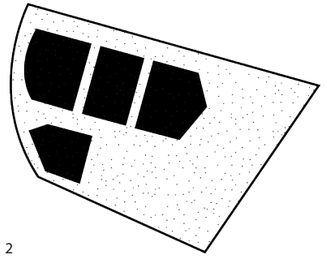


INTEGRATE



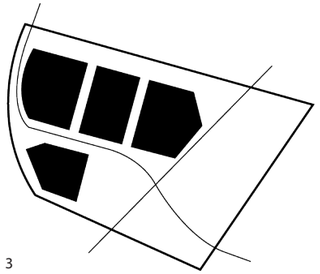
1

Pedestrian connection departs site in built and unbuilt areas.



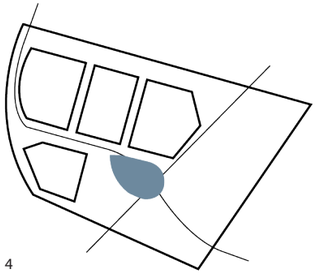
2

The built area is divided into building plots and open space ensure permeable surfaces



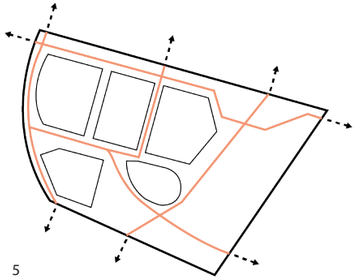
3

Main connections of the site



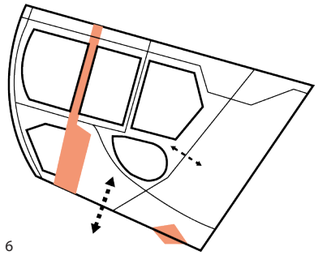
4

Activation of the site (through retention basin)



5

Accessibility of the site

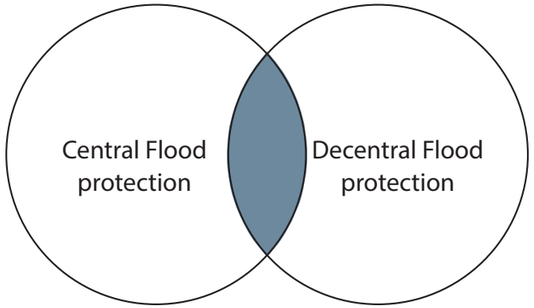


6

Urban integration of the dike into the site

How can you combine technical flood protection and water sensitive urban design while increasing the living quality at the same time?

Which design possibility offer integrated flood control measures and how can you arrange a new type of living with it?



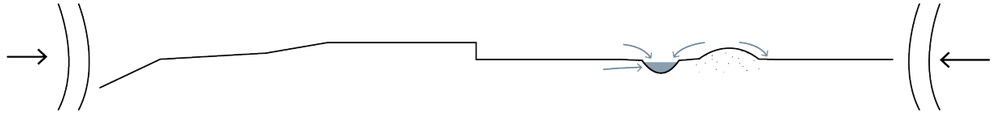
Goals for flood resilience

In order to make the site more flood resilient central flood measures, which is the dike will be combined with decentral flood measures such as building precaution and water sensitive urban design. The idea is to keep the water on site, which alleviates the pressure on stormwater and flood infrastructure and hence make the city more resilient.

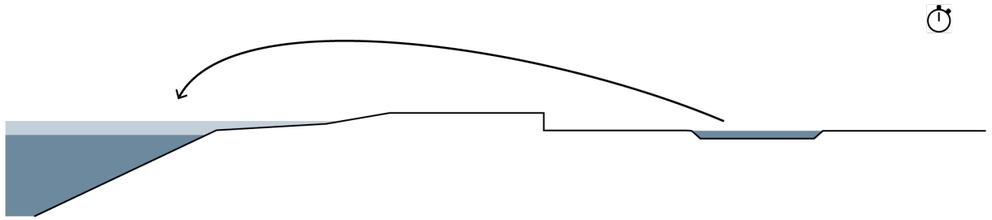
The completely flat topography aligned with small mounds (+1m) and bioswales (-1m) in order to channel and collect ground- and storm water and to block flood waters.

A large retention basin complements the flood defence through delaying the storm water discharge to the pumping station during high waters. This way the water is retained on site, which reduces the flood peak flows.

Finally a flood proofed building design applied to the site enables visual contact with the dike facade and the river and at the same time adapts to the site conditions.



Play with the topography
to channel, collect and block water



Retain water
to delay discharge

Flood proofed **Building Design**
that adapts to site conditions

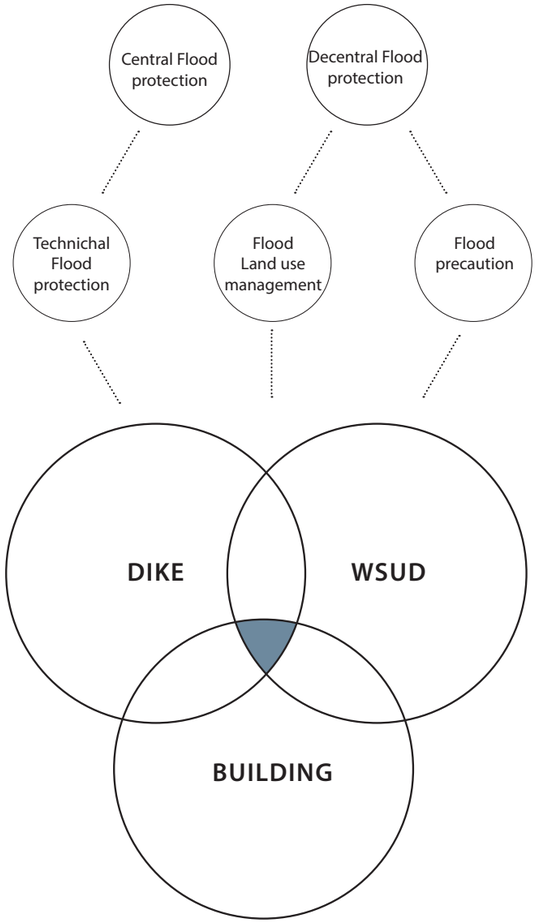
3.2. Flood resilience toolbox

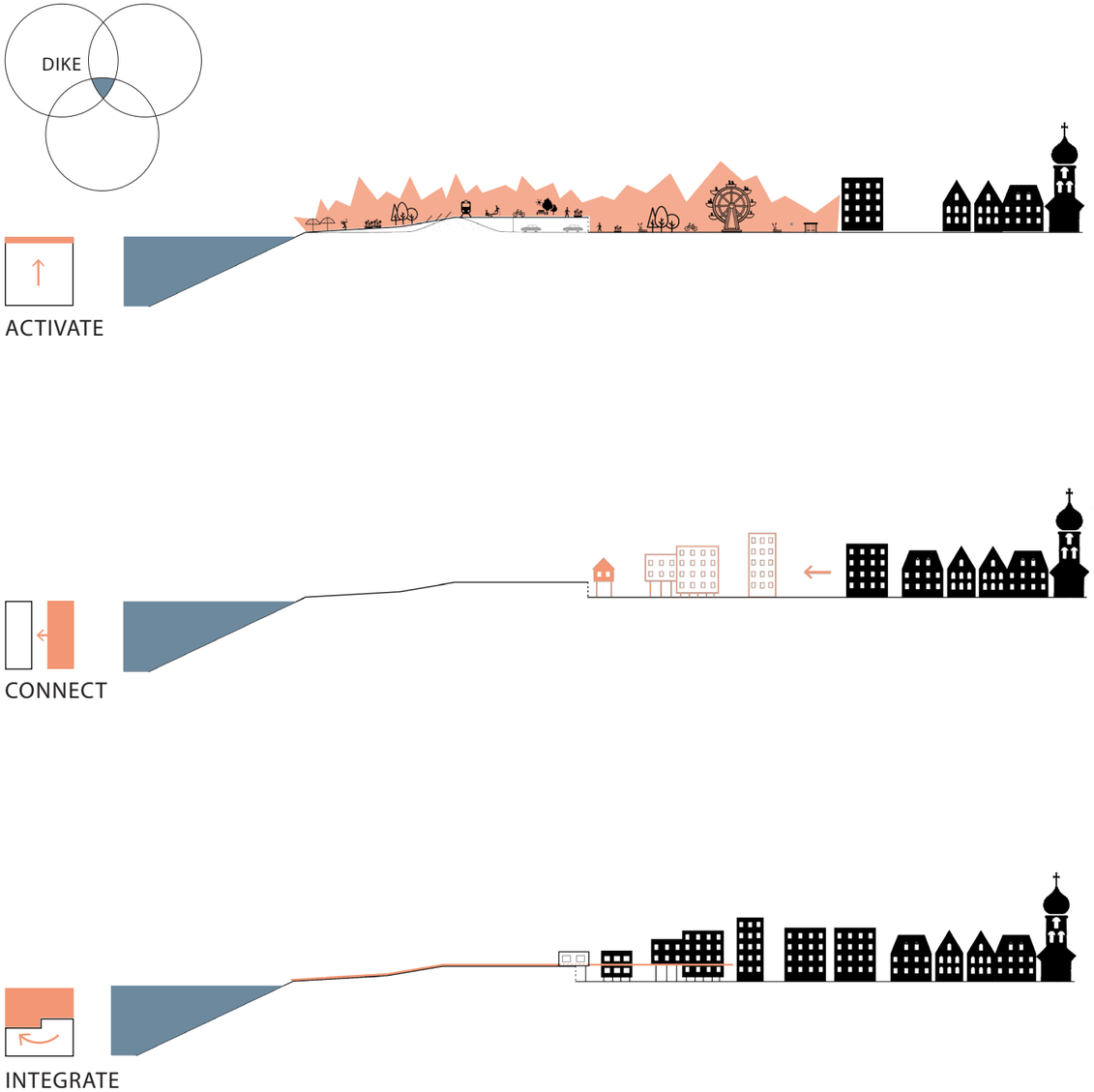
The concept of integrated flood control adapted to the site provides a toolbox to experiment with on site and develop flood resilient urban design.

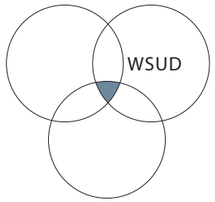
Dike

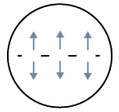
The first step is to activate the dike with various functions and use it as a qualitative green space. This will attract many people and bring the dike closer to the city. The next step is to connect the dike with the city by pushing buildings and urban functions towards the dike.
The final step is to integrate the dike with the city through urban expansion of the dike. This can be done through buildings or platforms to overcome the height difference.

ADAPTED
INTEGRATED FLOOD CONTROL

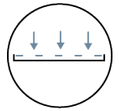








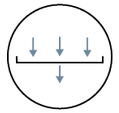
PERMEABLE SURFACES



RETAIN WATER

close WATER CIRCLE

DISCHARGE



REDUCE RUN OFF

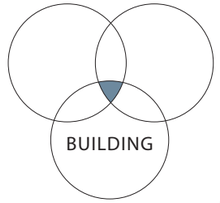
CHANNEL & COLLECT WATER

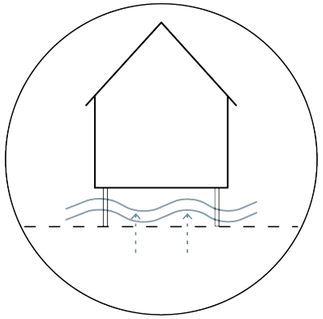
WSUD

WSUD (Water sensitive urban design) tools such as retention basins, bio swales and wetlands are used to retain, channel, collect or discharge the water and to reduce run off.

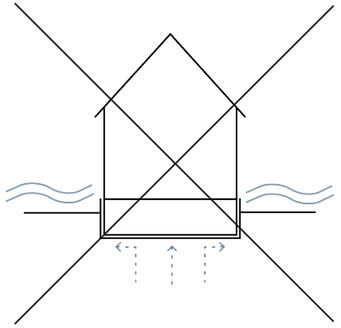
Because of the high groundwater level of the site, infiltration that is usually used in storm water management is not the first priority. More important is to provide permeable surfaces to let the water come and go.

The WSUD tools are site-specific and help to make the development more flood resilient.

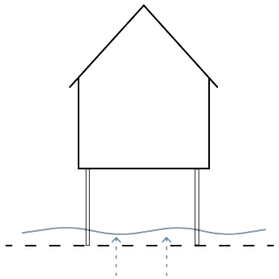




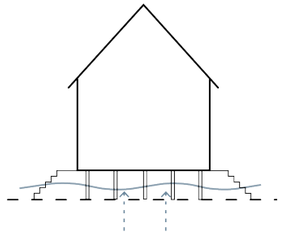
Wet- proofed buildings
(Flood resilience & avoidance)



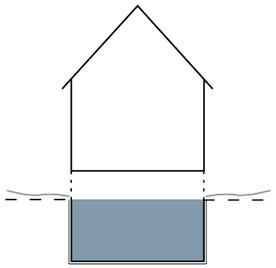
Dry- proofed buildings
(Flood resistance)



1. Building type: 4m elevated



2. Building type: 1m elevated



3. Building type: Sacrificial basement

Building

For a flood-proofed building design that adapts to the site conditions 3 types of buildings have been created after researching different flood proofed building types (see chapter 2.4.2).

The common practise in Germany is to develop buildings that resist floods through a more robust foundation. This building type has been neglected because they do not solve the problem but relocate it.
The first two chosen buildings allow the water to come and go, through permeable surfaces underneath them and do not increase the hydrostatic pressure and hence risk floods at another place or structural damage. They follow the principle of flood avoidance.

The first building type is elevated 4 m over the ground, which is the same height than the dike.

The second building type is 1 m elevated and accessible through stairs and ramps.

The third building type includes underground parking that reaches 2 m under the ground and 1 m over. This space is used as water retention space during flood events (Pelsmakers S. 2014).

3.3. Flood resilient urban design

The graphic shows the different levels that structure the design proposal.

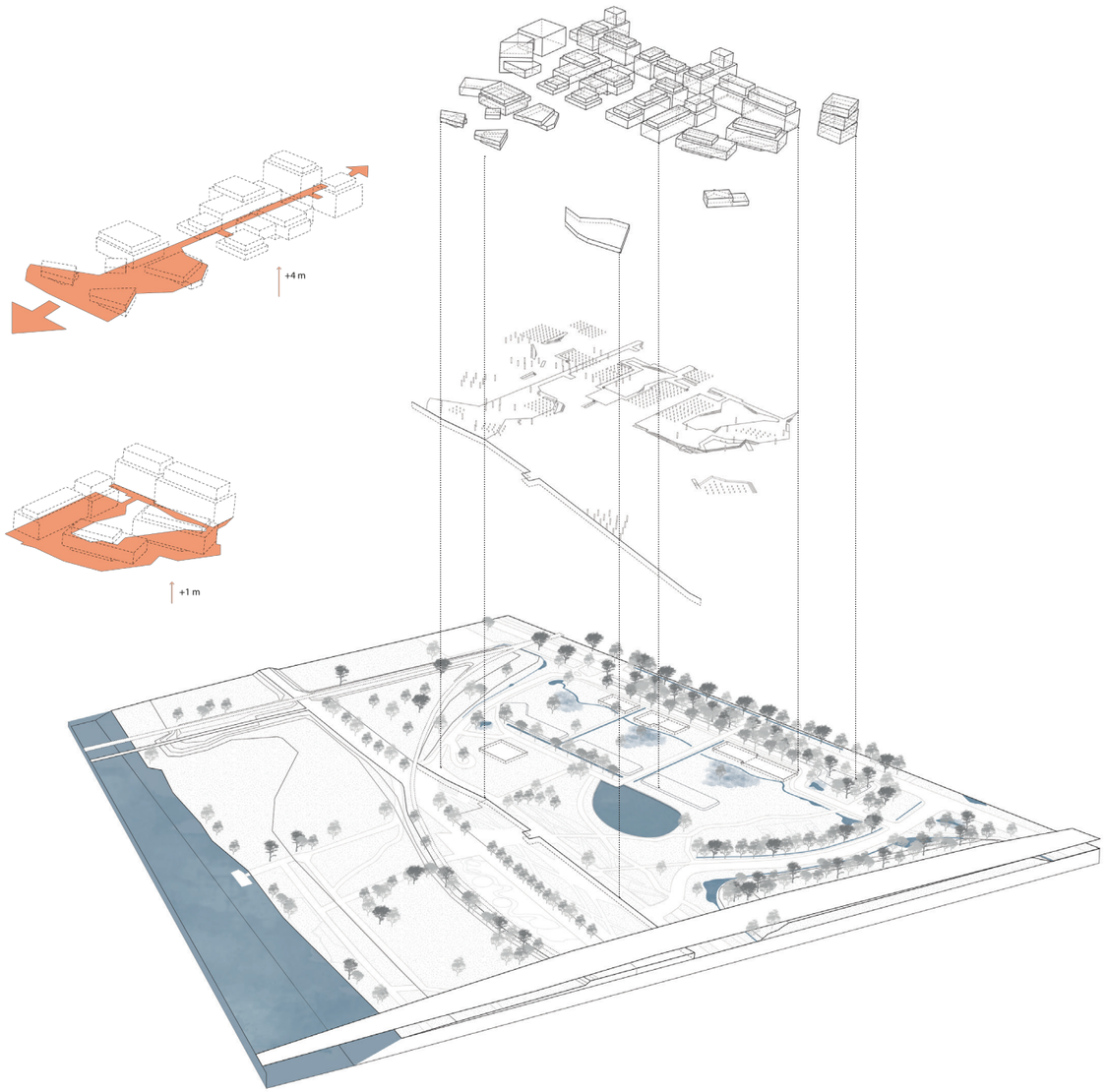
The first level are the topography and landscape.
The topography of the site is almost flat and lies just like a basin surrounded by geographical barriers, which are the dike, sound protection, highway and train tracks.
As mentioned before, permeable surfaces are essential for a flood resilient development of the site. Despite some existing streets the whole site has permeable surfaces to encounter the different flood risks.
Most of the existing trees are being kept and new ones planted. The public open space is , just as the buildings are, on different levels, which does not only have flood defence related reasons but also creates an exciting perception of the area and gives it its identity. A retention basin and bio swales are around 60 cm below the surface. Three mounds are 1m above the ground to block and channel water and provide a platform for buildings. The soil that has been removed for the bio swales, retention basin and basement can be used to create new mounds.

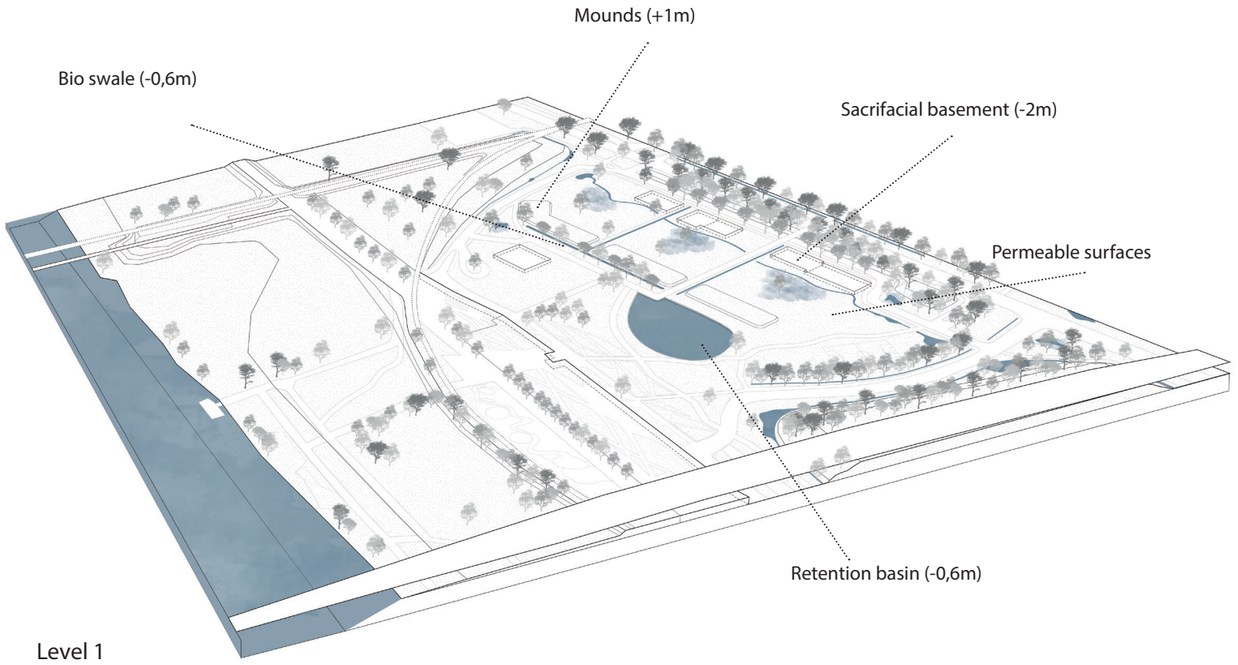
The second level are the columns, piers and platforms

Columns and piers made out of impermeable concrete are the foundations for the buildings and reach 1 or 4 m over the surface and around 1 m into the ground.
The 1 m elevated platforms around some of the buildings are accessible through stairs which in turn provide for seating along the green area.
Ramps ensure accessibility for wheelchair users and others.

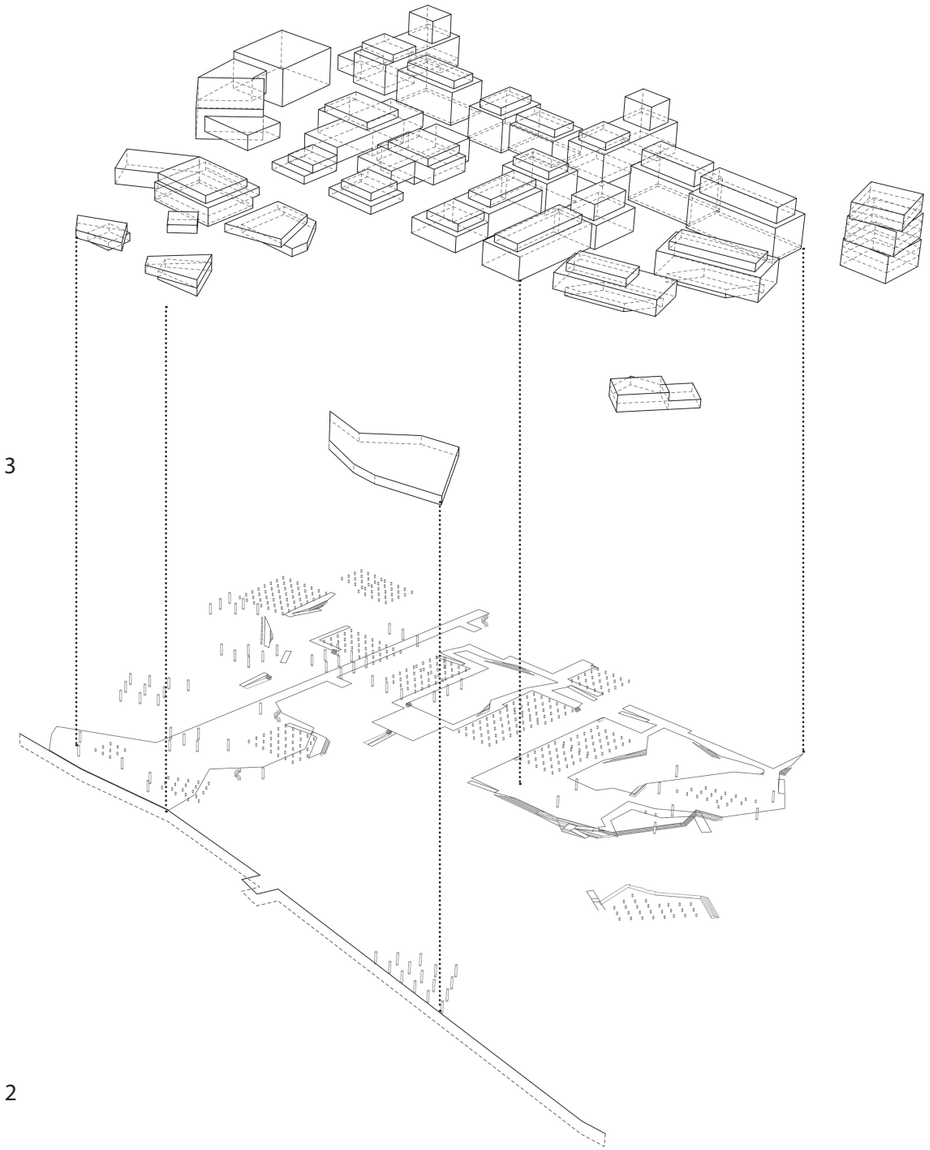
The third level are the Buildings
The indoor living space defines the last level and is fixed on the columns, piers, basements or mounds.
Most of the buildings are 16m wide and provide rooms for offices, commercial or student living. The residential space that is most of the times accommodated in the top floor is 12m wide. Campus buildings are around 24m wide.
The 3m elevated buildings are accessible through platforms or through adjoined buildings.

The prevalent material is wood, that is suitable for elevated buildings and platforms and represents the character of the Bavarian forest.



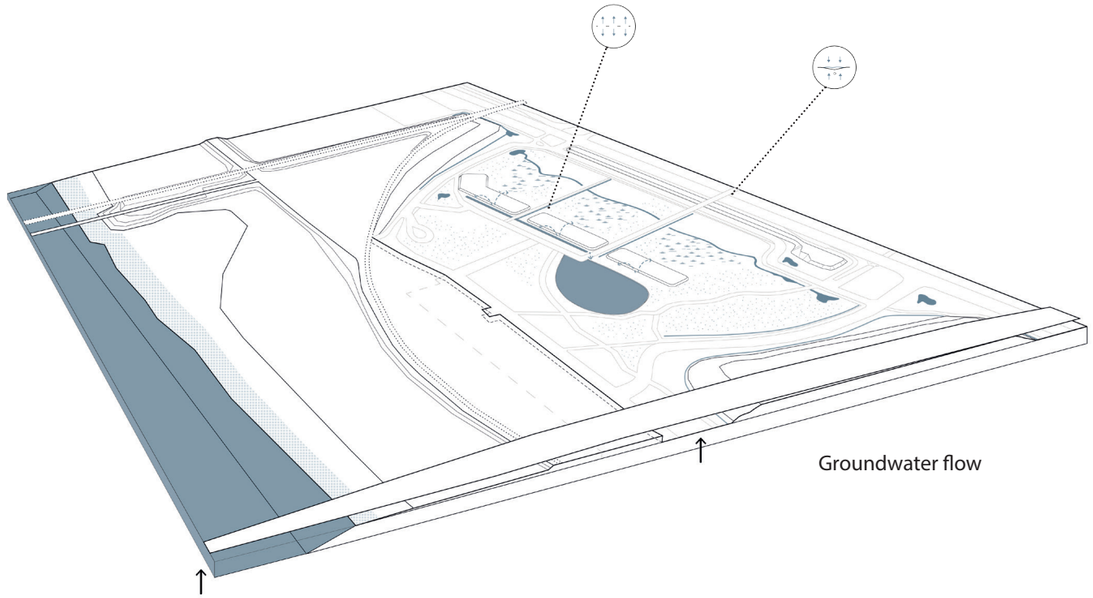


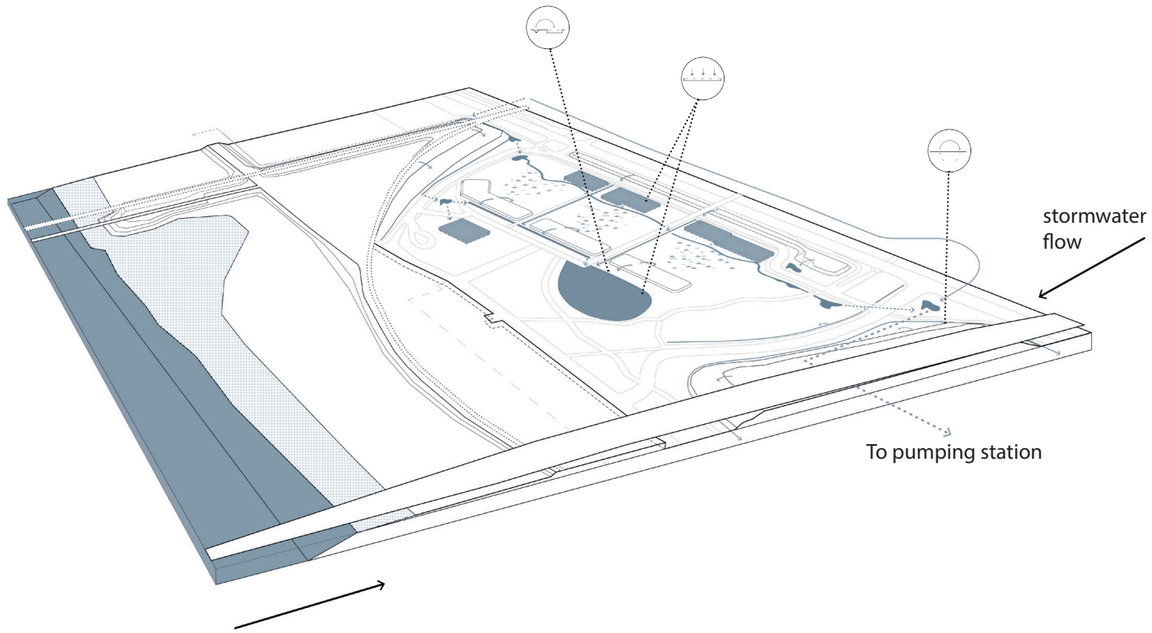
Level 1



Level 3

Level 2





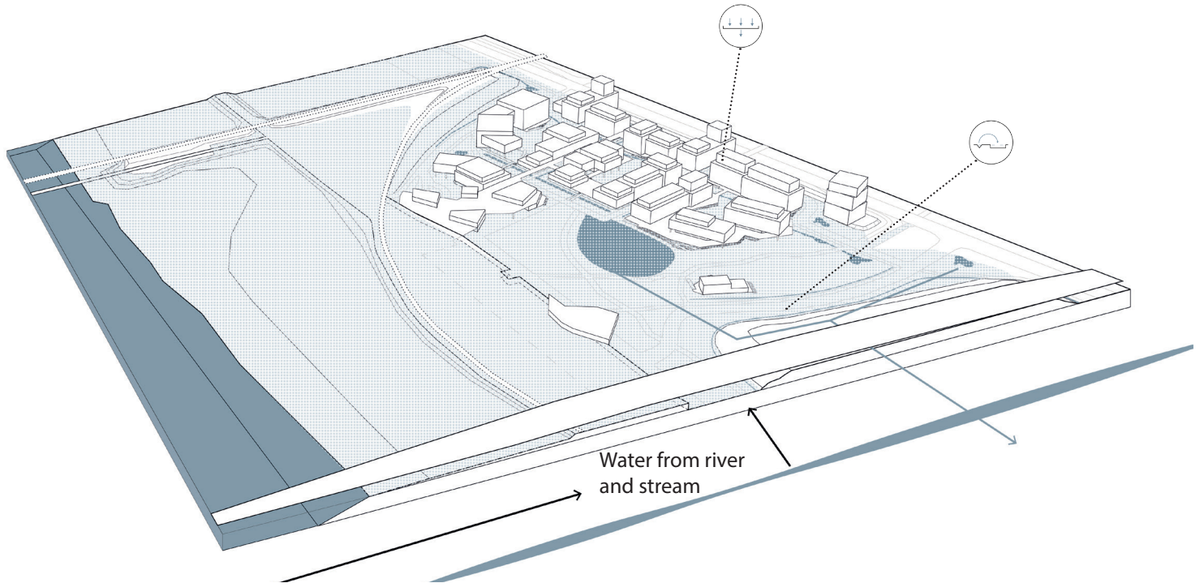
Flood scenarios

During **groundwater** floods, which usually occur when the water level of the river rises, the groundwater can come through the permeable surfaces to the surface. The applied WSUD tools and the little mounds help to channel the flood water to wetlands or retention basin where it can either discharge or infiltrate delayed.

During **heavy rainwater events**, the WSUD tools are working with the storm water on site to alleviate pressures on storm water infrastructure of the city.

By connecting the bio swales and channels with the existing ones next to the site, the water circle is closed and works efficiently.
Bio swales and detention ponds capture run off water from the hills to the west and the east.

Wetlands and the retention basin are filled with water from the bio swales and channels. The retention basin retains the water and discharge it to the pumping station only if the capacity is exceeded.
Green roofs can retain rainwater and reduce the run off speed. The basements can be filled with stormwater.



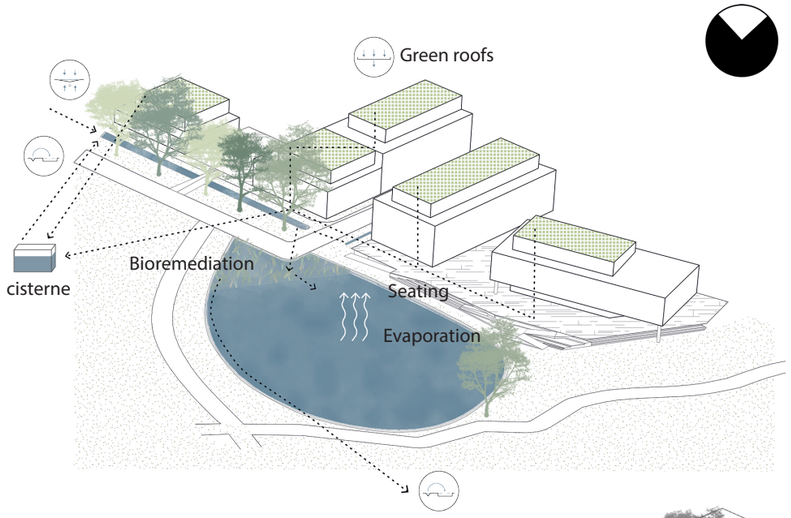
During **an extreme flood event,** the whole site could be flooded approximately up to 1 m.

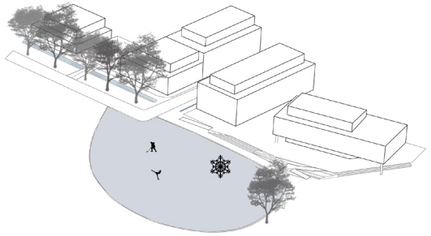
In this rare case the elevated buildings are not flooded and can be occupied and the platforms provide public space. The basements are flooded and can retain the flood water.

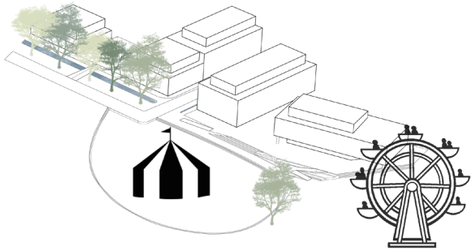
In this way the flooded site can protect surrounding areas from being flooded and alleviate the pumping station to a certain extent.

The retention basin, that represents the heart of the site, is permanently filled with water except for some time in summer, when its space can be used for a more effective water catchment during heavy rainwater events.

One part of the retention pond is a water bio tope that cleans the water through bioremediation and then release it to the larger pond. The bio tope is connected through an underground pipe with channels in order to maintain a water flow even when the pond is empty. The bio tope captures the water from the bio swale, channels and green roofs.







The cleaned water can be used for people to play in and adds an aesthetical aspect to the public space. The surrounding stairs can be used for seating.
The retention basin has a positive impact on the micro climate through the evaporation of the water that has cooling effect in hot summers. It has a capacity of 1638m^3.
The retention basin is activated through a multifunctional usage throughout the year. During the summer it can be emptied and used as a platform for the festivals that take place at least 2 times a year. In the cold winter months it can be used for ice skating, which makes it an all year multi- purpose water body.

3.3. Masterplan

The design focus lies on the connection between the dike park and the new development to overcome the visual and physical barrier a dike can create.

A platform that is on the same level than the dike continues until the north end of the site, expanding the dike park and enable a smooth transition between dike and new development. Public buildings fitted along the platform will supply recreational and cultural amenities that attract people.
Further east the dike is connected through a multi-purpose cultural building that can make also use of the parking house (underneath the dike garden). The area in front of it frames the dike garden and provides for seating and commercial purposes. In general, the dike connections add more functions to the dike garden and adapts its Danube river related design.

The existing pedestrian tunnel in the north of the site and the stairs to the dike park are linked through the main pedestrian path.
Hence, the visual contact to the stairs is maintained in order to enable physical and visual connection to the dike. This main path expands until the beach area of the dike park, which enables quick access to the river.
Another path is added to ensure barrier free access and winds through the new planned community garden.
The new paths also ensure a quick way to the transnational bicycle track along the dike garden. Therefore the second main path expands towards the east along greenery to the dike garden. It passes the university parking lots that have been recently planned by the municipality.
The area under the 4m elevated platform can be used as a E- bike centre, because of its already existing popularity together with the bicycle route..

Generally, to improve the accessibility of the site, pedestrian and cyclist paths connect the site with its surrounding and ensure quick ways to the train station, city centre and river/dike. One path continues over the state road to the newly planned development area to improve accessibility. Furthermore a new bus stop (north of the Hotel) along the state road demonstrates the importance and benefits of accessibility.
Along with the sustainable design of the site, car use and parking will be reduced to a minimum. Access in times of an emergency is given, but cars will not be allowed in the centre but will have to enter from the periphery, where parking houses are provided. Existing parking areas in close proximity will be better connected to increase its usage.

Overall the site is designed for pedestrians and cyclists and enable short walking distances to important locations.

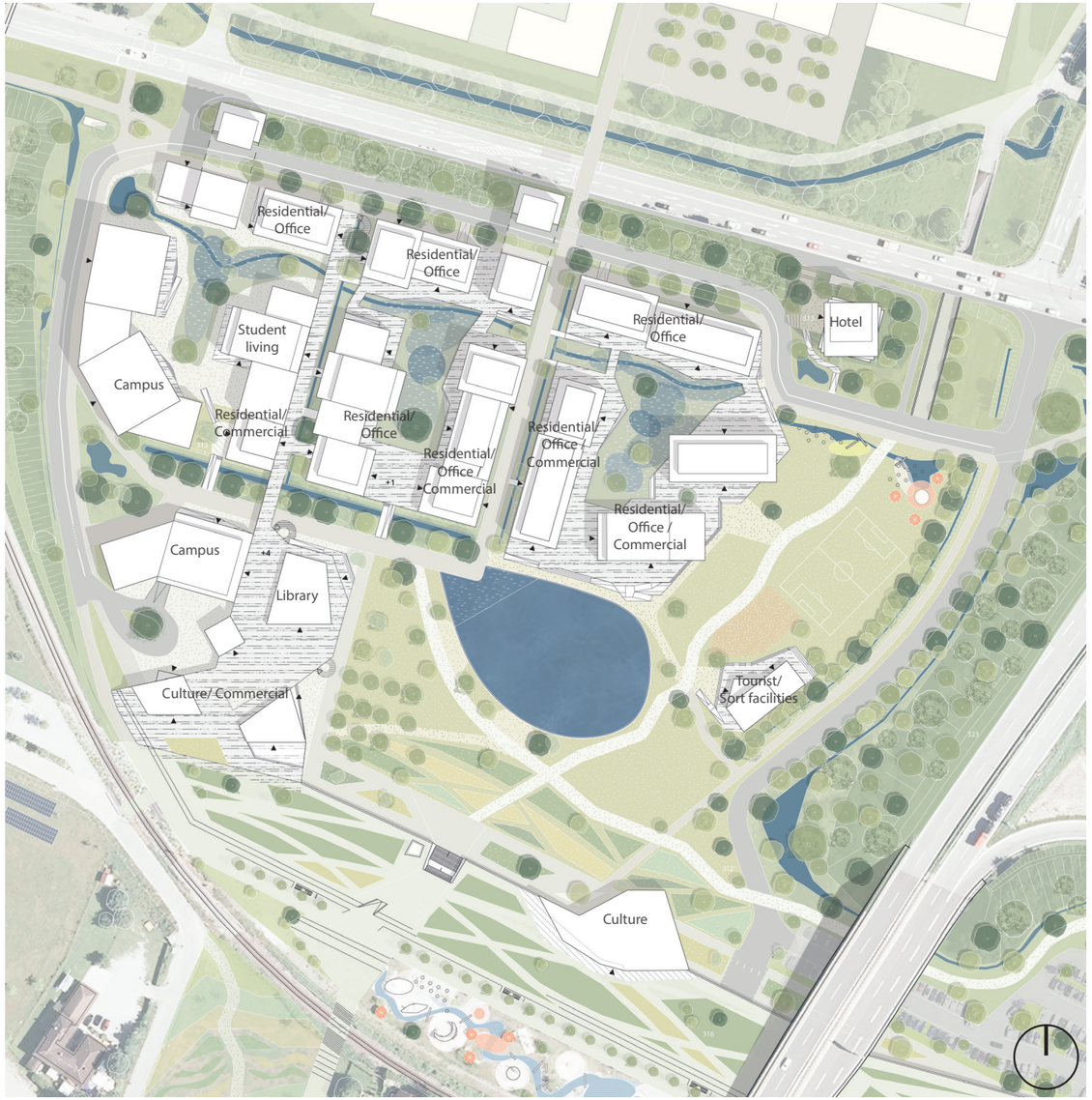
In order to maintain the site as a festival area and enable an expansion of the green space, approximately 50 % of it will be developed and the other half remains green space and multi-purpose area that allows for the festival to still take place.

The green space can be used for sport, recreation and cultural purposes and can be seen as an expansion of the dike park. The retention basin is the centre point of the site and the green space and makes the element of water predominant.
All in all the development of the site enables an urban and green expansion of the dike.

The dike will be transformed into a multifunctional dike park that will ease the transition to the site and the built area in general.
A multifunctional dike helps to maintain the technical flood defence and hence lowers the risk of breaches. Through varied uses and design a multifunctional dike can generate money to maintain the technical flood defence and promote an aesthetical integration into the urban landscape.

New functions, such as a community garden, additional wetlands and solar panels have been added to the existing design of the dike park. The community garden can make use of the usually valuable soil of the flood plain and brings people together. Wetlands create a further retention pond to improve the flood defence.
Solar panels make use of the dike slope and generate energy for the applied integrated flood control.
The mixed uses will attract many people and help to connect the city with the river.

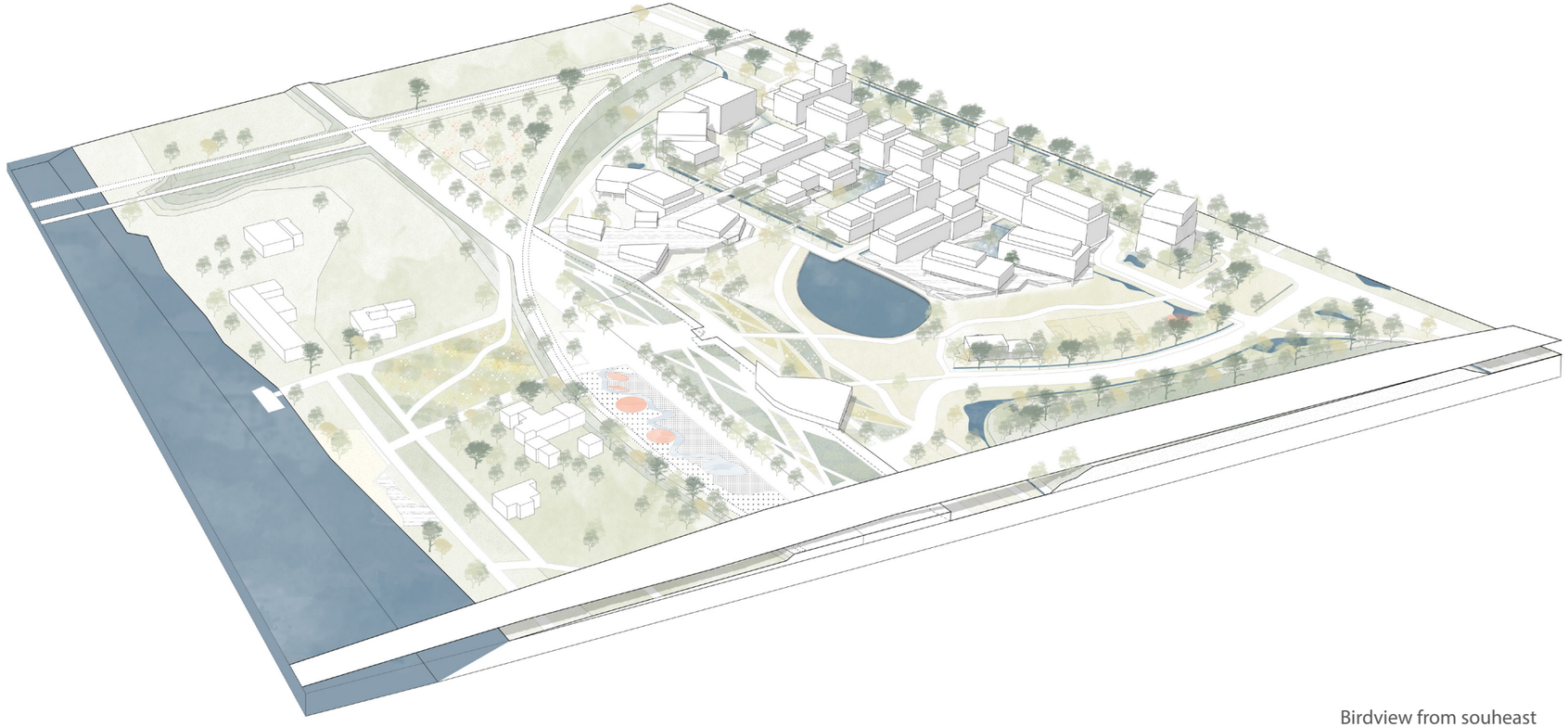
The site has a high land value due to its proximity to the popular dike park and the river and therefore is highly qualified to accommodate many uses to make the best value of it and to attract many people and their needs.
Due to its close proximity to the city centre, campus and the currently planned residential area adjacent to the north, the new design proposes a mixed uses development with an urban character.



It will provide for an expansion of the campus area, many working places such as administration, commercial and cultural buildings as well as living in the top floors. In order to create an urban area it is inevitable to include residential areas to create a vibrant and vivid place. Also the current population growth and the limited building land argue for it and the flood proof buildings enable the development. Therefore the land use plan have to be aligned to allow residential areas underneath the state road (see page 56).
Temporarily uses such as the flea market will be kept and enhanced and many more uses, such as sport fields and art exhibition areas will be introduced.

The buildings increase in height towards the north to optimise sun access and provide visual contact to the river. They will have slightly tilted green roofs with solar panels to supply the area with renewable energy.
Overall, public buildings with special function are facing south to highlight them from the others and make best use of the sun.

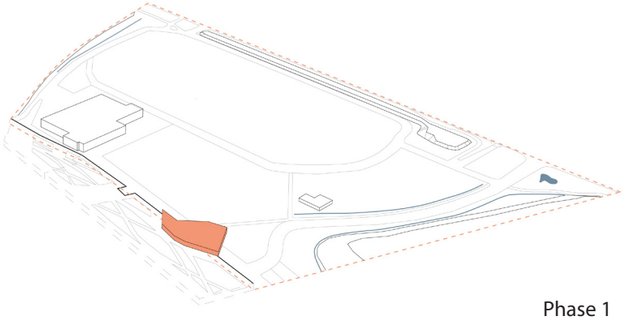
The buildings in the north block the sound from the state road. Together with the Hotel, there are three towers that are around 8 storey high that reflect the city´s panorama view of the three church steeples without exceeding them.
The buildings density seems quite high for Deggendorf but is justified through the high amount of greenery and water bodies and makes best use of the land value.



Birdview from souheast

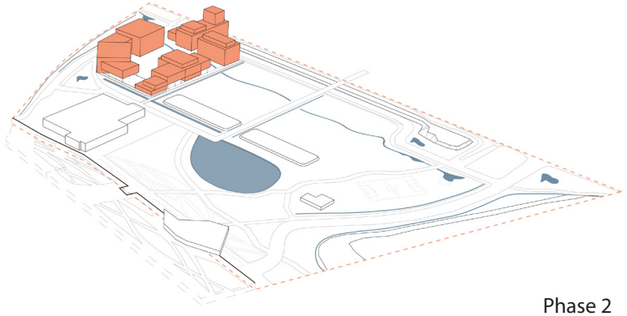
Phasing

Phase 1:
The cultural building integrated to the dike will be built first. The goal is to activate the dike park and its urban expansion from the beginning.



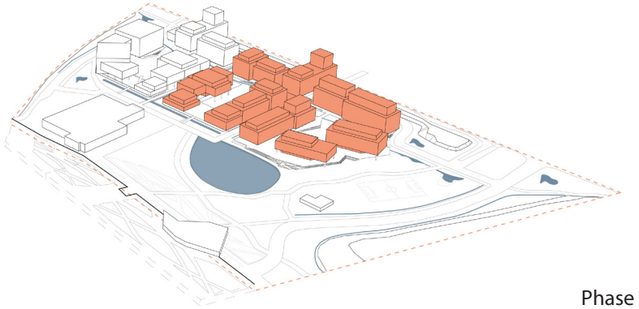
Phase 1

Phase 2:
The campus expansion follows. Students and cultural engaged people are involved in the design process and can help to increase the popularity of the area.
The new green and blue infrastructure enables a use of the park in the early stages.

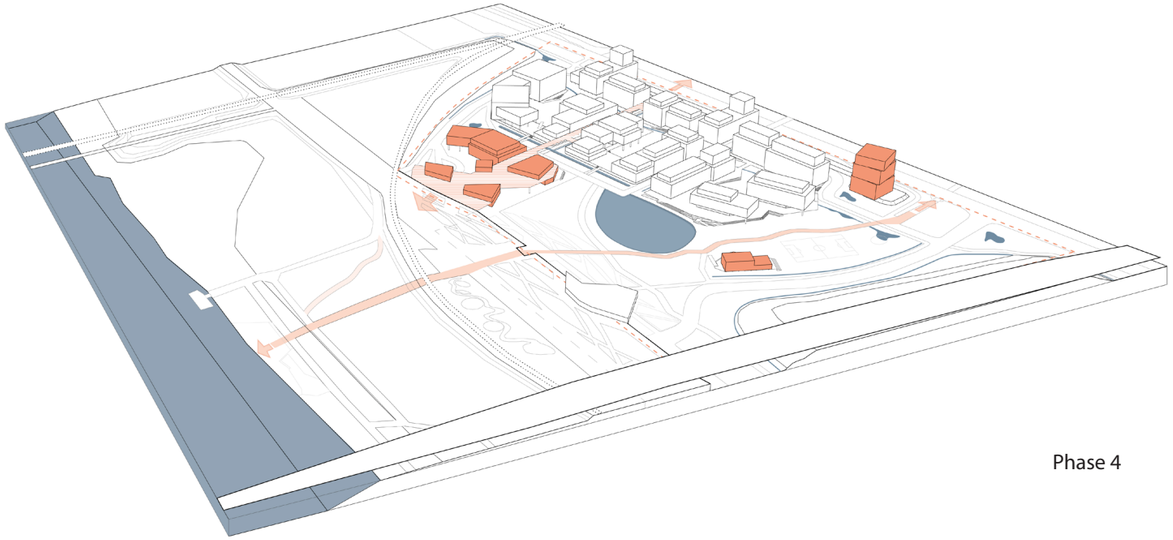


Phase 2

Phase 3:
The building along the sound protection follows in order to block the noise coming from the street and offer working and living places to further activate the area. The block buildings together with the platform and wetands create attractive working and living space.



Phase 3

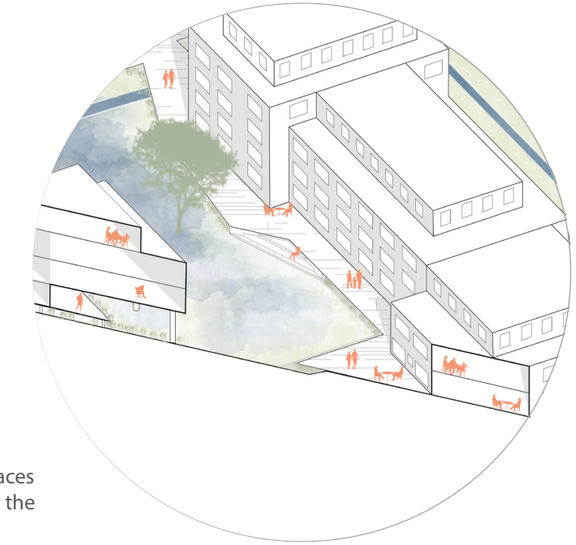


Phase 4

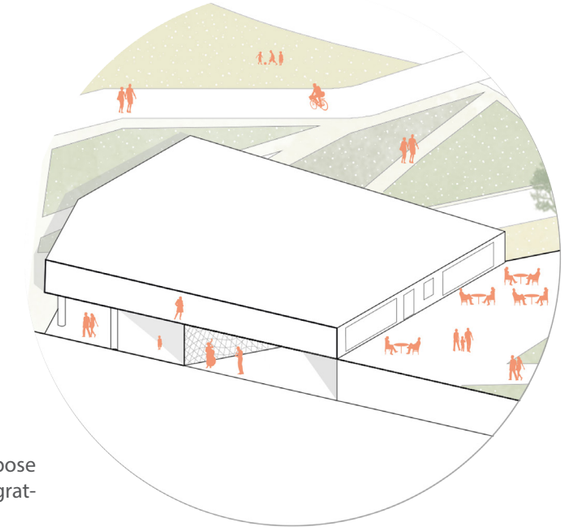
Phase 4:
The existing bowling centre and sanitaire facitlities make room for the new connecting platform and public buildings with cultural purposes. The hotel attracts and accommodates tourists and congress facilities.
The main path and platform connect the site with the river and finalise the urban integration of the dike.

Axonometric view to the east

Axonometric view of the site



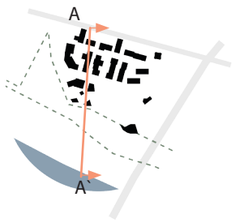
Zoom in showing public places around the wetland and on the platform

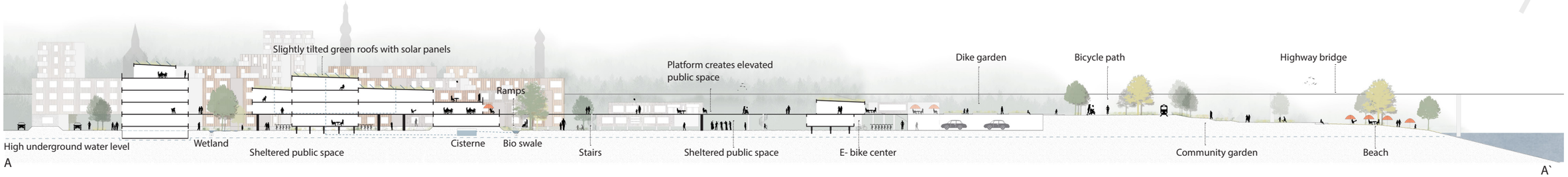


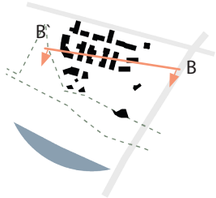
Zoom in showing multipurpose cultural building that is integrated into the parkade/ dike

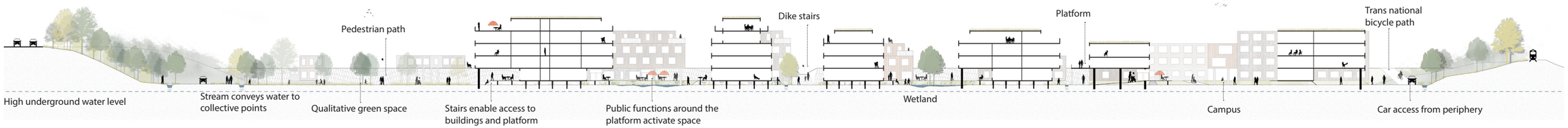
3.5. Details

Sections









Perception

Flood proofed building types and open space create a perception of the area that is rather different from usual developments.

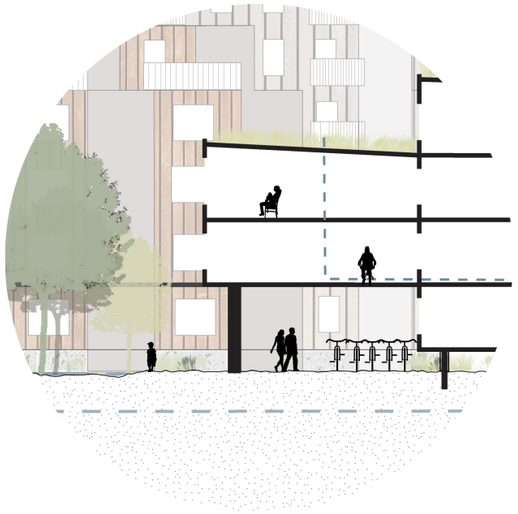
The gap between the buildings and the ground can be used in multiple ways. Vegetation or wooden facade can cover the 1 m gap to frame public spaces and reduces the permeability underneath the building. The technical building services will be situated underneath the buildings and protected through water resistant material.

In general, platforms and the space underneath 4 m eleveated buildings add different functions to the area and increase the amount of public space which further activates the area.

Because of the high groundwater level bio swales and wetlands are likely to be filled with water most time of the year. Together with the retention basin, water is the predominant element of the area and creates its identity.

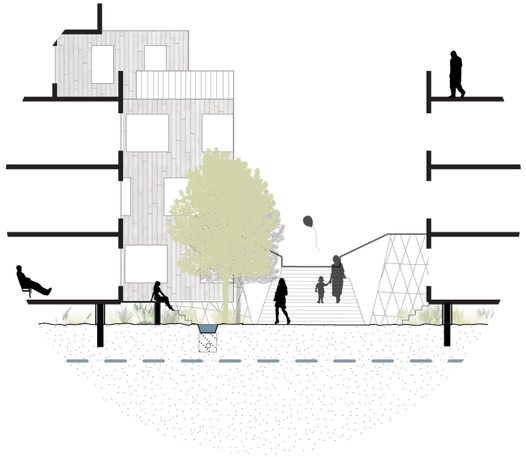
All in all the perception of the area is therefore rather exciting and adds a lot of qualities to the public space that create its unique characteristic.

4m elevated Building



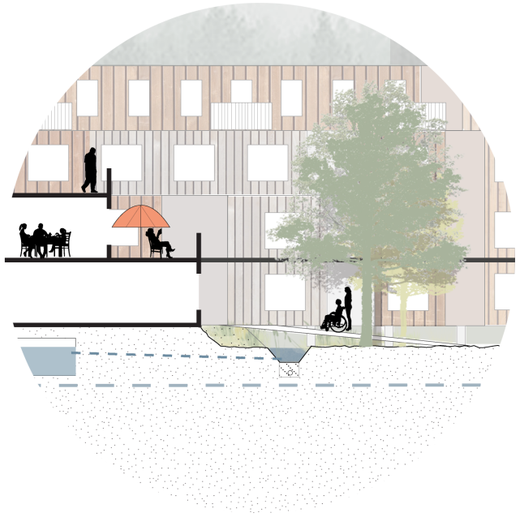
- People can pass under elevated buildings
- Space can be used for storage:
  e.g. Bicycle parking

1m elevated Building



- Vegetation along the buildings
- Stairs and platforms activate street life

Building sits on little mound



- Ramps ensure barrier free access
- Greenery along the mound
- Change in topography

3.4. City context

New pedestrian & bicycle paths are connected with the existing infrastructure

The applied water management creates a closed water circle with the existing one

The new green space in the context of existing open space

This thesis project emphasizes the importance of a climate adaptive urban design strategy for a city and gives insights into different design solutions to achieve that.
A climate adaptive urban design strategy requires the integration of small site- specific projects into the larger context which is shown in the following graphics.

The site is integrated well into the city through a comprehensive green and blue infrastructure and pedestrian and cyclist friendly connections.

Another topic that needs to be addressed within climate adaption is renewable energy. 50% of the residents in Deggendorf are still heating with oil, which also caused an environmental disaster when oil tanks leaked into flooded areas. Overall renewable energy sources and an economically usage of energy have to be promoted more.

Solar panels that have been installed on roofs and along the dike generate energy for the site. Overall solar panels are a suitable and profitable renewable energy source for Deggendorf.

3.5. Conclusion

How can adapted integrated flood control improve environmental, social and economic sustainabilty within a city?

The design proposal can be seen as an experimental pilot project for flood resilient urban design in the city Deggendorf.

The importance of permeable surfaces and the generally integration of water sensitive urban design and flood proofing into new developments are some conclusions that can be drawn from this thesis for the city Deggendorf and other cities with similar geographical conditions.
But the design proposal does not only reveal advantages of flood resilience through integrated flood control but demonstrates environmental, social and economic sustainability of the site.

Environmental sustainability:

The adapted integrated flood control approach protects the site from floods and ensures a low impact urban development. It further improves the microclimate and ensures that natural water flows and the hydrostatic pressure are not interrupted.
Permeabel surfaces together with sufficient green spaces, not only reduce stormwater run off and have many more advantages but increase the small amount of recreational and natural space in Deggendorf.

Social sustainability:

Many uses that have been applied to the site, such as cultural space, multipurpose WSUD systems and a multifunctional dike promote social sustainability. Public spaces generate meeting places for everyone and the area becomes more vibrant. The right mix of functions ensures a balance of working, living and recreation and a social mix.
Further more the flood resilient urban design makes climate change more noticable and brings the importance of climate adaption to the people´s mindset.

Economic sustainability:

The design proposal makes use of the high land value by addressing the housing and working needs and attracts many tourists and residents at the same time. Not to forget that qualitative green spaces and water bodies increase the land value further more and attract development. The popularity of the site will generate money for the city and renewable energy can make the area self-sufficient.
The flood proofed building design avoids expensive structural damage and the buildings costs are not more expensive than usual dry- flood proofed building types.

Illustration showing the green space with retention basin, public buildings and the dike in the background. Transition between built and unbuilt area

Overall the design proposal shows that integrated flood control can be used as a toolbox for flood resilient urban design and enables the development of areas behind flood defences and areas with flood risks in general.
The strategy connect, activate and integrate achieved an urban integration of the site and the dike.
The project further shows that a multifunctional dike can be used as an asset for the city rather than a problem and that barriers can be overcome and integrated into the design.

The development of the site close to the city centre states the importance of developing within existing built areas rather than on valuable flood plains. It does not only prevent urban sprawl but protects flood plains that are of extreme importance for comprehensive flood control.
The applied toolbox demonstrates that technical flood protection and water sensitive urban design can be combined and used to activate pubic space. Together with the applied buildings types integrated flood control creates a new type of living with water as its prevailing element.

DISCUSSION

"Sustainable solutions are no longer a choice for most societies:
they're a must.
Especially in our cities."

FRANK JENSEN
Lord Mayor of Copenhagen

Climate change has an effect on extreme weather events but is not necessarily the reason for floods in cities.
In many places in the world, urban process has not changed or adapt to new conditions such as urban growth or climate change since years.
Climate adaption is necessary if we want to enjoy the same or improve living qualities for future generations in our cities.
But instead inappropriate urban design can even deteriorate natural catastrophes within urban environments (Kelman, I. 2017).

To make our cities more flood resilient is not that complicated or complex than one might think.

Cities have to replace the "business as usual" concept and incorporate appropriate water management into not only new developments but also already existing structures.

Integrated flood control is cost effective and feasible when integrated at early stage into the planning process and benefits and synergies can be achieved in the development of new areas or within existing ones.
It is more expensive and problematic to wait until spatial planning is completed or extreme weather events occur.
Collaboration between stakeholders, a clear vision and public participation is additionally important for a climate adaptive design strategy.

Incorporated blue and green infrastructure within urban environments generates qualitative spaces and increases the land value (Hvilshoj, Soren and Klee, P., 2013).

But there are many more benefits that can be withdrawn from climate adaptive urban design. The design proposal can be seen as an example of flood resilient urban design and demonstrates benefits of climate adaption.

In general, clear guidelines and best practice examples can help to promote climate adaption and make it more feasible to implement.

All in all climate adaption and flood resilience in particular needs to be addressed more in urban design in order to make our cities more sustainable and protect the people who live in.

REFERENCE projects and visits 2017

1,2: Vietnam: Elevated buildings on stilts

3,4: India: Elevated buildings on stilts next to a flood defence system by the sea.
Palm tree was used to overcome the barrier.

5: Cambodia: Elevated buildings on stilts

6: Cambodia: Agriculture fields use reach soil in river bed. It gets flooded multiple times a year

7: Hamburg, GR: Integration of flood defence into the urban environement

8: Hamburg: Wooden platform surrounds elevated, flood proofed building to ensure accessibility

9: Dordrecht, NL: Building on stilts next to a river. Path continues underneath it

10: Rotterdam, NL: Water square Benthemheim Multifunctional retention basin

11: Berlin, GR: Potsdamer Platz.
Retention basin creates public space

12: Malmö, SE: Ecological city Augustenborg.
Best practice of WSUD

REFERENCES

Abhas K.,Bloch, R. and Lamond, J., (2012). *Cities and Flooding, A Guide to Integrated Urban Flood Risk Management for the 21st Century.* Washington DC: The World Bank. Avaiable at: https://www.gfdrr.org/sites/gfdrr/files/publication/World_Bank_Cities_and_Flooding_Guidebook.pdf

Bayrisches Landesamt für Statistik (2015). *Große Kreisstadt Deggendorf 09 271 119.* München: Bayrisches Landesamt für Statistik. Available at: https://www.statistik.bayern.de/statistikkommunal/09271119.pdf

Challengeforsustainability.org, (2017). *Wet Floodproofing.* A better city, Challenge for sustainability. [online] Available at: http://challengeforsustainability.org/resiliency-toolkit/wet-floodproofing/

Climate- Data.org, (2017). *Klima und Wetter in Deggendorf.* [online] Available at: https://de.climate-data.org/location/22676/

Deggendorf.de, (2013). *Gemeindeflächen nach Nutzungsarten*. Deggendorf. [online] Available at: http://www.deggendorf.de/index.php?id=366

Deggendorf.de, (2017). *Schachings Geschichte.* Deggendorf. [online] Available at: http://www.deggendorf.de/index.php?id=425

Deggendorf (2017). *Deggendorf.* [online] Available at: https://de.wikipedia.org/wiki/Deggendorf

Deutsches Komitee Katastrophenvorsorge e.V. (2015) *Das Hochwasser im Juni 2013, Bewährungsprobe für das-Hochwasserrisikomanagement in Deutschland.* Available at: http://www.dkkv.org/fileadmin/user_upload/Veroeffentlichungen/Publikationen/DKKV_53_Hochwasser_Juni_2013.pdf

Donau (2017). *Donau* [online] Available at: https://de.wikipedia.org/wiki/Donau

ga.gov.au, (2017). *What causes Floods?* [online] Available at: http://www.ga.gov.au/scientific-topics/hazards/flood/basics/causes

Global Greenhouse Warming.com, (2017) *Climate Mitigation and Adaption.* [online] Avaiable at: http://www.global-greenhouse-warming.com/climate-mitigation-and-adaptation.html

Hochwasser 2013, (2014). *Hochwasser 2013 (Deggendorf).* [online] Available at: https://regiowiki.pnp.de/wiki/Hochwasser_2013_(Deggendorf)

Hvilshoj, Soren and Klee, P., (2013). Adding new value to cities with urban water - Sustainable solutions of integrated urban water management. The Rethink Water network and Danish Water Forum white papers, Copenhagen. Available at: http://www.klimatilpasning.dk/media/872685/whitepaper_urbanwater_rethinkwater_ver_1.1.pdf

IÜG (2017). *Informationsdienst Überschwemmungsgefährdete Gebiete.* Bayrisches Landesamt für Umwelt. [online] Available at: https://www.lfu.bayern.de/wasser/hw_ue_gebiete/informationsdienst/index.htm

Kelman, I. (2017). *Urban design caused the Hurrican Harvey disaster.* De zeen. [online] Available at: https://www.dezeen.com/2017/09/01/urban-design-caused-hurricane-harvey-disaster-houston-flooding-ilan-kelman-opinion/

Landesgartenschau Deggendorf 2014 (2017). *Landesgartenschau Deggendorf 2014* [online] Available at: https://de.wikipedia.org/wiki/Landesgartenschau_Deggendorf_2014

Linham, M. and Nichols, R. (2017). *Flood- proofing.* ClimateTechWiki. [online] Available at: http://www.climatetechwiki.org/content/flood-proofing

Pelsmakers S. (2014). *Living with water: four buildings that will withstand flooding.* The conversation. [online] Available at: http://theconversation.com/living-with-water-four-buildings-that-will-withstand-flooding-23536
Reimer, N. and Lüdemann, D. (2017). *Ja, das ist der Klimawandel.* [online] Available at: http://www.zeit.de/wissen/umwelt/2017-07/starkregen-dauerregen-wetter-klimawandel-regen-meteorologie

Rösing, P. (2017). *So stark haben schwere Regenfälle zugenommen - und es wird noch schlimmer.* [online] Avaliable at: http://www.stern.de/panorama/wissen/natur/so-stark-hat-starkregen-in-deutschland-zugenommen-6874438.html

Röttcher, K. (2015). Dezentrale Maßnahmen Chancen und Grenzen. *DWA.* Available at: http://www.wwa-r.bayern.de/hochwasser/hochwasserschutzprojekte/flutpolder/doc/03_20151008_forum2_roettcher_dez_massnahmen.pdf

StMUV (2015). *Hochwasserrisikomanagement-Plan.* München: Bayrisches Staatsministerium für Umwelt und Verbraucherschutz. Available at: https://www.lfu.bayern.de/wasser/hopla_donau/doc/hwrmp_donau_endversion.pdf

Striffler, H. and Heiland, P. (2015). *Hochwasser- Risiko - bewusst planen und bauen.* Darmstadt: WBW Fortbildungsgesellschaft für Gewässerentwicklung mbH. Available at: https://www.lrasbk.de/_Resources/Persistent/5860b7af3a7089d2c50020379524ed642e5ba0e2/Brosch%C3%BCre_WBW_HwRisiko-bewusst_planen%20und%20bauen.pdf

Thieken, A. H., S. Kienzler, H. Kreibich, C. Kuhlicke, M. Kunz, B. Mühr, M. Müller, A. Otto, T. Petrow, S. Pisi, and K. Schröter (2016) Review of the flood risk management system in Germany after the major flood in 2013. *Ecology and Society 21(2):51.* Available at: http://dx.doi.org/10.5751/ES-08547-210251

Wasserwirtschaftsamt Deggendorf. *Ausnahme oder wiederkehrendes Ereignis.* Available at: http://www.wwa-deg.bayern.de/hochwasser/doc/hw_2013_web.pdf

List of figures from the internet

p.15: http://www.spiegel.de/fotostrecke/hochwasser-an-donau-und-elbe-norddeutschland-ruestet-sich-fuer-flut-fotostrecke-97668-3.html

p.15: https://www.detail.de/artikel/deggendorf-ist-ueberall-hochwasserpass-und-schutzfibel-als-instrumente-der-praevention-12067/

p.15: http://www.focus.de/panorama/welt/wetter-hochwasser-2013-viel-mehr-regen-als-2002_aid_1028305.html

p.28-29: http://www.muc365.de/2013/02/13/panorama-oberer-stadtplatz-deggendorf/

p.33: http://www.geschichtsverein-deggendorf.de/archiv

p.35: https://www.google.de/search?biw=1536&bih=730&tbm=isch&sa=1&ei=ug4cWvi0AYORgAbAj4DgCQ&q=Deggendorf&oq=Deggendorf&gs_l=psy-ab.3..0i67k1j0l9.70372.70372.0.70558.1.1.0.0.0.0.116.116.0j1.1.0....0...1c.1.64.psy-ab..0.1.115....0.6sCHFlbz6C0#imgdii=f6SnSos3oJHySM:&imgrc=4NMKDxlS4GEZrM:

p.35: https://wize.life/firmen-und-vereine/seiten/stadt-deggendorf/4377

p.42: https://www.muenchenarchitektur.com/news/24-architektur-stadtentwicklung/21983-landschaft-im-fliessen

p.43,45: http://www.raumzeit.org/NewFiles/parkdeck_deggendorf_09.html

p. 44: http://www.baunetz.de/meldungen/Meldungen-Bruecke_und_Parkdeck_in_Deggendorf_4147369.html?backurl=http%3A%2F%2Fwww.baunetz.de%2Fmeldungen%2Findex.html&bild=7

p.50: http://www.hans-feichtinger.de/schwimmsport.geschichte.html